DaimlerChrysler Aerospace

NFS Navigations-
und Flugführungs-Systeme GmbH

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CESAR

Erarbeitung von Zulassungsverfahren für satellitengestützte Navigations- und Landesysteme

- Abschlußbericht -

März 1999

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Certification Policies, Procedures and Requirements
for ***Sa***tellite based Navigation and Landing Systems and
corresponding ***R***esearch Activities

Leerseite

Die NFS Navigations- und Flugführungs-Systeme GmbH ist im Rahmen des Fördervorhabens CESAR Auftragnehmer des Deutschen Zentrums für Luft- und Raumfahrt (DLR).

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Zuwendungsempfänger ist die Dasa Ulm, NFS Navigations- und Flugführungs-Systeme GmbH.

Vorwort des Autors

Die Erarbeitung von Standards und Zulassungsverfahren erfordert eine enge Zusammenarbeit zwischen Forschung, Industrie, Systembetreibern und Behörden, wie sie im vorliegenden Vorhaben in hervorragender Weise demonstriert werden konnte. Mit diesem zusammenfassenden Abschlußbericht über den Arbeitsanteil der NFS im Fördervorhaben CESAR möchte ich mich beim Zuwendungsgeber und allen beteiligten Institutionen, Firmen und Kollegen für ihre konstruktive Mitarbeit bedanken.

Heinz-Georg Wippich

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1 Verzeichnis der Abkürzungen

AC	Aircraft
ADF	Automatic Direction Finder
ADS	Automatic Dependent Surveillance
AECMA	The European Association of Aerospace Industries
AP	Arbeitspaket
ARINC	Aeronautical Radio, Inc.
AWO	All Weather Operation
AWOG	All Weather Operation Group
AZB	Avionikzentrum Braunschweig
BMFT	Bundesministerium für Forschung und Technologie
BMV	Bundesministerium für Verkehr
CAT I	Category I; Betriebsstufe 1
CRC	Cyrclic Redundancy Check
DGPS	Differential Global Positioning System
DL RX	Datenlink-Empfänger
DME	Distance Measuring Equipment
DoD	Department of Defence
DoT	Department of Transportation
EDCD	ICAO-Kennung von Cottbus-Drewitz
EGNOS	European Geostationary Navigation Overlay Service
EIAG	Eurocontrol Industrial Advisory Group
EUROCAE	European Organisation for Civil Aviation Equipment
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulations
FAS	Final Approach Segment
GALILEO	European GNSS concept
GBAS	Ground-Based Augmentation System
GLNU	GPS Landing and Navigation Unit
GLONASS	Global Orbital Navigation Satellite System

GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HSI	Horizontal Situation Indicator
ICAO	International Civil Aviation Organization
ICD	Interface Control Document
IFF	Institut für Flugführung der Technischen Universität Braun-schweig
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
IMU	Inertial Measurement Unit
ISAN	Integrity for Satellite Navigation
JAA	Joint Aviation Administration
JAR	Joint Aviation Regulations
JTSO	Joint Technical Standard Order
LAAS	Local Area Augmentation System
LBA	Luftfahrt-Bundesamt
LGF	LAAS Ground Facility Specification
LSQ	Least Sum Square
MASPS	Minimum Aviation System Performance Standards
MLS	Microwave Landing System
MO-Disk	Magneto-optische Diskette
MOPS	Minimum Operational Performance Standards/Specification
NFS	Navigations- und Flugführungs-Systeme GmbH
PVT	Position, Velocity, Time
RAIM	Receiver Autonomous Integrity Monitoring
RALT	Radar Altimeter
RNAV	Area Navigation - Flächennavigation
RNP	Required Navigation Performance
RTCA	Requirements and Technical Concepts for Aviation
SCATMIG	The Special Category One Manufacturers Interoperability Group
SIS	Signal in Space

TMA	Terminal Control Area
TSO	Technical Standard Order
TU-BS	Technische Universität Braunschweig
TU-DR	Technische Universität Dresden
VHF	Very High Frequency
VOR	VHF Omnidirectional Range
WAAS	Wide Area Augmentation System
WG	Working Group

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2 Einleitung

Im Rahmen von Forschungs- und Entwicklungsarbeiten konnte in den letzten Jahren das hohe Potential satellitengestützter Navigations- und Landesysteme für Anwendungen in der Luftfahrt deutlich gemacht werden. Leider ist es wegen fehlender Zulassungsverfahren für derartige Systeme bisher nicht möglich, den national erreichten technisch-wissenschaftlichen Wissensstand in Produkte umzusetzen, um damit den Wirtschaftsstandort Deutschland auch auf diesem Gebiet abzusichern.

Aus diesem Grund hat sich eine Arbeitsgemeinschaft ohne gesellschaftlichen Zusammenschluß, bestehend aus Vertretern der Flugsicherung, der Luftraumnutzer, der Forschung und der Industrie formiert, um die Grundlagen zukünftiger Zulassungsverfahren für satellitenbasierte Navigations- und Landesysteme zu untersuchen und die Ergebnisse als Beitrag zum internationalen Prozeß der Harmonisierung von Zulassungsverfahren für derartige Systeme zur Verfügung zu stellen.

Die Aktivitäten der letzten Jahre auf dem Gebiet der Satellitennavigation lassen zunehmend erkennen, daß diese Technologie in einem Maße beherrschbar ist, daß sich Luftfahrzeuge mit ihrer Hilfe bis zu Landungen der Kategorie III, also bis zum Aufsetzen und Rollen, führen lassen. So wurde insbesondere in Deutschland die Differentialtechnologie sehr früh so weit entwickelt, daß die Genauigkeit für automatische Landungen bereits 1989 experimentell nachgewiesen wurde. Dies führte zur Entwicklung von kommerziellen Systemen zur hochpräzisen Navigation von Luftfahrzeugen. Eine Zulassung dieser Systeme ist zum gegenwärtigen Zeitpunkt nur auf der Basis US-amerikanischer Vorschriften möglich, da den zuständigen europäischen Ministerien mit den nachgeordneten Bereichen die dafür notwendigen Zertifizierungsgrundlagen sowohl in technischer als auch in juristischer Hinsicht noch nicht zur Verfügung stehen. Diese Grundlagen, vor allen Dingen aus technischer Sicht, sollen im Projekt "CESAR“ (Certification Policies, Procedures and Requirements for Satellite based Navigation and Landing Systems and corresponding Research Activities) geschaffen werden. "CESAR" ist damit die konsequente Weiterführung der Förderpolitik der Bundesrepublik Deutschland unter Wahrung der hoheitlichen Aufgaben auf dem Gebiet der Satellitennavigation. Durch das Projekt lassen sich die Ergebnisse aus den bisher im großen Umfang durch BMFT und BMV geförderten Programmen, wie beispielsweise dem Vorhaben ISAN, in international vermarktbare Produkte umsetzen.

2.1 Bezug auf hoheitliche Aufgaben der Bundesrepublik Deutschland

Bei keinem Navigationssystem hat es bei der Einführung derartige Unsicherheiten und Unwägbarkeiten gegeben, wie dies gegenwärtig bei der Satellitennavigation der Fall ist. Selbst die amerikanische Luftfahrtbehörde FAA hat in ihrer Strategie in den vergangenen Jahren mehrere Richtungsänderungen vollzogen und bis zum jetzigen Zeitpunkt nur ungenaue Vorstellungen über die kommerzielle Nutzung der Satellitennavigation;

dies liegt vor allem an der Abhängigkeit des amerikanischen Verkehrsministeriums (DoT) zum Verteidigungsministerium (DoD).

Ein Schlüsselelement auf dem Weg zur Nutzung der Satellitennavigation ist die Zuverlässigkeit. Bei der Konzeption des vorliegenden Projektes "CESAR" und in den internationalen Diskussionen kristallisieren sich zwei Schwerpunkte heraus, die es für eine Zulassung zu untersuchen gilt. Zum einen ist dies die Problematik der extrem hohen Integritätsanforderungen an ein Landesystem (mit der nachzuweisen Wahrscheinlichkeit von 10^{-9} für einen durch das Navigationssystem verursachten Unfall), die im Gegensatz zur prinzipiell niedrigen Integrität von satellitenbasierten Systemen steht (Probleme der Abschattung, Mehrwegeausbreitung, elektromagnetische Verträglichkeit etc.). Zum anderen stehen einer sicherheitskritischen Anwendung der Satellitennavigation die institutionellen Abhängigkeiten der existierenden Systeme GPS bzw. GLONASS des amerikanischen bzw. russischen Verteidigungsministeriums entgegen. An eine gleichberechtigte Beteiligung von fremden Nationen an den existierenden Satellitennavigationssystemen ist nach jetziger Lage auch längerfristig nicht zu denken. Dies bedeutet, daß sich insbesondere die europäischen Staaten um eine institutionelle Lösung für die Zukunft der Satellitennavigation bemühen müssen. Entsprechende Lösungsstrategien werden signifikanten Einfluß auf die Zulassung von satelliten-basierten Navigationssystemen haben. Ein Beispiel hierfür wird die Zulassung des europäischen geostationären Navigations-Overlaysystems EGNOS sein, bei dem die Integrität vom Streckenflug bis zum Anflug der Kategorie I sichergestellt werden muß.

Der geschilderte institutionelle Hintergrund führt konsequenterweise dazu, ein rein ziviles, d.h. von GPS und GLONASS unabhängiges (aber zu den existierenden Systemen kompatibles) Satellitennavigatiossystem zu konzipieren. Konzepte hierfür werden derzeit unter dem Stichwort GNSS II und Galileo diskutiert. Die Erfahrungen mit den existierenden Landesystemen (ILS, MLS) legen nahe, die für die Zulassung entwickelten Verfahren auch auf Satellitensysteme zu übertragen und die bisher bewährten institutionellen Strukturen auch auf das neue System abzubilden. Danach ist für die flugzeugseitige Ausrüstung der Flugzeughalter verantwortlich und für die Zulassung dieser Ausrüstung in Deutschland das Verkehrsministerium mit seiner nachgeordneten Dienststelle, dem Luftfahrt-Bundesamt. Für die bodenseitige Ausrüstung, d. h. die Landekurs- und Gleitwegsender sowie die Monitorstationen, sind die jeweiligen Nationalstaaten auf ihrem Hoheitsgebiet verantwortlich. Die nationalen Regierungen bzw. deren Verkehrsministerien nehmen die Aufsicht über die Flugsicherungsbehörden wahr. Die notwendigen Standards werden von der ICAO vorgegeben, die Nationalstaaten beschaffen, installieren und betreiben die Navigationssysteme in eigener Verantwortung.

Bei der Differential-Satellitennavigation wird es eine dem ILS vergleichbare Bodeninfrastruktur geben, beispielsweise in Form lokaler DGPS-Bodenstationen. Diese werden parallel von Monitorstationen überwacht.

Der wesentliche Unterschied zu den bisherigen Radionavigationssystemen liegt in der Tatsache, daß die Satellitensysteme auch ländergrenzen-übergreifend arbeiten. Dieser Schritt, der alle satelliten-basierten Systeme betrifft, ist von anderen Institutionen im

Kommunikationsbereich, wie beispielsweise bei der Telekom, schon erfolgreich vollzogen worden. Die damit verbundenen juristischen und institutionellen Probleme sind daher bekannt und lösbar.

3 Stand der Technik

Die Funknavigation in der Luftfahrt ist im kontinentalen Bereich derzeit das einzige zuverlässige Verfahren zur Durchführung eines Instrumentenfluges (IFR, Instrument Flight Rules) vom Start bis zum Ziel unter Schlechtwetterbedingungen (IMC, Instrument Meteorological Conditions). Die heute hierfür eingesetzten und zugelassenen Anlagen sind

- Winkelmeßsysteme (VOR)
- Abstandsmeßsysteme (DME)
- Radiopeiler (ADF)
- Anflugsysteme (ILS, MLS)
- Einflugzeichen (Marker).

Die weltweit veröffentlichten IFR-Routen richten sich im wesentlichen nach der lokalen Verteilung der Radionavigationsanlagen am Boden. Die Routen werden im allgemeinen von Funkfeuer zu Funkfeuer geführt. Daher ist die Anpassung und Ausbaufähigkeit der Routen nach den Anforderungen des heutigen Verkehrsaufkommens unter anderem durch die Verfügbarkeit derartiger Funkfeuer begrenzt.

Ein wesentlicher Schritt in Richtung der bordautonomen Navigation wurde durch Einführung von Inertial-Navigationssystemen unternommen. Mit derartigen Systemen wurden zuverlässige Interkontinentalverbindungen möglich. Daneben stützt die Trägheitsnavigation aber auch sogenannte Flächennavigationsverfahren (RNAV), also eine nicht strikt routengebundene Navigation im Verbund mit der klassischen Radionavigation.

Die bodengestützte Navigation wird aber weiterhin sowohl im kontinentalen Streckenflug als auch bei der Landung als primäres Navigationselement genutzt. Für die Führung des Anflugs bis zur Landung werden Signale aus verschiedenen Sendern am Boden durch die bordseitigen Empfänger kombiniert und als Führungsgröße dem Piloten dargestellt bzw. auf den Autopiloten geschaltet. Das gesamte Landesystem setzt sich aus folgenden boden- und bordseitigen Geräten zusammen:

- Instrumentenlandesystem (ILS mit Landekurs- und Gleitwegsender)
- Einflugzeichen (Vor- und Haupteinflugzeichen) und
- Abstandsmeßsystem (DME, nicht Teil des ILS, aber vielerorts verfüg bar).

Die Anforderungen an diese Anlagen richten sich nach den Sicht- und Wetterminima, wie sie nach ICAO Annex 10 in den Betriebsstufen 1 (CAT I) bis 3c (CAT IIIc) definiert sind.

Da von allen Flugphasen die Landung der kritische Abschnitt eines Fluges ist und das Instrumentenlandesystem trotz seiner Reife und Zuverlässigkeit gewissen Einschränkungen durch Frequenzverfügbarkeiten, Interferenzen und Mehrwegeausbreitungen unterliegt, hat in diesem Bereich die Entwicklung neuer Systeme zum Mikrowellen-Landesystem (MLS) geführt.

Wie beim derzeitigen ILS führte dieser Entwicklungsweg über nahezu zwei Jahrzehnte und war begleitet von einer die kontinuierlichen Schaffung von technischen Standards und der Definition operationeller Verfahrensweisen, die heute Grundlage für die weltweite Zulassung solcher Systeme sind. Die erarbeiteten Grundlagen finden sich heute in zahlreichen Dokumenten wieder, insbesondere:

- ICAO Annex 10,
- Regelungen nach FAR und in Europa nach JAR,
- Funktions- und Verfahrensvorschriften nach RTCA-MOPS; MASPS (Radio Technical Commission for Aeronautics), in Europa nach EUROCAE,
- Zulassungsvorschriften nach TSO (Technical Standard Order), in Europa auch nach JTSO,
- Regelungen nach AC (Advisory Circular),
- Gerätestandards nach ARINC.

Sie bilden international die Basis für die Zulassung von Geräten und Verfahren in der Luftfahrt. Die Sorgfalt, mit der dabei bei der Erarbeitung dieser Vorschriften und Empfehlungen vorgegangen wurde, läßt sich aus der Tatsache entnehmen, daß kein Unfall bekannt ist, der sich auf die Fehlfunktion eines Instrumentenlandesystems zurückführen läßt. Jedes zukünftige Schlechtwetter-Navigationssystem muß sich an diesem hohen Sicherheitsstandard orientieren.

Zu berücksichtigen ist dabei auch, daß derart kritische Systeme mit zwei- bis dreifacher Redundanz im Flugzeug vorhanden sein müssen.

Mit der zunehmenden zivilen Nutzung des militärischen Satellitennavigationssystems GPS hat sich eine neue Situation ergeben. Die technischen Möglichkeiten von GPS, die erarbeiteten Präzisionsverfahren und die Verfügbarkeit von leistungsfähigen GPS-Geräten hat zu einer erheblichen Verbreitung der Nutzung von GPS in allen Verkehrsbereichen geführt. Besonders in der Luftfahrt eröffnet die Möglichkeit zum Einsatz von GPS und Differential-GPS wirtschaftlich attraktive Verfahren in nahezu allen Flugabschnitten, vom Rollen über den Start und den Streckenflug bis zur Landung. In der Literatur findet man zunehmend den Begriff „Gate-to-Gate“ für ein Konzept, das in allen Phasen der Bewegung mit den gleichen Navigationsmitteln arbeitet.

Dabei beschränkt sich die Nutzung von GPS nicht nur auf die Navigation, sondern eröffnet auch neue Möglichkeiten der Luftraumüberwachung (Automatic Dependent Surveillance -ADS) und der Kontrolle des Rollverkehrs auf Flughäfen. Ein anderer Anwendungsfall im Sinne einer Kollisionswarnung ergibt sich durch die Verarbeitung der über Datenfunk ausgetauschten GPS-Positionsinformationen zur Konflikterkennung zwischen den Verkehrsteilnehmern. Die genannten Anwendungen von GPS beschränken sich nicht auf die Luftfahrt. Einige der genannten Anwendungen, gerade die Verkehrsüberwachung und zentrale Verkehrsführung, sind auch auf die Seefahrt oder den Landverkehr übertragbar.

Da bei der Entwicklung von GPS zunächst nicht an eine kommerzielle Nutzung gedacht wurde, sind kaum Standards und Verfahrensvorschriften zur zivilen Nutzung von GPS erarbeitet worden. Erst die Verfügbarkeit von GPS-Empfängern diverser Leistungsklassen für den allgemeinen Markt hat eine Vielzahl von Anwendungen in allen Verkehrsbereichen möglich gemacht. Diese Entwicklung ist, verglichen mit den oben beschriebenen Verfahren der Radionavigation, im Zeitraffer geschehen. Dabei hat die Schaffung von Standards und Verfahrensvorschriften nicht schritthalten können.

Bereits heute sind die technischen Voraussetzungen für GPS-gestützte Navigations- und Landesysteme vorhanden, Standards und Prüfvorschriften für die Zulassung derartiger Systeme und Geräte sind jedoch nur bedingt verfügbar. Bei einigen Anwendungen, beispielsweise bei der Nutzung von GPS im Streckenflug, ist ein dringender Handlungsbedarf für die Zulassung bereits praktizierter Verfahren zu erkennen. So wird heute die TSO C129a des DoT/FAA auch in Staaten außerhalb der USA als Basis für die Genehmigung der Streckennavigation verwendet.

Die Anwendung von GPS für den Streckenflug als unterstützendes (supplementary) Navigationssystem nach TSO C 129a deckt aber nur einen kleinen Anwendungsbereich ab und läßt einen dringenden Handlungsbedarf für weitere GPS- Nutzungen offen. So müssen auch der Präzisionsanflug und die Nutzung anderer Augmentierungsverfahren, wie EGNOS und WAAS, in einer neuen TSO berücksichtigt werden.

An dieser Stelle sei auf den Übergang der Bezeichnung GPS (Global Positioning System) auf die Bezeichnung GNSS (Global Navigation Satellite System) hingewiesen.
Bezeichnet GPS das derzeit existierende Satellitennavigationssystem des DoD der USA, so steht der Begriff GNSS für die Nutzung verschiedener Satellitensysteme innerhalb eines Gesamtsystems zur satellitengestützten Navigation. Da dieses Gesamtsystem heute noch nicht existiert, beziehen sich alle nachfolgenden Betrachtungen zwar auf GPS und das russische System GLONASS, die Ergebnisse müssen aber auch für ein GNSS Gültigkeit haben. In der weiteren Beschreibung wird der Begriff GNSS verwendet.

3.1 Anforderungen der Luftraumnutzer an GNSS

Die Satellitennavigation hat bei den Luftverkehrsteilnehmern sehr rasch große Akzeptanz gefunden. Die Anwendungsmöglichkeiten des heute verfügbaren GPS allein sind jedoch in einem Maße eingeschränkt, daß kaum ein wirtschaftlicher Nutzen für die kommerzielle Luftfahrt erreichbar ist. Bedingung hierfür wäre die Einsatzmöglichkeit als primäres (primary) Navigationssystem. Damit wären konventionelle Navigationssysteme mit ihrer aufwendigen Bodeninfrastruktur, wie z.B. VOR, verzichtbar. Ein noch bedeutenderes Anwendungspotential wird im Bereich der Instrumentenlandesysteme erwartet.

Einen wesentlichen Beitrag zur Steigerung der Sicherheit und Pünktlichkeit im Luftverkehr können GNSS-Landesysteme leisten, indem sie für weniger entwickelte Länder und Flughäfen bei geringeren Anforderungen eine finanziell überhaupt erst tragbare Alternative zu ILS ermöglichen. Viele dieser Flughäfen haben heute aus Kostengründen kein ILS, und gefährliche Situationen sind bei schlechtem Wetter nicht immer auszuschließen. Da neue Landesysteme zuerst für geringere Anforderungen (z.B. CAT I) zugelassen werden, ist hier ein frühzeitiger Nutzen zu erreichen. Hinzu kommt, daß durch den Ersatz von bestehenden CAT I-ILS Anlagen dringend benötigte Frequenzen für die noch länger erforderlichen CAT II- und CAT III-Anlagen frei werden.

Es wird erwartet, daß die Satellitentechnik die Navigation in der Luftfahrt revolutionieren wird und es ermöglicht, über den gesamten Flug (von „Gate“ zu „Gate“) das gleiche Basissystem zu verwenden. Damit wären nicht nur Kostenvorteile verbunden, es würden auch Probleme beim Übergang zwischen verschiedenen Systemen vermieden.

4 Arbeitsziele und Erfolgsaussichten

Um die Satellitennavigation in den nächsten Jahren ihren Möglichkeiten entsprechend auch in der Luftfahrt global einsetzten zu können, sind neben der Klärung institutioneller Fragen international abgestimmte Standards notwendig. Die Grundlagen für diese Standards sind umgehend zu erarbeiten; diese Untersuchungen liefern gleichzeitig Beiträge, die die nationale Zulassungsbehörde und ihre übergeordneten Dienststellen in die europäische Diskussion (z. B. JAA und EUROCAE) einbringen können. Die für die Zulassung zuständigen nationalen Stellen sind dabei auf die Unterstützung der Forschungsinstitute und der Industrie angewiesen. Diese Unterstützung betrifft vor allem die Lieferung von Ergebnissen aus theoretischen und experimentellen Untersuchungen zu

- Betriebskonzepten,
- Systemarchitekturen,
- Leistungseckdaten und
- Nachweisverfahren

geeigneter GNSS-Geräte und deren Integration in die vorhandene Bodeninfrastruktur sowie in Avionikstrukturen. Damit kann die zulassende Behörde in die Lage versetzt werden, bei der Erstellung internationaler Standards und Vorschriften für die Geräte-, Betriebs- und Verfahrenszulassung die nationalen Gegebenheiten und Forderungen in geeigneter Weise zu vertreten. Diese Gegebenheiten liegen institutionell in der Klärung der Zuständigkeiten, Kontrollfunktionen, Befugnisse und in der Verfügbarkeit notwendiger Frequenzen für die Datenkommunikation, aber auch in der Definition von Verkehrsprozeduren im nationalen Luftraum. Ferner wird erreicht, daß alle für die Zulassung entsprechender Satellitennavigationsverfahren, Geräte und Integrationskonzepte notwendigen Dokumente im international abgestimmten Rahmen entstehen, d. h. insbesondere

- Zulassungsvorschriften
  JAR TSO
  JAR AWO
  TSO

- Funktions- und Verfahrensvorschriften für Luftfahrtgerät
  EUROCAE ED
  RTCA DO.

Zur Unterstützung der Zulassungsbehörde in dieser Aufgabe besteht die Notwendigkeit, eine zielgerichtete und effiziente Zusammenarbeit aufzubauen, insbesondere zwischen den

- mit der Zulassung von Anlagen und Verfahren befaßten Behörden,
- mit dem Betrieb und der Kontrolle befaßten Institutionen,
- mit der Modellierung und theoretischen Analyse derartiger Systeme befaßten Forschung,
- mit der Herstellung von Navigationsanlagen befaßten Industrie,
- mit der Anwendung der Bord- und Bodenkomponenten befaßten Nutzer.

Damit wird auf bereits vorhandenem Wissen aus Arbeiten und Ergebnissen im Bereich GNSS aufgesetzt und es können die Verfahren für

- die theoretische Nachweisführung zur Absicherung der geforderten Systemzuverlässigkeit der Avionik im Rahmen der RNP (Required Navigation Performance) sowie

- die experimentelle Nachweisführung zur Absicherung der Funktionalität in verschiedenen Stufen bis hin zur Untersuchung im Flugzeug in realen Szenarien

erarbeitet werden. Es ist darauf zu achten, daß die gewählten Nachweisverfahren und Fehlermodelle den Prinzipien entsprechen, die auch für die Nachweisführung konventioneller Systeme und Verfahren zur Streckennavigation, wie VOR und DME, sowie zur Anflugführung, wie ILS oder MLS, angewendet werden oder zumindest daraus ableitbar sind, um eine größtmögliche internationale Akzeptanz zu erreichen.

Mit Blick auf den Handlungsbedarf ist zu klären, ob es Faktoren gibt, welche die Nutzung von Satellitennavigationssystemen für die Landung bis zur Kategorie III grundsätzlich in Frage stellen. Können derartige Faktoren nicht nachgewiesen werden, sollten die Voraussetzungen für die Zulassung von Geräten und Verfahren zumindest bis Kategorie 1 (CAT I) erarbeitet werden. Unterstellt man die Verfügbarkeit der MOPS

(Minimum Operational Performance Standards) für CAT III im Anschluß daran, so werden die technischen Voraussetzungen und institutionellen Konzepte für die Zulassungsfähigkeit derartiger Systeme auch für höhere Kategorien in der Folge erarbeitet.

Dieses Vorgehen berücksichtigend, hat im Auftrag des ISAN-Lenkungsausschusses des BMV die Projektgruppe "CESAR", bestehend aus Mitarbeitern der Organisationen

- Avionikzentrum Braunschweig (AZB)
- Deutsche Flugsicherung (DFS)
- Deutsches Zentrum für Luft- und Raumfahrt (DLR)
- Luftfahrt-Bundesamt (LBA)
- NFS Navigations- und Flugführungs-Systeme GmbH (NFS)
- Technische Universität Braunschweig (TU-BS)
- Technische Universität Dresden (TU-DR)

die Projektbeschreibung zur "Erarbeitung von Zulassungsverfahren für satellitengestützte Navigations- und Landesysteme" ausgearbeitet.

Der Luftfahrt kommt hier wegen der besonderen Systemanforderungen eine Vorreiterrolle zu. Darüber hinaus sind die Arbeitsergebnisse dieses Projektes auch auf andere Verkehrssysteme zu Land und zu Wasser erweiterbar. Hier bieten sich Anwendungen vor allem im Bereich der Verkehrsführung und Verkehrsüberwachung mit GNSS in Kombination mit der Datenkommunikation an.

5 Bisherige Arbeiten der NFS auf dem Gebiet der Satellitennavigation

Die NFS war bisher in folgende Aktivitäten eingebunden:

- Entwicklung und Installation einer DGPS-Bodenstation für den Münchener Flughafen, um Daten für eine RNP-Analyse des heutigen GPS zu erhalten und eine statistische Basis für Kollisionsrisiko-Berechnungen von GNSS-Landesystemen zu erzeugen.

- Entwicklung und Installation einer DGPS-Bordausrüstung für verschiedene Flugzeugtypen (z.B. A321, B757, BE200), um bordseitige Daten während der Anflüge auf den Münchener Flughafen zu sammeln und mit der gemessenen und aufgezeichneten Abweichungsinformationen aus den konventionellen ILS- und MLS-Bordempfängern zu vergleichen.

- Entwicklung und Betrieb eines Datenauswertungs- und Systemverifikations-Werkzeuges, um alle an Bord und am Boden gesammelten Daten hinsichtlich der Eigenschaft von DGPS-Bodenstationen und der zugehörigen Bordausrüstung zu bearbeiten.

- Entwicklung und Installation einer DGPS-„Autoland"-Ausrüstung an Bord von Testflugzeugen, um das Gebiet mehrkanaliger Autolandesysteme für Großraumflugzeuge zu untersuchen und den RAIM-Algorithmus für solche Systeme zu entwickeln, zu testen und zu validieren.

- Entwicklung und Produktion einer DGPS-Bodenstation nach RTCA 217 Special CAT I und Zulassung der Station durch die FAA.

- Entwicklung und Produktion eines kombinierten GPS- und GLONASS-Empfängers.

Bei den bodenbasierten Systemen konzentrierte sich NFS auf differentielle GNSS-Anforderungen und die Erzeugung und Nutzung von ADS-Daten.

6 Vorhabenbeschreibung

Das Vorhaben CESAR umfaßte folgendes Aufgabenspektrum:

- Erarbeitung von Betriebskonzepten,
- Definition von Systemanforderungen,
- Definition von Nachweis- und Auswerteverfahren,
- Experimenteller Nachweis,
- Einarbeitung der Ergebnisse in MASPS und MOPS.

Die verschiedenen Aufgaben wurden in einen Arbeitsstrukturplan gegliedert und gemäß der Kompetenz den Teilnehmen zur Bearbeitung zugeordnet.

6.1 Arbeitsstrukturplan

Der Arbeitsstrukturplan wurde zur weiteren Detaillierung in sieben Bereiche untergliedert. Diese Bereiche sind:

10.000	Institutionelle Aspekte und Konzepte
20.000	Systemanalyse
30.000	Strawman Proposal
40.000	Theoretische Nachweisführung
50.000	Experimentelle Nachweisführung
60.000	Zulassungsdokumente für GNSS-Navigations-/Landesysteme
70.000	Projekt Management

Die NFS führte das Gesamtarbeitspaket 30.000 und war an den Arbeitspaketen 50.000 und 60.000 beteiligt. Die Aufgabenstellungen an die NFS aus den verschiedenen Arbeitspaketen sind der nachstehenden Übersicht zu entnehmen.

6.2 Aufgabenstellung der NFS

30.000 Strawman Proposal

Da die wesentlichen Leistungsdaten neuer Systeme in den RTCA-Papieren (für Bordgeräte) bzw. EUROCAE-Papieren (für Bordgeräte und Bodenanlagen) festgelegt werden und diese Papiere die Basis für die Zulassung darstellen, sollte ein Entwurf dieser Dokumente erstellt werden. Dieser Entwurf stellte damit die Arbeitshypothese für die theoretische und experimentelle Nachweisführung dar. Dabei waren die wesentlichen Punkte

- Accuracy,
- Integrity,
- Availability und
- Continuity of Service

als sogenannte RNP-Parameter zu untersuchen. Es sollten sowohl die Leistungseckdaten als auch die Prüfverfahren definiert werden.

Voraussetzung für die Zulassung von Satellitennavigationsgeräten ist in Europa eine JTSO. Es war zu untersuchen, in welcher Weise vorhandene TSOs der FAA anwendbar sind. Der Entwurf für eine JTSO zur Vorlage bei der JAA als Basis für die Zulassung von Satellitennavigationssystemen war zu erarbeiten. Für das Raumsegment waren in diesem Rahmen "technische Anforderungen" und "Nachweisverfahren für die Systemleistungsdaten" zu spezifizieren.

Die NFS-Aufgabenstellung lautete im Detail:

AP : 30.000	**AP-Verantwortlicher :** NFS GmbH	**Strawman Proposal**
1. Ziel und Beschreibung: Ableitung von relevanten Leistungsdaten für ein GNSS-Landesystem unter Berücksichtigung der Anforderungen an heutige Landesysteme, wie ILS und MLS. Entwurf eines Strawman Proposal zur Definition von Minimum Operational Performance Specifications (MOPS) für GNSS Navigations- und Landesysteme (EUROCAE Dokument). Entwurf eines Strawman Proposal für eine Technical Standard Order (TSO) zur Zulassung von GNSS Navigations- und Landesystemen.		

AP : 32.000	**AP-Verantwortlicher :** NFS GmbH	**EUROCAE ED-Entwurf**

1. Ziel und Beschreibung:

- Strawman Proposal für ein Dokument EUROCAE ED „GNSS Navigation and Landing System“
- Definition der operationellen Randbedingungen
- Entwurf der Systemeckdaten
- Definition der Testverfahren

2. Voraussetzungen

Teilnahme an einer Arbeitsgruppe EUROCAE WG-28 zu GNSS Navigations- und Landesystemen

Vorlage eines nationalen Entwurfes aus AP 31.000

3. Aktivitäten /Lösungsweg

Erstellung eines EUROCAE-Entwurfes für GNSS-Landesysteme nach bekanntem Muster (ILS-, MLS-Vorlagen)

4. Entwicklungsstand/Ausgangsposition

Relevante Dokumente zu ILS, MLS und SCAT I, sowie RNAV mit GPS nach TSO C129

AP : 34.000	**AP-Verantwortlicher :** NFS GmbH	**Überarbeitung der Strawman Proposal**

1. Ziel und Beschreibung:

Überarbeitung des Strawman Proposal mit den Ergebnissen aus AP 40.000

2. Voraussetzungen

Ergebnisse der Arbeitspakete 40.000 und 55.000

50.000 Experimentelle Nachweisführung

Die Gesamtanlage, bestehend aus Bord- und Bodenelementen, war in einer definierten Testumgebung im Labor hinsichtlich ihrer Komplettfunktionalität zu überprüfen. Das Raumsegment wurde in geeigneter Weise simuliert, bzw. es wurde das aktuelle „Signal in Space“ (SIS) verwendet. Es wurden alle für die Nachweisführung relevanten Parameter untersucht und mit den Systemanforderungen verglichen.

Nach Abschluß der Labortests und einer Prüfung der Funktion des Gesamtsystems erfolgte die Nachweisführung im Flugversuch. Neben der Durchführung der präoperationellen Datensammlung fand eine gezielte Überprüfung bestimmter Grenzzustände im Flugversuch statt. Diese Grenzbedingungen werden im normalen operationellen Einsatz, d. h. im Linienflugverkehr, nicht erreicht und mußten daher gesondert untersucht werden. Die Erkenntnisse aus diesen betrieblichen Grenzzuständen stellten die Eckwerte für den operationellen Einsatz dar.

Die Mitnutzung von Anlagen und Geräten aus anderen Programmen, wie "ISAN" (Integrität bei Satellitennavigation) oder "Feldversuch ILS/MLS/DGPS München" wurde berücksichtigt.

Die Aufgabenstellung für NFS lautete im Detail:

AP : 51.000	**AP-Verantwortlicher :** NFS GmbH	**Realisierung der Boden- und Bordanlagen**

1. Ziel und Beschreibung:

Definition der Experimental-Systemauslegung sowie Anpassung und Bereitstellung von Gerätesätzen für:
- die Bodenanlagen eines GNSS-Landesystems,
- die Bordanlagen eines GNSS-Landesystems,
- die Datenkommunikation zwischen Bord und Boden.

Aufstellung eines Konzeptes für die Integration der Bordgeräte in das Versuchsflugzeug

2. Voraussetzungen

- Eckdaten von Boden- und Bordgerät
- Spezifikation der Funktionalität von Boden- und Bordgerät
- Spezifikation der Geräteintegration in das Versuchsflugzeug
- Berücksichtigung der Ergebnisse aus AP 22.000
- Testspezifikation aus AP 40.000
- Beistellung eines Lasertrackers und Inertialstützung durch AZB

3. Aktivitäten /Lösungsweg

- Spezifikation der Experimentalanlage mit den Komponenten Boden, Bord und Datenkommunikation
- Anpassung der Bord- und Bodengeräte an die jeweilige Test- und Integrationsumgebung
- Realisierung der notwendigen Installations-Infrastruktur am Boden und an Bord:
  - Schnittstellen
  - Einrüstsätze Bord, Datenaufzeichnung Bord
  - Shelter / Baumaßnahmen Boden

4. Entwicklungsstand/Ausgangsposition

Beistellung Prototyp Bodensystem mit den Fähigkeiten - Korrekturdatenermittlung
- Datenlink
- Datenaufzeichnung

Beistellung Prototyp Bordsystem mit den Fähigkeiten - Datenlink
- Navigationsrechner
- Datenaufzeichnung

Anmerkung: Die kursiv geschriebenen Unterpunkte des im folgenden beschriebenen Arbeitspakets 52.000 wurden im Verlauf des Vorhabens gegenüber der ursprünglichen Arbeitspaketbeschreibung konkretisiert.

AP : 52.000 AP : 52 100 AP : 52 200	**AP-Verantwortlicher :** NFS GmbH	**Benchtest**

1. Ziel und Beschreibung:

Durchführung des Benchtests nach Prüfrichtlinien aus AP 40.000

Untersuchungen zu ungewünschten Einstrahlungen aus zivilen Kommunikationssystemen (INMARSAT, Globalstar, Odyssey) nahe dem GPS/GLONASS-Frequenzbereich.

Validierung der Annahmen zur statistischen Verteilung von „Pseudorange Correction Bias Terms“ in „weighted LSQ position solution methods“.

Validierung der in DO-217 vorgeschlagenen „Protection Levels“ mit realen Meßdaten.

Untersuchung von Filterverfahren für Bord- und Bodenempfänger hinsichtlich des Fehlerverhaltens bei Verwendung unterschiedlicher Filter. Bestimmung der Spezifikationstiefe von Filtern für die MASPS.

2. Voraussetzungen

Definition der Prüf- und Auswerteverfahren
Verfügbarkeit der Bord- und Bodengeräte
Beistellung eines realtime-fähigen GPS-Simulators

3. Aktivitäten /Lösungsweg

Einrichtung einer Testbench für GNSS-Navigations- und -Landesysteme
Durchführung der Test- und Auswerteprozeduren sowie statischer Simulationen
Dokumentation der Testergebnisse
Beistellung und Integration einer 6-DF-Simulation

Entwurf eines Testplans zur Untersuchung der Störungen von Kommunikationsdiensten auf Basis GPS/GLONASS (Vorlage bei ICAO GNSSP Meeting, Oktober 1997).
Durchführung von Interference Tests auf der Bench.

Vergleich gemessener (simulierter) und mit verschiedenen Bias-Anteilen gerechneter Positionsdaten und Untersuchung der Genauigkeiten der verschiedenen Bias-Ansätze und Methoden. (Vorlage der Ergebnisse anläßlich ICAO GNSSP im Februar 1998)

Untersuchung und Vergleich von mit den bekannten Formeln bestimmten „Protection Levels“ unter Berücksichtigung realer Meßdaten (Korrekturdifferenzen und Standardabweichungen) von verschiedenen Orten. Vergleich von „Protection Level“ und zulässigem „Navigation System Error“ für ein CAT I-System. (Vorlage der Ergebnisse bei RTCA im September 1997).

Bestimmung der resultierenden Fehler bei Verwendung verschiedener Filter (Filter erster Ordung mit fester und/oder ansteigender Zeitkonstante und Filter zweiter Ordnung gemäß RTCA-Empfehlungen) und Nachweis des Fehlerverhaltens auf der Bench.

4. Entwicklungsstand/Ausgangsposition

Testprozeduren aus JTSO, EUROCAE-Entwurf für GNSS-Navigations- und -Landesysteme
RTCA DO-235

AP : 53.100	**AP-Verantwortlicher :** NFS GmbH	**Bodeninstallationen**

1. Ziel und Beschreibung:

Funktionsnachweis stationär
Funktionstest unter operationellen Bedingungen
Beistellung der Anlagen für die Zulassungsdokumente

2. Voraussetzungen

Beistellung der Geräte (Boden)

Testszenarien aus AP 40.000

3. Aktivitäten / Lösungsweg

Einrüstung der Bodenanlage, bestehend aus
- GPS-Station und GPS-Monitor
- DGPS-Datenlink und Link-Monitor
- Anlagensteuerung und Datenaufzeichnung
- geodätischer Vermessung der Referenzpunkte

4. Entwicklungsstand/Ausgangsposition

EMV- und VDE-Testvorschriften für das Bodensystem
Ergebnisse des DARA-Projektes „ISAN II“

AP : 53.200	**AP-Verantwortlicher :** NFS GmbH	**Bordinstallationen**

1. Ziel und Beschreibung:

Funktionsnachweis stationär
Funktionstests unter operationellen Bedingungen
Beistellung der Anlagen für die Zulassungsdokumente

2. Voraussetzungen

Beistellung der Geräte (Bord)

Testszenarien aus AP 40.000

3. Aktivitäten / Lösungsweg

Einrüstung der Bordanlage, bestehend aus GPS, GNSS-Landesystem und Datenlink
Vermessung der Bordanlage

4. Entwicklungsstand/Ausgangsposition EMV- und VDE-Testvorschriften für das Bordsystem (RTCA DO160) Ergebnisse des DARA-Projektes „ISAN II“

60.000 Auswertung und Vorschlag für Zulassungsdokumente

Mit den Ergebnissen der theoretischen und experimentellen Nachweisführung wurde das „Strawman Proposal“ überprüft und ergänzt. Aus der auf diesem Weg überprüften Arbeitshypothese wurde ein Dokument für ein EUROCAE ED für die Beratung in den jeweiligen europäischen Projektgruppen abgeleitet.

Die Aufgabenstellung für NFS lautete im Detail:

AP : 61.000	**AP-Verantwortlicher :** NFS GmbH	**EUROCAE ED**
1. Ziel und Beschreibung: Deutscher Beitrag zu EUROCAE ED für GNSS-Navigations- und -Landesysteme als Ergebnis des Programms zur Erarbeitung von Zulassungsverfahren derartiger Systeme 3. Aktivitäten / Lösungsweg Erstellung eines Dokumentes für GNSS-Navigations- und -Landesysteme analog zu EUROCAE EDs für den Bereich En-route, TMA, Approach, Landing und Departure		

7 Zu liefernde Ergebnisse

Die im Rahmen der Projektbearbeitung zu liefernden Ergebnisse gliedern sich in die Teile

- Dokumentenentwürfe
- Meßergebnisse
- Bereitstellung und Betrieb von Geräten (Bord und Boden).

In der Anlage zu diesem Bericht sind alle Dokumentenentwürfe und Meßberichte beigefügt. Die Teilnahme von NFS an den jeweiligen Arbeitsgruppen für die Erstellung der MASPS und MOPS ist der Aufstellung im Anhang 13.1 zu entnehmen.

8 Zeitlicher Ablauf

Die Arbeitsgruppe CESAR wurde im Januar 1994 durch eine Initiative des Luftfahrt-Bundesamtes, des Instituts für Flugführung der Technischen Universität Braunschweig, der Aerodata und der NFS Navigations- und Flugführungs-Systeme GmbH gegründet.

Im Juni des gleichen Jahres wurde dem INLS-Lenkungsausschuß des BMV ein Programmentwurf dieser Gruppe zur Erarbeitung von Zulassungsverfahren für satellitengestützte Navigations- und Landesysteme vorgestellt. Dieser Entwurf wurde auf Anregung des BMV, der Forschung und der Industrie inhaltlich überarbeitet und dem Koordinator des Luftfahrtforschungsprogramms im Mai 1995 zur Prüfung vorgelegt.

Die NFS Navigations- und Flugführungs-Systeme GmbH unterbreitete ihren Antrag auf Förderung der Erarbeitung von Zulassungsverfahren für satellitengestützte Navigations- und Landesysteme für die geplante Laufzeit vom 1.4.1996 bis zum 30.10.1997 dem Bundesministerium für Bildung, Wissenschaft, Forschung und Technologie am 14. März 1996.

Die Beauftragung erfolgte daraufhin mit dem Zuwendungsbescheid vom 30. Juli 1996 für den Projektzeitraum vom 1.7.1996 bis 31.12.1997.

Verschiedene Konkretisierungen der Aufgabenstellungen innerhalb der Arbeitspakete und die Anpassung des Vorhabenszeitplans an die internationalen Standardisierungsprozesse, aber insbesondere an die sich daraus ergebenden Anforderungen an die Systemvalidierung, erforderten eine Überarbeitung des Zeitplans. Mit dem Änderungsbescheid des Zuwendungsgebers vom 6.10.1997 wurde die Laufzeit des Vorhabens bis zum 31.12.1998 verlängert.

9 Beschreibung der Ergebnisse

Die Ergebnisse der NFS-Arbeitsanteile im Vorhaben lassen sich in zwei Bereiche einteilen. Aus den Aufgabenstellungen der Arbeitspakete 30.000 und 60.000 resultierten folgende Arbeitspapiere oder Beiträge zu den Arbeitspapieren:

- EUROCAE Discussion on RTCA GBAS Message Changes
- EUROCAE Alternative GBAS Messages Submitted to RTCA
- EUROCAE Time-to-Alert Proposal
- Fehlerdetektoren für GBAS Bodensysteme
- Draft ICAO GBAS Section A SARPS
- Draft ICAO GBAS Section B SARPS
- Draft EUROCAE GBAS MASPS
- Draft EUROCAE GBAS Ground System MOPS

Die vollständigen Papiere sind im Anhang unter Annex X 1 bis X 8 wiedergegeben.

Die in den Arbeitspaketen 50.000 geforderten Leistungen bezogen sich auf die Definition, Realisierung und Prüfung der Geräte und Systemkomponenten zur praktischen Untersuchung der DGPS-Funktionalität im realen Flugversuch und zur Validierung der in den theoretischen Ausarbeitungen definierten Systemleistungsdaten, soweit dieses über den Flugversuch zu erfolgen hatte.

9.1 Erläuterung der Arbeiten zu den Arbeitspaketen 30.000 und 60.000

Die Arbeiten aus den genannten Arbeitspaketen waren im wesentlichen an den laufenden Diskussionen in den RTCA- und EUROCAE-Arbeitsgruppen orientiert und lieferten jeweils Beiträge hierzu. Zusammenfassend ist die Entwicklung der internationalen Standardisierung auch unter Berücksichtigung der Arbeitsergebnisse des Vorhabens CESAR für das letzte Projektjahr nachfolgend dargestellt.

Die EUROCAE- und RTCA-Arbeitsgruppen kamen im Februar 1998 anläßlich der Arbeitsruppentagung der ICAO GNSSP in Neuseeland zu einer Einigung bezüglich der GBAS-Dateninhalte und Formate. Daraufhin konnte die RTCA SC-159 GW 4a ihre Entwürfe für die CATII / III MASPS und dazugehörende Interface Control Documents (ICD) vervollständigen. Allerdings wurden dabei wiederum Änderungen in den Dateninhalten vorgestellt. Die Arbeitsgruppe der ICAO GNSSP WG-B akzeptierte im August 1998 in Krasnoyarsk allerdings nur zwei dieser Änderungen.

Parallel dazu bearbeitete die RTCA-Arbeitsruppe wesentliche Anteile für die Bordgeräte-MOPS und die FAA legte erste Entwürfe für eine LAAS Ground Facility (LGF) Spezifikation vor. Es wurden dabei allerdings weitere Änderungen vorgenommen, die ihrerseits korrespondierende Änderungen in den MASPS und den ICAO SARPS nach sich zogen. Eine auch für die Arbeiten im Rahmen CESAR wesentliche Erkenntnis war die Einschränkung der MASPS, MOPS und ICD auf eine Anwendung für Landesysteme lediglich bis zur Betriebsstufe 1 (CAT I). Die von der Arbeitsgruppe CESAR bereits bei der Projektdefinition getroffenen Annahmen bezüglich der Arbeitsziele und Erfolgsaussichten (siehe Kapitel 3) wurden hierdurch bestätigt.

Etwa im gleichen Zeitraum intensivierte die EUROCAE-Arbeitsgruppe WG 28/2 ihre Aktivitäten und erarbeitete eine weitgehend ausgereifte Version ihrer MASPS. Die von der RTCA vorgestellten Änderungen ihrer MASPS veranlaßte die EUROCAE dazu, die Robustheit der zwischen RCTA und EUROCAE abgestimmten Dateninhalte nochmals zu prüfen. Als Ergebnis wurden von EUROCAE nun ebenfalls derart signifikante Änderungen vorgenommen, daß die beiden Entwürfe für die MASPS voraussichtlich zu einer deutlichen Verzögerung der Vorstellung der ICAO SARPS führen werden.

Beispiele für die Differenzen der beiden MASPS-Entwürfe sind im Anhang X1 und X3 dargestellt.

Neben diesen Aktivitäten in den Standardisierungsgremien fand sich eine Arbeitsgruppe der Gerätehersteller unter der Bezeichnung SCATMIG (The Special Category One Manufacturers Interoperability Group) zusammen, um eine Definition für den „Change 3“ bezüglich der Dateninhalte für ein Special Category I Landing System (SCAT I) gemäß RTCA DO 217 zu erarbeiten. Dieser „Change 3“ repräsentiert eine Kombination aus dem „Change 2“ und den Integritätskonzepten aus den RTCA MASPS vom Februar 1998. Dieser Entwurf wurde von der CESAR-Arbeitsgruppe als Basis für die Systemauslegung der Geräte und Anlagen für die Flugerprobungen verwendet (siehe hierzu auch Anhang X 4).

Die anhaltende Instabilität der MASPS hat die EUROCAE veranlaßt, die Arbeiten für die Boden- und Bordgeräte MOPS noch nicht zu beginnen. Das hatte allerdings erheblichen Einfluß auf die für CESAR geplanten Arbeiten und den ursprünglichen Zeitplan. Das Vorhaben konnte dennoch durch die Entscheidung der Arbeitsgruppe, die SCATMIG-Vorschläge als stabil anzusehen und für die Systemvalidierung zugrunde zu legen, im vorgesehen Zeitraum abgeschlossen werden.

Im Rahmen der Anlagenrealisierung wurde der „Message Type 4“, also die Übertragung der Wegpunkte des Anflugsegmentes (Final Approach Segment – FAS) softwaremäßig im Rahmen des Vorhabens ISAN II programmiert und für die Flugversuche CESAR in die Bodenanlage integriert. Hierbei ging die Arbeitsgruppe CESAR von der Annahme aus, daß dieses Datenelement in den Standards weitgehend stabil ist und sich nicht oder nur geringfügig ändern wird, zumal es für Bodenanlagen und Bordgeräte identisch ist. Allerdings wurden auch hierfür bereits von der FAA/Canadian Operational Group Änderungen für den FAS-Datenblock empfohlen. Einige Empfehlungen wurden von der EUROCAE aufgegriffen, andere nicht. Dies zeigt ein weiteres Mal in aller Deutlichkeit, wie schwierig eine Harmonisierung der Standards auf der Basis unterschiedlicher nationaler Forderungen ist.

9.2 Erläuterung der Arbeiten zu den Arbeitspaketen 50.000

Gemäß Aufgabenstellung der Arbeitspakete 50.000 wurden die Bord- und Bodengeräte und Anlagen realisiert, im Labor getestet und für die Flugerprobung in Braunschweig am Boden und an Bord eines Erprobungsflugzeugs der Technischen Universität Braunschweig, Institut für Flugführung, installiert. Hierbei sei darauf hingewiesen, daß die Versuchsanlagen durch Beistellung weiterer Geräte der Aerodata (Bord-Navigationssystem) und der TU Braunschweig (Navigation und Datenaufzeichnung) erweitert wurden. Die Beschreibung dieser Versuchserweiterungen erfolgt in den Abschlußberichten der genannten Partner.

9.2.1 Beschreibung der DGPS-Bodenstation

Basis für die im Projekt verwendete DGPS-Bodenstation bildete eine gemäß RTCA DO 217 bei der NFS entwickelte und von der FAA zertifizierte Anlage vom Typ D920-100. Diese Anlage wurde für die CESAR-Flugversuche im Datenlink um den „Message Type 4“ erweitert. Daneben wurden alle sonst stationär ausgeführten Anlagenteile (GPS- und VHF-Antennen) für die temporäre Installation ausgelegt (Modifikation der Kabel, Antennenstative).

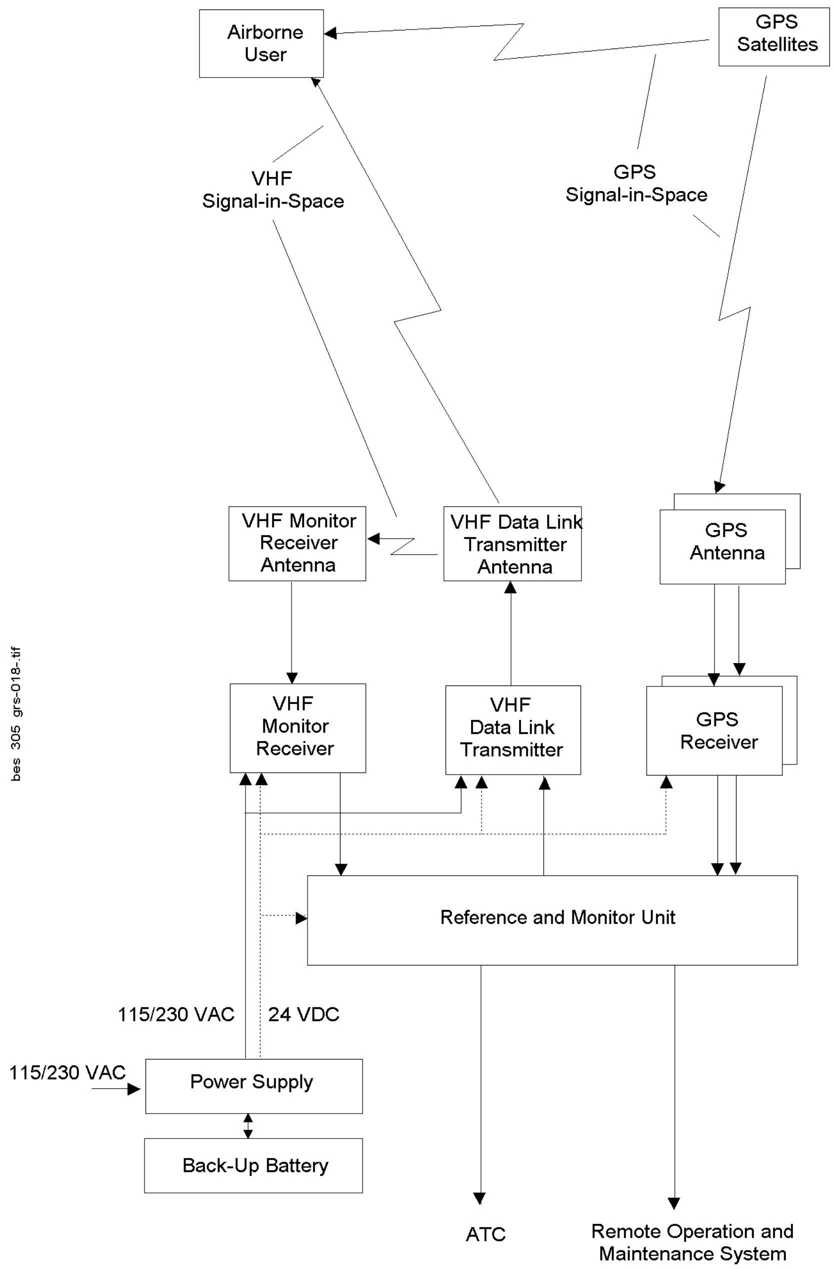

Abbildung 9.1 Blockschaltbild der DGPS-Bodenstation D920-100

Abbildung 9.2 DGPS-Bodenstation D920-100

9.2.2 Beschreibung der Bordgeräte

Für die Flugversuche wurde ein Bordgerätesatz, bestehend aus der Navigationseinheit, einem Datenlinkempfänger und einem Datenrecorder, aus vorhandenen, aber zum Teil für den Einsatz bei den CESAR-Flugversuchen modifizierten Geräten zusammengestellt. Alle wesentlichen Tests der Gesamtfunktionalität der Bord- und Bodenanlagen konnten damit im Labor durchgeführt werden. Die Modifikationen bestanden im wesentlichen aus Datenformatanpassungen wie der Lesbarkeit des „Message Type 4“ im Bordsystem und der Modifikation der Borddatenaufzeichung. Das nachfolgend dargestellte Blockschaltbild zeigt den Gesamtumfang der Bordanlage unter Berücksichtigung zusätzlicher Sensorinformationen aus einem Radarhöhenmesser und einem Inertialsystem. Diese Sensoren müssen im Rahmen von Systemvalidierungen nicht zwingend bei allen Systemeinrüstungen vorhanden sein.

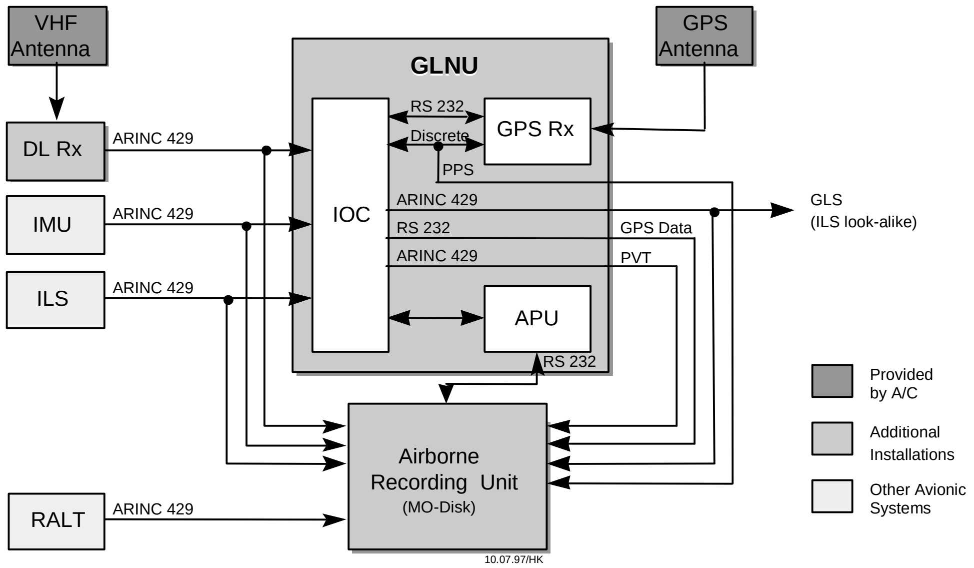

Abbildung 9.3 Blockschaltbild des Bordgerätesatzes für die Flugversuche CESAR

Der Blockstruktur liegen Anforderungen aus verschiedenen Flugerprobungsprogrammen zugrunde, die jeweils eine flexible Anpassung an verschiedene Sensoren zur Positionsstützung sowie verschiedene Ausgabeformate für Positions- oder Flugablageinformationen verlangen. Sowohl Eingangs- als auch Ausgangsschnittstellen sind an die gängigen ARINC-Standards angepaßt.

Abbildung 9.4 Datenrecorder, Navigationsempfänger GLNU und Datenlink-Empfänger VHF 900 (von links nach rechts)

Zur Datenaufzeichnung wurde ein von der Firma FieldWorks für den Einsatz im Flugbetrieb modifizierter PC zum Einsatz gebracht. Das Gerät besteht aus einem verzugsfesten Aluminiumrahmen, der den hohen Beschleunigungsanforderungen in der Luftfahrt genügt. Alle Kunststoffteile dieses Gerätes (Tasten, Platinen, Verkabelungen) müssen dabei die sehr strengen Auflagen der RCTA DO 160 C Umgegungsbedingungen bezüglich Entflammbarkeit und Rauchentwicklung erfüllen.

Als Navigationseinheit kam die von der NFS entwickelte GLNU (GPS Landing and Navigation Unit) zur Anwendung. Diese Einheit stellt ein Entwicklungssystem dar, das einerseits die hohen Luftfahrtanforderungen bezüglich DO 160 C erfüllt, andererseits aber in weiten Grenzen hinsichtlich der Vernetzung mit externen Sensoren (IMU, RALT) und der zu verarbeitenden DGPS-Korrekturdateninhalte weitgehend frei konfigurierbar ist.

9.2.3 Labortests

Flugversuche sind in der Regel sehr aufwendig, bedingt durch die Vorbereitungen der Einbauten, die Zulassung der Einbauten sowie die Verfügbarkeit des notwendigen Personals zur Versuchsdurchführung. Hinzu kommt die oft kritische Zeitplanung wegen der begrenzten Verfügbarkeit des Versuchsflugzeugs und die nicht kalkulierbaren Ausfallzeiten durch schlechtes Wetter. Umfangreiche Funktionstests im Labor sind deshalb unumgänglich, um später im Flugversuch Ausfälle durch Fehlfunktionen und damit verbundene Ausfallzeiten zu vermeiden. Hierzu ist ein Testbed erforderlich, das alle wesentlichen Funktion des Systems sowie alle notwendigen Senoranschlüsse und Ausgabeschnittstellen nachbildet. Ein derartiges Testbed zeigt das nachfolgende Blockschaltbild. Anzumerken ist hierbei, daß der GLONASS-Empfänger in diesem generischen Testbed nicht vom Simulator versorgt wird, sondern für GLONASS das „Signal-in-Space“ verwendet wird. Das dargestellte Testbed wurde für die Vorhaben ISAN und CESAR verwendet.

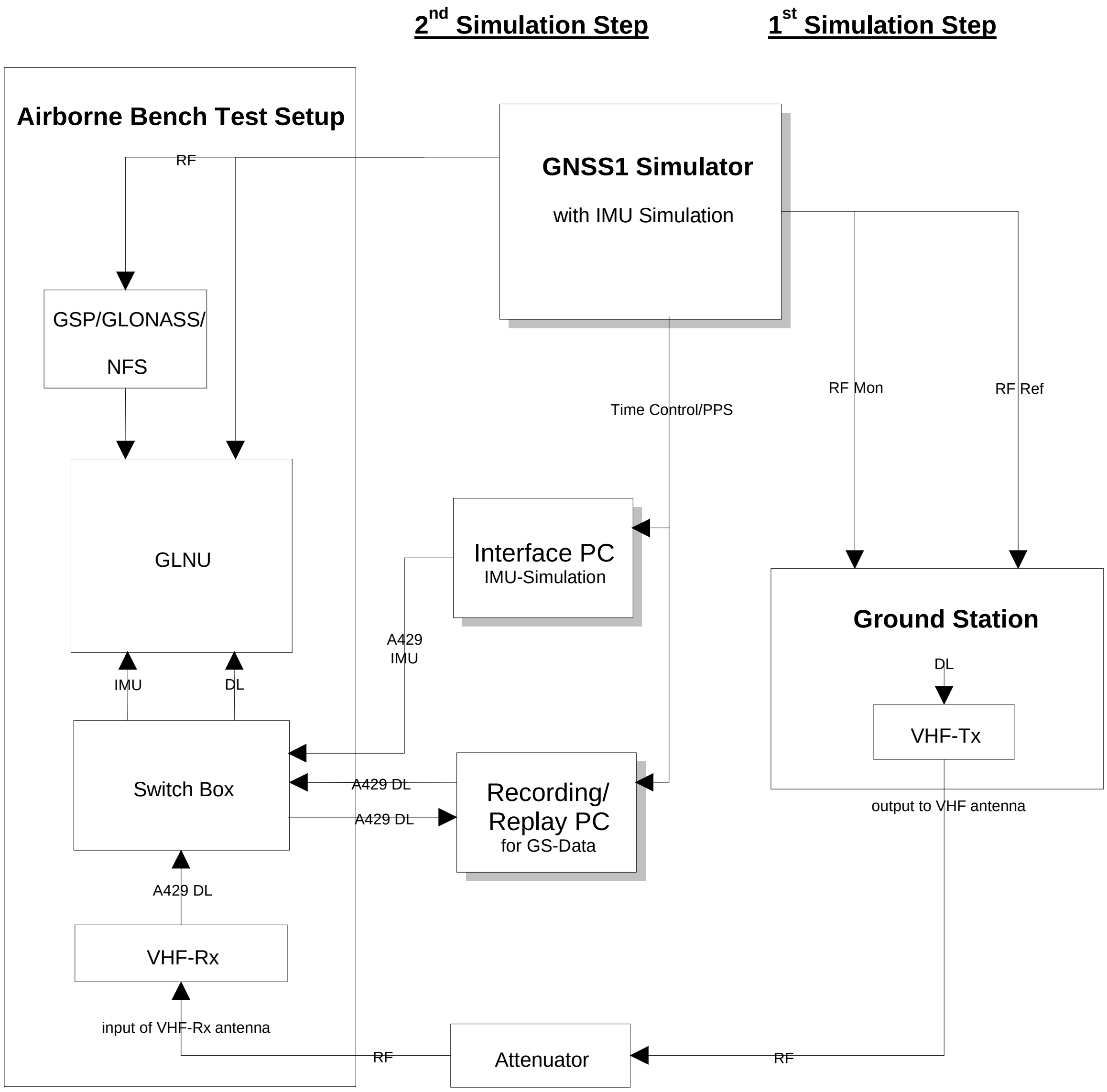

Abbildung 9.5 Blockschaltbild für ein generisches Testbed für GPS und GLONASS

9.2.4 Flugversuche

Neben den Untersuchungen der Systemkomponenten im Testbed führte NFS eingene Flugversuche zur Überprüfung aller Systemfunktionen unter realen Funkfeldbedingungen durch. Hierzu wurden die Bordgeräte in das NFS-Versuchsflugzeug, eine Piper PA 21 Navajo, eingerüstet und am Landeplatz Aalen Elchingen zusammen mit einer DGPS-Bodenstation getestet. Dabei wurden insbesondere der Datenlink nach Reichweite und Fehlerverhalten sowie die Datenausgabe auf einer Ablageanzeige (Horizontal Situation Indicator – HSI) untersucht. Die so geprüften Bordgeräte wurden im Anschluß an die Flugtests an die Technische Universität Braunschweig zur Durchführung der eigentlichen Flugversuche übergeben.

Abbildung 9.6 Geräteeinrüstung für Flugversuche (Flugzeug PA 31 der NFS)

9.2.5 Ergebnisübersicht der Arbeitspakete 50.000

9.2.5.1 Arbeitspaket 51.000

Gemäß Aufgabenstellung wurden alle Komponenten des Boden- und Bordsystems sowie die Datenkommunikation zwischen der Bodenstation und dem Bordsystem definiert und der Test- und Integrationsumgebung angepaßt. Es wurde ein Einrüstsatz (19"-Rahmen) für das Bordsystem hergestellt und die notwendigen Installationsmittel für den temporären Aufbau der Bodenstation in Braunschweig bereitgestellt.

9.2.5.2 Arbeitspaket 52.000

Neben den Basisfunktionen der Bodenstation und der Bordgeräte wurde im Testbed die Erstellung und Übertragung des „Message Type 4“ geprüft. Dabei wurde auch für die Übertragung der Wegpunktdaten für das Final Approach Segment (FAS) ein 32 bit CRC benutzt.

9.2.5.3 Arbeitspaket 52.100

Gemäß einem Vorschlag zum Integritätskonzept, der sowohl bei der RCTA- als auch bei der EUROCAE-Arbeitsgruppe diskutiert wurde, mußte der „Message Type 1“ für die CESAR-Versuchsanordnung geändert werden. Diese Änderungen betrafen die „Protection Levels“ und die „Alert Limits“. Daraus folgte, daß die „Alert Limits“ nun mit dem „Message Tye 4“ übertragen werden. Es sei allerdings darauf hingewiesen, daß die EUROCAE-Arbeitsgruppe diese Lösung anfangs nicht akzeptierte, da hierdurch eine hohe Variabilität der Bordanlage erforderlich ist, die an sich gegen eine einheitliche Auslegung der Bordanlage verstößt. Mittlerweile wird von beiden Arbeitsgruppen die Übertragung von ICAO-festgelegten Werten akzeptiert.

9.2.5.4 Arbeitspaket 52.200

Der internationale Kampf um Frequenzen und deren Schutz für bestimmte Dienste betrifft auch die Navigation mit GPS. Die Problematik der Störbarkeit von GPS und GLONASS durch Telekommunikationsdienste und militärische Funkdienste wurde untersucht und insbesondere für den GLONASS-Frequenzbereich wurden mit den Empfängern ASN 22 der NFS und GG 24 der Firma Ashtech Messungen zur Interferenz-Störempfindlichkeit durchgeführt. Der ausführliche Meßbericht befindet sich im Anhang.

9.2.5.5 Arbeitspaket 53.000, 53.100 und 53.200

Das NFS-Erprobungssystem wurde im September 1998 in Braunschweig installiert. Hierzu wurde eine DGPS-Bodenstation in den Räumen der Aerodata in Betrieb genommen. Die Bordgeräte wurden in das Versuchsflugzeug vom Typ DO 128 der Technischen Universität Braunschweig, Institut für Flugführung, eingerüstet. Neben den Bordgeräten der NFS wurden weitere Systeme zur Navigation und zur Datenaufzeichnung von der Aerodata und vom Institut für Flugführung bei der Versuchen geflogen. Die Ergebnisse der Flugversuche können dem CESAR-Abschlußbericht des IFF entnommen werden.

10 Zusammenarbeit mit anderen Partnern

Neben der sich aus dem Projekt und den jeweiligen Aufgabenstellungen der Projektpartner ergebenden Zusammenarbeit ist insbesondere ein projektübergreifender Kontakt außerhalb des Vorhabens zu nennen. NFS hat in Zusammenarbeit mit dem Landeplatz Cottub-Drewitz (EDCD) im Auftrag und mit Unterstützung durch das Ministerium für Stadtentwicklung und Verkehr des Landes Brandenburg ein Pilotvorhaben zur Untersuchung von DGPS am Landeplatz Cottbus-Drewitz durchgeführt. Im Rahmen dieses Projektes wurde in Drewtiz eine DGPS-Bodenstation für den Dauertestbetrieb installiert. Daten aus dieser Station konnten der Technischen Universität Dresden für vergleichende Datenanalysen zur Verfügung gestellt werden.

Daneben ist an dieser Stelle noch einmal die Gremienarbeit bei RTCA und EUROCAE durch NFS-Personal zu erwähnen (siehe hierzu auch Anhang : Teilnahme an Arbeitsgruppen).

11 Veröffentlichungen und Beiträge in internationalen Gremien

Veröffentlichungen und Beiträge wurden für die folgenden Gremien und Arbeitsgruppen erstellt:

ICAO-AWOG
ICAO GNSSP
AECMA EIAG
EUROCAE WG 28
RTCA SC 159
EUROCONTROL SNA, SRD, OCR, CBS

Vorträge wurden gehalten bei folgenden Veranstaltungen:

Global Navcom, Montreal 1995
European GNSS Symposium Munich 1997

Die Titel der Veröffentlichungen und Beiträge sind den Anhängen X 1 bis X 8 zu entnehmen.

12 Zusammenfassung

Der Standardisierungsprozeß innerhalb der RTCA und der EUROCAE ist weder innerhalb, noch zwischen den beiden Gruppen abgeschlossen. Die Arbeitsgruppe CESAR konnte, basierend auf den im Vorhaben erarbeiteten Erkenntnissen, effektive Beiträge in beide Gremien einbringen. Die Entwicklung der MASPS, MOPS, ICD und SARPS zeigt allerdings auch, wie langwierig der Prozeß ist und daß die Zeitplanung im Projekt trotz einer Verlängerung eher zu optimistisch war. So wird der Beschluß abgestimmter Standards leider außerhalb der Projektlaufzeit des Vorhabens CESAR liegen.

Um den Einfluß bei der Standardisierung von satellitenbasierten Landesystemen im internationalen Szenario nicht zu verlieren, sei an dieser Stelle dringend empfohlen, die mit dem Projekt CESAR begonnen Arbeiten in einem geeigneten Förderrahmen fortzusetzen.

Das Projekt CESAR hat gezeigt, daß es mit einem derartigen nationalen Zusammenschluß der Forschung, der Industrie sowie der DFS (als zukünftiger Dienstleistungsanbieter von GPS-basierten Verkehrsverfahren) und dem LBA (in seiner Zuständigkeit für die Zulassung von Luftfahrtgerät) gelingt, erheblichen Einfluß auf den internationalen Standardisierungsprozeß zu nehmen.

13 Anhänge

13.1 Teilnahme an Arbeitsgruppensitzungen

13.02.1995 GNSS-P WG B in London at INMARSAT
14.02.1995 GNSS-P WG B Meeting in London
15.02.1995 GNSS-P WG B Meeting in London
16.02.1995 GNSS-P WG B Meeting in London
17.02.1995 GNSS-P WG B Meeting in London
28.02.1995 AECMA EIAG Meeting in Brussels at AECMA
01.03.1995 SRD Meeting in Paris CDG
09.03.1995 DFS H. Bellen - GNSS Panel
10.03.1995 ITAEG-Air Guidelines drafting
21.03.1995 ITAEG-Air Meeting on Kim's List
27.03.1995 COM/OPS/DIV Meeting until 7.4.94
11.04.1995 ITAEG-Air
19.04.1995 SNA in Paris at ESA –A, Paris
20.04.1995 SNA in Paris at STNA
18.05.1995 SRD Meeting at NLR in Amsterdam
19.05.1995 SRD Meeting at NLR in Amsterdam
19.05.1995 ITAEG-Air
23.05.1995 Global Navcom in Montreal
24.05.1995 Global Navcom in Montreal
25.05.1995 Global Navcom in Montreal
30.05.1995 OCR TF Meeting in Rome
31.05.1995 OCR TF Meeting in Rome
07.06.1995 FCOT Meeting in Haren Brussels
08.06.1995 FCOT Meeting in Haren Brussels
08.06.1995 GNSS-P WG A&B Meeting in Stockholm
09.06.1995 GNSS-P WG A&B Meeting
12.06.1995 GNSS-P WG A&B Meeting
13.06.1995 GNSS-P WG A&B Meeting
14.06.1995 MMR Task Force, Brussels, DGVII
15.06.1995 GNSS-P WG A&B Meeting
16.06.1995 GNSS-P WG A&B Meeting
19.06.1995 GNSS-P WG A&B Meeting
20.06.1995 GNSS-P WG A&B Meeting
18.07.1995 DARA DGPS Koordinierungssitzung, Bonn
26.07.1995 MMR Plenary at DGVII
02.08.1995 Meeting with Jim Lawson
02.08.1995 Dougie Berndt Meeting (GEC Electronics)
03.08.1995 MMR Discussion with Collins
24.08.1995 OCR Meeting at LHR
25.08.1995 GNSS Panel preparation Meeting
07.09.1995 SRD in Ulm
07.09.1995 TEN - T ATM Meeting
08.09.1995 SRD in Ulm
20.09.1995 EUROCAE WG 28 in London
21.09.1995 EUROCAE WG 28 in London
26.09.1995 CIP Meeting
27.09.1995 CIP Meeting
27.09.1995 EACI Meeting in Haren
28.09.1995 EACI Meeting in Haren
28.09.1995 AECMA EqSG
02.10.1995 GNSS High Level Group
10.10.1995 MMR Meeting DGVIInd
10.10.1995 SNA Meeting in Haren
11.10.1995 SNA Meeting in Haren
24.10.1995 EUROCAE MMR WG-43
25.10.1995 EUROCAE MMR WG-43
26.10.1995 RTCA MOPS WG4 Precision Landing
06.11.1995 GNSS Ad Hoc Working Group
08.11.1995 GNSS Ad Hoc Working Group
14.11.1995 GNSS Panel 2 14.-24. Montreal
14.11.1995 ICAO GNSSP Members Meeting
15.11.1995 GNSS Panel 2 14.-24.
16.11.1995 GNSS Panel 2 14.-24.
17.11.1995 GNSS Panel 2 14.-24.
20.11.1995 GNSS Panel 2 14.-24.
21.11.1995 GNSS Panel 2 14.-24.
22.11.1995 GNSS Panel 2 14.-24.
23.11.1995 GNSS Panel 2 14.-24.
24.11.1995 GNSS Panel 2 14.-24.
28.11.1995 EUROCAE WG 28 in Paris at Eurocae
29.11.1995 EUROCAE WG 28 in Paris at Eurocae
30.11.1995 SRD TF in CAA House, Kingsway
01.12.1995 SRD TF in CAA House, Kingsway
07.12.1995 DGPS - DARA Meeting in Braunschweig
08.12.1995 DGPS - DARA Meeting in Braunschweig
13.12.1995 AECMA EqG Meeting in London
12.01.1996 EqG at AECMA in Brussels
23.01.1996 OCR 08 LBA (FAC) Frankfurt Airport
29.01.1996 IAG on SRD work in Pegasus contact Emma Berge 3143
29.01.1996 Dasa Team in Euroflat
30.01.1996 IAG on SRD work
31.01.1996 IAG on SRD work
01.02.1996 IAG on SRD work
02.02.1996 IAG on SRD work
08.02.1996 SRD TF in Germany
26.02.1996 GNSS WG in Nagoya
27.02.1996 GNSS WG
28.02.1996 GNSS WG
29.02.1996 GNSS WG
01.03.1996 GNSS WG
02.03.1996 GNSS WG
03.03.1996 GNSS WG
04.03.1996 GNSS WG
05.03.1996 GNSS WG
06.03.1996 GNSS WG
07.03.1996 GNSS WG
08.03.1996 GNSS WG
12.03.1996 AWOG in Paris
13.03.1996 AWOG in Paris
14.03.1996 AWOG in Paris
15.03.1996 AWOG in Paris
22.03.1996 BDLI - 5th Framework drafting in Stuttgart
27.03.1996 EACI Workshop preparation, review subm.
29.03.1996 AECMA EqG Meeting in Rom
10.04.1996 OCR TF 09 in Zurich
11.04.1996 OCR TF 09 in Zurich
18.04.1996 SRD Task Force in Brussels
23.04.1996 SNA Meeting in London
24.04.1996 SNA Meeting in London
20.05.1996 WG-D Meeting in Haren
21.05.1996 WG-D Meeting in Haren
22.05.1996 WG-D Meeting in Haren
23.05.1996 WG-D Meeting in Haren
24.05.1996 WG-D Meeting in Haren
04.07.1996 SRD TF in Toulouse
05.07.1996 SRD TF in Toulouse
09.07.1996 OCR10 in London Heathrow

10.07.1996 OCR10 in London Heathrow
23.08.1996 RLD Hoofdorf - Safety Case Impact Study
06.09.1996 Meeting on SRD Action Plan
09.09.1996 RTCA SC 159
10.09.1996 RTCA SC 159
11.09.1996 RTCA SC 159
15.09.1996 GNSSP Pre-Meeting
16.09.1996 GNSS WGs in Atlantic City
17.09.1996 GNSS WGs in Atlantic City
18.09.1996 GNSS WGs in Atlantic City
19.09.1996 GNSS WGs in Atlantic City
20.09.1996 GNSS WGs in Atlantic City
21.09.1996 GNSS WGs in Atlantic City
22.09.1996 GNSS WGs in Atlantic City
23.09.1996 GNSS WGs in Atlantic City
24.09.1996 GNSS WGs in Atlantic City
25.09.1996 GNSS WGs in Atlantic City
26.09.1996 GNSS WGs in Atlantic City
27.09.1996 GNSS WGs in Atlantic City
07.10.1996 SNA WG in Haren
07.10.1996 RTCA SC 159 WG4
08.10.1996 SNA WG in Haren
08.10.1996 RTCA Washington - Keith MacDonald
15.10.1996 OCR Meeting in Toulouse STNA
16.10.1996 OCR Meeting in Toulouse STNA
17.10.1996 EUROCAE WG 28
18.10.1996 EUROCAE WG 28
23.10.1996 ICCAIA CNS/ATM Committee in Toulouse
23.10.1996 CESAR in Offenbach
30.10.1996 SRD Meeting in Offenbach
12.11.1996 RTCA Meeting on FAA LARC in Anaheim
13.11.1996 RTCA Meeting on FAA LARC
13.11.1996 EUROCAE WG-43 in Toulouse
14.11.1996 RTCA Meeting on FAA LARC
14.11.1996 EUROCAE WG-43 in Toulouse
15.11.1996 RTCA overflow day.
15.11.1996 EIAG WG in Brussels at AECMA
20.11.1996 EUROCAE WG-28 in Toulouse at STNA
21.11.1996 EUROCAE WG-28 in Toulouse at STNA
22.11.1996 EUROCAE WG-28 in Toulouse at STNA
28.11.1996 LARC LAAS Presentation
02.12.1996 LARC LAAS continuation meeting
04.12.1996 CESAR Besprechung in Braunschweig
05.12.1996 George Ligler im Haus
06.12.1996 George Ligler im Haus
09.12.1996 Gremium und Standardisierungsarbeit
10.12.1996 Meeting with SEXTANT in Brussels at DB
16.12.1996 RTCA SC159 LARC assessment in Athens/Ohio
17.12.1996 RTCA SC159 LARC assessment in Athens/Ohio
18.12.1996 RTCA SC159 LARC assessment in Athens/Ohio
06.01.1997 RTCA Committee
07.01.1997 RTCA Committee
08.01.1997 RTCA Committee
09.01.1997 RTCA Committee
10.01.1997 RTCA Committee
14.01.1997 EUROCAE WG-28/2 in Stuttgart
15.01.1997 AECMA EqSG in Brussels
15.01.1997 EUROCAE WG-28/2 in Stuttgart
23.01.1997 SRD Meeting 12 in Rom
24.01.1997 SRD Meeting 12 in Rom
05.02.1997 OCR Meeting in Madrid
06.02.1997 OCR Meeting in Madrid
12.02.1997 CESAR Besprechung - Aerodata Braunschweig
16.02.1997 ICCAIA meeting
16.02.1997 Rapporteurs Meeting
17.02.1997 ICCAIA Breakfast Team Meeting
17.02.1997 GNSSP WGs in Brisbane
18.02.1997 GNSSP WGs in Brisbane
19.02.1997 GNSSP WGs in Brisbane
20.02.1997 GNSSP WGs in Brisbane
21.02.1997 GNSSP WGs in Brisbane
22.02.1997 GNSSP WGs in Brisbane
23.02.1997 GNSSP WGs in Brisbane
24.02.1997 GNSSP WGs in Brisbane
25.02.1997 GNSSP WGs in Brisbane
26.02.1997 GNSSP WGs in Brisbane
27.02.1997 GNSSP WGs in Brisbane
28.02.1997 GNSSP WGs in Brisbane
18.03.1997 WG-28 at EUROCAE in Paris
19.03.1997 WG-28 at EUROCAE in Paris
26.03.1997 CESAR Besprechung in Offenbach
02.04.1997 SNA in Toulouse at STNA
03.04.1997 SNA in Toulouse at STNA
07.04.1997 RTCA SC 159 Meeting
08.04.1997 RTCA SC 159 Meeting
09.04.1997 RTCA SC 159 Meeting
10.04.1997 RTCA SC 159 Meeting
11.04.1997 RTCA SC 159 Meeting
17.04.1997 SNA Group in Rome
18.04.1997 SNA Group in Rome
22.04.1997 European GNSS Symposium in Muenchen
23.04.1997 European GNSS Symposium in Muenchen
24.04.1997 European GNSS Symposium in Muenchen
25.04.1997 European GNSS Symposium in Muenchen
30.04.1997 WRC Preparation Meeting in Brussels
12.05.1997 RTCA SC-159 Sunnyvale
13.05.1997 RTCA SC-159
13.05.1997 OCR Meeting in Offenbach
14.05.1997 RTCA SC-159
14.05.1997 OCR Meeting in Offenbach
15.05.1997 RTCA SC-159
15.05.1997 EUROCAE WG-28/2
16.05.1997 EUROCAE WG-28/2
19.05.1997 ITU-R in Geneva
20.05.1997 ITU-R in Geneva
21.05.1997 ITU-R in Geneva
21.05.1997 OCR TF - GNSS/ATC Drafting Group in Haren.
22.05.1997 GNSS/Russia in Haren
26.05.1997 GNSSP WGs in Montreal
27.05.1997 GNSSP WGs in Montreal
28.05.1997 GNSSP WGs in Montreal
29.05.1997 GNSSP WGs in Montreal
30.05.1997 GNSSP WGs in Montreal
02.06.1997 GNSSP WGs in Montreal
03.06.1997 GNSSP WGs in Montreal
04.06.1997 GNSSP WGs in Montreal
05.06.1997 GNSSP WGs in Montreal
06.06.1997 GNSSP WGs in Montreal
09.06.1997 ITU WG-8D in Geneva
11.06.1997 CESAR Project Review in Ulm -12 people
16.06.1997 CESAR Project Review
24.06.1997 SCATMIG in Kansas City
25.06.1997 SCATMIG in Kansas City
26.06.1997 SCATMIG in Kansas City
01.07.1997 EUROCAE WG 28/2 in Chessington
02.07.1997 EUROCAE WG 28/2
03.07.1997 Dr. Drexler DARA PT-LF CESAR Workshop
09.07.1997 ESA GNSS-2 in Room Fresnel, Noordwijk, NL
10.07.1997 SRD TF Meeting in London
14.07.1997 RTCA Plenary in Washington
15.07.1997 RTCA Plenary in Washington
16.07.1997 RTCA Plenary in Washington
17.07.1997 RTCA Plenary in Washington
18.07.1997 RTCA Plenary in Washington
27.08.1997 OCR TF in Bretigny
28.08.1997 OCR TF in Bretigny
02.09.1997 EUROCAE WG-28/2 in Paris
03.09.1997 EUROCAE WG-28/2 in Paris

17.09.1997 CESAR Project Meeting in Offenbach
22.09.1997 RTCA/WG28 Meeting in Ulm
23.09.1997 RTCA/WG28 Meeting in Ulm
24.09.1997 RTCA/WG28 Meeting in Ulm
25.09.1997 RTCA/WG28 Meeting in Ulm
29.09.1997 ICAO GNSSP in Brussels
30.09.1997 ICAO GNSSP in Brussels
01.10.1997 ICAO GNSSP in Brussels
02.10.1997 ICAO GNSSP in Brussels
03.10.1997 ICAO GNSSP in Brussels
06.10.1997 ICAO GNSSP in Brussels
07.10.1997 ICAO GNSSP in Brussels
08.10.1997 ICAO GNSSP in Brussels
09.10.1997 ICAO GNSSP in Brussels
10.10.1997 ICAO GNSSP in Brussels
20.10.1997 AWOG in Paris
21.10.1997 AWOG in Paris
22.10.1997 AWOG in Paris
23.10.1997 AWOG in Paris
24.10.1997 AWOG in Paris
03.11.1997 EUROCAE WG28/8 in Toulouse
04.11.1997 EUROCAE WG28/8 in Toulouse
12.11.1997 RTCA / EUROCAE Requirements pre-meeting
13.11.1997 RTCA ICD meeting on SF
14.11.1997 RTCA ICD meeting on SF
17.11.1997 SCATMIG in Seattle
18.11.1997 SCATMIG in Seattle
26.11.1997 OCR TF in Noordrijk ESTEC
27.11.1997 OCR TF in Noordrijk ESTEC
02.12.1997 SRD Task Force in Frankfurt
08.12.1997 RTCA SC-159 in Washington DC
09.12.1997 RTCA SC-159 in Washington DC
09.12.1997 RTCA drafting group on messages
10.12.1997 RTCA SC-159
16.12.1997 EUROCAE WG-28/2 in London
17.12.1997 EUROCAE WG-28/2 in London
20.01.1998 Moscow GLONASS SARPS
21.01.1998 Moscow GLONASS SARPS
22.01.1998 Moscow GLONASS SARPS
23.01.1998 Moscow GLONASS SARPS
26.01.1998 RTCA WG 4a in Annapolis
27.01.1998 RTCA WG 4a in Annapolis
28.01.1998 RTCA WG 4a in Annapolis
28.01.1998 CESAR Besprechung in Braunschweig
29.01.1998 RTCA WG 4a
30.01.1998 RTCA WG 4a
03.02.1998 EUROCAE WG-28/2 in Toulouse
04.02.1998 EUROCAE WG-28/2 in Toulouse
11.02.1998 WG 28/3 in Toulouse
11.02.1998 SRD Meeting in Bretigny
12.02.1998 SRD Meeting in Bretigny
19.02.1998 SCATMIG Meeting at Raytheon
20.02.1998 SCATMIG Meeting at Raytheon
23.02.1998 GNSSP WGs in Wellington New Zealand
24.02.1998 GNSSP WGs in New Zealand
25.02.1998 GNSSP WGs in New Zealand
26.02.1998 GNSSP WGs in New Zealand
27.02.1998 GNSSP WGs in New Zealand
02.03.1998 GNSSP WGs in New Zealand
03.03.1998 GNSSP WGs in New Zealand
04.03.1998 GNSSP WGs in New Zealand
05.03.1998 GNSSP WGs in New Zealand
06.03.1998 GNSSP WGs in New Zealand
17.03.1998 AEA/ATA meeting in Brussels
19.03.1998 SCATMIG in Salt Lake City
20.03.1998 SCATMIG in Salt Lake City
23.03.1998 RTCA WG 4a in Salt Lake City
24.03.1998 OCR Meeting in Hoofdorff
24.03.1998 RTCA WG 4a
25.03.1998 OCR Meeting in Hoofdorff
25.03.1998 RTCA WG 4a
26.03.1998 RTCA WG 4a
27.03.1998 RTCA WG 4a
01.04.1998 WG-28/3 Meeting in Ulm
02.04.1998 EUROCAE Meeting in Ulm
03.04.1998 EUROCAE Meeting in Ulm
22.04.1998 EGNOS Ops Workshop in Brussels
27.04.1998 RTCA SC-159 Meeting
28.04.1998 RTCA SC-159 Meeting
29.04.1998 RTCA SC-159 Meeting
30.04.1998 RTCA SC-159 Meeting
01.05.1998 RTCA SC-159 Meeting
04.05.1998 Victor's editing group meeting
05.05.1998 Victor's editing group meeting
06.05.1998 Victor's editing group meeting
07.05.1998 Victor's editing group meeting
07.05.1998 CESAR in Ulm
18.05.1998 AWOG/4 in Brussels
19.05.1998 AWOG/4 in Brussels
20.05.1998 AWOG/4 in Brussels
26.05.1998 RTCA WG 4a in Minneapolis
26.05.1998 AEA GNSS-2 Workshop
27.05.1998 RTCA WG 4a in Minneapolis
27.05.1998 CESAR in Ulm
28.05.1998 RTCA WG 4a in Minneapolis
29.05.1998 RTCA WG 4a in Minneapolis
30.05.1998 RTCA WG 4a in Minneapolis
03.06.1998 WG-28/2 in Rome
04.06.1998 WG-28/2 in Rome
05.06.1998 WG-28/2 in Rome
17.06.1998 SRD TF at DLR
18.06.1998 SRD TF at DLR
22.06.1998 RTCA SC-159 in Cedar Rapids
23.06.1998 RTCA SC-159 in Cedar Rapids
24.06.1998 RTCA SC-159 in Cedar Rapids
25.06.1998 RTCA SC-159 in Cedar Rapids
26.06.1998 RTCA SC-159 in Cedar Rapids
10.07.1998 Offenbach - SARPS review -Hannover 1.3.45
21.07.1998 EUROCAE WG 28/2
22.07.1998 EUROCAE WG 28/2
23.07.1998 EUROCAE WG 28/2
17.08.1998 GNSSP WG-B in Krasnoyask
18.08.1998 GNSSP WG-B in Krasnoyask
19.08.1998 GNSSP WG-B in Krasnoyask
20.08.1998 GNSSP WG-B in Krasnoyask
21.08.1998 GNSSP WG-B in Krasnoyask
22.08.1998 GNSSP WG-B in Krasnoyask
23.08.1998 GNSSP WG-B in Krasnoyask
24.08.1998 GNSSP WG-B in Krasnoyask
25.08.1998 GNSSP WG-B in Krasnoyask
26.08.1998 GNSSP WG-B in Krasnoyask
27.08.1998 GNSSP WG-B in Krasnoyask
08.09.1998 Alcatel Espace Nanterre - GNSS-2
16.09.1998 EUROCAE WG 28/2 at LBA
17.09.1998 EUROCAE WG 28/2 at LBA
18.09.1998 EUROCAE WG 28/2 in Braunschweig
22.09.1998 Frequenzschutz in Offenbach
28.09.1998 RTCA - Ground spec. review
29.09.1998 RTCA - Ground spec. review
07.10.1998 SNA/10 at EUROCONTROL Haren
08.10.1998 SNA/10 at EUROCONTROL Haren
14.10.1998 CESAR Besprechung in Braunschweig
02.11.1998 RTCA SC-159 WG 4a in Washington
03.11.1998 RTCA SC-159 WG 4a in Washington
04.11.1998 RTCA SC-159 WG 4a in Washington
05.11.1998 RTCA SC-159 WG 4a in Washington
06.11.1998 RTCA SC-159 WG 4a in Washington
09.11.1998 GBAS WG in Washington

10.11.1998 GBAS WG in Washington
11.11.1998 GBAS WG in Washington
12.11.1998 GBAS WG in Washington
13.11.1998 GBAS WG in Washington
17.11.1998 EUROCAE WG 28/2 in Toulouse
18.11.1998 EUROCAE WG 28/2 in Toulouse
19.11.1998 EUROCAE WG 28/2 in Toulouse
07.12.1998 RTCA in Phoenix
08.12.1998 RTCA in Phoenix
09.12.1998 RTCA in Phoenix
10.12.1998 RTCA in Phoenix
11.12.1998 RTCA in Phoenix
12.01.1999 EUROCAE WG 28/2 in Roma
13.01.1999 EUROCAE WG 28/2 in Roma
14.01.1999 EUROCAE WG 28/2 in Roma
18.01.1999 RTCA SC-159 WG 4a in Seattle
19.01.1999 RTCA SC-159 WG 4a in Seattle
20.01.1999 RTCA SC-159 WG 4a in Seattle
21.01.1999 RTCA SC-159 WG 4a in Seattle
22.01.1999 RTCA SC-159 WG 4a in Seattle
25.01.1999 GNSSP WG-B in Kobe
26.01.1999 GNSSP WG-B in Kobe
27.01.1999 GNSSP WG-B in Kobe
28.01.1999 GNSSP WG-B in Kobe
29.01.1999 GNSSP WG-B in Kobe
30.01.1999 GNSSP WG-B in Kobe
31.01.1999 GNSSP WG-B in Kobe
01.02.1999 GNSSP WG-B in Kobe
02.02.1999 GNSSP WG-B in Kobe
03.02.1999 GNSSP WG-B in Kobe
04.02.1999 GNSSP WG-B in Kobe
05.02.1999 GNSSP WG-B in Kobe
04.03.1999 CESAR Präsentation

13.2 Interferenz-Störempfindlichkeit der GNSS-Empfängr ASN-22 und GG 24

Interferenz-Störempfindlichkeit der GNSS-Empfängr ASN-22 und GG 24

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Ulm, 17.2.98
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Interferenz-Störempfindlichkeit der GNSS-Empfänger: ASN-22 und GG24
- Testbericht zum GNSS-Frequenzschutz -

Zusammenfassung:

Eine kurze Beschreibung der technischen Eigenschaften von GNSS-Empfängern und das Empfangskonzept des ASN-22 wird gegeben. Ebenfalls erfolgt eine Beschreibung des Testaufbaus zur Messung der Interferenz-Empfindlichkeit des ASN-22-Empfängers (DASA-NFS) und des GG24-Empfängers (Ashtech).
Die Interferenz-Messungen werden mit dem Mathematik-Programm MATHCAD 6.0 ausgewertet und die Ergebnisse in mehreren Diagrammen als Funktion der Interferenz-Signalleistung, der Satelliten-Signalleistung und der Frequenz dargestellt. Im Anhang erfolgt noch eine Analyse der maximal erlaubten Interferenz-Signalleistung bzw. der Leistungs-Durchflußdichte an der Empfangsantenne.

Inhaltsverzeichnis Seite

1. Einleitung

Die bereits vorhandenen Satelliten-Navigationsempfänger für GPS und GLONASS, wie z.B. der ASN-22 (DASA-NFS), der GG24 (Ashtech) und der GNSS-300 (3S-Navigation), müssen geschützt werden, insbesondere vor den Interferenz-Störungen, die von den zur Zeit im Aufbau befindlichen Mobile Satellite Services (MSS, GLOBALSTAR, IRIDIUM, INMARSAT usw.) verursacht werden. So wird schon jetzt oder demnächst das GPS-L1-Band ab 1567 MHz abwärts und das GLONASS-L1-Band ab 1610 MHz aufwärts (derzeit GLONASS- Bandmitte bei 1609 MHz; erst ab dem Jahr 2005 eine Verschiebung zu tieferen Frequenzen geplant) durch die Seitenbänder dieser Dienste (1 bis 2 MHz Bandbreite, Spread Spectrum, teilweise CDMA) erheblich gestört.(Vorgesehen sind Störpegel bis zu -60 dBW/MHz der "Out-Band-Spurious").

Dazu wurden im Labor umfangreiche Vergleichsmessungen zwischen dem ASN-22-Empfänger und dem Konkurrenzempfänger GG24 der Fa. Ashtech ausgeführt. (Die Fa. Ashtech ist zur Zeit der Marktführer für kombinierte GPS-GLONASS-Empfänger in der USA). Hierbei zeigt sich, daß der ASN-22-Empfänger eine erheblich bessere Störfestigkeit für "Out-Band-Interferenzen", z.B. bei 1567 MHz - Beginn des INMARSAT-Down-Link-Bandes - von mehr als 40 dB gegenüber dem Konkurrenzprodukt GG24 aufweist.

In dem Bericht werden auch die Interferenz-Störleistungen für die Grenzfälle der Satelliten-Aquisition: "Tracking Lock" und "Tracking Loss" aus den gemessenen, effektiven Signal/Rausch-Verhältnissen $(S/No)_{eff}$ abgeleitet. Hierfür besitzt das effektive Signal/Rausch-Verhältnis $(S/No)_{eff}$ eine wesentliche Bedeutung für die Genauigkeit der Positionsbestimmung und für die Standardabweichung der "Pseudo-Range- und Carrier-Phase-Messung". Gleichermaßen bestimmt das $(S/No)_{eff}$ die "Bit-Error-Propability-Rate" (BER) der Navigations-Daten. Alle diese und weitere kritische Parameter werden aus den Messungen des $(S/No)_{eff}$ abgeleitet.

2. Technische Eigenschaften der GNSS-Empfänger

Da die Eigenschaften und Spezifikationen des GG24-Empfängers von Ashtech (simultaner Empfang und Auswertung von 12 GPS L1-Signalen und 12 GLONASS L1-Signalen) im wesentlichen vergleichbar mit denen des ASN-22-Empfängers sind, wird deshalb hier nur auf das ASN-22-Konzept und auf dessen Empfängerstruktur Bezug genommen. So gibt es trotz einiger größerer Unterschiede in der Empfänger Architektur der RF-FRONTEND's zwischen ASN-22 und GG24 kaum Unterschiede in der Navigationsauswertung und Genauigkeit der beiden Systeme (nur Ausnahme bei der Interferenz-Störfestigkeit).

Um die Vorteile einer kombinierten Satelliten-Navigation mit GPS und GLONASS vor allem für die Luftfahrt zu nutzen, hat zu Beginn des Jahres 1995 die Firma Daimler-Benz Aerospace (DASA) Navigation and Flight Guidance Systems (NFS) in Ulm und das Institut Russian Institut of Radionavigation and Time (RIRT) in St. Petersburg, Rußland, beschlossen in Zusammenarbeit ein hochintegriertes, kombiniertes GPS-GLONASS-Empfängermodul für die zivile Luftfahrt zu entwickeln. RIRT ist schon seit mehr als 30 Jahren in Rußland führend auf dem Gebiet Navigations- und Zeitstandard-Systeme. Insbesondere die ersten russischen GLONASS-Empfänger, die bereits die direkten Vorläufer des jetzigen ASN-22 darstellen, wurden von RIRT entwickelt (ASN ist die Abkürzung der russischen Bezeichnung für Apparatus for Satellite Navigation) . Folglich ist die Empfänger-Entwicklungsgruppe in St. Petersburg eingebunden in die ASN-22-SW-Entwicklung bei der DAVIA, eine "Joint Venture Company" zwischen der DASA-NFS und Aviapribor Corporation in Moskau.

Der innerhalb dieser Kooperation entwickelte ASN-22-Empfänger ist ein hochwertiges, vielkanaliges Empfängermodul (Karte), das zum unabhängigen Empfang und Signalnachführung (Tracking) des C/A-Codes sowie der L1-Träger-Phase (L1 Carrier Phase) von bis 12 GPS- und 6 GLONASS-Satelliten (künftig erweiterbar bis zu 12 GLONASS-Satelliten) geeignet ist. Wie in Fig. 1 aufgezeigt wird, besteht es aus einer austauschbaren Baugruppe, die alle Funktionen ausführt, die für den Empfang, Nachführung, Demodulation, Decodierung und Auswertung der GPS-und GLONASS-Satelliten-Signale notwendig sind. Jedoch ist hiervon die Antennen- und Vorverstärker-Funktion für das direkte Empfangssignal nicht enthalten (eine standardmäßige, aktive GPS-GLONASS-L1-Antenne wird mitgeliefert !). Der ASN-22-Empfänger besitzt eine hohe Empfangsempfindlichkeit (< - 160 dBm/Hz), eine sehr gute Interferenzstörfestigkeit, eine ausgezeichnete "Code- und Phase-Tracking-Genauigkeit " sowie eine schnelle Aquisition bzw. Neu-Aquisition der Satellitensignale nach dem Einschalten bzw. nach Empfangsunterbrechungen. So erfüllt der ASN-22-Empfänger alle Anforderungen nach den Vorschriften TSO-C-129 A (non-differential) und RTCA DO-217 (differential). Ebenfalls wurde die ASN-22-Software in Übereinstimmung mit dem Dokument RTCA DO-178 B entwickelt. Damit ist der ASN-22-Empfänger sowohl für differentielle als auch für nichtdifferentielle Satelliten-Navigation in Luftfahrtsystemen und gleichermaßen in Boden-Referenzstationen geeignet. In Tabelle 1 werden die wesentlichen Spezifikationen des ASN-22 aufgeführt.

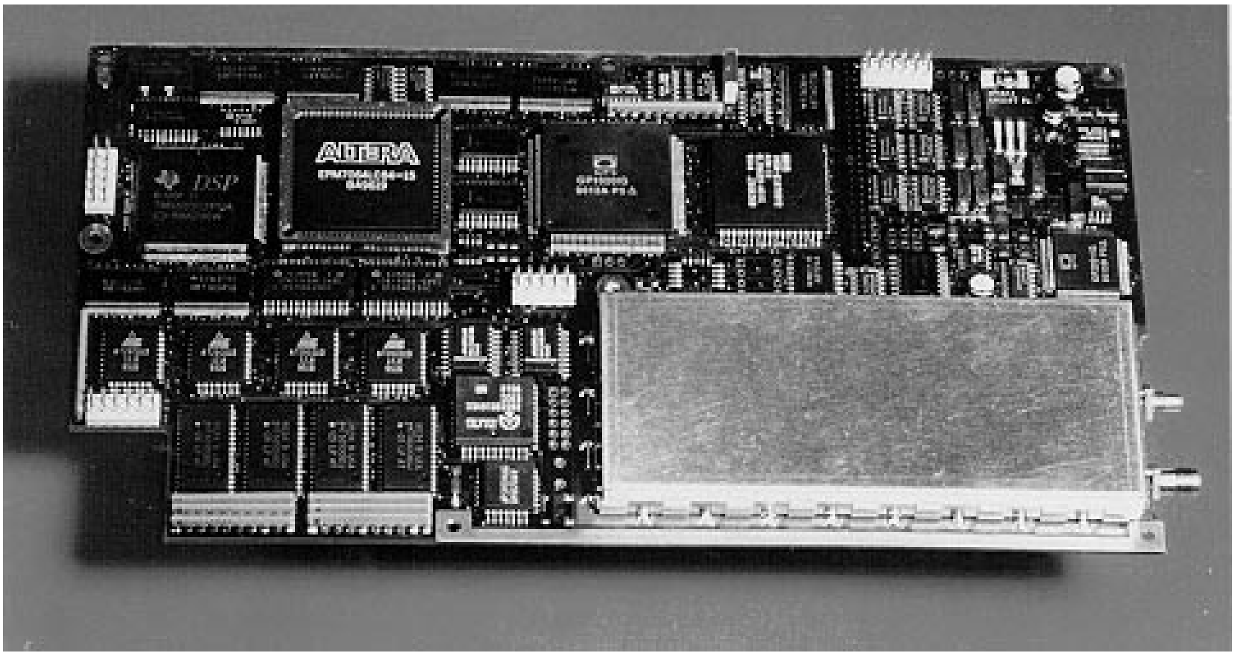

Fig. 1   ASN-22 GPS-GLONASS-Empfänger-Modul (Standard PCB-Technik)

General Features

Number of channels: 12 GPS, 6 GLONASS, (growth to 12 GLONASS channels)

Operating Frequency: GPS: L1 (1575.42 MHz), GLONASS:L1(1602-1616MHz)
(L1 C/A code and carrier phase tracking)

Navigation Outputs: PVT, 1 Hz rate, sync. to UTC reference marker pulse, one-second rollover

Raw Data outputs: Pseudo-range, integrated carrier phase measurements, almanac, ephemeris

Navigation modes: GPS only, GLONASS only, GPS+GLONASS (selectable via external command)

Performance Characteristics

Navigation accuracy: in compliance to TSO-C129A (non-differential) and RTCA DO-217 (differential mode)

TTFF: < 3.5 min (cold start),   < 90 s (warm start)

Reaquistion Time :   outage time: < 5s, max. 5s (full-court re-aquisition),
max. 3s (partial re-aquisition)

Max. dynamics: 800 knots ground speed, 4g acceleration, 0.8g/s jerk,

Sensitivity: < -130dBm, 37 dBHz (aquisition), < -134dBm, 34dBHz (tracking)

Integrity Monitoring:

Function.: RAIM, PRAIM (in compliance to TSO-C129A and RTCA DO-208, 217) , BITE

Operating Temp.: -40 C ... +70 C

Storage Temp.: -55 C ... +85 C

Electrical Characteristics

Power supply: +5V DC; +12V DC (100mA for Antenna LNA supply only)

Power consumption: ca. 5.5 W

Communication Interface: 1 serial (RS232), 19.2 -57.6 kBaud

Dimensions and Weight

Mechanical outlines: ca. 120x220x20 mm, weight < 240 g

Tabelle 1 Die wesentlichen, technischen Spezifikationen des ASN-22-Empfängers

In dem folgenden Abschnitt wird eine kurze Übersicht der ASN-22-Empfängerstruktur gegeben.

3. Das ASN-22-Empfänger-Konzept

Die Struktur des ASN-22 wird in Fig. 2 aufgezeigt. Das ASN-22-Empfängermodul kann grob in drei Funktionsgruppen, in das RF-FRONTEND, in die digitale Signal-Verarbeitungseinheit und in den Navigations-Rechnerkern aufgeteilt werden. In dem RF-FRONTEND erfolgt nach der Bandbegrenzung des Antennensignals im "Image Rejection Filter" (Spiegelfrequenz-Unterdrückung) und anschließender Signalverstärkung mit einem "Low Noise Amplifier" (LNA) die Trennung des Empfangssignals zur Weiterverarbeitung mittels eines "Power Splitter" in einen unabhängigen GPS-Zweig und in einen unabhängigen GLONASS-Zweig. In beiden Zweigen werden hochintegrierte "RF-Chips" zum Abwärtsmischen in eine niedere Zwischenfrequenz (GPS-ZF bei 4,31 MHz und GLONASS-ZF bei 70 MHz) und zur deren Signalfilterung (mehrkreisige LC-Filter und SAW-Filter) eingesetzt. Die Gesamtfilterung der Satelliten-Empfangssignale ist nach dem Dokument ARINC 743 A vor allem so dimensioniert, daß die Interferenzstörungen der Satelliten-Telekommunikations-Dienste an den Bandgrenzen und außerhalb des gemeinsamen GPS-GLONASS-Bandes minimisiert werden. Da bei GLONASS zur Kennzeichnung der Satellitenkanäle "Frequency Division Multiplex Access" (FDMA) verwendet wird, d.h. die Signale von verschiedenen SV's sind bei leicht unterschiedlichen, benachbarten Bandmittenfrequenzen angeordnet, ist im GLONASS-Prozessor-Zweig zur frequenzmäßigen Trennung der Satelliten-Kanäle ein sogenannter 6-kanaliger "Digital Down Converter" (DDC) der 70 MHz-GLONASS-ZF, realisiert als ein ASIC-Baustein, vorgesehen. Hiermit erfogt bei den GLONASS-Signalen die letzte Abwärtsmischung und Filterung rein digital (Digitaler Empfänger). Außerdem verringern sich erheblich bei diesem Konzept der digitalen Kanalseparierung im GLONASS-FRONTEND die Gruppenlaufzeit-Schwankungen (GD-Ripple) und ähnliche Signallaufzeit- und Phasen-Fehler der Satelliten-Signale beim Durchlauf durch das RF-FRONTEND. Letztlich werden für die Quantisierung und Abtastung (Digitalisierung) der analogen ZF-Signale sowohl für GPS als auch GLONASS 2 bit A/D-Umsetzer in Verbindung mit einer "Automatic Gain Control" (AGC) eingesetzt, die für die Quantisierung dieser "Spread-Spectrum-Signale" eine Degradation des Signal-Rausch- Verhältnisses (SNR) von nur ungefähr 0,56 dB ergeben. Hiermit wird ein guter Kompromis zwischen Hardware-Aufwand und Interferenz-Störfestigkeit bei dem Empfänger erreicht.

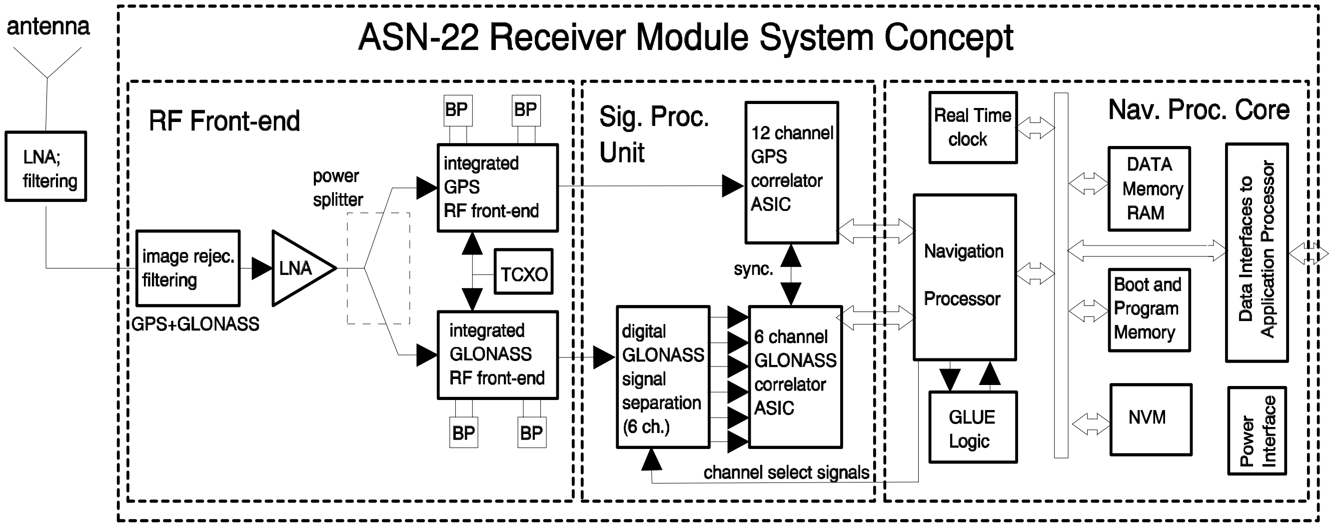

Fig. 2 Die ASN-22 Empfänger-Modul-Struktur

Die 2 bit Ausgangssignale der beiden A/D-Umsetzer werden dann getrennt der digitalen Signal-Verarbeitungseinheit, einschließlich des oben erwähnten DDC's (ASIC), zugeführt, die im wesentlichen besteht aus hochintegrierten 12-Kanal-GPS-und 6-Kanal-GLONASS-Korrelatoren in Form von weiteren ASIC's. Hierbei ist das DDC-ASIC dem GLONASS-Korrelator-ASIC zur simultanen Auswahl von jeweils 6 unabhängigen L1-Kanalsignalen vorgeschaltet, die parallel in der gleichen niederen ZF-Lage von ca. 1,43 MHz am Korrelator anliegen. (Die GLONASS-ZF-Lage entspricht hier dem unteren Abtast-Halbband der GPS-ZF-Lage des GPS-Korrelator-Inputs; daher sind vom Prinzip gleichartige Korrelator-Schaltkreise mit einer Abtastfrequenz von 5,71 MHz einsetzbar .) So erfolgt für jedes empfangene und in Kanäle selektiertes GLONASS-Signal simultan die Signalnachführung (Tracking) der Trägerfrequenz (Carrier), der Träger-Phase (Carrier Phase) und der C/A-Code-Phase durch interaktive Regelschleifen (FLL, PLL und DLL). Anzumerken ist, daß die Einstellungen (Regel-Parameter) dieser Regelschleifen gemäß der Signalverarbeitungs-Ergebnisse im Navigations-Prozessor den momentanen Empfangsbedingungen optimal angepasst werden, d.h. es werden bestimmt die Schleifen-Einrast-Schwellen, die Diskriminator-Auswertungs-Schwellen, die Schleifenfilter-Bandbreiten, die Regelzeit-Konstanten sowie die Code-Phasen- und Trägerfrequenz-Erzeugung in den DCO's. Dies ist natürlich mittels der Navigations-Software des Navigationsprozessors voll programmierbar.

Jeder einzelne Kanalausgang des Korrelator-ASIC's liefert somit die Digitalsignale, die notwendig sind für die Rohdatenberechnung, wie z.B. die "Pseudo-Range" abgeleitet aus der "Code-Phase", die integrierte "Carrier-Phase" oder "Delta-Range" und die Navigations-Daten für "Subframes/Lines". Mit dem Navigations-Prozessor TMS320C31 werden anschließend die Rohdaten so aufbereitet um sie in der Navigations-Endberechnung verwenden zu können. Insbesondere müssen im kombinierten GPS-GLONASS-Betrieb die unterschiedlichen Zeitbasen (GPS: UTC[USNO], GLONASS: UTC[SU]) und die Bezugskoordinaten-Systeme (GPS: WGS-84, GLONASS: PE-90) für die Positions-, Geschwindigkeits- und Zeit-Berechnungen voll berücksichtigt werden. Außerdem führt der Navigations-Prozessor eine erweiterte "Integrity-Monitoring-Berechnung" (RAIM, PRAIM, BIT usw.) und eine Navigationsparameter-Vorgabe aus, die zur Initialisierung der Signalkanäle in der Signal-Prozessor-Einheit benötigt wird.

Zusätzlich zum Navigations-Prozessorkern in Verbindung mit der "GLUE Logic" besitzt der ASN-22 einen "Real Time Clock", einen Datenspeicher (RAM), einen programierbaren Daten-Speicher (PROM), einen nichtflüchtigen Datenspeicher (NVM) sowie eine Schnittstelle (Interface) zur Stromversorgungs-Einheit und zu dem externen Applikations-Prozessor (AP), der zur Steuerung, Aufbereitung und Darstellung der Navigations-Ergebnisse (Terminal) dient. Hierbei kann der AP per Software auf einem herkömmlichen "Windows- Personal-Computer/Laptop" installiert werden. Der ASN-22 kommuniziert mit dem externen AP über ein serielles Daten-Interface (RS232) mit einer Baud Rate von 19,2 bis 57,6 kBaud. Zusätzlich zu dem externen Kommunikations-Interface und dem Stomversorgungs-Interface enthält der ASN-22 noch weitere Signal/Steuerungs-Ein- und Ausgänge, die in Fig. 3 genauer aufgezeigt werden.

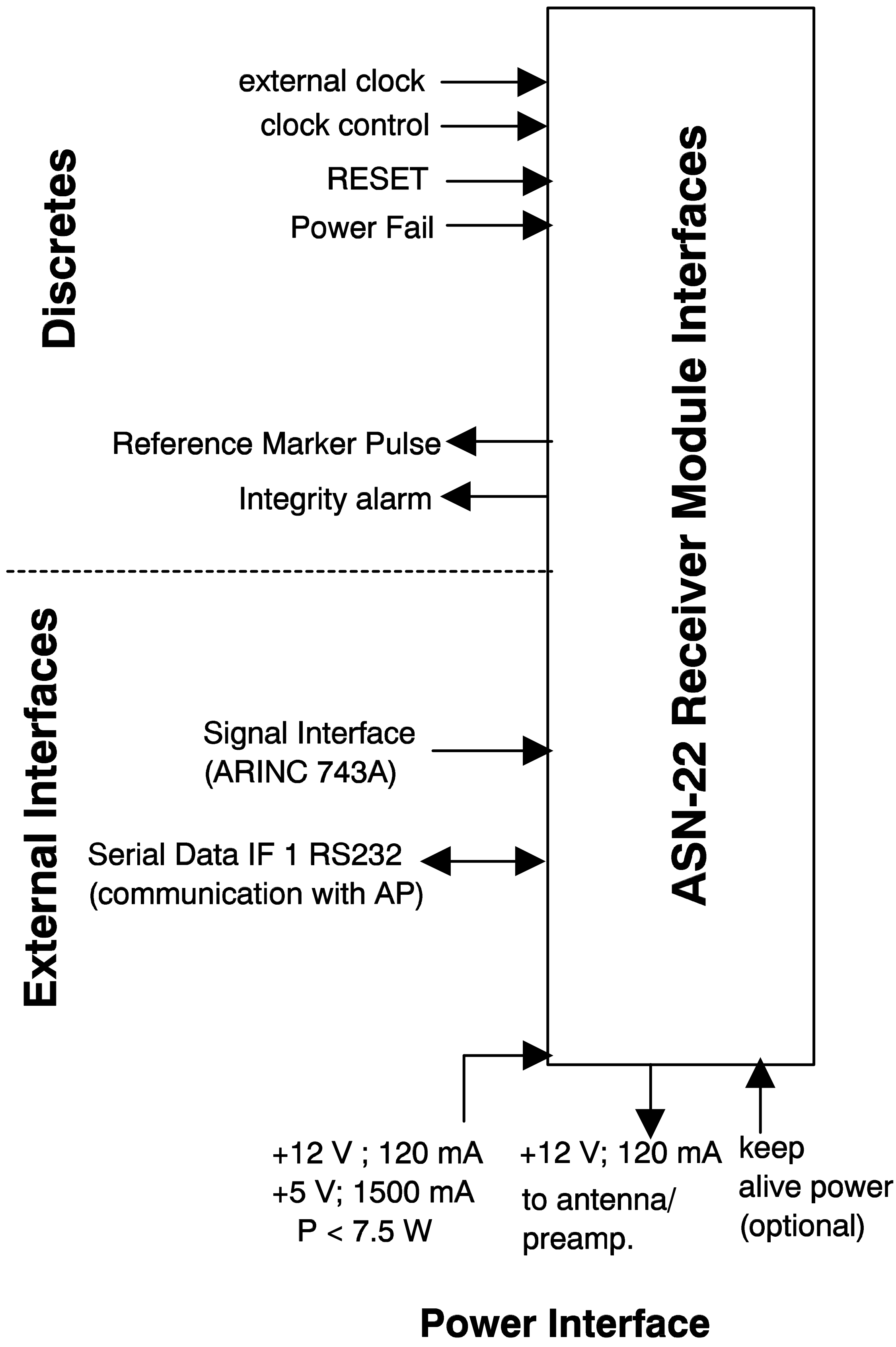

Fig. 3 Signalbelegungen der ASN-22 Schnittstelle (Interface)

4. Messungen der Interferenz-Störempfindlichkeit

4.1 Definition der kritischen Empfänger-Parameter

Die Empfangsqualität der Satelliten-Signale s(t) wird eindeutig durch das Signal/Rausch-Verhältnis S/N bestimmt. Die Rauschleistung N ist in der Regel proportional zu der Bandbreite B. Die Bandbreite des "Delay-Lock-Loop" (DLL), des "Carrier-Lock-Loop" (FLL/PLL) und des Daten-Diskriminators sind unterschiedlich, können jedoch mittels der Software an die erforderliche Empfangsdynamik angepaßt werden. Deshalb ist es üblich das S/N auf eine Bandbreite von 1 Hz zu beziehen, um so mit einem Signal/Rauschdichte-Verhältnis S/N_0 rechnen zu können.

Innerhalb der Bandbreite der "Tracking Loops" und des Daten-Diskriminators (1 Hz bis 100 Hz) sind die Leistungsdichte-Spektren S(f) der Satelliten-Signale s(t) und die Leistungsdichte-Spektren I(f) der Interferenz-Signale i(t) weitgehend unabhängig von der Frequenz ("Spread Spectrum") und besitzen somit fast konstante Werte von S/f_c bzw. von I/f_c (f_c = "Chip-Clock-Frequenz"), die den Maximalwerten S(0) oder I(0) der normierten $SINC^2$-förmigen Spektren wie folgt entsprechen:

$$S(f) = T \cdot \frac{\sin(\pi \cdot f \cdot T)^2}{(\pi \cdot f \cdot T)^2} \qquad \text{mit} \qquad T = \frac{1}{f_c}$$ ... Signal-Leistungsdichte-Spektrum (1)

$$S(0) = P_s \cdot T = \frac{P_s}{f_c}$$ ... Maximalwert der Signal-Leistungsdichte (2)

$$I(f) = \int_{-\infty}^{\infty} S(f_0) \cdot I(f - f_0)\, df_0$$ ... Inband-Interferenz-Leistungsdichte-Spektrum (3)

$$I(0) = \int_{-\infty}^{\infty} S(f_0) \cdot I(-f_0)\, df_0$$ ... Maximalwert der Inband-Interferenz-Leistungsdichte (4)

Da das Spektrum des thermischen Rauschens über alle Frequenzen nahezu konstant ist, kann das Interferenz-Signal i(t), das mit dem PN-Code in dem DLL multipliziert (gespreizt) wird, als ein künstlich erzeugtes, zusätzliches Rauschen der Rausch-Leistungsdichte von I/f_c im Spektrum betrachtet werden. Die Amplitudenwerte des thermischen und des künstlichen Rauschens sind zueinander unkorreliert. Deshalb dürfen ihre Leistungsdichten direkt addiert werden, um so die Gesamtleistungsdichte zu erhalten. Die Wirkung des additiven Rauschens auf die Empfangsqualität kann somit am besten mit dem sogenannten, effektiven Signal/Rausch-Dichten-Verhältnis beschrieben werden:

$$\left(\frac{S}{N_{eff}}\right) = \frac{S}{N_0 + I_0} \qquad (5)$$

Hierbei gilt für die künstlich erzeugte Rausch-Leistungsdichte I_0:

$$I_0 = \frac{P(f_I) \cdot I(0)}{f_c} \qquad (6)$$

wobei $P(f_I)$ die Gesamtübertragungsfunktion (Hüllkurve) der Signalleistung darstellt.

Eine weitere sehr nüztliche Rechengröße ist der sogenannte Prozeßgewinn G der PN-Code-Korrelation innerhalb der DLL . Er gibt den Verbesserungsfaktor der Signalleistungsdetektion gegenüber dem reinen Rauschpegel an, d.h. er ist ein Maß um wieviel die Nutzsignal-Leistung nach der Korrelation über die Rauschsignal-Leistung angehoben wird. Der Prozeßgewinn G von "Spread-Spectrum-Systeme" ist in der Regel durch die Relation zwischen der Bandbreite B_C der gespreizten Signalleistung P_c und der Bandbreite B_S der ungespreizten Signalleistung P_S wie folgt gegeben:

$$G = \frac{B_c}{B_s} = \frac{P_c \cdot f_c}{P_s \cdot f_s} \qquad \text{... fs = Wiederholrate des PN-Codes (1/Epochendauer = 1 kHz)} \qquad (7)$$

So errechnet sich theoretisch ein Prozeßgewinn G der reinen C/A-Code-Korrelation (Korrelation über genau eine Code-Epoche von 1 ms Dauer) für GPS: G_{GPS} = 30 dB und für GLONASS: $G_{GLONASS}$ = 27 dB. Infolge der Gewinne und Verluste der Filterung und Datendetektion wurden am ASN-22 (siehe Abschnitt 5.1) nur folgende Maximalwerte für GPS: G_{GPS} ~ 24 dB und für GLONASS: $G_{GLONASS}$ ~ 21 dB gemessen.

Damit kann ein effektiver Prozeßgewinn G_{eff} definiert werden, der die tatsächlichen Effekte der restlichen Signalverarbeitung miteinbezieht. Der effektive Prozeßgewinn G_{eff} läßt sich auch direkt anhand des Korrelations-Algorithmus des Empfänger-DLL's aus der Korrelations-Summe des I-Pfades und des Q-Pfades für den "Prompt-Channel" wie folgt ermitteln:

$$G_{eff} = \frac{\left(\sum_K IP_S\right)^2 + \left(\sum_K QP_S\right)^2}{\left(\sum_K IP_N\right)^2 + \left(\sum_K QP_N\right)^2} \qquad (8)$$

mit:

ΣIP_S, ΣQP_S: Korrelations-Summe im I- und Q-Pfad des "Prompt-Channel's" bei vorhandenem Signal
ΣIP_N, ΣQP_N: Korrelations-Summe im I- und Q-Pfad des "Prompt-Channel's" bei nur Grundrauschen (wird gewöhnlich nur einmal berechnet)
K: Anzahl der "Chips" bezüglich der Epochen-Länge (GPS: 1023 chips, GLONASS: 511 chips)

Ebenfalls ist das hier gemessene "Carrier-to-Noise-Ratio" (C/N) identisch mit dem effektiven Prozeßgewinn G_{eff} der C/A-Code-Korrelation bei einem betimmten Signal/Rauschabstand und deshalb wird im nachfolgenden in der Regel nicht mehr unterschieden zwischen C/N und G_{eff}. Damit ist dann folgender Zusammenhang für G_{eff} bzw. C/N zwischen den Größen G, G_{eff}, und S/N_{eff} gegeben durch:

$$G_{eff} = \left(G \cdot \frac{S}{N_{eff}}\right) = \frac{C}{N} \qquad (9)$$

Ein weiterer, wichtiger Punkt um den Einfluß von Interferenz-Störungen auf die Code-Korrelation abzuschätzen, stellt die C/N-Degradation $\Delta C/N$ bzw. die G-Degradation ΔG der Signal/Störabstände dar. Das $\Delta C/N$ bzw. ΔG gibt den Faktor bei einer gegebenen Frequenz an, um wieviel sich das S/N- oder C/N-Verhältnis in Abhängigkeit einer bestimmten Interferenz-Störleistung am Empfängereingang verschlechtern wird. Damit gelten für $\Delta C/N$ bzw. ΔG im Zusammenhang mit N_0, N_{eff} und G_{eff} folgende Beziehungen:

$$\Delta G = \left(\frac{N_0}{N_{eff}}\right)$$ ... N_0 = thermische Rauschleistungsdichte, N_{eff} = Summenrauschleistungsdichte (10)

bei Interferenz-Störungen

$$G_{eff} = (G \cdot \Delta G) \cdot \left(\frac{S}{N_0}\right) \qquad (11)$$

Die Werte von ΔC/N bzw. ΔG bei einer gegebenen Frequenz geben somit an mit welcher S/N- oder C/N-Degradation für eine bestimmte Interferenz-Störleistung gerechnet werden kann. Weitere Einzelheiten darüber folgen in dem Bericht noch.

Ebenso bestimmt das S/N_{eff} -Verhältnis und deren Ableitungen wesentlich die Genauigkeit der "Pseudo-Range"- und "Carrier-Phase"-Messungen als auch die Bit-Fehler-Rate (BER) der Navigations-Daten. Um den Wert des S/N_{eff} aus dem Wert von N_{eff} herzuleiten, muß er dividiert werden durch die Bandbreite der verwendeten "Tracking-Loops" (B_{DLL} oder B_{PLL}) oder des Daten-Diskriminators (B_{bit}). Damit stellt sich die Standard-Abweichung der "Pseudo-Range"-Messungen wie folgt dar ("Standard Early-Late-Correlation"):

$$\sigma_{PSR} = L \cdot \sqrt{\frac{B_{DLL} \cdot 2 \cdot d^2}{\left(\frac{S}{N_{eff}}\right)} \cdot \left[2 \cdot (1 - d) + \frac{B_{ID} \cdot 4 \cdot d}{\left(\frac{S}{N_{eff}}\right)}\right]} \quad [m] \qquad (12)$$

$$\sigma_{PSR} = L \cdot \sqrt{\frac{B_{DLL} \cdot 4 \cdot d^2 \cdot (1 - d)}{\left(\frac{S}{N_{eff}}\right)}} \quad [m] \qquad \text{... Näherung} \qquad (13)$$

$$\sigma_{PSR} = L \cdot \sqrt{\frac{B_{DLL}}{2 \cdot \left(\frac{S}{N_{eff}}\right)}} \quad [m] \qquad \text{... Näherung für } d = ½ \qquad (14)$$

wobei für GPS gilt (für GLONASS ähnliche Werte) :

L: Chip-Länge (C/A-Code L=293,26 m, P-Code L=29,326 m)
B_{DLL}: DLL-Rausch-Bandbreite [Hz]
d: Abstand zwischen "Early"- und "Prompt-Correlator" oder "Late"- und "Prompt-Correlator" (1/16 bis 1/2 Chip, d = 1/2 für 1 Chip E-L- Correlator)
S/N_{eff}: Effektives Signal/Rauschdichte-Verhältnis [W/Hz]
B_{ID}: Rausch-Bandbreite der Integrationsfilter in den Korrelatoren [Hz] (Integrate&Dump Filter)

Gleichermaßen ist die Genauigkeit der "Carrier-Phase"- Messungen gegeben durch:

$$\sigma_{\phi} = \frac{180}{\pi} \cdot \sqrt{\frac{B_{PLL}}{\left(\frac{S}{N_{eff}}\right)} \cdot \left[1 + \frac{B_{ID}}{2 \cdot \left(\frac{S}{N_{eff}}\right)}\right]} \quad [^{0}] \qquad (15)$$

$$\sigma_{\phi} = \frac{180}{\pi} \cdot \sqrt{\frac{B_{PLL}}{\left(\frac{S}{N_{eff}}\right)}} \quad [^{0}] \qquad \text{... Näherung} \qquad (16)$$

hierbei ist B_{PLL}: die Bandbreite des PLL's [Hz].

Ebenso hängt die Bit-Fehler-Wahrscheinlichkeits-Rate (Bit Error Rate, BER) der BPSK-modulierten Navigations-Daten (Almanach, Ephermeriden usw.) direkt von dem S/N_{eff} ab:

$$BER = \frac{1}{2} \cdot erfc \cdot \left[\sqrt{\frac{B_{Bit}}{\left(\frac{S}{N_{eff}}\right)}}\right] \qquad (17)$$

mit:

erfc: komplementäre Fehlerfunktion (Gauß'sches Fehler-Integral)
B_{Bit}: Bandbreite des Daten-Diskriminators [Hz]

Da σ_{PSR}, σ_{ϕ}, und BER Funktionen des S/N_{eff} sind, ist es möglich durch die Bestimmung der Interferenz-Auswirkung auf das S/N_{eff}, den Einfluß auf die Meßgenauigkeiten und auf die Bit-Fehler-Rate vorherzusagen. Um Grenzwerte für diese Werte festzulegen, muß man nur eine entsprechende Grenze für eine maximal erlaubbare Degradation $\Delta S/N$, $\Delta C/N$ oder ΔG vorgeben.

4.2 Beschreibung der Meßanordnung

Anhand von Fig. 4 wird das Blockschaltbild der experimentellen Anordnung zum Messen der Interferenz-Störempfindlichkeit sowohl vom ASN-22-Empfänger als auch vom GG24-Empfänger aufgezeigt. Ein "RF-Signal-Synthesizer" (Slumberger 4002) erzeugt ein sinusförmiges, unmoduliertes oder auch moduliertes Interferenz-Signal (CW- und/oder Breitband-Interferenz), das mit einem Satelliten-Signal kombiniert wird, das entweder von dem GPS-GLONASS-Simulator (JcAir GNS 743 A) oder von der aktiven Antenne (GG24- oder MAN- Antenne) auf dem Dach herstammt. Dieses Satelliten-Signal, das so mit einem additiven CW- oder auch Breitband-Interferenz-Störsignal beaufschlagt ist, wird zum RF-Eingang des Test-Objektes: ASN-22-Empfänger oder GG24-Empfänger geführt. Damit kann man dann in Verbindung mit einem gewöhnlichen "Personal Computer" für "Windows 3.11" und entsprechender Software (AP-Simulator bzw. Ashtech Evalute) das S/N_{eff} (Gl. 5) und das G_{eff} (G.9) bzw. das C/N direkt messen. Für diesen und weiteren Zweck wurde von den russischen Mitarbeitern die AP-Simulator-Software geschrieben, die diese Signal/Störverhältnisse direkt aus den angelieferten Rohdaten des ASN-22 berechnet (C/N-Ratio, Pseudo-Ranges, Integrated Carrier-Phase, Almanach, Ephermeriden usw.) Diese auf dem Computer-Bildschirm angezeigten Meßergebnisse können dann zur mathematischen Auswertung für den Bericht in das Programm MATHCAD 6.0 eingegeben werden. Außer der Meßwertauswertung erfüllt der Computer noch wichtige Steuerungsaufgaben für die Meßanordnung. So werden durch ihn die Einstellungen der Signalleistungen und Frequenzen vom GPS-GLONASS-Simulator GNS 743 A und vom RF-Synthesizer SL4002 über die Schnittstelle RS 232 bzw. IEEE 488 ausgeführt.

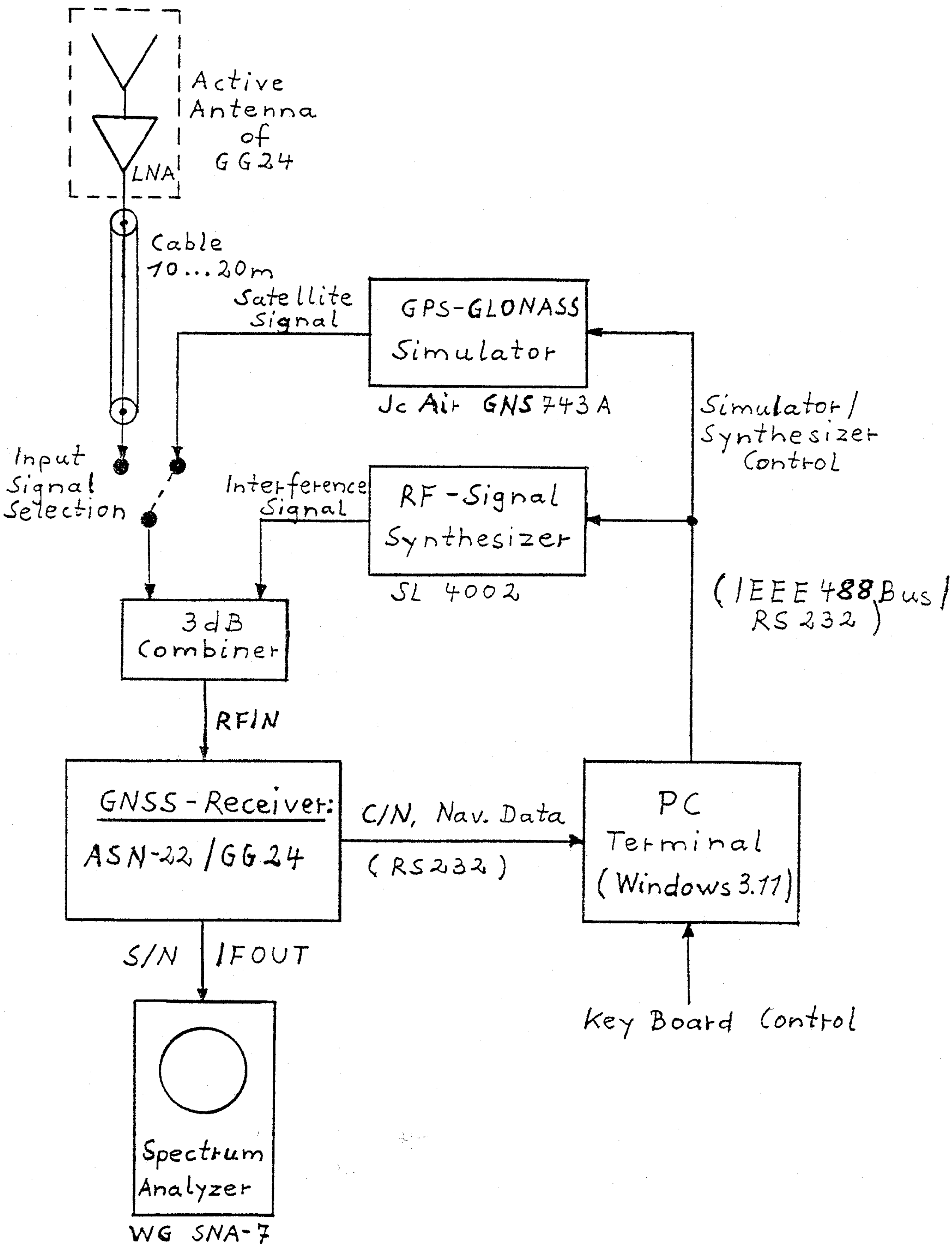

Fig. 4   Meßanordnung zur Bestimmung der Interferenz-Störempfindlichkeit des ASN-22 und GG24

Ein weiterer wichtiger Punkt des Interferenz-Einflusses auf die Empfangsgenauigkeit stellt das Signal/Rauschdichten-Verhältnis S/N_{IF} der niedrigsten Zwischenfrequenz (IF) der GNSS-Empfänger dar. Mit einem Spektrum-Analysator (z.B. Wander&Goltermann SNA-7) kann dieser Einfluß direkt an den Spektren der ASN-22-ZF-Ausgänge: GPS-IFOUT (4,31 MHz) und GLONASS-IFOUT (70 MHz) gemessen werden. Ebenfalls läßt sich aus den gemessenen ZF-Spektren das S/N_{eff} der Empfänger in Abhängigkeit der Interferenz-Signalleistung und der Frequenz bestimmen. Dies ist eine weitere Möglichkeit die Interferenz-Störfestigkeit der Empfänger herzuleiten. In einem der nachfolgenden Abschnitten wird dies durch ein Diagramm für den ASN-22 belegt.

5. Meßergebnisse

Unter der Voraussetzung, daß sich der Empfänger im stabilen "Satelliten-Signal-Tracking-Modus" (G_{eff} > 3 dB) befindet, zeigen die folgenden Kurven den Austeuerbereich ("Dynamic-Range") des effektiven Prozeßgewinns G_{eff} (Gl. 8, 9) auf, sowie die Interferenz-Störempfindlichkeit als eine Funktion der Interferenz-Störleistung und Interferenz-Frequenz bei konstanter Satelliten-Signalleistung am Empfänger-Eingang (bereitgestellt vom GPS-GLONASS-Simulator oder von der Antenne). In den Diagrammen beziehen sich die Signalleistungen sowohl auf die Satelliten-Empfangs-Signale als auch Interferenz-Empfangs-Signale direkt am "RF-Input", die am RFIN-Stecker der Empfänger anliegen. Hiermit werden sämtliche Signal-Verstärkungen (Gain) und Dämpfungen (Loss) der Interferenz-Signale, die durch den Ausbreitungsweg, Anntenne und Zuleitungskabel bis zum Empfänger-Eingang gegeben sind, nicht berücksichtigt. Nur so sind die Meßergebnisse im Labor reproduzierbar. Jedoch ist daraus sehr einfach die tatsächlich eingestrahlte Interferenz-Störleistung an der Antenne zu berechnen, wenn die entsprechenden Antennenparameter und Kabeldämpfungen bekannt sind (dies wird im Anhang anhand einer Analyse der Leistungs-Durchflußdichte der Antenne durchgeführt).

So zeigen die Kurven die Interferenz-Störleistungen bei einer bestimmten Frequenz und Satelliten-Signal-Empfangsleistung auf, die notwendig sind, um bei einem bestimmten Wert von C/N (Gl. 9) bzw. von G_{eff} (Gl. 11) das Einrasten (Lock) oder Ausrasten (Loss) der "DLL/PLL-Regelschleifen" zu bewirken. D.h. die Empfindlichkeits-Diagramme geben an, wieviel Interferenz-Störleistung bei einer gegebenen Frequenz benötigt wird, um eine bestimmte C/N-Degradation ΔC/N bzw. ΔG (Gl. 10, 11) zu verursachen.

5.1 Interferenz-Störempfindlichkeit des ASN-22-Empfängers

In den folgenden Abschnitten werden die Diagramme der Meßwert-Auswertungen vom ASN-22-Empfänger, Fig. 4, aufgezeigt, die für den effektiven Prozeßgewinn G_{eff} (Gl. 8), für das effektive "Carrier/Noise-Ratio" C/N_{eff} (Gl.9) und für das Signal/ Rauschdichten-Verhältnis S/N_{IF} der Zwischenfrequenzen in Bezug auf die Interferenz-Störempfindlichkeit und damit folglich auch auf das erforderliche S/N_{eff} am Empfängereingang bestimmend sind.

a) Die folgenden zwei Kurven, Fig. 5 und 6, zeigen, getrennt für den GPS- und GLONASS-Zweig, die gemessene Aussteuerungskurve ("Dynamic-Range") des effektiven Prozeßgewinns G_{eff} der C/A-Code-Korrelation im DLL, GL. 8, auf. Ein Prozeßgewinn des Daten-Diskriminators ist hierin nicht enthalten. Ebenfalls ist als Referenz-gerade der theoretische, lineare Prozeßgewinn G_{ref} eingetragen, der sich im Fall des Fehlends jeglicher physikalischer als auch technischer Begrenzungseffekte im Empfänger ergeben würde. Die Meßwerte, die im Datenfile: RATIO.PRN abgespeichert sind, werden hier nicht mehr gesondert aufgelistet. Die notwendige Kalibrierung der Signal-Eingangsleistungen am RFIN-Stecker wird mittels des JcAir Simulator GNS 743 über den PC, Fig.4, ausgeführt. (Das C/N_{eff}-Verhältnis wird in Anwesenheit des Empfänger-Rauschens als Funktion der Signal-Eingangsleistung direkt gemessen und damit werden dann zur Darstellung von G_{eff} die Zwischenergebnisse mit Programm MATHCAD 6.0 entsprechend umgeformt.)

$P := \mathrm{PRNLESEN}(\mathrm{RATIO})$ $\quad M := \mathrm{zeilen}(P)$ $\quad M = 41$ $\quad Fin := P^{<0>}$ $\quad GP := P^{<1>}$ $\quad GL := P^{<2>}$ $\quad i := 0..M-1$

$dBm := 1$ $\quad dB := 1$ $\quad RFIN_i := (-135 + i)\cdot dBm$

$GPref_i := 1\cdot i$ ... effektiver Prozeßgewinn für lineare Signal-Dynamik (ideal) des GPS-Zweiges

$GLref_i := 1\cdot i - 0.8$ ... effektiver Prozeßgewinn für lineare Signal-Dynamik (ideal) des GLONASS-Zweiges

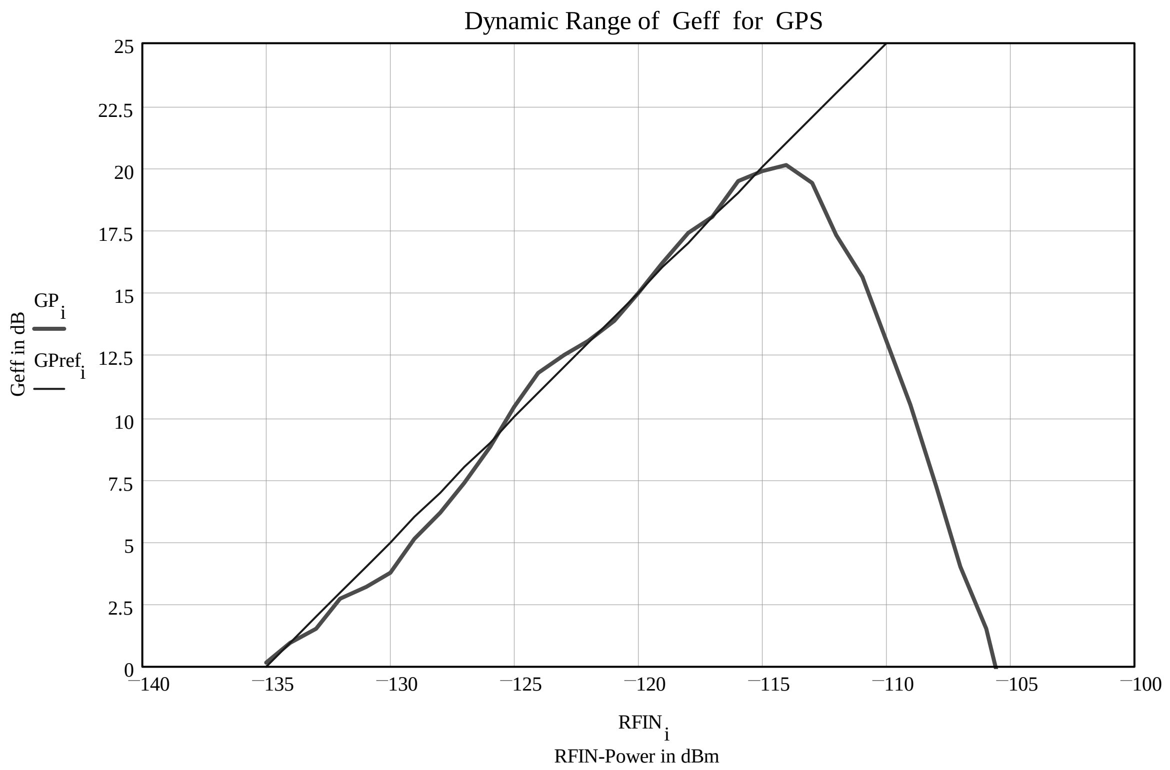

Fig. 5 Dynamischer Bereich des effektiven Prozeßgewinns G_{eff} für den GPS-Zweig (ASN-22, C1-Modell)

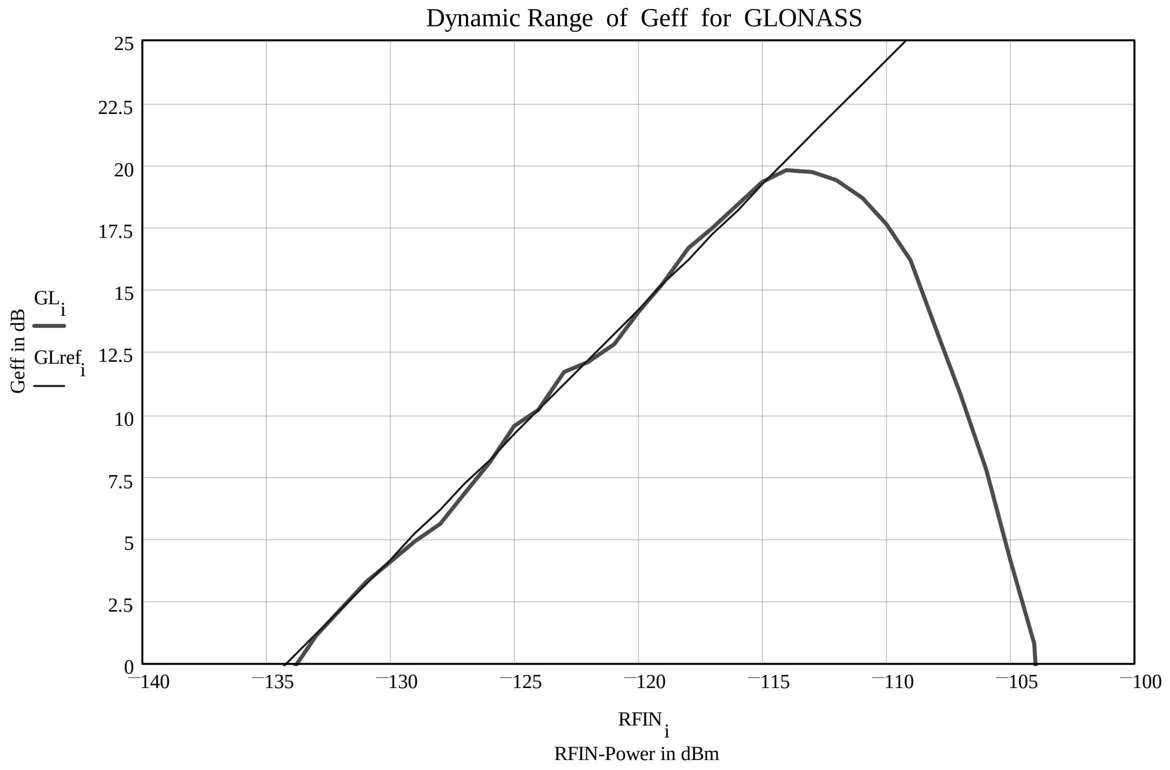

Fig. 6 Dynamischer Bereich des effektiven Prozeßgewinns G_{eff} für den GLONASS-Zweig (ASN-22, C1-Modell)

b) Die folgenden zwei Kurven, Fig. 7 und 8, zeigen, getrennt für den GPS- und GLONASS-Zweig, die gemessene Interferenz-G-Störempfindlichkeit des effektiven Prozeßgewinns G_{eff} (Gl. 8, 9) als Funktion der Interferenz-Eingangsleistung und Frequenz am RFIN-Stecker des ASN-22-Empfängers auf. Hierbei werden die Empfangs-leistungen der Satelliten-Signale konstant gehalten, die sowohl vom GPS-Simulator GNS 743 A als auch von der Antenne (MAN-Antenne) auf dem Dach angeliefert werden. Bei den Antennensignalen wird die Pegel-konstants durch die einstellbare Verstärkung des Antennen-LNA's mittels seiner Versorgungsspannung (von ca. +5 V bis ca. +12 V) erreicht. In den Diagrammen sind zum Vergleich die Ergebnisse beider Empfangsfälle eingetragen. Gemessen wird das C/N_{eff} innerhalb der 1 kHz-Bandbreite, die identisch mit der Wiederholrate der C/A-Code-Epoche (1ms Epochen-Dauer) ist. In diesem Fall sind die gemessenen C/N_{eff}-Werte gleich mit den G_{eff}-Werten (Gl. 9). Die Meßwerte, die in den Datenfiles: INP3A.PRN und ASN22.PRN abgespeichert sind, werden hier nicht mehr gesondert aufgelistet.

Die Messungen wurden hier auf der Basis folgender konstanter Signal-Einstellungen am GPS-GLONASS-Simulator GNS 743 (ebenfalls zum Eichen der Antennenempfangspegel verwandt) ausgeführt:

Satelliten-Input-SVID (JcAir-Simulator GNS 743 A): GPS # 2, -115 dBm,
GLONASS # 4, CH # 12 (1608,75 MHz), -119, 5 dBm
CW-Interferenz-Input (Synthesizer SL4002): 1520 MHz bis 1670 MHz, -110 dBm bis -10 dBm, B < 20 Hz
Processing Gain (G): 15 dB (GNSS-Empfang ohne Interferenz)
Effektiver Processing Gain (G_{eff}): 3 dB (GNSS-Empfang mit Interferenz)
Processing Gain Degradation (ΔG): -12 dB
Carrier to Noise Ratio(C/N_0): 33 dB/Hz (Dichte)
Combiner-Dämpfung (L_{com}): -4 dB
Meßgenauigkeit: +- 1,5 dB
AP-Simulator-Code für GNSS-Empfang aktiv : S, C, B, (nur bei GPS: S, C, B, F, M)

Damit beziehen sich die nachfolgenden Interferenz-Empfindlichkeits-Diagramme auf ein gemessenes C/N_{eff} bzw. G_{eff} ~ 3 dB bei einer Degradation von ca. -12 dB (Gl. 10, 11). Unter dieser Bedingung ist noch ein stabiles "Tracking" der Satelliten-Signale im eingerasteten Fall der "Empfänger-Loops" gewährleistet. Sollte jedoch während der Messungen die Satelliten-Signal-Nachführung einmal verloren gehen, so ist in der Regel unter dieser Interferenz-Störbedingung nicht mehr genug Empfangspegel für eine neue, sichere "Satellite-Signal-Aquisition" gegeben. Jedoch werden zur einheitlichen Darstellung der Empfindlichkeitskurven die Interferenz-pegel auf ein fiktives G_{eff} = 0 dB, einschließlich der weiteren Verluste des Meßaufbaus (Kabel, Combiner usw.), bezogen.

$P := \mathrm{PRNLESEN}(\mathrm{INP3A})$ $\quad M := \mathrm{zeilen}(P)$ $\quad M = 152$ $\quad Fin := P^{\langle 0\rangle}$ $\quad AG := P^{\langle 1\rangle}$ $\quad AL := P^{\langle 2\rangle}$

$Q := \mathrm{PRNLESEN}(\mathrm{ASN22})$ $\quad N := \mathrm{zeilen}(Q)$ $\quad N = 156$ $\quad GPSI := Q^{\langle 1\rangle}$ $\quad GPSG := Q^{\langle 2\rangle}$ $\quad GLOI := Q^{\langle 3\rangle}$

$GLOG := Q^{\langle 4\rangle}$ $\quad i := 0 .. M - 1$

$GP_i := GPSI_i + GPSG_i - 4.5$ $\quad GL_i := GLOI_i + GLOG_i - 4.5$

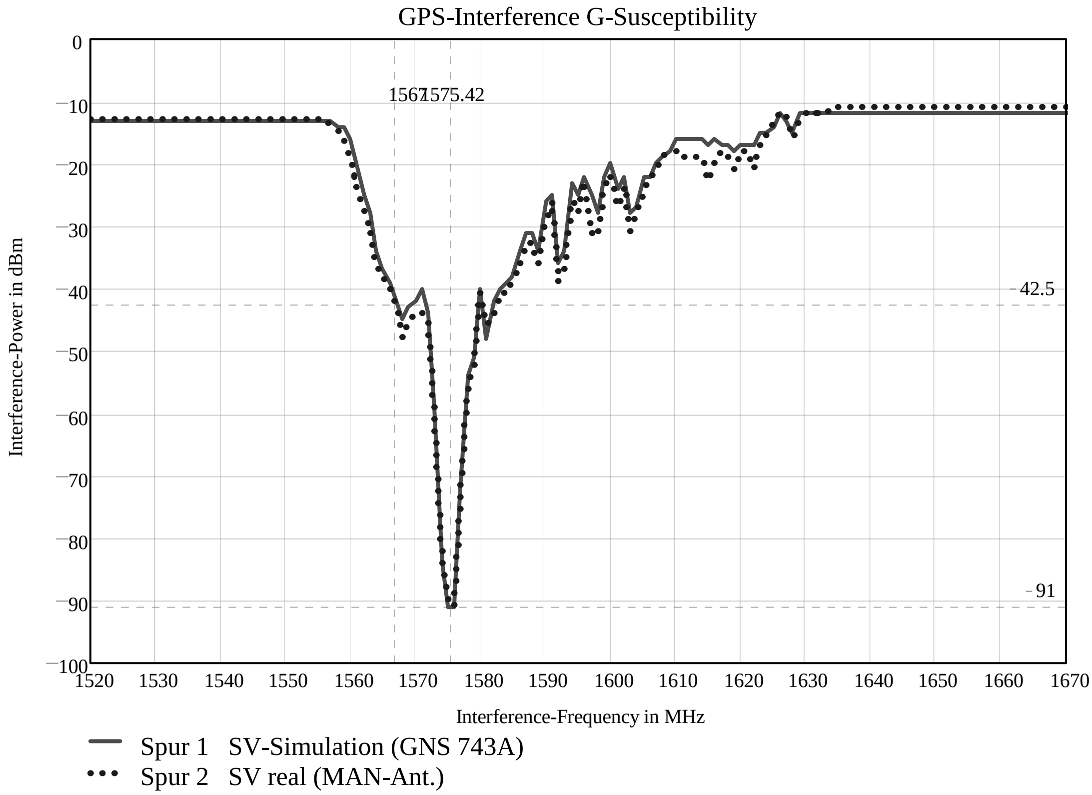

Fig. 7 Interferenz-Empfindlichkeit des GPS-Zweiges bei Simulator- und Antennen-Input in Bezug auf G_{eff} (ASN-22, P3-Modell, für G_{eff} = 0 dB)

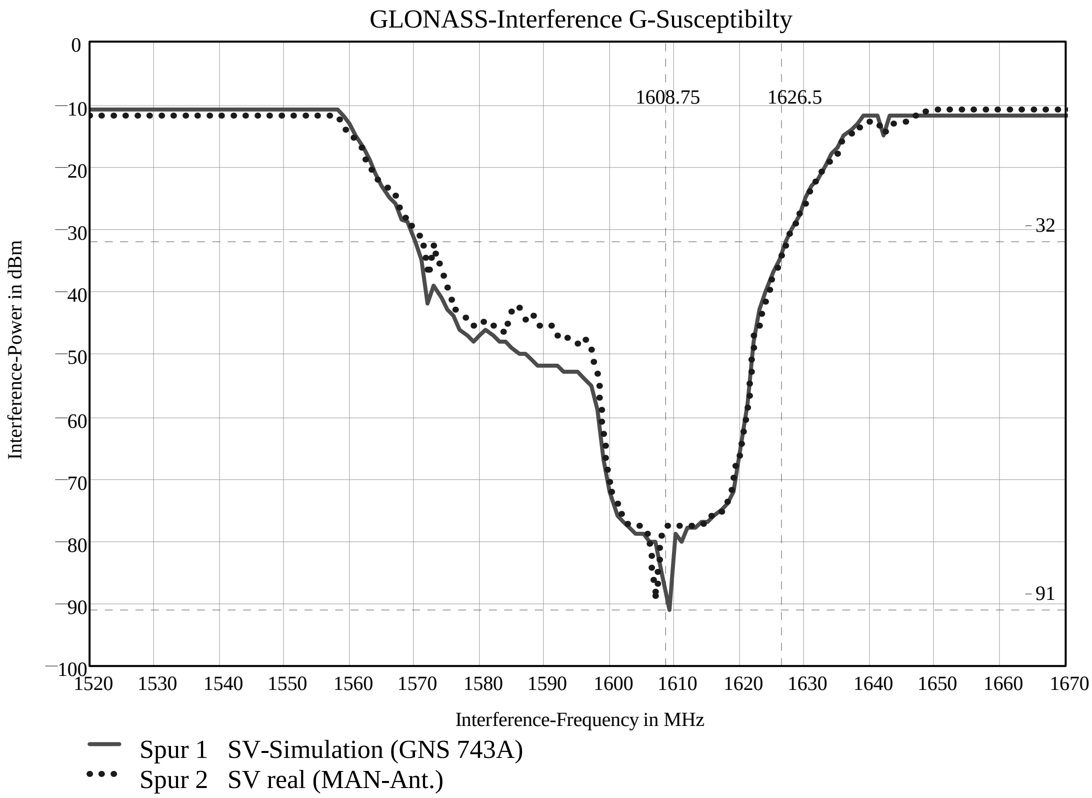

Fig. 8 Interferenz-Empfindlichkeit des GLONASS-Zweiges bei Simulator- und Antennen-Input in Bezug auf G_{eff} (ASN-22, P3-Modell, für G_{eff} = 0 dB)

c) Die folgenden zwei Kurven, Fig. 9 und 10, zeigen, hier getrennt für den GPS- und GLONASS-RF-Zweig des ASN-22-C1-Modell's (Vorgängermodell des P-Modells, das nur hierfür verwandt wird), den Einfluß der Interferenz-Signale auf das Signal/Rauschdichte-Verhältnis S/N_{IF} der niedrigsten Zwischenfrequenzen des RF-FRONTEND's auf. Hierbei ist die Interferenz-ZF-Störempfindlichkeit ebenfalls eine Funktion der Interferenz-Eingangsleistung und Frequenz am RFIN-Stecker bei konstanter Rauschleistung des ASN-22-Empfängers. Das S/N_{IF} der 70 MHz-Zwischenfrequenz für GLONASS wird an dem Test-Signal-Ausgang: GLONASS-IFOUT und das S/N_{IF} der 4,31 MHz-Zwischenfrequenz für GPS an dem Test-Signal-Ausgang: GPS-IFOUT mittels eines Spektrum-Analysators , Fig. 4, gemessen. Hierbei wird für eine Anhebung des Signal/Rauschdichte-Verhältnisses S/N_{IF} der Zwischenfrequenz um 7 dB über das Empfänger-Rauschen, eine entsprechende Interferenz-Leistung am Empfängereingang gewählt, d. h. der Interferenz-Signalpegel kommt bezüglich der Mittenfrequenz der ZF im Spektrum um 7 dB über die Hüllkurve des Empfänger-Rauschens zu liegen (Grund: höhere Ablesegenauigkeit der Pegelwerte vom Spektrumanalysator-Bildschirm, damit höhere Meßgenauigkeit). Die Meßwerte, die in den Datenfiles: INP1.PRN abgespeichert sind, werden hier nicht mehr gesondert aufgelistet.

Zum Kalibrieren der Interferenz-Signale für die S/N_{IF}-Messungen werden folgende unmodulierten Satelliten-Signale (CW-Signale) und Einstellungen des GPS-GLONASS-Simulators GNS 743 A verwandt:

GPS-Input an RFIN: 1575,42 MHz @ -100 dBm

GLONASS-Input an RFIN: 1609,00 MHz @ -100 dBm (GLONASS-Kanal # 12)

Die Genauigkeit der Pegelmessungen beträgt ca. +- 1,5 dB, wobei alle Verluste der Meßanordnung, Fig. 4, wie z.B. Kabel- und "Combiner"-Dämpfung von ca. 4,5 dB, bereits berücksichtigt sind.

$P := PRNLESEN(INP1)$ $M := zeilen(P)$ $M = 81$ $Fin := P^{<0>}$ $GL := P^{<1>}$ $GP := P^{<2>}$

$i := 0..M-1$ $MHz := 1$ $Fin_i := (1520 + 2 \cdot i) \cdot MHz$

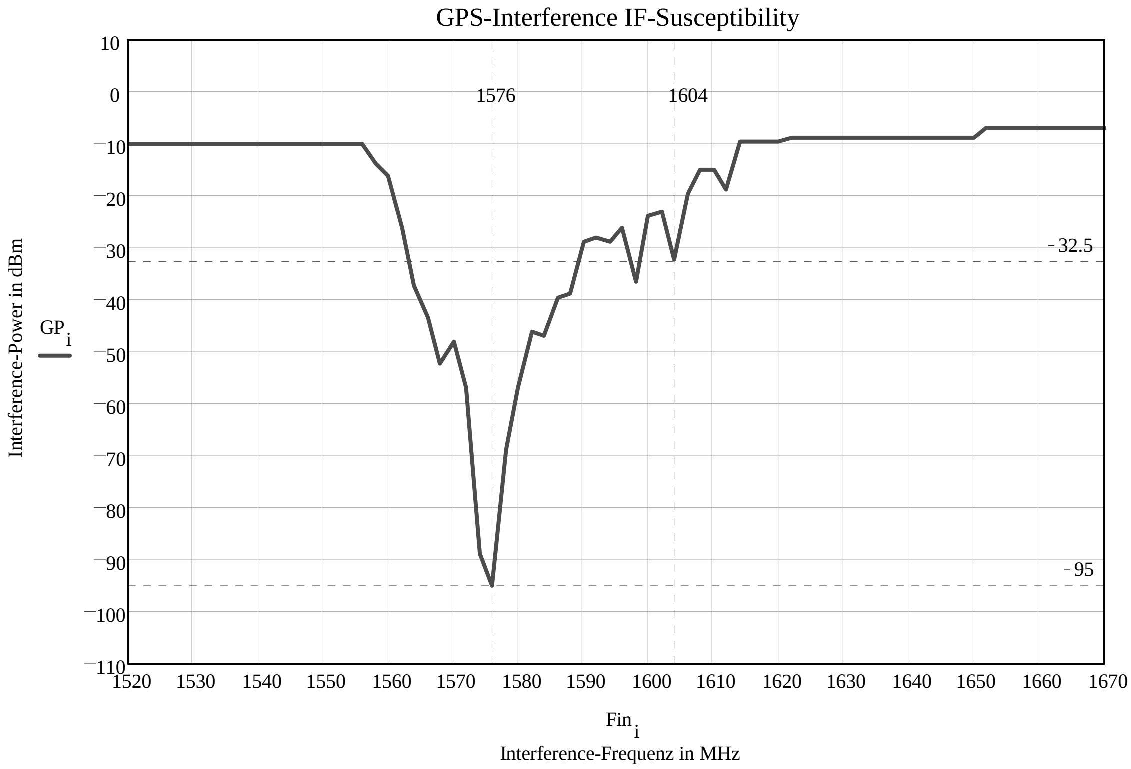

Fig. 9 Interferenz-Empfindlichkeit des GPS-Zweiges in Bezug auf S/N_{IF} der 4,31 MHz Zwischenfrequenz (ASN-22, C1-Modell, für IF-S/N-Ratio = 7 dB)

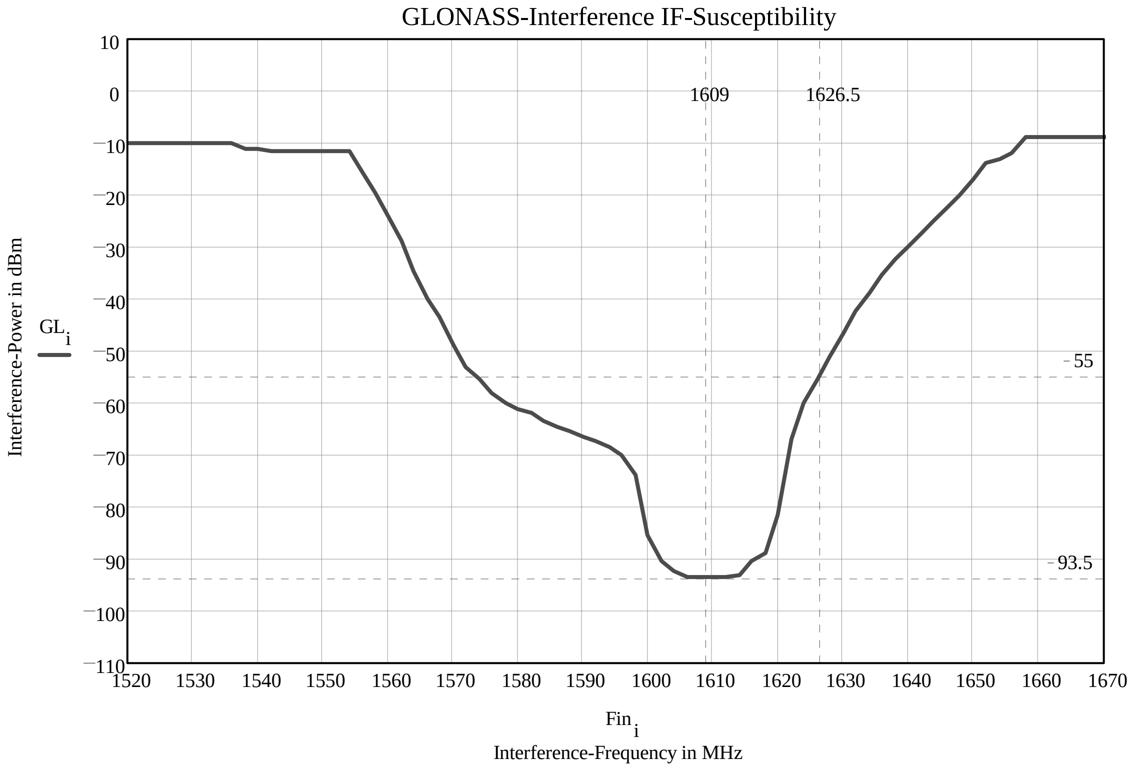

Fig. 10 Interferenz-Empfindlichkeit des GLONASS-Zweiges in Bezug auf S/N_{IF} der 70 MHz Zwischenfrequenz (ASN-22, C1-Modell, für IF-S/N-Ratio = 7 dB)

5.2 Interferenz-Störempfindlichkeit des GG24-Empfängers

Die folgenden beiden Diagramme, Fig. 11 und 12, stellen den gemessenen Einfluß von Interferenz-Störungen auf den Ashtech GG24-Empfänger im Fall von realen Satelliten-Empfangssignalen mit der aktiven MAN-Antenne (3S-Navigation-Antenne) auf dem Dach dar. Auch hier wird in Abhängigkeit eines vorgegebenen C/N_{eff} bzw. G_{eff} (Gl. 9) und einer kalibrierten Satelliten-Empfangsleistung, die Interferenz-Störleistung bei einer bekannten Frequenz bestimmt, die eine Degradation $\Delta C/N$ bzw. ΔG (Gl. 10, 11) von ca. 8 dB bis 14 dB verursacht. Die Kalibration der GNSS-Empfangspegel erfolgt hier ebenfalls mit dem GPS-GLONASS-Simulator GNS743 A. Die Meßwerte, die in den Datenfile: GG24.PRN abgespeichert sind, werden hier nicht mehr gesondert aufgelistet.

Damit werden folgende Meßeinstellungen für ein stabiles Satelliten-Signal-Tracking (G_{eff} > 3 dB) vorgenommen:

Satelliten-Input (SVID): GPS # 2, 9,10, (1575,42 MHz), GLONASS # 43, 47, CH # 4, (1604,24 MHz)
CW-Interferenz-Input (Synthesizer SL4002): 1520 MHz bis 1670 MHz, -110 dBm bis -10 dBm, B < 20 Hz
Processing Gain (G): 40 bis 80 Carrier-Amplitude am Korrelator-Ausgang, linear, (15 dB bis 19 dB)
Effektiver Processing Gain (G_{eff}): 3 dB bis 17 dB (GNSS-Empfang mit Interferenz)
Processing Gain Degradation (ΔG): -8 dB bis -14 dB
Carrier to Noise Ratio (C/N_0): 33 dBm/Hz bis 47 dBm/Hz (Dichte)
Combiner-Dämpfung (L_{com}): -4,5 dB
Meßgenauigkeit: +- 2,5 dB

$P := PRNLESEN(INP3A)$ $\quad M := zeilen(P)$ $\quad M = 152$ $\quad Fin := P^{\langle 0\rangle}$ $\quad AG := P^{\langle 1\rangle}$ $\quad AL := P^{\langle 2\rangle}$

$Q := PRNLESEN(GG24)$ $\quad N := zeilen(Q)$ $\quad N = 156$ $\quad GPSI := Q^{\langle 1\rangle}$ $\quad GPSE := Q^{\langle 4\rangle}$ $\quad GLOI := Q^{\langle 5\rangle}$

$GLOE := Q^{\langle 8\rangle}$ $\quad i := 0..M-1$

$GP_i := GPSI_i + 10\cdot\log(GPSE_i) - 4.5$ $\quad GL_i := GLOI_i + 10\cdot\log(GLOE_i) - 4.5$

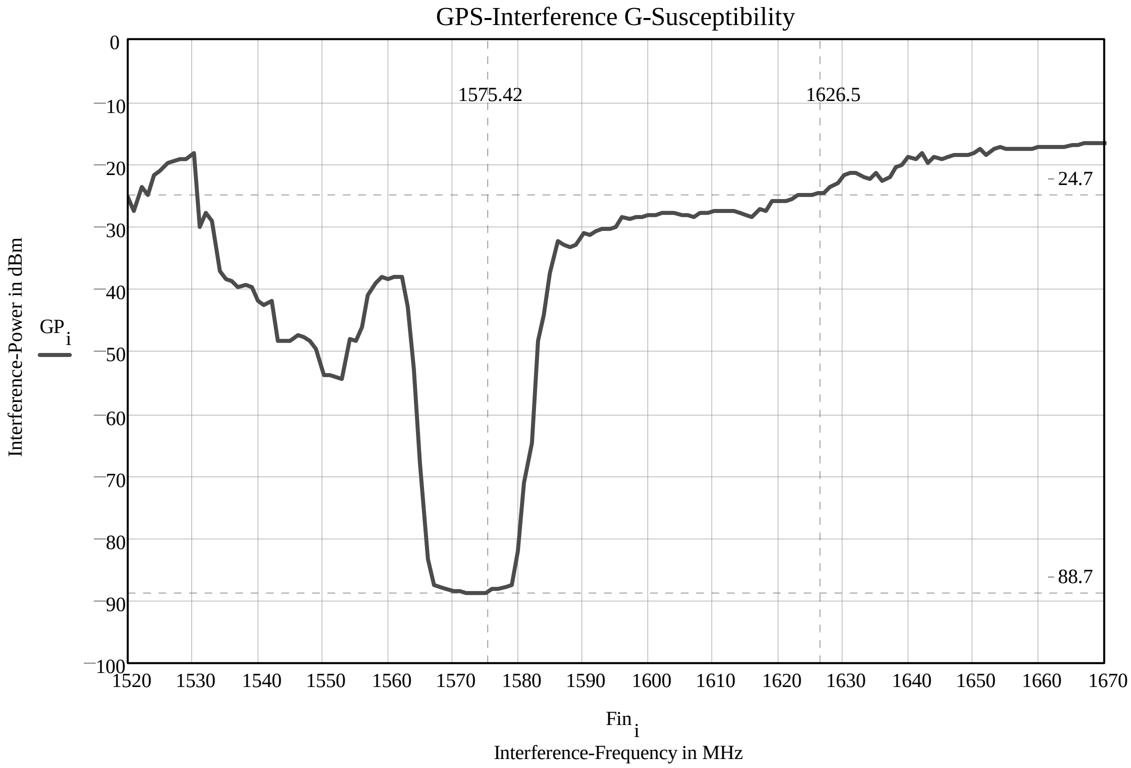

Fig. 11 Interferenz-Empfindlichkeit des GPS-Zweiges in Bezug auf C/N_{eff} oder G_{eff} (GG24 (Ashtech), für G_{eff} = 0 dB)

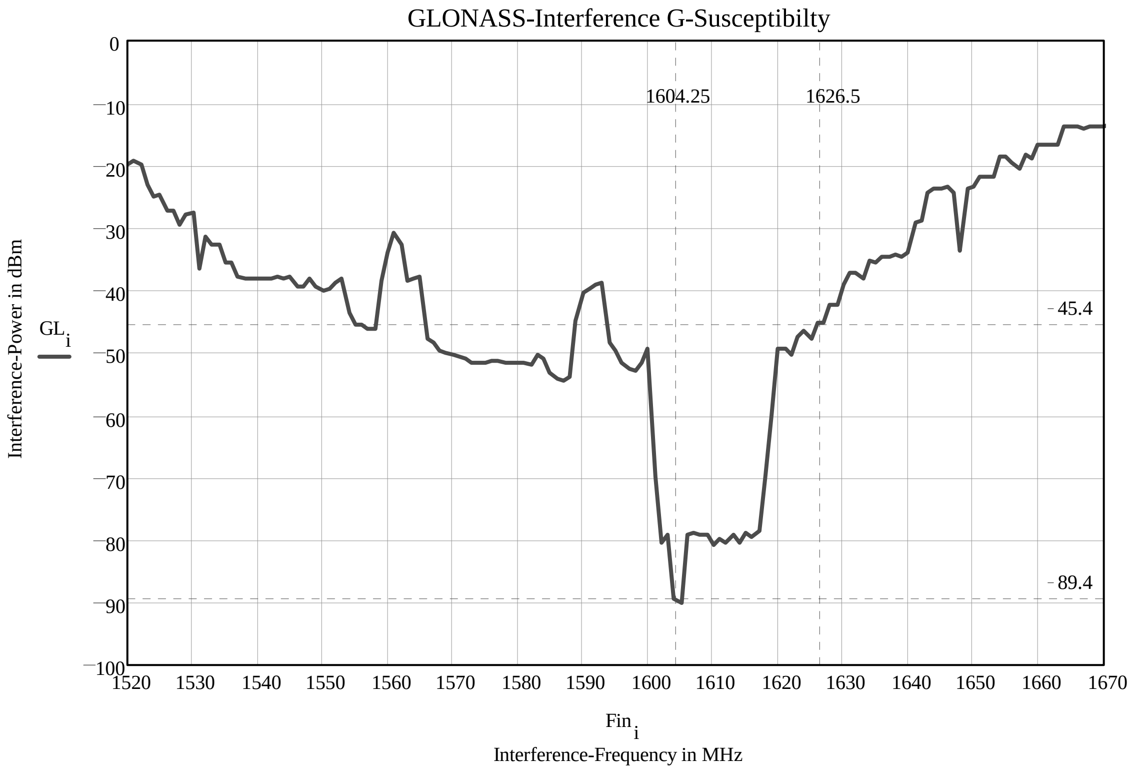

Fig. 12 Interferenz-Empfindlichkeit des GLONASS-Zweiges in Bezug auf C/N_{eff} oder G_{eff} (GG24 (Ashtech), für G_{eff} = 0 dB)

5.3 Vergleich der Interferenz-Störfestigkeit zwischen ASN-22 und GG24

In den nachfolgenden Bildern, Fig.13 und 14, werden hier zum Vergleich die bereits aufgezeigten Diagramme von Abschnitt 5.1 und 5.2, die dort für den ASN-22- und GG24-Empfänger getrennt vorliegen, zusammengefaßt.

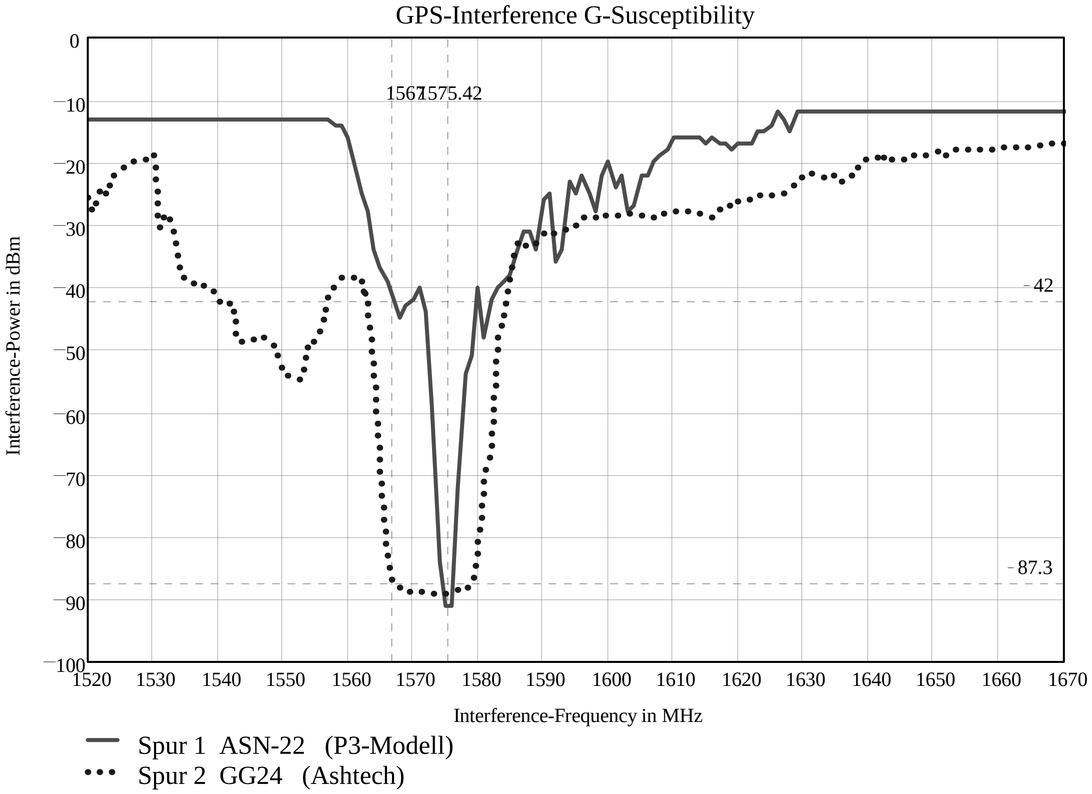

Fig. 13 Interferenz-Störfestigkeit des GPS-Zweiges zwischen ASN-22 und GG24 in Bezug auf C/N_{eff} oder G_{eff} (für G_{eff} = 0 dB)

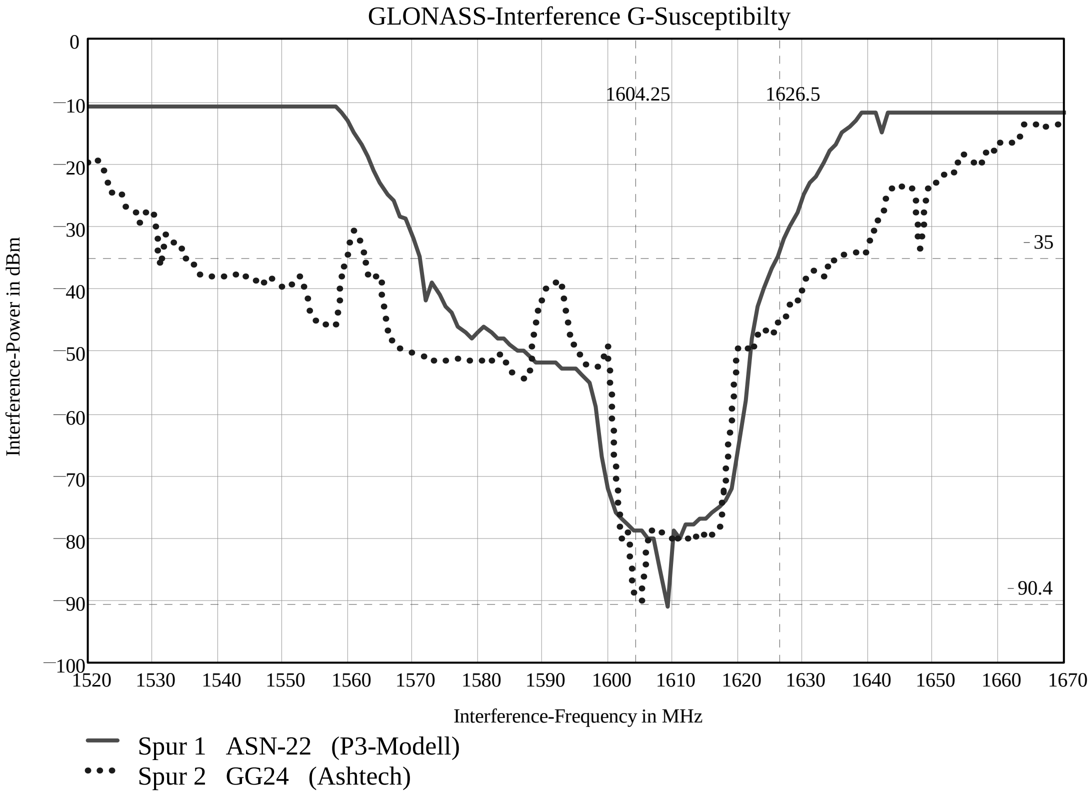

Fig. 14 Interferenz-Störfestigkeit des GLONASS-Zweiges zwischen ASN-22 und GG24 in Bezug auf C/N_{eff} oder G_{eff} (für G_{eff} = 0 dB)

6. Schlußfolgerungen

Die beiden getesteten GNSS-Empfänger ASN-22 (DASA-NFS) und GG24 (Ashtech) zeigen sowohl im GPS-Empfangsbereich als auch GLONASS-Empfangsbereich ähnliches Verhalten der Interferenz-Störempfindlichkeit. Die maximal erlaubte "Inband"-Interferenz-Leistung Iin_{max}, die direkt auf das Eingangssignal RFIN am Kartenstecker bezogen ist, ergibt somit für ein gerade noch stabiles "Satellite-Signal-Tracking" von G_{eff} ~ 3 dB folgende Werte:

für den ASN-22-Empfänger:

GPS-Signal: Iin_{max} = -94 dBm GLONASS-Signal: Iin_{max} = -94 dBm

und für den GG24-Empfänger:

GPS-Signal: Iin_{max} = -91,7 dBm GLONASS-Signal: Iin_{max} = -92,4 dBm

Nach einem eventuellen Verlust der Satelliten-Signalnachführung (Tracking Loss) ist für eine erneute, sichere Satelliten-Aquisition (Tracking Lock) dagegen mindestens ein G_{eff} > 6 dB erforderlich. Das bedeutet in diesem Fall eine Verringerung der Interferez-Störleistung um ca. weitere 4 dB am Empfängereingang.

Jedoch ergeben sich für die "Outband"-Interferenz-Störfestigkeit und vor allem an den Empfangsband-Grenzen (Flanken) zu den benachbarten Satelliten-Telekommunikationsbändern (Mobile Satellite Services, MSS, SATCOM, INMARSAT, GLOBALSTAR, IRIDIUM, usw.) zwischen den beiden Empfängertypen teilweise erhebliche Unterschiede. So wird das GPS-Band (1575,42 MHz) von dem unterhalb liegenden "INMARSAT-Down-Link-Band" von 1559 bis 1567 MHz mit breitbandiger Störleistung bis zu -64 dBm bedroht.

Für den GLONASS-Empfang werden insbesonders die zwei Satellitendienste: GLOBALSTAR und SATCOM, die dem GLONASS-Band von derzeit 1602 bis 1616 MHz oberhalb benachbart sind, erheblich gefährlich. Das "GLOBALSTAR-Up-Link-Band" belegt den Frequenzbereich von 1610 bis 1626,5 MHz und überlappt sich somit mit dem gegenwärtigen GLONASS-Band. Außerdem sind hierbei "Out-of-Band-Spurious" bis zu ca. -60 dBm zu erwarten. Bei dem schon länger bestehenden "SATCOM-Up-Link-Band" von 1626,5 bis 1660,5 MHz muß dagegen mit einer einstrahlenden Störleistung bis zu +10 dBm an der GNSS-Antenne bei Flugzeugen gerechnet werden (ARINC-743 A, RTCA DO-235, usw.).

Für die Interferenz-Störfestigkeit der GNSS-Empfänger sind damit zur Zeit besonders zwei Eckfrequenzen von Bedeutung: für GPS die 1567 MHz des "INMARSAT-Down-Link-Band's" und für GLONASS die 1626,5 MHz des "SATCOM-Up-Link-Band's". Die Messungen der maximal erlaubten Interferenz-Störpegel $Iout_{max}$ bei diesen Eckfrequenzen ergeben bezügliche eines gerade noch stabilen Satellite-Tracking-Verhaltens der Empfänger (G_{eff} ~ 3 dB) folgende Werte:

für den ASN-22-Empfänger:

GPS-Signal: $Iout_{max}$ = -45,5 dBm bei 1567 MHz GLONASS-Signal: $Iout_{max}$ = -35 dBm bei 1626,5 MHz

und für den GG24-Empfänger:

GPS-Signal: $Iout_{max}$ = -90,3 dBm bei 1567 MHz GLONASS-Signal: $Iout_{max}$ = -48,4 dBm bei 1626,5 MHz

Damit weist der ASN-22-Empfänger gegenüber dem GG24-Empfänger eine wesentlich bessere "Outband"-Interferenzstörfestigkeit auf, die sich bei der INMARSAT-Frequenz von 1567 MHz sogar um ca. 45 dB von dem Konkurrenzprodukt GG24 unterscheidet !

Auch zeigt der ASN-22 gegenüber dem GG24 bei der Meßgenauigkeit der horizontalen als auch vertikalen Positions-Angabe (PVT-Meßergebnis) - hier im Werksgelände zeitweise unter starken "Multipath-Bedingungen" für die GPS-GLONASS-Antenne auf dem Dach aufgenommen - leicht bessere Ergebnisse.

Beim ASN-22 ergibt nach Gl. 12 die Standardabweichung σ_{PSR} (1 Sigma) der "GPS-Pseudo-Range-Messung" rein rechnerisch ohne S/A-Effekt :

σ_{PSR} = 4,1473 m

und nach Gl. 15 für die Standardabweichung σ_{ϕ} der "GPS-Carrier-Phase-Messung" :

s_{ϕ} = 6,5575 ^{o} ,

bezogen auf folgende Empfänger-Parameter:

S/N_{eff} = 40 dBW/Hz bzw. G_{eff} = 10 dB, B_{DLL} = 10 Hz, B_{ID} = 1000 Hz, B_{PLL} = 100 Hz, d =1/4 und L = 293,26 m (GPS-C/A-Code-Länge).

Gemessen wurden hier - wie schon erwähnt, unter starken "Multipath-Einwirkungen" im Werksgelände - für die Standardabweichungen (1 Sigma) der horizontalen und vertikalen Positionen der beiden GNSS-Empfänger im kombinierten GPS-GLONASS-Betrieb mit der gleichen GPS-GLONASS-Antenne auf dem Dach und unter Einbezug des momentanen GPS-S/A-Effektes folgende Werte:

für den ASN-22-Empfänger:

Horz. Position: σ_{POS} : 12 bis 25 m Höhe: σ_{HOE} : 5 bis 15 m

und für den GG24-Empfänger:

Horz. Position: σ_{POS} : 20 bis 30 m Höhe: σ_{HOE} : 15 bis 30 m

Die hierbei aufgetretenen "Multipath-Effekte" können ebenfalls als eine Art von "Inband-Interferenzen" gedeutet werden und bedingen somit eine graduelle Verschlechterung der Navigationsmessungen. Die Bit-Fehler-Rate (BER) der "Navigations-Message" ist gleichermaßen davon betroffen. Aus meßtechnischen Gründen konnte sie hier aber nicht gemessen werden. Nach Gl. 17 liefert ein typisches Beispiel einer BER-Berechnung ohne "Multipath- und S/A-Code-Effekte" des ASN-22 den Wahrscheinlichkeitsdichte-Wert BER = 0,0056 für die empfängertypischen Parameter : B_{BIT} = 50 Hz und S/N_{eff} = 40 dBW/Hz bzw. G_{eff} = 10 dB.

Jedoch muß der ASN-22-Empfänger bezüglich den harten Interferenzanforderungen von MSS, SATCOM und ähnlichen Kommunikationsdiensten noch erheblich verbessert werden. Dies betrifft vor allem den GLONASS-Empfangsbereich, der vollkommen aus dem Sendebereich der künftigen "MSS-Handy's" (unterhalb 1610 MHz) zu schieben ist. Eine entsprechende Planung des russischen GLONASS-Betreibers bis zum Jahr 2005 liegt vor. Dies macht auf jeden Fall beim ASN-22 einige technische Änderungen im RF-FRONTEND (Filter, Mischerfrequenzen) erforderlich. Auch die Signal-Sättigungsgrenze (Interception Point) der gemeinsamen RF-FRONTEND-Eingangstufe (LNA, 1. Mischer) muß um mehr als 10 dB verbessert werden, um so besonders gegen die hohen Störpegel des SATCOM-Bandes ab 1626,5 MHz aufwärts bestehen zu können. Ebenfalls sollte auch die aktive GPS-GLONASS-Antenne in ihrer Frequenz-Selektivität sowie in der Übersteuerungs-festigkeit ihres "Antennen-Low-Noise-Amplifiers" (Antennen-LNA) den hohen Interferenzanforderungen angepaßt werden.

Dazu werden im Anhang der maximal erlaubte Grenzwert der realen "Inband-Interferenz-Störleistungen" des Wellenfeldes (Leistungs-Durchflußdichte) berechnet, das an der Antenne anliegen kann, um so noch eine stabile "Satelliten-Signal-Aquisition" und Signalnachführung (Tracking) zu gewährleisten. Hierbei werden außerdem die Streckendämpfung (Path Loss) der übertragenen Interferenzleistung, der Antennengewinn (Gain) und Verluste (Loss), sowie die Dämpfungen des Zuleitungskabels voll berücksichtigt.

Literaturverzeichnis

[1] Dokument: ICD-GPS-200, NAVSTAR GPS, Code Ident No. 29562, June 1994

[2] Dokument: GLONASS Interface Control Document (ICD), Moscow 1995

[3] Dokument: GNSS SENSOR, ARINC CHARACTERISTIC 743A-1, November 1993

[4] Dokument: RTCA/DO-229, MOPS for GPS/WAAS Airborne Equipment, January 1996

[5] Dokument: RTCA/DO-235, ASSESSMENT OF RADIO FREQUENCY INTERFERENCE RELEVENT TO THE GNSS, January 1997

[6] Elliott D. Kaplan: Understanding GPS: principles and applications, Artech House, Boston, London, 1996

[7] F. Butsch: GPS and GLONASS Interference in Germany, Institute of Navigation, University of Stuttgart, Proceedings of the 53 Annual ION-Meeting, 1997

[8] T. Felhauer et. al.: ASN-22 Combined GPS/GLONASS Receiver Module, DASA-NFS, August 1997

[9] Reference Manual: GG24 GPS+GLONASS Receiver, Ashtech, June 1996

[10] Evalute Software 2.0 User's Guide, Ashtech, May 1996

Anhang

Analyse der Leistungs-Durchflußdichte an der Empfangsantenne

Die Grenzwerte der Leistungs-Durchflußdichte für Interferenz-Störsignale an der Antenne des ASN-22-Empfängers (DASA-NFS) und des GG24-Empfänger (Ashtech) werden unter Einbezug der vorangegangenen Interferenz-Empfindlichkeits-Meßergebnisse berechnet. Die Berechnung zeigt die wesentliche Bedeutung des "Carrier-to-Noise ratio" (C/N_0) für die C/A-Code-Korrelation und für die "Pseudo-Range-Messungen" einschließlich deren Ableitungen auf. (Carrier-Phase-Lock/Loss, Code-Phase-Lock/Loss, Pseudo-Range-Genauigkeit, Carrier-Phase-Genauigkeit, BER der Navigations-Message usw.). So werden die Berechnungen der Leistungs-Durchflußdichten PFD, bezogen auf C/N_0 an der Antenne als Funktion der vorgegebenen Interferenz-Quellen-Leistungen von I_0 = -60 dBW/MHz, I_1 = -70 dBW/MHz und I_2 = -78 dBW/MHz sowie der Abstände R der Interferenzquellen zur GNSS-Antenne, wie folgt ausgeführt:

$c := 300\cdot 10^6$ ... Light velocity - m $f := 1600\cdot 10^6$ ... Centre frequency for L1-band receiving - Hz

$\lambda := \frac{c}{f}$ $\lambda = 0.188$ ... Wave length - m $G_o := 1$ ... Reference value for antenna gain

$A_o := \frac{G_o\cdot\lambda^2}{4\cdot\pi}$ $A_o = 2.798\cdot 10^{-3}$ ... Reference value for antenna apertur - m²

$G_A := \frac{1}{A_o}$ $G_A = 357.443$ ... Gain for a antenna of a 1-m²-Aperture

$G_{dB} := 10\cdot\log(G_A)$ $G_{dB} = 25.532$ ... Gain for a antenna of a 1-m²-Aperture - dB

a) <u>for a given transmitted interference power density of</u> $I_0 := -60$ <u>dBW/MHz :</u> $n := 0..9$ $dB := 1$

$R := (1\ \ 3\ \ 5\ \ 10\ \ 20\ \ 30\ \ 50\ \ 100\ \ 200\ \ 1000)^T$ **Distance of Interference Source - m**

$PL := \overrightarrow{(-36.5 - 20\cdot\log(R))}$ Path Loss (Relative to 1m) - dB

$MHzTOHz := -60$ Conversion, MHz to Hz, dB

$IRECEIVEDPERHz_0 := \overrightarrow{(I_0 + PL + MHzTOHz)}$ Received Interference - dBW/Hz

$IANTENNAGAIN := 15$ Gain of active Antenna minus Cable Loss - dB

$IRECEIVEDPORT_0 := IRECEIVEDPERHz_0 + IANTENNAGAIN$ Received Interference at Antenna Port - dBW/Hz

$CRECEIVED = -161$ Received Signal at Antenna @ 5 degrees elevation

$CANTENNAGAIN := -4.5$

$IMPLLOSS := 2.5$ Receiver Implementation Loss

$CRECEIVEDPORT := (CRECEIVED - CANTENNAGAIN)$ Received Signal at Antenna Port @ 5 degrees

$CRECEIVEDPORT = -165.5$

$CNI_0 := CRECEIVEDPORT - IRECEIVEDPORT_0 - IMPLLOSS$ Received Carrier to Interference Density - dB-Hz

$N0THERMAL := -201.5$ Thermal Noise Density

$CN0THERMAL := CRECEIVEDPORT - IMPLLOSS - N0THERMAL$ Received Carrier to Thermal Noise Density - dB-Hz

$CN0THERMAL = 33.5$

$$CN0RATIO_0 := \overrightarrow{\left(\frac{1}{10^{\frac{CNI_0}{10}}} + \frac{1}{10^{\frac{CN0THERMAL}{10}}}\right)^{-1}}$$

Combined Received Carrier to Noise Density - dB-Hz

$$CN0_0 := \overrightarrow{\left(10 \cdot \log\left(CN0RATIO_0\right)\right)}$$

C/N Ratio is here identical with effective Signal Processing Gain Geff - dB, there are saturation effects, which limited it about to 24 dB

$$G0eff_n := wenn\left(CN0_{0_n} < 24, CN0_{0_n}, 24\right)$$

$$PFD0_n := I_0 + PL_n + G_{dB}$$

Power Flux Desity PFD at Antenna Port - dBW/m^2/MHz

b) <u>for a given transmitted interference power density of</u> $I_1 := -70$ <u>dBW/MHz :</u> $dBW := 1$ $m := 1$ $MHz := 1$

$$R := (1\ \ 3\ \ 5\ \ 10\ \ 20\ \ 30\ \ 50\ \ 100\ \ 200\ \ 1000)^T$$

Distance of Interference Source - m

$$PL := \overrightarrow{(-36.5 - 20 \cdot \log(R))}$$

Path Loss (Relative to 1m) - dB

$$MHzTOHz := -60$$

Conversion, MHz to Hz, dB

$$IRECEIVEDPERHz_1 := \overrightarrow{\left(I_1 + PL + MHzTOHz\right)}$$

Received Interference - dBW/Hz

$$IANTENNAGAIN := 15$$

Gain of active Antenna minus Cable Loss - dB

$$IRECEIVEDPORT_1 := IRECEIVEDPERHz_1 + IANTENNAGAIN$$

Received Interference at Antenna Port - dBW/Hz

$$CRECEIVED = -161$$

Received Signal at Antenna @ 5 degrees elevation

$$CANTENNAGAIN := -4.5$$

$$IMPLLOSS := 2.5$$

Receiver Implementation Loss

$$CRECEIVEDPORT := (CRECEIVED + CANTENNAGAIN)$$

Received Signal at Antenna Port @ 5 degrees

$$CRECEIVEDPORT = -165.5$$

$$CNI_1 := CRECEIVEDPORT - IRECEIVEDPORT_1 - IMPLLOSS$$

Received Carrier to Interference Density - dB-Hz

$$N0THERMAL := -201.5$$

Thermal Noise Density

$$CN0THERMAL := CRECEIVEDPORT - IMPLLOSS - N0THERMAL$$

Received Carrier to Thermal Noise Density - dB-Hz

$$CN0THERMAL = 33.5$$

$$CN0RATIO_1 := \overrightarrow{\left(\frac{1}{10^{\frac{CNI_1}{10}}} + \frac{1}{10^{\frac{CN0THERMAL}{10}}}\right)^{-1}}$$

Combined Received Carrier to Noise Density - dB-Hz

$CN0_1 := \overrightarrow{\left(10 \cdot \log\left(CN0RATIO_1\right)\right)}$ — C/N Ratio is here identical with effective Signal Processing Gain Geff - dB,

$G1eff_n := wenn\left(CN0_{1_n} < 24, CN0_{1_n}, 24\right)$ — there are saturation effects, which limited it about to 24 dB

$PFD1_n := I_1 + PL_n + G_{dB}$ — Power Flux Desity PFD at Antenna Port - dBW/m²/MHz

c) <u>for a given transmitted interference power density of</u> $I_2 := -78$ <u>dBW/MHz :</u>

$R := (1\ \ 3\ \ 5\ \ 10\ \ 20\ \ 30\ \ 50\ \ 100\ \ 200\ \ 1000)^T$ — **Distance of Interference Source - m**

$PL := \overrightarrow{(-36.5 - 20 \cdot \log(R))}$ — Path Loss (Relative to 1m) - dB

$MHzTOHz := -60$ — Conversion, MHz to Hz, dB

$IRECEIVEDPERHz_2 := \overrightarrow{\left(I_2 + PL + MHzTOHz\right)}$ — Received Interference - dBW/Hz

$IANTENNAGAIN := 15$ — Gain of active Antenna minus Cable Loss - dB

$IRECEIVEDPORT_2 := IRECEIVEDPERHz_2 + IANTENNAGAIN$ — Received Interference at Antenna Port - dBW/Hz

$CRECEIVED = -161$ — Received Signal at Antenna @ 5 degrees elevation

$CANTENNAGAIN := -4.5$

$IMPLLOSS := 2.5$ — Receiver Implementation Loss

$CRECEIVEDPORT = (CRECEIVED - CANTENNAGAIN)$ — Received Signal at Antenna Port @ 5 degrees

$CRECEIVEDPORT = -165.5$

$CNI_2 := CRECEIVEDPORT - IRECEIVEDPORT_2 - IMPLLOSS$ — Received Carrier to Interference Density - dB-Hz

$N0THERMAL := -201.5$ — Thermal Noise Density

$CN0THERMAL := CRECEIVEDPORT - IMPLLOSS - N0THERMAL$ — Received Carrier to Thermal Noise Density - dB-Hz

$CN0THERMAL = 33.5$

$$CN0RATIO_2 := \overrightarrow{\left(\frac{1}{10^{\frac{CNI_2}{10}}} + \frac{1}{10^{\frac{CN0THERMAL}{10}}}\right)^{-1}}$$

Combined Received Carrier to Noise Density - dB-Hz

$CN0_2 := \overrightarrow{\left(10 \cdot \log\left(CN0RATIO_2\right)\right)}$ — C/N Ratio is here identical with effective Signal Processing Gain Geff - dB,

$G2eff_n := wenn\left(CN0_{2_n} < 24, CN0_{2_n}, 24\right)$ — there are saturation effects, which limited it about to 24 dB

$PFD2_n := I_2 + PL_n + G_{dB}$ — Power Flux Desity PFD at Antenna Port - dBW/m²/MHz

Damit ergeben sich folgende Streckendämpfungen PL, Leistungs-Durchflußdichten PFD und effektive Prozeßgewinne G_{eff} für die Interferenz-Quellen-Leistungen I_0, I_1, and I_2 an der Empfangsantenne :

I-Distance: Pathloss: For I_0 = -60 dBW/MHz: For I_1 = -70 dBW/MHz: For I_2 = -78 dBW/MHz:

$R_n \cdot m$	$PL_n \cdot dB$	$PFD0_n \cdot \frac{dBW}{m^2 \cdot MHz}$	$G0eff_n \cdot dB$	$PFD1_n \cdot \frac{dBW}{m^2 \cdot MHz}$	$G1eff_n \cdot dB$	$PFD2_n \cdot \frac{dBW}{m^2 \cdot MHz}$	$G2eff_n \cdot dB$
1	-36.5		-26.5		-16.5		-8.5003
3	-46.0424	-70.9679	-16.9576	-80.9679	-6.958	-88.9679	1.04
5	-50.4794	-80.5104	-12.5207	-90.5104	-2.5217	-98.5104	5.4726
10	-56.5	-84.9473	-6.5004	-94.9473	3.4957	-102.9473	11.4727
20	-62.5206	-90.9679	-0.4811	-100.9679	9.5033	-108.9679	17.4124
30	-66.0424	-96.9885	3.0385	-106.9885	13.0035	-114.9885	20.8026
50	-70.4794	-100.5104	7.4686	-110.5104	17.3722	-118.5104	24
100	-76.5	-104.9473	13.4568	-114.9473	23.0861	-122.9473	24
200	-82.5206	-110.9679	19.3503	-120.9679	24	-128.9679	24
1000	-96.5	-116.9885	24	-126.9885	24	-134.9885	24
		-130.9679		-140.9679		-148.9679	

Tabelle 2 Verfügbare Leistungs-Durchflußdichte PFD an der Antenne und effektiver Prozeßgewinn G_{eff} als Funktion der Interferenz-Inband-Leistung I und des Abstandes R zu einer Interferenz-Signalquelle

Für eine stabile Satelliten-Signal-Aquisition und Satelliten-Signalnachführung (Tracking Lock) in der Gegenwart von empfangenen Interferenz-Störsignalen ist ein effektiver Prozeßgewinn G_{eff} > 10 dB notwendig ! Deshalb muß ein minimaler Abstand zu der Inband-Interferenzquelle eingehalten werden, der nur von der Interferenzleistung abhängt, die in das Empfangsband der GNSS-Empfänger fällt (vorausgesetzt ist ein unkorreliertes Interferenz-Signal). So erfordert z.B. eine Interferenz-Leistung von -60 dBW/MHz einen Sicherheitsabstand zur GNSS-Antenne von mehr als 100 m. Bei einer Interferenz-Leistung von -70 dBW/MHz ist ein Abstand größer 30 m und bei einer Interferenz-Leistung von -78 dBW/MHz von größer 10 m zur Antenne einzuhalten. Diesen Empfangsbedingungen insgesamt entsprechen einer Inband-Leistungs-Durchflußdichte PFD < -111 dBW/m^2/MHz des Interferenz-Störsignals an der GNSS-Empfangsantenne !

Leerseite

13.3 EUROCAE DISCUSSION ON RTCA GBAS MESSAGE CHANGES

ANNEX X1

EUROCAE DISCUSSION ON RTCA GBAS MESSAGE CHANGES

Comments on proposed changes by the RTCA to GBAS Message Types

This document comments on various changes to GBAS Message Types that are being proposed by the RTCA from an EUROCAE WG 28/2 perspective.

MESSAGE TYPE 1

The DO 217, 8 time-slot frame, 2 frames per second form of TDMA was adopted to maximise the number of available channels and frequency availability. Since then, the GBAS Message Type 1 has expanded in length such that there are foreseeable situations where it would not fit into one time slot. This leads to the alternatives of:-

1. shortening the message,
2. allowing the message to be sent in two parts in consecutive time slots, or
3. adopting fewer but longer time slots.

The "Extended Message Flag" facilitates the splitting of the Message Type 1 into two parts in consecutive time slots. This opens the path to alternative 2 above. This change was adopted by the ICAO GNSSP WG-B in Krasnoyarsk, although the parameter name was changed to "Additional Message Flag".

The RTCA also proposed a change to the way that Message Type 1 is to be processed. This "triple repeat" is to overcome a problem generated by the reduced frequency of transmission of the ephemeris CRC for each satellite data measurement block. EUROCAE discussed this solution and found it to be insufficiently robust.

ALTERNATIVE METHOD OF PROCESSING EPHEMERIS CHANGES FOR GBAS MESSAGE TYPE 1

Proposal Part 1

The method of rotating satellite data measurement blocks, and then ceasing this rotation for three consecutive transmissions for each ephemeris change, (or introduction of a new correction) could be removed by **placing the ephemeris CRCs back into the measurement blocks.**

This lengthens the message unacceptably in some foreseeable situations but the proposal for an "Additional Message Flag" can be used to handle these. This solution has the advantage of removing both the necessities to rotate the measurement blocks and to cease this rotation with ephemeris changes.

In this concept, the "Source Availability Duration" parameter would also be deleted from the low frequency information section of Message Type 1, as the satellite measurement blocks would no longer be rotated. Message Type 5 would be used to carry the "Source Availability Duration" information as it is intended. As no VPL-predict is being required for PT1, the value of source availability duration information is unclear.

Nevertheless, the Message Type 1 will still be undesirably long and the use of the "Additional Message Flag" might cause problems in areas where frequency availability is limited during the transition phase. It is still desirable to have the option for ground subsystems to be able to operate with just one TDMA slot per frame.

Proposal Part 2

The Message Type 1 could still be shortened in two ways. The first is already partially adopted by using the "Integrity Parameter Type". For values other than "01", there is always one redundant B-value transmitted unnecessarily in each satellite data measurement block. This redundant B-value could be removed and computed from the remaining B-values in the aircraft receiver. For "Cat I" ground subsystem, which are more likely to be TDMA slot limited and be classed B3, this change would allow one extra satellite correction to be included.

Proposal Part 3

The message length could be further shortened by not transmitting the "Range Rate Correction" (RRC) parameter in each measurement block. The aircraft receiver can calculate this parameter from successive pseudorange corrections.

This results in the aircraft having to continue to extrapolate 0.5 seconds longer in the case of a message loss but otherwise should not affect the time-to-alert.

The pseudorange correction PRC is smoothed with a 100 second time constant (200 messages), the and the RRC is calculated from the difference between successive smoothed PRCs. This means that even if the PRC is at full scale (+327.67 m) and then reverses its polarity, the smoothed PRC changes in 1 second only by 2% and RRC cannot exceed 4% numerically. For the case of 5 seconds of lost signal, the system with a ground transmitted RRC will have only a slightly different corrected PRC from one with an aircraft computed RRC and then for only 0.5 seconds. (Note: it also means that the range of the RRC values in MT1 is probably too large.)

Table B.3.5.2.3.5-1 Format of message type 1

Data Content	*Bits Used*	*Range of Values*	*Resolution*
Modified Z-count	14		0.1 sec
Integrity Parameter Type	2		
Number of Measurements	5	0 - 31	1
Measurement Type	3		
Additional Message Flag	8	0 - 1	
Measurement Block 1			
Ranging Source ID	8	1 - 255	1
Issue of Data (IOD)	8		
Ephemeris CRC (Note 1)	16		
Pseudorange Correction (PRC)	16	±327.67 m	0.01 m
σ_{pr_gnd} (unsigned –Note 2)	8	0 - 5.08 m	0.02 m
B_1 (Note 3)	8	±6.35 m	0.05 m
B_2 (Note 3)	8	±6.35 m	0.05 m
B_3 (Note 3)	8	±6.35 m	0.05 m
B_4 (Note 3)	8	±6.35 m	0.05 m
• • •			
Measurement Block N			

NOTES.-
1. GBRSs have the Ephemeris CRC set to all 0's
2. 1111 1111 indicates the ranging source is invalid
3. 1000 0000 indicates the measurement is not available

MESSAGE TYPE 2

The RTCA is proposing adding further RPDS parameters to Message Type 2 and increasing its transmission rate. They have been introduced to aid the aircraft subsystem to select the correct TDMA time slots and to shorten the GBAS acquisition time.

The EUROCAE Group has discussed these changes. The purpose of MT2 is to provide data on the ground subsystem and its environment. The proposed additional RPDS parameters are associated with the Message Type 4.

The objectives of speeding GBAS acquisition time is not fulfilled by the proposed change in MT2 as the aircraft must in any case find the correct FAS block in MT4. Increasing the rate of transmission of either MT2 or MT4 also reduces the number of FAS blocks that can be transmitted, if the data broadcast is TDMA slot limited.

The proposed RPDS status parameter is intended to enable the ATC to disable specific approaches. Such a disablement is supposed to be long term and subject to a NOTAM. Hence there is no urgency associated with the ground subsystem transmitting an RPDS status parameter.

If ATC control of FAS block transmissions is really required, the need should be studied for other alternative methods. The same functionality will presumably also be desirable for SBAS and use the same controller / pilot interface. If this is by NOTAM, the FAS block could be removed from the GBAS ground subsystem or the SBAS aircraft subsystem with the same effect. The RPDS is already in the FAS block and in MT4 the most significant bit of the Approach Path Designator could be used to additionally show RPDS status.

MESSAGE TYPE 4

The RTCA is proposing a number of changes to MT4, both within the variable part of the message and within the FAS blocks. These changes include making the alert limits variable for each FAS block and adding runway width and length to the FAS block. A further proposal involves using ASCII coding within the FAS blocks.

The EUROCAE Group has discussed these changes. The purpose of MT4 is to provide static high integrity data on the approaches supported by the ground subsystem. The addition of the course width and length offset is desirable. Some definition of how the aircraft should use these parameters will be required in the MOPS. The desirability for using ASCII within the FAS block is not understood and seems unnecessary. ASCII is still a coding into binary system, just as that currently used.

The addition of the FAS block length parameter to MT4 is sensible if FAS blocks are likely to get longer.

The desirability of making the Alert Limits variable per FAS seems to make the aircraft certification process more difficult. The aircraft would in any case have to be certified to use the minimum Alert Limit values. This proposal to add the Alert Limits to MT4 should be studied further before adoption.

Transmitting one FAS block per approach procedure for Cat I, II and III will increase the demand for channel numbers and TDMA slots. It would be desirable if one set of path point data could serve all weather conditions.

MESSAGE TYPE 5

The ICAO GNSSP WG-B accepted the change proposed by the RTCA for reversing the order of transmission of obscured satellites and obscured approaches within MT5.

If the above EUROCAE MT1 proposals are adopted, they will increase the necessity for MT5 (currently optional for PT1). This necessity is however decreased by the removal of a VPL-predict requirement from PT1. The aircraft subsystem should have a default condition of calculating setting satellites itself based on a (5°)-mask angle. So MT5 should only be required for approaches where this standard mask angle is not valid.

EUROCAE is proposing a number of small changes to the ICAO definition of Message Type 5, as follows.

(Attachment from MT5.doc, to maintain marked changes)

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13.4 EUROCAE ALTERNATIVE GBAS MESSAGES SUBMITTED TO RTCA

ANNEX X2

EUROCAE ALTERNATIVE GBAS MESSAGES SUBMITTED TO RTCA

EUROCAE proposed changes to GBAS Message Types and VDB data acquisition time

The CAT I Ground-Based Augmentation System will be used by aircraft during approaches. The main concern in this flight phase is safety.

As a consequence, our general recommendation is **to keep the messages as simple, safe, reliable, repeatable and robust as possible** in order to avoid misunderstandings (between Ground stations and aircraft developers) or side effects (due to unforeseen or unvalidated combinations).

If the definition of the messages includes too many configurations, the validation tasks of the ground stations and airborne receivers will be very long. Concerning the flight tests, there is a risk that a given aircraft will be never tested against some ground stations using a specific feature. In this case, the first flight test would be performed in operations during revenue flights.

One of the main assumptions made is that, because of the new channels assignments, only 48 FAS are allowable per frequency (case of overlapping stations), therefore 6 FAS are allowable per slot. In order to carry out frequency capacity analysis, we have to make a hypothesis on the maximum number of slots that can be used by a station.

We have described, below, the content of messages for a Category I ground station that would
use one or two TDMA time slots,
provide corrections for up to 28 ranging sources,
provide data for up to 12 FAS, that can be transmitted within 4 seconds.
We consider that, in most cases, the use of only one slot (i.e. corrections for 14 satellites and 6 FAS), will be enough for a station intended to replace a Category I ILS.

Message Type 1:

Data content	Bits used	Range of values	Resolution	Bytes
Modified Z count	14	0-1119.9 s.	0.1 second	2 bytes
Additional message flag	2		00:All corrections on one time slot 01:Corrections on two time slots Other:Reserved	
Number of measurements	5	0 to 14	1	1 byte
Measurement type	3		000:C/A or CSA code L1 001: Reserved for C/A code L2 (GPS only) 010: Reserved for P(Y) code L1 (GPS only) 011: Reserved for P(Y) code L2 (GPS only) Other:Reserved for use with GLONASS / SBAS	
Spare	8			1 byte
Measurement block for each valid satellite				
Ranging source ID	8	1-255	1	1 byte
Issue of data IOD	8	1-255	1	1 byte
Ephemeris CRC	16			2 bytes

Data content	Bits used	Range of values	Resolution	Bytes
Pseudorange correction PRC	16	± 327.67 m	0.01 m	2 bytes
$\sigma_{pr\text{-}gnd}$	8	0-5.08 m	0.02 m , (5.11m:source invalid)	1 byte
B1	8	± 6.35 m	0.05 m , (-6.40m measurement invalid)	1 byte
B2	8	± 6.35 m	0.05 m, (-6.40m measurement invalid)	1 byte
B3	8	± 6.35 m	0.05 m, (-6.40m measurement invalid)	1 byte
B4	8	± 6.35 m	0.05 m, (-6.40m measurement invalid)	1 byte
Repeat measurement block over N satellites				

The complete set of satellite corrections may be distributed in one or two type one messages. If two type one messages are necessary, the additional message flag is set to 01 and the two messages are broadcast within the two different allocated time slots.
The complete set of satellite corrections contains only the ranging sources in view validated by the ground station. Any ranging source not included in the type one message(s) has to be considered as invalid.
Each type one message shall contain an integer number of measurement blocks.

Length of type one message:

Header + CRC	: 10 bytes
Common part for all sat	: 04 bytes
part per ranging source	: 11 bytes
Total length	: 14 + N.11 where N is the number of sat.

Rate of complete set of corrections : 2 Hz

Proposed changes on message type 1:

Integrity parameter type :

In the current definition there are some variations concerning the number of Bs broadcast (not always equal to the number of receivers).

Our proposal is to define the Measurement Block format with always 4 Bs in order to have only one Measurement Block length for all the GBAS ground stations and thus facilitate validation and certification.

Ephemeris CRC :

GBAS relies on the differential processing of the space signals. In order to do that, use of identical ephemeris data by the ground station and the aircraft receivers is paramount.

For this purpose, a given correction is to be applied by the aircraft receiver only if the following 3 parameters received via the data link are identical to the one directly decoded by aircraft from the space segment:

- Satellite ID,
- Satellite IOD,
- Ephemeris CRC.

As a consequence, availability and dependability of the Ephemeris CRC parameter attached to each Measurement Block of correction are very important.

In the current definition it is sent in a separate low frequency section. There is a risk of errors or lost of a new value (triple repeat was introduced in order to mitigate the risk but it add complexity thus potential error causes and additional combinations).

The method of rotating satellite data measurement blocks, and then ceasing this rotation for three consecutive transmissions for each ephemeris change, (or introduction of a new correction) can be removed by placing the ephemeris CRCs back into the measurement blocks. This solution has the advantage of removing both the necessities to rotate the measurement blocks and to cease this rotation with ephemeris changes.

This method had been proposed in order to shorten message type 1, so that it could fit into one time slot. Meanwhile, the data broadcast capacity problem has been solved through the "Extended Message Flag", which facilitates the splitting of the Message Type 1 into two parts in two time slots. This change was adopted by the ICAO GNSSP WG-B in Krasnoyarsk, although the parameter name was changed to "Additional Message Flag".

Source Availability Duration :

This parameter belongs to the low frequency section of the message requiring a rotation of the measurement blocks :

- This is an additional source of complexity, variability and then errors,
- There are no real needs for this parameter in a CAT I GBAS system. The ground station will only broadcast corrections for satellites above 5°. Problems will only occur in case of obstacles higher than 440 m located 5 km from the ground station). Sitting considerations would probably avoid locatation of Ground Stations at places where there are obstacles above 5°.
- In case of an obstacle above 5° and if the masking of a given satellite is foreseen:
- On-board means for crew information are very poor. When an aircraft enter the coverage of the selected Ground Station, the flag is normally removed. In case of lack of satellites (actual situation or foreseen situation according to the Source Availability Duration parameter) the flag will remain raised on the flight deck.
- Forecast of the approach duration is very imprecise because the aircraft receiver is not aware of the approach procedure. An estimate will be established according to the distance and the altitude.
- Annunciation of the unavailability of the ground station at the beginning of the approach instead of during the approach is of low interest.

In any case, a dispatch criteria will be established in order to guaranty a suitable availability level.

The "Source Availability Duration" parameter should also be deleted from the low frequency information section of Message Type 1, as the satellite measurement blocks would no longer be rotated. Message Type 5 would be used to carry the "Source Availability Duration" information as it is intended. As no VPL-predict is being required for PT1, the value of source availability duration information is unclear.

Range Rate Correction :

The message length can be shortened by not transmitting the "Range Rate Correction" (RRC) parameter in each measurement block. The aircraft receiver can calculate this parameter from successive pseudorange corrections. This results in the aircraft having to continue to extrapolate 0.5 seconds longer in the case of a message loss but otherwise should not affect the time-to-alert.

The pseudorange correction PRC is smoothed with a 100 second time constant (200 messages), and the RRC is calculated from the difference between successive smoothed PRCs. This means that even if the PRC is at full scale (+327.67 m) and then reverses its polarity, the smoothed PRC changes in 1 second only by 2% and RRC cannot exceed 4% numerically. For the case of 5 seconds of lost signal, the system with a ground transmitted RRC will have only a slightly different corrected PRC from one with an aircraft computed RRC and then for only 0.5 seconds.

RRC might be necessary to achieve Cat III accuracy. Then it should be transmitted by Message Type 6. As far as Cat I is concerned, the computation of RRC by the airborne receiver should besufficient, like for SBAS, which tolerates up to 12s. between two corrections.

Message Type 2:

Data content	Bits used	Range of values	Resolution	Bytes
GBAS Operating receivers	2		00:2 reference receivers 01:3 reference receivers 10:4 reference receivers 11:Reserved	
GBAS accuracy designator	2		00: GBAS has accuracy designation A 01: GBAS has accuracy designation B 10: GBAS has accuracy designation C 11: Reserved	1 byte
GBAS health	1		Spare	
GBAS continuity /integrity designator	3		000: GBAS supports terminal area operations 001: GBAS supports Performances Type 1 111:Do not use Others : reserved	
Reserved	16		Spare	2 bytes
Local Magnetic Variation	8	± 31.75°	0.25° (- 32 : don't use)	1 byte
Refractivity index	8	± 381	3, (-384 : don't use)	1 byte
Scale height	8	± 12 700 m	100 m (-12 800 : don't use)	1 byte
Refractivity Uncertainty	8	0- 254	1 (255 : don't use)	1 byte
Latitude	32	± 90.0°	0.0005 arc sec	4 bytes
Longitude	32	± 180°	0.0005 arc sec	4 bytes
Ellipsoid Offset	24	± 84 886.07 m	0.01 m	3 bytes

Length of type two message:

Header + CRC	: 10 bytes
Message block	: 26 bytes
Total length	: 28 bytes

Proposed changes on message type 2:

The RTCA is proposing adding further RPDS parameters to Message Type 2 and increasing its transmission rate. They have been introduced to aid the aircraft subsystem to select the correct TDMA time slots and to shorten the GBAS acquisition time.

The EUROCAE Group has discussed these changes. The purpose of MT2 is to provide data on the ground subsystem and its environment. The proposed additional RPDS parameters are associated with the Message Type 4 and should part of Message Type 4.

The objectives of speeding GBAS acquisition time is not fulfilled by the proposed change in MT2 as the aircraft must in any case find the correct FAS block in MT4. Increasing the rate of transmission of either MT2 or MT4 also reduces the number of FAS blocks that can be transmitted, if the data broadcast is TDMA slot limited.

The proposed RPDS status parameter is intended to enable the ATC to disable specific approaches. Such a disablement is supposed to be long term and subject to a NOTAM. Hence there is no urgency associated with the ground subsystem transmitting an RPDS status parameter.

If ATC control of FAS block transmissions is really required, the need should be studied for other alternative methods. The same functionality will presumably also be desirable for SBAS and use the same controller / pilot interface. If this is by NOTAM, the FAS block could be removed from the GBAS ground subsystem or the SBAS aircraft subsystem with the same effect. The RPDS is already in the FAS block and in MT4 the most significant bit of the Approach Path Designator could be used to additionally show RPDS status.

Our last point is that all the fields in MT2 should not be modified during the ground station operation («GBAS operating receivers », «GBAS Health »).

EUROCAE proposal is to send the RPDS parameters as part of Message Type 4 and increase MT4 rate.

Message Type 4:

FAS approach Path Designator :

Data content	Bits used	Range of values	Resolution	Bytes
FAS Approach Path Designator	8		00 : The approach is off 01 : TBD 10 : Lateral only 11 : Supports Cat I operations	1 byte

FAS data block :

Data content	Bits used	Range of values	Resolution	Bytes
Operation type	4		0000: Straight in approach Other: TBD	1 byte
SBAS Provider Identifier	4		0000: WAAS 0001: EGNOS 0010: MSAS 1111: All services provided Other : Reserved	
Airport ID	32		3 or 4 ISO#5 characters	4 bytes
Runway number	6		0- 36	1 byte
Runway letter	2		00: no letter 01: Right 10: Centre 11: Left	

Data content	Bits used	Range of values	Resolution	Bytes
Approach design information	3		000: Straight in approach FPAP at the end of the runway 0001: Straight in approach FPAP not at the end of the runway 010 : Offset approach Other : TBD	1 byte
Route indicator	5		1 ISO#5 character	
Reference path data selector	8	0 to 199		1 byte
Reference path ID	32		3 or 4 ISO#5 characters	4 bytes
RDP Latitude	32	± 90.0°	0.0005 arc sec	4 bytes
RDP Longitude	32	± 180.0°	0.0005 arc sec	4 bytes
RDP Height	16	- 512 m, + 6 041.5 m	0.1 m	2 bytes
FPAP Latitude	32	± 90.0°	0.0005 arc sec	4 bytes
FPAP Longitude	32	± 180.0°	0.0005 arc sec	4 bytes
Approach Datum Crossing Height	15	0 to 3 276.8 ft 0 to 1 638.4 m	0.1 ft 0.05 m	2 bytes
Approach DCH unit selector	1		0:feet, 1:meters	
Glide path angle	16	0 to 90°	0.01°	2 bytes
Course width	8	300 to 450 ft	1 ft	1 byte
Length offset	8	0 to 6 350 ft	10 ft	1 byte
FAS CRC	32		From 'Operation type' field to 'Length offset' field included	4 bytes

The complete set of Final Approach Segments may be distributed in one or more type four messages. A type 4 message shall contain at least one complete FAS or an integer number of complete FAS blocks.

Length of type 4 message:

Header + CRC	: 10 bytes
Per FAS	: 41 bytes
Total length	: 10 + P.41 where P is the number of approaches

Proposed changes on message type 4:

The RTCA is proposing a number of changes to MT4, both within the variable part of the message and within the FAS blocks. These changes include making the alert limits variable for each FAS block and adding runway width and length to the FAS block. A further proposal involves using ASCII coding within the FAS blocks.

The EUROCAE Group has discussed these changes. The purpose of MT4 is to provide static high integrity data on the approaches supported by the ground subsystem. The addition of the course width and length offset is desirable. Some definition of how the aircraft should use these parameters will be required in the MOPS. The desirability for using ASCII within the FAS block is not understood and seems unnecessary. ASCII is still a coding into binary system, just as that currently used.

The FAS Approach Path Designator can contain the approach status. The only drawback we can see is that, if this field can be modified , it is not possible to have the CRC of the whole MT4 static, which would improve reliability. At least, the FAS CRC has to be «hard coded »; modification of any data in the FAS data block should require a specific procedure (with Flight Inspection?).

The addition of the FAS block length parameter to MT4 is sensible if FAS blocks are likely to get longer.

The desirability of making the Alert Limits variable per FAS seems to make the aircraft certification process more difficult. The aircraft would in any case have to be certified to use the minimum Alert Limit values. This proposal to add the Alert Limits to MT4 should be studied further before adoption.

Transmitting one FAS block per approach procedure for Cat I, II and III will increase the demand for channel numbers and TDMA slots. It would be desirable if one set of path point data could serve all weather conditions.

Message type 5 :

The ICAO GNSSP WG-B accepted the change proposed by the RTCA for reversing the order of transmission of obscured satellites and obscured approaches within MT5.

The necessity for Message Type 5 is decreased by the removal of a VPL-predict requirement from PT1. The aircraft subsystem should have a default condition of calculating setting satellites itself based on a (5°)-mask angle. So MT5 should only be useful for ground stations or approaches where this standard mask angle is not valid.

Data content	Bits used	Range of values	Resolution	Bytes
Modified Z count	14	0 to 1199.9 sec	0.1sec	2 bytes
Spare	2			
Impacted sources (1)	8	0 to28		1 byte
Repeat over Nt impacted sources(1)				
Ranging source ID	8	0 to 255		1 byte
Source availability Sense	1			
Source availability duration	7	0 to 1270 sec	10 sec	1 byte
Obstructed approaches	8	0 to 255		1 byte
Repeat over P obstructed approaches :				
Reference Path data selector	8			1 byte
Impacted sources (2)	8	0 to28		1 byte
Repeat over Np impacted sources (2) for approach p :				
Ranging source ID	8	0 to 255		1 byte
Source availability Sense	1			
Source availability duration	7	0 to 1270 sec	10 sec	1 byte

Impacted sources (1) corresponds to the numbers of sources for which the duration is reduced due to unique constellation masking.
Impacted sources (2) corresponds to the number of sources for which the duration is reduced due to approach unique constellation masking.

The complete set of source availability may be distributed in one or more type five messages.

Length of type 5 message shall be limited to 54 bytes in order to fit into one time slot with a MT1 containing corrections for 14 satellites.

A Message Type 5 shall contain satellites and approaches for which the standard 5° mask is not adequate to describe measurement availability.

Proposal for message broadcast :

The number of useful bytes within a TDMA slot is = 222 bytes

In one slot, it is possible to broadcast one type 1 message followed either by one type 4 message containing data for only one FAS, or by one type 2 message, or by one type 5 message :

<u>First slot :</u>

T0																			*219 bytes*
Type one message																	**Type four message**		
Mess1 header	all sat	sat 1	sat 2	sat 3	sat 4	sat 5	sat 6	sat 7	sat 8	sat 9	sat 10	sat 11	sat 12	sat 13	sat 14	Mess CRC	Mess4 header	FAS block 1	Mess CRC
T0+0.5s																			*219 bytes*
Type one message																	**Type four message**		
Mess1 header	all sat	sat 1	sat 2	sat 3	sat 4	sat 5	sat 6	sat 7	sat 8	sat 9	sat 10	sat 11	sat 12	sat 13	sat 14	Mess CRC	Mess4 header	FAS block 2	Mess CRC
T0 + 1 s.																			*219 bytes*
Type one message																	**Type four message**		
Mess1 header	all sat	sat 1	sat 2	sat 3	sat 4	sat 5	sat 6	sat 7	sat 8	sat 9	sat 10	sat 11	sat 12	sat 13	sat 14	Mess CRC	Mess4 header	FAS block3	Mess CRC
T0+1.5s																			*219 bytes*
Type one message																	**Type four message**		
Mess1 header	all sat	sat 1	sat 2	sat 3	sat 4	sat 5	sat 6	sat 7	sat 8	sat 9	sat 10	sat 11	sat 12	sat 13	sat 14	Mess CRC	Mess4 header	FAS block 4	Mess CRC
T0 + 2 s.																			*219 bytes*
Type one message																	**Type four message**		
Mess1 header	all sat	sat 1	sat 2	sat 3	sat 4	sat 5	sat 6	sat 7	sat 8	sat 9	sat 10	sat 11	sat 12	sat 13	sat 14	Mess CRC	Mess4 header	FAS block 5	Mess CRC
T0+2.5s																			*219 bytes*
Type one message																	**Type four message**		
Mess1 header	all sat	sat 1	sat 2	sat 3	sat 4	sat 5	sat 6	sat 7	sat 8	sat 9	sat 10	sat 11	sat 12	sat 13	sat 14	Mess CRC	Mess4 header	FAS block 6	Mess CRC
T0 + 3 s.																			**196** *bytes*
Type one message																	**Type two message**		
Mess1 header	all sat	sat 1	sat 2	sat 3	sat 4	sat 5	sat 6	sat 7	sat 8	sat 9	sat 10	sat 11	sat 12	sat 13	sat 14	Mess CRC	Mess2 header	Mess block	Mess CRC
T0+3.5s																			*222 bytes*
Type one message																	**Type five message**		
Mess1 header	all sat	sat 1	sat 2	sat 3	sat 4	sat 5	sat 6	sat 7	sat 8	sat 9	sat 10	sat 11	sat 12	sat 13	sat 14	Mess CRC	Mess5 header	Mess block	Mess CRC

<u>Second slot, if corrections for more than 14 satellites or data for more than 6 FAS are to be transmitted</u>

T0+N*62.5ms																			*219 bytes*
Type one message																	**Type four message**		
Mess1 header	all sat	sat 15	sat 16	sat 17	sat 18	sat 19	sat 20	sat 21	sat 22	sat 23	sat 24	sat 25	sat 26	sat 27	sat 28	Mess CRC	Mess4 header	FAS block 7	Mess CRC
T0+N*62.5ms +0.5s																			*219 bytes*
Type one message																	**Type four message**		
Mess1 header	all sat	sat 15	sat 16	sat 17	sat 18	sat 19	sat 20	sat 21	sat 22	sat 23	sat 24	sat 25	sat 26	sat 27	sat 28	Mess CRC	Mess4 header	FAS block 8	Mess CRC
T0+N*62.5ms + 1 s.																			*219 bytes*
Type one message																	**Type four message**		
Mess1 header	all sat	sat 15	sat 16	sat 17	sat 18	sat 19	sat 20	sat 21	sat 22	sat 23	sat 24	sat 25	sat 26	sat 27	sat 28	Mess CRC	Mess4 header	FAS block 9	Mess CRC

T0+N*62.5ms +1.5s																		*219 bytes*	
Type one message																	**Type four message**		
Mess1 header	all sat	sat 15	sat 16	sat 17	sat 18	sat 19	sat 20	sat 21	sat 22	sat 23	sat 24	sat 25	sat 26	sat 27	sat 28	Mess CRC	Mess4 header	FAS block10	Mess CRC
T0+N*62.5ms + 2 s.																		*219 bytes*	
Type one message																	**Type four message**		
Mess1 header	all sat	sat 15	sat 16	sat 17	sat 18	sat 19	sat 20	sat 21	sat 22	sat 23	sat 24	sat 25	sat 26	sat 27	sat 28	Mess CRC	Mess4 header	FAS block11	Mess CRC
T0+N*62.5ms +2.5s																		*219 bytes*	
Type one message																	**Type four message**		
Mess1 header	all sat	sat 15	sat 16	sat 17	sat 18	sat 19	sat 20	sat 21	sat 22	sat 23	sat 24	sat 25	sat 26	sat 27	sat 28	Mess CRC	Mess4 header	FAS block12	Mess CRC
T0 +N*62.5ms + 3 s.																		*222 bytes*	
Type one message																	**Type five message**		
Mess1 header	all sat	sat 15	sat 16	sat 17	sat 18	sat 19	sat 20	sat 21	sat 22	sat 23	sat 24	sat 25	sat 26	sat 27	sat 28	Mess CRC	Mess5 header	Mess block	Mess CRC
T0+N*62.5ms +3.5s																		*222 bytes*	
Type one message																	**Type five message**		
Mess1 header	all sat	sat 15	sat 16	sat 17	sat 18	sat 19	sat 20	sat 21	sat 22	sat 23	sat 24	sat 25	sat 26	sat 27	sat 28	Mess CRC	Mess5 header	Mess block	Mess CRC

With this proposal, data for all the FAS are transmitted within 4 seconds, which is consistent with the operational requirements. It also provides the Message Type 2 every 4 seconds. Using only one slot allows to send information for up to 24 ranging sources in one MT5. With two slots, it is possible to send 3 MT5, since only one MT2 is required for a ground station.

To solve the problem of the rapid reselection of a new RPDS, if 4 seconds is considered as being too long, the airborne receiver could be required to record all FAS blocks in MT4, in all slots, and build a table of which ground stations are associated with which RPDS in the frame. This would allow to have an operational requirement, for the airborne receiver, to be capable of changing to another RPDS on the selected frequency within 1 second.

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13.5 EUROCAE TIME-TO-ALERT PROPOSAL

ANNEX X3

EUROCAE TIME-TO-ALERT PROPOSAL

1. A MORE DETAILED EXPLANATION OF THE TIME-TO-ALERT CONCEPT FOR CAT III

Discussions over the correct definition, allocation and application of the time-to-alert continue. This is an attempt to clarify the current EUROCAE MASPS (Version 17) concept when it would be applied to support Cat III.

1.1 System Level Time-to-Alert

The system level or total time-to-alert requirement is well accepted for a GBAS that supports precision approach in Category I conditions. EUROCAE WG 28/2 would have the requirement expressed as follows:-

1.1.1 System Time-To-Alert

The system Time-to-Alert is the total time between the onset of a failure condition that results in an unacceptable Navigation System Error (i.e. greater than the alarm limit), and the issue of a warning to the aircraft.

This time is a never to be exceeded limit and is intended to protect the aircraft against prolonged periods of guidance outside the lateral or vertical alert limits.

The never to be exceeded total system Time-to-Alert shall be 1 second (for Cat III).

2. ALLOCATION OF TIME-TO-ALERT TO SIGNAL-IN-SPACE AND AIRCRAFT

The simplest allocation of the 1 second System Time-to-Alert to the satellite + ground and aircraft segments of GBAS is to give each half, namely 0.5 seconds. However, this results in a non-minimum requirement in many situations. To illustrate this, various situations are considered below.

2.1 Normal fault free operation

This simple 0.5/0.5 split has the disadvantage of possibly increasing the false alarm rate in normal failure-free operation. This occurs when the only source of an alert comes from a geometry dependent error. This is detected in the aircraft by the horizontal or vertical protection limit calculations that continue to generate results greater than their respective alert limits for longer than the aircraft's time-to-alert period. In this situation the aircraft could be given the whole 1 second.

2.2 Fault free loss of data broadcast reception

Perhaps the next most likely situation is the aircraft flying into a combination of fade and data broadcast interference. This is mostly likely to occur far from the threshold. Here the aircraft is expected to be able to coast through a certain number of lost messages. Given that neither the satellites, nor the ground subsystem nor the aircraft are actually failed, the aircraft could use the whole second before raising an alert. The case of a ground fault combined with a loss of reception is addressed in the aircraft allocation section below.

2.3 Simple satellite failures

Simple satellite failures are defined to be those that the ground subsystem (and maybe also the aircraft) can detect within one computation cycle. The computation cycle is assumed to take at most 0.5 seconds to complete. Such failures include the satellite marking itself as unhealthy. Given the possibility of a transmission or reception error in one cycle, it is necessary for the ground subsystem to insert a warning into its message type 1 immediately. The only way to win time is use more than one time-slot per frame to provide a repeat transmission within 0.5.seconds. Depending on the failure, this might start with setting one or more B-values to "do not use", setting the σ_{pr_gnd} to "do not use" or removing the satellite measurement block. Whereby, the latter action should first be done after 6 seconds of "do not use" transmissions for that satellite.

2.4 Complex satellite failures

Complex satellite failures are defined to be those that the ground subsystem can only reliably detect after several computation cycles. Since satellite signal quality monitors are installed for all known failure modes of the satellites, it is a little difficult to estimate the probability of an unknown failure mode occurring. Nevertheless, a requirement has been introduced that such an failure shall be either detected within 0.5 seconds and the aircraft warned with a ”do not use” signal for 6 seconds prior to the satellite corrections being dropped from message type 1. *Note: one such failure might stem from an excessive* σ_{pr_gnd} *value but the method of measuring this parameter has not yet been defined.*

This requirement is likely to force the ground subsystem into parallel redundancy and a significant reduction in its computational cycle.

2.5 Simple ground subsystem failures

Simple ground subsystem failures are defined to be those failures in the ground subsystem’s own operation that the ground subsystem monitor can detect within one computation cycle. It is necessary to allow the ground subsystem only one cycle to correct this failure (for example, to switch to hot standby). This implies at least a doubling of the effective cycle rate over a Cat I ground subsystem.

These failures fall into two groups, those that resulted in a faulty transmission and those that were stopped by the monitor prior to transmission. Either of these could lead to the ground subsystem returning to normal operation or in shutting down. If the ground subsystem still has correct control of its data broadcast but cannot resume normal operation, it should signal this failure to the aircraft by transmitting an ”empty” message type 1 for 6 seconds prior to ceasing transmissions completely.

2.6 Complex ground subsystem failures

Complex ground subsystem failures are defined to be those failures that the ground subsystem can only reliably detect after several computation cycles. A failure modes and effects analysis is required of the ground station prior to type approval. In the absence of this, it is difficult to see what failures in a digital system could creep past a digital threshold for more than one computational cycle and require several cycles to detect. Nevertheless, the ground subsystem is required to detect such failures within 0.5 seconds. Once again, this requirement will force the ground station to increase its cycle rate.

2.7 Signal-in-Space (satellites and ground subsystem) allocation

EUROCAE WG 28/2 has the requirement expressed as follows:-

2.7.1 Signal-in-Space Time-to-Alert

For GBAS, the ground subsystem is monitoring not only itself but also the ranging sources. For satellite alert conditions, ceasing radiation of the data broadcast is typically not acceptable because the system may support multiple functions.

A failure condition that is solely due to inadequate geometry shall be detected by the aircraft subsystem. Other failure conditions within the constellation shall be detected as part of the normal operation of the ground subsystem and the broadcast messages shall be appropriately annotated.

If the data broadcast has not failed, the never to be exceeded Signal-in-Space Time-to-Alert refers to the time between the onset of the failure condition and the time that the last bit in the first message containing integrity information reflecting the failure condition is transmitted. The never to be exceeded Signal-in-Space Time-to-Alert shall be 0.5 seconds. The ground subsystem shall set, in message type 1, the σ_{pr_gnd} and B-values appropriately to signal the failure condition. Satellites that have been marked as ”do not use” for longer than 6 seconds shall be excluded from message type 1.

A failure condition within the ground subsystem shall result in the monitoring system taking action. This monitoring action shall prevent erroneous messages from being transmitted for longer than 0.5 seconds. An "empty" message type 1 shall be used to indicate this failure. (Number of measurements set to zero, no measurement blocks present.)

If the ground data broadcast monitoring function detects a failure condition in the transmission, the GBAS ground subsystem shall cease transmission within 0.5 second if the failure condition cannot be corrected within that 0.5 seconds.

2.8 Aircraft Perspective

The aircraft views the data broadcast signal as always being correct. The only integrity check required from the aircraft stems from the geometry of the satellites that the aircraft is using for generating guidance signals. This will always be a subset of the satellites for which the ground station is providing corrections.

As combinations of interference and signal fading can interrupt the reception of the data broadcast, the aircraft faces two cases. The first is continuous reception of the data broadcast; the second is intermittent reception degrading to complete loss of reception.

In the first case, if the aircraft is receiving corrections that contain no warnings, it can take 1 second to decide to raise a flag to indicate loss of integrity due to poor geometry. If the data broadcast includes σ_{pr_gnd} "do not use" warnings, the time-to-alert should be reduced to 0.5 seconds, should the resulting geometry be inadequate, as the aircraft must assume that the ground subsystem might have taken 0.5 seconds to raise these warnings. If the aircraft receives an "empty" message type 1, it should raise an alert flag within 0.5 seconds.

In the second case of intermittent reception, the aircraft can loose 1 second of reception before raising an alert flag, if the messages up to the loss of reception were all good but only 0.5 seconds if the last message received contained warnings.

This leaves the problem of the ground station starting to transmit messages containing warnings just as the aircraft looses reception. If these warnings would have resulted in a protection level alert in the normal reception case, the aircraft would have had 1 second to raise a flag. If these warnings were an "empty" message type 1, and the aircraft must assume this to be the case, the aircraft can wait only 0.5 seconds. Consequently, either the reception is recovered, the "empty" message received and then within 0.5 second an alert flag raised, or the alert flag is raised due to loss of reception after 1 seconds.

This still leaves the case where the ground subsystem has taken 0.5 seconds to find the complex failure and its first warning message is the first one that the aircraft fails to receive. In the EUROCAE concept this case is set aside as part of the integrity risk. The following logic is used.

The probability of losing any one message is small (specified as 0.001). The probability of losing 2 consecutive messages is thus 10^-6. This probability has to be multiplied by the probability of an unknown failure condition occurring and the probability that this failure occurs just when the aircraft has lost data broadcast reception. For Cat III this is inadequate, so the ground station must be allocated more time slots per frame. If three slots per frame are allocated to message type 1, then loss of one second of transmissions represents a probability of 10^-18 and the risk is small enough to be included in the remaining integrity risk.

2.9 Aircraft Allocation

EUROCAE WG 28/2 would have the Cat III requirement expressed as follows:-

2.9.1 Aircraft subsystem Time-to-Alert

In normal operation of the ground and aircraft subsystems, the latter may detect an excursion of the calculated geometry dependent integrity values beyond the permitted limits. This excursion shall not last longer 1 second without the aircraft receiving a warning.

If the data broadcast is being received, then the time between receiving the last bit of a message containing information that implies that the required NSE cannot be achieved and the issuing of a warning to the aircraft shall not exceed 0.5 seconds.

If the messages necessary for navigation have not been received from the data broadcast for a period longer than 1 seconds, the aircraft subsystem shall issue a warning to the aircraft.

Note:

Case 1: The ground subsystem is transmitting correct messages but they are not being received.

Case 2: The ground station has temporarily ceased transmission, its last message was good.

Case 3: The ground subsystem has detected that it was sending false data after 0.5 second has ceased transmission.

Case 4: The ground station has detected a constellation failure condition and taken 0.5 seconds. It then detects that it has a VDB failure and takes 0.5 seconds to cease transmission, the aircraft subsystem now has 0 seconds left to raise an alert.

For cases 1 and 2, the aircraft could have 1 second of coasting time. Case 3 drives the requirement and reduces the time left for the aircraft to receive an alert to 0.5 seconds. Case 4 is a dual independent failure situation effecting continuity to the order of 10^{-10}*, so can be ignored.*

The following tables illustrated this TTA concept.

Failure	gnd TTA – triggered by monitor function	air TTA – triggered by PL/AL, "empty MT1 or long VDB loss	comments
fault free normal	÷	❑ continuous VDB reception: ❑ no warnings transmitted (? geometry): 6 sec	❑ geometry dependent alert ❑ any warning reduces air TTA from 5 to 3 sec until at least 6 sec of warning free messages are received.
fault free loss of VDB reception	÷	❑ intermitted VDB reception: ❑ messages were good until interruption: 5 sec ❑ (if last message contained warnings: 3 sec)	❑ caused by fade + interference; ❑ (assumes no complex SV or gnd failure!)
simple SV failure	❑ detection: 1 sec ??"do not use " by σ_{gnd} ❑ remove SV after 6 sec	❑ continuous VDB reception: ❑ σ_{gnd} "do not use": 3 sec	❑ gnd detects within 1 cycle ❑ aircraft shortens TTA
simple SV failure loss of VDB reception	❑ detection: 1 sec ??"do not use " by σ_{gnd} ❑ remove SV after 6 sec	❑ simultaneous loss of VDB and raised gnd warnings: ❑ for missed σ_{gnd} "do not use" 5 sec ❑ recovered reception *and* σ_{gnd} "do not use" received: 0.5 sec	❑ Probability of missing one message = 0.001
complex SV failure	❑ detection (Req): 3 sec ? σ_{gnd} "do not use " for 6 sec before SV removal	❑ continuous VDB reception: ❑ σ_{gnd} "do not use": 3 sec	❑ gnd detects after several cycles ❑ no prob for unknown (hence not monitored?!) SV failure modes
complex SV failure loss of VDB reception	❑ detection (Req): 3 sec ? σ_{gnd} "do not use " for 6 sec before SV removal	❑ simultaneous loss of VDB and raised gnd warnings: ❑ messages were good till interruption: 5 sec	❑ gnd took 3 sec to detect (complex f.) **?** **integrity risk**

simple gnd failure	❑ still control but no normal operation: ? ”empty” MT1 for 6 sec before ceasing	❑ continuous VDB reception: ❑ ”empty” MT1 0.5 sec	❑ monitored within 1 cycle ❑ 2 cycles allowed to correct within ? error stopped or faulty transmission ? return to normal operation or shutdown
simple gnd failure loss of VDB reception	❑ still control but no normal operation: ? ”empty” MT1 for 6 sec before ceasing	❑ simultaneous loss of VDB and raised gnd warnings: ❑ messages were good till interruption: 5 sec ❑ recovered reception *and* ”empty” MT1 received: 0.5 sec	❑
Broadcast failure	❑ no broadcast control, shutdown 1 sec	❑ messages were good till interruption: 5 sec ❑ last received message contained warning: 3 sec	❑
complex gnd failure	❑ detection (Req): send MT1 ”empty” after: 3 sec ❑ shutdown after 6 sec transmission	❑ continuous VDB reception: ❑ ”empty” MT1 0.5 sec	❑ gnd detects after several cycles ❑ FMEA required prior type approval
loss of VDB reception	❑ detection (Req): send MT1 ”empty” after: 3 sec ❑ shutdown after 6 sec transmission	❑ simultaneous loss of VDB and raised gnd warnings: ❑ messages were good till interruption: 5 sec ❑ recovered reception *and* ”empty” MT1 received: 0.5 sec	❑ gnd took 3 sec to detect (complex f.) **? integrity risk**

”do not use”: coded in Bs and / or σ_{gnd} for each affected satellite or reference receiver (aircraft must test PL against AL to assess severity)
”empty” MT1: (no correction data, only message header and CRC, number of measurement blocks = 0) = Alert
Warning: ”do not use” set in some B-Values or σ_{gnd}

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13.6 Fehlerdetektoren für GBAS-Bodensysteme

ANNEX X4

Fehlerdetektoren für GBAS Bodensysteme

1 Fehlerdetektoren für GBAS Bodensysteme

1.1 Geforderte Monitoring Funktionen der FAA und Status der' FAA Specification LAAS Ground Segment'

Jede GBAS Bodenstation muß gemäß der FAA Specification LAAS Ground Segment, Draft Version 2.0 in der Lage sein, mindestens die folgenden Funktionen auszuführen:

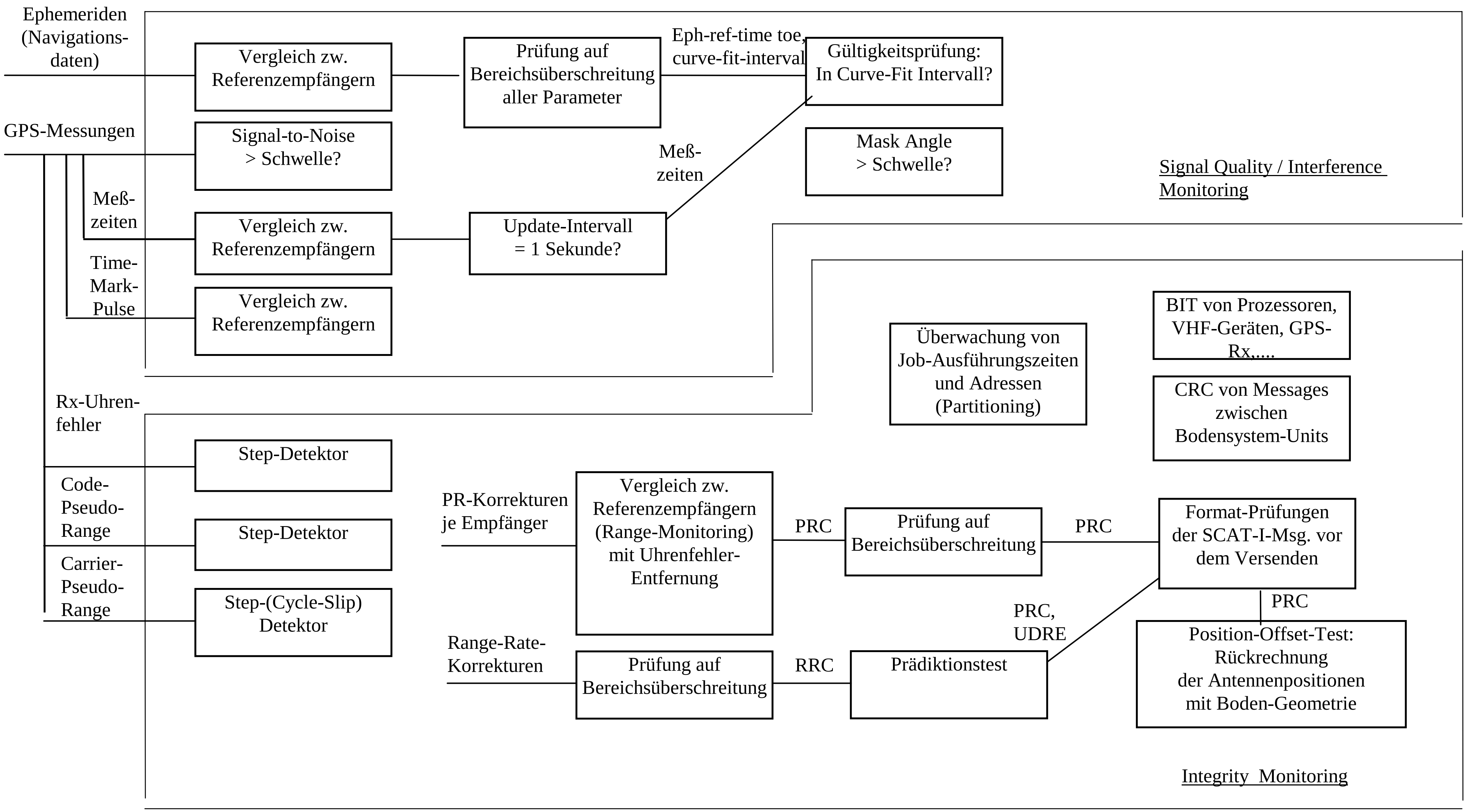
F1) Signal-in-Space Empfang und Dekodierung
F2) Signal Qualitäts-Monitoring
F3) Interferenz Monitoring
F4) Carrier Smoothed Code und Differential Korrektur Berechnung
F5) Integritäts Monitoring, einschließlich
    F5a) Monitoring der Qualität der Entfernungsmessungen(Step & Cycle-slip Detektion)
    F5b) Konsistenzprüfung zwischen den Referenzempfängern
F6) Bestimmung der Performance Kategorie
F7) UKW Daten-Sendefunktion
F8) Control und Status
F9) Wartung und Betrieb, einschließlich
    F9a) Schätzung der nominellen und aktuellen Mittelwerte und Standardabweichungen der Entfernungsmessungen

Anforderungen an die Überwachung der Differentialkorrekturen, bevor diese ausgestrahlt werden, sind in F2), F3), und F5) zu finden.
F7) enthält Anforderungen an die Überwachung des UKW Datenlinks, auf die hier nicht eingegangen werden soll.

Für F2), F3), F5a) und F9a) sind in der uns vorliegenden Draft Version 2.0 zwar einige erste Forderungen gegeben, rege Diskussionen in der WG4A des RTCA-SC159 deuten aber darauf hin, daß hier mit zusätzlichen Forderungen und größeren Modifikationen des bereits vorliegenden Textes zu rechnen ist. Insbesondere bei den RTCA-Diskussionen zur Spezifikation von F9a) wird deutlich, welche praktischen (statistischen) Probleme die Voraussetzung der Kenntnis zeitveränderlicher Standardabweichungen aufwirft. So ist wegen großer Korrelationsdauern (>100 s) der Entfernungsmeßfehler (Rangefehler), mit sehr langen Aufzeichnungsintervallen von Messungen zu rechnen, um Standardabweichungen mit hinreichend großer Genauigkeit zu verschiedenen Satellitenelevationen zu schätzen.

Bei der Formulierung von Anforderungen an F2) wird ein grundsätzliches Problem bei der Anwendung von GPS für sicherheitskritische Systeme deutlich: Wirkungsvolle Monitore der Entfernungsmessungen zu den GPS-Satelliten und der von den Satelliten ausgestrahlten Navigationsdaten erfordern die Kenntnis möglicher Fehlerzustände der GPS-Satelliten. Solche werden von den militärischen Betreibern des GPS-Space-Segments jedoch nur unbefriedigend veröffentlicht. Jeder Signal Qualitäts Monitor kann damit die Integrität der GPS-Daten nur für öffentlich bekannte oder vermutete Fehler gewährleisten. So ist z.B. die Ursache für den sog. Sv19-Fehler bis heute Gegenstand von Spekulationen, womit dann auch die Wirksamkeit verschiedener eigens gegen Sv19-Fehler entworfener Detektoren (z.B. Narrow minus Wide-Korrelator Detektoren) fraglich bleibt.

1.2 Fehlerdetektoren der CESAR Bodenstation



Die obige Abbildung zeigt wesentliche Fehlerdetektoren der CESAR Bodenstation, ausgenommen solche, die zum Datenlink-Monitoring gehören. Die Klassifikation von Monitorfunktionen der FAA GS Specification in Signal Quality-, Interference- und Integrity Montoring soll durch die gestrichelten Kästen angedeutet werden.

Da die CESAR Bodenstation auf der Basis der Dasa-NFS Bodenstation D920 entwickelt wurde, sind die gesendeten Korrekturmessages (Type 1) gemäß dem Change 1 der RTCA SCAT-I Spezifikation DO-217. Insbesondere bedeutet dies, daß keine Standardabweichungen der Korrekturfehler (‘Sigmas’) und ‘B-Werte’ als Integritätsparameter, sondern sog. UDRE (User Differential Range Error) gesendet werden. Demzufolge ist auch kein ‘Sigma-Monitoring’ zu finden.

Beim Datenlink-Monitoring werden die gerade gesendeten SCAT-I Messages als VHF-Signale empfangen und diese z.B. auf

- Minimale Leistung
- Empfang im richtigen Zeitschlitz,
- Anwendung von FEC
- Richtigkeit der Header und CRC Codes
- Inhalt durch Vergleich mit beabsichtigten Messages

geprüft.

Das Monitoring der Wegpunkt-Message (Type 4) ist im nächsten Kapitel beschrieben.

1.3 Test der Fehlerdetektoren

Im Rahmen der Typzulassung der Dasa-NFS Bodenstation D920 durch die FAA sind von Dasa-NFS umfangreiche Tests aller im obigen Bild gezeigten Detektoren durchgeführt worden. Hierzu sind auf die jeweiligen Detektoren abgestimmte Fehlerszenarien konstruiert worden, um deren Wirksamkeit unter Beweis zu stellen. Die Vorgehensweise und Ergebnisse dieser Tests sind auf der GNSS 97 in München vorgetragen worden.

2

Ein Schritt in Richtung Interoperabilität - eine einheitliche Anflugweg-Message

2.1 Einleitung

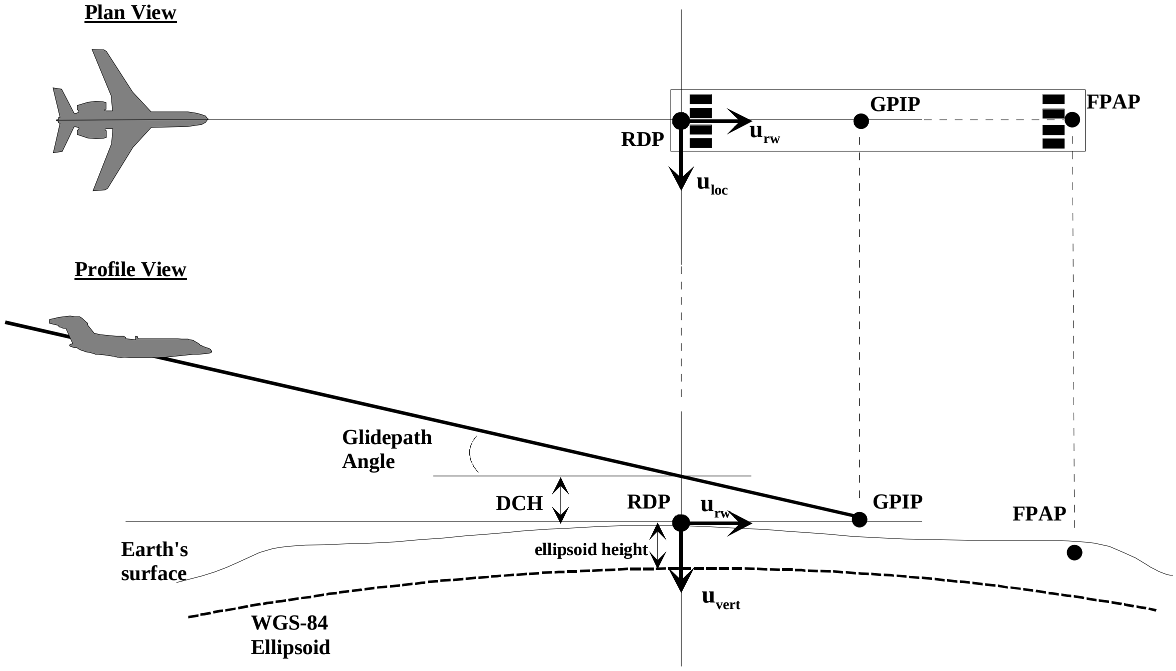
In Form der Anflugweg-Message verbreitet eine DGPS Bodenstation die Koordinaten möglicher Endanflugwege auf eine oder mehrere Landebahnen in der Umgebung der Bodenstation. Aus diesen Koordinaten berechnet das Bordsystem ILS ähnliche, gerade Gleitpfade zu denen dann mit Hilfe der DGPS gestützten Positionsschätzungen Abweichungen berechnet und dem Piloten angezeigt werden können. Die boden- und bordseitig international einheitliche Verwendung einer Anflugweg-Message ist demzufolge fundamental für die erfolgreiche Durchführung von Präzisions-Landeanflügen. In diesem Sinne fördert die Klärung potentieller Mißverständnisse bei Definition und Interpretation einer solchen Message die Interoperabilität.

Bereits in der ersten Version der SCAT-I Spezifikation DO-217 der RTCA ist im Anhang A eine solche Anflugweg-Message (Message Type 4) spezifiziert. Im Verlauf des Überarbeitungsprozesses der DO-217 über den Change 1 und 2 der DO-217 bis hin zur LAAS Definition im LAAS ICD der RTCA, ist der Inhalt dieser Type 4 Message häufig geändert worden. So hat man sich beispielsweise von dem Konzept entfernt, nur einen Referenzpunkt (Threshold Crossing Waypoint TCWP) je Type 4 Message für alle Anflüge anzugeben und alle anderen Anflugwege durch Angabe von Differenzkoordinaten auf diesen zu beziehen. Schon im Change 2 der DO-217 kann jede Type 4 Message aus mehreren sogenannten Final Approach Segment (FAS-) Blöcken zusammengesetzt sein, die jeweils einen eigenen, vollständigen ‘Threshold Datum Point’ festlegen und sogar unterschiedliche Airport-Identifikationen enthalten können. *Eine* Type 4 Message kann also Daten zu Anflügen *unterschiedlicher* Flughäfen übermitteln. Dieses Konzept ist im LAAS ICD beibehalten worden.
Zusätzlich zur Umdefinition des Message-Inhalts, hat auch eine Überarbeitung der jeweils zugehörigen Message Type 4 *Beispiele* stattgefunden. Mit diesen Beispielen ist stets versucht worden die Details der Binärkodierung und die Reihenfolge der gesendeten Bits eindeutig festzulegen. Leider ist dies, durch Fehler in den Beispielen oder mißverständliche Darstellungen, nicht immer geglückt, so daß Bord- und Bodengeräte unterschiedlicher Hersteller, hinsichtlich der Message Type 4, meist nicht kompatibel waren oder immer noch sind. Unten wird auf mögliche Mißverständnisse bei der Interpretation eines Beispiels etwas näher eingegangen.

Die Message Type 4 in der LAAS-Fassung ist immer noch Änderungen unterworfen; so wird z.B. versucht eine Form zu finden, die eine gemeinsame Nutzung für LAAS und WAAS/EGNOS gestattet. Die stabilste Fassung einer Type 4 Message scheint unseres Erachtens in der Spezifikation der SCAT-I Manufacturers Interoperability Group (SCATMIG) vorzuliegen. Gemäß dieser Definition ist in der CESAR Bodenstation der Dasa-NFS eine Type 4 Message implementiert worden. Im folgenden wird daher nur noch auf diese Definition eingegangen.

2.2 Definition der Type 4 Message gemäß der Spezifikation der SCAT-I Manufacturers Interoperability Group (SCATMIG)

Das folgende Bild ist dem LAAS ICD entnommen und stellt ein 'Final Approach Segment' dar



Obwohl im folgenden der Inhalt der Type 4 Message gemäß der SCATMIG Spezifikation ist, sind dennoch die Bezeichnungen (RDP, DCH,...) bereits entsprechend den RTCA-LAAS Dokumenten gewählt. Die folgende Tabelle soll der 'Übersetzung' dienen:

RTCA LAAS MASPS/ICD	SCATMIG
Runway Datum Point (RDP)	Threshold Datum Point (DP)
Datum Crossing Height (DCH)	Threshold Crossing Height (TCH)
Flight Path Alignment Point (FPAP)	Stop End Point (SEP)
Glide Path Angle (GPA)	Glide Slope

Jede Type 4 Message enthält einen SCAT-I Message Header, n FAS Datenblöcke und einen Gesamt-Message 32-Bit CRC

SCAT-I Header
FAS Datenblock 1
FAS Datenblock 2
:
FAS Datenblock n
Gesamt CRC

Jeder FAS Datenblock ist 37 Byte lang und enthält seinen eigenen CRC. Inhalt und Format eines FAS Datenblocks zeigt die folgende Tabelle

Data content	Bits in field	Bits used	Range of values	Units
Operation type	8	4	0 to 15	
Airport Identification	32	32	0000-ZZZZ	
Runway number	8	6	0 to 36	
Runway letter	8	2	0-3	
Route indicator	8	5	A-Z	
Validity indicator	8	4	1 to 9	
Reference path data selector	8	7	0-128	
Approach ID	32	32	0000-ZZZZ	
Runway Datum Point (RDP) Latitude	32	26	±324 000 arc-seconds	0.01 arc-second
Runway Datum Point (RDP) Longitude	32	27	±648 000 arc-seconds	0.01 arc-second
Runway Datum Point (RDP) Height	16	16	-512.0 to 6041.5m	0.1 m
Flight Path Alignment Point (FPAP) Latitude (Offset from RDP)	16	16	±327.68 arc-seconds	0.01 arc-second
Flight Path Alignment Point (FPAP) Longitude (Offset from RDP)	24	17	±655. 36 arc-seconds	0.01 arc-second
Datum Crossing Height (DCH)	16	14	-512 to + 1126.3 ft	0.1 ft
Glide Path Angle (GPA)	16	11	2 to 20.47 degrees	0.01 degree
CRC	32	32	-	

2.3 Beispiel einer Type 4 Message mit 4 FAS Blöcken für Braunschweig (EDVE)

Inhalt	**Wert**	**Bitmuster (Hex)**
SCAT-I Header		
Message Block ID	99	99
Reference Station ID	A0Z9	07 06 b9
Reserved Bits + Message Type	000100 00	10
Message Length	195	c3
1. FAS Block RDP =	Schwelle 26 Mitte FPAP =	Schwelle 08 Mitte
Operation Type	0	00
Airport Identification	EDVE	05 04 16 05
Runway number	26	1a
Runway letter	0	00
Route indicator	A	01
Validity indicator	0	00
Reference path data selector	10	0a
Approach ID	26G3	32 36 07 33
RDP Latitude	52.31964414 (18835072 arcsec)	01 1f 66 7f
RDP Longitude	10.56405203 (3803059 arcsec)	00 3a 07 b2
RDP Height	131.67 + 512 (6437*0.1m)	19 25
FPAP Latitude Delta	-0.00098625 (-355 arcsec)	fe 9d
FPAP Longitude Delta	0.01761564 (6342 arcsec)	00 18 c6
DCH	50 + 512 (562 ft)	15 f4
GPA	3 (300*0.01 degrees)	01 2c
FAS Block CRC		15 cc 30 6b
2. FAS Block RDP =	Schwelle 26 Mitte FPAP =	Schwelle 08 Mitte
Operation Type	0	00

Airport Identification	EDVE	05 04 16 05
Runway number	26	1a
Runway letter	0	00
Route indicator	A	01
Validity indicator	0	00
Reference path data selector	10	0a
Approach ID	26G6	32 36 07 36
RDP Latitude	52.31964414 (18835072 arcsec)	01 1f 66 7f
RDP Longitude	10.56405203 (3803059 arcsec)	00 3a 07 b2
RDP Height	131.67 + 512 (6437*0.1m)	19 25
FPAP Latitude Delta	-0.00098625 (-355 arcsec)	fe 9d
FPAP Longitude Delta	0.01761564 (6342 arcsec)	00 18 c6
DCH	50 + 512 (562 ft)	15 f4
GPA	6 (600*0.01 degrees)	02 58
FAS Block CRC		f6 41 c4 b9
3. FAS Block RDP =	Schwelle 08 Mitte FPAP =	Schwelle 26 Mitte
Operation Type	0	00
Airport Identification	EDVE	05 04 16 05
Runway number	08	08
Runway letter	0	00
Route indicator	A	01
Validity indicator	0	00
Reference path data selector	10	0a
Approach ID	08G3	30 38 07 33
RDP Latitude	52.31865789 (18834717 arcsec)	01 1f 65 1d
RDP Longitude	10.54643639 (3796717 arcsec)	00 39ee ed
RDP Height	126.02 + 512 (6380*0.1m)	18 ec
FPAP Latitude Delta	+0.00098625 (+355 arcsec)	01 63
FPAP Longitude Delta	-0.01761564 (-6342 arcsec)	01 e7 3a

DCH	50 + 512 (562 ft)	15 f4
GPA	3 (300*0.01 degrees)	01 2c
FAS Block CRC		10 47 b1 e4
4. FAS Block RDP =	Schwelle 08 Mitte FPAP =	Schwelle 26 Mitte
Operation Type	0	00
Airport Identification	EDVE	05 04 16 05
Runway number	08	08
Runway letter	0	00
Route indicator	A	01
Validity indicator	0	00
Reference path data selector	10	0a
Approach ID	08G6	30 38 07 36
RDP Latitude	52.31865789 (18834717 arcsec)	01 1f 65 1d
RDP Longitude	10.54643639 (3796717 arcsec)	00 39ee ed
RDP Height	126.02 + 512 (6380*0.1m)	18 ec
FPAP Latitude Delta	+0.00098625 (+355 arcsec)	01 63
FPAP Longitude Delta	-0.01761564 (-6342 arcsec)	01 e7 3a
DCH	50 + 512 (562 ft)	15 f4
GPA	6 (600*0.01 degrees)	02 58
FAS Block CRC		e7 74 37 44
Message CRC		26 e5 b3 41

Die Approach ID setzt sich hier aus Runway-Nummer und Glidepath-Winkel zusammen: 26G6 bedeutet z.B. Runway 26 mit GPA=6 Grad.

2.4 Ursachen für potentielle Mißverständnisse

2.4.1 Reihenfolge der Bits bei der Übertragung der Message

Die Reihenfolge, in der die Bytes übertragen (und empfangen) werden, erhält man durch Auslesen der 3.Spalte der obigen Tabelle von rechts nach links und oben nach unten, d.h. es ergibt sich für dieses Type-4 Message Beispiel folgender *Byte*-Strom:

99 b9 06 07 10 c3 .... 41 b3 e5 26

Dies entspricht dem folgenden *Bit*-Strom (von links nach rechts zu lesen):

Erstes übertragenes Bit   Letztes übertragenes Bit
↓   ↓
1001 1001 1001 1011 0110 0000 .... 0110 0100

Um vom Byte- zum Bit-Strom zu gelangen, muß also vom LSB zum MSB eines jeden Bytes ausgelesen werden.

Die zwischenzeitliche Betrachtung des Byte-Stroms mag verwirrend erscheinen, gelangt man doch von der 3. Spalte der obigen Tabelle in Binärdarstellung direkt zum Bit-Strom durch Auslesen der Bits von rechts nach links und oben nach unten. Die zu sendenden und empfangenen Daten werden jedoch meist in Puffern zwischengespeichert und diese Speicher sind häufig in *Bytes* (z.B. als array of character) strukturiert. Zur Kontrolle wird der Inhalt dieser Puffer in aller Regel statt in Binärdarstellung in Hex-Darstellung, d.h. *byte*-weise angezeigt. Damit liegt dann der angegebene Byte-Strom vor.

2.4.2 Reihenfolge der Bits des 32-Bit CRC

Die Bildung einer CRC Prüfsumme (des CRC-Codes) kann als Schieben des Bitstroms der zu schützenden Daten durch ein Schieberegister dargestellt werden. Dabei werden laufend die aktuellen Datenbits zu bestimmte Zellen des Schieberegisters modulo-2 addiert (siehe z.B. LAAS ICD, 5.4.3. End-to-End Cyclic Redundancy Check). Nach dem Durchschieben aller Bits und Auslesen des Schieberegisters liegt der CRC-Code vor.

Die Bits der Message Type 4 sind nun in der oben angegebenen *Reihenfolge des Versendens*, auch in ein solches CRC-Schieberegister einzuspeisen. Die im obigen Beispiel gegebenen CRCs sind wieder in Bytes organisiert, so wie sie aus einem 4 Byte langen Zwischenspeicher ausgelesen werden können. Auch von den CRC-Codes wird das LSB zuerst versendet.

2.4.3 Bits-Used-Vereinbarung

Negative Werte in RDP und FPAP Parametern werden im 2er Komplement dargestellt, wobei die jeweilige Anzahl der benutzten Bits zu berücksichtigen ist, d.h. die unbenutzten Bits sind *immer Null*, auch für negative Werte.

<u>Beispiel:</u> 4. FAS Block, FPAP-Longitude Delta = -0.01761564, Bits used = 17:

-0.01761564·3600 00	= -6342 [arcsec]
6342 = 00 18 c6 (Hex)	= 0000 0000 0001 1000 1100 0110
2er Komplement bis Bit 17	= 0000 0001 1110 0111 0011 1010
	= 0 1 e 7 3 a

Negative Werte in RDP und FPAP sind also nicht einfach am MSB (hier Bit 24) zu erkennen.

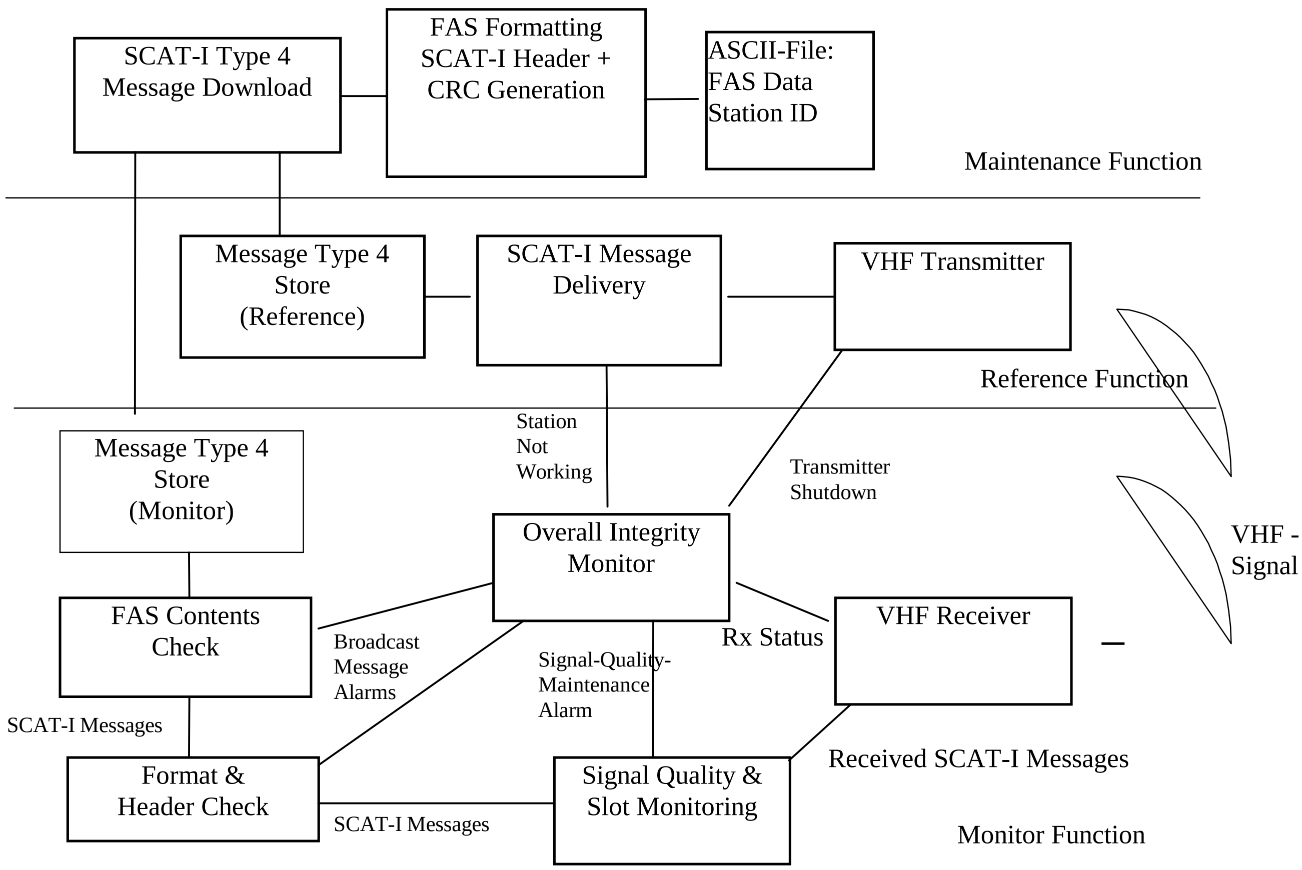
2.4.4 Invarianz des Gesamt CRC bei Austausch von FAS-Blöcken

Auf eine interessante Eigenschaft des CRC-Codes sei an dieser Stelle noch hingewiesen, die beim Test der CRC Routinen zur Verwirrung führen kann. Wird der Inhalt eines FAS Datenblocks geändert, für diesen neuen Datenblock ein neuer FAS-CRC Code berechnet und dieser neue CRC Code in den neuen FAS-Block eingetragen, so ändert sich der Gesamt-

Message CRC nicht. Der Inhalt der FAS Blöcke ist in diesem Sinne nur durch die FAS-CRCs geschützt.
Zwei Type 4 Messages mit identischem SCAT-I Header haben demnach immer denselben Message-CRC, unabhängig vom Inhalt der FAS-Blöcke mit korrektem FAS-CRC. Der Message-CRC schützt damit nicht vor irrtümlicher Verwechslung ganzer FAS-Blöcke von einer Bodenstation zu einer anderen. Darauf ist bei der Verwaltung mehrerer Type 4 Messages von den verantwortlichen Stellen zu achten.

2.5 Funktionen der bei CESAR verwendeten Bodenstation für Erzeugung und Monitoring der Message Type 4

Die folgende Abbildung stellt die wesentlichen Funktionen zur Erzeugung und Überwachung der Message Type 4 in der CESAR Bodenstation dar.



2.5.1 Erzeugung der Type 4 Message

Die Formatierung der FAS-Datenblöcke, Berechnung der FAS/Message CRC’s, Zusammenstellung der SCAT-I Message sowie das abschließende Download der Binärdaten geschieht mit PC-Tools im Maintenance/Download-Mode der Bodenstation. Das Download der Binärdaten der Type 4 Message erfolgt zusammen mit weiteren Stationsparametern wie GPS-Antennenpositionen und Frequenz/Leistungsparametern der VHF-Geräte.

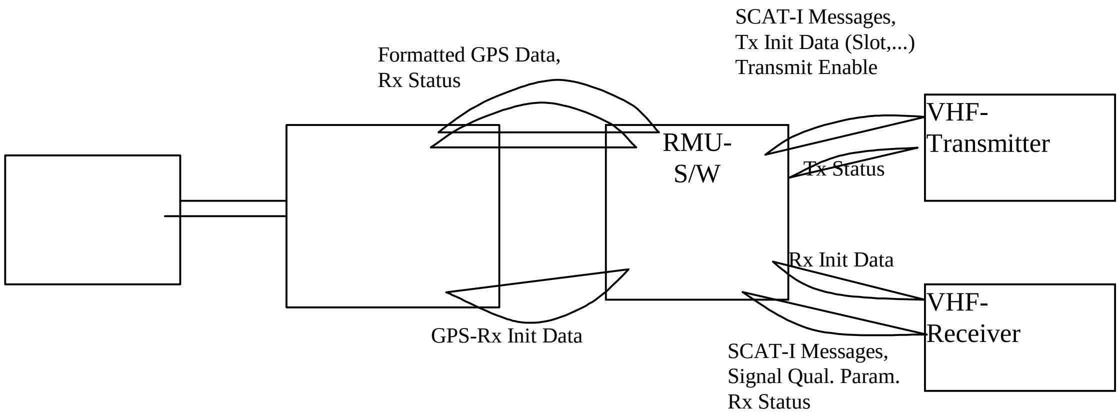
Die binäre Type 4 Message wird getrennt in Referenz und Monitorpartition der Bodenstation geladen. Die Type-4-Daten der Referenzpartition werden zyklisch an den VHF-Sender übergeben, die Type-4-Daten der Monitorpartition dienen dem Vergleich mit den vom VHF-Empfänger gelieferten Type-4 Messages.

2.5.2 Integritäts-Monitoring der Type 4 Message

Das Monitoring der empfangenen Type-4-Daten ist 3-stufig.
In der ersten Stufe wird verfolgt, ob die Message gemäß D8PSK vom VHF-Empfänger dekodiert werden konnte, die empfangene SCAT-I Message im richtigen Zeitschlitz (Slot) empfangen wurde, die Empfangsleistung der Spezifikation entspricht und ob FEC angewendet werden mußte. Gegebenenfalls wird ein Signal-Quality-Maintenance Alarm ausgelöst, der bei längerem Anhalten (2,5 Minuten) zum Einleiten der Shutdown-Prozedur führen kann.
Die zweite Stufe prüft Header-Informationen wie Message-Typ, Länge der Message und Bodenstations-ID; die dritte Stufe vergleicht schließlich den Inhalt der FAS Datenblöcke mit den abgespeicherten Daten. Zweite und dritte Stufe können Broadcast Message Alarme auslösen, die sofort die Shutdown Prozedur nach sich ziehen.

2.5.3 Software Modifikationen der Dasa-NFS Bodenstation D920

Die Software der Dasa-NFS Bodenstation D920 setzt sich im wesentlichen aus der Software der VHF-Geräte, der GPS-Receiver, der GPS-Receiver I/O-Controller Module (IOCM) und der Reference and Monitor Unit (RMU) zusammen (siehe Bild).



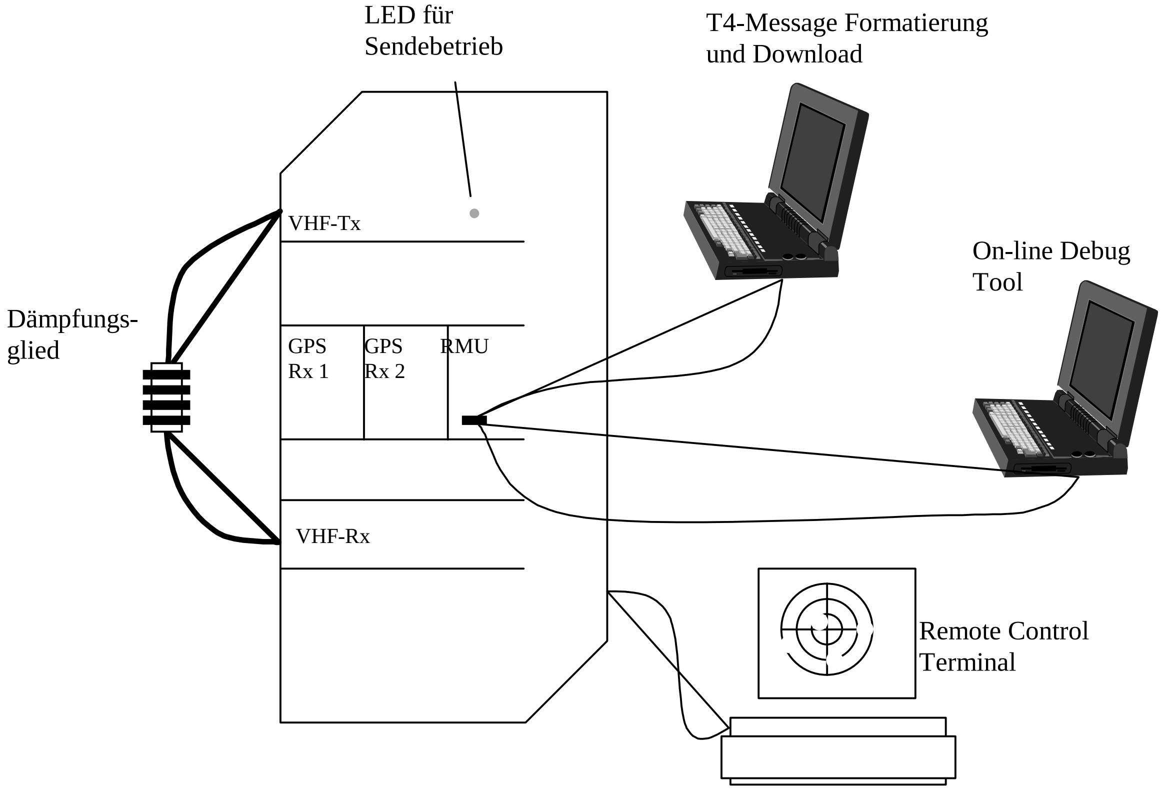
Die beiden angedeuteten Funktionen für Type 4 Message-Auslieferung und -Monitoring der CESAR Bodenstation werden diesem S/W-Design folgend zweckmäßigerweise von der RMU-Software realisiert. Referenz- und Monitorfunktionen sind in der D920-RMU in zwei strikt voneinander getrennten Partitionen implementiert. Zur Erweiterung der D920 um die Type 4 Funktionalität war nur RMU-Software zu modifizieren, dort allerdings die der Referenz- und Monitorpartition.

VHF-Transmitter und Receiver sind so ausgelegt, daß jede SCAT-I Message mit beliebigem Inhalt, im in der sekündlich übergebenen Init-Message definierten Zeitschlitz, gesendet und empfangen werden können. Software Modifikationen waren bei den VHF-Geräten daher nicht erforderlich.

Zu den Jobs der D920-RMU-Software sind 4 neue mit einer Gesamt-Laufzeit von etwa 40 ms hinzugefügt worden. Der Umfang der Code-Änderung beträgt hier etwa 200 Lines of Code.

Zudem waren die oben angesprochenen PC-Tools zur Type-4-Message Binär-Formatierung und FAS/Message-CRC Berechnung zu entwickeln sowie Download-Tools zu modifizieren.

2.5.4 Labortest



Die obige Abbildung zeigt den Laboraufbau zum Test der Type 4 Sende-Fähigkeit der CESAR Bodenstation. Für diesen Test können VHF-Sender und Empfänger ohne Antennen betrieben werden, indem sie direkt über ein Dämpfungsglied verbunden werden.

Testablauf:
Nach Erstellung einer Beispiel Type-4-Message (siehe Tabelle oben) inklusive Formatierung und CRC Berechnungen wird diese mit einem Laptop PC in Referenz- und Monitorpartition der RMU geladen. Hierzu ist die Bodenstation im Maintenance-Mode.

Nach Übergang zum Normal-Mode sendet die Bodenstation SCAT-I Messages. Die Anzahl der gesendeten Messages pro Sekunde kann bereits durch Beobachtung der VHF-Sender-LED für den Sendebetrieb festgestellt werden. Die CESAR Bodenstation sendet 3 Type 1 (Differentialkorrekturen) und eine Type 4 Message (Wegpunkte) pro Sekunde, d.h. die LED blinkt viermal pro Sekunde. Das Remote Control Terminal dient der Überprüfung des gesamten Bodenstationszustandes inklusive der ungestörten Sendung von Differentialkorrekturen mit der Message Type 1 (im Bild angedeutet durch einen ‚Skyplot‘ der zugehörigen Satelliten).

Die Software des Remote Control Terminals ist nicht modifiziert worden, d.h. nicht Type 4 fähig. Zur abschließenden Kontrolle, daß auch die beabsichtigten Daten gesendet werden, kann noch ein On-line Debug Tool auf einem Laptop-PC herangezogen werden. Mit diesem kann der Inhalt von Sende- und Empfangs-Puffern der RMU in Hexdarstellung betrachtet werden.

Testergebnis:
Die CESAR Bodenstation ist in der Lage alle eingegebenen Type 4 Messages in den gewählten Zeitschlitzen (z.B. T1: A,C,C‘ T4: C‘) zu senden und zu monitoren, ohne durch die hinzugekommene Type 4 Message Monitor-Alarme auszulösen oder dabei die Sendung der Type 1 Message zu stören.

Ein Test auf unerwünschte Shutdowns erstreckte sich auf 3 Wochen, in denen die Bodenstation ununterbrochen, ohne jeden Alarm, Type 1 und Type 4 Messages gesendet hat.

Der Austausch verschiedenster FAS Blöcke hat dabei die oben erwähnte Invarianz des Message-CRC’s erkennen lassen.

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13.7 DRAFT ICAO GBAS SECTION A SARPS

ANNEX X5

DRAFT ICAO GBAS SECTION A SARPS

A.3.5 Ground-based augmentation system (GBAS)

A.3.5.1 *Performance.* GBAS combined with one or more of the other GNSS elements shall meet the requirements for system accuracy, continuity, availability and integrity for the intended operation as stated in A.2.4.

Note.-GBAS is intended to support all types of approach, landing, departure and surface operations. . The following SARPS are developed to support Category I precision approach operations and may also support departure, en-route and terminal operations. Additional GBAS SARPS will be developed to support other operations, for example Category II/III precision approaches. In order to achieve interoperability and enable efficient spectrum utilization, it is intended that the data broadcast characteristics are the same for all operations.

A.3.5.2 *Functions*. GBAS shall perform the following functions:

a) provide locally relevant pseudorange corrections (B.x.x.x);
b) provide GBAS related data (B.x.x.x);
c) provide final approach segment data (B.x.x.x);
d) provide predicted ranging source availability data (B.x.x.x);and
e) provide integrity monitoring for GNSS ranging sources (B.x.x.x).

Note.- Additonal GBAS SARPS may be developed to provide a ground-based ranging function.

A.3.5.3 *Coverage*.

A.3.5.3.1The GBAS coverage to support each Category I approach shall be:

Laterally: beginning at 145 m (450 ft) each side of the runway datum point and projecting out ±35 degrees either side of the final approach path to 28.5 km (15 nm) and ±10 degrees either side of the final approach path to 37 km (20 nm); and

Vertically: within the lateral region, up to 1.75 promulgated glide path angle (GPA) above the horizontal with an origin at the Glide Path Intercept Point (GPIP) and 0.45 GPA above the horizontal or to such lower angle, down 0.30 GPA, as required to safeguard the promulgated glide path intercept procedure. This coverage applies between 30 m (100 ft) and 3000 m (10 000 ft) HAT.

Note 1. The Runway Datum Point and Glide Path Intercept Point are defined in (X.X.X.X)

Note 2.-The lateral and vertical coverages of GBAS are depicted in Attachment D, xxx.

A.3.5.3.2 *Recommendation.- The GBAS coverage should extend down to 4m (12 ft) above the runway surface*.

A.3.5.3.3 *Recommendation.- The Data Broadcast should be omnidirectional to support future applications)* .

A.3.5.4 *Data broadcast characteristics*.

A.3.5.4.1 *Carrier frequency*. The data broadcast shall operate on an assigned carrier frequency within the frequency band 108.000 MHz to 117.975 MHz. The assigned frequency shall be a multiple of 25 kHz.

Note 1.-Guidance material on frequency assignments is given in Attachment D, xxx.

Note 2.-ILS/GBAS geographical separation criteria are under development. Until these criteria are defined and included in SARPS, it is intended that frequencies in the band 112-117.975 MHz will be used.

A.3.5.4.2 *Access technique*. A time division multiple access (TDMA) technique shall be used with a fixed frame structure. The data broadcast shall transmit during one or more assigned time slots of each TDMA frame. The data broadcast shall transmit one or more messages during every frame.

A.3.5.4.3 *Modulation*. GBAS data shall be transmitted as 3-bit symbols, modulating the data broadcast carrier by differentially encoded 8 phase shift keying (D8PSK), at a rate of 10500 symbols per second.

A.3.5.4.4 *Polarization*. Right-hand elliptical polarization shall be used.

Note.-Criteria for application of elliptical polarization are under development. Until these criteria are developed and included in SARPS, it is intended that horizontal polarization will be used.

A.3.5.4.5 *Data broadcast RF field strength*. The effective radiated power (ERP) shall provide for its horizontal component a minimum field strength of 140 microvolts per meter (-103 dBW/metres-squared) and a maximum field strength of 0.383 volts per meter (-34 dBW/metres-squared), and for its vertical component a minimum field strength of 88 microvolts per meter (-107 dBW/metres-squared) and a maximum field strength of 0.241 volts per meter (-38 dBW/metres-squared) within the GBAS coverage. The field strength shall be measured as an average over the period of the unique word in the training sequence portion of the message.

Note 1.-When horizontal polarization only is in use, the minimum and maximum field strengths are intended to be equal to the horizontal component values of the elliptical polarization.

A.3.5.4.6 *Relative power transmitted in the first adjacent channel*. The amount of power during transmission under all operating conditions when measured over a 25 kHz bandwidth centred on either of the first adjacent channels shall not exceed -40 dB referenced to the on channel power.

A.3.5.4.7 *Relative power transmitted in the second and subsequent adjacent channels*. The amount of power during transmission under all operating conditions when measured over a 25 kHz bandwidth centred on either of the second adjacent channels shall not exceed -65 dB referenced to the on channel power and will decrease 5 dB per octave until -90 dB and remains less than –90dB thereafter.

Note.-Guidance material is provided in Attachment D, xxxx.

A.3.5.4.8 Spurious emissions.
Spurious emissions shall be kept at the lowest value that the state of the technique and the nature of the service permit.

Note.- Appendix 8 to the Radio Regulations contains the tolerances for the levels or spurious emission to which transmitters must conform in accordance with Radio Regulation 304.

A.3.5.5 *Navigation data content*. The navigation data shall include the following information: (See B.3.6.4)

a) pseudorange corrections, reference time and integrity data
b) airport data
c) final approach segment data. and;
d) ranging source availability data.

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13.8 DRAFT ICAO GBAS SECTION B SARPS

ANNEX X6

DRAFT ICAO GBAS SECTION B SARPS

B.3.6 GROUND BASED AUGMENTATION SYSTEM (GBAS)

B.3.6.1 *General*. The GBAS shall consist of a ground subsystem and an aircraft subsystem. The GBAS ground subsystem shall provide data and corrections for the GNSS ranging signals in a digital format over a VHF data broadcast to the aircraft subsytem.

B.3.6.2 *Radio frequency characteristics*.

B.3.6.2.1 *Carrier frequency stability*. The carrier frequency of the data broadcast shall be maintained within ± 0.0002 per cent of the assigned frequency**.**

B.3.6.2.2 *Bit-to-phase-change encoding*. GBAS messages shall be divided into symbols, each consisting of 3 consecutive message bits. The end of the message shall be padded by one or two fill bits set to zero if necessary to form the last 3-bit symbol of the message. Symbols shall be converted to D8PSK carrier phase shifts ($\Delta\phi_k$) in accordance with the Gray code of Table B 3.6-1.

Note.-The carrier phase for the k^{th} *symbol* (ϕ_k) *is given by:* $\phi_k = \phi_{k-1} + \Delta\phi_k$

Table B.3.6-1 Data encoding

Message Bits			Symbol Phase Shift
I_{3k-2}	I_{3k-1}	I_{3k}	$\Delta\phi_k$
0	0	0	$0\pi/4$
0	0	1	$1\pi/4$
0	1	1	$2\pi/4$
0	1	0	$3\pi/4$
1	1	0	$4\pi/4$
1	1	1	$5\pi/4$
1	0	1	$6\pi/4$
1	0	0	$7\pi/4$

Note.-I_j *is the* j^{th} *bit of the message to be transmitted, where* I_1 *is the first bit of the training sequence.*

B.3.6.2.3 *Modulation wave form and pulse shaping filters*.

The output of differential phase encoder shall be filtered by a pulse shape filter s(t) as follows:

$$s(t) = \sum_{k=-\infty}^{k=\infty} e^{j(\phi(kT))} h(t - kT)$$

Where :

h	is the impulse response of the raised cosine filter
Φk	is defined in paragraph B.3.6.2.2
t	is time
T	is the duration of each symbol (T=1/10500 second)

This pulse shape filter shall have a nominal complex frequency response of a raised-cosine filter with α=0.6. The time and frequency responses of the base band filters shall be as defined below:

$$h(t) = \frac{\sin\left(\frac{\pi t}{T}\right)}{\frac{\pi t}{T}} \frac{\cos\left(\frac{\pi \alpha t}{T}\right)}{1 - \left(\frac{2\alpha t}{T}\right)^2}$$

$$H(f) = \begin{cases} 1 & \text{for} \quad 0 \le f < \frac{1-\alpha}{2T} \\ \frac{1-\sin\left(\frac{\pi}{2\alpha}(2fT-1)\right)}{2} & \text{for} \quad \frac{1-\alpha}{2T} \le f \le \frac{1+\alpha}{2T} \\ 0 & \text{for} \quad f > \frac{1+\alpha}{2T} \end{cases}$$

The output s(t) of the pulse shape filter shall modulate the carrier frequency.

Ed. Note: Check the above sentence.

B.3.6.2.4 *Quadrature modulation*. The relationship between the quadrature components (I and Q) in the transmitted signal shall be ± 3º from quadrature and equal in amplitude within ± 1 dB. The carrier component of the RF signal shall be at least -20 dB relative to peak RF amplitude of the modulated signal.

Note.- The quadrature requirements were chosen for no more than 1 dB transmitter loss.

B.3.6.2.5 *RF data rate*. The symbol rate shall be 10 500 symbols/s ± 0.005%, resulting in a nominal bit rate of 31 500 bits/s.

B.3.6.2.6 *Emissions in unassigned time slots*. Under all operating conditions, the average power within the 25 kHz channel band width, centered on the assigned frequency, when measured over any unassigned time slot, shall not exceed -75 dB referenced to the assigned power.

Editorial Note.- This requirement will be reviewed at next WG-B meeting.

B.3.6.3 *Data structure*.

B.3.6.3.1 *Transmitter timing*.

B.3.6.3.1.1 *Data broadcast timing structure*. The TDMA timing structure shall be based on frames and time slots. Each frame shall be 500 milliseconds in duration. There shall be two such frames contained in each one-second UTC epoch. The first of these frames shall start at the beginning of the UTC epoch and the second frame shall start 0.5 seconds after the beginning of the UTC epoch. The frame shall be time division multiplexed such that it shall consist of 8 individual time slots (A - H) of 62.5 millisecond duration.

B.3.6.3.1.2 Bursts. Each assigned time slot shall contain at most one burst. A burst shall contain one or more messages as required by B.3.6.3.2.

Note.- Bursts, that contain one or more messages, may be of variable length up to the maximum allowed within the slot.

B.3.6.3.1.3 *Timing budget for bursts*. Each burst shall be contained in a 62.5 millisecond time slot. The beginning of the burst shall occur 95.2 μs after the beginning of the time slot with a tolerance of +/- 95.2 μs.

Note.- The Table below illustrates the burst timing.

Event	*Nominal event duration:*	*Nominal percentage of steady-state power*
Ramp-up	*190.5 μs*	*0% to 90%*
power stabilization	*285.7 μs*	*90% to 100%*
synchronization & ambiguity resolution	*1523.8 μs*	*100%*
transmission of scrambled data	*57 968.3 μs*	*100%*
ramp-down	*285.7 μs (note 1)*	*100% to 0 %*

Note 1.- Event time indicated is for maximum application data length of 1776 bits and two fill bits. The end of the burst always occurs 285.7 μs after the last symbol that contains the application FEC.

Note 2.-These timing requirements provide a propagation guard time of 1261 μs, allowing for a one way propagation range of approximately 370 km (200 NM).

B.3.6.3.1.4 *Transmitter power stabilization.* The transmitter shall ramp up to 90% of the steady state power level in less than 190.5 μs after the einning of the burst. The transmitter shall stabilise at the steady state power in no later than 476.2 μs after the beginning of the burst.

Note.- The transmitter power stabilisation period may be used by the aircraft receiver to settle its AGC.

B.3.6.3.1.5 *Ramp down*. After the final information symbol is transmitted in an assigned time slot, the transmitter output power level shall decrease such that it is at least 30dB below the steady state power after 285.7 μs (3 symbols).

B.3.6.3.1.6 *Mapping of application data onto bursts*. Messages shall be mapped directly into the Application Data portion of the GBAS message with no additional overhead of the intervening layers..

B.3.6.3.2 *Message encoding and format*. Encoding of the messages shall follow the sequence: message formatting, Reed Solomon FEC encoding and bit scrambling. Each burst shall consist of the data shown in Table B.3.6-3.

Note 1.- The Reed-Solomon codes are described in the recommendation for Space Data System Standards, Telemetry Channel Coding, by the Consultative Committee for Space Data Systems published in ISO 11754:1994.

Note 2.- The following applies to the message encoding process:

word - 8 bit elements in the Reed-Solomon code
byte - 8 bit application layer element

Note 3.- All pad, reserved and spare bits are set to zero.

Note 4.- The definition of the data to be transmitted in B.3.6.3.2.3 to B.3.6.3.3.2 is described prior to bit scrambling.

Table B.3.6-3
Burst Data Content

Event	Data content	Number of bits
beginning of burst	all zeros	15
power stabilization		
synchronization & ambiguity resolution	see B.3.6.3.2.2	48
scrambled data:	See B.3.6.3.3.3	
station slot identifier (SSID)	see B.3.6.3.2.3	3
transmission length	see B.3.6.3.2.4	17
training sequence FEC	see B.3.6.3.2.5	5
application data	(note 1)	≤ 1776
application FEC	see B.3.6.3.3.1	48
fill bits	all zeros	0 to 2 bits
ramp-down	n/a	

Note 1.- The application data consists of one or more messages, as defined in B.3.6.6.

B.3.6.3.2.2 *Synchronization and ambiguity resolution*. The Synchronization & Ambiguity Resolution shall consist of the Unique Word sequence shown below and shall be transmitted from left to right:

Unique Word Sequence
000 010 011 110 000 001 101 110 001 100 011 111 101 111 100 010

B.3.6.3.2.3 *Station slot identifier*. The station slot identifier (SSID) shall be a single symbol transmitted as a numeric value from 0 to 7 corresponding to the letter designation A through H of the first time slot assigned to the ground reference station. Slot A shall be represented by 0, slot B by 1, C by 2 and so on to H by 7.

Note.- Guidance on the use of the SSID is provided in Attachment D x.x.x.x
Ed.Note.- Move note to GM and explain.

B.3.6.3.2.4 *Transmission length*. The transmitter shall send a 17-bit word, from least significant bit (LSB) to most significant bit (MSB), indicating the total number of bits in both application data and application FEC.

B.3.6.3.2.5 *Training sequence FEC*. A (25,20) block code shall be computed over the SSID and transmission length segments and transmitted as the fifth segment of the training sequence. The five training sequence FEC bits to be transmitted shall be generated using the following equation:

$$[P_{1}, \ldots, P_5] = [SSID, TL_{1} \ldots TL_{17}]\ H^T$$

Where:

P_n	is the n^{th} training sequence FEC bits (P_1 shall be transmitted first)
SSID	is the Station slot identifier
TL_n	is the n^{th} bit in the transmission length (TL_1 = lsb)
^{T}	is the matrix transpose function and
H	is the parity matrix defined below:

$$H = \begin{matrix} 0 0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 \\ 0 0 1 1 1 1 1 1 0 0 0 0 1 1 1 1 1 1 1 1 1 \\ 1 1 0 0 0 1 1 1 0 0 1 1 0 0 0 0 1 1 1 1 1 \\ 1 1 0 1 1 0 1 1 0 1 0 1 0 0 1 1 0 0 1 1 1 \\ 0 1 1 0 1 0 0 1 1 1 1 0 0 1 0 1 0 1 0 1 1 \end{matrix}$$

Note.-This code is capable of correcting all single bit errors and detecting 75 of 300 possible double bit errors.
Ed.Note.- Put square brackets around the H-matrix and check the TL (lsb) definition.

B.3.6.3.3 *Order of data transmission*. The order of transmission, for both the application data and FEC bits, shall be LSB first followed by the higher order bits of that field. All data fields shall be transmitted in the order specified with LSB of each field transmitted first.

B.3.6.3.3.1 *Error correction encoding of application layer data (application FEC).* The application FEC shall be calculated using the Application Data, which includes one or more message blocks (see B 3.6.3.4). The Application FEC coding shall be accomplished by means of a systematic Reed-Solomon (255,249) 2^8-ary code. The field defining primitive polynomial of the code shall be:

$$p(x) = x^8 + x^7 + x^2 + x + 1$$

The generator polynomial is given by:

$$\prod_{i=120}^{125} \left(x - \alpha^i \right)$$

where α is a primitive element of a Galois field of size 256.

Note.- This code is capable of correcting up to three code word symbol errors

B.3.6.3.3.2 *Order of FEC processing*. The first parity word out of the application FEC encoder shall be treated as the most significant word of the six-word code and shall be the last parity word of the appended FEC transfered. In addition, each code word shall be transfered MSB first. The application FEC six-word code shall be appended to the data words. All of these words shall be transfered least significant word first. For blocks less than 1992 bits (249 bytes) long, the encoder and decoder shall fill the unused portion of the block with zeros. These zeros shall not be transfered to the bit scrambler.

Note.- An example is given in Appendix B of RTCA DO-246.

B.3.6.3.3.3 *Bit scrambling*. A pseudo-noise scrambler with a 15-stage generator register shall be exclusive OR'ed with the data stream starting with the SSID (i.e., everything after the synchronization and ambiguity resolution sequence).

The polynomial for the register of the scrambler and descrambler shall be $1 + X + X^{15}$. The scrambler and descrambler shall be clocked at the rate of one shift per bit, with the first scrambler bit in the register unshifted. The initial status of the register, preset at the beginning of the transmission shall be 1101 0010 1011 001 with the LSB in the first stage of the register.

Note.- See Attachment D x.x.x.x

B.3.6.3.4 *Message block format*. All messages shall be formulated into message blocks, which consist of a message header, a message and a 32 bit Cyclic Redundancy Check (CRC). Table B.3.6-5 shows the construction of the message block. All coding shall be signed fixed-point 2s complement numbers unless otherwise specified. The scaling of the data shall be as defined in the message tables. Co-ordinate parameters shall be expressed in WGS-84.

Table B.3.6-5 Format of a GBAS message block

Message Block	***Bits***
Message header	48
Message	<= 1696
CRC	32

B.3.6.3.4.1 *Message header*. The Message Header shall consist of a Message Block Identifier (MBI), a GBAS identifier (ID), Message Type and Message Length, as shown in Table B.3.6-6.

Message block identifier (MBI): the 8-bit identifier for the operating mode of the GBAS message block.

Coding: 1010 1010 = normal operations
1111 1111 = test operations
all other values are reserved.

Note 1.-The MBI aids a decoder in identifying the end of one message block and the beginning of another and verifying that this message block is intended to support GBAS precision approach.

Note 2.-Individual message transmissions can be set test by setting the MBI to "1111 1111" for that specific message.

GBAS ID: the unique 24 bit GBAS identification included to differentiate between broadcasting stations.

Coding: a four-character field, where each character is represented by the lower 6 bits of its International Alphabet No. 5 representation.

Note.-The GBAS ID is normally identical to the location indicator at the nearest airport and has to be coordinated as appropriate.

Message type: type of the message.

Coding:See Table 3.6-7.

Message length: length of the message in 8-bit bytes including the header and the CRC parameters.

Coding: unsigned fixed-point number.

Table B.3.6-6 Format of message block header

Message Header	***Bits***
Message Block Identifier	8
GBAS ID	24
Message Type	8
Message Length	8

B.3.6.3.4.2 *Cyclic redundancy check*.

Editorial Note.-The CRC material is under review for the next meeting. Material will be moved to B.3.10.

A 32 bit cyclic redundancy check (CRC) shall conclude each Message Block in order to ensure message integrity. The CRC word shall be calculated on the entire message, including the Message Header.

The CRC code shall consist of the coefficients of the remainder R(x) of the modulo-2 division of two polynomials:

$$[\, x^K \frac{M(x)}{G(x)} \,]_{\mathrm{mod}_2} = Q(x) + \frac{R(x)}{G(x)}$$

Where k is the number of bits in the CRC and the polynomial and M(x) consists of the sequence of data bits to be protected by the CRC (excluding the CRC bits):

$$M(x) = \sum_{i-1}^{n} m_i x^{n-i}$$

The data bits ($m_1, ..., m_n$) shall be treated as a single word of n bits, arranged in order of transmission without any byte-wise reversal of bits.

Numbering shall go from the LSB to the MSB, beginning with the header and following through all of the data. The CRC follows with R_1 as the MSB (ie. x^k) and the last bit is R_k (ie. x^1).

G(x) shall be the Message and FAS Data Block generator polynomial:

$$G(x) = x^{32} + x^{31} + x^{24} + x^{22} + x^{16} + x^{14} + x^8 + x^7 + x^5 + x^3 + x + 1$$

Q(x) is the quotient of the division.

The quotient Q(x) is obtained by dividing x^k *M(x) by G(x) starting with m_1(or m_i) and $G_1 = x^k$ considered as being the highest bits in their respective polynomial as follows (for the Message/FAS CRC):

$$[m_1{*}x^{(n+32)} + m_2{*}x^{(n-31)} ......m_n{*}x^{32}\ ] / [x^{32} + x^{31} + x^{24} + x^{22} + x^{16} + x^{14.} + x^8 + x^7 + x^5 + x^3 + x + 1]$$

The remainder of the division shall match the received CRC R_1 through R_{32} bits

$$R_1{*}x^{32} + R_2{*}x^{31} + R_3{*}x^{30 ....} + R_{32}{*}x^1$$

The CRC R(x), shall be coded with the coefficient of x^{32} as the LSB of the data field. The remainder shall initially set to zero, then n bits of data are sequentially clocked through the polynomial division circuit. After the n bits of data are clocked through, the output is switched to the remainder line, and 32 zeros are used to clock the remainder out. The 32 bits of remainder shall be the integrity check CRC.

Note 1.-x^1 is the output of the x^0 register element.

Note 2.-When the CRC is appended to the end of the message and the CRC is computed over the entire message (including the CRC) the resulting remainder is zero.

Note 3.-The MSB of the remainder is the first bit out of the polynomial generator and the first bit transmitted at the end of the message.

B.3.6.4 *Data content and transmission rates*. The message types that can be transmitted by GBAS shall be as in Table B.3.6-7. When transmitted, these messages shall have an update rate as shown in the Table. Message Types 1,2 and 4 shall be transmitted by all GBAS equipment.

Recommendation:
Message Type 5 should be transmitted.

Table B.3.6-7 GBAS VHF data broadcast messages

Message type	***Message name***	***Update rate***
1	Pseudorange corrections	Once per frame
2	GBAS related data	Once per 5 to 30 consecutive frames
3	Reserved For GBRS	N/A
4	Final Approach Segment (FAS) data	All FAS blocks once per 5 to 30 consecutive frames
5	Predicted ranging source availability	Once per 5 to 30 consecutive frames
6	Reserved	N/A
7	Reserved for national applications	N/A
8	Reserved for test applications	N/A
9-255	Spare	N/A

Note 1.- Message type 0 is undefined.

Note 2.-Currently only eight of the 255 available message types have been defined, with the intent that future needs can be addressed in the remaining message types. The message length is specified in eight-bit bytes, including the six bytes in the message header and the four bytes of the CRC field.

B.3.6.4.1 *Message type 1 –pseudorange corrections (see table xx)* .

Message Type 1 shall provide the differential correction data for individual GNSS ranging sources. The message shall contain three sections: a) message information (time of validity, integrity parameter type, number of measurements and the measurement type); b) low frequency information (satellite ephemeris CRC and satellite availability information); and c) the satellite data measurement blocks.

This message shall be compacted by transmitting only one ranging ”Ephemeris CRC” and ”Signal Availability” in each Type 1 Message. The ”Ephemeris CRC” and ”Signal Availability” shall correspond to the first ranging source in the message. The order of the transmission shall sequence so that the ”Ephemeris CRC” and ”Signal Availability” for each ranging source is transmitted as efficiently as possible. The Integrity Parameter Type shall set the length of the measurement blocks.

The correction data for a ranging source shall be valid only if both the ranging source IOD and the differential correction message IOD are identical and the ranging source ephemeris CRC and differential correction message ephemeris CRC are identical.

Note.-When four B values are transmitted, each of up to 18 ranging sources are transmitted first during each 9 second period allowing the aircraft receiver to validate the Ephemeris Data. No more than 18 satellites will fit into one slot. Therefore this information will be available at least twice each 20 second period. When one B value is transmitted, 25 *ranging sources can be transmitted and this information will be available at least twice each 26 second period.*

Pseudorange correction parameters shall be as follows:

Modified Z-count: the time of applicability for all the parameters in this message.

Coding: the clock shall be reset on the hour (xx:00), twenty minutes past the hour (xx:20) and forty minutes past the hour (xx:40) referenced to GPS time.
Editorial Note: The problem of a GLONASS only GBAS handling its leap seconds has not yet been resolved.

Integrity parameter type: the number of ’B”value fields transmitted in each measurement block .

Coding: 00 = 4
01 = 1
10 = Reserved for future applications
11 = 3

Number of measurements: the number of measurement blocks (N), which are transmitted in this message.

Coding: unsigned fixed-point number.
Measurement type: the type of ranging signal from which the corrections have been computed:

Coding: 000 = C/A or CSA code L1
001 = Reserved for C/A code L2
010 = Reserved for P(Y) code L1
011 = Reserved for P(Y) code L2
100 - 111 = Reserved for future measurement types

Additional Message Flag: identifies that additional measurements are included in a subsequent Message Type 1. Coding:
0 = This message type 1 contains all measurement blocks associated with this Z-Count.
1 = Additional measurement blocks in the subsequent message type 1.

Ephemeris CRC: CRC to validate the correctness of the data used for the satellite position determination.

A 16-bit cyclic redundancy check (CRC) shall be computed on the satellite ephemeris data set in order to ensure satellite position integrity.

The generator polynomial G(x) for the message block CRC shall be:

$$G(x) = x^{16} + x^{12} + x^{5} + 1$$

For GPS satellites, the ephemeris data to be applied to this 16 bit CRC circuit shall be defined in the first three subframes of the GPS satellite data transmission. The CRC is computed on words 3 through 10 of subframes 1,2, and 3 after being ANDed with mask in figure B.3.6-x. The CRC is not computed on the TLM or HOW which start each subframe or parity bits at the end of each word.

S1W3	**00000000 00000000 00000011**	**S1W4**	**00000000 00000000 00000000**
S1W5	**00000000 00000000 00000000**	**S1W6**	**00000000 00000000 00000000**
S1W7	**00000000 00000000 11111111**	**S1W8**	**11111111 11111111 11111111**
S1W9	**11111111 11111111 11111111**	**S1W10**	**11111111 11111111 11111111**
S2W3	**11111111 11111111 11111111**	**S2W4**	**11111111 11111111 11111111**
S2W5	**11111111 11111111 11111111**	**S2W6**	**11111111 11111111 11111111**
S2W7	**11111111 11111111 11111111**	**S2W8**	**11111111 11111111 11111111**
S2W9	**11111111 11111111 11111111**	**S2W10**	**11111111 11111111 10000000**
S3W3	**11111111 11111111 11111111**	**S3W4**	**11111111 11111111 11111111**
S3W5	**11111111 11111111 11111111**	**S3W6**	**11111111 11111111 11111111**
S3W7	**11111111 11111111 11111111**	**S3W8**	**11111111 11111111 11111111**
S3W9	**11111111 11111111 11111111**	**S3W10**	**11111111 11111111 11111100**

Figure B.3.6-1
Satellite Ephemeris Mask

For GLONASS satellites, the ephemeris data to be applied to this 16-bit CRC circuit shall be defined in the first four strings of the GLONASS satellite data transmission (B.3.2.1.2.2). The CRC is computed on string 1 to 4 after being ANDed with mask in figure B.3.5-2 (hexadecimal representation).

String 1 0 0 0 0 0 F F F F F F F F F F F F F F 0 0 0 0 0 0 0
String 2 0 0 0 0 0 F F F F F F F F F F F F F F 0 0 0 0 0 0 0
String 3 0 7 F F 0 F F F F F F F F F F F F F F 0 0 0 0 0 0 0
String 4 0 F F F F F C 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

Figure B.3.6 - 2
GLONASS Satellite Ephemeris Mask

For SBAS satellites the ephemeris data to be applied to this 16 bit CRC circuit shall be defined in the SBAS Message Type 9 212 bit data field (B.3.5.6) after being ANDed with the mask in figure B.3.6-3.

SBAS	1111	1111	1111	1111	1111	1000	0111	1111	1111	1111
Message	1111	1111	1111	1111	1111	1111	1111	1111	1111	1111
Type 9	1111	1111	1111	1111	1111	1111	1111	1111	1111	1111
	1111	1111	1111	1111	1111	1111	1111	1111	1111	1111
	1111	1111	1111	1111	1111	1111	1111	1111	1111	1111
	1111	1111	1111							

Figure B.3.6-3
SBAS Satellite Ephemeris Mask

Note.-Figure D.3.5.4.3.5-2 in Attachment D shows the polynomial division circuit used to generate the message Ephemeris CRC. After the 648 bits of data are transmitted the output is switched to the remainder line, and 16 zeros are used to clock the remainder out. The 16 bits of remainder is the integrity check CRC. The MSB of the remainder is the first bit out of the polynomial generator and the LSB of the CRC.

Source Availability Duration: the predicted minimum ranging source availability duration relative to the modified Z-count for the first measurement block.

Coding: unsigned fix-point number.

1111 1111 = the duration is greater than or equal to 2550 seconds.

Ranging Source ID: the identity of the ranging source to which subsequent corrections are applicable.

Coding: Unsigned fixed-point number
1-37 = the GPS satellite IDs (PRN).
38-61 = the GLONASS satellite IDs (slot number plus 37).
I62-119 = reserved for future applications.
120-138 = the SBAS satellite IDs (PRN).
139-255 = reserved for future applications.

Issue of data (IOD): the reference received by the GBAS and transmitted to the aircraft subsystem to validate the ephemeris data.

Coding: unsigned fixed-point number
For GPS, the IOD = the IODE parameter (see B.3.1.1.3.2.2)
For GLONASS, the IOD = the "tb" parameter (see B.3.2.1.3.1)
For SBAS, the IOD = the IODN parameter (see B.3.5.6)

Pseudorange correction (PRC): the correction to the ranging source pseudorange transmitted to the aircraft subsystem.

Range rate correction: the rate of change of the pseudorange correction.

σ_{pr_gnd}: the standard deviation of a normal distribution, which overbounds the signal-in-space contribution to the error in the corrected pseudorange, which causes an error in the position relative to the ground subsystem reference point.

Coding: unsigned fixed-point number
1111 1111 = ranging source correction invalid

B1 through B4: The differences between the broadcast pseudorange corrections and the corrections obtained excluding the specific reference receiver measurement.

Coding: 1000 0000 = reference receiver was not used to compute the pseudorange correction.
When the Integrity Parameter Type is set 1, B2 equals -B1 and 1000 0000 indicates that the pseudorange correction is invalid.

Note.-The relationship between the satellite measurements and the "B"values is provided in the Attachment D, Section D.3.5.4.3.4 .

B.3.6.4.2 *Message type 2 –GBAS related data (see table xx)* .

Message Type 2 shall identify the point coordinates to which the corrections provided by the GBAS are referenced (named the referenced point) and shall give other GBAS related data.

GBAS related data shall be as follows:

GBAS reference receivers: the number of GNSS reference receivers installed in this GBAS.

Coding: 00 = GBAS installed with 2 reference receivers
01 = GBAS installed with 3 reference receivers
10 = GBAS installed with 4 reference receivers
11 = Reserved for future use

GBAS accuracy designation letter: the minimum signal-in-space accuracy performance provided by GBAS (see B.3.6.7.1.1).

Coding: 00 = Accuracy designation A
01 = Accuracy designation B
10 = Accuracy designation C
11 = Reserved for future use.

GBAS continuity / integrity designator: the operational status of the GBAS.

Coding: 000 = Reserved for future use
001 = GCID = 1
010 = Reserved for future use
011 = Reserved for future use
100 = Reserved for future use
101 = Reserved for future use
110 = Reserved for future use
111 = Do not use.

Local magnetic variation: the magnetic variation at the reference point.

Coding: the sign bit shall be the direction of variation.
0 = east variation (clockwise from true north),
1 = west variation (counterclockwise from true north)

Refractivity index: the number, which is added to 400 to obtain the tropospheric refractivity at the reference point.

Coding: 1000 0000 = blank.

Scale height: a scale factor used for scaling the tropospheric refractivity as a function of differential altitude.

Coding: 1000 0000 = blank.

Refractivity uncertainty: the RMS error in the corrected tropospheric refractivity.

Coding: unsigned fixed-point number.

Latitude: the latitude of the reference point defined in arc seconds.

Coding: The sign bit shall indicate the hemisphere.
0 = Northern Hemisphere
1 = Southern Hemisphere

Longitude: the longitude of the reference point defined in arc seconds.

Coding: The sign bit shall indicate the hemisphere.
0 = Eastern Hemisphere
1 = Western Hemisphere

Ellipsoid height: The height of the reference point above the WGS-84 ellipsoid.

B.3.6.4.3 *Message type 3 –Reserved (see table xx).*

Note.-Message Type 3 is intended to provide the information required to use the GBRS and is reserved for future applications.

B.3.6.4.4 *Message type 4 –Final approach segment (FAS)*

Type 4 messages shall contain precision approach path reference data *(see table B.3.6-8 and 3.6-11)*. The Type 4 Message shall include the FAS approach path designator, which is followed by the FAS data block.

Note 1.-Type 4 message can contain a single FAS data block or multiple FAS data blocks. The Type 4 message contains an independent approach capability indication for each FAS data block within the message. Each FAS data block is terminated with a CRC, which wraps around the approach data and each Type 4 message is terminated with a separate CRC (as defined in the message definition) which, wraps the entire message including message header and all the individual FAS data block CRCs.

Final approach segment parameters shall be as follows:

FAS approach path designator: the level of service of FAS defined in the following FAS data block.

Coding: unsigned fixed-point number
1 = supports Cat I operations
all other values reserved.

B.3.6.4.4.1 *Final approach segment data block.* The Final Approach Segment Data Block shall contain the parameters, which define a single precision approach. Each FAS data block shall end with a CRC, which wraps around the approach data. A separate CRC shall be wrapped around the entire FAS Data Message (Type 4).

Note 1.-Attachment D Section D.3.5.4.3.7 contains an illustration of the Final Approach Segment and shows the relationship between the data points defined in the FAS Data Block.

Note 2.-The protected FAS data blocks are validated individually by the civil authorities. The data blocks include data that allow for an unambiguous FAS selection against the desired approach charts.

Final approach segment parameters shall be as follows:

Operation type: straight-in approach procedure or other operation types.

Coding: 0000 = straight-in approach procedure
1-15 = reserved for future applications

SBAS service provider ID: as defined in B.3.5.x

Airport ID: the three or four alphanumeric characters used to designate airport facilities.

Coding: Only numbers and upper case letters shall be used. The most significant two bits of every character (8-bit word) shall be zero. Alphanumeric characters shall be coded using bits b_1 to b_6 of International Alphabet No. 5. When a three-character identifier is used, the most significant character shall be set to blank ”10 0000”.

Runway number: the approach runway number.

Coding: unsigned binary
The valid range shall be 0-36 and
0 = heliport operations
1-36 = runway operations

Runway letter: the runway letter, where used to differentiate between parallel runways.

Coding: 00 = no letter
01 = R (right)
10 = C (center)
11 = L (left)

Approach design information: the general information about the approach design.

Coding: 000 = straight-in approach, FPAP at the end of the runway
001 = straight in approach, FPAP not at the end of the runway
010 = offset approach
011 - 111 = reserved for future applications

Route indicator: the route to or from the waypoint named by the basic indicator.

Coding: The route indicator shall be a single alphabetic character coded in accordance with bits b_1 to b_5 of International Alphabet No. 5. The letters "I" and "O" shall not be used. The most significant three bits of every character (8-bit word) shall be zero. Alphanumeric characters shall be coded using bits b_1 to b_5 of International Alphabet No. 5.

Ed.Note.- This definition must be corrected.

Reference path data selector: the numerical identifier that is unique in the broadcast region and used to select the FAS data block (desired approach).

Coding: unsigned fixed-point number.

Reference path identifier: the three or four alphanumeric characters used to uniquely designate the reference path.

Coding: Only numbers or upper case letters shall be used. The most significant two bits of every character (8-bit word) shall be zero. Alphanumeric characters shall be coded using bits b_1 to b_6 of International Alphabet No. 5. When a three-character identifier is used, the most significant character shall be set to blank "10 0000".

The runway datum point is a point over which the FAS path passes at a relative height specified by the datum crossing height, normally located at the intersection of the runway centerline and the threshold.

Runway datum point latitude: the latitude of the runway datum point in arc seconds.

Coding: The sign bit shall indicate the hemisphere
0 = Northern Hemisphere
1 = Southern Hemisphere

Runway datum point longitude: the longitude of the runway datum point in arc seconds.

Coding: The sign bit shall indicate the hemisphere:
0 = Eastern Hemisphere
1 = Western Hemisphere

Runway datum point (RDP) height: the height of the RDP above the WGS-84 ellipsoid.

Coding: This field shall be coded as an unsigned value with an offset of -512 m. A value of zero in this field shall place the RDP 512 m below the earth ellipsoid.

The flight path alignment point is a point at the same height as the RDP that is used to define the alignment of the approach..

Flight path alignment point –latitude : the latitude of the runway Flight Path Alignment Point (FPAP) in arc seconds.

Coding: The sign bit indicates the hemisphere:
0 = Northern Hemisphere
1 = Southern Hemisphere

Flight path alignment point –longitude : the longitude of the Flight Path Alignment Point in arc seconds.

Coding: The significant bit indicates the hemisphere
0 = Eastern Hemisphere
1 = Western Hemisphere

Approach datum crossing height (DCH): the height of the FAS above the RDP defined in either feet or meters as indicated in the DCH Units Selector bit.

Coding: unsigned binary number.

Approach DCH units selector: the units used to describe the DCH.

Coding: 0 = feet
1 = meters

Glide path angle (GPA): the angle of the approach path (glide path) with respect to the horizontal plane defined according to WGS-84 at the RDP.

Coding: unsigned fixed-point number.

FAS CRC code: the 32 bit CRC appended to the end of each FAS data block in order to ensure approach data integrity.

Table B.3. 6-8 Final approach segment (FAS) data block

Data Content	***Bits Used***	***Range of Values***	***Resolution***
Operation Type	4	0 to 15	1
Reserved for SBAS Provider ID	4		
Airport ID	32		
Runway Number	6	0 to 36	1
Runway Letter	2		
Approach Design Information	3		
Route Indicator	5		
Reference Path Data Selector	8	0 to 199	1
Reference Path identifier	32		
RDP Latitude	32	± 90.0 °	0.0005 arcsec
RDP Longitude	32	± 180.0 °	0.0005 arcsec
RDP Height	16	-512.0 to 6041.5 m	0.1 m
FPAP Latitude	32	± 90.0 °	0.0005 arcsec
FPAP Longitude	32	± 180.0 °	0.0005 arcsec
Approach Datum Crossing Height (DCH) (1)	15	0 to 3276.8 ft 0 to 1638.4 m	0.1 ft 0.05 m
Approach DCH Units Selector	1		
Glidepath Angle (GPA)	16	0 to 90.0 °	0.01°
Final Approach Segment CRC	32		

Note-.Information can be provided in either feet or meters.

Editorial Note.-Correct empty cells, range of values (units should be same as resolution units), and all ranges should use "to". *Action: Jim Dargue, Victor Iatsouk*

B.3.6.4.5 *Message type 5 –predicted ranging source availability* . Message Type 5 shall provide a means for the ground subsystem to indicate to the aircraft avionics the future availability of differential corrections to the ranging measurements. The message shall consist of rising and setting information for the currently visible or soon to be visible ranging sources.

Note.-This message allows the ground subsystem to broadcast predicted changes in the availability of differential corrections at future specific points in time to the aircraft so that the aircraft is able to anticipate the ranging sources that can be used for the duration of a specific precision approach.

Predicted ranging source availability parameters shall be as follows:

Impacted sources: the number (i) of sources for which the duration information is reduced due to unique constellation masking.

The number of impacted sources in this field shall be the number impacted on all approaches. This field shall be followed by N repetitions (maximum 31) of source information, where each repetition includes: a ranging source ID, the source availability sense, and the source availability duration.

Coding: unsigned integer

Ranging source ID: the identifier of the satellite or GBRSs to which subsequent corrections are applicable.

Coding: see B.3.6.4.1

Source availability sense: the sense of the subsequent ranging source availability duration term.

Coding: The parameter shall be "0" or "1" and
"0" = differential corrections will soon cease to be provided for the associated ranging source
"1" = differential corrections will soon start to be provided for the associated ranging source.

Note.- After a satellite has risen and differential corrections have started to be provided for the satellite, the satellite availability sense term will typically be set to '0' to indicate the next action of the satellite is to set and the satellite availability duration term will typically be set to '111 1111' indicating the satellite will not set for at least 1280 seconds after the modified Z-count time.

Source Availability Duration: the predicted minimum ranging source availability duration relative to the modified Z-count for the first measurement block.

Coding: unsigned fix-point number.
111 1111 = the duration is greater than or equal to 1270 seconds.

Obstructed approaches: the number (A) of approaches for which the corrections will be reduced due to approach unique constellation masking.

Coding: The number of "Obstructed Approaches" field shall be followed by (A) repetitions of reference path data selectors and source information. The source information shall be the number of impacted sources (N_A), followed by N repetitions of a ranging source ID, the source availability sense, and the source availability duration as defined above. Information in the repetitions shall supplement or modify the common impacted source information at the beginning of this message.

Reference path data selector: as message type 4 (B.3.6.4.4.1).
Editorial Note: Action Richard Idiens to review and propose modifications.

B.3.6.4.6 *Message type 6 – reserved* .

Note.- Message Type 6 is reserved for future use to provide the information required for CAT II/III precision approaches.

B.3.6.4.7 *Message type 7 – national (reserved)* .

Note.-Message Type 7 is reserved for national applications.

B.3.6.4.8 *Message type 8 – test (reserved)* .

Note.- Message Type 8 is reserved for local and regional test applications.

B.3.6.5 *Protocols for data application*.

This section defines the inter-relationships of the data broadcast message parameters. It provides definitions of parameters used by either or both non-aircraft and aircraft elements, which are not transmitted. These parameters define terms used to determine the navigation solution and its integrity (that is, protection levels).

Note. - Definitions for transmitted parameters are provided in section B.3.6.4.

B.3.6.5.1 Corrected Pseudorange

The corrected pseudorange for a given satellite at time *t* is the sum of the measured and carrier smoothed pseudorange, the broadcast correction and a projection term to account for the age of the broadcast correction:

$$PR_{corrected}(t) = PR_{measured}(t) + PRC + RRC \times (t - t_{zcount})$$

where:

PRC is the pseudorange correction defined in B.3.6.4.1

RRC is the pseudorange correction rate defined in B.3.6.4.1

$(t - t_{zcount})$ is the current time minus the reference time for broadcast corrections as indicated by the modified Z-count defined in B.3.6.4.1.

B.3.6.5 *Protocols for data application*.

This section defines the inter-relationships of the data broadcast message parameters. It provides definitions of parameters used by either or both non-aircraft and aircraft elements which are not transmitted. These parameters define terms used to determine the navigation solution and its integrity (that is, protection levels).

Note. - Definitions for transmitted parameters are provided in section B.3.6.4.

B.3.6.5.1 Corrected Pseudorange

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$$PR_{corrected}(t) = PR_{measured}(t) + PRC + RRC \times (t - t_{zcount})$$

where:

PRC is the pseudorange correction defined in B.3.6.4.1

RRC is the pseudorange correction rate defined in B.3.6.4.1

$(t - t_{zcount})$ is the current time minus the reference time for broadcast corrections as indicated by the modified Z-count defined in B.3.6.4.1

B.3.6.5.2 Tropospheric Delay

The tropospheric delay error in the measured pseudorange for a satellite is estimated as:

$$\Delta\tau(\theta) \equiv N_R \left(h_{air} - h_{ground}\right) \frac{10^{-6}}{\sin(\theta)}$$

where:

N_R is the refractivity index transmitted by the ground subsystem (see B.3.6.4.2)

h_{air} is the altitude of the aircraft subsystem

h_{ground} is the altitude of the ground subsystem (see B.3.6.4.2)

θ is the satellite elevation angle

If the tropospheric delay is used to correct the differential correction, then

$$PR_{corrected} \equiv PR_{corrected} - \Delta\tau(\theta)$$

and the residual tropospheric uncertainty is defined by:

$$\sigma_{tropo}(\theta) \equiv \sigma_N \left(h_{air} - h_{ground}\right) \frac{10^{-6}}{\sin(\theta)}$$

where:

σ_N is the refractivity uncertainty transmitted by the ground subsystem (see B.3.6.4.2)

B.3.6.5.3 Protection Levels

The Signal-in-Space(SIS) Vertical and Lateral Protection Levels (VPL and LPL) are upper confidence bounds on the error in the position solution such that:

Pr(Position Error > Protection Level) < Required Probability

The protection level computations are based on projecting an estimate of the probability density function (pdf) of the error in the corrected pseudoranges to the position domain. The requirements on these pdfs are given in B.3.6.7.3.3.

The projection method used to transform from the range domain to the position domain is consistent between the position and integrity computations. A weighted least squares position solution based on the basic linearized GPS measurement model is consistent with the integrity computations in this section.

B.3.6.5.3.1 Normal Measurement Conditions

The vertical protection level (VPL_{H0}) and lateral protection level (LPL_{H0}) assuming that normal measurement conditions (i.e., no faults) in all reference receivers and on all ranging sources (satellites) exist can be calculated as:

$$VPL_{H0} = K_{ffmd}\sqrt{\sum_{i=1}^{N} s_{i,vert}^2 \sigma_i^2}$$

$$LPL_{H0} = K_{ffmd}\sqrt{\sum_{i=1}^{N} s_{i,lat}^2 \sigma_i^2}$$

where:

K_{ffmd}	is the multiplier which determines the probability of fault-free missed detection
$s_{i,vert}$	is the projection of the vertical component for i^{th} ranging source; equal to $s_{i,3} + s_{i,1} * \tan\theta_{GS}$
$s_{i,lat}$	is the projection of the lateral component for i^{th} ranging source; equal to $s_{i,2}$.
$s_{i,1}$	is the i^{th} element of first column of the projection matrix ***S***
$s_{i,2}$	is the i^{th} element of second column of ***S***
$s_{i,3}$	is the i^{th} element of third column of ***S***
θ_{GS}	is the glidepath angle for the final approach path
N	is the number of ranging sources used in the position solution
i	is the ranging source index

For a general least-squares position solution, the projection matrix **S** is defined as:

$$\mathbf{S} \equiv \begin{bmatrix} s_{x,1} & s_{x,2} & \Lambda & s_{x,N} \\ s_{y,1} & s_{y,2} & \Lambda & s_{y,N} \\ s_{v,1} & s_{v,2} & \Lambda & s_{v,N} \\ s_{t,1} & s_{t,2} & \Lambda & s_{t,N} \end{bmatrix} = \left(\mathbf{G^T} \cdot \mathbf{W} \cdot \mathbf{G}\right)^{-1} \cdot \mathbf{G^T} \cdot \mathbf{W}$$

where:

$$\mathbf{G_i} = \begin{bmatrix} \cos El_i \cos Az_i & \cos El_i \sin Az_i & \sin El_i & 1 \end{bmatrix}$$ = i^{th} row of **G**

$$\mathbf{W}^{-1} = \begin{bmatrix} \sigma_1^2 & 0 & \Lambda & 0 \\ 0 & \sigma_2^2 & \Lambda & 0 \\ M & M & O & M \\ 0 & 0 & \Lambda & \sigma_N^2 \end{bmatrix}$$

$$\sigma_i^2 = \sigma_{p\_gnd}^2[i] + \sigma_{tropo}^2[i] + \sigma_{pr\_air}^2[i]$$

$\sigma_{pr\_gnd}[i]$	is the broadcast 1-sigma fault-free error value for the i^{th} satellite (see B.3.6.4.1)
σ_{pr_air} *and* σ_{tropo}	are supplied by the aircraft subsystem

B.3.6.5.3.2 Faulted Measurement Conditions

The vertical protection level (VPL_{H1}) and lateral protection level (LPL_{H1}) assuming that a latent fault associated with any one, and only one, reference receiver exists can be calculated as given below. A latent fault includes any erroneous measurement(s) that is not immediately detected by the ground subsystem, such that the broadcast data are affected and there is an induced position error in the airborne subsystem.

$$VPL_{H1} = \max[VPL_i]$$
$$LPL_{H1} = \max[LPL_i]$$

where VPL_j and LPL_j for all j (1 to MAX { M[i] }) is as follows:

$$VPL_j = |B_{j,vert}| + K_{md}\sigma_{vert,H1}$$
$$LPL_j = |B_{j,lat}| + K_{md}\sigma_{lat,H1}$$

and:

$$B_{j,vert} = \sum_{i=1}^{N} s_{i,vert} B[i,j]$$
$$B_{j,lat} = \sum_{i=1}^{N} s_{i,lat} B[i,j]$$

B[i,j] *is the broadcast B value for the* i^{th} *satellite and* j^{th} *reference receiver (see B.3.6.4.1)*
j *is the ground subsystem reference receiver index*
K_{md} *is the multiplier which determines the probability of missed detection given that the ground subsystem is faulted*

$$\sigma^2_{vert,H1} = \sum_{i=1}^{N} s^2_{i,vert}\sigma^2_{i,H1}$$
$$\sigma^2_{lat,H1} = \sum_{i=1}^{N} s^2_{i,lat}\sigma^2_{i,H1}$$
$$\sigma^2_{i,H1} = \frac{M[i]\cdot\sigma^2_{pr\_gnd}[i]}{M[i]-1} + \sigma^2_{pr\_air}[i] + \sigma^2_{tropo}[i]$$

M[i] is the number of ground subsystem reference receivers whose pseudorange measurement was used to determine the differential correction for the i^{th} ranging source for which the B value was transmitted to the airborne subsystem.

B.3.6.5.3.3 Definition of K Multipliers

The multipliers are given in the table below.

Multiplier	M[i]		
	2	3	4
K_{ffmd}	5.762	5.810	5.847
K_{md}	2.935	2.898	2.878

B.3.6.6 *Message tables.*

Table B.3.6-9 Format of message type 1

Data Content	*Bits Used*	*Range of Values*	*Resolution*
Modified Z-count	14	0 to 1199.9	0.1 sec
Integrity Parameter Type	2		
Number of Measurements	5	0 to 31	1
Measurement Type	3		
Additional Message Flag	1		
Spares	7		
Ephemeris CRC (Note 3)	16		
Source Availability Duration	8	0 - 2550 sec	10 sec
Measurement Block 1			
Ranging Source ID	8	1 - 255	1
Issue of Data (IOD)	8		
Pseudorange Correction (PRC)	16	±327.67 m	0.01 m
Range Rate Correction (RRC)	16	±32.767 m/s	0.001 m/s
σ_{pr_gnd} (unsigned –Note 4)	8	0 - 5.08 m	0.02 m
B_1 (Note 2)	8	±6.35 m	0.05 m
B_2 (Note 2)	8	±6.35 m	0.05 m
B_3 (Note 2)	8	±6.35 m	0.05 m
B_4 (Note 2)	8	±6.35 m	0.05 m
• • •			
Measurement Block N			

Notes.-
2.-1000 0000 indicates the measurement is not available
3.-GBRSs have the Ephemeris CRC set to all 0's
4.-1111 1111 indicates the ranging source is invalid

Table B.3.6-10 Format of message type 2

Data Content	***Bits Used***	***Range of Values***	***Resolution***
GBAS Reference Receivers	2		
GBAS Accuracy Designation Letter	2		
Spare	1		
GBAS Continuity/Integrity Designator	3		
Local Magnetic Variation	8	± 32.0°	0.25°
Spare	16		
Refractivity Index	8	± 381	3
Scale Height	8	± 12,700 m	100 m
Refractivity Uncertainty	8	0 - 255	1
Latitude (Note 1)	32	± 90.0°	0.0005 arcsec
Longitude (Note 1)	32	± 180.0°	0.0005 arcsec
Ellipsoid Height (Note 1)	24	± 83,886.07 m	0.01 m

Note.-The accuracy can be greater than the resolution by locating the reference point at the actual point defined in the message.

Table B.3.6-11 Format of message type 4

Data Content	***Bits Used***	***Range of Values***	***Resolution***
FAS Block 1			
FAS Block 1 Approach Path Designator	8		
FAS Data Block 1	304		
	•		
	•		
	•		
FAS Block N			
FAS Block **n** Approach Path Designator	8		
FAS Data Block **n**	304		

Table B.3.6-12 Format of message type 5

Data Content	*Bits Used*	*Range of Values*	*Resolution*
Impacted Sources (**N**)	8	1 - 31	1
Ranging Source ID	8	1 - 255	1
Source Availability Sense	1		
Source Availability Duration (note 1)	7	1270 sec	10 sec
•			
Obstructed Approaches (**A**)	8	0 - 255	1
Approach 1			
Reference Path Data Selector	8		
Impacted Sources (**N_1**)	8	1 - 31	1
Impacted Ranging Source 1 on Approach 1			
Ranging Source ID	8	1 - 255	1
Source Availability Sense	1		
Source Availability Duration (note 1)	7	1270 sec	10 sec
•			
Approach A			
Reference Path Data Selector	8		
Impacted Sources (**N_A**)	8	1 - 31	1
Impacted Ranging Source 1 on Approach A			
Ranging Source ID	8		
Source Availability Sense	1		
Source Availability Duration (note 1)	7	0 - 1270 sec	10 sec
•			

Note.- only unique to approach satellites are entered in the second half of this meesage.

B.3.6.7 *Non-aircraft element.*

B.3.6.7.1 *GBAS signal-in-space performance requirements.*

B.3.6.7.1.1 *GBAS signal-in-space accuracy*. The accuracy of a GBAS signal-in-space shall be classified according to the Ground Accuracy Designator (GAD). The GAD shall indicate the level of signal-in-space accuracy performance provided by the combination of particular GBAS Ground Subsystem and the space segment. The signal-in-space accuracy performance shall be specified in terms of the contribution to the error in the corrected pseudorange, which causes an error in the position relative to the ground subsystem reference point. Every ground subsystem shall meet the requirements for the GAD used to classify the ground subsystem.

Note.- Several levels of performance are defined. Each level of performance has an associated Ground Accuracy Designator (GAD).

The GAD shall consist of a letter indicating the measurement accuracy (independent of the number of reference receivers) and a number indicating the number of reference receivers included in the ground subsystem.

B.3.6.7.1.1.1 *Signal-in-space accuracy for GNSS satellites.*

The RMS of the total signal-in-space contribution to the error as a function of satellite elevation angle shall be:

$$RMS_{pr\_gnd,GNSS}(\theta_n) \leq \sqrt{\frac{\left(a_o + a_1 e^{-\theta_n/\theta_0}\right)^2}{M} + (a_2)^2 + \left(\frac{a_3}{\sin(\theta_n)}\right)^2}$$

Where M ≡ number of ground reference receivers used for the computation of the pseudorange correction for the given ranging source as indicated by the number of B parameters that are not set to"1000 0000"bit patterns.

$n \equiv n^{th}$ ranging source

$\theta_n \equiv$ elevation angle for the n^{th} ranging source

a_0, a_1, a_2, a_3, and θ_0 parameters are defined in Tables B.3.6-13 and B.3.6-14 for each of the defined Ground Accuracy Designators.

Table 3.6-13 GBAS - GPS accuracy requirement

Ground Accuracy Designation Letter	θ_n (degrees)	a_0 (meters)	a_1 (meters)	θ_0 (degrees)	a_2 (meters)	a_3 (meters)
A	≥5	0.5	1.65	14.3	0.08	0.03
B	≥5	0.16	1.07	15.5	0.08	0.03
C	> 35	0.15	0.84	15.5	0.04	0.01
	5 to 35	0.24	0	-	0.04	0.01

Table 3.6-14 GBAS - GLONASS accuracy requirement

Ground Accuracy Designation Letter	θ_n (degrees)	a_0 (meters)	a_1 (meters)	θ_0 (degrees)	a_2 (meters)	a_3 (meters)
A	≥5	0.5	1.66	14.3	0.06	0.03
B	≥5	0.16	1.07	15.5	0.06	0.03
C	> 35	0.15	0.84	15.5	0.037	0.01
	5 to 35	0.24	0	-	0.037	0.01

B.3.6.7.1.1.2 *Signal-in-space accuracy for GBAS measurements of SBAS satellites*

The RMS of the total signal-in-space contribution to the corrected SBAS pseudorange accuracy shall be:

$$RMS_{pr\_gnd,GEO}(\theta_n) \leq 1.91*(RMS_{pr\_gnd,GPS}(\theta_n)) + 0.15 \text{ meters}$$

Where $RMS_{pr\_gnd,GPS}(\theta_n)$ is derived in Section B.3.5.3.2.1.1 for the corresponding ground accuracy designation.

Note.-The factor of 1.91 is computed from the square root of the GPS C/A-code bandwidth assumed to be utilized by the reference receivers (8 MHz) divided by the 2.2 MHz bandwidth provided by the Inmarsat-3 GEO satellites. The 0.15 meters is due to code carrier divergence associated with transponder payload.

B.3.6.7.1.2 *GBAS ground subsystem continuity, integrity and time to alert*. A GBAS ground subsystem shall have a Ground Continuity and Integrity Designator (GCID) that will specify the highest level of service that can be supported by the Ground Subsystem. The GBAS ground subsystem shall meet the integrity, continuity and time to alert requirements given in Table B.3.6-11.

Note.-A GCID of 1 indicates that the ground subsystem meets the allocated requirements for continuity and integrity associated with terminal area through Category I precision approach. The ability of the ground subsystem to meet these requirements depends on the redundancy of elements in the ground station as well as the basic reliability of the elements. Hence, GCID is a function of the ground subsystem design and the current state of the ground subsystem.

Table B.3.6-15 Continuity, integrity and time to alert requirements

GCID	1
Integrity risk excluding the Protection Level integrity risk	$< 1.5 \times 10^{-7}$/approach
Continuity	>1 - 2.5×10^{-6}/15 seconds
Maximum Time to Alert	3 seconds

Note.- GBAS ground subsystem integrity risk is defined as the probability that the GBAS ground subsystem provides misleading information for longer than the Time to Alert without annunciation or shutting down. Misleading information is defined as ***(TBD). Action: All by WG-B.*** *Time to Alert is defined as the time between the onset of the misleading information and the transmission of the last bit of the message that contains the integrity data that reflects the condition or the first missing burst in case of subsystem shutdown.*

B.3.6.7.1.2.1 *Protection Levels.* The protection level integrity risk is the integrity risk due to undetected errors in position relative to the ground subsystem reference point greater than the alert limits under the two following conditions:

- errors in a the fault-free Signal-in-Space,
- the failure of one of the ground reference receivers affecting broadcast data that induce positioning error, taking into account the geometry of the ranging sources used by the user GNSS receiver.

The protection level integrity risk shall be assessed onboard by comparing Protection Levels against lateral and vertical alert limits given in Table B.3.6-16 and Table B.3.6-17 (B.3.6.8.3.1).

Table B.3.6-16 Lateral alert limit

Lateral Alert Limit (metres)	Horizontal distance of aircraft position from the RDP as translated along the final approach path (metres)
40.0	291 < D ≤ 873
0.0044*D(m)+36.15	873 < D ≤ 7212
68	D > 7212

Table B.3.6-17 Vertical alert limit

Vertical Alert Limit (metres)	Height above RDP of aircraft position translated onto the final approach path (ft)
10.0	100 < H ≤ 200
0.02925*H(ft)+4.15	200 < H ≤ 1290
41.75	H > 1290

B.3.6.7.1.2.2 *Continuity.*

The GBAS ground subsystem continuity is the probability that a fault-free user receiver provides valid outputs during any 15 second period of an approach, assuming that outputs were valid at the start of the period. These outputs are considered as valid if the relative position errors are lower than alert limits.

The GBAS ground subsystem continuity requirement shall be as given by the table B.3.6-15.

The losses of continuity due to:

- protection levels greater than the Alert Limits originated by the 2 conditions given in B.3.6.7.1.2.1
- or to the space segment,

do not count as loss of continuity of the GBAS Ground subsystem.

Note.- Attachment D.x.x.x. describes the allocation of the performance requirements.

Note.-Section C.x.x.x. describes the allocation of the performance requirements.

B.3.6.7.2 *Ground monitoring*. The ground subsystem shall include sufficient monitoring to ensure the integrity levels given in Table B.3.6-15.

B.3.6.7.2.1 *VHF data broadcast monitor*. The data broadcast transmissions shall be monitored.

B.3.6.7.2.1.1 *VHF Data Broadcast Monitoring. The data broadcast transmissions shall be monitored. The transmission of the data shall cease and an appropriate alert shall be raised within 0.5 seconds under the following conditions:*

a) Disagreement between the transmitted data and data derived or stored by the monitoring system prior to the transmission for more than 3 seconds;

Recommendation.- *The 3 second period should be reduced to 1 second.*

b) Change of the transmitted power by more than 3dB for more than 3 seconds;

c) Update rate of message type 1 is not met for a 3 second period;
d) Update of message types 2, 4, and 5 is not met for a 30 second period.

B.3.6.7.2.1.2 *TDMA slot monitoring.* The probability that the ground equipment fails to detect an out-of-slot transmission, which exceeds that allowed in Paragraph B.3.6.2.6, within 1 second, shall be less than 2x10-7 per 150-second period. If out-of-slot transmissions are detected, the ground equipment shall terminate all data broadcast transmissions within 0.5 seconds.

B.3.6.7.2.2 *Multiple receiver consistency checking*. The ground subsystem shall perform Multiple Receiver Consistency Checking (MRCC). The Probability of false detection shall support the continuity of function requirements given in Table B.3.6-15. The ground subsystem shall monitor all reference receiver measurements. The monitoring function shall detect faulted reference receivers and remove them from use. The monitoring function shall detect individual reference receiver measurements with large residual errors (e.g., due to unusually large multipath error) and exclude them from being used in generating differential corrections.

B.3.6.7.2.3 *Satellite signal quality monitoring*. The ground subsystem shall monitor the satellite signals to detect conditions that will result in improper operation of differential processing.

Additional Requirements TBD. Action: Barbara Clark for WG-B.

B.3.6.7.2.4 *Satellite signal measurement quality monitoring*. The ground subsystem shall perform sufficient monitoring to ensure that the measurements used in the production of the pseudorange corrections are TBD.

Additional Requirements TBD. Action: Barbara Clark for WG-B.

B.3.6.7.3 *GBAS functional requirements.*

B.3.6.7.3.1 *Ephemeris data*. The ground subsystem shall use the previous ephemeris data from each satellite. New ephemeris data shall become the basis for corrections only after it has been continuously received for at least two minutes but before three minutes have passed.

Note.-This enables the aircraft subsystem time to collect new ephemeris data.

B.3.6.7.3.2 *Broadcast Pseudorange Correction*. The GBAS pseudorange shall be calculated from the satellite broadcast data for a given satellite at the ground reference receiver.

Differential pseudorange corrections shall be determined as the average of the corrections based on measurements from multiple, ground reference receivers. The corrections shall be based on smoothed code pseudorange measurements for each satellite using the carrier measurement in such a manner that the steady state noise on the pseudorange measurement has a spectral density with a 3 dB bandwidth of 0.01 rad/s.

B.3.6.7.3.3 *Broadcast signal-in-space integrity parameters*. The ground subsystem shall provide a set of integrity qualifiers for each pseudorange correction. The integrity qualifiers shall include σ_{pr_gnd} and B parameters (B.3.6.6.1.1).

These parameters shall have values such that the following two conditions are met:

N(0, σ_{pr_gnd}) overbounds the error distribution for signal-in-space errors greater than TBD of the distribution for the fault-free case.

N(B_j^i, M σ_{pr_gnd} /(M-1)) overbounds the error distribution for signal-in-space errors greater than TBD of the distribution for the case of a fault in the j^{th} reference receiver.

Where:

M is defined in Section B.3.6.6.3.1
N(m, σ) defines a normal distribution with average m and a standard deviation σ.

B.3.6.7.3.4 Functional Requirements associated with message parameters

B.3.6.7.3.4.1 Only two MBI codes shall be used. In test mode….

B.3.6.7.3.4.2 The ground station shall set the Additional Message Flag field to "1" to indicate if there is a subsequent Type 1 Message that contains additional message blocks. The additional message shall have the same Modified Z-count.

B.3.6.7.3.4.3 The GBAS ground station shall set the IOD field in each ranging source measurement block to be the IOD value received from the ranging source that corresponds to the ephemeris data used to compute the pseudorange correction.

A GLONASS satellite shall not be used when its general unhealthy flag C_n^A is set to "0" in the almanac message. The satellite can be used again only when the flag has reverted to "1" in the almanac message and when a new ephemeris set is available (new tb value).

Editorial Note.- The continuity concept for GLONASS use needs to be developed.

B.3.6.7.3.4.4 Ionospheric and tropospheric corrections shall not be applied to the Pseudorange correction (PRC). (Add to protocol)

B.3.6.7.3.4.5 The ground station shall either set the refractivity index field to "1000 0000" to indicate no refractivity index is supplied by the ground station, or to a value that indicates the refractivity index that may be used in the tropospheric correction made by the aircraft equipment. *(Ed. Note: requirements on this parameter)*

The ground station shall either set the scale height field to "1000 0000" to indicate no scale factor is supplied by the ground station, or to a value which indicates the scale factor which may be used in the tropospheric correction made by the aircraft equipment. *(Ed. Note: requirements on this parameter)*

The ground station shall either set the Refractivity uncertainty field to "1000 0000" to indicate no scale factor is supplied by the ground station, or to a value which indicates the scale factor which may be used in the tropospheric correction made by the aircraft equipment. *(Ed. Note: requirements on this parameter)*

Editorial Note: Actions taken by Barbara Clark(Refractivity), Pierre Gayraud (IOD), Bob Jeans (MBI test mode), Richard Idiens (Message Type 5).

B.3.6.7.3.4 *Message Latency*. Message latency shall not exceed 0.5 seconds.

B.3.6.7.3.5 *Test mode*. When the station is operating in a test mode, the Message Block Identifier shall be set to "1111 1111".

Note.-Individual message transmissions can be set invalid by setting the Message Block identifier to "1111 1111" for that specific message.

B.3.6.7.3.6 FAS and GBAS reference point accuracy. The relative survey error shall be less than 5 cm.

Note.- The absolute survey error should be less than 10 m.

Ed.Note.- These survey accuracy values need to be checked.

B.3.6.7.4 *Ground based Ranging sources.*

Note.-Ground based ranging systems are expected to use a portion of the 1559-1610 MHz band, will be classified by the ITU as providing RNSS-ARNS service and require up to ± 10 MHz around their center frequency. As augmentations to GPS and/or GLONASS, they will constitute components of GNSS and will have associated avionics receivers. Their interference protection level will necessarily be consistent with that of GPS/GLONASS receiver.

B.3.6.8 *Aircraft elements*.

B.3.6.8.1 *GNSS Receiver*. The GBAS capable GNSS receiver shall process signals of GBAS in accordance with the requirements specified in this section as well as with requirements in B.3.1.3.1 GPS(GNSS) receiver and / or B.3.2.3.1

GLONASS (GNSS) receiver and /or B.3.5.8.1 SBAS capable GNSS receiver,

Note.-If there are conflicting requirements with the other section identified, the requirements in this section shall prevail.

B.3.6.8.2 *Performance requirements.*

B.3.6.8.2.1 *GBAS aircraft receiver accuracy*.

The RMS of the total aircraft receiver contribution to the error as a function of satellite elevation angle shall be:

$$RMS_{pr\_air,}(\theta_n) \leq a_0 + a_1\, e^{-(\theta_n/\theta_0)}$$

Where $n \equiv n^{th}$ ranging source
$\theta_n \equiv$ elevation angle for the n^{th} ranging source
a_0, a_1, and θ_0 parameters are defined in Tables 3.6-18 for GPS and Table 3.6-19 GLONASS and Section B.3.5.8.1 for SBAS for each of the defined Aircraft Accuracy Designators.

Table 3. 6-18 Aircraft - GPS accuracy requirement

Aircraft Accuracy Designation Letter	θ_n (degrees)	a_0 (meters)	a_1 (meters)	θ_0 (degrees)
A	≥ 5	0.16	0.23	19.6
B	≥ 5	0.074	0.18	27.7

Table 3.6-19 Aircraft - GLONASS accuracy requirement

Aircraft Accuracy Designation Letter	θ_n (degrees)	a_0 (meters)	a_1 (meters)	θ_0 (degrees)
A	≥ 5	0.3	0.76	9.5
B	≥ 5	0.7	0.22	22

Editorial Note.-The preceding table must be verified, particularly designator B, a_o.

B.3.6.8.2.2 *VHF data broadcast receiver performance*.

B.3.6.8.2.2.1 *VHF data broadcast bit error rate.* The uncorrected bit error rate shall be less than equal to 10^{-3}.

Note.-The bit error rate is expressed as the ration between the number of erroneous bits received and the total number of bits received. The uncorrected BER represents the BER without benefits of Forward Error Correction.

B.3.6.8.2.2.2 *Message error rate.* The message error rate shall less than or equal to 10^{-3}.

B.3.6.8.2.2. *VHF Data Broadcast interference immunity.* The receiving function shall not exceed the specified error rate with a minimum signal strength of [-87] dBm, and with one or more out of band signals, except for VHF FM broadcast signals, having a total interference level at the receiver input of [-33] dBm.

B.3.6.8.2.2.4 *VHF Data Broadcast co-channel signal rejection.* The aircraft receiver shall not exceed the specified error rate with a desired signal strength of -87 dBm in the presence of a co-channel signal that is 20 dB lower than the desired signal.

B.3.6.8.2.2.5 *VHF Data Broadcast adjacent channel signal rejection.* The aircraft receiver shall not exceed the specified error rate with a desired signal strength of -87 dBm in the presence of an undesired signal on the adjacent or any other assignable channel that is 30 dB higher than the desired signal.

B.3.6.8.2.2.6 *VHF Data Broadcast FM interference immunity.* The receiving function shall not exceed the specified error rate with a minimum signal strength of minus 87 dBm, in the presence of interference from one VHF FM broadcast signal having a level at the receiver input in compliance with the following table:

Frequency (Mhz)	Maximum level of unwanted siganl at receiver input
88-102	+15 dBm
104	+10 dBm
106	+5 dBm
107.9	-10 dBm

Note .-The relationship is linear between adjacent points designated by the above frequencies."

B.3.6.7.2.2.7 *VHF Data broadcast FM intermodulation immunity*. The receiving function shall not exceed the specified error rate with a minimum signal strength of minus 87 dBm, in the presence of interference from third order intermodulation products of two VHF FM broadcast signals.

B.3.6.8.3 *Functional requirements*.

B.3.6.8.3.1 *Use of GBAS integrity parameters*. The aircraft segment shall verify that the geometry dependent integrity risk is less than 1-5x10-8/ approach by comparing vertical and lateral protection levels to the vertical and lateral alert limits. (B.3.6.7.1.2.1) The aircraft segment shall compute the vertical and lateral protection levels using the GBAS broadcast σ_{pr_gnd} and B parameters (reference section B.3.5.3.3.4).

B.3.6.8.3.2 *Use of satellite ephemeris data*. In calculating the pseudorange to a satellite, the aircraft segment shall use the satellite broadcast ephemeris data, which matches the GBAS ground segment broadcast IOD.

B.3.6.8.3.3 *Channel number*. The number of channels shall be 20 000. Channel N shall have an integer value from 20 000 to 39 999. The data broadcast frequency F (MHz) and Reference Path Data Selector (RPDS) shall be defined as follows:

F(MHz)=108.0+((N-20000)mod 411)x0.025
RPDS = ((N-20000) div 411)

where: x mod y = x-ky, with k equal to the integer part of the quotient x/y
x div y = k, the integer part of the quotient x/y

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13.9 DRAFT EUROCAE GBAS MASPS

ANNEX X7

DRAFT EUROCAE GBAS MASPS

DRAFT

- EUROCAE -

THE EUROPEAN ORGANISATION FOR CIVIL AVIATION EQUIPMENT

ORGANISATION EUROPEENNE POUR L'EQUIPEMENT DE L'AVIATION CIVILE

MINIMUM AVIATION SYSTEM PERFORMANCE SPECIFICATION FOR A GLOBAL NAVIGATION SATELLITE SYSTEM GROUND BASED AUGMENTATION SYSTEM TO SUPPORT Cat I OPERATIONS

EUROMASPS 17
November 1998

EUROMASPS 17
Novembre 1998

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FOREWORD

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1. INTRODUCTION

1.1 Purpose and scope

This document contains Minimum Aviation System Performance Specification (MASPS) for a Ground Based Augmentation System (GBAS), as part of the Global Navigation Satellite System (GNSS), to support Cat I precision approaches and landing, with a growth capability to support Cat II / III operations.

The purpose of this MASPS is to define the system performance requirements and also to allocate the system performance requirements to the Minimum Operational Performance Specifications (MOPS) of the two major sub-systems.

To ease the introduction of GBAS, the operational concept uses pilot and auto-pilot interfaces, already approved for ILS operation, thereby minimising the impact at the cockpit level. Furthermore, ATC procedures for GBAS will be as close as possible to those of ILS.

Primary performance parameters are accuracy, integrity, availability, and continuity. These parameters are specified at system level and then allocated to the major sub-systems.

Functional specifications are used where possible so that implementers may have flexibility in developing the GBAS equipment.

Chapter 2 of this document provides system information and assumptions needed to understand the rationale for equipment characteristics and requirements stated in the remaining sections. It describes typical equipment applications and operational goals and forms the basis of the specifications in Chapter 3.

Chapter 3 contains the minimum system performance specifications for the complete system and for each sub-system that is a required element of the system. These standards specify the required performance under the standard environmental conditions.

Appendices A to G precise the broadcast message formats, the allocations of accuracy, continuity and integrity, the integrity Alert system latency, and the VHF and the C-Band implementations of the broadcast system.

Appendices A, F and G refer to the signal transmitted by the ground station and are normative:

- Appendix A specifies the broadcast message format
- Appendices F and G describe the VHF and C Band implementations of the broadcast system.

When the GBAS signal in space is specified by ICAO SARPS, these appendices will be superseded by the relevant ICAO documents.

Appendices B through E are informative and contain rationale for the requirements and allocations given in Section 3 on, respectively, accuracy, continuity, integrity and the integrity Alert system latency and availability.

1.2

Definitions, Abbreviation and References

1.2.1 Definitions:

Ed. Note: RTCA-Definitions in Italics, *definition should not be repeated here if they are in the main body of the text (e.g. availability). Superfluous items will be possibly removed at the end of the development of the MASPS*

Alert: An indication provided to other aircraft systems or annunciation to the pilot to identify that an operating parameter of a navigation system is out of tolerance.

Alert Limit: For a given parameter measurement, the error tolerance not to be exceeded without issuing an alert.

Altitude: The vertical distance of a level, point or object considered as a point, measured from mean sea level

Baud: A unit of signalling rate equal 1 bit/s in a first order transmission system.

Cyclic Redundancy Check (CRC): A very powerful form of parity check. The CRC algorithm associates a sequence of CRC code bits with a data block to preserve its integrity during storage and transmission operations.

Datum Crossing Height (DCH): The relative height at which the Final Approach Segment passes over the Runway Datum Point.

Datum Crossing Point (DCP): The point on the Final Approach Segment directly above the Runway Datum Point

Decision Altitude/Height (DA/H): A specified altitude or height in the precision approach at which a missed approach must be initiated if the required visual reference to continue the approach has not been established. Decision altitude (DA) is referenced to mean sea level, whereas decision height (DH) is referenced to the threshold elevation.

Differential Phase Shift Keying: A modulation technique in which information is transmitted by means of defined phase shifts of carrier. A binary « 0 » is represented by 0° phase shift and binary « 1 » by a 180° phase shift.

Error budget: A set of error allowances, partitioned to indicate the proportion of the total system error which will be permitted for each signal degradation factor.

Executive monitor: Equipment that assures that erroneous guidance or data are not transmitted for longer time periods than are operationally acceptable.

Fault-Free: An operating condition of a given subsystem for which all functions are performed in a normal manner.

Final Approach Path: The prescribed straight three-dimensional path in space to be flown on final approach. For GPS/GBAS, this path is defined in the FAS Path Data by the Runway Datum Point (RDP), the Datum Crossing Height (DCH), the Flight Path Alignment Point (FPAP), and the Glide Path Angle.

Flight Path Alignment Point (FPAP): A surveyed position used in conjunction with the Runway Datum Point to define the along track direction for the Final Approach Segment. The FPAP is specified in terms of (latitude, longitude), with height equal to the WGS-84 height of the RDP. It is also used by the aircraft to scale its deviation outputs.

Functional Requirement: A requirement other than those directly addressing one of the system performance parameters of accuracy, integrity, continuity, availability or coverage.

Glide Path Intercept Point: The point where the final approach path intersects the local level plane.

Lateral Deviation Reference Point (LDRP): A point beyond the FPAP along the procedure centreline used to compute lateral deviation in the aircraft GBAS receiver,

Local Level Plane: The plane containing the Runway Datum Point (RDP), tangential to the WGS-84 ellipsoid at the RDP.

Misleading Information: Any data which is output to other equipment or displayed to the pilot that has a navigation system error larger than the current protection level (LPL/VPL).

Navigation System Error (NSE): Error that results from the residual composite errors from both the ground subsystem and aircraft receiver after correcting the ranging source used to calculate deviations.

Performance Requirement: A requirement directly addressing one of the system performance parameters of accuracy, integrity, continuity, availability or coverage.

Protection Level: The statistical error value which bounds the actual error (NSE in particular) with a specified confidence.

Pseudolite: A ground-based GNSS augmentation which provides, at GNSS satellite signal-in-space frequencies, an additional navigation ranging signal.

Reference Receiver: A GNSS receiver incorporated into the GBAS ground subsystem, used to generate pseudorange correction measurements.

Runway Datum Point: A surveyed position on the ground over which the Final Approach Segment passes at a relative height specified by the Datum Crossing Height.

Signal-in-Space (SIS): The aggregate of guidance signals arriving at the antennas of an aircraft. The GPS/GBAS SIS is comprised of the satellite signals and all signals emanating from the GBAS ground subsystem, including the VDB and (optionally) the APL signals. (?APL?)

1.2.2 Abbreviations

A/C : Aircraft
APL : Airport Pseudolite
ATC : Air Traffic Control
CAT : Category (of precision approach operation)
COS : Continuity Of Service
CRC : Cyclic Redundancy Check
CW : Continuous Wave
DA/H : Decision Altitude/Height
DCH : Datum Crossing Height
DCP : Datum Crossing Point
DGNSS : Differential GNSS
DGPS : Differential GPS
DH : Decision Height
DPSK : Differential Phase Shift Keying
D8PSK : Differential 8 Phases Shift Keying
ERP : Effected Radiated Power
FAR : Federal Aviation Regulations (United States)
FAS : Final Approach Segment
FPAP : Flight Path Alignment Point
FTE : Flight Technical Error
GBAS : Ground Based Augmentation System
GLONASS : Global (Orbiting) Navigation Satellite System
GLS : GNSS Landing System
gnd : Ground
GNSS : Global Navigation Satellite System

GP *: Glide Path*
GPA *: Glide Path Angle*
GPI *: Glide Path Intercept*
GPIP *: Glide Path Intercept Point*
GPS *: Global Positioning System*
GS *: Geostationnary satellite*
HAT : Height Above Threshold
HIRF : *High Intensity Radiation Field*
HMI : *Hazardously Misleading Information*
ICAO : *International Civil Aviation Organization*
ICD : *Interface Control Document*
ILS : Instrument Landing System
IOD : *Issue of Data*
JAR *: Joint Aircraft Regulation*
LAAS : *Local Area Augmentation System*
LAL *: Lateral Alert Limit*
LOC : *Localizer*
LPL *: Lateral Protection Level*
MASPS (RTCA) : *Minimum Aviation System Performance Standards*
MLS : *Microwave Landing System*
MOPS : *Minimum Operational Performance Standards*
MTBO : Mean Time Between outage
NSE : Navigation System Error
PR : *Pseudorange*
PRC : *Pseudorange Correction*
PT : *Performance Type*
PVT : *Position, Velocity, Time*
RDCP : *Runway Datum Crossing Point*
RDP : *Runway Datum Point*
RF : Radio Frequency
RMS : *Root Mean Square*
RNAV : Area Navigation
RNP : *Required Navigation Performance*
RPDS : *Reference Path Data Selector*
RRC : *Range Rate Correction*
RSS : *Root Sum of Squares*
SBAS : Space Based Augmentation System
SIS : *Signal in Space*
SSID : *Station Slot Identifier*
TCH : Threshold Crossing Height
TCP : Threshold Crossing Point
TCWP : Threshold Crossing Way Point
TDMA : *Time Division Multiple Access*
TDP : Touch Down Point
UTC : *Universal Coordinated Time*
VAL : *Vertical Alert Limit*
VDB : VHF Data Broadcast
VHF : *Very High Frequency*
VOR : *VHF Omnidirectional Range*
VPL : *Vertical Protection Level*
WAAS : *Wide Area Augmentation System*
WGS-84 : World Geodetic System 1984

1.2.3 References

ICAO Standards And Recommended Practices (SARPS) Annex 10 - Aeronautical Telecommunications - Volume July 1996

EUROCAE ED-72A - MOPS for Airborne GPS Receiving Equipment Used for Supplemental Means of Navigation - April 1997

EUROCAE ED-79 - Certification Consideration for Highly-integrated or Complex Aircraft Systems - November 1996

EUROCAE ED-88 - MOPS for Multimode Receiver Including ILS, MLS and GPS Used for Supplemental Means of Navigation - 1997

U.S. Department of Defense, ICD-GPS-200 GPS Interface Control Document, GPS Standard Positioning Service (SPS) Signal Specification, June 2, 1995

RTCA, DO-217, Minimum Aviation System Performance Standards for DGNSS Instrument Approach System: Special Category I (SCAT-I)

ICAO, WGS-84 (???)

GLONASS ICD, October 4, 1995

Federal Aviation Administration, Advisory Circular AC 20-57A

Federal Aviation Administration, Advisory Circular AC 120-28()

Federal Aviation Administration, Advisory Circular AC 120-29()

Federal Aviation Administration, Title 14 of the Code of Federal Air Regulations (14 CFR) § 23 and § 25

Federal Aviation Administration, LAAS Operational Requirements Document

Joint Aviation Authority, JAR 13.09

International Civil Aviation Organization, Doc 8071, Manual on Testing of Radionavigation Aids, Volume 2 (ILS)

International Civil Aviation Organization, Required Navigation Performance for Approach, Landing and Departure Operations (Draft)

ED-47B, Minimum Operational Performance Specification for Airborne ILS Glide Path Receiving Equipment, September 1995

RTCA, DO-195, Minimum Operational Performance Standards for Airborne ILS Localizer Receiving Equipment, Setember 1995

2. OVERALL SYSTEM

The GNSS is a world-wide satellite based position, velocity and time determination system. It includes one or more satellite constellations, receivers and system integrity monitoring. It also includes augmentation systems to enable, where necessary, the required navigation performance for the desired operation.

The Ground Based Augmentation System (GBAS) is one such augmentation system and is intended primarily to support precision approach operations. It consists of a ground subsystem and an aircraft subsystem. One ground subsystem can support all the aircraft subsystems within its service volume. The ground subsystem provides the aircraft with approach path data, corrections and integrity information for each satellite in view. The corrections enable the aircraft to determine its position relative to the approach path more accurately.

The GBAS Signal in Space is defined to be only the data broadcast from the ground to the aircraft subsystem. The Satellite Signals in Space are part of the basic GNSS satellite constellations. The phrase "Signals in Space" alone is used to described all the transmissions together.

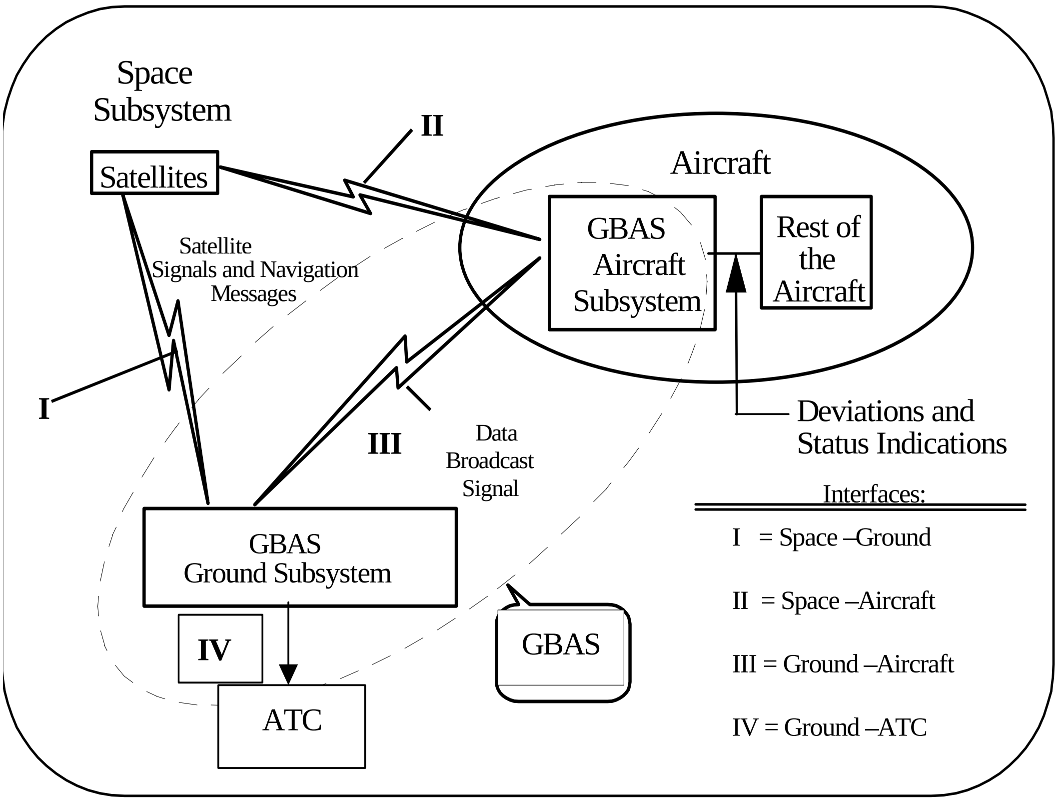


Figure 2.4-1. High Level Representation of GBAS

In the time frame of initial GBAS implementation, it is anticipated that GPS and GLONASS will be the only GNSS constellations declared operational for civil use. Additional ranging signals from geostationary satellites are also anticipated to be available in the future. The use of constellations additional to GPS and GLONASS for GBAS instrument approach operations should be in conformance with both this document and pertinent sections of the EUROCAE [WG 28/2] MOPS and RTCA [SC-159] MOPS.

The ground subsystem stores data, related to the serviced runway end(s), in the form of Final Approach Segment (**FAS**) path construction data blocks. It broadcasts this data regularly for reception by approaching aircraft.

The ground subsystem uses at least 2 reference receivers. They calculate pseudoranges for all satellites within view and the ground subsystem broadcasts **differential corrections** for them based on its own surveyed installation position in order that aircraft subsystems use it to correct their own measurement according to the differential principle. This principle requires that ground and aircraft subsystems use exactly the same ephemeris and satellite clock corrections. Moreover, since the differential principle removes all the ranging errors that are common to ground and aircraft subsystems, ionospheric, tropospheric or SBAS corrections are not applied by the two subsystems.

The aircraft subsystem then corrects its own pseudorange measurements for each satellite with the differential correction data received from the ground subsystem. The corrected pseudorange measurements are then used to more accurately determine the aircraft's position and velocity.

The **GBAS integrity concept** requires the aircraft subsystem to assess the « geometry dependent integrity risk » which is the risk integrity due to:

- errors corresponding to the normal accuracy of the system,
- the failure of one of the ground subsystem reference receivers,

taking into account the geometry of the satellites used by the aircraft subsystem. In order to do that, the ground subsystem broadcast specific integrity data to the aircraft subsystem for each pseudorange corrections (cf. Appendix D).

In the same manner the aircraft subsystem predicts the « geometry dependent loss of **continuity risk** » which is loss of continuity stemming from failure to meet the previous integrity assessment. In order to do that, the ground subsystem broadcasts specific continuity data to the aircraft subsystem (cf. Appendix C).

The aircraft subsystem uses specific integrity and continuity received data to check the « geometry dependent integrity risk » and the « geometry dependent loss of continuity risk ».

After selection of the desired FAS by the crew, the aircraft subsystem uses the differentially-corrected aircraft position to supply navigation guidance signals:

The GBAS aircraft subsystem specified in this MASPS is intended to provide ILS look-alike signals to the aircraft.

2.1 Ground Subsystem

The ground subsystem consists of two or more reference receivers and their respective geographically separated antennas, a data broadcast transmitter and monitor system and ground processing functions. These processing functions are: signals-in-space receive and decode, carrier smoothed code and differential correction calculation, integrity monitoring, performance categorisation, and data broadcast processing and monitoring.

Time-tagged differential correction information is generated for each satellite. Satellite integrity data are also elaborated. They are obtained by processing the received satellites' signals by reference to the surveyed and stored antenna co-ordinates in the WGS-84 co-ordinate system.

The GBAS ground subsystem stores FAS path construction data. It consists of Path Points describing approaches for each related runway. They are referenced to the WGS-84 co-ordinate system.

Data are formatted into a standard message formats at the link layer for broadcast (only levels 1 and 2 of the Open System Interconnection model are used under the GBAS message.)

The data broadcast may use either the VHF band or C Band aeronautical radionavigation frequencies. A detailed specification is given in chapter 3. and in appendices A, F and G.

The ground subsystem includes an integrity monitoring function. Indication of a loss of the required GBAS signal in space integrity level (except the « geometry dependent integrity risk ») will result in warnings being issued and if severe the shutdown of the broadcast.

The integrity monitoring processing function consists of five sub-functions: signal quality monitoring, measurement quality monitoring, data quality monitoring, multiple reference consistency check, and pseudorange noise standard deviation (sigma) monitor.

The ground subsystem provides its operational status to the appropriate air traffic service authorities.

2.2 Aircraft Subsystem

The primary functions of the aircraft subsystem are to receive and decode the GNSS satellite and GBAS signals, determine the aircraft position and its integrity, and to provide guidance signals.

The aircraft subsystem receives initially the desired approach label selected by the crew or transferred to it by the avionics. It uses the selected approach label to set the data broadcast frequency and the Reference Path Selector parameter. The approach label defines the runway end to be used according to the published instrument approach procedure. The aircraft subsystem tunes to the desired data broadcast VHF or C band channel and time slot.

The aircraft subsystem receives the data broadcast signal on the desired data broadcast channel and time slot. It extracts the satellite corrections, satellite integrity information and the FAS path construction data contained in 4 different message types.

From the various FAS path construction data blocks received from the ground subsystem, the aircraft subsystem extracts the one having the matching Reference Path Selector.

The aircraft subsystem receives the GNSS satellite signals in space and measures pseudoranges for each GNSS satellite. It applies the corrections received from the ground subsystem to the appropriate satellite measurements. From these it is able to calculate position, velocity and time.

The aircraft subsystem uses the specific integrity and continuity data carried in the data broadcast messages to assess the geometry dependent integrity and predict the geometry dependent continuity of the position solution derived from the corrected pseudoranges.

The GBAS aircraft subsystem then generates, with respect to the selected FAS, the following guidance signals:

- Horizontal Deviation from glidepath
- Vertical Deviation from glideslope
- Distance to the Runway Datum Point of the chosen FAS
- Possible integrity alert signals.

2.3 System Application

The GBAS is intended to be applied to the landing function and to provide an alternative precision approach system to ILS and MLS. While not required to do so by this MASPS, the aircraft subsystem may also output the aircraft's corrected position. This may be used by appropriate avionics to:

- Provide missed approach guidance,
- Offer enhanced RNAV capability,
- Provide surface movement guidance to the crew.

2.4 External Interfaces

The input interfaces for both ground and aircraft subsystems include the GNSS signals in space.

2.4.1 Aircraft Subsystem Input and Output Signals

The aircraft subsystem has similar external interfaces to those of ILS. It has inputs from the aircraft in the form of the channel select and annunciation functions and power supply.

The aircraft subsystem outputs guidance deviations, integrity and annunciation data to the aircraft in a similar fashion to that of an ILS receiver.

2.4.2 Ground Subsystem Input and Output Signals

The ground subsystem is provided with the co-ordinates of its GNSS antennas and the FAS data in secure form by the Air Traffic Services authority.

Ground equipment status shall be output for remote display to the appropriate air traffic services authority. Remote control inputs from the maintenance authority. It obtains a local power supply and has its own emergency power source.

2.5 Internal Interfaces

The GBAS has an internal interface between the ground and aircraft subsystems in the form of the data broadcast.

2.6 GBAS Classification

GBAS provides a level of service defined by the Performance Type. The Performance Type includes a requirement for accuracy, integrity and continuity. Performance Type 1 is intended to support Category I approach and landing operations.

NOTE: Additional Performance Types will be defined in the future to support Cat II/III approach, landing and guided takeoff operations. In order to guarantee interoperability and enable efficient spectrum utilisation, the radio frequency and data broadcast characteristics, and frame and message structure, will be the same for all performance types. Some messages may not be required for certain performance categories.

The GBAS ground subsystem shall transmit a Ground Continuity and Integrity Designator (GCID) parameter in its message set that will specify the highest Performance Type service that can be supported by the ground subsystem.

NOTE (1) A GCID of 1 indicates that the ground subsystem meets the allocated requirements for continuity and integrity associated with Performance Type 1.

NOTE (2) The ability of the ground subsystem to meet the continuity and integrity requirements allocated from the Signal In Space Level performance requirements defined by a Performance Type depend on the redundancy of elements in the ground station as well as the basic reliability of the elements. Hence, GCID is a function of the ground subsystem design and the current state of the ground subsystem.

The GBAS ground subsystem shall transmit a Ground Accuracy Designator (GAD). The GAD shall indicate the level of signal-in-space accuracy performance provided by the combination of particular GBAS Ground Subsystem and the space segment.

3. SYSTEM FUNCTIONAL PERFORMANCE

The GBAS shall meet the following functional requirements during normal operation.

These requirements include the concept of a fault-free aircraft subsystem as a means of combining the signals in space broadcast by the space subsystem and the ground subsystem. This aircraft subsystem is defined to have nominal accuracy performance and, because it is assumed to have no failure, it does not contribute to the GBAS signal in space integrity and continuity performance.

Thus, concerning the outputs of the aircraft subsystem:

- accuracy is related to the total system (using an onboard receiver with nominal accuracy performances).
- integrity and continuity are only related to the signal in space.

Note: GBAS accuracy is primarily limited by bias that stems from poor constellation geometry and multipath. This bias is detectable and therefore results in an availability limitation on the system. Failure to detect either this bias or other possible errors constitutes an integrity risk. Thus accuracy is not a critical factor for GBAS as compared to ILS or MLS.

These MASPS only apply to a GPS or GPS + GLONASS GBAS. A GLONASS alone GBAS is not considered.

In these requirements, the space subsystem is assumed to be compliant with ICAO SARPS (Annex 10).

3.1 Input and Output Signals and Data

3.1.1 Input Signals from the GNSS Space Subsystem

The GBAS is dependent on the correct operation of the GNSS space subsystem, initially GPS and GLONASS. These systems are considered to be operating as specified by ICAO Documents. (Ref: Annex 10 draft SARPS) The GBAS must use the GNSS signals correctly both within the ground station and its integrity monitor and within the aircraft subsystem.

SBAS satellites can be used as supplementary ranging sources by GBAS, provided that a suitable means shall prevent GBAS from using the differential corrections transmitted by SBAS.

GPS sensors shall be designed to operate with a signal in space that meets the requirements of the GPS Standard Positioning Service Signal Specification, 2nd edition, June 2, 1995 as issued by the Department of Defense of the United States of America. GLONASS sensors shall be designed to operate with a signal in space that meets the GLONASS ICD requirements.

Ionospheric and tropospheric correction models, defined in the GPS or GLONASS ICDs, shall not be used by GBAS.

3.1.2 Ground Equipment Input and Output Signals

Input Signals

In addition to the GNSS satellite signal in space and a power supply the ground station shall be capable of remote monitoring and control (On, Off, Warning Light).

Output Signals

The following output signals are required:

a) VHF or C-Band data broadcast signal.

b) Status information for use by the Air Traffic service provider.

3.1.2 Aircraft Equipment Input and Output Signals

Input Signals

_

The following input signals are required to enable the aircraft equipment to function correctly:

a) Selection of the VHF data broadcast frequency. This may be manually selected by the pilot or automatically selected by selection of the approach procedure.

b) Selection of the approach procedure (i.e. desired flight path).

c) Ranging signals from a GNSS antenna.

d) Data broadcast signals from a VHF or C-Band antenna.

e) Antenna offset information (if required).

Output Signals

The following output signals are required to provide deviations and warnings for presentation to the pilot or for processing by other aircraft systems:

a) ILS look-alike and rectilinear lateral and vertical deviations for driving a display. Optional outputs for autopilot coupling may also be provided.

b) Warning indications for a loss of navigation capability, and other failure modes.

c) An indication of the frequency and approach path selected.

d) Navigation facility identification.

e) Mode indication (where multiple operational modes are supported, e.g. multi-mode receivers).

f) Protection Level. (Optional.)

g) Position Velocity and Time (PVT). These are optional outputs to support non-landing applications, e.g. surface movement guidance.

h) Distance to Threshold

3.2 Accuracy

GBAS System Accuracy is defined as the degree of conformance between an estimated or measured value at a given time and its true value.

The NSE requirement is based upon ILS specifications to minimise the validation and aircraft certification impact. See appendix B for rationale on accuracy requirement and measurement methodology

3.2.1 System Lateral Accuracy

The GBAS lateral accuracy is defined in terms of lateral Navigation System Error (NSE).

The lateral NSE is the difference between the measured horizontal displacement from the final approach path and the actual one.

The probability that the lateral NSE value is within the limits shown below shall be at least 95% per approach. See Appendix B.

The lateral accuracy limits are given as a function of the horizontal distance (D) of aircraft position from the RDP as translated along the final approach path, for a 200ft decision Height:

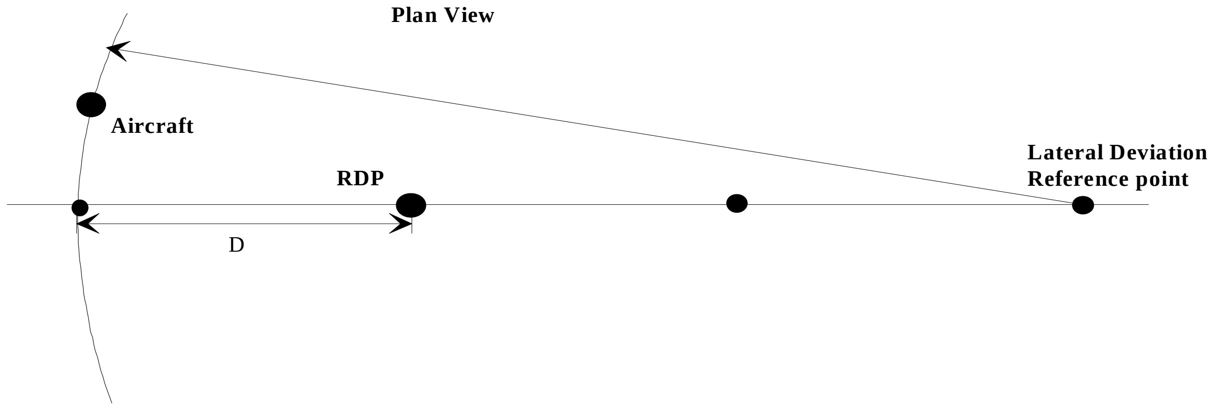
Between 291 m. and 873 m. from RDP, a constant value of 16 m. metres.

Between 873 m. and 7212 m. from RDP, a value linearly varying from 16 m. to 27.2 metres.

Over 7212 m. from RDP, in the limit of coverage a constant value of 27.2 metres.

NOTE (1) The aim of limiting 95% accuracy is to model the global distribution of positioning errors, whereas the integrity requirement limits the risk of exceeding excessive error values which could lead to a Hazardously Misleading Information (HMI).

NOTE (2) The accuracy requirement must be satisfied for the worst-case geometry. See Appendix B.



3.2.2 System Vertical Accuracy

The GBAS vertical accuracy is defined in terms of vertical Navigation System Error (NSE).

The vertical NSE is the difference between the measured vertical displacement from the final approach path and the actual one.

The probability that the vertical NSE value is within the limits shown below shall be at least 95% per approach. See Appendix B.

The vertical accuracy limits are given as a function of the height (H) above RDP of aircraft position translated onto the final approach path, for a 200ft decision Height:

Between 100 feet HAT and 200 feet HAT a constant value of 4. metres.

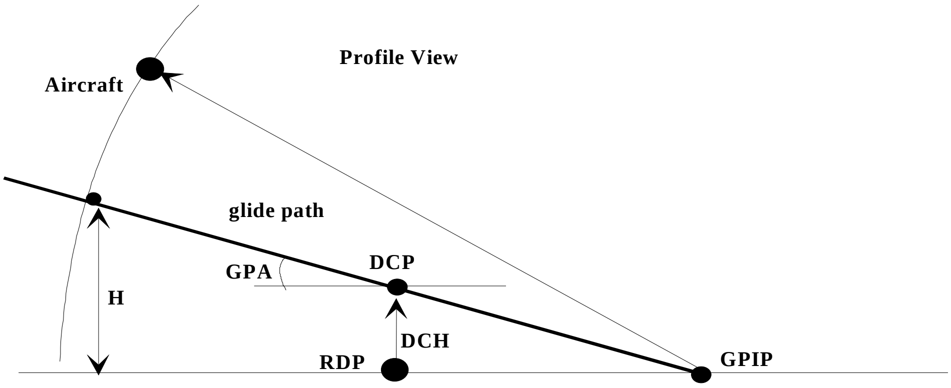
Between 200 feet and 1290 ft HAT , a value linearly varying from 4. m to 16.7 metres

Above 1290 ft HAT, in the limit of coverage, a constant value of 16.7 metres.

NOTE (1) The aim of limiting 95% accuracy is to model the global distribution of positioning errors, whereas the integrity requirement limits the risk of exceeding excessive error values which could lead to a Hazardously Misleading Information (HMI).

NOTE (2) The accuracy requirement must be satisfied for the worst-case geometry. See

Appendix B.



3.2.3 Ground Subsystem Accuracy

3.2.3.1 Signal-In-Space Accuracy for Measurements on GPS and GLONASS Satellites

The accuracy of a signal-in-space shall be classified according to the Ground Accuracy Designator (GAD). The GAD shall indicate the level of signal-in-space accuracy performance provided by the combination of particular GBAS ground subsystem and the space segment. The signal-in-space accuracy performance shall be specified in terms of the contribution to the error in the corrected pseudorange. Every ground subsystem shall meet the requirements for the GAD used to classify the ground subsystem.

Note.- When several levels of performance are defined. Each level of performance has an associated Ground Accuracy Designator (GAD)

The GAD shall consist of a letter indicating the measurement accuracy (independent of the number of reference receivers) and a number indicating the number of reference receivers included in the ground subsystem.

The RMS of the total signal-in-space contribution to the error as a function of satellite elevation angle shall be:

$$RMS_{pr\_gnd,GNSS}(\theta_n) \leq \sqrt{\frac{\left(a_o + a_1 e^{-\theta_n/\theta_0}\right)^2}{M} + (a_2)^2 + \left(\frac{a_3}{\sin(\theta_n)}\right)^2}$$

Where

M ≡ number of ground subsystem reference receivers as indicated in the GAD

$n \equiv n^{th}$ ranging source

$\theta_n \equiv$ elevation angle for the n^{th} ranging source

a_0, a_1, a_2, a_3, and θ_0 parameters are defined in the table below for each of the defined Ground Accuracy Designators.

Table GBAS - SIS Accuracy Requirement

Ground Accuracy Designation Letter	θ_n (degree)	a_0 (meters)	a_1 (meters)	θ_0 (degree)	a_2 (meters)	a_3 (meters)
A	**≥5**	**0.5**	**1.65**	**14.3**	**0.08**	**0.03**
B	**≥5**	**0.16**	**1.07**	**15.5**	**0.08**	**0.03**
C	**>35**	**0.15**	**0.84**	**15.5**	**0.04**	**0.01**
	5 to 35	**0.24**	**0**	**-**	**0.04**	**0.01**

3.2.3.2 Signal-In-Space Accuracy for Measurements on SBAS Satellites

Note.- SBAS employ geostationary (GEO) satellites to relay differential correction messages to users on the L1 frequency. The GEO satellites also transmit C/A-code ranging signals to augment the GPS constellation. These satellites may also be utilized as ranging sources by GBAS.

Ed note : the figures in following sections have to be confirmed

[First generation SBAS

For the first generation SBAS satellites, the L1 signal bandwidth is limited to 2.2 MHz, which can degrade the ranging accuracy relative to that which can be obtained from the GPS satellites. The RMS of the total signal-in-space contribution to the corrected SBAS pseudorange accuracy shall be:

$$RMS_{pr\_gnd,GEO}(\theta_n) \leq 1.91*(RMS_{pr\_gnd,GPS}(\theta_n)) + 0.15 \text{ meters}$$

Where $RMS_{pr\_gnd,GPS}(\theta_n)$ is derived in Section 3.2.3.1 for the corresponding ground accuracy designation.

Note.- The factor of 1.91 is computed from the square root of the GPS C/A-code bandwidth assumed to be utilized by the reference receivers (8 MHz) divided by the 2.2 MHz bandwidth provided by the Inmarsat-3 GEO satellites. The 0.15 meters is due to code carrier divergence associated with transponder payload.]

3.2.4 Aircraft Subsystem Accuracy

3.2.4.1 Aircraft Subsystem Accuracy for Measurements on GPS and GLONASS Satellites

The RMS of the aircraft receiver contribution to the error as a function of satellite elevation angle shall be:

$$RMS_{pr\_air,GNSS}(\theta_n) \leq a_o + a_1 e^{-\theta_n/\theta_0}$$

Where

$n \equiv n^{th}$ ranging source

$\theta_n \equiv$ elevation angle for the n^{th} ranging source

a_0, a_1, and θ_0 parameters are defined in the table below for each of the defined Aircraft Accuracy Designators.

Table Aircraft - GPS Accuracy Requirement

Constellation	θ_n (degree)	a_0 (meters)	a_1 (meters)	θ_0 (degree)
GPS	>5	0.16	0.23	19.6
GLONASS	>5	0.3	0.76	9.5

3.2.4.2 Aircraft Subsystem Accuracy for Measurements of SBAS satellites

The RMS of the total steady-state airborne error contribution to the corrected SBAS pseudorange accuracy shall be:

$$RMS_{pr\_air,GEO} \le RMS_{pr\_air,GPS}(\theta_i) + 0.15 \text{ meters} \qquad \text{Eq 0-1}$$

where $RMS_{pr\_air,GPS}(\theta_i)$ is computed from Section above, for Airborne Accuracy Designation A.

3.3 Continuity Of Service

3.3.1 System level:

The GBAS continuity of service risk is defined as the probability, that within any 15 second period, a Cat I approach cannot be continued due to an unscheduled loss of lateral or vertical guidance or warning annunciation onboard the aircraft.

The total GBAS system Continuity of Service shall be such that aircraft comply with Airworthiness and Operational requirements.

Note: Airworthiness requirements require that system loss of function occurrence rate is less than a level depending upon the severity of the effects at the aircraft level of the malfunction. It is up to the certification applicant to determine what are the effects with respect with the aircraft and systems definition as well as aircraft operations.

The total continuity of service of the navigation system is not quantified, because, in order to ease certification issues, airborne requirements are adopted from existing airworthiness requirements and cannot be easily compared to ILS-like Signal in Space continuity of service requirements.

3.3.2 Signal In Space Continuity Of Service

The Signal in Space continuity of service is the probability that a fault-free aircraft subsystem provides valid outputs during any 15s period of an approach, assuming that outputs were valid at the start of the period. Outputs are considered as valid if the NSE is lower than Alert limits and if there is no warning. Below 500 feet HAT, the fault-free receiver's failure to receiver differential correction information for longer than 3.5 seconds shall be considered as a loss of Signal in Space continuity.

The Signal In Space Continuity of Service risk shall be 8×10^{-6} during any 15s period of an approach. This includes 2.5×10^{-6} / 15s period allocated to the geometry independent Continuity of Service risk for the ground subsystem with a fault-free receiver. The allocation to the geometry dependent Continuity of Service risk is 1×10^{-6} / 15s period.

Refer to Appendix C.

Note: When a ground station supports more than one runway in simultaneous use, a lower continuity risk than 2.5 x 10^{-6} may be required from the ground station. This is an operational consideration specific to each airport.

3.3.3 Aircraft Subsystem

The aircraft subsystem shall guaranty that the risk of loss of continuity, due to signal in space geometry dependent causes, is less than 10^{-6} during any 15 s in the approach.

Taking into account the guarantied geometry independent part of the Signal in Space Continuity of Service and the data sent by ground subsystem, the GBAS aircraft subsystem shall be designed to meet the Airworthiness and Operational requirements.

Note: GBAS aircraft subsystem continuity is only a component in the global system safety of a Cat I operation.

3.4 Availability

Availability is the probability that the service will be available during the time which the system is to be used for navigation. The availability can be determined as

$$A = \frac{Actual\ Operating\ Time}{Specified\ Operating\ Time}.$$

This is discussed in Appendix E of this document. No additional requirement will be made on the system related to availability. However, in order to provide the same level of performance as an ILS Cat I, GBAS availability should be 0.9975.

Note : This requirement does not take into account the problem of GBAS supporting primary and alternate destinations.

3.5 Integrity

3.5.1 System Level

The total GBAS system integrity shall be such that aircraft comply with Airworthiness requirements.

Note: Airworthiness requirements require that system malfunctions occurrence rate is less than a level depending upon the severity of the effects at the aircraft level of the malfunction. It is up to the certification applicant to determine what are the effects with respect with the aircraft and systems definition as well as aircraft operations. Generally, for Cat I operations, the effects of landing system malfunctions are considered as Hazardous/Severe-major.

Note: The total integrity of the navigation system is not quantified, because, in order to ease certification issues, aircraft requirements are adopted from existing airworthiness requirements and cannot be easily compared to ILS-like Signal in Space integrity requirements.

3.5.2 Signal In Space Integrity

The SIS integrity risk is the probability that the NSE, at the deviation output of a fault-free airborne subsystem, exceeds the Alert limits (see section 3.6) without annunciation for a period longer than the Signal in Space time-to-Alert (see section 3.7).

The allowable integrity risk value shall be less than 2 x 10^{-7} per approach. Of this, 0.5 x 10^{-7} is allocated to geometry dependent integrity risk not assessed by a ground subsystem. The remaining 1.5 x 10^{-7} is allocated to other failure sources.

Note: These remaining failures can arise from:-

- *Failures in the ground system that cause erroneous data to be broadcast (e.g. failures of the processor computing the broadcast values); or*
- *Undetected failures in the GPS space segment that affect airborne receivers and ground subsystem reference receivers differently;*
- *Undetected failures of measurements from more than one reference receiver;*
- *Undetected VDB failures; and*
- *Other undetected events that produce residual errors in the signal in space that result in misleading information (e.g., incorrect FAS, tropospheric or ionospheric anomalies).*

See Appendix D.

3.5.3 Aircraft Subsystem

The aircraft subsystem shall assess signal in space geometry dependent integrity. The value allocated to this integrity risk is 0.5 x 10^{-7} per approach.

Taking into account the guarantied Signal in Space integrity and the data sent by the ground subsystem, the GBAS aircraft subsystem shall be designed to meet the Airworthiness requirements.

Note: GBAS aircraft subsystem integrity is only a component in the global system safety of a Cat I operations.

3.6 Alert Limits

The vertical and lateral Alert limits shall be set to 5/2 of the 95% NSE accuracy requirements

3.7 Time to Alert

3.7.1 System Time To Alert

The system Time-to-Alert is the total time between the onset of a failure condition that results in an unacceptable Navigation System Error (i.e. greater than the alarm limit), and the issue of a warning to the aircraft.

This time is a never to be exceeded limit and is intended to protect the aircraft against prolonged periods of guidance outside the lateral or vertical alert limits.

The never to be exceeded total system Time-to-Alert shall be 6 seconds.

3.7.2 Signal-in-Space Time-to-Alert

For GBAS, the ground subsystem is monitoring not only itself but also the ranging sources. For satellite alert conditions, ceasing radiation of the data broadcast is typically not acceptable because the system may support multiple functions.

A failure condition that is solely due to inadequate geometry shall be detected by the aircraft subsystem. Other failure conditions within the constellation shall be detected as part of the normal operation of the ground subsystem and the broadcast messages shall be appropriately annotated.

If the data broadcast has not failed, the never to be exceeded Signal-in-Space Time-to-Alert refers to the time between the onset of the failure condition and the time that the last bit in the first message containing integrity information reflecting the failure condition is transmitted. The never to be exceeded Signal-in-Space Time-to-Alert shall be 3 seconds. The ground subsystem shall set, in message type 1, the σ_{pr_gnd} and B values appropriately to signal the failure condition. Satellites that have been marked as "do not use" for longer than 6 seconds shall be excluded from message type 1.

A failure condition within the ground subsystem shall result in the monitoring system taking action. This monitoring action shall prevent erroneous messages from being transmitted for longer than 1 second. An "empty" message type 1 shall be used to indicate this failure. (Number of measurements set to zero, no measurement blocks present.)

If the ground data broadcast monitoring function detects a failure condition in the transmission, the GBAS ground subsystem shall cease transmission within 1 second if the failure condition cannot be corrected within that second.

3.7.3 Aircraft subsystem Time-to-Alert

In normal operation of the ground and aircraft subsystems, the latter may detect an excursion of the calculated geometry dependent integrity values beyond the permitted limits. This excursion shall not last longer 6 seconds without the aircraft receiving a warning.

If the data broadcast is being received, then the time between receiving the last bit of a message containing information that implies that the required NSE cannot be achieved and the issuing of a warning to the aircraft shall not exceed 3 seconds.

If messages necessary for navigation have not been received from the data broadcast for a period longer than 5 seconds, the aircraft subsystem shall issue a warning to the aircraft.

Note:

Case 1: The ground subsystem is transmitting correct messages but they are not being received.

Case 2: The ground station has temporarily ceased transmission, its last message was good.

Case 3: The ground subsystem has detected that it was sending false data after one second has ceased transmission.

Case 4: The ground station has detected a constellation failure condition and taken three seconds. It then detects that it has a VDB failure and takes one second to cease transmission, the aircraft subsystem now has only 2 seconds left to raise an alert.

For cases 1 and 2, the aircraft could have 6 seconds of coasting time. Case 3 drives the requirement but only reduces the time left for the aircraft to receive an alert by one second. Case 4 is a dual independent failure situation effecting continuity to the order of 10^{-10}, so can be ignored.

3.8 System Interoperability

Interoperability is required between the aircraft and non-aircraft components of the navigation system. Any airborne sub-system complying with the relevant certification requirements shall operate within specification when used with any ground station complying with the EUROCAE MOPS. This level of interoperability shall be provided by the MOPS for the ground and airborne sub-systems. To ensure interoperability both ground and airborne elements must be tested and approved independently, i.e. it shall not be necessary to carry out system level tests to ensure interoperability.

3.8.1 Navigation Data Acquisition

Navigation data stands for satellite parameters (clock and ephemeris data) processed from binary words contained in satellite navigation message.

For those satellites whose signals in space are acquired, bits from satellite navigation messages shall be continuously decoded.

These bits shall be packed into binary words whose parity is checked.

Satellite navigation data shall be processed from the words corresponding to the satellite navigation message.

To ensure that satellite navigation data is not corrupted due to Bit Error Rate, the following conditions shall be met.

- Satellite navigation data shall be processed only from words that are decoded when the signal-to-noise ratio estimate of the receiver, C/N_0 remains more than 30 dB-Hz.
- Satellite navigation data shall be processed only from navigation messages for those parity passes for each word.
- Satellite navigation data shall be processed only after a second satellite navigation message is received whose navigation binary words match that of the first one.
- Navigation Message components consistency shall be verified. For satellite GPS, data shall be processed only from three subframes that matches on IODE and IODC. For GLONASS satellite, data shall be processed on four consecutive string acquired after string #1

3.8.2 Navigation data modification

For those satellites for which a satellite navigation data set has been processed, satellite navigation message shall be continuously decoded in order to detect modification of navigation data. Once a modification is detected, the receiver shall process a new navigation data set according the requirements defined previously.

Detection of modification shall concern following event.

3.8.2.1 GPS satellite

The receiver shall monitor IODE values, and shall update ephemeris and clock data based upon a detected change in one of these values

3.8.2.2 Glonass satellite

A new satellite navigation data set shall be processed from a satellite navigation message whose « tb » differs from the « tb » of the current set of navigation data used.

If satellite n is tracked, a new satellite navigation data set shall be processed from a satellite navigation message when its « unhealthy flag » Cn^A parameter in the almanac reverts from « 0 » to « 1 ». [TBC]

3.8.2.3 SBAS satellite

The receiver shall monitor IODN value (type 9 message), and shall update ephemeris and clock data based upon a detected change on this value

3.8.3 Satellite Suitability Monitoring

The suitability of each received satellite shall be determined by the monitoring of health status and validity data content.

3.8.4 « Health status » monitoring

3.8.4.1 GPS satellite

A GPS satellite shall not be suitable if :

- The health word in ephemeris indicates that the satellite is unhealthy.
- Parity check has failed on more than 5 consecutive words.
- navigation data contains all 1's or all 0's
- alert bit (bit 18 of HOW) is set to 1
- URA field indicates absence of accuracy prediction

3.8.4.2 GLONASS satellite

A GLONASS satellite shall not be suitable if :

- The health information parameter Bn in ephemeris indicates a satellite malfunction.
- Parity check has failed on more than 5 consecutive words
- The general unhealthy flag CnA relative to the satellite is « 0 » in the almanac message. In GBAS mode, the satellite shall be suitable again only when the flag has reverted to « 1 » in almanac message, and when a new ephemeris set is available. (defined by a new value of « tb » parameter).

3.8.4.3 SBAS satellite

A SBAS satellite shall not be suitable if :

- if it is indicated has not usable in Tye 6 integrity failure.
- CRC check has failed on more than 5 consecutive words.
- Loss of four consecutive SBAS message.
- URA field in message type 9 indicates that she satellite must not be used
- Reception of a type 0 message

3.8.5 « Valid navigation data set content » monitoring:

This monitoring enables to prevent from SIS failures about erroneous ephemeris data transmission.

Before use of new clock or ephemeris of satellite parameters.

- The satellite position as determined by a new ephemeris data set differs from the satellite position as determined from the latest almanac by less than 3000 [TBR] meters.
- The satellite clock bias determined by a new clock data set differs from the satellite clock bias as determined from the latest almanac by less than 10µs [TBR].
- The satellite position as determined by a new ephemeris data set differs from the satellite position as determined from the previous ephemeris data by less than 30 [TBR] meters if the satellite was acquired.

3.8.5.1 GPS satellites data suitability

- Once a navigation data set has been processed, it shall be used to compute satellite position for a maximum duration of four hours.

- A satellite whose bit 17 of word 10 of sub frame 2 should not be used for navigation solution.
- TOE of ephemeris should be at maximum 6 hours earlier and 2 hours later than current GPS time.

3.8.5.2 GLONASS satellite navigation data suitability

- Once a navigation data set has been processed, it shall be used to compute satellite position for a maximum duration of one hour.
- A GLONASS satellite whose « En » parameter is greater than 1 should not be used for navigation solution

3.9 Interference

GPS equipment shall meet performance specifications in the presence of interfering signals as shown in ED-?? of WG 28/1. (Similar to Appendix C of DO-229).

3.9.1 Interference Susceptibility

GBAS shall meet the performance requirements defined in this MASPS when operating within the interference environment defined in Appendix H. The accuracy requirements in this document assume that this environment bounds the true environment under normal conditions. If there are interference conditions present that are outside the bounds of Appendix H, the probability that GBAS provides misleading information shall be within the appropriate integrity requirement.

3.9.2 Unwanted Emissions

The GBAS ground sub-system shall meet the following unwanted emission requirements:

a) To ensure that interference is not caused to ILS, VOR and other GBAS installations the power transmitted in the first, second and subsequent 25kHz bands shall be as specified in Appendix F, paragraphs 1.7.1 and 1.7.2.

b) To ensure that interference is not caused to GBAS installations operating on the same frequency with a different time slot, emissions in unassigned time slots shall be as specified in Appendix F paragraph 1.7.4.

c) Spurious emissions shall be as specified in appropriate ITU regulations, see Appendix F, Paragraph 1.7.3.

d) Spurious emissions in the GNSS L1 band shall be such that the interference environment specified in Appendix H is met for aircraft receivers at the minimum distance from the GBAS transmitter. Additional protection may be necessary to prevent interference to the GBAS reference receivers.

In addition to the above requirements the GBAS shall comply with EEC Directive 89/336/EEC, Electro Magnetic Compatibility.

Ed. Note: Add words for the C-Band data broadcast (Ref: Appendix G)

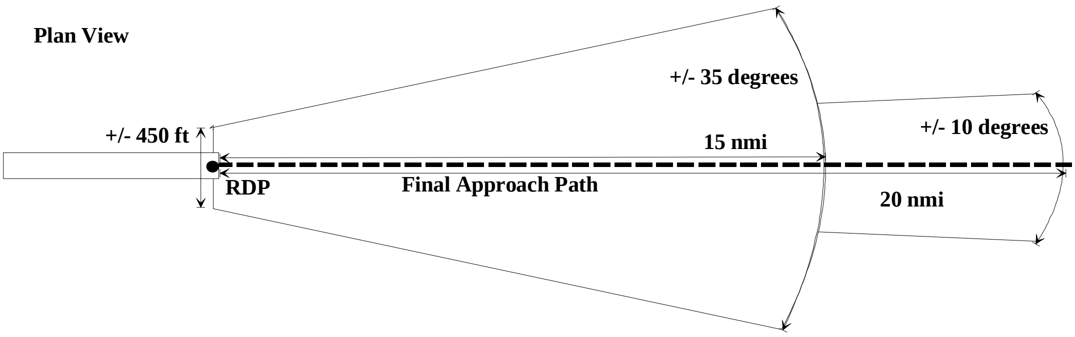
3.10 GBAS Service Volume

The service volume is defined as the region within which the system meets the accuracy, integrity and continuity requirements.

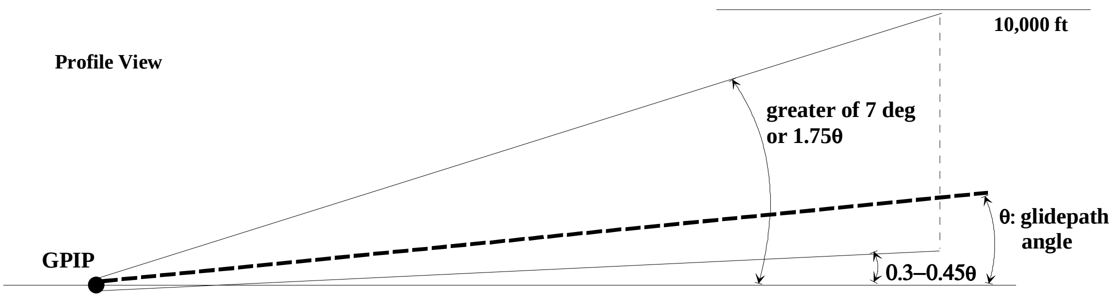
The minimum service volume to support precision approach operations in Category I conditions, depicted in Figure 1, shall be:

Laterally: beginning at 145 m (450 ft) each side of the runway datum point and projecting out ±35 degrees either side of the final approach path to 28.5 km (15 nm) and ±10 degrees either side of the final approach path to 37 km (20 nm); and

Vertically: within the lateral region, up to the maximum of 7 degrees or 1.75 promulgated glide path angle (GPA) with an origin at the GPIP, but not to exceed 6000 m (10,000 ft) HAT and down to 0.45 GPA above the horizontal or to such lower angle, down 0.30 GPA, as required, to safeguard the promulgated glide path intercept procedure.



0



1

Figure 1 Minimum Service Volume

In the case of multiple runway ends being supported by one ground subsystem, the minimum service volume for each supported runway end shall be as above.

3.11 Data Broadcast Coverage

The data broadcast coverage shall be sufficient to support the intended operation.

APPENDIX A
GBAS - Message format

18.9.98

TABLE OF CONTENTS

A. Message contents - Application layer

This section describes data content of the Application Layer for messages that support GBAS Cat I operations. The performance described in this appendix is subordinate to the requirements of the ICAO SARPS and is provided as information only.

1. A. Message Blocks

All data broadcast information shall be formatted into Message Blocks, which consist of a Message Header, a Message, and a 32-bit cyclic redundancy code (CRC). Figure A-1. displays the general construction of the Message Block.

FIGURE A-1. Format of the Message Block

Message Block	Length (bits)
Message Header	48 bits
Message	variable
Integrity Check (CRC)	32 bits

Note: The Message Header is described in section 1.2, the Messages in section 2.0 and the CRC in section 3.0.

1.2 A. Message Header.

The Message Header contains information relevant to every GBAS data transmission. It shall consist of a Message Block Identifier (MBI) and a twenty-four-bit GBAS ID that uniquely identifies the reference station. Figure A-1.2 diagrams a Message Block Header. The MBI and GBAS ID fields shall be followed by a eight-bit message type field and an eight-bit message length field.

FIGURE A-1.2. Format of the Message Header Block

Parameter	Bits
Message Block Identifier (`1010 1010’)	8
GBAS ID	24
Message Type	8
Message Length	8

Note: The GBAS ID is normally identical to the location indicator at the nearest airport. The MBI and GBAS ID fields are followed by an eight-bit message type field and an eight-bit message length field.

Note: Currently only eight of the 255 available message types have been defined, with the intent that future needs can be addressed in the remaining message types. The message length is specified in eight-bit words, <u>including</u> the six words in the message header and the four words of the CRC field. Thus messages are restricted to lengths of between 1 and 212 bytes (222 –10). See Appendix F.

<u>Message Block Identifier</u>*:* The 8-bit message block identifier (MBI) shall be given by the bit pattern: ‘1010 1010’. The MBI serves two purposes:

1) It aids a decoder in identifying the end of one message block;
2) It verifies that this message block is intended to support GBAS precision approach.

Note: This field provides a receiver with an identifier to locate quickly the beginning of a message block. It will also prevent accidental acceptance of non-GBAS messages across a shared data link.

GBAS ID: The 24-bit station identification number shall be unique and included to differentiate between broadcasting stations. It shall be a four-character field identifying the nearest airport, where each character is represented by the lower 6 bits of its ISO Alphabet #5 representation. Only capital letters and numbers shall be permitted.

Message Type: The Message Type shall be within the range 1 to 255. Message Type 0 is unused.

Message Length: The length of the Message in 8-bit bytes includes the header and the CRC field.

1.2.1 A. Test mode

When the station is operating in a test mode, the Message Block Identifier shall be set to ”1111 1111”.

Note: Individual message transmissions can be set invalid by setting the Message Block identifier to ”1111 1111” for that specific message.

2. A. Message Type Definitions.

The message types foreseen for the GBAS are:

1. GNSS Pseudorange Corrections
2. GBAS Reference Point
3. GBRS Acquisition Data (reserved)
4. Final Approach Segment
5. Satellite Availability
6. Differential Carrier Corrections (reserved)
7. Reserved (reserved for national use)
8. Reserved (reserved for experimental use)

Message types 9 to 255 are reserved for future use. Message Types 1, 2, and 4 shall be transmitted by the GBAS to support CAT I operations. Message Type 5 is optional. Message Type 0 shall not be used.

The message types are defined below. It is intended that proposed definitions of these reserved messages be co-ordinated through ICAO in subsequent years. It is also intended that these messages be assigned for common-use aviation applications only, so that they may be used by any system receiving approval for such operations.

It is an important integrity consideration that all systems shall recognise and reject any current or future messages not intended to be used by the system, e.g., simply checking the least significant bits of the message type for currently defined messages is not sufficient. The same consideration should be given to systems using primary and / or secondary sub-labels.

All parameters taking on negative values shall be in the form of 2’s complement.

2.1 A. Message Type 1 - GNSS Pseudorange Corrections

2.1.1 A. Scope

Message Type 1 shall provide the differential correction data for individual GNSS ranging sources. The message shall contain two sections: message information (time of validity, integrity parameter type, number of measurements, the measurement type and the additional message flag) and the satellite data measurement blocks.. The Integrity Parameter Type shall set the length of the measurement blocks by varying the number of B-values transmitted. The Additional Message Flag shall be used to indicate that there is a further Message Type 1 being transmitted within the same frame.

The correction data for a ranging source shall be valid only if both the ranging source IOD and the differential correction message IOD are identical and the ranging source ephemeris CRC and differential correction message ephemeris CRC are identical. The ground reference station shall continuously receive the Ephemeris data from each satellite, but shall not use the new Ephemeris data until it has been received continuously for at least two minutes. The new Ephemeris data becomes the basis for the corrections after two and before three minutes have passed.

2.1.2 A. Message rate

Message Type 1 shall be transmitted at least twice per second.

2.1.3 A. Message content

Table A.2.1.1-1 Format of Message Type 1

Data Content	***Bits Used***	***Range of Values***	***Resolution***
Modified Z-count	14	0-1200 sec	0.1 sec
Integrity Parameter Type	2		
Number of Measurements	5	0 - 31	1
Measurement Type	3		
Additional Message Flag	8	0 or 1	
Measurement Block 1			
Ranging Source ID	8	1 - 255	1
Issue of Data (IOD)	8		
Ephemeris CRC (Note 3)	16		
Pseudorange Correction (PRC)	16	±327.67 m	0.01 m
σ_{pr_gnd} (unsigned –Note 4)	8	0 - 5.08 m	0.02 m
B_1 (Note 2)	8	±6.35 m	0.05 m
B_2 (Note 2)	8	±6.35 m	0.05 m
B_3 (Note 2)	8	±6.35 m	0.05 m
B_4 (Note 2)	8	±6.35 m	0.05 m
• • •			
Measurement Block N			

Note 1 1111 1111 indicates 2550 seconds or longer
Note 2 1000 0000 indicates the measurement is not available
Note 3 GBRSs have the Ephemeris CRC set to all 0's (reserved)
Note 4 1111 1111 indicates the ranging source is invalid

Modified Z-count: The modified Z-count shall define the reference time for all the message parameters in this message (including pseudorange correction and range-rate correction) with a resolution of 0.1 seconds and an acceptable range of 20 minutes. Time shall correlate with GPS time as follows: the clock shall be reset on the hour (xx:00), twenty minutes past the hour (xx:20), and forty minutes past the hour (xx:40). The reference time shall be defined to be the time at which the pseudorange corrections for all ranging sources are valid, so that Equation A-1 accurately describes the corrected pseudorange. Higher values are not necessary because the user should already have exact knowledge of the time.

Note: GLONASS time (unlike GPS time) is not an independent continuous time scale. It is periodically corrected to integer number of seconds simultaneously with UTC corrections that are performed according to plan of BIH (Bureau International de l'Heure). These corrections are performed at 00 hours 00 minutes 00 seconds at midnight from June 30 to July 1 or from December 31 to January 1 - [GLONASS ICD, 3d edition]. Notification about these planned updates can be got from GPS navigation messages or by other means. There are plans for including such notification data into future GLONASS-M navigation message.

Integrity Parameter Type: shall define the number of 'B" values transmitted in this message as defined below:

00 - Reserved for future use
01 - GBAS shall transmit 1 'B" values (from 2 reference receivers)
10 –GBAS shall transmit 2 'B" values (from 3 reference receivers)
11 - GBAS shall transmit 3 'B" values (from 4 reference receivers)

Note: The remaining B-value will not be transmitted as the aircraft can calculate it from the others received.

Number of Measurements: This parameter shall identify the number of measurements, which are transmitted in the correction message.

Measurement Type: This parameter shall identify the type of ranging signal from which the corrections have been computed:

000 = C/A code L1
001 = C/A code L2
010 = P(Y) code L1
011 = P(Y) code L2
100 - 111 = Reserved for future measurement Type

Additional Message Flag: shall identify that an additional measurements will be included in another message type 1 within the same TDMA frame. The additional message will have the same modified Z-Count.

Ranging Source ID: This parameter shall define the identity of the satellite to which subsequent corrections are applicable. The range shall be 1-255, where 1 is specified by "0000 0001".

1. ID's 1-37 shall be reserved for the satellite IDs (PRN) consistent with the Global Positioning System (GPS).
2. ID's 38-61 shall be reserved for the satellite IDs (slot) consistent with the Global Navigation Satellite (GLONASS) - slot number plus 37.
3. ID's 62-119 shall be reserved for the satellite IDs (PRN) consistent with the future Global Navigation Satellite System (GNSS).
4. ID's 120-138 shall be reserved for the satellite IDs (PRN) consistent with the SBAS.
5. ID's 139-255 shall be reserved for GBRS IDs (PRN) consistent with the GBAS.

Issue of Data: The GNSS IOD stamp at the time of the corrections shall be included for comparison to the received satellite IOD value in the avionics. For GPS, the IOD time stamp format shall coincide with the word IOD in the data frames transmitted by the GPS satellites. For GLONASS, the IOD time stamp format shall coincide with the word Tb (7 significant bits) in the data frames transmitted by the GLONASS satellites.

Note: Use of the correction data is only recommended if the satellite IOD and the differential correction IOD are identical. The word Tb is time within the current day according to UTC(SU) time + 03 hours 00 minutes. The immediate information transmitted within the frame corresponds to Tb. The discreteness of Tb is amount to 15 minutes (sic. GLONASS ICD, 3d)

Ephemeris CRC: shall be used to validate the correctness of the data, used for the satellite position determination. A 16-bit cyclic redundancy check (CRC) shall be computed on the satellite ephemeris data set in order to ensure satellite position integrity.

The generator polynomial G(x) for the message block CRC shall be:

$$G(x) = x^{16} + x^{12} + x^{5} + 1$$

Note: Figure A. 3-2 in Section 3 shows the polynomial division circuit used to generate the message Ephemeris CRC. The Quotient is seeded with all zeros and after the 648 bits of data are transmitted the output is switched to the remainder line, and 16 zeros are used to clock the remainder out. The 16 bits of remainder is the integrity check CRC. The MSB of the remainder is the first bit out of the polynomial generator and the LSB of the CRC.

GPS Case:
The ephemeris data, which shall be applied to this 16-bit CRC circuit, is defined in the first three subframes of the GPS satellite data transmission. The CRC shall be computed on words 2 through 10 of subframes 1, 2 and 3. The CRC shall not be computed on the HOWZ, which starts each subframe or the parity bits at the end of each word.

GLONASS Case (Action NATS)

SBAS Case (action NATS)

Pseudorange Correction: shall be the correction to the ranging source pseudorange transmitted to the airborne subsystem.

The GBAS pseudoranges shall be calculated from the satellite broadcast data for each given satellite at each of the ground reference receivers. For each reference receiver, a correction for each pseudorange shall be calculated. The corrections shall be based on smoothed code pseudorange measurements for each satellite using the carrier measurement in such a manner that the steady state noise on the pseudorange measurement has a spectral density with a 3 dB bandwidth of 0.01 rad/s.

SBAS, Ionospheric and tropospheric corrections shall not be applied.

The differential pseudorange corrections that are transmitted shall be determined as the average of the corrections based on measurements from multiple ground reference receivers.

Note: The Pseudorange Correction (PRC) is added to the measured pseudorange at the time defined in the message.

Note: The Rang ... lated by the aircraft from ... ent time minus the modifi

PR$PR_{corrected}($

σ_{pr_gnd}: shall be t ... n to the error in the co ... normal distribution wit ... ground reference receiv ... with a mean of B_j [N(... ground reference receiv ... of valid measurements). ... invalid by the ground sy

B1 through B4: ... on the pseudorange co ... and the corrections obta ... by the aircraft from those received. The bit pattern "1000 0000" shall indicate that the associated GBAS reference receiver measurement was not used to compute the pseudorange correction.

The Integrity Parameter Type shall set the number of B values transmitted. When the Integrity Parameter Type is set to 1, the bit pattern "1000 0000" for the B-value shall indicate a reference receiver has failed and the system is no longer available.

Figure A 2.1-2
Illustration of Error Estimate (B) Parameters

2.2 A. Message Type 2 - GBAS Reference Point.

2.2.1

Mess ... the ground based augm ... The message shall conta ... GBAS Health, the local ... tainty, the GBAS Latitu

2.2.2

The M

2.2.3 A. Message content

Table A.2.2.1-1 Format of Message Type 2

Data Content	***Bits Used***	***Range of Values***	***Resolution***
GBAS Operating Receivers	2		
GBAS Accuracy Designator	2		
GBAS Health (Spare)	1		
GBAS Continuity/Integrity Designator	3		
Local Magnetic Variation	8	± 32.0°	0.25°
Refractivity Index	8	± 381	3
Scale Height	8	± 12,700 m	100 m
Refractivity Uncertainty	8	0 - 255	1
Latitude (Note 1)	32	± 90.0°	0.0005 arcsec
Longitude (Note 1)	32	± 180.0°	0.0005 arcsec
Ellipsoid Height (Note 1)	24	± 83,886.07 m	0.01 m

Note 1 the accuracy can be greater than the resolution by locating the reference point at the actual point defined in the message.

GBAS Operating Receivers*:* shall define the number of GNSS reference receivers installed in this GBAS.

00 - GBAS installed with 2 reference receivers
01 - GBAS installed with 3 reference receivers
10 - GBAS installed with 4 reference receivers
11 - Spare

GBAS Accuracy Designator: shall define the performance of the GNSS receivers used in this GBAS as designated below:

00 - GBAS has accuracy designation A
01 - GBAS has accuracy designation B
10 - GBAS has accuracy designation C
11 - Spare

GBAS Ground Station Health: (spare) This parameter is reserved for future use.

GBAS Continuity/Integrity Designator*:* shall define the operational status (including the greatest performance type) of the GBAS.

000 - GBAS redundancy supports terminal area operations
001 - GBAS redundancy supports Performance Type 1
010 - GBAS redundancy supports Performance Type 2
011 - GBAS redundancy supports Performance Type 3
100 - Reserved for future Performance Types
101 - Reserved for future Performance Types
110 - Reserved for future Performance Types
111 - GBAS not healthy

Local Magnetic Variation: This data parameter shall define the magnetic variation at the differential reference point. The most significant bit shall be the sign bit where:

0 = positive (east variation),
1 = negative (west variation)

a positive variation shall be clockwise from true north.

Refractivity Index*:* is the number added which shall be added to 400 to obtain the tropospheric refractivity.

Scale Height*:* This parameter shall be used for scaling the tropospheric refractivity as a function of differential altitude.

Refractivity Uncertainty*:* shall define the RMS error in the corrected tropospheric refractivity.

Ed Note: Words are needed to describe the default situation when the ground station has no weather station. Either all tropospheric parameters should be set to don't use, or nominal fixed values should be transmitted.

Latitude: The latitude of the identified point shall be defined in WGS-84 co-ordinates and transmitted in arc seconds. The most significant bit shall be the sign bit where:

0 = positive (Northern Hemisphere)
1 = negative (Southern Hemisphere)

Longitude: The longitude of the identified point shall be defined in WGS-84 co-ordinates and transmitted in arc seconds. The most significant bit shall be the sign bit where:

0 = positive (Eastern Hemisphere)
1 = negative (Western Hemisphere)

Ellipsoid Height*:* shall be the distance along the vector normal to the WGS-84 Ellipsoid to the data point of interest.

2.3 A. Message Type 3 - GBRS Acquisition Data (Reserved)

This message is reserved for use with Ground Based Ranging Sources (pseudolites). It is not required for Category I operations.

2.4 A. Message Type 4 - Final Approach Segment

2.4.1 A. Scope

Messages Type 4 shall contain the data necessary for the aircraft system to construct a precision approach path. The Message Type 4 shall include the performance type, which is followed by the path construction block.

Note: Message Type 4 can contain a single FAS data block or multiple FAS data blocks. The Type 4 message contains an independent approach capability indication for each FAS data block within the message. Each FAS data block is terminated with a CRC, which wraps around the approach data and each Type 4 message is terminated with a separate CRC (as defined in the message definition) which, wraps the entire message including message header and all the individual FAS data block CRCs.

Note: The FAS Data Block Performance Type of the message that precedes the FAS data block defines the maximum Performance Type of the approach.

2.4.2 A. Message rate

The Message Type 4 shall be transmitted at least every 15 seconds for Category I operations.

2.4.3 A. Message content

Message Type 4 shall contain a single or multiple FAS data blocks. The protected FAS data blocks shall be validated individually by the issuing authorities. The data blocks shall include data that allow unambiguous FAS selection against the desired approach charts.

Note: The Message Type 4 contains an independent approach capability message for each FAS data block. Each FAS data block contains a CRC, which wraps around the approach data and a separate CRC (as defined in the message definition) which wraps the entire Message Type 4 including message header and all FAS data blocks including the individual FAS data block CRCs.

Table A.2.4-1 Format of Message Type 4

Parameter	***Bytes***
FAS Data Block 1 Performance Type	1
FAS Data Block 1	38
FAS Data Block 2 Performance Type	1
FAS Data Block 2	38
. . .	
FAS Data Block n Performance Type	1
FAS Data Block n	38

<u>FAS approach path designator:</u> shall identify the designed Performance Type of Final Approach Segment defined in the following Final Approach Segment Data Block.

Note: As this MASPS is only concerned with straight-in Category I approaches, this parameter shall be set to "00000001".

<u>FAS Data Block (n):</u> Contains the construction data for the Final Approach Segment identified in the data block. The FAS data block is defined in Table A.2.4-2.

The FAS data is organised in data blocks for the purpose of computing the CRC. Each data block contains all the information necessary for one single path. Each data block includes an integrity mechanism introduced when the data is determined and validated. This section describes the data block structure only for the computation of the CRC.

The block contains data for a single operation. It is self-contained and includes a means to preserve integrity from the time it is generated and validated to the time that it is used in airborne equipment. All of the information necessary to describe the paths and its designation is contained within it. This primarily includes the following: airport identification, runway designation and position, procedure type (provides flexibility for advanced procedures such as departure or curved approach), procedure name, and runway surveyed points. The data block is generated, protected by a CRC code and validated by the appropriate authorities before distribution. The data block can be transported, reformatted and distributed as long as the original format can be recovered, thereby allowing the verification of the original CRC.

The data block structure consists of a series of fields of different size. The sequence of the fields depends on the operation type the data block supports. Fields common to the different types of operations are placed in the beginning of the data blocks. Fields are coded with the MSB toward the beginning (towards the preceding field) and the LSB towards the end of the block. For the purpose of calculating the CRC, each field is placed in an integral number of 8-bit words (divisible by an integer number of bytes).

Table A.2.4-2 indicates the overall structure for straight-in approaches. The data items are defined below. Note that the CRC field always terminates the data block.

The runway absolute location is defined by the position of two points. The Runway Datum Point (RDP) is typically located on centreline at the threshold end of the runway. The other point is the flight path alignment point (FPAP) typically located on runway centreline at the other end of the runway. This point is sometimes called the stop-end point. The absolute position of the RDP shall be referenced to the geodetic co-ordinate system in accordance with WGS-84. The FPAP position shall be given in latitude and longitude using the same co-ordinate system. The vertical co-ordinate is not necessary for the glidepath definition and is omitted. The FPAP is defined to be at the same height above the earth ellipsoid as the RDP.

Note that the actual departure end of a runway may be at a different height, but that information is not necessary for these operations.

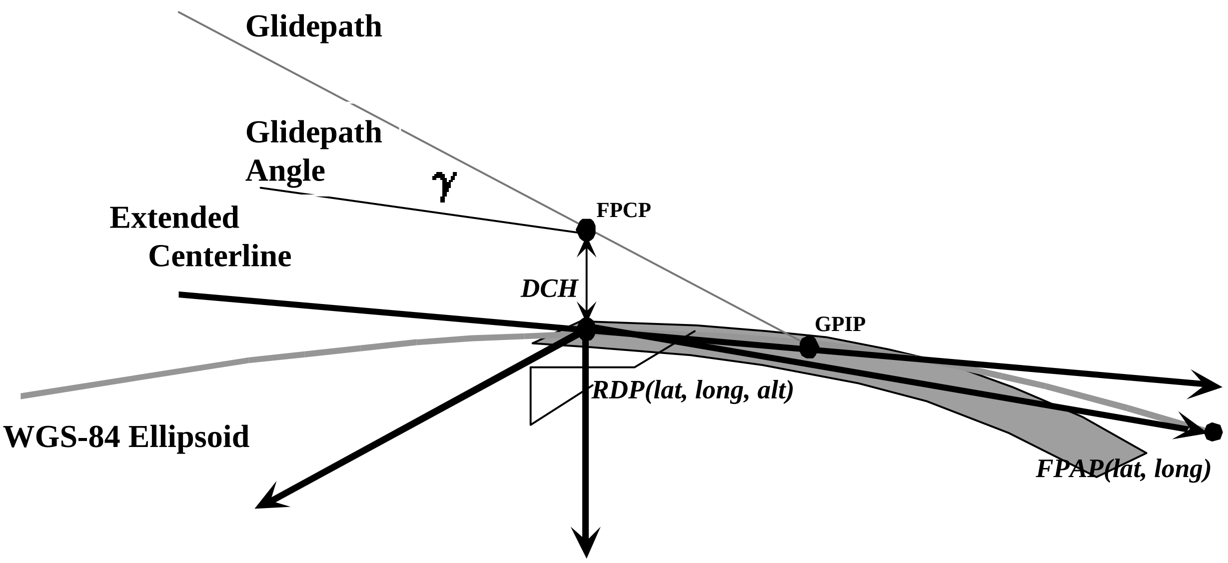
Note: The RDP and FPAP may be offset from the runway thresholds to support rotorcraft and offset approaches.

Glidepath Definition: The glidepath is defined by the following parameters:

- Runway Datum Point
- Flight Path Alignment Point (FPAP)
- Local WGS-84 vertical vector (normal to the local WGS-84 ellipsoid at the RDP)
- Approach Datum Crossing Height (DCH)
- Glidepath Angle

See Figure A.2.4-1. The glidepath is defined by the line in the vertical plane that passes through the flight path crossing point (FPCP) at the specified glidepath angle. The glidepath angle is relative to the horizontal plane tangent to the WGS-84 ellipsoid at the RDP. For other than exceptional cases, the RDP is at the runway threshold and the FPAP is located at the far end of the runway. The FPCP is located above the RDP at a distance called the Approach Datum Crossing Height DCH. The vertical plane is defined by the vector perpendicular to the WGS-84 ellipsoid at the RDP, by the RDP, and by the FPAP.

Figure A..2.4-1. Glidepath Definition



Structure for Straight-in Approaches Data blocks: The following items are contained in the data block:

- Operation Type: Straight-in Approaches
- Airport Identification (ID)
- Runway Number
- Runway Letter
- Approach Design Information
- Reference Path Selector
- Reference Path ID
- Reference Datum Point Co-ordinates
- Flight Path Alignment Point Co-ordinates
- Approach Datum Crossing Height
- Glidepath Angle
- FAS CRC

The first field (operation type) has a fixed coding corresponding to straight-in approaches. The data fields follow a fixed sequence. The data block size for this type is fixed. Table A.2.4-2 describes in detail the sequence of fields and their contents.

Advanced Procedures Data blocks: The data format has the capability through the procedure identifier, to accommodate advanced procedures. The format for those procedures is currently undefined.

Table A.2.4-2 Final Approach Segment (FAS)

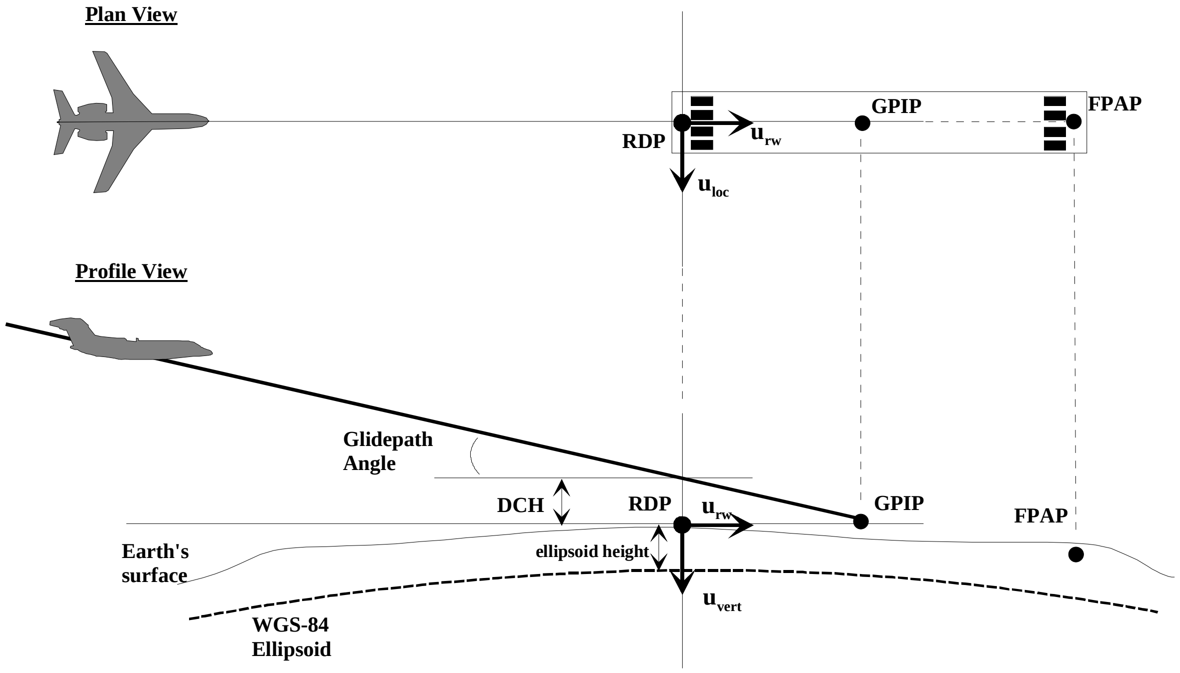
Data Content	***Bits Used***	***Range of Values***	***Resolution***
Operation Type	4		
Spare	4		
Airport ID	32		
Runway Number	6	0 - 36	1
Runway Letter	2		
Approach Design Information	3		
Route Indicator	5		
Reference Path Data Selector	8	0 - 199	
Reference Path ID	32		
RDP Latitude	32	± 90.0 °	0.0005 arcsec
RDP Longitude	32	± 180.0 °	0.0005 arcsec
RDP Height	16	-512.0 - 6041.5 m	0.1 m
FPAP Latitude	32	± 90.0 °	0.0005 arcsec
FPAP Longitude	32	± 180.0 °	0.0005 arcsec
Approach Datum Crossing Height (DCH) (Note 1)	15	0 - 3276.8 ft 0 - 1638.4 m	0.1 ft 0.05 m
Approach DCH Units Selector	1		
Glidepath Angle (GPA)	16	0 - 90.0 °	0.01°
Final Approach Segment CRC	32		

Note 1 Information can be provided in either feet or meters

The Final Approach Segment Data Block shall contain the parameters, which define a single precision approach. Each FAS data block shall end with a CRC, which wraps around the approach data. A separate CRC shall be wrapped around the entire FAS Data Message (Type 4).

Note: The protected FAS data blocks are validated individually by the civil authorities. The data blocks include data that allow for an unambiguous FAS selection against the desired approach charts.

2.4.3.1 A. Final approach segment parameter description



Operation Type: shall indicate whether the operation is an approach procedure, an advanced operation or others to be defined later. The convention for coding shall be as follows:

0 = straight-in approach procedure
1-15 = reserved for future definition

Spare: (undefined, set to '0000')

Airport Identification: shall be the three or four alphanumeric characters used to designate airport facilities. Only upper case alphabetic characters and numbers shall be used. The most significant two bits of every character (8-bit word) shall be zero. Alphanumeric characters shall be coded using bits b_1 to b_6 of International Alphabet No. 5. When a three-character identifier is used, the most significant character shall be set to blank ('10 0000').

Runway Number: shall represent the approach runway number. The valid range shall be 0-36 where Runway Numbers 1 through 36 designate runway operations and the designation 0 identifies heliport operations.

Runway Letter: shall represent the runway letter, where used to differentiate between parallel runways. The valid range is 00 through 11. The convention for coding shall be as follows:

00 = no letter	10 = C (centre)
01 = R (right)	11 = L (left)

Approach Design Information: shall provide the general information about the approach design. The convention for the coding shall be:

000 = Straight in approach FPAP at the end of the runway
001 = Straight in approach, FPAP not at the end of the runway
010 = Offset approach
011 - 111 = Not defined

Route Indicator: shall represent the route to or from the waypoint named by the basic indicator. The route indicator shall be a single alpha character coded in accordance with bits b_1 to b_5 of International Alphabet No. 5. The letters "I" and "O" shall not be used. The most significant three bits of every character (8-bit word) shall be zero.

Reference Path Data Selector: is a numerical identifier (unique in the broadcast region) and shall be used to select the FAS data block (desired approach).

Note: A GBAS supported precision approach requires tuning of a data broadcast channel in addition to the precision approach selection that can be accomplished by either unified or systematic type of tuning and approach selection.

Reference Path Identifier: shall represent the three or four alphanumeric characters used to uniquely designate the reference path. Only upper case alpha characters shall be used. The most significant two bits of every character (8-bit word) shall be zero. Alphanumeric characters shall be coded using bits b_1 to b_6 of International Alphabet No. 5. When a three-character identifier is used, the most significant character shall be set to blank ("10 0000").

Runway Datum Point Latitude: shall represent the latitude of the runway datum point defined in WGS-84 co-ordinates and transmitted in arc seconds. The most significant bit shall be the sign bit where:

0 = positive (Northern Hemisphere)
1 = negative (Southern Hemisphere)

Runway Datum Point Longitude: shall represent the longitude of the runway datum point defined in WGS-84 co-ordinates and transmitted in arc seconds. The most significant bit shall be the sign bit where:

0 = positive (Eastern Hemisphere)
1 = negative (Western Hemisphere)

Runway Datum Point Height: shall represent the height of the datum point above the WGS-84 ellipsoid. This field shall be coded as an unsigned value with an offset of -512 m. A value of zero in this field shall place the DP 512 m below the earth ellipsoid.

Flight Path Alignment Point – Latitude: shall define the latitude of the runway Flight Path Alignment Point (FPAP) in WGS-84 co-ordinates and transmitted in arc seconds. The most significant bit shall be the sign bit where:

0 = positive (Northern Hemisphere)
1 = negative (Southern Hemisphere)

Flight Path Alignment Point –Longitude: shall define the longitude of the Flight Path Alignment Point defined in WGS-84 co-ordinates and transmitted in arc seconds. The most significant bit shall be the sign bit where:

0 = positive (Eastern Hemisphere)
1 = negative (Western Hemisphere)

Note: The FPAP is also used by the aircraft for scaling its deviation outputs.

Approach Datum Crossing Height (DCH): shall represent the height of the DCP above the RDP. The height can be defined in either feet or meters as defined in the Approach DCH Units Selector bit.

Approach DCH Units Selector: shall define the units used to describe the Approach Datum Crossing Height. The definition of the bit shall be:

0 = feet
1 = meters

Glidepath Angle (GPA): shall define the angle of the approach path (glide path) with respect to the horizontal plane defined according to WGS-84 at the RDP.

CRC Code: the 32 bit Cyclic Redundancy Check (CRC) shall be appended to the end of each FAS Data Block in order to ensure approach data integrity. The generator polynomial G(x) for the message block CRC shall be:

$$G(x) = x^{32} + x^{31} + x^{24} + x^{22} + x^{16} + x^{14} + x^{8} + x^{7} + x^{5} + x^{3} + x + 1$$

Note: See section 3.0 for details.

2.4.4 A. Advanced procedures datablocks

The data format has the capability through the procedure identifier, to accommodate advanced procedures. The format for those procedures is currently undefined.

2.5 A. Message Type 5 - GNSS Satellite Availability

2.5.1 A. Scope

Message Type 5 is defined to provide an optional means for the ground subsystem to indicate to the aircraft avionics the future availability of differential corrections for satellites as the aircraft begins its decent into the final approach phase. Type 5 consists of setting/rising information for the currently visible or soon to be visible satellites as shown in table A.2.5.1. This message allows the ground subsystem to broadcast predicted changes in the availability of differential corrections at future specific points in time to the aircraft so that the aircraft shall be able to anticipate the satellites that can be used for the duration of the precision approach.

2.5.2 A. Message rate

The update rate for message Type 5 is expected to be driven by the maximum time allowed between the pilot's selection of the approach until the indication is displayed back to the pilot that the approach is available. This ideally would be the same update rate as the entire set of path points is broadcast (i.e., message Type 4, see paragraph A.2.5).

2.5.3 A. Message content

Table A.2.5-1 Format of Message Type 5

Data Content	***Bits Used***	***Range of Values***	***Resolution***
Obstructed Approaches (**A**)	8	0 - 255	1
Approach 1			
Reference Path ID	8		
Impacted Sources (**N**)	8	0 - 31	1
Impacted Ranging Source 1 on Approach 1			
Ranging Source ID	8	0 - 255	1
Source Availability Sense	1		
Source Availability Duration (Note 1)	7	1270 sec	10 sec
• • •			
Impacted Ranging Source N on Approach 1			
Approach 2			
• • •			
Approach A			
Reference Path ID	8		
Impacted Sources (**N**)	8	0 - 31	1
Impacted Ranging Source 1 on Approach A			
Ranging Source ID	8		
Source Availability Sense	1		
Source Availability Duration (Note 1)	7	0 - 1270 sec	10 sec
• • •			
Impacted Ranging Source N on Approach A			

Note 1 111 1111 indicates 1280 seconds or longer

Obstructed Approaches*:* This parameter shall indicate the number of approaches for which the corrections shall be reduced due to unique constellation masking. The number of ”Obstructed Approaches” field shall be followed by i repetitions of source information. Each repetition shall include the number of obstructed sources (i), followed by i repetitions of a source ID, the source availability sense, and the source availability duration.

Reference Path Identifier: shall have the same definition as used in Message Type 4.

Impacted Sources: shall indicate the number (i) of sources for which the duration information is reduced due to unique constellation masking. The number of Impacted Sources field shall be followed by i repetitions of source information, where each repetition includes: a ranging source ID, the source availability sense, and the source availability duration.

Ranging Source ID: This parameter shall have the same definition as for message type 1.

Source Availability Sense: This parameter shall identify the sense of the subsequent ranging source availability duration term. The parameter shall be '0' or '1', where '0' indicates differential corrections shall soon cease to be provided for the associated ranging source and '1' indicates corrections shall soon start to be provided for the associated ranging source.

Note: After a satellite has risen and differential corrections have started to be provided for the satellite, the satellite availability sense term will typically be set to '0'. This will indicate the next action of the satellite is to set and the satellite availability duration term will typically be set to '111 1111', indicating that the satellite will not set for at least 1280 seconds after the modified Z-count time.

Source Availability Duration: This parameter shall identify the predicted availability of the source relative to the modified Z-count time. When the Source Availability Sense is set to '0' in Type 5 Messages or in all Type 1 Messages, this field shall indicate the minimum availability duration. When the Source Availability Sense is set to '1' in Type 5 Messages, this field shall indicate the maximum duration. This parameter shall be set to all ones ('1111 1111') if the duration is greater than 2550 seconds for Type 1 Messages or ('111 1111') the duration is greater than 1270 seconds for Type 5 Messages.

Note: This parameter is a positive unsigned number. This parameter is 8 bits long for Type 1 Messages and 7 bits long for Type 5 Messages.

2.6 A. Message Type 6 - GNSS Carrier Phase Corrections

Note: The Type 6 message contains differential carrier corrections which may be required for Cat II / III performance categories.

2.7 A. Message Type 7 –National Use

Message Type 7 is reserved for national use.

2.8 A. Message Type 8 - Experimental (optional)

Message Type 8 is defined to allow special messages to be created for experimental, private-use, or proprietary system implementations or features. The first 8 bits in the body of the message (after the header) shall be used as the primary sub-label to uniquely identify the messages. It is intended that a unique primary sub-label be assigned to each experimental project, or private-use sponsor, or manufacturer that wishes to use this message type. Additional secondary sub-labels may be created by the project/sponsor/manufacturer, in the body of the message, to allow a family of special messages to be created, if desired.

It is intended that the primary message sub-labels be controlled by the EUROCAE to ensure that two incompatible systems do not use the same primary sub-label for different messages or families of messages. It is intended that secondary message sub-labels be defined and controlled by the project/sponsor/manufacturer in accordance with EUROCAE-approved configuration management and/or integrity requirements that may be applicable to the particular system implementation or application.

3. A. Cyclic Redundancy Code (CRC).

3.1 A: Message CRC

A 32-bit cyclic redundancy code (CRC) concludes each Message Block in order to ensure message integrity. The CRC word is calculated on the entire message, including the Message Header. A separate 32-bit CRC value concludes each FAS data block. Thus the probability of an undetected error in the intermediate system is less than $2^{-32} = 2.3283^{-10}$, which satisfies the data link integrity allocation for Cat I operations. Additional integrity is obtained by validating several data fields, including the GBAS ID. The data format integrity is designed to meet the CAT-I requirement independent of the data link. For Categories 2 and 3, the data link CRC is TBD

The responsibility of end-to-end integrity checking is grouped at the application layer of the ISO stack for document clarity, but it actually exists at the transport layer, in order to be consistent with the International Standards Organisation (ISO) protocol stack.

The CRC consists of the coefficients of the remainder R(x) of the modulo-2 division of two polynomials:

$$[x^{32}\frac{M(x)}{G(x)}]_{\text{mod}}2 = Q(x) + \frac{R(x)}{G(x)}$$

The polynomial M(x) consists of the sequence of data bits to be protected by the CRC (excluding the CRC bits) :

$$M(x) = \sum_{i=1}^{n} m_i x^n - i$$

The data bits (m_1, ...,m_n) are treated as a single word of n bits, arranged in order of transmission without any byte-wise reversal of bits.

For all message types only the message CRC applies. The bit numbering for the header is identical. Numbering of the data itself is straightforward following the header and goes from the LSB to the MSB. The CRC follows with R_1 as the MSB (i.e. x^{32}) and the last bit is R_{32} (i.e. x^0).

Refer to Appendix F for a type 1 message example, which employs the same CRC calculation.

G(x) is the generator polynomial:

$$G(x) = x^{32} + x^{31} + x^{24} + x^{22} + x^{16} + x^{14} + x^{8} + x^{7} + x^{5} +x^{3} + x + 1$$

Q(x) is the quotient of the division.

The quotient Q(x) is obtained by dividing x^{32} *M(x) by G(x) starting with m_1(or m_i) and $G_1 = x^{32}$ considered as being the highest bits in their respective polynomial as follows:

$$[m_1*x^{(n+32)} + m_2*x^{(n-31)} ......m_n*x^{32}\ ] / [x^{32} +x^{31} +x^{24} +x^{22} +x^{16} +x^{8}+x^{7} +x^{5} +x^{3} +x + 1]$$

The remainder of the division must match the received CRC R_1 through R_{32} bits

$$R_1*x^{32} + R_2*x^{31} +R_3*x^{30 ....} + R_{32}*1$$

The CRC R(x) is coded with the coefficient of x^{31} as the first bit transmitted. As shown in Figure A-10, with the remainder initially set to zero, n bits of data are sequentially clocked through the polynomial division circuit. After n bits of data, the output is switched to the quotient line, and 32 zeros are used to clock the remainder out. These 32 bits of remainder is the CRC.

Figure A 3-1 shows the polynomial division circuit used to generate the message CRC. The Quotient is initialy seeded to all 0's and after the (n) bits of data are transmitted the output is switched to the remainder line, and 32 zeros are used to clock the remainder out. The 32 bits of remainder is the integrity check CRC.

Note: The MSB of the remainder is the first bit out of the polynomial generator and the first bit transmitted at the end of the message.

Figure A 3-1
Message Block Polynomial Division Circuit

3.2

Using
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codev

Note 1: All arithmetic operations are performed modulo 2.

Note 2: G(x) is of the form (1 +x)P(x), where P(x) is a primitive and irreducible polynomial of order r-1 = n-k-1.

3.2.1 A. Datablock CRC selection

Qualcomm Corporation conducted performance comparisons of several Cyclic Redundancy Codes. The results of this performance analysis are presented in Reference 1. The code labelled *CRC-32Q* demonstrates a probability of undetected error below the upper bound of:

$$2^{-32} = 2.3283\text{x}10^{-10}$$

for a wide range of message lengths. The generator polynomial for this code is:

$$G(x) = (1 + x)p(x)$$

$$= x^{32} + x^{31} + x^{24} + x^{22} + x^{16} + x^{14} + x^{8} + x^{7} + x^{5} + x^{3} + x + 1$$

where:

$$P(x) = x^{31} + x^{23} + x^{22} + x^{15} + x^{14} + x^{7} + x^{4} + x^{3} + 1$$

3.3 A. Ephemeris CRC

The generator polynomial G(x) for the message block CRC is:

$$G(x) = x^{16} + x^{12} + x^{5} + 1$$

Figure A 3-2 shows the polynomial division circuit used to generate the message Ephemeris CRC. The Quotient is seeded with all 0's and after the 648 bits of data are transmitted the output is switched to the remainder line, and 16 zeros are used to clock the remainder out. The 16 bits of remainder is the integrity check CRC.

Note: The MSB of the remainder is the first bit out of the polynomial generator and the LSB of the CRC.

Figure A 3-2
16 Bit CRC Ephemeris CRC Polynomial Generator Circuit

The ephemeris data which is applied to this 16 bit CRC circuit is defined in the first three subframes of the GPS satellite data transmission as shown in Figure A 3-3. The CRC is computed on words 3 through 10 of subframes 1, 2 and 3 after being "anded" with the mask in Figure A 3-4. The CRC is not computed on the HOWZ, which starts each subframe or the parity bits at the end of each word.

Figure A 3-3
Satellite Ephemeris Data

S2W9	11111111 11111111 11111111	S2W10	11111111 11111111 10000000
S3W3	11111111 11111111 11111111	S3W4	11111111 11111111 11111111
S3W5	11111111 11111111 11111111	S3W6	11111111 11111111 11111111
S3W7	11111111 11111111 11111111	S3W8	11111111 11111111 11111111
S3W9	11111111 11111111 11111111	S3W10	11111111 11111111 11111100

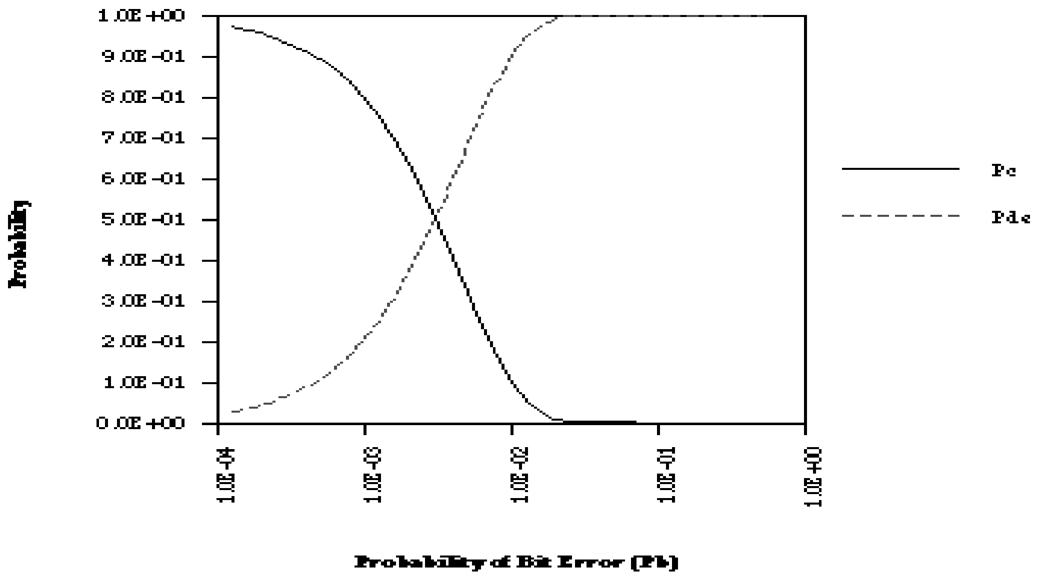
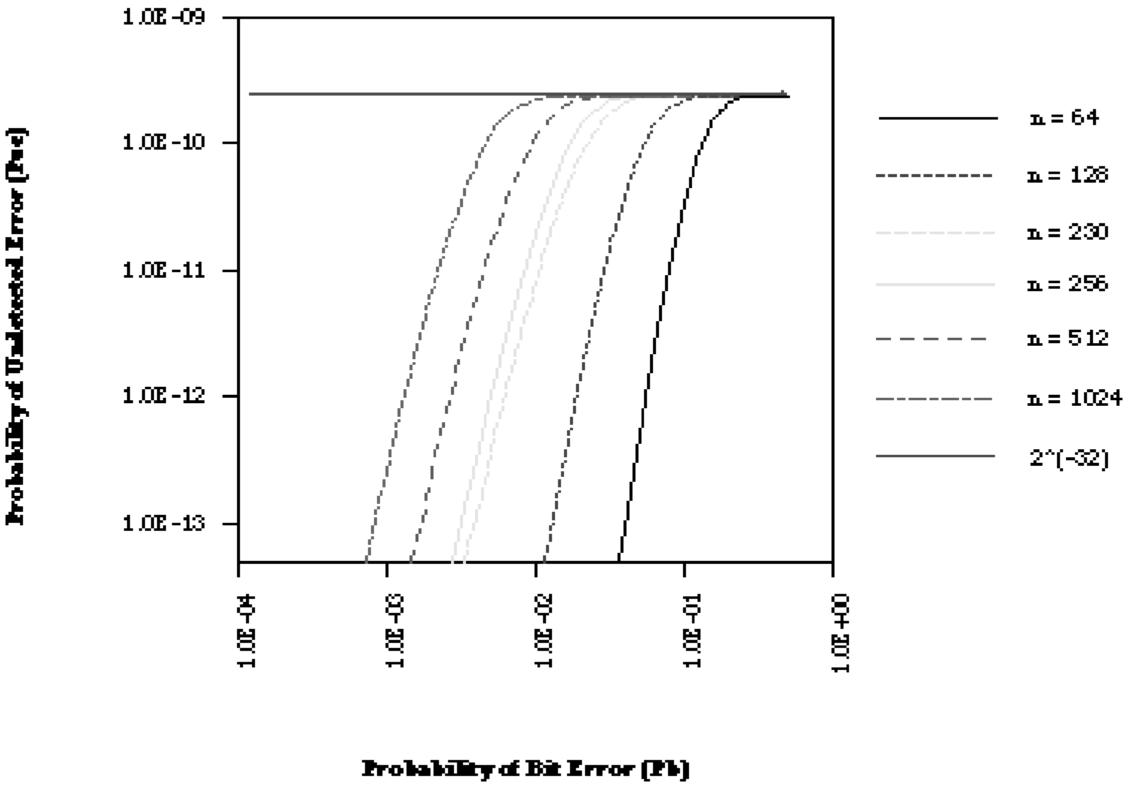


Figure 3. Probabilities of Correct Decoding (P_c) and Detected Errors (P_{de}) of a Proposed CRC-32Q Code ($g(x) = (1 + x)\,p(x)$, $p = 20060140231$)

Fehler! Schalterargument nicht angegeben.



Fehler! Schalterargument nicht angegeben.

APPENDIX B

SYSTEM ACCURACY

B.1 GBAS Accuracy concept

At system level, the accuracy requirements are given in terms of NSE, in order to ensure that the indications provided are accurate enough to fly a Cat I approach.
Specifications in sections 3.2.1 and 3.2.2 stem from analysis of existing ILS requirements. An example of ILS performances analysis is given in sections B.2. GBAS and ILS are very different systems and several interpretations of existing requirements are possible. RTCA and EUROCAE agreed on accuracy specifications, which are within ILS Cat I requirements.
One of the main differences between GBAS and ILS is the distribution of the error in terms of noise and bias. Bias and noise allocation is not specified for GBAS error. Differential GNSS based landing systems error show less noise than ILS error. Therefore it is assumed that FTE will be smaller with GBAS than with ILS. This also impacts on accuracy measurement methodology, which is discussed in section B.3.

For GBAS, the position computation is processed by the airborne subsystem, based on ranging measurements made by itself and by the ground subsystem. Accuracy comes from differential processing, which removes ranging errors that are common to the ground and airborne subsystems. Therefore, subsystem accuracy requirements are specified in the range domain and relate to the non-common error contributions.
The position accuracy results from the combination of ground and airborne subsystems' accuracy, which are specified in this document, with the geometry of the GNSS constellations considered, which cannot be specified. In order to meet the system-level requirements, the ranging source geometry should be verified at the time of the approach.
Such a verification is also necessary for system integrity, which, unlike accuracy requirement, involves safety. The system function, which ensures that the position provided is within alert limits with the required confidence level, inherently ensures that the ranging source geometry is compatible with the accuracy requirements.

Subsystem accuracy requirements are driven by considerations on system availability, which combines system accuracy, integrity and continuity of service requirements, resulting in more stringent specifications than what would be strictly necessary to satisfy the system accuracy specifications. These requirements stem from empirical data and engineering analysis.

B.2 System-level accuracy requirements rationale:

The GBAS accuracy requirement is based on existing standards for ILS ground and airborne subsystems.
The ILS Navigation System Error (NSE) is made up of four components, which are the course alignment (or bias), the bends (or Noise), the displacement sensitivity variation and the receiver centring error.
The deflection error in the receiver is considered nil.
The following values are evaluated in terms of Gaussian random bias and noise:
-The course alignment error, converted into 95 % value taking into account the alignment monitor threshold.
-The 95% bends error, calculated in meters considering the nominal displacement sensitivity.
-The displacement sensitivity variation error, converted into 95 % value taking into account the displacement sensitivity variation monitor threshold.
-The 95% receiver centring error is calculated in metres, considering the nominal displacement sensitivity
The Root Sum Square (RSS) of every error is computed to give a 95% NSE error at 200 ft.
A fifth component contribution to the vertical NSE error budget (the Threshold Crossing Height TCH variation) is discussed in B 2.2 ,which provides a rationale for the vertical accuracy requirement.

ASSUMPTIONS:

The performance requirements are based on the following assumptions:

- localizer antennas to threshold distance 3000 m
- glide path angle θ=3°
- course alignment and displacement sensitivity: as per Annex 10 monitor limits (assumed to be 5 σ values; see B 2.3)
- nominal height of the ILS Reference Datum point (as per ICAO Annex 10 chapter 3.1.5.1.5 :15 m).

REFERENCE DOCUMENTS:

The NSE values are derived from Annex 10 ILS performance standards for the ground subsystem and EUROCAE MOPS for the aircraft receiver.

- ICAO Annex 10
- ICAO DOC 8071
- EUROCAE ED 46B (LOC) and ED 47B (GP)
- EUROCAE ED 53A and ED 36A (MLS)

B 2.1 Cat 1 Lateral ILS Navigation System Error:

Ground course alignment contribution (Bias):

- ICAO Annex 10 chapter 3.1.3.6: Mean Course line shall be *adjusted and maintained* within a 10.5 m limit from the runway centre line at the ILS reference Datum Point (Point T).

- ICAO Annex 10 chapter 3.1.3.11.2: executive monitors action if a shift of the mean course line from the runway centre line is equivalent to more than 10.5 m at the ILS Datum Point.

This 10.5 m value given by ICAO is ambiguous. The adjusted and maintained 10.5 m value is interpreted as 99.7% (3 σ) value in ICAO DOC 8071 chapter 4.3.3.2 and is also a threshold value for the monitor (assumed to be a 5. σ value in B 2.3).
Two reasonings are possible to calculate the 95% accuracy value. The first is to consider the adjusted and maintained 10.5 m value as a 3 σ value, the second is to consider the 10.5 m monitor threshold as a 5 σ value.

First solution:
An ILS bias of 7 m (95% value based on 10.5 m as a 3σ value) would lead to some problems with the continuity of service risk requirement ($4*10^{-6}$).
In addition, as we have to consider that ICAO standards for alignment course error have to be satisfied whatever the displacement sensitivity error is, the alignment course monitor ddm threshold (in µA units) is adjusted to respect the 10.5 m alignment course tolerance with the worse displacement sensitivity limit value.

Second solution:
B2.3 provides an interpretation of monitor threshold as a 5 σ value.
Some statistics made on some ILS show that the adjusted and maintained accuracy value is much better than 7 m, this explains that the continuity requirement is met.
As the 10.5 m value is an alarm threshold limit, the 95% accuracy performance is better than 10.5 m.

To be close to the reality and to be compatible with continuity requirement, this 10.5 m limit value is assumed to be 5 sigmas value.

If 10.5 m is assumed to be the 5 sigmas value, the 95% accuracy requirement at the threshold is therefore:

$$\frac{10.5}{5} \times 2 = 4.20m$$

So the lateral bias requirement at the distance corresponding at the 200 ft D/H is:

$$4.20 \times \frac{(3000 - 286 + 1163)}{3000} = 5.43m$$

95% Lateral CAT 1 ILS Bias at 200ft D/H: 5.43 m

95% course structure contribution (NOISE):

- ICAO Annex 10 chapter 3.1.3.7.1:The nominal displacement sensitivity within the half course sector at the ILS reference datum shall be 0.00145 ddm/m
- ICAO Annex 10 chapter 3.1.3.4 (course structure): bends in the course line shall not have amplitudes which exceed the following ***(95% probability***):
  - Outer limit of coverage to ILS Point A: 0031 DDM
  - ILS Point A to ILS Point B: 0.031 DDM at ILS Point A decreasing at a linear rate to 0.015 DDM at ILS Point B
  - ILS Point B to ILS Point C: 0.015DDM

The amplitude bends in the course line are measured by periodic flight inspections but not by monitor.
At the ILS CAT 1 D/H the bends are equal to 0.015 DDM (95%).
The nominal displacement sensitivity at the ILS point T is 0.00145 ddm/m so 689.66 m/ddm. This value has to be calculated at the CAT 1 D/H (200ft) because it corresponds to an angular value.

So at the CAT 1 D/H (200ft) the nominal displacement sensitivity is:

$$689.66 \times \frac{(3000 - 286 + 1163)}{3000} = 891.3m / ddm$$

The 0.015 ddm bends (95%probability) at the CAT 1 D/H (between ILS Point B and ILS Point C) corresponds to

$$0.015 \times 891.3 = 13.37m$$

95% Lateral CAT 1 ILS bends at D/H: 13.37 m

95% Displacement sensitivity variation contribution:

This error affects the conversion between ddm and meters.
This displacement sensitivity variation have to be applied to the bias 95% ddm value and the 95% bends ddm value.

- ICAO Annex 10 chapter 3.1.3.7.1:The nominal displacement sensitivity within the half course sector at the ILS reference datum shall be 0.00145 ddm/m
- ICAO Annex 10 chapter 3.1.3.7.2:The lateral displacement sensitivity shall be *adjusted and maintained* within the limits of plus or minus 17% of the nominal value.
- ICAO Annex 10 chapter 3.1.3.11.2: executive monitors action if a change of the displacement sensitivity to a value differing by more than 17% from the nominal value.

This 17% value given by ICAO is ambiguous. Adjust and maintain the displacement sensitivity value within 17% of the nominal value is interpreted as 99.7% (3 σ) value in ICAO DOC 8071 chapter 4.3.3.2 and is also a threshold value for the displacement sensitivity variation monitor (assumed to be a 5 sigmas value in B 2.3).
Two reasonings are possible to calculate the 95% displacement sensitivity variation value. The first is to consider the adjusted and maintained 17% value as a 3 σ value, the second is to consider the 17% monitor threshold as a 5 σ value.

First solution:
An ILS displacement sensitivity variation of 11% (95% value) would lead to some problems with the continuity of service requirement ($4*10^{-6}$).
In addition, as we have to consider that ICAO standards for displacement sensitivity variation error have to be satisfied whatever the alignment course error is, the ddm displacement sensitivity variation threshold is adjusted to respect the 17% displacement sensitivity variation tolerance with the limit alignment course error value.

Second solution:
B2.3 provides an interpretation of monitor threshold as a 5 σ value.
As the 17% displacement sensitivity variation value is an alarm threshold limit, the 95% value is better than 17%.
To be close to the reality and to be compatible with continuity requirement this 17% value is assumed to be 5 sigmas value.

So the 2σ lateral sensitivity displacement variation requirement is $7 \times \frac{2}{5} = 6.8\%$ of the nominal value.

The 95% 4.20 m bias ddm value is 4.2*0.00145=0.00609 ddm.
The 95% bends ddm value is 0.015 ddm.
As these two values are independent parameters the RSS is 0.016 ddm.
As at the CAT 1 D/H (200ft) the nominal displacement sensitivity is 891.3 m/ddm, the 2 σ displacement sensitivity variation is 6.8%*891.3=60.6 m/ddm.
The displacement sensitivity variation contribution is 0.016*60.6=0.97m.

95% Lateral CAT 1 displacement sensitivity variation at D/H: 0.97 m

95% Airborne error contribution:

EUROCAE ED 46B: the max error due to the centring tolerance is 11% of standard deflection so 11% of 0.093 ddm so 0.01023 ddm (95%).
This value may be converted into metric difference using the nominal displacement sensitivity value used above:

$$0.01023 \times 891.3 = 9.12m$$

95% Lateral receiver error at ILS CAT 1 D/H = 9.12 m

95% ILS Lateral Navigation System Error:

The 95% lateral navigation system error at the ILS CAT 1 D/H may be estimated to the RSS of the ground system error plus the aircraft system error so:

$$\sqrt{5.43^2 + 13.37^2 + 0.97^2 + 9.12^2} = 17.09m$$

95% Lateral ILS N.S.E. at ILS CAT 1 D/H = 17.09 m

B 2.2 Cat 1 vertical ILS Navigation System Error:

In the case of ILS glide path, the ILS Reference datum varies from one approach to another. The ICAO recommended tolerance for the ILS Reference datum for category 1 operations is 10 ft (chapter 3.1.5.1.4). Several factors are given in ICAO A10 Attachment C chapter 2.4.3.but experience has shown that the dominant reason for the ILS Reference datum not to be placed at the nominal value is a antenna siting problem. The TCH height is measured by flight inspection commissioning (extension of straight line of course alignment measured between ILS point A and B) and, then, the TCH variation is checked by the course alignment limit.
This TCH variation would not exist for GBAS approaches if a fixed glideslope angle and TCH are chosen, therefore, we propose to remove the TCH variation contribution to obtain the vertical bias requirement.

Considering the following assumptions:

for ground alignment :

- ICAO Annex 10 chapter 3.1.5.1.2.2.: the GP angle shall be *adjusted and maintained* within 0.075θ from θ .
- ICAO Annex 10 chapter 3.1.5.7: the automatic monitor system shall provide a warning to the designated control points and cause radiation to cease within the period specified if the following condition persists: shift of the mean ILS GP angle equivalent to more than minus 0.075θ to plus 1.10θ.
- 0.075θ considered as a 5 sigmas value.

for course structure contribution (Noise):

- ICAO 3.1.5.6.the nominal angular displacement sensitivity shall correspond to a DDM of 0.0875 at angular displacements above and below the glide path between 0.07θ and 0.14θ.
- ICAO Annex 10 chapter 3.1.5.4 (path structure): bends in the glide path shall not have amplitudes which exceed the following *(95% probability*):
- Outer limit of coverage to ILS Point C: 0035 DDM

for displacement sensitivity variation contribution:

- ICAO 3.1.5.6.the nominal angular displacement sensitivity shall correspond to a DDM of 0.0875 at angular displacements above and below the glide path between 0.07θ and 0.14θ.
- ICAO 3.1.5.6.6: the angular displacement sensitivity shall be adjusted and maintained within plus or minus 25 per cent of the nominal value.
- ICAO Annex 10 chapter 3.1.5.7.1: the automatic monitor system shall provide a warning to the designated control points and cause radiation to cease within the period specified if the following condition persists: a change of the angle between the glide path and the line below the glide path (150 Hz predominating) at which a ddm of 0.0875 is realized by more than plus or minus 0.03750θ.

and for airborne error contribution:

- EUROCAE ED 47B: the max error due to the centring tolerance is 13% of standard deflection so 13% of 0.091 ddm so 0.01183 ddm (95%)

The 95% vertical navigation system error at the ILS CAT 1 D/H may be estimated to the quadratic summ of the ground system error plus the airborne subsystem error:

$$\sqrt{1.83^2 + 3.41^2 + 0.41^2 + 1.15^2} = 4.06m$$

95%Vertical ILS N.S.E. at ILS CAT 1 D/H= 4.06 m

B 2.3 Interpretation of monitor threshold value as a 5 sigmas value

ILS Localiser:

The time to alarm for ILS CAT 1 Localiser is fixed to 10 s. This implies that the monitor shall react (shutdown for a single system) if the bias error is exceeding the threshold during more than 10 seconds.
Taking into account that the COS requirement is 4 10^{-6} for a 15 seconds exposition time, the probability to have an interruption of the service during a 10 seconds period is 2.66 10^{-6}.

$4x10^{-6}$ x (10/15) = $2.66x10^{-6}$

An interruption of the service may be due to a failure in the equipment or a drift of the guidance signal without failure in the equipment. In the case of ILS, the experience gained by European CAA during a long period of time shows that ratio between these two events probabilities may be evaluated to 1/10 (90% of the service interruptions are due to failures). The probability of a shutdown of the system during a 10 seconds period due to a drift of the signal-in-space may be estimated to 2.66 10^{-7}.
This value corresponds to a 5.15 sigmas value.
So the10.5 m threshold bias monitor value can be assimilated to a 5 sigmas value.

The same methodology can be used for the displacement sensitivity variation monitor so the 17% displacement sensitivity variation threshold monitor value can be assimilated to a 5 sigmas value.

ILS Glide path:

The time to alarm for ILS CAT 1 Glide Path is fixed to 6 s.
The continuity risk for a 6 seconds period is therefore 1.6 10^{-6}.

$4x10^{-6}$ x (6/15) = $1.6x10^{-6}$

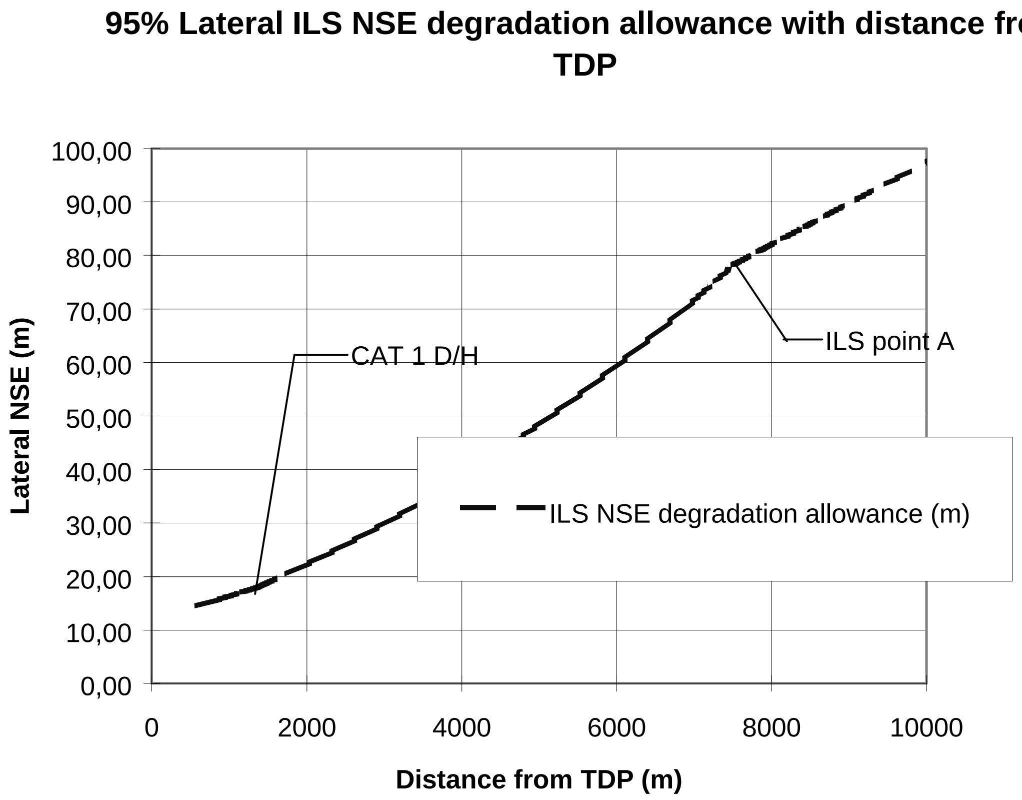
As in localiser case, 10% (TBC) are associated to a drift. The probability of a shutdown of the system during a 6 seconds period due to a drift of the signal-in-space may be therefore estimated to 1.6 10^{-7}. This value corresponds to a 5.25 sigma value.
So the 0.075θ threshold bias monitor value can be assimilated to a 5 sigmas value.

The same methodology can be used for the displacement sensitivity variation monitor so the 03750 displacement sensitivity threshold monitor value can be assimilated to a 5 sigmas value.

B.2.4 : Lateral Accuracy degradation with distance

Following tables give the allowed accuracy degradation with distance discussed in 3.2.1.3 and 3.2.2.3.

ILS POINT	Height	Distance from TDP	ILS NSE degradation allowance
	(ft)	(m)	(m)
T	50	286	
C (DH/2 CAT1)	100	582	14.53
	150	872	15.82
DH CAT1	200	1163	17.10
B	230	1338	17.87
	250	1454	18.61
	300	1745	20.53
	350	2036	22.54
	400	2326	24.64
	450	2617	26.84
	500	2908	29.13
	550	3199	31.51
	600	3490	33.99
	650	3780	36.57
	700	4071	39.24
	750	4362	42.02
	800	4653	44.88
	850	4944	47.85
	900	5234	50.92
	950	5525	54.08
	1000	5816	57.34
	1050	6107	60.70
	1100	6398	64.16
	1150	6688	67.72
	1200	6979	71.38
	1250	7270	75.14
A	1290	7503	78.22
	1300	7561	78.67
	1350	7852	80.90
	1359	7904	81.30
	1400	8142	83.13
	1450	8433	85.36
	1500	8724	87.59
	2000	11632	109.93
	2500	14540	132.32
	3000	17448	154.76
	3500	20356	177.28
	4000	23264	199.86
	4500	26172	222.54
	5000	29080	245.31
	5500	31988	268.18
	6000	34896	291.17
	6500	37804	314.28


95% Lateral ILS NSE degradation allowance with distance from TDP
Lateral NSE (m)
100,00
90,00
80,00
70,00
60,00
50,00
40,00
30,00
20,00
10,00
0,00
0
2000
4000
6000
8000
10000
Distance from TDP (m)
CAT 1 D/H
ILS point A
ILS NSE degradation allowance (m)

B.3 Estimation of GBAS Accuracy

Accuracy is specified in terms of a probability that the NSE is within required values. A 5% probability that the position error exceeds the required accuracy for an entire approach is considered as acceptable.

Things are different for ILS or MLS, with a sliding window methodology being recommended by annex 10. This kind of methodology is not applicable to GBAS because of the differences in error characteristics:

The orbiting of satellites results in position error which changes over a period of hours, unlike stationary systems (e.g. ILS), which show repeatable error characteristics.

The errors experienced with GNSS systems vary slowly over the time of an approach, as compared to ILS.

Besides, this specification only represents the typical error that will be experienced; the same level of safety as ILS is achieved through the integrity requirement, which ensures that the position error is within alert limits and therefore acceptable.

Acceptable means of compliance for such a requirement can be found in ACJ-JAR AWO 231 Section 2 «Analysis methods ». However, the requirements have to be satisfied for the worst-case geometry. A scaling factor has to be applied to measurement data in order to take into account the possible changes in geometry. This factor can be found out as the ratio of the alert limit over the protection limit computed by the integrity function.

APPENDIX C

GBAS - Continuity of Service

18.9.98

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1. GBAS CONTINUITY OF SERVICE CONCEPT

The risk of activation of the two tests intended to process the "geometry dependent" integrity risk (see section 1 of Appendix D), and hence the risk of loss of continuity, depends on the geometry of the satellites used by the aircraft subsystem. It was therefore chosen to have the aircraft subsystem also evaluate the risk of loss of continuity related to these two tests.

It should be noted that any « geometry dependent » loss of continuity due to errors detected by the aircraft subsystem as greater than the Alert Limits are converted into loss of availability.

2. REQUIREMENT ALLOCATION

Only the continuity of service of the Signal in Space is specified (see § 3.3).

The Signal in Space continuity of service is the **probability** that a **fault-free aircraft subsystem**[1] provides valid outputs during any 15s period of an approach, assuming that outputs were valid at the start of the period. Outputs are considered as valid if the NSE is lower than Alert Limit and if there is no warning (§ 3.3.2).

The value adopted is the same as that for the level 2 ILS ground equipment. This is the continuity of service performance required for category II operations and the desirable objective for category I operations (ICAO Annex 10, Attachment C to part I, § 2.14).

Ed. Note: provide the new references in white pages ?

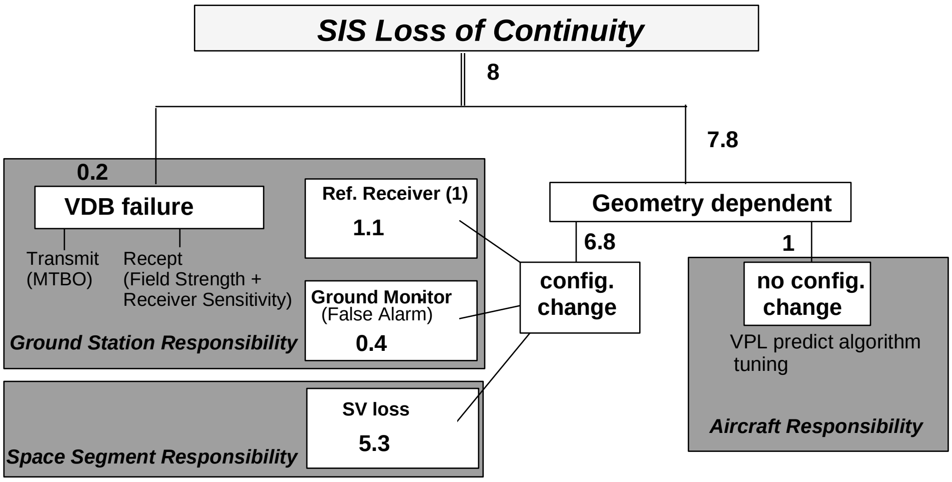
For the ILS, the requirements are specified separately for the Glide Slope and Localizer:
> 1 - 4 x 10-6 per 15s period for each of them.
In the case of the GBAS, the value chosen is 1 - 8 x 10-6 during any 15s period of an approach for the two axes together.

[1] Cf. Appendix C section 2.4

3.

CONTINUITY OF THE SIGNAL IN SPACE

The figure below shows the different causes of loss of continuity.



Loss of Continuity causes (in 10^{-6}/15 sec)

The loss of continuity of service of the Signal in Space has several causes:

1 - "Geometry dependent" Causes

These are all the cases where the aircraft subsystem detects a "geometry dependent" integrity defect (cf. Appendix D).

- If there is no unexpected configuration change of the satellites used, at the start of approach the aircraft subsystem must evaluate the risk of loss of continuity of service throughout the approach (due to the detection of a "geometry dependent" integrity defect)[2]. To do this, it uses the information of the type 5 message (Predicted Ranging Sources Availability) which indicates the future availability of differential corrections to the ranging measurements. If the risk of loss of continuity is higher than 1 x 10-6 / 15 s, the system is declared to be unavailable for the approach.
- In case of unexpected loss of one satellite, if it is a "critical" satellite (i.e. a satellite whose loss results in the detection of a "geometry dependent" integrity defect by the aircraft subsystem, and hence the loss of continuity of service).
  The causes of unexpected loss of satellites are the following:
  - Satellite outage. Assuming that there are a maximum of seven critical satellites, the probability of loss of continuity is: 7 x 7.5 x 10-7 / 15 s (7.5 x 10-7 / 15 s corresponds to a satellite MTBO of 5 550 hours).
  - Unjustified rejection of a satellite by the ground station (either through loss of a reference receiver for the ground subsystems with only two reference receivers, or through unjustified detection by the Ground Monitor (1.1 + 0.4 = 1.5 x 10-6 / 15s).

2 - All other causes

For example in case of loss of airborne reception (shutdown of the VHF Data Broadcast, insufficient field strength, etc.)

A maximum value of 0.2 x 10-6 /15s is allocated for this last point.

[2] "VPL/HPL Predict algorithm "

To recapitulate:

- The risk of loss of continuity of service of the station must be less than 1.7 x 10-6 / 15s, given that this includes:
  - the interrupted transmission of the corrections related to a satellite which is not justified by the change of the satellite constellation.
  - non-reception of the VDB by a fault-free aircraft subsystem.
- The aircraft subsystem must check at the start of approach that the probability of loss-of-integrity detection being activated is less than 1 x 10-6 during any 15 s period of the approach.

This is based on the assumption that the satellites have an MTBO of more than 5 550 hours.

APPENDIX D

GBAS - Integrity

18.9.98

TABLE OF CONTENTS

1. GBAS INTEGRITY CONCEPT

The integrity constraint makes it necessary to detect any errors of the deviations supplied on board the aircraft (errors greater than the Alert Limit) with a sufficient probability and within a specified time (Time to Alert). It is therefore concerned with quantities in the position domain.

The choice made is to have the following detected by the aircraft subsystems:

- position errors greater than the Alert Limit due to the **fault free measurement inaccuracy** of the whole system (space, ground and aircraft subsystems).
  To do this, the aircraft subsystem:
  - uses a normal distribution which overbounds in the tails the error distribution on the pseudoranges coming from the whole system. For this purpose, it uses (among others) the numbers σ_{pr_gnd} sent by the ground subsystem for each pseudorange correction. They characterize the normal distribution that overbounds in the tails the errors on the pseudorange corrections sent by the ground subsystem.
  - projects this distribution in the position domain, considering the geometry of the satellites that it uses.
  - deduces an alert if the probability of having a position error greater than the Alert Limit exceeds the specified value.

- the position errors greater than the Alert Limit that are due to a **failure of one ground subsystem reference receiver.**

Their detection is based on multiple measurements of the pseudoranges by several reference receivers in the ground subsystem. These multiple measurements (or their combinations Prc, B1, B2, B3 and B4 in fact) are transmitted to the aircraft subsystems. They detect the errors by comparison of the resulting positions and taking the distribution of the measurement errors into account.

These two types of integrity risk are called "**geometry dependent**". Although they are partly due to the ground subsystem, they are processed on board the aircraft.

The reasons for this choice are as follows:

- Because the maximum permissible errors (Alert Limit) are expressed in terms of position, their transposition into terms of maximum permissible error on the pseudorange corrections sent by the ground subsystem and that are valid for all the possible constellation geometries would have resulted in:
  - accuracy requirements for the pseudorange corrections that would be excessively severe for the first case,
  - comparison thresholds for the outputs of the reference receivers that would be too low, giving rise to numerous unjustified detections in the second case (due to the uncertainties in receiver clock bias removal there are significant discrepancies between the pseudorange measurements delivered by different receivers).

  This therefore means that the two tests cannot be performed in the pseudorange domain but in the position domain.
- The changeover to the position domain could easily be done by the ground subsystem but:
  - it is not certain that the aircraft subsystems use the same set of satellites. This is why these tests are performed on board, taking in account the exact geometry of the satellite configuration used to change over from the pseudorange domain to the position domain.
  - the value of the Alert Limit depends on the altitude and distance of the aircraft.

It should be noted that any « geometry dependent » error greater than the Alert Limit are converted into loss of continuity by the aircraft subsystem.

2. REQUIREMENT ALLOCATION

Only the integrity of the Signal in Space is specified (see § 3.5).

The Signal in Space integrity risk is the **probability** that the NSE, at the deviation output of **a fault-free aircraft subsystem**, exceeds the **Alert Limit** without annunciation for longer than the Signal in Space **Time to Alert** (§ 3.7.2).

2.1. Probability

The value chosen is the same as that of the level 2 ILS ground equipment. This is the integrity performance required for category II operations and the desirable objective for category I operations (ICAO Annex 10, Attachment C to part I, § 2.14).
Ed. Note: provide the new references in white pages ?

For the ILS, the requirements are specified separately for the Glide Slope and Localizer: < 1 x 10-7 per approach for each of them.
In the case of the GBAS, the value chosen is **2 x 10-7 per approach** for the two axes together.

2.2. Alert Limit

Considerations in Appendix B (§ 2.3) about the monitor thresholds of ILS given by ICAO Annex 10 (§ 3.1.3.11.2 and § 3.1.7.7) show that they approximately correspond to 5 sigma values. Thus, for GBAS this relationship is extended to the whole coverage and the Alert Limit is allocated to 5/2 of the GBAS 95 % NSE accuracy requirements.

2.3.

Signal in Space Time to Alert

See § 3.7.

2.4. Fault-free aircraft subsystem

The integrity risk is expressed in terms of position. As the Signal in Space does not directly include the position, the notion of fault-free aircraft subsystem is used for certain requirements: an aircraft subsystem with nominal accuracy performance and which, because it is assumed to have no failures, does not affect the integrity and continuity performance. This is simply a means of converting the Signal in Space into terms of position.

3. Integrity of the Signal in Space

The integrity risk of the Signal in Space has several causes:

3.1. "Geometry Dependent" integrity risk

For the reasons given above (§ 1), the elimination of the two integrity risks described in section 1 is the responsibility of the aircraft subsystem.

The maximum probability allocated to the risk of having an error greater than the Alert Limit is 25 % of the SIS integrity risk, i.e. 0.5 x 10-7 per approach.

To do this, the ground subsystem sends the following information:

- Pseudorange Corrections: They are calculated from the satellite broadcast data for a given satellite at the ground reference receiver. Ionospheric and tropospheric corrections are not applied.
  Pseudorange corrections are the average of the corrections based on measurements from multiple ground reference receivers.
- B_1 through B_4: the differences between the broadcast pseudorange correction and the corrections obtained excluding the specific reference receiver measurement.
- σ_{pr_gnd}: defines two normal distributions relative to the pseudorange corrections sent by the ground subsystem:
  1 - a normal distribution with a zero mean [$N(0, \sigma^2_{pr\_gnd})$], which overbounds in the tails the error probability density function if there is no failed receiver,
  2 - a normal distribution with a mean of B_j [$N(B_j, M\sigma^2_{pr\_gnd}/(M-1))$], which overbounds in the tails the error probability density function in the case where there is a fault in the jth receiver measurement. (Where M is the number of valid measurements. All ones ('1111 1111') indicate that a ranging source's corrections have been identified as invalid by the ground system.*)*

Ed. Note: It is important to describe precisely the responsibilities of the aircraft subsystem. On the other hand, the standardization of the maximum probability level is not strictly necessary for interoperability (it is up to the aircraft subsystem designer to balance the different integrity risk figures).

Ed. Note: In so far as the ground subsystems do not have to estimate the availability, it is not necessary to standardize the airborne algorithms[1] that process the "geometry dependent" integrity (or include the description of a possible algorithm implementation for information?).
Similarly, it is not necessary to standardize the fault-free aircraft subsystem (if it had to be standardized, the requirement of 0.5 x 10-7 would be included).

[1] "VPL/HPL algorithm" (Vertical Protection Level/ Horizontal Protection Level)

3.2. All the other risks

The elimination of all the other risks is the responsibility of the ground subsystem.

The maximum probability allocated to the risk of having an error greater than the Alert Limit is 75 % of the SIS integrity risk, i.e. 1.5 x 10-7 per approach.

Among others, this includes:

- Failures in the ground system that cause erroneous data to be broadcast (e.g. failures of the processor computing the broadcast values); or
- Undetected failures in the space subsystem that affect aircraft subsystem and ground subsystem reference receivers differently;
- Undetected failures of measurements from more than one reference receiver (including failures introducing common errors among the reference receivers or preventing the Bi values to reflect the results of independent reference receivers);
- Undetected VDB failures; and
- Other undetected events that produce residual errors in the Signal in Space that result in misleading information (e.g., incorrect FAS, tropospheric or ionospheric anomalies).

In addition, in order to not jeopardize integrity and continuity of service of surrounding GBAS, the probability of a TDMA out-of-slot transmission, which exceeds the allowed threshold, within 1 second shall be less than [2×10^{-7}] per 150 second period.

APPENDIX E

GBAS AVAILABILITY

1 GBAS Availability concept

Availability is considered as an operational, more than a safety requirement. However, availability is a key parameter in the design of GBAS. As it is shown in the previous appendices, integrity is linked to accuracy requirements (Alert limits) and loss of integrity (geometry dependent) is converted into loss of continuity, which is converted into loss of availability. GBAS availability results from the concepts developed to meet the previous requirements, combined with the status of the ranging sources constellations.

A landing system availability can be defined as the following equation (AWOP 15th meeting) :

$$A = A_P * A_F * A_M \qquad \text{(Equation C1)}$$

For ILS Cat I, AWOP considers the following values :

A = 0.9975

A_P : Fault free system availability, is set to 1.

A_F : Availability of the ground and airborne subsystems, as determined by MTBO and MTTR. For ILS Cat I, ICAO Annex 10 requires 500hr MTBO for the ground subsystem (1000hr for the Localizer and 1000hr for the Glide Path), which results in a 0.998 factor and AWOP considers a 2000hr MTBO, with 1 hr MTTR, which gives 0.9995. The product is 0.9975.

A_M : Availability of the ground and airborne subsystems, taking into account scheduled maintenance operations. This factor is set to 1, considering that maintenance is performed when the system is not needed

This can be adapted to GBAS, if:

- A_P takes into account the ranging sources constellation and the accuracy performances of the ground and airborne subsystems. This could be considered as the ”Geometry dependent ”component of availability.
- Scheduled maintenance operations for the space segment are included in A_P.

Only assumptions can be made on the status of the ranging sources constellations (number of satellites, presence of SBAS), which has a direct impact on the availability of GBAS. Moreover, the availability requirement depends upon operational need. The minimum availability value of 0.99 taken into account by ICAO is considered as practical but not sufficient to replace non-GNSS navigation aids. In order to provide the same level of performance as an ILS Cat I, GBAS availability should be 0.9975.

This can be achieved with the following values:

A_P = 0.9986. Estimations of this parameter are given in part 2 of this appendix.

A_F = 0.9989 This parameter represents the combination of ground and airborne subsystems failures probability. This could be obtained with the following allocation:

Ground subsystem: 0.99934

To be consistent with the continuity of service requirement of 2.5 10^{-6} (see appendix B), the ground subsystem MTBO will be better than 1666 hr. The figure above has been obtained considering a 1 hr MTTR.

Airborne subsystem: 0.9995. This would be equivalent to ILS.

2 Evaluation of GBAS Availability

This section presents the result of simulations run in order to evaluate the "Geometry dependent" component of availability; A_P of equation C1 in the case of GBAS.

Main inputs for simulations:

- ***Almanac***: it can be input with a YUMA format (option) or directly in SPS format (ICD-200 GPS). For availability simulations, a special function allows us to de-select one or more satellites and test any sub-constellations (N-1, N-2, N-3, N-4).
- *Number of* ***SBAS Ranging Sources***
- ***Simulation time***: the inputs are the initial and final time, and the granularity (step time)
- ***Station location***: in this version, the station and user location are the same and fixed, but errors due to decorrelation are taken into account through the use of residual differential errors (function of the distance between the differential reference point and the remote user) in the total error model.
- ***Accuracy Designators*** for Ground and Airborne receivers: the accuracy models for ground and airborne receivers are defined in section 3.2.3 of this MASPS. Residuals errors refer to factors a_2 and a_3 in the equation of SIS error given in 3.2.3.1. Some simulations don't take into account theses terms (a_2 and a_3 are then set to 0).
- ***Alarm limit*** for Performance Type 1 (to PT 3) operations
- ***Number of reference receivers***: 2, 3 or 4 receivers
- ***Elevation mask*** for ground and airborne receivers

Simulation hypotheses:

Long term availability

GPS constellation

- Ideal 24 SVs GPS constellations (Appendix B RTCA-DO 229) with N, N-1, N-2, N-3, N-4 satellites
Probabilities of N operational satellites are:

Number of operational satellites (N)	Number of sub-constellations	Durand-Caseau Model	Normalised Durand-Caseau Model	RTCA MASPS Model
24	**1**	**70.05 %**	**70.08 %**	**72.0 %**
23	**24**	**23.69 %**	**23.70 %**	**17.0 %**
22	**276**	**5.04 %**	**5.04 %**	**6.4 %**
21	**2024**	**1.00 %**	**1.00 %**	**2.6 %**
20	**10626**	**0.18 %**	**0.18 %**	**2.0 %**
Total	**12951**	**99.96 %**	**100.00 %**	**100.0 %**

Source: W.S.Phlong and B.D.Elrod, "Availability Characteristics of GPS and Augmentation Alternatives" Navigation, Vol.40, n°4, Winter 93-94

Durand-Caseau model assumes that the probability that i satellites out of 24 are simultaneously functional is determined by considering the constellation as a homogeneous, finite-state Markov process. For any given N, all possible combinations of N operational satellites are assumed to be equally likely. Only the Durand-Caseau Model will be used for the simulations.

Geo Satellites Augmentation

Three GS (AOR-E, AOR-W and IOR) have been taken into account in the simulations.

- OR-E Almanac: $\begin{cases} X = 40617500m \\ Y = -11287500m \\ Z = 25000m \end{cases}$
- AOR-W W 54°
- IOR E 64.5°

- GS Operational Probabilities:

Number of GS SVs Failed	1 GS Case	2 GS Case	3 GS Case
0	99.05 %	98.11 %	97.17 %
1	0.95 %	1.88 %	2,79 %
2	N/A	0.01 %	0.04 %
3	N/A	N/A	< 0.001 %

Operational Availability

Final Operational Capability was declared for GPS on July 17, 1995. Shown below is the percentage of time that a particular number of satellites were operational between July 17, 1995 and November 1997.

Number of Operational Satellites (N)	**Percentage of Time with N Operational Satellites**
26	3.48 %
25	46.55 %
24	43.70 %
23	6.18 %
22	0.09 %
≤ 21	0.00 %

Given this service history, it is reasonable to consider a 22-satellite GPS constellation when evaluating the operational availability. Individual service providers should consider the issues identified above and determine what failure modes are to be considered.
In this case, the hypotheses on the ranging sources constellation for the simulations are based on observations of the actual GPS constellation. Simulation results show more realistic estimation of availability that can be expected and the impact of the status of the constellation.

Availability Conditions

GBAS service is defined to be available if the requirements about accuracy (95% Vertical NSE < 4 m), integrity (VAL = 10 m) and continuity are declared met at the initiation of the approach. Actually, only vertical measurements are simulated since requirements for the vertical axis are the most stringent and related performances worse than those of the lateral axis. VPL concept, as described in RTCA LAAS MASPS, has been used for these simulations to provide integrity and continuity.

ED note: simulations below take into account two levels of accuracy for the airborne receiver which are AAD A and B defined by RTCA MASPS. EUROCAE now only consider AAD A for GPS but values have been introduced for GLONASS receiver. New simulations have to be run and results about AAD B will be replaced by results with GLONASS.

Accuracy configurations

Numerous configurations between Ground Accuracy Designators (GAD 'A' or 'B'), number of reference receivers (M=2 to 4) and Airborne Accuracy Designators (AAD 'A' or 'B') have been tested: A3/A, A3/B, A4/A, A4/B, B2/A, B2/B, B3/A, B3/B, B4/A, B4/B.
Ground Accuracy Designator 'C' is not evaluated since it is designed for Performance Type higher than I (PT2, PT3).

NB. *Simulations with residual differential errors are addressed as A3*/A while the same simulations without residual differential errors are A3/A. Generally, residual errors have been introduced in the simulations in order to represent a worst case.*

Other hypotheses

- Duration: 23 h56min period (granularity: 1 min., except for N-3 and N-4 sub-constellations: 2 min.)
- Locations:

LOCATION		Latitude (°)	Longitude (°)	Altitude (m)	AOR-E elevation (°)
ALGER	**ALG**	N 36.833	E 3.00	0	43.05
AMSTERDAM	**AMS**	N 52.35	E 4.9	0	27.22
ATHENS	**ATH**	N 38.00	E 23.733	0	30.10
COPENHAGEN	**COP**	N 55.717	E 12.567	0	21.75
DUBLIN	**DUB**	N 53.333	W 6.25	0	28.50
FRANKFORT	**FRA**	N 50.10	E 8.683	150	28.17
GENEVA	**GEN**	N 46.217	E 6.15	550	32.73
HAMBURG	**HAM**	N 53.55	E 10.00	0	24.54
KRASNOYARSK	**KRA**	N 56.083	E 92.767	200	not vis.
LISBON	**LIS**	N 38.733	W 9.133	0	44.68
LONDON	**LON**	N 51.5	W 0.167	50	29.34
MADRID	**MAD**	N 40.417	W 3.717	650	41.73
MUNICH	**MUN**	N 48.133	E 11.583	450	28.86
OSLO	**OSL**	N 59.933	E 10.75	0	18.48
PARIS	**CDG**	N 49.02	E 2.57	164	31.15
RABAT	**RAB**	N 34.033	W 6.85	0	49.39
ROME	**ROM**	N 41.833	E 12.5	0	33.94
ST PETERSBURG	**PET**	N 59.917	E 30.417	0	11.92
STOCKHOLM	**STO**	N 59.333	E 18.083	0	16.84
TOULOUSE	**TLS**	N 43.6	E 1.3	200	36.97
TUNIS	**TUN**	N 36.833	E 10.217	0	39.45

Availability Results:

GPS only

Toulouse

- **GAD = 'A'**

With Residual Differential Errors

	Long term Availability		Operational Availability	
Accuracy Designation Ground / Airborne	**Durand-Caseau Model**	**Normalised Durand-Caseau Model**	**Worst case (22 SVs)**	**Full constellation**
A3*/A	99.587	99.627	97.624	99.948
A3*/B	99.617	99.657	97.820	99.953
A4*/A	99.791	99.831	98.889	99.978
A4*/B	99.807	99.847	98.990	99.981

- **GAD = 'B'**

	Long term Availability		Operational Availability	
Accuracy Designation Ground / Airborne	**Durand-Caseau Model**	**Normalised Durand-Caseau Model**	**Worst case (22 SVs)**	**Full constellation**
B2*/A	99.765	99.805	98.695	99.976
B2*/B	99.789	99.829	98.804	99.978
B3*/A	99.896	99.936	99.567	99.993
B3*/B	99.906	99.946	99.632	99.994

Roissy

- **GAD = 'A'**

With Residual Differential Errors

	Long term Availability		Operational Availability	
Accuracy Designation Ground / Airborne	**Durand-Caseau Model**	**Normalised Durand-Caseau Model**	**Worst case (22 SVs)**	**Full constellation**
A3*/A	99.710	99.750	98.325	99.969
A3*/B	99.730	99.770	98.436	99.971
A4*/A	99.835	99.875	99.168	99.985
A4*/B	99.849	99.889	99.235	99.986

- **GAD = 'B'**

	Long term Availability		Operational Availability	
Accuracy Designation Ground / Airborne	**Durand-Caseau Model**	**Normalised Durand-Caseau Model**	**Worst case (22 SVs)**	**Full constellation**
B2*/A	99.810	99.850	98.946	99.981
B2*/B	99.852	99.892	99.236	99.987
B3*/A	99.901	99.941	99.600	99.993
B3*/B	99.910	99.950	99.650	99.994

GPS + 1 GS (AOR-E) - Location: Toulouse

- **GAD = 'A'**

With Residual Differential Errors

	Long term Availability		Operational Availability	
Accuracy Designation Ground / Airborne	**Durand-Caseau Model**	**Normalised Durand-Caseau Model**	**Worst case (22 SVs)**	**Full constellation**
A3*/A	99.729	99.769	98.475	99.971
A3*/B	99.745	99.785	98.579	99.973
A4*/A	99.899	99.939	99.541	99.995
A4*/B	99.907	99.947	99.596	99.995

- **GAD = 'B'**

	Long term Availability		Operational Availability	
Accuracy Designation Ground / Airborne	**Durand-Caseau Model**	**Normalised Durand-Caseau Model**	**Worst case (22 SVs)**	**Full constellation**
B2*/A	99.844	99.884	99.191	99.987
B2*/B	99.899	99.939	99.552	99.994
B3*/A	99.934	99.974	99.817	99.997
B3*/B	99.938	99.978	99.849	99.998

GPS + 2 GS - Location: Toulouse

- **AD = 'A3*/A'**

	Long term Availability		Operational Availability	
Accuracy Designation Ground / Airborne	**Durand-Caseau Model**	**Normalised Durand-Caseau Model**	**Worst case (22 SVs)**	**Full constellation**
AOR-E / AOR-W	99.921	99.961	99.716	99.9961
AOR-E / IOR	99.937	99.977	99.776	99.9992
AOR-W / IOR	99.938	99.978	99.800	99.9986

- **GAD = 'B3*/A'**

	Long term Availability		Operational Availability	
Accuracy Designation Ground / Airborne	**Durand-Caseau Model**	**Normalised Durand-Caseau Model**	**Worst case (22 SVs)**	**Full constellation**
AOR-E / AOR-W	99.959	99.999	99.989	99.99995
AOR-E / IOR	99.958	99.998	99.976	99.99995
AOR-W / IOR	99.959	99.999	99.988	99.99995

GPS + 3 GS (AOR-E/AOR-W/IOR) - Location: Toulouse

	Long term Availability		Operational Availability	
Accuracy Designation Ground / Airborne	**Durand-Caseau Model**	**Normalised Durand-Caseau Model**	**Worst case (22 SVs)**	**Full constellation**
A3*/A	99.950	99.990	99.901	99.9998
B3*/A	99.960	99.99996	99.9997	$100 - 1.10^{-6}$

European Cities

Simulations have been performed for constellations of 24 SVs down to 21 SVs only.

- **GAD = 'A3*/A + AOR-E'**

	Long term Availability		Operational Availability	
Cities	**Durand-Caseau Model**	**Normalised Durand-Caseau Model**	**Worst case (22 SVs)**	**Full constellation**
Alger	99.733	99.773	98.422	99.9715
Amsterdam	99.792	99.832	98.855	99.9785
Athens	99.609	99.649	97.776	99.9499
Copenhagen	99.775	99.815	98.803	99.9744
Dublin	99.807	99.847	98.963	99.9801
Frankfort	99.756	99.796	98.673	99.9721
Geneva	99.745	99.785	98.565	99.9715
Hamburg	99.767	99.807	98.759	99.9733
Krasnoyarsk	*GS not visible*			
Lisbon	99.764	99.804	98.636	99.9754
London	99.803	99.843	98.917	99.9802
Madrid	99.725	99.764	98.399	99.9693
Munich	99.734	99.774	98.538	99.9686
Oslo	99.739	99.779	98.599	99.9685
Rabat	99.744	99.784	98.534	99.9720
Rome	99.749	99.789	98.559	99.9729
St Petersburg	99.555	99.595	97.766	99.9346
Stockholm	99.698	99.738	98.387	99.9614
Toulouse	99.734	99.774	98.475	99.9706
Tunis	99.731	99.771	98.425	99.9710

- **GAD = 'B2*/A'**

	Long term Availability		**Operational Availability**	
Cities	**Durand-Caseau Model**	**Normalised Durand-Caseau Model**	**Worst case (22 SVs)**	**Full constellation**
Alger	99.824	99.864	99.037	99.9836
Amsterdam	99.822	99.862	99.070	99.9824
Athens	99.758	99.798	98.667	99.9728
Copenhagen	99.812	99.852	99.018	99.9803
Dublin	99.842	99.882	99.165	99.9857
Frankfort	99.824	99.864	99.073	99.9827
Geneva	99.818	99.858	99.021	99.9821
Hamburg	99.818	99.858	99.052	99.9814
Krasnoyarsk	99.784	99.824	98.850	99.9761
Lisbon	99.838	99.878	99.109	99.9860
London	99.827	99.867	99.094	99.9831
Madrid	99.808	99.847	98.959	99.9805
Munich	99.829	99.869	99.093	99.9837
Oslo	99.772	99.811	98.784	99.9739
Paris-CDG	99.799	99.839	98.784	99.9812
Rabat	99.835	99.875	99.098	99.9855
Rome	98.848	99.880	99.167	99.9877
St Petersburg	99.643	99.683	98.228	99.9497
Stockholm	99.753	99.793	98.687	99.9708
Toulouse	99.769	99.809	98.695	99.9756
Tunis	99.842	99.882	99.107	99.9875

- **GAD = 'B3*/A'**

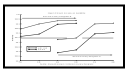
	Long term Availability		**Operational Availability**	
Cities	**Durand-Caseau Model**	**Normalised Durand-Caseau Model**	**Worst case (22 SVs)**	**Full constellation**
Alger	99.910	99.950	99.648	99.9942
Amsterdam	99.907	99.947	99.615	99.9940
Athens	99.888	99.928	99.477	99.9919
Copenhagen	99.931	99.971	99.749	99.9979
Dublin	99.917	99.957	99.686	99.9953
Frankfort	99.908	99.948	99.613	99.9946
Geneva	99.902	99.942	99.579	99.9934
Hamburg	99.918	99.958	99.676	99.9960
Krasnoyarsk	99.926	99.966	99.707	99.9975
Lisbon	99.928	99.968	99.719	99.9979
London	99.906	99.946	99.626	99.9935
Madrid	99.899	99.939	99.586	99.9923
Munich	99.915	99.955	99.589	99.9936
Oslo	99.920	99.960	99.690	99.9962
Paris-CDG	99.901	99.941	99.600	99.9929
Rabat	99.927	99.967	99.712	99.9977
Rome	99.920	99.960	99.670	99.9967
St Petersburg	99.855	99.895	99.477	99.9825
Stockholm	99.921	99.961	99.686	99.9966
Toulouse	99.898	99.938	99.567	99.9927
Tunis	99.911	99.951	99.643	99.9948

Analysis

Impact of the main parameters on availability performance

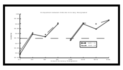
		Ground Accuracy Designator A			Ground Accuracy Designator B		
		M = 2	M = 3	M = 4	M = 2	M = 3	M = 4
Airborne Accuracy Designator A	GPS	N	N	Y	Y	Y	Y
	GPS + 1 GS	N	N	Y	Y	Y	Y
Airborne Accuracy Designator B	GPS	N	N	Y	Y	Y	Y
	GPS + 1 GS	N	N	Y	Y	Y	Y

The above table shows the configurations needed for A_P = 0.9975, which corresponds to a total system availability of 0.996. It could be said that generally, Ground Accuracy Designator 'A' does not allow a sufficient availability without any other augmentations, except for cases M=4 (4 reference receivers).



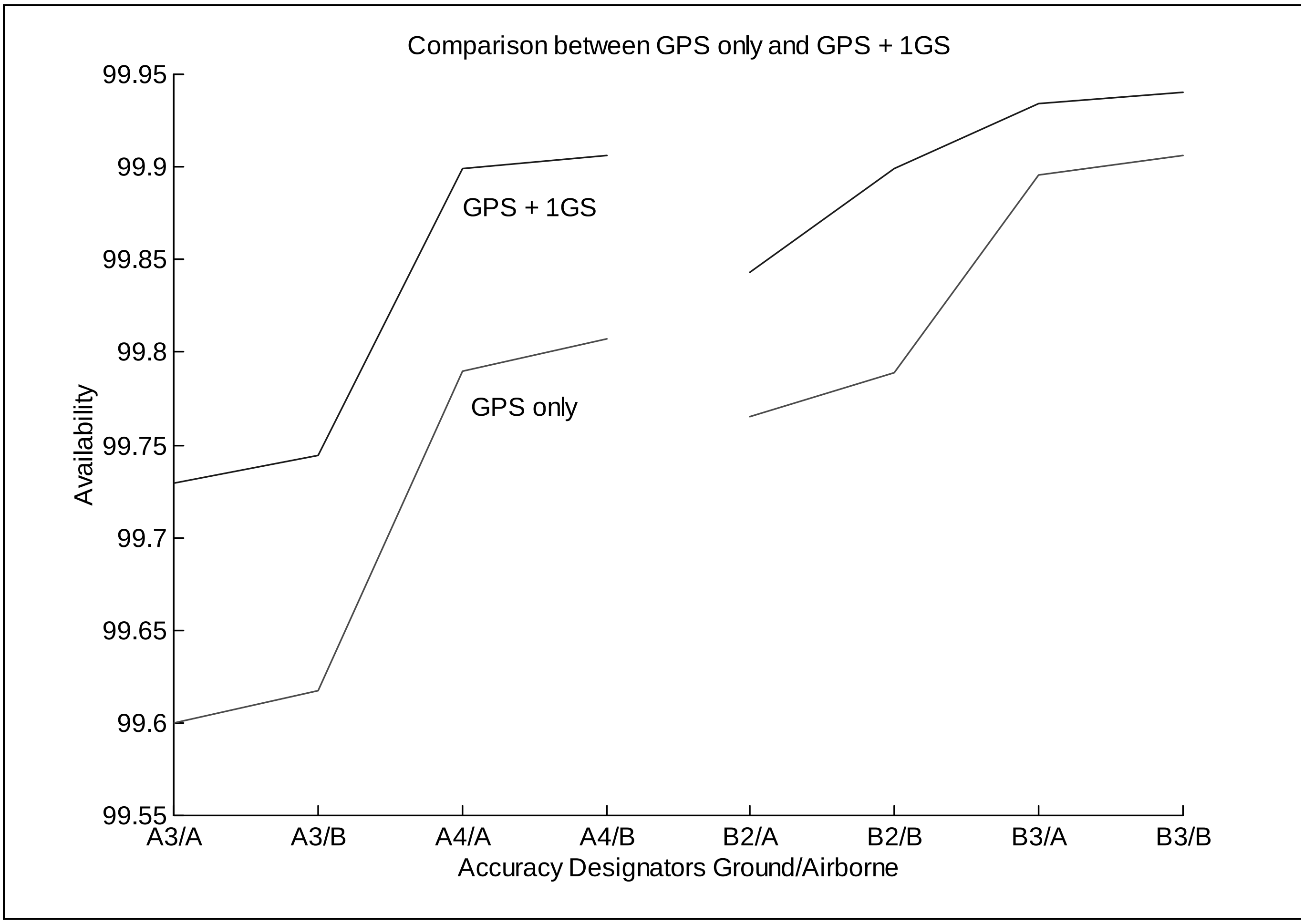
The graph presented above shows also that ground configurations A4 without GS ranging sources are better than ground configuration B2 without GS, and ground configurations A4 with one GS ranging source are also better than B3 without one GS ranging source.
Therefore, Ground Configuration A4, especially with SBAS, even if it could represent an expensive and complex solution, are not to be ignored.

Airborne Accuracy Comparison



This graph clearly demonstrates that Ground Accuracy Designators and the number M of receivers are the determining parameters of availability performance as the improvement with Airborne Accuracy Designator 'B' compared to 'A' is not tremendous.
It also confirms that A4 configuration is better than B2, in spite of the greater accuracy of B2. This demonstrates the importance of the M parameter on availability.

Comparison between "GPS only" and "GPS + 1GS (AOR-E)"



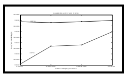
SBAS ranging source greatly improve the availability. However, the improvement is not as important as for an extra reference receiver as shown for instance by A3/A with one GS and A4/A without GS. However, as shown in the table below, the improvement in availability depends on which SBAS is taken into account.(Simulation for Toulouse with AOR-W, IOR):

A3*/A ***(24 to 21 SVs const.)***	**Long term Availability**		**Operational Availability**	
Accuracy Designation Ground / Airborne	**Durand-Caseau Model**	**Normalised Durand-Caseau Model**	**Worst case (22 SVs)**	**Full constellation**
AOR-E (elev. 37°)	99.734	99.774	98.475	99.9706
AOR-W (elev. 16°)	99.869	99.909	99.338	99.9896
IOR (elev. 10.5°)	99.862	99.902	99.267	99.9891
GPS only	99.592	99.632	97.624	99.9482

Even if the elevation of the IOR and AOR-W GSs is lower than AOR-E one, the better geometric effect on availability is stronger than the relative loss of accuracy.

All these simulations have taken into account measurements on the SBAS pseudorange about twice less accurate than for GPS pseudorange measurements. This is due to first generation GSs and could be improved in the future

Availability with 2 and 3 GSs

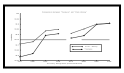


Once again, the effect of additional SBAS ranging sources is more sensitive on low accuracy configurations ('A3/A') because the geometric improvement on constellations is predominant.

From 2 to 3 SBAS ranging sources, the availability improvement is really important (> 99.92 %) even with low accuracy configurations like ‘A3’. With a Ground Accuracy Designator ‘B3’, Category 1 availability requirement is met with comfortable margins. Hence, these configurations could be useful for higher performance types

Comparison between different locations: ”Toulouse”and ”Roissy”

The following graph shows that we can experience a great difference in availability results between to different ground station locations. This is obviously due to relative geometry of the GPS constellation between these two sites.
It is also important to notice that these geometric effects are reduced with an increased accuracy or with a greater number of reference receivers (which has the same effect as the number of reference receivers improved the accuracy of the composite pseudorange correction). And for a Ground Accuracy Designator 'B3', the difference is negligible.



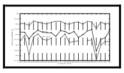
European locations

Simulations have been performed for three different accuracy configurations and over 21 cities in order to highlight geographical effects in Europe. It is difficult to determine better regions than other because relative availability performances are different for two given locations depending on the accuracy designators (for instance Oslo and Paris for B3/A and A3/A). Therefore, it is impossible to say a priori that availability is always better in a certain place than in an other.

Comparing B3/A, B2/A and A3/A results, we could say that better the accuracy is, lesser is the impact of the geographical differences on availability performances. as shown by the three different curves.

As said before, the availability requirement is generally met from B2/A and higher accuracy designations. But this is not true for St Petersburg for instance. For that point also, it is therefore impossible to fix definite rules since exceptions exist.

However, the geographical effect is more sensitive on simulations with a SBAS ranging source (A3/A + 1GS).



Conclusions

- Ground Accuracy Designator and the number M of reference receivers are the main parameters which determine the availability performance for a particular site.
- Ground Accuracy Designator ‘B’ with the 2 reference receivers is needed for A_P = 0.9975 (which corresponds to a total system availability of 0.996) at most of the European locations tested. However, in certain cases an ‘A4’ GAD could give a better availability, but a ‘B2’ GAD is preferable since it is more accurate and could be augmented by additional reference receivers.

- For a given configuration, a single SBAS ranging source greatly improve the availability only if the elevation of geostationary satellite at the reference station is low (< 20°).
- From 2 to 3 SBAS ranging sources, the availability improvement is really important (> 99.92 %) even with low accuracy configuration like ‘A3’. With a Ground Accuracy Designator ‘B3’, Category 1 availability requirement is met.
- Simulations on several European cities have demonstrated that availability performances are also very sensitive to geographic locations and it is really difficult to extrapolate results from an particular location to another close location. This is why ‘comfortable‘ accuracy configurations are preferable in order to provide performance margins useful for the robustness of the system performances. Comparisons with operational requirements will also demonstrate the need of these margins.

APPENDIX F

VHF IMPLANTATION OF DATA BROADCAST

18.11.98

TABLE OF CONTENTS

1. F. DATA BROADCAST radio frequency (RF) characteristics.

This Appendix describes the Signal-in-Space for the GBAS VHF Data Broadcast (VDB). The broadcast is a Time Division Multiple Access (TDMA), VHF data broadcast which complies with the physical layer of the ISO stack protocol described in ICAO Document AMCP/3-R/8A (VHF Digital Link Manual).

1.1 F. Carrier Frequency.

The Data Broadcast shall operate on 25 kHz channels within the frequency band 108.000 MHz to 117.975 MHz. The first channel shall be centred on 108.000 MHz and the highest channel shall be centred at 117.975 MHz.

Note .-ILS/GBAS geographical separation criteria are under development. Until these criteria are defined and included in SARPS, it is intended that frequencies in the band 112-117.975 MHz will be used.

1.2 F. Carrier frequency stability.

The long-term frequency stability of the ground station transmitter carrier shall be ± 0.0002% of the assigned frequency (± 2 parts per million). This shall be maintained during all operational periods and over all the operating environmental conditions of ground transmitter.

1.3 F. Polarization.

Right hand polarization shall be used.

Note. Criteria for application of elliptical polarization are under development. Until these criteria are developed and included in SARPS, it is intended that horizontal polarization will be used.

1.4 F. Field Strength.

. The effective radiated power (ERP) shall provide for its horizontal component a minimum field strength of 140 microvolts per meter (-73 dBm/metres-squared) and a maximum field strength of 0.383 volts per meter (-4 dBm/metres-squared), and for its vertical component a minimum field strength of 88 microvolts per meter (-77 dBm/metres-squared) and a maximum field strength of 0.241 volts per meter (-8 dbm/metres-squared) within the whole GBAS service volume. The field strength shall be measured as an average over the period of the Synchronisation & Ambiguity Resolution in the training sequence portion of the message.

Note 1. –When horizontal polarization only is in use, the minimum and maximum field strengths are intended to be equal to the horizontal component values of the elliptical polarization.

Note 2: The minimum and maximum field strength is consistent with a minimum receiver sensitivity of –90 dBm and minimum distance of 200 meters from the transmitter antenna for a range of 30 nm. A rationale for Data Broadcast power budget is provided in Table F.1-1

Note 3: To achieve the desired operational goals of seamless GPS/GBAS operations, the minimum receiver sensitivity is derived from the link budget given in Table F.1-1. This is to support precision approach and landing guidance, terminal area guidance and surface guidance, within the minimum service volume. The Field Strength Requirement is derived from the minimum receiver sensitivity taking into account some aircraft implementation losses and margins as *shown in Table F.1-1. It is anticipated that many aircraft implementations will share the already installed localizer antenna and cabling.*

The link budget for horizontal polarized signal shown is Table F.1-1 utilizes an ERP that is similar to a typical VOR transmitter ERP of 47 dBm. It is desirable to improve the operational margin shown in table F.1-1 without increasing the ERP. For small separations between transmitter antenna and receiving antenna, the link budget includes the maximum possible constructive multipath of 6 dBm.

To minimize the effect of elliptic polarization to civil aircraft using horizontal polarization antenna, with a minimum increasing of the transmitter power, it is proposed that 80% of the available power have to be transmitted in the horizontal plane. For this case the use of an elliptic polarization drives a theoretical 6 dB lower vertical power level than the horizontal power level obtained. The link budget for vertical polarized signal shown is Table F.1-2 utilizes an ERP that is 6 dB lower than the ERP shown in table F.1.1 (horizontal polarized signal).

The broadcast power of an installed VDB is constrained by many factors, only one of which is the desired field strength in the defined coverage region. Other constraints include adjacent and co-channel interference to neighbouring systems and the VDB receiver sensitivity. In the absence of other transmitters (ILS, VOR or VDB), the minimum field strength is based on a maximum distance of 30 nm from the transmitting antenna (not from the threshold) and the maximum field strength is based on a minimum distance of 200 meters from the transmitting antenna.

It is desirable to design the transmitter to be capable of 100% duty cycle to promote potential growth to other approach performance categories (e.g. CAT II/III).

Table F.1-1 Data Broadcast Link Budget

Horizontal polarized signal

	VDB Link Elements	Link Budget at 200 meters separation between transmitter and receiver antenna [2]	Link Budget at Coverage Limit [2]
1	Effective Horizontal Radiated Power (ERP) [dBm/m^2]	47	47
2	Free Space Path Loss [dB]	-57	-106
3	Fade Margin [dB]	6	-10
4	Flight Inspected Minimum Field Strength (Power) at the A/C Antenna [µV/M (dBm/m^2)] {row 1+ (row 2 + row 3)}	N/A	154 (-69)
4'	Flight Inspected Maximum Field Strength (Power) at the A/C Antenna [µV/M (dBm/m^2)] {row 1+ (row 2 + row 3)}	547000 (-4)	N/A
5	Absolute required Minimum Field Strength (Power) at the A/C Antenna [µV/M (dBm/m^2)]	N/A	140 (-73)
5'	Absolute required Maximum Field Strength (Power) at the A/C Antenna [mV/M (dBm/m^2)]	383 (-4)	N/A
6	Operating margin at the antenna input [dB] {row5-row4}	0	4
7	Total AC Implementation Loss [dB] Plus Isotropic Antenna factor	6 [3]	-17 [3]
8	Power at A/C Rx Input {row 5 + row 7} [dBm]	2	-90
9	Total Operating Margin {row 3 + row 6} [dB]	6	14

Notes:

1: *At 108 MHz free space loss for 30 nm (55,560 m) is 108 dB and for 117.95 MHz is 108.7 dB.*

2: *The requirements are derived from precision approach and landing requirements only.*

3: *With isotropic antenna factor conversion (dBm/m^2 to dBm)*

Table F.1-2 Data Broadcast Link Budget

Vertical polarized signal

	VDB Link Elements	Link Budget at 200 meters separation between transmitter and receiver antenna [2]	Link Budget at Coverage Limit [2]
1	Effective Vertical Radiated Power (ERP) [dBm/m^2]	41	41
2	Free Space Path Loss [dB]	-57	-106
3	Fade Margin [dB]	6	-10
4	Flight Inspected Minimum Field Strength (Power) at the A/C Antenna [µV/M (dBm/m^2)] {row 1+ (row 2 + row 3)}	N/A	109 (-75)
4'	Flight Inspected Maximum Field Strength (Power) at the A/C Antenna [mV/M (dBm/m^2)] {row 1+ (row 2 + row 3)}	194 (-10)	N/A
5	Absolute required Minimum Field Strength (Power) at the A/C Antenna [µV/M (dBm/m^2)]	N/A	88 (-77)
5'	Absolute required Maximum Field Strength (Power) at the A/C Antenna [mV/M (dBm/m^2)]	241 (-8)	N/A
6	Operating margin at the antenna input [dB] {row5-row4}	2	2
7	Total AC Implementation Loss [dB] Plus Isotropic Antenna factor	6 [3]	-13 [3]
8	Power at A/C Rx Input {row 5 + row 7} [dBm]	-2	-90
9	Total Operating Margin {row 3 + row 6} [dB]	8	12

Notes:

1: At 108 MHz free space loss for 30 nm (55,560 m) is 108 dB and for 117.95 MHz is 108.7 dB.

2: The requirements are derived from precision approach and landing requirements only.

3: With isotropic antenna factor conversion (dBm/m^2 to dBm)

1.5 F. Modulation

GBAS data shall be transmitted as 3-bit symbols, modulating the data broadcast carrier by differentially encoded 8 phase shift keying (D8PSK), at a rate of 10500 symbols per second.

1.5.1 Bit-to-phase-change encoding

GBAS messages shall be divided into symbols, each consisting of 3 consecutive message bits. The end of the message shall be padded by one or two zero bits, if necessary, to form the last 3-bit symbol of the message.

Symbols shall be converted to D8PSK carrier phase shifts ($\Delta\phi_k$) in accordance with the Gray code of Table B 3.5-1.
Note 1.- The carrier phase for the k^th symbol (ϕ_k) is given by:

$$\phi_k = \phi_{k-1} + \Delta\phi_k$$

Table F.1-5 Data encoding

Message Bits			Symbol Phase Shift
I_{3k-2}	I_{3k-1}	I_{3k}	$\Delta\phi_k$
0	0	0	$0\pi/4$
0	0	1	$1\pi/4$
0	1	1	$2\pi/4$
0	1	0	$3\pi/4$
1	1	0	$4\pi/4$
1	1	1	$5\pi/4$
1	0	1	$6\pi/4$
1	0	0	$7\pi/4$

Note 3.- I_j is the j^{th} bit of the message to be transmitted, where I_1 is the first bit of the training sequence.

D8PSK may be produced as shown in Figure F.1-6 by combining two quadrature RF signals which are independently-suppressed-carrier amplitude-modulated by base band filtered impulses. A positive increase in $\Delta\phi$ represents a counter clockwise rotation in the complex I-Q plane of Figure F.1-6.

Figure F.1-6 Example Data Modulation

1.5.2 F. Pulse shaping filters

Ed.Note: This section needs to be rewritten.

The transmitted signal shall be $H(e^{j(2\pi ft + \phi(t))})$, where H(•) is a raised cosine filter.

Where: f is the absolute value of the frequency offset from the channel centre,
t is time and
ϕ is the relative phase.

Impulses shall be applied to base band filters, which have the shape of a raised cosine function. The frequency and time response of the base band filters shall be as defined below:

$$H(f) = \begin{cases} 1 & \text{for} \quad 0 < f < \dfrac{1-\alpha}{2T} \\ \dfrac{1 - \sin\left(\dfrac{\pi}{2\alpha}(2fT - 1)\right)}{2} & \text{for} \quad \dfrac{1-\alpha}{2T} \le f \le \dfrac{1+\alpha}{2T} \\ 0 & \text{for} \quad f > \dfrac{1+\alpha}{2T} \end{cases}$$

$$h(t) = \frac{\sin\left(\frac{\pi t}{T}\right)}{\frac{\pi t}{T}} \frac{\cos\left(\frac{\pi \alpha t}{T}\right)}{1 - \left(\frac{2\alpha t}{T}\right)^2}$$

Where T is the symbol period of 1/10500 s and α is = 0.6.

1.5.3 F. Quadrature modulation

The relationship between the quadrature components (I and Q) in the transmitted signal shall be ± 3º from quadrature and equal in amplitude within ± 1 dB. The carrier component of the RF signal shall be at least -20 dB relative to peak RF amplitude of the modulated signal.

Note:_ The quadrature requirements were chosen allowing for no more than 1 dB transmitter implementation loss.

Ed Note: Need for above to be confirmed

1.5.4 F. RF data rate

The symbol rate shall be 10,500 symbols/s ± 0.005%, resulting in a nominal bit rate of 31,500 bits/s.

1.6 F. Access technique.

A time division multiple access (TDMA) technique shall be used with a fixed frame structure. The data broadcast shall transmit during one or more assigned time slots of each TDMA frame. The data broadcast shall transmit one or more messages during every frame.

1.6.1 F. Maximum message size

The maximum application data message size shall be 1776 bits.

1.6.2 F. Data Broadcast timing structure.

The TDMA timing structure shall be based on frames and time slots. Each frame shall be 500 milliseconds in duration. There shall be two such frames contained in each one second epoch. The first of these frames shall start at the beginning of the epoch and second shall start midway through the epoch. The frame shall be time division multiplexed such that it shall consist of 8 individual time slots (A - H) of 62.5 millisecond duration.

Note.- Within each time slot a burst may be transmitted. Bursts, that consist of one or more messages, may be variable length up to the maximum allowed within the slot.

The following Figure F.1.7 shows the timing structure

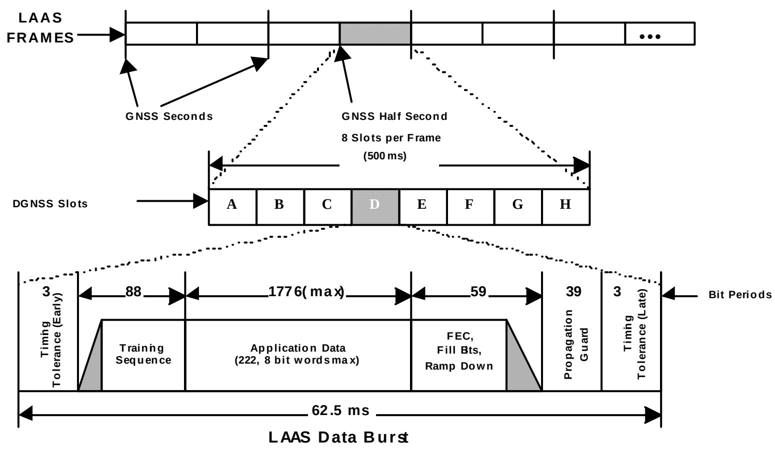


Figure F.1-7 TDMA Timing Structure

1.6.3 F. Timing budget for DB bursts.

Each burst shall be contained in a 62.5 millisecond time slot. The timing budget (in bit periods) for the burst shall be in chronological order as shown in Table F.1.8. Two symbol periods (6 bits) shall be allowed for the transmitter timing tolerance.

Table F.1-8 TDMA timing budget

Budget Item	Number of Bit Periods
Timing Tolerance (Early)	3
Training Sequence (as per Table F-2)	88
Application Data	1776 (max)
Application FEC	48
Fill Bits*	2
Ramp Down	9

Propagation Guard	39
Timing Tolerance (Late)	3
Total	1968

Required for transmission of whole symbols.

Note 1: Fill bits are required for transmission of whole symbols.

Note-2: At a rate of 10.5 k symbols per second, each time slot contains just over 656 symbol periods (1968 bits). As shown in Table B.3.5-2, timing tolerance (early), training sequence, application FEC, ramp down, propagation guard, and timing tolerance (late) require 190 bits, leaving 1778 bits for the application layer. However, the application layer messages in Sections B.3.5.2.3 are structured in increments of 8-bit bytes so the actual maximum length message that the TDMA architecture can accommodate is 222 bytes.

Note 3.- The timing tolerance provides a transmitter triggering tolerance of ±1 symbol period (95.2 µs) of the nominal burst time. A propagation guard time of 13 symbols allows for a one way propagation range of approximately 370 km (200 NM).

1.6.4 F. Mapping of Application Data onto TDMA Bursts.

A maximum of 1776 bits (222, 8 bit words) are available per burst after the overhead associated with the physical layer and media access sub-layer. Messages shall be mapped directly into the Application Data portion of the data broadcast burst with no additional overhead of the intervening layers. No broadcasting of messages across multiple bursts shall be supported; messages shall be completely contained within a single burst.

Note: When multiple messages are mapped into a single transmission burst, the successful receipt of the second and subsequent messages is dependent on the successful reception of the preceding messages in the burst.

Ed Note: we have to check with SARPS (the field "additional message flag" has been added in message type 1)

1.6.5 F. Integrity Alarm Transmission Protocol.

To ensure that integrity alarm latency requirements are met, integrity alarm message shall be transmitted within different transmission bursts. In addition, multiple integrity alarm messages shall be transmitted sequentially without interruption from non-integrity alarm related messages.

Note: Depending upon the size of the integrity alarm message, an allotted time slot may contain more than one integrity alarm transmission burst.

1.7 F. Transmitter Characteristics

1.7.1 F. Relative Power Transmitted in the first Adjacent Channels

The amount of power during transmission, under all operating conditions, when measured over a 25 kHz bandwidth centred on either of the first adjacent channels, shall not exceed -40 dB referenced to the on channel power.

1.7.2 F. Relative Power Transmitted in the second and subsequent Adjacent Channels

The amount of power during transmission under all operating conditions, when measured over a 25 kHz bandwidth centred on either of the second adjacent channels, shall not exceed -65 dB referenced to the on-channel power. On subsequent channels it shall decrease 5dB per octave until -90 dB. Table F.1-2 shows the maximum adjacent channel power allowed.

Table F.1-2: Adjacent Channel Power

Adjacent Channel #	Channel Offset (kHz)	Max Allowed Power referenced to the on channel power in dB
1st	25 kHz	-40 dB
2nd	50 kHz	-65 dB
4th	100 kHz	-70 dB
8th	200 kHz	-75 dB
16th	400 kHz	-80 dB
32nd	800 kHz	-85 dB
64th	1,600 kHz	-90 dB
.	.	-90 dB

1.7.3 F. Spurious Emissions.

Note: Spurious emissions are defined as emission on a frequency or frequencies which are outside the necessary bandwidth and the level of which may be reduced without affecting the corresponding transmission of information. Spurious emissions include harmonic emissions, parasitic emissions, intermodulation products and frequency conversion products, but exclude out-of-band emissions. The ITU-R spurious requirements may not provide adequate protection of nearby aircraft or ground subsystem GNSS receivers from harmful interference, especially from the VHF 14th harmonics. Depending upon the implementation, additional filtering, shielding and/or separation from GNSS receivers in the same area may be required.

According to the frequency used the limits on spurious emissions begin from 9 kHz to 1 GHz (without measurement on the 14th harmonics). Ref ITU-R Spurious requirements.
For the measurements the transmitter is terminated in a resistive load (artificial antenna).

The power of any spurious emissions at the output of the transmitter shall not exceed the limits shown in the following table:

Spurious power (dBm)	Bandwidth filter (kHz)	Frequency range
-36	1	9 kHz to 150 kHz
-36	10	150 kHz to 30 MHz
-36	100	30 MHz to 108 MHz
-36	100	118 MHz to 137 MHz
-36	100	137 MHz to 1 GHz

Within the frequency range 108 MHz to 117.975 MHz the transmitter shall meet the spectrum requirements.

The power of any spurious emissions at the output of the transmitter at discrete frequencies in the following bands shall not exceed:

Spurious power (dBm)	Bandwidth filter (kHz)	Frequency range
-54	100	47 MHz to 68 MHz
-54	100	162 MHz to 244 MHz
-54	100	328 MHz to 336 MHz
-54	100	470 MHz to 862MHz

1.7.4 F. Emissions in unassigned time slots

Under all operating conditions, the average power within the 25 kHz channel bandwidth, centred on the assigned frequency, when measured over any unassigned time slots, shall not exceed -75 dB referenced to the assigned power.

Note: This provides 75 dB of desired/undesired signal isolation between co-frequency time slots for a +40 dBm transmitter (35 dB for co-channel interference and 40 dB for near-far effect).

1.7.5 F. Duty Cycle.

The transmitter duty cycle shall be at least 25% for CAT I applications. For CAT II/III applications, it shall be capable of 100%.

1.7.6 F. Transmitter power stabilization

The"transmitter power stabilization and the maximum receiver AGC settling time"field shown in table F.2-2 shall consist of 5 symbols (15 bits) each representing 000.

The transmitter shall be within 90% of the nominal output power level (manufacturer declared) in a time less than 2 symbols.

Note: The ground transmitter may transmit an arbitrary number of zeros prior to the transmitter power stabilization provided the requirements of adjacent temporal interference are met.

1.7.7 F. RF Power release time

After the final information symbol is transmitted in an assigned time slot, the transmitter output power level : 1) shall decrease such that it is at least 30dB below the nominal power after 286 microseconds (3 symbols), and 2) shall not be more than 20dB down after 190 microseconds (2 symbols).

1.8 F. Receiver Characteristics

1.8.1 F. Specified Error Rate.

The uncorrected BER shall be less than or equal to 10^{-3}. The uncorrected BER performance shall be achieve in the presence of channel interference degradations.

Note: The Bit Error Rate (BER) is expressed as the ratio between the number of erroneous bits received and the total number of bits received. The uncorrected BER represents the BER without benefits of Forward Error Corrector (FEC).

1.8.2 F Message error rate

The message error rate shall be less than or equal to 10^{-3}.

1.8.3 F. Sensitivity

The receiver function shall satisfy the specified error rate with a desired power of not more than –90 dBm.

Note: The required signal in the whole coverage service volume takes into account the requirements of the system and signal losses within the system and considers environment noise sources.

1.8.4 F. Interference immunity.

Note: -Interference immunity is achieved through technical means as well as regulatory control. Regulatory control includes usage of protected spectrum and strict control over the number of authorised transmitters and their operation by authorised/trained personnel. Technical means for achieving interference immunity include, inter alia, appropriate transmit power levels, forward error correction coding, data validation/authentication, receiver filtering, link diversity, guards bands, time diversity and possibly control of antenna radiation patterns.

1.8.4.1 Data Broadcast interference immunity

The receiving function shall not exceed the specified uncorrected BER with a minimum signal strength of -87 dBm, and with one or more out of band signals, having a total interference level at the receiver input of -33 dBm.

1.8.4.2 Data Broadcast FM interference immunity

The receiving function shall not exceed the specified error rate with a minimum signal strength of minus 87 dBm, and with one VHF FM broadcast signal having a level at the receiver input in compliance with the following table:

Frequency (Mhz)	*Maximum level of unwanted siganl at receiver input*
88-102	*+15 dBm*
104	*+10 dBm*
106	*+5 dBm*
107.9	*-10 dBm*

Note 1 : The relationship is linear between adjacent points designated by the above frequencies."

1.8.4.3 Data broadcast FM intermodulation immunity

The receiving function shall not exceed the specified error rate with a minimum signal strength of minus 87 dBm to interference from two signal, third order intermodulation products caused by VHF FM broadcast signals.

1.8.4.4 Co-channel signal rejection

The co-channel signal rejection corresponds to the receiver capability to met the specified uncorrected BER requirement in the presence of an undesired signal at same assigned frequency.

The aircraft receiver shall not exceed the specified error rate with a signal strength of -87dBm in the presence of a undesired co-channel signal that is 20 dB lower than the desired signal.

1.8.4.5 Adjacent channel signal rejection

Adjacent channel rejection corresponds to the receiver capability to meet the uncorrected BER requirement in the presence of an adjacent interfering signal in addition to a wanted signal. The ratio in dB between the wanted signal level and the adjacent interfering signal level is the adjacent rejection protection.

The aircraft receiver shall not exceed the specified error rate with a signal strength of -87 dBm (TBC) in the presence of an undesired signal on the adjacent or any other assignable channel that is 30 dB higher than the desired signal.

1.8.5 F. Channel Number

The channel number shall designate a particular FAS data set and GBAS frequency via the channel mapping algorithm. For a channel number N, which can take on any integer value from 20000 to 99999, a unique physical frequency F (MHz), and Reference Path Data Selector (RPDS) shall exist such that:

$$F\ (\text{MHz}) = 108.0 + ((N-20000) \bmod 400)*0.025$$

RPDS = ((N-20000) div 400)

where: x mod y = x - k*y, with k equal to the integer part of the quotient x/y
x div y = k, the integer part of the quotient x/y

The frequency, F, shall be used to tune the proper frequency for the aircraft receiving equipment. The aircraft receiver shall demodulate data on that frequency and search for a Type 4 message with a FAS data selector field which matches the computed RPDS. The RPDS shall be assigned only once within radio range of particular ground equipment.

Note: Once the RPDS has been matched in a Message Type 4, the Station Identifier in the same message is used to segregate the other messages transmitted from the same ground equipment. When a Type 4 message with a matching RPDS has been found, the desired FAS data has been located.

The FAS data block identified by the approach selection process shall include an RPI field, to verify that the correct approach data has been selected. The RPI shall be 4 characters and shall be uniquely associated with a particular set of FAS data within the coverage of a given ground equipment.

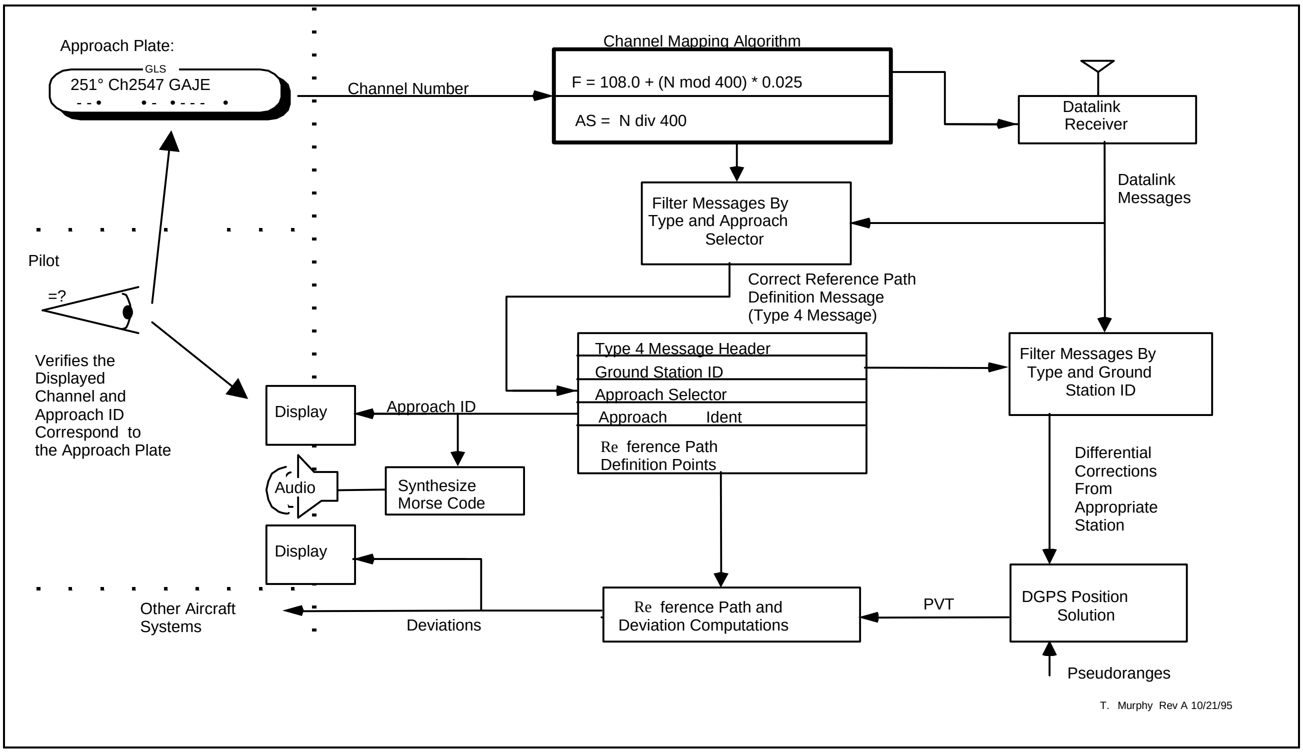
The GCS shall express a unique precision approach corresponding to the selected broadcast channel. Both channel and Reference Path Data Selection (RPDS) are combined within this value. The broadcast data block shall be selected when the value of the RPDS derived from the selection entry matches the corresponding value in the data block. The Reference Path Identifier, (RPI) contained in the message, shall provide confirmation of the selected approach path.

Note 1: The 4 character RPI may be provided to the pilot, visually or aurally (via synthesised Morse code audio) for positive confirmation that the desired approach path has been selected.

Note 2: After the desired FAS data block has been identified, the Type 4 message containing the FAS construction data block then includes a ground equipment identifier field, which is used to identify all data coming from the ground equipment.

The aircraft receiver equipment shall use the ground station identifier field to ensure that only differential corrections from the appropriate ground equipment are used.

Figure F.13 Approach Selection and Verification Procedure



[Editorial Note: This diagram is currently inconsistent with the channel mapping algorithms given in the SARPS. This shall be updated once the channel mapping algorithms are finalised]

The following table F.1-4 shows examples of this relation.

Table F.1-4 Example of Channel Mapping

Channel Number N	Frequency, MHz	Reference Path Data Selector Number RPDS
20000	108.000	0
20001	108.025	0
20002	108.050	0
....	....	....
20398	117.950	0
20399	117.975	0
20400	108.000	1
20401	108.025	1
20402	108.050	1
…	....	....
20798	117.950	1
20799	117.975	1
...	...	...
99600	108.000	199
99601	108.025	199
...	...	...
99997	117.925	199
99998	117.950	199
99999	117.975	199

1.8.6 F. Dynamic range.

The receiving function shall not exceed the specified uncorrected BER with a minimum signal strength of –90 dBmto a maximum field strength of 5 dBm.

1.8.7 F. AGC Performance

The maximum AGC receiver settling time shall be lower than 2.5 symbols (see table F.2.2).

The receiver AGC shall provide the specified performance over the dynamic range at the tuned frequency when maximum sized application messages (1776 bits) are present in adjacent time slots but separated in signal level by up to 40 dB.

Note: To provide future growth, the receiver should be able to receive signals in all time slots under these conditions

1.8.8 F. Processing requirements.

The receiver shall be capable of receiving and processing data for any two specified time slots in a single frame for CAT I operations. For CAT II, or III precision operations, the receiver shall be capable of receiving and processing all time slots.

1.8.9 F. Spectrum Management.

Data broadcast operators should be issued a VHF TDMA data broadcast license to transmit such that they have both a frequency assignment and one or more data broadcast time slot assignments. Frequency assignments *should be issued for 25 kHz channel centres (i.e. 108.000, 108.025, etc.) in the band 108.000-117.975 MHz. Time slot assignments should be issued for slots «A » through «H » relative to GPS time. A data broadcast ground system should not use more than two (2) slots per frame (3926 bit periods), and should demonstrate that the additional throughput, offered by a second slot, is required. Note that CAT-I, II, and III ground systems may utilise more than 2 time slots, depending upon the requirements implemented.*

2. F. Message encoding and format.

Encoding of the Data broadcast message for transmission to the airborne sub-system shall follow the sequence of, message formatting, FEC encoding, bit scrambling and then modulation. The Data broadcast messages shall consist of a demodulator training sequence followed by application data and Forward Error Correction (FEC), as shown in Table F.2-1. The Data broadcast message shall begin with a 5 segment demodulator training sequence as shown in Table F.2-2.

Note 1-The Reed-Solomon codes are described in the recommendation for Space Data System Standards Telemetry Channel Coding, by the Consultative Committee for Space Data Systems.

Note 2.- The following applies to the message encoding process:

symbol - a change in phase that represents 3 bits
word - 8 bit elements in the Reed-Solomon code
byte - 8 bit application layer element
bit period - dependent upon time base used

Note 3.- All pad, reserved and spare bits are set to zero.

symbol - a change in phase that represents 3 bits
word - 8 bit elements in the Reed-Solomon code
byte - 8 bit application layer element
bit period - approximately 31.75 µS

Table F.2-1. Data Broadcast message format

Training Sequence
Application Data
FEC

Table F.2-2. Training sequence format

Segment Sequence	Training Sequence Description	# of Bits
1	Transmitter Power Stabilisation And maximum Receiver AGC response	15
2	Synchronisation & Ambiguity Resolution	48
3	Station Slot Identifier (SSDI)	3
4	Transmission Length	17
5	Training Sequence FEC	5
	TOTAL	88

Note: The definition of the physical layer modulation and training sequence is defined to be consistent with the ICAO VDL SARPs. Consequently, some unnecessary functionality is included.

2.1 F. Transmitter Power stabilization and maximum receiver settling time.

The"transmitter power stabilization and the maximum receiver AGC settling time"field shown in table F.2-2 shall consist of 5 symbols (15 bits) each representing 000 (see transmitter or receiver characteristics).

2.2 F. Synchronisation and ambiguity resolution.

The second segment of the training sequence shall consist of the Synchronisation & Ambiguity Resolution sequence shown below and shall be transmitted from left to right:

Synchronisation & Ambiguity Resolution Sequence
000 010 011 110 000 001 101 110 001 100 011 111 101 111 100 010

Note. - This sequence is designed to have a good auto-correlation sequence and to facilitate estimation of the centre frequency.

2.3 F. Station Slot Identifier.

The station slot identifier (SSID) shall be a single symbol transmitted as a numeric value from 0 to 7 corresponding to the letter designation A through H of the first time slot assigned to the ground reference station. Slot A shall be represented by 0, slot B by 1, C by 2 and so on to H by 7.

Note.- The purpose in identifying the first time slot the ground station is transmitting in is to provide a low overhead, high integrity way for the aircraft receiver to decide whether to process the rest of the message. This provides the avionics manufacturer the opportunity to reduce unnecessary traffic on the data bus.

2.4 F. Transmission length.

The transmitter shall send a 17-bit word, from least significant bit (LSB) to most significant bit (MSB), indicating the total number of bits in both application data and application FEC.

2.5 F. Training Sequence FEC.

A (25,20)-block code shall be computed over the SSID and the transmission length segments and then transmitted as the fifth segment. The encoder shall accept the header in the bit sequence that is being transmitted.. The five parity bits to be transmitted shall be generated using the following equation:

$$[P_{1},....., P_5] = [SSID, TL_{1.........}TL_{17}]\ H^T$$

Where:

P_n	is the parity symbol (P_1 shall be transmitted first)
SSID	is the Station Slot IDentifier symbol
TL	is the transmission length
^{T}	is the matrix transpose function and
H	is the parity matrix defined below:

$$H = \begin{matrix} 0&0&0&0&0&0&0&0&1&1&1&1&1&1&1&1&1&1&1&1 \\ 0&0&1&1&1&1&1&1&0&0&0&0&1&1&1&1&1&1&1&1 \\ 1&1&0&0&0&1&1&1&0&0&1&1&0&0&0&0&1&1&1&1 \\ 1&1&0&1&1&0&1&1&0&1&0&1&0&0&1&1&0&0&1&1 \\ 0&1&1&0&1&0&0&1&1&1&1&0&0&1&0&1&0&1&0&1 \end{matrix}$$

Note. - This code is capable of correcting all single bit errors and detecting 75 of 300 possible double bit errors.

2.6 F. Order of data transmission.

The order of transmission, for both the application data and FEC parity bit, shall be Least Significant Bit (LSB) first followed by the higher order bits of that field. All data fields shall be transmitted in the order specified with the least significant bit of each field transmitted first.

2.7 F. Data formatting example.

An example of how a Type 1 message is formatted for transmission is provided below. The example contains a six-step process that may be used to assist in the development and test of Data Broadcast specified in this document.

{Ed.Note: This example shall have to be revised with the new message type 1}

2.7.1 F. Step 1: Generate Application Layer Message.

Step 1 contains a sample application layer message that is desired to be transmitted and conforms to the Type 1 message format specified in F.2. Table F.2 -3 represents an example of a Type 1 Application Layer message format for a single satellite and the equivalent bit-oriented representation. Refer to Appendix A for the definition and functionality of the specific data fields shown in this example.

Table F.2-4. - Example Message Type 1

Data Field	Engineering Units	Bit-Oriented Equivalent
Message Block Identifier	10011001	10011001
Station ID.	KDFW	001011000100000110010111
Reserved Bits	00	00
Message Type	1	000001
Message Length	18 bytes	00010010
Modified Z-Count	60 sec.	0000100101100
Acceleration Error	0.003 m/s/s	001
Satellite I.D.	12	001100
Pseudorange Correction	139.00 m	0001101100100110*
Issue-of-Data	150	10010110
Range-Rate Correction	-3.298 m/s	100110001111*
UDRE	2.4 m	001100

* The PRC and RRC binary representations are the 2's compliment of the value.

2.7.2 F. Step 2: Arrange Data Bits for Transmission and Append CRC.

Each data field in Step 1 is arranged to transmit the least significant bit (LSB) first and as shown below. The 32-bit Application Layer CRC described in Appendix A is then calculated and appended to the message (CRC seed set to all zeros and LSB first). Note that paragraph F.2.6 requires that all data fields be transmitted in the order specified with the least significant bit of each field transmitted first.

1st Field LSB

Application Data Separated By Fields

10011001 | 111010011000001000110100 | 00 | 100000 | 01001000
0011010010000 | 100 | 001100 | 0110010011011000 | 01101001
111100011001 | 001100 |

For clarity in this example, this data is separated into a byte-by-byte version. Note that no bit stuffing is performed.

Application Data Separated By Bytes

1001 1001 | 1110 1001 | 1000 0010 | 0011 0100 | 0010 0000 | 0100 1000
0011 0100 | 1000 0100 | 0011 0001 | 1001 0011 | 0110 0001 | 1010 0111
0100 0110 | 0100 1100 |

This message stream, starting with the LSB of the first byte of the first field is injected into a 32-bit shift register implementation. Note that the seed/register is initialised to all zeros. The shift register implements the polynomial:

$$G(x) = x^{32} + x^{31} + x^{24} + x^{22} + x^{16} + x^{14} + x^{8} + x^{7} + x^{5} + x^{3} + x + 1$$

Note: If the CRC is being mathematically verified, then it is necessary to append 32 zero bits to the message stream.

Once the M(x) has been sent through the CRC, the resultant CRC for the example shown above is (separated by bytes):

1110 1000 | 1101 1000 | 0111 0101 | 0100 1111

Note: If this value is then input to the shift register, or appended in place of the zeros used when mathematically validating the CRC, the resultant value shall be all zeros.

The entire 32-bit CRC is appended to the end of the application data as shown below with the coefficient of x^{31} as the first bit to be transmitted:

Application Data & CRC Separated by Bytes

1001 1001	1110 1001	1000 0010	0011 0100	0010 0000	0100 1000
0011 0100	1000 0100	0011 0001	1001 0011	0110 0001	1010 0111
1100 0110	0100 1100	1110 1000	1101 1000	0111 0101	0100 1111

2.7.3 F. Step 3: Compute Physical Layer FEC.

The physical layer FEC is calculated over the application and CRC data bits shown in Step 2 above. In generating the FEC, the application and CRC data bits are arranged in eight bit-bytes with the first bit of each byte identified as the MSB as shown below.

Application Data, CRC, & 48-Bit FEC Separated by Bytes

1001 1001	1110 1001	1000 0010	0011 0100	0010 0000	0100 1000
0011 0100	1000 0100	0011 0001	1001 0011	0110 0001	1010 0111
1100 0110	0100 1100	1110 1000	1101 1000	0111 0101	0100 1111
1101 1110	1100 1010	1101 0000	1011 0000	0001 0011	0001 1111

2.7.4 F. Step 4: Insert Training Sequence.

The Station Slot Identifier bits, message length, and Training Sequence FEC fields of the training sequence are inserted into the data stream shown in Step 3 above. The Station Slot Identifier is set to slot A for this example.

TRAINING SEQUENCE (Separated By Field)

Station Slot Ident.	Transmission Length	Header FEC
000	00000011000000000	00110

1001 1001	1110 1001	1000 0010	0011 0100	0010 0000	0100 1000
0011 0100	1000 0100	0011 0001	1001 0011	0110 0001	1010 0111
1100 0110	0100 1100	1111 0010	1010 1110	1011 0001	0001 0111
1101 1110	1100 1010	1101 0000	1011 0000	0001 0011	0001 1111

Application Data, 32 Bit CRC, & 48-Bit FEC Separated by Bytes

2.7.5 F. Step 5: Scramble Message block and Arrange into Message Symbols.

The data bit stream shown in Step 4 is scrambled. The resultant scrambled data stream is shown below. The scrambled data stream is grouped into 3-bit symbols (low bit first). It is ready for conversion into three separate binary streams in preparation for data modulation. Note that the scrambled data stream does not contain an even multiple of 3-bits as shown in the last symbol of the data stream shown below.

Scrambled Data Shown as Modulation Symbols

000 100 110 111 101 111 000 111 011 010 011 111 101 101 001 101 000
011 111 111 111 110 001 001 011 100 001 010 111 010 000 001 101 001
111 001 001 110 111 011 100 110 000 100 011 011 010 000 111 011 011
011 010 010 100 101 111 110 001 001 110 101 011 101 000 001 111 011
101 010 100 101 1

2.7.6 F. Step 6: Add Synchronisation & Ambiguity Resolution Sequence and Generate Absolute Modulation Symbols.

The Synchronisation & Ambiguity Resolution (shown in modulation symbols) is then inserted at the beginning of the message. Each 3-bit symbol is then converted into three separate data streams X, Y, Z, which are the transmitted carrier phase (ϕ) for each symbol transmitted. Note that two zeros (00) have been padded in the last symbol (100) of the transmitted message below.

Synchronisation & Ambiguity Resolution Sequence

000 010 011 110 000 001 101 110 001 100 011 111 101 111 100 010

Synchronisation & Ambiguity Resolution Seq.
X : 0001001101011110 |
Y : 0111000100110101 |
Z : 0010011010111100 |
ϕ : ADFBBCAEFEGDBGFA |

Scrambled Data
x : 01111101000111010011110001001000101001101101000010000011110011010010101111
y : 00110101111100000111110010011100001001110100111011111100110010100011010000
z : 00011101101111110111101110101001111110110000110011110001101101110111100010
ϕ : AHDAGDDACFHECABHHBGDAEFGAHADADDECDABCGDFEAAHBDGGDFHBEHGEBFGHDBDB
BCHBHCB

The absolute phase (ϕ) is the accumulated differential phase and is encoded so that A = 0π, B = π/4, C = 2π/4, etc..

2.8 F. Type 4 Message Format Example

Table B-1 Type 4 Message Example

Data Content Description	Bits Total	Bits Used	Example Values	Message Bit Pattern for Example Values transmitted from left to right	Message in Hexadecimal LSB First
TRAINING SEQUENCE					
Power Ramp-up & Settling	15	15		000 000 000 000 000	
Synchronisation & Ambiguity Resolution	48	48		000 010 011 110 000 001 101 110 001 100 011 111 101 111 100 010	
Slot Group identifier	3	3		000	
Transmission Length (bits)	17	17	440	00011101100000000	
Training Sequence FEC	5	5		10011	
MESSAGE BLOCK					
Message Header					
Message Block ID	8	8	AA	01010101	AA
GBAS ID	24	24	KACY	100110 110000 100000 110100	D9 10 2C
Message Type	8	8	4	00100000	04
Message Length	8	8	49	10001100	31
FAS Message Block 1					
FAS approach path designator	8	8	1	10000000	01
FAS Block 1					
Operation Type	4	4	0	0000	
Spare	4	4	0	0000	00
Airport ID	32	24	KACY	10011000 11000000 10000000 11010000	19 03 01 0B
Runway Number	6	6	13	101100	
Runway Letter	2	2	no letter	00	0D
Approach Design Info	3	3	0	000	
Route Indicator	5	5	A	10000	08
Reference Path Data Selector	8	8	10	01010000	0A
Reference Path ID	32	24	GACY	10011000 11000000 10000000 11100000	19 03 01 07
RDP Latitude	32	32	N 39.464259°	10010010 00110101 11110111 00001000	49 AC EF 10
RDP Longitude	32	32	W 74.5910131°	01000011 11110100 10111111 11111011	C2 2F FD DF
RDP Height	16	16	-12.2 meters	01100001 11001000	86 13
FPAP Latitude	32	32	N 39.5092547°	01010011 10111001 00101111 00001000	CA 9D F4 10
FPAP Longitude	32	32	W 74.5202869°	01110111 00101111 00100000 00000111	EE F4 04 E0
Approach Datum Crossing Height (DCH)	15	15	50 feet	000101111100000	
Approach DCH Units Selector	1	1	feet	0	E3 08
Glidepath Angle	16	16	3°	00110100 10000000	2C 01
FAS Block CRC	32	32		TBD	
Message CRC	32	32		TBD	
FEC	48	48		00010001 00010010 10101001 11000000 01101001 01101111	88 48 95 03 96 F6
Power Ramp Down	9	9	0	000 000 000	

Table B-1 Type 4 Message Example

Binary Representation of Transmitted Message Data:
(read these bits left-to-right, top-to-bottom)

Power Ramp-up and Synchronisation & Ambiguity Resolution:
000 000 000 000 000 000 010 011 110 000 001 101 110 001 100 011 111 101 111 100 010

Slot ID, Transmission Length, & Training Sequence FEC:
000 00011101100000000 10011

Type 4 Message Header:
01010101 100110 110000 100000 110100 00100000 10001100

FAS Block 1 Performance Category:
10000000

FAS Block 1:
00000000 10011000 11000000 10000000 11010000 10110000 00010000 01010000 10011000 11000000 10000000 11100000 10010010 00110101 11110111 00001000 01000011 11110100 10111111 11111011 01100001 11001000 01010011 10111001 00101111 00001000 01110111 00101111 00100000 00000111 00101111 10101000 00110100 10000000

FAS Block CRC:
11000101 10110111 01010101 11111011

Message CRC:
01110110 00000101 10100001 01111101

FEC:
00010001 00010010 10101001 11000000 01101001 01101111

Power Ramp Down:
000 000 000

Transmitted Carrier Phase: (absolute phase)

```
AAAAAADF   BBCAEFEG   DBGFAAHA   DBGHFEGD   CDDEEEGD   AFBCEFAG   CGADBBDC   GHGGGHHD
HGBCBFHB   FCDDGABG   AAHFCABB   DFEFHFCB   DCEADHAB   GGBDEBDG   BAAFGFEG   FAFBGHDH
AEFBHEBG   FGAGDEED   CEAHHDBG   EEAFBDHG   HEFCCBGA   DEGBGEDG   GGG
```

3. F. Error correction encoding of application layer data.

In order to improve the effective channel throughput, by reducing the number of required re-transmissions, Forward Error Correction (FEC) shall be calculated using the application data , which includes the Message Header, Message and Integrity Check bits. The application FEC coding shall be accomplished by means of a systematic Reed-Solomon (255,249) 2^8-ary (3 error correcting) code capable of correcting up to three code word symbol errors.

The field defining primitive polynomial of the code shall be:

$$p(x) = x^8 + x^7 + x^2 + x + 1$$

The generator polynomial is given by :

$$\prod_{i=120}^{125} (X - \alpha^i)$$

where α is a primitive element of a Galois field of size 256.

Note 1: For more information on Reed-Solomon codes, see Consultative Committee for Space Data Systems, «Recommendation for Space Data System Standards: Telemetry Channel Coding. »

Note 2: Shorter transmissions than 1992 bits long must be extended by virtual fill with trailing zeros.,. These zeros need not be transmitted.

Note 3: This RS code is capable of correcting up to three octets for data block of 249 octets (1992 bits).

Note 4: Six RS-check octets are appended for a total block of 255 octets.

4. F. Bit scrambling.

In order to aid clock recovery and to stabilize the shape of the transmitter spectrum, a pseudo-noise (PN) scrambler with a 15-stage generator register shall be exclusive-ORed with the transmitted data stream starting with the SSID. The concept of a PN scrambler is shown in Figure F.4-1 (the descrambler is identical). The polynomial for the register of the scrambler and descrambler shall be $1 + X + X^{15}$. The scrambler and descrambler are clocked at the rate of one shift per bit, with the first scrambler bit in the frame unshifted. The initial status of the register, preset at the beginning of the transmission, shall be 1101 0010 1011 001 with the leftmost bit in the first stage of the register.

Figure F.4-1. Scrambler /descrambler
Initial State Represented

Note: The concept of a PN scrambler is explained in the International Radio Consultative Committee (CCIR) Report 384-3, Annex 3, Section 3, Method 1.

5. F. Data Broadcast Ground monitoring

The ground subsystem shall include sufficient monitoring to ensure the integrity levels given in Table B.3.5.3.2

5.1. F Data Broadcast monitor

The data broadcast transmissions shall be monitored.

The transmission of the data shall cease and an appropriate alert shall be raised within 0.5 seconds under the following conditions:

a) Disagreement between the transmitted data and data derived or stored by the monitoring system prior to the transmission for more than 1 seconds;
b) Change of the transmitted power by more then 3dB for more than 3 seconds;
c) Update rate of message type 1 is not met for a 3 second period;
d) Update of message types 2,4,and 5 is not met for a 30 second period.

5.2. F TDMA slot monitoring

The probability that the ground equipment fails to detect an out-of-slot transmission, which exceeds that allowed in Paragraph B.3.6.2.7, within 1 second shall b less than 2x10-7 per 150 second period. If out-of-slot transmissions are detected, the ground equipment shall terminate all data broadcast transmissions within 0.5 seconds.

Appendix G - C-Band Data Broadcast

TABLE OF CONTENTS

1. G. Frequency Allocations

The band from 5.000 GHz to 5.150 GHz has been allocated to aeronautical navigation. Use of the spectrum is given for allocation of MLS or other standardised aeronautical services. The spectrum allocated from 5.091 GHz to 5.150 GHz is currently shared with MSS (Mobile Satellite Service) on a co-primary basis. A guard band has been assigned to protect the aeronautical services in this band so that it does not suffer in the ways that ILS has done. This guard band is from 5.025 to 5.030 GHz

The GBAS C-band data broadcast is able to use any of the un-allocated 200 MLS channel assignments made between 5.0310 GHz and 5.0907 GHz. For the spectrum allocated between 5.091 to 5.150 GHz (MLS expansion band also shared with MSS), the GBAS data broadcast is able to use any of the 197 channel assignments which have been made.

1.1. G. SIGNAL FREQUENCY

The GBAS transmitter shall be capable of operating on 397 channels within the frequency band 5.031 GHz to 5.150 GHz. The first channel shall be centred upon 5.031 GHz and the highest channel shall be centred at 5.1498 GHz. The ICAO plan for current and future channels in this frequency region is shown ED-36A Appendix B.

1.2. G. CARRIER FREQUENCY TOLERANCE AND STABILITY

The GBAS transmitter shall meet the requirements in ED-53A para. 3.2.3.

1.3. G. POLARISATION

All transmissions from the ground equipment shall be nominally vertically polarised.

1.4. G. SIGNAL POWER LEVEL

The RF spectrum of the data broadcast shall meet the requirements for data signal transmissions in ED-53A para 3.1.3.

The effective radiated power (ERP) specifications for the data broadcast transmitter is based on the calculations found in Table G.-1. The minimum ERP quoted is the level where the executive monitor action should occur. Actual radiated power levels must be greater than the minimum by at least 1.5 dB to ensure a margin is maintained to prevent false alarm,

In Table G.-1. the propagation losses are assumed to be worst case scenarios and a measure of the Root-Sum-Square (RSS) for the probabilistic losses is taken. Propagation loss is calculated using a distance of 41.7 km (22.5 NM) for the omnidirectional C band data broadcast.

Power Budget Items	
IF SNR (dB) required for acquisition and decode	8.0
Noise Power in 150 kHz IF bandwidth (dBm)	-122.0
Signal Power required at IF (dBm)	-114.0
a) Noise Figure	11.0
b) Cable Loss (dB)	5.0
c) Margin (dB)	3.0
Signal Required at Aircraft (dBm)	-95.0
Propagation Loss (dB)[2])	138.7
Probabilistic Losses (dB)	
a) Polarisation	0.5
b) Rain	2.2
c) Atmospheric	0.3
d) Horizontal Mutipath	3.0
e) Vertical Mutipath	2.0
Root Sum Square (RSS) total a) through e) (dB)	4.3
Horizontal and Vertical Pattern Loss (dB)	-
Monitor Margin (dB)	1.5
Antenna Gain (dB)[3]	-
Net Power gain at coverage extremes (dB)	-2.5
Required transmitter power (dBm)	47.0
Example transmitter power peak (dBm)	50.0

Table G.-1. System Power Budget.

1.5. G. SPURIOUS EMISSIONS

The requirements for the ITU-R spurious emissions shall be met to minimise the emissions on a frequency or frequencies which are outside the necessary bandwidth and the level of which may be reduced without affecting the corresponding tradition of information.

1.6. G. CHANNEL NUMBER

The channel number shall designate a particular FAS data set and GBAS frequency via the channel mapping algorithm. For a channel number N, which may take any integer value from 60000 to 99699, a unique physical frequency F (MHz), and Reference Path Data selector (RPDS) shall exist such that:

F(MHz) = 5031 + ((N - 60000)mod 397)*0.3
RPDS = ((N - 60000)div397)

where x mod y = x - k * y, with k equal to the integer part of the quotient x/y
x div y = k, the integer part of the quotient x/y
The application of the RPDS shall conform to the requirements in 1.6. F.

The following Table shows examples of this relation:

Channel Number N	Frequency, MHz	Reference Path Data Selector Number RPDS
60000	5031.0	0
60001	5031.3	0
….	….	….
60395	5149.5	0
60396	5149.8	0
60397	5031.0	1
60398	5031.3	1
...	...	...
...	...	...
…	….	….
99300	5149.5	98
99301	5149.8	98
99302	5130.0	99
99303	5130.3	99
...	...	...
99698	5149.5	99
99699	5149.8	99

Table G.-2 Example of Channel Mapping

1.7. G. MODULATION

1.7.1. G. Differential Phase Shift Keying

All C-band data broadcast transmissions for GBAS shall meet the requirements for differential phase shift keying as detailed in ED-53A para. 3.2.4..

1.7.2. G. RF Data Rate

The RF modulation rate shall be 15 625 baud (ref. ED-53A para. 3.2.4).

1.8. G. ACCESS TECHNIQUE

Like the VHF GBAS data broadcast, the RF data rate of the physical layer offers more capacity than is required by a single GBAS ground station. Spectrum efficiency is increased through the use of Time Division Multiple Access (TDMA).

1.8.1 G. Data Broadcast timing Structure.

The TDMA timing structure is based on a two level hierarchy as shown in Figure G.-1.

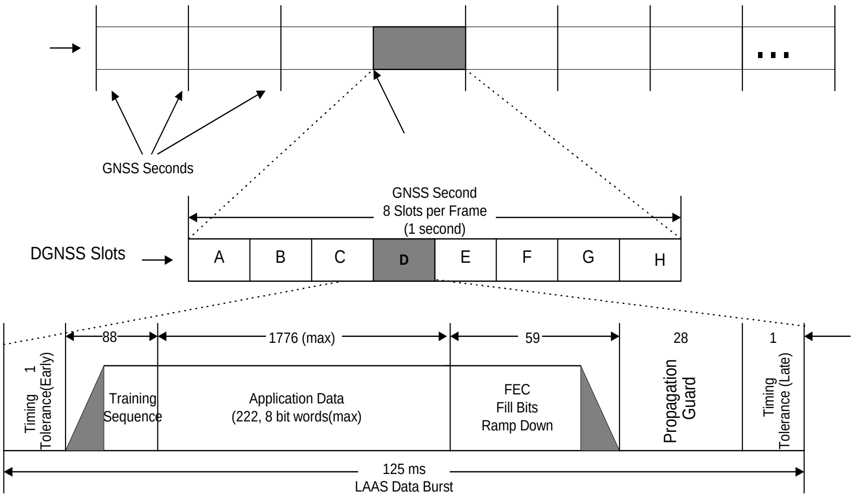


Figure G.-1 C-band Data Broadcast TDMA Timing Structure

There is one data broadcast frame contained in each GPS one second epoch. Like the VHF data broadcast, the C-band data broadcast frame is time division multiplexed such that it shall consists of eight individual time slots (A - H). Whereas each frame for the C-band data broadcast occupies 125 millisecond and each frame for the VHF data broadcast occupies 62.5 milliseconds, the update rates for individual message types remain the same per frame.

A data broadcast time slot establishes the incremental capacity resource that can be assigned to an individual data broadcast ground station. Within each time slot, data broadcast bursts can be transmitted. Data broadcast bursts can be of variable length, up to the maximum allowed within the slot.

1.8.2. G. Timing Budget for Data Broadcast Bursts.

The timing budget (in bit periods) for the data broadcast burst is given in chronological order in Table G.-3 and for clarification in Figure F.-2. At a rate of 15 625 baud, each time slot contains 1953 bits. As shown in Table G.1-2, timing tolerance (early), training sequence, FEC, ramp-down, propagation guard, and timing tolerance (late) require 175 bits, leaving 1778 bits for the application layer. However, the application layer messages are structured in increments of 8-bit bytes, so the actual maximum length message that the TDMA architecture can accommodate is 1776 bits (222 bytes).

Table G1-3 C-band Data Broadcast Timing Budget

Budget Item	Number of Bit Periods
Timing Tolerance (Early)	1
Training Sequence (as per Table F-2)	88
Application Data	1776 (max.)
Application FEC	48
Fill Bits*	2
Ramp Down	9
Propagation Guard	28
Timing Tolerance (Late)	1
Total	1953

Note: Two symbol periods shall be allowed for the transmitter timing tolerance.

Note: This provides a transmitter triggering tolerance of ±1 symbol period (64 µs) of the nominal burst time. A propagation guard time of 28 bits allows for a one way propagation range of approximately 540 km (290 NM).

1.8.3 G. Mapping of Application Data onto TDMA Bursts

As detailed in para 1.8.3 F.

1.8.4 G. Integrity Alarm Transmission Protocol

As detailed in para 1.8.4 F.

1.9 G. DUTY CYCLE

As detailed in para 1.8.5 F.

1.10 G. EMISSIONS IN UNASSIGNED TIME SLOTS

Under all operating conditions, the average power within the 300 kHz channel bandwidth, centred on the assigned frequency, when measured over any unassigned time slots, shall not exceed -70 dB referenced to the on-channel power.

2. G. Data Broadcast Timing Structure

As detailed in Section 2. F.

3. G. Error Correction Encoding of Application Layer Data

As detailed in Section 3. F.

4. G. Bit Scrambling

As detailed in Section 4. F.

5. G. Ground Monitoring Equipment

As detailed in Section 5. F.

6. G. Airborne Data Broadcast Receiving Equipment

6.1. G. ACQUISITION TIME

As detailed in para 6.1 F.

6.2. G. INTERFERENCE IMMUNITY

6.2.1. G. Data Broadcast Interference Immunity

The receiver shall meet the specified error rate in the presence of unwanted CW signals as defined in ED-36A Tables 3-2.

6.2.2. G. Co-channel Signal Rejection

The receiver shall meet the specified error rate when, in addition, interference on the same channel is received at a level not exceeding that specified for DPSK data signals in ED-53A para 3.1.3.

6.2.3.G. Adjacent Channel Signal Rejection

The receiver shall meet the specified error rate when a data broadcast signal within the range specified in ED-36A para. 1.11.1.1 is being tracked in the presence of undesired GBAS data broadcast or MLS signal with relative level described in ED-36A para. 3.2.4.

6.3. G. SPECIFIED ERROR RATE

As detailed in 6.3 F.

6.4. G. DYNAMIC RANGE

The receiver shall meet the specified error rate when the power level of DPSK transmissions is increased to a maximum value specified in ED-36 para. 3.2.2.

6.5. G. RECEIVER SELECTIVITY AND BANDWIDTH

The receiver shall acquire and decode GBAS data according to the requirements detailed for DPSK in ED-36A Section 3.2.3.

6.6. G. PROCESSING REQUIREMENTS

The receiver shall meet the requirements in 6.6 F.

6.7. G. SPECTRUM MANAGEMENT

The separation criteria are determined in terms of co-frequency and adjacent frequency desired to undesired (D/U) signal rations, when combined with appropriate propagation loses to allow evaluation of C-band GBAS data broadcast frequency assignments. When selecting a frequency for data broadcast, use may be made of any unused allocations under MLS frequency assignment plan as the co-channel and adjacent frequency requirements for the C-band GBAS data broadcast are the same as those determined for MLS. (Ref. ICAO Annex 10 Attachment G Part 9.

Appendix H Interference Environment

Ed Note 1: Levels of in-band and out-of-band pulse interference are TBC

Ed Note 2: the GLONASS interference environment needs to be included.

H.1 Introduction

This appendix specifies the RF interference environment, at and around L-band frequencies, for GBAS ground and airborne receivers.

All signal levels in this Appendix are specified in dBm measured at the output port of an ideal 0-dBi gain right-hand circularly polarized receive antenna. For antennas with a different gain the signal and interference levels can be adjusted accordingly, as long as the relative interference to signal level is maintained.

H.2 Operating Interference Environment

Receivers shall meet the performance requirements of this MASPS when operated within the specified operating interference environment, given ranging signal levels of -130 dBm for GPS satellite signals and -131 dBm for SBAS satellite signals

Figure H-1 represents the operating interference environment. The regions of this figure indicated as having interference with bandwidths other than CW are considered to represent in-band and near-band interference with received power levels defined in Figure H-2 as a function of bandwidth.

H.2.2 Out-of-Band Interference

The out-of-band continuous wave (CW) interfering signals can be as high as the levels shown in Figure H-1. The CW interference level below 1500 MHz increases linearly to 30 dBm at 1315 MHz. The CW level increases linearly above 1640 MHz to 26 dBm at 2 GHz, accounting for High Intensity Radiation Fields (HIRF).

H.2.2.1 Out-of-Band Pulse Interference

After steady state navigation has been established, the equipment could receive pulsed interference in the out-of-band frequency ranges specified above having the characteristics described in Table H-1.

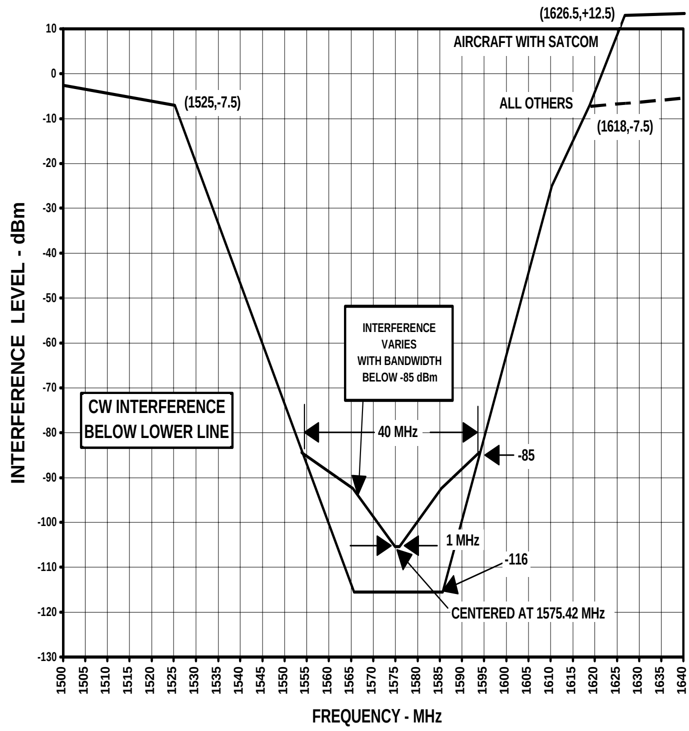


FIGURE H-1 INTERFERENCE LEVELS AT OUTPUT OF IDEALIZED 0 dBi ANTENNA

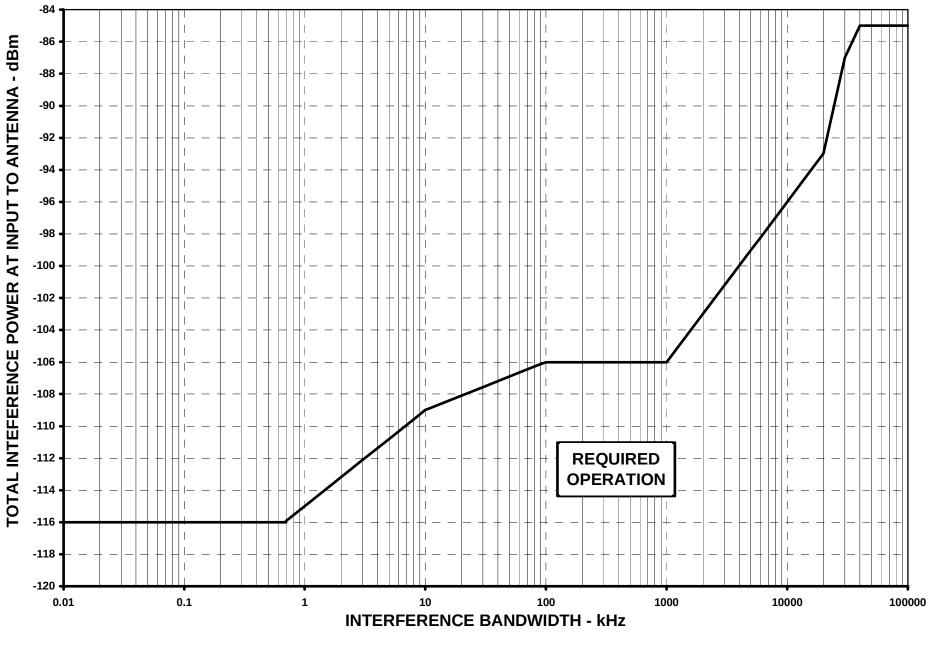


FIGURE H-2 IN-BAND AND NEAR-BAND INTERFERENCE ENVIRONMENTS

TABLE H-1 OUT-OF-BAND PULSE INTERFERENCE

	GPS/SBAS/APL	**GPS/APL Only**
Peak Power	+30 dBm	+30 dBm
Pulse Width	125 μsec	1 ms
Pulse Duty Cycle	10%	10%

H.2.2 In-Band and Near-Band Interference

Figure H-1 and Figure H-2 are related as follows: The upper mask of Figure H-1 (the mask that varies with bandwidth) at 1575.42 MHz ±0.5 MHz relates to the level in Figure H-2 between the bandwidths of 100 and 1000 kHz. For interference bandwidths outside of that range, the level of the mask in Figure H-1 shall be adjusted up or down according to the levels of Figure H-2. For example, interference with a bandwidth of 0.1 Hz lowers the mask to the CW interference mask at 1575.42 MHz, while interference with of bandwidth of 20 MHz raises the mask at 1575.42 MHz to a level of -93 dBm. In addition, if the center of the interference moves away from 1575.42 MHz, the levels of Figure H-2 are raised according to the mask of Figure H-1. For example, for interference centered at 1565.42 MHz, the curve of Figure H-2 shall be increased by 13 dB.

The baseline in-band and near-band interference environments apply to all precision approach operations.

After steady state navigation has been established, the equipment could receive an interfering signal in the frequency range of $1575.42 \pm BW_I/2$ MHz that is as high as the levels in Table H-2 which are given as a function of the interfering signal bandwidth BW_I.

TABLE H-2 IN-BAND AND NEAR-BAND INTERFERENCE BANDWIDTH DEFINITIONS

BANDWIDTH	INTERFERENCE LEVEL
$0 \le BW_I \le 700$ Hz	-116 dBm
700 Hz < $BW_I \le 10$ kHz	$-115 + 6 \log_{10}(BW_I/1000)$ dBm
10 kHz < $BW_I \le 100$ kHz	$-109 + 3 \log_{10}(BW_I/10000)$ dBm
100 kHz < $BW_I \le 1$ MHz	-106 dBm
1 MHz < $BW_I \le 20$ MHz	Linearly increasing from -106 to -93 dBm*
20 MHz < $BW_I \le 30$ MHz	Linearly increasing from -93 to -87 dBm*
30 MHz < $BW_I \le 40$ MHz	Linearly increasing from -87 to -85 dBm*
40 MHz < BW_I	-85 dBm*

*Interference levels will not exceed -106 dBm/MHz in the frequency range of 1575.42 ± 10 MHz.

H.2.2.1 In-Band and Near-Band Pulsed Interference

After steady state navigation has been established, the equipment operating could receive pulsed interference in the in-band and near-band frequency ranges specified above having the characteristics described in Table H-3. In addition, the in-band pulsed interference environment includes pulsed APL signals from two APL signals

TABLE H-3 IN-BAND AND NEAR-BAND PULSE INTERFERENCE

	GPS/SBAS/APL	GPS/APL Only
Peak Power	+20 dBm	+20 dBm
Pulse Width	125 µsec	1 ms
Pulse Duty Cycle	10%	10%

Leerseite

13.10 DRAFT EUROCAE GBAS GROUND SUBYSTEM MOPS

ANNEX X8

DRAFT EUROCAE GBAS GROUND SUBYSTEM MOPS

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- EUROCAE -

MINIMUM OPERATIONAL PERFORMANCE SPECIFICATION FOR GNSS LANDING SYSTEM GROUND SUBSYSTEMS

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FOREWORD

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CHAPTER 1

GENERAL

1.1 PURPOSE AND SCOPE

This minimum operational performance specification for a Ground Based Augmentation System (GBAS) is designed to ensure that ground equipment certificated to it will be compatible with the SARPS material being generated by the ICAO Global Navigation Satellite System Panel (GNSSP). It is associated with the EUROCAE MASPS for GBAS – EDXX.

Chapter 1 of this document provides the information required to understand the need for the equipment characteristics and tests defined in the remaining chapters. It describes typical equipment applications and operational objectives and is the basis for the performance criteria stated in Chapter 2 to Chapter 4. Definitions essential to proper understanding of this document are also provided in Chapter 1.

Chapter 2 contains general design requirements.

Chapter 3 contains the minimum performance specification for the equipment, defining performance under standard operating conditions.

Chapter 4 prescribes the environmental test conditions which provide a laboratory means of determining the overall performance characteristics of the equipment under conditions representative of those which may be encountered in actual operations.

Chapter 5 describes recommended test procedures for demonstrating compliance with Chapters 3 and 4.

Chapter 6 specifies the performance required of the installed equipment. Ground and flight tests for the installed equipment are included when performance cannot be adequately determined through testing under standard test conditions.

1.1.1 Mandating and Recommendation Phrases

a. "Shall"

The use of the word "Shall" indicates a mandated criterion; i.e. compliance with the particular procedure or specification is mandatory and no alternative may be applied.

b. "Should"

The use of the word "Should" (and phrases such as "It is recommended that...", etc.) indicate that though the procedure or criterion is regarded as the preferred option, alternative procedures, specifications or criteria may be applied, provided that the manufacturer, installer or tester can provide information or data to adequately support and justify the alternative.

1.2 APPLICATIONS

GBAS is intended to support all types of approach, landing, departure and surface operations within the area of its coverage. The following MOPS are developed to support Category I precision approach operations within the GBAS coverage volume. A GBAS compliant with this MOPS can also support departure, en-route and terminal operations. Other GBAS MOPS will be developed at a later date to support, for example, landing operations down to Category II/III conditions and surface operations. In order to guarantee interoperability and enable efficient spectrum utilization, the radio frequency, data broadcast characteristics and frame and message structure are the same for all operations and are capable of supporting all types of approach, landing, departure and surface operations. Some messages may not be required to support certain operations.

The GBAS is initially applied to the landing function and provides an alternative precision approach system to ILS and MLS.

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The fundamental function of the GBAS Ground Subsystem is to calculate differential corrections for the received GNSS satellite signals and broadcast them to aircraft GBAS receivers.

The aircraft GBAS receivers utilise the corrections provided by the Ground Subsystem and compute precise position of the aircraft based on these corrections. Utilising this precise position, the aircraft is able to perform precision approach guidance into an airport facility under poor visibility conditions.

Compliance with this MOPS by manufacturers, installers and users is recommended as a means of assuring that the equipment will satisfactorily perform its intended function(s) under all conditions normally encountered in routine operations.

Any regulatory application of this document in whole or in part is the sole responsibility of appropriate government agencies.

As the measured values of equipment performance characteristics may be a function of the method of measurement, standard test conditions and methods of test are recommended in this document.

1.3 DESCRIPTION OF SYSTEM

The GBAS is part of GNSS and consists of two distinct functional segments that use the space segment to provide navigation support. In addition to the GNSS Space segment (GNSS satellites providing positioning signals) these functional segments are:

- the GBAS Ground Subsystem;
- the GBAS aircraft subsystem;

Only the BAS Ground Subsystem is specified in this MOPS.

The GNSS satellites provide the aircraft and ground GBAS subsystems with positioning information.

The satellite signals received by the GNSS receivers are contaminated with various error sources such as Selective Availability (SA), which is the intentional degradation of GPS signals for civilian users, certain atmospheric effects, multipath reflections, etc.. The GBAS Ground Subsystem has a precise knowledge of its GNSS antennas' locations and thus is able to compute the corrections for the received GNSS signals. These computed corrections (formatted as Type 1 Messages) are transmitted via data broadcast (or C-Band) Data Broadcast to aircraft GBAS receivers. In addition, the Ground Subsystem has the capability to broadcast Type 2 Ground Subsystem and Type 4 FAS Messages to the aircraft users via the same Data Broadcast. The Message content is built from pre-stored parameters that are specific to the Ground Subsystem installation.

After selection of the desired Final Approach Segment by the crew, the aircraft subsystem uses the differentially corrected aircraft position to supply navigation guidance signals:

- Horizontal Deviation with regard to the FAS,
- Vertical Deviation with regard to the selected FAS,
- Distance to the Threshold Crossing Point (TCP) of the selected FAS, with its associated integrity data.

1.3.1 Space Segment

The GNSS is a world-wide position, velocity, and time determination system, that includes one or more satellite constellations, receivers, and system integrity monitoring, augmented as necessary to support the required navigation performance for the actual phase of operation.

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In the time frame of initial GBAS implementation, it is anticipated that GPS and GLONASS will be the only GNSS constellations declared operational for civil use. Additional ranging signals from geostationary satellites are also anticipated to be available in the future. The use of constellations additional to GPS and GLONASS for GBAS instrument approach operations should be in conformance with both this document and pertinent sections of the EUROCAE WG-28 MOPS and RTCA DO-2XX MOPS for GPS and GLONASS augmented with other Systems / Equipment / Techniques.

1.3.2 Ground Subsystem

The GBAS Ground Subsystem broadcasts differential corrections and three-dimensional FAS path construction data to the aircraft subsystem. The subsystem consists of a Ground Receiver Function, which receives the GNSS satellite signals and generates the necessary differential information by using the surveyed known positions of the reference receiver antenna(s). A Ground Reference Function performs the necessary calculations to format the differential correction message. The Ground Subsystem also contains a Data Broadcast Function, which transmits the differential correction and FAS messages to all aircraft in the vicinity of the GBAS Ground Subsystem.

The Ground Subsystem also contains a Monitoring Function, which will provide an alert should the broadcast signal not achieve its performance specifications. Additional notification of outage is to be provided in co-ordination with the appropriate air traffic service authority.

The GBAS ground sub-system is the subject of this MOPS. It is described in greater detail in section 1.4 below.

1.3.3 Aircraft Subsystem

The GBAS aircraft subsystem consists of:

- An Aircraft GNSS Receiver Function,
- A Data Broadcast Receiver Function.
- An Aircraft Navigation Processing Function,
- An Aircraft GNSS Receiver Function

The Aircraft GNSS Receiver Function will receive the GNSS satellite signals in space and measure pseudorange to, and range rates for, each GNSS satellite. The Aircraft GNSS Receiver Function will provide these pseudoranges and range rates to the Aircraft Navigation Processing Function. The aircraft GNSS receiver will conform to ED 72A.

b. Data Broadcast Receiver Function

The aircraft Data Broadcast Receiver Function will receive the broadcast signal containing the differential corrections and the FAS path construction data. It will remove the communications protocols from the message, perform link-level data integrity calculations, and forward the differential corrections and the FAS data to the Aircraft Navigation Processing Function. It is tuned on the desired broadcast Channel according to the GLS Channel Selector (see 1.2.4.3).

There is no requirement for a down link capability for the GBAS application. The Data Broadcast Receiver Function will be able to recognise compatible differential signals for use by the GBAS aircraft subsystem and reject other signals.

c. Aircraft Navigation Processing Function

The Aircraft Navigation Processing Function receives the measurement of the pseudoranges to each GNSS satellite from the GNSS Receiver Function and applies the differential corrections received from the ground broadcast subsystem.

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It also receives the GLS Channel Selector (5 numeric characters) tuned by the crew, or transferred by the avionics, defining the runway end to be used according to the published instrument approach procedure. It contains:

- the desired Reference Path Selector,

- the desired broadcast channel.

The Aircraft Navigation Processing Function extracts from the different FAS path construction data, received from the Aircraft GNSS Receiver Function, the one having the desired Reference Path Selector. (The Reference Path Identifier, contained in the message, is a 5 character identifier uniquely designating each FAS and mentioned in the published instrument approach procedure. It provides confirmation of the selected FAS).

The differentially corrected aircraft position is subsequently processed, using selected FAS path construction data and differential corrections.

The Aircraft Navigation Processing Function elaborates with respect with the selected FAS:

- Horizontal Deviation,

- Vertical Deviation,

Distance to the Threshold Crossing Way Point of the FAS, with their associated integrity data.

While not required to do so by this MOPS, the Aircraft Navigation Processing Function may also output the aircraft corrected position for testing purposes. It may be used by the appropriate avionics to:

- provide missed approach guidance,

- offer enhanced RNAV capability,

- provide surface guidance to the crew.

1.3.4 System External Interfaces

The system has similar external interfaces to those of ILS. The Ground Subsystem provides integrity information to the local air traffic services provider. The aircraft subsystem provides deviations and integrity data to the aircraft in a similar fashion to that of an ILS receiver.

The input interfaces for both ground and aircraft subsystems are the GNSS signals in space and appropriate electrical power supplies. The Ground Subsystem is provided, in secured form, the co-ordinates of its GNSS antennas and the FAS data. The aircraft system receives channel select and runway selection data from the aircraft.

1.4 **FUNCTIONAL COMPOSITION**

The GBAS Ground Subsystem functional requirements contained in this specification have been divided into convenient functional groups that are briefly described below. No Ground Subsystem architecture or sub-assembly packaging should be implied from this functional sub-division.

1.4.1 Ground GNSS Receiver Function

The ground-based GNSS Reference Receiver Function receives the ”GNSS satellite signals” and provides ”GNSS Data” for each satellite to the reference and monitoring functions. This includes, time-tagged pseudorange information referenced to the WGS-84 co-ordinate system and satellite integrity information. Two or three geographically separated GNSS receivers are required to support Category I landing operations. Multiple receivers are required to suppress multi-path effects.

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1.4.2 Ground Reference Function

This function takes the "GNSS Data", calculates Pseudo-range Correction data, builds Type 1 Messages for transmission over the Data Broadcast. It also builds Type 2, 4 and 5 Messages, using stored data specific to the Ground Subsystem installation, that can also be transmitted via the Data Broadcast. All message types are provided (as Proposed Messages) to the Monitoring Function for validation before being provided to the Data Broadcast function.

The Reference Function will process information from the Ground GNSS Receiver Function in order to determine the differential corrections by reference to the stored antenna positions in the WGS-84 co-ordinate system.

A FAS path construction data-base is included in Reference Function. Path points describing approaches for each applicable runway are referenced to the WGS-84 co-ordinates system.

Differential corrections and FAS path construction data will be formatted into standard message formats by the Reference Function and provided for the physical and data link layers for transmission by the Data Broadcast Function. (Only levels 1 and 2 of the Open System Interconnection model are used under the broadcast message.)

1.4.3 Ground Data Broadcast Function

The Ground Data Broadcast Function transmits differential corrections and FAS path construction data to all the aircraft within the coverage area.

The broadcast may use the VHF or C-band aeronautical radionavigation frequencies. A detailed specification is given in § 3.3 and in Annexes A, F and G of the MASPS EDXX.

1.4.4 Data Broadcast Receive Function

This function receives and monitors the Data Broadcast signals at the Ground Subsystem's designated Data Broadcast frequency. The GBAS Messages received and other monitoring parameters, such as signal power, are provided to the Monitoring Function for further comparison and evaluation.

1.4.5 Ground Monitor Function

This function independently monitors all messages before and after transmission over the Data Broadcast. It uses independently stored GNSS data and FAS parameters as a basis for the monitoring. It provides a message release for validated messages and prevents transmission of any faulty messages detected. It is responsible for issuing integrity alerts over the Data Broadcast, alerts to the controlling ground facilities and Ground Subsystem shutdown commands according to the situation detected. Indication of a loss of signal integrity will result in either an integrity alert being transmitted or a shutdown of the broadcast.

1.4.6 Subsystem Interface Function

This function manages and monitors the general Ground Subsystem operation. It provides and manages interfaces to the ATC and Maintenance facilities. It provides an interface to a status display on the equipment rack, and an interface to a local control and display console which supports maintenance and installation activities.

1.4.7 Local Control and Display Function

This function provides an operational and maintenance status display at the Ground Subsystem. It enables a local operator to determine the current operational status of the Ground Subsystem and provides an indication of the fault status of any replaceable sub-assemblies. It also provides an authorised operator with the capability to download software and subsystem specific data, and the ability to access Ground Subsystem non-volatile fault logs, and to run diagnostic test routines.

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1.4.8 Remote Control and Display Function

This function provides the ATC facility with an operational status display and enables ATC personnel to determine the Ground Subsystem availability. It also provides the maintenance facility with a maintenance status display to allow maintenance personnel to determine the fault status of any replaceable sub-assemblies. Optionally, a terminal is also provided to allow access to detailed Ground Subsystem status information as well as allowing authorised personnel to control of Ground Subsystem mode switching.

A simplified functional block diagram of the GBAS Ground Subsystem is shown in Figure 2-1.

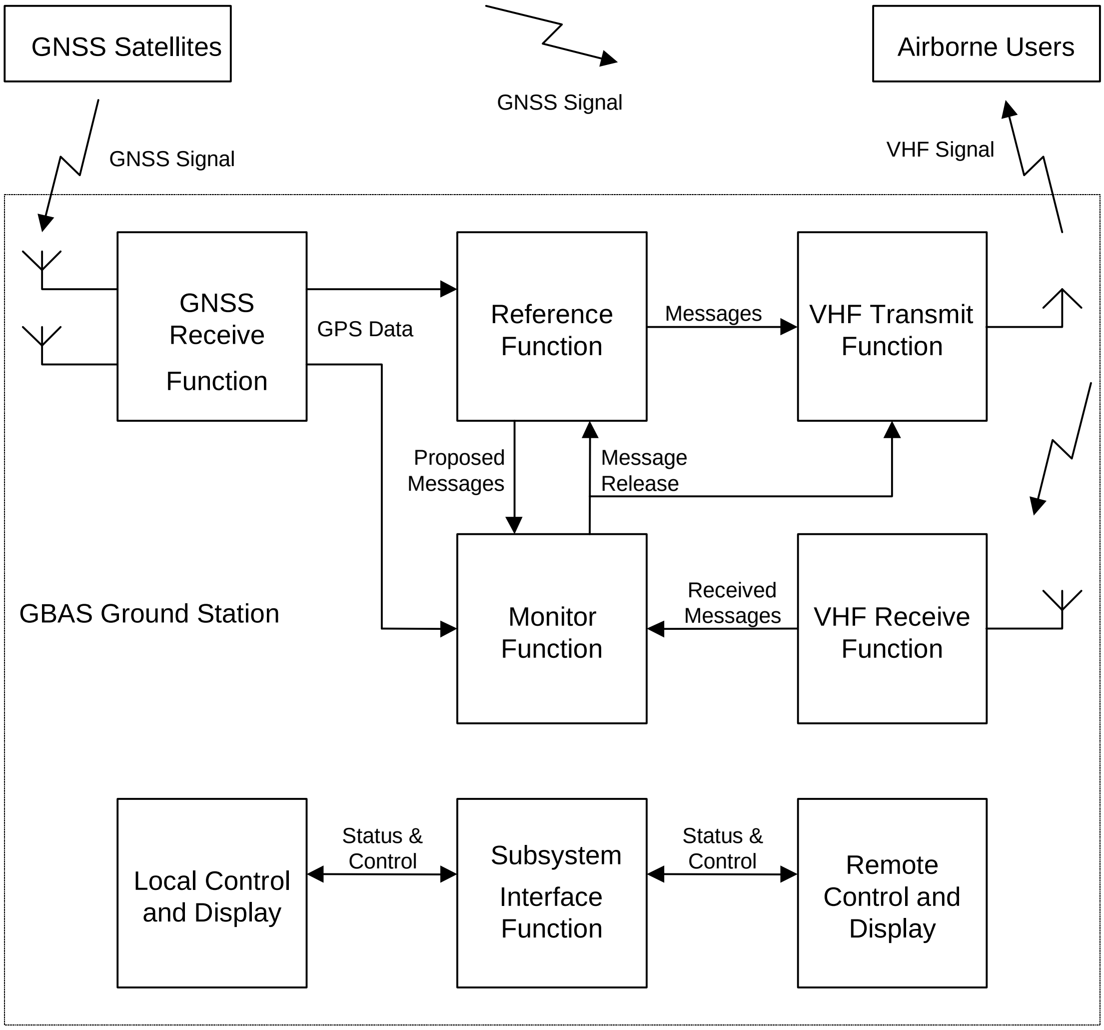

Figure 2-1: Simplified Functional Block Diagram

1.5 DEFINITIONS AND ABBREVIATIONS

List and define all terms and abbreviations used in the MOPS, particularly those which are specific to the equipment/system or otherwise unusual.

1.5.1 Definitions

Altitude:

The vertical distance of a level, point or object considered as a point, measured from mean sea level.

Ambient Temperature:

The temperature of the air surrounding the outside of any particular unit.

Antenna phase centre:

Nominally the geometrical centre of antenna front surface.

Approach reference datum point:

A point at a specific height above the intersection of runway centre line and the threshold.

Availability:
The availability of a navigation system is the ability of the system to provide the required guidance at the initiation of the intended operation. Availability risk is the probability that the required guidance will not be present at the initiation of the intended operation. (RTCA/DO-217) The system may be called upon to perform the intended function at any random time during which it is operating. The system requirement is normally specified as "Long-Term Availability", where the effects of climate, mission type and any local anomalies are averaged over a long period time.

Baud:

A unit of signalling rate equal 1 bit/s in a first order transmission system.

Built In Test Equipment (BITE):

Circuits, modules or features built into a GBAS equipment, to permit the verification of the system performance without the use of external equipment.

Continuity Of Service (COS):

The probability that the equipment will continue to radiate the guidance signals required to support landing operations during a specified time interval. The COS requirement is expressed in terms of the outages per million hours experienced over the specified time interval.

Continuity-of-Function
The continuity-of-function is the ability of the total system to perform its function without unscheduled interruptions during the intended operation time period.

Control Motion Noise (CMN):

That portion of the guidance signal error which causes control surface, wheel and column motion and could affect aircraft attitude angle during coupled flight, but does not cause aircraft displacement from the desired course and/or glide path.

Critical areas:

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Areas designated about the azimuth transmitter antenna and elevation transmitter antenna in which environmental changes including the presence of vehicles and aircraft will cause disturbances to the GBAS signals which will probably be unacceptable to an aircraft using the signal.

Differential Phase Shift Keying:

A modulation technique in which information is transmitted by means of defined phase shifts of carrier. A binary « 0 » is represented by 0° phase shift and binary « 1 » by a 180° phase shift.

Error budget:

A set of angular errors allowances, partitioned to indicate the proportion of the total system error which will be permitted for each signal degradation factor.

Executive monitor:

That equipment assures that erroneous guidance or data are not transmitted for longer time periods than are operationally acceptable.

Integrity:

The probability that potentially hazardous signal will not be radiated.

Integrity
The integrity of a system is that quality which relates to the trust which can be placed in the correctness of the information supplied by the total system. Integrity risk is the probability of an undetected (latent) failure of the specified accuracy (where the accuracy in this case refers to the outer containment tunnel). The integrity includes the ability of the system to provide timely warnings to the user when the system should not be used for the intended operation. (RTCA/DO-217)

Line Replaceable Unit (LRU):

A sub unit designed to be replaced on site to rectify a fault condition existing in the equipment.

Mean course error:

The mean value of the azimuth error along the specified azimuth radial.

Mean glide path error:

The mean value of the elevation error along the specified glide path.

Minimum glide path:

The lowest angle of descent along the zero azimuth radial that is consistent with published procedures and obstacle clearance criteria.

Path Following Error (PFE):

That portion of angle guidance signal error which could cause aircraft displacement from desired course and/or glide path. It's composed of path following noise and the mean course error (bias) or the mean glide path error (bias) as applicable.

Path Following Noise (PFN):

That fluctuation portion of the path following error which could cause aircraft displacement from the mean course line or glide path as applicable.

Sensitive area:

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An area extending beyond the critical area where the parking and/or movement of vehicles and aircraft will affect the GBAS signals and may be unacceptable to aircraft using the signals for automatic landing or roll out guidance.

Shelter:

A structure which protects equipment and personnel from direct exposure to open air environmental conditions.

1.5.2

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Abbreviations

AGC Automatic Gain Control
ARINC Aeronautical Radio, Inc.
ASIC Application-Specific Integrated Circuit. This refers to a custom-designed IC which is not generally available to all companies and users, and which does not have wide and general usage in the industry.
ATC Air Traffic Control, the agency which has IFR authority at the terminal area in question, and which has responsibility for the day-to-day operations of all equipment associated with supporting IFR operations in civil aviation.

BIT Built-In Test, the general ability of the system to autonomously detect and isolate faults.
BW Bandwidth

CBIT Continuous Built in Test
CDC Control and Display Console

CMN : Control Motion Noise

COS : Continuity Of Service

CRC Cyclic Redundancy Code: Checks a high-integrity error detection scheme applied to blocks of data transmitted via serial or parallel Broadcasts.

CW : Continuous Wave

CWI Continuous Wave Interference

DGNSS Differential Global Navigation Satellite System; refers to the generic concept of a system of satellites (e.g., GPS, GLONASS, geo-Subsystemary, etc.) and a system of ground Subsystems used to form an integrated civil aviation navigation aid.
DIAS DGNSS Instrument Approach System. An ILS-Look-Alike landing aid as defined in the RTCA/DO-217 document.
DIN DeutscheIndustrieNorm
DOP Dilution of Precision, is a measure of the geometric strength of the GPS navigation solution based upon the given constellation of satellites. The higher the OP, then the weaker the solution in that direction.

DPSK : Differential Phase Shift Keying

D8PSK : Differential 8 Phase Shift Keying

E Exponent(e.g. 1.0E-5)
EIA Electronics Industries Association, publishers of the RS-232 and RS-422 standards.

EMC : Electro Magnetic Compatibility

EMI Electro-Magnetic Interference.

ERP : Effected Radiated Power

FAA Federal Aviation Administration.

FAS : Final Approach Segment

FCC Federal Communications Commission.
FEC Forward Error Correction
FM Frequency Modulation
FMEA Failure Modes and Effects Analysis

GBAS : Ground Based Augmentation System

GLONASS : Global (Orbiting) Navigation Satellite System

GLS : GNSS Landing System

GNSS : Global Navigation Satellite System

GPS : Global Positioning Service

GPS Time See UTC.
GPSRX GPS Receiver Unit

HDOP Horizontal DOP

IBIT Initiated Built-in Test
IC Integrated Circuit.
ICAO International Civil Aviation Organization (Montreal)
ICD Interface Control Document
ID Identification
ILS Instrument Landing System
IOD Issue of Data
INIT Initialization
ISO International Standards Organisation

LCDC Local Control and Display Console

LCSU Local Control Status Unit

LSB Least Significant Bit (normally with Binary numbers)

LRU Line replaceable Unit

MBI Message Block Identifier

MCE Mean Course Error

MGE Mean Glide path Error

Module A line replaceable sub-assembly of a Ground Subsystem Unit
MSB Most Significant Bit
MSL Mean Sea Level
MTBA Mean Time Between Alarms, according to the stress analysis methodology.

MTBF Mean Time Between Failure, in the sense established in MIL-HDBK-217 reliability prediction.

MTBO Mean Time Between Outages
MTTR Mean Time to Repair

NAS National Aerospace System
nmi Nautical Miles
NVM Non-Volatile Memory

O&M Outline and Mounting

PBIT Power up Built in Test
PDOP Position Dilution of Precision

PFE Path Following Error

PFN Path Following Noise

PN Pseudo Noise
PRC Pseudorange Correction
PRN Pseudo-random Number (codes used for satellites)
Primary Power The Power input to an equipment or Sub-System
PROM Programmable Read-only Memory
PT Position (three-dimensional), and Time.
PBIT Power up Built in Test

RAM Random Access Memory

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RCSU Remote Control Status Unit

RF Radio Frequency

RMM Remote Maintenance Monitor

RMS Root Mean Squared
RMU Reference and Monitor Unit

RNAV Area Navigation

RRC Range Rate Correction
RTCA Radio Technical Commission for Aeronautics, also Requirements and Technical Concepts for Aviation

SA Selective Availability
SAE Society of Automotive Engineers
SCAT-1 Special Category 1
Secondary Power
The internal power line(s) of an equipment or Sub-System that is generated from the Primary Power
SPS Standard Positioning Service (as opposed to Precision Positioning Service), available to all GPS receiver users, but degraded by the selective availability disturbances so that the horizontal accuracy is only guaranteed to 100 meters, 2D-RMS.

TBD To Be Determined, the information is not known at this time

TCH Threshold Crossing Height

TDMA Time Division Multiple Access
TTFF Time to First Fix (time for a GPS to determine position after switch on or reset)

Unit A line replaceable assembly of the Ground Subsystem
UTC Universal Time Co-ordinate, a new time system since 1972, that is co-ordinated with the official atomic time (Zulu, or Greenwich Mean Time) to within +/-0.7 seconds. GPS System Time is the same as UTC, except that the "leap seconds" are ignored (i.e., GPS System time does not have the jumps).

VA Volt-Amperes
VDOP Vertical DOP
VG Verteidungs Geräte
data broadcast Very High Frequency (30 to 300 MHz). In this document the aviation navigation band is meant (108.000 to 117.975 MHz).
Vpp Volts peak-to-peak

WGS World Geodetic System.

1.6 REFERENCES

References may be tabulated in this section or may be quoted in other appropriate paragraphs of the text. References should include relevant ICAO SARPS annexes, and other EUROCAE, RTCA and SAE documents.

1.7 APPLICABLE DOCUMENTS

The following documents of the exact issue shown form a part of this specification to the extent specified herein. In the event of conflict between the documents referenced herein and the contents of the specification, the contents of this specification shall be considered to have precedence over the documents listed in this section.

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1.7.1 US Government Documents

1 ICD-GPS-200 Navstar GPS Space Segment/ Navigation User Interfaces, Rev. C

FAA Specifications

2 FAA Order 6000.32 Security Requirements for Remote Access of NAS Facilities

3 FAA Order 8400.11 IFR Approval of Differential Global Positioning System (DGPS) Special Category I Instrument Approaches using Private Ground Facilities, 15 Sept 94

TAT&E SCAT-I DGPS, Type Acceptance Test & Evaluation Plan, Rev. 5, Dated 12 June 95, National Airways System Engineering Division, AOS-200.

FAA Standards

1 FAA-D-2494/b Technical Instruction Book Manuscript: Electronic, Electrical and Mechanical Equipment, Requirements for Preparation of Manuscript and Production of Books, Appendix I Commercial Instruction Books

2 FAA-G-2100F Electronic Equipment, General Requirements, 15 Nov 93.

3 FAA-STD-019 Lightning Protection, Grounding, Bonding and Shielding Requirements for Facilities, Rev. b, 28 Aug 90.

4 FAA-STD-020 Transient Protection, Grounding, Bonding and Shielding Requirements for Electronic Equipment, Rev. b, 26 Sept 85.

US Military Standards

5 MIL-STD-1472D "Human Engineering Design Criteria for Military Systems, Equipment, and Facilities", 14 Mar 89

6 MIL-STD-1629A "Procedures for Performing a Failure Mode, Effects, and Criticality Analysis", 24 Nov 80

7 MIL-STD-461D "Requirements for the Control of Electromagnetic Interference Emissions and Susceptibility"

8 MIL-STD-810E "Environmental Test Methods and Engineering Guidelines", 14.07.89, Notice 2, 01 Sept 93

Other Publications

9 AC 25.1309-1A, FAA Advisory Circular, "System Design and Analysis" 21 June 88

10 FCC Regulation 47 Code of Federal Regulations "Aviation Services", Part 87

11 MIL-HDBK-217F "Military Handbook: Reliability Prediction of Electronic Equipment", 2 Dec 91

1.7.2 Non-Government Documents

Specifications

1 Manufacturer Front Panel & Name Plate Design, Rev. 1.0

Standards

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2 IEC 1000-4 Electromagnetic Compatibility (EMC) part 4: Testing and Measurement Techniques, Feb 1995

3 IEC 950 Safety of Information Technology Equipment, Including Electrical Business Equipment, 1991/A3 1995

4 RTCA/DO-178B Software Considerations in Aircraft Systems and Equipment Certification, 01.12.92

5 RTCA/DO-217 Minimum Aviation System Performance Standards DGNSS Instrument Approach System: Special Category I (SCAT-I), Change 1, 13 July 94

6 RTCA/DO-217 Change 2, 15 Nov 96

7 RTCA/DO-229 Minimum Operational Performance Standards for GPS/WAAS Aircraft Equipment, 16 Jan 96

Other Publications

8 58.0038.800.17 UE NFS Document: D920-100 Project Quality Assurance Plan, Rev. 2.0

9 ICAO Annex 10 Part I Dated 21 Nov 85

10 SAE, ARP 4761 Guidelines and Methods for Conducting the Safety Assessment Process on Civil Aircraft Systems and Equipment,

11 Manufacturer Type Approval Plan,

12 Manufacturer Equipment Qualification Plan

13 Manufacturer Traceability Matrix

CHAPTER 2

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GENERAL DESIGN REQUIREMENTS

2.1 INTRODUCTION

This chapter establishes the design considerations and general specification for the equipment comprising the GBAS Ground Subsystem.

The GBAS Ground Subsystem contains all essential functions that are needed to fulfil the requirements for the ground element of the differential GNSS Landing System.

2.2 CHARACTERISTICS

2.2.1 Performance Characteristics

The GBAS equipment, when viewed at the overall system level or at the individual sub-system level, must perform the functions described in the following sub-sections to the specified performance in the environments specified in chapter 4, when applied singly or in any combination.

The requirements specified in this General section are aggregate requirements for all Ground Subsystem functions.

2.2.1.1 Basic Ground Subsystem Function

The Ground Subsystem must continuously receive GPS (optionally GLONASS and SBAS) signals in space and provide GBAS messages transmitted as a data broadcast signal, without the need for operator attendance or intervention.

The GBAS message set contain Type 1 Differential Correction Messages and Integrity Alarms plus Type 2 and Type 4 Messages. Optionally, Type 5 Messages may also be transmitted.

2.2.1.2 Integrity

The total integrity risk shall be less than 3.0E-8 per approach for all functions and system aspects associated with the Ground Subsystem that could lead to an undetected GBAS Message corruption. An approach is defined to be a 2.5 minute time period.

GBAS Message Corruption is defined as any falsification of parameters in the broadcast GBAS message that could cause an aircraft performing a GBAS approach to generate a Navigation System Error greater than the specified Alert Limit, that is:

For the Ground Subsystem, Message Corruption shall be interpreted to be:

1) Any corruption of the Type 4 FAS Data transmitted on the Data Broadcast

2) Any deviation of the Type 1 Differential Corrections Data which cause the "Pseudorange Accuracy" requirement in this document to be violated.

Note: The integrity budget for the Ground Subsystem is derived from the total GBAS integrity requirement of 1.0E-7 per approach.

The Data Broadcast is required to have an integrity risk of less than 1.0^{-8}. This is achieved by use of 32-bit CRC on the GBAS Messages. This 32-bit CRC provides end to end protection of 2.3^{-10} on each message.

2.2.1.3 FAS Stored Data Integrity

The integrity risk of any undetected corruption or falsification of stored FAS data in the Ground Subsystem shall be less than 3.0E-8. This includes the process of downloading the data from an external data carrier and storage in the Ground Subsystem's Non-Volatile

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Memory, whereby the FAS data shall be protected at all times by CRCs, which were added during source generation and validation.

2.2.1.4 Continuity of Service

The total Ground Subsystem Continuity-of-Service failure probability shall not exceed 3.8E-5 per approach including any Ground Subsystem failure or Ground Subsystem issued integrity alarm which leads to the loss of the navigation function. An approach is defined to be a 2.5 minute time period.

For the GBAS Ground Subsystem, a loss of continuity is defined to be a loss of functionality (due to hardware failure or integrity alarm) during approach.

The continuity of service risk is based upon the combined MTBO for Ground Subsystem hardware and the MTBA for Ground Subsystem issued integrity alarms but does not include the risk due to satellite outages or inadequate quality of the geometry, resulting from such outages.

Note: The continuity-of-service requirement is to be verified via analysis, since performance probabilities this small cannot be feasibly demonstrated. This continuity-of-service requirement is derived from the normative allocation made in Appendix C of the EUROCAE MASPS. The total GBAS continuity-of-function requirement is 1.0^{-4}.

2.2.1.5 Long Term Availability

The Ground Subsystem availability in an operational environment shall exceed 98% averaged over a typical one-year period, excluding periods of loss of availability attributable to satellite signal and data broadcast signal outages.

Ground subsystem availability is defined as the probability that the GBAS ground equipment is operating within the system performance requirements specified in this document.

Note: The availability requirement is to be initially verified by analysis. After sufficient operational experience has been gained, the requirement will be verified by the use of empirical data.

2.2.1.6 Data Transport Delay

The time delay, measured from the one-second roll-over of the GPS time to start of transmission of the respective Type 1 GBAS Message as a data broadcast signal, shall be less than 1 second.

2.2.1.6.1 Nominal Update Period for Type 1 Messages

The nominal update period of the Type 1 differential corrections message (defined as the average interval between unique sets of broadcast corrections from the Ground Subsystem during normal operation) shall not exceed 0.6 seconds.

The maximum update period shall not exceed 6 seconds.

2.2.1.6.2 Update Period for Type 4 Messages

The nominal update period of Type 4 FAS information (defined as the average interval between unique sets of broadcast FAS data from the Ground Subsystem when enabled during normal operation) shall not exceed 15 seconds.

The maximum update period shall not exceed 20 seconds.

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2.2.1.7 Alert Latency

The ground segment integrity alert latency shall be a maximum of 3.0 seconds and is defined as the total delay between the onset of a condition requiring a ground-based alert and completion of transmission of the integrity alert from the ground to the aircraft system.

2.2.2 World-wide Operation

World-wide navigation shall be supported without any system degradation beyond the performance limits of this document, due to mathematical singularities (such as at the poles, equator, or longitude equal to ±180°). This requirement refers ONLY to the performance of algorithms used in the Ground Subsystem.

"World-wide" is defined as any combination of latitude and longitude on the earth's surface for altitudes between -5000 and +25000 meters MSL (Mean Sea Level).

2.3 GPS RECEIVER FUNCTION

This function receives the L1 GPS Signal (GLONASS and SBAS optional) from each satellite in view. Using the SPS C/A code, it automatically acquires and tracks each GPS satellite in view and makes pseudorange measurements. It extracts timing information from the GPS signal. It takes Integrated Carrier Phase measurements that are needed for improved accuracy. Orbital parameters of the satellites are decoded from the GPS Signal (i.e., ephemeris data). All these parameters and measurement data are output as GPS data, which is then used for further computations in the Reference Function and the Monitoring Function.

2.3.1 GPS Signal Reception

The GPS Receiver Function shall be capable of receiving and demodulating an L1 (1575.42 Mhz) GPS input signal defined to be between -130 dBmic (dB relative to 1 mW into an isotropic circular polarized antenna) and -123 dBmic incident on the antenna at and above the designed mask angle.

The GPS Signal characteristics are defined in Navstar GPS Interface Control Document ICD-GPS-200 (Ref.).

2.3.1.1 GPS Interference Immunity - CWI

The GPS Receiver Function shall be capable of operating without performance degradation beyond the requirements of this specification in the presence of out-of-band continuous wave interfering signals incident on the antenna port.

Note: All the interference levels specified are defined with the assumption that the received satellite signal levels at the GPS antenna port are -134.5 dBm. These signal levels represent that which would be present at the antenna port of an antenna whose gain above the 5^o elevation angle is -4.5 dBic. If a GPS antenna is used whose gain differs from this assumption, then the interference levels should be adjusted accordingly.

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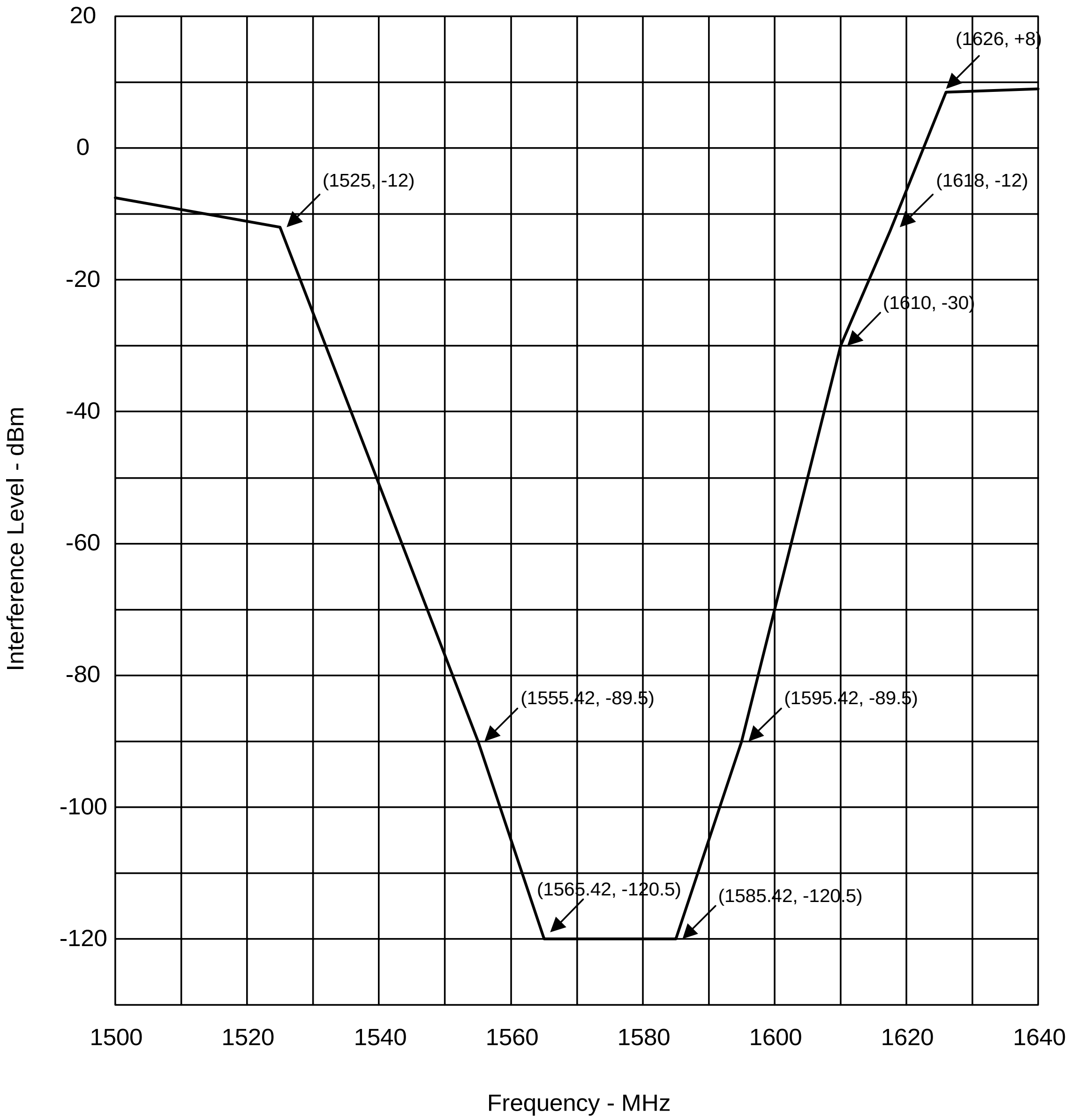

Figure 2-2 : Interference Levels

Note: The CW interference level below 1500 Mhz increases linearly to 25.5 dBm at 1315 Mhz. Above 1640 Mhz the levels increase linearly to 21.5 dBm at 2 Ghz.

The equipment could receive an interference signal in the frequency range of $1575.42 \pm BW_I / 2$ MHz that is a function of the interfering bandwidth (BW_I) as defined in RTCA/DO-229.

2.3.1.2 GPS Interference Immunity - EMC

The GPS Receiver Function shall be capable of operating without performance degradation beyond the requirements of this specification in the presence of RF interference from other sources (both pulsed and CW) typically found in airport environments, including the Ground Subsystem data broadcast transmitter.

A sufficient verification, prior to installation at the specific airport, is considered to be the EMC Compatibility tests detailed in this document.

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2.3.2 GPS Antenna

The GPS Antenna shall use a right hand circular polarised (RHCP) design.

The interface to the antenna shall be a coaxial cable suitable for exposed environmental conditions.

2.3.3 Multi-path errors

The ground Reference Function and ground Integrity Monitoring Function shall employ multiple independent antennas, in order to reduce the effects of multi-path errors. Choke rings should be used on GPS antennas in order to increase antenna gain roll-off below 0^o elevation.

The antenna gain roll-off between 5^o and 0^o elevation should be at least 0.4 dB/deg and should continue with this trend below 0^o elevation.

2.3.4 Pseudorange Measurement Frequency

The pseudorange measurements shall be made at least once per second.

2.3.5 Continuous Acquisition and Tracking

The GPS Receiver function shall continuously acquire and track all satellites in view up to a maximum of 12 GPS satellites.

The satellites "in view" are defined as all healthy GPS satellites which have an unobstructed line-of-sight to the antenna, taking the assigned masking patterns into consideration.

2.3.6 Time-To-First-Fix

The TTFF shall be sufficient to allow the warm-up time and system availability requirements of this specification to be met.

Assuming the following conditions the TTFF shall be 3.5 minutes (with a 95% confidence level):

1) the stored or initialised almanac data is valid and less than 7 days old,

2) the stored or initialised position data is valid to within 100 kilometres,

3) the time/date initialisation is accurate to within one minute,

4) the GPS signal level is within the specified range

The abnormal TTFF should be less than 10 minutes. The abnormal TTFF is defined as when the available initialisation data are absent or are invalid.

2.3.7 Re-Acquisition

Re-acquisition is defined as the situation when tracking has been lost on one or more satellites, but not so many that navigation capability has been lost (i.e., more than 3 satellites could be tracked during the outage). This can happen if the antenna suffered partial shadowing.

The partial re-acquisition times should be as indicated in the table below.

Total Outage Time (sec)	Re-Acquisition Time (sec)
< 5	5
5 to 10	10

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10 to 60	30

2.3.8 Provide Raw Pseudo-range Measurements

The GPS Receiver function shall provide raw Pseudo-range measurements for each satellite tracked using the SPS C/A code only (i.e., not smoothed or otherwise corrected). No corrections (e.g., ionospheric or tropospheric) or datum-to-datum transformations shall be made.

Note: These outputs are used for computing the data needed for generating the Type 1 GBAS Message.

2.3.9 Provide Integrated Carrier Phase Measurements

The GPS Receiver shall make integrated carrier phase measurements for each satellite being tracked, at a frequency of 1.0 Hz or more. The measurements should be synchronised to the GPS time one-second roll-over.

Note: The use of a high-performance GPS Receiver with narrow correlator is recommended in order to provide the necessary accuracy along with the low noise.

2.3.10 Provide Precision GPS Time

The GPS Receiver Function shall compute and output precision timing information synchronized to the universal GPS Time in the form of both digital data words and discrete timing pulses. The time data shall be associated with the measurement time, and shall be accurate to within 500 nanoseconds. In addition to accurately identifying the time of the measurement, this information will be used to identify the second, hour, day and year relative to the GPS time.

The discrete timing (marker) pulses shall identify the one-second roll-over of GPS Time by its rising edge, to an accuracy of +/-250 nanoseconds. The discrete timing pulse signals are used to provide an accurate timing reference to the Data Broadcast and Receiver Functions.

2.3.11 Provide Channel-Specific Status Data

For each satellite being tracked, the GPS Receiver function shall provide signal-to-noise ratio, satellite ID, Pseudorange and Integrated Carrier Phase status signals, as a minimum, for the purposes of monitoring internal to the Ground Subsystem.

2.3.12 Provide Ephemeris Data

For each satellite being tracked, the GPS Receiver function shall extract the current ephemeris from the GPS signal. This data is included in the GPS Data provided to the Reference and Monitor functions.

2.4 **REFERENCE FUNCTION**

The Reference Function receives the GPS Data (pseudorange measurements, integrated carrier phase, timing information, status and ephemeris data) from the GPS Receiver Function. It validates the data, then, based upon the known antenna positions, computes the differential corrections for each satellite in view. In addition, it detects any faulty or unhealthy satellite data and provides status information. It then prepares a Type 1 (Differential Corrections) message. The Reference Function also prepares a Type 4 (FAS message), based on data pre-stored in non-volatile memory which represents Final Approach Segment data for the specific runway ends (or Ground Subsystem installation). Type 2 Messages and optionally Type 5 Messages are also generated. Messages (formatted as Application Layer Data) are sent to the Data Broadcast Function after monitoring and successful message release granted by the Monitoring Function. Alternatively, a message containing an Integrity Alert can be commanded if an Alert condition is detected by the Monitoring Function.

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2.4.1 Provide Differential Correction Data

The Reference Function shall process the GPS data as provided by the GPS Receive Function in each 1 second epoch (pseudo-ranges, ephemeris data, integrated carrier phase, GPS time) and provide Differential Correction Data for inclusion in a GBAS Type 1 Application Layer message to the Data Broadcast Function.

The Type 1 differential correction data falls into one of two categories; satellite specific, and Ground Subsystem general. The satellite specific data consists of Satellite ID, Pseudo-range Correction (PRC), Issue of Data (IOD), Ephemeris CRC, Range Rate Correction (RRC) and integrity parameters. A complete set of these data must be provided in the GBAS Type 1 Application Layer message for each satellite that is being tracked. The Ground Subsystem general data consists of the Modified Z-count and other parameters. One set of these data must be provided in each GBAS Type 1 Application Layer message.

2.4.2 Satellite Specific Data

The GBAS Ground Subsystem shall generate ranging source measurement block for up to 18 ranging sources. The maximum time between transmission for each ranging source measurement block shall be 0.5625 seconds.

2.4.2.1 Provide Satellite ID

The received satellite ID (PRN) shall be provided for each satellite being tracked.

The ID's 1 to 32 are reserved for the satellites/code phases consistent with ICD GPS-200 (Ref.).

2.4.2.2 Compute Pseudorange Correction Data

The Pseudorange Correction (PRC) shall be computed for each satellite being tracked.

The Pseudorange Correction (PRC) is defined as the difference between the theoretical range (based on the satellite position (as derived from the ephemeris data and a precise knowledge of the Ground Subsystem GPS antenna positions) and the measured satellite pseudorange. The measured pseudorange is contained in the data received from the GPS Receiver Function.

2.4.2.3 Provide Issue of Data

The received Issue of Data (IOD) shall be provided for each satellite being tracked.

The Issue of Data identifies the ephemeris data issue used when calculating the PRCs. The correction data provided by the Ground Subsystem will only be used by aircraft equipment when the satellite IOD and Ground Subsystem issued IOD are identical.

2.4.2.4 Ehemeris CRC

The Reference Function shall compute a 32-bit CRC for the ephemeris data being used by the Receiver Function to computer the pseudoranges. This CRC is broadcast in Message Type 1.

2.4.2.5 Compute Range Rate Correction Data

The Range-Rate Correction (RRC) shall be computed for each satellite being tracked.

The range-rate correction (RRC) is defined as the rate of change in the PRC. It is not intended to be a velocity correction, but merely a rate of change applied to the PRC to allow aircraft equipment to extrapolate from the time when the pseudoranges were valid to the time when the PRCs are applied.

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2.4.2.6 ***Valid Global Positioning System Ranging Sources***

The GBAS Ground Subsystem shall detect any error not accounted for in the σ_{pr_gnd} and B-values that result in an exceedance of the values in Table 3-3 with a probability greater than 1 - $1x10^{-8}$. After detection, the GBAS Ground Subsystem shall cease broadcast of the ranging source measurement block.

Table 3-3. Error Values – Global Positioning System

M(n)*	VALUE
M(n)=2	1.9 TBC metres
M(n)=3	1.1 TBC metres
M(n)=4	0.7 TBC metres

*M(n) is the number of elements of S_n (the set of RRs with valid measurements for satellite n).

The following failure modes are assumed to be independent and shall be accounted for:

a. signal deformation (a fault that causes correlation peak asymmetry that results in code correlation biases due to different correlator spacing in ground and aircraft receivers);

b. RF Interference (RFI) in excess of levels defined in the GBAS SARPS;

c. signal levels below those specified in the GPS SPS Signal Specification, Section 2.3.4;

d. code/carrier divergence; and

e. the impact of excessive acceleration, such as step or other rapid changes, of the code and carrier phases on the differential correction process.

2.4.2.7 ***Valid Space Based Augmentation System Ranging Sources***

If the GBAS Ground Subsystem is providing corrections for SBAS ranging signals, it shall cease broadcast of an SBAS ranging source measurement block if the maximum error on the broadcast pseudorange corrections exceeds the values relative to the number of RRs as shown in Table 3-4.

Table 3-4. Error Values – Space Based Augmentation System

M(n)	VALUE
M(n)=2	1.9 TBC metres
M(n)=3	1.1 TBC metres
M(n)=4	0.7 TBC metres

The probability that exceedance of values are not detected shall be less than or equal to $1x10^{-8}$ TBC due to

a. signal deformation (a fault that causes correlation peak asymmetry that results in code correlation biases due to different correlator spacing in ground and aircraft receivers);

b. RFI in excess of levels defined in Appendix A;

c. signal levels below those specified in the WAAS Specification FAA-E-2892C, Appendix 2, Section 2.5.6;

d. code/carrier divergence; and

e. the impact of excessive acceleration, such as step or other rapid changes, of the code and carrier phases on the differential correction process.

2.4.2.8 ***Time to Exclude***

The total period of radiation of any data that are out of tolerance shall not exceed 3 seconds under any circumstances.

2.4.2.9 ***Valid Global Positioning System Ephemeris***

The GBAS Ground Subsystem shall broadcast the ranging source measurement block when

a. no more than three parity errors have been detected in any six seconds, in accordance with the parity algorithm equations defined in the GPS SPS Signal Specification;

b. all RRs used to compute the PRC have received and decoded the same ephemeris and clock data; and

c. new broadcast ephemerides have been validated to be accurate within 500 meters of true satellite position at all times in the orbit.

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New ephemerides shall not be used to compute broadcast corrections until they have been continuously present for at least two minutes and have been validated by confirming conditions a - c. The new ephemerides shall be used to compute broadcast corrections within one minute of validation.

2.4.2.10 ***Valid Space Based Augmentation System Navigation Messages (Optional)***

The GBAS Ground Subsystem shall broadcast the SBAS ranging source ID when

a. no more than three parity errors have been detected in any six seconds, in accordance with the parity algorithm equations defined in the WAAS Specification FAA-E-2892 Appendix 2, Section 4.3.3;

b. all RRs used to compute the PRC have received and decoded the same ephemeris and clock data;

c. new broadcast ephemerides have been validated to be accurate within 500 meters of true satellite position at all times in the orbit; and

New ephemerides shall not be used to compute broadcast corrections until they have been continuously present for at least two minutes and have been validated by confirming conditions a - c. The new ephemerides shall be used to compute broadcast corrections within one minute of validation.

2.4.2.11 ***Issue of Data***

The Issue of Data (IOD) shall be set to the IOD Ephemeris (IODE) used to determine the broadcast correction.

2.4.2.12 ***Pseudorange Corrections***

The GBAS Ground Subsystem shall set the broadcast pseudorange correction. Ionosphere and troposphere corrections shall not be applied to the measurements.

2.4.2.13 ***Smoothed Pseudorange***

In steady state, each pseudorange measurement from each RR shall be smoothed using the filter

$$PR_s(k) = \left(\frac{1}{N}\right) PR_r(k) + \left(\frac{N-1}{N}\right)\left[PR_s(k-1) + \phi(k) - \phi(k-1)\right]$$

$$N = S/T$$

where PR_r is the raw pseudorange,

PR_s is the smoothed pseudorange,

N is the number of samples,

S is equal to 100 seconds (filter time constant),

T is sample interval (0.5 sec),

ϕ is the accumulated phase measurement,

k is the current measurement, and

$k-1$ is the previous measurement.

2.4.2.14 ***Global Positioning System Predicted Range***

The predicted range (R) to each GPS ranging source shall be computed from the corresponding RR antenna location and the validated ephemeris. The ephemeris shall be determined in accordance with the GPS ICD 200 C Section 20.3.3.4.3.

2.4.2.15 ***Space-Based Augmentation System Predicted Range (Optional)***

The predicted range (R) to each SBAS ranging source shall be computed from the corresponding RR antenna location and the validated ephemeris. The ephemeris shall be determined in accordance with the WAAS Specification FAA-E-2892C Appendix 2.

2.4.2.16 ***Global Positioning System Smoothed Pseudorange Correction***

The smoothed pseudorange correction (PR_{sc}) shall be calculated using the equation

$$PR_{sc} = PR_s - R - \tau_{sv}$$

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where τ_{sv} is the correction due to the satellite clock from the decoded GPS Navigation Data in accordance with the algorithm given in the GPS ICD 200 C Section 20.3.3.3.3.

2.4.2.17 ***Space-Based Augmentation System Smoothed Pseudorange Correction (Optional)***

The smoothed pseudorange correction (PR_{sc}) shall be calculated using the equation

$$PR_{sc} = PR_s - R - \tau_{sv}$$

where τ_{sv} is the correction due to the satellite clock from the decoded WAAS Navigation Data Message Type 9 in accordance with the algorithm given in the WAAS Specification FAA-E-2892C Appendix 2.

2.4.2.18 ***Broadcast Correction***

The broadcast correction (PR_{corr}) shall be calculated using the equations

$$PR_{corr}(n) \equiv \frac{1}{M(n)} \sum_{m \in S_n} PR_{sca}(n,m)$$

$$PR_{sca}(n,m) \equiv PR_{sc}(n,m) - \frac{1}{N_c} \sum_{n \in S_c} PR_{sc}(n,m)$$

where PR_{corr} is the average pseudorange correction for broadcast;

PR_{sca} is the carrier smoothed and receiver clock adjusted pseudorange correction;

m is the RR index;

n is the satellite index;

S_c is the maximum set of common valid ranging sources tracked by all RRs;

S_n is the set of RRs with valid measurements for satellite n;

N_c is the number of elements in set S_c, where N_c shall be equal to a minimum of 4; and

M_n is the number of elements of S_n.

2.4.2.19 ***Ground Based Augmentation System Ground Facility Accuracy Performance***

The GBAS Ground Subsystem Signal-in-Space (SIS) accuracy is stated in terms of total error measured at the GBAS Ground Subsystem reference point introduced into the average pseudorange correction broadcast to the GBAS aircraft subsystem. The GBAS Ground Subsystem reference point is defined to be the RR "1" antenna location. The SIS performance requirements contained in this section shall be met under the interference conditions identified in Appendix A.

2.4.2.20 ***Global Positioning System***

The Root Mean Square (RMS) of the total SIS contribution to the GPS/GBAS error given as a function of satellite elevation angle and number of independent measurements shall not exceed

$$BCE_{GPS}(\theta_n, M) = \sqrt{\frac{(0.16 + 1.07e^{-\theta_n/15.5})^2}{M}}$$

where BCE_{GPS} is the RMS of the GBAS Ground Subsystem Broadcast Correction Error for GPS at the time of applicability (modified Z-count),

θ_n is the n^{th} satellite elevation angle, and

M is the number of independent pseudorange corrections per satellite as depicted in Figure 3-2.

This requirement shall be satisfied under the following conditions:

a. M shall be no less than 3 for the fault free configuration.

b. Each RR measurement (*m,n*) used to determine the broadcast corrections shall be updated at a minimum 2 Hz rate.

c. Each RR measurement (*m,n*) used to determine the broadcast corrections shall be based on identical signal processing techniques and tracking loop characteristics, where correlator spacing shall be XX chip width.

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The RMS error requirement shall be met in 1º increments from 5º elevation to 10º elevation, and at every azimuth in 5º increments from 0º to 360º.
The RMS error requirement shall be met in 5º increments from 10º to 90º elevation, and at every azimuth in 5º increments from 0 to 360º.

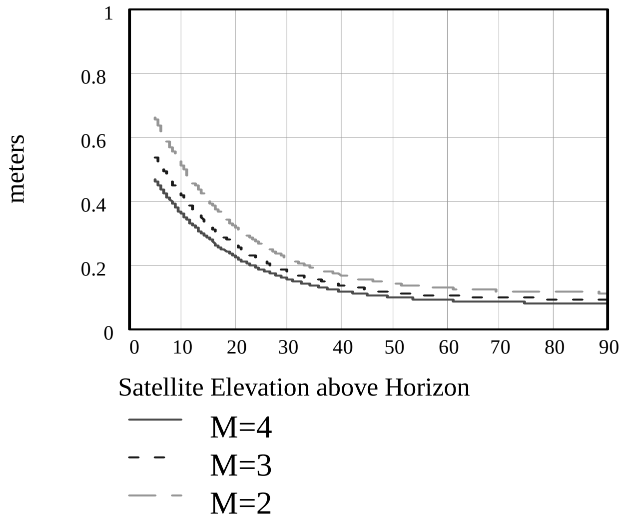

Figure 3-2. Broadcast Correction Error, Global Positioning System

2.4.2.21 ***Space-Based Augmentation System (Optional)***

The RMS of the total SIS contribution to the SBAS/GBAS error given as a function of satellite elevation angle and number of independent measurements shall not exceed

$$BCE_{SBAS}\left(\theta_n, M\right) = 0.15 + 1.91\sqrt{\frac{(0.16 + 1.07e^{-\theta_n/15.5})^2}{M}}$$

where BCE_{SBAS} is the RMS of the GBAS Ground Subsystem Broadcast Correction Error for SBAS as depicted in Figure 3-3.
This requirement shall be satisfied under the following conditions:

a. M shall be no less than 3 for the fault free configuration.

b. Each RR measurement (*m,n*) used to determine the broadcast corrections shall be updated at a minimum 2 Hz rate.

c. Each RR measurement (*m,n*) used to determine the broadcast corrections shall be based on identical signal processing techniques and tracking loop characteristics, where correlator spacing shall be XX chip width.

The RMS error requirement shall be met in 1º increments from 5º elevation to 10º elevation, and at every azimuth in 5º increments from 0º to 360º.
The RMS error requirement shall be met in 5º increments from 10º to 90º elevation, and at every azimuth in 5º increments from 0 to 360º.

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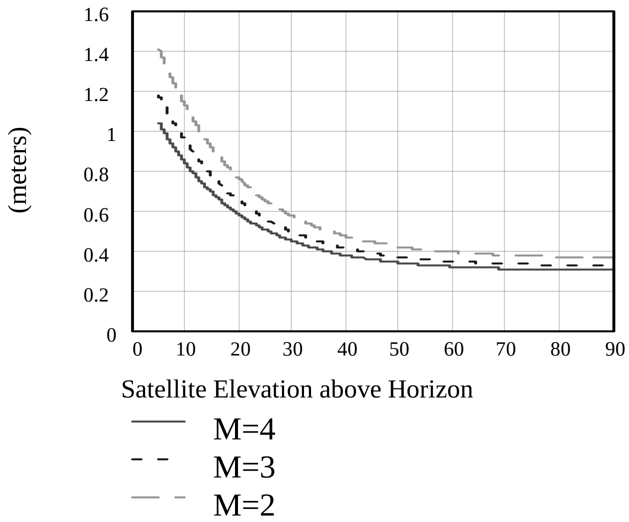

Figure 3-3. Broadcast Correction Error, Satellite-Based Augmentation System

2.4.2.22 ***Integrity of Corrections***

The GBAS Ground Subsystem shall broadcast the ranging source measurement block when

a. continuous lock has been maintained on the ranging signals used in determining the correction;

b. the magnitude of the associated B values does not exceed 5.6xBCE_{GPS} / sqrt[M(n)-1] for GPS ranging sources and does not exceed 5.6x(BCE_{SBAS}-0.15) / sqrt[M(n)-1] for SBAS ranging sources;

c. the magnitude of the pseudorange correction does not exceed 327.67 meters;

d. under fault free conditions, the distribution of the broadcast correction error is symmetrical, monotonically decreasing, and over-bounded by a normal distribution N (0, $\sigma^2_{pr\_gnd}$) for all errors more improbable than 0.001 TBC; and

e. the absolute value of the statistical correlation coefficient between the measurement errors of any two RRs is no greater than 0.1, with at least 99.9% confidence.

The probability that an undetected single RR failure exists that violates condition d or e shall be less than $1x10^{-5}$ in any 150 second interval.
The probability of any undetected failure on multiple RRs that violates condition d or e shall be less than $1x10^{-8}$ in any 150 second interval.

2.4.2.23 ***Pseudorange Correction Rate***

The GBAS Ground Subsystem shall determine the pseudorange correction rate for all valid broadcast corrections. The pseudorange correction rate shall be computed as the difference between the broadcast correction of current, and immediately prior, epochs divided by the sampling interval between them (maximum 0.5 seconds). The Type 1 Message shall contain the pseudorange correction rate for all valid pseudorange corrections using 16 bits, with a range of ±32.76 meters per second.
2.4.2.23.1 Condition for Valid Pseudorange Correction Rate

If the pseudorange correction rate exceeds ±3.4 meters per second, then the ranging source measurement block shall not be included in the Type 1 Message.

2.4.2.24 ***Sigma Pseudorange Ground***

For each valid ranging source, the GBAS Ground Subsystem shall set the Sigma Pseudorange Ground (σ_{pr_gnd}) using equation (a) for ranging source ID 1 - 37

$$\text{(a) } \sigma_{pr\_gnd}(\theta_n, M) \le BCE_{GPS}(\theta_n, M)$$

or equation (b) for ranging source ID 120 - 138

$$\text{(b) } \sigma_{pr\_gnd}(\theta_n, M) \le BCE_{SBAS}(\theta_n, M).$$

2.4.2.24.1 Condition for Valid Sigma Pseudorange Ground

The GBAS Ground Subsystem shall monitor the characteristics of the error in the broadcast correction to ensure continued compliance with the requirements such that the broadcast σ_{pr_gnd} remains valid.
The GBAS Ground Subsystem shall detect for the following conditions that may lead to nonconformance, including

a. excessive receiver tracking noise due to antenna, cable, or receiver anomalies affecting measurements for all ranging sources,
b. excessive receiver tracking noise affecting measurements from individual channels, if receiver hardware channels are implemented,
c. multipath at receiver antenna,
d. external interference, and
e. ranging source anomalies.

The probability of a false exclusion of a ranging source shall be less than $1x10^{-7}$. The probability of a false exclusion of a reference receiver channel shall be less than $1x10^{-7}$.
The GBAS Ground Subsystem shall perform the tests summarized in Tables 3-5 and 3-6.

Table 3-5. Conformance Tests on Each Ranging Source

Non-Conformance Conditions	Test Data	Test	Time Period
Items a & d	B values for all ranging sources	$\mu \geq 0, \sigma > \sigma_{pr\_gnd}$	1 hour and 2 days
		3.2.1.2.10.8 (d)	1 month, since initialization
Items c & d	B values for all ranging sources in azimuth and elevation bins	$\mu \geq 0, \sigma > \sigma_{pr\_gnd}$	1 hour and 2 days
		3.2.1.2.10.8 (d)	1 month, since initialization
Items c & d	B values for each ranging source	$\mu \geq 0, \sigma > \sigma_{pr\_gnd}$	1 hour and 2 days
Items c, d, & e	Code-minus-carrier* each ranging source	3.2.1.2.10.8 (d)	1 hour

*will reference Braach paper on code-minus carrier

Table 3-6. Conformance Tests on Each Reference Receiver Channel

Condition	Test Data	Test	Time Period
Item b	B Value, all ranging sources in each channel	$\mu \geq 0, \sigma > \sigma_{pr\_gnd}$	1 hour and 2 days
		3.2.1.2.10.8 (d)	1 month, since initialization

The thresholds must be set as tight as possible given the specified false detection rate taking into account the correlation time of the samples due to smoothing. The monitor is intended to automate continued compliance to the specification, reducing the reliance on periodic inspection.

2.4.2.25 B-Values

The GBAS Ground Subsystem shall set the B-values for all valid ranging signals at each RR.
2.4.2.25.1 B-Value Calculation

The B value shall be calculated using the equation

$$B_{PR}(n,m) \equiv PR_{corr}(n) - \frac{1}{M(n)-1} \sum_{\substack{i \in S_n \\ i \neq m}} PR_{sca}(n,i)$$

where $B_{PR}(n,m)$ is the estimate of the bias error on the PRC.
The PRC measurement error for the n^{th} satellite and the m^{th} RR (scaled by a factor of 1/M to reflect its impact on the average correction) shall be estimated by the B value $B_{n,m}$.

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2.4.3 General GBAS Data

2.4.3.1 Modified Z-count

The Reference Function shall provide a Modified Z-count containing the reference time for all the message parameters in the GBAS message. The reference time is defined to be the time at which the pseudorange corrections are valid, which is the time of measurement in the reference receiver for all satellites.

The Modified Z-count shall roll over at 20 minute intervals.

Broadcast of the Type 1 Message shall be within 1 second of the modified Z-count.

2.4.3.2 Use of Ephemeris Data

The Reference function shall wait at least 2.0 minutes from the time that new ephemeris data (new IOD) are obtained, before including them in the pseudorange corrections computation. Until this time has elapsed, the previously valid ephemeris data shall be used.

2.4.3.3 Non-Application of Ionospheric/Tropospheric Corrections

The Pseudorange corrections computed shall not be corrected for ionospheric or tropospheric effects.

2.4.3.4 Provide FAS Data

The Reference function shall format FAS data for inclusion in a GBAS Type 4 application layer FAS data message to the data broadcast transmitter.

It shall be possible to inhibit the Type 4, FAS message from being transmitted, via a GBAS Ground Subsystem Installation or update procedure.

Comment: the aviation authorities may prohibit FAS message transmission.

2.4.3.5 Provide GBAS Message Header Data

The Reference Function shall prepare a Subsystem ID code for inclusion in the Header of all GBAS Application Layer messages to the data broadcast.

The Subsystem ID code shall be the same as the four-letter ICAO identifier of the airport that is geographically closest to the ground facility.

2.4.3.6 Send GBAS Application Layer Messages

The Differential Correction Data and FAS Data required above shall be sent to the data broadcast function as GBAS Application Layer messages as defined in the following sub-sections.

The Application Layer Message Block shall be built up as follows:

Message block item	Length (bits)
Message header	48 bits
Message	variable
Integrity check (CRC)	32 bits

The Application Layer Message Block shall be the same structure for all messages.

The extended message flag shall be set to 0.

2.4.3.7 Type 4 FAS Message

The function shall provide a GBAS Type 4, FAS Application Layer message according to the formatting requirements specified in Appendix A of the MASPS.

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2.4.3.8 Manage Message Release

Only independently monitored and validated GBAS Messages shall be released for data broadcast transmission.

"Independently monitored and validated GBAS Messages" are defined as only those messages which have been completely verified by the Monitoring Function and for which an unambiguous Message Release indication has been received (i.e., the lack of such an indication does not constitute validation).

2.5 DATA BROADCAST FUNCTION

The Data Broadcast Function shall process all validated and released GBAS Messages from the Reference Function (Application Layer data) and transmit these as modulated Data Broadcast messages (Physical Layer).

The GBAS Ground Subsystem shall be capable of transmitting in any of eight time slots on the allocated frequency.

2.5.1 Message Encoding

Encoding of the data broadcast, message for transmission to the aircraft, subsystem follows the sequence shown in Figure 0-3.

The following definitions pertain to the message encoding:

Term	Definition
symbol	a change in phase that represents 3 bits
word	8 bit elements in the Reed-Solomon code
octet	8 bit application layer element
bit period	approximately 31.75 µs

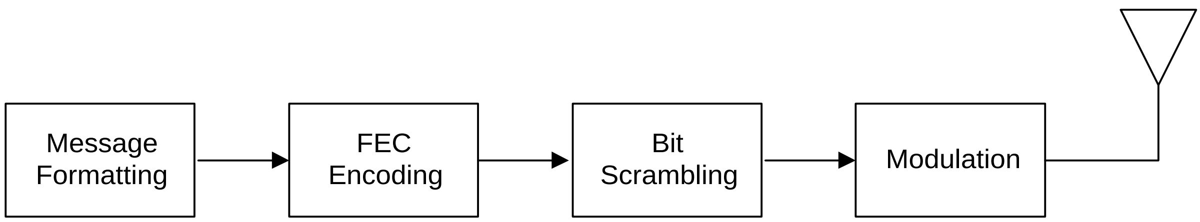

Figure 0-3 : Message Encoding Block Diagram

2.5.2 Application Layer Data

The Data broadcast function shall insert the GBAS message (as received from the Reference Function) into the Application Layer data segment of the Data Broadcast message. The message shall be mapped directly into the Application Layer data segment (with no additional overhead) in accordance with the following requirements.

The order of transmission, for the Application Layer data, shall be Least Significant Bit (LSB) first followed by the higher order bits of that field for each GBAS message field (including the 32 bit CRC field). For a Type 4 message, each data block is one field.

2.6 DATA BROADCAST RECEIVER FUNCTION

The data broadcast Receiver Function is expected to have similar characteristics to the aircraft receiver. It receives and monitors the GBAS Message transmissions at the designated data broadcast frequency and in the designated TDMA slot(s) and provides the demodulated Messages (Application Layer) to the Monitoring Function for further validation.

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It provides status information on signal quality and the transmission Physical Layer. The format and protocol is specified in paragraph 3.2.2 of this document.

2.6.1 Data Broadcast Receiver Operation

The data broadcast Receiver function shall receive and monitor all transmitted GBAS data broadcast Data Broadcast messages (Physical Layer) on the designated Data Broadcast frequency for the Ground Subsystem and provide the demodulated GBAS messages (Application Layer) to the Monitor function.

2.6.2 Data Broadcast Receiver Independence

In order to maintain an independent monitoring capability, the Data Broadcast Receiver Function shall be completely independent from the Data Broadcast function.

Independence of the Data Broadcast Receiver function and the Data Broadcast Function is defined such that a single failure, which induces the generation of invalid data by the Data Broadcast Function, cannot also induce inappropriate verification of that data by the Integrity Monitoring function.

2.6.3 Data Broadcast TDMA Monitoring

The Data Broadcast Receive function shall monitor the reception time of broadcast messages to verify that there are no ”out-of-slot” transmissions. An out-of-slot transmission is defined to be a transmission that exceeds the allowable threshold of ±95.2µs.

The time reference used in monitoring such transmissions shall be independent of any time reference used by the Data Broadcast function.

2.6.4 TDMA Timing Monitor Detection Probability

The probability that the Data Broadcast Receiver Function fails to detect an "out-of-slot” transmission (as defined above) within 3 seconds shall be less than 2.0E-7.

2.6.5 Data Broadcast Monitoring, Data Error Rates

When passing on received GBAS messages, the data broadcast Receiver function shall report status on whether error correction was required.

2.6.6 Data Broadcast Signal Power Monitoring

The power of the received data broadcast data Broadcast signal (the power during the active transmit times, and not the average power) shall be monitored.

2.6.7 Data Broadcast Receiver Frequency Stability

The long-term frequency stability of the receiver carrier shall be +/-0.0005% (i.e., +/-5 parts per million), including the effects of ageing over one year and over the operating temperature and other environmental conditions.

2.6.8 Data Broadcast Receiver, Unintended Transmission of Noise

The output radiation from the data broadcast Receiver function in the entire data broadcast band shall be less than -60 dBm when in the normal operating mode and when measured at the antenna cable connection of the data broadcast Receiver.

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2.6.9 Data Broadcast Reception, In Band Interference Immunity

The data broadcast Receive function shall provide the specified error rate with a desired signal strength of -84 dBm, in the presence of any one of the following interfering signals:

- a co-channel GBAS D8PSK signal 20 dB lower than the desired signal

- a GBAS D8PSK signal, 40 dB higher than the desired signal, on an adjacent, or any other assignable channel,.

2.6.10 Data Broadcast Reception, Out of Band Interference Immunity

The data broadcast Receive function shall provide the specified error rate with a minimum signal strength of -84 dBm, and with one or more out-of-band signals, except for data broadcast FM broadcast signals, having a total interference level at the receiver input of -33 dBm.

The receiving function shall provide the specified error rate with a minimum signal strength of -84 dBm, and with one or more data broadcast FM broadcast signals having a total interference level at the receiver input of -5 dBm.

2.6.11 Data Broadcast Receiver Antenna

The interface to the antenna shall be a coaxial cable suitable for exposed environmental conditions.

2.7 **MONITORING FUNCTION**

The Monitoring Function monitors and validates messages generated and submitted by the Reference Function prior to transmission by comparing their content with expected values based on independently sourced data and verifying the accuracy of the proposed pseudo-range correction and range-rate correction data. Erroneous messages detected prior to transmission are not granted a Message Release, which inhibits transmission on the Data Broadcast. The Monitoring function is also used to monitor and verify all GBAS messages as transmitted by the Ground Subsystem. Integrity Alerts are commanded to be transmitted on the Data Broadcast if Ground Subsystem conditions are detected that could lead to the aircraft user generating an unacceptably large NSE. The Monitoring function is able to independently shut-down Ground Subsystem transmissions if a critical failure affecting integrity is detected. The Monitoring Function is also responsible for determining the availability of the GBAS service (the status is communicated by the Subsystem Interface Function to external facilities).

2.7.1 *Functionally Separate Monitoring*

The Ground Subsystem shall include a Monitoring Function separate and independent from the Reference Function.

It shall be possible to demonstrate that the integrity monitoring function is functionally separate from the ground reference subsystem function (refer to the section on Certification Aspects in this document).

The Monitoring Function shall validate the accuracy and correctness of all GBAS Messages prior to transmission as an RF signal and must validate continued acceptable performance of the GBAS data broadcast as defined below.

Independence of the DGNSS Reference function and the Integrity Monitoring function is defined such that a single failure which induces the generation of invalid data by the Reference function (including the effects of faulty GPS data) cannot also induce inappropriate verification of that data by the Integrity Monitoring function.

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The Monitoring Function must use independent sources of FAS data and GPS raw data in the validation of the Messages produced by the Reference Function.

2.7.2 *Check Outgoing Message*

The Monitoring Function shall independently verify the correctness and accuracy of the Application Layer GBAS messages prepared by the Reference Function prior to transmission over the data broadcast.

The fixed data fields of the Application Layer message shall compared against an independently stored record within the Monitoring function. The accuracy of the variable data fields shall be independently validated to ensure that the Ground Subsystem integrity requirements can be met. Validation of the accuracy of data for each satellite shall be performed by applying the PRC, RRC, modified Z-count, IOD, sigma and B-values parameters to an independent solution derived within the Monitoring Function.

2.7.3 *Release of Outgoing Messages*

The Monitor function shall prevent GBAS Messages from being released for data broadcast transmission if they cannot be validated or if any condition is detected, which may cause faulty or un-monitored data broadcast transmission.

2.7.4 *Check Incoming (Data Broadcast Receiver) Message*

The Monitoring function shall verify the GBAS Message Application Layer data, which have been received as broadcast signals, against the messages that were intended for transmission.

2.7.5 *Verify Broadcast Signal Monitoring Capability*

It shall be verified that the Broadcast Signal Monitoring capability is intact, at least once per second. This includes the installation settings, health and status of the Receiver Function and any communication Broadcast involved between the Receiver and the Monitoring Function.

2.7.6 *Broadcast Monitoring*

The GBAS Ground Subsystem shall shutdown the data broadcast when

a. the CRC fails,

b. an out-of-slot transmission exceeds the timing tolerance,

c. the broadcast power is out of tolerance,

d. the time between updates for any message type exceeds the specified time between transmissions, or

e. the broadcast frequency is out of tolerance.

2.7.7 *Evaluate Signal Monitoring Information*

The following Signal Monitoring information shall be verified with respect to expected values or ranges:

Received signal power level

Received signal quality

Conformity of the received messages with the allocated TDMA slots

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2.7.8 *Co-ordinate Integrity Monitoring Actions*

The Monitoring Function shall assess the monitoring results and co-ordinate the Alarms, Alerts, Shutdowns and GBAS Availability Advisories as defined in the remainder of this section in order to provide the necessary safe response to the situation.

2.7.9 *Integrity Alarms*

There are two categories of Integrity Alarm generated by the Ground Subsystem. The Subsystem-Not-Working Alarm is generated (by setting the Sigma field of the GBAS message to 1111 1111) on detection of a general failure of the Ground Subsystem or on detection of general corruption to GBAS message data. The Satellite-Specific Alarm is generated (by tagging a satellite as unusable in the GBAS message) when the correction data for an individual satellite is determined to be exhibiting excessive errors.

2.7.10 *Subsystem-Not-Working Integrity Alarm*

A Subsystem-Not-working Integrity Alarm shall be issued if any of the following situations occur:

a Message Content Alarm Condition is detected

a Broadcast Message Alarm condition is detected

a Communication Broadcast Alarm condition is detected

a Ground Subsystem Failure condition is detected

The Subsystem-Not-Working Integrity Alarm shall be executed by setting the "Subsystem Not Working" flag in the Type 1 Message. No other messages shall be transmitted during this period. The "Subsystem Not Working" flag is set by setting Sigma field in the Type 1 message to all ones (1111 1111) as required by the GBAS SARPS.

Once a Subsystem-Not-Working Integrity Alarm has been transmitted, it shall continue to be transmitted for at least 5 messages within the next 5 seconds. The Satellite-Not-Working Integrity Alarm shall be transmitted within 3 seconds of the error condition occurring.

A ”Message Content Alarm” condition exists if the information intended for Data Broadcast transmission cannot be validated by the Monitoring function, or when the information intended for Data Broadcast transmission exceeds the limits of the GBAS message structure.

A ”Broadcast Message Alarm” condition exists if the broadcast message received by the integrity monitoring function has been successfully decoded (including valid reference Subsystem ID. and computed CRC) and the differential, FAS, or integrity data content do not agree with the data intended for transmission.

A ”Communications Broadcast Alarm” condition exists if there is a failure in communication between the Monitor function and either the Reference function or the Data broadcast Function such that the capability to monitor the data broadcast signal transmissions is lost or impaired.

A ”Ground Subsystem Failure” condition exists if any Ground Subsystem failure occurs that can affect the integrity of the GBAS correction data to be transmitted but does not affect the Ground Subsystem’s ability to correctly transmit a validated Subsystem-Not-Working Integrity Alarm.

2.7.11 *Detection of Faulty Satellites*

Satellites that exhibit excessive errors, or which have observed characteristics which may not allow the specified differential navigation accuracy to be achieved shall be excluded from the Type 1 Message prior to transmission as a GBAS message over the data broadcast.

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The offending satellite may be excluded from the Type 1 message by either deleting the satellite or tagging the PRCs for that satellite as unusable by setting the satellite's sigma field to all ones.

Once a satellite has been removed from the Type 1 message, it shall continue to be removed for at least 5 messages within the next 5 seconds. Satellites that exhibit excessive errors shall be removed from the Type 1 message within 3 seconds of the error condition occurring.

2.7.12 *Transmitter Shutdowns*

The data broadcast Data Broadcast transmissions shall be shutdown if any of the following situations occur:

i) Immediately following the issue of a Subsystem Not Working Integrity Alarm

ii) Ground Subsystem GBAS transmissions in the wrong TDMA time slot(s) or violating the TDMA time slot tolerance limits

iii) Signal Quality Maintenance Alert condition exists for more than 2.5 minutes

iv) Differential Accuracy Maintenance Alert condition exists for more than 1 minute

v) a fault which prevents GBAS transmission persists for more than 1 minute

vi) the Monitoring function fails

vii) a failure of the Data broadcast function occurs which could affect the integrity of the transmitted GBAS messages

A shutdown is defined as a latched state where no further data transmissions are possible until intervention by an authorised operator restores normal operation by a defined start-up procedure.

2.7.13 Maintenance Alerts

A Maintenance Alert shall be notified to the responsible maintenance facility, under the following conditions:

i) if a Subsystem-Not-Working Integrity Alarm is transmitted as a data broadcast signal

ii) for a Differential Accuracy Maintenance Alert condition

iii) for a Signal Quality Maintenance Alert condition

iv) for a Hardware Maintenance Alert condition

The Maintenance Alert shall signify that the Ground Subsystem has been deemed unusable and shall identify the sub-assembly(s) likely to be responsible.

The Differential Accuracy Maintenance Alert condition exists if any non-varying data field (such as reference Subsystem ID) cannot be validated by comparison to an independent source within the Monitoring function.

The Signal Quality Maintenance Alert condition exists if any of the conditions listed below are detected:

i) >1 of the last 20 broadcast messages received over the Data Broadcast are not correctly demodulated or contain errors which cannot be detected by the Forward Error Correction processing.

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ii) The transmitted data broadcast signal power has dropped below an acceptable signal power level threshold defined for the specific installation site.

A Hardware Maintenance Alert condition exists when the self-test has detected and confirmed a Ground Subsystem failure requiring the initiation of a maintenance action on the Ground Subsystem.

2.7.14 GBAS System Availability Advisory

The Ground Subsystem shall have the capability to report the GBAS system availability to the air traffic control facility having instrument flight rule responsibility pertinent to the airport or airports being served by GBAS system. Loss of GBAS availability shall be automatically logged by the system for later retrieval and reported within 1 minute of its detection.

2.8 **SUBSYSTEM INTERFACE FUNCTION**

The Interface Function controls the mode switching and operation of the entire Ground Subsystem. It monitors operation and status of the other functions and supports test and maintenance activities. It manages the interfaces to the local control and display console, to the ATC and to other remotely located monitoring and maintenance facilities.

2.8.1 Operating Modes

From switch-on, the Ground Subsystem shall automatically sequence through its start-up modes to normal GBAS operation without the need for any external human intervention to initiate or maintain operation.

The Ground Subsystem modes and mode transitions shall be as defined in the following sub-sections and summarised in Figure 0-4.

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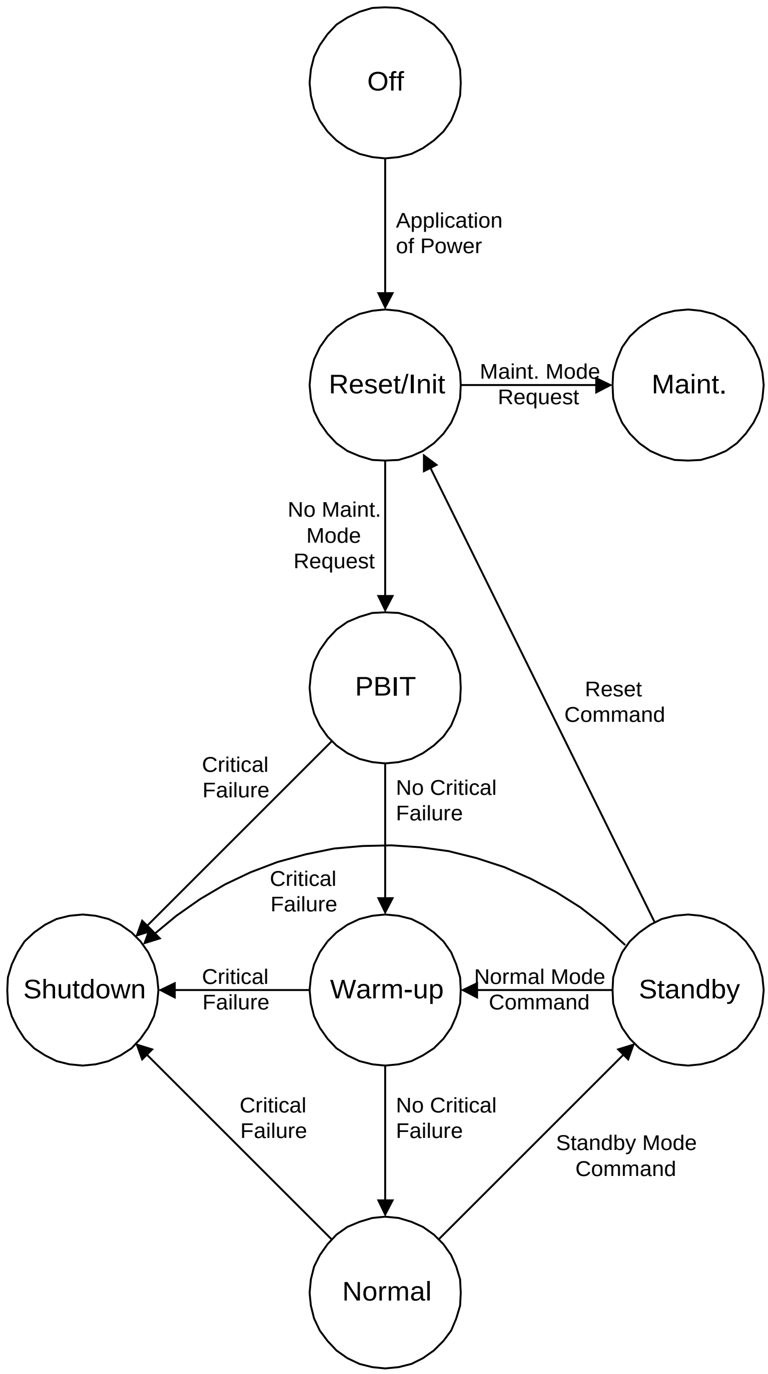

Figure 0-4 : Ground Subsystem Moding

2.8.1.1 OFF Mode

The OFF mode shall be entered when all electrical power is removed (AC and DC). Entry into this mode may be from any other mode.

In the OFF mode the Ground Subsystem shall be de-energised.

The OFF mode shall be exited on application of electrical power.

2.8.1.2 RESET/INIT Mode

The RESET/INIT mode shall be entered under the following conditions:

- from the OFF mode, following application of electrical power

- from the STANDBY mode, following an external operator command

If entered from the STANDBY mode, a RESET command shall be sent to all Ground Subsystem units.

In the RESET/INIT mode, the Local Control and Display Console interface shall be monitored to determine whether entry into the MAINTENANCE mode is being requested. Data Broadcast transmissions shall inhibited.

The RESET/INIT mode shall be exited under the following conditions:

- to the PBIT mode, if the MAINTENANCE mode is not being requested

- to the MAINTENANCE mode, following an external request over the LCDC interface

2.8.1.3 Power-up Built In Test (PBIT) Mode

The PBIT mode shall be entered under the following condition:

- from the RESET/INIT mode, if no MAINTENANCE mode request was received

In the PBIT mode, Power-up BIT routines shall be performed in support of the BIT detection. During this mode, there shall be no communications on the Ground Subsystem external interfaces and Data Broadcast transmissions shall inhibited.

The PBIT mode shall be exited under the following conditions:

- to the WARM-UP mode, automatically if no critical failures were detected

- to the SHUTDOWN mode, automatically if any critical failures were detected

Note : A Critical Failure is defined to be any failure which can affect the Ground Subsystem Integrity.

2.8.1.4 WARM-UP Mode

The WARM-UP mode shall be entered under the following conditions:

- from the PBIT mode, automatically if no critical failures were detected

- from the STANDBY mode, following an operator command to enter the NORMAL mode

While in the WARM-UP mode, the Ground Subsystem shall wait for all units to be able to achieve GBAS operation (GPS Receivers acquiring satellite signals, Data Broadcast's RF circuits stabilising).

Once able to support GBAS operation, a test message shall be transmitted and monitored in order to ensure the RF circuits are able to support GBAS data broadcast and reception.

During the WARM-UP mode, a "Not_Ready" indication shall be sent to the ATC and Maintenance facilities.

The WARM-UP mode shall be exited under the following conditions:

- to the NORMAL mode, automatically if no critical failures were detected and all modules signal ready.

- to the SHUTDOWN mode, automatically if any critical failures were detected or if GBAS operation could not be supported within 20 minutes from application of power

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2.8.1.5 NORMAL Mode

The NORMAL mode shall be entered under the following condition:

- from the WARM-UP mode, automatically if no critical failures were detected and all modules signal ready.

The NORMAL mode is the default mode of operation of the Ground Subsystem. During this mode, the Ground Subsystem must provide GBAS operation within the functional and performance requirements contained in this document.

All external interfaces shall be serviced and a "Normal" indication shall be sent to the ATC and Maintenance facilities.

The NORMAL mode shall be exited under the following conditions:

- to the STANDBY mode, following an external operator command

- to the SHUTDOWN mode, automatically if any critical failures were detected

2.8.1.6 STANDBY Mode

The STANDBY mode shall be entered under the following condition:

- from the NORMAL mode, following an operator command

During the STANDBY mode the Ground Subsystem shall continue to receive and track satellites in view, however, all data broadcast shall be inhibited.

All external interfaces shall be serviced and a "Standby" indication shall be sent to the ATC and Maintenance facilities.

The STANDBY mode shall be exited under the following conditions:

- to the WARM-UP mode, following an operator command to enter the NORMAL mode

- to the RESET/INIT mode, following an external operator command

- to the SHUTDOWN mode, automatically if any critical failures were detected.

2.8.1.7 SHUTDOWN Mode

The SHUTDOWN mode shall be entered under the following condition:

- from any other mode, automatically following detection of a critical failure.

During the SHUTDOWN mode the Ground Subsystem shall enter a passive condition with data broadcast inhibited.

Automatic recovery from the SHUTDOWN Mode shall not be possible. A pre-determined re-start procedure (manual intervention) shall be required to exit from the SHUTDOWN mode.

All external interfaces shall be serviced and a "SHUTDOWN" indication shall be sent to the ATC and Maintenance facilities.

The SHUTDOWN mode shall be exited under the following condition:

- removal and re-application of all electrical power.

2.8.1.8 MAINTENANCE Mode

The MAINTENANCE mode shall be entered under the following condition:

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- from the RESET/INIT mode, following external request over the LCDC interface.

The MAINTENANCE mode shall allow off-line testing and diagnostics, software loading, and access to Non-Volatile Memory, logged status data, and download of Subsystem Specific Data using the LCDC. There shall be no communication on any external interface except the LCDC interface.

The MAINTENANCE mode shall be exited under the following condition:

- removal of electrical power, disconnection of the LCDC, and re-application of electrical power.

In MAINTENANCE mode two sub-modes shall be available.

2.8.1.8.1 Test Mode

The GBAS Ground Subsystem is under maintenance control, and when the data broadcast is transmitting, the operational status indicates the GBAS Ground Subsystem is not available for operational use. Test mode allows maintenance personnel to conduct testing and flight inspection check of monitor alarm conditions, while inhibiting its use for normal operations.

2.8.1.8.2 Setup Mode

The GBAS Ground Subsystem is under maintenance control, the data broadcast is not transmitting, and the facility is being initialized. Setup is intended for use when the facility is being calibrated or undergoing other initialization procedures, prior to its being available for operational use. This would also include maintenance and changing any site dependent parameters such as the Final Approach Segment (FAS) data in Type 4 messages or monitor threshold values.

2.8.2 Operating Conditions

The following operating conditions are defined:

2.8.2.1 Performance Level:

1. The GBAS Ground Subsystem complies with performance requirements to support operations in Category I conditions.
2. Terminal Area Operations. The GBAS Ground Subsystem complies with limited performance requirements.
3. GBAS Ground Subsystem not Healthy. The GBAS Ground Subsystem has either entered the Test or Setup Mode, an alarm exists, or the system is in restart.

2.8.2.2 Control:

4. Operational. Control is at the Remote Control and Status Unit (RCSU) and Air Traffic RCSU.
5. Maintenance. Control is at the Local Control and Display Console (LCDC), RCSU, or the ATC Interface Management System (IMS) interface.

2.8.2.3 Data Broadcast Status:

6. On. The GBAS data broadcast is transmitting.
7. Off. The GBAS data broadcast is not transmitting.

2.8.2.4 Monitor Status:

8. Normal. The Monitor is operating such that any detected integrity alarm will result in a Monitor action. There are no existing alarms.
9. Alarm. An alarm exists.
10. Bypass. The Monitor has been inhibited from any actions that would be taken following a detected integrity alarm.
11. Restart. A restart condition exists when the GBAS Ground Subsystem attempts to transmit following a data broadcast shutdown due to an Monitor action.

2.8.2.5 Restart

During restart, the GBAS Ground Subsystem shall clear all alarms, clear all integrity alerts, and resume data broadcast.

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2.8.3 Operating States

The GBAS Ground Subsystem shall operate in the states defined in Table 3-2. An operating state is a unique combination of modes and conditions.

Table 3-2. Allowable Operating States

Modes		Allowable Operating States												
		Normal					Test					Setup		
Conditions		1	2	3	4	5	1	2	3	4	5	1	2	3
Performance Level	PT 1	x												
	Terminal area		x											
	Ground Subsystem not Healthy			x	x	x	x	x	x	x	x	x	x	x
Control	Operational	x	x	x	x	x								
	Maintenance						x	x	x	x	x	x	x	x
DB Status	On	x	x				x		x					
	Off			x	x	x		x		x	x	x	x	x
Monitor	Normal	x	x	x			x					x		
	Alarm				x			x					x	
	Bypass								x	x				x
	Restart					x					x			

2.9 OPERATIONAL CONTROL

The GBAS Ground Subsystem shall have local and remote control and status display facilities. The local facilities shall include panel mounted status and switching functions and a Local Control and Display Console (LCDC). The remote facilities will include a Remote Control Terminal (RCT) with extensions for a Remote Control and Status Unit (RCSU) for maintenance, an interface for an Air Traffic Remote Control and Status Unit (AT-RCSU) and an Infrastructure Management System (IMS).
The LCDC, RCT, RCSU, and AT-RCSU software shall be provided as part of the GBAS Ground Subsystem.

2.9.1 GBAS Ground Subsystem Control Access Protection

The local or remote access and log-on to the GBAS Ground Subsystem shall include user name and password authentication to allow for levels of access.

2.9.1.1 Log-On Limitations

Log-on control authority of the GBAS Ground Subsystem shall be enabled for only one local or remote data terminal unit at any time.
Only the highest level of access shall allow changes and additions to the access list.

2.9.1.2 Installation Settings Security

The Subsystem Interface function shall provide the means to protect Ground Subsystem software, and Subsystem Specific Data and FAS Data from unintentional, unauthorised or otherwise malicious access or corruption.

2.9.1.3 Access Security

The control of Ground Subsystem operation and functionality shall be protected from unintentional, unauthorised or otherwise malicious tampering or corruption. The Subsystem Interface Function shall implement the necessary functionality to achieve the remote access security measures of FAA Order 6000.32.

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2.9.1.4 Log-Off/Time-Out

Log-off of a local or remote terminal shall be automatic if no keyboard entries have been made within a predetermined period.

2.9.2 Power Switching

2.9.2.1 AC Power Switch

The Ground Subsystem equipment shall provide a Power ON/OFF switch (which controls the AC power for all sub-assemblies of the Ground Subsystem) on the front panel which is easily accessible to the operator. The front panel shall have an indicator light that is illuminated whenever AC Power is switched on to the equipment.

In addition, it should be possible to disconnect all power from each individual sub-assembly.

Notes: The ON/OFF switch may also be a circuit breaker if the device was designed specifically to be used as an ON/OFF control.

The ON/OFF switch must be protected in order to prevent inadvertent or unauthorised activation.

2.9.2.2 Circuit Breakers

The Ground Subsystem equipment shall provide a circuit breaker or other overcurrent protection device on the front panel. It shall control the power for all sub-assemblies of the Ground Subsystem. When circuit breakers are used, the restoring or switching device shall be readily accessible to the operator. The circuit breaker shall give a visual indication when the breaker is tripped. Holding the switching device closed on an overload shall not prevent tripping of the breaker. Circuit breakers shall not be used as switches unless such breakers have been specifically designed and tested for that type service.

Each equipment unit energised by direct connection to the AC line shall have, front panel mounted AC line indicating type fuse-holders, if circuit breakers are not provided.

Note: The device must be protected in order to prevent inadvertent or unauthorised activation.

2.9.3 Local Control and Display Functions

2.9.3.1 Local Status Display

The Ground Subsystem equipment shall provide a status display on the front panel that is readily visible to the operator. The status display shall provide information on the operational status of the whole Ground Subsystem.

(As a minimum, the same status information as defined for the ATC Interface).

2.9.3.2 Local Control and Display Console

The Ground Subsystem shall have an information display capability for each of the Ground Subsystem components, with adequate precision and accuracy, to support installation, testing, maintenance and monitoring the equipment's normal and abnormal operation.

This capability may be achieved by a combination of displays on the individual components (sub-assemblies) and displayed information on the Local Control and Display Console.

A stand-alone Local Control and Display Console (LCDC) shall be provided in order to allow access to BIT Status and Subsystem Specific Data as stored in Non-Volatile Memory (NVM), and to download Ground Subsystem software and Subsystem Specific Data.

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Note that Ground Subsystem NVM may be distributed among all Ground Subsystem sub-assemblies. If so, the LCDC shall be capable of accessing all such NVM in each individual sub-assembly.

Operation of the Ground Subsystem shall be possible without the LCDC connected.

2.9.3.3 LCDC Data Downloading

The Local Control and Display Console shall have provisions for the downloading of Ground Subsystem software as well as Subsystem Specific Data to Non-Volatile Memory (NVM) in the Ground Subsystem.

Subsystem Specific Data includes:

Subsystem ID
Antenna positions
Data Broadcast Frequency
Designated TDMA Slots
Transmitter Power
Expected Received power
Data Broadcast Parameters
Monitor Thresholds
Message related input data
User ID 1
Password 1
User ID 2
Password 2

The LCDC shall also be capable of erasing Ground Subsystem BIT and Status data from NVM following sub-assembly repair as part of a maintenance action.

2.9.3.4 LCDC Data Retrieval

The LCDC shall be capable of retrieving all Ground Subsystem Message, BIT and Status data as stored in Ground Subsystem NVM.

2.9.4 Data Broadcast Interface

The Ground Subsystem shall provide interfaces to support the downloading of transmission and reception of the Data Broadcast Physical Layer GBAS Messages.

2.9.5 Local Control and Display Console Interface

The Ground Subsystem shall provide a standard, commercially available bi-directional interface to support access to Subsystem Specific Data, BIT Status Records, Diagnostics, and Software Download by an authorised operator using an LCDC.

2.9.6 Message Related Input Data

The LCDC shall provide for input for the following site-specific parameters:

a. Message Header
   1. Message Block Indicator
   2. Reference Station ID

b. Type 1 Message
   1. Integrity Parameter Type
   2. Measurement Type

c. Type 2 Message
   1. GBAS Ground Subsystem Installed RRs
   2. GBAS Ground Subsystem Accuracy Designator
   3. Local Magnetic Variation
   4. Refractivity Index

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5. Scale Height
6. Refractivity Uncertainty
7. Latitude
8. Longitude
9. Vertical Ellipsoid Offset

d. Type 4 Message

1. FAS Performance Designator
2. FAS Data Block - manually entered as a block in its entirety:

i) Operation Type
ii) Airport Identification
iii) Runway Number
iv) Runway Letters
v) Approach Design Information
vi) Route Indicator
vii) Performance Path Data Selector
viii) Reference Path Identifier
ix) RDP Latitude
x) RDP Longitude
xi) RDP Height
xii) FPAP Latitude
xiii) FPAP Longitude
xiv) DCH
xv) DCH Unit Selector
xvi) GPA
xvii) FAS CRC

2.9.7 Output Data

2.9.7.1 Alerts and Alarms

Alerts and alarms generated by the GBAS Ground Subsystem shall be provided to the LCDC interface. Information associated with the source and cause of the alerts and alarms shall be provided to the LCDC interface.

2.9.7.2 GBAS Ground Subsystem Status

The GBAS Ground Subsystem shall provide the capability to access operational mode, condition, and status data via the LCDC.

2.9.7.3 Recording

2.9.7.3.1 System Events and Performance Data

The GBAS Ground Subsystem shall maintain a chronological record of system events (log-on, log-off, alert and alarm events) and system performance data related to each event over a minimum of the last 96 hours.

The record shall be accessible by an GBAS Ground Subsystem LCDC.

2.9.7.3.2 Data Broadcast Data

Upon command, the GBAS Ground Subsystem shall, for a maximum requested period of 24 hours, record and send differential correction data, integrity parameter data, approach FAS data, alert and alarm events, and designated critical operational data, to the requesting data terminal.

2.9.7.3.3 Reference Receiver Recording

Upon command, the GBAS Ground Subsystem shall for a maximum requested period of 24 hours, record RR data for all RRs and provide recorded data on a portable media.

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2.9.8 Maintenance Status and Control

2.9.8.1 Control

GBAS Ground Subsystem control shall reside with maintenance when the GBAS Ground Subsystem is in Test and Setup Mode.
When the GBAS Ground Subsystem is in the Setup mode, site-specific parameters (e.g., antenna locations, FAS data) and GBAS Ground Subsystem software shall be entered and verified through the LCDC.

2.9.9 Maintenance Facility Interface

The Ground Subsystem shall provide a bi-directional interface to support remote notification of the Ground Subsystem maintenance status to the airport maintenance facility and remote control of the operational mode of the Ground Subsystem.

2.9.9.1 Maintenance Facility Interface – remote separation

It shall be possible to drive a RCT located up to 100 meters from the Ground Subsystem via the Maintenance Facility interface.

The Ground Subsystem should be capable of supporting greater separations by the use of telephone lines and modems. Any equipment connecting to the telephone network must comply with FCC Rules and Regulations part 68.

2.9.9.2 Maintenance Facility Interface - Operation Details

The interface to the Maintenance Facility should conform to an established electrical standard (e.g. RS 422), so as to avoid the need for significant changes depending on the specific installation.

2.9.10 Maintenance Status Reporting

2.9.10.1 Summary Maintenance Status Information

A Ground Subsystem maintenance status summary shall be sent over the Maintenance Facility Interface in a message sent at least once per second.

The maintenance summary message shall be communicated to the Maintenance Facility with a delay of not more than 30 seconds.

As a minimum, the maintenance summary message shall be capable of indicating the following Ground Subsystem status information:-

- Operational Status (Not Ready, Normal, Shutdown)
- Sub-assembly GO/NO-GO Status (Indication of a Sub-assembly failure)
- Over-temperature
- Battery In Use (Ground Subsystem running off the Back-up Supply)

The operational status, over-temperature, and Battery In Use information shall be an indication of the current status of the Ground Subsystem.

If a sub-assembly failure has been indicated, the indication shall be latched until the Ground Subsystem has been powered-down or Reset.

2.9.10.2 Detailed Status Information

Detailed Ground Subsystem status information shall be sent over the Maintenance Facility Interface in a message (or group of messages) sent at least once per second.

The detailed status message(s) shall be communicated to the Maintenance Facility with a delay of not more than 30 seconds.

The detailed maintenance status message(s) shall contain sufficient information to allow a diagnostic analysis of the nature of any failure causing a failure indication in the maintenance summary message.

The detailed status message(s) shall also contain detailed operational status information such as:-

- ID of satellites being tracked
- UDRE for satellites being tracked
- Acceleration Error Bound
- PRCs for satellites being tracked
- RRCs for satellites being tracked
- IODs for satellites being tracked

The information contained in the detailed status messages shall be an indication of the current status of the Ground Subsystem.

Access to Ground Subsystem Non-Volatile Memory

The Ground Subsystem shall include a non-volatile memory capable of storing data, for up to two years without power.

The memory shall be used to hold Subsystem-Specific parameters (e.g., antenna locations, local terrain masking, Ground Subsystem ID, designated data Broadcast frequency, power, and TDMA slots, expected reception power etc.), runway approach and landing FASs, as well as BIT/maintenance data. A storage capacity of at least 64 kilobytes is recommended.

2.9.10.3 Download of External Data

The Subsystem Interface shall provide the means to download software and Subsystem specific data parameters relevant to the specific GBAS Ground Subsystem Installation into the NVM, during the Maintenance mode using a Local Control and Display Console via the Ground Subsystem LCDC interface.

Subsystem Specific Data includes as a minimum:

Subsystem ID

Antenna positions

Data Broadcast Frequency

Designated TDMA Slots

Transmitter Power

Expected Received power

FAS Data

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User ID 1

Password 1

User ID 2

Password 2

2.9.10.4 Reading / Erasing of BIT and Maintenance Data

The Ground Subsystem shall provide the means to read and/or erase the BIT/Maintenance data log stored in NVM during the Maintenance Mode using an LCDC via the LCDC interface.

2.9.10.5 Remote Control

The Ground Subsystem shall be capable of receiving and acting upon the following mode commands when received over the Maintenance Facility interface:-

- Reset command
- Normal command
- Standby command

Software and Subsystem Specific Data download shall not be possible remotely.

2.9.11 Remote Control and Status Unit

2.9.11.1 Interfaces

2.9.11.1.1 GBAS Ground Facility

The GBAS Ground Subsystem shall include a standard, commercially available, bi-directional interface to facilitate communication between the GBAS Ground Subsystem and the RCT.

The control and status display capabilities of the RCT shall be expandable to another location within 400 feet of the RCT.

2.9.11.1.2 Airspace System Infrastructure Management System

The RCT shall include a standard, commercially available, bi-directional interface to facilitate communication between the IMS and the RCSU.

This interface and the structure of the GBAS Ground Subsystem's data items (e.g., system parameters, alarms, and alerts) residing in the RCT shall comply with the IMS Interface Requirements Document (IRD).

The RCT/RCSU/IMS interface shall provide the capability to access GBAS Ground Subsystem status information and event data.

2.9.11.2 Input Data

The IMS shall provide for input for the following site-specific parameters:

a. Message Header
   1. Reference Station ID
b. Type 1 Message
   1. Integrity Parameter Type
   2. Measurement Type
c. Type 2 Message
   1. GBAS Ground Subsystem Installed RRs

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2. GBAS Ground Subsystem Accuracy Designator
3. Local Magnetic Variation
4. Refractivity Index
5. Scale Height
6. Refractivity Uncertainty
7. Latitude
8. Longitude
9. Vertical Ellipsoid Offset

d. Type 4 Message

1. FAS Performance Designator
2. FAS Data Block - manually entered as a block in its entirety:
    i. Operation Type
    ii. Airport Identification
    iii. Runway Number
    iv. Runway Letters
    v. Approach Design Information
    vi. Route Indicator
    vii. Performance Path Data Selector
    viii. Reference Path Identifier
    ix. RDP Latitude
    x. RDP Longitude
    xi. RDP Height
    xii. FPAP Latitude
    xiii. FPAP Longitude
    xiv. DCH
    xv. DCH Unit Selector
    xvi. GPA
    xvii. FAS CRC

e. Data Broadcast Parameters

1. Data Broadcast Frequency
2. Time Division Multiplex Access Time Slot(s)

f. Monitor Thresholds

2.9.11.3 Output Data

2.9.11.3.1 Alerts and Alarms

Alerts and alarms generated by the GBAS Ground Subsystem shall be provided to the RCSU.

Information associated with the source and cause of the alerts and alarms shall be provided to the RCSU.

2.9.11.3.2 GBAS Ground Facility Status

The GBAS Ground Subsystem shall provide operational mode, condition, and status information to the RCSU.

2.9.11.4 Recording

2.9.11.4.1 System Events and Performance

The GBAS Ground Subsystem shall maintain a chronological record of system events (log-on, log-off, alert, and alarm events) and system performance data related to each event over a minimum of the last 96 hours.

This record shall be accessible by an GBAS Ground Subsystem RCSU.

2.9.11.4.2 Data Broadcast Recording

Upon command, the GBAS Ground Subsystem shall, for a maximum requested period of 24 hours, record and send differential correction data, integrity parameter data, approach FAS data, alert and alarm events, and designated critical operational data to the requesting RCSU.

2.9.11.4.3 Reference Receiver Data

Upon command, the GBAS Ground Subsystem shall for a maximum requested period of 24 hours, record RR data for all RRs and provide recorded data on a portable media.

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2.9.12 Remote Control and Display Equipment

2.9.12.1 Remote Operational Status Display

A remote operational status display shall be provided for installation in the ATC facility having instrument flight rule responsibility pertinent to the airport(s) being served by the Ground Subsystem.

This status display shall be connected to the Ground Subsystem main rack via the ATC interface.

The status display shall be capable of showing when the Ground Subsystem is in the following states:-

- System Not Ready (Warm-up, Standby, Not Enough Satellites)
- Normal Operation (GBAS Service)
- Shutdown (data broadcast transmissions disabled)

An audible warning shall be activated when the Ground Subsystem enters the Not Ready or Shutdown state from the Normal state.

There shall be an "Alarm Acknowledge" switch on the front panel of the status display.

The audible alarm shall remain active until an Alarm Acknowledgement is received.

2.9.12.2 Remote Operational and Maintenance Display

A Remote Operational and Maintenance Display shall be provided for installation in the Maintenance Facility pertinent to the airport(s) being served by the Ground Subsystem.

This display shall be connected to the Ground Subsystem main rack via the Maintenance Facility interface.

The Operational and Maintenance Display shall be capable of indicating the following Ground Subsystem status information:-

- Operational Status
- Sub-assembly GO/NO-GO Status (Indication of a Unit failure)
- Over temperature
- Battery In Use (Ground Subsystem running off the Back-up Supply)

An audible warning shall be activated when the Ground Subsystem exits the Normal state.

There shall be an "Alarm Acknowledge" switch on the front panel of the Remote Operational and Maintenance Display.

The audible alarm shall remain active until an Alarm Acknowledgement is received.

2.9.13 ATC Interface

The Ground Subsystem shall provide an interface to support remote notification of the Ground Subsystem operational status to the ATC facility having instrument flight rule responsibility pertinent to the airport(s) being served by the Ground Subsystem.

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2.9.13.1 ATC Interface - Capability

It shall be possible to drive a Remote Operational Status Display located up to 1 kilometer from the Ground Subsystem equipment, via the ATC interface.

The interface to the ATC should conform to an established electrical standard (e.g. RS 422), so as to avoid the need for significant changes depending on the specific installation.

2.9.13.2 ATC Interface Operational Display Details

The method in which ATC personnel will be notified of the Ground Subsystem availability shall be determined in a specific agreement with the local ATC authorities.

2.9.14 ATC Status and Control

2.9.14.1 Operational Status

A Ground Subsystem availability summary shall be sent over the ATC Interface in a message sent at least once per second.

The summary message shall be communicated to the ATC with a delay of not more than 30 seconds.

As a minimum, the summary message shall be capable of indicating when the Ground Subsystem is in one of the following states:

- System Not Ready (Warm-up, Standby, Not Enough Satellites)
- Normal Operation (GBAS Service)
- Shutdown (data broadcast transmissions disabled)

2.9.14.2 Approach Control

The performance level for each runway end supported shall be supplied to the AT RCSU.
The AT RCSU shall provide for the capability to individually select operational runways for up to 16 runway ends at an airport. Deactivation of a runway end shall occur within 15 seconds of air traffic controller input. Activation of a runway end shall occur no less than 20 seconds and within 35 seconds of air traffic controller input. The FAS data shall indicate that an approach is not available for a period of 180 seconds before the FAS data cease to be transmitted.

2.10 **MAINTENANCE**

2.10.1 Maintenance Concept

The GBAS Ground Subsystem design shall be capable of a two level maintenance concept such that on-site maintenance is defined to be the removal and replacement of LRUs
The GBAS Ground Subsystem shall provide the capability to isolate faults to the LRU.

2.10.2 Periodic Maintenance

The GBAS Ground Subsystem shall provide the capability for Periodic Maintenance. Periodic maintenance includes all mandatory activities performed on a routine or scheduled basis to maintain or verify system performance, minimize service interruptions and major system breakdowns, and extend the useful life of the equipment.

2.10.2.1 Periodic Maintenance Interval

The minimum interval for periodic maintenance of the GBAS Ground Subsystem shall not be less than 2190 hours (quarterly) and shall be limited to cleaning, inspecting, adjusting, and replacing parts in accordance with their service life expectancy or as found necessary during inspection.

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2.10.2.2 Periodic Maintenance Service Interruptions

GBAS Ground Subsystem Periodic maintenance shall not interrupt service for more than 8 hours per year.

2.10.2.3 System Specialist Workload

Completion of periodic maintenance actions shall require one system specialist.

2.10.3 Corrective Maintenance

2.10.3.1 Corrective Maintenance Service Interruptions

Corrective maintenance of the GBAS Ground Subsystem shall not interrupt service for more than 8 hours per year.

2.10.3.2 Fault Diagnostics and Isolation

Fault diagnostics, including BIT and manual isolation, shall detect and isolate the following faults.

a. Automatic fault diagnostics shall be initiated upon detection of an GBAS Ground Subsystem alarm condition by the monitor.

b. Fault isolation rates shall be 90% or greater to an ambiguity group of three LRUs or less using automatic diagnostics.

c. Fault isolation rates shall be 95% or greater to one LRU using automatic and manual diagnostics.

d. Troubleshooting, using all available means, shall achieve 100% fault isolation capability for all failures not detected and isolated to a single LRU according to items b and c.

2.11 DESIGN AND CONSTRUCTION

2.11.1 Parts and Materials

2.11.1.1 Selection, Approval and Use

All parts shall be specified and qualified to be appropriate for use in the equipment and intended applications. Furthermore, the supplier/manufacturer shall be known, and documented to have a quality assurance system in place.

In other words, all parts must be selected from:

Parts qualified to internationally recognised standards (e.g., military standards and specifications, national standards, industry standards) which have been manufactured by approved manufacturers.

Note: Each component must be controlled with proper specifications and subjected to a qualification (via test and/or analysis). In addition, each source for obtaining the component must be documented to prove that it is able to maintain the level of performance and quality verified by the one-time qualification. These requirements may be fulfilled by purchasing already qualified components from already qualified suppliers, or by qualifying component and manufacturer.

2.11.1.2 Components - Hermetic Sealing

All integrated circuits should be either in hermetically sealed packages, or should have glass passivation, unless it can be shown that there is no reliability impairment for the intended environment.

2.11.1.3 *External Interface Interference Requirements*

The management and control of the Ground Subsystem Interfaces to external equipment shall be designed such that normal or abnormal operation of other equipment shall not adversely affect the operation of the ground Subsystem equipment. Abnormal Operation is defined to include:

Open circuits

Short circuits

Corrupted data transfers from the external equipment

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2.11.1.4 Electrical Connectors

The external electrical connectors shall be types defined in internationally accepted standards (e.g., MIL-STD, DIN, VG norms, ARINC, etc.), and shall be available from at least two independent sources.
All operational connector contacts shall have gold plating. This does not include connectors used exclusively for test purposes.
To reduce costs and increase reliability, sockets for integrated circuits should be avoided. If sockets are used they should comply with MIL-S-12883 or MIL-S-83734.

2.11.1.5 Electromagnetic Compatibility

2.11.1.5.1 EMC, Conducted Emissions on Power Leads

The equipment shall be designed to operate to within specification requirements when subjected to conducted EMI on the power lines.
Verification testing will be conducted in accordance with MIL-STD-461, CE102.

2.11.1.5.2 EMC, Conducted Emissions on Antenna Terminals

The equipment shall be designed to minimise the radiation of disturbing signals from any of the antenna terminals (Data broadcast, Receiver and GPS Receiver), when operating in any of its modes.
Verification testing will be conducted in accordance with MIL-STD-461, CE106.

2.11.1.5.3 EMC, Conducted Susceptibility, Power Leads

The equipment shall be designed to operate to within specification requirements when subjected to conducted EMI on the power leads.
Verification testing will be conducted in accordance with MIL-STD-461, CS101.

2.11.1.5.4 EMC, Conducted Susceptibility, Bulk Cable

The equipment shall be designed to operate to within specification requirements when subjected to conducted EMI on all cables connecting to devices external to the Ground Station.
Verification testing will be conducted in accordance with MIL-STD-461, CS114.

2.11.1.5.5 EMC, Radiated Emissions, Electric Field, 10 kHz- 18 GHz

The equipment shall be designed to minimise the radiation of disturbing signals when operating in any of its modes, excluding the intended transmission frequencies.
Verification testing will be conducted in accordance with MIL-STD-461, RE102.

2.11.1.5.6 EMC, Radiated Susceptibility

The equipment shall be designed to operate to within specification requirements when subjected to radiated EMI.
Verification testing will be conducted in accordance with MIL-STD-461, RS103.

2.11.1.5.7 EMC, Lightning Direct Effects

Not Applicable.

2.11.1.5.8 EMC, Lightning-Induced Transient Susceptibility

The equipment shall be compatible with operating in an environment where lightning may strike nearby. The features for lightning protection, grounding, bonding and shielding shall be in accordance with FAA-STD-019 and FAA-STD-020.
Verification testing will not be conducted, however grounding and bonding and shielding measures must be evaluated for conformance with the specified standards.

2.11.1.6 Nameplates and Product Marking

2.11.1.6.1 Front Panel and Nameplate Design

The complete Ground Station equipment rack and each replaceable assembly shall have nameplates. As a minimum, the nameplate must indicate:

(1) the assembly part number and revision code,
(2) to which level of RTCA/DO-178 the software was generated and verified.

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2.11.1.7 Workmanship

2.11.1.7.1 Workmanship Standards and Guidelines

The requirements of FAA-G-2100, paras 3.2.2.1, 3.3.1.3.4.26 and 3.3.4 shall be used as a guideline.

2.11.1.8 Interchangeability

2.11.1.8.1 Replaceable Assemblies

All replaceable assemblies having the same part number shall be interchangeable, and shall be replaceable without the need for manual adjustment or calibration.

2.11.1.9 Reserve Growth Capacity

The design of the ground station should allow for the later addition of both hardware and software functions with a minimal impact on the overall system. As a minimum, the growth potential listed in the Table below shall be provided.

2.11.2 Mechanical Characteristics

2.11.2.1 Weight

There are no specific requirements for the weight of the ground equipment. Due to logistics considerations, lighter weight equipment would be advantageous, but this should not incur significantly increased cost. The weight lifting limits of para 3.3.7.3 of FAA-G-2100F should be observed.

The weight of each replaceable assembly shall be placed on the Outline and Mounting (O&M) drawing, along with the total weights of the major assemblies.

2.11.2.2 Rack Mounting

All units except antennae and the Local Control and Display shall be mounted in a rack system.

2.11.2.3 Centre of Gravity

The design of rack mounted equipment shall locate the center of gravity as low as practical to minimize tipping over.

2.11.2.4 Durability

The equipment shall be rugged so as not to be damaged by handling from unskilled technicians during installation and repair. {This requirement may be verified by inspection and joint consensus between the Verification Engineer and the Logistic Support Engineer.}

The equipment shall be designed to be sufficiently rugged so as to provide a practical service life of at least 15 years. (This may be verified by inspection).

2.11.3 Thermal Characteristics

2.11.3.1 Cooling Aspects

The equipment may be designed using either free-air convection cooling, or forced-air cooling integrated into the equipment cabinets. When subjected to the environments of section 3.2.6, no exposed components or portions of equipment housings shall become warmer than 20 deg C above the steady-state ambient air temperature.

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2.11.3.2 Exhaust Air Temperature

The exhaust air temperature, measured inside the cabinet or console in front of the exhaust air vent, shall not exceed the input air temperature (measured outside the cabinet or console directly in front of the input air vent) by more than 15° C with the equipment operating under normal service conditions.

2.11.4 Type Approval

The equipment shall not, under normal of fault conditions, impair the operations of the airport in which it is installed.

2.11.4.1 *Certification Aspects / Type Acceptance*

The requirements for Type Acceptance are defined in the document "GBAS Type Acceptance Test & Evaluation Plan" (Ref.). These requirements are considered minimum requirements for Type Acceptance. The documentation to be provided showing the Means of Compliance to these requirements are listed in the Type Acceptance Plan (Ref. ***11****), which covers all aspects related to the Ground Station. Type Acceptance of the aircraft equipment is a separate activity outside the scope of this document.*

After Type Acceptance, the Ground Station will be eligible for operational approval (of the installed facility) according to FAA Order 8400.11. In addition to FCC licensing (or licensing by the responsible telecommunication authority for the country concerned), flight testing and site survey activities considering the aircraft elements to be used in actual operation will be necessary before operational approval can be obtained for each individual installation.

2.11.5 Software Management

Software design shall follow the guidelines specified in document EUROCAE ED-12B/ RTCA DO-178B "Software Considerations in Aircraft Systems and Equipment Certification " (Dec. 1992). The software criticality level will depend on the particular equipment function and application.

Ed.Note: The version of ED-12/DO-178 current at the time of drafting should be inserted here.

2.11.5.1 Software Design Process

Software contributing to the integrity of the navigation solution whose failure is classified as Severe-Major or worse (as defined in DO-178B) shall be developed to at least Level B unless otherwise justified and approved.

The use of any commercial off-the-shelf software must be approved by the responsible Safety Engineer.

2.11.6 Human Engineering

2.11.6.1 Human Engineering Guideline

In order to assure a reasonable and effective product, the design process should have used MIL-STD-1472 as a guideline. The human engineering aspects of the maintenance activities should be included in the design considerations.

2.11.6.2 Controls

The operation of controls intended for use during operation, in all possible positions, combinations and sequences, shall not result in a condition whose presence or continuation would be detrimental to the continued performance of the equipment.

Controls which are not intended to be adjusted in operation shall not be readily accessible to ground personnel.

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2.11.6.3 Operator Interfaces

All equipment controls and displayed data shall be readily accessible and easily interpreted by an operator who does not have special training in this particular equipment.

2.11.6.4 Foolproofness

All assemblies, which are by design not interchangeable, shall be designed and constructed in such a manner that they cannot be installed in the incorrect position. In addition, all replaceable assemblies, circuit cards, and modules shall be designed so that they cannot be installed incorrectly (i.e., backwards, displaced, mirror-imaged). Electrical connectors shall be keyed, or otherwise mechanically configured, so that incorrect connections cannot be made during equipment servicing.

The equipment should be designed so that no human error or equipment fault during the maintenance action could lead to an unsafe condition. For example, it should not be required to manually set the transmitter frequency upon replacing any assembly. The system should either inhibit transmissions after servicing, or automatically set the proper frequency.

2.11.7 System Security

2.11.7.1 Physical Security and Data Protection

The GBAS and each of its sub-systems shall be designed and installed so as to prevent unintentional, as well as unauthorised, alteration of system operation (e.g., mode changes, shutdowns, resets) or critical system data (e.g., software programs, frequency assignments, FAS data, subsystem ID, antenna positions). The design features should include physical security, electronic security, as well as software security features. In the event that any of the operational characteristics or data items are incorrectly altered, the system design should be conceived so that the error can be readily detected.

The ground equipment, except for the antennas and associated electronics, may be assumed to be installed inside of a secure building. *(The building itself is outside the scope of this specification.)*

2.11.7.2 Remote Access Security

In the event that remote access features are provided via the test and monitor data bus or via a modem connection, the security functions required in FAA order 6000.32 shall be provided. The system shall be capable of indicating every actual remote access to an ATC facility, and each time the access is terminated by the timeout / disconnect feature.

2.12 **ELECTRICAL POWER**

2.12.1 Warm-up time

The warm-up period shall not exceed 15 minutes, and shall complete without the need for operator inputs or control of any kind during or after the warm-up. This is defined as the time from power turn-on required for the equipment to warm up or stabilise before being able to operate up to full performance.

2.12.2 Primary Power

The Ground Subsystem equipment shall be capable of fulfilling the performance requirements when subjected to any of the input power conditions defined in this section.

2.12.2.1 Input Power Type

The input power to the GBAS Ground Subsystem shall be a two-wire, single-phase AC connection, plus a third wire for ground connection.

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2.12.2.2 Live and Neutral Reversal

This function shall not be damaged, nor present an unsafe condition, in the event that the "live" and "neutral" of the AC input power are exchanged.

2.12.2.3 Power Input

The input power to the GBAS Ground Subsystem is defined to have the following characteristics:

	115 VAC Systems	230 VAC Systems
Voltage range (Note 1)	102 to 138 VAC	200 to 276 VAC
Frequency	47 to 63 Hz	47 to 63 Hz
Voltage modulation (20 to 800 Hz)	3.5 Vpp	7.0 Vpp
Fast transients on power supply port, 50 nsec (Note 2)	500 Volts	1000 Volts
Surges on power supply port, 1.2/50 µs (Note 3)	Line-line, 500V Line-earth, 1000V	Line-line, 1000V Line-earth, 2000V

Note 1: The nominal voltage in various countries and at various installation sites can vary. Once the installation has been made, it may be assumed that the input AC power source voltage does not vary more than ± 10%.

Note2: Verification method according IEC 1000-4, section 4 (test required for 230Vac systems only)

Note3: Verification method according IEC 1000-4, section 5 (test required for 230Vac systems only)

2.12.3 Power Interrupts

The input power to the Ground Subsystem can have power interrupts of varying duration up to 200 ms.

2.12.4 Power Outages

The GBAS Ground Subsystem shall be able to maintain the GBAS service without interruption through primary power outages of any duration up to 1 hour. This also applies when the system is soaked at the worst-case temperature environment specified. It is assuming that the primary power was continuously available for 24 hours prior to the outage. Transitions between primary and back-up supplies shall be automatic and completely transparent to Ground Subsystem operation.

Any heaters and fans may be automatically disabled for power outages.

2.12.5 Inrush Current

The instantaneous inrush current shall not exceed 10 times the nominal operating current, and the inrush current after the first 100 ms after power application shall be less than 6 times the nominal operating current.

2.12.6 Power Factor

The power factor shall be within the following range:

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Power factor 0.7 (lag) - 0.7 (lead).

2.12.7 Overcurrent Protection

The input power to the Ground Subsystem shall be protected against excessive currents due to shorts or other equipment malfunctions by use of fuses, circuit breakers, or other protective devices for primary circuits.

2.12.8 Equipment Power Consumption

The equipment power consumption shall not exceed 1000 VA.

This includes the current required for Ground Subsystem equipment operation as well as any power required to charge backup power devices (batteries).

2.12.9 Battery Backup Capability

The GBAS Ground Subsystem shall operate from the Direct Current (DC) output of a Battery Charger Power Supply (BCPS) with a nominal battery bus voltage of 24 volts. In the event of AC supply failure, the GBAS Ground Subsystem shall operate from the output of the battery bank without interruption or loss of performance.

2.12.9.1 Battery Charger Power Supply Backup Capacity

The BCPS shall be of sufficient capacity to charge the provided storage batteries from a 50% charged condition to a full charge condition within 24 hours of continuous operation while simultaneously operating the GBAS Ground Subsystem at maximum RF output power and maximum duty cycle.

2.12.9.2 Battery Capacity

The provided batteries shall operate the GBAS Ground Subsystem at maximum RF output power and maximum duty cycle for a period of not less than 8 hours before automatic battery disconnection.

2.12.9.3 Battery Bank Effect

All GBAS Ground Subsystem performance requirements shall be met when operating from the BCPS, both with and without the battery bank in place. Additionally, all GBAS Ground Subsystem performance requirements shall be met under all normal conditions of battery charge and recharge, including transition from AC to battery power and transition from battery power to AC power.

2.12.9.4 Alternate Current Power Restart

After automatic battery disconnection and GBAS Ground Subsystem shutdown, when continuous stable AC power is restored, the GBAS Ground Subsystem shall resume normal operation.

2.12.10 Isolation

The earth leakage current from either line of the power input shall be less than 3.5 mA when subjected to the isolation tests specified in IEC 950, para 5.2 (Ref. **3**).

2.12.11 Dielectric Strength

The dielectric strength shall be 1500 volts, verified according to paragraph 5.3 of IEC950.

2.12.12 Earth Continuity - Bonding Resistance

2.12.12.1 Power Connection Ground

The input ground wire shall be connected to the equipment chassis immediately upon entering the main power connector. The ground conductor shall be rated for at least the

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amount of current required to trip the overload protection; a low RF impedance path to the equipment's central grounding point must be provided.

2.12.12.2 Ground Strap

Provisions for connecting a facility ground strap capable of carrying at least 50 Amperes to the rear of the equipment shall be provided. This connection point shall be used as the central chassis grounding point (also referred to as the "common tie point for the static ground").

All externally visible metal components shall be connected to the central chassis grounding point with an impedance of less than 100 milli-Ohms. Note that hinges, slides, or other moving mechanical interfaces are not considered to be adequate grounding connections.

2.13 SAFETY

The functional aspects of equipment safety include the concepts of integrity and continuity-of-function and are defined in section 3.2.1.1 of this document.
The aspects of equipment safety not directly involved with the system's intended functions are fireproofness, toxic components, and electrical safety. These are defined in the following sections.

2.13.1 General Safety

In general, equipment must be designed so that in normal operation, as well as in any foreseeable abnormal operation, the equipment does not cause material damage, personal injury, or loss of life. The design should reflect operational and personnel safety factors, including minimisation of potential human error. A fail-safe design shall be provided in those areas where a fault or failure could cause severe material damage, personal injury, or loss of life.{The FMEA will be used to verify this requirement.} The equipment shall be designed to conform to the safety-related requirements of FAA-G-2100F, paragraph 3.3.6.

2.13.2 Fireproofness

Except for very small parts (e.g., knobs, fasteners, seals, grommets), the materials and components used shall not significantly contribute to the propagation of fire, and shall be self-extinguishing.

2.13.3 Toxic Components

Unless specifically approved in writing by the Project Manager and the Safety Engineer, materials and components used in the equipment shall not contain substances which, in the final manufactured form, are radioactive or could be toxic to humans or animals. This requirement should be construed to include the possible effects after years of disposal.

2.13.4 Electrical Safety

Where voltages in excess of 30 Volts can exist, or where currents in excess of five Amperes could be generated, the equipment should be designed so as to prevent the inadvertent exposure of operators, as well as maintenance personnel, to these voltages and currents. The electrical safety standards shall be in accordance with IEC 950.

2.13.5 Safety Assessment

During the approach phase of flight, loss of integrity in the Ground Station would be expected to have catastrophic effects. Due to the safety-critical nature of this equipment and its operational application, a safety assessment in accordance with AC 25.1309 shall be performed. In the assessment, it should be shown that the integrity monitoring function is independent of the reference function and that the integrity requirements of this specification are fulfilled. SAE ARP 4761 should be used as a guideline in conducting the analysis. In addition, the reliability analyses identified in section 3.2.5.1 will serve as important inputs to the Safety Assessment.

Minimum required growth potential

Potential in each processor:	As of Preliminary	As of Production

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Spare RAM/PROM	40%	25%
Processor duty cycle	40%	25%
Spare card slots in each major assembly	2 slots	1 slot
Secondary power	40%	25%

2.14 **EFFECTS OF TESTS**

2.14.1 Testability

2.14.1.1 Test Coverage

Testability features shall facilitate detection and isolation of 100% of failures (identified in the FMEA) using Module-Level and Special Factory Test Equipment.

2.14.1.2 Test Limit Funnelling

The overall testing shall include test limit funnelling concepts. This means that a test hierarchy is established, where the test limits become progressively looser as one proceeds down the hierarchical list. This assures that false alarms are not caused simply due to noise or other marginal problems. The hierarchy is as follows (from the tightest limits to the most relaxed).

1) Module-Level Testing and Special Factory Tests

2) Acceptance Testing of Major Assemblies

3) Continuous Self-Test and Power-Up Self-Test

2.14.1.3 Test Access

Sufficient box test connectors shall be designed into the equipment so that it will be possible to perform the acceptance test procedure on each major assembly without the need remove sealed covers and/or gain access into internal areas of the equipment.

Each replaceable circuit card and module shall provide sufficient test points so that all internal functions may be tested.

For each processor, a dedicated test connector shall be provided which allows the connection of an in-circuit emulator while the card is plugged into the housing in its normal position (but with the covers removed). From this test connector, it shall be possible to force the processor into a passive mode, then have external access to all memory and I/O functions. Also from this test connector, it shall be possible to monitor data on the processor data bus during normal running operation without significantly degrading the system's real-time operation.

For test purposes, it shall be possible to disable the watchdog timer for each processor by connecting to the appropriate test point.

For test purposes, it shall be possible to disable all internally-generated free-running clocks on digital circuit cards and supply the clocking externally. For example, processor systems will be tested at clock rates which are 5 to 10% higher than their design clock frequencies.

All power supply and reference voltages generated within a circuit card or module shall be accurately testable via the test connector or operational connector.

Unless otherwise stated, the design of the equipment shall be such that, during and after the application of the specified tests, no condition exists which would be detrimental to the subsequent performance of the equipment.

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2.15 **EQUIPMENT LIFE**

2.15.1 Non-Operating and Storage Life

The storage life of the equipment when suitably packaged and stored in typical warehouse conditions shall not be limited by design or component selection to less than 10 years. *It may be assumed that the non-operational/storage failure rates are at least 24 times lower than the operational failure rates.*

2.15.2 Operational Life

The equipment design shall include no components and no features (such as parameter drift) which would limit the economically useful life to less than 10 years. *The design should be modular so as to permit easy updating, and the adding of new features.*

2.16 **DOCUMENTATION**

2.16.1 Dimensions and Mechanical Mounting - Documentation

For each replaceable assembly, and for each major assembly, O&M drawings shall be provided which give detailed mechanical dimensions. In addition, the O&M drawings shall provide all details relevant to the mechanical interfaces, and in particular concerning the mechanical mounting interfaces. The O&M drawings shall also detail the locations of all markings and labels.

The O&M drawing shall identify all external electrical connectors by part number, and the electrical bonding mechanisms needed to assure safety as well as undisturbed operation shall be clearly identified.

2.16.2 Document Preparation

Instruction Books and Manuals for the Ground Station shall be prepared in accordance with FAA-D-2494, "Technical Instruction Book Manuscript: Electronic and Mechanical Equipment, Requirements for the preparation of Manuscript and Books.

2.17 **QUALITY ASSURANCE PROVISIONS**

The development life cycle and design process shall be accompanied by an adequate QA support. An adequate quality assurance system would be one that meets the requirements of standard DIN ISO 9001 with respect to the application of the airworthiness standards invoked for this project.

Quality Assurance must check, review and audit the design/engineering and verification processes in order to verify compliance the standards defined for use in this project. All documents that are used to establish proof of compliance shall be checked and signed off by the responsible person(s) in the Quality Assurance function. The detailed responsibilities for checks and inspections will be defined in the project Quality Assurance Plan.

The Quality Assurance function shall ensure that all material and products procured satisfy the requirements of this specification. Any sub-contract shall contain appropriate agreements about quality assurance, including the necessary requirements for the supplier's quality assurance system. The Quality Assurance organisation responsible for this project shall audit the QA system of each supplier that serves this project.

2.17.1 Responsibility for Inspection

Inspections shall be carried out according to released inspection plans / procedures by skilled and authorised inspection personnel only. QA shall monitor the qualification of the inspection personnel.

CHAPTER 3

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MINIMUM PERFORMANCE SPECIFICATION UNDER STANDARD CONDITIONS

Use separate paragraphs to specify performance parameters and standards which the equipment described in paragraph 1.4 shall meet when operating in a standard environment specified in paragraph 5.1

Specified performance should be expressed in MINIMUM terms, i.e. the threshold of performance and tolerance that must be achieved in a prescribed operational environment.

When specifying performance criteria, it is important to restrict the specification to performance and not design specification, thereby allowing manufacturers maximum freedom of design and development.

Equipment classes should be considered where aircraft performance characteristics could result in undue equipment complexity.

Performance parameters must be specified in measurable terms related to the test procedures of chapter 5.

The working group should attempt to anticipate any optional features or functions additional to those demanded for minimum performance likely to be incorporated by manufacturers to provide added capability or facilities.

The working group should consider establishing minimum performance specifications for those optional features that are likely to have an effect on the performance of the "standard" equipment.

If peripheral items (e.g. control unit, an antenna and its transmission line, etc.) are critical to the operation and/or performance of the equipment, appropriate minimum performance specifications and related test procedures should be included.

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3.1 GROUND SUB-SYSTEM REQUIREMENTS

This section contains the minimum requirements for the ground-based GBAS equipment to support operations in CAT 1 conditions. The GBAS ground equipment is comprised of four primary components:

3.1.1 Design Assurance

Note: The following requirements are given as a means to ensure compliance with the integrity and continuity requirements. These requirements may be further defined in future FAA documents.

3.1.1.1 *Functional Hazard Assessment*

A Functional Hazard Assessment (FHA) shall be produced that identifies and defines the GBAS Ground Subsystem functions, hazards, effects, and mitigating measures associated with particular hazards, and shall classify failure conditions associated with each function.

3.1.1.2 *Preliminary System Safety Assessment*

A Preliminary System Safety Assessment (PSSA) shall be produced for the GBAS Ground Subsystem.
The PSSA shall document the allocation of safety requirements to the subsystems and components.
The PSSA shall indicate the level of hardware and software development assurance and the hardware reliability required of the subsystem and components.

3.1.1.3 *System Safety Assessment*

A qualitative and a quantitative System Safety Assessment (SSA) shall be generated for the GBAS Ground Subsystem as implemented.
The SSA shall show that the safety objectives were achieved in the system implementation based on a Failure Modes and Effects Analysis (FMEA), a Failure Modes and Effects Summary (FMES), and a Fault Tree Analysis (FTA).
The results of the SSA shall be documented in a SSA Report.

3.1.1.4 *Software Design Assurance*

All GBAS Ground Subsystem software levels shall be based upon the contribution of the software to potential failure conditions as determined by the SSA process.
All GBAS Ground Subsystem software functions shall be compliant with the guidelines and objectives associated with the appropriate software level specified in RTCA/DO-178B ”Software Considerations in Aircraft Systems and Equipment Certification” (RTCA, 1993).

3.1.1.5 *Complex Electronic Hardware Design Assurance*

Complex electronic hardware devices (i.e., Application Specific Integrated Circuits (ASICs) and Programmable Logic Devices [PLDs]), shall be produced with structured development, verification, configuration management, and quality assurance processes.
The level of production process rigor associated with complex electronic hardware shall be based on the contribution of the hardware to potential failure conditions as determined by the SSA process (i.e., analogous to software development ”Software Considerations in Aircraft Systems and Equipment Certification” [RTCA, 1993]).

3.1.2 Reliability and Maintainability

3.1.2.1 *Mean Time Between Failure*

The GBAS Ground Subsystem integrity and continuity requirements are specified in Sections 3.1.2 and 3.1.3.

3.1.2.2 *Mean Time Between Corrective Maintenance Action*

The GBAS Ground Subsystem shall exhibit a mean time between corrective maintenance action of no less than 2190 hours. Corrective maintenance actions are those required to

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maintain full operational capability. This includes failure to meet requirements for integrity, continuity, operational control, and maintenance.

3.1.2.3 *Mean-Time-to-Repair*

The GBAS Ground Subsystem shall exhibit a Mean-Time-to-Repair (MTTR) of less than 30 minutes. MTTR shall include the time to

a. complete fault isolation and diagnostics,
b. remove and replace the failed Line Replaceable Unit (LRU)(s),
c. perform functional test and checkout of replacement LRU(s), and
d. verify normal GBAS Ground Subsystem operations.

Reference Receiver Function,

Reference Function,

Integrity Monitoring Function, and

Data Broadcast Function.

Data Broadcast Receiver Function

3.2 COVERAGE

The coverage area for the data broadcast and the service volume for precision approach within which the GBAS performance requirements of accuracy, availability, integrity and continuity of service shall apply is provided in the GNSS GBAS SARPS and EUROCAE MASPS.

3.3 FRAME STRUCTURE AND DATA CONTENT

The data content and message format are described by the appendix A and the frame structures, which depend on GBAS radio frequency characteristics, by the appendices F and G.

3.4 DATA CONTENT

All transmissions shall be formatted into Message Blocks, which consist of a Message Header, a Message, and a Cyclic Redundancy Check (CRC) as described by appendix A. of the EUROCAE GBAS MASPS.

3.5 MESSAGES

The data transmitted shall include :

a) Subsystem identification, runway number, and runway identification

b) code tracking differential corrections

c) optionally : phase tracking carrier phase measurements

d) integrity information

e) data base information

f) optionally : predictive availability of constellations

These messages are standardised by ICAO. MASPS Annex A contains a current extract.

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3.6 **INFORMATION THROUGHPUT**

Information throughput is message dependant and related to MASPS appendix A for each message type.

3.7 **TRANSIT AND PROCESSING DELAYS.**

3.7.1 Message Transit Delay

The maximum transmit delay shall be 62.5 milliseconds (one time slot interval).]

Note: -This transmit delay requirement should be validated using ground and aircraft GNSS subsystem latencies in order to ensure that required times-to-alarm can be met.

3.7.2 Ground System Message Processing Delay

The Ground System Message Processing Delay shall not exceed one second.

3.8 **INTERFERENCE IMMUNITY - GENERAL**

Note: -Interference immunity is achieved through technical means as well as regulatory control. Regulatory control includes usage of protected spectrum and strict control over the number of authorised transmitters and their operation by authorised/trained personnel. Technical means for achieving interference immunity include, inter alia, appropriate transmit power levels, forward error correction coding, data validation/authentication, receiver filtering, link diversity, guards bands, time diversity and possibly control of antenna radiation patterns.

The data broadcast system shall provide sufficient protection from interference caused by, inter alia:

a) natural phenomena, including weather and atmospheric conditions;

b) man made sources, including interference produced by radio navigation, telecommunications, radar facilities (including aircraft equipment) and adjoining GBAS Subsystems;

c) industrial, domestic and other items of electrical, electronic or radio equipment, either on the ground or in the aircraft;

d) aircraft in flight, vehicles or aircraft on the ground;

e) buildings, snow banks or other raised objects; and

f) signal reflections and shadowing caused by aircraft in flight, vehicles or aircraft on the ground, buildings, snow banks or other raised objects in or near the operating environment.

3.9 **GBAS RADIO FREQUENCY (RF) CHARACTERISTICS**

GBAS radio frequency bands, identified in appendices F and G, reflect the bands for CAT 1 operations with growth capacity to CAT 2/3 operations. The radio frequency bands selected are :

data broadcast band : 108 MHz to 117.95 MHz (see appendix F for characteristics)

C band : 5 000 MHz to 5 250 MHz (see appendix G for characteristics)

The ICAO SARPS define the exact properties, Annexes F and G are current extracts.

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3.10 **PRECISION APPROACH FUNCTIONAL REQUIREMENTS**

Precision approach functional requirements apply within the limits of coverage.

Equipment at a particular location will be approved for use as far along the precision approach as its capabilities justify. Local conditions also affect the minimums that can be approved. As with ILS/MLS, equipment providing service to decision altitudes (heights) (DA(H)) higher than 200 feet may be approved at some sites.

3.11 **INTEROPERABILITY**

To ensure the interoperability between all GBAS aircraft and ground elements, the ground Subsystem shall:-

Transmit differential corrections for a minimum of four satellites.

Check that all corrections when used together result in a position accuracy of better than (3.5) metres for Cat I operations.

3.12 **MONITORING**

3.12.1 Executive Monitoring

The GBAS Ground Subsystem shall perform the following Executive Monitor (EM) functions:

a. The GBAS Ground Subsystem shall determine the current performance type.

b. When the integrity requirements of Section 3.1.2 are not met, the DATA BROADCAST shall be shutdown.

c. When the continuity requirements of Section 3.1.3 are not met, the GBAS Ground Subsystem Ground Station Continuity Integrity Designator (GCID) transmitted shall be 000 (Section 3.2.1.3.3).

3.12.1.1 *Fault Monitoring*

The GBAS Ground Subsystem shall perform fault detection and isolation.
The set of possible actions include, but are not limited to

a. excluding an individual RR pseudorange measurement(s) from the Pseudorange Correction (PRC) and B-value calculation,

b. excluding individual ranging sources from Type 1 Message broadcast,

c. excluding all measurements from an individual RR from the PRC and B-value calculation, and

d. DATA BROADCAST shutdown.

For each fault condition identified in Table 3-1, the GBAS Ground Subsystem shall take the identified action. Performance checks not explicitly specified in this document (e.g., Built-in-Test [BIT]) may require actions to isolate and detect failed ranging sources and RRs.

3.12.1.2 *Fault Recovery*

Upon exclusion of a single measurement, ranging source, or RR, the GBAS Ground Subsystem shall continue to monitor the excluded single measurement, ranging source, or RR and include it when the fault condition no longer exists.

3.12.1.3 *Environmental Monitoring*

The GBAS Ground Subsystem shall monitor environmental parameters including; facility temperature, humidity, input power supply, battery voltage, facility intrusion, and presence of smoke.

It shall be possible to individually bypass the monitoring of each environmental parameter.

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3.12.1.4 *Critical System Parameters*

The GBAS Ground Subsystem shall monitor critical system parameters. Critical system parameters shall include those parameters associated with the faults identified in Table 3-1 and any other parameters that can affect the normal operation of the GBAS Ground Subsystem.

Table 3-1. Executive Monitor Actions

Section	Fault	Action
Ranging Source		
3.2.1.2.8.3.1/ 3.2.1.2.8.3.1 (a)	Correlation peak asymmetry	a. Exclude ranging source from Type 1 Message broadcast.
3.2.1.2.8.3.1/ 3.2.1.2.8.3.1 (b)	Radio Frequency (RF) interference	b. Exclude ranging source from Type 1 Message broadcast.
3.2.1.2.8.3.1/ 3.2.1.2.8.3.1 (c)	Signal level below threshold	c. Exclude ranging source from Type 1 Message broadcast.
3.2.1.2.8.3.1/ 3.2.1.2.8.3.1 (d)	Code-carrier divergence	d. Exclude ranging source from Type 1 Message broadcast.
3.2.1.2.8.3.1/ 3.2.1.2.8.3.1 (e)	Excessive acceleration, impulse, or step increase on code or carrier	e. Exclude ranging source from Type 1 Message broadcast.
Navigation Data		
3.2.1.2.8.3.4/ 3.2.1.2.8.3.5 (a)	Navigation message parity	f. Exclude ranging source from Type 1 Message broadcast.
3.2.1.2.8.3.4/ 3.2.1.2.8.3.5 (b)	Inconsistency between RR navigation message	g. Exclude ranging source from Type 1 Message broadcast.
3.2.1.2.8.3.4/ 3.2.1.2.8.3.5 (c)	New ephemerides inconsistent with previous ephemerides	h. Exclude ranging source from Type 1 Message broadcast.
Corrections		
3.2.1.2.8.5.8 (a)	Carrier lock failure	k. Exclude PR_{mn}[1] from PRC and B-value calculation.
3.2.1.2. 8.5.8 (b)	B value exceeds limit	l. Exclude PR_{mn}[1] from PRC and B-value calculation.
3.2.1.2. 8.5.8 (c)	Pseudorange correction exceeds limit	m. Exclude ranging source from Type 1 Message broadcast.
3.2.1.2.8.5.8 (d)	Distribution of errors not bounded	n. Exclude ranging source from Type 1 Message broadcast.
3.2.1.2.8.7.1	Sigma variation	o. Exclude PR_{mn}[1] from PRC and B-value calculation.
3.2.1.2. 8.5.8	RR failure	p. Exclude all measurements from RR from PRC and B-value calculation.
Data Broadcast		
3.2.2.2. (a)	Cyclic Redundancy Check (CRC) error	q. Shutdown DATA BROADCAST.
3.2.2.2. (b)	DATA BROADCAST TDMA out-of-slot	r. Shutdown DATA BROADCAST.
3.2.2.2. (c)	DATA BROADCAST power failure	s. Shutdown DATA BROADCAST.
3.2.2.2. (d)	DATA BROADCAST update rate failure	t. Shutdown DATA BROADCAST.
3.2.2.2. (e)	DATA BROADCAST frequency out of tolerance	u. Shutdown DATA BROADCAST.

[1] Pseudorange (PR), where *m* indicates an individual RR and *n* indicates an individual satellite.

3.12.1.5 *Generation of Alerts*

The GBAS Ground Subsystem shall generate an alert when a critical system parameter exceeds predetermined maintenance thresholds, but does not cause a loss of continuity or

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degradation of service. Degradation of service refers to the performance status as given in 3.1.6.1, items b and c.
Alerts do not affect GBAS Ground Subsystem operation.

3.12.1.6 *Generation of Alarms*

The GBAS Ground Subsystem shall generate an alarm when the DATA BROADCAST is shutdown. The GBAS Ground Subsystem shall generate an alarm when performance level is downgraded or there is a reduction in continuity.

3.12.1.7 *Monitor Verification*

The GBAS Ground Subsystem shall allow maintenance personnel to verify that no latent faults that affect integrity or continuity exist in the system.

This capability shall be provided through either embedded equipment (including software) or through the use of special test equipment. If provided with embedded equipment, the verification shall be performed automatically, and shall also be capable of initiation through the NAS Infrastructure Management System (IMS) and Maintenance Data Terminal (LCDC) interfaces.

CHAPTER 4 MINIMUM PERFORMANCE SPECIFICATION UNDER ENVIRONMENTAL TEST CONDITIONS

4.1 **INTRODUCTION**

4.1.1 Laboratory Testing

The environmental test conditions and performance criteria described in this section provide a laboratory means of determining the overall performance characteristics of the equipment under conditions representative of those that may be encountered in actual operation.

For each environmental condition, and with regard to the nature of the equipment and its operational role, the working group must consider which of the performance criteria specified in chapter 3 should be tested and whether the test should be performed during or after the application of the environmental condition.

4.1.2 Standard Test Procedures

Unless otherwise specified, the test procedures applicable to the determination of equipment performance under environmental test conditions are contained in document EUROCAE ED-14C/RTCA DO-160C "Environmental Conditions and Test Procedures for Aircraft Equipment" (December 1989).

Note: Working groups must be aware that this document in under constant revision and reference must be made to the most recent or appropriate version.

4.1.3 Optional Tests

Some of the environmental tests contained in this section do not have to be performed unless the manufacturer wishes to qualify the equipment for that particular environmental condition; these tests are identified by the phrase "If Required". If the manufacturer wishes to qualify the equipment to these additional environmental conditions, then the "If Required" tests shall be performed.

4.1.4 Environmental Conditions, Operating

Unless specifically otherwise defined, the performance requirements of section 3.2.1 will be fulfilled when the system is subjected to the environmental conditions defined in this section, either singly or in any combination. The absence of a test procedure, the non-existence of appropriate test equipment, or simply the non-performance of a test for a particular

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parameter will not relieve the system design authority from the responsibility to fulfil the specified performance under the environmental conditions defined herein.

4.1.5 Environmental Conditions (Non-Operating)

During shipment and storage, the equipment must be able to survive the following environments in a non-operating condition without damage or degradation or impact on the specified Useful Storage Life.

The equipment is not required to withstand temperatures below -10 °C for more than 2 hours. The average temperature over a year can be assumed to be 18 +/- 15 °C.

4.2 **TEMPERATURE**

Temperature (Non-Operating)

The equipment shall be compatible with non-operating temperatures in the following range:

-50 °C to +70 °C

4.2.1 Low Temperature (ED-14C/DO-160C, para 4.5.1)

During this test,

a. establish compliance with the following paragraphs:

State the performance parameters of Chapter 3, which shall be tested; list the paragraphs using the following format.

3.x.x Frequency stability

3.y.y Transmitter power output

3.z.z Modulation symmetry

etc.

b. ensure that all mechanical devices operate satisfactorily.

4.2.2 High Temperature (ED-14C/DO-160C, para 4.5.2, 4.5.3, and 4.5.4)

4.2.2.1 *During the high, short-time operating temperature and loss of cooling test,*

a. establish compliance with the following paragraphs:

Format as in paragraph 4.2.1

b. ensure that all mechanical devices operate satisfactorily.

4.2.2.2 *During the high operating temperature test,*

a. establish compliance with the following paragraphs:

Format as in paragraph 4.2.1

b. ensure that all mechanical devices operate satisfactorily.

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4.2.3 Solar Radiation

All environmentally exposed equipment (especially the antennas, and any electronics which may be packaged therewith) shall be compatible with an environment where it is exposed to solar radiation (sunshine) equivalent to the intensity and duration defined in MIL-STD-810, Method 505.3, Procedure II.

Verification may by achieved by evaluation/analysis of the exposed materials used or inspection of documented evidence of the materials' resistance to solar radiation.

4.3 ALTITUDE, DECOMPRESSION AND OVERPRESSURE (ED-14C/DO-160C para 4.6)

Altitude (Non-Operating)

The equipment shall be compatible with non-operating altitudes in the following range:

-1,000 ft to +50,000 ft (-305 m to +15240 m) MSL

Altitude

Operating altitude: at least up to 12000 feet above sea level.

4.3.1 4.3.1 Altitude (ED-14C/DO-160C, para 4.6.1)

a. establish compliance with the following paragraphs:

Format as in paragraph 4.2.1

b. ensure that all mechanical devices operate satisfactorily.

4.4 WIND

All environmentally exposed equipment (especially the antennas, and any electronics that may be packaged therewith) shall be compatible with operating in an environment where it is exposed to high winds. The equipment shall be able to operate within the specified requirements when subjected to winds up to 100 mph (160.1 km/hr).

Note: Due to the fact that wind-tunnel testing is difficult and expensive, this requirement may be verified by any combination of analysis, simulation, and test.

4.5 TEMPERATURE VARIATION (ED-14C/DO-160C, Section 5)

During this test,

a. establish compliance with the following paragraphs:

Format as in paragraph 4.2.1

b. ensure that all mechanical devices operate satisfactorily.

4.6 HUMIDITY (ED-14C/DO-160C, Section 6)

Humidity (Non-Operating)

The equipment shall be compatible with non-operating humidities in the following range:

10% to 95%

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After subjection to this text and the application of primary power for 15 minutes, immediately,

Humidity (Operating)

The equipment, except for the antennas and any electronics which may be packaged therewith, shall be compatible with operating humidities in the following range:

0% to 90%

Verification testing will be conducted in accordance with Method 507.3, Procedure II, of MIL-STD-810.

The antennas, and any electronics which may be packaged therewith, shall be compatible with operating humidities in the following range:

5% to 100%, including free condensate

Verification testing will be conducted in accordance with Method 507.3, Procedure III, of MIL-STD-810.

a. establish compliance with the following paragraphs:

Format as in paragraph 4.2.1

b. ensure that all mechanical devices operate satisfactorily.

4.7 **SHOCK ((ED-14C/DO-160C, Section 7)**

4.7.1 Shock (Non-Operating)

The equipment, in the form of the Ground Subsystem's major replaceable assemblies, shall not suffer damage or degradation when subjected to the handling shock as defined in Method 516.4, Procedure IV, of MIL-STD-810. During the testing the equipment may be mounted in a rack identical to, or similar to, the actual Ground Subsystem racks.

Verification may be achieved by inspection of the assemblies and there associated transportation packaging. It is not necessary to perform the shock test.

Following the application of the crash safety shocks, the equipment shall remain in its mounting and no part of the equipment or its mounting shall have become detached and free of the shock test table.

NOTE: The application of this test may result in damage to the equipment. It may therefore be conducted after the other tests and paragraph 2.4 "Effects of Tests" does not apply.

4.7.2 Shock (Operating)

Not Applicable.

4.8 **VIBRATION (ED-14C/DO-160C, Section 8)**

4.8.1 Vibration (Non-Operating)

The equipment, in the form of the Ground Subsystem's major replaceable assemblies, shall be capable of withstanding Transportation Vibration without damage or degradation.

Transportation Vibration is defined as Category I transportation vibration in Method 514.4, Procedure I, of MIL-STD-810 (60 minutes in each axis)

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Verification may be achieved by inspection of the assemblies and there associated transportation packaging. It is not necessary to perform the vibration tests.

4.8.2 Vibration (Operating)

Not Applicable.

During this test,

a. establish compliance with the following paragraphs:

Format as in paragraph 4.2.1

b. ensure that all mechanical devices operate satisfactorily.

4.9 EXPLOSION PROOFNESS (If required) (ED-14C/DO-160C, Section 9)

While the equipment is being subjected to this test, it shall not cause detonation of the explosive mixture within the test chambers under normal and fault conditions.

NOTE: The application of this test may result in damage to the equipment. It may therefore be conducted after the other tests and paragraph 2.4 does not apply.

4.10 WATER PROOFNESS (If required) (ED-14C/DO-160C, Section 10)

The antennas, and any electronics that may be packaged therewith, shall be compatible with operating in rain and other streams of water. All exposed equipment shall be able to perform to within the performance requirements of this specification when subjected to driving rain of up to 25 mm/hr.

Verification testing will be conducted in accordance with Method 506.3, Procedure I, of MIL-STD-810.

After subjection to this test,

a. establish compliance with the following paragraphs:

Format as in paragraph 4.2.1

b. ensure that all mechanical devices operate satisfactorily.

4.11 FLUIDS SUSCEPTIBILITY (If required) (ED-14C/DO-160C, Section 11)

a. Subsequent to the 24 hour test, ensure that no failures have occurred.

b. Subsequent to a 2 hour operational period at ambient temperature, after the 160 hour exposure period, establish compliance with the following paragraphs:

Format as in paragraph 4.2.1

c. Ensure that all mechanical devices operate satisfactorily.

4.12 SAND AND DUST (If required) (ED-14C/DO-160C, Section 12)

Not Applicable.

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4.13 **FUNGUS RESISTANCE (If required) (ED-14C/DO-160C, Section 13)**

Not Applicable.

4.14 **SALT SPRAY (If required) (ED-14C/DO-160C, Section 14)**

The antennas, and any electronics that may be packaged therewith, shall be compatible with operating in a salt spray environment.

Verification testing will be conducted in accordance with Method 509.3, Procedure I, of MIL-STD-810.

4.15 **MAGNETIC EFFECT (ED-14C/DO-160C, Section 15)**

Determine the magnetic effect of the equipment and establish that it meets the category to which it is declared.

4.16 **POWER INPUT (ED-14C/DO-160C, Section 16)**

4.15.1 When subjected to this test, for the category corresponding to the type of aircraft electrical supply system used, the equipment shall comply with the following paragraphs for Normal Operating Conditions (ED-14C/DO-160C, paragraphs 16.5.1 and 16.5.2).

Format as in paragraph 4.2.1

Equipment performance standards different from the defined voltage and frequency modulation conditions should be stated.

4.15.2 When subjected to the Abnormal Operating Conditions (ED-14C/DO-160C, paragraphs 16.5.3 and 16.5.4), the equipment shall comply with the following paragraphs.

Format as in paragraph 4.2.1

Equipment performance standards different from the defined voltage and frequency modulation conditions should be stated.

NOTE : *Equipment operating on DC power: the gradual reduction to zero of the primary power voltage(s) shall produce no detrimental effects, (see paragraph 2.4).*

4.17 **VOLTAGE SPIKE (ED-14C/DO-160C, Section 17)**

The following sub-paragraphs refer to the relevant test conditions specified in Section 17 of ED-14C/DO-160C.

4.17.1 Category A

The equipment shall be subjected to the test conditions specified in ED-14C/DO-160C, paragraph 17.3, and shall comply with the following paragraphs:

Format as in paragraph 4.2.1

Equipment performance required during this test should be stated.

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4.17.2 Category B

The equipment shall be subjected to the test conditions specified in ED-14C/DO-160C, paragraph 17.4, and shall comply with the following paragraphs immediately following the ten second test period of the Intermittent Transient test (paragraph 17.4.1) and during the Repetitive Transient test (paragraph 17.4.2).

Format as in paragraph 4.2.1

4.18 AUDIO FREQUENCY CONDUCTED SUSCEPTIBILITY (ED-14C/DO-160C, Section 18)

During this test, establish compliance with the following paragraphs:

Format as in paragraph 4.2.1

4.19 INDUCED SIGNAL SUSCEPTIBILITY (ED-14C/DO-160C, Section 19)

During this test, establish compliance with the following paragraphs:

Format as in paragraph 4.2.1

4.20 RADIO FREQUENCY SUSCEPTIBILITY (Radiated and Conducted) (ED-14C/DO-160C, Section 20)

During this test, establish compliance with the following paragraphs:

Format as in paragraph 4.2.1

4.21 EMISSION OF RADIO FREQUENCY ENERGY (ED-14C/DO-160C, Section 21)

Establish compliance with the category to which the equipment is declared.

4.22 LIGHTNING INDUCED TRANSIENT SUSCEPTIBILITY (ED-14C/DO-160C, Section 22)

Following the application of these tests,

a. ensure compliance with the following paragraphs:

   Format as in paragraph 4.2.1

b. ensure that all mechanical devices operate satisfactorily.

4.23 LIGHTNING DIRECT EFFECTS (ED-14C/DO-160C, Section 23)

Following the application of these tests,

a. ensure compliance with the following paragraphs:

   Format as in paragraph 4.2.1

b. ensure that all mechanical devices operate satisfactorily.

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4.24 **HAIL STONES**

All environmentally exposed equipment (especially the antennas, and any electronics that may be packaged therewith) shall be compatible with operating in an environment where it is exposed to Hail Stones of 1.25 centimeters (0.5 inch) diameter.

Note: Due to the fact that there is no standard MIL test for hailstones, this requirement may be verified by any combination of analysis, simulation and test.

4.25 **ICING (ED-14C/DO-160C, Section 24)**

The antennas, and any electronics that may be packaged therewith, shall be compatible with operating in an environment where icing can occur. The equipment shall be able to operate within the specified requirements when subjected to an environment where up to 0.5 inches of ice (measured radially from the equipment surface) would form.

Verification testing will be conducted in accordance Method 521.1, Procedure I, of MIL-STD-810.

Note: This requirement may be fulfilled by using designs that will prevent ice from forming (e.g., built-in heaters or use of anti-icing agents). Antenna testing in a temperature chamber is often difficult. Therefore the testing may be distributed between temperature chambers and antenna testing facilities as long as the intent of this section is fulfilled.

Whilst the equipment is being subjected to this test, establish compliance with the requirement of the following paragraphs:

Format as in paragraph 4.2.1

CHAPTER 5

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TEST PROCEDURES

5.1 GENERAL

5.1.1 Power Input Voltage

Unless otherwise specified, all tests shall be conducted with the power input voltage adjusted to design voltage ± 2%. The input voltage shall be measured at the equipment input terminals.

5.1.2 Power Input Frequency

a. In the case of equipment designed for operation from an AC power source of essentially constant frequency (e.g. 400 Hz), the input frequency shall be adjusted to design frequency ± 2%.

b. In the case of equipment designed for operation from an AC power source of variable frequency (e.g. 300 Hz to 1000 Hz), unless otherwise specified, tests shall be conducted with the input frequency adjusted to within 5% of a selected frequency within the range for which the equipment is designed.

5.1.3 Adjustment of Equipment

The circuits of the equipment under test shall be properly aligned and adjusted in accordance with the manufacturer's recommended practice prior to application of the specified tests.

5.1.4 Test Instrument Precautions

Precautions shall be taken during conduct of the tests to prevent the introduction of errors resulting from the improper connection of test instruments across the input and output impedance of the equipment under test.

5.1.5 Ambient Conditions

All tests shall be conducted under conditions of ambient room temperature, pressure and humidity, as defined in ED-14C/DO-160C, paragraph 3.4.

5.1.6 Connected Loads

Unless otherwise specified, all tests shall be performed with the equipment connected to loads having the impedance values for which it is designed.

5.1.7 Warm-up Period

Unless otherwise specified, all tests shall be conducted after a warm-up period of not less than 5 minutes.

5.1.8 Recording of Test Results

When test results are being recorded for incorporation in the type report, it is not sufficient to note merely that the specified performance was achieved. Except where tests are obviously GO/NO GO in character (e.g. the determination of whether or not mechanical devices function correctly) the actual numerical values obtained for each of the parameters tested shall be recorded.

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5.1.9 Test Procedures

a. The following test procedures are considered to be a satisfactory means of establishing compliance with the performance specification of Chapters 2 and 3.

b. Alternative procedures which provide equivalent information may be used. In such cases, the procedures described in this chapter shall be used as one criterion in evaluating the acceptability of the alternative procedures.

5.2 DETAILED TEST PROCEDURES

Paragraph titles should be the same as the performance specification titles of chapter 3; reference the relevant paragraph number and, as far as possible, follow the same order as in the following example.

5.2.1 Frequency Stability (Paragraph 3.x.x)

5.2.1.1 Test Equipment Required

List all test equipment needed to perform the test. Test equipment should be identified by essential characteristics, especially where non-standard test equipment is needed. It is not EUROCAE policy to prescribe particular makes or models of test equipment.

5.2.1.2 Measurement Procedure

Describe the step-by-step procedures to be used in conducting the test. Provide cautionary notes where necessary. Particular care must be taken to ensure that the procedures are compatible with the environmental test procedures required by ED-14C/DO-160C.

CHAPTER 6

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INSTALLED EQUIPMENT PERFORMANCE

6.1 INTRODUCTION

This chapter specifies the minimum acceptable level of performance, and test procedures for verifying that performance, for the equipment when installed.

Installed performance criteria are generally the same as those contained in Chapter 3, which were verified through bench and environmental tests. However, certain performance parameters may be affected by the physical installation (e.g., antenna patterns, receiver sensitivity, etc.) and can only be verified after installation. The installed performance limits specified below take these situations into consideration.

6.2 TRANSPORTABILITY

6.2.1 Handling and Transport

The equipment will be designed and constructed so as to be transportable via the usual means when packaged in simple cartons and packing material. It should also survive handling by unskilled workers without suffered significant degradation. This will be verified via the vibration and shock tests.

6.3 EQUIPMENT INSTALLATION

6.3.1 Siting and Installation

Requirements and procedures for siting and installing the GBAS Ground Subsystem are outside the scope of this specification. Full details are provided in the Ground Subsystem Site Survey, Installation and Commissioning document. Some aspects are however defined here which could influence the definition and design of the Ground Subsystem components.

6.3.2 Antenna Installation and Mounting

All data Broadcast and GPS antennas shall be mounted to withstand all predicted environmental conditions for that region in which they are installed. The installation of any ground equipment shall not impair the performance of any existing structure or system.

6.3.3 GPS Antenna Installation

In order to assure that each receiver/antenna is independent with respect to multi-path disturbances and other deleterious effects (e.g., local EMI), the antennas shall be capable of being installed with mutual separations of at least 100 meters. As a future growth capability with minimum equipment modification, it should be possible to locate the GPS receiver plus antenna up to 3 km from the main Subsystem.

The GPS receiver equipment design must allow for the separation between the antenna itself and the main GPS Receiver module to be between 3 and 100 meters. (The actual separation will depend upon the imperatives of the individual application.)

Comment: It may be assumed that the location of the antennas have been surveyed to an accuracy of 10 cm in the horizontal, and 20 cm in the vertical, according to the requirements in Appendix I of RTCA/ DO-217.

The GPS antenna(s) shall be placed in a location to minimise GPS signal-in-space blockage by any obstructions. To the maximum extent possible, the GPS antenna site(s) must provide an unobstructed (5° or higher relative to the horizon) view so that four useable GPS satellite signals are made available to the GPS reference receiver(s). The antenna(s) must also be sited in such a manner as to minimise possible RF interference from any nearby RF transmitting antennas. Consideration should be given to co-locating the data broadcast Data

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Broadcast antenna and the GPS antenna, whereby the separation between the antennas may be a small as 0.5 meters (assuming the GPS antenna is mounted on top of the data broadcast antenna).

6.3.4 Data broadcastter Antenna Siting

The transmitter antenna will be located in a geographical position that makes it possible to have line-of-sight with all relevant airspace. Particular care needs to be exercised to ensure that minimum fading occurs within the service volume.

The equipment design shall allow the Data broadcastter antenna to be located remotely from the main electronics of the Data broadcastter function by a cable of as long as 200 meters.

6.3.5 Data Broadcast Receiver Antenna Siting

It shall be possible to locate the antenna remotely from the main receiver electronics, connected via a coaxial cable of up to 200 meters when high-quality coaxial cable is used.

Comment: It is desired that the location of the monitoring antenna represent the using aircraft to the extent feasible. In addition, the monitor antenna should be placed in a representative position not far from the runways that it is serving.

6.3.6 Accessibility

Controls and monitors provided for operation shall be readily accessible from the operator's normal seated position.

6.3.7 Installed Environment

Installed equipment shall be compatible with the environmental conditions present in the specific location where the equipment is installed.

6.3.8 Display Visibility

The appropriate operator(s) shall have an unobstructed view of displayed data when in the normal seated position.

Display intensity shall be suitable for data interpretation under all ambient light conditions ranging from total darkness to reflected sunlight.

NOTE: *Visors, glareshields or filters may be an acceptable means of controlling daylight visibility.*

6.3.9 Failure Protection

Any probable failure of the equipment shall not degrade the normal operation of any other equipment or systems connected to it. The failure of interfaced equipment or systems shall not degrade normal operation of the subject equipment.

6.3.10 Interference Effects

The equipment shall not be the source of harmful conducted or radiated interference, and shall not be adversely affected by conducted or radiated interference from other equipment or systems installed nearby.

NOTE: *Electromagnetic compatibility problems observed after installation of the equipment may result from such factors as the design characteristics of previously installed systems or equipment and the physical installation itself. It is not intended that the equipment manufacturer design for all installation environments. The installer will be responsible for resolving any incompatibility*

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between the equipment and previously installed equipment. The various factors contributing to the incompatibility shall be considered.

6.3.11 Inadvertent Turnoff

Protection shall be provided to prevent the inadvertent turnoff of the equipment.

6.3.12 Power Source

State any special conditions to be observed when connecting the equipment to the power source(s).

6.3.13 Other aspects and conditions

Continue with other aspects/conditions concerning equipment installation items such as antenna, etc.

6.4 **INSTALLED EQUIPMENT PERFORMANCE**

The installed equipment shall achieve the specified levels of performance of Chapters 3 and 4 in addition to, or as modified by, the following.

Specify performance criteria, which the equipment must meet when installed in the aircraft.

The following guidelines, although not all-inclusive, illustrate some of the more important aspects that should be considered;

- in general, use one paragraph to express a single performance criterion,
- particular care must be taken to ensure that the performance standard statement is compatible with test procedures to be developed for paragraph 6.5,
- care should be taken in defining performance standards which may conflict with those specified in chapter 3 due to physical or other installation constraints
- specified performance criteria should:
    - include those criteria which the equipment must meet to perform its intended function(s) but can only be verified after installation,
    - be limited to those criteria which the working group considers necessary for all applications and user classes,
    - be expressed in a manner that does not constrain design innovation,
    - not place undue constraints on installation flexibility,
    - be expressed in measurable terms.

6.5 **CONDITIONS OF TEST**

The following subparagraphs define the conditions under which the tests specified in paragraph 6.? shall be conducted.

6.5.1 Safety Precautions

State any equipment safety precautions that must observed with regard to persons or equipment related to unique characteristics of the equipment or installation.

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6.5.2 Power Input

Unless otherwise specified, tests shall be conducted with the equipment powered by the facility's electrical power supply system.

6.5.3 Associated Equipment or Systems

Unless otherwise specified, all electrically operated equipment and systems shall be turned on before carrying out interference tests.

6.5.4 Environment

During the tests, the equipment shall not be subjected to environmental conditions that exceed those specified by the equipment manufacturer.

6.5.5 Adjustment of Equipment

Circuits of the equipment under test shall be properly aligned and adjusted in accordance with the manufacturer's recommended practices before the application of the specified tests.

6.5.6 Warm-up Period

Unless otherwise specified, tests shall be conducted after a warm-up (stabilisation) period of not more than fifteen minutes.

6.5.7 Other conditions

Continue with other conditions as necessary.

6.6 **TEST PROCEDURES FOR INSTALLED EQUIPMENT PERFORMANCE**

The following test procedures provide one means of determining installed equipment performance.

Although specific test procedures are prescribed, it is recognised that other methods may be preferred by the installer/manufacturer. Such alternative procedures may be used if they provide at least equivalent information. In which case, the procedures described in this chapter should be used as one criterion in evaluating the acceptability of the alternative procedures.

The equipment shall be tested to demonstrate compliance with the performance criteria specified in Chapter 3.

Test results, or other proof of conformity, supplied by the equipment manufacturer, may be accepted in lieu of bench tests performed by the installer.

6.6.1 Ground Test Procedures

6.6.1.1 Conformity Inspection

(1) Visually inspect the installed equipment to determine the use of acceptable workmanship and engineering practices.

(2) Verify that proper mechanical and electrical connections have been made and that the equipment has been located and installed in accordance with the manufacturer's recommendations.

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6.6.1.2 Equipment Function

Vary all controls of the equipment through their full range to determine that the equipment is operating according to the manufacturer's instructions and that each control performs its intended function.

6.6.1.3 Interference Effects

(1) With the equipment energised, individually operate each of the other electrically operated equipment and systems to determine that no significant levels of conducted or radiated interference exist.

(2) Evaluate all combinations of control settings and operating modes.

(3) Operate communication and navigation equipment on the lowest, highest and at least one but preferably four mid-band frequencies.

(4) Make note of systems or modes of operation that should also be evaluated during flight testing.

(5) If appropriate, repeat the tests using emergency power with the facility's batteries alone and the inverters operating.

6.6.1.4 Power Supply Fluctuations

Under normal conditions, cycle the normal power settings and verify the proper operation of the equipment as specified by the equipment manufacturer.

6.6.1.5 Equipment Accessibility

Determine that all equipment controls and displayed data are readily accessible and easily interpreted.

6.6.1.6 Other test procedures

Continue with other test procedures to verify those installed performance criteria of paragraphs 6.2 and 6.3 which can be demonstrated with the aircraft on the ground.

6.7 SYSTEM QUALITY FACTORS

6.7.1 Reliability

6.7.1.1 Mean Time Between Failure (MTBF)

The equipment should be designed so that the overall Ground Subsystem MTBF is greater than 10,000 hours when operating under the typical environmental conditions defined for "Reliability Prediction".

The MTBF requirement does not include any back-up power system (if used), the Optional - Control/Display Console, or the cables interconnecting the major sub-systems.

Note that the MTBF requirement may be verified on the basis of a MIL-HDBK-217 analysis.

6.7.1.2 Reliability Prediction

As a minimum, a reliability prediction using the parts count method shall be performed in accordance with MIL-HDBK-217 using the "Ground, Fixed" environment (GF).

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In the event that extensive service history exists for a component or assembly, then this may be used in place of the reliability prediction analysis. However, it must be established that the service history is truly applicable to the Ground Subsystem application.

A part stress analysis in accordance with MIL-HDBK-217 may used to support or improve the prediction.

6.7.1.3 Component Selection and De-rating Criteria

The parts and materials selected in the equipment design shall be used within their specified electrical ratings and environmental capabilities. Where needed, transient over-stress protection shall be included in the design. In particular, sensitive components shall be provided with electrostatic discharge protection.

Each component should be applied in the design with the appropriate de-rating so as to be able to fulfil the overall MTBF requirement. In particular, the de-rating levels shown below shall not be exceeded.

Minimum Component De-rating Requirements

Parameter	De-rating
resistor power rating	70%
coil/choke current rating	50%
capacitor voltage rating	80%
discrete semi-conductor power rating	70%
discrete semi-conductor current rating	80%
discrete semi-conductor voltage rating	80%
IC supply voltage	90%
Connector Pin Current Rating	70%
Connector Pin Voltage Rating	70%

To reduce costs and increase reliability, the equipment should be designed to reduce the total number of connector pins.

6.7.2 Failure Modes and Effects Analysis (FMEA)

A Failure Modes and Effects Analysis shall be conducted in accordance with MIL-STD-1629 in order to verify that the requirements of this document have been fulfilled by the final equipment design, and to uncover any weaknesses in the design. The analysis shall be performed down to the function level, and shall include all hardware in the Ground Subsystem. In particular, the effects of single-event upsets shall be considered.

The FMEA shall identify which level of testing would be able to detect each assumed failure: Continuous Self-Test, Power-Up Self-Test, or Acceptance Testing.

6.8 **MAINTAINABILITY**

6.8.1 Mean Time to Repair (MTTR)

6.8.1.1 Major Assembly Level

The mean time to localise a faulty replaceable major assembly, then effect its replacement, shall be less than 30 minutes. This time shall include the commanded self-test to verify that the repair has been effective, but does not include the time to re-load operational software or the data-base (if applicable). This time also does not include the time to replace antennas if remotely located or if located on tall masts.

6.8.1.2 Circuit Card and Replaceable Module Level

Once the faulty major assembly has been removed, the mean time to localise a faulty replaceable circuit or module, then effect its replacement, shall be less than 60 minutes. This

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time shall include the commanded self-test to verify that the repair has been effective, but does not include the time to re-load operational software or the data-base (if applicable).

The MTTR requirements may be verified by planting several failures in the equipment, then measuring the time required by a technician with typical training to perform the maintenance actions. For the purposes these tests, all Ground Subsystem equipment will be located in one laboratory.

6.8.1.3 Maintainability - Software Load Capability

Each ground sub-system shall provide the possibility of loading updates to the software programs of all application processors from an external connector.

6.8.2 BIT Requirements

Built-in test provisions must be provided in the Ground Subsystem equipment in order to support the Ground Subsystem Integrity by detecting those failures which could cause a Ground Subsystem integrity hazard (especially latent failures).

6.8.2.1 General BIT Requirements

The design of the test provisions shall permit accurate, decisive, and repeatable measurements of equipment characteristics and parameters. The self-test shall be designed to ensure that unsafe conditions caused by latent faults do not occur.

6.8.2.2 BIT Mode - PBIT

The Ground Subsystem shall support the PBIT Mode:

Power-up BIT Mode shall be entered automatically on each power-up and shall take less than 1 minute to complete. The testing involves the sequencing through a set of pre-defined test routines. Testing may be interruptive to normal functions and external inputs may be ignored.

6.8.2.3 BIT Mode - CBIT

The Ground Subsystem shall support the CBIT Mode:

Continuous BIT shall be performed automatically as a continuous background mode whenever the equipment is in its warm-up or normal operating mode. CBIT shall complete one complete set of tests (i.e., fulfilling the BIT coverage requirements) per 1 Hz cycle and shall be non-interruptive to normal operation.

Note: CBIT must complement the Integrity Monitoring performed, so as to minimise the risk of erroneous GBAS messages being transmitted, such that the specified Integrity requirements are met.

6.8.2.4 Response to BIT Failures

BIT shall be designed such that any failure of BIT devices will neither result in hazardous situations nor cause subsequent main equipment failure.

6.8.2.5 BIT Reporting

The results of all CBIT testing shall be made available over the Ground Subsystem's interfaces to the Local and Remote Operational and Maintenance Displays and to the Remote Control Terminal within 10 seconds of detection. Only confirmed failures shall be flagged. Provision shall be made to latch failures flagged either in the Ground Subsystem equipment or the console/terminal until manually cleared (by reset or power-down).

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The results of PBIT may be reported at the completion of the sequence of tests involved. The reported failures shall not be overwritten by CBIT results and shall be latched until cleared by a reset or power-down or repeat of the IBIT is commanded.

6.8.2.6 BIT Visual Indications

Each module (if visible from the outside of the equipment), and/or each sub-assembly shall include LED indicators which provide easily interpretable status and self-test results.

6.8.2.7 BIT Result Storage

The details of all confirmed failures, with a time stamp, shall be stored in NVM within the sub-assembly affected. Failure records in NVM shall not be erasable except by a maintenance action. The NVM shall be accessible via a maintenance interface for the sub-assembly concerned.

6.8.2.8 BIT Coverage

BIT coverage shall be as follows:

CBIT	>90% of all single failures
PBIT + CBIT	>98% of all single failures (see Note 1)

For verification purposes, the list of failures shall be determined from the FMEA and may be weighted by the failure rate.

Note 1: The coverage is specified for PBIT + CBIT because there is functionality associated with the Transmitter which cannot be fully tested until Warm-up of the equipment is completed and some transmissions have been performed (i.e. checking the complete transmitter/receiver/monitoring loop). The Integrity Monitoring capability is also given credit for fault detection capability.

6.8.3 Fault Isolation

Fault Isolation capability shall be as follows:

Percentage of detected failures using the results of PBIT + CBIT

80%	isolated to a single sub-assembly
90 %	isolated to two sub-assemblies
100%	isolated to three sub-assemblies

6.8.3.1 Multiple Failures

Provided multiple failures are non-interacting, the equipment BIT should detect all single failures constituting the multiple failure.

6.8.3.2 False Alarm Rate

The false alarms shall constitute less than 5% of all failures indicated. False alarms are defined as reported failures that prove to be false indications in subsequent diagnosis.

Note: The use of filtering and fault confirmation techniques must be applied to achieve the required false alarm rate. Correct tolerancing of BIT thresholds is also essential to minimising the false alarm rates. Verification of this requirement can only be achieved by long term field-service monitoring.

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6.9

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PROCEDURE FOR PERFORMANCE REQUIREMENT VERIFICATION

This paragraph describes the necessary verification required for a GBAS approval. Three distinct means of compliance shall be used: The bench test, the ground test and the flight test.

6.9.1 General verification of ground installation.

The applicant shall demonstrate that the GBAS ground facility is suitable for the intended operation.

6.9.2 System Accuracy.

The applicant shall demonstrate through analysis and flight testing that the GBAS ground installation provides the level of accuracy necessary for safe operation.

6.9.3 Continuity of function.

The applicant shall demonstrate through analysis and testing that the operational reliability of the system meets the continuity of function criteria.

6.9.4 Integrity.

The applicant shall provide a system safety assessment, based on a fault-tree and failure modes effects analysis (FMEA), to show that the integrity of the ground installation meets the integrity requirement.

Note: The AMJ 25-1309 describes various acceptable means for showing compliance concerning the system design and analysis.

6.9.5 Frequency protection.

The applicant shall also obtain any required radio license to operate on the data-link frequency.

6.9.6 General verification of the GBAS Signal in Space.

The applicant shall demonstrate that the GBAS Signal in Space fulfils the requirements of this MASPS.

The applicant shall demonstrate the GBAS Signal in Space robustness against error bit transmission through analysis and bench testing. The GBAS function shall be tested in presence of interference signal (i.e. intermodulation effects, etc..).

The minimum performance of the GBAS shall be tested in normal and environmental conditions. The representative GBAS parameters shall be verified during this test conditions (i.e. sensitivity, selectivity, etc., for the aircraft part; power transmission, spectrum for the ground part).

6.9.7 Bench test procedure.

The applicant must define the required equipment for performing the bench test. Both the ground and aircraft test must be verified during this procedure.

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6.10 **GROUND TEST PROCEDURE.**

6.10.1 Interference Effects.

The GBAS Ground Subsystem should not be the source of objectionable electromagnetic interference, nor be adversely affected by electromagnetic interference from other equipment around it.

Verify that there is no harmful conducted or radiated interference between the GBAS and other systems. Intermodulation effects are possible between multiple channel SATCOM installations and GBAS. Harmonic interference from data broadcast transmissions on 121.150, 121.175, 121.200, 131.250, 131.275, and 131.300 MHz may also adversely affect reception of the GBAS signal.

This test should also be conducted with the GBAS data broadcast receiver antenna as close as possible to the transmitting antenna of the reference subsystem to verify that the GBAS receiver is not damaged.

6.10.2 System accuracy.

Static ground accuracy test shall be conducted to verify that the installed GBAS equipment configuration (including complete Ground Subsystem, aircraft equipment and antennas) provides differential correction position data meeting the 95% accuracy criteria specified at the 200 ft.

These tests shall cover a continuous period of 24 hours with a maximum sample of 2 minutes.

Note: The 24 hour ground accuracy test may be performed on the aircraft or by use of a representative mock-up configuration. The actual Ground Subsystem must be used. In this case the GBAS equipment configuration of the mock-up aircraft fixture must be representative of the installed system configuration.

6.11 FLIGHT TEST PROCEDURES

Flight inspection tests are conducted to verify proper operation of the GBAS Ground Subsystem.

Satisfactory system performance should be demonstrated over a representative range of altitudes and ground speeds expected in service during approach operations.

The flight inspection shall include tests for all combinations of sensor, sensor selection methods and position fixing methods. These tests also must be conducted with the appropriate ground equipment in place and functioning.

Flight test should include at least the following tests described here bellow:

- 1. Evaluation of all operational modes of the GBAS equipment. Particular attention should be given to mode switching and transition requirements associated with the approach mode.

- 3. Review of various failure modes and associated annunciation such as loss of electrical power, loss of signal reception, GBAS equipment failure, autopilot/flight director response to GNSS flags, etc. Verify that all advisory, caution, and warning annunciation are readily discernible by the flight crew under all anticipated operating conditions.

- 12. Validate GBAS operation in each operating mode by conducting at least 5 CAT-I approaches. Verify that the equipment navigation accuracy is compliant with paragraph 3.4 . A trajectory measurement means may be required for this test.

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- 13. Verify continuity of navigation data during normal aircraft manoeuvring, including up to at least 30 degrees of bank angle for at least 20 seconds, and demonstrate approaches at the maximum approved pitch angle for the aircraft type.

For the GBAS coverage area, verify that when the aircraft is within the nominal GBAS transmitter coverage area the installed equipment meet the performance requirement. This verification shall include 360 degree left and right with bank angles of up to 30 degrees in landing configuration at a distance of at least 10 Nm.

Depending upon the approach the distance can be increased from 10 Nm to the adequate distance value.

Full capability to complete the approach must be available at the start of the final approach segment.

This test must be accomplished with a ground Subsystem operating at minimum transmitting power

- 14. Verify that flight technical error (FTE) can be maintained to meet the accuracy requirements. At least 10 CAT I approaches in each mode (e.g. autopilot coupled, flight director, raw data) with a minimum of 20 total approaches must be conducted. At least 95 % of the approaches must remain within the accuracy value.

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