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Minimum Operational Performance Standards for Avionics Supporting Next Generation Satellite Systems (NGSS)

RTCA DO-262B
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Prepared by: SC-222

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FOREWORD

This doucment was prepared by Special Committee 222 (SC-222) and was approved by the RTCA Program Management Committee (PMC) on June 17, 2014.

RTCA, Incorporated is not-for-profit corporation formed to advance the art and science of aviation and aviation electronic systems for the benefit of the public. The organization functions as a Federal Advisory Committee and develops consensus-based recommendations on contemporary aviation issues. RTCA's objectives include but are not limited to:

- coalescing aviation system user and provider technical requirements in a manner that helps government and industry meet their mutual objectives and responsibilities;
- analyzing and recommending solutions to the system technical issues that aviation faces as it continues to pursue increased safety, system capacity and efficiency;
- developing consensus on the application of pertinent technology to fulfill user and provider requirements, including development of minimum operational performance standards for electronic systems and equipment that support aviation; and
- assisting in developing the appropriate technical material upon which positions for the International Civil Aviation Organization and the International Telecommunications Union and other appropriate international organizations can be based.

The organization's recommendations are often used as the basis for government and private sector decisions as well as the foundation for many Federal Aviation Administration Technical Standard Orders.

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1 PURPOSE AND SCOPE

1.1 Introduction

This document contains minimum operational performance standards (MOPS) for avionics that provide Aeronautical Mobile Satellite (R) Services (AMS(R)S) by means of satellite communications technologies scheduled to become operational after the year 2000. Each of these technologies is individually and collectively referred to as a "Next Generation Satellite System" (NGSS), and the NGSS nomenclature will be used throughout this document. This document does not apply to avionics that provide AMS(R)S in accordance with the Standards and Recommended Practices defined in ICAO Annex 10, Part I, Volume III, Chapter 4 (Chapter 4 SARPS). Such equipment is specified in the current version of RTCA DO-210.

Compliance with these standards is recommended as one means of assuring that NGSS avionics will perform its intended function(s) satisfactorily under all conditions normally encountered in routine aeronautical operations. Any regulatory application of this document is the sole responsibility of appropriate governmental agencies.

This document contains a generic description of a satellite communication system configuration including Ground Subnetworks; NGSS Satellite Subnetworks, of which the Aircraft Earth Station (AES) is one part; and Aircraft Subnetworks. However, the specified Minimum Operational Performance Standards in this document address only the AES portion of the Satellite Subnetwork.

To comply with the minimum requirements of an application for certification or other approval, an NGSS applicant is required to submit information regarding the technical characteristics of the NGSS. These technology-specific technical requirements for each such system will become normative appendices to this document. It is anticipated that such technology-specific appendices will be created as the particular NGSS becomes operational for AMS(R)S.

This document covers typical NGSS avionics requirements and tests for the aircraft avionics. It includes the purpose, scope and equipment performance requirements, recommended bench tests and other performance verification procedures, and installed-equipment tests and operational performance characteristics. Detailed requirements and test procedures are based on the technical characteristics documented in the normative appendices, as discussed in the previous paragraph.

A companion document, *Minimum Aviation System Performance Standards (MASPS) for the Aeronautical Mobile-Satellite (R) Service (AMS(R)S) as Used in Aeronautical Data Links*, should be available in early 2001. The MASPS should be consulted for operational requirements at the air/ground system level, and for details of specific systems providing AMS(R)S. RTCA documents DO-215A and DO-231 provide guidance on overall data and voice performance issues.

1.2 Document Overview

Section 1 of this document provides general background information needed to understand the NGSS equipment and system characteristics and requirements stated in the remaining sections. It describes typical applications and operational goals as envisioned by the members of Special Committee 165 and establishes the basis for the standards stated in Section 2 and Section 3. Definitions and assumptions essential to proper understanding of this document are also provided in this section, while a more extensive glossary appears as Appendix A. A more detailed informative explanation of the operation of each of the aeronautical services provided by particular NGSS systems is contained in the appropriate technique-specific appendix. Section 1 of this MOPS is intended to be informative in nature and contains no requirements applicable to the avionics equipment covered by this document.

Section 2 contains the minimum performance standards for the aircraft NGSS equipment. These standards specify the required performance under standard operating and environmental conditions, and are common to all NGSS AES equipment. Specific values which quantify the requirements are contained in the technique- or technology-specific appendix prepared for each system. The main body of the MOPS also includes bench test procedures necessary to demonstrate equipment and network compliance with the stated minimum requirements.

Section 3 describes the performance required of the installed aircraft avionics equipment. Tests specifically for the installed equipment are included when performance cannot be adequately determined through bench testing.

Section 4 describes the operational performance characteristics for equipment installations and for network operation and defines conditions that will assure the equipment user that operations can be conducted safely and reliably in the expected operational environment.

Appendix A is an informative appendix containing an extended glossary, abbreviation, and acronym list.

Appendix B is a normative appendix and associated test procedures for AES equipment that implements an ISO-8208-compliant ATN interface.

Appendix C is an informative appendix containing specific recommendations tailoring the requirements contained in this MOPS for equipment that supports only non-safety AMSS communications.

Additional technique-specific normative appendices are included. These are intended to be part of certification or approval documentation information. Each of these normative appendices is divided into two sections. Section 1 contains a detailed informative description of system operation, focusing on those aspects particular to AMS(R)S. Subsequent sections contain normative information regarding the technique- or technology-specific requirements unique to the particular NGSS.

The following list summarizes the industry standard documents and their specific versions referenced within this MOPS:

Reference Document Name	Version or Date
RTCA DO 178B	December 1, 1992
RTCA DO-215A	February 21, 1995
RTCA DO-222	
RTCA DO-231	

ISO-8208 (English)	Release 2, including amendment 1
RTCA DO-160D	July 29,1997
ITU-R RA.769-1	1995 (reference/information only)

In the event of any conflict between documents, this MOPS shall take precedence.

Document references within these MOPS are used to assure common requirements between various documents, to minimize the risk of conflict, and to reduce the complexity of this document. The user of this MOPS should keep in mind that the referenced documents may or may not contain actual references to NGSS equipment and, therefore, some editorial translations may be necessary.

As used in this document, the terms "aircraft avionics" and “Aircraft Earth Station” include all components and units necessary for the aircraft system to provide voice and/or data communications using the satellite constellation, but not including the aircraft user subnetwork defined in DO-215A. The NGSS avionics comprises multiple components, including antennas, couplers, voice digitization circuitry and modulators/demodulators. A particular NGSS avionics complement will not necessarily include all components or units referred to herein but will perform all required functions.

The guidelines contained in RTCA/DO-178B, *Software Considerations in Airborne Systems and Equipment Certification*, should be considered with respect to NGSS avionics software.

1.3 System Overview

The Aeronautical Mobile-Satellite (R) Service, abbreviated as AMS(R)S, is the designation by the ICAO and ITU for two-way communications via satellite(s) pertaining to the safety and regularity of flight along national or international civil air routes. The designator (R) is added to indicate that the international spectrum allocation is intended for aeronautical communications for aircraft flying civil aviation routes. Equipment and services operating in radio spectrum designated as (R) are historically accorded special measures of protection from interference and normally are used only for communications related to the safety and regularity of flight. In the case of AMS(R)S, non-safety communications are also permitted on a non-interference basis when priority and preemption can guarantee the precedence of safety communications. The term Aeronautical Mobile Satellite Service, AMSS, without the (R), is often used (e.g., in ICAO documentation) and is considered to comprise both AMS(R)S and the non-safety aeronautical services, which can include specialized government and administrative communications as well as public correspondence.

End-to-end AMS(R)S data communications are provided by several subnetworks (aircraft user, avionics, satellite, terrestrial and ground user) as shown in Figure 1-1. This MOPS addresses only the avionics portion of a subsystem which consists of satellites, Aeronautical Earth Stations (AESs), Ground Earth Stations (GESs), radio-frequency propagation paths, and associated ground facilities including a Network Control Center (NCC) function.

Figure 1-1 depicts a single satellite served by multiple GESs for illustrative simplicity only. Depending on the architecture of a particular system, multiple satellites may be in view of an aircraft; and a satellite may not require any GES in its own view by maintaining connectivity via intersatellite links.

Ownership and operation of the satellites, aeronautical stations, ground stations and network control functions may be responsibility of one or several organizations or corporate entities.

An important element of the system architecture is the NCC function. Again depending on the architecture of a given system, this function may be entirely contained in the ground segment, comprising GES(s) and control centers; or the NCC functionality may be shared between the ground segment and the satellite constellation. It is not assumed that GESs are completely autonomous but it is expected that a system's GESes conform to common operating policies and rules and utilize with some form of intersite communication. The NCC function could be distributed among a domain's GESs and/or satellites; however, it is expected that all NCC functions have some form of intercommunication.

1.3.1 System Elements and Functions

1.3.1.1 Aircraft Earth Station (AES)

An Aircraft Earth Station (AES) serves as the radio transceiver that provides RF path connectivity with the satellite(s), and provides the digital data and/or analog voice and/or digital voice interfaces with other aircraft user subsystems. Its primary functions are the modulation and demodulation of transmitted and received signals, respectively; signaling and protocol interactions with corresponding satellites and/or Ground Earth Stations (GESs); channel management; and switching and interconnections with the aircraft and their attached avionics.

The sensitivity, gain, polarization, and spurious requirements specified in Section 2.2.3 of this document are intended to support the system-level link budgets contained in the corresponding MASPS or other RTCA document.

Figure 1-2 provides a generic block diagram of the AES described in this document. This document contains requirements for the antenna and transceiver subsystems of the generic AES. Figure 1-2 is intended to be informative, not normative; there is no requirement to design equipment that corresponds to the partitioning of the block diagram. No functionality beyond that stated in Section 2.2 is required.

The requirements contained in Section 2.2 are designed to be tested or measured at either the external antenna interfaces or at the transceiver interfaces. The transceiver interfaces are indicated by points A and B in Figure 1-2. Special control signals may be required to execute the recommended tests.

1.3.1.2 Ground Earth Station (GES)

A Ground Earth Station (GES) provides the connectivity between the ground network(s) and the satellite(s) via RF transmission and reception feeder links. Components of a GES include antenna(s), modulators and demodulators for the transmitted and received signals, respectively; computers controlling the signaling and protocol interactions with corresponding Aircraft Earth Stations (AESs); and channel management. A GES may also host some or all of the Network Control and Coordination functionality.

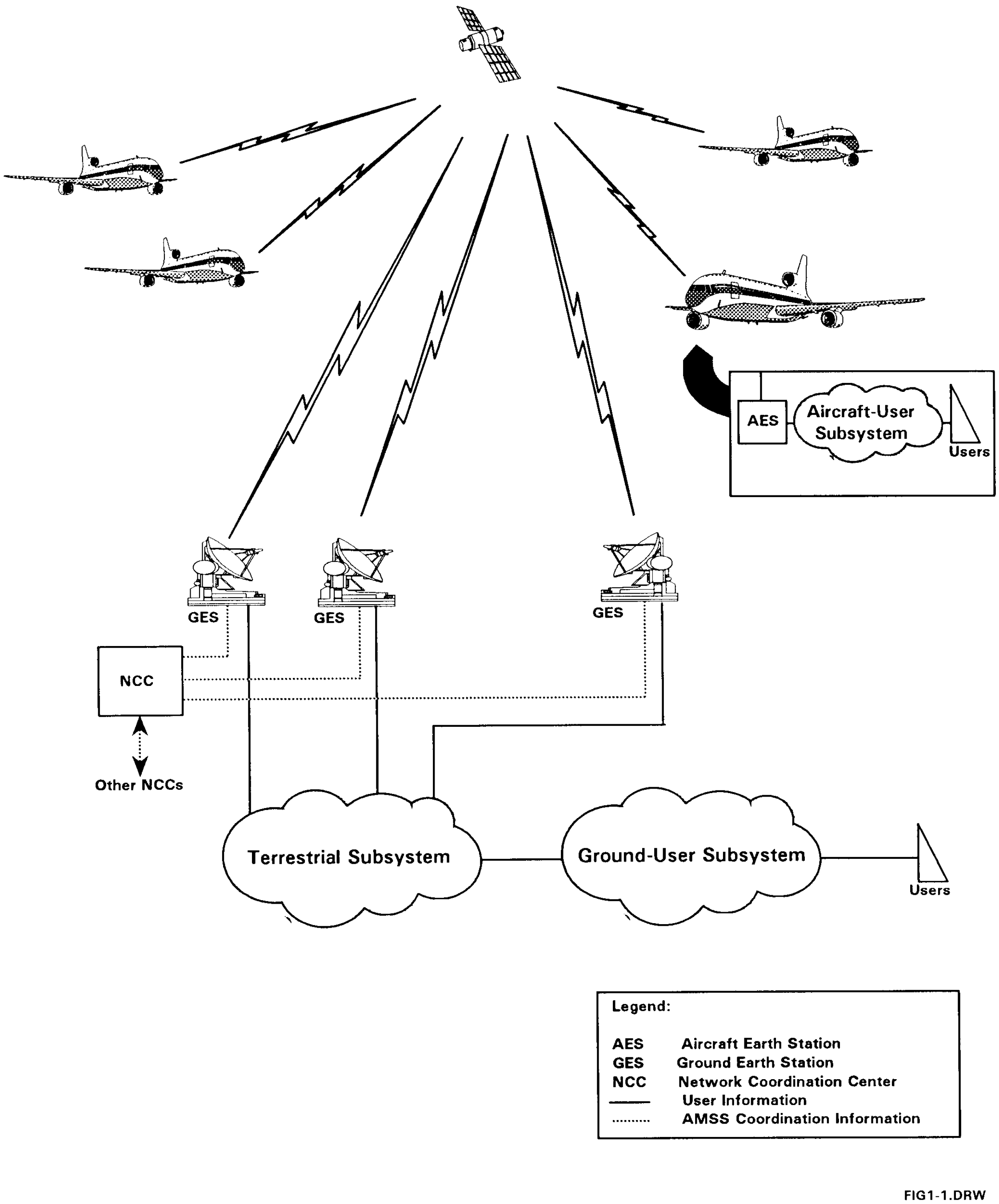

Figure 1-1 Aeronautical Mobile Satellite Service (AMSS) End-to-End Model

1.3.1.3 Network Control and Coordination Function

The Network Control and Coordination Function performs administrative and technical management functions for an AMSS Subsystem. Among the functions essential to the provision of AMSS services are satellite tracking, telemetry and control (TT&C); overall system management and performance monitoring; maintenance of data bases of satellite and user parameters; frequency management; inter- and intra-system coordination; and billing.

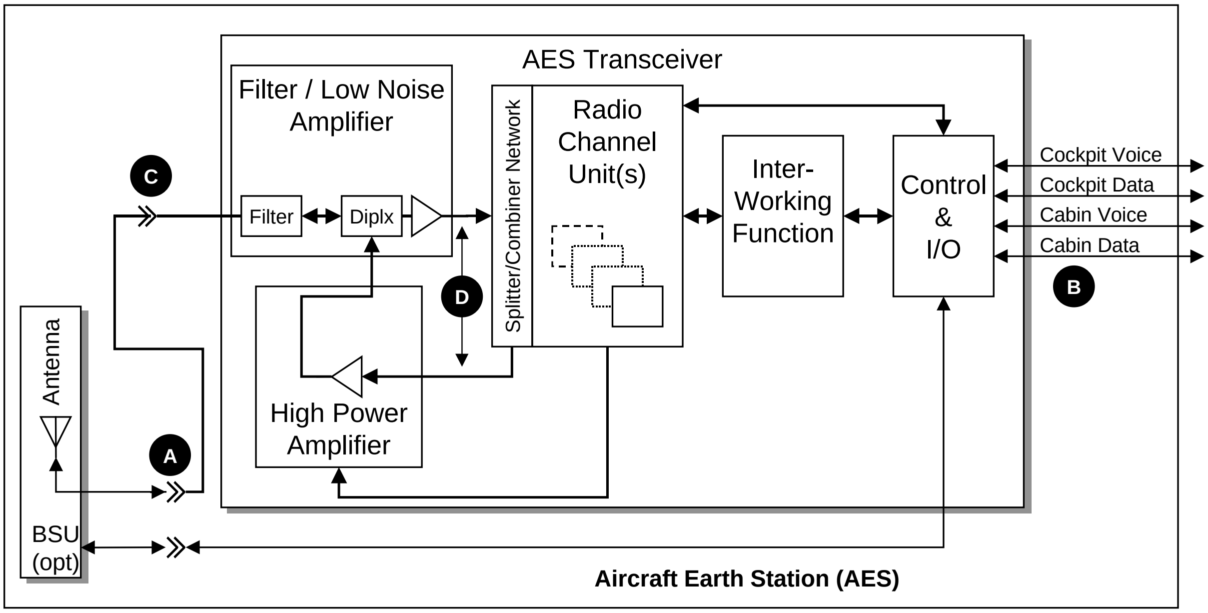

Figure 1-2 Generic Block Diagram of Aircraft Earth Station

1.3.1.4 Satellites

This document does not assume a particular type of NGSS satellite constellation for AMS(R)S use. Satellite constellations are typically characterized by their orbital parameters, and are generally segregated into four groups: Low-Earth Orbit (LEO), Medium Earth Orbit (MEO), Highly Elliptical Orbit (HEO), and near-Geosynchronous Orbit (GEO).

LEO systems contain a multiplicity of satellites in orbits between 500 km and 1500 km altitude. The Low-Earth nature of the orbits dictates that the velocity of the satellites is much greater than the platform velocity of even high-performance aircraft, thus the system design must compensate for relatively high Doppler shifts at all times. Typical LEO communications systems depend on a multiplicity of antenna spot beams to service the user service link. Some LEO systems require continuous connectivity between the satellite providing service and an associated Ground Earth Station, while others allow for indirect connectivity by means of intersatellite radio links.

MEO systems rely on constellations with orbits in the range of 1500 km to 15,000 km altitude. Because the higher orbit permits coverage of a larger portion of the Earth's surface by each satellite, MEO constellations generally have fewer satellites than LEO constellations. Most MEO constellations are likely to use a "bent pipe" communications technique that requires continuous connectivity between the satellite providing service and an associate Ground Earth Station.

HEO constellations are designed to allow each satellite to service a particular region of the Earth's surface for long periods of time. A typical HEO orbit has a perigee in the range of 1000 km and an apogee of approximately 10,000 km. Satellites in HEO orbits may be used as a supporting element of LEO, MEO or GEO constellations.

GEO constellations consist of satellites at an orbital altitude of 35,800 km. At this altitude, the orbital period is 24 hours, and the ground track of the satellite varies only slightly with time. From the viewpoint of a user aircraft, the satellite is nearly stationary. Typical GEO constellations consist of only four or five satellites in equatorial orbits, spaced nearly uniformly in longitude. The AMS(R)S/AMSS communications described in ICAO Chapter 4 SARPs and in the current version of DO-210 utilize such a constellation of GEO satellites. This document specifically allows for the possibility of future GEO constellations that comply with the more generic requirements of NGSS, vice the original requirements detailed in Chapter 4 SARPs and in DO-210.

1.3.1.5 Satellite System Coverage

The coverage area of a satellite system is determined by the aggregation of all service-link beams formed by all satellites in its constellation. In current AMSS systems, coverage of an individual beam can range from that portion of the Earth's surface within line of sight of a given satellite (roughly one-third of the Earth's surface for a GEO satellite) to a portion of the Earth's surface as small as 800 km in diameter. These beams can be stationary (as in GEO system) or can be continuously moving over the Earth's surface (as in a LEO/MEO system).

This document defines coverage area as that airspace over a delineated portion of the Earth's surface, within which all service/performance criteria are met by a given Satellite Subsystem. It is the responsibility of the Satellite Subsystem service provider to define, declare, and verify its coverage areas. Information on the service area provided by a specific NGSS system can be found in the applicable technique-specific appendix to this MOPS.

1.3.2 Communications Protocols

The Aeronautical Telecommunication Network (ATN) is being implemented on a world-wide basis to provide a common set of interfaces and protocols for aeronautical data communications (see also Section 1.4.1). The requirements of this document are based on the assumption that NGSS data services will be constituent subnetworks of the ATN.

The ATN is based on the Open System Interconnect (OSI) data communications model. The OSI Reference Model defines seven such functional layers with responsibilities ranging from control of data transfer on the physical media (radio, wire, fiber, etc.) to control of the application user interface. The seven layers are named: (1) Physical, (2) Data Link, (3) Network, (4) Transport, (5) Session, (6) Presentation and (7) Application. Each layer provides communication services to the layer above it. The particular protocol for a given layer may be optimized for the environment in which it operates; e.g., a satellite communications subnetwork must operate in a medium prone to errors, has long propagation times, and has limited bandwidth.

Each layer incorporates well-defined operations designed to optimize control and information flow across the layer boundaries. To carry out its function, each layer may add protocol control information fields to the service-data-unit supplied by the layer above. However, each layer leaves the control information added by previous layers intact, treating it as data to be passed on unaltered. The aircraft avionics and its counterpart of the ground station implement either the lowest two or the lowest three layers of the OSI model to provide packet-mode data services.

This document recognizes two potential modes of data operation. These modes are referred to as Data-2 and Data-3, to be consistent with existing industry standards (see RTCA/DO-210D). Data-2 operation provides transparent data communications by enveloping the packets received from a higher-layer entity (HLE) without using internal network layer protocols. Data-3 operation provides to the user a packet-switched subnetwork that implements the lowest three layers of the OSI model (physical, data link and network) and is intended for use with the Aeronautical Telecommunications Network (ATN). One proven means of providing an OSI compliant interface for ATN data is by using the standard interface defined in ISO-8208.

At initial operational capability, it is anticipated that all equipment compliant with this standard will support Data-2, with Data-3 available when ATN equipment and procedures are established.

1.4 Operational Applications

Applications for the NGSS satellite communications include both safety and non-safety services. Safety services are always given priority, and can, if necessary to secure system resources, preempt non-safety traffic. A detailed description of safety and non-safety services falling into the four categories described below can be found in DO-215A.

The AES equipment specified here is intended to support the following categories of aeronautical communications related to the safety and regularity of the flight:

Air Traffic Services (ATS) – Safety communications between the flight crew and air traffic control as necessary for safe air navigation (e.g., air traffic control, navigation system operation, weather information collection and dissemination). This includes tactical control of aircraft to ensure safe separation and sequencing, clearances to enter controlled airspace, approach clearances, weather information collection and dissemination, and the coordination of handoffs between adjacent control areas. Although current procedures provide ATS services primarily via voice networks, future ATN applications will primarily use data communications to performed the same functions.

Aeronautical Operational Control (AOC) – Safety communications between the flight crew and flight operations as necessary for initiation, continuation, diversion, or termination of a flight in the interest of the safety of the aircraft and the regularity and efficiency of a flight. Current procedures provide AOC services via both voice and data networks.

In addition to safety communications, the equipment specified herein may also support the following non-safety communciations:

Aeronautical Administrative Communications (AAC) – Non-safety communications between the cabin crew or flight crew and airline business operations as necessary for passenger services or cabin support services.

Aeronautical Public Correspondence (APC) – Non-safety communications between an aircraft passenger and party/parties on the ground or in another aircraft for the passenger's private or business use. APC services are provided via both voice and data networks.

1.4.1 Compatibility and Interoperability

NGSS satellite communications must be compatible and interoperable with external avionics systems and external terrestrial communications networks for users ranging from private aircraft through widebody commercial jet transports. This requires implementation of well-defined interfaces and peer-to-peer protocols; therefore, a NGSS satellite system must provide standard end-user subnetwork interfaces among satellite systems and associated terrestrial systems on a global basis. One such standard is the ISO/IEC 8208 mobile sub-network dependent convergence function. Other standard interfaces are permissible.

For packet data transmissions, NGSS will implement the OSI Reference Model and will ultimately be integrated in the ATN. When the ATN is operational, NGSS communications will be interoperable at the subnetwork interface level with High Frequency (HF), Very High Frequency (VHF) and Mode Select (Mode-S) data links. It is expected that common operating procedures will be used among all three systems.

For worldwide ATN compatibility among these constituent subnetworks, a common routing and addressing scheme is required. The twenty-four (24) bit International Civil Aviation Organization (ICAO) aircraft identification numbers will be recognized by the NGSS systems. Translation from ICAO standard address to an identity number consistent with the number used internally by the satellite subnetwork is performed in a manner transparent to airborne and ground users.

NGSS equipment is intended to co-exist with AMSS equipment specified by DO-210D at least to the extent that use of either type of equipment within a given airspace will not preclude use of the other type of equipment. Certain protection separations may apply, but these separations will be well within the standards established for routine aircraft operations within the airspace in which NGSS operations are permitted. It is expected that the service providers of NGSS services and existing AMSS services will coordinate system operations to assure operations on a non-interfering basis in accordance with ITU Radio Regulations. This system level coordination will not directly affect the design, test, or installation of NGSS equipment. Changes in system operation, if necessary, will be instituted at the appropriate network control facility or appropriate ground station.

While these MOPS do not require that dissimilar AMSS equipment be able to operate simultaneously and independently on the same aircraft, manufacturers are urged to consider such interoperability as a very desireable feature of their equipment design.

1.4.1.1 Protection of Radio Astronomy

Worldwide deployment of AES terminals means that transmissions can occur near sensitive Radio Astronomy sites, and that those sites could experience harmful interference from out-of-band spurious AES emissions. The standards established in this document protect Radio Astronomy (RA) data collection from harmful effects of AES emissions in the L-Band during normal over flight and maneuvers near the RA station. The maximum permissible power spectral flux density and averaging parameters of ITU-R RA.769-1 have been applied for the purposes of establishing these spurious emissions levels. Each AES design should complete a thorough analysis to assure that it complies with ITU-R RA.769-1 given the specific operational characteristics of the satellite subnetwork it supports.

1.4.2 End-to-End Service Criteria

The criteria for NGSS service provided among end users of the system are contained in RTCA DO-215A.

1.5 Assumptions and Postulated Environment

1.5.1 Coverage

This MOPS assumes an NGSS communications system which provides coverage with a common user link signal format and satellite sub-network protocol over an extended portion of the Earth's surface, preferrably worldwide. It assumes that communications capabilities do not depend on the location of the NGSS user aircraft within the defined coverage volume, nor on the availabililty of a line-of-sight between the AES and the GES. Ideally, the system should allow any aircraft to communicate with any location on Earth, regardless of the position of the aircraft or the originating or terminating location.

1.5.2 Data versus Voice Communications

Although voice communications will be used for the foreseeable future, as the capacity and precision capabilities of aeronautical data links become more apparent, routine air-ground-air communications will evolve toward being computer-tocomputer. Pilots and controllers will use digital data for many purposes but will continue to use voice communication for non-routine and emergency communications. The NGSS system design is assumed to support voice services, data services, or both, as declared in the technique-specific appendix. This MOPS allows both data-only and voice-only capabilities. Combined voice and data units are encouraged, but this MOPS does not require that all types of AES equipment be capable of both data and voice services or of simultaneous data and voice services.

1.5.3 Safety

Safety communications, by ICAO and International Telecommunication Union (ITU) regulations, are assured of always having the highest priority and are accorded special measures for protection from interference. A system supporting safety communications is assumed to have the appropriate priority and preemption control mechanisms embodied in all elements comprising the system.

1.5.4 Priority, Precedence and Preemption

The primary mechanism for assuring that safety related communications are always available is the mechanism for priority, precedence and preemption. This MOPS assumes that the NGSS system design implements the priority structure necessary for Aeronautical Mobile (R) Service safety services. This includes the mechanisms for controlling the precedence of both safety and non-safety messages, for the preemption of system resources as needed to support safety services and to provide for the added measure of protection to be accorded the safety services. Priority, precedence and preemption mechanisms are assumed to apply to both data and voice transmissions, with voice communications taking priority over data transmissions at the same level of priority.

1.5.5 Assumptions on Higher Layer Packet Data Interfaces

To support the evolving ATN environment, this MOPS emphasizes data communications. Data link operations are defined in terms of a user application, also known as a Higher Level Entity (HLE). For the purpose of specifying these interfaces, this document assumes the HLE performs the following functions:

a. Is able to initiate, accept and terminate calls via the interface.

b. Is prepared to accept error messages from the AES.

c. Monitors the AES operation in case of unrecoverable error conditions and reinitializes the AES as necessary.

1.5.6 Assumptions on Voice Communications Using Digitized Voice

Despite the fact that the evolving ATN environment will utilize digital data communications, there is still a desire to maintain voice communications for some operations, especially distress/urgency communications. This document assumes that the underlying communications infrastructure exists and has not been created solely for the purpose of AMS(R)S communications. To the extent that the underlying infrastructure provides voice communications, it is expected that such voice capability will be provided by digital means, and not by conventional analog modulation techiques.

When such "digital voice" technology is implemented, the techniques used to translate the spoken word into digital form and back will be established by the specific subnetwork. This document only establishes the high level requirements for such voice encoding and decoding techniques, which are collectively referred to as "the vocoder". Previous RTCA efforts have indicated that the suitability of a particular vocoder for a particular AMS(R)S function involves a subjective evaluation of voice communications using that vocoder in a variety of channel environments and ambient audio noise environments. Furthermore, complete interoperablility between two different vocoder implementations is extremely problematic. Thus, this document assumes that voice communications, if provided, will utilize the standard vocoder employed by the satellite subnetwork and sets an extremely high standard for the use of any alternate vocoder. This is the only manner in which both interoperability and suitability for a particular application can be assured.

1.5.7 Assumptions on Aircraft Motion

The minimum requirements stated in this document assume that the AES is to be operated on a commercial air transport vehicle operating at approximately 550 knots true air speed with a 250 knot tail wind. Thus the frequency tracking requirements are for 800 knots ground speed, with a recommendation for supersonic aircraft.

1.5.8 Assumptions on Same-Aircraft Interference

The minimum requirements stated in this document assume that all AES equipment will be located on-board aircraft that use GNSS receivers for navigation and location. GNSS equipment is assumed to comply with the ICAO GNSS SARPS. Unless explicitly stated otherwise, all interference requirements assume an AMS(R)S-antenna- input-port-to-GNSS-antenna-output-port-isolation of 40 dB.

This document also assumes that it is a minimum requirement for AMS(R)S equipment to operate simultaneously with and independently from other AMS(R)S equipment, possibly using different communications infrastructure, when the different equipment is installed on different aircraft operating in the same airspace. Furthermore, it is highly desirable that AMS(R)Sequipment operate simultaneously with and independently from other AMS(R)Sequipment on the same aircraft. In such case, the assumed AMS(R)S-system-A-antenna-input-port-to-AMS(R)S-system-B-antenna-output-port is 40 dB.

1.6 Overview of Test and Performance Verification Procedures

The test and performance verification procedures specified in this document are intended to be used as one means of demonstrating compliance with the performance requirements. Although specific test and performance verification procedures are cited, it is recognized that other methods may be preferred and may be used if they provide at least equivalent information. In such cases, the procedures cited should be used as one criterion in evaluating the acceptability of the alternate procedures.

The specified order of procedures suggests that the equipment be subjected to a succession of tests or analyses as it moves from design to design qualification and into operational use.

Since NGSS systems are expected to utilize a significant amount of commercial telecommunications functionality, this standard specifically allows pre-qualification of embedded core hardware and software, subject to verification that the hardware and software which implement AMS(R)S-specific functionality do not alter the previously qualified functions.

Four types of procedures are described in the following Sections.

1.6.1 Environmental Tests and Performance Verification

Environmental test and/or analysis requirements are specified in Section 2.3. The procedures and their associated limit requirements are intended to provide a laboratory means of determining the electrical and mechanical performance of the equipment under the environmental conditions expected to be encountered in actual operations.

Unless otherwise specified, the environmental conditions and test procedures contained in RTCA/DO-160D, Environmental Conditions and Test Procedures for Airborne Equipment, will be used to demonstrate equipment compliance.

1.6.2 Bench Tests and Performance Verification

Bench test and/or analysis procedures are specified in Section 2.4, and provide a laboratory means of demonstrating compliance with the requirements of Section 2.2. Test results may be used by equipment manufacturers as design guidance for monitoring manufacturing compliance and, in certain cases, for obtaining formal approval of equipment design.

1.6.3 Installed Equipment Tests and Performance Verification

The installed equipment test and/or analysis procedures and their associated limits are specified in Section 3.0. Successful completion of bench and environmental test procedures is a precondition to completion of the installed equipment tests. In certain instances, however, installed equipment tests may be used in lieu of bench test simulation of such factors as power supply characteristics, interference from or to other equipment installed on the aircraft, etc. Installed-equipment tests are normally performed under two conditions:

a. With the aircraft on the ground and using simulated or operational system inputs

b. With the aircraft in flight using operational system inputs appropriate to the equipment under test

Test results may be used to demonstrate functional performance in the intended operational environment.

1.6.4 Operational Tests and Performance Verification

Operational tests and/or analyses are specified in Section 4.0. These test procedures and their associated limits are intended to be conducted by operating personnel as one means of ensuring that the equipment is functioning properly and can be reliably used for its intended function(s).

1.7 Definitions of Standard Terms Used in this Document

Aeronautical Mobile Satellite (R) Services AMS(R)S: Safety-related services offered by a satellite communications system for the purpose of enhancing the safety and regularity of flight.

Aeronautical Telecommunications Network (ATN): A worldwide telecommunications network for aeronautical communications which comprises application entities and communication services which allow ground, air-to-ground and avionics data subnetworks to interoperate by adopting common interface services and protocols based on the OSI reference model.

Air Traffic Management (ATM): An evolving means of controlling aircraft in less structured airspace based heavily on automatic communication of data between controllers and pilots with only minimal reliance on voice communications.

Average Output Power: For satellite systems using TDMA format, the average power output is be defined as the average power **over any TDMA frame**, with the specified number of carriers active in a single TDMA time slot. The average power output is defined with respect to a TDMA frame, under the assumption that a carrier is active for only a single timeslot in each frame. If a carrier is active for more than a single timeslot in the frame, the combined duration of all active timeslots is used. For satellite systems using a CDMA format, the average power output is the average power over the length of the CDMA code, measured with the specified number channels active throughout that interval. For simple FDMA system in which the channel bandwidth is dedicated to a single user, the average shall be over one second.

Burst Output Power: For satellite systems using TDMA format, the transmitter power output is be defined as the average power over any **single TDMA timeslot** with the maximum data and voice carriers declared by the manufacturer active at their maximum output power in the same timeslot. The transmitter power output is defined with respect to a single TDMA timeslot, not a TDMA frame. If a carrier is active for more than a single timeslot in the frame, the combined duration of all active timeslots is used. For satellite systems using a CDMA format the power output is the average power over the length of the CDMA code, measured with the all voice and data channels active. For simple FDMA system in which the channel bandwidth is dedicated to a single user, the average shall be over one second.

Circuit Mode Data: Binary Data, such as facsimile and personal computer modem, which is transferred via a dedicated point-to-point connection or circuit between the local (airborne) and remote users. For the purposes of this document, Circuit Mode Data refers to the methods used for satellite subnetwork access, not necessarily to the internal data communications processes within the specific sub-network.

Code Division Multiple Access (CDMA): A technique for multiplexing many users onto the same RF carrier in which each user is assigned a unique pseudo-random code that is uncorrelated with all other user codes. The pseudo-random code is used in a direct sequence spread spectrum manner, with the result that undesired users are rejected by the receiver correlation function.

Frequency Division Multiple Access (FDMA): A technique for multiplexing several users within the same RF bandwidth by assigning each user a unique sub-band of the designated transmit and receive frequency bands. FDMA techniques may be combined with either TDMA or CDMA techniques to increase the re-use of available spectrum.

Left-Hand Circular Polarization (LHCP): An elliptically or circularly polarized wave in which the electric field vector, observed in a fixed plane that is normal to the direction of propagation while looking in the direction of propagation, rotates with time in a left-hand or counter-clockwise direction (ITU-R definition).

Multi Carrier: A descriptive term applying to AES equipment that is capable of generating or receiving multiple radio frequency carriers at the same time.

Multi Channel: A descriptive term applying to AES equipment that is capable of communicating multiple voice and/or data channels simultaneously. Depending on the specifics of the signal format, an AES may be capable of offering multi-channel service without having multi-carrier capability.

Next Generation Satellite System (NGSS): A satellite communications system that provides AMS(R)S which may be voice, data or both. An NGSS includes AESs, satellites, GESs and network control system facilities that perform administrative and operational management functions. An NGSS may provide non-AMS(R)S communications.

Packet Mode Data: Binary Data that is transmitted by transferring independent units of information over the subnetwork interface. In general, Packet Mode Data will utilize either Data 2 or Data 3 protocols defined in this document, and may utilize a technique-specific Air-Ground Protocol (AGP) sublayer within the Satellite Subnetwork Dependent Protocol (SSNDP). For the purposes of this document, Packet Mode Data refers to the methods used for satellite subnetwork access, not necessarily to the internal data communications processes used within the specific sub-network.

Residual Packet Error Rate: The likelihood that a particular packet will be duplicated or delivered incorrectly. An incorrectly delivered packet is one in which the user data is delivered to the satellite subnetwork interface with one or more bit errors or the user data is deliverd to an incorrect higher level entity. See DO-215A, Change 1, for additional details.

Right-Hand Circular Polarization (RHCP): An elliptically or circularly polarized wave in which the electric field vector, observed in a fixed plane that is normal to the direction of propagation while looking in the direction of propagation, rotates with time in a right-hand or clockwise direction (ITU-R definition).

Single Carrier: A descriptive term applying to AES equipment that can generate or receive only a single radio frequency carrier. Depending on the specific structure of the system-specific signal format, single carrier equipment may be capable of serving multiple voice and/or data channels. As used in this document, the terms "single carrier" and "single channel" are not synonymous.

Single Channel: A descriptive term applying to AES equipment that is only capable of communicating a single channel of voice or data at any given time. Designation as single channel may not preclude the interleaving of voice and data traffic in the same single communications channel. The terms "single carrier" and "single channel" are not synonymous.

Self-Organising Time Division Multiple Access (STDMA): A multiple access technique based on time-shared use of a radio frequency (RF) channel employing: (1) discrete contiguous time slots as the fundamental shared resource; and (2) a set of operating protocols that allows users to mediate access to these time slots without reliance on a master control station. As used in this document, all references to TDMA apply to systems that operate with STDMA protocols, as well.

Time Division Multiple Access (TDMA): A technique for multiplexing several users onto the same RF carrier in which each user is assigned a unique time slot on either a fixed, repetitive bases or on the bas

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2 EQUIPMENT PERFORMANCE REQUIREMENTS AND TEST PROCEDURES

2.1 General Requirements

2.1.1 Airworthiness

The design and manufacture of the equipment shall provide for an installation that does not impair the airworthiness of the aircraft.

2.1.2 Intended Function

The equipment shall perform its intended function, as defined by the manufacturer, and its proper use shall not create a hazard to users of the National Airspace System.

2.1.3 Federal Communications Commissions Rules

The equipment shall comply with all applicable rules of the Federal Communication Commission (FCC).[1]

2.1.4 Fire Protection

All materials used shall be self-extinguishing except for small parts (such as knobs, fasteners, seals, grommets and small electrical parts) that would not contribute significantly to the propagation of a fire.

<u>Note</u>: *One means of showing compliance is contained in the Federal Aviation Regulations (FAR), Part 25, Appendix F.*

2.1.5 Operation of Controls

The operation of controls intended for use during flight, in all possible combinations and sequences, shall not result in a condition detrimental to the continued performance of the equipment. Controls shall be designed to maximize operational suitability and minimize pilot workload. Reliance on pilot memory for operational procedures shall be minimized.

2.1.6 Accessibility of Controls

Controls that are not normally adjusted in flight shall not be readily accessible to flight personnel. Controls that are normally adjusted in flight shall be readily accessible and properly labeled as to their intended function. The controls shall be operable with the use of only one hand.

2.1.7 Effects of Tests

The equipment shall be designed so that the application of specified test procedures shall not be detrimental to equipment performance following the application of these tests, except as specifically allowed.

[1] It is not intended that this requirement relating to FCC rules be interpreted as a precondition for obtaining other applicable approvals such as an FAA TSO authorization.

2.1.8 Performance in a Shared Environment

All requirements for data integrity and timing shall consider the effect of other active aircraft data links performing transfer operations in both directions at their nominal rates.

It is strongly recommended that the AES receiver design take into account the existence and/or probable deployment of other mobile communications systems operating in the airspace, on-board the aircraft, or in the proximate airport environment. Because the power flux densities (both composite and per carrier) of such systems may be very much higher than the power flux density of the desired NGSS downlink carriers, particular attention needs to be paid to the dynamic range of the AES receiver, to avoid saturation and consequent intermodulation products. At the same time, the receiver design should provide as much selectivity as possible as near to the input port as possible in the receiver down-conversion process. Despite these precautions, it may prove infeasible to independently and simultaneously operate two NGSSs or a NGSS and a Chapter 4 SARPs-compliant satellite communications equipment on the same aircraft.

2.2 Equipment Performance Requirements, Standard Conditions

Figure 2-1 provides a graphical guide to the organization of the equipment performance requirements discussed in the following subsections.

In the event of a conflict between a requirement stated in Section 2 of this document and a requirement stated in a system-specific[2] appendix, the requirement in the system-specific appendix shall take precedence.

Note: Precedence is given to the system-specific appendices because, by their very nature, these appendices represent later, more up-to-date information than the main body of this document.

2.2.1 Avionics Subsystem Definitions and Overall Requirements

Single-channel AES equipment shall support voice-only or packet-data-only or non-simultaneous voice-or-data operations. Enhancements to single channel AES equipment may include optional data rates or simultaneous voice and data operations.

Multi-channel AES equipment shall support either voice-only or packet-data only, or a combination of simultaneous voice and packet mode data, and may support circuit mode data services. The manufacturer shall declare any limitations on the combination of voice and data services supported by the equipment.

Note 1: *For the purposes of this requirement, a distinction is made between packet mode data and circuit mode data services. Packet mode data utilizes services that operate by transferring independent packets of information over the subnetwork interface. Circuit mode data, such as facsimile is transferred via a point-to-point connection between the local (airborne) and remote users. This document places no restriction on the method used to implement either packet mode or circuit mode data. Because AMS(R)S circuit mode data*

[2] In this document, the terms system-specific, technique-specific, and satellite-specific all refer to requirements contained in the normative appendices (Appendix D and later) of this document.

requirements have not yet been established, the minimum requirement is for packet mode.

Digitized voice shall utilize the protocol, including any forward-error-correction coding and interleaving, determined for the vocoder implementation specified in the technique-specific appendix.

Note 2: *Digitized voice operation is expected, but not required, to utilize a circuit mode connection.*

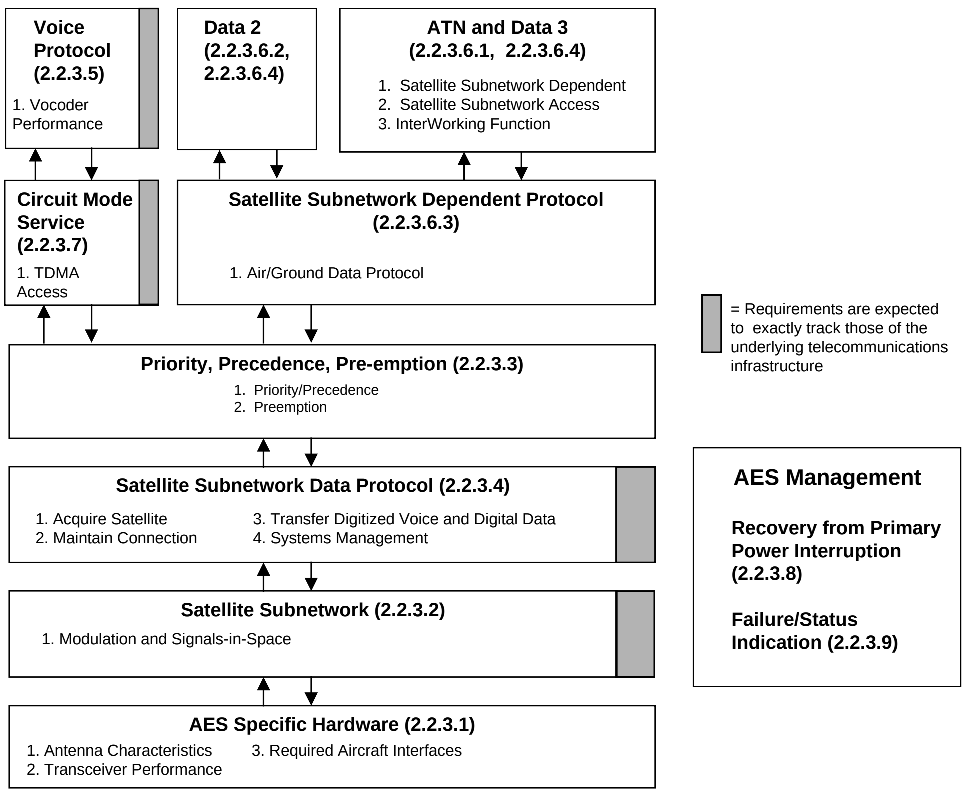


Figure 2-1 Requirements Mapping

2.2.2 Definition of System Specific Parameters

The normative system-specific appendix contain requirements that apply only to a particular NGSS system or technology. It is expected that such appendix will heavily reference requirements documents created as part of the systems engineering process followed by the satellite system architects and designers. In addition to this very specific information, the normative appendices shall contain a table that defines the basic configurations of avionics supporting each system. Table 2-1 defines parameters that shall be specified for each configuration of avionics defined in the normative appendices s.

Table 2-1 List of Parameters to be Quantified in Normative Technique-Specific Appendices

System Level Parameters Applicable to All AES Equipment	
A_{RSV}	System-specific axial ratio for space vehicle. This parameter is used only to compute the gain necessary to overcome losses due to mismatch of the axial ratios.
f_{RMX}	Maximum operating frequency for space vehicle transmissions (AES reception)
f_{RMN}	Minimum operating frequency for space vehicle transmissions (AES reception)
f_{TMX}	Maximum operating frequency for AES transmissions
f_{TMN}	Minimum operating frequency for AES transmissions
f_{M}	Channel modulation rate in bits per second
P	Nominal polarization of AES antenna
P_{NC}	Maximum output power allowed during intervals when no transceiver channel is transmitting
S_{DS}	Minimum data channel carrier level for sensitivity test
S_{HSNt}	Maximum level of harmonic, spurious and noise allowed within the designated transmit band
S_{HSNR}	Maximum level of harmonic spurious and noise within the designated receive band
S_{IMT}	Maximum level of 2-tone intermodulation products allowed within the designated transmit band
S_{IMR}	Maximum level of 2-tone intermodulation products allowed within the designated receive band
S_{UW}	Maximum level of undesired wideband noise from interfering sources external to the NGSS system that can be accepted within the designated receive band, expressed as a power spectral density.
S_{UN}	Maximum level of undesired narrowband interference from interfering sources external to the NGSS system that can be accepted within the designated receive band, expressed as an absolute power level.
S_{VS}	Minimum voice channel carrier level for sensitivity test
Θ_{SA}	Minimum separation angle between the line of sight to two satellites within the NGSS constellation

(continued)

Table 2-1 (cont.) List of Parameters to be Quantified in Normative Technique-Specific Appendices

Performance Parameters that May Differ Among Classes of AES Equipment	
A_{RA}	Maximum axial ratio for AES antenna
D/U	Minimum pattern discrimination between two potential satellite positions above the minimum elevation angle, Θ_{MIN}
$\Delta\phi$	Maximum phase discontinuity permitted between beam positions of a steered AES antenna. If the system design does not require steered antennas, this value may be set to "not applicable", (N/A).
G_{MAX}	Maximum gain of the aeronautical antenna pattern in the upper hemisphere above the minimum elevation angle Θ_{MIN}
G_{MIN}	Minimum gain of the aeronautical antenna pattern in the upper hemisphere above minimum elevation angle Θ_{MIN}
L_{MAX}	Maximum cable loss between AES antenna port and the AES transceiver input port
L_{MSG}	Maximum length in octets of user data sequence using Data 2 transmissions
L_{SNDP}	Maximum length in octets of user data contained in a maximum length sub-network dependent protocol data block
N	Maximum number of simultaneous data and voice carriers. For the single carrier, N = 1.
N_D	Maximum number of simultaneous data carriers which are permitted in the maximum number of simultaneous carriers, N. For single carrier systems, this term is not applicable.
N_V	Maximum number of simultaneous voice carriers which are permitted in the maximum number of simultaneous carriers, N. For single carrier systems, this term is not applicable.
P_D	Maximum single carrier power for each of N_d data carriers in a multi-carrier capable AES
P_{RNG}	Range over which the AES transmit power must be controlled
P_{SC-SC}	Maximum burst output power of single carrier AES
P_{STEP}	Maximum acceptable step size for controlling AES transmit power
P_V	Maximum single carrier power for each of N_v voice carriers in a multi-carrier capable AES
R_{SC-UD}	Minimum average single channel user data rate sustainable at a residual packet error rate of 10^{-6}
Θ_{MIN}	Minimum elevation angle for satellite coverage
τ_{SW}	Maximum switching time between electronically steered antenna patterns. For systems that do not require steered antennas, value may be declared as "N/A".
ρ_{RA}	Minimum exclusion zone radius necessary for protection of Radio Astronomy
C/M	Carrier-to-multipath discrimination ratio measured at the mininimum elevation angle, given in decibels
V_{SWR}	Maximum Voltage Standing Wave Ratio measured at a single input port of the AES antenna

2.2.3 Detailed Requirements

2.2.3.1 AES Application Requirements

This section and its subsections contain AMS(R)S-specific requirements for functionality over and above that required for basic access to the satellite network.

2.2.3.1.1 Antenna

<u>Notes</u>:

1. *Unless otherwise noted, the following specifications generally apply to unsteered antennas, with fixed, near-omnidirectional patterns for both transmit and receive functions. However, in certain instances (e.g., to increase data throughput) higher gain, mechanically or electronically steered antennas may be required by the NGSS system design. For steered antennas, the following specifications are to be met over the specified coverage volume when supplied with steering data having the worst-case specified accuracy.*

2. *The receiver sensitivity specified herein is a bench-test requirement. When coupled with the antenna performance specified in the following subsections, and when compensated for the effective sky temperature of typical operations, this sensitivity is consistent with the Figure of Merit G/T requirements of the MASPS and DO-215A. Manufacturers are cautioned that antenna designs may degrade the achieved G/T, and that these effects must be considered in the overall system performance estimates required by the [MASPS].*

2.2.3.1.1.1 Coverage Volume, Polarization and Antenna Gain

2.2.3.1.1.1.1 Coverage Volume

When measured on an antenna range over a representative ground plane, the antenna shall meet its polarization, antenna gain and axial ratio requirements over a partial hemispheric volume from the minimum elevation angle, Θ_{MIN}, declared by the satellite system operator to 90^o in elevation angle relative to the horizontal and throughout 360^o of azimuth.

2.2.3.1.1.1.2 Polarization

The antennas shall be circularly polarized, with the sense of the polarization, P, as declared by the service provider in the technique-dependent appendix.

2.2.3.1.1.1.3 Antenna Gain

Over the declared coverage volume, the AES antenna shall provide a minimum gain of at least G_{MIN} relative to an isotropic antenna and a maximum gain of G_{MAX} relative to an isotropic antenna.

2.2.3.1.1.2 Axial Ratio

The AES antenna voltage axial ratio shall not exceed A_{RA} relative to a perfect circularly polarized antenna over the declared coverage volume, or else the antenna shall have sufficient gain to compensate for excess polarization losses caused by an axial ratio greater than A_{RA}. To calculate the gain compensation required, the satellite antenna axial ratio shall be assumed to be A_{RSV}, and the major axes of the satellite and AES polarization ellipses assumed to be orthogonal to each other.

Note: It is recommended that the maximum axial ratio not exceed 6 dB over the coverage volume.

2.2.3.1.1.3 Power Handling Capabilities

2.2.3.1.1.3.1 Single Carrier Units

Note: This requirement refers to the number of carriers, not necessarily the number of channels.

For avionics designed to transmit only a single carrier, the maximum power handling capability of the AES antenna shall be sufficient to support at least one individual data or one individual voice carrier, whichever requires the higher burst output power consistent with the requirements of Section 2.2.3.1.2.1.2, below. The choice of data or voice shall be dependent on the capabilities of the specific AES as declared by the manufacturer.

2.2.3.1.1.3.2 Multi-Carrier Units

Note: This requirement refers to the number of carriers, not necessarily the number of channels.

For avionics designed to operate simultaneously on multiple carrier frequencies, the maximum power handling capability of the AES antenna shall be sufficient to support simultaneous transmission of at least N_D individual data carriers and N_V individual voice carriers meeting the requirements of Section 2.2.3.1.2.1.1 below.

2.2.3.1.1.4 Passband

The operational frequency band(s) of the AES shall be declared by the manufacturer by specifying values for f_{RMX}, f_{RMN}, f_{TMX}, and f_{TMN}. In the event that a wider band is licensed for AMS(R)S use, emissions susceptibility requirements of this document shall apply at the licensed band edges.

The AES antenna shall meet all of its requirements over the frequency bands of at least f_{RMN} to f_{RMX} and f_{TMN} to f_{TMX}.

2.2.3.1.1.5 Antenna Voltage Standing Wave Ratio

When measured at the transmit and receive RF port(s) of the antenna, the Voltage Standing Wave Ratio (VSWR) shall not exceed the value V_{SWR} declared by the manufacturer when correctly mated with the appropriate connector. The nominal characteristic impedance shall be 50 ohms.

2.2.3.1.1.6 Radiated Antenna Intermodulation Products

The following requirements apply to AES equipment capable of operating simultaneously on multiple radio frequency carriers within the frequency band f_{TMN} to f_{TMX}.

2.2.3.1.1.6.1 Radiated Antenna Intermodulation Products in the GNSS Band

When tested by transmitting two unmodulated carriers, the average power output produced by antenna-generated wideband intermodulation products in the frequency bands 1559-1605 MHz, 1164-1233 MHz, and 1260-1300 MHz shall not exceed –122 dBm when measured in a direction toward a likely location(s) of a GNSS antenna(s) on the same aircraft. For the purpose of this requirement, the intermodulation products shall be measured at the GNSS antenna output port. Both carriers shall be generated at the maximum permissible individual carrier power level in accordance with Section 2.2.3.1.2.1.2, and both carriers shall be on assignable carrier frequencies within the band f_{TMN} to f_{TMX}. Average power output shall be as defined in Section 1.7, above. Narrowband intermodulation products shall be limited to –125 dBm under the same conditions. For the purposes of this requirement, the GNSS antenna is taken to be a quarter-wave monopole antenna matched to its load and the isolation between the AES antenna and the GNSS antenna is taken to be 40 dB. Systems that declare a different antenna isolation in accordance with the provisions of Section 2.2.3.1.2.1.3 may adjust this requirement based on the declared antenna isolation, with more isolation resulting in an increase in the allowable intermodulation product level.

<u>Note</u>: *For the purposes of this requirement, "wideband" intermodulation is defined as occurring when the following inequality is satisfied:*

$$\sqrt{N_{ORDER}}\, f_M > 25{,}000 \text{ Hz}$$

where N_{ORDER} is the lowest order of two-tone intermodulation product falling in the band of interest and f_M is the system modulation rate defined in the technique-specific appendix.

For steered antennas, this specification shall apply for the worst-case beam direction within the declared sytem coverage.

2.2.3.1.1.6.2 Radiated Antenna Intermodulation in AMS(R)S Bands

When tested under the same conditions as in Section 2.2.3.1.1.6.1, the antenna subsystem shall not radiate harmful interference due to internally generated intermodulation products in a direction toward likely locations of antennas on the same aircraft serving other AMS(R)S systems. For the purpose of this requirement, harmful interference is defined as an interference power level that increases the effective noise temperature of the victim AMS(R)S system by more than 6%. In this condition, the other antenna is taken to be a quarter-wave monopole antenna matched to its load and the isolation between the AES antenna and the victim AMS(R)S antenna is taken to be 40 dB. Relaxation for increased isolation is permitted under the same conditions as in Section 2.2.3.1.1.6.1.

For steered antennas, this specification shall apply for the worst-case beam direction within the declared system coverage.

<u>Note</u>: *Although the preceding two paragraphs apply to specific bands because of the specific susceptibility of satellite navigation and communication downlinks to high level interference, manufacturers are cautioned that antenna intermodulation has*

the potential to adversely affect terrestrial and airborne CNS functions as well. Guidance on aeronautical spectrum planning is provided in DO-237.

2.2.3.1.1.7 Carrier-to-Multipath Discrimination

When measured over a representative ground plane, the difference in decibels between the minimum antenna gain measured at the minimum declared elevation angle, Θ_{MIN}, and the maximum antenna gain measured at the same angle below the horizon, shall be greater than the minimum carrier-to-multipath discrimination, C/M, required by the technique specific appendix.

2.2.3.1.1.8 Pattern Discrimination

When measured over a representative ground plane, the difference in decibels between the antenna pattern measured at any two potential satellite positions above the minimum elevation angle, Θ_{MIN}, and separated by the minimum separation angle, Θ_{SA}, shall be greater than the minimum pattern discrimination, D/U, required by the technique specific appendix.

Note: *Some systems, such as those with omindirectional antennas, may not have a pattern discrimination requirement.*

2.2.3.1.1.9 Steered Antenna Requirements

The following additional requirements apply to AES equipment with steered antennas.

2.2.3.1.1.9.1 Phase Discontinuity

For electronically-steered antennas, when switching between adjacent beams, the carrier phase at the antenna output shall not change by more than an amount $\Delta\phi$, as declared in the technique specific appendix.

2.2.3.1.1.9.2 Beam Switching Time

For electronically-steered antennas, when switching between adjacent beams, the beam switching shall be accomplished within a time, τ_{SW}, as declared in the technique specific appendix.

Note: *Both phase discontinuity and beam switching transients may affect the performance of the demodulator, which is heavily system-dependent. Factors such as data rate, modulation method, error correction and interleaving characteristics, as well as the demodulator design itself, can determine by how much the integrity of the received data is affected. In addition, different systems may have different overall requirements for the integrity/availability of the received/transmitted data.*

2.2.3.1.1.9.3 Steering Rate

The antenna shall meet all performance specifications over the coverage volume when subjected to angular rates of 6° per second in pitch, roll and azimuth axes.

2.2.3.1.1.9.4 Pattern Discrimination

A steered antenna shall meet the requirements of Section 2.2.3.1.1.8 when steered to any valid steering angle that can be used within the declared coverage volume. Straight and level flight may be assumed.

2.2.3.1.2 Transceiver Subsystem

2.2.3.1.2.1 Transmitter Function

2.2.3.1.2.1.1 Minimum Power Output

When measured at Point A of Figure 1-2, the transceiver function shall be capable of providing an on-channel power output of at least

$$P_{OUT} = L \times \frac{N_D P_D + N_V P_V}{G_{MIN}}$$ watts for multi-carrier systems,

$$P_{OUT} = L \times \frac{NP_S}{G_{MIN}}$$ watts for single carrier systems.

where:

P_{OUT}	=	HPA average output power in watts (not envelope peak power)
N	=	See Table 2-1
N_D	=	See Table 2-1
N_V	=	See Table 2-1
P_V	=	EIRP per voice carrier in watts necessary to provide the required RF link availability, as determined from the corresponding MASPS system link budget
P_D	=	EIRP per data carrier in watts necessary to provide the required RF link availability and channel bit error rate, as determined from the corresponding MASPs system link budget
P_S	=	maximum of P_V and P_D
L	=	Cable and connector loss between amplifier output (Point C) and antenna input (Point A)
G_{MIN}	=	minimum antenna gain over coverage volume.

All values used in this equation are numeric values, not decibels.

For the purposes of this requirement, on-channel power output shall be as defined for "burst power output" in Section 1.7 of this document.

2.2.3.1.2.1.2 Maximum Individual Carrier Output

When measured at Point A of Figure 1-2 the on-channel power output of a single-carrier transceiver shall be no more than P_{SC-SC} on any uplink frequency.

When measured at Point A of Figure 1-2, the on-channel power output of an AES capable of multi-carrier operation shall be no more than 2 dB greater than $\frac{\max(P_V, P_D)}{G_{MIN}}$ on any uplink frequency for any single carrier, in any mode of operation permitted by the NGSS system design.

The on-channel power output shall be defined as in the definition for "burst power output" in Section 1.7.

2.2.3.1.2.1.3 Maximum Total Transceiver Output

For multi-carrier systems, the total average power output of the transceiver when operating on assignable carrier frequencies with $N = N_V + N_D$ carriers active, each at the maximum applicable power, P_V and P_D, respectively, shall not exceed the values given in Table 2-2. The average power output shall be as defined in Section 1-7.

For single carrier systems, the total average power output of the transceiver when operating on an assignable frequency at the maximum applicable power defined in section 2.2.3.1.2.1.1 shall not exceed the values given in Table 2-2. The average power output shall be defined in Section 1.7

Table 2-2 Maximum Total Transceiver Output Level

Minimum Carrier Frequency (MHz)	Maximum Carrier Frequency (MHz)	Total Transmitter Power
1315	1525	-0.179 × (f – 1315) + 35.5 dBW
1525	1565	-2.65 × (f – 1525) – 2 dBW
1565	1585	-110.5 dBW
1585	1605	-109.0 dBW
1605	1614	7.67 × (f – 1605) – 109 dBW
1614	1626.5	4.64 × (f – 1614) – 40 dBW
1626.5	2000	0.036 × (f –1626.5) + 18 dBW
2000	above	31.5 dBW

Note 1: *This requirement is included to provide compatibility with the GNSS receiver susceptibility requirements. The linear segments were determined from Appendix B of the GNSS SARPS. The absolute power levels are given at the input to the AMSS/AMS(R)S antenna. The absolute power levels assume a minimum isolation between the GNSS antenna output to the GNSS receiver and the AMS(R)S antenna input of 40 dB. This value is consistent with the assumptions made in DO-210D and the Chapter 4 SARPs.*

The manufacturer may establish a system-specific requirement different from the assumed 40 dB. Any such a requirement shall be declared in the system-specific appendix. When an isolation value different from 40 dB is declared in the system-specific appendix, the allowable power output values in Table 2-2 may be changed by an equivalent amount.

Note 2: For example, if a system-specific isolation of 50 dB is declared, the values in Table 2-2 may be adjusted by (50 – 40) = +10 dB. Thus, the adjusted requirement of Table 2-2 in the 1614-1626.5 MHz band is:

$$4.64 \times (f - 1614) - 40 \text{ dB} + (50\text{-}40) \text{ dB}$$
$$4.64 \times (f - 1614) - 30 \text{ dB dB}$$

2.2.3.1.2.1.4 Transmitter Function Intermodulation Performance.

Transceivers capable of simultaneously transmitting on two or more carriers shall meet either the requirements of Section 2.2.3.1.2.1.4.1 or the requirements of Section 2.2.3.1.2.1.4.2 below.

2.2.3.1.2.1.4.1 Narrow-band (CW) Intermodulation Performance

This requirement applies only to AES equipment capable of operating simultaneously on multiple carriers.

When tested by transmitting two unmodulated carriers, the average power output produced by intermodulation products that do not fall within either the band $0.99675 f_{TMN}$ to $1.00325 f_{TMX}$ or the band $0.99675 f_{RMN}$ to $1.00325 f_{RMX}$ shall not exceed the values of Table 2-3. Both carriers shall be generated at the maximum permissible individual carrier power level in accordance with Section 2.2.3.1.2.1.2, or one-half of the maximum total output power of the transceiver, whichever is less. Both carriers shall be on assignable carrier frequencies within the band f_{TMN} to f_{TMX}. Average power output shall be as defined in Section 1.7, above. For transition regions, the terms "increasing" and "decreasing" are defined by a linear slope in decibels versus a linear frequency scale connecting the two endpoints of the designated range.

Table 2-3 Intermodulation Products for Unmodulated Transceiver Output

Min Freq (MHz)	Max Freq (MHz)	Two-tone Intermodulation (dBW)	Power Averaging Interval
0.01	1525	-120	1 frame or 1 second whichever is shorter (1f / 1s)
1525	1559	-127	1f / 1s
1559	1585	-115.5	2 ms
1585	1605	-118	20 ms
1605	1610.6	-105	20 ms
1610.6	1613.8	(see note)	1f / 1s plus 2000 second average HSN + IM
1613.8	1618.0	increasing to –72	1f/1s
1618.0	1656.5	-72	1f/1s
1656.5	1660.0	decreasing to –90	1f/1s
1660.0	1670.0	(see note)	1f/1s plus 2000 second average HSN+IM
1670.0	1735	increasing to –72	1f/1s
1735	2500	-72	1f/1s
2500	18,000	-72	1f/1s

Note: Within the band 1610.6-1613.8 MHz, see the requirements of Section 2.2.3.1.2.1.6.

When tested under the conditions established above, the average power output produced by intermodulation products that fall within the band $0.99675 f_{TMN}$ to $1.00325 f_{TMX}$ and the band $0.99675 f_{RMN}$ to $1.00325 f_{RMX}$ shall not exceed the values of Table 2-4.

Table 2-4 In-Band and Transition Intermodulation Requirements

Minimum Frequency (MHz)	Maximum Frequency (MHz)	Two-tone Intermodulation Product Level (dBW)	Power Averaging Interval
$0.99675 f_{TMN}$	f_{TMN}	increasing from the requirement of Table 2-2 to the in-band requirement, S_{IMT}	1 frame or 1 second whichever is shorter (1f / 1s)
f_{TMN}	f_{TMX}	S_{IMT}	1f/1s
f_{TMX}	$1.00325 f_{TMX}$	decreasing from the in-band requirement S_{IMT}, to the requirement of Table 2-2	1f/1s
$0.99675 f_{RMN}$	f_{RMN}	increasing from the requirement of Table 2-2 to the in-band requirement, S_{IMR}	1f / 1s
f_{RMN}	f_{RMX}	S_{IMR}	1f/1s
f_{RMX}	$1.00325 f_{RMX}$	decreasing from the in-band requirement S_{IMR}, to the requirement of Table 2-2	1f/1s

2.2.3.1.2.1.4.2 Modulated Intermodulation Performance

As an alternative to 2.2.3.1.2.1.4.1, the transceiver shall satisfy the requirements of Table 2-5 and Table 2-6 when transmitting two modulated carriers each of which is at the maximum single-carrier power permitted by 2.2.3.1.2.1.2 or one-half the maximum output power of the transceiver, whichever is less. Both carriers shall be on assignable carrier frequencies within the band f_{TMN} to f_{TMX}. The emission that does not fall within the band 0.99675 f_{TMN} to 1.00325 f_{TMX} or the band 0.99675 f_{RMN} to 1.00325 f_{RMX} shall not exceed the values of Table 2-5. For transition regions, the terms "increasing" and "decreasing" are defined by a linear slope in decibels versus a linear frequency scale connecting the two endpoints of the designated range.

The emission that falls within the band 0.99675 f_{TMN} to 1.00325 f_{TMX} or the band 0.99675 f_{RMN} to 1.00325 f_{RMX} shall not exceed the values of Table 2-6.

For measured IM products generated by modulated signals, having bandwidth less than 100kHz, and falling within the frequency range 1565 MHz to 1605 MHz, the requirements of Table 2-5 shall be modified by Figure 2-2 or 2-3 as appropriate."

2.2.3.1.2.1.5 Transmitter Function Harmonics, Discrete Spurious and Noise Density

When tested with a single modulated signal at the maximum permissible single carrier level specified by Section 2.2.3.1.2.1.2, the average power output of the composite harmonic, discrete spurious and noise density, including phase noise, at the transceiver output shall not exceed the values in Table 2-5, except for frequencies falling within the band band $0.99675 f_{TMN}$ to $1.00325 f_{TMX}$ and the band $0.99675 f_{RMN}$ to $1.00325 f_{RMX}$. For transition regions, the terms "increasing" and "decreasing" are defined by a linear slope in decibels versus a linear frequency scale connecting the two endpoints of the designated range.

For equipment capable of simultaneously transmitting on multiple different carrier frequencies, the requirements for composite harmonics, spurious and noise shall be reduced by the quantity 10log10(N) + 3 dB, when N is defined in Section 2.2.3.1.2.1.1 as the maximum number of independent carriers supported by the AES. This more stringent requirement does not apply if the multi-carrier AES is capable of allocating its entire power capability to a single carrier frequency.

<u>Note 1</u>: *For example, in a system capable of 4 independent carriers, each with a maximum power of P_D, the HSN in the band 1618-1650 MHz must meet a requirement of:*

$$-55-(10\log_{10}(4)+3)=-64 \text{ dBW/100 kHz}.$$

If the maximum power in each of the four equal-level carriers is limited to $P_D/4$, the HSN must meet –55 dBW/100 kHz.

Under the same transmitter conditions, within the band $0.99675 f_{TMN}$ to $1.00325 f_{TMX}$ and the band $0.99675 f_{RMN}$ to $1.00325 f_{RMX}$, the average power output of the composite harmonic, discrete spurious and noise density, including phase noise, at the transceiver output shall not exceed the values of Table 2-6.

In addition to the requirements of Table 2-5 and Table 2-6, individual discrete spurious signals falling in the bands 1164-1233 MHz, 1260-1300 MHz, and 1559-1585 MHz and having spectral bandwidth less than 100 kHz shall not exceed the average power levels of the applicable table adjusted for spurious bandwidth in accordance with Figure 2-2.

Note 2: *Figure 2-2 is taken from the Table B.3.7-3 of the GNSS SARPs, adjusted for a nominal interference bandwidth of 100 kHz.*

In addition to the requirements of Table 2-5 and Table 2-6, individual discrete spurious signals falling in the band 1585-1605 MHz and having spectral bandwidth less than 100 kHz shall not exceed the average power level of the applicable table adjusted for the spurious bandwidth in accordance with Figure 2-3.

Table 2-5a Harmonic, Spurious and Noise Requirements for Protection of GPS and GLONASS

Frequency (MHz)	Measurement Bandwidth (kHz)	Single-Carrier Composite HSN Requirement (dBW)	Power Averaging Interval
0.01-1525	3.0	-120.0	1 frame or 1 second whichever is shorter (1f / 1s)
1525-1559	3.0	-143	1f / 1s
1559-1585	1000.0	-115.5	2 ms
1585-1605	1000.0	-118	20 ms
1605-1610.6	1000.0	-118 increasing to -80 (Note 1)	20 ms
1610.6-1613.8	10	-100 (Note 2)	2000 second combined HSN+IM
1613.8-1618	100	-90 increasing to -55	1f / 1s
1618-1650	100	-55	1f / 1s
1650-1660	1000	-45 decreasing to -88	1f / 1s
1660-1670	1000	-88 decreasing to -98	2000 second combined HSN+IM
1670-1735	3000	-88	1f / 1s
1735-12000	3000	Decreasing to -98	1f / 1s
12000-18000	3000	-98	1f / 1s

Table 2-6b Harmonic, Spurious and Noise Requirements for Protection of only GPS

Frequency (MHz)	Measurement Bandwidth (kHz)	Single-Carrier Composite HSN Requirement (dBW)	Power Averaging Interval
0.01-1525	3.0	-120.0	1 frame or 1 second whichever is shorter (1f / 1s)
1525-1559	3.0	-143	1f / 1s
1559-1585	1000.0	-115.5	2 ms
1585-1592.9525	1000.0	-115.5 increasing to -81.5	20 ms
1592.9525-1605	1000.0	-81.5	20 ms
1605-1610.6	1000.0	-81.5 increasing to -80 (Note 1)	20 ms
1610.6-1613.8	10	-100 (Note 2)	2000 second combined HSN+IM
1613.8-1618	100	-90 increasing to -55	1f / 1s
1618-1650	100	-55	1f / 1s
1650-1660	1000	-45 decreasing to -88	1f / 1s
1660-1670	1000	-88 decreasing to -98	2000 second combined HSN+IM
1670-1735	3000	-88	1f / 1s
1735-12000	3000	Decreasing to -98	1f / 1s
12000-18000	3000	-98	1f / 1s

Notes:

1. *At 1610.6 MHz, the transceiver performance is as specified for the 1610.6-1613.8 MHz band. The slope between –100 dBW/10 kHz and the 1610.6-1613.8 MHz band is linear in decibels.*

2. *See either Section 2.2.3.1.2.1.6.1 or Section 2.2.3.1.2.1.6.2.*

Table 2-7 In-Band and Transition Harmonic, Spurious and Noise Requirements

Minimum Frequency (MHz)	Maximum Frequency (MHz)	Harmonic, Spurious and Noise (dBW)	Power Averaging Interval
$0.99675\,f_{TMN}$	f_{TMN}	increasing from the requirement of Table 2-5 to the in-band requirement, S_{HSNT}	1 frame or 1 second whichever is shorter (1f / 1s)
f_{TMN}	f_{TMX}	S_{HSNT}	1f/1s
f_{TMX}	$1.00325\,f_{TMX}$	decreasing from the in-band requirement , S_{HSNT} , to the requirement of Table 2-5	1f/1s
$0.99675\,f_{RMN}$	f_{RMN}	increasing from the requirement of Table 2-5 to the in-band requirement, S_{HSNR}	1f / 1s
f_{RMN}	f_{RMX}	S_{HSNR}	1f/1s
f_{RMX}	$1.00325\,f_{RMX}$	decreasing from the in-band requirement , S_{HSNR}, to the requirement of Table 2-5	1f/1s

Notes:

1. *Figure 2-3 is taken from the Table B.3.7-3 of the GNSS SARPs, adjusted for a nominal interference bandwidth of 100 kHz.*

2. *In the preceding requirements, the adjustment to the requirements Figure 2-2 or Figure 2-3 is made by adding the value obtained from the appropriate figure for the measured interference bandwidth to the value obtained from Table 2-5 or Table 2-6. For example, if a discrete spurious signal with bandwidth 400 Hz is measured at a center frequency of 1587 MHz, the appropriate specification level is:*

3. *Requirement = Value from HSN Table 2-5 + value from Figure 2-3 at appropriate bandwidth*
   = -121 dBW + value at Point "o" from Figure 2-3
   = -121 dBW + (-0.7) dB = -121.7 dBW

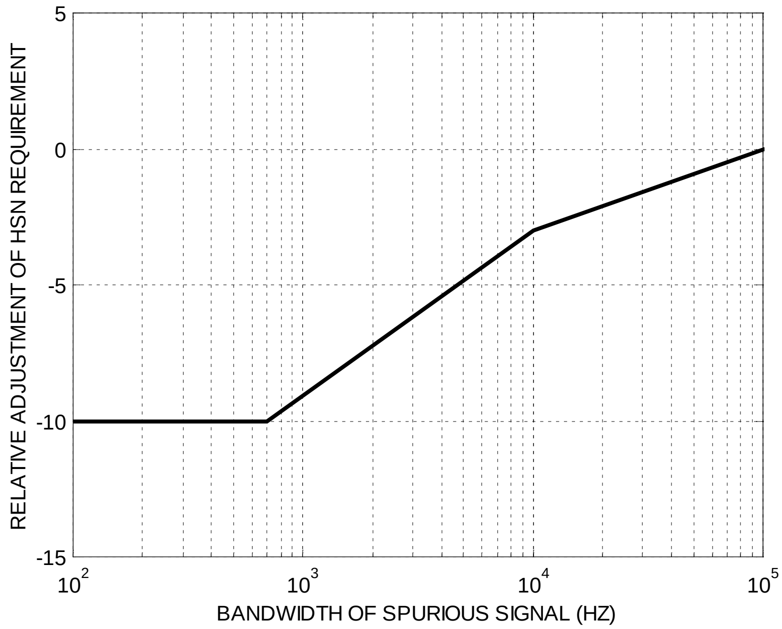


Figure 2-2 Discrete Spurious Adjustment in 1565-1585 MHz Band

2.2.3.1.2.1.6 Protection of Radio Astronomy

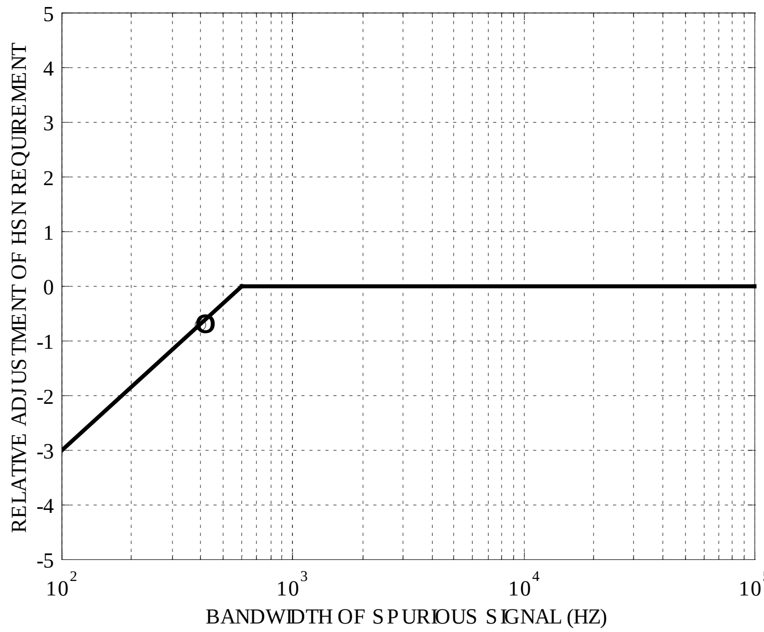
2.2.3.1.2.1.6.1 AES Transmitting on Frequencies Outside of the 1610-1626.5 MHz Band

An AES that transmits on any assignable frequency except those in the 1610-1626.5 MHz band shall meet the requirements of Table 2-5.

1. When operating with the maximum combination of channels permitted by the equipment design.

2. When averaged over 2000 seconds of normal operation, including any frequency switching and power control due to normal satellite motion during that interval, and typical call duration and voice or data activity statistics.

When operating under the same conditions, the average power spectral density due to the composite of HSN and intermodulation emissions in the band 1660-1670 MHz shall meet the requirements of Table 2-5.



<u>Figure 2-3</u> Discrete Spurious Adjustment in the 1585-1605 MHz Band

<u>Note</u>: *The required composite emissions levels stated values in the 1610.6-1613.8 MHz and 1660-1670 MHz bands are sufficient to protect Radio Astronomy to the levels of ITU-R RA.769-1 during normal air route operations without additional lateral protection zones. If the system design precludes operations within a specific distance of active RA sites, the allowable levels may increase by* $20\log_{10}(\rho_{RA}/3)$ *decibels, where* ρ_{RA} *is the radius of the RA protection zone in kilometers. For example, equipment designated for operation with a 30 km protection zone will have the values increased by 20log10(30/3) = 20 dB. Therefore, the requirements on such a system will be –80 dBW/10 kHz in the 1610.6-1613.8 MHz band and –68 dBW/MHz decreasing to –78 dBW/MHz in the 1660-1670 MHz band.*

The manufacturer shall declare the radius of any exclusion zone necessary to protect Radio Astronomy Services in the technique-specific appendix.

2.2.3.1.2.1.6.2 AES Transmitting on Frequencies Within the 1610-1626.5 MHz Band

AES equipment that transmits on assignable frequencies within the 1610-1626.5 MHz band shall comply with the requirements of FCC Rule 47CFR25.213(a). Any emissions levels negotiated under the provisions of this rule shall be declared in the system-specific appendix and shall be interpreted as a minimum requirement under this MOPS. Emissions levels should be measured under the conditions identified in items 1 and 2 of Section 2.2.3.1.2.1.6.1.

When operating under the same conditions identified in Section 2.2.3.1.2.1.6.1, the average power spectral density due to the composite of HSN and intermodulation emissions in the band 1660-1670 MHz shall meet the requirements of Table 2-5.

2.2.3.1.2.1.7 Carrier Off Level

The burst output power measured on any valid carrier frequency when no carriers are transmitting shall be less than P_{NC}.

2.2.3.1.2.1.8 Power Control

The transceiver shall be capable of controlling the power level of its emissions on any individual carrier over a range of at least P_{RNG}, with nominal steps of P_{STEP} or less.

2.2.3.1.2.1.9 On-Channel Output Spectrum

The output spectrum of a single modulated carrier shall satisfy the in-band requirements of the specific satellite subnetwork, as given in the appropriate normative portion of the techique-specific appendix.

2.2.3.1.2.1.10 Transmitter Operation in Moving Aircraft

Any AES capable of AMS(R)S voice and/or AMS(R)S data communications shall comply with the satellite network interface requirement specified in the appropriate normative portion of the system-specific appendix of this document when installed in aircraft operating at ground speeds of up 800 knots (1480 km/hr).

It is recommended that all AES equipment comply with the satellite network interface requirements of the appropriate normative portion of the system-specific appendix of this document when installed in aircraft operating at ground speeds of up to 1500 kts (2800 km/hr).

<u>Note</u>: *For the purposes of verifying these requirements and recommendations, it may be advantageous to design an interface to allow external adjustment of the frequency reference used internal to the AES.*

2.2.3.1.2.2 Receiver Function

For the purposes of this section, the reference point for all signal level measurements is the input port to the AES, Point C in Figure 1-2. The contractor shall declare the maximum allowable cable loss, L_{MAX}.

2.2.3.1.2.2.1 Receiver Sensitivity

2.2.3.1.2.2.1.1 Data

When operated with a single active data channel, an AES capable of packet data service shall output user data at average rate of of R_D bps or higher with input signal level of S_D from an appropriately configured satellite system test set. When transferring packets of 128 octets of user data, the receiver data output shall exhibit a residual packet error rate of no more than 1×10^{-6}.

<u>Note</u>: *The receiver sensitivity specified here is a bench-test requirement, which takes into account the satellite-subnetwork error correction and/or retransmission*

properties. When coupled with the antenna performance specified earlier, and when compensated for the effective sky temperature of typical operations and any increase in the effective noise temperature due to antenna effects, this sensitivity is consistent with the Figure of Merit G/T requirements of the MASPS and DO-215A.

2.2.3.1.2.2.1.2 Voice

The vocoder shall satisfy its performance requirements when provided with an input signal of S_V from an appropriately configured satellite system test set.

Note: *The receiver sensitivity specified here is a bench-test requirement. When coupled with the antenna performance specified earlier, and when compensated for the effective sky temperature of typical operations and any increase in the effective noise temperature due to antenna effects, this sensitivity is consistent with the Figure of Merit G/T requirements of the MASPS and DO-215A.*

2.2.3.1.2.2.2 Receiver Bandwidth

The receiver shall meet its requirements for an input carrier frequency anywhere in the range of f_{RMN} to f_{RMX}.

2.2.3.1.2.2.3 Rejection of Signals Outside the NGSS Receive Band

The receiver shall acquire and track a satellite downlink signal with a minimum signal level given by the minimum of S_V and S_D in the presence of a CW interference signal of +3 dBm in the frequency range 470 to 18,000 MHz, excluding the band $0.95 f_{RMN}$ to $1.05 f_{RMX}$.

Within the excluded band, the level of the CW interference signal shall be reduced linearly from +3 dBm at $0.95 f_{RMN}$ to –72 dBm at $0.99938 f_{RMN}$ and from +3 dBm at $1.05 f_{RMX}$ to –72 dBm at $1.00062 f_{RMX}$.

2.2.3.1.2.2.4 Rejection of Carrier Signals Generated by Other AMS(R)S Equipment

In addition to the general CW interference requirements described in Section 2.2.3.1.2.2.3, the receiver shall acquire and track a satellite downlink signal with a minimum signal level given by the minimum of S_V and S_D in the presence of a CW interfering signal of the following levels and carrier frequencies. This requirement need not be met when the specified CW interfering signal is within +/-0.325% the declared operational band of the receiver.

Carrier Frequency Band	CW Interference Level
1610-1631.5 MHz	+3 dBm
1631.5-1660.5 MHz	+7 dBm

Note: *These levels assume an antenna-port-to-antenna-port isolation of –40 dB between AMS(R)S equipment on the same aircraft, and includes the effects of DO-210D compliant avionics on the same aircraft.*

2.2.3.1.2.2.5 Receiver Operation in Moving Aircraft

Any AES capable of AMS(R)S safety voice and/or data communications shall comply with the satellite network interface requirement specified in the appropriate normative portion of the system-specific appendix when installed in aircraft operating at ground speeds of up to 800 knots (1480 km/hr).

It is recommended that the AES comply with the satellite network interface requirements of the appropriate normative portion of the system-specific appendix when installed in aircraft operating at ground speeds of up to 1500 kts (2780 km/hr).

2.2.3.1.2.2.6 Receiver Susceptibility

The receiver shall properly acquire and track the required signals and shall output data at the specified rate when subjected to wideband interference noise of level S_{UW} across the designated receive band.

The receiver shall properly acquire and track the required signals and shall output data at the specified rate when subjected to CW interference of level S_{UN} on any assignable channel within the designated receive band.

For the purposes of this requirement, narrowband interference shall be defined as interference with a bandwidth of less than the modulation rate, f_M, of the NGSS under consideration. Wideband interference shall be defined as interference with a bandwidth greater than f_M.

2.2.3.1.3 Required Aircraft Interfaces

2.2.3.1.3.1 External Position

Although not required as part of this minimum standard, it is recommended that the AES utilize external geolocation methods, such as GPS, GLONASS, FMS or Loran C to provide an accurate position reference, and thereby minimize the subnetwork-specific geolocation requirements.

2.2.3.1.3.2 External Time Reference

Although not required as part of this minimum standard, it is recommended that the AES be capable of accepting an external time reference, such as GPS, to provide an accurate, consistent source of time information.

2.2.3.2 User Link Modulation and Signal in Space

The AES shall generate and accept a user link signal-in-space with the modulation and signal format characteristics set forth in the applicable normative appendix.

Note: *The modulation and signal in space characteristics of NGSS are completely determined by the underlying telecommunications infrastructure. Since that infrastructure is assumed to provide at least regional and preferrably near-world-wide, coverage, and since there are potentially several different systems which* *may provide AMSS, there are no AMSS- or AMS(R)S-specific signal-in-space or modulation requirements. Detailed requirements for operation within the satellite subnetwork are identified in system-specific* appendices. *These* appendices, *in turn, reference commercial documentation maintained by the various satellite and service providers. The commercial documents may be obtained from the appropriate source for use in support of this document, subject to certain distribution restrictions. Except as necessary to specifically identify safety-related performance, system-specific details are not reproduced within this MOPS or its* appendices *s.*

2.2.3.3 Priority, Precedence and Preemption

The requirements of this section shall apply to all communications channels available for assignment to users, specifically excluding channels used for internal NGSS signaling and system management functions.

All AES equipment used for AMS(R)S services shall provide at least three levels of priority for safety communications, all of which are higher than the priority provided for any non-safety communications, as illustrated in Table 2-7.

When the AES supports both voice and data communications, voice communications shall have priority over data within any given application or priority level.

Table 2-8 Minimum AMS(R)S Priority Structure

Application (Voice and/or Data)	Priority Identifier
Distress, Urgency	4 (high)
Direction Finding, Flight Safety	3
Other Safety & Regularity of Flight	2
All other non-safety communications, including public correspondence	1 (low)

Notes:

1. *The numeric Priority Identifier scheme indicated in Table 2-7 is a logical scheme only and is intended for the purpose of unambiguously identifying test conditions within this document. There is no requirement that the actual interface(s) to pilots, to the satellites, or to the terrestrial users use this method for identifying priorities. Specific NGSS implementations may incorporate more than the minimum four priority levels specified above, and may utilize various specific priority/precedence numbering schemes for the levels.*

2. *Schemes identified in other RTCA and ICAO standards include 1 (highest) through 4 (lowest) and 15 (highest) through 0 (lowest), etc. In particular, the priority labeling convention listed in Table 2-7 is different from that used to identify circuit mode priorities in Chapter 4 SARPs and DO-210D. The convention of using a larger numeric value to indicate a higher priority is consistent with that used for ATN, Chapter 4 SARPs, and DO-210D packet mode data communications.*

2.2.3.3.1 Packet Data

The AES shall provide for prioritization of data packets input at the AES data port(s). The AES shall support the system-level prioritization techniques described in the appropriate normative portion of the system-specific appendix.

This document recognizes that messages may be subject to segmentation in accordance with technique specific internal protocols. Transmission preemption, if necessary, shall be effected by changing the order of data transmission such that the data units of the internal protocols comprising the higher-priority message are transmitted before corresponding lower-priority data units. Any reordering necessary to comply with this requirement shall take effect immediately upon completion of currently active data unit transmission. Preemption of lower-priority messages, if necessary, shall be effected by any means necessary to preserve the higher-priority message(s).

This document recognizes that a given network may choose to provide packet-mode data services over circuit-mode connections. If packet-mode data services are implemented over circuit mode connections, the requirements of Section 2.2.3.3.2 shall apply to the circuit mode connections themselves. Within such a circuit mode connection, packet priority, precedence and preemption shall be in accordance with Table 2-7.

If an AES does not support Priority Level 1 (low) non-safety communications, a request for Priority Level 1 (low) packet service shall be ignored.

2.2.3.3.2 Circuit Mode Communications

For circuit mode communications, the AES shall establish the priority structure shown in Table 2-7. When providing AMS(R)S services, the AES shall always have sufficient communications resources to detect a request to establish an incoming call, except in the rare case when all AES resources are consumed by distress/urgency communications.

Signaling and system management actions for circuit-mode calls in either the air-originated or ground-originated direction shall be queued and processed within the AES in an order corresponding to each call's Circuit-mode Priority per Table 2-7, with the higher Circuit-mode Priority numbers having the higher precedence. The lowest priority in-progress shall be interrupted immediately if necessary to make AES resources (e.g., transmitter power, channel unit, vocoder) available for a higher-priority call of either air or ground origination. If a new ground-originated call has the same or lower priority as the lowest-priority call in progress, and if sufficient AES resources are not available to support the new circuit, then the AES shall indicate "busy" to the originating party.

If an AES does not support Priority Level 1 (low) non-safety communications, a request for Priority Level 1 service shall be refused.

When circuit-mode preemption is necessary, the AES channel resources shall be available within 4 seconds of the user request.

2.2.3.4 Satellite Subnetwork Data Protocol (Satellite Layer 2)

The AES shall support the satellite subnetwork data protocols specified for the individual satellite network, as detailed in the appropriate normative appendix. Implementation of the Satellite Layer 2 Protocols shall include any actions and protocols necessary to acquire the satellite, maintain a connection over an extended period of time, transfer digital data and digitized voice information, and participate in the overall system management functions of the satellite subnetwork.

The AES shall register itself with the satellite system so that it is enabled to receive or transmit data or voice, as appropriate, on the subnetwork. This registration may occur either automatically or by manual command.

Notes:

1. *Satellite Layer 2 is a generic term for the internal protocol(s) used by the NGSS. For information on the context see the MASPS or RTCA DO-215A, Change 1. This document uses the term Satellite Layer 2 to avoid confusion with the Satellite Subnetwork Dependent Protocols discussed in Section 2.2.3.6.3.*

2. *This registration action is referred to as "system log on", and an AES which has completed this action is referred to as being in a "logged-on" state.*

2.2.3.5 Voice Protocol

Vocoded voice information shall be transmitted and processed in accordance with the system-specific protocols identified in the appropriate normative portion of the system-specific appendix. Any voice services supported by the avionics shall be certified by the satellite network operator as compliant with the voice protocol specified in the technique-specific appendix or underlying technique-specific documents.

Note: As evidenced by this requirement, this MOPS assumes digital transmission of voice, as explained in Section 1.5.6.

2.2.3.5.1 Vocoder Interoperability With Satellite Subnetwork

The vocoder algorithm implemented in the AES shall exhibit 100% interoperability with the standard vocoder algorithm used by the underlying satellite telecommunications architecture. In the event the vocoder algorithm is not identical to the algorithm used in the satellite subnetwork, the manufacturer shall be responsible for demonstrating the required 100% interoperability to the satisfaction of the satellite network operator, and shall be certified as achieving this compliance by the satellite network operator.

2.2.3.5.2 Vocoder Performance in an Aeronautical Environment

Voice services intended for safety applications shall provide overall intelligibility performance that is statistically equivalent to or better than the 9.6 kbps vocoder algorithms defined in the ICAO Standards and Recommended Practices found in Annex 10, Volume III, Part I, Chapter 4, when operating with a system-specific test signal level of S_V. This requirement shall be satisfied when tested in audio noise environments representative of aeronautical cockpit applications in a variety of airframes, including wide-body air-transport cockpit background noise, helicopter cockpit background noise, prop-jet cockpit background noise, ATC Control Center background noise. It is highly desirable that performance also be verified in the turbo-prop cockpit acoustic environment.

2.2.3.6 User Data Interfaces

Packet-mode data services shall provide an Aeronautical Telecommunications Network- (ATN-) compliant protocol, or the Data-2 protocol, or both, as defined in the following sections.

ATN-compliant protocols implement a subnetwork interface in which the AES contains the physical layer, link-layer and network layer functionality, where the layers are defined according to the Open System Interconnect terminology.

One particular implementation that is known to be ATN-compliant is an ISO-8208 compliant interface. If the AES implements an ISO-8208 compliant interface, that interface shall comply with the requirements of Appendix B of this document. Implementation of this interface will assure maximum compatibility with AMSS avionics designed and qualified in accordance with DO-210D.

Data-2 provides a link-level service, which has been used to support ACARS in other air-to-ground subnetworks. In Data-2 implementations, a minimum AES provides only the physical and link layer functionality. Management of priority and preemption are implemented in higher level entities. If these higher level entities support the necessary priority and ISO 8473 convergence functions, Data 2 may also be useful for ATN communications.

Notes:

1. *It is highly desirable that the minimum data services include support for both ATN and Data-2 protocols as defined in DO-210D.*

2. *It is not the intent of this minimum standard to preclude the inclusion of additional satellite subnetwork access protocols, if desired by the avionics manufacturer*

2.2.3.6.1 ATN-Compliant Protocol

The Satellite Subnetwork Layer (SSNL) in the AES shall offer connection-oriented packet data service to the Higher Layer Entities (HLEs) by facilitating satellite subnetwork switched virtual circuits (SVCs) with its peer entity in the subnetwork GES function. It also shall offer methods to convert addressing from the HLE to the SSNL. Figure 2-4 illustrates the ISO-style protocol stacks associated with ATN-compliant operations.

Notes:

1. *The terminology used in the high-level description of and requirements for an ATN-compliant protocol is based on ISO-8208. Use of this terminology should not be interpreted to require an ISO-8208 compliant interface as a minimum standard.*

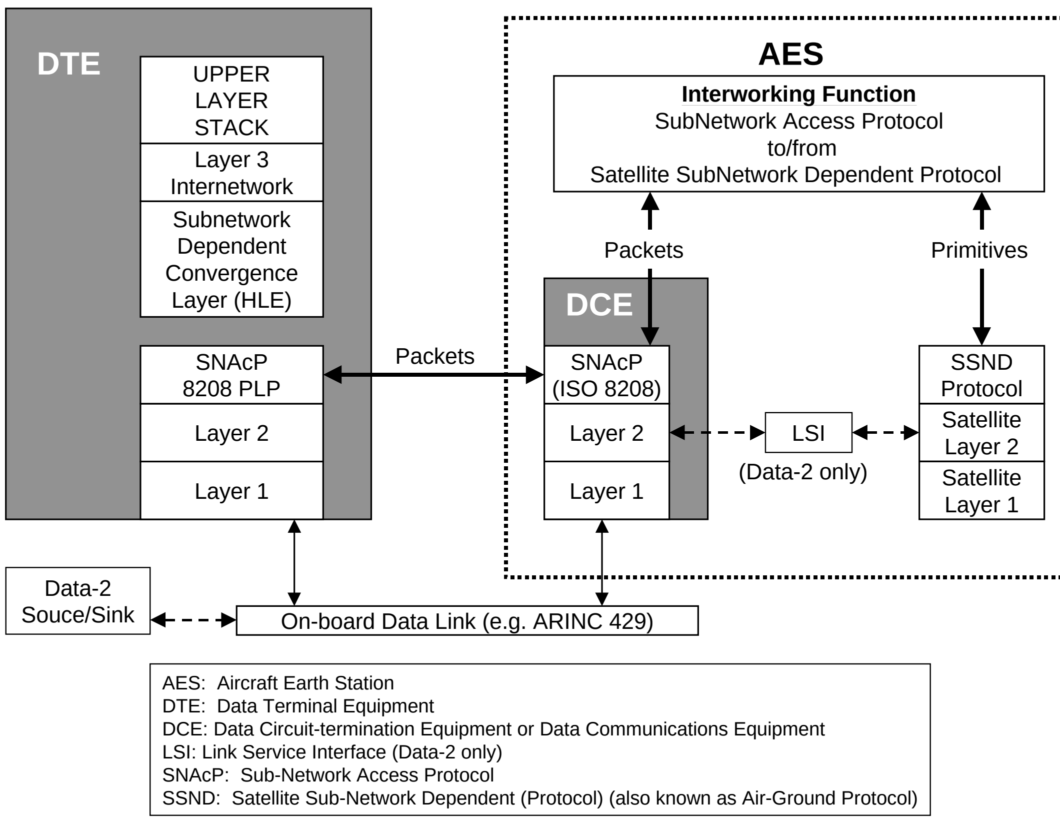
2. *Figure 2-4 is intended to be representative of a typical implementation, not normative. In particular, certain applications within the AES may function as a "Higher Level Entity" in their use of the communications resource. The existence of such internal applications is not shown in Figure 2-4, but this omission should not be*

construed as a prohibition against such internal applications. This document neither encourages nor prohibits such implementations.

The SSNL in the AES shall support the following three main functions:

a. The Satellite Subnetwork Dependent (SSND) sublayer
b. The Satellite Subnetwork Access (SSNAc) sublayer
c. The Satellite Subnetwork InterWorking Function (IWF)

The SSND sublayer shall perform the SSND protocol between the AES and a GES as defined in the appropriate normative portion of the system-specific appendix of this document by exchanging SubNetwork Protocol Data Units (SNPDUs). The SubNetwork Protocol and definition of the SNPDUs are completely determined by the underlying communications infrastructure, and are defined in either the appropriate normative appendix or the documents referenced by such an appendix.



<u>Figure 2-4</u> Satellite Subnetwork Architecture (Airborne Side)

The SSNAc sublayer in the AES shall perform the ATN-compliant protocol between the AES and the connected airborne HLE (DTE). The IWF shall provide the protocol conversion functions and the flow control operation required between the SSND and SSNAc protocols.

<u>Notes</u>:

1. *The role of the ATN is to define an environment within which reliable end-to-end data transfer may take place, spanning the envisioned airborne, air/ground, and*

ground-based data subnetworks, including the satellite subnetwork, while providing interoperability among those networks. The critical emphasis is on end-system data transfer interoperability. In the ATN environment, the Satellite Subnetwork Layer must support the transparent transfer of Network Protocol Data Units between adjacent interworking entities (or HLEs as seen by the satellite subnetwork). This also implies the transparent transfer of global addresses (or Network Service Access Points (NSAPs) and of quality of service information (including network priority) as well as of user data.

2. *In Data-3 communications, HLEs communicate with the SSND sublayer by means of a DTE/Data Circuit-terminating (or Communication) Equipment (DCE) interface, as indicated in Figure 2-4. The DTE contains the DTE portion of SSNAc functions. One or more DTE/DCE interfaces are provided as logical entities within the AES. Each DTE/DCE interface is configured to connect to not more than one DTE. The AES contains and implements the DCE side of the interface.The satellite subnetwork acts as a relay between the HLE and its peer(s) on the ground. The need to send user information to, or receive user information from, the ground is not determined in any way by the AES but by the HLEs.*

3. *The HLE (in addition to the incorporation of the SSNAc function) will also support additional functions. As a minimum, the DTE incorporates an internetwork function and may also incorporate transport, session, presentation and application functions. In some AES implementations, certain HLEs may be contained within the AES software itself, but this configuration is not illustrated in Figure 2-4.*

2.2.3.6.1.1 Join and Leave Requirements

An AES that provides ATN-compliant packet-mode data service shall provide Join and Leave event information to the aircraft routing function to indicate that the air/ground data link is either available or not available, respectively. The Join/Leave information shall include sufficient information for the routing function to determine the address(es) of the attached terrestrial DTE(s).

2.2.3.6.1.2 ATN-Compliant Mapping for Priority, Precedence and Preemption

The target and selected values of the priority of data on an ATN-compliant interface shall be mapped to the equivalent values at the opposite end of the satellite subnetwork.

2.2.3.6.2 Data-2

Data-2 is intended as a legacy interface.

An AES offering packet-mode Data-2 service shall include a Link Service Interface that provides direct access to the highest level of the Satellite Layer 2 Protocol, so that bits may be sent in a first-in-first-out manner over the subnetwork. For AES implementations that provide both ATN-compliant and Data-2 interfaces, it is permissible for this Link Service Interface to utilize portions of the SSNDP, if desired.

Note: *One potential implementation is shown in Figure 2-4. The Data-2 depiction in Figure 2-4 is intended to be informative only.*

In Data 2 operations, Link Service Data Units (LSDUs) are injected or collected at the Link Service Interface in the AES. In order to ensure the forward compatibility of the Data-2 architecture with an ATN-compliant subnetwork architecture, the AES shall add a two-octet header to the external user's message to form an LSDU before transmission, as shown in Figure 2-5. The user's message may consist of binary data and may contain up to L_{MSG} octets. The two-octet dedicated header shall be set to the hexadecimal value FFFF. Unless otherwise established by the Link Service Interface user, a packet mode priority equivalent to Flight Regularity Communications shall be used for transmission of Data-2 LSDUs.

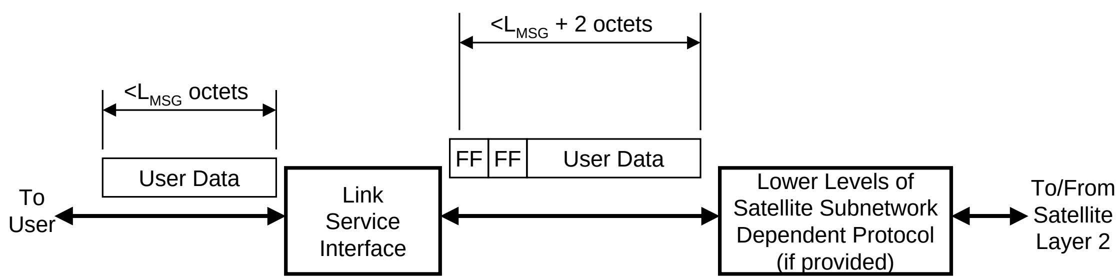


Figure 2-5 Adjustment of Higher Level Entity User Data for Data 2 Transmissions

While the AES is in a logged on state, all LSDUs passed to the Link Service Interface shall be transmitted to the GES. If the AES is not in the logged on state, any LSDU passed to the AES shall be discarded. Conversely, while the AES is logged on, any messages received from the GES shall be forwarded to the Link Service Interface regardless of the availability of the destination avionics equipment.

Notes:

1. *On the ground, a separate Switched Virtual Circuit (SVC) may be established for each AES between the GES and a predefined SubNetwork Point of Attachment (SNPA) DTE using X.25/X.75 protocol. The terrestrial SVC is established by the GES when an AES is logged onto the GES and is cleared when the AES is logged off of the GES.*

2. *When packet-mode operations are conducted using a Data-2 implementation, priority, precedence and preemption are managed by a higher-layer entity.*

2.2.3.6.3 Satellite Subnetwork Requirements

2.2.3.6.3.1 Satellite Subnetwork Dependent Protocol Requirements

The combination of the Satellite Subnetwork Dependent Protocol and the Satellite Layer 2 protocol is expected to provide a reliable link service to assist the overall AMSS air-to-ground subnetwork in delivering high integrity data. The Satellite Subnetwork Dependent Protocol (SSNDP) shall provide the additional error control mechansims, if any, necessary to assure a residual packet error rate, including misdirected packets, of 1 x 10^{-6} or less for a standard 128-octet message.

The SSNDP shall operate in accordance with the requirements referenced in the appropriate appendix.

The SSNDP may include a separate Air-Ground Protocol sublayer (AGP) between peer entities in the AES and GES. When the Air-Ground Protocol sublayer is included, it shall be defined in the technique-specific appendix, and the AES shall comply with the defined protocol.

2.2.3.6.3.2 ATN-compliant Requirements

If an ATN-compliant SNAcP is provided, the SSNDP shall provide ATN-compliant subnetwork services to the HLE. ATN compliance is achieved by satisfying the following requirements:

1. The SSNDP shall be byte and code independent

2. The SSNDP shall maintain the sequence and order of data (i.e. data submitted to the SSNDP for transmission shall arrive at the destination peer in the same order it was transmitted)

3. The SSNDP shall inform its interworking function whenever its connectivity with the satellite network changes

2.2.3.6.3.3 Data 2 Requirements

To the extent that the SSNDP is utilized for Data 2 transmissions, the following requirements shall be met:

1. The SSNDP shall be code and byte independent

2. The SSNDP shall maintain the sequence and order of data

3. The SSNDP shall inform the associated DTE when its connectivity with the satellite network changes

2.2.3.6.4 External Physical and Data Link Layer Requirements

At the physical and data link layer of the HLE/AES connection:

1. the interface shall be "bit-oriented" (i.e., there shall be no restrictions on the sequence, order or pattern of the bits transferred within a packet between the HLE and the AES);

2. the interface shall support the transfer of variable length network layer packets; and

3. the data link layer shall provide an undetected bit error rate consistent with the satellite subsystem performance requirements, reference RTCA DO-215A, Section 3.2.1.1.2.

2.2.3.6.5 Avionics Subnetwork Interface Requirements for ISO-8208 Service

All AES equipment that supports an ISO-8208-compliant (Data-3) packet-mode service shall have the Packet Layer Protocol (PLP) interface specified in detail in the ISO-8208 standard, as modified by Appendix B of this document.

The correspondence between ISO-8208 primitives Appendix B and SSNDP protocol data units, if any, shall be as defined in the relevant technique-specific appendix. There is no required mapping of ISO-8208 primitives to technique dependent Satellite Subnetwork Protocol Data Units. The use of the underlying satellite communications system is unspecified, providing that the DCE/DTE interface actions act and respond appropriately as defined in ISO-8208 as modified by Appendix B.

The operation of the AES as specified in this standard assumes that the HLE operates in accordance with Section 1.5.5.

2.2.3.6.6 Alternative ATN-compliant Subnetwork Access Protocols

Any manufacturer wishing to implement an ATN-compliant SNAcP that differs from the ISO-8208 implementaiton specified in Appendix B to this MOPS shall provide the detailed protocol implementation and associated verification procedures in the technique-specific appendix. The level of detail included in the SNAcP definition shall be equivalent to or better than the detail provided in Appendix B.

2.2.3.7 Circuit Mode Service Requirements

Circuit-mode voice and/or data services, if provided, shall comply with the requirements of this section. The AES may provide voice communications capability to the cockpit and/or the passenger cabin areas.

<u>Note 1</u>: *At the time this document was published, RTCA had not yet published a MASPS dealing with safety-voice capabilities and operations. Until such a document is available, AES manufacturers are encouraged to follow the recommedations of DO-231 when implementing safety voice capabilities.*

Circuit-mode data service, which provides a circuit-switched data channel to support a variety of communication applications that require the allocation of dedicated channel capacity for the duration of a call (such as interactive or bulk data, encrypted voice/data and facsimile), may optionally be provided in AESs capable of voice communications.

The minimum requirements for circuit-mode voice service on the satellite subnetwork, if such service is provided by an AES, shall be the minima specified for that subnetwork in the appropriate normative appendix.

Circuit-mode voice and data service shall comply with the priority, precedence and preemption requirements established in Section 2.2.4.2 of this document.

<u>Note 2</u>: *Samples of cockpit voice interworking can be found in ARINC-741 Part 2. These interworking connections are installation specific, and are not addressed in this minimum standard.*

2.2.3.8 Recovery from Primary Power Interruption

The NGSS equipment shall conform to the following requirements after encountering primary power interruptions from any cause.

1. Power interruptions of less than 5 milliseconds duration shall be indistinguishable from outages in the RF transmission path of equal duration.

2. Power interruptions from five to 200 milliseconds duration shall require no more than five seconds recovery time, beginning from when primary power has been restored. Recovery is defined as automatically returning to the previous operating state (without user intervention) such that data channels resume in the same configuration they were in before the power interruption occurred. This assumes a channel signal with at least the minimum quality characteristics specified in Section 2.2.3.1.2.2.

Note: *In-transit data service packets which have been acknowledged on either the DTE or DCE interface, but not yet transferred to the opposite interface, may be lost. Higher-layer entities that employ end-to-end acknowledgment protocols may choose to retransmit such lost data. Synchronization and RF output power may be lost during the power interruption and recovery time. There shall be no more than a momentary effect on cockpit displays.*

2.2.3.9 Failure/Status Indication

The NGSS equipment shall provide, independent of any operator action, an indication of a failure of NGSS equipment resulting in loss of data or voice communications, as appropriate.

2.3 Equipment Performance – Environmental Conditions

2.3.1 General Requirements

The environmental tests and their associated performance requirements described in this Section are intended to provide a laboratory means of determining the overall performance characteristics of the equipment under environmental conditions representative of those which may be encountered in actual operations.

Unless otherwise specified, the test procedures applicable to a determination of equipment performance under environmental test conditions are contained in RTCA Document DO-160D, *Environmental Conditions and Test Procedures for Airborne Equipment*. General information regarding the use of the procedures in RTCA DO-160D is contained in Sections 1.0 through 3.0 of that document. Also, a method of identifying which environmental tests were conducted and other amplifying information on the conduct of the tests is contained in Appendix A of RTCA DO-160D.

Some of the minimum performance requirements in Section 2.2 of this MOPS are not required to be qualified to all of the conditions contained in RTCA DO-160D. Judgment and experience have indicated that these particular performance parameters are not susceptible to certain environmental conditions and that the level of performance specified in Section 2.2 will not be measurably degraded by exposure to these conditions. There it is sufficient to verify compliance at ambient conditions for many requirements, and then continued compliance is inferred by successfully meeting the requirements.

Table 2-8 is a compliance matrix that cross-references the RTCA DO-160D environmental test requirements with the performance requirements listed in Section 2.2.3 of this document. Only those tests specifically identified by "X" or by a numerically referenced footnote need be repeated in the various environments. Furthermore, unless otherwise noted successful verification of compliance to a requirement section implies compliance to all lesser sections as well.

In addition to the exceptions above, certain environmental tests contained in this section are not required for minimum performance equipment unless the manufacturer wishes to qualify the equipment for additional environmental conditions. If the manufacturer wishes to qualify the equipment to these additional conditions, then these tests shall be performed.

2.3.2 Equipment Configurations

This document contains provisions to subject different AES configurations to environmental qualification. Specific AES performance tests have been included for use in conjunction with the environmental procedures of RTCA DO-160D. These tests are a subset of the full AES performance tests contained in Section 2.4. Normally, a minimum performance standard does not provide specific equipment performance tests to be used in conjunction with the environmental procedures of RTCA DO-160D. However, the large number of performance tests in Section 2.4 indicates that a test procedure that includes all of the performance tests combined with the appropriate environmental procedures would be impractical.

2.3.3 Configuration Control

Nominal environment testing, followed by extreme environment testing, shall be conducted on the AES with the Operational Flight Program (OFP) installed according to the correct software version number as specified in the AES configuration documentation.

2.3.4 Specific Environmental Test Conditions

In addition to the specific functional tests to be repeated in various operational environments, the equipment as a whole shall be subjected to the test conditions as specified in RTCA DO-160D, in the sections identified in Table 2-8. By performing (and passing) those tests, the corresponding requirements of this standard shall be met.

2.3.5 Performance vs. Test Requirements Matrix

Detailed test procedures for performance requirements contained in Section 2.2 are found in Section 2.4. The subsection numbering in Section 2.4, at the third and lower levels, corresponds identically to that in Section 2.2. Consequently, this document does not provide a detailed cross-reference matrix.

Table 2-8 DO-160D Performance vs. Test Requirements Matrix

ANTENNA SUBSYSTEM **DO-160D Section**

Section	Title	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
2.2.3.1.1.1	Coverage Volume, etc.	1	-	-	-	-	2	2	2	2	2	2	-	-	-	-	-	1	-	-	-	-	-
2.2.3.1.1.1.2	Polarization	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-
2.2.3.1.1.1.3	Antenna Gain	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
2.2.3.1.1.2	Axial Ratio	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
2.2.3.1.1.3	Power Handling Capabilities	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.1.1.4	Passband	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.1.1.5	Antenna Voltang Standing Wave Ratio	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
2.2.3.1.1.6	Antenna IM, etc	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

TRANSMITTER SUBSYSTEM **DO-160D Section**

Section	Title	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
2.2.3.1.2.1.1	Minimum Power Output	X	-	X	-	-	-	-	-	-	-	-	X	X	X	X	X	X	X	-	-	-	-
2.2.3.1.2.1.2	Maximum Individual Carrier Output	X	-	X	-	-	-	-	-	-	-	-	X	X	X	X	X	X	X	-	-	-	-
2.2.3.1.2.1.4	Transmitter IM	18	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.1.2.1.5	Transmitter HSN	18	-	X	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-
2.2.3.1.2.1.6	Protection of Radio Astronomy	X	-	X	-	-	-	-	-	-	-	-	-	-	X	X	X	X	-	-	-	X	-
2.2.3.1.2.1.7	Carrier Off Level																						
2.2.3.1.2.1.8	Power Control	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.1.2.1.9	On-Channel Output Spectrum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.1.2.1.10	Transmitter Operation in Moving Aircraft	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	X	X	-	-	-	-	-

(continued)

(continued)

RECEIVER SUBSYSTEM **DO-160D Section**

Section	Title	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
2.2.3.1.2.2.1	Receiver Sensitivity	X	-	X	-	X	-	-	-	-	-	-	-	-	-	-	-	X	-	X	-	-	-
2.2.3.1.2.2.2	Receiver Bandwith	X	-	X	-	X	-	-	-	-	-	-	-	-	-	-	-	X	-	X	-	-	-
2.2.3.1.2.2.3	Rejection of Signals Outside the NGSS Receive Band	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.1.2.2.4	Rejection of Carrier Signals Generated by other AMS(R)S equipment	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.1.2.2.5	Receiver Operation in Moving Aircraft	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	X	X	-	-	-	-	-
2.2.3.1.2.2.6	Receiver Sensitivity	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

OTHER REQUIREMENTS **DO-160D Section**

Section	Title	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
2.2.3.1.3	Required Aircraft Interfaces	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.2	User link Modulation and Signal in Space	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.3	Priority, Precedence and Preemption	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.4	Satellite Subnetwork Data Protocol (Satellite Layer 2)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.5	Voice Protocol	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.6	User Data Interfaces	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.7	Circuit Mode Service Requirements	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.8	Recovery from Primary Power Interruption	X	X	-	-	-	-	-	-	-	-	-	-	X	X	-	-	-	-	X	X	-	-
2.2.3.9	Failure/Status Indication																						-

Table 2-9 DO-160D Sections Applicable to the AES

4	Temperature and Altitude (See Note 1)
4.5.1	Ground Survival Low Temperature Test and Operating Temperature Test
4.5.2	Ground Survival High Temperature Test and Short-Term Operating High Temperature Test
4.5.3	Operating High Temperature Test
4.5.4	In-flight Loss of Cooling Test (See Note 16)
4.6.1	Altitude Test (See Note 18)
4.6.2	Decompression Test (See Note 3)
4.6.3	Overpressure Test (See Note 3)
5	Temperature Variation
6	Humidity
7	Shock
7.2	Operational Shock (See Note 17)
7.3	Crash Safety Test (See Note 4)
8	Vibration
9	Explosion Proofness (See Note 3)
10	Waterproofness (See Note 3)
10.3.1	Drip Proof Test (See Note 3)
10.3.2	Spray Proof Test (See Notes 3, 5)
10.3.3	Continuous Stream Test (See Notes 3, 5)
11	Fluids Susceptibility (See Notes 3, 6)
11.4.1	Spray Test (See Note 3)
11.4.2	Immersion Test (See Note 3)
12	Sand and Dust (See Note 3)
13	Fungus Resistance (See Note 3)
14	Salt Spray (See Note 3)
15	Magnetic Affect
16.5.1	Normal Operating Conditions (AC) (See Notes 7, 12, 13)
16.5.2	Normal Operating Conditions (DC) (See Notes 7, 12, 13)
16.5.3	Abnormal Operating Conditions (AC) (See Notes 7, 12)
16.5.4	Abnormal Operating Conditions (DC) (See Notes 7, 8, 12)
17	Voltage Spikes (See Note 9)
17.3	Category A
17.4	Category B
17.4.1	Intermittent Transients
17.4.2	Repetitive Transients
18	Audio Frequency Conducted Susceptibility – Power Inputs
19	Induced Signal Susceptibility
20	Radio Frequency Susceptibility (Radiated and Conducted) (See Notes 10, 11)
21	Emission of Radio Frequency Energy
22	Lightning Induced Transient Susceptibility (See Note 14)
23	Direct Lightning Strike (See Note 15)
24	Icing Conditions
25	Electro Static Discharge (ESD)

Consolidated Notes for Table 2-8 and Table 2-9:

1. *Due to the difficulties in performing radiating measurements while changing the environmental conditions of the antenna, acceptable alternative test procedures may be implemented. Portions of the antenna subsystem may be measured over the operating environmental conditions range. The measurement data thus obtained may be used in an analysis to show that the specified antenna performance can be achieved under all operating environmental conditions. This analysis shall include the effects of materials and construction of the individual radiating elements and account for the effects of beam pointing errors versus environmental conditions on other specification requirements within the declared coverage volume.*

2. *Performance parameters of the antenna subsystem will not be measured during these environmental tests. These environmental tests are for survivability and apply only to equipment which is mounted on the outside of the aircraft.*

3. *These tests are not listed for the receiver and transmitter subsystems and need not be performed unless the manufacturer wishes to qualify the equipment for the particular environmental condition.*

4. *The application of the Crash Safety Shock test may result in damage to the equipment under test. Therefore, this test may be conducted after the other tests have been completed. In this case, Section 2.1.7, "Effects of Test" does not apply.*

5. *This test shall be conducted with the spray directed perpendicular to the equipment.*

6. *Applicable requirements:*

    a) *At the end of the 24-hour exposure period, the equipment shall function.*

    b) *Following the 2-hour operation period at ambient temperature after the 160-hour exposure period at elevated temperature, the performance requirements shall be met.*

7. *The appropriate test will depend upon whether the equipment is AC or DC powered.*

8. *The application of the Low Voltage Conditions (DC) (Category B equipment) test may result in damage to the equipment under test. Therefore, this test may be conducted after the other tests have been completed. Section 2.1.7, "Effects of Test," does not apply.*

9. *Select Category A (high degree of protection against voltage spikes required) or Category B (lower standard of protection acceptable) as applicable for the equipment under test.*

10. *Excluding frequency to which receiver is tuned and the response within its resonant pass band.*

11. *Equipment is not required to meet performance specifications during the application of HIRF, (Category U, 20 v/m). The equipment must meet all requirements following the application.*

12. *Meet requirements of DO-160C except as noted by Section 2.2.9.*

13. *Phase Noise (Section 2.2.4.2.12) performed under normal conditions only.*

14. *Equipment is not required to meet performance specifications during the period of application of the Lightning Induced Transient test, but must meet all requirements following the test.*

15. *Not required for AMSS.*

16. *Applicable to equipment requiring cooling. Modify test length to three hours. Verify no smoke or fire; compliance to performance specifications not required.*

17. *During operational shock testing, measure maximum output stability only.*

18. *Altitude tests, 4.6.1, not applicable; not applicable to receiver tests.*

19. *Gaussian only; not multipath.*

20. *Steady state conditions only (Paragraphs 16.5.1.1 and 16.5.3.1, or 16.5.2.1 and 16.5.4.1, as applicable).*

21. *Notes 19 and 20 apply.*

2.4 Equipment Performance Verification Procedures

The following procedures provide guidelines for tests to ensure compliance with the MOPS performance requirements. Except for Section 3.4.5, these do not require flight testing. Regarding secondary references from this section, any reference to "flight tests" in lower level documents should be ignored.

Some of the following tests may require additional test equipment not shown in the test setup figures. Such equipment would be associated with the interface between the satellite system emulator and the AES or radio channel unit.

2.4.1 Definitions of Terms and Conditions of Test

The following are definitions of terms and the conditions under which the tests described in this Section should be conducted:

a. **Power Input Voltage** – Unless otherwise specified, all tests shall be conducted with the power input voltage adjusted to design voltage $\pm$2%. The input voltage shall be measured at the input terminals of the equipment under test.

b. **Power Input Frequency**

   (1) In the case of equipment designed for operation from an AC source of essentially constant frequency (e.g., 400 Hz), the input frequency shall be adjusted to design frequency $\pm$2%.

(2) In the case of equipment designed for operation from an AC source of variable frequency (e.g., 300 to 1,000 Hz), unless otherwise specified, tests shall be conducted with the input frequency adjusted to within 5% of a selected frequency and within the range for which the equipment is designed.

c. **Adjustment of Equipment** – The circuits of the equipment under test shall be properly aligned and otherwise adjusted in accordance with the manufacturer's recommended practices prior to application of the specified tests.

d. **Test Equipment** – All equipment used in the performance of the tests should be identified by make, model and serial number where appropriate, and its latest calibration date. When appropriate, all test equipment calibration standards should be traceable to national and/or international standards.

e. **Test Instrument Precautions** – Due precautions shall be taken during the tests to prevent the introduction of errors resulting from the connection of voltmeters, oscilloscopes and other test instruments across the input and output impedances of the equipment under test.

f. **Ambient Conditions** – Unless otherwise specified, all tests shall be made within the following ambient conditions:

(1) Temperature: +15 to +35 degrees C (+59 to +95 degrees F)
(2) Relative Humidity: Not greater than 85%
(3) Ambient Pressure: 84 to 107 kPa (equivalent to +5,000 to -1,500 ft) (+1,525 to -460 m)

When tests are conducted at ambient conditions which differ from the above values, allowances shall be made and the differences recorded.

g. **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.

h. **EMI Testing** – Only the AES in (not the test equipment) need be subjected to the electromagnetic environment as specified in Table 2-8. For the antenna subsystem, a matched load should be connected, and the antenna subsystem performance verified to requirements after application of HIRF.

Note: For specific airframes, the aircraft manufacturer may require the interconnecting wiring to be included in the specified electromagnetic environment.

i. **Warm-up and Stabilization Requirements** – Unless otherwise specified, all tests shall be conducted after a minimum equipment warm-up period of not less than five minutes. In addition, the frequency reference source shall have completed its warm-up cycle, if any, and any power-on self test(s) shall have been completed prior to testing.

j. **Special Cooling Requirements** – The manufacturer shall specify any special cooling requirements for any of the specified tests.

2.4.1.1 AES Application Test Conditions

2.4.1.1.1 Antenna Subsystem Test Conditions

Note: *The Low Earth Orbit characteristics of the satellite system make passive, near-omni-directional antennas highly desirable. The requirements contained below assume a non-steered antenna system. Installations desiring to use actively switched or steered antenna systems are referred to RTCA Document DO-210D, Section 2.4.3, for appropriate test procedures.*

2.4.1.1.1.1 Antenna Under Test

The antenna under test shall not include the LNA, HPA, or front end filter(s) associated with the RF Front End subsystem. For steered antennas, or active antennas requiring any other type of control, a suitable control unit shall be included in the test. If a radome forms part of the antenna, this shall also be installed during the measurements. The antenna test installation shall also include any adapter plates, where used, or other hardware used to interface the antenna to the fuselage in a flight installation.

In the case of multiple antenna installations which are normally located at different areas of the aircraft (e.g., two side-mounted antennas), one antenna may be tested at a time.

2.4.1.1.2 Transceiver Subsystem Test Conditions

Unless otherwise noted, the transciever subsystem detailed verification procedures are assumed to be performed at normal laboratory ambient temperature and humidity.

2.4.1.1.3 Required Aircraft Interfaces Test Conditions

The required aircraft interfaces shall be tested with the AES operating under the standard conditions noted in Section 2.4.1.

2.4.1.2 Satellite Subnetwork Test Conditions

The satellite subnetwork shall be tested with the AES operating under the standard conditions noted in Section 2.4.1 and under normal satellite constellation dynamics as appropriate for the specific satellite sub-network. Care should be taken to ensure that worst case elevation angles and worst case, constellation-specific, geometries are included in the standard test conditions. These conditions shall be applied with the appropriate temporal constraints, as determined by the constellation dynamics.

2.4.1.3 Priority, Precedence, and Preemption Test Conditions

The Priority, Precedence and Preemption performance shall be tested with the AES operating under the standard conditions noted in Section 2.4.1. These tests may be performed using the actual satellite constellation, provided that the conditions of Section 2.4.2 are satisfied.

2.4.1.4 Satellite Subnetwork Data Protocol Test Conditions

The Satellite Subnetwork Data Protocol shall be tested with the AES operating under the standard conditions noted in Section 2.4.1.

2.4.1.5 Voice Protocol Test Conditions

The voice protocol compliance shall be tested with the AES operating under the standard conditions noted in Section 2.4.1.

Voice protocol compliance with the requirements of Section 2.2.3.5.2 shall be tested in the following audio noise environments in the following audio noise environments:

- Air Transport Aircraft Cockpit background noise (747 or similar)
- Helicopter cockpit background noise
- Prop-jet cockpit background noise
- Light twin-engine piston powered cockpit noise
- ATC Control Center background noise

2.4.1.6 User Data Interfaces Test Conditions

The User Data Interface shall be tested with the AES operating under the standard conditions noted in Section 2.4.1.

2.4.1.7 Circuit Mode Service Test Conditions

The Circuit Mode Services, if provided, shall be tested with the AES operating under the standard conditions noted in Section 2.4.1. The performance of any voice services, if provided, shall be tested under the ambient audio noise test environments specified in Section 2.4.3.5.

2.4.1.8 Recovery from Primary Power Failure Test Conditions

Recovery from Primary Power Failure shall be tested with the AES operating under the standard conditions noted in Section 2.4.1, with the exception that the power input to the AES shall be as described in the specific tests.

2.4.1.9 Failure/Status Indication Test Conditions

Failure/Status Indications shall be tested with the AES operating under the standard conditions noted in Section 2.4.1.

2.4.2 Required Test Equipment

2.4.2.1 AES Application

2.4.2.1.1 Antenna Subsystem Required Test Equipment

2.4.2.1.1.1 Standard Test Equipment

Testing shall be performed in accordance with the Institute of Electrical and Electronics Engineers (IEEE) St 169, 1983. It is suggested than an antenna test range with a minimum path length of 14 meters (40 feet) be used have a reflectivity level less than or equal to –25 dB within a quiet zone containing the antenna under test and ground plane. “Compact” ranges and/or near-field probing techniques may also be employed if analysis shows that an equivalent accuracy may be obtained.

Other items of standard test equipment include:

- Range instrumentation, including a 2-axis (minimum) positioner, positioner controller, L-band transmitter, receiver, pattern recorder and polarization measurement instrumentation.
- Reference standard gain antenna(s) of the appropriate, technique-specific polarization with gain calibration traceable to National Institute for Standards and Technology (NIST) or other national standards.
- Components of the receive and transmit systems are necessary to perform system level verifications in conjunction with the antenna system verifications. These include the LNA, HPA, splitter/combiner, and front end filters.

2.4.2.1.1.2 Special Test Equipment

An antenna ground plane shall be used to simulate the conductive mounting surface on the intended aircraft. The ground plane shall extend at least 0.5 m beyond any active portion of the antenna under test, and shall extend beyond any radome employed. The ground plane should be curved to simulate the radius of curvature of the portion of the aircraft in which the antenna may be mounted. Where the antenna is to be installed on an aircraft with a radius of curvature which differs by more than 20% from that used in the antenna tests, the validity of the results shall be justified by analysis and/or measurement.

2.4.2.1.2 Transciever Subsystem Required Test Equipment

2.4.2.1.2.1 Standard Test Equipment

The test procedures assume access to a variety of standardized test equipment, including directional couplers, high power loads, spectrum analyzers and oscilloscopes. Wherever possible, specific model numbers are identified. It is permissible to substitute alternate items of standard test equipment provided that the equivalent performance is maintained.

2.4.2.1.2.2 Special Test Equipment

The test procedures assume that the following special test equipment may be required.

Satellite System Emulator – For the tests described herein, a Satellite System Emulator is highly desirable. Transceiver functions and characteristics can be verified only when coupled through an L-Band RF link with its Space Vehicle counterpart, each controlling or reacting to various states (or changes of state) of the other. It is very desirable to be capable of strictly controlling this interation by use of test equipment rather than the satellite constellation itself.

The Satellite System Emulator is not necessarily a single definable piece of test instrumentation, but it will likely comprise an assemblage of test equipment appropriate for a given test procedure capable of providing the functions necessary for that test. For example, in certain RF tests, the Emulator would establish a "link" with the transceiver, providing the properly-modulated RF signals with appropriate accuracy and precision. As another example, the Emulator is necessary to verify correct operation of the signaling and communications protocols embodied in the transceiver.

Because there are many ways in which the Emulator can be realized, a detailed description is not necessary, or possible, herein. However, in each procedure involving the Emulator, the particular characteristics essential for that procedure are described.

Despite the fact that an emulator is an acceptable means by which performance can be verified, the complexity of modern LEO and MEO satellite constellations used for voice and data communications dictate that a Satellite System Emulator will be an extremely complex and, as a result, extremely costly, device. This standard, therefore, permits testing the critical functionality of the AES using the satellite constellation directly, provided that the following conditions are satisfied:

1. Permission of the Satellite System Operator must be obtained in advance of any such testing.
2. Whenever possible, testing of high priority communications shall be performed during periods of low network demand as determined by the Satellite System Operator.
3. Any sensitivity testing performed using the operational Satellite Constellation must accommodate both the link budget statistical performance margin and the multipath fade margin by means of a calibrated attenuator inserted between the antenna and the AES transceiver under test.

Protocol Analyzer (Air) – This device consists of a computer capable of bi-directional communications with the AES under test by means of one of the provided digital data bus formats. The PAA shall permit user control of data content and message timing for transmitted messages, and shall permit user examination of incoming and outgoing messages on both octet and message levels.

Protocol Analyzer (Ground) – This device consists of a computer capable of bi-directional data communications with the GES by means of one of the GES-supported digital data bus formats (e.g., X.25). The PAA shall permit user control of data content and message timing for transmitted messages, and shall permit user examination of incoming and outgoing messages on both an octet and an message level.

Data Generation Unit – This device consists of a computer capable of generating random binary messages of programmable length. It may be combined with PAG and PAA.

Transceiver Test Controller – This device may be required to initialize the AES or to induce the AES to a certain state, or to initialize a certain condition. It is permissible for the transceiver test controller to use existing AES interfaces for this purpose.

2.4.2.1.3 Required Aircraft Interfaces Required Test Equipment

There are no requirements to test under this topic.

2.4.2.2 Modulation and Signal in Space Required Test Equipment

Compliance with the technique-specific modulation and signal-in-space requirements will be verified by means of a certification from the Satellite System Operator that the AES is permitted to operate within the subnetwork. Required test equipment, if any, will be determined by the satellite system operator certification procedure, which is not an integral part of this MOPS or its technique-specific appendices.

2.4.2.3 Priority, Precedence, and Preemption Test Equipment

2.4.2.3.1 Packet Data

Theses test requires the ability to initiate and terminate multiple virtual circuit communications channels by means of the PAA and PAG.

2.4.2.3.2 Circuit Mode Communications

This test requires the ability to initiate and terminate *N* simultaneous circuit-mode calls through the satellite network. Depending on the specific sub-network, this may require *N* telephone lines or *N* satellite network mobile terminal channels. This test makes no assumptions about the capabilities of these circuit-originating and circuit-terminating devices. It is permissible to utilize a separate AES, independent of the AES under test, in this role.

This test is not intended to verify the ability of the satellite network or the satellite sub-network as a whole, to satisfy the Priority, Precedence and Preemption requirements of the MASPS. This test should be coordinated with the satellite network operator to ensure that appropriate satellite capacity exists for the completion of the test. Such coordination may require that the test be performed in off-peak traffic hours.

2.4.2.4 Satellite Subnetwork Data Protocol Test Equipment

Compliance with the overall technique-specific satellite subnetwork dependent protocol will be verified by means of a certification from the Satellite System Operator that the AES is permitted to operate within the subnetwork. Required test equipment, if any, will be determined by the satellite system operator certification procedure, which is not an integral part of this MOPS or its technique-specific appendices.

Compliance with an aeronautical application specific Air-Ground Protocol sub-layer, if applicable, will be determined using the Protocol Analyzer (Ground) and Protocol Analyzer (Air) defined above.

2.4.2.5 Voice Protocol Required Test Equipment

Compliance with the overall technique-specific voice protocol, if applicable, will be verified by means of a certification from the Satellite System Operator that the AES is permitted to operate within the subnetwork. Required test equipment, if any, will be determined by the satellite system operator certification procedure, which is not an integral part of this MOPS or its technique-specific appendices.

Compliance with the requirements of Section 2.2.3.5.2 requires special test equipment capable of accurately reproducing the required environments. The tests are complex, and are typically carried out by organizations with expertise in the evaluation of vocoder or voice modem capabilities.

2.4.2.6 User Data Interface Required Test Equipment

ISO-8208 Test Set/Protocol Analyzer (2), one designated as Protocol Analyzer Air (PAA), one designated as Protocol Analyzer Ground (PAG).

Remote access equipment to ISO-8208 compatible data port at GES.
or, alternative, GES Emulator.

2.4.2.7 Circuit Mode Service Test Equipment

No special test equipment is required to verify these requirements.

2.4.2.8 Recovery from Primary Power Interruption Test Equipment

No special test equipment is required to verify these requirements.

2.4.2.9 Failure/Status Indication Test Equipment

No special test equipment is required to verify these requirements.

2.4.3 Detailed Test Procedures

The test procedures set forth below constitute a satisfactory method of determining required performance. Although specific test procedures are cited, it is recognized that other methods may be preferred. Such alternate methods may be used if the manufacturer can show that they provide at least equivalent information. Therefore, the procedures cited herein should be used as one criterion in evaluating the acceptability of the alternate procedures.

For performance verification purposes, this section includes procedures for transceiver and the antenna. The term Satellite Subnetwork Physical Layer is also used for this subsystem in regard to the layered ISO concepts for data communications protocols.

Some of the following receiver-related tests require a Satellite System Emulator and may require additional test equipment not shown in the test figures. The transceiver frequency, mode, etc. are controlled by commands from the emulator. In cases where a Satellite System Emulator is not available, it shall be permissible to use the operational satellite constellation, provided the criteria established in Section 2.4.1.1.2 are satisfied.

The detailed equipment lists given in the following procedures have been developed under the assumption that the operational frequencies of the system under test are in the 1.5 GHz to 1.6 GHz band. Some modification to the specific model numbers may be required for NGSS operating outside of this band. The possibility of such modification is recognized by means of the text "or appropriate equivalent" in the equipment lists of the following procedures.

2.4.3.1 AES Application Requirements

2.4.3.1.1 Antenna Test Requirements

Note: *The following test procedures anticipate that the antenna performance in both the transmit and receive bands is reciprocal and can be adequately measured by using the test setup of Figure 2-6. Depending on the individual antenna design, it may be necessary to modify the setup of Figure 2-6 to use the antenna under test as a transmit source and the reference antenna as a receiver. Such modifications are fully compliant with the intent of the following test procedures.*

2.4.3.1.1.1 Polarization, Gain and Coverage Volume

Reference: Sections 2.2.3.1.1.1.1, 2.2.3.1.1.1.2, and 2.2.3.1.1.1.3

Equipment Required

Antenna Measurement Range
Antenna Ground Plane
Filter/LNA
Antenna-Filter/LNA cable

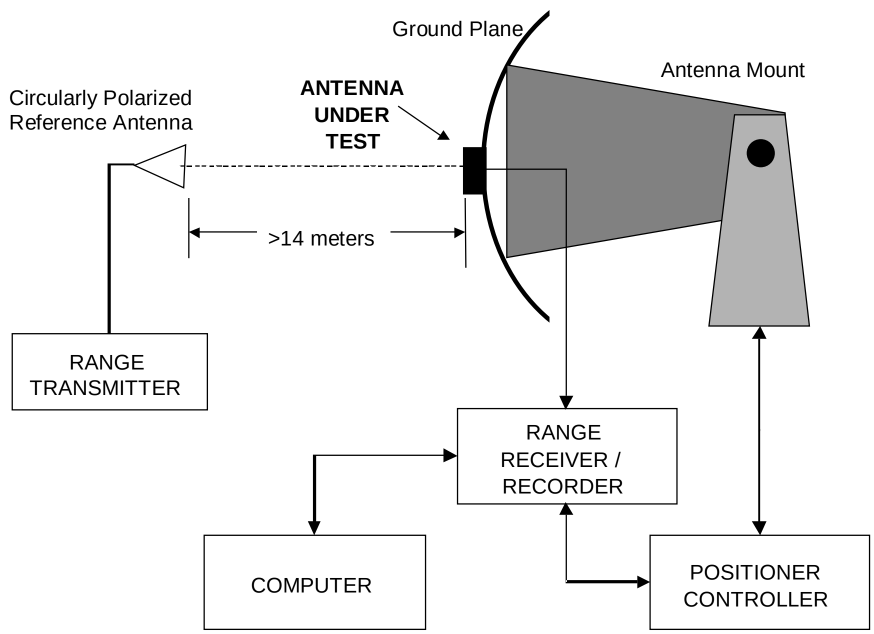


Figure 2-6 Antenna Gain/Polarization/Axial Ratio Test Setup

Measurement Requirements

1) With the equipment set up as in Figure 2-6, and with operating frequency of $\frac{f_{TMX} + f_{TMN}}{2}$, measure the antenna gain via a series of patterns collected over a range of 0^o to 90^o in elevation and at azimuth angles of 0^o, 45^o, 90^o, 135^o, 180^o, 225^o, 270^o

and 315°. Verify that the antenna gain at all points in the elevation coverage volume where $\Theta_{MIN} \le \theta \le 90^o$ meet the gain requirements of Section 2.2.3.1.1.1.3.

2) Selecting the minimum gain measured in Step 1 as a reference point for normalization, measure the antenna gain via an azimuth pattern measured at the minimum elevation angle Θ_{MIN}. Verify that the minimum gain at any azimuth angle meets the requirements of Section 2.2.3.1.1.1.3
3) Selecting the maximum gain and the corresponding elevation angle, θ, measured in Step 1, as reference points for normalization, measure the antenna gain via an azimuth pattern measured at the elevation angle θ. Verify that the maximum gain at any elevation angle meets the requirements of Section 2.2.3.1.1.1.3.

Repeat Steps 1-3 at the following transmit and receive test frequencies:

$$f_{RMN},\ f_{RMX},\ f_{TMN},\ f_{TMX},\ \text{and}\ \frac{f_{RMX} + f_{RMN}}{2}.$$

Note: *It may be efficient to perform the tests of Section 2.4.3.1.1.7 in conjunction with the tests of this section.*

2.4.3.1.1.2 Antenna Axial Ratio
Reference: Section 2.2.3.1.1.2

Equipment Required

Antenna Measurement Range
Antenna Ground Plane
Filter/LNA
Antenna-Filter/LNA cable

Measurement Requirements

Connect the equipment as shown in Figure 2-6. For each of the test frequencies and each of the antenna patterns described in Section 2.4.3.1.1.1 measure the antenna axial ratio. In all cases, verify that the axial ratio meets the requirements of Section 2.2.3.1.1.2.

Measurement points where the axial ratio does not comply with the requirements of Section 2.2.3.1.1.2 may be included in coverage volume if the measured gain at the corresponding elevation and azimuth angles (G_{MEAS}) exceeds the minimum value required by Section 2.2.3.1.1.1.3 (G_{REQD}) by at least a compensating amount (G_{COMPp}). Points which should be included in the coverage volume because of axial ratio are those where:

$$G_{MEAS} \ge G_{REQD} + G_{COMP}$$

and where all gain values are measured in decibels.

Note: *The compensation value, G_{COMP}, is computed using the Friis power transmission formula, while assuming that both AES and satellite antennas are nominally polarized in the appropriate manner defined in the appropriate normative portion of the system-specific* appendix. *The Friis transmission computation is as follows:*

$$G_{COMP} = 20\log_{10}\left(\frac{r_0 + r_1}{r_1 + 1}\right) - 20\log_{10}\left(\frac{r_o + r_2}{r_2 + 1}\right)$$

where:
r_0 *is the satellite antenna voltage axial ratio*
r_1 *is the AES antenna reference voltage axial ratio, and*
r_2 *is the AES antenna actual voltage axial ratio*

Using the Friis formula for RHCP, the reference axial ratio for low-gain antennas, (10 dB, a power ratio factor of 10.0, or a voltage axial ratio of 3.16), and a satellite antenna axial ratio worst-case assumption of $A_{RSV} = 3.5\text{ dB}$*, and and actual axial ratio of 12 dB, the* G_{COMP} *values for low-gain antennas corresponding is computed as follows:*

$$r_o = \sqrt{10^{3.5/10}} = 1.50$$

$$r_1 = \sqrt{10^{10/10}} = 3.16$$

$$r_2 = \sqrt{10^{12/10}} = 3.98$$

$$G_{COMP} = 20\log_{10}\left(\frac{1.5 + 3.16}{3.16 + 1}\right) - 20\log_{10}\left(\frac{1.5 + 3.98}{3.98 + 1}\right)$$

$$= 0.99 - 0.83 = 0.16\text{ dB}$$

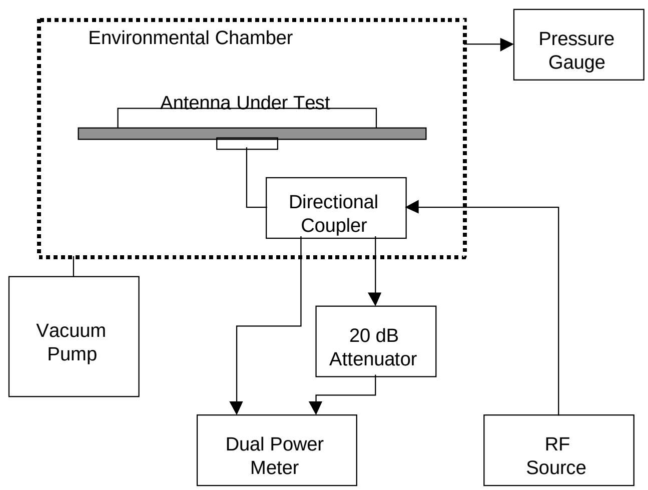
2.4.3.1.1.3 Maximum Power Handling
Reference: Section 2.2.3.1.1.3

Equipment Required

Environmental chamber
Vacuum pump/vacuum gauge
RF absorber panels
Dual directional coupler
RF attenuator (NARDA 757C-20 or appropriate equivalent)
Dual RF power meter (HP 438)
Antenna Test Set – refer to Section 2.4.3.2.2
RF Power Source

Measurement Requirements

Connect the equipment as shown in Figure 2-7. The environmental chamber should be pumped down to and maintained at or above the maximum pressure altitude found in DO-160D at the ambient temperature (maintaining *above* the minimum pressure altitude is the same as maintaining the pressure *below* a threshold level). After achieving temperature and pressure stability, apply an RF signal as specified in Section 2.2.3.1.1.3.



CAUTION: Radiation from this test setup may pose a safety hazard, and should be conducted so as to avoid harmful emissions.

<u>Figure 2-7</u> Power Handling Test Setup

Remove the RF signal. Remove the antenna from the environmental chamber. Measure the gain performance in an anechoic chamber or equivalent at ambient temperature and altitude. Reverify compliance to the requirements of Section 2.2.3.1.1.1.3 and the VSWR requirements of Section 2.2.3.1.1.5.

<u>*Notes*</u>*:*

1. *The incident and reflected power at the antenna input should be monitored for the duration of the power handling test and any changes noted to observe changes in the antenna.*

2. *This is an altitude test only.*

2.4.3.1.1.4 Antenna Passband

Reference: Section 2.2.3.1.1.4

Repeat the tests of Section 2.4.3.1.1.1, and Section 2.4.3.1.1.2 at the five additional transmit test operating frequencies spaced equally across the transmit operating band.

Repeat the tests of Section 2.4.3.1.1.1, and Section 2.4.3.1.1.2 at additional receive test frequencies operating frequencies spaced equally across the receive operating band and verify compliance with the requirements of the applicable paragraphs. To the extent that the receive and transmit bands overlap, overlapping frequencies need only be tested once.

2.4.3.1.1.5 Antenna VSWR

Reference: Section 2.2.3.1.1.5

<u>Equipment Required</u>

Automatic Network Analyzer with optional plotter
NGSS Antenna mounted on Ground Plane

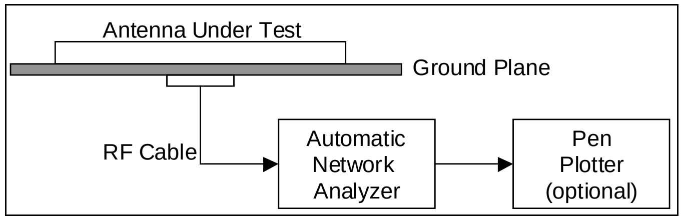


Figure 2-8 Voltage Standing Wave Ratio (VSWR) Test

Measurement Procedure

Connect the equipment as shown in Figure 2-8. Measure and record the VSWR at a test frequency of $\frac{f_{TMN} + f_{TMX}}{2}$. Precautions should be taken to reduce the effects of nearby reflections on the VSWR measurements. Confirm that the VSWR meets the requirements.

Repeat the test at a test frequency of $\frac{f_{RMN} + f_{RMX}}{2}$ and confirm the required performance.

2.4.3.1.1.6 Radiated Antenna Intermodulation Products

2.4.3.1.1.6.1 Antenna Intermodulation in the GNSS Band
Reference: Section 2.2.3.1.1.6.1

This test applies to all antennas utilized for multi-carrier capable installations.

Equipment Required

Two frequency synthesizers (HP 8665A, option 004 or appropriate equivalent)
Directional Coupler, 30 dB coupling, 20 watts or greater average power rating (NARDA Model 3002-30 or appropriate equivalent)
Attenuator, 20 dB (NARDA Model 757C-20 or appropriate equivalent)
High Power Load, 50 Ohms, 20 watts or greater average power rating (RLC Electronics, Inc. Model T-1005 or appropriate equivalent)
Two RF Power Amplifiers, f_{TMN} to f_{TMX} MHz, (ARINC 741 HPA or appropriate equivalent)
Two Spectrum Analyzers (HP 8563A or appropriate equivalent)
RF Anechoic Chamber
Matched quarter wave GNSS monopole at 1610 MHz (VSWR < 1.5:1)
Ground Plane compliant with Section 2.4.3.2.2 and with provisions to mount the GNSS monopole at least 5 feet away from the Antenna Under Test (AUT)
GNSS pass-band filter with $\leq$ 1 dB insertion loss at 1610 MHz and $\geq$50 dB isolation from f_{TMN} to f_{TMX}

Note: A circulator-bandpass filter combination such as that used in the wideband noise test of Section 2.4.3.1.2.1.5 may be used.

GNSS amplifier, 1610 MHz, with gain $\geq$ 50 dB and NF $\leq$ 1.3 dB
Measurement Requirements for Unsteered Antennas

Connect the equipment as shown in Figure 2-9, follow the steps below.

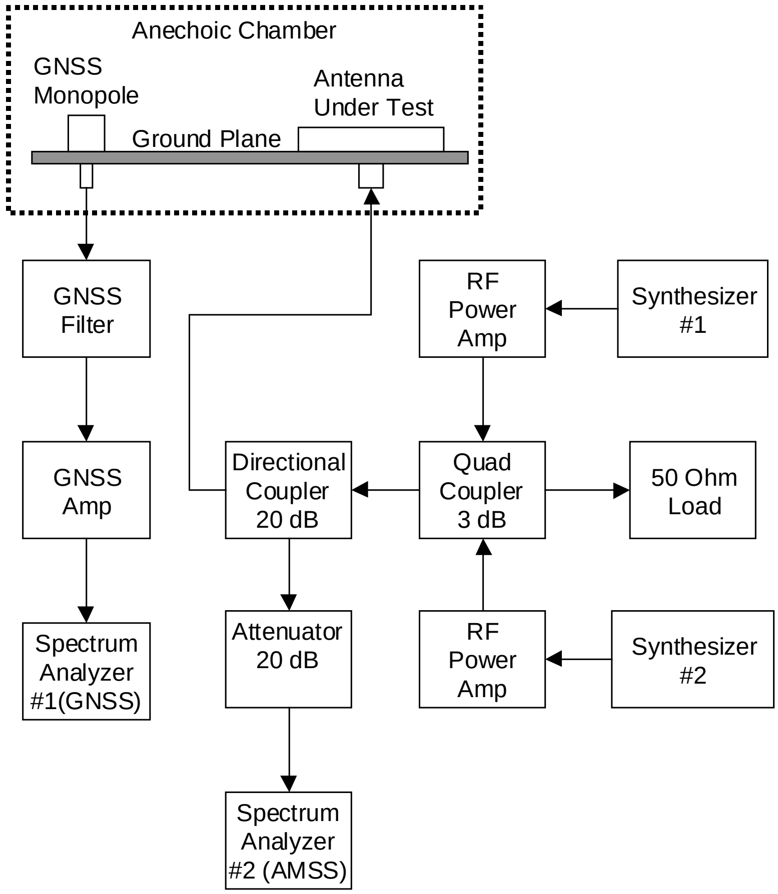


Figure 2-9 Radiated Antenna Intermodulation Products in the GNSS Band

1) Mount the Antenna Under Test (AUT) and the GNSS monopole on the ground plane.

2) Use a spectrum analyzer to measure the isolation, in dB, between the two antenna ($ANTISO_{dB}$) at 1610.

3) Set RF synthesizer 1 (f_1) to the f_{TMN} .

4) The RF Synthesizer number 2 (f_2) frequency is defined by the following:

$$f_2(MHz) = \frac{(N+1)*f_1 - 2*(1610)}{N-1} \text{ MHz}$$

for N = odd values 3 to 11, where N is the IM order. If, for a particular order of N, the value of f_2 does not fall within the band f_{TMN} to f_{TMX}, skip this order and proceed to the next higher N.

5) Set the RF synthesizer number 2 (f_2) for the lowest value of N determined by the results of Step 4.

6) Set the RF power amplifiers to an output power equal to the single-carrier output power defined in Section 2.2.3.1.2.1.2.

7) Measure the IM product level in decibels relative to one Watt (dBW) at the GNSS spectrum analyzer at 1610 MHz and refer it back to the GNSS antenna output port ($IMGNSS_{dBm}$).

8) Normalize the IM product level to a 40 dB antenna isolation by performing the following:

$$IMLEVEL = IMGNSS_{dBm} - 40\ dB + ANTISO_{dB}$$

9) Repeat Steps 7 and 8 for N = 5, 7, 9 and 11, respectively.

In each case, determine that the IM product levels determined in Step 8 (IMLEVEL) do not exceed the values of Section 2.2.3.1.1.6.1.

Measurement Requirements for Steered Antennas

Perform the test procedure for Unsteered Antennas with the peak of the antenna beam steered as closely as possible to the direction of the GNSS test monopole.

2.4.3.1.1.6.2 Antenna Intermodulation in AMS(R)S Band(s)
Reference: Section 2.2.3.1.1.6.2

Equipment Required

Two frequency synthesizers (HP 8665A, option 004 or appropriate equivalent)
Directional Coupler, 30 dB coupling, 20 watts or greater average power rating (NARDA Model 3002-30 or appropriate equivalent)
Attenuator, 20 dB (NARDA Model 757C-20 or appropriate equivalent)
High Power Load, 50 Ohms, 20 watts or greater average power rating (RLC Electronics, Inc. Model T-1005 or appropriate equivalent)
Two RF Power Amplifiers, f_{TMN} to f_{TMX} MHz, (ARINC 741 HPA or appropriate equivalent)
Two Spectrum Analyzers (HP 8563A or appropriate equivalent)
RF Anechoic Chamber
Matched quarter wave monopole at appropriate AMS(R)S receive frequecies (VSWR < 1.5:1)
Ground Plane compliant with Section 2.4.3.2.2 and with provisions to mount the AMS(R)S monopole at least 5 feet away from the Antenna Under Test (AUT)
AMS(R)S pass-band filter with $\leq$ 1 dB insertion loss at throughout the AMS(R)S receive band and $\geq$50 dB isolation from f_{TMN} to f_{TMX}

Measurement Requirements for Unsteered Antennas

Connect the equipment as shown in Figure 2-9, replacing the GNSS antenna, amplifier and filter by the appropriate devices for the AMS(R)S system. Perform the following steps:

1. Mount the Antenna Under Test (AUT) and the AMS(R)S monopole on the ground plane.

2. Use a spectrum analyzer to measure the isolation, in decibels, between the two antenna (ANTISOdB) at f_{AMSRS}, where f_{AMSRS} is the frequency in the AMS(R)S receive band of interest that lies closest to the transmit band of the unit under test.

3. Set RF synthesizer 1 (f1) to either f_{TMN} or f_{TMN}, whichever is closer to f_{AMSRS}.

4. The RF Synthesizer number 2 (f2) frequency is defined by the following:

$$f_2(MHz) = \frac{(N+1)*f_1 - 2*(f_{AMSRS})}{N-1} \text{ MHz}$$

   for N = odd values 3 to 11, where N is the IM order. If, for a particular order of N, the value of f2 does not fall within the band f_{TMN} to f_{TMX}, skip this order and proceed to the next higher N.

5. Set the RF synthesizer number 2 (f_2) for the lowest value of N determined by the results of Step 4.

6. Set the RF power amplifiers to an output power equal to the single-carrier output power defined in Section 2.2.3.1.2.1.2.

7. Measure the IM product level in decibels relative to one Watt (dBW) at the GNSS spectrum analyzer at 1610 MHz and refer it back to the GNSS antenna output port (IMGNSSdBm).

8. Normalize the IM product level to a 40 dB antenna isolation by performing the following:

   IMLEVEL = IMGNSSdBm - 40 dB + ANTISOdB

9. Repeat Steps 7 and 8 for N = 5, 7, 9 and 11, respectively.

In each case, determine that the IM product levels determined in step 8 (IMLEVEL) do not exceed the values of Section 2.2.3.1.1.6.2.

Note: For example, if the transmit band is 1621-1626 MHz and the receive band of interest is 1650-1660 MHz, select $f_{TMX} = 1626$, and $f_{AMSRS} = 1650$ MHz. Then applying Step 4, only the 11-th order IM product need be evaluated.

Measurement Requirements for Steered Antennas

Perform the test procedure for Unsteered Antennas with the peak of the antenna beam steered as closely as possible to the direction of the AMS(R)S test monopole.

2.4.3.1.1.7 Carrier-to-Multipath Discrimination
Reference: Section 2.2.3.1.1.7

Equipment Required
See Section 2.4.3.1.1.1

Measurement Requirements for Unsteered Antennas

With the equipment set up as in Figure 2-6, and with operating frequency of $\frac{1}{2}(f_{TMX} + f_{TMN})$, measure the antenna gain by making an azimuthal sweep at the elevation angles of $\theta = \pm\Theta_{MIN}$. At each azimuth angle verify that the difference in pattern, measured in decibels, meets the rejection requirements of Section 2.2.3.1.1.7.

Repeat the test using the transmit frequencies of f_{TMX}, f_{TMN}.

Repeat the test using the receive frequencies of $\frac{1}{2}(f_{RMX} + f_{RMN}), f_{RMX}, f_{RMN}$.

Measurement Requirements for Steered Antennas

Steer the antenna to the angle, θ, appropriate for the minimum elevation angle Θ_{MIN}, and to an azimuth angle of 0°. Perform the test as described for unsteered antennas. Repeat the test at azimuth angles of 90°, 180°, and 270°.

Notes:

1. *It may be efficient to perform this test in conjunction with the tests of Section 2.4.3.1.1.1.*

2. *There is no implied requirement to actually steer to Θ_{MIN}, unless the system design requires it. For example, a system might only require steering to one-half of elevation beamwidth above Θ_{MIN}. In such a case, the "elevation angle corresponding" to Θ_{MIN} would be $\Theta_{MIN} + \frac{1}{2}\text{elevation beamwidth}$.*

2.4.3.1.1.8 Pattern Discrimination
Reference: Section 2.2.3.1.1.8

Equipment Required
See Section 2.4.3.1.1.1

Measurement Requirements for Unsteered Antennas

Utilize the data collected in the tests defined in Step 1 of Section 2.4.3.1.1.1 to verify that the antenna under test meets the requirements of Section 2.2.3.1.1.8 for elevation angle separations and azimuth angle separations of Θ_{SA}.

Measurement Requirements for Unsteered Antennas

Connect the equipment as shown in Figure 2-6. Choose and measure the patterns of a minimum of 10 beams, five evenly distributed over the declared coverage and five at the expected worst-case discrimination points as identified by the manufacturer through simulation or measurement. Sufficient points over the antenna pattern shall be obtained to determine that the requirements are satisfied.

2.4.3.1.1.9 Steered Antenna Requirements

2.4.3.1.1.9.1 Phase Discontinuity
Reference: Section 2.2.3.1.1.9.1

Equipment Required
See Section 2.4.3.1.1.1

Measurement Requirements

Connect the equipment as shown in Figure 2-6. In a beam-switched antenna, position the antenna at a switchover point (the point where at least one phase shifter changes state) between two adjacent beams. Measure the phase difference by switching between these two beams and recording the difference in phase of the carrier. Compliance to the requirement may be demonstrated by analysis which is verified by measured data.

2.4.3.1.1.9.2 Beam Switching Time
Reference: Section 2.2.3.1.1.9.2

Equipment Required

Antenna Test Set
L-band signal generator
Storage oscilloscope
L-band RF detector
Source antenna

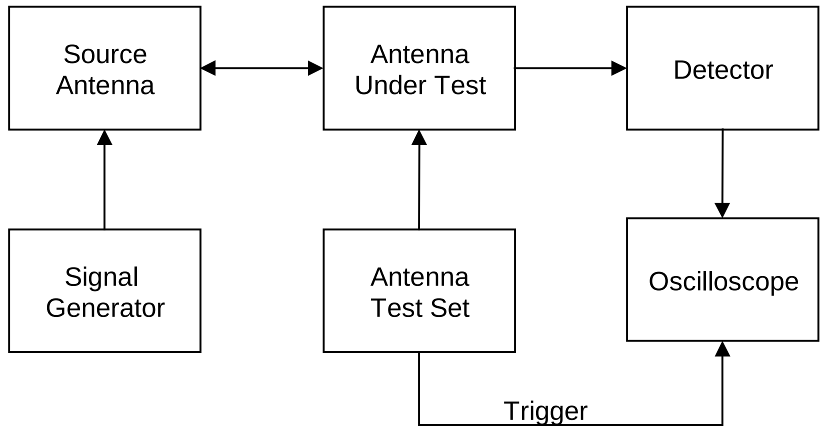


Figure 2-10 Beam Switching Time

Measurement Requirements

Connect the equipment as shown in Figure 2-10. Measure the duration of the RF signal outage at the mid-band frequencies for transmit and receive when the antenna is switched between adjacent beams. Where it can be justified by measurement or analysis, the switching time of only the phase-shifter portions of the antenna may be measured.

2.4.3.1.1.9.3 Steering Rate
Reference: Section 2.2.3.1.1.9.**3**

Equipment Required.
See Section 2.4.3.1.1.1

Measurement Requirements

For each of the transmit and receive test frequencies defined in Section 2.4.3.1.1.1, steer the antenna to the elevation angle corresponding to the minimum elevation angle, Θ_{MIN}, and an azimuth angle of zero degrees. Rotate the test fixture so that the source elevation angle is Θ_{MIN}. Record the antenna gain. Rotate the test fixture in elevation at a rate of 6 degrees per second over the range $\Theta_{MIN} \leq \theta \leq 90^\circ$ while steering the antenna to maintain the beam center as close as possible to the source. Verify that the gain meets the minimum gain requirements of Section 2.2.3.1.1.1.3, and the axial ratio requirements of Section 2.2.3.1.1.2. Return the test fixture to the original orientation. Rotate the test fixture to an azimuth angle of -180°. Repeat the test by rotating the test fixture in azimuth from $-180^\circ \leq \theta_{AZ} \leq 180^\circ$ at a rate of 6 degrees per second.

2.4.3.1.1.9.4 Pattern Discrimination
Reference: Section 2.2.3.1.1.9.4

This requirement is verified by means of the steered antenna test procedure detailed in Section 2.2.3.1.1.8.

2.4.3.1.2 Transceiver Subsystem Test Requirements

2.4.3.1.2.1 Transmitter Performance

2.4.3.1.2.1.1 Transmitter Minimum Power Output
Reference: Section 2.2.3.1.2.1.1

Equipment Required

Dual Calibrated Directional Coupler, 20 dB coupling, 20 watts or greater average power rating
Directional Coupler, 30 dB coupling, 20 watts average power (NARDA Model 3002-30 or appropriate equivalent)
High Power Load, 50 ohms, 20 watts or greater average power rating (RLC Electronics Inc. Model T-1005 or appropriate equivalent)
Two Precision Calibrated Attenuators, 20 dB (NARDA 757C-20 or appropriate equivalent)
Dual Power Meter Two Power Sensors, -30 to +20 dBm, 0.1-4.2 GHz (HP 8482A or appropriate equivalent)
Satellite Network Simulator (if required)
Transceiver Test Controller (if required)

Note: *This and following tests can be conducted with a single power meter and with two single calibrated directional couplers, but the convenience and additional accuracy of a complete dual system is highly desirable, especially for the Load VSWR Capability test. For that reason, components for a dual system are specified for all of the tests requiring power measurements.*

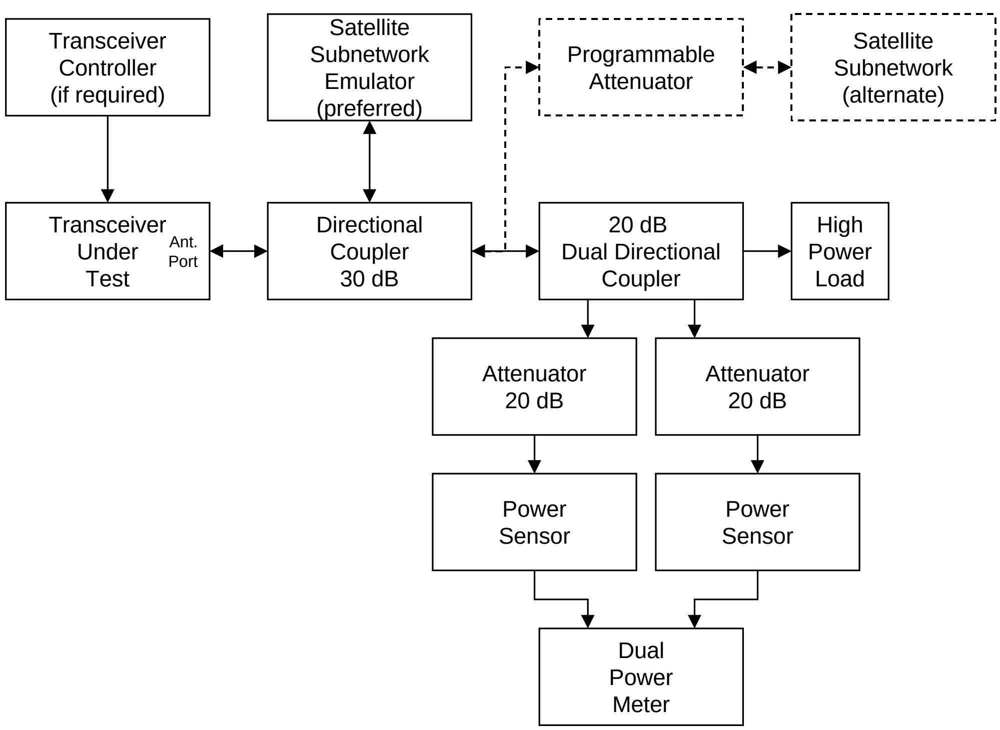


Figure 2-11 Minimum Power, Maximum Power, Power Control Test Setup

Measurement Procedure

For multi-carrier equipment, connect the equipment as shown in Figure 2-11. Command the transceiver to CW mode. Command the transceiver to create N_D data carriers and $N_V = (N\text{-}N_D)$ voice carriers, where N_V , N_D and N are defined in Table 2-1. The carriers shall be grouped as closely as possible consistent with normal system operation and centered about midpoint of the transmit frequency band. Set the power level for the voice channels to P_V and for the data channels to P_D , as defined in Table 2-1. For multi-carrier capable TDMA systems, all carriers shall be in the same TDMA slot, consistent with normal system operation. Measure the Transmitter power output as defined by Section 1.7. Confirm compliance with Section 2.2.3.1.2.1.1.

For single carrier equipment, connect the equipment as shown in Figure 2-11. Set the power level to the maximum power, P_S , defined in Section 2.2.3.1.2.1.1. Confirm compliance with Section 2.2.3.1.2.1.1.

Note: *This test may produce peak instantaneous power levels significantly above the average Transmitter Power Output.*

Repeat the above measurements at carrier frequencies equal to the transmission test frequencies established in Section 2.4.3.1.1.4.

2.4.3.1.2.1.2 Maximum Individual Carrier Output
Reference: Section 2.2.3.1.2.1.2

Equipment Required
Same as Section 2.4.3.1.2.1.1

Measurement Procedure

Connect the equipment as shown in Figure 2-11. Command the transceiver to CW mode. Command the transceiver to create a single data carrier at the valid operating frequency closest to the center of the transmit operating band. Force the transceiver to output the maximum carrier power. Measure the Transmitter Power Output, as defined in Section 1.7. Confirm compliance with Section 2.2.3.1.2.1.2.

Repeat the above measurements at the transmission test frequencies given in Section 2.4.3.1.1.4.

2.4.3.1.2.1.3 Maximum Total Transceiver Output Carrier Power
Reference: Section 2.2.3.1.2.1.3

Equipment Required

Same as Section 2.4.3.1.2.1.1, with the addition of:
Spectrum Analyzer, to 2.9 GHz (Rohde and Schwartz FSEA20 or appropriate equivalent)

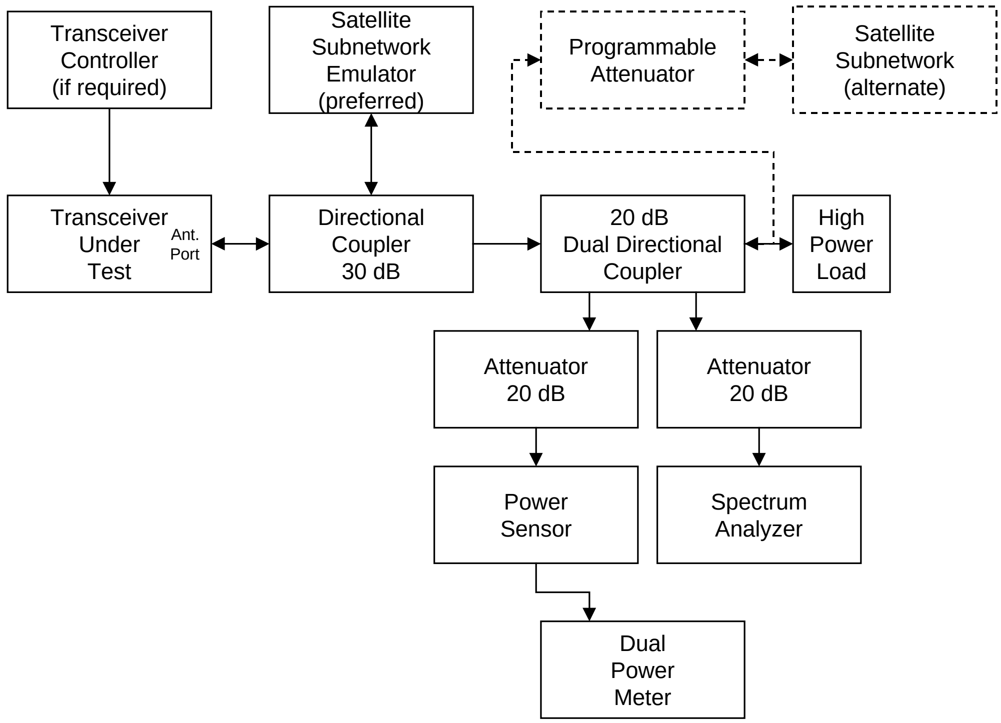


Figure 2-12 Maximun Total Transceiver Output Test Setup

Connect the equipment as shown in Figure 2-12. Command the transceiver to CW mode. Command the transceiver to create N_D data carriers and $(N\text{-}N_D)$ voice carriers, where N_D and N are as defined in Section 2.2.3.1.2.1.1. The carriers shall be grouped as closely as possible consistent with normal system operation. For multi-carrier capable TDMA systems, the number of carriers active in any single TDMA time slot shall be the maximum permitted by AES design and shall be consistent with system channel assignments. Using the Spectrum Analyser with resolution set to 30 kHz, measure the Transmitter Power Output as defined in Section 1.7 over the frequency range defined in Section 2.2.3.1.2.1.3. Reference the measurements to the transceiver output port and confirm compliance with the requirements of Section 2.2.3.1.2.1.3.

2.4.3.1.2.1.4 Transceiver Intermodulation Products

Reference: Section 2.2.3.1.2.1.4

The manufacturer may choose to verify intermodulation performance by means of either the procedure described in Section 2.4.3.1.2.1.4.1 or Section 2.4.3.1.2.1.4.2.

2.4.3.1.2.1.4.1 Narrow Band Intermodulation Performance

Equipment Required

Dual Calibrated Directional Coupler, 20 dB coupling, 20 watts or greater average power rating

Directional Coupler, 30 dB coupling, 20 watts average power (NARDA Model 3002-30 or appropriate equivalent)

High Power Load, 50 ohms, 20 watts or greater average power rating (RLC Electronics Inc. Model T-1005 or appropriate equivalent)

Precision Calibrated Attenuator, 20 dB (NARDA 757C-20 or appropriate equivalent).

Dual Power Meter (HP 438A or appropriate equivalent)

Power Sensor, -30 to +20 dBm, 0.1-4.2 GHz (HP 8482A or e0quivalent)
Single Directional Coupler, 20 dB coupling, 1-2 GHz (NARDA Model 4012C-20 or appropriate equivalent)
Spectrum Analyzer, 100 Hz - 18 GHz (HP 8566B or appropriate equivalent)
Satellite Network Simulator (if required)
Transceiver Test Controller (if required)

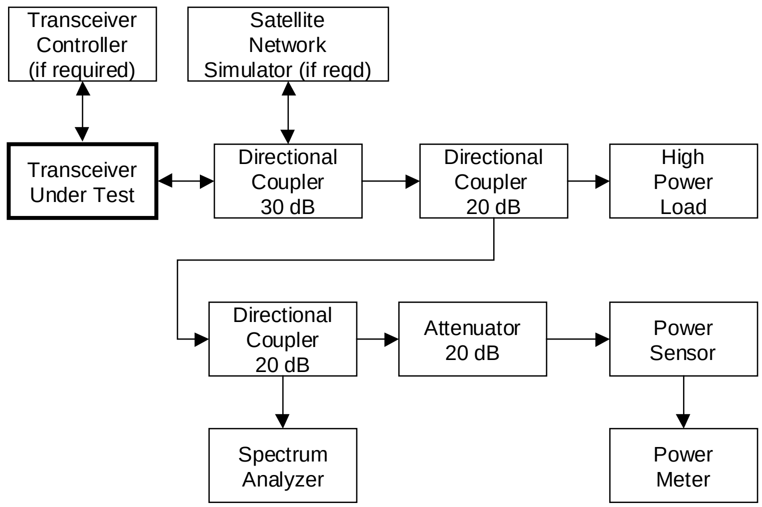


Figure 2-13 Transceiver Intermodulation Product Test Set Up

Measurement Procedure

This test applies only to transceivers capable of simultaneous operation on multiple carrier frequencies. Perform the following steps:

Note: *Operation with single or multiple unmodulated carriers is not anticipated to be a normal operating mode of the AES, but will substantially simplify the measurement of intermodulation performance.*

1. After connecting the equipment as shown in Figure 2-13, command the transceiver to output a single unmodulated carrier at maximum individual carrier output power level defined in Section 2.2.3.1.2.1.2, or at one-half the total maximum power available at the transceiver output, whichever is less. Set the carrier frequency to $f_1 = \frac{1}{2}(f_{TMN} + f_{TMX})$. This may be done with either the transceiver controller or the satellite network simulator, or both, depending on the specific operational characteristics of the subnetwork.

2. Turn off this carrier and select another channel at a frequency separated from the first frequency by approximately 2 MHz or the maximum permitted by the allowed transmit frequency band, whichever is less. Adjust the new channel unit output level to be the same as the first channel.

3. Turn on the first channel again so that the unit is transmitting both unmodulated carriers. Use the spectrum analyzer to measure the intermodulation products resulting from the two signals with the measured single carrier power level as a

reference. Intermodulation products shall be measured in the following bands: 1530-1559 MHz, 1565-1605 MHz, 1610.6-1613.8 MHz, 1616-1626.5 MHz, 1660-1670 MHz, and any other bands used by AMS(R)S systems for reception of satellite downlink transmissions.

4. Repeat Steps 1 through 3 for channel frequency separations corresponding to the minimum channel spacing permitted by the system design.

5. Repeat Steps 1 through 4 with f1 equal to the transmit test frequencies specified in Section 2.2.3.1.1.4.

6. Repeat Steps 1 through 3 with one carrier tuned to f_{TMX} and the other carrier tuned to f_{TMN}.

2.4.3.1.2.1.4.2 Modulated Intermodulation Performance

The modulated intermodulation performance may be tested by the procedure described in Section 2.2.3.1.2.1.4.1 with the following modifications in each step. If a TDMA format is used, the measurements made under this test procedure shall be gated during the TDMA transmit burst. Compliance shall be determined by reference to Table 2-5, without any adjustment for multiple carriers.

1. Replace the unmodulated carrier with a carrier modulated with random digital data.
2. Use a second carrier modulated with random digital data.
3. Each carrier shall be modulated with different random data sequences.
4. No change.
5. No change.
6. No change.

2.4.3.1.2.1.5 Composite Harmonics, Spurious and Noise
Reference: Section 2.2.3.1.2.1.5

<u>Equipment Required</u>

Directional Coupler, 30 dB coupling, 20 watts average power, 0.95-2.0 GHz (NARDA Model 3002-30 or appropriate equivalent)
Attenuator, 30 dB attenuation, 50 watts or greater average power (Bird 50AFFN30 or appropriate equivalent)
Attenuator, 10 dB, attenuation, 25 watts (Bird 10dB 25W or appropriate equivalent)
Attenuator, 6 dB attenuation, 50 watts (Weinschel Corp 102-090700 or appropriate equivalent)
Attenuator, 3 dB attenuation, 25 watts (Bird 3dB 25W or appropriate equivalent)
2 each, Circulator (UTE Microwave CT-2004-0 or appropriate equivalent)
2 each, Band Pass Filter, maximum insertion loss 1.5 dB f_{TMN} to f_{TMX}, minimum rejection 30 dB 960-1215 MHz, 1559-1610 MHz, 1631.5-1660.5 MHz and 1.00325 f_{TMX} to 18 GHz
Hi Pass Filter, maximum insertion loss 1 dB $2f_{tmn}$ to 18 GHz, minimum rejection 20 dB f_{TMN} to f_{TMX}
2 each, 50 ohm load, DC – 18 GHz, 50 watts (Pasternack PE6040 or appropriate equivalent)

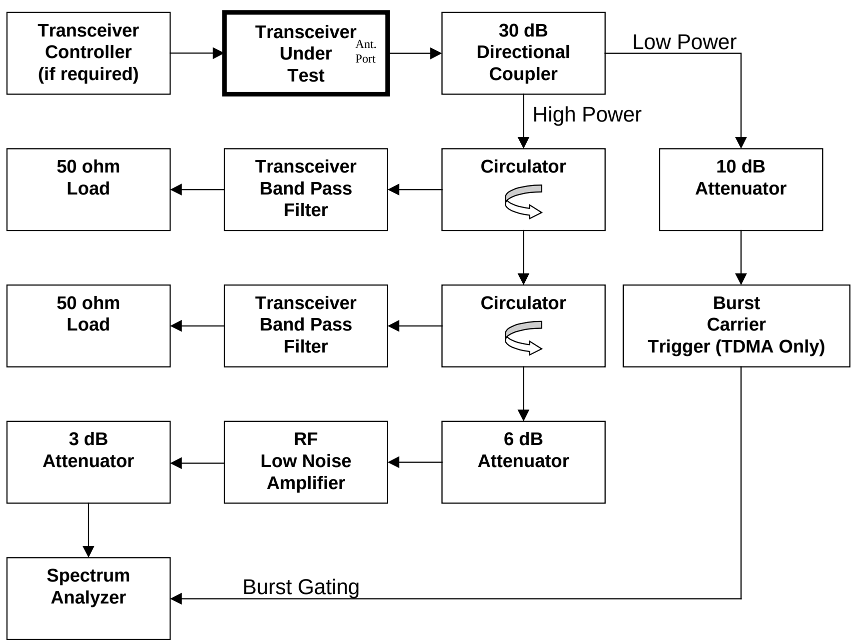
Network Analyzer, 100 Hz - 3 GHz (HP 8753A or appropriate equivalent)
Spectrum Analyzer, to 2.9 GHz (Rohde and Schwartz FSEA20 or appropriate equivalent)
Spectrum Analyzer, to 22 GHz (HP 8593A or appropriate equivalent)
Burst Carrier Trigger, 10 MHz - 2 GHz (HP 85902A or appropriate equivalent)
RF Ampiflier, 0.1-1300MHz (HP 8447D or appropriate equivalent)
Satellite Network Simulator (if required)
Transceiver Test Controller (if required)

<u>Measurement Procedure</u>

<u>Notes</u>:

1. *For multicarrier transceivers, test engineers are cautioned to include the multicarrier adjustment factor of –10log10(N)-3 dB given Section 2.2.3.1.2.1.5 when determining compliance. Multicarrier transceivers are permitted less HSN power than single carrier units.*

2. *The HP8447D amplifier must be characterized for each band of interest between 10 kHz and 1675 MHz.*

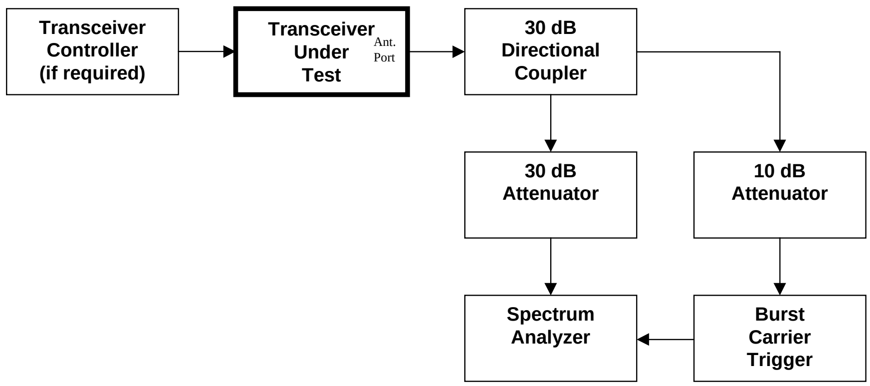


<u>Figure 2-14</u> Harmonic, Spurious, Noise Wide Band Emissions Test Set Up

<u>Emissions from 950 MHz to 1675 MHz, not including</u> $0.99675\, f_{TMN}$ to $1.00325\, f_{TMX}$

Connect the equipment as shown in Figure 2-14. Measure and record the loss from the transceiver output to the spectrum analyzer input within an accuracy of +0.5 dB for each band of interest. Command the transceiver transmitter to output a single modulated carrier at maximum individual carrier power level at the valid operating frequency closest to the center of the transmit operating band. Measure the power out of the 3 dB attenuator using the spectrum analyzer.

With the transmitter operating at the maximum rated power output setting, use the spectrum analyzer to determine the composite harmonic, spurious and noise output of the transmitter in each band of interest from 0.01 kHz to 1675 MHz, excluding the band $0.99675\,f_{TMN}$ to $1.00325\,f_{TMX}$. Using the total know loss of the 30 dB directional coupler, the two circulators, and the 6 dB and 3 dB attenuators, the RF low noise amplifier gain, and all associated interconnects, correct the measured power levels to provide an absolute transceiver output power. Compute the average power output level as defined in Section 1.7, and verify compliance.



<u>Figure 2-15</u> Harmonic, Spurious, Noise Near Passband Frequency Test Set Up

<u>Emissions within</u> $0.99675\,f_{TMN}$ to $1.00325\,f_{TMX}$

Connect the equipment as shown in Figure 2-15. Command the transceiver transmitter to output a single modulated carrier at maximum individual carrier power level at the valid operating frequency closest to the center of the transmit operating band. With the transmitter operating at the power level above, use the spectrum analyzer to measure the composite harmonic, spurious and noise output of the transmitter over the frequency ranges of $0.99675\,f_{TMN}$ to $1.00325\,f_{TMX}$. Using the normalization factor computed above, convert this measurement to the Average power output at the transceiver output port, as defined in Section 1.7, and verify compliance.

Repeat the above measurements with a modulated individual carrier output at the transmission test frequencies given in Section 2.2.3.1.1.4.

<u>Harmonics Testing from 1675 MHz to 18GHz</u>

Connect the equipment as shown in Figure 2-16. Command the transceiver transmitter to output a single modulated carrier at maximum individual carrier power level at the valid operating frequency closest to the center of the transmit operating band. With the transmitter operating at the power level above, use the spectrum analyzer to measure the composite harmonic output of the transmitter over the frequency ranges of the 2nd through *M-th* harmonics of the carrier frequency, where $M = \left\lfloor \frac{18 \times 10^9 \text{ Hz}}{f_{tmn}} \right\rfloor$ and $\lfloor * \rfloor$ is the "greatest integer less than" function. Span for $\pm M \times (f_{TMX} - f_{TMN})$ about each harmonic with a resolution bandwidth of 3 MHz or $\frac{1}{2}(f_{TMX} - f_{TMN})$, whichever is less. Convert the measured spectral densities to the equivalent levels at the transceiver output using the reference level measured above. Compute the average power output level as defined in Section 1.7, and verify compliance.

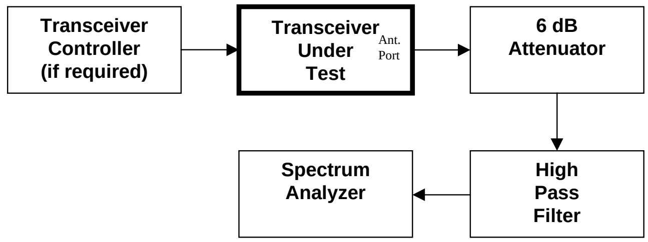


Figure 2-16 Harmonic Emissions Test Set Up

Repeat the above measurements with a modulated individual carrier output at the transmission test frequencies given in Section 2.4.3.1.1.4.

2.4.3.1.2.1.6 Composite Emissions in the Radio Astronomy Band
Reference: Section 2.2.3.1.2.1.6.1, 2.2.3.1.2.1.6.2

This test applies only to equipment capable of radiating multiple carriers. The same test procedure is used for an AES subject to Section 2.2.3.1.2.1.6.1 and AES subject to Section 2.2.3.1.2.1.6.2.

Equipment Required

Same as Section 2.4.3.1.2.1.3. This test must be conducted using the active satellite constellation, and is subject to the constraints noted in Section 2.4.1.1.2.

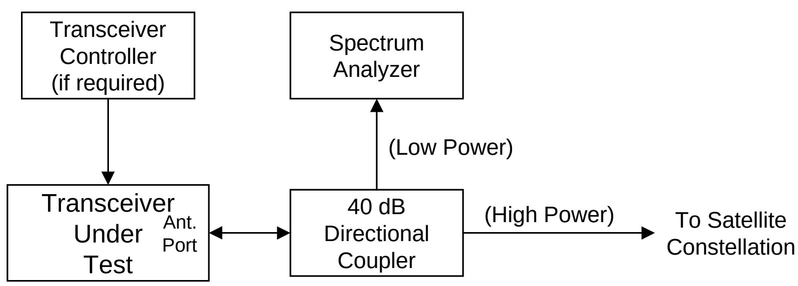


Figure 2-17 Composite IM/HSN Test Setup

Measurement Procedure

1. Connect the equipment as shown in Figure 2-17.
2. Set the spectrum analyzer measurement bandwidth to 10 kHz.
3. Enable the mutichannel AES and establish two data channels or virtual circuits (voice circuits shall be used if the nominal voice power is higher) through the constellation.

4. Transmit random data over both data channels or virtual circuits and collect spectrum analyzer estimates in the 1610.6-1613.8 MHz band as rapidly as possible. During the test period, any period in which both circuits are not operational shall not be counted as part of the test. In the event a connection is lost, re-establish the failed connection and continue the measurement as if the communications had been continuous. Continue until the test period reaches one hour. Using a computer-generated 2000 second window, compute the average power over the 2000 second interval. Offset the window by 100 seconds and repeat. This allows 16 measurements in the 1 hour data sample.

5. Repeat Steps 2-3 until 100 2000 second windows have been collected.

6. Find the maximum average power among the 2000 second data sets. Adjust the spectrum by the measured value of the directional couplers. Verify compliance with the requirements of Section 2.2.3.1.2.1.6.

7. Repeat Steps 1-6, with the frequency range of interest being 1660-1670 MHz.

2.4.3.1.2.1.7 Carrier Off Level

Reference: Section 2.2.3.1.2.1.7

Equipment Required

Dual Calibrated Directional Coupler, 20 dB coupling, 20 watts or greater average power rating
Directional Coupler, 30 dB coupling, 20 watts average power (NARDA Model 3002-30 or appropriate equivalent)
High Power Load, 50 ohms, 20 watts or greater average power rating (RLC Electronics Inc. Model T-1005 or appropriate equivalent)
Precision Calibrated Attenuator, 20 dB (NARDA 757C-20 or appropriate equivalent)
Power Meter (HP 435B, HP438A, or appropriate equivalent)
Power Sensor, -30 to +20 dBm, 0.1 to 4.2 GHz (HP 8482A or appropriate equivalent)
Satellite Network Simulator (if required)
Transceiver Test Controller (if required)

Measurement Procedure

Connect the equipment as shown Figure 2-18. Replace the spectrum analyzer with the power meter and measure the output power. Using the measured value of couplers, establish the reference level at the receiver output. Replace the spectrum analyzer. Command the transceiver transmitter to output a single unmodulated carrier at maximum individual carrier output power, and at the valid operating channel closest to the center of transmitting band. Measure the level of the carrier with the spectrum analyzer.

Command the transmitter off; i.e., no carrier present. Measure the total power output within the transmit band to verify that operation is within specifications.

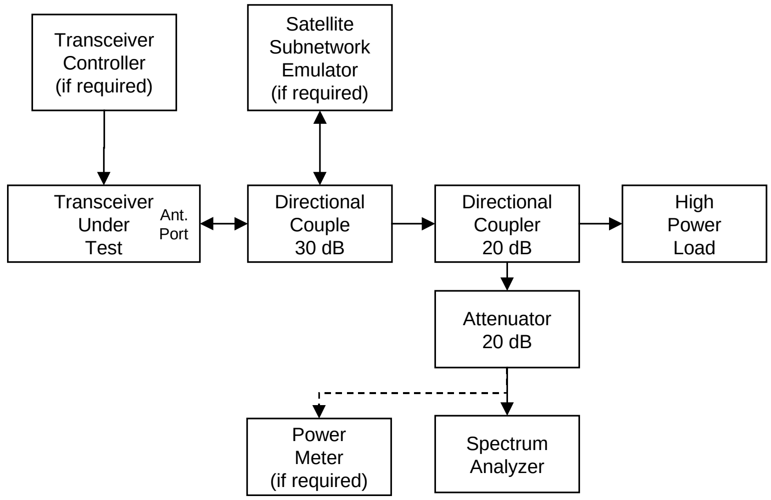


Figure 2-18 Carrier Off Level Test Setup

2.4.3.1.2.1.8 Power Control

Reference: Section 2.2.3.1.2.1.8

Equipment Required

Dual Calibrated Directional Coupler, 20 dB coupling, 20 watts or greater average power rating
Directional Coupler, 30 dB coupling, 20 watts average power (NARDA Model 3002-30 or appropriate equivalent)
High Power Load, 50 ohms, 20 watts or greater average power rating (RLC Electronics Inc. Model T-1005 or appropriate equivalent)
Two Precision Calibrated Attenuators, 20 dB (NARDA 757C-20 or appropriate equivalent)
Dual Power Meter (HP 438A or appropriate equivalent)
Two Power Sensors, -30 to +20 dBm, 0.1-4.2 GHz (HP 8482A or appropriate equivalent)
Satellite Network Simulator (if required)
Transceiver Test Controller (if required)

Configure the test as in Figure 2-11.

Enable the transmitter and initiate a communications session on a single channel at a mid-band test frequency. Use the transceiver control or satellite system emulator, as appropriate; to adjust the burst output power from the minimum to the maximum and back in the minimum steps.

At each power setting, measure the average power transmitted over a 10 second interval. Verify that the transmissions can be adjusted in accordance with Section 2.2.3.1.2.1.8.

2.4.3.1.2.1.9 On-Channel Output Spectrum

Reference: Section 2.2.3.1.2.1.9

The on-channel spectrum shall be verified as part of the Satellite Network operational certification process, as described in the appropriate technique-specific appendix.

2.4.3.1.2.1.10 Transmitter Operation in Moving Aircraft
Reference: Section 2.2.3.1.2.1.10

Equipment Required

Calibrated Directional Coupler, 20 dB coupling, 20 watts or greater average power rating
Directional Coupler, 30 dB coupling, 20 watts average power (NARDA Model 3002-30 or appropriate equivalent)
High Power Load, 50 ohms, 20 watts or greater average power rating (RLC Electronics Inc. Model T-1005 or appropriate equivalent)
Precision Calibrated Attenuator, 20 dB (NARDA 757C-20 or appropriate equivalent)
Single Directional Coupler, 20 dB coupling, 1-2 GHz (NARDA Model 4012C-20 or appropriate equivalent)
Spectrum Analyzer, 100 Hz - 18 GHz (HP 8566B or appropriate equivalent)
Satellite Network Simulator
Transceiver Test Controller (if required)

For constellation-based testing

Adjustable precision frequency generator suitable for specific AES design.

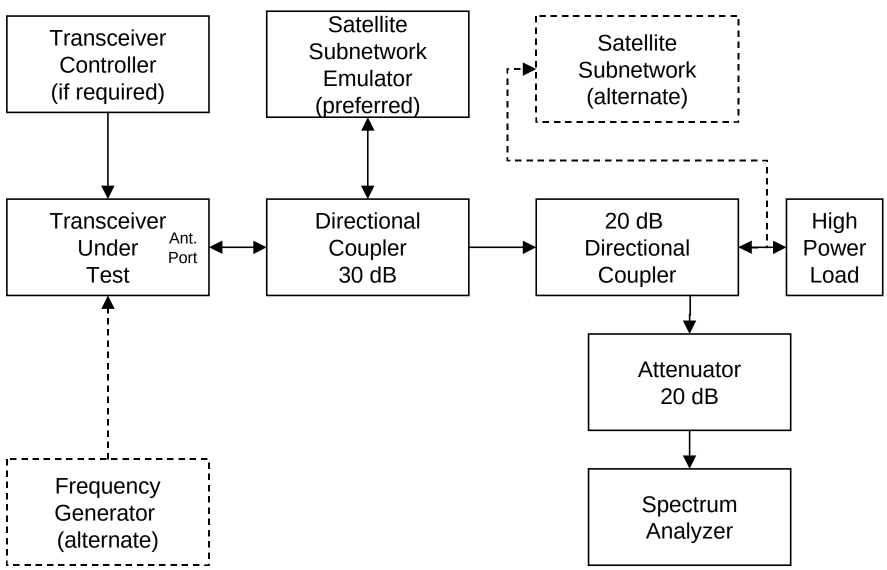


Figure 2-19 Moving Aircraft (Doppler) Test Setup

Measurement Procedure

Connect the equipment as shown in Figure 2-19. Adjust the Satellite Subnetwork Emulator to reduce its communications frequencies by an amount in Hertz equal to

$$1.715 \times 10^{-3} \times v \times f_{TMX},$$

where v is the maximum relative aircraft-satellite velocity in knots,
and f_{TMX} is the maximum transmit frequency in MHz.

Set the Satellite Subnetwork Emulator to simulate a satellite geometry corresponding to the worst case relative velocity between the satellite and the AES. Verify that the AES can initiate and receive communications in all specified modes. Verify that the AES can maintain a continuous connection with the Satellite Subnetwork Emulator for at least 60 seconds under the worst case relative velocity.

Repeat the test with the transmit frequencies increased by the amount given above.

Alternatively, it is acceptable to offset the AES reference frequency so that the AES maximum transmit frequency is reduced by the amount computed above, and then, with the AES offset in this manner, communicate with the operational constellation. If the constellation is used, the requirements of Section 2.4.1.1.2 shall be observed. If the constellation is used, the testing shall be timed to coincide with the occurance of the worst case relative velocity between the satellite and the stationary AES.

Note: Use of the alternative test procedure may require additional AES interfaces, as noted in Section 2.2.3.1.2.1.10.

2.4.3.1.2.2 Receiver

2.4.3.1.2.2.1 Receiver Sensitivity

2.4.3.1.2.2.1.1 Receiver Sensitivity (Data)

Reference: Section 2.2.3.1.2.2.1.1

Equipment Required

Dual Calibrated Directional Coupler, 20 dB coupling, 20 watts or greater average power rating
Precision Calibrated Attenuator, 20 dB (NARDA Model 757C-20 or appropriate equivalent)
Dual Power Meter (HP 438A or appropriate equivalent)
Power Sensor, -30 to +20 dBm, 0.1-4.2 GHz (HP 8482A or appropriate equivalent)
Directional Coupler, 30 dB coupling, 20 watts average power
High Power Load, 50 ohms, 20 watts or greater average power rating
Satellite Network Simulator (if required)
Transceiver Test Controller (if required)
Computerized Data Collection Unit

Measurement Requirments

Notes:

1. *Considering the very low signal levels required and the small tolerance allowed, measures should be taken to avoid possible leakage problems from the test signal generator.*

2. *This test uses a digital data interface to collect data transmitted over the network. It is permissible to use the data interface tested in Section 2.4.3.6.4, provided that the "number of bits received" includes any protocol bits required for interfaces to the "higher level entity". In any case, the manufacturer shall verify that the digital data*

interface has sufficient bandwidth to service the declared end-user throughput. For example, a 2400 bps satellite path must be tested with a digital data interface of not less than 2400 bps.

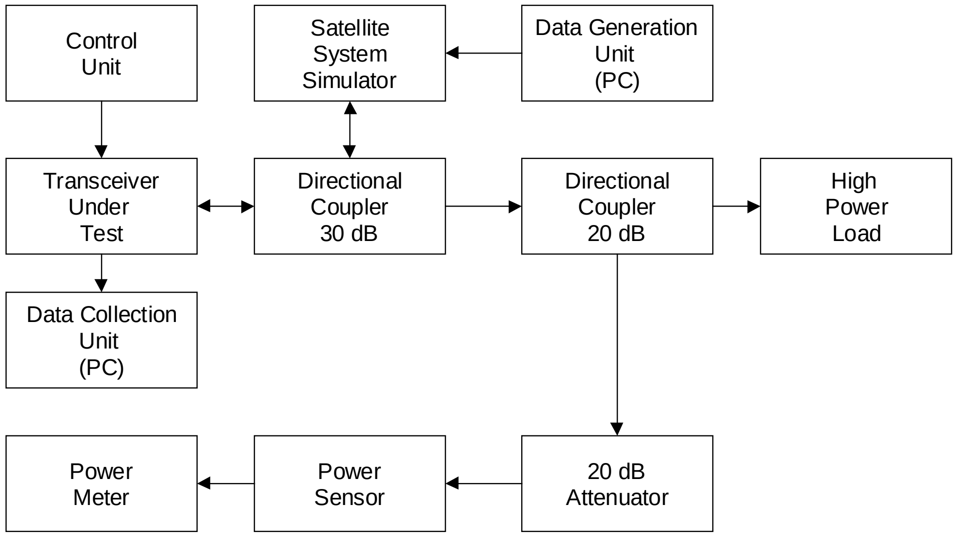


Figure 2-20 Transceiver Sensitivity Test Set Up

Perform the following steps:

1. Connect the equipment as shown in Figure 2-20. The sensitivity of the transceiver will first be measured at ambient temperature. Command the transceiver to receive a data signal on a valid traffic channel, on a channel frequency near the center of the receive band.

2. Command the Satellite Network Simulator to establish a data connection with the AES.

3. Generate an extended sequence of data bits from a simulated user source using a suitable Data Generation Unit. The total number of data bits, N_{DATA}, and the test duration time, T_{TEST}, shall be chosen to ensure that the probability of accepting a unit which sustains a rate of less than 99% of the nominal user throughput rate is less than 5%.

4. Command the Satellite Network Simulator to send the entire sequence of data bits to the AES. Adjust the test signal level at the antenna port to the Input Signal Power as listed in Section 2.2.3.1.2.2.1 for the desired nominal rate.

5. Using a suitable external device, collect the all output bits from the external data interface of the AES received during the test interval T_{TEST}. At the conclusion of the test interval, compute the average throughput rate during the interval by:

$$\bar{R}_{USER} = \frac{\text{number of bits received}}{T_{TEST}} \geq R_{SC-UD}.$$

For this computation, the number of bits received must be adjusted to account for any SSNDP protocol bits which are transmitted within the user payload as well as any external interface protocol bits generated between the AES and the data collection unit. Internal protocol bits are not included in the number of bits received. SSNDP protocol bits may be included only if they are passed to the data collection device.

6. Determine compliance by comparing the average value of the throughput, computed in Step 5, with the selected data rate from Section 2.2.3.1.2.2.1.

7. Repeat Steps 1-6 for the nominal user data rates specified in Section 2.2.3.1.2.2.1.

8. Repeat Steps 1-7 for the receive frequencies corresponding to the transmitter test frequencies identified in Section 2.4.3.1.1.4.

Note: *If the AES provides a Data-2 interface capability, it may simplify the test to use the Data-2 interface, thereby eliminating a layer of protocol.*

2.4.3.1.2.2.1.2 Receiver Sensitivity (Voice)

Reference: Section 2.2.3.1.2.2.1.2

Note: *The receiver sensitivity for Voice Services is tested as part of the Voice Test Procedures detailed in Section 2.4.3.5.*

2.4.3.1.2.2.2 Receiver Bandwidth

Reference: Section 2.2.3.1.2.2.2

Note: *The receiver bandwidth has been tested by Step 8 of the test procedure specified in* Section 2.4.3.1.2.2.1.

2.4.3.1.2.2.3 Rejection of Signals Outside NGSS Receive Band
Reference: Section 2.2.3.1.2.2.3

Required Equipment:

Directional Coupler, 30 dB coupling, 20 watts average
Synthesized Signal Generator, f_{RMN} to f_{RMX} MHz frequency range
Synthesized Signal Generator(s), 470 MHz to f_{RMN} MHz
Synthesized Signal Generator(s), f_{RMX} to 18,000 MHz
Directional Coupler, 20 dB coupling (NARDA Model 3002-20 or appropriate equivalent)
High Power Load (RLC Electronics Inc. Model T-1005, or appropriate equivalent)
Transceiver controller (if required)
Satellite Subnetwork Emulator (preferred)
AES antenna (alternate)

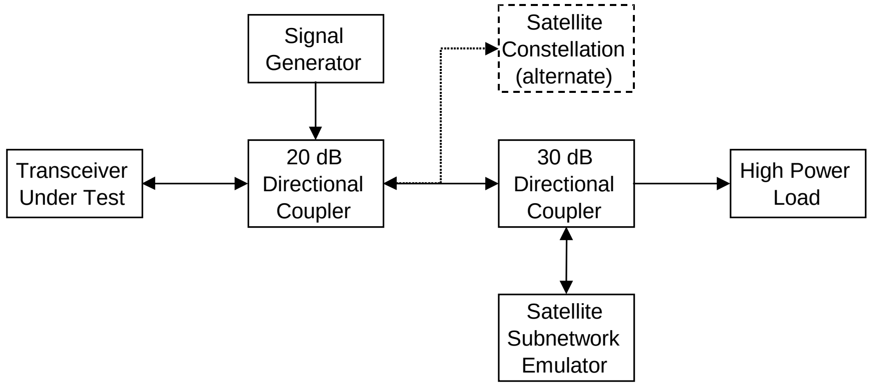


Figure 2-21 Test Set Up for Rejection of Signals Inside and Outside of Band Tests

Measurement Procedure

This is a two-part procedure. In Part One, the receiver design is analyzed to identify potential analog image and spurious response frequencies and possible digitally-induced aliases. In Part Two, the receiver is tested to determine if the receiver performance is degraded, causing loss of communications, by any of the signals identified in Part One.

Part One:

Prior to the start of the test, analyze the transceiver under test to determine required input test frequencies. All IF and reference frequencies used within the transceiver must be known. Using these frequencies, calculate all frequencies within the ranges specified in Section 2.2.3.1.2.2.3, which have the potential to produce image or spurious signals. The calculations should include image frequencies and mixer harmonic intermodulation distortions through 11th order which are capable of producing IF frequencies used within the transceiver, or subharmonics of these IF frequencies, and such frequencies that may lead to digital aliasing problems or other spurious responses.

Part Two:

Connect the measurement equipment as shown in Figure 2-21. Tune the receiver to the operational frequency closest to $\frac{1}{2}(f_{RMN} + f_{RMX})$. With the sweep generator turned off, set the Satellite Subnetwork Emulator to initiate communications with the transceiver, Turn on the sweep generator. Adjust its output to produce signal levels into the transceiver as specified for each of the frequency ranges in Section 2.2.3.1.2.2.3. Sweep the frequency over the critical frequency sub-ranges identified in Part One. Choose the sweep rate so that any satellite sub-network timers designed to coast through interference bursts time out during the sweep of any specific subband. Verify that communications are not interrupted by observing that voice connections are not lost and data connections maintain the desired user throughput rate.

Repeat the test over the entire frequency range of Section 2.2.3.1.2.2.3 using the sweep rate identified in the previous step.

Repeat these tests with the transceiver tuned to frequencies of f_{RMN} and f_{RMX} and verify operation to specification.

Note: As an alternative to Part Two, this test may be performed using the operational constellation, provided the considerations of Section 2.4.1.1.2 are met. If the operational constellation is used, tests should be timed to coincide with the worst case satellite geometry declared by the satellite system operator.

It is anticipated that some NGSS-based AES equipment may use embedded transceiver devices for the underlying satellite network. In such cases, transceiver manufacturer test data on the individual transceiver units may be acceptable alternative to performing the tests at the AES level, provide that such data essentially reproduces the tests described above.

2.4.3.1.2.2.4 Rejection of Carrier Signals Generated by Other AMS(R)S Equipment
Reference: Section 2.2.3.1.2.2.4

Required Equipment:
Same as Section 2.4.3.1.2.2.3

Measurement Procedure

Repeat the test procedure of the Section 2.2.3.1.2.2.4 using the interference frequencies and signal levels given in Section 2.2.3.1.2.2.4.

2.4.3.1.2.2.5 Receiver Operation in Moving Aircraft
Reference: Section 2.2.3.1.2.2.5

Required Equipment:
Same as Section 2.4.3.1.2.1.10

Measurement Procedure:

Repeat the tests of Section 2.4.3.1.2.1.10, substituting the appropriate receive frequencies defined in the technique specific appendix for the transmit frequencies of Section 2.4.3.1.2.1.10 wherever appropriate. Verify that communications can be established and maintained with frequency offsets corresponding to the maximum velocities give in Section 2.2.3.1.2.2.5.

2.4.3.1.3 Required Aircraft Interfaces
Reference: Section 2.2.3.1.3

To the extend that specific aircraft interfaces are required by the specific satellite subnetwork, they shall be tested in accordance with the satellite network provider certification process discussed in the technique specific appendix.

2.4.3.2 Satellite Subnetwork Specific Test Requirements
Reference: Section 2.2.3.2

This document envisions the use of commercial satellite communications systems for AMS(R)S and general AMSS services. It is expected that each commercial satellite system operator will have a unique set of access requirements that must be satisfied before a terminal, or family of terminal, is granted access to the network. The AES shall satisfy all network access requirements, including compatibility and interoperability testing, required by the satellite network operator. The AES manufacturer shall make the results of such network access certification testing available to civil aviation authorities as required to facilitate certification for safety service.

The satellite network access certification procedures shall be identified in the system-specific appendix. Appendices applicable to specific systems are identified in Section 2.2.3.2 of this document.

2.4.3.3 Priority, Precedence and Preemption

The test procedures of the following subparagraphs assume that the AES is capable of serving both AMSS (Priority Level 1 [low] in Table 2-4) and AMS(R)S (Priority Level 2 Priority Level 3, and Priority Level 4 [high]). If the system being tested support solely AMS(R)Service, references to Priority Level 1 may be replaced with Priority Level 2.

2.4.3.3.1 Packet Data

Reference: Section 2.2.3.3.1

Equipment Required

This test requires the ability to establish N_D simultaneous packet data channels using the AES under test. This may require multiple AES control units or multiple digital interfaces from a single control unit. Each interface must be capable of sustaining a bit rate of at $2R_{SC\text{-}UD}$. If a single interface is used to contol all N_D packet data channels, that interface must be capable of sustaining a bit rate of $2(N_D)R_{SC\text{-}UD}$.

Measurement Procedure

The precedence and preemption test procedures are designed to verify the AES's ability to determine the precedence of packet-mode data and preempt, if necessary, lower-priority AGPDUs.

1. Data Communications Setup

Utilizing the appropriate SNAcP interface and commands, create N_D independent packet data channels between the AES and either the system test simulator or an appropriate GES. For the purpose of this test, label these independent channels Channel A, Channel B, etc. (For the purposes of this test description, we will assume N_D=4).

2. DATA packets from Data packets

This test verifies proper ordering of AGPDUs according to the link layer precedence of the data packets arriving at the AES.

a. Using the external interface send a message consisting of L_{SNDP} +10 octets of data over the established channels in the following order: Channel A, Channel C, Channel B, Channel D. Fill the User Data Field with following patterns:

For	For	Pattern
channel D	priority 4 (high)	01010101
channel C	priority 2	10101010

channel B	priority 3	11001100
channel A	priority 1 (low)	00110011

These packets shall be sent to the AES interface at the maximum rate supported by the external interface hardware.

Verify that the AES sends data packets over the subnetwork in priority order, with higher priority packets transmitted first.

b. For equipment that does not support Priority Level 1 (low, non-safety) communications, create a data stream that alternates the data fields from step (a) and the Priority 1 data stream from step (a). Verify that only Priority 2, 3, and 4 packets are transmitted.

Note: *AES designs that choose to implement an ISO-8208 compliant interface may satisfy this requirement by means of the tests specified in Appendix B,* Section *3.1.2.*

2.4.3.3.2 Circuit Mode Communications

Reference: Section 2.2.3.3.2

Equipment Required

This test requires the ability to initiate and terminate *N* simultaneous circuit-mode calls through the satellite network. Depending on the specific sub-network, this may require *N*telephone lines or *N*satellite network mobile terminal channels. This test makes no assumptions about the capabilities of these circuit-originating and circuit-terminating devices. It is permissible to utilize a separate AES, independent of the AES under test, in this role.

This test is not intended to verify the ability of the satellite network or the satellite sub-network as a whole, to satisfy the Priority, Precedence and Preemption requirements of the MASPS. This test should be coordinated with the satellite network operator to ensure that appropriate satellite capacity exists for the completion of the test. Such coordination may require that the test be performed in off-peak traffic hours.

Test Procedure

This test assumes that the AES is capable of *N* channels of simultaneous circuit-mode operation. The value of *N* shall be declared before the test is started. Perform the following steps:

1. Establish *N* voice calls at non-safety circuit-mode priority, Priority Level 1 (low), identified in Table 2-7.

2. While monitoring the Priority Level 1 (low) calls, attempt to establish an air-to-ground call at Circuit-Mode Priority 2 identified in Table 2-7. Verify that one of the non-safety circuits is terminated and made available for the safety call, and that the call is completed.

3. Repeat Step 2 until all channels are consumed by Priority 2 calls.

4. Repeat Steps 2 and 3 with Priority 3 calls.

5. Repeat Steps 2 and 3 with Priority 4 (high) calls.
6. At the completion of Step 5, there will be N Priority 4 (high) calls established. Attempt to initiate an air-to-ground call at Priority 3, and verify that the call is not accepted.

7. Attempt to initiate an air-to-ground call at Priority 2, and verify that the call is not accepted.

8. Attempt to initiate an air-to-ground call at Priority 1 (low), and verify that the call is not accepted. This step shall be performed for all equipment, including equipment that does not support Priority 1 (low) non-safety communications.

9. Terminate all calls, and re-establish Step 1 with Priority 1 (low) calls.

10. Repeat Steps 2 through 8 using ground-to-air calls and verify that the same results are obtained.

2.4.3.4 Satellite Subnetwork data Protocol (Satellite Layer 2)

Reference: Section 2.2.3.4

AES compliance with Sub-network specific protocol requirements shall be verified by means of the satellite network access certification identified in the system-specific appendix. Appendices applicable to specific systems are identified in Section 2.2.3.2 of this document. The comments contained in Section 2.4.3.1.3 apply to this verification procedure as well.

2.4.3.5 Voice Protocol

Reference: Section 2.2.3.5

Compliance with the system-specific protocols shall be verified by means of the satellite network operator certification process identified in the normative technique-specific appendix. Acceptable evidence of such compliance is a certification document from the satellite network provider.

2.4.3.5.1 Vocoder Interoperatiblity With Satellite Subnetwork

Section 2.2.6 permits the use of a "100% compatible" vocoder algorithm. If algorithm other than the specific algorithm identified in the relevant system-specific appendix, including version and part number, is selected, it shall be the responsibility of the manufacturer to develop test procedures and documentary evidence that complete interoperability is achieved. These procedures shall be approved by satellite network operator prior to the start of testing. Because of the complexity of such vocoder design and testing issues, these tests are not specifically identified in this document.

All AES vocoders shall demonstrate compliance with Sub-network specific vocoder requirements by means of the satellite network access certification identified in the system-specific appendix. Appendices applicable to specific systems are identified in Section 2.2.3.2 of this document. The comments contained in Section 2.4.3.1.3 apply to this verification procedure as well.

2.4.3.5.2 Vocoder Performance in an Aeronautical Environment

For AES equipment intend for safety voice applications shall verify that the vocoder is suitable for the aeronautical cockpit environment when operating in the noise environments identified in Section 2.2.3.5.2 by conducting statistically significant comparison tests with the 9600 bps vocoder specified in RTCA DO-210D and the Annex 10, Chapter 4 SARPs.

2.4.3.6 User Data Interfaces

The option of providing an ATN-compliant protocol is tested in Section 2.4.3.6.1. The option of providing a Data-2 interface is tested in Section 2.2.3.6.2. An AES must pass either or both sets of tests, depending on the capabilities declared in the technique-specific appendix.

If an ISO-8208 compliant interface is provided as the ATN interface, the tests are described in Appendix B. Satellite subnetwork-dependent validation is discussed in the appropriate appendix to this document.

2.4.3.6.1 ATN Interfaces

Reference: Section 2.2.3.6.1

The requirements established in Section 2.2.3.6.1 concern the implementation of an Data Circuit-terminating Equipment (DCE) interface on the digital side of the AES. To verify the proper functionality of that interface, it is necessary to issue certain commands and analyze certain responses from both a simulated Data Terminal Equipment (DTE) external to the AES and from a correponding simulated DTE external to the GES. One means of verifying compliance would be to probe the radio-frequency emissions of the AES, back out the satellite-network signal-in-space, Layer 1 and Layer 2 and possible Satellite Subnetwork Dependent Protocols, and confirm transmission of the proper DCE-DCE message traffic. This approach requires the ability to simulate the signal processing of the entire satellite network, including its ground terminals and gateways to the public and private networks. This is a complex and expensive process.

The same information can be obtained, however, by using the satellite network directly, and examining the data at the output of the GES. The potential exists to remotely access this information so that the entire testing is performed in a closed loop from a single location, as shown in Figure 2-22.

<u>Note</u>: *Use of the Active Satellite Sub-Network for performance testing is subject to the restrictions identified in Section 2.4.1.1.2 of this document.*

2.4.3.6.1.1 Join and Leave Requirements

Reference: Section 2.2.3.6.1.1

Verify that a Join event message in accordance with Section 2.2.3.6.1.1 is transmitted to the routing function upon determination of availability of the air/ground data link. Similarly, verify that a Leave event message is transmitted upon determination of non-availability of the air/ground data link.

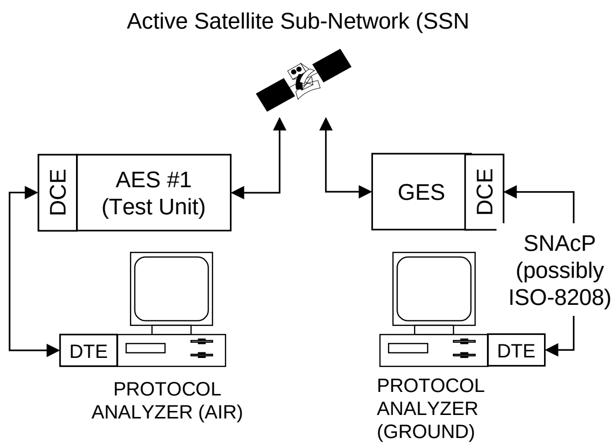


Figure 2-22 High-Level Test Set Up for DCE Interface Testing

2.4.3.6.1.2 ATN-compliant Mapping for Priority, Precedence, and Preemption
Reference: Section 2.2.3.6.1.2

This test establishes only that the satellite subnetwork properly maintains the subnetwork priority field, not that the priority, precedence and preemption mechanisms are implemented. Perform the following steps:

1. Using the standard packet data test setup up shown in Figure 2-22, use the PAG to send packets with values the priority field in the appropriate call set-up packet set to the value corresponding to the lowest priority. Use the PAA to verify that the associated received packet contains the same value. Verify that the priority is confirmed back to the PAG. Use the appropriate procedure to clear the resulting call.

2. Repeat Step 1 with values in the priority field set to increasing levels of priority. For systems capable of both safety and non-safety communications, verify that a minimum of four levels of priority are supported, in accordance with Table 2-7. For systems capable of only safety communications, verify that a minimum of three levels of priority are supported, in accordance with Table 2-7.

3. Repeat the Step 1 and Step 2 tests with the roles of the PAA and PAG reversed.

2.4.3.6.2 Data 2
Reference: Section 2.2.3.6.2

Systems providing Data-2 interface shall be tested in accordance with the test procedures referenced in the appropriate subnetwork-specific appendix.

2.4.3.6.3 Satellite Subnetwork

2.4.3.6.3.1 Satellite Subnetwork Dependent Protocol
Reference: Section 2.2.3.6.3.1

Experimental verification that the requirements of Section 2.2.3.6.3.1 have been met could require an inordinate amount of test time, due to the extremely small packet error rates permitted. Therefore, compliance these requirements shall be demonstrated by analysis or simulation of the protocols involved in reliable packet transmission. Guidance for such analytical methods may be found in the MASPs and DO-215A, Change 1.

SSNDP test procedures and AGP sub-layer test procedures are specified in the technique-specific appendix or referenced documents.

2.4.3.6.4 Avionics Subnetwork Interface
Reference: Section 2.2.3.6.4

Equipment Required

Test Set/Protocol Analyzer (2), one designated as Protocol Analyzer Air (PAA), one designated as Protocol Analyzer Ground (PAG)
Remote access equipment to compatible data port at GES; or, alternatively, a GES Emulator
Appropriate cabling and antenna for access to the Satellite Subnetwork, or, alternatively,
Directional Coupler, 30 dB coupling, 20 watts average power rating
High Power RF Load, 50 ohms, minimum 20 watts average power rating

2.4.3.6.4.1 ATN Compliant Physical and Data Link Requirements

If an ISO-8208 compatible interface is provided to meet the ATN interface requirements, it shall be tested in accordance with the provisions of Appendix B.

If an alternate ATN interface is provided, it shall be tested in accordance with the test provisions for that interface. All test provisions shall provide equivalent rigor to the procedures contained in Appendix B.

2.4.3.7 Circuit Mode Test Procedures
Reference: Section 2.2.3.7

The requirements for circuit-mode voice service shall be tested during the satellite network operator certification process. Performance of circuit mode voice service in an AMS(R)S environment is tested in Section 2.4.3.5.2.

The requirements for circuit-mode priority, precedence and preemption have been tested in Section 2.4.3.3.2.

2.4.3.8 Recovery from Primary Power Interrupt Test Procedure
Reference: Section 2.2.3.8

Equipment Required

Oscilloscope
Programmable Interruptible Power Supply, HP6834A or equivalent

This test requires access to the satellite network, in accordance with the constraints of Section 2.4.2.1.2.2.

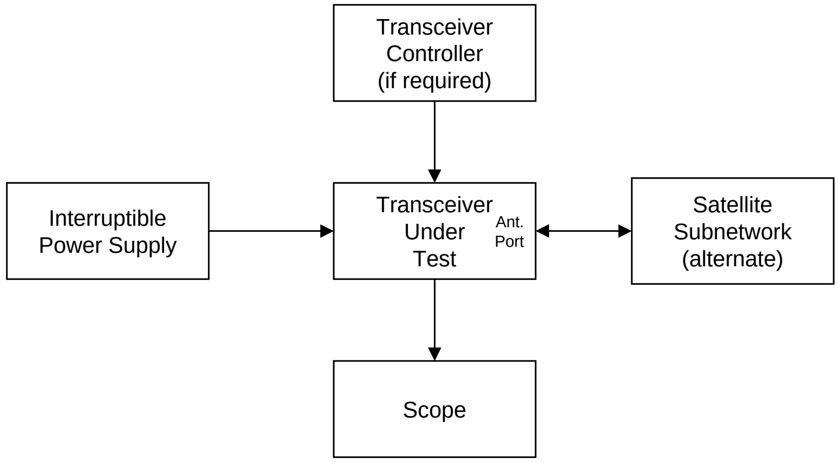


Figure 2-23 Power Interruption Test Set-Up

Setup the equipment as shown in Figure 2-23. Initiate a communications session in every mode (i.e., voice, packet data, circuit data) supported by the AES. While continuously maintaining the communications session, monitor the receiver digital or audio output on the scope. Apply power interruptions of 5 ms and observe no dropout of output whatsoever. Apply 200 ms interruptions and verify that the output recovers within 5 seconds and verify the data link functions are unaffected.

2.4.3.9 Failure/Status Indication Test Procedure

Reference: Section 2.2.3.9

Equipment Required

Programmable Attenuator, 20 W, 0-30 dB in 3 dB steps
Transceiver Controller
AES status monitor – This may be a protocol analyzer for any convenient digital data bus supported by the equipment under test, such as ARINC 429, IEEE 802.3, etc. The PAG may be used for this purpose, if desired.
This test requires access to the satellite network, in accordance with the constraints of Section 2.4.2.1.2.2.

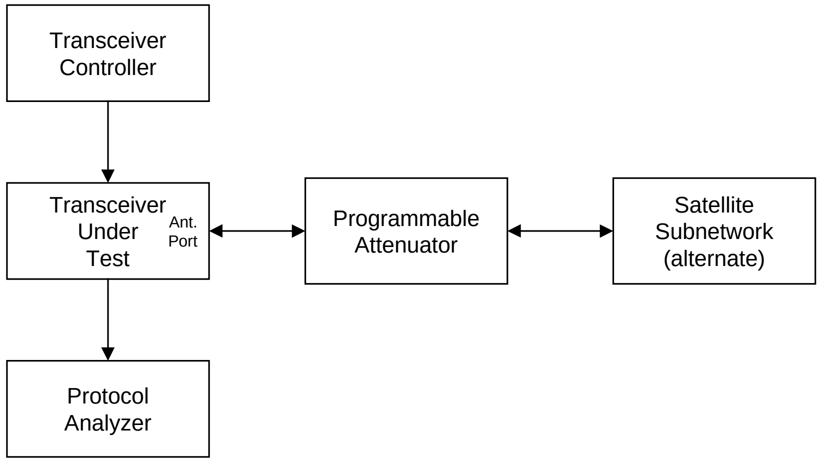


Figure 2-24 Failure/Status Indication Test Setup

Test Procedure

Connect the equipment as shown in Figure 2-24. For each of the communications modes supported by the AES (i.e., voice, packet data, circuit data as applicable) initiate a communications session through the satellite network with the AES. Use the protocol analyzer to verify that the AES communications is reported as AVAILABLE or its equivalent. Using the programmable attenuator, increase the loss between the AES and the satellite until communications with the satellite are lost. Verify that the status is reported as UNAVAILABLE or its equivalent. Return the attenuation to its original setting and verify that the status returns to AVAILABLE.

3 INSTALLED EQUIPMENT PERFORMANCE

3.1 Equipment Installation

3.1.1 Accessibility

Controls and monitors provided for in-flight operation shall be readily accessible from the appropriate operator's normal seated position. The operator/crew member(s) shall have an unobstructed view of the display(s) or controls when in the normal seated position.

3.1.2 Aircraft Environment

Equipment shall be compatible with the environmental conditions present in the specific location in the aircraft where the equipment is installed.

3.1.3 Display Visibility

All installed system displays shall be readily visible and readable from the operator's/-crew member's normal position in all ambient lighting conditions for which system use is required.

<u>Note</u>: *Visors, glareshields, or filters may be an acceptable means of obtaining daylight visibility.*

3.1.4 Inadvertent Turn-Off

Where controls for transceiver operation are provided, they shall be equipped with adequate protection against inadvertent turn off.

3.1.5 Failure Protection

Any probable failure of the equipment shall not degrade the normal operation of equipment or systems that are connected to it. Likewise, the failure of interfaced equipment or systems shall not induce failures of this equipment.

3.1.6 Interface Interference Effects

The equipment shall not be the source of harmful conducted or radiated interference, and shall not be affected by conducted or radiated interference from other equipment or systems installed in the aircraft.

3.1.7 Aircraft Power Source

The voltage and frequency tolerance characteristics of the equipment shall be compatible with the aircraft power source of appropriate category as specified in RTCA DO-160D.

3.2 Installed Equipment Performance Requirements

The installed equipment shall meet the requirements of Section 2.0 in addition to the requirements stated below. To meet the requirements of this section, test results supplied by the equipment manufacturer may be accepted in lieu of tests performed by the equipment installer.

However, performance characteristics that cannot be tested by the equipment manufacturer shall be tested by the installer. These include: (1) performance characteristics of equipment required for the transceiver installation that have not been tested or verified by the manufacturer, and (2) interactions with other equipment installed on the aircraft.

3.2.1 Radiated Antenna Intermodulation Products in AMS(R)S Bands

This requirement applies only to installations that utilize two independent AMS(R)S systems.

When operating with two modulated carriers anywhere within the frequency band with each carrier f_{TMN} to f_{TMX}, each carrier having the maximum allowable single carrier power permitted by Section 2.2.3.1.2.1.2 of this document, the antenna subsystem shall not radiate internally generated intermodulation products in a direction toward a likely location(s) of antenna(s) on the same aircraft serving other AMS(R)S systems so as to cause a average power level that increases the effective noise temperature of the other AMS(R)S system by more than 6% In this condition, the other antenna is taken to be a quarter-wave monopole antenna matched to its load and the isolation between the AES antenna and the AMS(R)S antenna is taken to be 40 dB, or different value as declared in the system-specific appendix.

Assessment may be performed with unmodulated carriers and a calculation to account for the spreading factor due to the modulation which would normally be used.

Detailed test procedure shall be provided in the system specific material.

3.2.2 Declaration of Additional Isolation

If the AES design is based on a declaration of isolation greater than 40 dB, as allowed by Section 2.2.3.1.2.1.3, then all installations shall provide at least the declared minimum isolation.

3.3 Conditions of Test

The following Sections define conditions under which the tests specified in Section 3.4 shall be conducted.

3.3.1 Power Input

Tests may be conducted either with the equipment powered by the aircraft's electrical power generation system or by an appropriate external power source connected to the aircraft.

3.3.2 Environment

During the tests, the equipment shall not be subjected to environmental conditions that exceed those in RTCA/DO-160D as specified by the equipment manufacturer.

3.3.3 Adjustment of Equipment

Circuits of the equipment under test shall be properly aligned and otherwise adjusted in accordance with the manufacturer's recommended practices prior to application of the specified tests.

3.3.4 Warm-up Period

Unless otherwise specified, tests shall be conducted after a warm-up (stabilization) period of twenty (20) minutes.

3.4 Test Procedures for Installed Equipment Performance

The following test procedures provide one means of determining installed equipment performance. Although specific test procedures are cited, it is recognized that the installing activity may prefer alternate procedures, which may be used if they provide at least equivalent information. In such cases, the procedures cited herein should be used as one criterion in evaluating the acceptability of the alternate procedures.

3.4.1 Conformity Inspection

Visually inspect the installed equipment to determine the use of acceptable workmanship and engineering practices. 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.

3.4.2 Interference Tests

Unless otherwise specified, all aircraft electrically-operated equipment and systems shall be on, using the aircraft's electrical power generating equipment before conducting interference tests.

With the transceiver operating, including transmission of messages and voice calls, individually operate each of the other electrically-operated aircraft equipment and systems to determine that no significant conducted or radiated interference exists. Evaluate all reasonable combinations of control settings and operating modes. Operate communication and navigation equipment on at a minimum the low, high, and a mid-band, frequencies.

Operate the aircraft controls (e.g., flaps) through their range to activate all associated aircraft systems which may cause electrical power fluctuations.

<u>Notes</u>:

1. *Some aircraft contain cooling fans to augment airflow under certain low-speed conditions. These fans are activated with flaps extended and low- to mid-throttle, and cause aircraft power fluctuations when activated.*

2. *See Section 3.4.4 for requirements for message generation.*

The equipment shall not be the source of harmful conducted or radiated interference, and shall not be affected by conducted or radiated interference from other equipment or systems installed in the aircraft.

Adequate protection of on-board GNSS equipment from harmful interference due to equipment meeting the requirements of Section 2 is based on an average power level not exceeding –122 dBm referenced to the port of the GNSS antenna, the spectral width of the interfering signal(s) lies in the range of 100 to 1000 kHz.
Notes:

3. *In a typical installation, this could be achieved if:*

    a) *the transceiver meets all requirements of Sections 2.2.3.1.2.1.2, 2.2.3.1.2.1.4, 2.2.3.1.2.1.5;*

    b) *the isolation between AMSS and GNSS antennas is not less than 40 dB; and*

    c) *interfering intermodulation products generated external to the transceiver do not increase the average average power level referenced to the port of the GNSS antenna by more than 1.5 dB.*

4. *Interference problems noted upon installation of this 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 installing facility will be responsible for resolving any incompatibility between this equipment and previously installed equipment in the aircraft.*

If the equipment is installed on an airframe as part of a "dual-dissimilar" satellite communications suite, the following test procedures shall be performed. In the following discussions, "SATCOM A" refers to the system covered by this MOPS, for which installed equipment tests are currently being performed, while "SATCOM B" refers to the other satellite communications system. It is possible that this document and a particular technique-specific appendix may apply to the SATCOM B system, as well.

3.4.2.1 Antenna Isolation

If the declared isolation between the AMS(R)S and any GNSS antenna is greater than 40 dB, in accordance with the provisions of Section 2.2.3.1.2.1.2, the installed isolation shall be tested for each aircraft installation.

3.4.2.2 SATCOM B Interference to SATCOM A

Perform the following steps:

1. With SATCOM B inactive, establish a circuit-mode communications session on SATCOM A, if appropriate. Verify that this session is maintained when SATCOM B is switched on and commanded to initiate a packet mode communications session, if appropriate. Verify that the SATCOM A communications session is maintained when the SATCOM B transfers a package message of 4000 octets containing

random binary data. Terminate the SATCOM B packet mode communications session and verify that the SATCOM A communications session is maintained.

2. Repeat the process of Step 1 with SATCOM B circuit mode data communications, if appropriate.

3. Repeat the process of Step 1 with SATCOM B voice communications, if appropriate.
4. Repeat the process of Steps 1, 2, and 3, with SATCOM A circuit mode data communications, if appropriate.

5. Repeat the process of Steps 1, 2, and 3 with SATCOM A voice communications, if appropriate. Test the ability of SATCOM A to sustain packet data communications by sending messages of 4000 octets.

6. With SATCOM A inactive, initiate a SATCOM B packet mode communications session. Transmit a series of test messages of 4000 octets each. While the transmission is in progress, activate SATCOM A. Verify that SATCOM A can acquire the network. Verify that the AES can initiate and sustain SATCOM A voice communications session for a period of 60 seconds during SATCOM B packet mode operations. Verify that the AES can properly terminate its voice call.

7. Repeat Step 6 with SATCOM A operating in circuit data mode, if applicable. Verify that SATCOM A can initiate and complete a transaction by transmitting a 4000 octet message. Verify that the AES can properly terminate its circuit mode call.

8. Repeat Step 7 with SATCOM A operating in packet data mode, if applicable. Verify that SATCOM A can initiate and complete a transaction by transmitting a 4000 octet message. Verify that the AES can properly terminate its packet mode communications session.

3.4.2.3 SATCOM A Interference to SATCOM B

Repeat the tests of the previous section with the roles of SATCOM A and SATCOM B reversed. This will make SATCOM B the victim and SATCOM A the interferer.

3.4.3 Power Fluctuation Tests

Transceiver aircraft power sources shall be cycled through all normal configurations to verify that the transceiver performance for power interruption recovery during and after power changeover is satisfactory with no discernible abnormal operation.

In-transit data service packets which have been acknowledged on either the DTE or DCE interface, but not yet transferred to the opposite interface, may be lost. Non-transceiver higher layer entities which employ end-to-end acknowledgment protocols may choose to retransmit such lost data.

3.4.4 Ground Test Procedures

Perform the ground test portions of tests defined in manufacturer's installation instructions.

3.4.5 Flight Test Procedures

Flight tests of installed systems are desirable to confirm or supplement bench and ground tests of installed performance. Flight tests may be defined in the manufacturer's installation instructions.

3.4.6 Installed System Performance Verification

3.4.6.1 Installed Functionality

Performance of the installed avionics, consisting of the Antenna Subsystem and the Transceiver Subsystem, should be verified in accordance with the manufacturer's instructions. The following general functional categories shall be validated:

Subnetwork Physical Layer – Verify by initiating and terminating multiple communications session in all applicable modes and with all applicable channels. This test shall include test of the maximum capability of N_v and N_D simultaneous communications channels as declared by the manufacturer.

Network Management Tests – Verify the ability of the AES to acquire and register with the network from a cold start. Verify that the AES performs the appropriate registration or log-on functions as specified in the technique-specific appendix. If multiple data channels are available, verify that they can be assigned and released as required.

Message Transfer Tests – For all operational modes (i.e., voice, circuit mode data, packet data, as appropriate) ensure that the AES can initiate and receive data and sustain communications in its installed environment. Voice calls should extend for at least five minutes. Data transfers should include at least 4 blocks of 4000 octets in each direction.

Circuit Mode Services – Verify that the mechanisms for selecting, dialing, and releasing a circuit are operational. Verify that the mechanisms for accepting, and rejecting an incoming call through operator action are operational.

3.4.6.2 Installed Antenna Coverage

The antenna tests of Section 2.4.3.1.1 provide sufficient verification of coverage for top-mounted antenna installation using steered antennas and non-steered antennas with essentially hemispherical patterns. These installations are expected to be the common installation for most platforms.

4 EQUIPMENT OPERATIONAL PERFORMANCE CHARACTERISTICS

AMSS AES installations are expected to be accomplished in a variety of ways to fit the aircraft equipment and intended usage. This will also be the case with associated cockpit interfaces. The requirements of this section shall be suitably interpreted for the particular installation under consideration.

4.1 Operational Performance Requirements

The following sections identify requirements to ensure the operator that operations can be conducted safely and reliably in the expected operational environment.

4.1.1 Power Input

Prior to flight, the primary power must be available for proper operation.

4.1.2 Communications Displays

The required display(s) for the selection of various communication modes/functions of operation shall be available for use.

4.1.3 Communications Controls

Cockpit control(s) required for proper operation of the equipment shall be available for use.

4.1.4 System Operational Indication

Communication failure of degradation below minimum acceptable performance shall be readily discernible.

4.1.5 Equipment Operating Limitations

Equipment operating limitations of the aircraft Earth station should be contained in the aircraft flight manual.

4.2 Test Procedures for Operational Performance Requirements

Operational equipment tests may be conducted as part of normal preflight tests. For those tests which can only be run in flight, procedures should be developed to perform these tests as early in the flight as possible to verify that the equipment is performing its intended function(s).

4.2.1 Power Input

With the aircraft's electrical power generating system operating, energize the equipment and verify that electrical power is available to the equipment.

4.2.2 Communications Displays

With the equipment operating, verify that the required display(s) are operational.

4.2.3 Communications Controls

The communications control(s) shall be operated, as required, to verify satisfactory equipment response.

4.2.4 System Operational Indication

System operational readiness shall be monitored either by means of Built-In-Test-Equipment (BITE) and/or by suitable preflight tests contained in a check list or flight manual. All equipment failure annunciators shall be tested during preflight tests to verify proper operation.

5 MEMBERSHIP

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APPENDIX A GLOSSARY, ACRONYMS AND DEFINITIONS

AC	Alternating Current
AMS(R)S	Aeronautical Mobile (R) Service
AOC	Airline Operational Control
APC	Aircraft Passenger Communications
ARINC	Aeronautical Radio, Inc., or Aeronautical Research, Inc.
ATC	Air Traffic Control
ATN	Aeronautical Telecommunications Network
ATS	Air Traffic Services
bps	Bits per second
C	Celsius
CDMA	Code Division Multiple Access
Data Link	A system that allows the exchange of digital data over a communications network
Data-2	A Data Link implementation for the enveloping of user data with a unique Initial Protocol header of FF_H
Data-3	A Data Link implementation for the transmission of user data using ISO-8208 protocol
dB	Decibel
DC	Direct Current
DCE	Data Circuit-terminating Equipment
DTE	Data Terminal Equipment
EMI	Electromagnetic Interference
FCC	Federal Communications Commission
FDMA	Frequency Division Multiple Access
FMS	Flight Management System
Gaussian	The "normal" bell-shaped probability density function described by $p(x) = (2\pi\sigma^2)^{-\frac{1}{2}} e^{\frac{-(x-m)^2}{2\sigma^2}}$, where m is the mean value and σ^2 is the variance
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GES	Ground Earth Station
HLE	Higher Layer Entity
Hz	Hertz; a unit of frequency measurement equal to one cycle per second
ICAO	International Civil Aviation Organization (part of United Nations)
ISO	International Organization for Standardization
ITU	International Telecommunications Union
IWF	Interworking Function
kHz	Kilohertz; a unit of frequency measurement equal to 1,000 cycles per second
LSDU	Link Service Data Unit
MHz	Megahertz; a unit of frequency measurement equal to 1,000,000 cycles per second
modem	Modulator/Demodulator
MOPS	Minimum Operational Performance Standard(s)
ms	Millisecond; a unit of time measurement equal to 0.001 second
NSAP	Network Service Access Point
OSI	Open System Interconnect
SATCOM	Satellite Communication
SNAcP	SubNetwork Access Protocol
SNC	SubNetwork Connection
SNPDU	SubNetwork Protocol Data Unit
STDMA	Self-Organising Time Division Multiple Access

SVC	Switched Virtual Circuit
TDMA	Time Division Multiple Access
W	Watt

APPENDIX B INTERFERENCE MODEL FOR EMISSIONS ASSOCIATED WITH ANCILLIARY TERRESTRIAL COMPONENT (ATCT) GROUND STATIONS

1 INTRODUCTION

This normative appendix defines the requirements and verification procedures for an ATN-compliant interface based on ISO-8208. This interface is intended to be compatible with the Data-3 interface defined in DO-210D.

All AES equipment desiring to implement an ISO-8208 compatible interface to provide ATN services shall comply with the requirements and verification procedures stated in this appendix.

The reference model of Figure B-1 will be used throughout this appendix.

In keeping with the structure of the main body of these MOPS, this appendix has been organized so that the requirements of each sub-paragraph of Section 2 are verified by the procedures described in the corresponding sub-paragraph of Section 3. For example, the priority mapping requirements of 2.1 are verified by the procedures of 3.1. As a result of this mapping, this appendix does not contain a verification cross reference matrix.

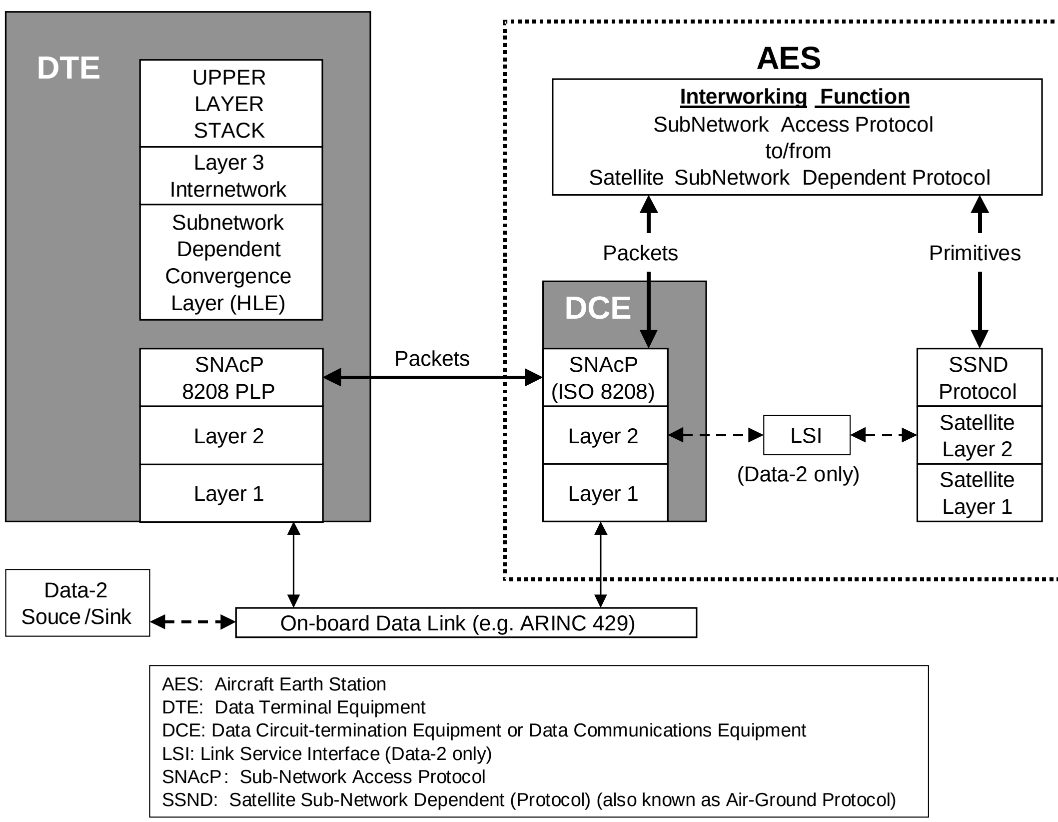

Figure B-25: Satellite Subnetwork Architecture (ISO-8208)

1.1 Assumptions on Higher Layer Packet Data Interfaces

To support the evolving ATN/ATM environment, this MOPS emphasizes data communications. As noted earlier, one proven means of supporting an ATN-compliant interface is by use of ISO-8208 compatible interfaces. ISO-8208 operations are defined in terms of a user application, also known as a Higher Level Entity (HLE). For the purpose of specifying these interfaces, Appendix B of this document assumes the HLE performs the the following functions:

a. Supports the operations of the DTE as specified in The ISO-8208 standard.

b. Is able to initiate, accept and terminate calls via the interface.

c. Is prepared to accept error messages from the AES .

d. Monitors the AES operation in case of unrecoverable error conditions and reinitializes the AES as necessary.

2 ISO-8208 PROTOCOL REQUIREMENTS

2.1 ISO-8208 Priority Mapping

The values contained in the ISO-8208 SNC_Priority Field in the CALL_REQUEST, CALL_ACCEPTED, INCOMING_CALL and CALL_CONNECTED packets shall be assumed to be assigned as given in Table B-1, and shall be transparently transmitted across the satellite network.

Note: It is recommended, but not required, that packets received at AES with SNC_Priority of 4, 9, 10, 12, and 14 be transparently transmitted across the satellite network, and that packets with these SNC_Priority received from the network be transparently transmitted to the HLE.

2.2 ISO-8208 Protocol Implementation Conformance

The interface between the Higher Level Entity (HLE) and the AES shall conform to the ISO-8208 standard with the following characteristics. It shall provide for the following:

a. A User Data Field (in the CALL REQUEST, DATA, CLEAR REQUEST and CALL ACCEPTED packets) of up to 128 octets.

b. Expedited Data Delivery, i.e., the use of INTERRUPT packets with a User Data Field of up to 32 octets.

c. Called and Calling Address Extension Facilities.

d. Fast Select (without restrictions).

e. Fast Select Acceptance (without restrictions).

f. Throughput Class Negotiation.

g. Transit Delay Selection and Indication.

h. Default maximum user data field length of 128 octets in DATA packets.

i. Priority (of data on a connection).

Notes:
1. End-to-end data delivery confirmation service is not supported. The D-bit shall be transmitted as a zero.

2. Additional ISO-8208 facilities may be found necessary in the future. These may include Minimum Throughput Class Negotiation and End-to-End Transit Delay Negotiation.

Table B-9: NGSS Packet-Mode Connection Precedence Mapping

Category of Messages	**SNC Priority in CALL_REQUEST / CALL_ACCEPTED packet**[1,2]	**SNC Priority in INCOMING_CALL / CALL_CONNECTED packet**[1,2]
Safety Packet-Mode Data Communications		
Distress Communications, Urgent Communications, and Network/Systems Management[5]	14	14
Reserved[4]	13	13
Reserved[4]	12	12
Flight Safety Messages and Communications Relating to Direction Finding	11	11
Reserved[4]	10	10
Reserved[4]	9	9
Meteorological Communications	8	8
Flight Regularity Communications	7	7
Aeronautical Information Service Messages (NOTAMSs, ATIS, etc.)	6	6
Aeronautical Administrative Messages and Network/Systems Administration[5]	5	5
Non-Safety Packet-Mode Data Communications		
Unspecified (ISO-8208 explicit)	255	None[3] or 255
Reserved (ISO-8208 explicit)	254 - 15	Not Applicable
Reserved[4]	4	4
Urgent Priority Administrative and UN Charter Communications (AAC/ACP)	3	3
High Priority Administrative and State/Government Communications	2	2

(AAC/APC)		
Normal Priority Administrative (AAC/APC)	1	1
Low Priority Administrative (AAC/APC)	0	None[3] or 0
Not specified	None[3]	None[3]

Note to Table B-1:

1. *Priority levels at the ISO-8208 interface to the AMSS Subnetwork are mapped to equivalent ATN priority levels by the ATN Subnetwork Dependent Convergence Function (SNDCF) contained in external ATN facilities.*
2. *ISO-8208 priorities range from] 0 (lowest priority) to 14 (highest priority). The value 255 (all ones) indicates "unspecified". All other values (i.e., 15 through 254) are reserved."]*
3. *"None" means that the optional ISO-8208 Priority Facility is not invoked in the CALL_REQUEST, CALL_ACCEPTED, INCOMING_CALL, or CALL_CONNECTED packets, as appropriate for the specific entry. Note that some AMSS implementations receiving a packet with priority level other than 1 - 14 may forward the equivalent packet with no requested priority.*
4. *Certain levels are identified as Reserved. The response to a DTE/DCE request for communications at these levels may vary between AMSS systems. Users should consult the technique-specific MASPS appendix or the applicable MOPS for details.*
5. *Network/System Management and Administration are not categories of end-use messages but may be used by ATN management or for other network management/administration functions.*

2.3 AES Operation as DCE in ISO-8208 Environment

The Data Communications Equipment (DCE) process within the AES shall function as a peer process to the external Data Terminal Equipment (DTE). The DCE shall support the operations of the DTE with the facilities specified in Section 2.1 of this appendix.

The following requirements do not include those relating to format definitions, diagnostic and cause codes, and flow control on the ISO-8208 interface. The default or standard values defined in the ISO-8208 standard shall apply in these cases.

2.4 State Transitions

The DCE is defined as a state machine. An ISO-8208 packet received from the DTE can cause state transitions, as can a packet received from the Interworking Function illustrated in Figure B-1. The next state transition (if any) occurs when the DCE receives a packet from the DTE as specified by Table B-3 through Table B-10. These tables are organized according to the substate hierarchy illustrated Figure B-3.

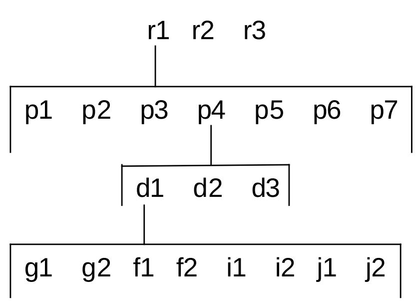

Figure B-26: DCE Substate Hierarchy

Upon receiving a packet, the Action is classified as normal or erroneous under the entry "A =". Normal actions, if not defined in the Table itself, are defined via a parenthetical reference {e.g., (4.2)} to the ISO-8208 standard. The resulting state is shown under the entry "S =".

If a state transition is specified, the actions taken shall be as specified in Table B-3 through Table B-10. In addition, the actions specified for transition to that state as specified in Table B-3 shall be performed.

Table B-3 through Table B-10 also specify the disposition of the received packet. When a packet is received from the DTE, the expressions in parentheses in Table B-3 through Table B-10 specify whether the packet shall be forwarded or not forwarded to the SSNIW. If no remark in parentheses is listed or listed as "not forwarded," then the packet shall be discarded. The ISO-8208 DCE shall either forward or not forward a packet from the SSNIW to the DTE in a manner that is compatible with ISO-8208.

Table B-10: DCE Actions at State Transition

DCE State	State Definition	Action When Entering State
r1	Packet LAYER READY	All SVCs are returned to the p1 State (see p1 State READY explanation), and all PVCs are returned to the d1 (FLOW CONTROL READY) State.
r2	DTE RESTART REQUEST	The DCE returns each SVC to the p1 State (see p1 State explanation) and issues a RESTART CONFIRMATION to the DTE.
r3	DCE RESTART INDICATION	The DCE returns each SVC to the p1 State (see p1 State explanation) and issues a RESTART INDICATION to the DTE.
p1	READY	Release all resources assigned to SVC channel. The correspondence between the DTE/DCE channel and the AES SSND/GES SSND channel is no longer in effect. Note that the AES SSND/GES SSND channel may not yet be in the p1 State.
p2	DTE CALL REQUEST	Determine if sufficient resources exist to support request; if so, allocate resources and forward ISO-8208 packet to SSNIW; if not, enter DCE CLEAR INDICATION to DTE State (p7). Determination of resources and allocation is as defined in the ISO-8208 standard.
p3	DCE INCOMING CALL	Determine if sufficient resources exist to support request; if so, allocate resources and forward ISO-8208 packet to DTE; if not, send a CLEAR REQUEST packet to the SSNIW. Determination of resources and allocation is as defined in the ISO-8208 standard.
p4	DATA TRANSFER	No Action.
p5	CALL COLLISION	Send a CLEAR REQUEST packet to the SSNIW, corresponding to the incoming call (the DTE in its Call Collision State ignores the incoming call), and proceed with the DTE Call request.
p6	DTE CLEAR REQUEST	Release all resources assigned to SVC channel. Send an ISO-8208 CLEAR CONFIRMATION packet to the DTE and enter p1 State.
p7	DCE CLEAR INDICATION TO DTE	Forward ISO-8208 CLEAR INDICATION packet to DTE.
d1	FLOW CONTROL READY	No Action.
d2	RESET REQUEST BY DTE	Remove DATA packets transmitted to DTE from window; discard any DATA packets that represent DTE partially transmitted M-bit sequences and discard INTERRUPT and INTERRUPT CONFIRMATION packets awaiting transfer to the DTE; reset all window counters to zero. Send RESET CONFIRMATION packet to DTE. Return channel to d1 State.
d3	RESET INDICATION BY DCE to DTE	Remove DATA packets transmitted to DTE from window; discard any DATA packets that represent partially transmitted M-bit sequences and discard INTERRUPT and INTERRUPT CONFIRMATION packets awaiting transfer to the DTE; reset all window counters to zero. Forward RESET INDICATION packet to DTE.
i1	DTE INTERRUPT READY	No Action.
i2	DTE INTERRUPT SENT	Forward INTERRUPT packet received from DTE to SSNIW.
j1	DCE INTERRUPT READY	No Action.
j2	DCE INTERRUPT SENT	Forward INTERRUPT packet received from SSNIW to DTE.
f1	DCE RECEIVE READY	No Action.
f2	DCE RECEIVE NOT READY	No Action.
g1	DTE RECEIVE READY	No Action.
g2	DTE RECEIVE NOT READY	No Action.

NOTE:State nomenclature in this Table may differ from that used in the ISO-8208 standar

Table B-11: DCE Special Cases

Received from DTE	DCE Special Cases Any State
Any packet less than two octets in length	A = DIAG D = 38
Any packet with an invalid General Format Identifier	A = DIAG D = 40
Any packet with unassigned Logical Channel Identifier	A = DIAG D = 36
Any packet with a valid General Format Identifier and an assigned Logical Channel Identifier (includes a Logical Channel Identifier of 0)	See Table B-5

Table B-12: DTE Effect on DCE Restart States

PACKET RECEIVED FROM DTE	DCE RESTART STATES (SEE NOTES 6 AND 7)		
	packet LAYER READY (See Note 1) r1	**DTE RESTART REQUEST (See Note 4) r2**	**DCE RESTART INDICATION (See Note 5) r3**
Packets having a Packet Type Identifier shorter than one byte with assigned logical channel identifier (not = 0)	See Table B-7	A = ERROR S = r3 D = 38 (See Note 3)	A = DISCARD
Any packet, except RESTART, with a logical channel identifier of 0	A = DIAG D = 36	A = DIAG D = 36	A = DIAG D = 36
Packet with a Packet Type identifier that is undefined or not supported by DCE, and with assigned logical channel identifier (not = 0)	See Table B-7	A = ERROR S = r3 D = 33 (See Note 3)	A = DISCARD
RESTART REQUEST, or RESTART CONFIRMATION packet with a Logical Channel Identifier not = 0	See Table B-7	A = ERROR S = r3 D = 41 (See Note 3)	A = DISCARD
RESTART REQUEST	A = NORMAL (4.2) (Forward) S = r2	A = DISCARD	A = NORMAL (4.3) S = r1
Packets having a Packet Type Identifier shorter than one byte and a Logical Channel Identifier equal to 0	A = DIAG D = 38	A = ERROR S = r3 D = 38 (See Note 3)	A = DISCARD
Packets with a Packet Type Identifier that is undefined or not supported by DCE and a Logical Channel Identifier equal to 0	A = DIAG D = 33	A = ERROR S = r3 D = 33 (See Note 3)	A = DISCARD
RESTART CONFIRMATION	A = ERROR S = r3 D = 17 (See Note 8)	A = ERROR S = r3 D = 18 (See Note 3)	A = NORMAL (4.4) S = r1
RESTART REQUEST orRESTART CONFIRMATION packet with format error	A = DIAG D = 38, 39, 81 or 82	A = DISCARD	A = ERROR D = 38, 39, 81 or 82 (See Note 3)
Call Setup, Call Clearing, DATA, Interrupt, Flow Control or RESET Packet	See Table B-7	A = ERROR S = r3 D = 18 (See Note 3)	A = DISCARD

<u>*NOTES to*</u> Table B-5*:*

1. *The AES Subnetwork has no restart states. Receipt of a RESTART REQUEST causes the DCE to respond with a RESTART CONFIRMATION. The RESTART REQUEST causes the ISO-8208-to-satellite interworking function to clear all SVCs associated with the DTE/DCE interface.*

2. *(Reserved for future use).*

3. *The RESTART REQUEST packet is not forwarded to the ISO-8208-to-satellite interworking, and thus is not forwarded to the ground over the satellite subnetwork.*

4. *If the DCE enters the r3 state, then the RESTART CONFIRMATION is not sent.*

5. *The DCE upon entering the r3 state checks for the completion of r2 processing and issues an ISO-8208 RESTART INDICATION packet to the DTE, when the r3 state is entered via the r2 state. If the r3 state is not entered via the r2 state, the DCE performs all of the actions normally performed when entering r2 and issues an ISO-8208 RESTART INDICATION to the DTE, and causes the ISO-8208 to satellite interworking function to clear all SVCs associated with the DTE/DCE interface.*

6. *Table B-entries are defined as follows: A = Action to be taken, S = State to be entered, D = Diagnostic code to be used in packets generated as a result of this action, DISCARD indicates that the received packet is to be cleared from the AES buffers.*

7. *The number in the parentheses below an "A = NORMAL" Table B-entry is the Section number in the ISO-8208 standard. The DCE shall take the same actions as the ones taken by the DTE, acting as a DCE, to perform nominal processing on the received packet. If no Section number is referenced, the normal processing is defined in the Table B-entry.*

8. *The error procedures consist of entering the r3 state, and causing the 8208 to satellite interworking function to clear all SVCs associate with the DTE/DCE interface.*

Table B-13: DTE Effect on DCE Call Setup and Clearing States

Packet Received from DTE	DCE CALL SETUP AND CLEARING STATES (See Notes 5 and 6)						
	READY p1	**DTE CALL REUEST p2**	**DCE INCOMING CALL p3**	**DATA TRANSFER p4**	**CALL COLLISION p5; See Notes 1 &4**	**DTE CLEAR REQUEST p6**	**DCE CLEAR INDICATION to DTE p7**
Packet having a Packet Type Identifier shorter than one byte	A = ERROR S = p7 D = 38	A = ERROR S = p7 D = 38 See Note 2	A = ERROR S = p7 D = 38 See Note 2	See Table B-9	A = ERROR S = p7 D = 38 See Note 2	A = ERROR S = p7 D = 38 See Note 2	A = DISCARD
Packet having a Packet Type Identifier that is undefined or not supported by DCE	A = ERROR S = p7 D = 33	A = ERROR S = p7 D = 33 See Note 2	A = ERROR S = p7 D = 33 See Note 2	See Table B-9	A = ERROR S = p7 D = 33 See Note 2	A = ERROR S = p7 D = 33 See Note 2	A = DISCARD
RESTART REQUEST or RESTART CONFIRMATION packet with Logical Channel Identifier not =0	A = ERROR S = p7 D = 41	A = ERROR S = p7 D = 41 See Note 2	A = ERROR S = p7 D = 41 See Note 2	See Table B-9	A = ERROR S = p7 D = 41 See Note 2	A = ERROR S = p7 D = 41 See Note 2	A = DISCARD
CALL REQUEST	A = NORMAL (5.2.2) S = p2 (Forward) see Note 7	A = ERROR S = p7 D = 21 See Note 2	A = NORMAL (5.2.5) S = p5	A = ERROR S = p7 D = 23 See Note 2	A = ERROR S = p7 D = 24 See Note 2	A = ERROR S = p7 D = 25 See Note 2	A = DISCARD
CALL ACCEPTED (See Note 7)	A = ERROR S = p7 D = 20	A = ERROR S = p7 D = 21 See Note 2	A = NORMAL (5.2.4) S = p4 (Fwrd)/ A = ERROR S = p7; D = 42 Notes 2 and 3	A = ERROR S = p7 D = 23 See Note 2	A = ERROR S = p7 D = 24 See Notes 2 and 4	A = ERROR S = p7 D = 25 See Note 2	A = DISCARD
CLEAR REQUEST (See Note 7)	A = NORMAL (5.5.2) S = p6	A = NORMAL (5.5.2) S = p6 (Forward)	A = NORMAL (5.5.2) S = p6 (Forward)	A = NORMAL (5.5.2) S = p6 (Forward)	A = NORMAL (5.5.2) S = p6 (Forward)	A = DISCARD	A = NORMAL (5.5.4) S = p1 (do not forward)
CLEAR CONFIRMATION (See Note 7)	A = ERROR S = p7 D = 20	A = ERROR S = p7 D = 21 See Note 2	A = ERROR S = p7 D = 22 See Note 2	A = ERROR S = p7 D = 23 See Note 2	A = ERROR S = p7 D = 24 See Note 2	A = ERROR S = p7 D = 25 See Note 2	A = NORMAL (5.5.4) S = p1 (do not forward)
DATA, Interrupt, Flow Control or Reset Packets	A = ERROR S = p7 D = 20	A = ERROR S = p7 D = 21; Note 2	A = ERROR S = p7 D = 22; Note 2	See Table B-9	A = ERROR S = p7 D = 24; Note 2	A = ERROR S = p7 D = 25; Note 2	A = DISCARD

NOTES to Table B-7*:*

1. *On entering the p5 state, the DCE cancels the outgoing call to the DTE, issuing a CLEAR REQUEST to the SSNIW (no CLEAR INDICATION is issued) and responds to incoming DTE call as appropriate with a CLEAR INDICATION or CALL CONNECTED packet.*

2. *The error procedure consists of performing the actions specified when entering the p7 state (including sending a CLEAR INDICATION packet to the DTE) and additionally sending a CLEAR REQUEST packet to the SSNIW.*

3. *The use of Fast Select Facility with restriction on response prohibits the DTE from sending a CALL ACCEPTED packet.*

4. *The DTE in the event of a Call Collision must discard the CALL INDICATION packet received from the DCE.*

5. *Table B-entries are defined as follows: A = Action to be taken, S = the State to be entered, D = Diagnostic code to be used in packets generated as a result of this action, DISCARD indicates that the received packet is to be cleared from the AES buffers.*

6. *The number in parentheses below an "A = NORMAL" Table B-entry is the Section number in the ISO-8208 standard. The DCE shall take the same actions as the ones taken by the DTE, acting as a DCE, to perform normal processing on the received packet. If no Section number is referenced, the normal processing is defined in the Table B-entry.*

7. *If the packet is accepTable B-to the state of the logical channel (i.e., Action = Normal), but contains a format error or is otherwise unacceptable, then the DCE shall initiate a CONNECTION RELEASE procedure (diagnostic codes that may apply include 34, 38, 39, 65, 66, 67, 68, 69, 73, 77 and 82). If such an error is detected in states p1 or p7, the DCE does not send a CLEAR REQUEST packet to the SSNIW.*

Table B-14: DTE Effect on DCE Reset Status

Packet Received from DTE	**DCE RESET STATES (See Notes 2 and 3)**		
	FLOW CONTROL READY d1	**RESET REQUEST by DTE d2**	**RESET INDICATION by DCE to DTE d3**
Packet with a Packet Type Identifier Shorter than one byte	A = ERROR S = d3 D = 38 (See Note 1)	A = ERROR S = d3 D = 38 (See Note 1)	A = DISCARD
Packet with a Packet Type Identifier that is undefined or not supported by DCE	A = ERROR S = d3 D = 33 (See Note 1)	A = ERROR S = d3 D = 33 (See Note 1)	A = DISCARD
RESTART REQUEST or RESTART CONFIRMATION packet with Logical Channel Identifier not = 0	A = ERROR S = d3 D = 41 (See Note 1)	A = ERROR S = d3 D = 41 (See Note 1)	A = DISCARD
RESET REQUEST	A = NORMAL (8.2) S = d2 (Forward) (See Note 4)	A = DISCARD	A = NORMAL (8.3) S = d1 (Do not forward)
RESET CONFIRMATION	A = ERROR S = d3 D = 27 (See Notes 1 and 4)	A = ERROR S = d3 D = 28 (See Note 1)	A = NORMAL (8.4) S = d1 (Do not forward)
INTERRUPT OR INTERRUPT CONFIRMATION Packet	see Table B-11	A = ERROR S = d3 D = 28 (See Note 1)	A = DISCARD
DATA or Flow Control PAcket	See Table B-10	A = ERROR S = d3 D = 28 (See Note 1)	A = DISCARD

NOTES for Table B-9*:*

1. *The error procedure consists of performing the specified actions when entering the d3 state (which includes forwarding a RESET INDICATION packet to the DTE) causes the 8208 to satellite interworking function to clear all SVCs associated with the DTE/DCE interface.*

2. *Table B-entries are defined as follows: A=Action to be taken, S=the State to be entered, D=the Diagnostic code to be used in packets generated as a result of this action, DISCARD indicates that the received packet is to be cleared from the AES buffers.*

3. *The number in parentheses below an "A=NORMAL" Table B-entry is the Section number in The ISO-8208 standard. The DCE shall take the same actions as the ones taken by the DTE to perform normal processing on the received packet. If no Section is referenced, the normal processing is defined in the Table B-entry.*

4. *If the packet is accepTable B-to the state of the logical channel (i.e., Action = Normal), but contains a format error, then the DCE shall initiate a connection reset procedure (diagnostic codes that may apply include 38, 39, 81 and 82).*

Table B-15: DTE Effect on DCE Interrupt Transfer Status

Packet Received From DTE	DTE/DCE INTERRUPT TRANSFER STATES (See Notes 2 and 3)	
	DTE INTERRUPT READY i1	**DTE INTERRUPT SENT i2**
INTERRUPT (See Note 1)	A = NORMAL (6.8.2) S = i2 (Forward)	A = ERROR S = d3 D = 44 (See Note 4)

Packet Received From DTE	DTE/DCE INTERRUPT TRANSFER STATES (See Notes 2 and 3)	
	DCE INTERRUPT READY j1	**DCE INTERRUPT SENT j2**
INTERRUPT CONFIRMATION (See Note 1)	A = ERROR S = d3 D = 43 (See Note 4)	A = NORMAL (6.8.3) S = j1 (Forward)

<u>*NOTES for*</u> Table B-11*:*

1. *If the packet is accepTable B-to the state of the logical channel (i.e., Action = Normal), but contains a format error, then the error procedure applies (See Note 4).*

2. *Table B-entries are defined as follows: A=Action to be taken, S=the State to be entered, D=the Diagnostic code to be used in packets generated as a result of this action, DISCARD indicates that the received packet is to be cleared from the AES buffers.*

3. *The number in parentheses below an "A=NORMAL" Table B-entry is the Section number in the ISO-8208 standard. The DCE shall take the same actions as the ones taken by the DTE to perform normal processing on the received packet. If no Section is referenced, the normal processing is defined in the Table B-entry.*

4. *The error procedure consists of performing the specified actions when entering the d3 state (which includes forwarding a RESET INDICATION packet to the DTE) and causes the 8208 to satellite interworking function to clear all SVCs associated with the DTE/DCE interface.*

Table B-16: DTE Effect on Flow Control Transfer States

Packet Received From DTE	DCE FLOW CONTROL TRANSFER STATES (See Notes 1, 2 and 3)	
	DCE RECEIVE READY (f1)	DCE RECEIVE NOT READY (f2)
DATA packet with invalid PR	A=ERROR S=d3 D=2 (See Note 4)	A=ERROR S=d3 D=2 (See Note 4)
DATA packet with valid PR but invalid PS or User Data Field with improper format	A=ERROR S=d3 D=(See Note 5) (See Note 4)	A=DISCARD (Process PR data)
DATA packet with valid PR but with M-bit set to 1 and the D-bit set to 0 when the User Data Field is partially full, or the D-bit set to 1	A=ERROR S=d3 D=165 or 166 (See Note 4)	A=DISCARD (Process PR data)
DATA packet with valid PR, PS and User Data Field with proper-Format	A=NORMAL (Forward)	A=DISCARD (Process PR data) (See Note 6)

Packet Received From DTE	DCE FLOW CONTROL TRANSFER STATES (See Notes 1, 2 and 3)	
	DTE RECEIVE READY(g1)	DTE RECEIVE NOT READY (g2)
RR, or RNR packet with an invalid PR	A=ERROR S=d3 D=2 (See Note 4)	A=ERROR S=d3 D=2 (See Note 4)
RR packet with a valid PR (See Note 7)	A=NORMAL (7.1.5)	A=NORMAL (7.1.5) S=g1
RNR packet with a valid PR (See Note 7)	A=NORMAL (7.1.6) S=g2	A=NORMAL (7.1.6)

NOTES to Table B-10*:*
1. The RR, and RNR procedures are a local DTE/DCE matter and the corresponding packets are not forwarded to the SSNIW.

2. Table B-entries are defined as follows: A=Action to be taken, S=the State to be entered, D=the Diagnostic code to be used in packets generated as a result of this action, DISCARD indicates that the received packet is to be cleared from the AES buffers.

3. The number in parentheses below an "A=NORMAL" Table B-entry is the Section number in the ISO-8208 standard. The DCE shall take the same actions as the ones taken by the DTE to perform normal processing on the received packet. If no Section is referenced, the normal processing is defined in the Table B-entry.

4. The error procedure consists of performing the specified actions when entering the d3 state (which includes forwarding a RESET INDICATION packet to the DTE) and sending a RESET REQUEST packet to the SSNIW.

5. The diagnostic codes are as follows: D=1 for invalid PS; D=39 for a User Data Field greater than 128 Octets; D=82 for a User Data Field not octet aligned.

6. If possible, the DCE should process these packets normally. On the other hand, the DCE may define an internal mechanism to indicate that valid DATA packets have been discarded during a receive-not-ready condition. In this case, when the receive-not-ready condition clears, the DCE should reset the logical channel, forwarding both a RESET INDICATION packet to the DTE (D = 0, no additional information) causes the ISO-8208-to-satellite-interworking function to clear all SVCs associated with the DTE/DCE interface.

7. For RR, or RNR packets, the presence of one or more octets beyond the third octet is considered an error. Although a valid P(R) may be accepted to update the status of outstanding DATA packets, the DCE shall invoke the ERROR procedure, as defined in Note 4 (with D = 39).

Diagnostic and Cause Codes

The tables for certain conditions indicate a diagnostic code that shall be included in the packet that is generated when entering the state indicated. The term "D =" defines the diagnostic code. When "A = DIAG" appears in a Table B-entry, the action taken shall be to generate an ISO-8208 DIAGNOSTIC packet and transfer it to the DTE; the diagnostic code indicated defines the entry in the diagnostic field of the packet. Bit 8 of the cause field of any packet type shall always be set to 0, indicating that the condition was recognized by the ISO-8208 interface.

2.5 DCE Timer

Under certain circumstances, the DTE shall respond to a packet issued from the DCE within a given time.

Table B-14 covers these circumstances and the actions that the DCE shall initiate upon the expiration of that time.

Whenever a timer action defined in Table B-14_causes a CLEAR REQUEST or signals a CLEAR INDICATION, the clear action shall extend to the satellite subnetwork, that is, the equivalent of a CLEAR REQUEST shall be issued to the interworking function.

Table B-17: DCE TIMER

Timer Design	Time Limit Value	Start Event	Normally terminated by	Action when timer expires
tN10	60 sec	DCE issues a RESTART INDICATION packet	Reception of RESTART CONFIRMATION or RESTART REQUEST packet	DCE enters the r1 state and shall issue a DIAGNOSTIC packet (D=#52)
tN11	180 sec	DCE issues an INCOMING CALL packet	Reception of CALL ACCEPTED or CLEAR REQUEST or CALL REQUEST packet	DCE enters the p7 state signalling a CLEAR INDICATION packet (D=#49) (see note)
tN12	60 sec	DCE issues a RESET INDICATION packet	Receipt of RESET CONFIRMATION or RESET REQUEST packet	DCE enters the p7 state signalling a CLEAR INDICATION packet (D=#51) (see note)
tN13	60 sec	DCE issues a CLEAR INDICATION packet	Reception of a CLEAR CONFIRMATION or CLEAR REQUEST packet	DCE enters the p1 state and shall issue a DIAGNOSTIC packet (D=#50)

3 ISO-8208 PROTOCOL VERIFICATION PROCEDURES

This section defines a succession of test procedures for a comprehensive logical state test for ISO-8208 DCE. The tests are defined using the configuration illustrated in Figure 5 . For all test procedures, the transceiver is logged on to the GES. The AES and the Protocol Analyzer (Air) exchange ISO-8208 packets, the AES and GES communicate via the satellite sub-network, and the GES and Protocol Analyzer (Ground) communicate via ISO-8208 packets. packet content will be monitored at both ends to confirm proper state transitions.

<u>The Use of ISO-8208 Default Parameters</u>

Unless otherwise specified, this procedure assumes that relevant parameters of the DTE/DCE interface are set to their standard default values as defined in ISO-8208.

<u>NOTE</u>: These include, for example, packet sizes, flow control window sizes, timers and retry counters.

<u>Maintaining Flow Control</u>

Unless otherwise specified, the tester shall ensure that flow control is maintained across the transceiver/HLE interface through the use of RECEIVE READY packets, or DATA packets with updated PR/PS Subfields.

Network Conditions

Unless otherwise specified, the following test procedures assume that only one DTE will be connected to the transceiver during a given test. Failure to observe this precaution may cause test results to differ from the expected values.

Standard Test Signals

The network protocol selected for the transceiver/HLE interface is ISO Standard 8208.

NOTE: The manufacturer is free to choose the appropriate physical data bus for connection between the transceiver and the HLE. Characteristics such as amplitude, timing, and waveform shapes of test signals applied to the transceiver shall be consistent with the standards definition of the selected data bus. Moreover, the manufacturer should adhere to system impedance requirements of the appropriate standards whether the equipment under test has power applied or not, or is in an active or quiescent state (i.e., standby).

General Characteristics - Transceiver/HLE Test Signals

a. Data Formats: Data transmitted across this interface shall be in packets conforming to ISO Standard 8208.

b. Electrical Characteristics: Test signals on this interface shall be consistent with the appropriate standards for the connecting data bus.

c. ISO-8208 Channel Assignments: The test procedures in this MOPS use 12 ISO-8208 channels in the range 2805 through 2816. This assignment of channels is introduced as a documentation aid. The manufacturer is free to choose any block of 12 ISO-8208 channels in the range 2565 through 2816 in a particular transceiver implementation.

d. Data Content: The test equipment shall be capable of generating or accepting messages with the following content: packet fields such as sequence numbers, addresses, packet types or any other control fields shall be capable of being loaded with any combination of ones and zeros, including all ones and all zeros. Data fields within the packets shall be capable of being loaded with any combination of ones and zeros, including all ones and all zeros.

Message Validation

The test equipment shall provide a means of validating the information content of any message received from the AES . This requirement applies to either the AES /HLE interface or the GES/DTE interface.

3.1 Packet Data Priority, Precedence and Preemption

3.1.1 ISO-8208 Priority Mapping

This test establishes only that the satellite subnetwork properly maintains the SNC Priority field, not that the priority, precedence and preemption mechanisms are implemented.

Step 1: Using the standard packet data test setup up shown in Figure 5, use the PAG to send packets with values the SNC_Priority field in the CALL_REQUEST packet set to 1. Use the PAA to verify that the associate INCOMING CALL packet contains the same value in the SNCPriority field. Verify that the PAA responds with the same SNC_Priority field in its CALL_CONNECTED packet. Verify that the PAG receives the same value in the CALL_ACCEPTED packet. Use the appropriate procedure to clear the resulting call.

Step 2: Repeat Step 1 with SNC_Priority field set to the following values: 2, 3, 5, 6, 7, 8, 11, and 14.

Step 3: Repeat the Step 1 and Step 2 tests with the roles of the PAA and PAG reversed.

3.1.2 ISO-8208 Priority Implementation

The Precedence and Preemption capability is test via the following procedure:

<u>Equipment Required</u>

ISO-8208 Test Set/Protocol Analyzer (2), one designated as Protocol Analyzer Air (PAA), one designated as Protocol Analyzer Ground (PAG).

Remote access equipment to ISO-8208 compatible data port at GES.
or, alternative, GES Emulator.

Appropriate cabling and antenna for access to the Satellite Subnetwork,
or, alternatively,
Directional Coupler, 30 dB coupling, 20 watts average power rating
High Power RF Load, 50 ohms, minimum 20 watts average power rating

<u>Test Procedure</u>

The precedence and preemption test procedures are designed to verify the AES's ability to determine the precedence of packet-mode data and preempt, if necessary, lower-priority AGPDUs.

Use the PAA to perform the airborne HLE functions, and use the PAG to perform the ground HLE functions.

Step 1 - Virtual Call Setup

This test opens multiple channels with the AES.

a. Program the PAA to send four CALL REQUEST packets to the AES with the following channel numbers and corresponding link layer precedence: channel 2816, precedence 14; channel 2815, precedence 11; channel 2814, precedence 8; and channel 2813, precedence 3. Use the PAG to verify that the PAG receives INCOMING CALL packets with four distinct logical channel numbers.

b. Program the PAG to send four CALL ACCEPTED packets to the AES. Verify that the AES sends four CALL CONNECTED packets to the PAA with the following channel numbers: 2816, 2815, 2814, and 2813.

Step 2 - DATA packets from Data packets

This test verifies proper ordering of AGPDUs according to the link layer precedence of the data packets arriving at the AES.

a. Program the PAA to send an ISO-8208 M-bit sequence consisting of four DATA packets, time sequence in the following order: 2813, 2815, 2814, 2816., each with L_{SNDP} +10 octets of data in the User Data field on each opened channel to the AES. Fill the User Data Field with following patterns:

channel 2816	01010101
channel 2815	10101010
channel 2814	11001100
channel 2813	00110011

These packets shall be sent to the AES 8208 interface at the maximum rate supported by the external interface hardware.

Note: Like the equivalent tests in DO-210C, this test implicitly assumes that the external I/O bandwidth significantly exceeds the satellite subnetwork bandwidth available to any single AES for packet data operations. If such is not the case, priority, precedence and preemption mechanisms must be supplied at the external I/O controller, effectively overriding AES mechanisms.

b. Use the PAG to verify that the AES sends data packets awaiting transmission over the SSNDP in accordance with the data packet precedence with User Data Fields contents as follows.

channel 2813	00110011
channel 2815	10101010
channel 2815	10101010
channel 2816	01010101
channel 2816	01010101
channel 2814	11001100
channel 2814	11001100
channel 2813	00110011

Step 3 - Clear Channels

Perform the procedure in Section 3.4.1.1Call Setup and Clearing States Step 3 to clear the four open channels.

3.2 ISO-8208 Protocol Implementation Conformance

The basic ISO-8208 functionality is verified by the detailed tests that follow, and is not explicitly tested.

3.3 AES Operation as a DCE in ISO-8208 Environment

The peer-to-peer relationship of the AES as a DCE and the support of the required facilities is verified by the detailed tests which follow, and is not explicitly tested.

3.4 State Transition Test Procedures

The channel state test procedures are designed to test the restart, call setup and clearing, reset, interrupt, flow control and data transfer state tables of the transceiver. The tests are divided into two subgroups: the Normal State Test Procedures and the Error Recovery State Test Procedures.

Unless otherwise indicated, the tests all occur on one logical channel.

3.4.1 Normal State Test Procedures

Reference: Section 2.3, 2.4

These procedures are designed to test the transceiver actions when receiving the logically correct ISO-8208 packets, from either interface, for the state of the logical channel. A series of packets will be transferred across the transceiver interfaces to stimulate the logical states. packets generated using the Protocol Analyzer (Ground) will arrive at the AES via the Satellite Subnetwork Protocol Data Units using the Satellite Subnetwork Dependent Protocol (SSNDP). Failure of these tests could be indicative of a failure to fully comply with the SSNDP.

3.4.1.1 Call Setup and Clearing States

Steps 1-3 must be performed sequentially.

Step 1 - Virtual Call Setup from HLE

Program the PAA to send an CALL REQUEST packet to the transceiver. The use of NSAP addressing is optional. Invoke the Expedited Data Negotiation Facility in the Optional CCITT-specified DTE Facilities Field. Use PAG to return a CALL ACCEPTED packet for the corresponding channel. Use the PAA to verify that the AES generates the corresponding CALL CONNECTED packet with the correct fields.

Step 2 - Data Transmission

Program the PAA to send two DATA packets to the AES on the open channel. Set the M-bit to zero on each of these DATA packets. Maintain flow control for the channel, i.e. the PS Subfields for the first and second packet should be zero and one, respectively. Use a 32-bit User Data Field, and fill the Fields with alternate one-zero patterns.

Verify that the DATA packets received in the proper order at the PAG. After both DATA packets are accepted by the AES , verify that the AES sends a RECEIVE READY packet to the PAA.

Step 3 - Clear Request Procedures from HLE

Program the PAA to send a CLEAR REQUEST packet on the open channel to the AES . Verify that the AES returns a CLEAR CONFIRMATION packet to the HLE and sends a corresponding CLEAR INDICATION packet to the PAG. Use the PAG to return a CLEAR CONFIRMATION packet. Verify that there is no output on the transceiver/HLE interface.

Steps 4-6 must be performed sequentially.

Step 4 - Virtual Call Setup from PAG

Program the PAG to send an CALL REQUEST packet to the AES. The use of NSAP addressing is optional. Invoke the Expedited Data Negotiation Facility in the Optional CCITT-specified DTE Facilities Field. Use PAA to return a CALL ACCEPTED packet for the corresponding channel. Use the PAG to verify that the AES generates the corresponding CALL CONNECTED packet with the correct fields.

Step 5 - Data Transfer from the PAG

Program the PAG to send two DATA packets to the AES on the open channel. Set the M-bit to zero on each of these DATA packets. Maintain flow control for the channel, i.e. the PS Subfields for the first and second packet should be zero and one, respectively. Use a 32-bit User Data Field, and fill the Fields with alternate one-zero patterns.

Verify that the DATA packets received in the proper order at the PAA. After both DATA packets are accepted by the AES , verify that the AES sends a RECEIVE READY packet to the PAG.

Step 6 – Ground DTE Requests to Clear the Channel

Program the PAG to send a CLEAR REQUEST packet on the open channel to the AES . Verify that the AES returns a CLEAR CONFIRMATION packet to the PAG and sends a corresponding CLEAR INDICATION packet to the PAA. Use the PAA to return a CLEAR CONFIRMATION packet. Verify that there is no output on the PAG interface.

Steps 7 – 12 can be performed in any order, if desired.

Step 7 - HLE Aborts a Call Request

Program the PAA to send a CALL REQUEST packet to the transceiver. Use the PAG to verify that the CALL REQUEST packet is output to the ground DTE. Have the PAA send a CLEAR REQUEST packet for that channel to the transceiver. Use the PAA to verify that the AES returns a CLEAR CONFIRMATION packet to the HLE. Use the PAG to verify the Clearing and Diagnostic Cause Fields in the corresponding CLEAR INDICATION packet and to return a CLEAR CONFIRMATION packet. Verify that there is no corresponding output at the transceiver/HLE interface.

Step 8 - GES Aborts a Call Request

Program the PAG to send a CALL REQUEST packet to the AES. Use the PAA to verify that the CALL REQUEST packet is output from the AES. Have the PAG send a CLEAR REQUEST packet for that channel to the transceiver. Use the PAG to verify that the AES returns a CLEAR CONFIRMATION packet to GES. Use the PAA to verify the Clearing and Diagnostic Cause Fields in the corresponding CLEAR INDICATION packet and to return a CLEAR CONFIRMATION packet. Verify that there is no corresponding output at the PAG.

Step 9 - GES rejects a Call Request

Program the PAA to send a CALL REQUEST Packet. Use the PAG to verify that a CALL REQUEST packet is produced by the GES, and to return a CLEAR REQUEST packet the GES. Verify that the GES returns a CLEAR CONFIRMATION packet to the PAG. Use the PAA to verify that the CLEAR INDICATION packet is output from AES, and to send a CLEAR CONFIRMATION packet back to the GES. Verify that there is no corresponding output to the PAG.

Step 10 - HLE Rejects a Call Request

Program the PAG to send a CALL REQUEST Packet. Use the PAA to verify that a CALL REQUEST packet is produced by the transceiver, and to return a CLEAR REQUEST packet to transceiver. Verify that the AES returns a CLEAR CONFIRMATION packet to the HLE. Use the PAG to verify that the CLEAR INDICATION packet is output from the ground entity, and to send a CLEAR CONFIRMATION packet back to the AES. Verify that there is no corresponding output to the PAA.

Step 11 - CLEAR REQUEST packet for a Channel in the Ready State (p1)

Program the PAA to send a CLEAR REQUEST packet to the transceiver. Verify that the AES returns a CLEAR CONFIRMATION packet.

Step 12 - Call Collision

Program the PAG to send a CALL REQUEST packet to the AES. Verify that the AES forwards an INCOMING CALL packet to the HLE. Program the PAA to return a CALL REQUEST packet to the AES with the same channel number. Verify that the AES forwards a CLEAR INDICATION packet to the PAG Packet, followed by a CALL REQUEST packet to the PAG.

Step 13 - Clear Channels

Perform the procedures in Step 3, to clear the channels used in Step 12.

At this point, there are no active communications channels.

3.4.1.2 Restart Request States

Steps 1 and 2 must be performed sequentially.

Step 1 - DTE Restart Procedures

Perform the procedure in 3.4.1.1, Call Setup and Clearing States, Step 1, to open two channels. Program the PAA to send a RESTART REQUEST packet to the AES. Verify the RESTART CONFIRMATION packet is returned from the AES to the PAA. Use the PAG to verify that the AES sends a CLEAR INDICATION Packet to the GES for each channel not in the p1 State. Program the PAG to send the corresponding CLEAR CONFIRMATION packet to the AES. Verify that there is no corresponding output at the PAA.

At this point, the channels have been cleared.

Step 2 - DCE Restart Procedures

Without changing the system state from that produced in Step 1, program the PAA to send a RESTART CONFIRMATION packet to the AES. Use the PAA to verify that the AES will return a RESTART INDICATION packet to the HLE with diagnostic code set to 17. Program the PAA to return a RESTART CONFIRMATION packet to the transceiver. Verify that there is no corresponding output at the AES interfaces.

Step 2 is a *negative* test, i.e., it assures robust operation in the face of an unexpected input during a restart operation.

3.4.1.3 Reset States

Step 1 - Reset Procedures by HLE

Perform the procedure in Section 3.4.1.1, Call Setup and Clearing States, Step 1, and Step 2. Program the PAA to send a RESET REQUEST packet on the open channel to the transceiver. Verify that the AES returns a RESET CONFIRMATION packet to the HLE. Use the PAG to verify that the RESET INDICATION packet sent from the AES contains the appropriate Resetting and Diagnostic Cause Fields. Program the PAG to send RESET CONFIRM packet. Verify that there is no corresponding output at the transceiver/HLE interface.

Step 2 - Reserved

Step 2 is not used at this time.

Step 3 - Reset Procedure from GES.

Perform the procedure in Section 3.4.1.1, Call Setup and Clearing States Step 1 and Step 2. Program the PAG to send a RESET REQUEST packet on the open channel to the transceiver. Verify that the GES returns a RESET CONFIRMATION packet to the PAG. Use the PAA to verify that the RESET INDICATION packet sent from the GES contains the appropriate Resetting and Diagnostic Cause Fields. Program the PAA to send RESET CONFIRM packet. Verify that there is no corresponding output at the transceiver/HLE interface.

Step 4 - Reset Request from GES. HLE responds with a RESET REQUEST packet.

Program the PAG to send a RESET REQUEST Packet on the open channel to the AES. Verify that the AES returns a RESET CONFIRM packet to the PAG and transmits the corresponding RESET INDICATION packet with the appropriate Diagnostic and Resetting Fields to the HLE. Use the PAA to return a RESET REQUEST packet to the AES. Use the PAG to verify that there is no corresponding output at the GES/DTE interface.

Step 4 is a *negative* test, in that it tests an *incorrect* response of RESET REQUEST from the PAA.

Step 5 - Clear Opened Channel

Perform the clear request procedure in Perform the procedure in Section 3.4.1.1, Call Setup and Clearing States, Step 3.

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3.4.1.4 Interrupt Transfer States

Steps 1 – 4 must be performed sequentially.

Step 1 - Virtual Call Setup

Perform the call setup procedure in 3.4.1.1, Call Setup and Clearing States Call Setup and Clearing States, Step 1.

Step 2 - Interrupt packet from the HLE

Program the PAA to send a DATA packet to the AES. Set M-bit to one. User Data Field contains 128 octets, the value of each byte increments from 0 to 127. Program the PAA to send an INTERRUPT packet with a 32-bit User Data Field containing a bit pattern of alternating one's and zero's, and another DATA packet with M-bit set to zero. Use the PAG to verify that the corresponding INTERRUPT DATA packet is not the last packet sent from the AES. Also, verify content and length of the User Data Fields. Use the PAG to send a INTERRUPT CONFIRMATION packet. Verify the INTERRUPT CONFIRMATION packet at the PAA.

Step 3 - Interrupt packet from the GES.

Program the PAG to transmit the following packets to the transceiver: a DATA packet with M-bit set to one and L_{SNDP} octets of User Data, an INTERRUPT DATA packet with 32 octets of User Data, and a second DATA packet that has the M-bit set to zero. Use the PAA to verify that the AES forwards the corresponding ISO-8208 INTERRUPT packet followed by the ISO-8208 M-bit sequence. Program the PAA to return an INTERRUPT CONFIRMATION packet to the AES. Verify the corresponding INTERRUPT CONFIRMATION packet at the PAG.

Step 4 - Clear Opened Channel

Perform the procedure in Section 3.4.1.1, Call Setup and Clearing States Step 3 to clear the open channel.

3.4.2 Error Recovery Procedures

The Error Recovery State Test Procedures are designed to test the capability of the AES to recover from erroneous packets received over the transceiver/HLE or transceiver/GES interface. A series of ISO-8208 packets will be transferred across the AES boundaries to stimulate the logical states. Unless otherwise noted, all tests occur on a single logical channel.

3.4.2.1 DCE Call Setup and Clearing States

Step 1 - Ready State (p1)

This test verifies the DCE p1 State.

a. Program the PAA to send a CALL ACCEPTED packet to the AES. Verify that the AES returns to the HLE a CLEAR INDICATION packet with diagnostic code set to 20. Program the PAA to return a CLEAR CONFIRMATION packet to the AES. Verify there is no corresponding output on the PAG.

b. Perform the procedure in Step 1a replacing the CALL ACCEPTED packet sent to the AES with each of the following packets: RESET REQUEST, CLEAR CONFIRMATION, RESET CONFIRMATION, DATA, INTERRUPT, RECEIVE READY and RECEIVE NOT READY. Verify the results as in Step 1a.

c. Program the PAA to send a RESTART REQUEST packet to the AES with channel number not equal to zero. Verify that the AES sends a CLEAR INDICATION packet to the HLE with diagnostic code set to 41. Program the PAA to return a CLEAR CONFIRMATION packet to the AES. Verify that there is no corresponding output on the PAG.

d. Perform the procedure in Step 1a, replacing the CALL ACCEPTED packet sent to the AES with an ISO-8208 packet having a packet type identifier shorter than one byte. Verify that the diagnostic code is set to 38 in the CLEAR INDICATION packet.

e. Perform the procedure in Step 1a, replacing the CALL ACCEPTED packet sent to the AES with an ISO-8208 packet having a packet type identifier which is undefined or not supported. Verify that the AES returns a CLEAR INDICATION packet with diagnostic code set to 33.

Step 2 - DTE Call Request State (p2)

This test verifies the DCE p2 State.

a. Program the PAA to send a CALL REQUEST packet to the AES. Use the PAG to verify that the AES sends a INCOMING CALL Packet to the PAG.

b. Program the PAA to send a RESET REQUEST packet on the same channel to the AES. Verify that the AES generates a CLEAR INDICATION packet to the PAA and a CLEAR INDICATION packet to the PAG with diagnostic codes set to 21. Program the PAA to return a CLEAR CONFIRMATION packet and the PAG to return a CLEAR CONFIRMATION packet to the AES.

c. Perform the procedures in Steps 2a and 2b, replacing the RESET REQUEST packet sent to the AES in procedure 2b with each of the following ISO-8208 packets: CALL REQUEST, CALL ACCEPTED, CLEAR CONFIRMATION, DATA, INTERRUPT, RECEIVE READY and RECEIVE NOT READY. The Logical Channel Number should remain the same for all test packets. Verify the results as in Step 2b.

d. Perform the procedures in Steps 2a and 2b, replacing the RESET REQUEST packet sent to the AES in procedure 2b with an ISO-8208 packet having a packet type identifier shorter than one byte. Verify that the diagnostic code is set to 38 in the CLEAR INDICATION packets.

e. Perform the procedures Steps 2a and 2b, replacing the RESET REQUEST packet sent to the AES in procedure 2b with an ISO-8208 packet having a packet type identifier which is undefined or not supported. Verify that the diagnostic code is set to 33 in the CLEAR INDICATION packets.

f. Perform the procedures in Steps 2a and 2b, replacing the RESET REQUEST packet sent to the AES in procedure 2b with an RESTART REQUEST packet or a RESTART CONFIRMATION packet with a logical channel number not equal to zero. Verify that the diagnostic code is set to 41 in the CLEAR INDICATION packets.

Step 3 - DCE Call Request State (p3)

This test verifies the DCE p3 State.

a. Program the PAG to send CALL REQUEST packet to the AES. Verify the INCOMING CALL packet.

b. Program the PAA to send a RESET REQUEST packet on the same channel to the AES. Verify that the AES senda a CLEAR INDICATION packet to the HLE and a CLEAR INDICATION packet to the PAG with diagnostic codes set to 22. Program the PAA to send a CLEAR CONFIRMATION packet to the transceiver, and program the PAG to send a CLEAR CONFIRMATION packet to the AES. Verify that there is no corresponding output at the PAA or PAG.

c. Perform the procedures in Steps 3a and 3b five times. For each iteration replace the RESET REQUEST packet sent to the AES in Step 3b with one of the following packets: CLEAR CONFIRMATION, DATA, RECEIVE READY, RECEIVE NOT READY and INTERRUPT. Verify the results as in Step 3b.

d. Perform the procedures in Steps 3a and 3b, replacing the RESET REQUEST packet sent to the AES in Step 3b with an ISO-8208 packet having a packet Type Identifier shorter than one byte. Verify that the diagnostic code is set to 38.

e. Perform the procedures in Steps 3a and 3b, replacing the RESET REQUEST packet sent to the AES in Step 3b with an ISO-8208 packet having a packet Type Identifier which is undefined or not supported. Verify that the diagnostic code is set to 33.

f. Perform the procedures in Steps 3a and 3b, replacing the RESET REQUEST packet sent to the AES in Step 3b with a RESTART REQUEST packet with the logical channel identifier not equal to zero. Verify that the diagnostic code is set to 41.

Step 4 - Data Transfer State (p4)

This test verifies the DCE p4 State.

a. Perform the procedure in Section 3.4.1.1, Call Setup and Clearing States Call Setup and Clearing States, Step 1.

b. Program the PAA to send a CALL REQUEST packet on the open channel to the AES. Verify that the AES sends a CLEAR INDICATION packet and a CLEAR INDICATION packets to the PAA and PAG with diagnostic codes set to 23. Bit eight of the Clearing Cause Field should be set to zero because the error originated at the DTE/DCE interface. Program the PAA to return a CLEAR CONFIRMATION packet, and program the PAG to send a CLEAR INDICATION to the transceiver. Verify that neither confirmation appears in the other interface.

c. Perform the procedures in Steps 4a and Step 4b two times. For the first iteration replace the CALL REQUEST packet sent to the AES with a CALL ACCEPTED packet. For the second iteration, replace the CALL REQUEST packet sent to the AES with a CLEAR CONFIRMATION packet. Verify the results as in Step 4b.

Step 5 - Call Collision State (p5)

The error recovery procedure for the Call Collision (p5) State is transitory and therefore is not tested.

Step 6 - Clear Request by DTE State (p6)

The error recovery procedure for the Clear Request by DTE (p6) State is transitory and therefore is not tested.

Step 7 - DCE Clear to DTE State (p7)

This test verifies the DCE p7 State.

a. Perform the call setup procedure in Step 2a.

b. Program the PAA to send a RESET REQUEST packet on the same channel to the AES. Verify that the AES generates a CLEAR INDICATION packets to the PAA and PAG. Both packets should have the with diagnostic code set to 21.

c. Program the PAA to send a CALL ACCEPTED packet to the AES. Verify that the packet is discarded.

d. Perform the procedure in Step 7c five times. For each iteration, replace the CALL ACCEPTED packet sent to the AES with one of the following packets: DATA, INTERRUPT, RECEIVE READY, RECEIVE NOT READY and RESET REQUEST. Verify that the packets are discarded.

e. Perform the procedure in Step 7c, replacing the CALL ACCEPTED packet sent to the AES with an ISO-8208 packet having a packet Type Identifier which is undefined or not supported.

f. Perform the procedure in Step 7c, replacing the CALL ACCEPTED packet sent to the AES with an ISO-8208 packet having a packet Type Identifier shorter than one byte.

g. Program the PAA to send a CLEAR CONFIRMATION ppacket to the AES. Program the PAG to return a CLEAR CONFIRMATION packet to the AES. Verify that there is no corresponding output at that AES interfaces.

3.4.2.2 DCE Restart States

Step 1 - packet Level Ready State (r1)

This test verifies the DCE r1 State.

a. Program the PAA to send a CALL REQUEST packet to the AES with a channel number equal to zero. Verify that the AES sends a DIAGNOSTIC packet to the PAA with diagnostic code set to 36, and that the Diagnostic Cause Field contains the first three octets of the CALL REQUEST packet.

b. Program the PAA to send a RESTART REQUEST packet with a format error to the AES. Verify that the AES returns a DIAGNOSTIC packet to the HLE with diagnostic code set to either 38, 39, 81 or 82, and the Diagnostic Cause Field contains the first three octets of the RESTART REQUEST packet.

c. Program the PAA to send a RESTART CONFIRMATION packet to the AES. Verify that the AES returns a RESTART INDICATION packet to the HLE with diagnostic code set to 17.

d. Program the PAA to send a RESTART CONFIRMATION packet to the AES. The AES enters the r1 State.

Step 2 - DTE Restart Request State (r2)

The DTE Restart Request State (r2) error recovery procedure is transitory and therefore is not tested.

Step 3 - DCE Restart Request State (r3)

This test verifies the DCE r3 State.

a. Perform again the procedure in Step 1d. The AES enters the r3 State.

b. Perform the procedure in Step 1a.

c. Program the PAA to send a RESTART REQUEST packet with format error to the AES. Verify that the AES returns a RESTART INDICATION packet to the HLE with diagnostic code set to either 38, 39, 81, or 82.

d. Perform the procedure in Step 1d.

Step 4 - DCE Special Cases

a. Program the PAA to send an ISO-8208 packet to the AES that is less than two octets in length. Verify that the AES returns a DIAGNOSTIC packet to the PAA with the Diagnostic Code Field set to 38. Also, verify the Diagnostic Cause Field.

b. Program the PAA to send a CALL REQUEST packet to the AES with a invalid General Format Identifier Field. Verify the AES returns a DIAGNOSTIC packet to the HLE with the Diagnostic Code Field set to 40. Also, verify the Diagnostic Cause Field.

3.4.2.3 DCE Reset States

Step 1 - Erroneous ISO-8208 packets for the Flow Control Ready State (d1)

This test verifies the DCE d1 State.

a. Perform the call setup procedure in 3.4.1.1, Call Setup and Clearing States Step 1.

b. Program the test set to send a RESTART REQUEST packet to the transceiver with a logical channel identifier unequal to zero on the open channel. Verify that the transceiver sends a RESET INDICATION packet to the HLE and a RESET INDICATION packet to the PAG with diagnostic codes set to 41.

c. Program the test set to send a RESET CONFIRMATION packet and the PAG to send a RESET CONFIRMATION packet to the transceiver.

d. Perform the procedures in Steps 1b and 1c. For this iteration, replace the RESTART REQUEST packet the transceiver in Step 1b with a packet having an invalid packet Type Identifier shorter than one byte. Verify that the diagnostic codes are set to 38 in the corresponding RESET CONFIRMATION packets at the HLE and PAG.

e. Perform the procedures in Steps 1b and Step 1c. For this iteration, replace the RESTART REQUEST packet with a packet having a packet Type Identifier which is undefined. Verify that the diagnostic codes are set to 33 in the corresponding RESET INDICATION packets sent to the HLE and the PAG
.

f. Perform the Clear Request procedure 3.4.1.1, Call Setup and Clearing States, Step 3.

Step 2 - Reset Request by DTE (d2)

The DTE Reset Request (d2) State error recovery procedure is transitory and therefore is not tested.

Step 3 - Reset Request by DCE to DTE (d3)

This test verifies the DCE d3 State.

a. Perform the call setup procedure in Section 0 Call Setup and Clearing States Step 1.

b. Program the PAA to send a RESET CONFIRMATION packet on the opened channel to the transceiver. Verify that the transceiver sends a RESET INDICATION packet to the PAA and a RESET CONFIRMATION packet to the PAG with diagnostic codes set to 27.

c. Program the PAA to return an INTERRUPT packet to the AES. Verify that there is no corresponding output.

d. Perform the procedure in Step 3c, replacing the INTERRUPT packet sent to the AES in Step 3c with each of the following ISO-8208 packets: INTERRUPT CONFIRMATION, RESTART REQUEST with channel number not equal to zero, DATA, RECEIVE READY, RECEIVE NOT READY, REJECT, a packet having a Packet Type Identifier shorter than one byte, and a packet having a packet Type Identifier which is undefined. Program the PAA to send a RESET CONFIRMA-TION packet and the PAG to send a RESET CONFIRMATION packet to the AES. Verify the results as in 3c.

e. Perform the clear request procedure in 3.4.1.1, Call Setup and Clearing States, Step 3.

3.4.2.4 DCE Flow Control Transfer States

Step 1 - DCE Receive Ready State (f1)

This test verifies the DCE f1 State.

a. Perform the call setup procedure 3.4.1.1, Call Setup and Clearing States Step 1.

b. Program the PAA to send a DATA packet that contains an invalid PS Field. Verify that the AES sends a RESET INDICATION packet to the PAA and a RESET INDICATION packet to the PAG with diagnostic codes set to one. Program the PAA to return a RESET CONFIRMATION packet to the AES and the PAG to return a RESET CONFIRMATION packet.

c. Program the PAA to send a DATA packet to the AES that contains an invalid PR. Verify that the AES sends a RESET INDICATION packet to the

PAA and a RESET INDICATION packet to the PAG, with diagnostic codes set to two.

d. Perform the reset confirmation procedure in Step 1b.

e. Perform the procedures in Steps 1c and 1d. Replace the DATA packet sent to the AES in Step 1c with a DATA packet that has M-bit set to one and a partially full User Data Field. Verify that the diagnostic codes are equal to 165 or 166.

f. Perform the clear request procedure 3.4.1.1, Call Setup and Clearing States, Step 3.

Step 2 - DCE Receive Not Ready (f2)

This test verifies the DCE f2 State.

a. Perform the call setup procedure in 3.4.1.1, Call Setup and Clearing States Step 1.

b. Program the PAG to send a FLOW CONTROL (Suspend) packet.

c. Program the PAA to send DATA packets to the AES until the AES returns a RECEIVE NOT READY packet to the HLE.

d. Verify that the AES will discard the following ISO-8208 packets sent from the PAA: DATA packet with a valid PR but an invalid PS, a valid DATA packet and a DATA packet that has M-bit set to one and a partially full User Data Field.

e. Perform the procedure in Step 1c. Verify the results.

f. Perform the reset confirmation procedure in Step 1b.

g. Perform the clear request procedure 3.4.1.1, Call Setup and Clearing States Step 3.

Step 3 - DTE Receive Ready (g1)

This test verifies the DTE g1 State.

a. Perform the call setup procedure 3.4.1.1, Call Setup and Clearing States Step 1.

b. Program the PAA to send a RECEIVE READY packet with a invalid PR Field to the AES. Verify that the AES sends a RESET INDICATION packet to the PAA and a RESET INDICATION packet to the PAG with diagnostic codes set to two.

c. Perform the reset confirmation procedure in Step 1b.

d. Perform the procedures in Steps 3b and Step 3c two times. For the first iteration, replace the RECEIVE READY packet sent to the AES in Step 3b with a RECEIVE NOT READY packet. For the second iteration, replace the RECEIVE READY packet sent to the AES in Step 3b with a REJECT packet. Verify the results as in 3b.

e. Perform the Clear Request procedure 3.4.1.1, Call Setup and Clearing States Step 3.

Step 4 - DTE Receive Not Ready (g2)

This test verifies the DTE g2 State.

a. Perform the call setup procedure 3.4.1.1, Call Setup and Clearing States Step 1.

b. Program the PAA to send a RECEIVE NOT READY packet to the AES.

c. Perform the procedures in Steps 3b, 3c, 4b, and 3d.

d. Perform the clear request procedure 3.4.1.1, Call Setup and Clearing States Step 3.

3.4.2.5 DCE Interrupt Transfer States

Step 1 - DTE Interrupt Sent State (i2)

This test verifies the DCE i2 State.

a. Perform the call setup procedure in 3.4.1.1, Call Setup and Clearing States Step 1.

b. Program the PAA to send an INTERRUPT packet to the AES. Use the PAG to verify that the AES sends a INTERRUPT DATA packet to the PAG. Program the PAA to send another INTERRUPT packet on the same channel to the AES.

c. Verify that the AES sends a RESET INDICATION packet to the PAG and a RESET INDICATION packet to the PAA with diagnostic codes set to 44.

d. Perform the reset confirmation procedure in 3.4.2.3, Step 1b.

e. Perform the procedure in 3.4.1.1, Call Setup and Clearing States, Step 3 to clear an open channel.

Step 2 - DCE Interrupt Ready State (j1)

This test verifies the DCE j1 State.

a. Perform the procedure in Section 3.4.1.1, Call Setup and Clearing States, Step 1 to open a channel.

b. Program the PAA to send an INTERRUPT CONFIRMATION packet to the AES.

c. Verify that the AES sends a RESET INDICATION packet to the PAG and a RESET INDICATION packet to the HLE with diagnostic codes set to 43.

d. Perform the reset confirmation procedure in 3.4.2.3, Step 1b.

e. Perform the procedure in 3.4.1.1, Call Setup and Clearing States, Step 3 to clear a channel.

3.5 Packet Assembly

The packet assembly test procedures are designed to test the AES's ability to assemble and disassemble ISO-8208 packets. These tests also verify SSNDP operation, since the confirmations are monitored at the far end of the sub-network.

The M-bit linking test procedures are designed to verify the AES's ability to combine User Data Fields of packets to form a larger packet and also to determine how the User Data Field of a packet can be subdivided to form smaller packets.

Use the PAA to perform the HLE functions, and use the PAG and PAG to perform the PAG functions.

Step 1 - Virtual Call Setup

This test opens multiple channels with the AES.

a. Program the PAA to send four CALL REQUEST packets to the AES with the following channel numbers: 2816, 2815, 2814, and 2813. Use the PAG to verify that the PAG receives INCOMING CALL packets with the four distinct logical channel numbers.

b. Program the PAG to send four CALL ACCEPTED packets to the AES. Verify that the AES sends four CALL CONNECTED packets to the PAA with the following channel numbers: 2816, 2815, 2814, and 2813.

Step 2 - M-bit Linking DATA packets from Data packets

This test verifies ISO-8208 M-bit sequence to DATA packet assembly procedure in the AES.

a. Program the PAA to send an ISO-8208 M-bit sequence consisting of four DATA packets each with L_{SNDP} +10 octets of data in the User Data field on each opened channel to the AES. Fill the User Data Field with following patterns:

channel 2816 01010101
channel 2815 10101010
channel 2814 11001100
channel 2813 00110011

b. Use the PAG to verify that the AES sends a sequence of two DATA packets to the PAG for each channel. Verify that each of the first DATA packets contain L_{SNDP} octets of the User Data Field and has M-bit set to one. Verify that the second packet for each channel contains ten octets of the User Data Field and has M-bit set to zero. Also verify that the User Data Field content corresponds with logical channels defined in step a.

Step 3 - DATA packets from the PAG

This test verifies ISO-8208 packet assembly procedures in the AES.

a. Program the PAG to send a sequence of two DATA packets to the AES for each opened channel. The first DATA packet for each channel should have the M-bit set to one. All DATA packets in each sequence should contain L_{SNDP} octets of the User Data Field listed below.

channel 2816 01010101
channel 2815 10101010
channel 2814 11001100
channel 2813 00110011

b. Verify that the AES sends the correct number, *n*, of packets on each opened channel to the PAA. Also verify that the first *n-1* DATA packets for each channel have the M-bit set to one and contain 128 octets of User Data Field listed below, and the final packet for each channel shall have M-bit set to zero and $L_{SNDP} - 128 \times (n-1)$ octets of user data.

channel 2816 01010101
channel 2815 10101010
channel 2814 11001100
channel 2813 00110011

Step 4 - Clear Channels

a. Program the PAA to send four CLEAR REQUEST packets to the AES on channels 2816, 2815, 2814, and 2813. Use the PAG to verify that the AES sends four CLEAR INDICATION packets to the PAG. Use the PAA to verify that the AES returns a CLEAR CONFIRMATION packet to the HLE on each channel (2816, 2815, 2814, and 2813).

b. Program the PAG to return four CLEAR CONFIRMATION packets on the corresponding channels to the AES.
Perform the procedure in Section 3.4.1.1, Call Setup and Clearing States, Step 3 to clear the four open channels.

3.5.1 Call Setup and Maintenance

The Call Setup and Maintenance test procedures are designed to test the AES's ability to process various requests for Virtual Call Setup. The tests are divided into five subgroups: Fast Select, Called and Calling Address (NSAP) Extension, Throughput Class Negotiation, Transit Delay Selection and Indication, and Priority.

3.5.1.1 Fast Select Facilities

The Fast Select test procedures are designed to test the AES's ability to process the Fast Select Facility request with restrictions. The ISO-8208 Fast Select Facility without restrictions is not used by ATN.

Step 1 - CALL REQUEST packet with Fast Select from the HLE

This test verifies the AES's ability to process a Fast Select request from the HLE.

a. Program the PAA to send a CALL REQUEST packet to the AES with the Facilities Field containing a Fast Select request with no restriction on response. Fill the User Data Field with 128 octets of the bit pattern 01010101.

b. Use the PAG to verify that the AES transmits the related INCOMING CALL packet to the PAG containing a Fast Select request with no restriction on response. Verify the User Data Field for content and length as established in Step 1a.

c. Program the PAG to send a CALL ACCEPTED packet to the AES. Fill the User Data Field with 128 octets of the bit pattern 10101010. Verify that the AES sends the related CALL CONNECTED packet to the PAA with the correct User Data Field.

d. Program the PAA to send a DATA packet to the AES with a User Data Field of four octets of 00110011. Verify that the GES sends the correct DATA packet to the PAG.

e. Program the PAG to send a DATA packet to the AES with a User Data Field of eight octets of 11110000. Verify that the AES sends the correct DATA packet to the PAA.

f. Program the PAA to send a CLEAR REQUEST with a Clear User Data field with 128 octets of the bit pattern 11001100 to the GES. Verify that the GES generates the associated CLEAR INDICATION containing the proper data.

g. Program the PAA to send the requisite CLEAR CONFIRMATION packet is sent to the GES, and verify that CLEAR CONFIRMATION is output from the AES.

Step 2 - CALL REQUEST packet with Fast Select from the PAG

This test verifies the AES's ability to process a Fast Select request from the PAG.

a. Program the PAG to send a CALL REQUEST packet to the AES with the Facilities Field containing a Fast Select request with no restriction on response. Fill the User Data Field with 128 octets of the bit pattern 01010101.

b. Use the PAA to verify that the AES transmits the related INCOMING CALL packet to the PAA containing a Fast Select request with no restriction on response. Verify the User Data Field for content and length as established in Step 1a.

c. Program the PAA to send a CALL ACCEPTED packet to the AES. Fill the User Data Field with 128 octets of the bit pattern 10101010. Verify that the AES sends the related CALL CONNECTED packet to the PAG with the correct User Data Field.

d. Program the PAG to send a DATA packet to the GES with a User Data Field of four octets of 00110011. Verify that the AES sends the correct DATA packet to the PAA.

e. Program the PAA to send a DATA packet to the GES with a User Data Field of eight octets of 11110000. Verify that the GES sends the correct DATA packet to the PAG.

f. Program the PAG to send a CLEAR REQUEST with a Clear User Data field with 128 octets of the bit pattern 11001100 to the AES. Verify that the AES generates the associated CLEAR INDICATION containing the proper data.

g. Program the PAG to send the requisite CLEAR CONFIRMATION packet is sent to the AES, and verify that CLEAR CONFIRMATION is output from the GES.

3.5.1.2 Called and Calling Address Extension (NSAP) Test

The Called and Calling Address Extension (NSAP) tests are designed to test the AES's ability to process packets which contain the NSAP addressing scheme.

Step 1 - Call Request from PAA

Program the PAA to send a CALL REQUEST packet to the AES. Fill the Facilities Field with the following facilities: Calling Address Extension Facility, and Called Address Extension Facility. Use the PAG to verify that the AES transmits a corresponding CALL INDICATION packet to the PAG, and that the NSAP addresses have been transparently transferred.

Step 2 - Call Accept from the PAG

Program the PAG to return a CALL ACCEPTED packet to the AES without the Responding NSAP Address Field from the request in Step 1. Use the PAA to verify that the AES transmits the corresponding CALL CONNECTED packet with the same called NSAP address that was in the original CALL REQUEST packet.

Step 3 - CALL REQUEST from PAG

Program the PAG to send a CALL REQUEST packet to the AES. Fill the Facilities Field with the following facilities: Calling Address Extension Facility, and Called Address Extension Facility. Use the PAA to verify that the AES outputs a corresponding CALL INDICATION packet to its HLE, and that the NSAP addresses have been transparently transferred.
Step 4- Clear Request Procedures

This test clears the open channel. Program the PAA to send a CLEAR REQUEST packet to the AES. Use the PAG to verify that the AES transmits the corresponding CLEAR INDICATION packet to the PAG. Use the PAG to return the corresponding CLEAR CONFIRMATION packet to the AES. Verify the corresponding CLEAR CONFIRMATION packet.

Step 5 - CALL ACCEPT from PAA

Program the PAA to return a CALL ACCEPTED packet to the AES without the Responding NSAP Address Field from the request in Step 1. Use the PAG to verify that the AES transmits the corresponding CALL CONNECTED packet to the PAG with the same called NSAP address that was in the original CALL REQUEST packet.

Step 6 – Clear Request
Repeat Step 3 to clear the open channel.

Step 7 - CALL ACCEPT from PAA - (Different NSAPs)

Repeat Step 4. Program the PAA to return a CALL ACCEPTED packet to the AES with a Responding NSAP Address Field that is different than the the request in Step 3. Use the PAG to verify that the AES transmits the corresponding CALL CONNECTED packet to the PAG with the same called NSAP address generated by the PAA.

Step 8 - Clear Request Procedures
Repeat Step 3 to clear the open channel.

3.5.1.3 Throughput Class Negotiation Facility

This test verifies the AES's ability to process a CALL REQUEST packet and CALL CONNECTED packet with Throughput Class Negotiation Facility.

Step 1 - Call Request from the PAA

Program the PAA to send a CALL REQUEST packet to the AES with the Facilities Field containing Throughput Class Negotiation facility with requested throughput class of 7 in both directions. Use the PAG to verify that the AES transmits a INCOMING CALL packet to the PAG with the same throughput classes in both directions.

Step 2 - Call Accept from the PAG

Program the PAG to send a CALL ACCEPTED packet to the AES with throughput classes less than or equal to the requested throughput classes. Verify that the AES sends the corresponding CALL CONNECTED packet to the PAA with the same throughput classes.

Step 3 - Clear Request from the PAA

Perform the procedure in Section 3.4.1.1, Call Setup and Clearing States ,Step 3 to clear the channel.

3.5.1.4 Transit Delay Selection and Indication Facility

This test verifies the AES's ability to process a CALL REQUEST packet and CALL CONNECTED packet with Transit Delay Selection and Indication Facility.
Step 1 - Call Request from the PAA

Program the PAA to send a CALL REQUEST packet to the AES with the Facilities Field containing the Transit Delay Selection and Indication Facility with a desired delay of 100 ms. Use the PAG to verify that the AES transmits a INCOMING CALL packet to the PAG with the same value of delay.

Step 2 - Call Accept from the PAG

Program the PAG to send a CALL ACCEPTED Packet to the AES with the applicable transit delay value of 5 s. Verify that the AES sends the corresponding CALL CONNECTED packet with the same transit delay value to the PAA.

Step 3 - Clear Request from the PAA

Perform the procedure in Section 3.4.1.1, Call Setup and Clearing States, Step 3 to clear the channel.

3.5.1.5 Priority Facility

The Priority Facility test procedure is designed to test the AES's ability to process the Priority facility during connection establishment and to forward a DATA packet with the agreed upon priority.

NOTE: Testing organizations are cautioned that use of the Distress/Urgency priority messages must be coordinated in advance with the cognizant aviation authorities and the satellite network operator. If permission to operate with Distress/Urgency priority is not granted, the following tests may be performed with other target values, as indicated by the parenthetical notations in the following requirements. The manufacturer shall be responsible for demonstrating by other means that priority 14 messages are handled appropriately.

Step 1 - Call Request with Distress Priority from the PAA

Program the PAA to send a CALL REQUEST packet to the AES with the Facilities Field containing a Priority facility with a target value of 14 (11) for priority of data on a connection. Use the PAG to verify that the INCOMING CALL packet from the GES has Q precedence level of 14.

Step 2 - Call Accept from the PAG. PAG Responds with the Same Priority.

Program the PAG to send the AES a CALL ACCEPTED packet with Q precedence level of 14 (11). Verify that the AES sends the corresponding CALL CONNECTED packet to the PAA with the selected value of 14 for priority of data on a connection.

Step 3 - Data from the PAA

Program the PAA to send a DATA packet to the AES. Use the PAG to verify that the the DATA packet received from the GES has Q precedence level of 14 (11).

Step 4 - Clear Request from the PAA

Perform the procedure 3.4.1.1, Call Setup and Clearing States, Step 3 to clear the channel.

Step 5 - Call Request from the PAA

Perform the call setup procedure in Step 1 above.

Step 6 - Call Accept from the PAG. PAG Responds with a Lower Priority.

Program the PAG to send to the AES a CALL ACCEPTED packet with Q precedence level of 11 (9). Verify that the AES sends the corresponding CALL CONNECTED packet to the PAA with the selected value of 11 (9) for priority of data on a connection.

Step 7 - Data from the PAA

Program the PAA to send a DATA packet to the AES. Use the PAG to verify DATA packet received from the GES has Q precedence level of 11(9)

Step 8 - Clear Request from the PAA

Perform the procedure in Section 3.4.1.1, Call Setup and Clearing States, Step 3 to clear the channel.

3.5.2 Multiple Channel Transactions

The Multiple Channel Transactions test procedures are designed to test the AES's ability to process a transaction on one logical channel while not affecting the operation of the other open logical channels. The test procedures are designed to be conducted in the given sequence. Unexpected or ambiguous test outputs may result from failure to observe the sequence.

3.5.3 Call Request Procedures

This test opens multiple logical channels with the AES. Perform the virtual call setup procedure in 3.4.1.1, Call Setup and Clearing States Step 1 twelve times to open the following ISO-8208 channel numbers: 2816, 2815, 2814, 2813, 2812, 2811, 2810, 2809, 2808, 2807, 2806, and 2805. Verify that the AES selects the a corresponding set of logical channels. Record the assignments for later reference. That is, if channel 2816 is assigned AES logical channel 255, record the pair 2816-255.

3.5.4 Data Transmission Procedures

This test transmits data from the PAA. Perform the data transmission procedure in 3.4.1.1, Call Setup and Clearing States, Step 2 for each open channel. Verify that all 12 channels are operating.

3.5.5 Clear Request Procedures

This test clears opened channels. Perform the clear request procedure in Section 3.4.1.1,Call Setup and Clearing States, Step 3, for channels 2814 and 2809. Perform the data transmission procedure in 3.4.1.1, Call Setup and Clearing States, Step 2 for the remaining 10 channels. Verify that the clearing procedures did not affect the operation of the other channels by confirming that the AES forwards the corresponding DATA packets to the PAG on all 10 channels.

3.5.6 Reset Request Procedures

This test resets channels. Perform the reset request procedures in 3.4.2.3, Reset States Step 1 for channels 2815, 2811 and 2806. Perform the data transmission procedure in Section 0 Call Setup and Clearing States Step 2 for the 10 channels. Verify that the resetting procedures did not affect the operations of the AES by confirming that the AES forwards the DATA packets to the PAG.

3.5.7 Receive Not Ready Status

Note: See the introductory material regarding selection and assignments of ISO channels contained in Section 3.

Step 1 - Data Transfer
This test transfers data from the PAG to the AES.

a. Program the PAG to send two DATA packets to the AES for each open channel, each containing 56 bits of user data. Set M-bit to zero in both packets. Verify the corresponding ISO-8208 packets sent by the AES to the PAA.

b. Program the PAA to return RECEIVE READY packets to the AES for all open channels except 2816, 2810 and 2805.

c. Perform the procedure in Step 1a for the following corresponding to channels 2815, 2813, 2812, 2807, 2806, 2805. Verify that the receive not ready conditions on channels 2816, 2810 and 2805 do not affect the operations of the other channels by confirming that the AES forwards the corresponding DATA packets to the PAA.

Step 2 - Clear Request Procedures

This test clears channels. Perform the clear request procedure in 3.4.1.1, Call Setup and Clearing States, Step 3, for channels 2816, 2810 and 2805. Repeat step 1c and verify that no data was transmitted to the PAA.

3.5.8 Error Recovery Procedures

Step 1 - Force an Error Condition

This test forces channels into an error recovery state.

a. Program the PAA to send a CALL REQUEST packet to the AES on channels 2815 and 2807. Verify that the AES returns a CLEAR INDICATION packet to the PAA on channels 2815 and 2807. Also verify that the AES transmits, on the logical channels corresponding to 2815 and 2807, a CLEAR INDICATION packet to the PAG. Diagnostic codes should be set to 23.

b. Perform the data transmission procedure in 3.4.1.1, Call Setup and Clearing States, Step 2, for channels 2813, 2812, 2811, 2808, and 2806. Verify that the error recovery conditions on channels 2815 and 2807 do not affect the operations of the other open channels by confirming that the AES forwards the corresponding DATA packets to the PAG.

Program the PAA to send a CLEAR CONFIRMATION packet to the AES on channels 2815 and 2807. Program the PAG to respond to the AES with a CLEAR CONFIRMATION packet for logical channels corresponding to 2815 and 2807.

Step 2 - Clear Open Channels

This test clears open channels. Perform the clear request procedure in Section 3.4.1.1, Call Setup and Clearing States Step 3 for channels 2813, 2812, 2811, 2808 and 2806.

3.6 ISO-8208 DCE Timer Test Procedures

Reference: Section 2.6
The DCE Timer test procedures are designed to test the AES's ability to perform corrective actions when the ISO-8208 DCE timers tN10 through tN13 expire.

3.6.1 tN10 Timer Procedure

Program the PAG to send a RESTART REQUEST packet to the AES via the subnetwork. Verify that the AES sends a RESTART INDICATION packet to the PAA. Disable any PAA response to this packet. Wait for an interval of tN10 seconds after sending the RESTART INDICATION. Use the PAA to send a CALL REQUEST packet to the AES and verify that there is no corresponding response to the PAG.

<u>NOTE</u>: To facilitate the next test, initialize the AES by using the PAA to return a RESTART CONFIRMATION packet to the AES; there should be no ISO-8208 outputs from the AES.

3.6.2 tN11 Timer Procedure

Program the PAG to send a CALL REQUEST packet to the AES. Verify that the AES sends a corresponding INCOMING CALL packet to the PAA. Disable any PAA response to this packet. Wait and verify that within the interval tN11 to tN11+5 seconds after sending the INCOMING CALL packet, the AES sends a CLEAR INDICATION packet to the PAA with D=49.

<u>NOTE</u>: To facilitate the next test, initialize the AES by using the PAA to send a CLEAR CONFIRMATION packet to the AES, and use the PAG to send a CLEAR CONFIRMATION packet to the AES; there should be no ISO-8208 outputs at the AES/PAA interface and no packet outputs at the AES/PAG interface.

3.6.3 tN12 Timer Procedure

Perform the call setup procedure in 3.4.1.1, Call Setup and Clearing States, Step 3, Step 1. Program the PAG to send a RESET REQUEST packet to the AES. Verify that the AES sends a corresponding RESET INDICATION packet to the PAA. Disable any PAA response to this packet. Wait and verify that within the interval tN12 to tN12+5 seconds after sending the RESET INDICATION packet, the AES sends a CLEAR INDICATION packet to the PAA with D=51.

NOTE: To facilitate the next test, initialize the AES by using the PAA to send a CLEAR CONFIRMATION packet to the AES, and use the PAG to send a CLEAR CONFIRMATION packet to the AES; there should be no ISO-8208 outputs at the AES/PAA interface and no packet outputs at the AES/PAG interface.

3.6.4 tN13 Timer Procedure

Perform the call setup procedure in 3.4.1.1, Call Setup and Clearing States, Step 1. Use the PAG to send a CLEAR REQUEST packet to the AES. Verify that the AES sends a CLEAR INDICATION packet to the PAA. Disable any PAA response to this packet. Wait for the interval tN13 seconds. Perform the call setup procedure in Section 3.4.1.1, Step 1, using the same logical channel number used at the start of this timer test. Verify that a corresponding INCOMING CALL with that logical channel number is received at the PAG.

4 TEST EQUIPMENT

4.1 Standard Test Equipment

4.2 Special Test Equipment

Protocol Analyzer (Air) – this device consists of a computer capable of bi-directional communications with the AES under test by means of one of the provided digital data bus formats. The Protocol Analyzer (Air) (PAA) shall be capable of acting as an ISO-8208/ANSI X.25 Data Transmitting Equipment (DTE). The PAA shall permit user control of data content and message timing for transmitted messages, and shall permit user examination of incoming and outgoing messages on both octet and message levels.

Protocol Analyzer (Ground) -- this device consists of a computer capable of bi-directional data communications with the GES by means of one of the GES-supported digital data bus formats (e.g. X.25). The Protocol Analyzer (Ground) (PAG) shall be capable of acting as an ISO-8208/ANSI X.25 Data Transmitting Equipment (DTE). The PAA shall permit user control of data content and message timing for transmitted messages, and shall permit user examination of incoming and outgoing messages on both an octet and an message level.

Data Generation Unit --

A *transceiver test controller* may be required to initiate or induce the AES to a certain state, or to initialize a certain condition. It is permissible for the transceiver test controller to use existing AES interfaces for this purpose.

4.3 Test Configuration

The requirements established by this appendix concern the implementation of an ISO-8208 compatible Data Circuit-terminating Equipment (DCE) interface on the digital side of the AES . To verify the proper functionality of that interface, it is necessary to issue certain commands and analyze certain responses from both a simulated Data Terminal Equipment (DTE) external to the AES and from a corresponding simulated DTE external to the GES. One means of verifying compliance would be to probe the radio-frequency emissions of the AES , back out the satellite-network signal-in-space, Layer 1 and Layer 2 and possible Satellite Subnetwork Dependent Protocols, and confirm transmission of the proper DCE-DCE message traffic. This approach requires the ability to simulate the signal processing of the entire satellite network, including its ground terminals and gateways to the public and private networks. This is a complex and expensive process.

The same information can be obtained, however, by using the satellite network directly, and examining the data at the output of the GES. The potential exists to remotely access this information so that the entire testing is performed in a closed loop from a single location, as shown in Figure 5.

Note: Use of the Active Satellite Sub-Network for performance testing is subject to the restrictions identified in Section 2.4.2.1.2.2 of the MOPS.

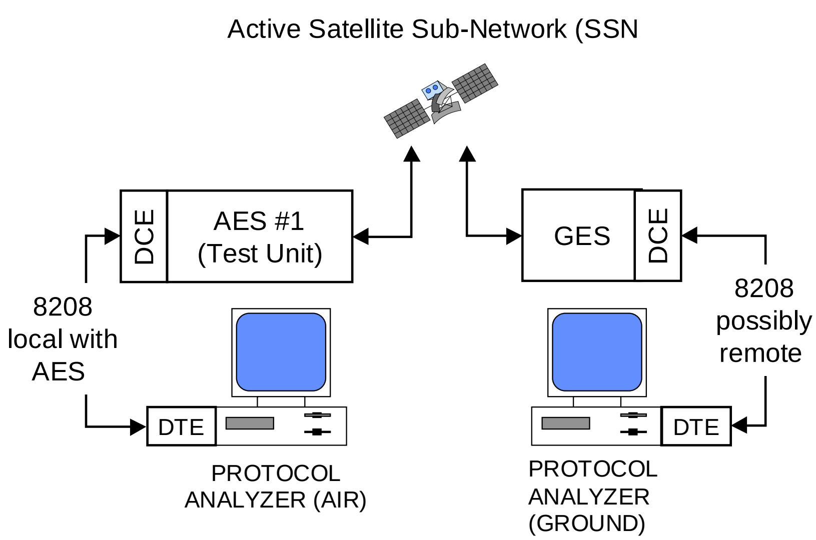


Figure 27: High-Level Test Set Up for DCE Interface Testing

APPENDIX C – RECOMMENDED STANDARDS FO AMSS EQUIPMENT NOT PROVIDING AMS(R)S

This appendix provides guidance on the tailoring of the MOPS requirements for AMSS equipment that does not provide AMS(R)S. For such equipment, which supports only non-safety data and/or voice communications, many of the needs for interoperability features specified in the MOP no longer exist. However, the provision of AMS(R)S by terminals operating within the same satellite subnetwork, and the necessity of protecting other CNS systems on-board the same aircraft and within the same airspace make it desirable that all AMSS equipment be held to a subset of the minimum standards established for AMS(R)S.

Table C-1 provides a cross-reference to the paragraphs of the MOPS body and an indication of what specific paragraphs should apply to a non-safety AMSS system. Paragraphs have been listed to the sixth level of indenture. In general, lower-level paragraphs have been deleted for brevity. In the case where a higher-level requirement does not apply to non-safety AMSS, then it can be assumed that no lower-level unlisted requirements apply. In cases where lower-level requirements may or may not apply, the table has been expanded to a depth consistent with clearly identifying which requirements should be met by non-safety AMSS equipment.

To the extent that a requirements sub-paragraph of Section 2.2 applies, the associated verification paragraph(s) of Section 2.3 and 2.4 apply as well.

Manufacturers of non-safety AMSS equipment using NGSS technologies are urged to consider all of the antenna (Section 2.2.2.1), transmitter (Section 2.2.2.1.1) and receiver (Section 2.2.2.1.2) requirements as guidance in their design.

Table C- 1: Recommended Tailoring of AMS(R)S MOPS to AMSS Equipment that Provides No Safety Services

MOPS Paragraph	MOPS Paragraph Title	Apply to Non-Safety AMSS?	Comments or AMSS-specific recommendation
1.	PURPOSE AND SCOPE	N/A	Section 1 contains no requirements
2.	EQUIPMENT PERFORMANCE REQUIREMENTS AND TEST PROCEDURES	N/A	Title sections containing no requirements are listed as not applicable ("N/A")
2.1	GENERAL REQUIREMENTS	N/A	
2.1.1	Airworthiness	YES	
2.1.2	Intended Function	YES	
2.1.3	Federal Communications Commissions Rules	YES	
2.1.4	Fire Protection	YES	
2.1.5	Operation of Controls	YES	
2.1.6	Accessibility of Controls	YES	
2.1.7	Effects of Tests	YES	
2.1.8	Performance in a Shared Environment	NO	
2.2	EQUIPMENT PERFORMANCE REQUIREMENTS, STANDARD CONDITIONS	N/A	
2.2.1	Avionics Subsystem Definitions and Overall Requirements	NO	
2.2.2	Definition of System Specific Parameters	PARTIAL	AMSS parameters necessary to establish compliance with suggested requirements ("YES" in this table) should be declared.
2.2.3	Detailed Requirements	N/A	
2.2.3.1	AES Application Requirements	N/A	
2.2.3.1.1	Antenna	NO	
2.2.3.1.1.1	Coverage Volume, Polarization, and Antenna Gain	NO	
2.2.3.1.1.2	Axial Ratio	NO	
2.2.3.1.1.3	Power Handling Capabilities	NO	
2.2.3.1.1.4	Passband	NO	
2.2.3.1.1.5	Antenna Voltage Standing Wave Ratio	NO	
2.2.3.1.1.6	Radiated Antenna Intermodulation Products	YES	
2.2.3.1.1.7	Carrier-to-Multipath Discrimination	NO	
2.2.3.1.1.8	Pattern Discrimination	NO	
2.2.3.1.1.9	Steered Antenna Requirements	NO	
2.2.3.1.2	Transceiver Subsystem	N/A	
2.2.3.1.2.1	Transmitter Function	N/A	
2.2.3.1.2.1.1	Minimum Power Output	NO	
2.2.3.1.2.1.2	Maximum Individual Carrier Output	NO	
2.2.3.1.2.1.3	Maximum Total Transceiver Output	YES	
2.2.3.1.2.1.4	Transmitter Function Intermodulation Performance	YES	
2.2.3.1.2.1.5	Transmitter Function Harmonics, Discrete Spurious and	YES	

MOPS Paragraph	MOPS Paragraph Title	Apply to Non-Safety AMSS?	Comments or AMSS-specific recommendation
	Noise		
2.2.3.1.2.1.6	Protection of Radio Astronomy	YES	
2.2.3.1.2.1.7	Carrier Off Level	YES	
2.2.3.1.2.1.8	Power Control	NO	
2.2.3.1.2.1.9	Transmitter Operation in Moving Aircraft	NO	
2.2.3.1.2.2	Receiver Function	NO	No sub-paragraphs apply to non-safety-AMSS equipment, but non-safety AMSS designers may wish to consider the requirements as guidance
2.2.3.1.3	Required Aircraft Interfaces	N/A	
2.2.3.1.3.1	External Position	NO	
2.2.3.1.3.2	External Time Reference	NO	
2.2.3.2	User Link Modulation and Signal in Space	NO	
2.2.3.3	Priority, Precedence and Preemption	YES	If the satellite network offers AMS(R)S service, an AES designed to offer only non-safety AMSS should implement the technique-specific methods defined to allow preemption of AMSS communications by AMS(R)S equip-ment Non-safety AMSS equipment need not include the ability to actively preempt, and need not include internal priority or precedence capabilities for its own data or voice traffic.
2.2.3.3.1	Packet Data	NO	
2.2.3.3.2	Circuit Mode Communications	NO	
2.2.3.4	Satellite Subnetwork Data Protocol (Satellite Layer 2)	NO	
2.2.3.5	Voice Protocol	NO	
2.2.3.5.1	Vocoder Interoperability With Satellite Subnetwork	NO	
2.2.3.5.2	Vocoder Performance in an Aeronautical Environment	NO	
2.2.3.6	User Data Interfaces	NO	
2.2.3.6.1	ATN-Compliant Protocol	NO	
2.2.3.6.1.1	Join and Leave Requirements	NO	
2.2.3.6.1.2	ATN-compliant Mapping for Priority, Precedence, and Preemption	NO	
2.2.3.6.2	Data-2	NO	
2.2.3.6.3	Satellite Subnetwork Requirements	NO	
2.2.3.6.3.1	Satellite Subnetwork Dependent Protocol Requirements	NO	
2.2.3.6.3.2	ATN-compliant Requirements	NO	
2.2.3.6.3.3	Data 2 Requirements	NO	
2.2.3.6.4	External Physical and Data Link Layer Requirements	NO	
2.2.3.6.5	Avionics Subnetwork Interface Requirements for ISO-8208	NO	

MOPS Paragraph	MOPS Paragraph Title	Apply to Non-Safety AMSS?	Comments or AMSS-specific recommendation
	Service		
2.2.3.6.6	Alternative ATN-compliant Subnetwork Access Protocols	NO	
2.2.3.7	Circuit Mode Service Requirements	NO	
2.2.3.8	Recovery from Primary Power Interruption	NO	
2.2.3.9	Failure/Status Indication	NO	
2.3	EQUIPMENT PERFORMANCE – ENVIRONMENTAL CONDITIONS	N/A	
2.3.1	General Requirements	YES	
2.3.2	Equipment Configurations	YES	
2.3.3	Configuration Control	YES	
2.3.4	Specific Environmental Test Conditions	YES	
2.3.5	Performance vs. Test Requirements Matrix	YES	
2.4	EQUIPMENT PERFORMANCE VERIFICATION PROCEDURES	N/A	
2.4.1	Definitions of Terms and Conditions of Test	NO	
2.4.1.1	AES Application Test Conditions	PARTIAL	These test conditions should be followed to the extent necessary to comply with the recommended requirements ("YES" in this table)
2.4.1.1.1	Antenna Subsystem Test Conditions	PARTIAL	
2.4.1.1.1.1	Antenna Under Test	PARTIAL	
2.4.1.1.2	Transceiver Subsystem Test Conditions	PARTIAL	
2.4.1.1.3	Required Aircraft Interfaces Test Conditions	PARTIAL	
2.4.1.2	Satellite Subnetwork Test Conditions <Modulation and Signals in Space>	NO	
2.4.1.3	Priority, Precedence, and Preemption Test Conditions	PARTIAL	These test conditions should be followed to the extent necessary to comply with the recommended requirements ("YES" in this table)
2.4.1.4	Satellite Subnetwork Data Protocol Test Conditions	NO	
2.4.1.5	Voice Protocol Test Conditions	NO	
2.4.1.6	User Data Interfaces Test Conditions	NO	
2.4.1.7	Circuit Mode Service Test Conditions	NO	
2.4.1.8	Recovery from Primary Power Failure Test Conditions	NO	
2.4.1.9	Failure/Status Indication Test Conditions	NO	
2.4.2	Required Test Equipment	N/A	
2.4.2.1	AES Application	PARTIAL	The test equipment required for the suggested tests should be equivalent to the equipment identified in the MOPS. Only tests conditions necessary to comply with the recommended requirements ("YES" in this table) need to be performed
2.4.2.1.1	Antenna Subsystem Required Test Equipment	PARTIAL	
2.4.2.1.1.1	Standard Test Equipment	PARTIAL	
2.4.2.1.1.2	Special Test Equipment	PARTIAL	
2.4.2.1.2	Transceiver Subsystem Required Test Equipment	PARTIAL	
2.4.2.1.2.1	Standard Test Equipment	PARTIAL	
2.4.2.1.2.2	Special Test Equipment	PARTIAL	
2.4.2.1.3	Required Aircraft Interfaces Required Test Equipment	PARTIAL	
2.4.2.2	Modulation and Signal in Space Required Test Equipment	PARTIAL	

MOPS Paragraph	MOPS Paragraph Title	Apply to Non-Safety AMSS?	Comments or AMSS-specific recommendation
2.4.2.3	Priority, Precedence, and Preemption Test Equipment	PARTIAL	
2.4.2.3.1	Packet Data	NO	
2.4.2.3.2	Circuit Mode Communications	NO	
2.4.2.4	Satellite Subnetwork Data Protocol Test Equipment	NO	
2.4.2.5	Voice Protocol Required Test Equipment	NO	
2.4.2.6	User Data Interface Required Test Equipment	NO	
2.4.2.7	Circuit Mode Service Test Equipment	NO	
2.4.2.8	Recovery from Primary Power Interruption Test Equipment	NO	
2.4.2.9	Failure/Status Indication Test Equipment	NO	
2.4.3	Detailed Test Procedures	N/A	An AES that does not provide AMS(R)S service should follow the test procedures corresponding to the Section 2.2.3 requirements indentified above.
3.	INSTALLED EQUIPMENT PERFORMANCE	N/A	
3.1	Equipment Installation	N/A	
3.1.1	Accessibility	NO	
3.1.2	Aircraft Environment	YES	
3.1.3	Display Visibility	NO	
3.1.4	Inadvertent Turn-Off	NO	
3.1.5	Failure Protection	YES	
3.1.6	Interface Interference Effects	YES	
3.1.7	Aircraft Power Source	YES	
3.2	Installed Equipment Performance Requirements	YES	
3.2.1	Radiated Antenna Intermodulation Products in AMS(R)S Bands	YES	The requirements should apply with the AMSS-only equipment as the source and the AMS(R)S system as the victim. The complementary requirement need not apply.
3.3	Conditions of Test	YES	
3.3.1	Power Input	YES	
3.3.2	Environment	YES	
3.3.3	Adjustment of Equipment	YES	
3.3.4	Warm-up Period	YES	
3.4	Test Procedures for Installed Equipment Performance	YES	
3.4.1	Installation Inspection	YES	
3.4.2	Interference Tests	YES	
3.4.2.1	SATCOM B Interference to SATCOM A	NO	
3.4.2.2	SATCOM A Interference to SATCOM B.	YES	The test should be applied with the AMSS-only equipment as the source ("SATCOM A") and the AMS(R)S system as the victim ("SATCOM B").

MOPS Paragraph	MOPS Paragraph Title	Apply to Non-Safety AMSS?	Comments or AMSS-specific recommendation
			The complementary tests defined in 3.4.2.1 need not be applied.
3.4.3	Power Fluctuation Tests	NO	
3.4.4	Ground Test Procedures	NO	
3.4.5	Flight Test Procedures	NO	
3.4.6	Installed System Performance Verification	N/A	
3.4.6.1	Installed Functionality	NO	
3.4.6.2	Installed Antenna Coverage	NO	
4.	EQUIPMENT OPERATIONAL PERFORMANCE CHARACTERISTICS	NO	
4.1	Operational Performance Requirements	NO	
4.1.1	Power Input	NO	
4.1.2	Communications Displays	NO	
4.1.3	Communications Controls	NO	
4.1.4	System Operational Indication	NO	
4.1.5	Equipment Operating Limitations	NO	
4.2	TEST PROCEDURES FOR OPERATIONAL PERFORMANCE REQUIREMENTS	NO	
4.2.1	Power Input	NO	
4.2.2	Communications Displays	NO	
4.2.3	Communications Controls	NO	
4.2.4	System Operational Indication	NO	

APPENDIX D NORMATIVE REQUIREMENTS FOR IRIDIUM AMS(R)S EQUIPMENT

1 INTRODUCTION

1.1 Scope and Objectives

This normative appendix provides Iridium-specific technical requirements and information regarding the technical characteristics of an Aircraft Earth Station (AES) operating over the Iridium satellite network for the purpose of providing Aeronautical Mobile Satellite (Route) Service or AMS(R)S. The International Civil Aviation Organization (ICAO) and International Telecommunications Union (ITU) reserve the designation "(Route)" for services related to the "safety and regularity of flight along national and international air routes."

This normative appendix has been developed in accordance with RTCA DO-262 as a technique-specific attachment to an application for certification or other approval document. This appendix covers Iridium Satellite avionics requirements and tests for the AES only, including the Iridium transceiver and auxiliary equipment and the associated antenna. As required by DO-262, this appendix contains both detailed requirements and test procedures. Compliance with these requirements and test procedures is intended to provide one means of providing evidence for certification or other approval for Iridium AMS(R)S services. Alternative means of compliance that provide equivalent information are acceptable.

The focus in this document is on ensuring correct behavior of the AES at the services interfaces, where the user avionics interact with the AES, and at the signals-in-space interface, where the AES has desired interaction with the network, and potentially undesired interaction with other aircraft systems and the outside world.

1.1.1 Document Overview

Section 1 of this normative appendix provides an informative description of the Iridium Satellite network, focusing on those aspects particular to AMS(R)S. Definitions and assumptions essential to proper understanding of this normative appendix are provided in this Section, while a more extensive glossary can be found in Appendix A of the DO-262 MOPS main document. Section 1 is intended to be informative in nature and contains no requirements applicable to the avionics equipment covered in this normative appendix.

The remaining sections contain normative information regarding technique or technology-specific requirements that are unique to the Iridium Satellite network. These sections are organized based on the numbering and format of the DO-262 MOPS.

Section 2 contains minimum performance standards that specify the required performance under standard operating and environmental conditions and provides values which quantify requirements specific to Iridium AMS(R)S.

Section 3 describes the performance required of installed Iridium aircraft avionics equipment. Tests specifically for installed Iridium equipment are included when performance cannot be adequately determined through bench testing.

Section 4 describes the operational performance characteristics for Iridium equipment installations and for network operation, and defines conditions that will assure the Iridium equipment user that operations can be conducted safely and reliably in the expected operational environment.

1.1.2 Iridium as a Commercial Service

Iridium is a commercially operated telephony and data communications system operated by Iridium Satellite LLC (ISLLC). Some aspects of the system design and service offerings have been specifically modified to support AMS(R)S data and voice communications, while other aspects of the system design are common with the standard commercial service offerings. A

Technical Manual for Iridium AMS(R)S was approved by ICAO in November 2007. A description of the Iridium network is contained in Section 1.2 *et seq.*

1.1.3 Applicable Documents

Detailed descriptions of some portions of the design and operation of Iridium AMS(R)S are contained in proprietary company documents referenced in this normative appendix. The following list summarizes documents referenced in this normative appendix:

Reference Name	**Reference Document Name**	**Version**
A	Iridium Speech Coder Overview	NDR-G0609.SYS
B	Report on the Certification of an Iridium Satellite LLC Daytona L-Band Transceiver with Respect to FCC Rules CFR-47, Part 25	
C	Report on the Certification of an Iridium Satellite LLC SBD Transceiver with Respect to the FCC Rules CFR 47, Part 25	
D	Iridium Satellite Compliance and Test Requirements for Value Added Manufacturing (VAM) Products	
E	Iridium Packet Error Rate Calculations Paper	V1
F	Iridium Aircraft Multi-Modem	V0.32
G	Iridium ATS Operator Guide MAN-2000-IR	V2.0
H	Iridium Doppler Requirements/ Performance for Aeronautical Communication GEN-0020	V1.0

The documents in this list fall under the RTCA proprietary disclaimer note at the beginning of this document. In the event of any conflict between documents, this MOPS shall take precedence. Note that Iridium Reference G does not require an NDA for disclosure.

These are proprietary documents of Iridium Satellite LLC that must be obtained from ISLLC under a non-disclosure agreement (NDA).

The following references are used in the document and are not controlled by Iridium but may not be public documentation. Developer is responsible for obtaining access to these documents.

#	**Reference Title**
1	Environmental Conditions and Test Procedures for Airborne Equipment, RTCA DO-160G.
2	ARINC Standards 761, 741 part 2, 429 as referenced in the document
3	Minimum Operational Performance Standards for Geosynchronous Orbit Aeronautical Mobile Satellite Services (AMSS) Avionics, RTCA DO-210D plus changes 1, 2 and 3.
4	Minimum Aviation System Performance Standards (MASPS) for the Aeronautical Mobile-Satellite (R) Service (AMS(R)S as used in Aeronautical Data Links RTCA DO-270 MASPS
5	Minimum Operational Performance Standards (MOPS) for Avionics Supporting Next Generation Satellite Systems (NGSS) RTCA DO-262
6	ICAO Global Operation Data Link Document (GOLD), 2nd Edition – 26 April 2013.
7	ICAO SATCOM Voice Guidance Material (SVGM), 1st Edition – 24 July 2012.

8	Satellite Earth Stations and Systems (SES); Aircraft Earth Stations (AES) Operating below 3 GHz under the Aeronautical Mobile Satellite Service (AMSS) / Mobile Satellite Service (MSS) and/or the Aeronautical Mobile Satellite on Route Service (AMS(R)S) / Mobile Satellite Service (MSS), ETSI EN 301 473 version 1.4.1 March 2013.
9	ICAO Annex 10 Chapter 4 AMSS and AMS(R)S SARPs.
10	ICAO GNSS SARPs Annex 10 Sixth Edition
11	Airworthiness Security Process Specification RTCA DO-326

1.2 Iridium Satellite Network

1.2.1 Overview

Iridium Satellite Network, with its constellation of 66 low Earth orbit (LEO) satellites, is a global mobile satellite communication network, with complete coverage of the entire Earth, including polar regions, offering voice and data service to and from remote areas.

Iridium data services include Circuit-Switched Data with a throughput rate of up to 2.4 Kbps, Router-Based Unrestricted Digital Interworking Connectivity Solution (RUDICS), and Iridium Short Burst Data (SBD) service.

Iridium Satellite operates its Satellite Network Operations Center (SNOC) in Virginia, USA. Gateways for Iridium are in Arizona and Hawaii, USA. Telemetry, Tracking, and Control (TTAC) facilities are located in Arizona and Alaska, USA; Yellowknife and Iqaluit, Canada; and Svalbard, Norway, with backup facilities located around the globe.

ISLLC has contracted The Boeing Company to operate and maintain its satellite constellation. The Iridium constellation, gateway facilities, testing and development laboratories, TTAC facilities, as well as overall network and system health, are continuously monitored. ISLLC manufactures its subscriber equipment, satellite handsets, L-band[3] Transceivers (LBT) 95xx, and Short Burst Data (SBD)-only Transceivers 96xx. The LBT and SBD devices are installed in the Iridium SATCOM Data Units (SDUs).

Multiple tests and analyses have demonstrated satellite constellation longevity to provide service through the transition plan of the next generation constellation. Plans are underway for manufacture and launch of the next generation constellation starting in 2015 with completion planned for full operation by 2017. Continuity of service is core part of the satellite transition with fully backward compatibility.

1.2.2 International Telecommunication Union (ITU) Frequency Assignment

The Iridium network uses radio frequency assignments that have been coordinated and notified in accordance with the provisions of the Radio Regulations under the aegis of the International Telecommunication Union (ITU).

ITU RR5.367 states that AMS(R)S can be provided on a primary basis after completion of coordination under RR9.21.

At this time, coordination required under RR9.21 for AMS(R)S on a primary basis pursuant to RR5.367 is completed except for 8 countries.

1.2.3 System Architecture

The Iridium Satellite Network is a satellite-based, wireless personal communications network, based on Global System for Mobile Communications standard (GSM), providing voice and data services to virtually any destination on earth.

[3] For the purpose of this document, the term “L-band” specifically refers to the band 1616-1626.5 MHz.

The Iridium communication system comprises three principal components: the satellite network, the ground network and the Iridium subscriber products. The design of the Iridium network allows voice and data to be routed virtually anywhere in the world. Voice and data calls originated by a terrestrial user to an aircraft AES are relayed from the Gateway (GES) to the satellite communicating directly with the Gateway through a series of satellites until the call is received at the Aircraft Earth Station (AES), which includes the Iridium transceiver. For aircraft to ground communications, the system functions in the reverse.
The key elements of the Iridium communication system are illustrated in Figure 1-1.

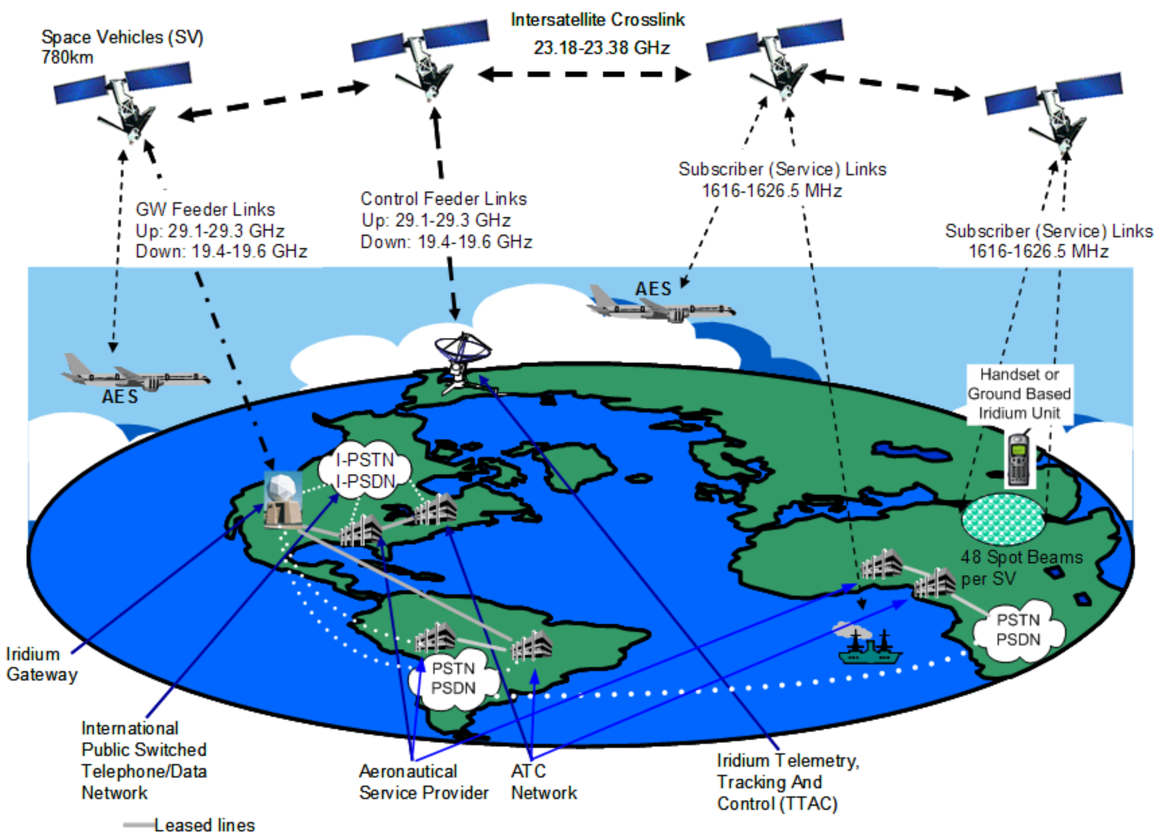


Figure 1-1 Key Elements of the Iridium AMS(R)S

1.2.4 Space Segment

The Iridium space segment utilizes a constellation of 66 operational satellites in low-Earth orbit, as shown in Figure 1-2. The satellites are located in six distinct planes in near-polar orbit at an altitude of approximately 780 km and circle the Earth approximately once every 100 minutes, travelling at a rate of roughly 27,088 km/h. The 11 mission satellites within each plane are spaced approximately every 32.7 degrees and perform as nodes in the communications network. Satellite positions in adjacent odd and even numbered planes are offset from each other by one-half of the satellite spacing. This constellation ensures that every region on the globe is covered by at least one satellite at all times. As of July 2008 there were 10 additional satellites in-orbit spares ready to replace any unserviceable satellite in case of a failure.
Each satellite communicates with the AES, which includes the SDUs, through tightly focused antenna beams that form a continuous pattern on the Earth's surface. Each satellite uses three

phased-array antennas for the user links, each of which contains an array of transmit/receive modules. The phased-array antennas of each satellite create 48 spot beams arranged in the configuration shown in Figure 1-3 covering a circular area with a diameter of approximately 4,700 km. These arrays are designed to provide user-link service by communicating within the 1616-1626.5 MHz band.

The near-polar orbits of Iridium satellites (commonly referred to as space vehicles or satellites) cause the satellites to be closer together as the sub-satellite latitude increases, as illustrated in Figure 1-2. This orbital motion, in turn, causes the coverage of neighbouring satellites to increasingly overlap as the satellites approach the poles. A consistent sharing of load among satellites is maintained at high latitudes by selectively deactivating outer-ring spot beams in each satellite. This beam control also results in reduced inter-satellite interference and increased availability in high latitudes due to overlapping coverage.

The Iridium Satellite Network architecture incorporates certain characteristics which allow the Space Segment communications link with subscriber equipment to be transferred from beam to beam and from satellite to satellite as such satellites move over the area where the subscriber is located. This transfer is transparent to the user, even during real-time communications.

Each satellite has four cross-link antennas to allow it to communicate with and route traffic to the two satellites that are fore and aft of it in the same orbital plane, as well as to neighbouring satellites in the adjacent co-rotating orbital planes. These inter-satellite links operate at approximately 23 GHz. Inter-satellite networking is a significant technical feature of the Iridium Satellite Network that enhances system reliability and capacity and reduces the number of gateways or Ground Earth Stations (GESs) required to provide global coverage to one with redundant back-up switch, processors and an earth terminal station which is physically separated from the primary GES.

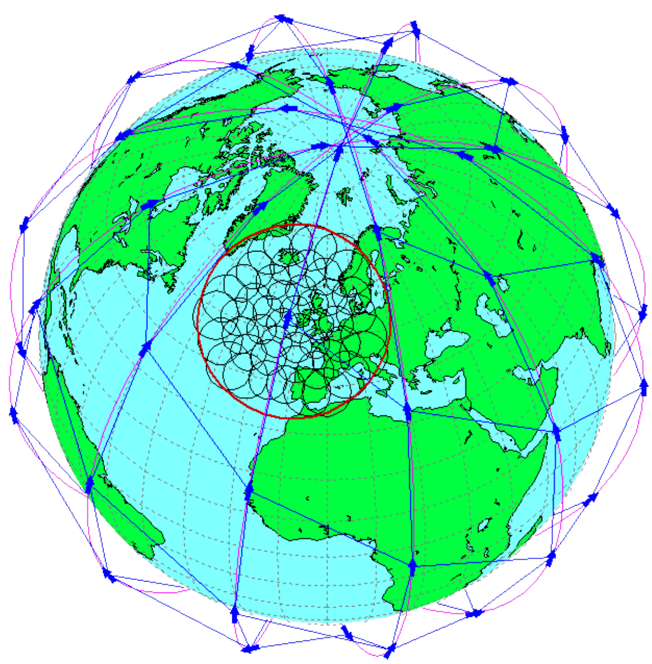
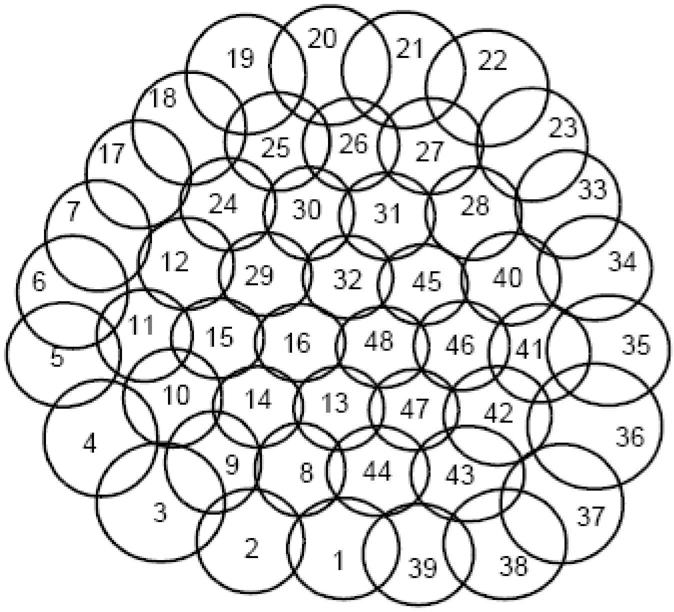


Figure 1-2 Iridium 66-Satellite Constellation



<u>Figure 1-3</u> Iridium Spot-Beam Configuration

1.2.5 Terrestrial Segment

The terrestrial segment is comprised of the System Control Segment and Iridium Gateways that connect into the terrestrial telephone/data network.

The System Control Segment is the central management component for the Iridium system. It provides global operational support and control services for the satellite constellation, delivers satellite-tracking data to the Iridium Gateways, and performs the termination control function of messaging services.

The System Control Segment consists of three main components: five TTAC sites, the Operational Support Network (OSN), and the SNOC. The primary linkage between the System Control Segment, the satellites, and the gateways is via control feeder links and inter-satellite cross-links throughout the satellite constellation.

The Iridium Gateway provides call processing and control activities such as subscriber validation and access control for all calls. The gateway connects the Iridium satellite network to ground communication networks, such as the terrestrial Public Switched Telephone Networks (PSTNs) and Public Switched Data Networks (PSDNs), and communicates via ground-based antennas with the gateway feeder-link antennas on the satellite. The gateway can also serve as a gateway to the aeronautical telecommunication network (ATN) for forwarding ATN messages from the aircraft to the required Air Traffic Command (ATC) or Aircraft Operational Communication (AOC) unit or vice versa. The gateway includes a subscriber database used in call processing activities such as subscriber validation, keeps a record of all traffic, and generates call detail records used in billing.

1.2.6 Channel Classifications

Each Iridium communications channel consists of a time-slot and a carrier frequency. Channels provided by the system can be divided into two broad categories: system overhead channels and bearer service channels. Bearer service channels include traffic channels and messaging channels, while system overhead channels include ring alert channels, Broadcast Channels, acquisition and synchronization channels. A specific time-slot-and-frequency combination may be used for several types of channels, depending on what specific activity is appropriate at each instant. Each time-slot-and-frequency combination is only used for one purpose at a time. Figure 1-4 illustrates the hierarchy of Iridium channel types. Iridium aeronautical services utilize only the indicated channel types.

In the discussions that follow, the term "channel" will always refer to a time-slot-and-frequency combination. The terms "frequency" or "frequency access" will denote the specific radio frequency of an individual channel.

1.2.6.1 Overhead Channels

The Iridium Satellite Network has four overhead channels: 1) Ring Channel; 2) Broadcast Channel; 3) Acquisition Channel; and 4) Synchronization Channel.

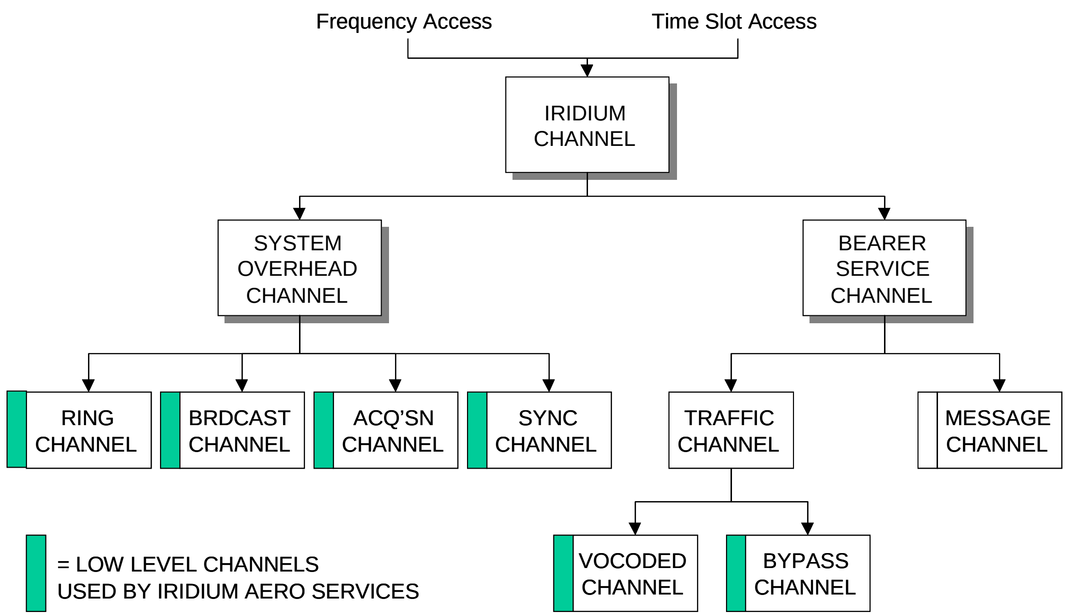


Figure 1-4 Iridium Channel Structure Hierarchy

The Ring Channel is a downlink-only channel used to send ring alert messages to individual subscriber units. Its downlink frequency is globally assigned in order to be the same known frequency throughout the world. The Ring Channel uses a time division format to send ring alert messages to multiple subscriber units in a single frame.

Broadcast Channels are downlink channels used to support the acquisition and handoff processes. These channels provide frequency, timing, and system information to SDUs before they attempt to transmit an acquisition request. In addition, Broadcast Channels provide downlink messages which acknowledge acquisition requests and make channel assignments. Finally, Broadcast Channels are used to implement selective acquisition blocking to prevent local system overloads.

Acquisition channels are uplink-only channels used by individual subscriber equipment to transmit an acquisition request. These channels use a slotted ALOHA random access process. The time and frequency error tolerances are larger for an Acquisition Channel to allow for initial frequency and timing uncertainties. SDUs determine which Acquisition Channels are active by monitoring the Broadcast Channel.

The Synchronization Channel is a duplex channel used by the SDU to achieve final synchronization with a satellite before it begins traffic channel operation. The Synchronization Channel occupies the same physical channel time slots and frequency accesses as the traffic channel that the SDU will occupy when the synch process is complete. During the synch process, the satellite measures the differential time of arrival (DTOA) and differential frequency of arrival (DFOA) of the uplink synch burst and sends correction information to the SDU in the downlink synch burst. A synchronization channel is assigned to an SDU by the satellite. The synchronization procedure is accomplished by the SDU transmitting an uplink burst which the satellite measures for time and frequency error relative to the assigned channel. The satellite sends time and frequency corrections for the latest uplink burst over the downlink channel. This process is repeated until the satellite determines that both the SDU transmit time and frequency are within the tolerance for a traffic channel. When this occurs, the satellite transmits a message to that effect to the SDU and reconfigures the channel for traffic channel operation.

1.2.6.2 Bearer Service Channels

The Iridium subscriber link provides two basic types of bearer service channels: traffic channels and messaging channels.

Messaging channels support downlink only simplex messaging service. This service carries numeric and alphanumeric messages to Message Termination Devices.

Traffic channels support duplex services which include portable mobile telephony and a variety of duplex bearer data services. Each traffic channel consists of an associated uplink and downlink channel. A duplex user has exclusive use of the assigned channels until service terminates or until handed off to a different channel.

1.2.7 Channel Multiplexing

Channels are implemented in the Iridium Satellite Network using a hybrid Time Division Multiple Access/Frequency Division Multiple Access (TDMA/FDMA) architecture based on Time Division Duplex (TDD) using a 90 millisecond frame. Channels are reused in different geographic locations by implementing acceptable co-channel interference constraints. A channel assignment comprises both a frequency carrier and time slot.

1.2.7.1 TDMA Frame Structure

The fundamental unit of the TDMA channel is a time-slot. Time-slots are organized into TDMA frames as illustrated in Figure 1-5. The frame consists of a 20.32 millisecond downlink simplex time-slot, followed by four 8.28 millisecond uplink time-slots and four downlink time-slots, which provide the duplex channel capability. The TDMA frame also includes various guard times to allow hardware set up and to provide tolerance for uplink channel operations.

The simplex time-slot supports the downlink-only, ring and messaging channels. The Acquisition, Synchronization, and Traffic channels use the uplink time-slots. The Broadcast, Synchronization, and Traffic channels use the downlink duplex time-slots.

There are 2250 symbols per TDMA frame at a channel burst modulation rate of 25 Kilosymbols-per-second (25 ksps). A 2400 bps traffic channel uses one uplink and one downlink time-slot per frame.

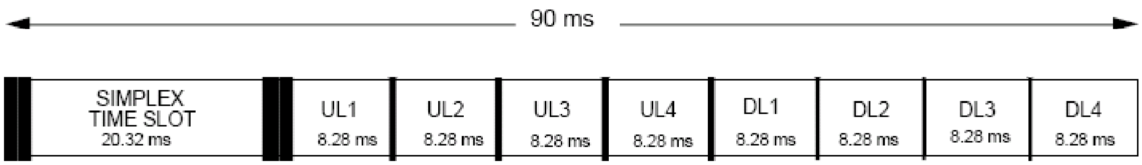


Figure 1-5 Iridium TDMA Structure

1.2.7.2 FDMA Frequency Plan

The fundamental unit of frequency in the FDMA structure is a frequency access that occupies a 41.667 kHz bandwidth. Each channel uses one frequency access. The frequency accesses are divided into the duplex channel band and the simplex channel band. The duplex channel band is further divided into sub-bands.

1.2.7.3 Duplex Channel Band

The frequency accesses used for duplex channels are organized into sub-bands, each of which contains eight frequency accesses. Each sub-band, therefore, occupies 333.333 kHz (8 x 41.667 kHz). In duplex operation, the Iridium Satellite Network is capable of operating with up to 30 sub-bands, containing a total of 240 frequency accesses. Table 1-1 shows the band edges for each of the 30 sub-bands. Iridium's current band usage includes sub-bands 8-30.

Table 1-1 Sub- Band Frequency Allocation

Sub-band	Lower Edge (MHz)	Upper Edge (MHz)
1	1616.000000	1616.333333
2	1616.333333	1616.666667
3	1616.666667	1617.000000
4	1617.000000	1617.333333
5	1617.333333	1617.666667
6	1617.666667	1618.000000
7	1618.000000	1618.333333
8	1618.333333	1618.666667
9	1618.666667	1619.000000
10	1619.000000	1619.333333
11	1619.333333	1619.666667
12	1619.666667	1620.000000
13	1620.000000	1620.333333
14	1620.333333	1620.666667
15	1620.666667	1621.000000
16	1621.000000	1621.333333
17	1621.333333	1621.666667
18	1621.666667	1622.000000
19	1622.000000	1622.333333
20	1622.333333	1622.666667
21	1622.666667	1623.000000
22	1623.000000	1623.333333
23	1623.333333	1623.666667
24	1623.666667	1624.000000
25	1624.000000	1624.333333
26	1624.333333	1624.666667
27	1624.666667	1625.000000
28	1625.000000	1625.333333
29	1625.333333	1625.666667
30	1625.666667	1626.000000

The Iridium Satellite Network reuses duplex channels from beam to beam when sufficient spatial isolation exists to avoid interference. Channel assignments are restricted so that interference is limited to acceptable levels. A reuse pair is the minimum group of duplex channels that can be assigned to an antenna beam. A reuse unit pair consists of an uplink reuse unit and a downlink reuse unit. A reuse unit consists of one time-slot and the eight contiguous frequency accesses of a sub-band for a total of eight channels. The frequency accesses are numbered 1 through 8 from lowest to highest frequency.

Table 1-2 lists the lower, upper and center frequencies for each of the 8 frequency accesses within a reuse unit. These frequencies are relative to the lower edge of the sub-band defined in Table 1-1.

Reuse unit pairs can be assigned to a beam, reassigned or activated/deactivated at the beginning of each TDMA frame. Dynamic beam assignment and reclassification are used to provide additional capacity to beams that have heavy traffic loading.

Table 1-2 Reuse Unit Frequency Accesses

Frequency Access Number	Lower Edge Frequency (kHz)	Upper Edge Frequency (kHz)	Center Frequency (kHz)
1	0.000	41.667	20.833
2	41.667	83.333	62.500
3	83.333	125.000	104.167
4	125.000	166.667	145.833
5	166.667	208.333	187.500
6	208.333	250.000	229.167
7	250.000	291.667	270.833
8	291.667	333.333	312.500

1.2.7.4 Simplex Channel Band

A 12-frequency access band is reserved for the simplex (ring alert and messaging) channels. These channels are located in a globally allocated 500 kHz band between 1626.0 MHz and 1626.5 MHz. These frequency accesses are only used for downlink signals and they are the only frequencies that may be transmitted during the simplex time-slot. As shown in Table 1-3, four messaging channels and one ring alert channel are available during the simplex time-slot.

Table 1-3 Simplex Frequency Allocation

Channel Number	Center Frequency (MHz)	Allocation
1	1626.020833	Guard Channel
2	1626.062500	Guard Channel
3	1626.104167	Quaternary Messaging
4	1626.145833	Tertiary Messaging
5	1626.187500	Guard Channel
6	1626.229167	Guard Channel
7	1626.270833	Ring Alert
8	1626.312500	Guard Channel
9	1626.354167	Guard Channel
10	1626.395833	Secondary Messaging
11	1626.437500	Primary Messaging
12	1626.479167	Guard Channel

1.2.8 L-Band (1616-1626.5 MHz) Transmission Characteristics

1.2.8.1 Signal Format

All L-Band uplink and downlink transmissions used in the Iridium Satellite Network employ variations of 25 ksps quadrature phase shift keying (QPSK) modulation and are implemented with 40% square root raised cosine pulse shaping. The variations of QPSK used include differential encoding (DE-QPSK) and binary phase shift keying (BPSK), which is treated as a special case of QPSK. Figure 1-6 illustrates the relevant FDMA frequency characteristics.

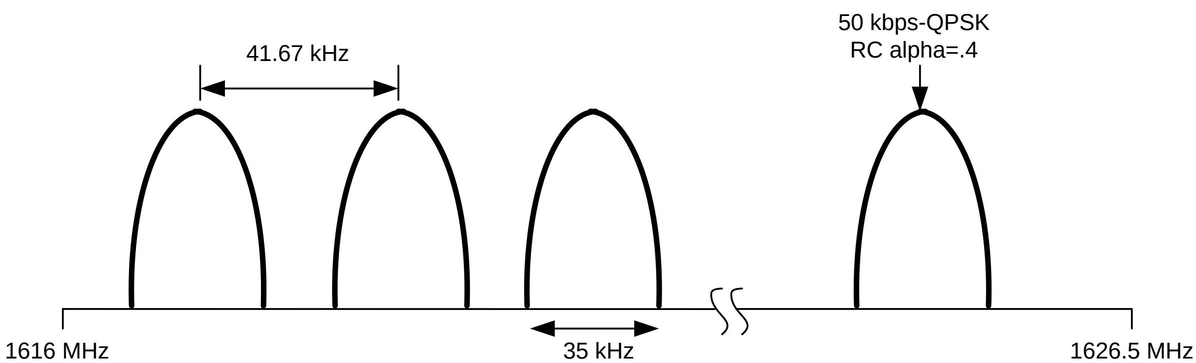


Figure 1-6 FDMA Frequency Plan

The modulation structure used for the uplink and downlink traffic data includes differential encoding to allow demodulators to rapidly reacquire phase and resolve phase ambiguities in case there is a momentary loss of phase-lock due to a link fade.

Downlink traffic, broadcast, synchronization, ring alert, and messaging channels all use DE-QPSK modulation with 40% square root raised cosine pulse shaping. In all cases, the burst transmission rate is 25 ksps and provides a burst data rate of 50 kilobits-per-second (kbps).

Uplink traffic channels use DE-QPSK modulation with 40% square root raised cosine pulse shaping and burst transmission rates of 25 ksps, or 50 kbps. Uplink acquisition and synchronization channels both use DE-BPSK with 40% square root raised cosine pulse shaping and burst transmission rates of 25 ksps, or 25 kbps. BPSK is used because it provides a 3 dB link advantage, which improves the burst acquisition probability.

Certain, control, and traffic applications implement error correction coding to improve the link bit error rate, with characteristics tailored for certain traffic and signalling message applications. The vocoder algorithm provides its own interleaving and forward error correction. Most of the administrative transmissions used in granting access to and exerting control of the link implement their own internal error correction and interleaving.

The link protocol does not provide forward error correction to user generated data transmitted in the payload. Such data is protected from transmission errors by a 24-bit Frame Check Sequence (FCS) transmitted in every traffic burst containing a data payload (as opposed to a voice payload). If the FCS does not validate that the payload data was correctly received, the L-Band Protocol implements error by retransmission of the Iridium frame. Erroneous information, i.e., payload data that does not satisfy the Frame Check Sequence, is not passed to the end user. Therefore, a decrease in channel quality which causes any increase in channel bit-error-rate results in an increase in the number of retransmissions and a corresponding decrease in the number of user-generated bits provided to the end user. Iridium circuit-switched data service has been designed to provide a minimum throughput of 2400 bps user generated information.

Traffic channels operate with adaptive power control, discussed below, which acts to limit power transmissions beyond what is required for appropriate voice and data quality.

1.2.8.2 Power Control

The L-Band link has been designed for a threshold channel bit error of 0.02, which is sufficient to support voice services and data services. Note this does not include any Forward Error Control (FEC) or other methods that are employed in the network. This level is achieved at an Eb/(No+Io) of 6.1 dB in clear line of sight conditions. When used with a standard Iridium handset, the basic Iridium Satellite Network will operate with a link margin of 15.5 dB above this level with respect to an average received signal level. This margin is required to mitigate fading due to the Rayleigh multipath and shadowing typical of handheld phone operation in urban environments. This margin is available on a statistical basis based on the underlying Rayleigh statistics. Under good channel conditions, this level is reduced by adaptive power control. Even under adaptive power control, the link margin is maintained to mitigate fades that are too short in duration to be compensated by the power control loop.

In the aeronautical environment, the fading statistics are Rician and the spread of possible received signal levels is less. Iridium has agreed to make some of the Rayleigh statistical margin available to meet the needs of aeronautical installations for the AES2 type of terminal in use. In effect, this increases the average demand on the satellite transmitter power necessary to support aeronautical users by a factor of two with respect to the aggregate average power demand for handheld users. The remainder of the handheld margin is required to meet the statistical variations of Rician aeronautical environment. The transmitter power and receiver sensitivity requirements of this document are based on this 3 dB installation loss allowance, except as specifically noted in the accompanying explanatory notes. The Class AES1 and AES3 operate at Iridium Network Nominal levels.

Adaptive power control uses a closed loop algorithm in which the space vehicle and AES receivers measure the received energy per bit per noise power spectral density (Eb/No) and command the transmitters to adjust their transmitted power to the minimum value necessary to maintain high link quality. When the entire available link margin is not required to mitigate channel conditions, adaptive power control has the effect of reducing system power consumption. There are slight differences in the power control algorithms used for voice and data operations. For data operations, the algorithm is biased toward higher power levels and does not use adaptive power control, hence ensuring low channel bit error rates and high user throughput.

1.2.9 Call Processing

Call processing in the Iridium Satellite Network consists of Acquisition, Access, Registration and Auto-Registration, Telephony, and Handoff. This is managed through the Iridium ATS Network which is co-located with the Iridium Gateway location currently located in Tempe, AZ. The Iridium ATS Network manages all aspects of acquisition, access, registration, telephony and Handoff. See Iridium Reference G – "Iridium ATS Operator Guide".

1.2.9.1 Acquisition

Acquisition is the first step in obtaining service from the Iridium Satellite Network. It is the process of establishing a communication link between a satellite and the SDU. Acquisition by an SDU is necessary for registration, call setup, answering call terminations, or to initiate any service on the Iridium Satellite Network.

To enter the Iridium Satellite Network, a subscriber unit must go through an Acquisition sequence. The first steps in Acquisition are to achieve frame timing alignment, determine the correct downlink time slot, and detect the Doppler shift of the received signal. Then the SDU must pre-correct the transmitted signal so the received signal, at the satellite, arrives during the correct receive time window and has, at most, a small Doppler offset.

To acquire the system, an SDU turns on its receiver and acquires the satellite Broadcast Channel transmission for the beam in which the SDU is located. The Ring Channel includes the broadcast time/frequency for each beam, and the SDU can use this to determine which channel to use. The decoded satellite broadcast (Broadcast Acquisition Information message) indicates to the SDU if Acquisition is permitted; this is done via the Acquisition Class control. Acquisition denial might occur as a result of network capacity or some other system constraints. If the network permits Acquisition, the SDU extracts the beam ID and selects a random Acquisition Channel.

The SDU estimates Doppler offset and predicts uplink timing based on beam ID. It pre-corrects its timing and frequency and then transmits a ranging burst (Acquisition Request message) to the satellite on the Acquisition Channel. Upon receipt of the Acquisition Request message from the SDU, the satellite calculates the time and frequency error of the received signal. It then sends a Channel Assignment message to the SDU along with time and frequency corrections.

After each transmission on the uplink Acquisition Channel, the SDU decodes the Broadcast Channel and checks for an acknowledgment of its request (Channel Assignment message) and makes sure its acquisition class is still allowed on the system. Receiving no acknowledgment after a request, the SDU repeats its request after a random time interval (Slotted Aloha) and on a random Acquisition Channel. This minimizes the number of collisions between the acquiring SDU and other SDUs attempting to use the Acquisition Channel.

The SDU, upon receiving the Channel Assignment message, immediately transitions to the new Sync Channel and acknowledges the change by sending a Sync Check message to the satellite. The satellite measures the time and frequency offset error of the received burst and responds with a Sync Report message. The Sync Report message contains a Sync Status information element. The satellite will set Sync Status to "Sync OK" if the time and frequency errors are within the tolerance for Traffic Channel operation. If the satellite sends a Repeat Burst in the Sync Status information element, the SDU adjusts its timing and frequency and retransmits a Sync Check message. If the satellite sends "Sync OK" in the Sync Report message, the SDU acknowledges by sending a Sync Check message and waits for a Sync/Traffic Switch message from the satellite. Upon receipt of the Sync/Traffic Switch message, the SDU exits the Acquisition process and initiates the Access process. The satellite then switches the Sync Channel to a Traffic Channel.

1.2.9.1.1 Acquisition Control

Under certain circumstances, it may be necessary to prevent users from making Acquisition attempts. Such situations may arise during states of emergency or in the event of a beam overload. During such times, the Broadcast Channel specifies, according to populations, which SDUs may attempt Acquisition. All subscribers are members of one out of ten randomly allocated populations, referred to as Acquisition Class 0 to 9. The subscriber equipment reads the Acquisition Class from the SIM card that was programmed when it was initially provisioned. In addition, subscribers may be members of one or more special categories (Acquisition Class 11 to 15), also held in the SDU. The system provides the capability to control a user's acquisition to the system based on the following acquisition classes:

15. ISLLC Use
14. Aeronautical Safety Service
13. Reserved
12. Reserved
11. Fire, Police, Rescue Agencies
10. Emergency Calls
0-9. Regular Subscribers (randomly allocated)

The use of acquisition classes allows the network operator to prevent overload of the acquisition or traffic channels. Any number of these classes may be barred from attempting Acquisition at any one time. If the subscriber is a member of at least one Acquisition Class that corresponds to a permitted class, the SDU proceeds with Acquisition.

1.2.9.2 Access

The Access process determines the SDUs location with respect to Service Control Areas defined in earth fixed coordinates. Based on the Service Control Area within which the SDU is found to be located and on the identity of the SDUs service provider, a decision is made regarding whether or not to allow service, and which gateway should provide that service. The process is initiated immediately following Acquisition.
Location information may be reported by the SDU based on an external source such as an aircraft navigation system, or it may be determined by the Geolocation function contained within the Access function.

1.2.9.3 Registration and Auto-Registration

Registration is the process of the SDU communicating its location to the system, and requires the prior completion of Acquisition and Access. The registration process allows the network to maintain an estimate of the location of roaming users as part of mobility management. This location estimate is required to allow the network to notify the subscriber when an incoming call is available (i.e., 'ring' an SDU for a mobile terminated call). The SDU must be registered in the gateway serving its location to initiate or terminate a call. An SDU registration occurs for one of five reasons:

1. The SDU presently contains an invalid Temporary Mobile Subscriber Identification (TMSI) or Location Area Identity (LAI)
2. The TMSI presently assigned to an SDU expires

3. A call termination or origination is performed and, based on the new location, the SDU is told to re-register by the system
4. A mobile subscriber initiates a manual SDU registration procedure
5. The SDUs present location exceeds the re-registration distance from the point of its last registration.

The procedures used for SDU registration (Location Update) after acquisition and access are GSM procedures.

Auto-registration refers to the capability of an SDU to re-register with the network only on an as-needed basis. The SDU will automatically re-register with the system when it knows its current location exceeds a specified distance from the point it last registered. In order to make this decision, the SDU passively estimates both its location and its positional error, based upon information gathered from the Ring Channel of the passing satellites.

1.2.9.4 Telephony

Telephony is the process of establishing a connection between two telephone users and releasing the connection at the end of the call. For mobile terminated calls, Telephony also includes the process of alerting a user of an incoming call.

Functions supporting Telephony are distributed between the SDU, satellite and gateway components. The functions are partitioned to group similar procedures together. The SDU supports a set of protocols used to communicate among the components of the system. In order to reduce the complexity of individual components, the protocols are partitioned to group similar functionality together. The partition is shown in Figure 1-7 below.

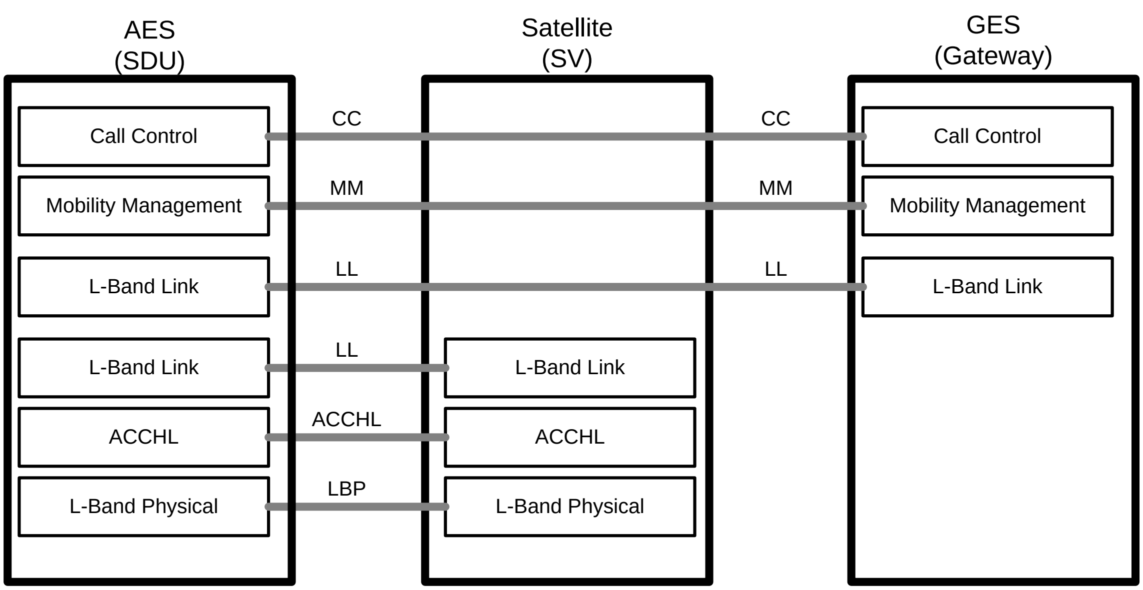


Figure 1-7 Protocol Partitions

Five protocol partitions are supported by the SDU:

1. Call Control (CC)
2. Mobility Management (MM)
3. L-Band Link (LL)
4. L-Band Physical (LBP)

5. Associated Control Channel, L-Band (ACCHL)

Call Control - The CC partition is equivalent to Call Control in the GSM standard. This includes Mobile Switching Center to Mobile Subscriber (MSC-MS) signalling in the GSM Mobile Radio Interface CC sub-layer and associated procedures and the general Telephony Call Control capabilities included in a standard GSM switching subsystem.

Mobility Management - The MM partition is equivalent to Mobility Management in GSM. This includes the MSC-MS signalling in the GSM Mobile Radio Interface MM sub-layer and associated procedures, along with the portions of Mobile Application Part that support it.

L-Band Link - The LL control provides the functionality to control and monitor the air channels, determine access privileges, update system programmable data, and establish and release connections.

LL is responsible for the Call Processing-related signalling associated with Mobile origination or termination and provides for the signalling procedures associated with the Access portion of the Iridium Network. Additionally, LL controls the real-time aspects of radio resource management on the L-band link, such as the allocation and maintenance of L-band resources and handoff procedures.

L-Band Physical - LBP represents the control interface that exists between the satellite and the SDU. The primary distinguishing characteristic of LBP is that unlike ACCHL, the delivery of messages is not guaranteed. Examples of messages carried in this manner are ring alerts, directed messaging, Broadcast Channel messages, handoff candidates, handoff candidate lists, and Doppler/timing/power control corrections.

Associated Control Channel, L-Band - The ACCHL transmission protocol is used by all entities that need to (reliably) send data via the L-Band traffic channel burst between the satellite and the SDU. The ACCHL protocol permits sharing the traffic channel burst with other protocols. The ACCHL Logical Channel is bi-directional and uses portions of the uplink and downlink Traffic Channel, Link Control Word and the Payload Field between the satellite and the SDU. The Traffic Channel is described in the next section. The ACCHL protocol will transport variable size messages on the ACCHL Logical Channel and is used to guarantee the delivery of messages between the satellite and the SDU. It relies on LBP only in that LBP arbitrates the access to the physical layer when there is contention for the Physical Layer resources.

1.2.9.5 Handoff

The Iridium satellites, in low earth polar orbit, have highly directional antennas providing Iridium system access to SDUs. These antennas are configured to project multiple beams onto the surface of the earth. The beams move rapidly with respect to SDUs and with respect to other satellites. Handoff, the process of automatically transferring a call in progress from one beam to another (or sometimes within a beam) to avoid adverse effects of either user or satellite movement in this highly mobile environment, is required in three situations. First, an SDU must be handed off between satellites as they move relative to the SDU (Inter-satellite).

Second, an SDU must be handed off between beams on a satellite as beam patterns move relative to the SDU (Intra-satellite). Last, an SDU must be handed off to another channel within a beam for frequency management and to reduce interference (Intra-beam). Although the Iridium system may force a handoff, handoff processing is primarily SDU initiated.

As a satellite moves away (for example, moves over the horizon) and a new satellite approaches (for example, comes into view over the horizon), an SDU must transfer from the current satellite (the losing satellite) to the new satellite (the gaining satellite). This Inter-satellite handoff, on the average, occurs approximately every five minutes during a telephone call. It may be initiated as frequently as five seconds or as long as 10 minutes, depending on link geometry.

As satellites move from the equator to a pole, the actual distance between adjacent satellites decreases to a few kilometers and then increases to several thousand kilometers as the satellites again approach the equator. To avoid radio interference, beams near the edges of a satellite's coverage field are turned off as the satellite approaches a pole and then turned on again as it approaches the equator. Additionally, the same radio channels are never available in adjacent beams on a satellite or between nearby satellites. Thus, as the satellite and its beams pass by, an SDU must frequently transition to a new beam. This Intra-satellite handoff occurs approximately every 50 seconds during a call.

As the inter-satellite geometry changes, radio channels must be reallocated among the beams to avoid interference. This process can cause an SDU to be handed off to a different channel in the same beam. This is called Intra-beam handoff. An SDU can also request an Intra-beam handoff to reduce interference. If the Iridium system detects an allocation change coming up where it will not have enough channels to support the number of current users, the satellite will ask for volunteers to handoff into other beams so calls will not have to be dropped when the resource change takes place. Handoffs made under these conditions are called Volunteer handoffs. Volunteer handoffs may result in one of two situations requiring handoff, namely Inter-satellite or Intra-satellite, but are initiated by the SDU (at the request of the Iridium system) rather than by the Iridium system itself.

1.2.10 Voice and Data Traffic Channel

Traffic channels provide two-way connections between space vehicles and subscriber equipment that support Iridium services. These channels transport the system voice and data services along with the signalling data necessary to maintain the connection and control the services.

The uplink and downlink Traffic Channels use identical burst structures. Each burst is 8.28 ms long and contains 414 channel bits. The bursts are divided into four major data fields: Preamble, Unique Word, Link Control Word and Payload Field. The preamble and unique word are used in the receiving demodulator for burst acquisition. The preamble and unique word patterns are different for the uplink and downlink. The Link Control Word provides a very low data rate signalling channel that is used to support link maintenance, the associated control channel and handoff. The payload field furnishes the primary Traffic Channel that carries the mission data and signalling messages.

The Link Control Word field provides a low rate signalling channel used for control of the subscriber link. The uplink and downlink Traffic Channels use the same Link Control Word format. The Link Control Word is used to support link maintenance, handoff and the ACK/NAK of the associated control channel transmission protocol. The Link Control Word field is protected by FEC code.

The Traffic Channel payload field provides the primary Traffic Channel. This field carries the mission data and mission control data. This field supports a channel bit rate of 3466.67 bps. Typically error correction coding, error detection, and other overhead functions provide a nominal information throughput on this channel of 2400 bps.

Mission data may be either vocoded voice data or data services. For voice service, the proprietary Iridium vocoder uses FEC to achieve an optimal MOS of 2.5 to 2.7 depending on AES type (based on mean opinion score for a basic telephony voice call, where 1 is bad and 5 is toll quality). For data service, the L-band transport employs a frame check sequence to provide essentially error free data transport service.

Some Iridium data services also provide additional service specific interfaces to facilitate user access. In summary, the Iridium communication channel appears to the end users as an efficient and reliable data transport.

1.2.11 Iridium Data Services – RUDICS and SBD

1.2.11.1 Iridium RUDICS Service

The Iridium RUDICS service "Iridium Router-based Unstructured Digital Information Connectivity Solution" is an enhanced gateway termination and origination capability for circuit switched data calls across the Iridium Satellite network. RUDICS offers an optimized data connection service for various end to end data applications or solutions.

There are four key benefits of using RUDICS as part of a data solution over conventional PSTN circuit switched data connectivity or mobile-to-mobile data solutions:

1. Elimination of analog modem training time, hence faster connection establishment time.
2. Increased call connection quality, reliability, and maximized throughput.
3. Protocol independence.
4. Both Mobile Originated and Mobile Terminated calls are rated at the same rate.

Remote applications use commands to control a circuit switched data capable SDU. Figure 1-8 illustrates the call set up process of a Mobile Originated (MO) data call. Iridium pre-assigns RUDICS Server Number(s) to Satellite Communications Service Providers who assign and provision these numbers to customers. The remote application dials the customer's assigned RUDICS Server Number which connects the call through a telephony switch to the RUDICS server. Each SDU is authenticated using Calling Line Identification for the RUDICS Server Number that it dialed. Once authenticated, the call is routed over the terrestrial connection to a customer-specified Internet Protocol (IP) address and Port. The RUDICS service supports the follow service transport types: transport control protocol/Internet protocol (TCP/IP) encapsulation, point to point protocol (PPP), and Multi-link PPP (MLPPP).

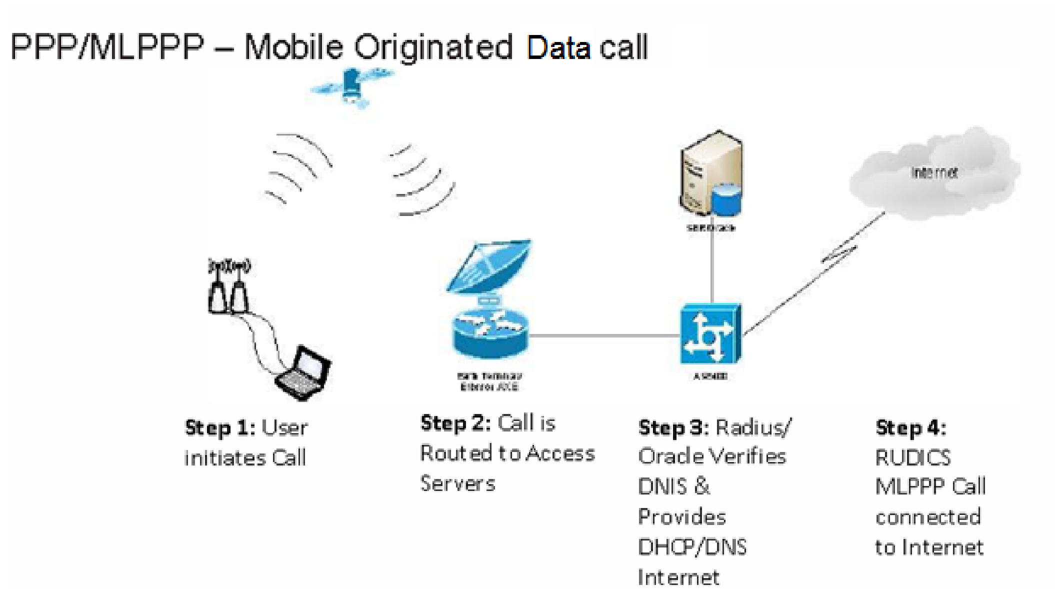


Figure 1-8 Iridium RUDICS Mobile Originated Data Call Setup

The Host application can make a Mobile Terminated call by opening a Telnet session to the RUDICS server. Once authenticated, a series of AT Commands are used to connect to the remote SDU and establish a circuit switched data call. Mobile Terminated access must specifically be requested at the time of the initial configuration and set up. Connectivity between the Iridium Gateway and the end user Host Server can be via a number of options, including:

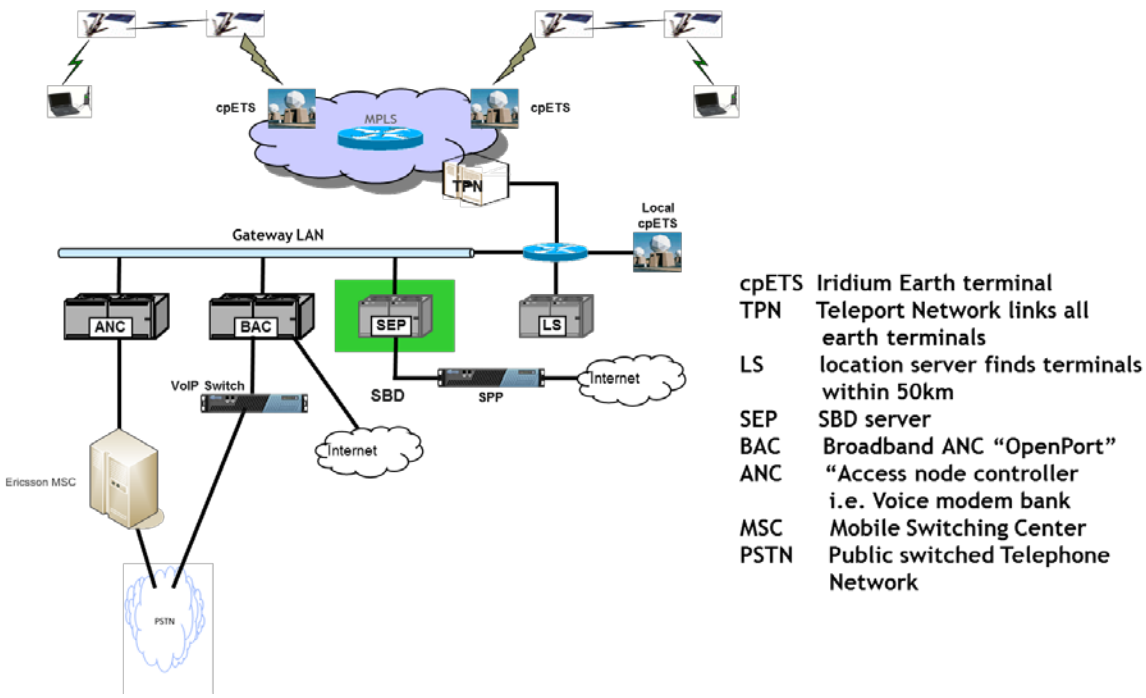
- Internet
- Internet with Virtual Private Network
- Private leased line such as:
  - Frame Relay
  - T1/E1 Leased Line

Additionally, the RUDICS capability offers the capability for Multi-Link Point to Point Protocol (MLPPP). This is where multiple SDUs can be used to send data simultaneously and the data can be delivered in an N x 2400 bps PPP connection.

1.2.11.2 Iridium SBD Service

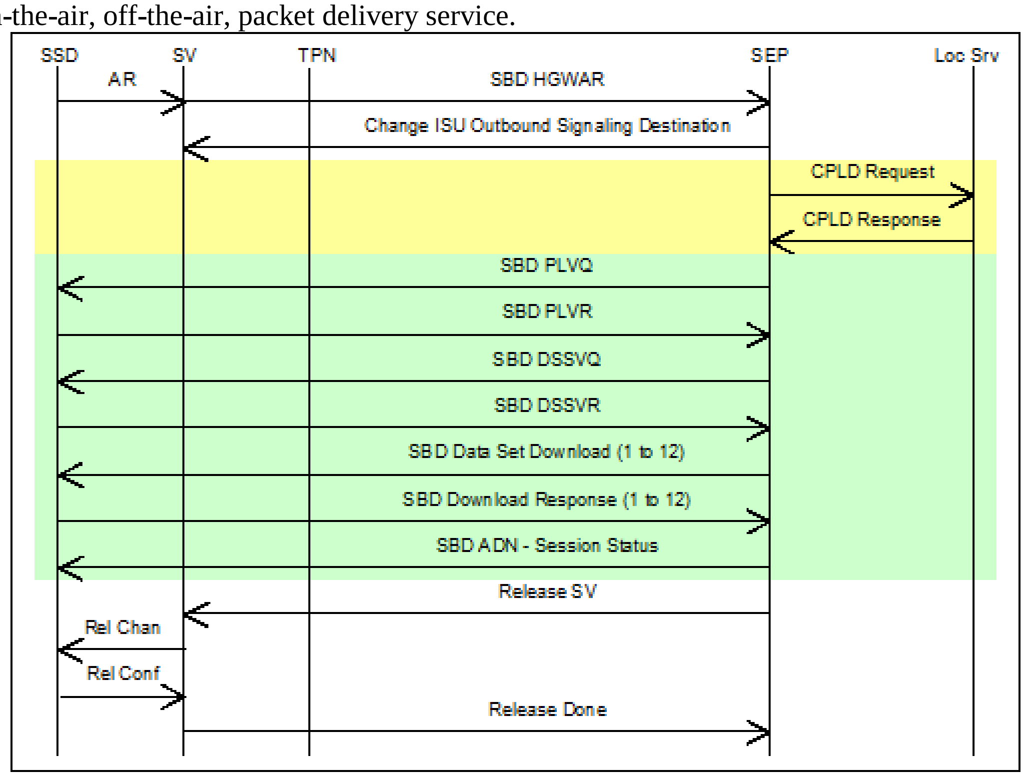
The Iridium Short Burst Data Service is a satellite network transport capability to transmit short data messages between (data) terminal equipment (TE) and a centralized host computing system. A Mobile Originated SBD message can be up to 1960 bytes for an AES2 or AES3 and 340 bytes for an AES1 device; a Mobile Terminated SBD message can be up to 1890 bytes for an AES2 or AES3 device and up to 270 bytes for an AES1 device.

Figure 1-9 shows the system architecture of the Iridium SBD service while Figure 1-10 depicts the MO call set up process. The original SBD service delivers SBD messages to email addresses provisioned on the SBD Subsystem. The newer SBD service added direct IP capability allowing SBD messages to be delivered directly to IP sockets provisioned on the SBD Subsystem. For mobile terminated application, a SBD message is sent to the SBD Subsystem by the Host via the Internet or leased line. A Ring Alert is then sent by the SBD Subsystem to the addressed SDU to notify it of the arrival of a new message. The SDU then initiated a MO call to the SBD Subsystem to pull down the message.



<u>Figure 1-9</u> System Architecture of Iridium Services

Since an SBD message utilizes the Iridium signaling transport (ILap) during the access phase of a circuit-switched voice call set up process, it has the benefits of additional FEC protection as well as on-the-air, off-the-air, packet delivery service.



<u>Figure 1-10</u> MO SBD Call sequence diagram

For the MT SBD cycle there is a ring cycle that wakes up the modem on the receiving side for receiving the message. This process is very straight forward by the unit auto-answering the ring for the receipt of the SBD message.

1.3 Iridium AMS(R)S System

End-to-end AMS(R)S data communications are provided by several sub-networks. Sub-networks may be classified as ground-ground (fixed), air-ground (mobile) or airborne sub-networks. More information on ATN, including mobile sub-networks are contained in ICAO documents, *Manual of Technical Provisions for the Aeronautical Telecommunication Network (ATN)* (Doc 9705) and *Comprehensive Aeronautical Telecommunication Network (ATN) Manual* (Doc 9739). See also Iridium Reference G – "Iridium ATS Operator Manual".

An Iridium AES will be capable of both AMS(R)S safety communications and AMSS non-safety communications. Safety communications refer to communications for Air Traffic Services (ATS) and Aeronautical Operational Control (AOC) to the flight deck. Non-safety communications to the cabin crew and passengers are known as Aeronautical Administrative Communications (AAC) and Aeronautical Public Correspondence (APC), respectively.

To support these services, a SATCOM data unit (SDU) will be deployed and will interoperate with the Iridium global satellite communications system and existing aircraft voice and data communication systems. In addition, a ground-based server will be deployed by Iridium-approved) ATSP (Aeronautical Telecommunications Service Provider) for data service. This server will provide connectivity with existing aviation terrestrial data networks, such as ARINC and SITA or other, in support of AAC, AOC, and ATC data communications.

The three main components of the aviation safety service are as follows:

- Iridium Network for AMS(R)S
- Iridium-based AES for AMS(R)S
- Iridium Ground-based Server for AMS(R)S

There is a fourth pre-existing component of the aviation safety service – the aviation terrestrial data network. This network has been in existence for a number of years, evolving to meet the changing needs of the aviation industry. This network will not be described in detail but may be referenced throughout this document. SITA or ARINC should be contacted directly for further details about the aviation network.

End-to-end models of Iridium Aviation Safety Services for both voice and data are found in Figure 1-11 (air-to-ground voice / ground-to-air voice) and Figure 1-12 (air-to-ground data / ground-to-air data).

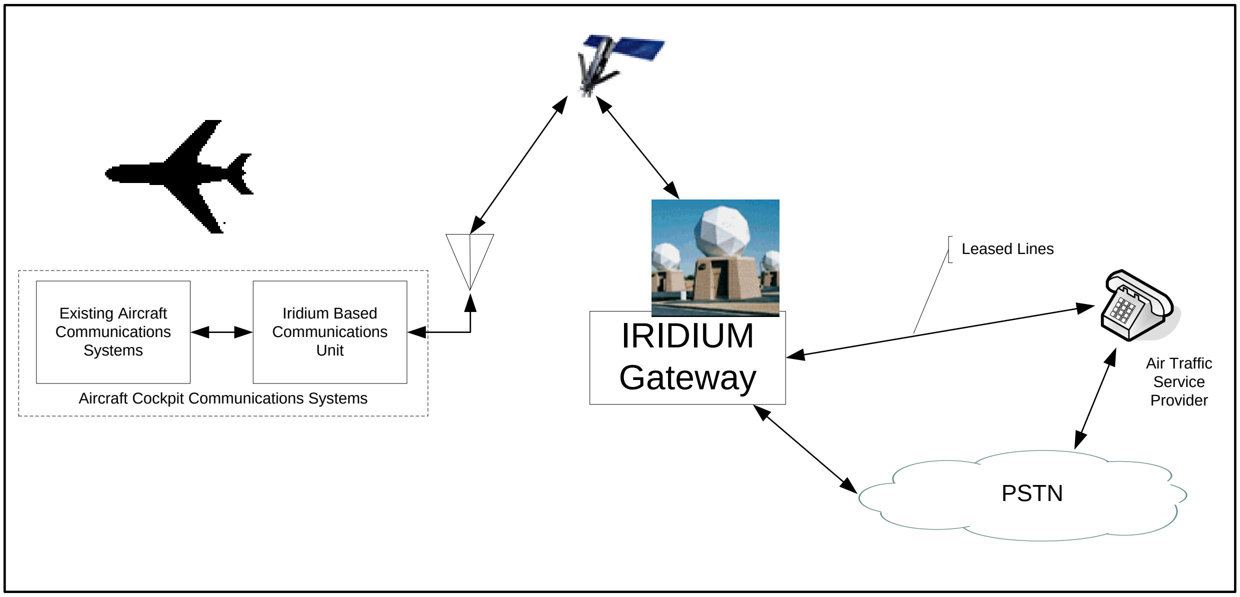


Figure 1-11 **Iridium Aviation Safety Services Air-to-Ground (AtG) Voice (End-to-End Model)**

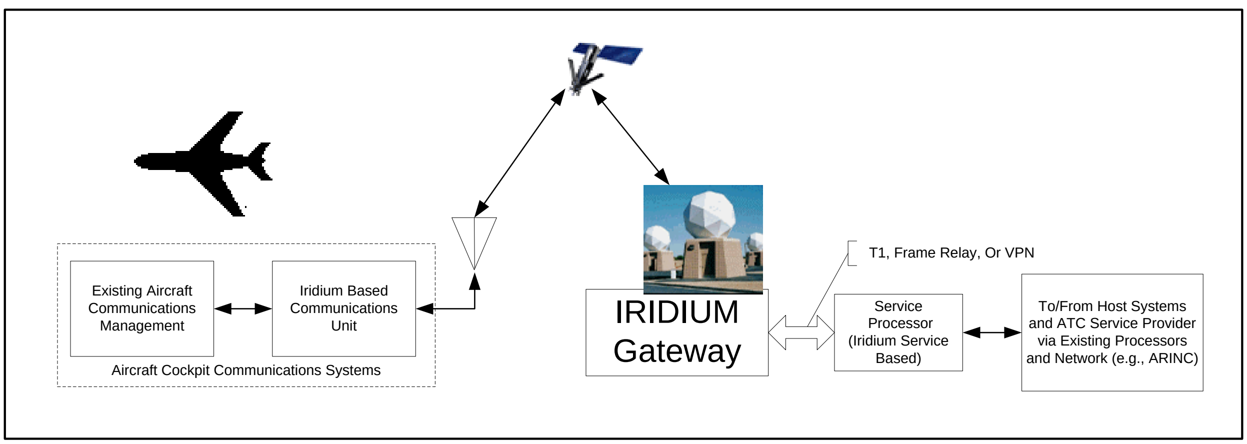


Figure 1-12 **Iridium Aviation Safety Services Air-to-Ground (AtG) Data (End-to-End Model)**

1.3.1 Iridium Network for AMS(R)S

The major elements of an Iridium AMS(R)S system are the Aircraft Earth Station (AES), Iridium space segment, ground earth stations (GES) or Gateways, and the network control stations. In addition, for data communication services, a ground-based server is required for connectivity between the Iridium satellite network and the aviation-centric data communication network. The aviation network provides connectivity to the end user, e.g., air traffic service units, airline operations, flight departments and aviation support application services, such as meteorological information.

Use of the Iridium network for air traffic services, particularly in remote areas where connectivity between the Iridium gateways and responsible air traffic service units is difficult to achieve, could be facilitated by the deployment of ground-based Iridium units. This set up can support voice service but is not recommended for data communication services.

1.3.2 Iridium-Based AES for AMS(R)S

An AES includes all avionics on board an aircraft necessary for implementing satellite communications. An Iridium AES includes the SDU, the antenna(s), cabling, and any required RF power amplifiers (PA/LNA). An Iridium SDU consists of one or more Iridium LBT's 95XX and/or SBD 96XX modems which serve as radio transceivers and provide the actual modem and signal processing functions. Modem functions include Iridium satellite sub-network protocol management and modulation/demodulation of the Iridium signal. The Iridium modem(s) allow the SDU to establish voice/data communication over the Iridium Network. The Iridium SDU, in turn, provides data and voice interfaces with other aircraft systems. See Iridium Reference B and Iridium Reference C for more information on Iridium LBT and SBD transceivers.

Figure 1-13 to Figure 1-15 provides a generic block diagram of the AES1, AES2, and AES3 systems described in this document.

AES1 and AES2 utilize passive antenna(s) while AES3 requires active antennas and/or additional PA/LNA components. Configurations of AES class are identified by antenna input. An AES may have consist of a single box that has two or more antenna inputs (See Section 5.1). Each antenna input is connected to a specific AES configuration. For example, an AES with four (4) 95XX transceivers and two antenna inputs (two 95XX per antenna), classifies as two AES2 configurations where intermodulation testing and validation for multi-channel system must be performed.

The points A, B, C and D as shown in Figure 1-13, Figure 1-14 and Figure 1-15 are referenced for measurements or calculations as indicated in Table 2-4. The manufacture will measure the data at Point A for the transmit path, and calculate or measure the data at Point D for the receive path. Point D may be integrated as a test point for an AES design to allow direct measurement versus calculations. The manufacturer is responsible for mapping the data from A and D to a value at point C for each installation configuration to allow for meaningful field measurements.

The AES shall provide adequate domain segregation to prevent the data stream from influencing the data streams used for the ACARS or priority voice functions. Information security requirements may be found in DO-326.

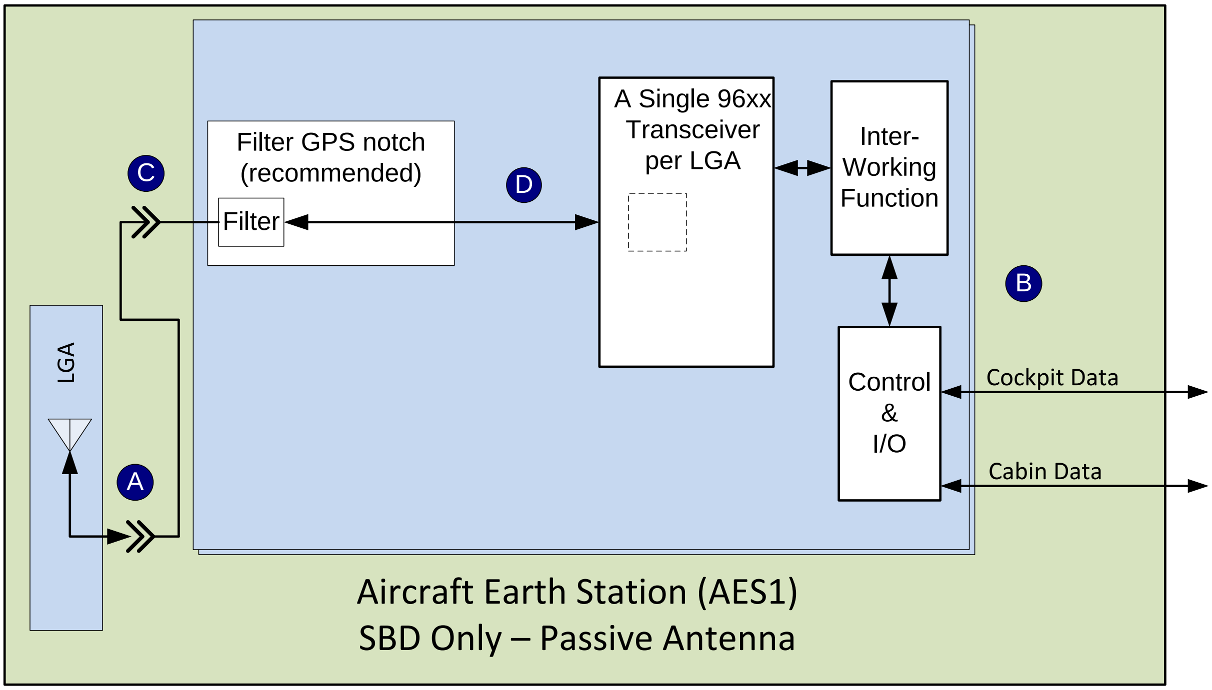


Figure 1-13 Block Diagram of Aircraft Earth Station AES1

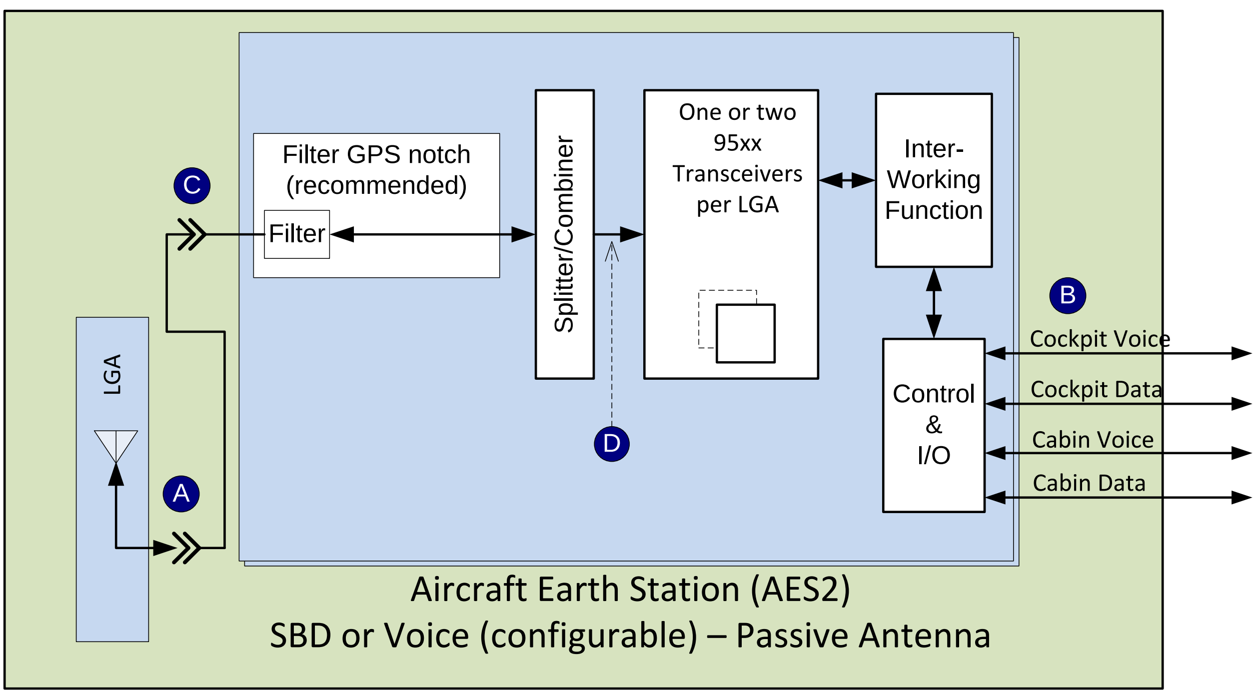


Figure 1-14 Block Diagram of Aircraft Earth Station AES2

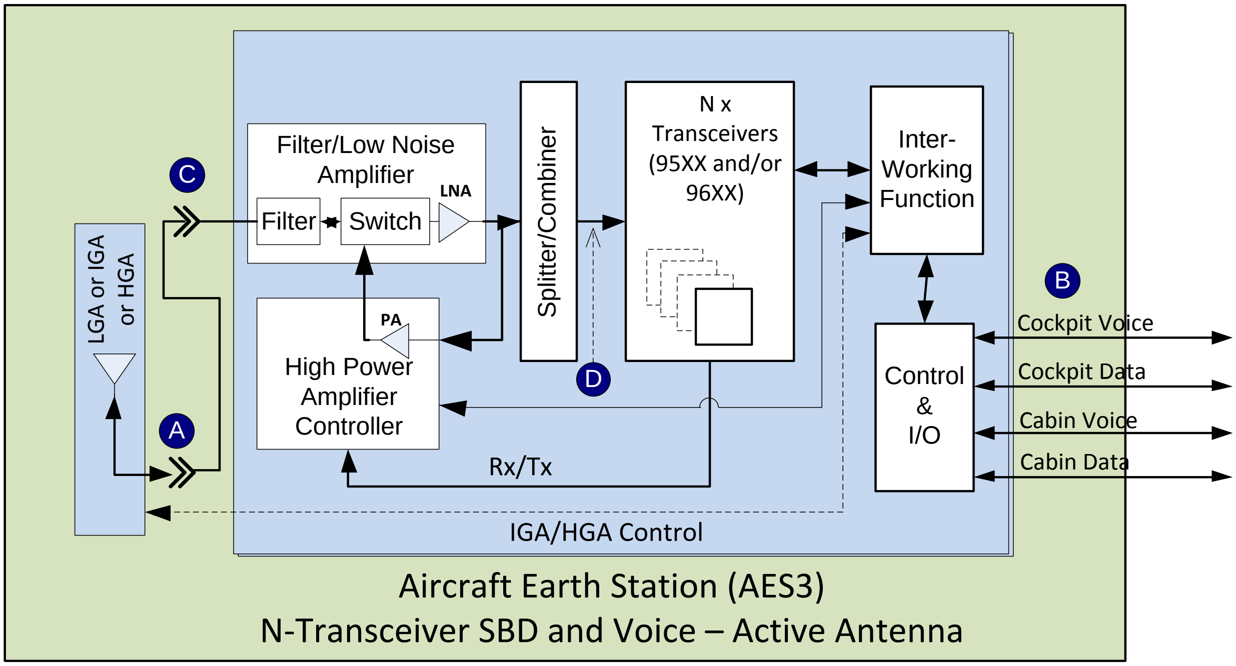


Figure 1-15 Block Diagram of Aircraft Earth Station AES3

1.3.3 Iridium Space Segment

Information on the Iridium Satellite constellation is provided in Section 1.2.4.

1.3.4 Iridium Ground-Based Server for AMS(R)S

The Iridium Ground-based Server for AMS(R)S is co-located with the main satellite gateway. The gateway may also be referred to as a Ground Earth Stations (GES). The GES provide appropriate interface between the space segment and the fixed voice and data networks, public switched telephone, and aviation terrestrial data networks (e.g ARINC, SITA or other).
All voice and data calls for AMS(R)S are routed through the GES. Priority, pre-emption and call waiting are all managed by the AMS(R)S server in the GES.

1.3.5 Installation Environment

1.3.5.1 Simultaneous Operation of Iridium and Inmarsat Aeronautical Services

The minimum performance standards contained in this document are intended to assure proper operation of Iridium AMS(R)S on all aircraft. This section, however, addresses operational scenarios occurring beyond that of minimum performance standards, including aircraft that desire simultaneous independent operation of both Iridium and Inmarsat AES terminals without a demonstrated means of cooperation. Owners, operators and installers are cautioned that simultaneous independent operation of Iridium and Inmarsat AES equipment on the same aircraft has the potential to cause significant interference to all Iridium AMSS and AMS(R)S services. This caution applies to Inmarsat equipment that is compliant with RTCA DO-210D, including all changes, AEEC Characteristic 741, AEEC Characteristic 761, and AEEC Characteristic 781. At

the time of publication of this document, simultaneous independent operation of Iridium and Inmarsat equipment on the same aircraft had been reported in special cases. However, no generally applicable and technically feasible means of mitigating the potential for interference could be identified.
This caveat specifically excludes installations where Iridium and Inmarsat are intended for use in separate airspace. For example, no special installation or other considerations are required for Iridium use in polar airspace that is outside of the Inmarsat coverage volume.
At the time of the publication of this document, there is neither regulatory guidance nor AMS(R)S operational need to require Iridium and Inmarsat systems to work simultaneously on the same aircraft. Some operators may choose to use Iridium and Inmarsat as backup or in a non-simultaneous mode of operation.

1.3.5.2 Co-location of Iridium AES with GPS/GNSS Systems

The ARINC 761 standard provide guidance on the required isolation between antennae of Iridium and GNSS system.
Interference from the GNSS antenna to the SATCOM antenna is not regarded as a high risk.
Requirements for emissions from the SATCOM terminal for GNSS compatibility are given in Sections 2.2.3.1.1.6.1, 2.2.3.1.2.1.3, and 2.2.3.1.2.1.5.
The declared isolation between the AES antenna and a GNSS may differ between GNSS systems (GPS and GLONASS). See Section 2.2.3.1.1.6.1, 2.2.3.1.2.1.3, and 2.2.3.1.2.1.5 for additional details.

1.3.5.3 Co-location of Iridium AES with other Iridium SATCOM Systems

Co-location of multiple Iridium SATCOM systems may be achieved. Installation guidance is given in Section 3.1.9

2 EQUIPMENT PERFORMANCE REQUIREMENTS AND TEST PROCEDURES

2.1 General Requirements

2.1.1 Airworthiness

The design and manufacture of the equipment shall provide for an installation that does not impair the airworthiness of the aircraft.

2.1.2 Intended Function

The equipment shall perform its intended function, as defined by the manufacturer, and its proper use shall not create a hazard to users of procedural airspace.

2.1.3 Federal Communications Commission's Rules

The equipment shall comply with all applicable rules of the Federal Communication Commission (FCC).[4]

2.1.4 Fire Protection

All materials used shall be self-extinguishing except for small parts (such as knobs, fasteners, seals, grommets and small electrical parts) that would not contribute significantly to the propagation of a fire.

Note: *One means of showing compliance is contained in the Federal Aviation Regulations (FAR), Part 25, Appendix F.*

2.1.5 Operation of Controls

The operation of controls intended for use during flight, in all possible combinations and sequences, shall not result in a condition detrimental to the continued performance of the equipment. Controls shall be designed to maximize operational suitability and minimize pilot workload. Reliance on pilot memory for operational procedures shall be minimized.

2.1.6 Accessibility of Controls

Controls that are not normally adjusted in flight shall not be readily accessible to flight personnel. Controls that are normally adjusted in flight shall be readily accessible and properly labeled as to their intended function. The controls shall be operable with the use of only one hand.

2.1.7 Effects of Tests

The equipment shall be designed so that the application of specified test procedures shall not be detrimental to equipment performance following the application of these tests, except as specifically allowed.

2.1.8 Performance in a Shared Environment

All requirements for data integrity and timing shall consider the effect of other active aircraft data links performing transfer operations in both directions at their nominal rates.

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[2] It is not intended that this requirement relating to FCC rules be interpreted as a precondition for obtaining other applicable approvals such as an FAA TSO authorization.

It is strongly recommended that the AES receiver design take into account the existence and/or probable deployment of other mobile communications systems operating in the airspace, on-board the aircraft, or in the proximate airport environment. Because the power flux densities (both composite and per carrier) of such systems may be very much higher than the power flux density of the desired NGSS downlink carriers, particular attention needs to be paid to the dynamic range of the AES receiver, to avoid saturation and consequent intermodulation products. At the same time, the receiver design should provide as much selectivity as possible as near to the input port as possible in the receiver down-conversion process. Despite these precautions, it may prove infeasible to independently and simultaneously operate two NGSSs or an NGSS and an ICAO Annex 10 Chapter 4 AMS(R)S SARPs-compliant satellite communications equipment on the same aircraft. Solutions may include operating procedures or mechanisms which disable transmission from one system while the other system is being used to provide AMS(R)S.

As described in Section 1.3.5.1, this document provides minimum performance standards for Iridium AMS(R)S which do not take into account simultaneous and independent use of Iridium equipment and equipment of another dissimilar satellite system. Table 2-1 provides a list of requirements that have been identified as applicable for same-aircraft installation of Iridium equipment with equipment of another satellite system intended for simultaneous independent use. For installations that do not intend to use dual dissimilar SATCOM systems, these requirements are considered not applicable and can be disregarded for certification purposes.

Table 2-1 DO-262 Requirements Sections Applicable for Dual Dissimilar SATCOM Installations

Section	Section Title
2.2.3.1.1.6.2 / 2.4.3.1.1.6.2	Radiated Antenna Intermodulation in AMS(R)S Bands
2.2.3.1.2.2.4 / 2.4.3.1.2.2.4	Rejection of Carrier Signals Generated by Other AMS(R)S Equipment
3.1.8	Antenna Location/Installation (new section)
3.2.1	Radiated Antenna Intermodulation Products in AMS(R)S Bands
3.4.2	Interference Tests
3.4.2.2	SATCOM B Interference to SATCOM A
3.4.2.3	SATCOM A Interference to SATCOM B

2.1.9 AES Availability

Note: Appendices B and C of ICAO GOLD specify the availability for the data link capability on the aircraft as 0.999, assuming an average flight of 6 hours. Allocating 50% of the unavailability to the AES yields an availability requirement for the AES of 0.9995. Availability = 1 - (MTTR/MTBF). Failures (on average) occur halfway through the flight. The MTTR = 3 hours because failed equipment is repaired or replaced after the flight. This implies that an MTBF of 6000 hours or better is required for the AES to achieve the

0.999 availability requirement for the aircraft. Evaluating this number at the time of MOPS testing is considered impractical. In-service MTBF measurement and reliability management may be required, but this considered beyond the scope of this MOPS.

2.2 Equipment Performance Requirements, Standard Conditions

Figure 2-1 provides a graphical representation of how AES requirements map to the following subsections.

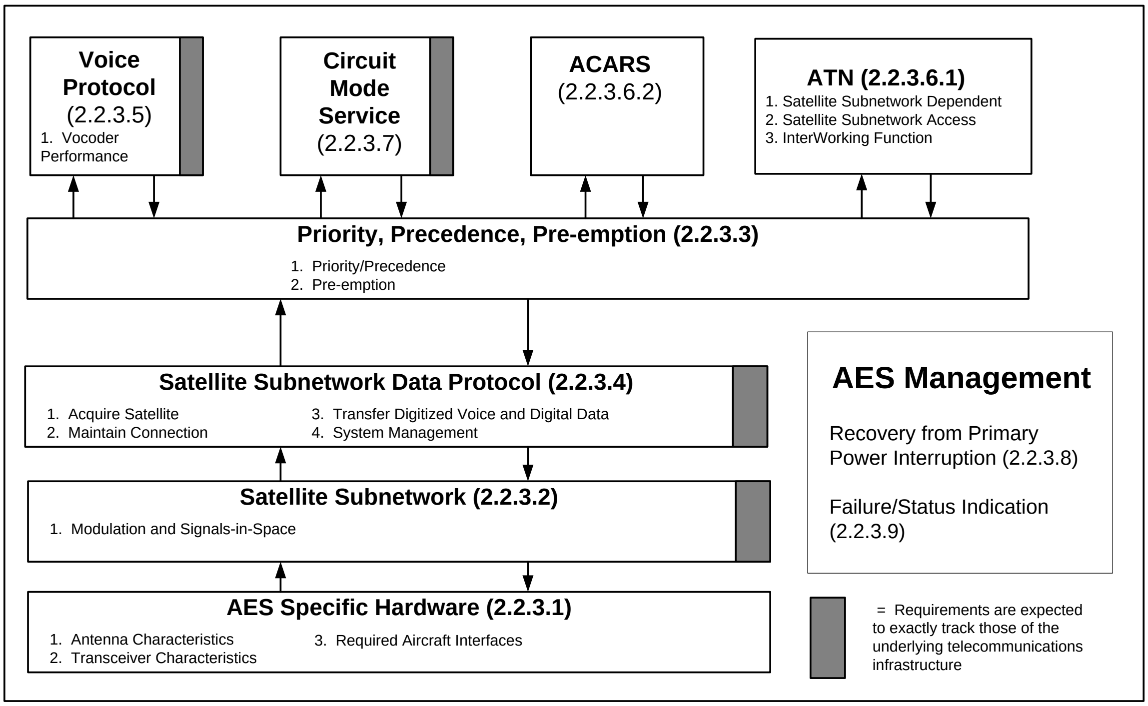

Figure 2-1 Requirements Mapping

In the event of a conflict in requirements between the DO-262 MOPS main document and this technic-specific appendix, this technic-specific appendix shall take precedence.

Note: *This precedence is established because the technic-specific material contained in this document is, by its very nature, more up-to-date and more detailed than the DO-262 MOPS main document.*

2.2.1 Avionics Subsystem Definitions and Overall Requirements

An Iridium AES shall be capable of AMS(R)S safety communications but may also support AMSS non-safety communications.

Single-channel AES equipment shall support voice-only or packet-data-only or non-simultaneous voice-or-data operations. Single-channel AES equipment will transmit on a single frequency at any given time.

Multi-channel AES equipment shall support either voice-only or packet-data only, or a combination of simultaneous voice and packet mode data, and may support circuit mode data services. Multi-channel AES equipment may simultaneously transmit on multiple frequencies. The manufacturer shall declare any limitations on the combination of voice and data services supported by the equipment.

Note 1: *For the purposes of this requirement, a distinction is made between packet mode data and circuit mode data services. Packet mode data utilizes services that operate by transferring independent packets of information over the subnetwork interface. Circuit mode data is transferred via a point-to-point connection between the local (airborne) and remote users. This document places no restriction on the method used to implement either packet mode or circuit mode data. However, because AMS(R)S circuit mode data requirements have not yet been established, the minimum requirement is for packet mode.*

Digitized voice shall utilize the protocol, including any forward-error-correction coding and interleaving, determined for the vocoder implementation specified in this normative appendix.

Note 2: *Digitized voice operation is expected, but not required, to utilize a circuit mode connection*

Further validation of the ability of AES equipment to meet the requirements in Section 2 of this attachment shall be demonstrated during ISLLC acceptance and certification testing, as outlined in Section 1.1.3 Iridium Reference D – Iridium Satellite Compliance and Test Requirements for Value Added Manufacturing (VAM) Products.

The following table describes the AES class identifiers as used in this document:

Equipment Class Identifier	**Description**
AES1	AES using one SBD transceiver and a passive Low Gain Antenna (LGA)
AES2	AES using one or two LBT transceiver and a passive Low Gain Antenna (LGA)
AES3	AES using a combination of N of the SBD and/or LBT transceivers (where N ≥2) and a passive Low Gain Antenna (LGA) or an active (powered) antenna such as IGA switched or IGA/HGA phased steering array

Table 2-2 AES Class Identifiers

2.2.1.1 AES1 Subsystem Definition

The AES1 configuration is a single channel SDU that contains one SBD (96XX) transceiver for AMS(R)S data only applications. The AES1 cannot support voice calling. A passive LGA is required for use with the AES1. The system specific parameters of an AES1 are contained in Table 2-4.

See Section 5 on AES Configurations and Test Requirements.
The valid combination of AES components is shown in Table 2-3.

The testing and validation requirements for AES1 class SDU are contained in Table 5-2.

2.2.1.2 AES2 Subsystem Definition

The AES2 configuration is a single or dual channel SDU that contains one or two LBT (95XX) transceivers for voice and/or data applications. An AES2 shall be capable of AMS(R)S safety communications (voice and/or data) but may also support AMSS non-safety communications (voice and/or data).

If two 95XX transceivers are contained, an antenna splitter shall be required for sharing the antenna signal. A passive LGA is required for use with the AES2. The system specific parameters of an AES2 are contained in Table 2-4.

See Section 5 on AES Configurations and Test Requirements.
The valid combination of AES components is shown in Table 2-3.
The testing and validation requirements for AES2 class SDU are contained in Table 5-2.

2.2.1.3 AES3 Subsystem Definition

The AES3 configuration contains a total quantity of N (where N ≥2) of the LBT (95XX) transceivers and/or of the SBD (96XX) transceivers for N-channel data and/or voice applications. An AES3 shall be capable of AMS(R)S safety communications (voice and/or data) but may also support AMSS non-safety communications (voice and/or data).

An AES3 shall support a minimum of one (1) AMS(R)S voice line to a maximum of two (2) AMS(R)S voice lines. Depending on the design, an AES3 may also support AMS(R)S data or AMSS non-safety communication (voice and/or data) in addition to the line(s) used for AMS(R)S voice.

Depending on the design of the AES3, a passive LGA omni antenna or an active (powered) antenna subsystem, such as an IGA switched beam or IGA/HGA phased steering array is required. The system specific parameters of an AES3 are contained in Table 2-4.

See Section 5 on AES Configurations and Test Requirements.
The valid combination of AES components is shown in Table 2-3.
The testing and validation requirements for AES3 class SDU are contained in Table 5-2.

2.2.1.4 Valid Combination of AES System Components

The previous sections outlined the details of the major AES components. The following table lists the valid combinations of transceivers and antenna type that comprise a valid AES combination.

Valid Combi-nations		Transceivers by Type		Antenna			Complete System
				Passive	Active		
		SBD	LBT	LGA	IGA switched beam	IGA/HGA phased steering array	
AES1	1						X
	2	X		X			
AES2	3						X
	4		X	X			
AES3	5						X
	6	X	X	X			
	7	X	X		X		
	8	X	X			X	

Table 2-3 Valid Combination of AES System Components

2.2.2 Definition of System Specific Parameters

This normative appendix contains requirements applicable only to the Iridium Satellite system and references requirements documents created as part of the systems engineering process followed by Iridium architects and designers. In addition to system specific information, this normative appendix contains a table that defines the basic configurations of avionics supporting the Iridium Satellite system. Table 2-4 defines the parameters that shall be specified for each configuration of avionics defined in this normative appendix.

Table 2-4 List of Parameters Quantified in the Iridium Normative Appendix

Symbol	Parameter	All types	AES1 with LGA -	AES2 with LGA -	AES3 with LGA -	Measurement point	Units
A_{RSV}	Iridium Satellite axial ratio for space vehicle. This parameter is used only to compute the gain necessary to overcome losses due to mismatch of the axial ratios. Over the operating frequency range	<2 RHCP(1)					dB
f_{RMX}	Maximum operating frequency for space vehicle transmissions (AES reception)	1626.5					MHz
f_{RMN}	Minimum operating frequency for space vehicle transmissions (AES reception)	1616.0					MHz
f_{TMX}	Maximum operating frequency for AES transmissions	1626					MHz
f_{TMN}	Minimum operating frequency for AES transmissions	1616.0					MHz
f_M	Channel modulation rate in bits per second	50k					Bps
P	Nominal polarization of AES antenna	RHCP (1)					
P_{NC}	Maximum output power allowed during intervals when no transceiver channel is transmitting. Levels are referred to the connector of the antenna.	Table 2-8				(A)	dBm
S_{DS}	Minimum data channel carrier level for sensitivity test to achieve a BER of 2% or less.	-112				(D)	dBm
S_{HSNt}	Maximum level of harmonic, spurious and noise allowed within the designated transmit band	Table 2-6 or Table 2-7				(A)	
S_{HSNR}	Maximum level of harmonic spurious and noise within the designated receive band (Iridium system is Simplex so TX is off when RX on)	n/a					
S_{IMT}	Maximum level of 2-tone intermodulation products allowed within the Iridium transmit band	-38				(A)	dBc
S_{IMR}	Maximum level of 2-tone intermodulation products allowed within the designated receive band (Iridium system is simplex so TX is off when RX on)	n/a					
S_{UW}	Maximum level of undesired wideband noise from interfering sources external to the AES that can be accepted within the designated receive band. (Outside the active receive channel)	-110				(D)	dBm/Hz
S_{UN}	Maximum level of undesired narrowband interference from interfering sources external to the NGSS system that can be accepted within the designated receive band, expressed as an absolute power level.[5]	-113				(D)	dBm
S_{VS}	Minimum voice channel carrier level for sensitivity test.		n/a	-112	-112	(D)	dBm

Symbol	Parameter	**All types**	**AES1 with LGA -**	**AES2 with LGA -**	**AES3 with LGA -**	**Measurement point**	**Units**
Θ_{SA}	Minimum separation angle between the line of sight to two satellites within the NGSS constellation	*Reference Section 1.2.4*					Deg
A_{RA}	Maximum axial ratio for AES antenna	2.5	For AES3 this 2.5dB limit may be exceeded if compensated for by additional antenna and or PA/LNA gain			Free Space	dB
Θ_{MIN}	Minimum elevation angle for satellite coverage.	8				Free Space	deg
D/U	Minimum pattern discrimination between two potential satellite positions above the minimum elevation angle, Θ_{MIN}	n/a					
$\Delta\phi$	Maximum phase discontinuity permitted between beam positions of a steered AES antenna. If the system design does not require steered antennas, this value may be set to "not applicable" (n/a).		n/a	n/a	<8	(D)	deg
G_{MAX}	Maximum gain of the aeronautical antenna pattern in the upper hemisphere above the minimum elevation angle Θ_{MIN}	n/a					dBic
G_{MIN}	Minimum gain of the aeronautical antenna pattern in the upper hemisphere above minimum elevation angle Θ_{MIN}		-2 LGA	-2 LGA	-2 LGA 6 IGA 10 HGA	Free Space	Weighted dBic
G/T	Minimum G/T performance of the AES based on antenna performance, associated equipment and installation parameters		-35	-35	-35	(D)	dB/K
L_{MAX}	Maximum cable loss between AES antenna port and the AES transceiver input port (A) to (C)		3	3	based on, associated equipment and installation parameters(3) (4)	(A) to (C)	dB
L_{MSG}	Maximum length in octets of user data sequence using ACARS transmissions	SBD	340/270	1960/1890	1960/1890	(B)	Octets
L_{SNDP}	Maximum length in octets of user data contained in a maximum length sub-network dependent protocol data block	Circuit switched, internet	340/270	No Limit	No Limit	(B)	Octets
N_D	Maximum number of simultaneous data carriers which are permitted in the maximum number of simultaneous carriers, *N*. For single-carrier systems, this term is not applicable.		1	2	16	(A)	
N_V	Maximum number of simultaneous voice carriers which are permitted in the maximum number of simultaneous carriers, *N*. For single-carrier systems, this term is not applicable.		0	2	16	(A)	
N	Maximum number of simultaneous data and voice carriers. For a single carrier system, *N* = 1.		1	2	16	(A)	

Symbol	Parameter	All types	AES1 with LGA -	AES2 with LGA -	AES3 with LGA -	Measurement point	Units
$EIRP_{MIN}$	Minimum single carrier power for each of N_D data carriers in a Single or multi-carrier capable AES, with no TX back-off, and maximum cable losses (A) to (C) and LGA antenna	-5.3/24.7				Free Space {can calculate from (A)}	dBW / dBm
$EIRP_{MAX}$	Maximum single carrier power for each of N_D data carriers in a Single or multi-carrier capable AES, with no TX back-off, and maximum cable losses (A) to (C) and LGA antenna		9.0/39.0 LGA	9.0/39.0 LGA	9.0/39.0 LGA 15.2/45.2 IGA 20.0/50 HGA	Free Space {can calculate from (A)}	dBW / dBm
P_D	Maximum single carrier power for each of N_d data carriers in a multi-carrier capable AES	Total power not to exceed EIRPmax				(A)	dBW dBm
P_{RNG}	Back off range over which the AES transmit power is controlled by the Iridium Modem	8					dB
P_{SC-SC}	Maximum burst output power of single carrier AES, or a multi-carrier when only one is active		9.0/39.0 LGA	9.0/39.0 LGA	9.0/39.0 LGA 15.2/45.2 IGA 20.0/50 HGA	(A)	dBW/ dBm
P_{STEP}	Step size for controlling AES transmit power from Iridium Modem	0.5					dB
P_V	Maximum single carrier power for each of N_v voice carriers in a multi-carrier capable AES	Total power not to exceed EIRPmax				(A)	dBW dBm
R_{SC-UD}	Minimum average single channel user data rate sustainable at a residual packet error rate of 10^{-6}		n/a	2400	2400	(B)	bps
τ_{SW}	Maximum switching time between electronically steered antenna patterns. For systems that do not require steered antennas, value may be declared as "n/a".		n/a	n/a	100		us
ρ_{RA}	Minimum exclusion zone radius necessary for protection of Radio Astronomy	0					km
C/M	Carrier-to-multipath discrimination ratio measured at the minimum elevation angle, given in decibels	3					dB
V_{SWR}	Maximum Voltage Standing Wave Ratio measured at a single input port of the AES antenna	1.8:1					

Notes to Table 2-4:

1. *Antennas are right-hand circularly polarized in the sense of clockwise rotation of the E-field vector when viewed looking in the direction of propagation.*
2. *Values shall be declared by manufacturers and will be dependent on manufacturer design.*
3. *The value for AES3 L_{MAX} is variable based on the active antenna design. If the weighted average antenna gain is greater/less than -G_{MIN} circuitry, calculations should be done to maintain the EIRP and sensitivity requirements.*
4. *Note the AES3 can be fitted with an LGA Omni-antenna, or an IGA switched beam, or IGA/HGA phase steering array.*
5. *Narrow band is defined as 25KHz or less*

2.2.3 Detailed Requirements

2.2.3.1 AES Application Requirements

This section and its subsections contain requirements for an AMS(R)S terminal and subsystem. Where possible, reference has been made to Reference D, Iridium Satellite Compliance and Test Requirements for Value Added Manufacturing (VAM) Products. The aim is to achieve a commonality between the requirements and test methods in this document and those required to obtain access to the Iridium network through the Iridium Compliance and Test Requirements

In addition to any other requirements stated in this document, achieving Iridium Compliance and Test Requirements is a specific requirement of this MOPS.

Note: The relevant Communication Network Provider (e.g. ARINC or SITA or other) may require additional validation of a particular AES as being fit for use on their network (e.g. ARINC AQP or SITA VAQ testing or other). Such validation is beyond the scope of this document and is the sole responsibility of the given Communication Network Provider.

2.2.3.1.1 Antenna

Notes:

The receiver sensitivity specified herein is a bench-test requirement. When coupled with the antenna performance specified in the following subsections, and when compensated for the effective sky temperature of typical operations, this sensitivity is consistent with the Figure of Merit G/T requirements of the DO-270 MASPS. Manufacturers are cautioned that antenna designs may degrade the achieved G/T, and that these effects must be considered in the overall system performance estimates required by the MASPS.

2.2.3.1.1.1 Coverage Volume, Polarization and Antenna Gain

2.2.3.1.1.1.1 Coverage Volume

When measured on an antenna range over a representative ground plane, the antenna shall meet its polarization, antenna gain and axial ratio requirements over a partial hemispheric volume from the minimum elevation angle Θ_{MIN} to 90° in elevation angle relative to the horizontal and throughout 360° of azimuth.

2.2.3.1.1.1.2 Polarization

The antenna shall be right hand circularly polarized (per ITU-R Recommendation 573), that is, having a clockwise rotation when viewed in the direction of transmitted signal propagation.

2.2.3.1.1.1.3 Antenna Gain

An LGA, IGA or HGA antenna shall maintain G_{MIN} weighted gain over all the elevation angles and azimuth angles. The weighting factors for computing the weighted antenna gain over elevation angle can be found in Section 2.2.3.1.1.1.4

2.2.3.1.1.1.4 Weighted Average Gain Coefficients

To calculate the weighted average gain of the antenna (for multi-beam antennas (un-weighted) average across the beams)

1) RHCP gains in dBic (from antenna measurement including connector) are converted to power gain.
2) For each elevation angle listed in Table 2-5 below, samples are selected for the positive and negative elevation angles from the 0, 45, 90, 135 degree azimuth cuts.
3) These eight samples are combined using a simple (un-weighted) average.
4) The average of the eight samples is weighted by the respective values in Table 2-5 below. (Elevation angle in table is measured from horizon 0degrees).
5) The resulting values are then summed over all listed elevation angles and converted back to dBic.

Angle (deg)	Probability	Angle (deg)	Probability	Angle (deg)	Probability
08 to 10	0.020888	36 to 38	0.0268299	64 to 66	0.0057093
10 to 12	0.0526807	38 to 40	0.0241294	66 to 68	0.0050253
12 to 14	0.0770963	40 to 42	0.0219969	68 to 70	0.004538
14 to 16	0.0821484	42 to 44	0.0198284	70 to 72	0.0040149
16 to 18	0.0820098	44 to 46	0.0170834	72 to 74	0.0034649
18 to 20	0.076287	46 to 48	0.0155364	74 to 76	0.0029642
20 to 22	0.0687848	48 to 50	0.0136363	76 to 78	0.0025574
22 to 24	0.0605406	50 to 52	0.0125006	78 to 80	0.0021863
24 to 26	0.0525376	52 to 54	0.0110503	80 to 82	0.0017392
26 to 28	0.0471501	54 to 56	0.0099925	82 to 84	0.0013681
28 to 30	0.0420131	56 to 58	0.0091072	84 to 86	0.0010015
30 to 32	0.0369252	58 to 60	0.008222	86 to 88	0.0006751
32 to 34	0.0325742	60 to 62	0.0073412	88 to 90	0.0001788
34 to 36	0.0291503	62 to 64	0.0065365		

Table 2-5 Antenna Weighting Factor

2.2.3.1.1.2 Axial Ratio

See Table 2-4 for Axial ratio information.

2.2.3.1.1.3 Power Handling Capabilities

2.2.3.1.1.3.1 Single Carrier Units

Note: This requirement refers to the number of carriers, not necessarily the number of channels.

For avionics designed to transmit only a single carrier, the maximum power handling capability of the AES antenna shall be sufficient to support at least one individual data or one individual voice carrier, whichever requires the higher burst output power consistent with the requirements of Section 2.2.3.1.2.1.2 Maximum Individual Carrier Output.

2.2.3.1.1.3.2 Multi-Carrier Units

<u>Note</u>: *This requirement refers to the number of carriers, not necessarily the number of channels. This is applicable when two 95XX or 96XX transceivers (or one of each) are used with a single antenna or two 95XX or 96XX transceivers (or one of each) are used with two antennas packaged in one radome or two antennas at 1.0 m separation minimum.*

For avionics designed to operate simultaneously on multiple carrier frequencies, the maximum power handling capability of the AES1 and AES2 antenna shall be 20W CW. AES3 antennas need to be designed to carry the power of the N transmitters, and the resultant Peak to average ratio which is dependent on the number of carriers.

2.2.3.1.1.4 Passband

As a minimum, the antenna shall meet all of its requirements for transmit frequencies between 1616-1626 MHz and receive frequencies between 1616 and 1626.5 MHz.

f_{TMN}, f_{RMN} : 1616.0 MHz
f_{TMX}, f_{RMX} : 1626.0 MHz, 1626.5 MHz

2.2.3.1.1.5 Antenna Voltage Standing Wave Ratio

When measured at the transmit (and receive) RF port(s) of the antenna, the Voltage Standing Wave Ratio (VSWR) shall not exceed the value V_{SWR} as per <u>Table 2-4</u>, when correctly mated with the appropriate connector. The nominal characteristic impedance shall be 50 ohms.

2.2.3.1.1.6 Radiated Antenna Intermodulation Products

The following requirements apply to AES equipment capable of operating simultaneously on multiple radio frequency carriers within the frequency band f_{TMN} to f_{TMX}.

2.2.3.1.1.6.1 Radiated Antenna Intermodulation Products in the GNSS Band

For multi-carrier operation, when operating two unmodulated carriers, each with a power of 7 dBW (HGA) or 7 dBW (IGA), anywhere in the antenna's declared transmit band, the antenna shall not generate intermodulation products with levels and frequencies as follows:

In the frequency range 1559 to 1585 MHz, the level of the intermodulation product shall not exceed -158.5 dBW.

In the frequency range 1585 to 1605 MHz, the level of the intermodulation product shall not exceed -157 dBW.

Intermodulation levels should be referenced to the output port of an external 1/4-wave monopole GNSS antenna mounted on a common ground plane with the AES antenna under test. The isolation between the monopole and the AES antenna shall be 55 dB or other declared antenna isolation applicable to GPS and GLONASS respectively, or suitable compensation to the measurement shall be applied.

<u>Note</u>: *Additional filters maybe required to meet this requirement.*

2.2.3.1.1.6.2 Radiated Antenna Intermodulation in AMS(R)S Bands

Note: This requirement is only applicable under the conditions described in Section 2.1.8.

When tested under the same conditions as in Section 2.2.3.1.1.6.1, the antenna subsystem shall not radiate harmful interference due to internally generated intermodulation products in a direction toward likely locations of antennas on the same aircraft serving other AMS(R)S systems. For the purpose of this requirement, harmful interference is defined as an interference power level that increases the effective noise temperature of the victim AMS(R)S system by more than 6%. In this condition, the other antenna is taken to be a quarter-wave monopole antenna matched to its load and the isolation between the AES antenna and the victim AMS(R)S antenna is taken to be 40 dB. Relaxation for increased isolation is permitted under the same conditions as in Section 2.2.3.1.1.6.1.

Note: Section 2.2.3.1.1.6.1 applies to specific bands but because of the specific susceptibility of satellite navigation and communication downlinks to high level interference, manufacturers are cautioned that antenna intermodulation has the potential to adversely affect terrestrial and airborne AES functions as well

2.2.3.1.1.7 Carrier-to-Multipath Discrimination

C/M When measured over a representative ground plane, the difference in decibels between the minimum antenna gain measured at the minimum declared elevation angle, Θ_{MIN}, and the maximum antenna gain measured at the same angle below the horizon, shall be greater than 3 dB.

2.2.3.1.1.8 Pattern Discrimination

D/U Not Applicable for LEO Satellite Systems

2.2.3.1.1.9 Steered Antenna Requirements

Not Applicable for non-steerable, fixed pattern LGA antennas
The manufacturer of an active IGA, HGA antenna array system shall work with the AES3 terminal manufacture to implement a steered antenna control system.

Note:

1) The purpose of the antenna control system is to point the Primary TX/RX beam at the SV that is currently providing the link, and provide a Secondary RX only beam which is used to search for handoff SV.
2) IGA and HGA antennas require at least two RF paths, the primary TX/RX and an Secondary RX only (which can be an omni-directional as the search path does not need the high gain and only needs to meet G_{min} for the LGA). With suitable RF design the two RX paths are allowed to be combined post TX/RX switch if needed by the terminal modem.

2.2.3.1.1.9.1 Phase Discontinuity

Not Applicable for non-steerable, fixed pattern antennas LGA.
IGA and HGA shall meet the value of $\Delta\phi$ as described in Table 2-4

2.2.3.1.1.9.2 Beam Switching Time

Not Applicable for non-steerable, fixed pattern antennas LGA.
IGA and HGA shall meet the value of τ_{SW} as described in Table 2-4

2.2.3.1.1.9.3 Steering Rate

Not Applicable for non-steerable, fixed pattern antennas LGA.
For IGA and HGA the Secondary RX path (See section 2.2.3.1.1.9) shall be able to search the entire hemisphere in 4 seconds where each IGA/HGA antenna beam has a dwell time of 4ms.

2.2.3.1.1.9.4 Pattern Discrimination

The LGA, IGA, HGA antenna D/U is not applicable.
Note: *For the IGA and HGA antenna, the Secondary RX beam is considered to be fully independent from the Primary RX beam and by definition D/U is not applicable to the IGA, HGA. This is because the terminal is not trying to get two SV(s) in the same RF path. Similarly this does not apply to an LGA as it is an omni-diriectional antenna.*

2.2.3.1.2 Transceiver Subsystem

2.2.3.1.2.1 Transmitter Function

The transmitter shall meet all its requirements over the following frequency bands: 1616-1626

2.2.3.1.2.1.1 Minimum Power Output

The AES shall be capable of providing an on-channel power output, measured in free space or other suitable measurement technique, in order to achieve a single carrier power level of at least $EIRP_{MIN}$ as per Table 2-4. *The* $EIRP_{MIN}$ shall be converted to equivalent Transmit Power Limits, referred to the connector of the antenna, using the appropriate antenna gain as described in the test procedure in Section 2.4.3.1.2.1.1.

2.2.3.1.2.1.2 Maximum Individual Carrier Output

When measured at Point A of any AES configuration, the on-channel power output of the transceiver shall be no more than P_D or P_V depending on the AES class.

The on-channel power output shall be defined as in the definition of Burst Output Power found in Section 1.7 of the DO-262 main document.

2.2.3.1.2.1.3 Maximum Total Transmitter Output

When measured at Point A with the minimum practical cable loss for the specific AES design, the average power during a transmission burst from the output of the transceiver on any assignable frequency f, with N_D data channels and/or N_V voice channels simultaneously active, shall not exceed 15dBW- Antenna Gain (for clarity 15dBW minus the value of the antenna gain).

This is based on an assumed -55 dB coupling between the AES antenna and the GNSS antenna. If a different coupling level is used, the highest average maximum total transmit power limit shall be adjusted accordingly or appropriate filtering methods applied. All channels shall be assumed to be transmitting with the maximum duty cycle.

Notes:

1) This value of 15dBW is governed by ETSI EN V1.4.1, Section 5.3.2 for peak EIRP density within operational band, using with iridium's declared bandwidth for a single carrier of 208kHz
2) This requirement maintains compatibility with GNSS susceptibility requirements as stated in the ICAO GNSS SARPS

2.2.3.1.2.1.4 Transmitter Intermodulation Performance

2.2.3.1.2.1.4.1 Narrow-band (CW) Intermodulation Performance

Not Applicable

2.2.3.1.2.1.4.2 Modulated Intermodulation Multi-Carrier Performance

This requirement does not apply to AES1 configurations unless it is part of a combined system as outlined in Section 5.1.

A transceiver capable of multi-carrier operation, including any associated HPA and output filter, shall satisfy the requirements of Table 2-6 or Table 2-7, depending on $EIRP_{max}$) with a 4 dB relaxation when transmitting two modulated carriers each of which is at the maximum single-carrier power permitted by 2.2.3.1.2.1.2 or one-half the maximum output power of the transceiver, including HPA, whichever is less. Both carriers shall be on assignable carrier frequencies within the band f_{TMN} to f_{TMX}. The emission that does not fall within the band 0.99675 f_{TMN} to 1.00325 f_{TMX} or the band 0.99675 f_{RMN} to 1.00325 f_{RMX} shall not exceed the values of Table 2-6 or Table 2-7 by more than 4 dB.

The emission that falls within the band 0.99675 f_{TMN} to 1.00325 f_{TMX} or the band 0.99675 f_{RMN} to 1.00325 f_{RMX} shall not exceed the two-tone intermodulation signal level S_{IMT} given in Table 2-4.

Notes:

1) *Manufacturers may demonstrate compliance with the standards established in Table 2-6 or Table 2-7, depending on $EIRP_{max}$,by testing with CW carriers and applying a mathematically justifiable spreading factor to account the modulation rate and the order of the intermodulation product. Such spreading factor should not increase with IM order faster than sqrt(k), where k is the lowest order of the IM product capable of producing products in the specified band.*

2) ***Intermodulation requirements do not apply to AES equipment, or combination of AES systems as outlined in Section 5.1, that only transmit on a single carrier frequency.***

2.2.3.1.2.1.5 Transmitter Harmonics, Discrete Spurious and Noise Density Limits

Notes:

This section excludes requirements for emissions in the transmit band, which are covered in Section 2.2.3.1.2.1.9.

When tested with a single modulated signal at the maximum permissible single carrier level specified by Section 2.2.3.1.2.1.2, the average power output of the composite harmonic, discrete spurious and noise density, including phase noise, at the transceiver output shall not exceed the values in Table 2-6 or Table 2-7, except for frequencies falling within the band .99675 f_{TMN} to 1.00325 f_{TMX} and the band 0.99675 f_{RMN} to 1.00325 f_{RMX}

A modulated single carrier transmitted from equipment with a maximum EIRP greater than or equal to 15 dBW shall meet the requirements of Table 2-6. A modulated signal carrier transmitted from equipment that with maximum EIRP of less than 15 dBW shall meet the requirement of Table 2-7.

Table 2-6 and Table 2-7 specify power limits at the transceiver output (including the HPA and output filter) and in EIRP. The EIRP values may be mathematically adjusted to an equivalent transceiver output value using the specific antenna configuration specified for the equipment. If the equipment is configured to operate with several different antennas, the adjustment resulting in the lowest emission at the transceiver output shall be used. The assumed antenna gain(s) shall be clearly declared in Section 3 of the system-specific appendix.

The values contained in Table 2-6 and Table 2-7 are based on a standard assumption of 40 dB isolation between the SATCOM and any GNSS antennas. System-specific specifications may relax such requirements by increasing the assumed isolation on a decibel-for-decibel basis up to a maximum isolation of 60 dB. Such a relaxation in performance shall be accompanied by a specific statement as to the assumed isolation. The declared isolation may be different for different GNSS systems, for example GPS and GLONASS. The assumed isolation shall clearly be stated as an installation requirement in Section 3 of the system-specific appendix.

The required test category in Table 2-6 or Table 2-7 shall be declared for GPS & GLONASS or GPS Only. See Notes on the tables regarding GPS only test requirements.

Table 2-6 Harmonic, Spurious and Noise Requirements for AES Equipment with $EIRP_{MAX}$ greater than or equal to 15 dBW

Frequency (MHz)	Measurement Bandwidth (kHz)	EIRP limit (dBW)	Single-Carrier Transmit Power Limit (dBW)	Power Averaging Interval
0.01-1525	10		-118	1 frame or 1 second whichever is shorter (1f /
1525-1559	10		-146 (note 9)	1f / 1s
1559-1585	1000.0 1		-122 -125	20 ms

1585-1605	1000.0 1		-118 (note 10) -125	20 ms
1605-1610	500 1		-119 (note 10) -125	20 ms
1610-1614	10		-78	2000 second combined HSN+IM
1614 - 1616	100		increasing to -55	1f / 1s
1616-1626.5	See Section 2.2.3.1.2.1.9			
1626.5-1650	100		-55	1f / 1s
1650-1660	1000		increasing to -49.5	1f / 1s
1660-1670	10 1000		-56 -39.5	2000 second combined
1670-1690	1000	-36		1f / 1s
1690-12000	1000	-61		1f / 1s
12000-18000	1000	-49		1f / 1s

Notes to Table 2-6.

1. *Additional filters maybe required to meet these requirements.*
2. *The values in the "Transmit Power Limit" column refer to power at the connector of the antenna.*
3. *The values in the "EIRP Limit" column shall be converted to equivalent Transmit Power Limits, referred to the connector of the antenna, using the appropriate antenna gain as declared in Section 3.*
4. *All measurements shall use an averaging detector.*
5. *In the band 3253.0 MHz to 3321.0 MHz the maximum EIRP in one, and only one, 300 kHz measurement bandwidth shall not exceed -38 dBW. Elsewhere in this band the power limit in Table 2-6 shall be applied.*
6. *In each of the bands 4 879.5 MHz to 4 981.5 MHz, 6 506.0 MHz to 6 642.0 MHz and 8 132.5 MHz to 8 302.5 MHz the maximum EIRP in one, and only one, 300 kHz measurement bandwidth shall not exceed -48 dBW. Elsewhere in this band the power in Table 2-6 shall be applied.*
7. *In the band 9 759.0 MHz to 9 963.0 MHz the maximum EIRP in one, and only one, 300 kHz measurement bandwidth shall not exceed -59 dBW. Elsewhere in this band the power limit in Table 2-6 shall be applied.*
8. *If measured on one channel of a multi-channel system, this level shall be reduced by 10*log(N) dB, where N is the number of channels the system is capable of transmitting on simultaneously.*
9. *This value assumes an isolation of 40 dB between the transmitter antenna port and the antenna port of a receiver operating in this band. If additional isolation is explicitly*

required in the satellite-specific appendix, this value may be increased on a decibel-per-decibel basis up to a maximum of 20 dB (60 dB total isolation).

10. *If the satellite-specific material explicitly provides for a class of equipment that is intended for operation only on aircraft where GLONASS is not used, the linear increase shown in the 1605-1610 MHz band may be used across the 1585-1610 MHz band.*

Table 2-7 Harmonic, Spurious and Noise Requirements for AES Equipment with *$EIRP_{MAX}$* less than 15 dBW

Frequency (MHz)	**Measurement Bandwidth (kHz)**	**EIRP limit (dBW)**	**Single-Carrier Transmit Power Limit (dBW)**	**Power Averaging Interval**
0.01-1525	10		-118	1 frame or 1 second whichever is shorter (1f /
1525-1559	10		-146 (note 11)	1f / 1s
1559-1585	1000.0		-118	2 ms
1585-1605	1000.0 1		-118 (note 12) -125	20 ms
1605-1610	500 1		-115 to -80 linear (note 2) -118 to -103 linear	20 ms
1610-1614	10		-78	2000 second combined
1614-1616	1000	46		1f / 1s
1616-1626.5	See Section 2.2.3.1.2.1.9			
1626.5-1650	100		-55	1f / 1s
1650-1660	1000		increasing to -49.5	1f / 1s
1660-1670	10 1000		-56 -39.5	2000 second combined
1677-1680	30	-60		
1680-1685	300	-60		1f / 1s
1685-1705	1000	-60		1f / 1s
1705-18000	3000	-49		1f / 1s

Notes to Table 2-7:

1. *Additional filters maybe required to meet these requirements.*
2. *Sections marked "linear" are linearly interpolated in dB vs. frequency.*

3. The values in the "Transmit Power Limit" column refer to power at the connector of the antenna. For Class 4 antennas with integrated DLNA this physical connector does not necessarily exist. In this case the equivalent measurement may be performed using a specially prepared unit, or by measuring at a different point and calculating the equivalent levels.

4. The values in the "EIRP Limit" column shall be converted to equivalent Transmit Power Limits, referred to the connector of the antenna, using the appropriate antenna gain as described in the test procedure in relevant satellite-specific Appendix

5. All measurements shall use an averaging detector.

6. In the band 3 253.0 MHz to 3 321.0 MHz the maximum EIRP in one, and only one, 300 kHz measurement bandwidth shall not exceed -38 dBW. Elsewhere in this band the power limit in Table 2-7 shall be applied.

7. In the bands 4 879.5 MHz to 4 981.5 MHz and 5 004.0 MHz to 5 025.0 MHz the maximum EIRP in one, and only one, 3 MHz measurement bandwidth shall not exceed -48 dBW. Elsewhere in these bands the power limit in Table 2-7 shall be applied.

8. In the bands 6 506.0 MHz to 6 642.0 MHz and 6 672.0 MHz to 6 700.0 MHz the maximum EIRP in one, and only one, 3 MHz measurement bandwidth shall not exceed -48 dBW. Elsewhere in these bands the power limit in Table 2-7 shall be applied.

9. In the bands 8 132.5 MHz to 8 302.5 MHz and 8 340.0 MHz to 8 375.0 MHz the maximum EIRP in one, and only one, 3 MHz measurement bandwidth shall not exceed -48 dBW. Elsewhere in these bands the power limit in Table 2-7 shall be applied.

10. In the bands 9 759.0 MHz to 9 963.0 MHz and 10 008.0 MHz to 10 050.0 MHz the maximum EIRP in one, and only one, 3 MHz measurement bandwidth shall not exceed -59 dBW. Elsewhere in these bands the power limit in Table 2-7 shall be applied.

11. This value assumes an isolation of 40 dB between the transmitter antenna port and the antenna port of a receiver operating in this band. If additional isolation is explicitly required in the satellite-specific appendix, this value may be increased on a decibel-per-decibel basis up to a maximum of 20 dB (60 dB total isolation).

12. If the satellite-specific material explicitly provides for a class of equipment that is intended for operation only on aircraft where GLONASS is not used, the linear increase in the 1605-1610 MHz band may be used across the 1585-1610 MHz band.

2.2.3.1.2.1.6 Protection of Radio Astronomy

Requirements for protection of the radio astronomy bands are included in Section 2.2.3.1.2.1.5, Section 2.2.3.1.2.1.7, and Section 2.2.3.1.2.1.9.

2.2.3.1.2.1.7 Carrier Off Level

After the transmitter has not transmitted for more than two seconds, the transmitted EIRP, referred to the connector of the antenna, shall be below the levels specific in Table 2-8.

In no circumstances shall the unwanted emissions from an AES in its carrier-off state exceed the unwanted emissions from the AES when in its carrier-on state.

In Table 2-8, whenever a change of limit between adjacent frequency bands occurs, the lower of the two limits shall apply at the transition frequency.

Table 2-8 Maximum EIRP of the Unwanted Emissions in the Carrier-off State

Frequency (MHz)	EIRP (dBW)	Measurement bandwidth	Measurement method
0.01 to 30	-87	10kHz	Peak hold
30 to 1,000	-87	100 kHz	Peak hold
1,000 to 1559	-77	100 kHz	Peak hold
1559 to 1605 (1)	-103	500kHz	Average 20ms
1605 to 1610(1)	-88	500 kHz	Average 20ms
1610 to 1613.8	-77	20 kHz	Average over 2,000s
1613.8 to 1660	-77	100 kHz	Peak hold
1660 to 1670	-77	20 kHz	Average over 2,000s
1670 to 18,000	-77	100 kHz	Peak hold
Note 1: Assumes 55dB of isolation exists between AES and the GNSS antenna. Adjust EIRP for alternative isolation value.			

2.2.3.1.2.1.8 Power Control

Note: *The transceiver function of controlling the power level of its emissions on any individual carrier over a range of P_{RNG}, with nominal steps of 1dB or less is controlled by Iridium through the satellite network communications and is not testable in the transceiver.*

2.2.3.1.2.1.9 On-Channel Output Spectrum

The maximum EIRP spectral density of the unwanted emissions from an AES in any 30 kHz band within the band 1610 – 1626.5 MHz is stated in Table 2-9.

Note: *The Iridium transceiver meets the adjacent carrier power ratio requirements of the Iridium system. This parameter is verified on each unit in production testing prior to being provided to the avionics manufacturer for installation into the SDU.*

Table 2-9 Maximum Unwanted Emissions Within the Band 1610 – 1626.5 MHz and the Band 1626.5 – 1628.5 MHz of an AES Operating Such That the Nominated Bandwidth is Entirely or Partially Contained in the Frequency Band 1618.25 – 1626.5 MHz (ETSI EN 301 473 v1.4.1 Table 3)

Frequency Offset (kHz) (*see Note 1*)	Carrier-on		
	EIRP (dBW)	Measurement bandwidth (khz) (*see Note 2*)	Measurement Method
0 to 160	-35	30	Average
160 to 225	-35 to -38.5 (*see Note 3*)	30	Average
225 to 650	-38.5 to -45 (*see Note 3*)	30	Average

650 to 1,365	-45	30	Average
1,365 to 1,800	-53 to -56 (*see Note 3*)	30	Average
1,800 to 16,500	-56	30	Average

Notes to Table 2-9

1. *Frequency offset is determined from:*
   i) *The nearest edge of the nominated bandwidth of the nominal carrier closest to the MSS system operating in another operational band within the band 1,610 MHz to 1,626.5 MHz. The frequency offset is measured in the direction of the adjacent MSS system;*
   ii) *The upper edge of the nominated bandwidth of the carrier under test for emissions within the band 1,626.5 MHz to 1,628.5 MHz.*
2. *The measurement bandwidth used may be 3 kHz if the unwanted EIRP limits are reduced correspondingly.*
3. *Linearly interpolate in dBW vs frequency offset.*

2.2.3.1.2.1.10 Transmitter Operation in Moving Aircraft

Any AES capable of AMS(R)S voice and/or AMS(R)S data communications shall comply with the Iridium satellite network interface requirements when installed in aircraft operating at ground speeds of up to 800 knots (1481.6km/hr). See Iridium Reference H- Iridium Doppler Requirements/ Performance for Aeronautical Communication GEN-0020 as an analysis reference.

2.2.3.1.2.1.11 Manufacturer Defined Transmitter Tests

The manufacturer shall define the tests required to detect degradation in performance before, during, or after environmental tests (depending on the environmental category) and shall be used to verify the Transceiver operates correctly over the indicated DO-160G categories.

Note: The manufacturer may choose to combine environmental tests when able to avoid excessive time and cost.

2.2.3.1.2.2 Receiver Function

For the purposes of this section, the reference point for all signal level measurements is the input port to the AES, Point C in Figure 1-13, Figure 1-14 and Figure 1-15.

2.2.3.1.2.2.1 Receiver Sensitivity

2.2.3.1.2.1.4.3 Data Sensitivity

When operated with a single active data channel, an AES capable of packet data service shall output user data at average rate of $R_{SC\text{-}UD}$ bps or higher with input signal level greater than or equal to S_{DS}. When transferring packets of 128 octets of user data, the receiver data output shall exhibit a residual packet error rate of no more than 1×10^{-6}.

Note: The receiver sensitivity specified here is a bench-test requirement, which takes into account the satellite-subnetwork error correction and/or retransmission properties. When coupled with the antenna performance specified earlier, and when compensated for the *effective sky temperature of typical operations and any increase in the effective noise temperature due to antenna effects, this sensitivity is consistent with the Figure of Merit G/T requirements of the DO-270 MASPS and DO-215A.*

As allowed under DO-270 MASPS, a calculation of the residual packet error rate is allowable given the excessive number of tests required to validate 1 x 10^{-6}. See Iridium Packet Error Rate Calculations Paper (Reference E) on a calculation of the packet error rate that demonstrates the network FEC and other mechanisms that contribute to data sensitivity. This calculation is part of the validation when coupled with a test requirement of no more than 2% Bit Error Rate (BER).

Note: Iridium Certification will validate the 2% BER at S_{DS} at average rate of R_{SC-UD} bps or higher.

2.2.3.1.2.1.4.4 Voice Sensitivity

The vocoder shall satisfy its performance requirements when provided with an input signal of S_{VS} from an appropriately configured satellite system test set.

See Iridium Packet Error Rate Calculations Paper (Reference E) that covers the circuit switch data analysis of the Iridium system. The same 2% BER that is references in 2.2.3.1.2.2.1.1 will enable the validation of this requirement based on the analysis in Iridium Reference E - Iridium Packet Error Rate Calculations Paper.

2.2.3.1.2.2.2 Receiver Bandwidth

The receiver shall meet its requirements for an input carrier frequency anywhere in the range of 1616 – 1626.5 MHz.

Note: The Iridium system is an TDD/FDD system with a channelization system based on 47.7kHz channel spacing. (Table 2-4 F_M with RRC 0.4) The RF path at the LGA, IGA, HGA has to cover the entire Iridium band as described above. At any given time the modem is TX/RX over one or more carriers centered in the channel spacing and is defined here as receiver tuned bandwidth.

For systems where MAX(N_D, N_V) = 1 the receiver tuned bandwidth shall be at least Bw = 180kHz. This is due to the 47.7kHz modulation bandwidth + /- 60kHz Doppler shift + tolerance.

For systems where MAX(N_D, N_V) > 1 the receiver tuned bandwidth shall be Bw = ({Max() -1} * 50) + 180kHz.

e.g. if N_D = 16 the receiver has to have a bandwidth of at least 930kHz.

2.2.3.1.2.2.3 Rejection of Signals Outside the NGSS Receive Band

The receiver shall acquire and track the satellite downlink signal with a minimum signal level given by the S_{VS} and S_{DS} in the presence of CW interference signal of -10 dBm in the frequency range 470 to 18,000 MHz, excluding the band 0.95 f_{RMN} to 1.05 f_{RMX}.

Within the excluded band, the level of the CW interference signal shall be reduced linearly from -50dBm at 0.95 f_{RMN} to -72 dBm at 0.99938 f_{RMN} and from -10 dBm at 1.05 f_{RMX} to -72 dBm at 1.00062 f_{RMX}.

2.2.3.1.2.2.4 Rejection of Carrier Signals Generated by Other AMS(R)S Equipment

Note: This requirement is only applicable under the conditions described in Section 2.1.8.

In addition to the general CW interference requirements described in Section 2.2.3.1.2.2.3, the receiver shall acquire and track the satellite downlink signal with a minimum signal level given by the minimum S_{VS} and S_{DS} in the presence of CW interfering signal of the following levels and carrier frequencies.

Carrier Frequency Band	CW Interference Level
1626.5-1660.5 MHz	-2dBm

Note: These levels assume an antenna-port-to-antenna-port isolation of 40 dB between AMS(R)S equipment on the same aircraft, and includes the effects of DO-210D compliant avionics on the same aircraft. For AES installations that can provide more than 40 dB of isolation, the interference level can be reduced on a decibel for decibel basis. .

2.2.3.1.2.2.5 Receiver Operation in Moving Aircraft

Any AES capable of AMS(R)S voice and/or AMS(R)S data communications shall comply with the Iridium satellite network interface requirements when installed in aircraft operating at ground speeds of up to 800 knots (1481.6km/hr). See Iridium Reference H- Iridium Doppler Requirements/ Performance for Aeronautical Communication GEN-0020 as an analysis reference.

Note: For aircraft that may operate above 800 knots, the same requirement applies. This 800 knot is not a limiting factor for AES functionality but is referenced here based on existing aircraft technology.

2.2.3.1.2.2.6 Receiver Susceptibility

The receiver shall properly acquire and track the required signals and shall output data at the specified rate when subjected to wideband interference noise of level S_{UW} across the designated receive band.

The receiver shall properly acquire and track the required signals and shall output data at the specified rate when subjected to CW interference of level S_{UN} on any assignable channel within the designated receive band.

For the purposes of this requirement, narrowband interference shall be defined as interference with a bandwidth of less than the modulation rate, f_M of the NGSS under consideration. Bandwidth with modulation rate greater than f_M shall be defined as wideband interference.

2.2.3.1.2.2.7 Receiver Damage

The AES receiver shall operate properly after exposure to an RF signal of 10 dBm at Point C of and AES class as shown in Figure 1-13, Figure 1-14, or Figure 1-15. The AES receiver shall be powered on during this test.

2.2.3.2 User Link Modulation and Signal in Space (Physical Layer)

The AES classes shall use, as a basis, an Iridium supplied modem which creates the modulated signal according to Iridium Specifications which may change from time to time and is not part of this requirement appendix. For testing purposes using a 8.32ms burst every 90ms with 41.667 kHz bandwidth, 50ksps, DE-QPSK with a 0.4 RRC filter is sufficient to model the air interface.

2.2.3.3 Priority, Precedence and Preemption

The requirements of this section shall apply to all communications channels available for assignment to users, specifically excluding channels used for internal NGSS signaling and system management functions.

An AES shall provide mechanisms to enable prioritization of priority-related communications over lower priority and non-priority communications. The priority levels are indicated in Table 2-10.

An AES1 is a packet data only system with details covered in Section 2.2.3.3.1.

An AES2 or AES3 shall support circuit switch voice and/or packet data, covered in 2.2.3.3.2 and 2.2.3.3.1 respectively.

If an AES supports voice and data communications, voice communications shall have priority over data within any given application or priority level.

The Iridium ATS switch supports three levels of call priority for safety communication and one level of non-safety communication as outlined in Table 2-10.

Table 2-10 Minimum AMS(R)S Priority Structure

Application (Voice and/or Data)	Priority Identifier
Distress, Urgency	4 (high)
Direction Finding, Flight Safety	3
Other Safety & Regularity of Flight	2
All other non-safety communications, including public correspondence	1 (low)

Notes:

1. *The numeric Priority Identifier scheme indicated in Table 2-10 is a logical scheme only and is intended for the purpose of unambiguously identifying test conditions within this document. There is no requirement that the actual interface(s) to pilots, to the satellites, or to the terrestrial users use this method for identifying priorities. Specific NGSS implementations may incorporate more than the minimum four priority levels specified above, and may utilize various specific priority/precedence numbering schemes for the levels.*

2. *Schemes identified in other RTCA and ICAO standards include 1 (highest) through 4 (lowest) and 15 (highest) through 0 (lowest), etc. In particular, the priority labeling*

convention listed in Table 2-10 is different from that used to identify circuit mode priorities in DO-210D. The convention of using a larger numeric value to indicate a higher priority is consistent with that used for ATN, ICAO Annex 10 Chapter 4 AMS(R)S SARPs, and DO-210D packet mode data communications.

3. *The required priority mechanism may be protocol based or may be hardware-specific. For example, an AES implementing the ISO 8208 protocol described in Appendix B of the DO-262 main document may rely on the packet priority mechanism inherent in the ISO 8208 protocol. AES's that implement other protocols may use either an inherent mechanism that is essentially equivalent to that of 8208. Other methods, including hardware-based methods and provision of dedicated Iridium hardware for AMS(R)S services, are permissible. Hardware-based mechanisms may include segregation of data priority by input port, identification of data priority via interface bus (e.g., ARINC 429) protocol separate from the packet protocol, a discrete hardware interface, or any other means that permits near-real-time determination of packet priority.*

2.2.3.3.1 Packet Data

The AES shall ensure that data packets are transferred to and from the Iridium network in such a way that higher priority data is not affected by lower priority data.

Notes:

1) *This requirement is considered a subset of the requirements for protection from a Denial-Of-Service (DOS) attack. This requirement is more thoroughly covered in the Information Security Section 2.2.3.10.*
2) *This normative appendix recognizes that messages may be subject to segmentation in accordance with Iridium Satellite protocols. Transmission preemption, if necessary, will be effected by changing the order of data transmission such that the data units of the internal protocols comprising the higher-priority message are transmitted before corresponding lower-priority data units. Any reordering necessary to comply with this requirement will take effect immediately upon completion of currently active data unit transmission. Preemption of lower-priority messages, if necessary, will be effected by any means necessary to preserve the higher-priority message(s).*

2.2.3.3.2 Circuit Mode Communications (Voice)

The AES shall apply priority and preemption mechanisms to air-to-ground and ground-to-air voice calls. Each call shall be assigned one of four levels of priority as shown in Table 2-10 using the prioritization mechanism required by 2.2.3.3. When providing AMS(R)S services, the AES shall always have sufficient communications resources to detect a request to establish an incoming call, except in the rare case when all AES resources are consumed by distress/urgency communications.

Notes:

1) *The Iridium ATS Safety Voice Switch is co-located at the Iridium gateway and controls all aspects of the priority, precedence and preemption of voice calling. The AES equipment receives the voice calls as directed by the ATS Safety Voice Switch based on the priority of the calls. The ATS Safety Voice Switch allows for at least three levels of priority for safety communications, all of which are higher than the priority provided for any non-safety communications, as illustrated in Table 2-10.*

2) *The ATS Safety Voice Switch management of actions for circuit-mode calls in either the air-originated or ground-originated direction are queued and processed within the AES in an order corresponding to each call's Circuit-mode Priority per Table 2-10, with the higher Circuit-mode Priority numbers having the higher precedence. The lowest priority in-progress call will be interrupted immediately if necessary to make AES resources (e.g., transmitter power, channel unit, vocoder) available for a higher-priority call. If a new ground-originated call has the same or lower priority as the lowest-priority call in progress, and if sufficient AES resources are not available to support the new circuit, then the AES shall indicate "busy" to the originating party. See Iridium Reference G - Iridium ATS Operator Guide MAN-2000-IR.*

2.2.3.4 Satellite Subnetwork Data Protocol (Satellite Layer 2)

The AES shall support the satellite subnetwork data protocols specified for the individual satellite network. Implementation of the Satellite Layer 2 Protocols shall include any actions and protocols necessary to acquire the satellite, maintain a connection over an extended period of time, transfer digital data and digitized voice information, and participate in the overall system management functions of the satellite subnetwork.

The AES shall register itself with the satellite system so that it is enabled to receive or transmit data or voice, as appropriate, on the subnetwork.

Notes:

1. *Satellite Layer 2 is a generic term for the internal protocol(s) used by various NGSS. For information on the context see the DO-270 MASPS. . This document uses the term Satellite Layer 2 to avoid confusion with the Satellite Subnetwork Dependent Protocols discussed in Section 2.2.3.6.3.*

2. *This registration action is referred to as "system log on", and an AES which has completed this action is referred to as being in a "logged-on" state.*

2.2.3.5 Voice Protocol

Vocoded voice information shall be transmitted and processed in accordance with the ISLLC protocols identified in Iridium Reference A. Any voice services supported by the avionics shall be certified by the ISLLC as compliant with the voice protocol specified in Iridium Reference A.

Note: As evidenced by this requirement, this normative appendix assumes digital transmission of voice.

2.2.3.5.1 Vocoder Interoperability with Satellite Subnetwork

Not Applicable

The vocoder algorithm shall be implemented by means of an Iridium LBT (95XX transceiver) that complies with Iridium Reference A. The Iridium LBT is 100% compatible with the Iridium network.

2.2.3.5.2 Vocoder Performance in an Aeronautical Environment

The vocoder intended for safety applications shall provide overall intelligibility performance suitable for the intended operational and ambient noise environment when operating with an Iridium satellite test signal level of S_{VS}. This requirement shall be satisfied when tested in audio noise environments representative of aeronautical cockpit applications in a variety of airframes, including wide-body air-transport cockpit background noise, helicopter cockpit background noise, prop-jet cockpit background noise, and ATC Control Center background noise.

2.2.3.6 User Data Interfaces

Short burst data (SBD), as defined in Section 1.2.11.2, shall support ACARS, or Aeronautical Telecommunications Network (ATN) service, or both.

One particular implementation that is known to be ATN-compliant is an ISO-8208 compliant interface. If the AES implements an ISO-8208 compliant interface, that interface shall comply with the requirements of Appendix B of the DO-262 main document. Implementation of this interface will assure maximum compatibility with AMSS avionics designed and qualified in accordance with DO-210D.

SBD provides only the physical and link layer functionality. Management of priority and preemption are implemented in higher level entities. If these higher level entities support the necessary priority and ISO 8473 convergence functions, SBD may also be useful for ATN communications.

<u>Notes</u>:

1. *It is highly desirable that the minimum data services include support for both ATN protocols as defined in DO-210D.*

2. *It is not the intent of this minimum standard to preclude the inclusion of additional satellite subnetwork access protocols, if desired by the avionics manufacturer*

2.2.3.6.1 ATN-Compliant Service Interface

The Satellite Subnetwork Layer (SSNL) in the AES shall offer connection-oriented packet data service to the Higher Layer Entities (HLEs) by facilitating satellite subnetwork switched virtual circuits (SVCs) with its peer entity in the subnetwork GES function. It also shall offer methods to convert addressing from the HLE to the SSNL. Figure 2-2 illustrates the ISO-style protocol stacks associated with ATN-compliant operations.

<u>Notes</u>:

1. *The terminology used in the high-level description of and requirements for an ATN-compliant protocol is based on ISO-8208. Use of this terminology should not be interpreted to require an ISO-8208 compliant interface as a minimum standard.*

2. *Figure 2-2 is intended to be representative of a typical implementation, not normative. In particular, certain applications within the AES may function as a "Higher Level Entity" in their use of the communications resource. The existence of such internal applications is not shown in Figure 2-2, but this omission should not be construed as a prohibition against such internal applications. This document neither encourages nor prohibits such implementations.*

The SSNL in the AES shall support the following three main functions:

a. The Satellite Subnetwork Dependent (SSND) sublayer
b. The Satellite Subnetwork Access (SSNAc) sublayer
c. The Satellite Subnetwork InterWorking Function (IWF)

The SSND sublayer shall perform the SSND protocol between the AES and a GES as defined in this document by exchanging SubNetwork Protocol Data Units (SNPDUs). The SubNetwork Protocol and definition of the SNPDUs are completely determined by the underlying communications infrastructure, and are defined in either the appropriate normative attachment or the documents referenced by such an attachment.

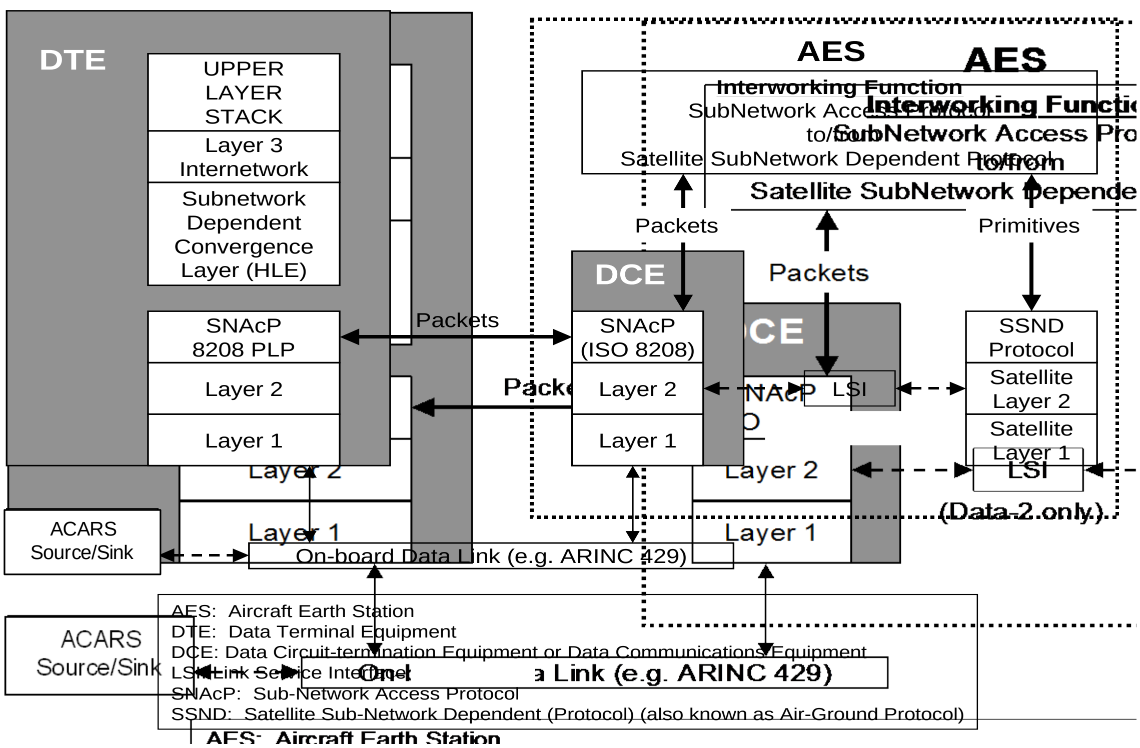

Figure 2-2 Satellite Subnetwork Architecture (Airborne Side)

The SSNAc sublayer in the AES shall perform the ATN-compliant protocol between the AES and the connected airborne HLE (DTE). The IWF shall provide the protocol conversion functions and the flow control operation required between the SSND and SSNAc sublayers.

Notes:

1. *The role of the ATN is to define an environment within which reliable end-to-end data transfer may take place, spanning the envisioned airborne, air/ground, and ground-based data subnetworks, including the satellite subnetwork, while providing interoperability among those networks. The critical emphasis is on end-system data transfer interoperability. In the ATN environment, the Satellite Subnetwork Layer must support the transparent transfer of Network Protocol Data Units between adjacent interworking entities (or HLEs as seen by the satellite subnetwork). This also implies the transparent transfer of global addresses (or Network Service Access Points (NSAPs) and of quality of service information (including network priority) as well as of user data.*

2. *The HLE (in addition to the incorporation of the SSNAc function) will also support additional functions. As a minimum, the DTE incorporates an internetwork function and may also incorporate transport, session, presentation and application functions. In some AES implementations, certain HLEs may be contained within the AES software itself, but this configuration is not illustrated in Figure 2-2.*

2.2.3.6.1.1 Join and Leave Requirements

An AES that provides ATN-compliant packet-mode data service shall provide Join and Leave event information to the aircraft routing function to indicate that the air/ground data link is either available or not available, respectively. The Join/Leave information shall include sufficient information for the routing function to determine the address(es) of the attached terrestrial DTE(s).

2.2.3.6.1.2 ATN-Compliant Mapping for Priority, Precedence and Preemption

The target and selected values of the priority of data on an ATN-compliant interface shall be mapped to the equivalent values at the opposite end of the satellite subnetwork.

2.2.3.6.2 ACARS

Note: *Sections 2.2.3.6.2 and 2.2.3.6.3, as well as related figure and table references, have been changed from the DO-262 main document to reflect that Data-2 is not applicable to the Iridium Satellite system. This requirement has been adjusted to reflect the ACARS interface.*

An AES supporting ACARS services shall utilize the Iridium SBD data service.

The ACARS protocol itself does not capture or convey priority information. Therefore the AES and the Iridium network both handle all ACARS messages transparently at the same priority level.

RUDICS is not approved for use as method of ACARS messaging and does not require testing for ACARS under this MOPS.

SBD is an Iridium Satellite network packet-mode data type protocol. Figure 1-9 shows the system architecture of the Iridium SBD service while Figure 1-10 depicts the MO (aircraft originated) call set-up process. As outlined in Section 1.2.9.2, SBD messages benefit from additional FEC protection. SBD messages are routed from the AES through the Iridium Satellite Gateway to the ground-based Safety Service Provider processor, serving as a higher level entity. The ground-based safety service processor converts the unmodified message for distribution via the aviation terrestrial network as a standard ACARS ground-ground message. Aircraft bound

ACARS messages are handled in the opposite fashion; the safety service processor converts the standard ACARS ground-ground message to an ACARS air-ground message for delivery to the aircraft via the Iridium sub-network.

2.2.3.6.3 Satellite Subnetwork Requirements

2.2.3.6.3.1 Satellite Subnetwork Dependent Protocol Requirements

The combination of the Satellite Subnetwork Dependent Protocol and the Satellite Layer 2 protocol is expected to provide a reliable link service to assist the overall AMS(R)S air-to-ground subnetwork in delivering high integrity data. The Satellite Subnetwork Dependent Protocol (SSNDP) shall provide the additional error control mechanisms, if any, necessary to assure a residual packet error rate, including misdirected packets, of 1 x 10^{-6} or less for a standard 128-octet message. See Section 2.2.3.1.2.2.1 Receiver Sensitivity for more information on this requirement.

The SSNDP shall operate in accordance with the requirements referenced in this normative appendix.

The SSNDP may include a separate Air-Ground Protocol (AGP) sublayer between peer entities in the AES and GES. When the Air-Ground Protocol sublayer is included, it shall be defined in this attachment, and the AES shall comply with the defined protocol.

2.2.3.6.3.2 ATN-compliant Requirements

If an ATN-compliant SNAcP is provided, the SSNDP shall provide ATN-compliant subnetwork services to the HLE. ATN compliance is achieved by satisfying the following requirements:

1. The SSNDP shall be byte and code independent.

2. The SSNDP shall maintain the sequence and order of data (i.e. data submitted to the SSNDP for transmission shall arrive at the destination peer in the same order it was transmitted or its sequence shall be identifiable by the destination peer).

3. The SSNDP shall inform its interworking function whenever its connectivity with the satellite network changes.

2.2.3.6.3.3 ACARS Requirements

To the extent that the SSNDP is utilized for ACARS transmissions, the following requirements shall be met:

1. The SSNDP shall be code and byte independent.

2. The SSNDP shall maintain the sequence and order of data.

3. The SSNDP shall inform the associated DTE when its connectivity with the satellite network changes.

2.2.3.6.4 External Physical and Data Link Layer Requirements

At the physical and data link layer of the HLE/AES connection:

1. The interface shall be "bit-oriented" (i.e., there shall be no restrictions on the sequence, order or pattern of the bits transferred within a packet between the HLE and the AES).

2. The interface shall support the transfer of variable length network layer packets.

3. The data link layer shall provide an undetected bit error rate consistent with the satellite subsystem performance requirements (reference RTCA DO-215A, Section 3.2.1.1.2).

2.2.3.6.5 Avionics Sub-network Interface Requirements for ISO-8208 Service

All AES equipment that supports an ISO-8208-compliant (Data-3) packet-mode service shall have the Packet Layer Protocol (PLP) interface specified in detail in the ISO-8208 standard, as modified by Appendix B of the DO-262 main document.

The correspondence between ISO-8208 primitives in Appendix B of the DO-262 main document and SSNDP protocol data units, if any, shall be as defined in this appendix. There is no required mapping of ISO-8208 primitives to technique-dependent Satellite Sub-network Protocol Data Units. The use of the underlying satellite communications system is unspecified, providing that the DCE/DTE interface actions act and respond appropriately as defined in ISO-8208 as modified by Appendix B of the DO-262 main document.

The operation of the AES as specified in this attachment assumes that the HLE performs the following functions:

a. Is able to initiate, accept and terminate calls via the interface
b. Is prepared to accept messages from the AES
c. Monitors the AES operation in case of unrecoverable error conditions and reinitializes the AES as necessary

2.2.3.6.6 Alternative ATN-compliant Subnetwork Access Protocols

Any manufacturer wishing to implement an ATN-compliant SNAcP that differs from the ISO-8208 implementation specified in Appendix B to the DO-262 main document shall provide the detailed protocol implementation and associated verification procedures in the technique-specific attachment. The level of detail included in the SNAcP definition shall be equivalent to or better than the detail provided in Appendix B to the DO-262 main document.

2.2.3.7 Circuit Mode Service Requirements

Circuit-mode voice and/or data services, if provided, shall comply with this normative appendix. The AES may provide voice communications capability to the cockpit and/or the passenger cabin areas.

The minimum requirements for circuit-mode voice service on the satellite subnetwork, if such service is provided by an AES, shall be the minima specified for that subnetwork in this normative appendix.

Circuit-mode voice and data service shall comply with the priority, precedence and preemption requirements established in Section 2.2.3.3 of this attachment.

Notes :

1) *Samples of cockpit voice interworking can be found in ARINC-741 Part 2. These interworking connections are installation specific and are not addressed in this minimum standard.*
2) *Circuit-mode data service, which provides a circuit-switched data channel to support a variety of communication applications that require the allocation of dedicated channel capacity for the duration of a call (such as interactive or bulk data, encrypted voice/data and facsimile), may optionally be provided in AESs capable of voice communication. Circuit-mode data is not approved for FANS/1A messaging but maybe used for non-safety data exchanges with the aircraft.*

2.2.3.8 Recovery from Primary Power Interruption

The NGSS equipment shall conform to the following requirements after encountering primary power interruptions from any cause.

1. Power interruptions of less than 5 milliseconds duration shall be indistinguishable from outages in the RF transmission path of equal duration.

2. Power interruptions from five to 200 milliseconds duration shall require no more than five seconds recovery time, beginning from when primary power has been restored. Recovery is defined as automatically returning to the previous operating state (without user intervention) such that data channels resume in the same configuration they were in before the power interruption occurred. This assumes a channel signal with at least the minimum quality characteristics specified in Section 2.2.3.1.2.2.

Note: *In-transit data service packets which have been acknowledged on either the DTE or DCE interface, but not yet transferred to the opposite interface, may be lost. Higher-layer entities that employ end-to-end acknowledgment protocols may choose to retransmit such lost data. Synchronization and RF output power may be lost during the power interruption and recovery time. There shall be no more than a momentary effect on cockpit displays.*

2.2.3.9 Failure/Status Indication

The NGSS equipment shall provide, independent of any operator action, an indication of a failure of NGSS equipment resulting in loss of data or voice communications, as appropriate.

2.2.3.10 Information Security

The AES shall provide adequate domain segregation to prevent the data stream to or from any interface from influencing the data streams used for the ACARS or priority voice functions.

An Information Security Risk Assessment shall be performed in accordance with the methodology provided in DO-326 Airworthiness Security Process Specification, Section 3.2.

With respect to the influence on the ACARS service at least the following shall be mitigated in the design of the AES:

Threat Condition	Impact Level
Undetected corruption of FANS messages (includes spoofing)	III (major) Spoofed FANS messages could result in false CPDLC messages instructing

	the flight crew to change heading or flight level, causing a reduction in safety margins.
Loss of availability of services	IV (minor) Loss of ACARS over Iridium function is considered to be a minor failure condition.

Notes:

1. RTCA DO-326 Section 3.3 provides guidance on how the Information Security Risk Assessment should influence the design.

2. An analysis using the methodology in RTCA DO-326 will be required to determine if a specific design fulfills the requirements.

2.3 Equipment Performance - Environmental Conditions

2.3.1 General Requirements

The environmental tests and their associated performance requirements described in this Section are intended to provide a laboratory means of determining the overall performance characteristics of the equipment under environmental conditions representative of those which may be encountered in actual operations.

Unless otherwise specified, the test procedures applicable to a determination of equipment performance under environmental test conditions are contained in RTCA Document DO-160G, *Environmental Conditions and Test Procedures for Airborne Equipment*. General information regarding the use of the procedures in RTCA DO-160G is contained in Sections 1.0 through 3.0 of that document. Also, a method of identifying which environmental tests were conducted and other amplifying information on the conduct of the tests is contained in Appendix A of RTCA DO-160G.

Some of the minimum performance requirements in Section 2.2 of this normative appendix are not required to be qualified to all of the conditions contained in RTCA DO-160G. Judgment and experience have indicated that these particular performance parameters are not susceptible to certain environmental conditions and that the level of performance specified in Section 2.2 will not be measurably degraded by exposure to these conditions. There it is sufficient to verify compliance at ambient conditions for many requirements, and then continued compliance is inferred by successfully meeting the requirements.

Table 2-11 is a compliance matrix that cross-references the RTCA DO-160G environmental test requirements with the performance requirements listed in Section 2.2.3 of this document. Only those tests specifically identified by "X" or by a numerically referenced footnote need be repeated in the various environments. Furthermore, unless otherwise noted successful verification of compliance to a requirement section implies compliance to all lesser sections as well.

In addition to the exceptions above, certain environmental tests contained in this section are not required for minimum performance equipment unless the manufacturer wishes to qualify the equipment for additional environmental conditions. If the manufacturer wishes to qualify the equipment to these additional conditions, then these tests shall be performed.

2.3.2 Equipment Configurations

This document contains provisions to subject different AES configurations to environmental qualification. Specific AES performance tests have been included for use in conjunction with the environmental procedures of RTCA DO-160G. These tests are a subset of the full AES performance tests contained in Section 2.4. Normally, a minimum performance standard does not provide specific equipment performance tests to be used in conjunction with the environmental procedures of RTCA DO-160G. However, the large number of performance tests in Section 2.4 indicates that a test procedure that includes all of the performance tests combined with the appropriate environmental procedures would be impractical.

2.3.3 Configuration Control

Nominal environment testing, followed by extreme environment testing, shall be conducted on the AES with the operational software installed according to the correct software version number as specified in the AES configuration documentation.

Note: the operational software may include test utilities in support of DO-160G test functions.

2.3.4 Specific Environmental Test Conditions

In addition to the specific functional tests to be performed under nominal ambient environmental conditions, the equipment as a whole shall be subjected to the test conditions as specified in RTCA DO-160G, in the sections identified in Table 2-11 and Table 2-12. By performing (and passing) those tests, the corresponding requirements of this standard shall be met.

2.3.5 Performance vs. Test Requirements Matrix

Detailed test procedures for performance requirements contained in Section 2.2 are found in Section 2.4. The subsection numbering in Section 2.4, at the third and lower levels, corresponds identically to that in Section 2.2. Consequently, this document does not provide a detailed cross-reference matrix.

Table 2-11 DO-160G Performance vs. Test Requirements Matrix

ANTENNA SUBSYSTEM		**DO-160G Section**																						
		4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Section	Title	TEMPERATURE / ALTITUDE	TEMP VARIATION	HUMIDITY	OPERATIONAL SHOCKS /CRASH SAFETY	VIBRATION	EXPLOSIVE ATMOSPHERE	WATERPROOFNESS	FLUIDS SUSCEPTIBILTY	SAND AND DUST	FUNGUS RESISTANCE	SALT FOG	MAGNETIC EFFECT	POWER INPUT	VOLTAGE SPIKE	AUDIO FREQ. CONDUCTED SUSC.	INDUCED SIGNAL SUSCEPTIBILITY	RADIO FREQ. SUSC. (CONDUCTED. & RADIATED)	EMISSION OF RADIO FREQUENCY ENERGY	LIGHTNING INDUCED TRANSIENT SUSC.	LIGHTNING DIRECT EFFECTS	ICING	ESD	FIRE/FLAMMABILITY
2.2.3.1.1.1	Coverage Volume, Polarization & Antenna Gain	(1)	(2)	(2)	(2)	(2)	-	(2)	(2)	(2)	(2)	(2)	-	(2)	(2)	(2)	(2)	(1)	-	(2)	(2) (22)	(2)	(2)	-
2.2.3.1.1.2	Axial Ratio	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.1.1.3	Power handling capabilities	(1)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.1.1.4	Passband	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.1.1.5	Antenna Voltage Standing Wave Ratio	(1)	X	X	X	X	-	X	X	X	X	X	-	-	-	-	-	-	-	-	X	X	-	-
2.2.3.1.1.6	Radiated Antenna Intermodulation Products	X		-	(18)	(18)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.1.1.7	Carrier-to-Multipath Discrimination	(1)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

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TRANSMITTER SUBSYSTEM

		DO-160G Section																						
		4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Section	Title	TEMPERATURE / ALTITUDE	TEMP VARIATION	HUMIDITY	OPERATIONAL SHOCKS /CRASH SAFETY	VIBRATION	EXPLOSIVE ATMOSPHERE	WATERPROOFNESS	FLUIDS SUSCEPTIBILTY	SAND AND DUST	FUNGUS RESISTANCE	SALT FOG	MAGNETIC EFFECT	POWER INPUT	VOLTAGE SPIKE	AUDIO FREQ. CONDUCTED SUSC.	INDUCED SIGNAL SUSCEPTIBILITY	RADIO FREQ. SUSC. (CONDUCTED. & RADIATED)	EMISSION OF RADIO FREQUENCY ENERGY	LIGHTNING INDUCED TRANSIENT SUSC.	LIGHTNING DIRECT EFFECTS	ICING	ESD	FIRE/FLAMMABILITY
2.2.3.1.2.1.1	Minimum Power Output	X	X	X	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-
2.2.3.1.2.1.2	Maximum Individual Carrier Output	X	X	X	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-
2.2.3.1.2.1.3	Maximum Total Transmitter Output	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.1.2.1.4	Transmitter Intermodulation Performance.	(17)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.1.2.1.5	Transmitter Harmonics, Discrete Spurious and Noise Density	(17)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.1.2.1.6	Protection of Radio Astronomy	(17)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.1.2.1.7	Carrier-Off Level	(17)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.1.2.1.8	Power Control	(17)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.1.2.1.9	On-Channel Output Spectrum	(17)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.1.2.1.10	Transmitter Operation in Moving Aircraft	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.1.2.1.11	Manufacturer-Defined Transmitter Test	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	X	X		(13)	-	-	X	-

(continued)

RECEIVER SUBSYSTEM

Section	Title	DO-160G Section 4 TEMPERATURE / ALTITUDE	5 TEMP VARIATION	6 HUMIDITY	7 OPERATIONAL SHOCKS /CRASH SAFETY	8 VIBRATION	9 EXPLOSIVE ATMOSPHERE	10 WATERPROOFNESS	11 FLUIDS SUSCEPTIBILTY	12 SAND AND DUST	13 FUNGUS RESISTANCE	14 SALT FOG	15 MAGNETIC EFFECT	16 POWER INPUT	17 VOLTAGE SPIKE	18 AUDIO FREQ. CONDUCTED SUSC.	19 INDUCED SIGNAL SUSCEPTIBILITY	20 RADIO FREQ. SUSC. (CONDUCTED. & RADIATED)	21 EMISSION OF RADIO FREQUENCY ENERGY	22 LIGHTNING INDUCED TRANSIENT SUSC.	23 LIGHTNING DIRECT EFFECTS	24 ICING	25 ESD	26 FIRE/FLAMMABILITY
2.2.3.1.2.2.1	Receiver Sensitivity	(19) (17)	-	-	(19)	(19)	-	-	-	-	-	-	-	(19)	-	(19)	(19)	(19)	-	(19) (13)	-	-	-	-
2.2.3.1.2.2.2	Receiver Bandwidth	(17)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	(13)	-	-	-	-
2.2.3.1.2.2.3	Rejection of Signals outside the NGSS Receive Band	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.1.2.2.5	Receiver Operation in Moving Aircraft	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.1.2.2.6	Receiver Susceptibility	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.1.2.2.7	Receiver Damage	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

(continued)

OTHER REQUIREMENTS		DO-160G Section																						
Section	Title	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
		TEMPERATURE / ALTITUDE	TEMP VARIATION	HUMIDITY	OPERATIONAL SHOCKS /CRASH SAFETY	VIBRATION	EXPLOSIVE ATMOSPHERE	WATERPROOFNESS	FLUIDS SUSCEPTIBILTY	SAND AND DUST	FUNGUS RESISTANCE	SALT FOG	MAGNETIC EFFECT	POWER INPUT	VOLTAGE SPIKE	AUDIO FREQ. CONDUCTED SUSC.	INDUCED SIGNAL SUSCEPTIBILITY	RADIO FREQ. SUSC. (CONDUCTED. & RADIATED)	EMISSION OF RADIO FREQUENCY ENERGY	LIGHTNING INDUCED TRANSIENT SUSC.	LIGHTNING DIRECT EFFECTS	ICING	ESD	FIRE/FLAMMABILITY
2.2.3.2	User link Modulation and Signal in Space	(17)	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.3	Priority, Precedence and Preemption	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.4	Satellite Subnetwork Data Protocol	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.5	Voice Protocol	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.6	User Data Interfaces	(17)	-	-	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.7	Circuit Mode Service Requirements	(17) (23)	-	(23)	-	(23)	-	-	-	-	-	-	-	(23)	-	(23)	(23)	(23)	(23)	-	-	-	-	-
2.2.3.8	Recovery from Primary Power Interruption	-	-	-	-	-	-	-	-	-	-	-	-	(12)	-	-	-	-	-	-	-	-	-	-
2.2.3.9	Failure/Status Indication	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.10	Information Security	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 2-12 DO-160G Sections Applicable to the AES

DO-160G Section	Environment
4	Temperature and Altitude (See Note 1)
4.5	Temperature Tests
4.5.1	Ground Survival Low Temperature Test and Short-Time Operating Low Temperature Test
4.5.2	Operating Low Temperature Test
4.5.3	Ground Survival High Temperature Test and Short-Time Operating High Temperature Test
4.5.4	Operating High Temperature Test
4.5.5	In-flight Loss of Cooling Test (See Note 15)
4.6.1	Altitude Test (See Note 17)
4.6.2	Decompression Test (See Note 3,17)
4.6.3	Overpressure Test (See Note 3,17)
5	Temperature Variation
6	Humidity
7	Operational Shocks and Crash Safety
7.2	Operational Shock (See Notes 18, 24)
7.3	Crash Safety Test (See Notes 3,4)
8	Vibration (See Notes 18)
9	Explosion Atmosphere (See Note 3)
10	Waterproofness (See Note 3)
10.3.1	Condensing Water Drip Proof Test (See Note 3)
10.3.2	Drip Proof Test (See Notes 3)
10.3.3	Spray Proof Test (See Notes 3, 5)
10.3.4	Continuous Stream Proof Test (See Notes 3, 5)
11	Fluids Susceptibility (See Notes 3, 6)
11.4.1	Spray Test (See Note 3)
11.4.2	Immersion Test (See Note 3)
12	Sand and Dust (See Note 3)
13	Fungus Resistance (See Note 3)
14	Salt Fog (See Note 3)
15	Magnetic Effect
16	Power Input
16.5.1	Normal Operating Conditions (AC) (See Notes 7, 12)
16.5.2	Abnormal Operating Conditions (AC) (See Note 7)
16.6.1	Normal Operating Conditions (DC) (See Notes 7, 12)
16.6.2	Abnormal Operating Conditions (DC) (See Notes 7, 8)
16.7	Load Equipment Influence on Aircraft Electrical Power System (AC and DC) (See Note 7)
17	Voltage Spike (See Note 9)
18	Audio Frequency Conducted Susceptibility – Power Inputs
19	Induced Signal Susceptibility
20	Radio Frequency Susceptibility (Radiated and Conducted) (See Notes 10, 11)
21	Emission of Radio Frequency Energy
22	Lightning Induced Transient Susceptibility (See Note 13)
23	Lightning Direct Effects (See Note 14)

24	Icing
25	Electrostatic Discharge (ESD)
26	Fire, Flammability

<u>Notes to Tables 2-11 and 2-12</u>:

3. *Due to the difficulties in performing radiating measurements while changing the environmental conditions of the antenna, acceptable alternative test procedures may be implemented. Portions of the antenna subsystem may be measured over the required range of operating environmental conditions. The measurement data thus obtained may be used in an analysis to show that the specified antenna performance is achieved under the declared operating environmental conditions. This analysis shall include the effects of materials and construction of the individual radiating elements and account for the effects of beam pointing errors versus environmental conditions on other specification requirements within the declared coverage volume.*

4. *Performance parameters of the antenna subsystem will not be measured during these environmental tests. These environmental tests are for survivability and apply only to equipment which is mounted on the outside of the aircraft. Testing of the antenna RF performance properties to determine the serviceability of the antenna <u>after</u> exposure is acceptable. This test could take the form of a production test procedure or other test and shall verify the antenna RF and control functionality has not degraded compared to any baseline testing performed prior to environmental exposure (within test accuracy limits). If a TSOA antenna is used, only Section 2.2.3.1.1.6, 2.2.3.1.1.6.1 and 2.2.3.1.1.6.2 are required.*

5. *These tests are not listed for the receiver and transmitter subsystems and need not be performed unless the manufacturer wishes to qualify the equipment for the particular environmental condition. For example, an antenna intended for use under an additional radome (e.g. tail-mounted antennas) may only need to meet the drip-proof category of waterproofness.*

6. *The application of the Crash Safety Shock test may result in damage to the equipment under test. Therefore, this test may be conducted after the other tests have been completed. In this case, Section 2.1.7, "Effects of Test" does not apply.*

7. *This test shall be conducted with the spray directed perpendicular to the equipment.*

8. *Applicable requirements:*

   a) *At the end of the 24-hour exposure period, the equipment shall function.*

   b) *Following the 2-hour operation period at ambient temperature after the 160-hour exposure period at elevated temperature, the performance requirements shall be met.*

9. *The appropriate test will depend upon whether the equipment is AC or DC powered.*

10. *The application of the Low Voltage Conditions (DC) (Category B equipment) test may result in damage to the equipment under test. Therefore, this test may be conducted after the other tests have been completed. Section 2.1.7, "Effects of Test," does not apply.*

11. *Select Category A (high degree of protection against voltage spikes required) or Category B (lower standard of protection acceptable) as applicable for the equipment under test.*

12. *Excluding frequency to which receiver is tuned and the response within its resonant pass band.*

13. *Equipment is not required to meet performance specifications during the application of HIRF, (Category U, 20 v/m). The equipment must meet all requirements following the application.*

14. *Meet requirements of DO-160G except as noted by Section 2.2.3.8.*

15. *According to AC20-136B, lightning protection is not required for systems certified to Design Assurance Level D (or lower). For systems certified to Design Assurance Level C or higher, protection from effects on electrical and electronic systems due to lightning transients induced or conducted onto equipment and wiring is required. For systems certified to Design Assurance Level C or higher, equipment is not required to meet performance specifications during the period of application of the Lightning Induced Transient test, but must meet all requirements following the test.*
16. *Only required for AMSS antennas.*
17. *Applicable to equipment requiring cooling. Modify test length to three hours. Verify no smoke or fire. Only essential services, namely one voice channel plus ACARS are required to be provided.*
18. *UNUSED*
19. *The Altitude tests in DO-160G Sections 4.6.1, 4.6.2 and 4.6.3 are not applicable.*
20. *The antenna equipment shall be subjected to vibration and operational shock testing exposure equivalent to the qualification levels for which the antenna is being certified prior to subjecting the antenna to intermodulation testing.*
21. *See Section 2.4.3.1.2.2.1.1 on the Receiver Sensitivity. For Induced Lightning category, test is performed only after subjecting to environment.*
22. *UNUSED*
23. *UNUSED*
24. *After the Lightning Direct Effects test the antenna under test shall be functional if the manufacturer specifies this in the product's performance specification. In all cases it is a requirement that the antenna does not pose a danger to the aircraft after such exposure. If the antenna is limited to installation in positions on the aircraft where lightning strikes are not expected (e.g. under another radome which provides protection) this shall be declared as a limitation.*
25. *Circuit mode service: perform test as in Section 2.4.3.7 For DO-160G Section 4, only testing over temperature is required, not altitude.*
26. *Operational shocks (DO-160G Section 7): Performance is only verified after (not during) exposure to shocks*

An “X“ in Table 2-11 indicates that testing of performance is required before/during/after exposure to the environmental tests as specified in DO-160G.

A “-“ in Table 2-11 indicates that no testing of performance is required before/during/after exposure to the environmental tests in DO-160G.

2.4 Equipment Performance Verification Procedures

The following procedures provide guidelines for tests to ensure compliance with the MOPS performance requirements. Except for Section 3.4.5, these do not require flight testing. Regarding secondary references from this section, any reference to "flight tests" in lower level documents should be ignored.

Some of the following tests may require additional test equipment not shown in the test setup figures. Such equipment would be associated with the interface between the satellite system emulator and the AES or radio channel unit.

2.4.1 Definitions of Terms and Conditions of Test

The following are definitions of terms and the conditions under which the tests described in this Section should be conducted:

a. **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 input terminals of the equipment under test.

b. **Power Input Frequency**

(3) In the case of equipment designed for operation from an AC source of essentially constant frequency (e.g., 400 Hz), the input frequency shall be adjusted to design frequency ±2%.

(4) In the case of equipment designed for operation from an AC source of variable frequency (e.g., 300 to 1,000 Hz), unless otherwise specified, tests shall be conducted with the input frequency adjusted to within 5% of a selected frequency and within the range for which the equipment is designed.

c. **Adjustment of Equipment** – The circuits of the equipment under test shall be properly aligned and otherwise adjusted in accordance with the manufacturer's recommended practices prior to application of the specified tests.

d. **Test Equipment** – All equipment used in the performance of the tests should be identified by make, model and serial number where appropriate, and its latest calibration date. When appropriate, all test equipment calibration standards should be traceable to national and/or international standards. Specific Transceiver Controller PC software is only available through Iridium for partners under development agreements. Contact Iridium for more information on obtaining this software.

e. **Test Instrument Precautions** – Due precautions shall be taken during the tests to prevent the introduction of errors resulting from the connection of voltmeters, oscilloscopes and other test instruments across the input and output impedances of the equipment under test.

f. **Ambient Conditions** – Unless otherwise specified, all tests shall be made within the following ambient conditions:

1. Temperature: +15 to +35 degrees C (+59 to +95 degrees F)
2. Relative Humidity: Not greater than 85%
3. Ambient Pressure: 84 to 107 kPa (equivalent to +5,000 to -1,500 ft) (+1,525 to -460 m)

When tests are conducted at ambient conditions which differ from the above values, allowances shall be made and the differences recorded.

g. **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.

h. **EMI Testing** – Only the AES (not the test equipment) need be subjected to the electromagnetic environment as specified in Table 2-11. For the antenna subsystem, a matched load should be connected, and the antenna subsystem performance verified to requirements after application of HIRF.

Note: For specific airframes, the aircraft manufacturer may require the interconnecting wiring to be included in the specified electromagnetic environment.

i. **Warm-up and Stabilization Requirements** – Unless otherwise specified, all tests shall be conducted after a minimum equipment warm-up period of not less than five minutes. In addition, the frequency reference source shall have completed its warm-up cycle, if any, and any power-on self-test(s) shall have been completed prior to testing.

j. **Special Cooling Requirements** – The manufacturer shall specify any special cooling requirements for any of the specified tests.

2.4.1.1 AES Application Test Conditions

2.4.1.1.1 Antenna Subsystem Test Conditions

Note: The Low Earth Orbit characteristics of the satellite system make passive, near-omni-directional antennas highly desirable. The requirements contained below assume a non-steered antenna system. Installations desiring to use actively switched or steered antenna systems are referred to RTCA Document DO-210D, Section 2.4.3, for appropriate test procedures.

2.4.1.1.1.1 Antenna Under Test

The antenna under test shall not include the LNA, HPA, or front end filter(s) associated with the RF Front End subsystem. If a radome forms part of the antenna, this shall also be installed during the measurements. The antenna test installation shall also include any adapter plates, where used, or other hardware used to interface the antenna to the fuselage in a flight installation.

In the case of multiple antenna installations which are normally located at different areas of the aircraft (e.g., two side-mounted antennas), one antenna may be tested at a time.

In the case of dual patch Iridium LGA antenna where two LGA are combined in a single exterior antenna with two antenna connections, these antenna shall comply with the intermodulation and multi-carrier HSN requirements.

2.4.1.1.2 Transceiver Subsystem Test Conditions

Unless otherwise noted, the transceiver subsystem detailed verification procedures are assumed to be performed at normal laboratory ambient temperature and humidity as defined in Section 2.4.1.

The transceiver shall be tested under frequencies as defined in Section 2.2.3.1.1.4

Where the PC software is to be used in the testing, access to the serial DPL interface and 90ms sync connections are required. Special test connectors on the device may be required to perform the testing.

2.4.1.1.3 Required Aircraft Interfaces Test Conditions

The required aircraft interfaces shall be tested with the AES operating under the standard conditions noted in Section 2.4.1. Each voice line requires an operable SIM card. An ATS SIM card, provisioned in the Iridium system for ATS voice service, is required for access to the ATS Safety Voice service.

2.4.1.2 Satellite Sub-network Test Conditions

The satellite subnetwork shall be tested with the AES operating under the standard conditions noted in Section 2.4.1 and under normal satellite constellation dynamics as appropriate for the specific satellite sub-network. Care should be taken to ensure that worst case elevation angles and worst case, constellation-specific, geometries are included in the standard test conditions. These conditions shall be applied with the appropriate temporal constraints, as determined by the constellation dynamics.

2.4.1.3 Priority, Precedence and Preemption Test Conditions

The Priority, Precedence and Preemption performance shall be tested with the AES operating under the standard conditions noted in Section 2.4.1. These tests may be performed using the actual satellite constellation, provided that the conditions of Section 2.4.2 are satisfied. An ATS SIM card is required for testing the priority, precedence and preemption capabilities of the ATS Safety Voice service. One ATS SIM card is needed for each voice line participating in the ATS voice system. The ATS system supports up to two voice lines. Voice calls will be made both to and from the avionics in order to validate the priority, precedence and preemption capabilities.

2.4.1.4 Satellite Sub-network Data Protocol Test Conditions

The Satellite Sub-network Data Protocol shall be tested with the AES operating under the standard conditions noted in Section 2.4.1.

2.4.1.5 Voice Protocol Test Conditions

The voice protocol compliance shall be tested with the AES operating under the standard conditions noted in Section 2.4.1.

Voice protocol compliance with the requirements of Section 2.2.3.5.2 shall be tested in the following audio noise environments:

- Air Transport Aircraft Cockpit background noise (747 or similar)
- Helicopter cockpit background noise
- Prop-jet cockpit background noise
- Light twin-engine piston powered cockpit noise
- ATC Control Center background noise

2.4.1.6 User Data Interfaces Test Conditions

The User Data Interface shall be tested with the AES operating under the standard conditions noted in Section 2.4.1.

2.4.1.7 Circuit Mode Service Test Conditions

The Circuit Mode Services, if provided, shall be tested with the AES operating under the standard conditions noted in Section 2.4.1. The performance of any voice services, if provided, shall be tested under the ambient audio noise test environments specified in Section 2.4.3.5.

2.4.1.8 Recovery from Primary Power Failure Test Conditions

Recovery from Primary Power Failure shall be tested with the AES operating under the standard conditions noted in Section 2.4.1, with the exception that the power input to the AES shall be as described in the specific tests.

2.4.1.9 Failure/Status Indication Test Conditions

Failure/Status Indications shall be tested with the AES operating under the standard conditions noted in Section 2.4.1.

2.4.1.10 Information Security

Network security mechanisms shall be tested with the AES operating under the standard conditions noted in Section 2.4.1, unless otherwise indicated as a result of the plan for a Security Verification in accordance with DO-326 Section 3.3.4.

2.4.2 Required Test Equipment

2.4.2.1 AES Application

2.4.2.1.1 Antenna Subsystem Required Test Equipment

2.4.2.1.1.1 Standard Test Equipment

Testing shall be performed in accordance with the Institute of Electrical and Electronics Engineers (IEEE) St 169, 1983. It is suggested than an antenna test range with a minimum path length of 14 meters (40 feet) be used have a reflectivity level less than or equal to –25 dB within a quiet zone containing the antenna under test and ground plane. “Compact” ranges and/or near-field probing techniques may also be employed if analysis shows that an equivalent accuracy may be obtained.

Other items of standard test equipment include:

- Range instrumentation, including a 2-axis (minimum) positioner, positioner controller, L-band transmitter, receiver, pattern recorder and polarization measurement instrumentation.
- Reference standard gain antenna(s) of the appropriate, technique-specific polarization with gain calibration traceable to National Institute for Standards and Technology (NIST) or other national standards.
- Components of receive and transmit systems are necessary to perform system level verifications in conjunction with the antenna system verifications. These include the LNA, HPA, splitter/combiner, and front end filters.

2.4.2.1.1.2 Special Test Equipment

An antenna ground plane shall be used to simulate the conductive mounting surface on the intended aircraft. The ground plane shall extend at least 0.5 m beyond any active portion of the antenna under test, and shall extend beyond any radome employed. The ground plane should be curved with a radius of approximately 100 inches in order to simulate the radius of curvature of the portion of the aircraft in which the antenna may be mounted. Where the antenna is to be installed on an aircraft with a radius of curvature which differs by more than 30% from that used in the antenna tests, the validity of the results shall be justified by analysis and/or measurement.

2.4.2.1.2 Transceiver Subsystem Required Test Equipment

2.4.2.1.2.1 Standard Test Equipment

The test procedures assume access to a variety of standardized test equipment, including directional couplers, high power loads, spectrum analyzers and oscilloscopes. Wherever possible, specific model numbers are identified. It is permissible to substitute alternate items of standard test equipment provided that the equivalent performance is maintained.

2.4.2.1.2.2 Special Test Equipment

Transceiver Controller PC software is only available through Iridium for partners under development agreements. The serial DPL port connection on the Iridium modem under test must be made available. For BER testing, the 90ms clock input is also required as outlined in the test section.

2.4.2.1.3 Required Aircraft Interfaces Required Test Equipment

These test procedures assume access to a variety of standardized test equipment, including ARINC 429 simulators

2.4.2.2 Modulation and Signal in Space Required Test Equipment

Compliance with the Iridium Satellite modulation and signal-in-space requirements will be verified by means of a certification from Iridium Satellite LLC that the AES is permitted to operate within the sub-network. Required test equipment, if any, will be determined by the Iridium Satellite certification procedure, which is not an integral part of this normative appendix.

2.4.2.3 Priority, Precedence and Preemption Test Equipment

2.4.2.3.1 Packet Data

Reference: Section 2.2.3.3.1

This test requires the ability to initiate and terminate multiple packet data transmissions in order to verify that higher priority packet data is not impacted by lower priority packet data.

2.4.2.3.2 Circuit Mode Communications

This test requires the ability to initiate and terminate *N* simultaneous circuit-mode calls through the satellite network depending on the number of voice lines available in the avionics. The calls made will test the priority, preemption and precedence of the voice system. An ATS SIM card is required for use with the avionics LBT transceiver that is being tested for ATS. Calls will be made a different priority levels to or from the aircraft.

This test, while not intended to verify the ability of the satellite network (or the satellite sub-network) as a whole, will satisfy the Priority, Precedence and Preemption requirements of the MASPS.

2.4.2.4 Satellite Sub-network Data Protocol Test Equipment

Compliance with the overall Iridium satellite sub-network dependent protocol will be verified by means of a certification from Iridium Satellite LLC that the AES is permitted to operate within the sub-network. Required test equipment, if any, will be determined by Iridium Satellite's certification procedure, which is not an integral part of this normative appendix.

2.4.2.5 Voice Protocol Required Test Equipment

Compliance with the overall Iridium Satellite voice protocol, if applicable, will be verified by means of a certification from Iridium Satellite LLC that the AES is permitted to operate within the sub-network. Required test equipment, if any, will be determined by the Iridium Satellite certification procedure, which is not an integral part of this normative appendix.

<u>Note</u>: *Compliance with the requirements of Section 2.2.3.5.2 requires special test equipment capable of accurately reproducing the required environments. The tests are complex, and are typically carried out by organizations with expertise in the evaluation of vocoder or voice modem capabilities.*

2.4.2.6 User Data Interface Required Test Equipment

ISO-8208 Test Set/Protocol Analyzer (2), one designated as Protocol Analyzer Air (PAA), one designated as Protocol Analyzer Ground (PAG).

Remote access equipment to ISO-8208 compatible data port at GES.

2.4.2.7 Circuit Mode Service Test Equipment

No special test equipment is required to verify these requirements.

2.4.2.8 Recovery from Primary Power Interruption Test Equipment

The power supply utilized in the AES must conform to DO-160G momentary power interrupt requirements

2.4.2.9 Failure/Status Indication Test Equipment

No special test equipment is required to verify these requirements.

2.4.2.10 Information Security Test Equipment

The plan for Security Verification, required under Section 2.4.3.10, shall identify any special test equipment required.

2.4.3 Detailed Test Procedures

The test procedures set forth below constitute a satisfactory method of determining required performance. Although specific test procedures are cited, it is recognized that other methods may be preferred. Such alternate methods may be used if the manufacturer can show that they provide at least equivalent information. Therefore, the procedures cited herein should be used as one criterion in evaluating the acceptability of the alternate procedures.

For performance verification purposes, this section includes procedures for the transceiver and the antenna. The term Satellite Sub-network Physical Layer is also used for this subsystem in regard to the layered ISO concepts for data communications protocols.

Because a Satellite System Emulator is not available, it shall be permissible to use the operational satellite constellation, provided the criteria established in Section 2.4.1.1.2 are satisfied.

2.4.3.1 AES Application Requirements

2.4.3.1.1 Antenna Test Requirements

Note 1: The following test procedures anticipate that the antenna performance in both the transmit and receive bands is reciprocal and can be adequately measured by using the test setup of Figure 2-3. Depending on the individual antenna design, it may be necessary to modify the setup of Figure 2-3 to use the antenna under test as a transmit source and the reference antenna as a receiver. Such modifications are fully compliant with the intent of the following test procedures.

Test Frequencies: Antenna Subsystem measurements shall be performed at the following test frequencies:

Test Frequency	Receive/Transmit
IRIDIUM AES Lower Band-edge	1616 MHz
IRIDIUM AES Mid-Band	1621 MHz
IRIDIUM AES Upper Band-edge	1626 MHz

Note 2: Frequency accuracy shall be within +/- 0.5 MHz

2.4.3.1.1.1 Polarization, Gain and Coverage Volume

Reference: Sections 2.2.3.1.1.1.1, 2.2.3.1.1.1.2, and 2.2.3.1.1.1.3

Equipment Required

Antenna Measurement Range
Antenna Ground Plane

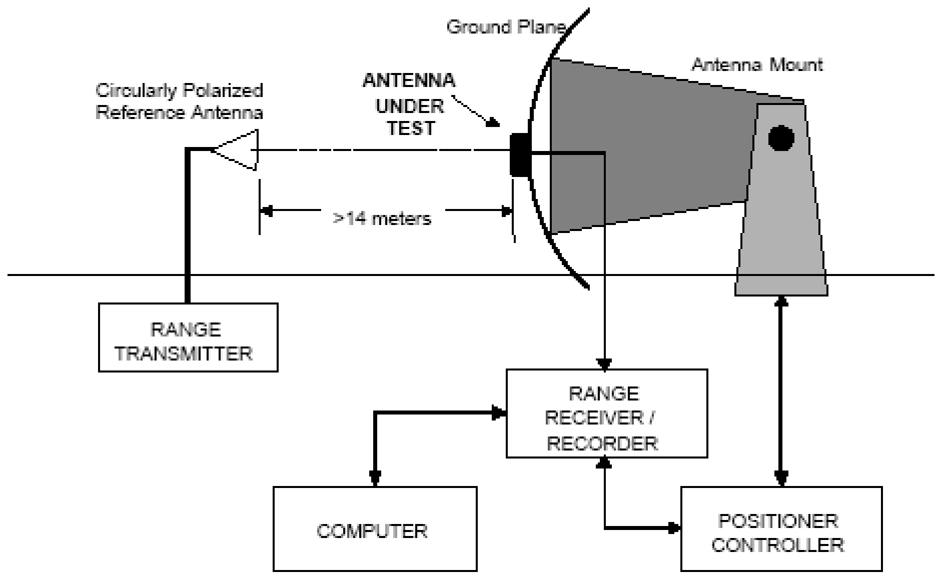


Figure 2-3 Antenna Gain/Polarization/Axial Ratio Test Setup

Measurement Requirements

With the equipment set up as in Figure 2-3, and with operating frequency of 1621 MHz, measure the antenna gain via a series of patterns collected in 2˚ steps over a range of Θ_{MIN} to 90˚ in elevation and at azimuth angles of 0˚, 45˚, 90˚, 135˚, 180˚, 225˚, 270˚ and 315˚. Verify that the average Weighted Antenna Gain (WAG) over the elevation and azimuth coverage volume meets the gain requirements of Section 2.2.3.1.1.1.3.

Repeat the procedure at the other test frequencies of 1616.0 MHz and 1626.5 MHz

Note: *It may be efficient to perform the tests of Section 2.4.3.1.1.7 in conjunction with the tests of this section.*

2.4.3.1.1.2 Antenna Axial Ratio

Reference: Section 2.2.3.1.1.2

Not Applicable

2.4.3.1.1.3 Power Handling

Reference: Section 2.2.3.1.1.3

Equipment Required
Altitude environmental chamber
Vacuum pump/vacuum gauge
RF absorber panels
Dual directional coupler
RF attenuator (NARDA 757C-20 or appropriate equivalent)

Dual RF power meter (HP438 or appropriate equivalent)
RF Power Source

Measurement Requirements

This is an altitude only test, performed at ambient temperature. Pressure tolerances in DO-160G apply. Radio-absorbent foam should be used in the environmental chamber.

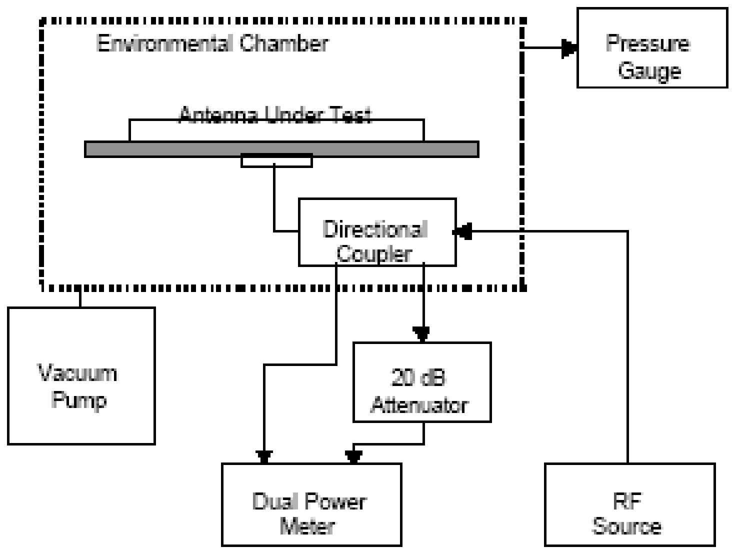


Figure 2-4 Power Handling Test Setup

1) Connect the equipment as shown in Figure 2-4.
2) Pump down the environmental chamber to and maintained at or above the maximum pressure altitude found in DO-160G at the ambient temperature (maintaining *above* the minimum pressure altitude is the same as maintaining the pressure *below* a threshold level).
3) After achieving temperature and pressure stability, apply an RF signal as specified in Section 2.2.3.1.1.3.
4) Remove the RF signal. Remove the antenna from the environmental chamber.
5) Measure the gain performance in an anechoic chamber or equivalent at ambient temperature and altitude.
6) Re-verify compliance to the requirements of Section 2.2.3.1.1.1.3 and the VSWR requirements of Section 2.2.3.1.1.5.
7) Inspect the antenna for signs of arcing or melting. No permanent damage to the antenna is permissible.

Notes:

1. *The incident and reflected power at the antenna input should be monitored for the duration of the power handling test and any changes noted to observe changes in the antenna.*

2. *This is an altitude test only.*

2.4.3.1.1.4 Antenna Passband

Reference: Section 2.2.3.1.1.4

Repeat the tests of Section 2.4.3.1.1.1, and Section 2.4.3.1.1.2 at the two additional transmit test operating frequencies spaced equally across the transmit operating band.

Repeat the tests of Section 2.4.3.1.1.1, and Section 2.4.3.1.1.2 at additional receive test frequencies operating frequencies spaced equally across the receive operating band and verify compliance with the requirements of the applicable paragraphs. To the extent that the receive and transmit bands overlap, overlapping frequencies need only be tested once.

2.4.3.1.1.5 Antenna VSWR

Reference: Section 2.2.3.1.1.5

Equipment Required

Automatic Network Analyzer, with optional plotter (HP 8753,8720, 8510 or equivalent
HP Calibration kit as required
Antenna Ground Plane
Anechoic or semi-anechoic room or an outdoor test range

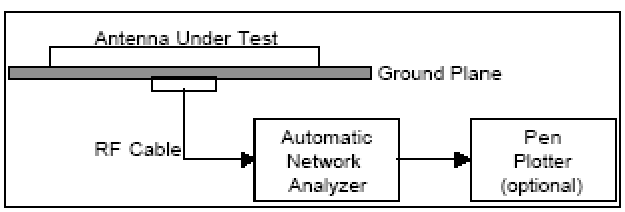


Figure 2-5 Voltage Standing Wave Ratio (VSWR) Test

Measurement Requirements

1) Connect the equipment as shown in Figure 2-5.
2) Measure and record the VSWR for all frequencies defined in Section 2.4.3.1.1. Precautions should be taken to reduce the effects of nearby reflections on the VSWR measurements.
3) Confirm that the VSWR meets the requirements in Section 2.2.3.1.1.5.

2.4.3.1.1.6 Radiated Antenna Intermodulation Products

2.4.3.1.1.6.1 Antenna Intermodulation in the GNSS Band

Reference: Section 2.2.3.1.1.6.1

Equipment Required

Two frequency synthesizers
Directional Coupler, 30 dB coupling, 20 watts or greater average power rating
Attenuator, 20 dB
High Power Load, 50 Ohms, 20 watts or greater average power rating
Two RF Power Amplifiers, f_{TMN} to f_{TMX} MHz
Two Spectrum Analyzers
RF Anechoic Chamber
Matched quarter wave GNSS monopoles at 1585 MHz and 1605 MHz (VSWR < 1.5:1)
Ground Plane compliant with Section 2.4.3.2.2 and with provisions to mount the GNSS monopole at least 5 feet away from the Antenna Under Test (AUT)
GNSS pass-band filters with < 1 dB insertion loss at 1585 MHz and 1605 MHz and >50 dB isolation from f_{TMN} *to* f_{TMX} MHz
GNSS amplifiers, 1585 MHz (for GPS equipped aircraft) and 1605 MHz (for GLONASS equipped aircraft), with gain > 50 dB and NF < 1.3 dB

Measurement Requirements for Antennas

Connect the equipment as shown in Figure 2-6, follow the steps below.

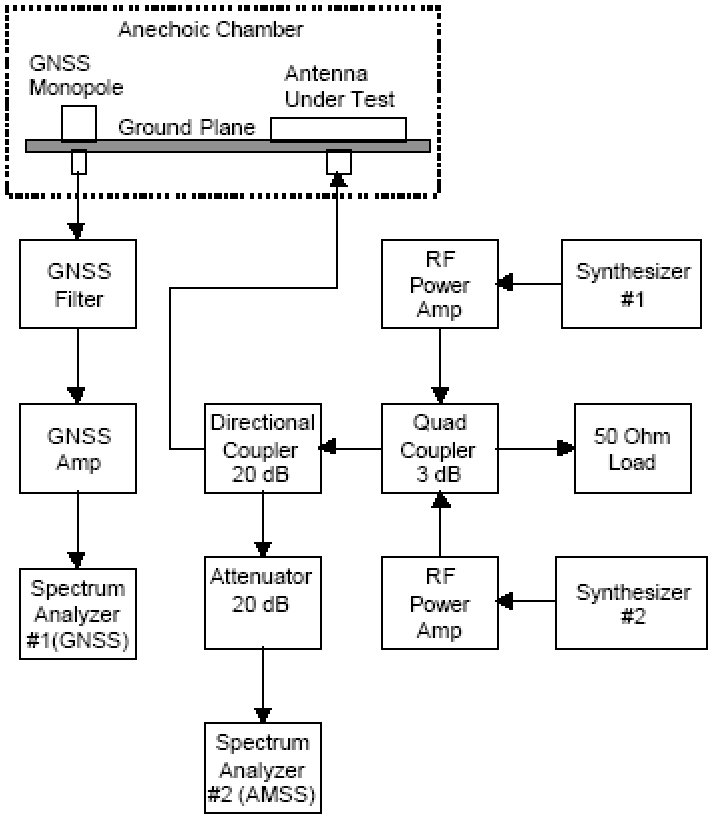


Figure 2-6 Radiated Antenna Intermodulation Products in the GNSS Band

1. Mount the Antenna Under Test (AUT) and the GNSS monopole on the ground plane with at least 5 ft of separation.

2. Use a spectrum analyzer to measure the isolation, in dB, between the two antenna (ANTISOdB) at 1605 MHz.

3. Set RF synthesizer 1 (*f1*) to the f_{TMN} .

4. The RF Synthesizer number 2 (*f2*) frequency is defined by the following:

   $$f2\ (\text{MHz}) = \frac{(N+1) * f1 - 2 * (1605)}{N-1}\ \text{MHz}$$

   for *N* = odd values 3 to 11, where *N* is the IM order. If, for a particular order of N, the value of *f2* does not fall within the band to f_{TMN} to f_{TMX}, skip this order and proceed to the next higher *N.*

5. Set the RF synthesizer number 2 (*f*2) for the lowest value of *N* determined by the results of Step 4.

6. Set the RF power amplifiers to an output power equal to the single-carrier output power defined in Section 2.2.3.1.2.1.2.

7. Measure the IM product level in decibels relative to one Watt (dBW) at the GNSS spectrum analyzer at 1605 MHz and refer it back to the GNSS antenna output port (IMGNSSdBm).

8. Normalize the IM product level to a 55 dB antenna isolation by performing the following: IMLEVEL = IMGNSSdBm - 55 dB + ANTISOdB

9. Repeat Steps 7 and 8 for N = 5, 7, 9 and 11, respectively.

In each case, determine that the IM product levels determined in Step 8 (IMLEVEL) do not exceed the values of Section 2.2.3.1.1.6.1.

Note: Figure 2-6 shows the set up for single element multi-carrier configuration only as a reference. The set-up varies depending on the AUT configuration.

2.4.3.1.1.6.2 Antenna Intermodulation in AMS(R)S Band(s)

Reference: Section 2.2.3.1.1.6.2

Note: The requirement for this test is only applicable under the conditions described in Section 2.1.8.

Prior to performing the IM test, the AUT shall be subjected to 1 hour of vibration in each of the three principal axes (per DO-160G; Section 8) for the vibration category/curve to which the AUT is to be certified.

Equipment Required

Two frequency synthesizers
Directional Coupler, 30 dB coupling, 20 watts or greater average power rating
Attenuator, 20 dB
High Power Load, 50 Ohms, 20 watts or greater average power rating
Two RF Power Amplifiers, f_{TMN} to f_{TMX} MHz
Two Spectrum Analyzers
RF Anechoic Chamber
Matched quarter wave monopole at appropriate AMS(R)S receive frequencies (VSWR < 1.5:1)
Ground Plane compliant with Section 2.4.3.2.2 and with provisions to mount the AMS(R)S monopole
at least 5 feet away from the Antenna Under Test (AUT)
AMS(R)S pass-band filter with < 1 dB insertion loss at throughout the AMS(R)S receive band and
>50 dB isolation from f_{TMN} to f_{TMX}.

Measurement Requirements for Unsteered Antennas

Connect the equipment as shown in Figure 2-6, replacing the GNSS antenna, amplifier and filter by the appropriate devices for the AMS(R)S system. Perform the following steps:

1. Mount the Antenna Under Test (AUT) and the AMS(R)S monopole on the ground plane at least 5ft away.

2. Use a spectrum analyzer to measure the isolation, in decibels, between the two antenna (ANTISOdB) at f_{AMSRS}, where f_{AMSRS} is the frequency in the AMS(R)S receive band of interest that lies closest to the transmit band of the unit under test.

3. Set RF synthesizer 1 (f_1) to either f_{TMN} or f_{TMX}, whichever is closer to f_{AMSRS}.

4. The RF Synthesizer number 2 (f_2) frequency is defined by the following:

$$f_2\,(MHz) = \frac{(N+1) * f_1 - 2 * (f_{AMSRS})}{N-1}\ \text{MHz}$$

   for N = odd values 3 to 11, where N is the IM order. If, for a particular order of N, the value of f2 does not fall within the band to f_{TMN} *to* f_{TMX}, skip this order and proceed to the next higher N.

5. Set the RF synthesizer number 2 (2 f_2) for the lowest value of N determined by the results of Step 4.

6. Set the RF power amplifiers to an output power equal to the single-carrier output power defined in Section 2.2.3.1.2.1.2.

7. Measure the IM product level in decibels relative to one Watt (dBW) at the AMS(R)S spectrum analyzer at the closest valid AMS(R)S operating frequency, and refer it back to the AMS(R)S antenna output port (IMAMSRSdBm).

8. Normalize the IM product level to a 40 dB antenna isolation by performing the following:

   IMLEVEL = IMAMSRSdBm - 40 dB + ANTISOdB

9. Repeat Steps 7 and 8 for N = 5, 7, 9 and 11, respectively.

In each case, determine that the IM product levels determined in step 8 (IMLEVEL) do not exceed the values of Section 2.2.3.1.1.6.2.

<u>Note</u>: *For example, if the transmit band is 1621-1626 MHz and the receive band of interest is 1650-1660 MHz, select* f_{TMX} = 1626 *and* f_{AMSRS} = 1650 MHz. *Then applying Step 4, only the 11-th order IM product need be evaluated.*

2.4.3.1.1.7 Carrier-to-Multipath Discrimination
Reference: Section 2.2.3.1.1.7

Equipment Required

See Section 2.4.3.1.1.1

Measurement Requirements

With the equipment set up as in Figure 2-3, and with operating frequency of 1621.5 MHz, measure the antenna gain by making an azimuthal sweep at the elevation angles of $\theta = \pm\Theta_{MIN}$. At each azimuth angle verify that the difference in pattern, measured in decibels, meets the rejection requirements of Section 2.2.3.1.1.7.

Repeat the test using the transmit frequencies of, 1616.0 MHz and 1626.5 MHz

2.4.3.1.1.8 Pattern Discrimination
Reference: Section 2.2.3.1.1.8

Not Applicable for LEO satellite systems

2.4.3.1.1.9 Steered Antenna Requirements

Installations desiring to use actively switched or steered antenna systems (IGA or HGA) are referred to RTCA Document DO-210D, Section 2.4.3, for appropriate test procedures

2.4.3.1.1.9.1 Phase Discontinuity
Reference: Section 2.2.3.1.1.9.1

Not Applicable for non-steer able, fixed pattern antennas.

Installations desiring to use actively switched or steered antenna systems (IGA or HGA) are referred to RTCA Document DO-210D, Section 2.4.3, for appropriate test procedures

2.4.3.1.1.9.2 Beam Switching Time
Reference: Section 2.2.3.1.1.9.2

Not Applicable for non-steer able, fixed pattern antennas.

Installations desiring to use actively switched or steered antenna systems (IGA or HGA) are referred to RTCA Document DO-210D, Section 2.4.3, for appropriate test procedures

2.4.3.1.1.9.3 Steering Rate
Reference: Section 2.2.3.1.1.9.3

Not Applicable for non-steer able, fixed pattern antennas’

Installations desiring to use actively switched or steered antenna systems (IGA or HGA) are referred to RTCA Document DO-210D, Section 2.4.3, for appropriate test procedures

2.4.3.1.1.9.4 Pattern Discrimination

Reference: Section 2.2.3.1.1.9.4

Not Applicable for LEO satellite systems

2.4.3.1.2 Transceiver Subsystem Test Requirements

2.4.3.1.2.1 Transmitter Performance

2.4.3.1.2.1.1 Transmitter Minimum Power Output

Reference: Section 2.2.3.1.2.1.1

Note: The Transceiver Test Controller as indicated is a PC based software package that allows for frequency control of the Iridium transceiver. As an alternative, use of the operational Iridium constellation is allowable provided the considerations of Section 2.4.1.1.2 are met.

Equipment Required

Directional Coupler, 30 dB coupling, 20 watts average power
High Power Load, 50 ohms, 20 watts or greater average power rating
Burst Power Meter or Spectrum Analyzer
Transceiver Test Controller – software run on PC
DPL Serial port on transceiver must be available for PC serial connection

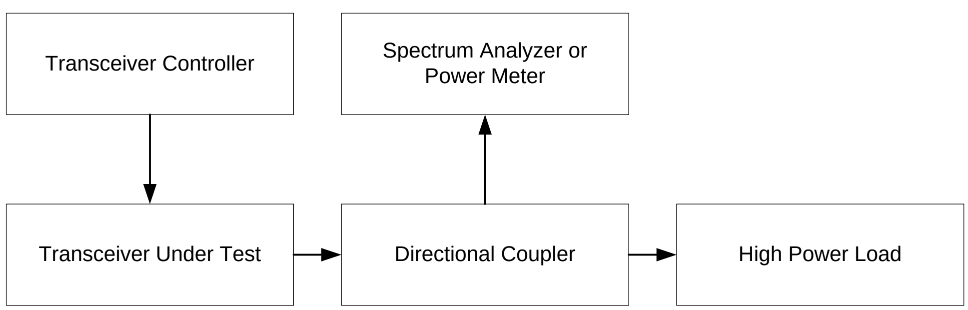


Figure 2-7 Minimum Power, Maximum Power Test Setup

Measurement Procedure

1) Connect the equipment as shown in Figure 2-7.
2) Command the transceiver to create a single data carrier at the valid operating frequency closest to the center of the transmit operating band.
3) Force the transceiver to output the maximum carrier power.
4) Measure the Burst Output Power, as defined in Section 1.7 of the DO-262 main document. Confirm compliance with Sections 2.2.3.1.2.1.1 and 2.2.3.1.2.1.2.

5) Repeat test at the Iridium AES Lower Band-edge of 1611 MHz
6) Repeat test at the Iridium AES Upper Band-edge of 1626 MHz
7) Confirm compliance with Sections 2.2.3.1.2.1.1 and 2.2.3.1.2.1.2

2.4.3.1.2.1.2 Maximum Individual Carrier Output

Reference: Section 2.2.3.1.2.1.2

Refer to test procedure of Section 2.4.3.1.2.1.1.

2.4.3.1.2.1.3 Maximum Total Transceiver Output Carrier Power

Reference: Section 2.2.3.1.2.1.3

<u>Equipment Required</u>

Same as Section 2.4.3.1.2.1.1, with the addition of:
Spectrum Analyzer, to 2.9 GHz

<u>Measurement Procedure</u>

1) Connect the equipment as shown in <u>Figure 2-7</u>.
2) Command the AES to create N_d data carriers and $(N\text{-}N_d)$ voice carriers, where N_d and N are as defined in Section 2.2.3.1.2.1.1.
3) The carriers shall be grouped as closely as possible consistent with normal system operation.
4) For multi-carrier capable TDMA systems, the number of carriers active in any single TDMA time slot shall be the maximum permitted by AES design and shall be consistent with system channel assignments.
5) Using the Spectrum Analyzer with resolution set to 30 kHz, measure the Burst Output Power as defined in Section 1.7 of the DO-262 main document over the frequency range defined in Section 2.2.3.1.2.1.3.
6) Reference the measurements to the transceiver output port and confirm compliance with the requirements of Section 2.2.3.1.2.1.3.

2.4.3.1.2.1.4 Transmitter Intermodulation Products

Reference: Section 2.2.3.1.2.1.4

2.2.3.1.2.1.4.5 Narrow Band Intermodulation Performance

Not Applicable

2.2.3.1.2.1.4.6 Modulated Intermodulation Performance

<u>Note:</u> The Transceiver Test Controller as indicated is a PC based software package that allows for frequency control of the Iridium transceiver. As an alternative, use of the operational Iridium constellation is allowable provided the considerations of Section 2.4.1.1.2 are met.

Equipment Required

Directional Coupler, 30 dB coupling, 20 watts average power
High Power Load, 50 ohms, 20 watts or greater average power rating
Spectrum Analyzer, 100 Hz - 18 GHz
AES under test
Iridium band reject filter – may be required
Transceiver Test Controller(s) – software run on PC
DPL Serial port on transceiver must be available for PC serial connection
90ms frame clock into the transceiver to synchronize the transmissions connects as per Iridium Instructions (See Reference D - Iridium Satellite Compliance and Test Requirements for Value Added Manufacturing (VAM) Products)

Note: *An Iridium band reject filter may be needed between the directional coupler and the spectrum analyzer to accurately measure the intermodulation terms*

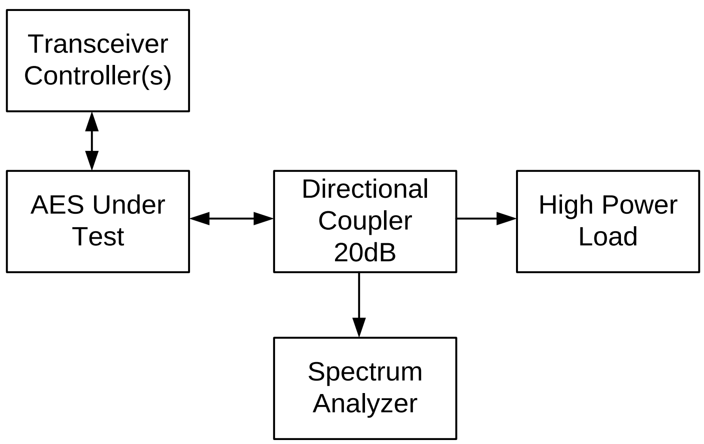


Figure 2-8 AES Intermodulation Product Test Set Up

Measurement Procedure

This test applies only to AES's capable of simultaneous operation on multiple carrier frequencies. Perform the following steps:

1) Connect the equipment as shown on Figure 2-8.
2) Using the transceiver controller, command one of the transceivers to transmit a tone-modulated burst signal at maximum power at frequency $f_1 = f_{TMN}$ on one channel.
3) Set the second transceiver to transmit a tone-modulated burst signal at maximum power at a valid Iridium frequency f_2 on another channel such that a k-th order intermodulation product is formed on frequency $f_{IM} = (k+1)/2 \times f_1 + (k-1)/2 \times f_2$ desired within one of the frequency bands defined in Table 2-6 or Table 2-7, depending on $EIRP_{max}$.
4) The smallest possible odd integer k should be used for each band.
5) **If it is not** possible to accurately set the timing of the bursts from each channel to transmit at the same time, the carrier setting sequence shall be

repeated every few seconds for ten minutes, so that statistically, the channels' transmit bursts will be simultaneous – therefore generating intermodulation – at least some of the time. Set the spectrum analyzer resolution bandwidth to the bandwidth specified in Table 2-6 or Table 2-7, depending on $EIRP_{max}$,and set to peak hold mode over the frequency band of interest. Monitor the spectrum analyzer and allow enough time for each pair of frequencies such that the intermodulation products become visible and can be measured. Correct all spectrum analyzer readings to incorporate the power averaging interval specified in Table 2-6 or Table 2-7, depending on $EIRP_{max}$.

6) **If it is** possible to synchronize the timing of the bursts from each channel to transmit at the same time, the spectrum analyzer can be used to observe the IMD products using zero span. In this case, observe the average IMD signal level over the burst.
7) Repeat steps 2 through 6 for all f_2 as necessary to measure intermodulation products of desired order in all the bands specified in Table 2-6 or Table 2-7, depending on $EIRP_{max}$.
8) Command both channels to stop transmitting when the testing is done.

2.4.3.1.2.1.5 Transmitter Harmonics, Discrete Spurious and Noise Density

Reference: Section 2.2.3.1.2.1.5

Note: The Transceiver Test Controller as indicated is a PC based software package that allows for frequency control of the Iridium transceiver. As an alternative, use of the operational Iridium constellation is allowable provided the considerations of Section 2.4.1.1.2 are met.

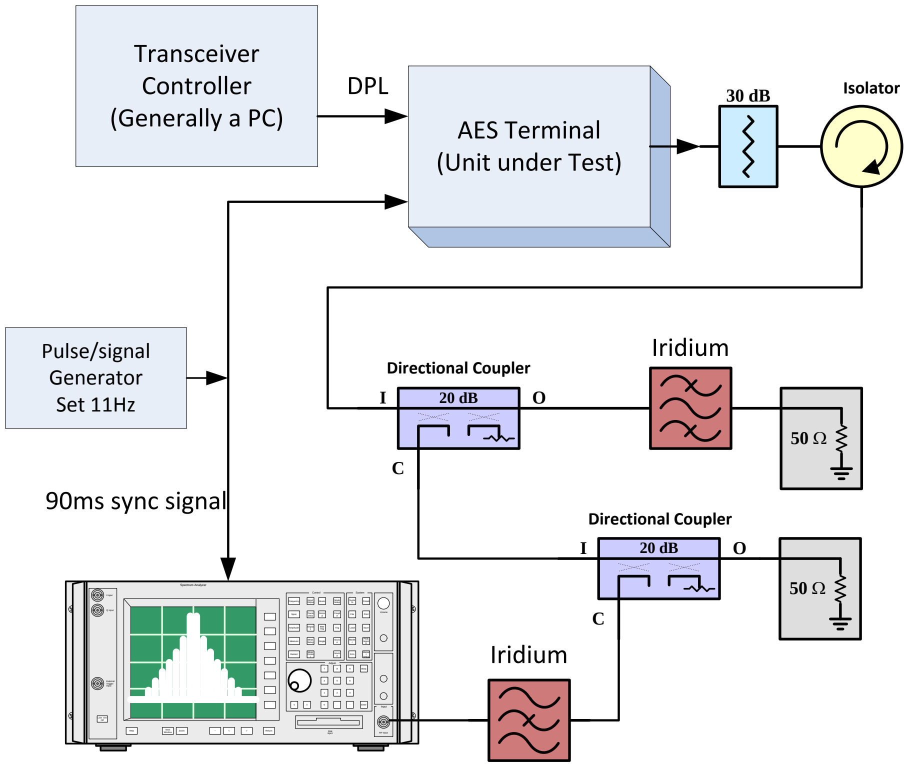
Table 2-6 and Table 2-7 contain requirements for GPS& GLONASS. See the table notes for information on GPS Only. Testing shall be done on only one of these categories as declared at the time of test.

Equipment Required

Note: Alternate setups such as using attenuators instead of couplers, or not using an isolator are acceptable provided they can measure the required test requirements.

Directional Coupler, 20 dB coupling, 20 watts average power, 100 kHz-18 GHz
Qty 2 50 ohm load, DC – 18 GHz, 50 watts
Spectrum Analyzer, at least 18GHz range
Burst Carrier Trigger, 10 MHz
Transceiver Test Controller – software run on PC
DPL Serial port and 90ms frame clock on transceiver must be available for PC serial connection - see
Reference D - Iridium Satellite Compliance and Test Requirements for VAM Products)
Fairview Microwave Circulator (used as isolator) 1-2GHZ SMA-F'S P# SFC1020 or equivalent
Iridium Notch Filter by Lorch 6CSX-1621/10-S or equivalent
Iridium Cavity Bandpass filters by Lorch or equivalent

- 8CFX-1621.25/10.5-T Cavity Bandpass or 6CFX-1621/10-S Cavity Bandpass or equivalent



<u>Figure 2-9</u> Transmitter Harmonic, Discrete Spurious, Noise Density Wide Band Emissions Test Set Up

<u>Measurement Procedure</u>

<u>Emissions from 0.01kHz to 1675 MHz, not including</u> $0.99675 f_{TMN}$ to $1.00325 f_{TMX}$

1) Connect the equipment as shown in <u>Figure 2-9</u> or equivalent setup.
2) Calibrate the equipment for the cable loses, etc.
3) Measure and record the loss from the transceiver output to the spectrum analyzer input within an accuracy of +0.5 dB for each band of interest.
4) Command the transceiver transmitter to output a single modulated carrier at maximum individual carrier power level at the valid operating frequency closest to the center of the transmit operating band.
5) Measure the power out of the notch filter using the spectrum analyzer.
6) With the transmitter operating at the maximum rated power output setting, use the spectrum analyzer to determine the transmitter harmonic, discrete spurious and noise density output of the transmitter in each band of interest from 0.01 kHz to 1675 MHz, excluding the band $0.99675 f_{TMN}$ to $1.00325 f_{TMX}$.
7) Compute the average power output level as defined in Section 1.7 of the DO-262 main document plus the effects of the power averaging interval of <u>Table 2-6</u> or <u>Table 2-7</u>, depending on $EIRP_{max}$, and verify compliance.

8) Repeat Steps 3 through 7 at transceiver output frequencies f_{TMN} and f_{TMX} as provided in Table 2-4 and confirm compliance.

Testing for the band $0.99675 f_{TMN}$ to $1.00325 f_{TMX}$ is covered in Section 2.2.3.1.2.1.9 for On-Channel Spectrum testing.

Transmitter Harmonics Testing from 1675 MHz to 18GHz

1) Connect the equipment as shown in Figure 2-9 or equivalent setup.
2) Calibrate the equipment for the cable loses, etc.
3) Command the transceiver transmitter to output a single modulated carrier at maximum individual carrier power level at the valid operating frequency closest to the center of the transmit operating band.
4) With the transmitter operating at the power level above, use the spectrum analyzer to measure the composite harmonic output of the transmitter over the frequency ranges of the 2nd through *M-th* harmonics of the carrier frequency, where $M = \left\lfloor \frac{18 \times 10^9 \text{ Hz}}{f_{tmn}} \right\rfloor$ and $\lfloor * \rfloor$ is the "greatest integer less than" function. Span for $\pm M \times (f_{TMX} - f_{TMN})$ about each harmonic with a resolution bandwidth of 3 MHz or $\frac{1}{2}(f_{TMX} - f_{TMN})$, whichever is less.
5) Convert the measured spectral densities to the equivalent levels at the transceiver output using the reference level measured above.
6) Compute the average power output level as defined in Section 1.7 of the DO-262 main document plus the effects of the power averaging interval of Table 2-6 or Table 2-7, depending on $EIRP_{max}$ and verify compliance.
7) Repeat Steps 2 through 5 at transceiver output frequencies f_{TMN} and then f_{TMX} as provided in Table 2-4 and confirm compliance.

2.4.3.1.2.1.6 Protection of Radio Astronomy

Reference: Section 2.2.3.1.2.1.6.1 and 2.2.3.1.2.1.6.2

See Section 2.4.3.1.2.1.5 for testing as radio astronomy is included in the HSN testing.

2.4.3.1.2.1.7 Carrier Off Level

Reference: Section 2.2.3.1.2.1.7

Note: *The Transceiver Test Controller as indicated is a PC based software package that allows for frequency control of the Iridium transceiver. As an alternative, use of the operational Iridium constellation is allowable provided the considerations of Section 2.4.1.1.2 are met.*

Equipment Required

See Section 2.4.3.1.2.1.5 for equipmen

Measurement Procedure

1) Connect the equipment as shown Figure 2-9.
2) Remove the Iridium Notch filter
3) Calibrate the equipment for the cable loses, etc.
4) Command the transceiver to be in receive only mode for a single carrier at the valid operating channel closest to the center of transmitting band.
5) Measure the total power output within the transmit band to verify that operation is within specifications as given in Table 2-8.

2.4.3.1.2.1.8 Power Control

Reference: Section 2.2.3.1.2.1.8

Not applicable, no test required. This is done in relation with satellite communication and not directly controllable outside of the Iridium system.

2.4.3.1.2.1.9 On-Channel Output Spectrum

Reference: Section 2.2.3.1.2.1.9

Note: *The Transceiver Test Controller as indicated is a PC based software package that allows for frequency control of the Iridium transceiver. As an alternative, use of the operational Iridium constellation is allowable provided the considerations of Section 2.4.1.1.2 are met.*

Equipment Required

See Section 2.4.3.1.2.1.5 for equipment

Emissions within $0.99675 f_{TMN}$ to $1.00325 f_{TMX}$

1) Connect the equipment as shown in Figure 2-9.
2) Remove the notch filter and recalibrate the system.
3) Command the AES transmitter to output a single modulated carrier at maximum individual carrier power level at the valid operating frequency closest to the center of the transmit operating band.
4) With the transmitter operating at the power level above, use the spectrum analyzer to measure the transmitter harmonic, discrete spurious and noise density output of the transmitter over the frequency ranges of $0.99675 f_{TMN}$ to $1.00325 f_{TMX}$ for frequency band as given Table 2-9.
5) See Table 2-9 for compliance requirements.
6) Repeat Steps 2 through 4 at f_{TMN} and then f_{TMX} as provided in Table 2-4 and confirm compliance.

2.4.3.1.2.1.10 Transmitter Operation in Moving Aircraft
Reference: Section 2.2.3.1.2.1.10

Iridium Satellite LLC shall provide evidence that any transceiver approved for AES use meets requirements stated in Section 2.2.3.1.2.1.10. See Reference H -Iridium Doppler Requirements/ Performance for Aeronautical Communication GEN-0020 for analysis.

2.4.3.1.2.2 Receiver Performance

2.4.3.1.2.2.1 Receiver Sensitivity

The DO-270 MASPS Appendix D (Methodology for Computing and Partitioning Communication Integrity) allows for the calculation of a residual packet error rate given the excessive number of test required to validate a packet error rate (PER) of no more than 1 x 10^{-6}. See Iridium Reference E -Iridium Packet Error Rate Calculations Paper that provides the full scope of the analysis.

The following is a summary of the final results of the calculations found in Iridium Reference E:

CSD maximum PER (calculation)= **3x10^{-7}**

SBD maximum PER (calculation) = **5.47x10^{-7}**

Notes:
1) *These values are a **0dB of link margin** for receiver threshold testing.*
2) *Even partial amounts of link margin increase shall result in significant PER performance metrics.*

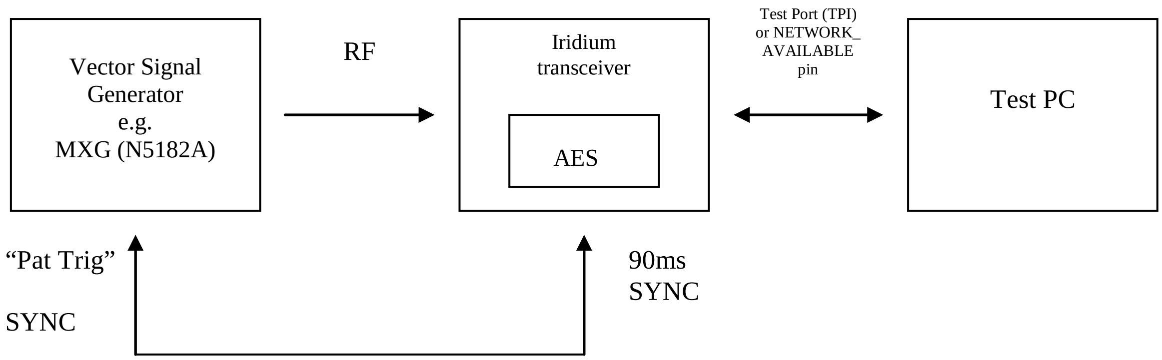
This analysis demonstrates that Iridium AMS(R)S packet data can provide a residual error rate no greater than 10^{-6}, whether it is from-aircraft or to-aircraft.

In order to establish the basis for the analysis, the 2% BER (bit error rate) point of the AES receiver is required. The 2% BER point is established by the Space Vehicle (SV) based on the AES meeting its minimum EIRP requirements of S_{DS} for data and S_{VS} for voice. The procedure for this is listed in Section 2.4.3.1.2.1.1. Once Section 2.4.3.1.2.1.1 has been validated, the sensitivity testing may proceed.

Required Equipment

- 96XX SBD modem, or 95XX LBT modem
- Available serial DPL port and 90ms clock tick (NETWORK AVAILABLE Pin) on the Iridium modem PC with serial port or USB adaptor
- Stable function generator with 50% duty cycle, 90 mS period square wave 5 volt CMOS output.

- RF signal generator with DQPSK modulation
- SimpleTPI software



<u>Figure 2-10</u> Test Set Up receiver sensitivity

<u>Test Setup</u>

<u>Figure 2-10</u> indicates the required setup for the testing. The following sections describe the components or aspects of the test software used to test the receiver sensitivity.

Iridium Modem
The modem is connected to the DPL Serial Port as usual, and supplied with the 90 mS period (11.1 Hz) square wave from the function generator to the NETWORK_AVAILABLE pin on the modem system connector. These connections to the modem under test are required for this testing . See Iridium technical information on the transceiver being tested for detailed pin-out information on the NETWORK_AVAILABLE pin on Iridium modems.

SYNCH signal timing
It should be noted that all SBER timings are referenced to the **falling** edge of the synch signal. The user must enable the RF generator burst start time ~58.4 ms after the falling edge, since this is when the receiver enable period begins. It has been noted that various Iridium documents refer to rising edges, this is only correct for a specific duty cycle and is a not valid for this test. As mentioned, the SBER SW uses the falling edge so it should be used to determine the timing delay.

Signal Generator
The RF Vector signal generator can be any model that has the ability to generate a DQPSK modulated signal, at a 25 KHz symbol rate, with user defined data. However, the user must be aware of a few key points as covered in the details below on burst timing, DQPSK Symbol Mapping, and the Frame and Data Pattern.

Burst Timing

The Iridium burst consists of 207 data symbols. The start of this burst must occur ~58.4 ms after the falling edge of the synch pulse in order to center the burst in the receive slot window. This can be checked by attaching a scope to the RX EN signal on the modem, and examining the actual RF burst using a pulse trigger unit or RF detector. The burst should be centered in the RX EN slot time. Different generators will have unique trigger requirements and delays, so this should be checked.

DQPSK Symbol Mapping

Most generators with built-in DQPSK modes use a standard symbol map. This is apparently not the same as the Iridium map. The user can either use the published map to create the correct Iridium symbol phase from the bits, or use a different unique word, and payload to “fool” the Iridium demodulator. The latter method works by essentially mapping the standard to Iridium symbols. The Iridium specified ***unique word*** is 3F C0 C3. Using standard DQPSK symbol mapping, the ***unique word*** that maps is 30 30 F3. The Iridium ***data pattern*** used for BER testing is 00 FF 4B 4B. Using standard DQPSK symbol mapping, the ***data pattern*** that maps is C0 C0 55 55.

In other words, SBER looks for the unique word 3F C0 C3 and the data pattern 00 FF 4B 4B. The generator with standard DQPSK mapping is programmed with unique word 30 30 F3 and data pattern C0 C0 55 55, which the 9602/9603 module interprets as the correct unique word 3F C0 C3 and data pattern 00 FF 4B 4B.

Frame and Data Pattern

The data pattern is a total of 32 bits, and there are 358 data bits in each frame. For each frame the complete data pattern is repeated 11 times and the last 6 bits of the frame are the first six bits of the data pattern. For example, if the data pattern is 00 FF 4B 4B, then the last six bits of the frame will be the first six bits of the pattern, in binary 000000. If the data pattern is C0 C0 55 55, then the last six bits of the frame will be the first six bits of the pattern, in binary 110000.

00000000	00000000	00000000	00000000	00111111	11000000
11000011	00000000	11111111	01001011	01001011	…
… repeat data pattern hex 00 FF 4B 4B for total of 11 times…					
…repeat the beginning of the data pattern for the last 6 bits…					
11111111	01001011	01001011	000000		

Example frame with unique word 3F C0 C3 and data pattern 00 FF 4B 4B

SBER command and TPI version number

The SimpleTPI.exe is used to setup the DUT for testing and the SBER.exe is used to run the SBER command. Both SimpleTPI and SBER applications are provided by Iridium. Details on the SBER command are found in the *9602 TPI Protocol Definition (C7893-S-020v1.8)*. The SBER command is intended to return the following information: number of frames received and the number of bit errors in hex. The SBER application also returns the number of bit errors in decimal, but this is not the percentage BER. See Section *Bit Error Rate Calculation*.

Commands to Run the Bit Error Rate Measurement

The following commands are used to make a bit error rate measurement.

1. Run simpleTPI from the command prompt, then enter the following commands

etst	enter test mode
uift 01	use external frame synch
schn 79 79	set desired channel in hex (0x79 = Ch 121)
srfp 04	set receiver on, bursted mode
quit	quit SimpleTPI in order to run SBER application

2. Run SBER application from the command line: SBER <com port> ie SBER 1

100 sync <# frames> 00ff4b4b	run SBER for # of frames with repeating pattern 00 FF 4B 4B.
example:	
100 sync 10 00ff4b4b	run SBER for 10 frames

The SBER application shows the rsyn response message for each frame with either an "in sync: yes" or "in sync: no" response, followed by the first eight bytes of data received by the DUT. The last response (RBER message) displays the received number of frames, number of bit errors in hex, and an invalid BER. Percent BER must be calculated manually using the bit error count as described above. See Section *DQPSK Symbol Mapping* for more details on the data pattern transmitted.

If rsyn response is "frame in sync: No," the RF burst delay may need to be adjusted. As stated previously the delay of the RF burst from the falling edge of the sync signal is ~58.4 mS.

Bit Error Rate Calculation
The SBER application displays the number of bit errors in decimal as "BER: XXX.XX%" but it is NOT a calculated percent BER. The percent BER must be manually calculated. The number of received data bits in a frame is equal to 358 (414 bits in a frame minus 56 bits for the preamble and unique word). Percent BER is calculated using the following formula:

Number of received bits per frame = 358
Number of received frames = F
Total number of bit errors = B

$$\%\,BER = \left(\frac{B}{358 \times F}\right) \times 100$$

<u>Measurement Procedure</u>

1) Setup the test equipment as outlined in Figure 2-10
2) Read and understand all section regarding the use of the SBER test program
3) Run the test commands as indicated in Section *Commands to Run the Bit Error Measurement*
4) Calculate the BER using the formula in Section *Bit Error Rate Calculation*
5) Validate that the transceiver under test satisfies less than 2% BER

2.4.3.1.2.2.2 Receiver Sensitivity (Voice)

Reference: Section 2.2.3.1.2.2.1.2

See Section 2.4.3.1.2.2.1.

The 2% BER established in Section 2.4.3.1.2.2.1 shall also satisfy the voice sensitivity test requirement. The Iridium Reference E - Iridium Packet Error Rate Calculations Paper provides analysis of the FEC and other error correction aspects of the Iridium network which are based on the 2% BER of the Iridium transceiver.

2.4.3.1.2.2.3 Test Method for Environmental Conditions

Reference: Section 2.2.3.1.2.1.11

Receiver sensitivity testing is required to be repeated a large number of times over different environmental conditions (particularly in RF susceptibility and induced signal susceptibility). See Table 2-11 and Table 2-12 for information on DO-160G environmental testing requirements.

As the receiver is mounted inside of “box” or housing, the mounting and housing specifications must protect the transceiver from the adverse environmental conditions as specified in DO-160G for the specific category of product.

Testing of the AES under DO-160G requirements shall demonstrate baseline of system performance before, during and after environmental condition testing as required.

See Section 2.4.3.1.2.2.1 for testing procedures while validating DO-160G environmental tests. As stated, the FEC in the satellite network is based on the transceiver maintaining less than 2% BER. Meeting this standard while undergoing DO-160G testing as per Section 2.4.3.1.2.2.1 is required.

2.4.3.1.2.2.4 Receiver Bandwidth

Reference: Section 2.2.3.1.2.2.2

No separate testing required. The Iridium transceiver is factory tested to verify bandwidth reception prior to shipment. This includes the full spectrum of Iridium bandwidth, including bandwidth that is released only in times of emergency usage.

2.4.3.1.2.2.5 Rejection of Signals Outside NGSS Receive Band

Reference: Section 2.2.3.1.2.2.3

Notes:

1) *Specific testing of this section is available as an additional part of Iridium Certification procedure. Special DVT testing is required using specific test equipment which is impractical for partners to acquire. Contact Iridium for support on the validation of this testing. The process below outlines the testing performed by Iridium. As an alternative, use of the operational Iridium constellation is allowable provided the considerations of Section 2.4.1.1.2 are met.*

2) *The Transceiver Test Controller, as indicated, is a PC based software package that allows for frequency control of the Iridium transceiver. As an alternative, use of the operational Iridium constellation is allowable provided the considerations of Section 2.4.1.1.2 are met.*

Required Equipment

Synthesized Signal Generator, f_{RMN} to f_{RMX} MHz frequency range

Synthesized Signal Generator(s), 470 MHz to f_{RMN} MHz

Synthesized Signal Generator(s), f_{RMX} to 18,000 MHz

Directional Coupler, 20 dB coupling
AES antenna
Transceiver Test Controller– software run on PC
DPL Serial port on transceiver must be available for PC serial connection

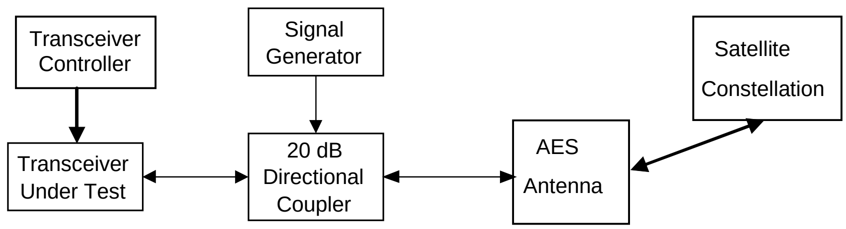


Figure 2-11 Test Set Up for Rejection of Signals Inside and Outside of Band Tests

Measurement Procedure

This is a two-part procedure. In Part One, the receiver design is analyzed to identify potential analog image and spurious response frequencies and possible digitally-induced aliases. In Part Two, the receiver is tested to determine if the receiver performance is degraded, causing loss of communications, by any of the signals identified in Part One.

Part One

1) Prior to the start of the test, analyze the transceiver under test to determine required input test frequencies.
2) All IF and reference frequencies used within the transceiver must be known.
3) Using these frequencies, calculate all frequencies within the ranges specified in Section 2.2.3.1.2.2.3, which have the potential to produce image or spurious signals.
4) The calculations should include image frequencies and mixer harmonic intermodulation distortions through 11th order which are capable of producing IF frequencies used within the transceiver, or sub-harmonics of these IF frequencies, and such frequencies that may lead to digital aliasing problems or other spurious responses.

Part Two
This test will use the operational Iridium constellation where the full bandwidth is tested. Considerations of Section 2.4.1.1.2 must be met. Tests should be timed to coincide with the worst case satellite geometry declared by the satellite system operator. It is anticipated that some NGSS-based AES equipment may use embedded transceiver devices for the underlying satellite network. In such cases, transceiver manufacturer test data on the individual transceiver units may be an acceptable alternative to performing the tests at the AES level, provided that such data

essentially reproduces the tests described below. Alternative testing using operational Iridium constellation are also indicated below.

1) Setup the equipment as shown in Figure 2-11.
2) With the sweep generator off, use the Transceiver Test Controller to tune the receiver to the operational frequency closest to $\frac{1}{2}(f_{RMN} + f_{RMX})$ (not applicable for alternative test)
3) Turn on the sweep generator. Adjust its output to produce signal levels into the transceiver as specified for each of the frequency ranges in Section 2.2.3.1.2.2.3.
4) Sweep the frequency over the critical frequency sub-ranges identified in Part One.
5) Choose the sweep rate so that any satellite sub-network timers designed to coast through interference bursts time out during the sweep of any specific sub-band.
6) Verify that communications are not interrupted by observing that voice connections are not lost and data connections maintain the desired user throughput rate.)
7) Repeat the test over the entire frequency range of Section 2.2.3.1.2.2.3 using the sweep rate identified in the previous step.
8) Repeat these tests with the transceiver tuned to frequencies of f_{RMN} and f_{RMX}
9) Verify that communications are not interrupted by observing that voice connections are not lost and data connections maintain the desired user throughput rate.)
10) Verify operation to specification required

2.4.3.1.2.2.6 Rejection of Carrier Signals Generated by Other AMS(R)S Equipment
Reference: Section 2.2.3.1.2.2.4

Note: The requirement for this test is only applicable under the conditions described in Section 2.1.8.

Required Equipment
Refer to Section 2.4.3.1.2.2.3

Measurement Procedure

Repeat the test procedure of the Section 2.2.3.1.2.2.4 using the interference frequencies and signal levels given in Section 2.2.3.1.2.2.4.

2.4.3.1.2.2.7 Receiver Operation in Moving Aircraft
Reference: Section 2.2.3.1.2.2.5

Iridium Reference H (Iridium Doppler Requirements/ Performance for Aeronautical Communication GEN-0020) provides means of analysis in meeting the requirements stated in Section 2.2.3.1.2.2.5.

2.4.3.1.2.2.8 Receiver Susceptibility

Reference: 2.2.3.1.2.2.6

The receiver susceptibility shall be tested to ensure that, while exposed to wideband or narrowband interference, the receiver shall properly acquire and track the required signals and shall output data at the specified rate.

Narrow Band interference is covered in the Iridium DVT testing as part of the Iridium Certification process. See Reference H -Iridium Satellite Compliance and Test Requirements for Value Added Manufacturing (VAM) Products.

The following covers the testing for wideband interference.

Required Equipment

Signal Noise Generator - Agilent Vector Signal Generator, Model ESG E4438C-503
or Agilent Spectrum Analyzer, Model PSA E4440A
or Agilent Signal Studio, Model N7621
or equivalent

Directional Coupler, 20 dB coupling
AES antenna
Iridium Operational Constellation

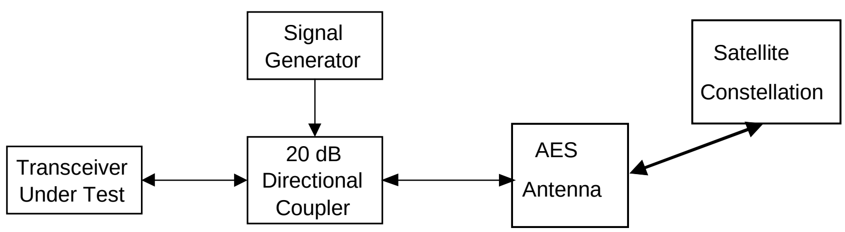


Figure 2-12 Test Set Up for Receiver Susceptibility

Measurement Procedure

1) Setup the equipment as per Figure 2-12
2) Refer to Section 2.2.3.1.2.2.6 for wideband and narrowband definition and Table 2-4 for test parameters for interference testing
3) The wideband noise shall occupy the entire receiver band, with a 200kHz wide notch around the test frequency
4) The level of the wideband noise shall be as per S_{UW} in Table 2-4
5) The depth of the notch shall be at least 40dB.

6) The frequency should be close to center band, but is left to the manufacturer's discretion to allow for tuning of the notch
7) Measure at Point D to validate specification or measure at Point C and calculate the value at point D to take into account for the design of the AES.

2.4.3.2 Satellite Subnetwork Specific Test Requirements

Reference: Section 2.2.3.2

The AES SDU design shall be tested and approved by Iridium Satellite before the SDU is approved for use on the Iridium network.

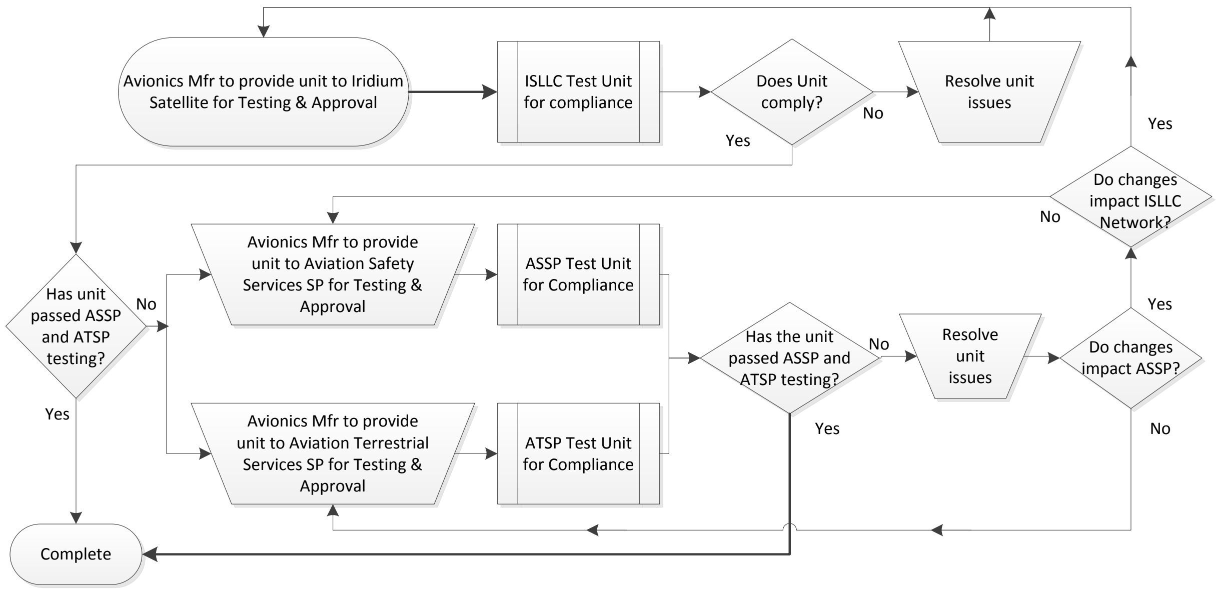
SDUs with data capabilities shall be tested and approved by the aviation safety services SP (ASSP) before the equipment is authorized for use with the aviation safety service provider's ground server.

SDUs with ACARS and/or ATN/CPDLC capability must be provided to the ATSP (*e.g.*, ARINC, SITA, or other civil aviation authority approved SP) for qualification testing and approved before the equipment is authorized for use with the respective aviation terrestrial network(s).

If the SDU fails to gain approval and must be modified, the unit must undergo regression testing by Iridium Satellite and each of the other SP's, as required, before the unit can receive final approval.

The SDU manufacturer shall make available results of such network testing and approvals to civil aviation authorities as required to facilitate certification for safety services.

A description of the SDU testing and approval process is shown in Figure 2-13.



Satellite Subnetwork Compliance Testing and Approval Process

Figure 2-13 Satellite Sub-network Compliance Testing and Approval Process

2.4.3.3 Priority, Precedence and Preemption

The test procedures of the following subparagraphs assume that the AES is capable of serving both AMSS (Priority Level 1 [low] in Table 2-10) and AMS(R)S (Priority Level 2, Priority Level 3, and Priority Level 4 [high]). If the system being tested support solely AMS(R)S, references to Priority Level 1 may be replaced with Priority Level 2.

Alternatively, compliance may be demonstrated by ensuring that there is no contention for shared channel resources for safety services.

2.4.3.3.1 Packet Data

Reference: Section 2.2.3.3.1

This test shall use the priority establishing mechanism required by 2.2.3.3, as described by the AES manufacturer.

Equipment Required

This test requires the ability to establish N_D simultaneous packet data channels using the AES under test. This may require multiple AES control units or multiple digital interfaces from a single control unit. Each interface must be capable of sustaining a bit rate of at $2R_{SC\text{-}UD}$. If a single interface is used to control all N_D packet data channels, that interface must be capable of sustaining a bit rate of $2(N_D)R_{SC\text{-}UD}$.

Measurement Procedure

The precedence and preemption test procedures are designed to verify the AES's ability to determine the precedence of packet-mode data and preempt, if necessary, lower-priority air-to-ground data units (AGPDUs). See Iridium Reference E Iridium Packet Error Rate Calculations Paper for more details on AGPDUs

1. Data Communications Setup

Utilizing the appropriate SNAcP interface and commands, create N_D independent packet data channels between the AES and either the system test simulator or an appropriate GES. For the purpose of this test, label these independent channels Channel A, Channel B, etc. (For the purposes of this test description, we will assume $N_D=4$).

2. DATA packets from Data packets

This test verifies proper ordering of AGPDUs according to the link layer precedence of the data packets arriving at the AES.

a. Using the external interface send a message consisting of L_{SNDP} +10 octets of data over the established channels in the following order: Channel A, Channel C, Channel B, Channel D. Fill the User Data Field with following patterns:

For	For	Pattern
channel D	priority 4 (high)	01010101
channel C	priority 2	10101010
channel B	priority 3	11001100
channel A	priority 1 (low)	00110011

These packets shall be sent to the AES interface at the maximum rate supported by the external interface hardware.

Verify that the AES sends data packets over the subnetwork in priority order, with higher priority packets transmitted first.

c. For equipment that does not support Priority Level 1 (low, non-safety) communications, create a data stream that alternates the data fields from step (a) and the Priority 1 data stream from step (a). Verify that only Priority 2, 3, and 4 packets are transmitted.

Note: AES designs that choose to implement an ISO-8208 compliant interface may satisfy this requirement by means of the tests specified in Appendix B of the DO-262 main document, Section 3.1.2.

2.4.3.3.2 Circuit Mode Communications (Voice)

Reference: Section 2.2.3.3.2

Equipment Required

An ATS SIM card is required for each voice line participating in the ATS voice system in the system under test (Max 2 voice lines for ATS). The ATS SIM cards must be provisioned in the Iridium system for ATS service and, in the case of two ATS SIM cards, they must be linked in the setup as under the same ICAO code.

This test, while not intended to verify the ability of the satellite network (or the satellite sub-network) as a whole, will satisfy the Priority, Precedence and Preemption requirements of the MASPS.

Test Procedure

This test assumes that the AES is capable of one or two channels of simultaneous circuit-mode operation. The number of channels shall be declared before the test is started. Perform the following steps:

Note:

1) *The use of Priority Level in this procedure agrees with the details in Table 2-10.*
2) *Actual in use Priority Level convention should be used in place of those given in these steps to ensure the same testing of high vs. low priority.*
3) *See the Iridium Reference G "ATS Operator Guide" for information on priority.*
4) *GtA refers to ground-to-air and AtG refers to air-to-ground*

1) Establish *N* voice GtA calls at non-safety circuit-mode priority, Priority Level 1 (low), identified in Table 2-10 so that all lines are in use.
2) While monitoring the Priority Level 1 (low) calls, attempt to establish a GtA call at Circuit-Mode Priority 2 identified in Table 2-10.
3) Verify that one of the non-safety circuits is terminated and made available for the safety call, and that the call is completed.
4) Repeat Step 2 until all channels are consumed by Priority 2 calls.
5) Repeat Steps 2 and 3 with Priority 3 calls.
6) Repeat Steps 2 and 3 with Priority 4 (high) calls.
7) At the completion of Step 6, there will be *N* Priority 4 (high) calls established
8) Attempt to initiate an GtA call at Priority 3, and verify that the call does not preempt an existing call and that the call is placed into Call Waiting status
9) Attempt to initiate an GtA call at Priority 2, and verify that the call does not preempt a current in process call nor the call in Call Waiting.
10) Attempt to initiate an GtA call at Priority 1 (low), and verify that the call does not preempt a current call nor the call in Call Waiting. This step shall be performed for all equipment, including equipment that does not support Priority 1 (low) non-safety communications.
11) Terminate a current call in process. Verify that the call in Call Waiting is connected.
12) Terminate all calls, and re-establish Step 1 with Priority 1 (low) calls.
13) Repeat Steps 1 but first establish calls from AtG. Repeat steps 2 through 10 and verify that the same results are obtained.

2.4.3.4 Satellite Subnetwork Data Protocol (Satellite Layer 2)

Reference: Section 2.2.3.4

AES compliance with Sub-network specific protocol requirements shall be verified by means of the satellite network access certification referenced in Section 2.2.3.2 of this document.

2.4.3.5 Voice Protocol

Reference: Section 2.2.3.5

Compliance with Iridium satellite-specific protocols shall be verified by means of the Iridium Satellite LLC certification process referenced in this normative appendix. Acceptable evidence of such compliance is a certification document from Iridium Satellite LLC.

2.4.3.5.1 Vocoder Interoperability With Satellite Subnetwork

Section 2.2.6 permits the use of a "100% compatible" vocoder algorithm. If an algorithm other than the specific algorithm identified in this technique-specific attachment, including version and part number, is selected, it shall be the responsibility of the manufacturer to develop test procedures and documentary evidence that complete interoperability is achieved. These procedures shall be approved by Iridium Satellite, the satellite network operator, prior to the start of testing. Because of the complexity of such vocoder design and testing issues, these tests are not specifically identified in this attachment.

All AES vocoders shall demonstrate compliance with Sub-network specific vocoder requirements by means of the satellite network access certification identified in Iridium Reference A. Appendices applicable to specific systems are identified in Section 2.2.3.2.

2.4.3.5.2 Vocoder Performance in an Aeronautical Environment

AES equipment intended for safety voice applications shall verify that the vocoder is suitable for the aeronautical cockpit environment when operating in the noise environments identified in Section 2.2.3.5.2 by conducting statistically significant tests to identify the Mean Opinion Score as outlined in the Annex 10 Chapter 4 AMS(R)S SARPs.

2.4.3.6 User Data Interfaces

The option of providing an ATN-compliant protocol is tested in Section 2.4.3.6.1. The option of providing an ACARS interface is tested in Section 2.2.3.6.2. An AES utilizing packet data must pass either or both sets of tests, depending on the capabilities declared in this normative appendix.

If an ISO-8208 compliant interface is provided as the ATN interface, the tests are described in Appendix B of the DO-262 main document. Satellite subnetwork-dependent validation is discussed in this normative appendix.

2.4.3.6.1 ATN Interfaces

Reference: Section 2.2.3.6.1

The requirements established in Section 2.2.3.6.1 concern the implementation of a Data Circuit-terminating Equipment (DCE) interface on the digital side of the AES. To verify the proper functionality of that interface, it is necessary to issue certain commands and analyze certain responses from both a simulated Data Terminal Equipment (DTE) external to the AES and from a corresponding simulated DTE external to the AES and from a corresponding simulated DTE external to the GES. The means of verifying compliance involves using the satellite network directly, and examining the data at the output of the GES. The potential exists to remotely access this information so that the entire testing is performed in a closed loop from a single location, as shown in Figure 2-14.

Note: An alternative means of demonstration would be to probe the radio-frequency emissions of the AES, back out the satellite-network signal-in-space, Layer 1 and Layer 2 and possible Satellite Subnetwork Dependent Protocols, and confirm transmission of the proper DCE-DCE message traffic. This approach requires the ability to simulate the signal processing of the entire satellite network, including its ground terminals and gateways to the public and private networks.

Note: Use of the Active Satellite Sub-Network for performance testing is subject to the restrictions identified in Section 2.4.1.1.2.

2.4.3.6.1.1 Join and Leave Requirements

Reference: Section 2.2.3.6.1.1

Verify that a Join event message in accordance with Section 2.2.3.6.1.1 is transmitted to the routing function upon determination of availability of the air/ground data link. Similarly, verify that a Leave event message is transmitted upon determination of non-availability of the air/ground data link.

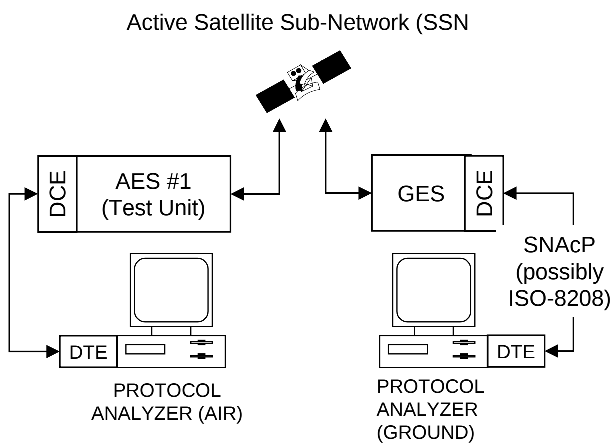


Figure 2-14 High-Level Test Set Up for DCE Interface Testing

2.4.3.6.1.2 ATN-Compliant Mapping for Priority, Precedence and Preemption

Reference: Section 2.2.3.6.1.2

This test establishes only that the satellite subnetwork properly maintains the subnetwork priority field, not that the priority, precedence and preemption mechanisms are implemented. Perform the following steps:

1) Using the standard packet data test setup up shown in Figure 2-14, use the PAG to send packets with values the priority field in the appropriate call set-up packet set to

the value corresponding to the lowest priority. Use the PAA to verify that the associated received packet contains the same value. Verify that the priority is confirmed back to the PAG. Use the appropriate procedure to clear the resulting call.

2) Repeat Step 1 with values in the priority field set to increasing levels of priority. For systems capable of both safety and non-safety communications, verify that a minimum of four levels of priority are supported, in accordance with Table 2-10. For systems capable of only safety communications, verify that a minimum of three levels of priority are supported, in accordance with Table 2-10.
3) Repeat the Step 1 and Step 2 tests with the roles of the PAA and PAG reversed.

2.4.3.6.2 ACARS

Reference: Section 2.2.3.6.2

Systems providing an ACARS interface shall be tested in accordance with test procedures provided by the aviation terrestrial network SP (e.g., ARINC, SITA or other civil aviation authority approved aviation terrestrial network SP) as outlined in section 2.4.3.2.

2.4.3.6.3 Satellite Subnetwork

2.4.3.6.3.1 Satellite Subnetwork Dependent Protocol

Reference: Section 2.2.3.6.3.1

Verification that the requirements of section 2.2.3.6.3.1 have been met shall be demonstrated by Iridium Satellite and the Aviation Safety Service SP during avionics qualification testing as outlined in section 2.4.3.2

2.4.3.6.4 Avionics Subnetwork Interface

Reference: Section 2.2.3.6.4

Verification that the requirements of section 2.2.3.6.4 have been met shall be demonstrated by the Aviation Safety Service SP and the aviation terrestrial network SP (e.g., ARINC, SITA or other civil aviation authority approved aviation terrestrial network SP) during avionics qualification testing as outlined in section 2.4.3.2.

2.4.3.6.4.1 ATN Compliant Physical and Data Link Requirements

If an ISO-8208 compatible interface is provided to meet the ATN interface requirements, it shall be tested in accordance with the provisions of Appendix B of the DO-262 main document.

If an alternate ATN interface is provided, it shall be tested in accordance with the test provisions for that interface. All test provisions shall provide equivalent rigor to the procedures contained in Appendix B of the DO-262 main document.

2.4.3.7 Circuit Mode Test Procedures

Reference: Section 2.2.3.7

The requirements for circuit-mode voice service shall be tested during the satellite network operator certification process. Performance of circuit mode voice service in an AMS(R)S environment is tested in Section 2.4.3.5.2.

The requirements for circuit-mode priority, precedence and preemption have been tested in Section 2.4.3.3.2.

2.4.3.8 Recovery from Primary Power Interrupt Test Procedure

Reference: Section 2.2.3.8

Equipment Required
Oscilloscope
Programmable Interruptible Power Supply

This test requires access to the satellite network, in accordance with the constraints of Section 2.4.3.1.2.2.

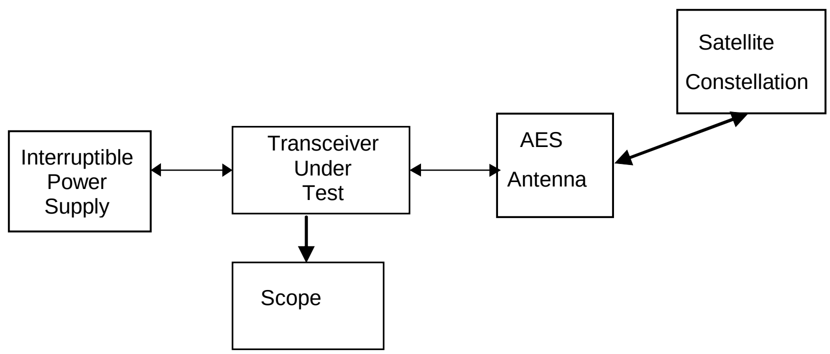


Figure 2-15 Power Interruption Test Set-Up

Setup the equipment as shown in Figure 2-15. Initiate a communications session in every mode (*i.e.*, voice, packet data, circuit data) supported by the AES. While continuously maintaining the communications session, monitor the receiver digital or audio output on the scope. Apply power interruptions of 5 ms and observe no dropout of output whatsoever. Apply 200 ms interruptions and verify that the output recovers within 5 seconds and verify the data link functions are unaffected.

2.4.3.9 Failure/Status Indication Test Procedure

Reference: Section 2.2.3.9

Equipment Required

Programmable Attenuator, 20 W, 0-30 dB in 3 dB steps
AES status monitor – This may be a protocol analyzer for any convenient digital data bus supported by the equipment under test, such as ARINC 429, IEEE 802.3, etc. The PAG may be used for this purpose, if desired.

This test requires access to the satellite network, in accordance with the constraints of Section 2.4.2.1.2.2.

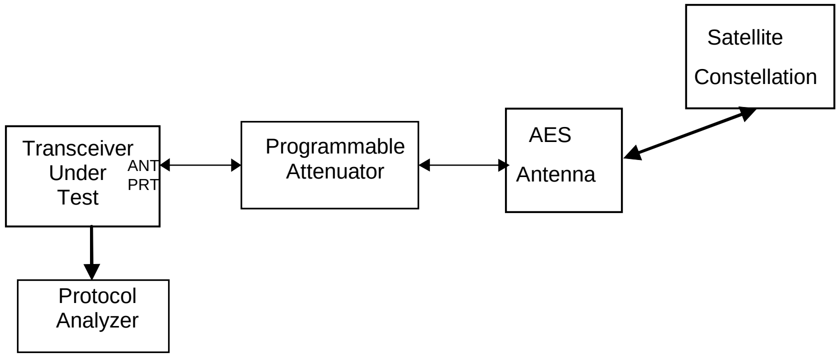


Figure 2-16 Failure/Status Indication Test Setup

Test Procedure

1) Connect the equipment as shown in Figure 2-16.
2) For each of the communications modes supported by the AES (i.e., voice, packet data, and circuit data as applicable) initiate a communications session through the satellite network with the AES.
3) Use the protocol analyzer to verify that the AES communications is reported as AVAILABLE or its equivalent.
4) Using the programmable attenuator, increase the loss between the AES and the satellite until communications with the satellite are lost.
5) Verify that the status is reported as UNAVAILABLE or its equivalent.
6) Return the attenuation to its original setting and verify that the status returns to AVAILABLE.

2.4.3.10 Information Security Test Procedure

Reference: Section 2.2.3.10

A plan for Security Verification in accordance with DO-326 Section 3.3.4 shall be developed and executed to verify that the security countermeasures designed in as a result of the Security Risk Assessment are effective.
Verification shall include:

- Intended function tests for countermeasures
- Robustness tests
- Vulnerability tests

3 INSTALLED EQUIPMENT PERFORMANCE

3.1 Equipment Installation

3.1.1 Accessibility

Controls and monitors provided for in-flight operation shall be readily accessible from the appropriate operator's normal seated position. The operator/crew member(s) shall have an unobstructed view of the display(s) or controls when in the normal seated position.

3.1.2 Aircraft Environment

Equipment shall be compatible with the environmental conditions present in the specific location in the aircraft where the equipment is installed.

3.1.3 Display Visibility

All installed system displays shall be readily visible and readable from the operator's/crew member's normal position in all ambient lighting conditions for which system use is required.

Note: Visors, glareshields, or filters may be an acceptable means of obtaining daylight visibility.

3.1.4 Inadvertent Turn-Off

Where controls for transceiver operation are provided, they shall be equipped with adequate protection against inadvertent turn off.

3.1.5 Failure Protection

Any probable failure of the equipment shall not degrade the normal operation of equipment or systems that are connected to it. Likewise, the failure of interfaced equipment or systems shall not induce failures of this equipment.

3.1.6 Interface Interference Effects

The equipment shall not be the source of harmful conducted or radiated interference, and shall not be affected by conducted or radiated interference from other equipment or systems installed in the aircraft.

3.1.7 Aircraft Power Source

The voltage and frequency tolerance characteristics of the equipment shall be compatible with the aircraft power source of appropriate category as specified in RTCA DO-160G.

3.1.8 Antenna Location/Installation

Note: This requirement is only applicable under the conditions described in Section 2.1.8.

Due to the potential for harmful interference from a simultaneously transmitting Inmarsat SATCOM transceiver, it is suggested that installers allow a minimum of 45 feet separation between the Inmarsat system antenna and the Iridium system antenna.

Unless otherwise authorized by the equipment manufacturer, the Iridium antenna must be mounted on a level horizontal plane, such as on the top centerline of the aircraft fuselage. Any deviation from this requirement must demonstrate compliance with the weighted average gain requirement of Section 2.2.3.1.1.1.3 when measured over a ground plane with a radius of curvature representative of the intended installation.

3.1.9 Co-Location with other Iridium SATCOM Systems

When co-locating more than one Iridium SATCOM system on one aircraft, the location of antenna required shall be considered:

- If more than one exterior mounted antenna needs to be installed, they need to be spaced far enough apart so as to avoid distortion of the antenna beams.
- Advice should be sought from antenna manufactures if planned separation is less than 1m.

3.2 Installed Equipment Performance Requirements

The installed equipment shall meet the requirements of Section 2.0 in addition to the requirements stated below. To meet the requirements of this section, test results supplied by the equipment manufacturer may be accepted in lieu of tests performed by the equipment installer.

However, performance characteristics that cannot be tested by the equipment manufacturer shall be tested by the installer. These include: (1) performance characteristics of equipment required for the transceiver installation that have not been tested or verified by the manufacturer, and (2) interactions with other equipment installed on the aircraft.

3.2.1 Radiated Antenna Intermodulation Products in AMS(R)S Bands

Note: This requirement is only applicable under the conditions described in Section 2.1.8.

When operating with two unmodulated carriers anywhere within the frequency band with each carrier f_{TMN} to f_{TMX}, each carrier having the maximum allowable single carrier power permitted by Section 2.2.3.1.2.1.2 of this document, the antenna subsystem shall not radiate internally generated intermodulation products in a direction toward a likely location(s) of antenna(s) on the same aircraft serving other AMS(R)S systems so as to cause a average power level that increases the effective noise temperature of the other AMS(R)S system by more than 6% In this condition, the other antenna is taken to be a quarter-wave monopole antenna matched to its load and the isolation between the AES antenna and the AMS(R)S antenna is taken to be 40 dB.

3.2.2 Declaration of Additional Isolation

Extensive testing has shown that any intermodulation products generated by two or more Iridium channels operating simultaneously are significantly below the levels that could cause any interference to GNSS systems on the same aircraft if proper installation procedures and guidelines are followed.

3.3 Conditions of Test

The following Sections define conditions under which the tests specified in Section 3.4 shall be conducted.

3.3.1 Power Input

Tests may be conducted either with the equipment powered by the aircraft's electrical power generation system or by an appropriate external power source connected to the aircraft.

3.3.2 Environment

During the tests, the equipment shall not be subjected to environmental conditions that exceed those in RTCA/DO-160G as specified by the equipment manufacturer.

3.3.3 Adjustment of Equipment

Iridium systems, by design, incorporate an L-Band Transceiver module that does not provide facilities for alignment or adjustment by the operator. Therefore, no alignment or adjustment will be performed prior to application of the specified tests.

3.3.4 Warm-up Period

Unless otherwise specified, tests shall be conducted after a warm-up (stabilization) period of twenty (20) minutes.

3.4 Test Procedures for Installed Equipment Performance

The following test procedures provide one means of determining installed equipment performance. Although specific test procedures are cited, it is recognized that the installing activity may prefer alternate procedures, which may be used if they provide at least equivalent information. In such cases, the procedures cited herein should be used as one criterion in evaluating the acceptability of the alternate procedures.

3.4.1 Conformity Inspection

Visually inspect the installed equipment to determine the use of acceptable workmanship and engineering practices. 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.

3.4.2 Interference Tests

Unless otherwise specified, all aircraft electrically-operated equipment and systems shall be on, using the aircraft's electrical power generating equipment before conducting interference tests.

With the transceiver operating, including transmission of messages and voice calls, individually operate each of the other electrically-operated aircraft equipment and systems to determine that no significant conducted or radiated interference exists. Evaluate all reasonable combinations of control settings and operating modes. Operate communication and navigation equipment on at a minimum the low, high, and a mid-band, frequencies.

Operate the aircraft controls (e.g., flaps) through their range to activate all associated aircraft systems which may cause electrical power fluctuations.

Notes:

1. *Some aircraft contain cooling fans to augment airflow under certain low-speed conditions. These fans are activated with flaps extended and low- to mid-throttle, and cause aircraft power fluctuations when activated.*

2. *See Section 3.4.4 for requirements for message generation.*

The equipment shall not be the source of harmful conducted or radiated interference, and shall not be affected by conducted or radiated interference from other equipment or systems installed in the aircraft.

Adequate protection of on-board GNSS equipment from harmful interference due to equipment meeting the requirements of Section 2 is based on an average power level not exceeding –122 dBm referenced to the port of the GNSS antenna, the spectral width of the interfering signal(s) lies in the range of 100 to 1000 kHz.

Notes:

3. In a typical installation, this could be achieved if:

a) the transceiver meets all requirements of Section 2.2.3.1.2.1.2, 2.2.3.1.2.1.4, 2.2.3.1.2.1.5;

b) the isolation between AMSS and GNSS antennas is not less than 55 dB; and

c) interfering intermodulation products generated external to the transceiver do not increase the average power level referenced to the port of the GNSS antenna by more than 1.5 dB.

4. Interference problems noted upon installation of this 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 installing facility will be responsible for resolving any incompatibility between this equipment and previously installed equipment in the aircraft.

Note: The following requirement is only applicable under the conditions described in Section 2.1.8.

If the equipment is installed on an airframe as part of a "dual-dissimilar" satellite communications suite, the following test procedures shall be performed. In the following discussions, "SATCOM A" refers to the system covered by this MOPS, for which installed equipment tests are currently being performed, while "SATCOM B" refers to the other satellite communications system. It is possible that this document and a particular technique-specific appendix may apply to the SATCOM B system, as well.

If the SATCOM B system consists of Inmarsat AES equipment compliant with RTCA/DO-210D, all changes, or ARINC Characteristic 741, or ARINC Characteristic 781, owners, operators, and installers are specifically referred to the limitations identified in Section 1.1.4 of this document. The following SATCOM A / SATCOM B interference tests (Sections 3.4.2.2 and 3.4.2.3) shall be performed only when the intention of operation of the equipment(s) is to provide simultaneous independent operation of Iridium AMS(R)S and Inmarsat AMS(R)S and/or AMSS equipment. If such simultaneous independent operation is not desired, the SATCOM A/SATCOM B interference tests identified in the following sections need not be performed.

3.4.2.1 Antenna Isolation

If the declared isolation between the AMS(R)S and any GNSS antenna is greater than 55 dB, in accordance with the provisions of Section 2.2.3.1.2.1.2, the installed isolation shall be tested for each aircraft installation.

3.4.2.2 SATCOM B Interference to SATCOM A

Note: This requirement is only applicable under the conditions described in Section 2.1.8.

Perform the following steps:

1. With SATCOM B inactive, establish a voice call on SATCOM A. Verify that the call is maintained when SATCOM B is switched on and commanded to initiate a packet mode communications session, if appropriate. Verify that the SATCOM A voice call is maintained when the SATCOM B transfers a package message of 4000 octets containing random binary data. Terminate the SATCOM B packet mode communications session and verify that the SATCOM A voice call is maintained.

2. Repeat the process of Step 1 with SATCOM B circuit mode data communications, if appropriate.

3. Repeat the process of Step 1 with SATCOM B voice communications if, appropriate.

4. Repeat the process of Steps 1, 2, and 3, with SATCOM A circuit switched data communications.

5. Repeat the process of Steps 1, 2, and 3, with SATCOM A Short Burst Data (SBD) communications. Test the ability of SATCOM A to perform 10 SBD transactions of at least 220 bytes each.

6. With SATCOM A inactive, initiate a SATCOM B packet mode communications session. Transmit a series of test messages of 4000 octets each. While the transmission is in progress, activate the SATCOM A. Verify that SATCOM A can acquire the network. Verify that the AES can initiate and sustain a SATCOM A voice call lasting 60 seconds during SATCOM B packet mode operations. Verify that the AES can properly terminate its voice call.

7. Repeat Step 6 with SATCOM A operating in circuit switched data mode, if applicable. Verify that SATCOM A can initiate and complete a transaction by transmitting a 4000 octets message. Verify that the AES can properly terminate it circuit switched data call.

8. Repeat Step 6 with SATCOM A operating in SBD mode, if applicable. Verify that SATCOM A can perform 10 SBD transactions of at least 220 bytes each. Verify that the AES can properly terminate each SBD transaction.

3.4.2.3 SATCOM A Interference to SATCOM B

Note: This requirement is only applicable under the conditions described in Section 2.1.8.

Repeat the tests of the previous section with the roles of SATCOM A and SATCOM B reversed. This will make SATCOM B the victim and SATCOM A the interferer.

3.4.3 Power Fluctuation Tests

Transceiver aircraft power sources shall be cycled through all normal configurations to verify that the transceiver performance for power interruption recovery during and after power changeover is satisfactory with no discernible abnormal operation (Reference Section 2.2.7).

Note: In-transit data service packets which have been acknowledged on either the DTE or DCE interface, but not yet transferred to the opposite interface, may be lost. Non-transceiver higher layer entities which employ end-to-end acknowledgment protocols may choose to retransmit such lost data.

3.4.4 Ground Test Procedures

Perform the ground test portions of tests defined in manufacturer's installation instructions.

3.4.5 Flight Test Procedures

Flight tests of installed systems are desirable to confirm or supplement bench and ground tests of installed performance. Flight tests may be defined in the manufacturer's installation instructions.

3.4.6 Installed System Performance Verification

3.4.6.1 Installed Functionality

Performance of the installed avionics, consisting of the Antenna Subsystem and the Transceiver Subsystem, should be verified in accordance with the manufacturer’s instructions. The following general functional categories shall be validated:

Subnetwork Physical Layer – Verify by initiating and terminating multiple communications sessions in all applicable modes and with all applicable channels. This test shall include test of the maximum capability of N_V and N_D simultaneous communications channels as declared by the manufacturer.

Network Management Tests – Verify the ability of the AES to acquire and register with the network from a cold start. Verify that the AES performs the appropriate registration or log-on functions as specified in the technique-specific appendix. If multiple data channels are available, verify that they can be assigned and released as required.

Message Transfer Tests – For all operational modes (e.g., voice, circuit switched data, and SBD) ensure that the AES can initiate and receive data and sustain communications in its installed environment. Voice calls should extend for at least five minutes. Circuit switched data transfers should include at least 4000 octets in each direction. SBD transactions should be at least 220 bytes in length.

Circuit Mode Services – Verify that the mechanism for selecting, dialing, and releasing a circuit are operational. Verify that the mechanisms for accepting, and rejecting an incoming call are through operator action operational.

3.4.6.2 Installed Antenna Coverage

The antenna tests of Section 2.4.3.1.1 provide sufficient verification of coverage for top-mounted antenna installation using non-steered antennas with essentially hemispherical patterns. These installations are expected to be the common installation for most platforms.

4 EQUIPMENT OPERATIONAL PERFORMANCE CHARACTERISTICS

AMSS AES installations are expected to be accomplished in a variety of ways to fit the aircraft equipment and intended usage. This will also be the case with associated cockpit interfaces. The requirements of this section shall be suitably interpreted for the particular installation under consideration.

4.1 Operational Performance Requirements

The following sections identify requirements to ensure the operator that operations can be conducted safely and reliably in the expected operational environment.

4.1.1 Power Input

Prior to flight, the primary power must be available for proper operation.

4.1.2 Communications Displays

The required display(s) for the selection of various communication modes/functions of operation shall be available for use.

4.1.3 Communications Controls

Cockpit control(s) required for proper operation of the equipment shall be available for use.

4.1.4 System Operational Indication

Communication failure or degradation below minimum acceptable performance shall be readily discernible.

4.1.5 Equipment Operating Limitations

Equipment operating limitations of the aircraft Earth station should be contained in the aircraft flight manual.

4.2 Test Procedures for Operational Performance Requirements

Operational equipment tests may be conducted as part of normal preflight tests. For those tests which can only be run in flight, procedures should be developed to perform these tests as early in the flight as possible to verify that the equipment is performing its intended function(s).

4.2.1 Power Input

With the aircraft's electrical power generating system operating, energize the equipment and verify that electrical power is available to the equipment.

4.2.2 Communications Displays

With the equipment operating, verify that the required display(s) are operational.

4.2.3 Communications Controls

The communications control(s) shall be operated, as required, to verify satisfactory equipment response.

4.2.4 System Operational Indication

System operational readiness shall be monitored either by means of Built-In-Test-Equipment (BITE) and/or by suitable preflight tests contained in a check list or flight manual. All equipment failure annunciators shall be tested during preflight tests to verify proper operation.

5 AES CLASSIFICATION CONFIGURATION AND TEST REFERENCE

Different classes of AES configurations are outlined in Sections 2.2.1.1 through 2.2.1.3. The classes defined are AES1, AES2 and AES3. These classes are defined by the antenna type and all are based on a single Iridium antenna for both transmitting and receiving Iridium Satellite signals. AES1 and AES2 require a passive antenna while an AES3 requires either a passive or active antenna.

5.1 AES Configurations

Developers may desire to include more than one AES class into a single unit for installation in an aircraft. Such a design will require an independent antenna path for each AES class. Such an installation is different from the AES3 class where N transceivers share a single active antenna. For clarity, the following table identifies the expected combination of AES classes.

All AES classes shall support AMS(R)S (voice and/or data) services nut may also support AMSS non-safety (voice and/or data) communication. See Section 2.2.2 for more information on AES classes.

<u>Note</u>:

1) *While the table outlines the most likely combinations, in theory a single unit could be configured with N transceivers with equal number N antenna connections. The same requirements would apply for intermodulation and other for multiple AES configurations.*
2) *If more than one AES is combined into a design, each AES must be certified independently and in combination of intermodulation requirements for multi-channel system given simultaneous transmit capability of separate AES class.*

AES Configurations Combinations in one avionics box	**# of Antenna Connections & Type**	**Notes:**
AES1 and AES1	Two (2) Passive LGA	Two SBD for primary and secondary ACARS
AES1 and AES2	Two (2) Passive LGA	One or two LBT for voice and/or data and one SBD for ACARS
AES2 and AES2	Two (2) Passive LGA	Two to four LBT for any combination of voice and/or data lines – 4 max total
N# AES2	N# Passive LGA	N min to N*2 max total of voice and/or data lines maximum using N to N*2 LBTs
AES3	One (1) - Passive LGA or Active IGA/HGA	2 to 16 LBT and/or data for 2 or more voice and/or data lines

Table 5-1 AES Configurations

5.2 AES Test Reference

The following table identifies the testing requirements as outlined in this document by AES class.

Table 5-2 AES Test Reference

		AES1	AES2	AES3
	AES class as defined in relevant Section	2.2.1.1	2.2.1.2	2.2.1.3
2	EQUIPMENT PERFORMANCE REQUIREMENTS AND TEST PROCEDURES			
2.1	General Requirements			
2.1.1	Airworthiness	X	X	X
2.1.2	Intended Function	X	X	X
2.1.3	Federal Communications Commission's Rules	X	X	X
2.1.4	Fire Protection	X	X	X
2.1.5	Operation of Controls	X	X	X
2.1.6	Accessibility of Controls	X	X	X
2.1.7	Effects of Tests	X	X	X
2.1.8	Performance in a Shared Environment	X	X	X
2.1.9	AES Availability	X	X	X
2.2	Equipment Performance Requirements, Standard Conditions			
2.2.1	Avionics Subsystem Definitions and Overall Requirements	X	X	X
2.2.1.1	AES1 Subsystem Definition	X		
2.2.1.2	AES2 Subsystem Definition		X	
2.2.1.3	AES3 Subsystem Definition			X
2.2.2	Definition of System Specific Parameters	X	X	X
2.2.3	Detailed Requirements			
2.2.3.1	AES Application Requirements	X	X	X
2.2.3.1.1	Antenna	X	X	X
2.2.3.1.1.1	Coverage Volume, Polarization and Antenna Gain	X	X	X
2.2.3.1.1.1.1	Coverage Volume	X	X	X
2.2.3.1.1.1.2	Polarization	X	X	X
2.2.3.1.1.1.3	Antenna Gain	X	X	X
2.2.3.1.1.1.4	Weighted Average Gain Coefficients	X	X	X
2.2.3.1.1.2	Axial Ratio	X	X	X
2.2.3.1.1.3	Power Handling Capabilities	X	X	X
2.2.3.1.1.3.1	Single Carrier Units	X	X	X
2.2.3.1.1.3.2	Multi-Carrier Units	X	X	X
2.2.3.1.1.4	Passband	X	X	X
2.2.3.1.1.5	Antenna Voltage Standing Wave Ratio	X	X	X

		AES1	AES2	AES3
	AES class as defined in relevant Section	2.2.1.1	2.2.1.2	2.2.1.3
2.2.3.1.1.6	Radiated Antenna Intermodulation Products	X	X	X
2.2.3.1.1.6.1	Radiated Antenna Intermodulation Products in the GNSS Band	X	X	X
2.2.3.1.1.6.2	Radiated Antenna Intermodulation in AMS(R)S Bands	X	X	X
2.2.3.1.1.7	Carrier-to-Multipath Discrimination	X	X	X
2.2.3.1.1.8	Pattern Discrimination	X	X	X
2.2.3.1.1.9	Steered Antenna Requirements			X
2.2.3.1.1.9.1	Phase Discontinuity			X
2.2.3.1.1.9.2	Beam Switching Time			X
2.2.3.1.1.9.3	Steering Rate			X
2.2.3.1.1.9.4	Pattern Discrimination			X
2.2.3.1.2	Transceiver Subsystem	X	X	X
2.2.3.1.2.1	Transmitter Function	X	X	X
2.2.3.1.2.1.1	Minimum Power Output	X	X	X
2.2.3.1.2.1.2	Maximum Individual Carrier Output	X	X	X
2.2.3.1.2.1.3	Maximum Total Transmitter Output	X	X	X
2.2.3.1.2.1.4	Transmitter Intermodulation Performance	X	X	X
2.2.3.1.2.1.4.1	Narrow-band (CW) Intermodulation Performance	X	X	X
2.2.3.1.2.1.4.2	Modulated Intermodulation Multi-Carrier Performance	X	X	X
2.2.3.1.2.1.5	Transmitter Harmonics, Discrete Spurious and Noise Density	X	X	X
2.2.3.1.2.1.6	Protection of Radio Astronomy	X	X	X
2.2.3.1.2.1.7	Carrier Off Level	X	X	X
2.2.3.1.2.1.8	Power Control	X	X	X
2.2.3.1.2.1.9	On-Channel Output Spectrum	X	X	X
2.2.3.1.2.1.10	Transmitter Operation in Moving Aircraft	X	X	X
2.2.3.1.2.1.11	Manufacturer Defined Transmitter Tests	X	X	X
2.2.3.1.2.2	Receiver Function	X	X	X
2.2.3.1.2.2.1	Receiver Sensitivity	X	X	X
2.2.3.1.2.2.1.1	Data Sensitivity	X	X	X
2.2.3.1.2.2.1.2	Voice Sensitivity	X	X	X
2.2.3.1.2.2.2	Receiver Bandwidth	X	X	X
2.2.3.1.2.2.3	Rejection of Signals Outside the NGSS Receive Band	X	X	X
2.2.3.1.2.2.4	Rejection of Carrier Signals Generated by Other AMS(R)S Equipment	X	X	X

		AES1	AES2	AES3
	AES class as defined in relevant Section	2.2.1.1	2.2.1.2	2.2.1.3
2.2.3.1.2.2.5	Receiver Operation in Moving Aircraft	X	X	X
2.2.3.1.2.2.6	Receiver Susceptibility	X	X	X
2.2.3.1.2.2.7	Receiver Damage	X	X	X
2.2.3.2	User Link Modulation and Signal in Space (Physical Layer)	X	X	X
2.2.3.3	Priority, Precedence and Preemption	X	X	X
2.2.3.3.1	Packet Data	X	X	X
2.2.3.3.2	Circuit Mode Communications (Voice)		X	X
2.2.3.4	Satellite Subnetwork Data Protocol (Satellite Layer 2)	X	X	X
2.2.3.5	Voice Protocol		X	X
2.2.3.5.1	Vocoder Interoperability with Satellite Subnetwork		X	X
2.2.3.5.2	Vocoder Performance in an Aeronautical Environment		X	X
2.2.3.6	User Data Interfaces	X	X	X
2.2.3.6.1	ATN-Compliant Service Interface	X	X	X
2.2.3.6.1.1	Join and Leave Requirements	X	X	X
2.2.3.6.1.2	ATN-Compliant Mapping for Priority, Precedence & Preemption	X	X	X
2.2.3.6.2	ACARS	X	X	X
2.2.3.6.3	Satellite Subnetwork Requirements	X	X	X
2.2.3.6.3.1	Satellite Subnetwork Dependent Protocol Requirements	X	X	X
2.2.3.6.3.2	ATN-compliant Requirements	X	X	X
2.2.3.6.3.3	ACARS Requirements	X	X	X
2.2.3.6.4	External Physical and Data Link Layer Requirements	X	X	X
2.2.3.6.5	Avionics Sub-network Interface Requirements for ISO-8208	X	X	X
2.2.3.6.6	Alternative ATN-compliant Subnetwork Access Protocols	X	X	X
2.2.3.7	Circuit Mode Service Requirements	X	X	X
2.2.3.8	Recovery from Primary Power Interruption	X	X	X
2.2.3.9	Failure/Status Indication	X	X	X
2.2.3.10	Information Security	X	X	X
2.3	Equipment Performance - Environmental Conditions			
2.3.1	General Requirements	X	X	X
2.3.2	Equipment Configurations	X	X	X
2.3.3	Configuration Control	X	X	X
2.3.4	Specific Environmental Test Conditions	X	X	X
2.3.5	Performance vs. Test Requirements Matrix	X	X	X
2.4	Equipment Performance Verification Procedures			
2.4.1	Definitions of Terms and Conditions of Test	X	X	X

		AES1	AES2	AES3
	AES class as defined in relevant Section	2.2.1.1	2.2.1.2	2.2.1.3
2.4.1.1	AES Application Test Conditions	X	X	X
2.4.1.1.1	Antenna Subsystem Test Conditions	X	X	X
2.4.1.1.1.1	Antenna Under Test	X	X	X
2.4.1.1.2	Transceiver Subsystem Test Conditions	X	X	X
2.4.1.1.3	Required Aircraft Interfaces Test Conditions	X	X	X
2.4.1.2	Satellite Sub-network Test Conditions	X	X	X
2.4.1.3	Priority, Precedence and Preemption Test Conditions	X	X	X
2.4.1.4	Satellite Sub-network Data Protocol Test Conditions	X	X	X
2.4.1.5	Voice Protocol Test Conditions		X	X
2.4.1.6	User Data Interfaces Test Conditions	X	X	X
2.4.1.7	Circuit Mode Service Test Conditions	X	X	X
2.4.1.8	Recovery from Primary Power Failure Test Conditions	X	X	X
2.4.1.9	Failure/Status Indication Test Conditions	X	X	X
2.4.2	Required Test Equipment	X	X	X
2.4.2.1	AES Application	X	X	X
2.4.2.1.1	Antenna Subsystem Required Test Equipment	X	X	X
2.4.2.1.1.1	Standard Test Equipment	X	X	X
2.4.2.1.1.2	Special Test Equipment	X	X	X
2.4.2.1.2	Transceiver Subsystem Required Test Equipment	X	X	X
2.4.2.1.2.1	Standard Test Equipment	X	X	X
2.4.2.1.2.2	Special Test Equipment	X	X	X
2.4.2.1.3	Required Aircraft Interfaces Required Test Equipment	X	X	X
2.4.2.2	Modulation and Signal in Space Required Test Equipment	X	X	X
2.4.2.3	Priority, Precedence and Preemption Test Equipment	X	X	X
2.4.2.3.1	Packet Data	X	X	X
2.4.2.3.2	Circuit Mode Communications	X	X	X
2.4.2.4	Satellite Sub-network Data Protocol Test Equipment	X	X	X
2.4.2.5	Voice Protocol Required Test Equipment		X	X
2.4.2.6	User Data Interface Required Test Equipment	X	X	X
2.4.2.7	Circuit Mode Service Test Equipment	X	X	X
2.4.2.8	Recovery from Primary Power Interruption Test Equipment	X	X	X
2.4.2.9	Failure/Status Indication Test Equipment	X	X	X
2.4.3	Detailed Test Procedures	X	X	X
2.4.3.1	AES Application Requirements	X	X	X
2.4.3.1.1	Antenna Test Requirements	X	X	X
2.4.3.1.1.1	Polarization, Gain and Coverage Volume	X	X	X
2.4.3.1.1.2	Antenna Axial Ratio	X	X	X

		AES1	AES2	AES3
	AES class as defined in relevant Section	2.2.1.1	2.2.1.2	2.2.1.3
2.4.3.1.1.3	Power Handling	X	X	X
2.4.3.1.1.4	Antenna Passband	X	X	X
2.4.3.1.1.5	Antenna VSWR	X	X	X
2.4.3.1.1.6	Radiated Antenna Intermodulation Products	X	X	X
2.4.3.1.1.6.1	Antenna Intermodulation in the GNSS Band	X	X	X
2.4.3.1.1.6.2	Antenna Intermodulation in AMS(R)S Band(s)	X	X	X
2.4.3.1.1.7	Carrier-to-Multipath Discrimination	X	X	X
2.4.3.1.1.8	Pattern Discrimination	X	X	X
2.4.3.1.1.9	Steered Antenna Requirements			X
2.4.3.1.1.9.1	Phase Discontinuity			X
2.4.3.1.1.9.2	Beam Switching Time			X
2.4.3.1.1.9.3	Steering Rate			X
2.4.3.1.1.9.4	Pattern Discrimination			X
2.4.3.1.2	Transceiver Subsystem Test Requirements	X	X	X
2.4.3.1.2.1	Transmitter Performance	X	X	X
2.4.3.1.2.1.1	Transmitter Minimum Power Output	X	X	X
2.4.3.1.2.1.2	Maximum Individual Carrier Output	X	X	X
2.4.3.1.2.1.3	Maximum Total Transceiver Output Carrier Power	X	X	X
2.4.3.1.2.1.4	Transmitter Intermodulation Products	X	X	X
2.4.3.1.2.1.4.1	Narrow Band Intermodulation Performance	X	X	X
2.4.3.1.2.1.4.2	Modulated Intermodulation Performance	X	X	X
2.4.3.1.2.1.5	Transmitter Harmonics, Discrete Spurious and Noise Density	X	X	X
2.4.3.1.2.1.6	Protection of Radio Astronomy	X	X	X
2.4.3.1.2.1.7	Carrier Off Level	X	X	X
2.4.3.1.2.1.8	Power Control	X	X	X
2.4.3.1.2.1.9	On-Channel Output Spectrum	X	X	X
2.4.3.1.2.1.10	Transmitter Operation in Moving Aircraft	X	X	X
2.4.3.1.2.2	Receiver	X	X	X
2.4.3.1.2.2.1	Receiver Sensitivity	X	X	X
2.4.3.1.2.2.2	Receiver Sensitivity (Voice)		X	X
2.4.3.1.2.2.3	Test Method for Environmental Conditions	X	X	X
2.4.3.1.2.2.4	Receiver Bandwidth	X	X	X
2.4.3.1.2.2.5	Rejection of Signals Outside NGSS Receive Band	X	X	X
2.4.3.1.2.2.6	Rejection of Carrier Signals Generated by Other AMS(R)S Equipment	X	X	X
2.4.3.1.2.2.7	Receiver Operation in Moving Aircraft	X	X	X
2.4.3.1.2.2.8	Receiver Susceptibility	X	X	X

		AES1	AES2	AES3
	AES class as defined in relevant Section	2.2.1.1	2.2.1.2	2.2.1.3
2.4.3.2	Satellite Subnetwork Specific Test Requirements	X	X	X
2.4.3.3	Priority, Precedence and Preemption	X	X	X
2.4.3.3.1	Packet Data	X	X	X
2.4.3.3.2	Circuit Mode Communications	X	X	X
2.4.3.4	Satellite Subnetwork Data Protocol (Satellite Layer 2)	X	X	X
2.4.3.5	Voice Protocol		X	X
2.4.3.5.1	Vocoder Interoperability With Satellite Subnetwork		X	X
2.4.3.5.2	Vocoder Performance in an Aeronautical Environment		X	X
2.4.3.6	User Data Interfaces	X	X	X
2.4.3.6.1	ATN Interfaces	X	X	X
2.4.3.6.1.1	Join and Leave Requirements	X	X	X
2.4.3.6.1.2	ATN-Compliant Mapping for Priority, Precedence & Preemption	X	X	X
2.4.3.6.2	ACARS	X	X	X
2.4.3.6.3	Satellite Subnetwork	X	X	X
2.4.3.6.3.1	Satellite Subnetwork Dependent Protocol	X	X	X
2.4.3.6.4	Avionics Subnetwork Interface	X	X	X
2.4.3.6.4.1	ATN Compliant Physical and Data Link Requirements	X	X	X
2.4.3.7	Circuit Mode Test Procedures	X	X	X
2.4.3.8	Recovery from Primary Power Interrupt Test Procedure	X	X	X
2.4.3.9	Failure/Status Indication Test Procedure	X	X	X
3	INSTALLED EQUIPMENT PERFORMANCE			
3.1	Equipment Installation			
3.1.1	Accessibility	X	X	X
3.1.2	Aircraft Environment	X	X	X
3.1.3	Display Visibility	X	X	X
3.1.4	Inadvertent Turn-Off	X	X	X
3.1.5	Failure Protection	X	X	X
3.1.6	Interface Interference Effects	X	X	X
3.1.7	Aircraft Power Source	X	X	X
3.1.8	Antenna Location/Installation	X	X	X
3.1.9	Co-Location with other Iridium SATCOM Systems	X	X	X
3.2	Installed Equipment Performance Requirements			
3.2.1	Radiated Antenna Intermodulation Products in AMS(R)S Bands	X	X	X
3.2.2	Declaration of Additional Isolation	X	X	X
3.3	Conditions of Test			
3.3.1	Power Input	X	X	X
3.3.2	Environment	X	X	X

		AES1	AES2	AES3
	AES class as defined in relevant Section	2.2.1.1	2.2.1.2	2.2.1.3
3.3.3	Adjustment of Equipment	X	X	X
3.3.4	Warm-up Period	X	X	X
3.4	Test Procedures for Installed Equipment Performance			
3.4.1	Conformity Inspection	X	X	X
3.4.2	Interference Tests	X	X	X
3.4.2.1	Antenna Isolation	X	X	X
3.4.2.2	SATCOM B Interference to SATCOM A	X	X	X
3.4.2.3	SATCOM A Interference to SATCOM B	X	X	X
3.4.3	Power Fluctuation Tests	X	X	X
3.4.4	Ground Test Procedures	X	X	X
3.4.5	Flight Test Procedures	X	X	X
3.4.6	Installed System Performance Verification	X	X	X
3.4.6.1	Installed Functionality	X	X	X
3.4.6.2	Installed Antenna Coverage	X	X	X

6 ABBREVIATIONS

AAC	Aeronautical Administrative Communications
AC	Alternating Current
ACARS	Aircraft Communications and Reporting System
ACCHL	Associated Control Channel, L-Band
AES	Aircraft Earth Station
AGPDUs	Air-to-Ground Data Units
AMS(R)S	Aeronautical Mobile Satellite (Route) Services
AMSS	Aeronautical Mobile Satellite Services
AOC	Aeronautical Operational Control
ARINC	Aeronautical Radio Inc.
ASSP	Aviation Safety Service Provider (e.g. FAA)
ATC	Air Traffic Control
AtG	Air to Ground
ATN	Air Traffic Network
ATS	Air Traffic Service
ATSP	Aeronautical Telecommunications Service Provider
APC	Aeronautical Public Correspondence
AUT	Antenna Under Test
BER	Bit Error Rate
BPSK	Binary Phase Shift Keying
CC	Call Control
C/M	Carrier to Multipath Ratio
CPDLC	Controller-Pilot Datalink Communications
CSD	Circuit Switched Data
CW	Continuous Wave
°C	Degrees Celsius
dB	Decibel
dBi	Decibels-isotropic
dBm	Decibel referenced to 1 milliwatt
dBW	Decibel referenced to 1 watt
DC	Direct Current
DCE	Data Communications Equipment
DE-QPSK	Differential Encoding
DFOA	Differential Frequency of Arrival
DQPSK	Differential Quadrature Phase Shift Keying
DTE	Data Terminal Equipment
DTOA	Differential Time of Arrival
DUT	Device Under Test
EIRP	Effective Isotropic Radiated Power
EMI	Electromagnetic Interference
ESD	Electrostatic Discharge
ETSI	European Telecommunications Standards Institute
F	Fahrenheit
FAA	Federal Aviation Administration
FANS/1A	Future Air Navigation System
FAR	Federal Airworthiness Regulations

FCC	Federal Communications Commission
FCS	Frame Check Sequence
FDMA	Frequency Division Multiple Access
FEC	Forward Error Correction
GAVG	Weighted Average Gain
GES	Ground Earth Station (Gateway)
GLONASS	Globalnaya navigatsionnaya sputnikovaya sistema (or Global Navigation Satellite System)
GNSS	Global Navigation Satellite System
GOLD	Global Operational Data Link Document
GPS	Global Positioning System
GSM	Global System for Mobile Communications
G/T	Gain to Noise Temperature Ratio
GtA	Ground to Air
HGA	High Gain Antenna
HIRF	High Intensity Radiated Field
HLEs	Higher Layer Entities
HSN	Harmonic Spurious Noise
ICAO	International Civil Aviation Organization
IEEE	Institute of Electrical and Electronic Engineers
IGA	Intermediate Gain Antenna
IM	Intermodulation
IP	Internet Protocol
ISO	International Organization of Standards
ISLLC	Iridium Satellite LLC
ITU	International Telecommunications Union
IWF	InterWorking Function
K	Kelvins
kHz	kilo hertz
ksps	kilo symbols per second
kPa	kilo pascals
LAI	Location Area Identity
LBT	L-Band Transceiver
LBP	L-Band Physical
LEO	Low Earth Orbit
LGA	Low Gain Antenna
LL	L-Band Link
LSI	Link Service Interface
m	meters
MASPS	Minimum Aircraft System Performance
Specification	
MHz	Mega hertz
MLPPP	Multi-link PPP
mm	millimeters
MM	Mobility Management
MO	Mobile Originated
MODEM	Modulator-Demodulator
MOPS	Minimum Operational Performance
Specification	
MOS	Mean Opinion Score

ms	milli seconds
MSC-MS	Mobile Switching Center to Mobile Subscriber
MSS	Mobile Satellite Service
MT	Mobile Terminated
MTBF	Mean Time Between Failure
MTTR	Mean Time to Repair
NDA	Non-Disclosure Agreement
NF	Noise Figure (in dB)
NGSS	Next Generation Satellite Systems
NIST	National Institute for Standards and Technology
OSN	Operational Support Network
PAA	Protocol Analyzer Air
PAG	Protocol Analyzer Ground
PER	Packet Error Rate
PLP	Packet Layer Protocol
PPP	Point to Point Protocol
PSTN	Public Switched Telephone Network
PSDN	Public Switched Data Network
QPSK	Quadrature Phase Shift Keying
RHCP	Right Hand Circular Polarization
RF	Radio Frequency
RRC	Root Raised Cosine
RTCA	Radio Technical Commission for Aeronautics
Rx	Receive
RUDICS	Router-Based Unrestricted Digital Interworking Connectivity Solution
SARPS	Standards and Recommended Practices
SBD	Short Burst Data
SDU	Satellite Data Unit
SITA	Formerly - Société Internationale de Télécommunications Aéronautiques
SNOC	Satellite Network Operations Center
SNPDU	SubNetwork Protocol Data Units
SSNAc	Satellite Subnetwork Access
SSND	Satellite Subnetwork Dependent
SSNDP	Satellite Subnetwork Dependent Protocol
SSNL	Satellite Subnetwork Layer
SVGM	SATCOM Voice Guidance Material
SV	Satellite Vehicle
SVC’s	Subnetwork Switched Virtual Circuits
TCP/IP	Transport Control Protocol/Internet Protocol
TDD	Time Division Duplex
TDMA	Time Division Multiple Access
TMSI	Temporary Mobile Subscriber Identification
TSO	Technical Standard Order
TTAC	Telemetry, Tracking, and Control
Tx	Transmit
VAM	Value Added Manufacturer
VSWR	Voltage Standing Wave Ratio

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APPENDIX E – NORMATIVE REQUIREMENTS FOR INMARSAT SWIFTBROADBAND AMS(R)S EQUIPMENT

1 INTRODUCTION

1.1 Scope and Objectives

This appendix to DO-262 provides information and requirements specific to an Aircraft Earth Station (AES) using the Inmarsat SwiftBroadband system for the purpose of providing Aeronautical Mobile Satellite (Route) Service (AMS(R)S). The International Civil Aviation Organization (ICAO) and the International Telecommunication Union (ITU) reserve the designation “(Route)” for services related to the “priority and regularity of flights along national and international air routes”.

This appendix forms a “technique-specific appendix” to DO-262. It provides information about the Inmarsat SwiftBroadband service provided over the Inmarsat satellite network. As required by the main body of DO-262, a normative section of the appendix provides the detailed requirements and test procedures for an AES providing SwiftBroadband service to an aircraft. Compliance with these requirements and test procedures is intended to provide one means of providing evidence for certification or other approval of an AES for SwiftBroadband AMS(R)S. Alternative means of compliance that provide equivalent information are acceptable.

The performance requirements for the end-to-end communications network, as shown in Figure 1-1, are contained in the MASPS [6]. The MASPS aims to comply with data link requirements in the ICAO Global Operational Data Link Document (GOLD) [7] document and the voice link requirement in the ICAO Satellite Voice Guidance Material (SVGM) [8]. This appendix aims to define requirements for the AES which are harmonized with the MASPS, GOLD and SVGM documents.

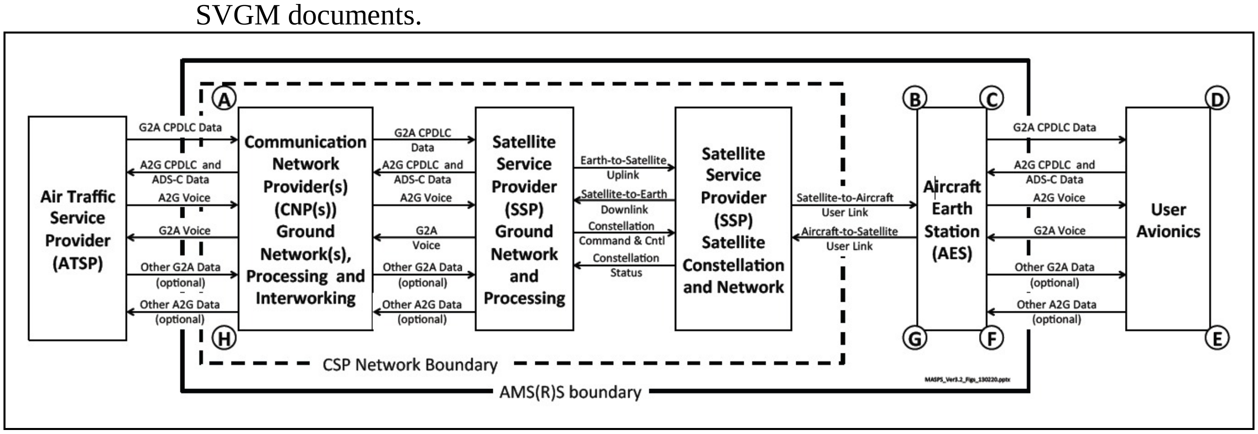

Figure 1-1 AMS(R)S System, with Notional Partitioning.

The focus of this appendix is on ensuring that the AES will functionally deliver the intended services over the AMS(R)S network, without necessarily exploring all the detail of the underlying mechanisms which enable the service.

A graphical representation of the requirements for the AES is shown in Figure 1-2. The focus in this appendix is on ensuring correct behavior of the AES at the services interfaces, where the user avionics interact with the AES, and at the signals-in-space interface, where the AES has desired interaction with the network, and potentially undesired interaction with other aircraft systems and the outside world. For this reason this appendix contains much detail on the radio characteristics at the physical layer. Likewise, there is ample detail of the observable behavior of the AES at the AMS(R)S service application level.

The details of the protocol layers (Layers 2 and 3) between the physical layer and the service applications are defined in great detail in the Inmarsat SDM [1], and verified by performing Inmarsat MTRs [2]. These layers are verified as part of the Inmarsat Type Approval process. Evidence of Inmarsat's approval is considered sufficient evidence that these layers operate correctly. Furthermore, the verification at service level which is provided by this appendix gives further evidence that the underlying layers are operating as intended.

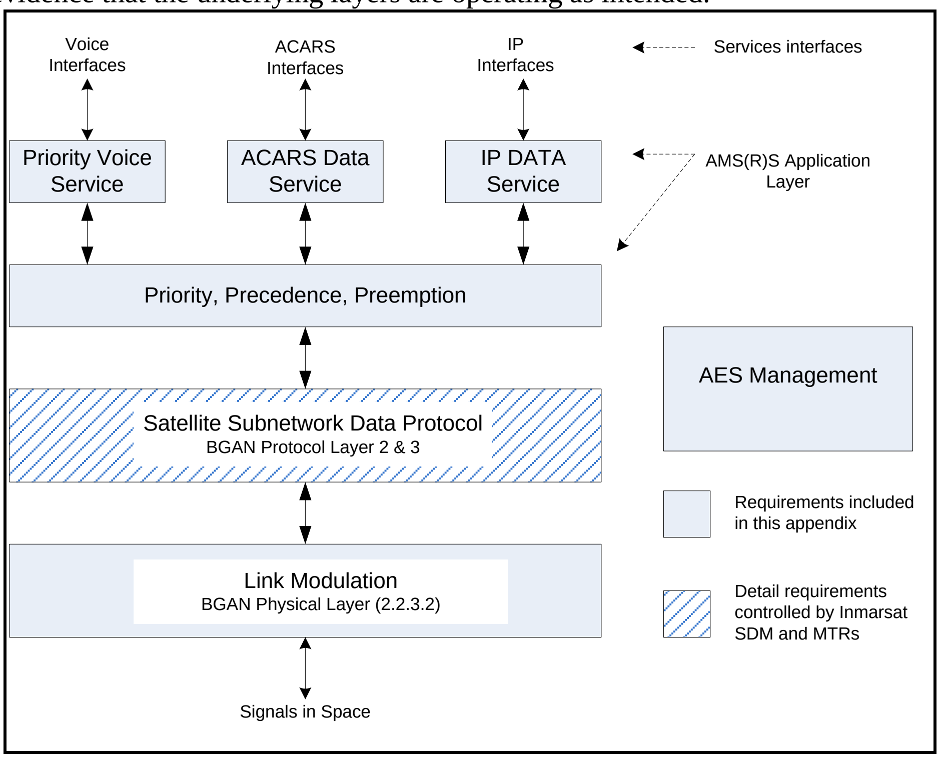

Figure 1-2 AES Requirements Map

Key aspects of the MASPS [6] deal with various parameters related to availability and latency of the communication capabilities offered by the end-to-end network. Portions of these key parameters have been allocated to the AES, and are specified in this appendix. Referring to Figure 1-1, these allocated parameters apply between points B and C in forward (ground-to-air) direction and points F and G in the return (air-to-ground) direction.

AES management functions (see Figure 1-2) which are important to AMS(R)S are also described, for example satellite handovers and handling of short power outages.

The emissions requirements in this appendix ensure compliance to the requirements of ETSI EN 301 473 [9]. This appendix provides requirements conveniently extracted and interpreted from ETSI EN 301 473 [9]. The text of this appendix therefore makes minimal reference to ETSI EN 301 473.

1.2 Document Overview

Section 1 of this appendix provides an informative description of the Inmarsat SwiftBroadband network, focusing on aspects particular to AMS(R)S (also known as "SBB Priority Services"). Section 1 is aimed at providing background knowledge required to understand the normative requirements for the AES, contained in the subsequent sections. Section 1 therefore does not include any normative requirements.

Section 2 contains the SwiftBroadband-specific normative performance requirements and test procedures for testing of the equipment before installation onto an aircraft. The section is divided into general requirements (Section 2.1), performance requirements (Section 2.2), performance to be verified under environmental conditions (Section 2.3) and equipment verification procedures (Section 2.4). These sections are organized based on the numbering and format of the DO-262 document.

Section 3 contains requirements that apply when planning and executing an installation and type certification (TC or STC) of a specific AES on a specific aircraft type.

Section 4 gives guidance when verifying operational performance of equipment already installed on an aircraft.

This appendix makes frequent use of references to the Inmarsat System Definition Manual (SDM) [1] in order to harmonize requirements for Inmarsat Type Approval and MOPS testing. This is particularly prevalent in Section 2.2.3 (Detailed Requirements).

Similarly, the Inmarsat Mandatory Test Requirements (MTRs) are frequently referenced in individual subsections of Section 2.4 (Equipment Performance Verification Procedures). This is done to avoid unnecessary duplication of tests.

1.2.1 Applicable Documents

The detailed description of the SwiftBroadband service and the BGAN network is contained in Inmarsat proprietary documents. The RTCA proprietary disclaimer notice, at the beginning of the DO-262 document, applies to these referenced documents. The documents may be obtained from Inmarsat PLC in London under a non-disclosure agreement.

The specific versions of these documents listed below should be used. Where later versions are used, applicants may be required to ensure that the requirements of the listed versions are still met.

Table 1-1 Applicable Documents

Reference	Document Name
[1]	Inmarsat BGAN System Definition Manual (SDM) Release 3.4.
[2]	Inmarsat MTRs as listed in Table 1-3.
[3]	Environmental Conditions and Test Procedures for Airborne Equipment,

	RTCA DO-160G.
[4]	Mark III Aviation Satellite Communication Systems, ARINC Characteristic 781-6.
[5]	Minimum Operational Performance Standards for Geosynchronous Orbit Aeronautical Mobile Satellite Services (AMSS) Avionics, RTCA DO-210D plus changes 1, 2 and 3.
[6]	Minimum Aviation System Performance Standard For AMS(R)S Data And Voice Communications Supporting Required Communications Performance (RCP) And Required Surveillance Performance (RSP) In Procedural Airspace, RTCA DO-343( ). (Latest version). Abbreviated to "MASPS" in this appendix.
[7]	ICAO Global Operational Data Link Document (GOLD), 2nd Edition – 26 April 2013.
[8]	ICAO Satcom Voice Guidance Material (SVGM), 1st Edition – 24 July 2012.
[9]	Satellite Earth Stations and Systems (SES); Aircraft Earth Stations (AES) Operating below 3 GHz under the Aeronautical Mobile Satellite Service (AMSS) / Mobile Satellite Service (MSS) and/or the Aeronautical Mobile Satellite on Route Service (AMS(R)S) / Mobile Satellite Service (MSS), ETSI EN 301 473 version 1.4.1 March 2013.
[10]	Airworthiness Security Process Specification, DO-326A ( ) (Latest version)
[11]	RF Test Procedure, Inmarsat Aeronautical Antenna System, David Florida Laboratory Document No DFLD 2253206 Issue A8 12/11/2008

The Inmarsat SDM and MTRs are updated in sections. The tables below give the version numbers of the sections of these documents which make up the SDM and MTR versions listed in Table 1-1 above.

Table 1-2 Applicable Inmarsat SDM Chapters and version numbers

Reference	Volume & Chapter	Version	Description
[20]	V1c1	3.0.0 (CN6)	Introduction to Volume 1
[21]	V1c2	3.0.0 (CN6)	BGAN Services
[22]	V1c3	3.0.0 (CN6)	System Architecture & Interfaces
[23]	V1c4	3.0.0 (CN6)	BGAN System Operation
[24]	V1c5	3.0.0 (CN6)	Applied UMTS Concepts For BGAN
[25]	V1c6	3.0.0 (CN6)	Satellite Air Interface Overview
[26]	V2c1	3.0.0 (CN6)	Introduction to Volume 2
[27]	V2c2	4.1.0 (CN13)	Adaptation Layer Interface
[28]	V2c3	3.0.0 (CN6)	Bearer Connection Layer Interface
[29]	V2c4	4.2.0 (CN14)	Bearer Control Layer Interface
[30]	V2c5	4.2.0	Physical Layer Interface

		(CN14)	
[31]	V2c6	3.0.0 (CN6)	Iu User Plan Interface
[32]	V3C03	4.1.X(CP15)	SwiftBroadband Oceanic Safety Service Requirements
[33]	V4c1	3.0.0 (CN6)	Introduction to Volume 4
[34]	V4c2	4.1.0 (CN13)	Adaptation Layer
[35]	V4c3	4.2.0 (CN14)	Bearer Connection Layer Operation
[36]	V4c4	4.2.0 (CN14)	Bearer Control Layer Operation
[37]	V4c5	3.0.0 (CN6)	RANAP/Relay Operation
[38]	V4c6	3.2.0 (CN8)	User Plane Operation
[39]	V5c1	4.2.0 (CN14)	User Terminal Technical Requirements Specification
[40]	V5c1app1	3.0.0 (CN6)	General UT Behaviour Recommendations
[41]	V5c2	3.0.0 (CN6)	Voice Codec Specification
[42]	V5c3	4.2.0 (CN14)	Aeronautical UT Technical Requirements

Table 1-3 Applicable Inmarsat MTRs and version numbers

Reference	MTR Number	Version	MTR Name
[30]	01	4.2.6	Radiation Pattern
[31]	02	4.2.6	Antenna Polarisation
[32]	03	4.2.6	Antenna Axial Ratio
[33]	04	4.2.6	Pointing Loss
[34]	05	4.2.6	G/T Determination
[35]	06	4.2.7	Receiver Tuning Range
[36]	07	4.2.7	QPSK Frame Acquisition
[37]	08	4.2.7	QPSK Packet Error Rate
[38]	09	4.2.7	QAM Frame Acquisition
[39]	10	4.2.7	QAM Packet Error Rate
[40]	11	4.2.7	QPSK Selectivity
[41]	12	4.2.7	QAM Selectivity
[42]	13	4.2.7	Receiver Dynamic Range
[43]	14	4.2.7	EIRP Determination And Stability
[44]	15	4.2.7	Transmitter Off Level

[45]	16	4.2.7	Spurious And Harmonics
[46]	17	4.2.7	Transmitter Phase Noise
[47]	18	4.2.7	Transmitter Tuning Performance
[48]	19	4.2.7	Transmitter Frequency Accuracy & Stability
[49]	20	4.2.7	Modulator Performance
[50]	21	4.2.7	Transmit Burst Characteristics
[51]	23	4.2.7	C/N_0-Measurement And Reporting
[52]	24	4.2.7	Transmitter Coding Performance
[53]	25	4.2.7	Transmitter Burst Timing Accuracy & Stability
[54]	26	4.2.7	Transmitter Power Spectral Density
[55]	28	4.2.7	Code Rate Detection
[56]	29	4.0	Doppler Compensation
[57]	31	4.2.7	HDR Dynamic Modulation
[58]	ASV01	1.0.1	Aeronautical CS Safety Services MTR
[59]	ASV02	Draft A	SwiftBroadband Oceanic Safety PS Voice Tests
[60]	DC-350201	1.4	AAGW Test Case Descriptions
[61]	43	3.0	Voice Codec Testing using Voice Codec Test Set.

Later versions of MTRs and scripts may be used when testing equipment for a TSO application. The applicant is responsible for showing that an equivalent level of safety has been achieved. The Inmarsat change history for MTRs shall be considered as sufficient justification.

1.3 System Design and Description

1.3.1 SwiftBroadband System Overview

This section provides a brief overview of the SwiftBroadband system. A more complete description is given in the MASPS [6].

The Inmarsat SBB-Safety system provides data and voice communication services that will enable widespread implementation of the 30-30nmi separation standards for oceanic operations along international air routes. Data communication (using ACARS) complies with the RCP240 and RSP180 requirements in GOLD [7], while voice communications complies with the RCP400/V and RSP400/V requirements in SVGM [8].

SBB is composed of four segments:

- Airborne (or user) segment known as an Aircraft Earth Station (AES).
- The satellites.
- The Inmarsat ground infrastructure.
- The Communication Network Provider's (CNP's) ground infrastructure.

The SBB data and voice communication services described in this appendix are delivered between the AES avionics interface and the CNPs' ATSP interfaces as shown in Figure 1-1. Although not shown in the figure, the CNPs also deliver voice and data services to airlines, for operational communications with their aircraft fleet.

SBB is delivered over the Inmarsat-4 satellites (3 satellites launched between 2005 and 2008) and the Alphasat satellite (launched in 2013) using user links in the L band and feeder links in C band. The satellites are geostationary with inclination typically less than 3 degrees, and provide worldwide coverage with the exception of polar regions. Key aspects of the I4 satellites are a single 9m aperture antenna and a transparent, bent-pipe, digital signal processor (DSP) that performs the channelization and beam forming functions. Each satellite provides a global beam, 19 regional beams and typically 192 narrow spot beams. Alphasat has a similar architecture, but has a larger antenna aperture.

Three classes of SBB AES are defined:

- AES4 which uses an Enhanced Low Gain Antenna (ELGA).
- AES7 which uses an Intermediate Gain Antenna (IGA).
- AES6 which uses a High Gain Antenna (HGA).

Inmarsat owns and operates the satellite ground infrastructure and delivers traffic at Meet Me Points (MMPs) to CNPs such as ARINC and SITA. The CNPs provide key elements of the end-to-end ACARS and Voice service and deliver traffic to ATSPs and airlines.

The Aeronautical service offered by the satellites is known as SwiftBroadband (SBB). SBB shares the same satellite and ground infrastructure that is used to deliver similar services to the land and maritime segments. Collectively the service is known as BGAN (Broadband Global Area Network) and this term is often used to describe the totality of the system across all market segments. The maritime service is known as FleetBroadband.

BGAN is based on UMTS 3G technology and delivers standard 3G voice and IP data services. In addition, gateway functions are included that utilize the 3G bearer services to provide the ACARS service and the Voice Over Internet Protocol (VoIP) component of the voice service.

An AES may be designed to offer automatic reversion to the Classic Aero service as described in Section 1.3.9.

The AES provides voice and data communications interfaces to the avionics on the aircraft (see Figure 1-1). The AES connects to the Satellite Service Provider (Inmarsat) ground network through the satellite constellation. A Communication Network Provider delivers these services to the Air Traffic Service Provider (ATSP). The AES is responsible for maintaining its allocated portion of the end-to-end performance parameters between its boundaries at points F and G for air-to-ground communications and points B and C for ground-to-air communications.

1.3.2 Services Provided by SwiftBroadband

Figure 1-3 gives an overview of the priority services and non-priority services provided by SwiftBroadband. The priority services are described below in Section 1.3.2.1 and its subsections. Non-priority services are described in Section 1.3.2.2.

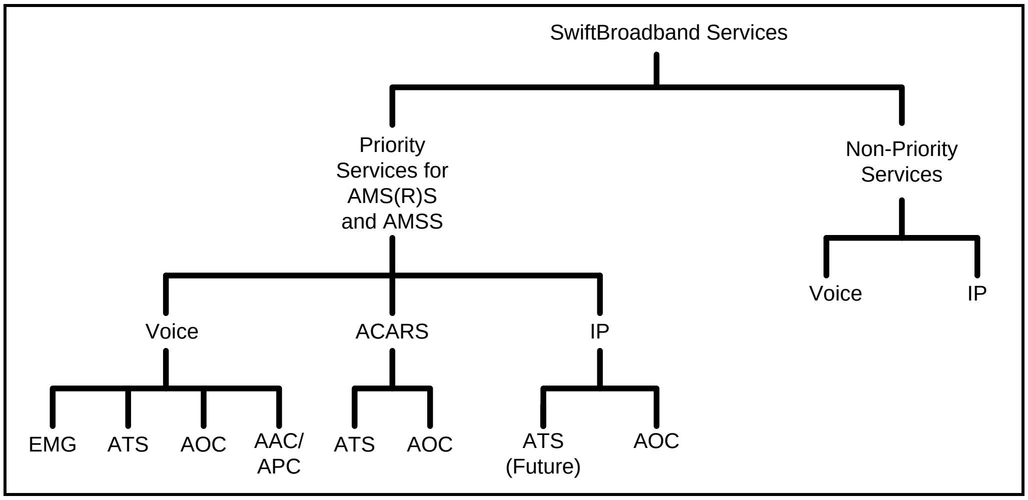

Figure 1-3 SwiftBroadband Services

1.3.2.1 Priority Services

The SBB safety system is capable of providing the priority services described in the following subparagraphs to aircraft within the declared antenna coverage volume. A more detailed description of the priority services may be found in the MASPS [6].

1.3.2.1.1 ACARS Data Service

The ACARS data service is a high availability data service, protected by priority and pre-emption, supporting ATS and AOC ACARS applications. ACARS precedence is established by a higher level entity, typically the CMU and the ACARS network. The interface to the CMU is typically Williamsburg protocol over ARINC 429. Both the air and ground side interfaces are typically the same as for Classic Aero and hence the use of Classic Aero or SBB for ACARS can be transparent to pilots and ground users. The service handles one ACARS block at a time to an aircraft due to the inherent ACARS limitation of being a ‘stop and wait’ protocol.

1.3.2.1.2 Voice Service

The voice service provides one or two channels of priority voice to the cockpit. In addition, the following security provisions are provided: ciphering on the air interface to provide confidentiality, and use of PINs on ground to air calls to restrict access to calling the cockpit from non-authorized callers. The interface to the flight deck avionics is typically analog 4 wire voice and ARINC 429 control from an MCDU or similar function. Both the air and ground side interfaces are typically the same as for Classic Aero, including addressing using the ICAO 24-bit aircraft address, and hence the use of Classic Aero or SBB for voice is typically transparent to pilots and ground users. Calls to and from the cockpit are protected by priority, precedence and preemption - in the AES as well as on the network.

1.3.2.1.3 Priority IP Service

The Priority IP Data service supports IP based applications that require a timely and prioritized service compared to the non-priority SBB IP service. Examples are:

- Meteorological applications
- Engine data
- Flight data downloaded after a critical event
- ATS applications
- AOC applications
- Access to ATN over satellite

Both fixed rate (streaming) and variable bit rate (standard) IPv4 services are provided.
The standard IP service class is a variable bit rate IP service, also known as background class. Capacity is allocated dynamically by the network on the basis of the user's demand, the user's current link quality and the competing demands of other users sharing the same L-Band frequency in the same spot-beam. The background class connection provides reliable in-order delivery over the satellite, i.e. any data lost due to random errors on the radio link is automatically retransmitted and re-ordered by the SBB infrastructure before being presented to the user.
The streaming class IP service is a fixed bit rate IP service. The user sets the bit rate at the start of the connection and this rate is fixed for the duration of that connection. This class is designed for real-time applications that benefit from low delay variations but can tolerate a somewhat higher packet error rate.

1.3.2.2 Non-Priority Services

Depending on the configuration of the AES, it may be capable of providing the following non-priority services:

- multiple voice calls
- background class IP data connections
- streaming class IP data connections

An AES can also be designed or configured to provide non-priority services only. Because all AMS(R)S services are supported within the prioritized services, non-priority services are outside the scope of this appendix.

1.3.3 Space Segment

The Inmarsat I4 network consists of three satellites (in 2012). A new satellite (Alphasat) is planned to replace the existing Europe- Middle East-Africa (EMEA) satellite, which in turn will become an in-orbit spare. Being geostationary, the satellites are nominally positioned over the equator, approximately equally spaced and in fixed positions. Each of the three satellites provides three beam types, distinguished by the size of their footprints: Global, regional and narrow spot beams.

The satellites provide service specified down to 5 degree satellite elevation, as viewed from the AES. Near the poles, however, the beams are extended below the 5 degree limit. This reduces the uncovered area at the poles to a very small percentage of the earth's surface.

The global and regional spot beams are used to support some of the older Inmarsat services (including the Aero H+ service) and also support call set-up procedures for the BGAN services. The narrow spot beams are used by the BGAN services. A 3-color frequency re-use scheme is used for the regional beams, whilst a 4-color scheme is used on the more densely packed narrow spot beams.

Figure 1-4 and Figure 1-5 show examples of global, regional beams and narrow spot beams. Inmarsat has the ability to reconfigure spot beams based on changing requirements.

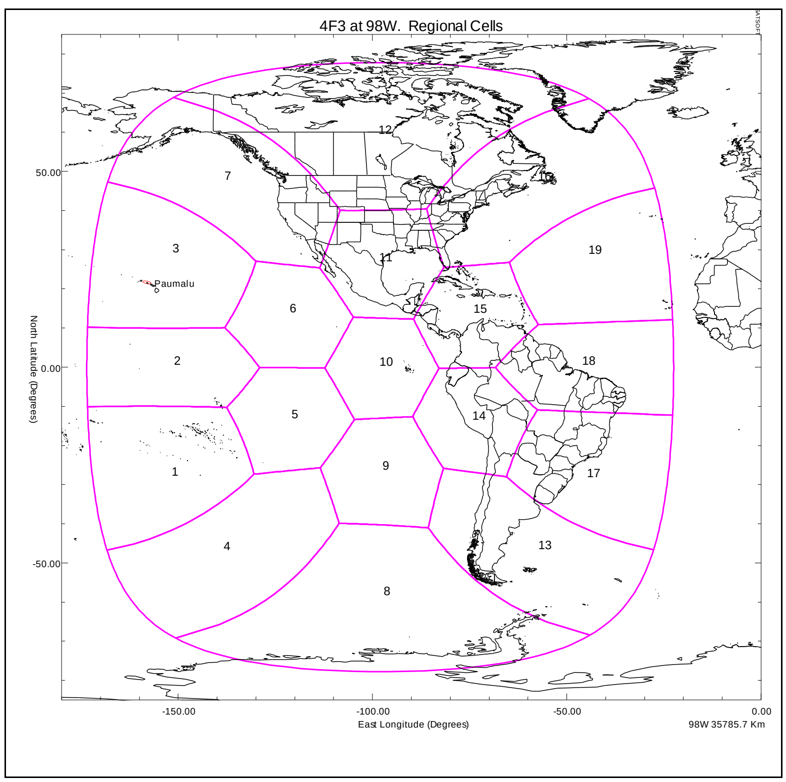

Figure 1-4: Example I4 Regional Beams

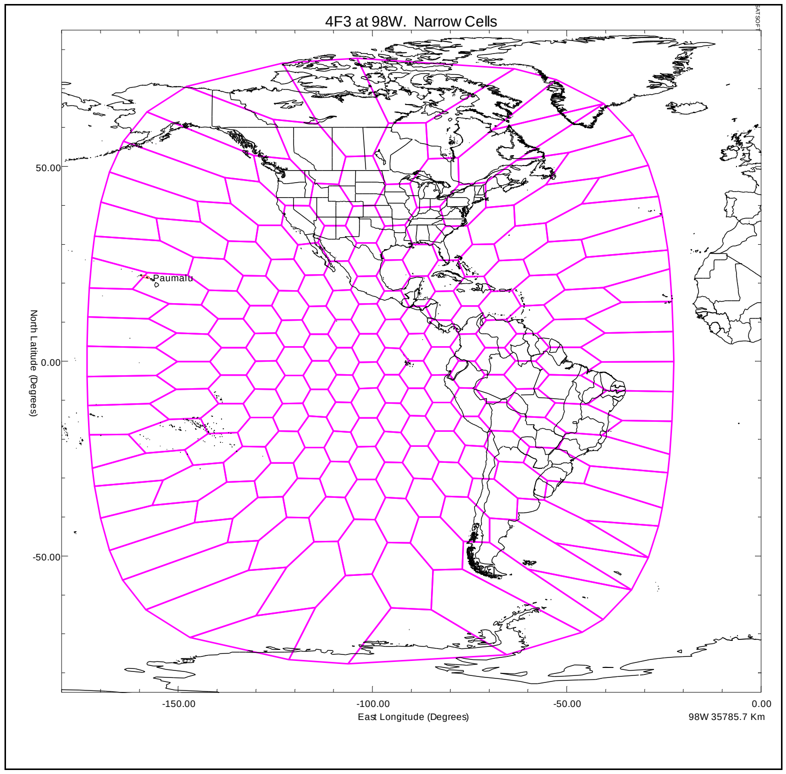

Figure 1-5: Example I4 Narrow Spot Beams

1.3.4 Airborne Segment

The airborne segment, known as the Aircraft Earth Station (AES), is the subject of this appendix. Performance requirements for the AES are given in Sections 2, 3 and 4 of this appendix. The AES consists of all the functionality to translate between the RF signal in space and the baseband voice and data interfaces to and from the aircraft.

The key main functions of the AES are:

- Antenna
- Diplexer / Low-noise Amplifier (DLNA)
- High Power RF Amplifier
- Up/ down converters
- Modem, or multiple modems
- ACARS gateway
- VoIP gateway
- Data interfaces
- Voice interfaces

The AES and its main functions are shown in Figure 1-6. The main functions are discussed in the remainder of this section.

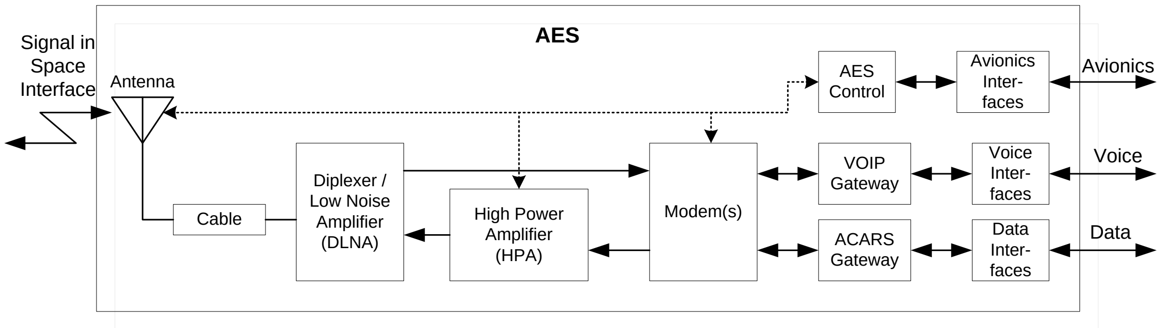

Figure 1-6 Main Functions of an AES

Antenna

For a SwiftBroadband AES, the antenna is required to have directional gain, and therefore a steered beam is required. The amount of gain required depends on the class of AES. The beam is pointed at the satellite despite changes in the aircraft's position and attitude. Typically the AES receives position, altitude, attitude and velocity data from the aircraft's avionics. Antennas are typically either steered mechanically or electrically using a phased antenna array.

DLNA

The SwiftBroadband system uses full duplex communications – transmitting and receiving simultaneously in different frequency bands, as shown in Figure 1-7. The diplexer is a pair of filters which prevent the transmitter from interfering with the operation of the receiver. The low-noise amplifier is typically close-coupled with the receive filter in the diplexer to achieve a low noise figure. The diplexer also provides out-of-band rejection which prevents mutual interference between the AES and other radio systems on or near the aircraft, for example the GNSS systems on the aircraft.

High-Power Amplifier (HPA)

The HPA amplifies the transmitted signal to the appropriate power level. The output power is carefully managed to achieve near-constant received power density levels at the satellite. The HPA is linear, to allow transmission of complex modulation schemes. In the case of a multi-channel AES, increased linearity is required from the HPA to suppress intermodulation products that may be formed in the HPA.

Modem

The modem performs the modulation and demodulation functions in the AES. For SwiftBroadband the modem is required to be agile, switching on command between frequencies, modulation modes and forward error correcting codes. The modulator is required to transmit bursts of data according to the return burst schedule allocated by the network. This agility allows the BGAN network to dynamically allocate spectrum and other resources on demand. It also allows the network to assign resources to priority services, even when demand is high.

The radio bearer handled by the modem may be used to transfer a multiplexed data stream, providing multiple services like voice, ACARS and IP data over one transmit and one receive bearer at a time.

An AES6 or AES7 may have one or more modems for single or multi-channel operation as required. An AES4 only contains one modem. Priority services only require one modem. Additional modems typically provide non-priority services.

ACARS Gateway

The ACARS Airborne Gateway (AAGW) is typically a software function in the AES. In the air-to-ground direction the AAGW encapsulates ACARS messages sent from the aircraft avionics into data packets which are then sent to the modem for transmission to the ACARS Ground Gateway (AGGW). The data packets contain additional information for error checking and time stamping of messages. Data packets containing ACARS messages are sent through a dedicated priority background PDP context. This PDP context is set up when the AES starts up, and forms a virtual connection between the AAGW and the AGGW.

In the ground-to-air direction the reverse operation is performed by the AAGW. Time stamping of data packets allows measurement of latency between the AAGW and the AGGW.

The aircraft avionics only send one ACARS message at a time, and then waits for confirmation from the ground. The ACARS gateway in the AES therefore does not arbitrate on priority of different ACARS messages.

VoIP Gateway

Every SwiftBroadband modem provides a single circuit-switched voice channel using an AMBE+2 voice codec. Furthermore, at least one voice channel using Voice over IP (VoIP) technology is provided per AES. These two voice channels enable two voice calls (telephone calls) for the flight deck.

The VoIP facility is provided by a VoIP gateway in the AES, which connects to a VoIP gateway on the ground. The airborne VoIP gateway sets up a background priority PDP context at start-up for signaling related to the priority VoIP call. A streaming context is set up on demand to handle the voice sample stream.

Apart from the two voice channels for the flight deck, an AES may provide for additional VoIP channels, which would typically be used outside the flight deck.

Data Interfaces

ACARS messages are normally sent to and from the aircraft avionics through an ARINC 429 interface. Ethernet ports are typically used to interface IP data to the AES. Other formats such as Wi-Fi are also possible.

Voice Interfaces

An industry-standard interface between the AES and the flight deck audio system is described in ARINC 781. The interface emulates, in broad terms, the speaker / microphone / PTT interface of a VHF radio transceiver. Additional discrete lines provide for visual and audible indication of incoming calls. Other interfaces are possible.

Avionics Interfaces

Other interfaces to aircraft avionics may be required for the AES to receive information such as aircraft speed, position and attitude, weight on wheels etc. Additional functions like built-in testing, software loading etc. may be supported. These functions may vary in different AES designs, and are not prescribed in this appendix.

AES Control

The AES control function is responsible for internal AES management, including such tasks as initializing and assigning modem resources, controlling high power amplifier output power, controlling or directing antenna steering, self-test, fault isolation, etc. The actual implementation of these functions is manufacturer-dependent. Tests for the correct operation of such functions are inherent in the functional tests defined in Section 2.4 of this appendix, therefore, the control function is not separately or explicitly tested.

AES Configuration

The main functions of the AES may be grouped and packaged in a variety of formats. The format of an AES is not prescribed by this appendix. ARINC Characteristic 781 describes a typical implementation of the AES which consists, for the large form factor variant, of an antenna, a Diplexer/Low Noise Amplifier (DLNA), a Satellite Data Unit (SDU), an SDU Configuration Module (SCM), and an optional Flange Mount High Power Amplifier (FMHPA). A small form factor variant is also described in ARINC Characteristic 781 which consists of a small antenna, a Compact Satellite Data Unit (CSDU), an SDU Configuration Module (SCM), and an optional High Power Amplifier/Low Noise Amplifier/Diplexer (HLD).

Information security requirements may be found in DO-326 [10] and suggested architectures may be found in ARINC Characteristic 781 Attachment 8, which shows methods of segregation of different information domains that are sharing a common SBB modem or 'channel card'.

1.3.5 Air Interface

The purpose-designed air interface is known as IAI-2 (Inmarsat Air Interface 2). Right hand circular polarization is used for both the forward (ground-to-air) and return (air-to-ground) user links.

1.3.5.1 Frequency Range

The forward user link (to aircraft) operates in the frequency range 1518-1559MHz (Extended plus Standard L-Band). Some AES equipment and the I4 satellites only support a frequency range of 1525-1559MHz (Standard L-band).

The return user link (air-to-ground) operates in the frequency range 1626.5-1660.5 and 1668-1675MHz (Extended plus Standard L-band). Some AES equipment and the I4 satellites only support a frequency range of 1626.5-1660.5MHz.

Alphasat supports the full frequency range, known as Extended L-band or "XL band" plus Standard L-Band. The XL band will not be used outside the Alphasat footprint. Multi-channel equipment is not expected to operate in the XL band.

The band layout, as well as some neighboring spectrum allocations, is shown in Figure 1-7, although it does not reflect all of the shared service allocations or other services in use in the neighboring bands.

Note: ICAO WG-F agreed in March 2013 that use of the Extended L Band (1518-1525 MHz and 1668-1675 MHz) for AMS(R)S operations would require additional study.

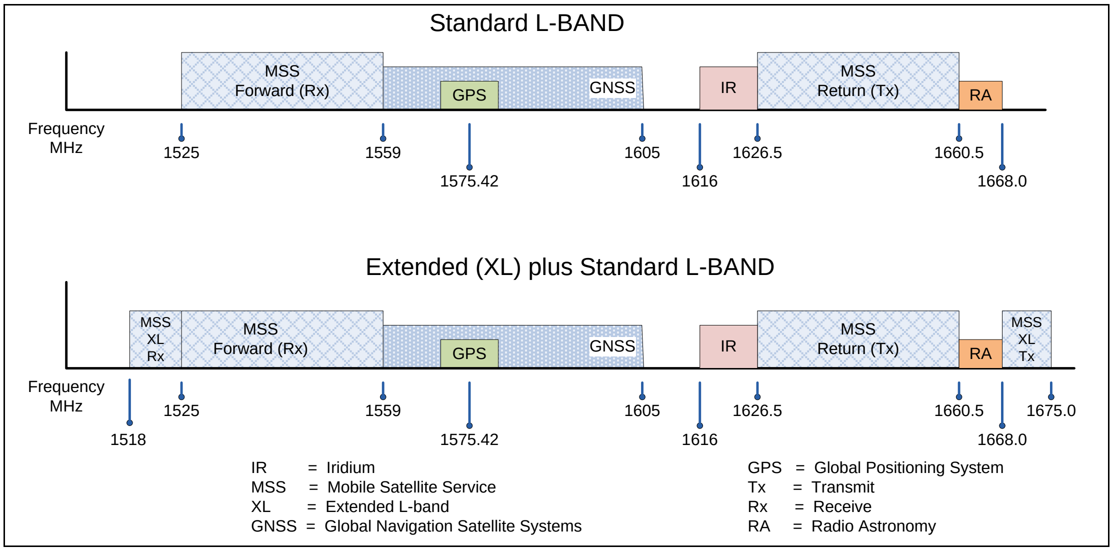

Figure 1-7. Frequency plan for Standard L-Band and Extended L-Band

1.3.5.2 Bearers

The SBB air interface supports a matrix of carriers and bursts of different modulation type, symbol rate and code rate. Inmarsat configuration settings and the Radio Access Network (RAN) determine which bearers and code rate are used on a dynamic basis. In SBB terminology carriers and bursts are known collectively as bearers.

SBB RF bearers in the forward (to aircraft) direction are a continuous transmission of time division multiplexed (TDM) carriers shared between a number of users. RF bearers in the return direction (air-to-ground) are based on time division multiple access (TDMA) between a number of users.

Power efficient QPSK and π/4 QPSK (Quadrature Phase Shift Keying) and bandwidth efficient 16, 32 and 64 QAM (Quadrature Amplitude Modulation) is used, together with a number of frame burst durations. Symbol rates between 8.4 kilo symbols per second (kSym/s) and 168 kSym/s are used with each symbol rate being a fraction or multiple of 33.6 kSym/s. Variable coding rate is used with rates corresponding to 1 dB changes in C/No. In the main the bearers operate at constant power and as the C/No varies the coding rate (and hence the user data rate) is adjusted accordingly. Bearers use Root Raised Cosine (RRC) filtering with roll-off of $\alpha = 0.13$ for T5 and T2.5 bearers and $\alpha = 0.25$ for other bearers. Channel spacing for the 151.2 and 168 kSym/s bearers is 200 kHz. Other bearers are spaced at fractions of 200 kHz.

1.3.6 Registration

When an AES is powered up, it follows the following steps:

- Determines its geographical position, directly or indirectly from a GPS receiver or from the aircraft's IRS.

- Determines which satellite is in the best position.
- Points its antenna at the desired satellite, if the antenna is steerable.
- Tunes its receiver to the global beam Primary Shared Access Bearer (PSAB) and receive the system information, including the regional beam map and regional beam frequencies.
- Tunes to the best regional beam PSAB and receives the relevant system information.
- Transmits on the regional beam to register. An AES never transmits on the global beam.
- Tunes to the appropriate regional beam or narrow spot beam bearer as directed by the RAN. This is usually in response to a demand for bandwidth in either the forward or return direction.
- Sets up required PDP contexts (acting as virtual data channels) over which data can be communicated.
- The AAGW uses a priority PDP context to independently register with the AGGW for ACARS service.
- The pilot initiates CPDLC communications with the required Flight Information Region (FIR).
- ADS-C operation is initiated from the ground.

1.3.7 Mobility and Handoff

Handover between all beams within a satellite is supported within the network. Telephone calls and data connections remain connected.

Handover between satellites is not supported by the network and hence is implemented by the AES. During satellite handover there is a loss of data and voice communication between the air and ground. Data connections, including ACARS, are automatically reestablished by the AES. A voice call should be re-established manually. According to SVGM [8] this should be done by the party that originally established the call.

The process described above should not be confused with CPDLC registration performed by a priority services AES when entering a flight information region.

1.3.8 Priority, Precedence and Preemption

SBB uses the 3G principles of Quality of Service (QoS) to provide priority and preemption capability for packet-switched data. QoS is similar to the ICAO concept of Required Communication Performance (RCP).

For network congestion scenarios on the PS domain, the use of Allocation/Retention Priority (ARP) is required for pre-emption of lower priority users. The ARP level is not negotiated by the mobile terminal, but forms part of the provisioning of a SB-Safety terminal. Access to the highest priority level is authorized only for aeronautical mobile terminals supporting cockpit communications and maritime mobile terminals with distress capabilities – this priority level is not accessible to users via normal mobile terminal interfaces for commercial traffic.

In the CS domain the enhanced Multi-Level Precedence and Pre-emption (eMLPP) attribute is used to indicate priority. Admission control and bearer control use eMLPP to prioritize and if necessary preempt lower priority (or non-priority) users, thus ensuring that an SBB AES achieves the appropriate performance even in congestion situations. VoIP calls make use of a priority PDP context.

For the second (PS) voice channel, the AES creates PDP contexts at the configured priority level. A PS call to or from a priority AES may therefore preempt calls to or from non-priority AESs or other BGAN terminals.

In addition when an SBB priority AES requests registration to the Radio Access Network, the AES is identified as a priority AES and is accepted on to the network with priority. This is particularly relevant during “registration storms” after, for example, ground station site switches.

1.3.9 Redundancy Including Fallback to Classic Aero

The AES and the SBB network are designed to allow an AES to automatically and seamlessly take advantage of additional satellites and ground stations if and when they become available in the network.

An AES design may offer the capability for two AESs to be installed together on one aircraft to form a 1+1 hot standby system to improve redundancy.

An AES may be designed to offer automatic reversion to the Classic Aero service. These AESs and the SBB network are designed for tight interoperability with the Classic Aero service operating on the I3 and I4 satellites, and an AES with Classic reversion capability may switch between the three networks. One possible mode of operation is where services are provided over SBB by default, with the AES automatically reverting to Classic Aero mode over I4 or I3 when the SBB service or an I4 satellite is unavailable. Aspects of the fallback mechanism are specified in the SBB SDM, while other details are left to the individual manufacturers. These details are outside the *minimum* requirements of this appendix.

The system is designed to make this switching between networks near-seamless. ACARS and voice services remain available. The Classic Aero networks do not support IP services.

Note: This appendix deals only with the performance requirements for an SBB AES. The performance requirements of the AES in Classic Aero mode are outside the scope of this appendix, but are covered in DO-210D [5].

1.3.10 Installation Environment

1.3.10.1 Iridium AMS(R)S On The Same Aircraft

The minimum performance standards contained in this appendix are intended to assure proper operation of Inmarsat priority services on all aircraft, and compatibility of such services with other communication, navigation, and surveillance radios operating on the same aircraft and in the same airspace. A significant caveat to this intent is the ability to support simultaneous independent operation of both Iridium and Inmarsat AESs on the same aircraft without a demonstrated means of cooperation. Owners, operators and installers are cautioned that simultaneous independent operation of Inmarsat and Iridium AES equipment on the same aircraft has the potential to cause significant interference to all Iridium AMSS and AMS(R)S services on that aircraft. This caution applies to Inmarsat equipment that is compliant with RTCA DO-210D, including all changes, ARINC Characteristic 741, ARINC Characteristic 761, ARINC Characteristic 781, and any AES complying with this appendix. At the time of publication of this appendix, simultaneous independent operation of Inmarsat and Iridium equipment on the same aircraft had been reported in special cases. However, no generally applicable and technically feasible means of mitigating the potential for interference could be identified.

This caveat specifically excludes installations where Inmarsat and Iridium are intended for use in a non-simultaneous mode of operation. For example, no special installation or other considerations are required for Iridium use in polar airspace that is outside of the coverage volume of the Inmarsat services described in this appendix.

At the time of publication of this appendix, there is no regulatory guidance nor AMS(R)S operational need to require Inmarsat and Iridium systems to work simultaneously on the same aircraft. Some operators may choose to use Iridium and Inmarsat as backup or in a non-simultaneous mode of operation.

1.3.10.2Iridium AMS(R)S In The Same Procedural Airspace

The caveats of the previous paragraph apply to simultaneous independent operation of Inmarsat and Iridium AMS(R)S or AMSS on the same aircraft. ICAO Aeronautical Communications Panel, Working Group M in 2008 accepted analyses indicating that Inmarsat safety and non-safety communication services do not induce harmful interference to Iridium AMS(R)S equipment on other aircraft operating under 30/30 nautical mile separation in procedural airspace.

1.3.10.3Co-location with GPS / GNSS Systems

The ARINC 741 and ARINC 781 standards give guidance on the required isolation between antennas of Inmarsat and GNSS systems. The GNSS system can potentially be affected mainly by two mechanisms:

- Intermodulation products of two carriers transmitted by the Inmarsat system falling in the GNSS band may affect the GNSS receiver. This effect does not occur in single channel SwiftBroadband systems. Intermodulation products can be formed either in the transmitter of the Inmarsat system or in the receiver chain of the GNSS receiver.
- The GNSS receiver chain may be saturated by signals transmitted from the Inmarsat system. This problem is common to co-location of any transmitter with any other receiver. This effect can be mitigated by isolation between the antennas combined with adequate filtering in the receiver chain.

Interference may be very dependent on the frequencies allocated by the network. This calls for special care during interference tests.

Interference from the GNSS antenna to the satcom antenna is not regarded as a high risk.

Requirements for emissions from the AES for GNSS compatibility are given in sections 2.2.3.1.2.6.1 and 2.2.3.1.3.1.3.

The declared isolation between the AES antenna and a GNSS antenna may differ for different GNSS systems (e.g. GPS and GLONASS). The standard assumption in GPS and GLONASS documents is an antenna port-to-antenna port isolation of 40 dB. The requirements in Section 2.2.3.1.2.6.1 do not provide sufficient protection of the upper 5 MHz of the GLONASS frequency band (1605 to 1610 MHz) for a GLONASS receiver on the same aircraft with this standard isolation, but can achieve appropriate protection with the larger spatial isolations typical of large aircraft.

1.3.10.4 Co-location with Other Inmarsat Satcom Systems

Co-location of multiple Inmarsat satcom systems may be achieved. Installation guidance is given in Section 3.1.10.

2 EQUIPMENT PERFORMANCE REQUIREMENTS AND TEST PROCEDURES

2.1 General Requirements

2.1.1 Airworthiness

The design and manufacture of the equipment shall provide for an installation that does not impair the airworthiness of the aircraft.

2.1.2 Intended Function

The equipment shall perform its intended function, as defined by the manufacturer, and its proper use shall not create a hazard to users of procedural airspace.

2.1.3 Federal Communications Commission's Rules

The equipment shall comply with all applicable rules of the Federal Communication Commission (FCC).[5]

2.1.4 Fire Protection

All materials used shall be self-extinguishing except for small parts (such as knobs, fasteners, seals, grommets and small electrical parts) that would not contribute significantly to the propagation of a fire.

Note: One means of showing compliance is contained in the Federal Aviation Regulations (FAR), Part 25, Appendix F.

[5] It is not intended that this requirement relating to FCC rules be interpreted as a precondition for obtaining other applicable approvals such as an FAA TSO authorization.

2.1.5 Operation of Controls

The operation of controls intended for use during flight, in all possible combinations and sequences, shall not result in a condition detrimental to the continued performance of the equipment. Controls shall be designed to maximize operational suitability and minimize pilot workload. Reliance on pilot memory for operational procedures shall be minimized.

2.1.6 Accessibility of Controls

Controls that are not normally adjusted in flight shall not be readily accessible to flight personnel. Controls that are normally adjusted in flight shall be readily accessible and properly labeled as to their intended function. The controls shall be operable with the use of only one hand.

2.1.7 Effects of Tests

The equipment shall be designed so that the application of specified test procedures will not be detrimental to equipment performance following the application of these tests, except as specifically allowed.

2.1.8 Performance in a Shared Environment

All requirements for data integrity and timing shall consider the effect of other active aircraft data links performing transfer operations in both directions at their nominal rates.

In the case of simultaneous and independent operation of dissimilar AMS(R)S equipment on different aircraft in the same airspace, 30 nmi minimum lateral separation and 30 nmi along-track separation between aircraft at the same altitude shall be assumed.

In the case of simultaneous and independent operation of dissimilar AMS(R)S equipment on the same aircraft, sufficient isolation between equipment must be established. This may be difficult to achieve, particularly if sufficient guard band does not exist. Solutions may include operating procedures or mechanisms which disable transmission from one system while the other system is being used to provide AMS(R)S services.

2.1.9 AES Availability

Note: Appendices B and C of ICAO GOLD [7] specify the availability for the data link capability on the aircraft as 0.999, assuming an average flight of 6 hours. Allocating 50% of the unavailability to the AES yields an availability requirement for the AES of 0.9995. Availability = 1 - (MTTR/MTBF). Failures (on average) occur halfway through the flight. The MTTR = 3 hours because failed equipment is repaired or replaced after the flight. This implies that an MTBF of 6000 hours or better is required for the AES to achieve the 0.999 availability requirement for the aircraft. Evaluating this number at the time of MOPS testing is considered impractical. In-service MTBF measurement and *reliability management may be required. Meaningful specification of MTBF and reliability management is considered beyond the scope of this MOPS.*

2.2 Equipment Performance Requirements – Standard Conditions

2.2.1 SwiftBroadband AES Classes, Subsystem Definitions and Overall Requirements

2.2.1.1 Definition of SwiftBroadband AES Classes

This appendix contains performance requirements for three classes of AES equipment, designated AES4, AES6 and AES7. The three AES classes are listed with their descriptions in Sections 2.2.1.1.1 to 2.2.1.1.3. An AES is a complete satcom terminal as installed on an aircraft. It includes the transceiver, DLNA, SCM and antenna functions, as shown in Figure 2-1, Figure 2-2 and Figure 2-3. The three classes are mainly differentiated based on the gain (and by implication, size) of the antenna.

In addition, this appendix contains requirements for major components of the AES6 and AES7 classes of equipment. These major components are listed in Sections 2.2.1.1.4 to 2.2.1.1.11. The class and component identifiers in these sections are frequently used in this appendix to unambiguously refer to these systems and system components.

Notes:

27. *In the event this appendix is used to establish functional requirements for equipment certification purposes of complete AES6 or AES7 equipment, compliance of the AES's underlying components to their requirements in this appendix should be demonstrated. The valid combinations of standardized components that make up acceptable AES6 or AES7 equipment are given in Table 2-1.*

28. *In the event this appendix is used to establish functional requirements for equipment certification purposes of an incomplete AES6 or AES7 system, the individual major components of AES6 and AES7 equipment may be demonstrated to be compliant to their requirements in this appendix.*

29. *In the event this appendix is used to establish functional requirements for equipment certification purposes of AES4 equipment, compliance to the requirements in this appendix applicable to an AES4 should be demonstrated. Components of an AES4 are not individually specified, allowing trade-off of major component characteristics by manufacturers. Nevertheless, this appendix requires some measurements to be performed on parts of the AES system in order to demonstrate compliance of the complete AES by calculation.*

AES4 Definition and Requirements

An AES4 is defined to be an AES using an Enhanced Low Gain Antenna (ELGA), or an antenna capable of enabling the performance requirements associated with an AES4.

An AES4 shall meet the functional requirements of the sub-sections of 2.2.1.2 through 2.2.3.10 and the associated environmental test requirements of Section 2.3 and sub-sections, and the associated functional test requirements of Section 2.4 and sub-sections, as identified by an "X" in the AES4 column of Table 5-1 of this appendix.

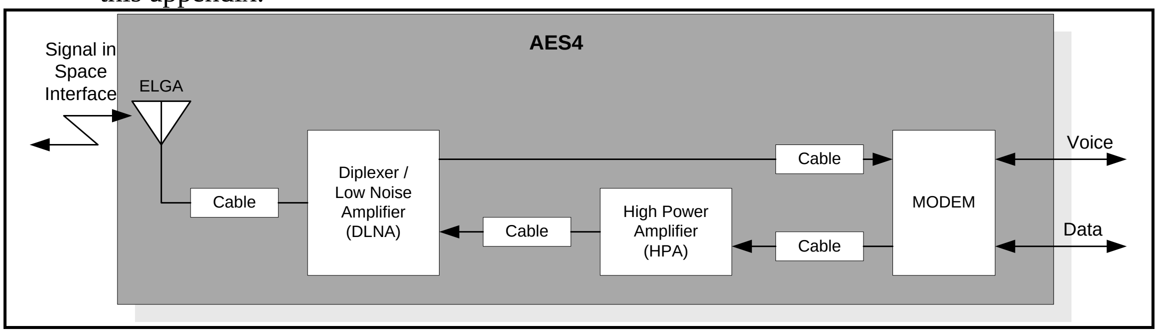

Figure 2-1 Block Diagram of an AES4 and its Major System Components

AES6 Definition and Requirements

An AES6 is defined to be an AES using High Gain Antenna (HGA), or equivalent functionality, plus a diplexer and associated transceiver. For the purpose of certification or approval, the AES6 is defined as an entire system. An AES6 system may be aggregated from subclass equipment as identified in Table 2-1.

An AES6 shall meet the functional requirements of the sub-sections of Section 2.2.1.2 through 2.2.3.10 and the associated environmental test requirements of Section 2.3 and sub-sections, and the associated functional test requirements of Section 2.4 and sub-sections, as identified by an "X" in the AES6 column of Table 5-1 of this appendix.

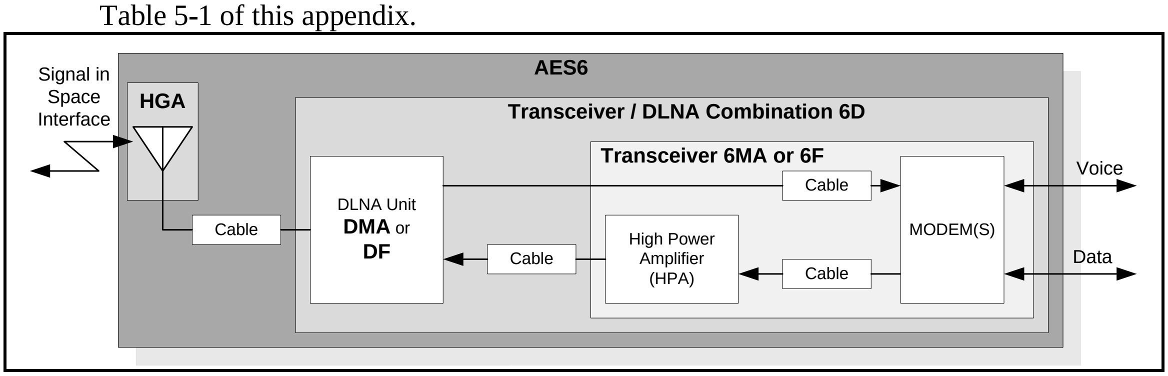

Figure 2-2 Block Diagram of an AES6 and its Major System Components

AES7 Definition and Requirements

An AES7 is defined to be an AES using Intermediate Gain Antenna (IGA), or equivalent functionality, plus a diplexer and associated transceiver. For the purpose of certification or approval, the AES7 is defined as an entire system. An AES7 system may be aggregated from subclass equipment as identified in Table 2-1.

An AES7 shall meet the functional requirements of the sub-sections of Section 2.2.1.2 through 2.2.3.10 and the associated environmental test requirements of Section 2.3 and sub-sections, and the associated functional test requirements of Section 2.4 and sub-sections, as identified by an "X" in the AES7 column of Table 5-1 of this appendix.

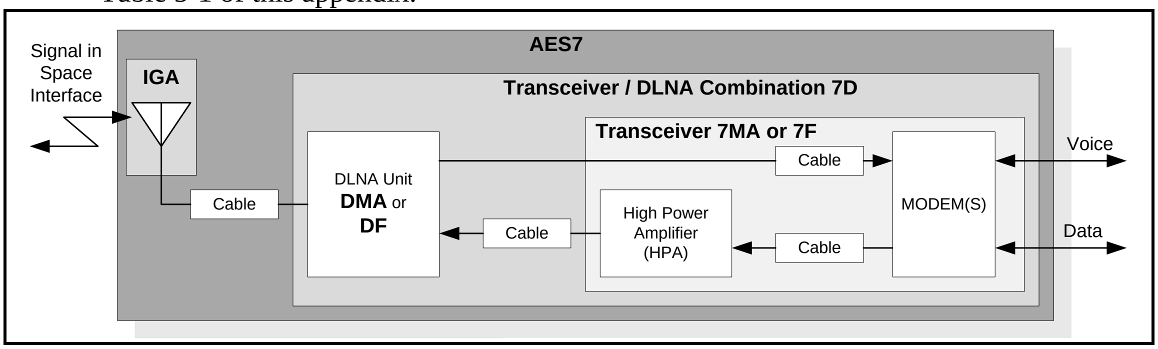

Figure 2-3 Block Diagram of an AES7 and its Major System Components

6MA Definition and Requirements

A 6MA transceiver is defined as a transceiver unit capable of operating within an AES6 system. A 6MA transceiver is defined to use a DMA diplexer and a HGA antenna. The 6MA transceiver unit includes Satellite Data Unit (SDU), and SDU Configuration Module functions.

A 6MA transceiver shall meet the functional requirements of the sub-sections of Sections 2.2.1.2 through 2.2.3.10 and the associated environmental test requirements of Section 2.3 and sub-sections, and the associated functional test requirements of Section 2.4 and sub-sections, as identified by an "X" in the 6MA column of Table 5-1 of this appendix.

6F Definition and Requirements

A 6F transceiver is defined as a transceiver unit capable of operating within an AES6 system. A 6F transceiver is defined to use a DF diplexer and a HGA antenna. The 6F transceiver unit includes Satellite Data Unit (SDU), and SDU Configuration Module functions.

A 6F transceiver shall meet the functional requirements of the sub-sections of Sections 2.2.1.2 through 2.2.3.10 and the associated environmental test requirements of Section 2.3 and sub-sections, and the associated functional test requirements of Section 2.4 and sub-sections, as identified by an "X" in the 6F column of Table 5-1 of this appendix.

7MA Definition and Requirements

A 7MA transceiver is defined as a transceiver unit capable of operating within an AES7 system. A 7MA transceiver is defined to use a DMA diplexer and an IGA antenna. The 7MA transceiver unit includes Satellite Data Unit (SDU), and SDU Configuration Module functions.

A 7MA transceiver shall meet the functional requirements of the sub-sections of Sections 2.2.1.2 through 2.2.3.10 and the associated environmental test requirements of Section 2.3 and sub-sections, and the associated functional test requirements of Section 2.4 and sub-sections, as identified by an “X” in the 7MA column of Table 5-1 of this appendix.

7F Definition and Requirements

A 7F transceiver is defined as a transceiver unit capable of operating within an AES7 system. A 7F transceiver is defined to use a DF diplexer and an IGA antenna. The 7F transceiver unit includes Satellite Data Unit (SDU), and SDU Configuration Module functions.

A 7F transceiver shall meet the functional requirements of the sub-sections of Sections 2.2.1.2 through 2.2.3.10 and the associated environmental test requirements of Section 2.3 and sub-sections, and the associated functional test requirements of Section 2.4 and sub-sections, as identified by an “X” in the 7F column of Table 5-1 of this appendix.

6D Definition and Requirements

A 6D transceiver is defined as a transceiver unit capable of operating within an AES6 system. A 6D transceiver is defined to use a HGA antenna. The 6F transceiver unit includes Satellite Data Unit (SDU), an integrated DLNA, and SDU Configuration Module functions.

A 6D transceiver shall meet the functional requirements of the sub-sections of Sections 2.2.1.2 through 2.2.3.10 and the associated environmental test requirements of Section 2.3 and sub-sections, and the associated functional test requirements of Section 2.4 and sub-sections, as identified by an “X” in the 6D column of Table 5-1 of this appendix.

7D Definition and Requirements

A 7D transceiver is defined as a transceiver unit capable of operating within an AES7 system. A 7D transceiver is defined to use an IGA antenna. The 7D transceiver unit includes Satellite Data Unit (SDU), an integrated DLNA, and SDU Configuration Module functions.

A 7D transceiver shall meet the functional requirements of the sub-sections of Sections 2.2.1.2 through 2.2.3.10 and the associated environmental test requirements of Section 2.3 and sub-sections, and the associated functional test requirements of Section 2.4 and sub-sections, as identified by an “X” in the 7D column of Table 5-1 of this appendix.

DMA Definition and Requirements

A DMA performs the diplexer function, offering filtering on both the transmit and the receive sides of the transceiver. A DMA diplexer may be used in either an AES6 or AES7 configuration.

A DMA shall meet the functional requirements of the sub-sections of Sections 2.2.1.2 through 2.2.3.10 and the associated environmental test requirements of Section 2.3 and sub-sections, and the associated functional test requirements of Section 2.4 and sub-sections, as identified by an "X" in the DMA column of Table 5-1 of this appendix.

DF Definition and Requirements

A DF is a Type F diplexer as described in ARINC-781. A DF diplexer may be used in either an AES6 or AES7 configuration.

A DF shall meet the functional requirements of the sub-sections of Sections 2.2.1.2 through 2.2.3.10 and the associated environmental test requirements of Section 2.3 and sub-sections, and the associated functional test requirements of Section 2.4 and sub-sections, as identified by an "X" in the DF column of Table 5-1 of this appendix.

2.2.1.2 Valid Combinations of System Components

Although several major AES components are identified in the previous section, the performance of a complete AES relies on a valid combination of major components being used together in an installation. Table 2-1 below lists the valid combinations of major components that may be combined to form an AES. Adherence to this list is particularly important to control unwanted emissions.

Table 2-1 Valid Combinations of System Components

Valid Combinations		**Transceiver**				**Transceiver & DLNA Combination**		**DLNA**		**Antenna**		**Complete System**
		6MA	**6F**	**7MA**	**7F**	**6D**	**7D**	**DMA**	**DF**	**HGA**	**IGA**	
AES4	1											X
AES6	2	X						X		X		
	3		X						X	X		
	4					X				X		
	5	X							X	X		
	6											X
AES7	7			X				X			X	
	8				X				X		X	
	9						X				X	
	10			X					X		X	
	11											X

2.2.1.3 Services Provided by an AMS(R)S AES

A SwiftBroadband AES intended for AMS(R)S services shall, as a minimum, simultaneously support:

- 2 channels of AMS(R)S voice,
- ACARS packet data services over a single radio channel.

Optionally the AES may also provide any or all of the following services:

- AMS(R)S IP data service ("Priority IP")
- Additional non-AMS(R)S voice channels
- Additional non-AMS(R)S IP data and voice services

Note: At the time of publication of this appendix the Priority IP service has not been approved for operational AMS(R)S communications.

2.2.1.4 RF Interconnecting Cables

In addition to the system components listed in sections 2.2.1.1.4 to 2.2.1.1.11, three RF co-axial cables are required to interconnect the standard subsystems of an AES6 or AES7. As cable lengths and types may be dependent on the AES design and the installation, these cables are not assigned equipment class identifiers.

For multicarrier operation, when operating with two CW carriers, each of power 9.4 dBW anywhere in the band 1626.5 to 1660.5, the intermodulation products generated by the DLNA to antenna cable shall satisfy the following requirements:

- Third and fifth order intermodulation products shall be below -100 dBm in the frequency range of 1559 to 1605 MHz and
- Seventh or higher order intermodulation products shall be below -133 dBm in the frequency range of 1525 to 1559 MHz.

The L-band cable losses in Table 2-2 and passive intermodulation characteristics above are assumed in this appendix for AES6 and AES7 and are required for proper interoperation of subsystems defined in this appendix. The cable characteristics should be verified before installation, as required in Section 3.1.9.

Table 2-2 Cable losses for AES6 and AES7

Cable	Loss at L-band
Antenna to DLNA	Not to exceed 0.3 dB
Transceiver to DLNA (transmit path)	Not to exceed 1.4 dB
DLNA to Transceiver (receive path)	Within the range 6 to 25 dB

Where the transceiver consists of an SDU and an HPA, the interconnecting cable between these units shall be specified by the manufacturer.

Cables for an AES4 shall be specified by the manufacturer.

2.2.2 Definition of System-specific Parameters

The system specific parameters in this section are intended to enable the determination of the cross-impact (e.g. interference) of other equipment on the same aircraft or the same operating environment. Where different operating modes are possible, only the worst case is listed (e.g. highest transmit power or lowest receiver sensitivity).

Table 2-3 List of Parameters Applicable to a Complete SwiftBroadband AES

Symbol	Parameter	Value			Units
A_{RSV}	Axial Ratio of antenna on Inmarsat I4 satellite.	2.5 RHCP.			dB
f_{RMX}	Maximum operating frequency for space vehicle transmissions (AES reception).	Extended + Standard L-Band.(2)		Standard L-Band	MHz
		1559		1559	
f_{RMN}	Minimum operating frequency for space vehicle transmissions (AES reception).	Extended + Standard L-Band.(2)		Standard L-Band	MHz
		1518		1525	
f_{TMX}	Maximum operating frequency for AES transmissions.	Extended + Standard L-Band (1) (2)		Standard L-Band	MHz
		1675. (1) (2)		1660.5	
f_{TMN}	Minimum operating frequency for AES transmissions.	Extended + Standard L-Band (1) (2)		Standard L-Band	MHz
		1626.5		1626.5	
f_M	Channel modulation rate in kilobits per second.		Return (AES Transmit)	Forward (AES Receive)	kb/s
		AES 4	33.6 to 672	16.8 to 672	
		AES 6	33.6 to 1008	16.8 to 1008	
		AES 7	33.6 to 1008	16.8 to 1008	
P	Polarization of AES antenna.	RHCP			
P_{NC}	Maximum output power allowed during intervals when no transceiver channel is transmitting.	AES 4	As listed in Table 2-7.		
		AES 6 & AES 7	As listed in Table 2-8.		
S_{DC}	Minimum data channel carrier level for sensitivity test. Signal and noise levels are referred to the connector of the antenna.	Bearer type F80T0.25Q-L8 F80T1Q- L8 F80T1X-L3 F80T45X-L3 F80T1Q1B-L8 FR80T2.5X4-L8 FR80T2.5X16-L3 FR80T5X4-L8 FR80T5X16-L3 FR80T2.5X32-H1 FR80T2.5X64-RE FR80T5X32-H1 FR80T5X64-R	C/No 40.1 46.1 50.6 56.8 45.4 49.6 54.2 52.6 57.4 62.0 61.6 64.3 65.1	dBm (3) -134.5 -128.5 -124.0 -117.8 -129.2 -125.0 -120.4 -122.0 -117.2 -112.6 -113.0 -110.3 -109.5	dBHz and dBm
S_{HSNT}	Maximum level of harmonic, spurious and noise allowed within the designated transmit band.	See Section 2.2.3.1.3.1.5			
S_{HSNR}	Maximum level of harmonic spurious and noise within the designated receive band.	Comply with G/T on any receive channel while transmitting modulated signals on any two carriers.			
S_{IMT}	Maximum level of 2-tone intermodulation products allowed within the designated transmit band.	See Section 2.2.3.1.3.1.4.			

Symbol	Parameter	Value	Units
S_{IMR}	Maximum level of 2-tone intermodulation products allowed within the designated receive band, measured at the connector of the antenna.	Comply with G/T on any receive channel while transmitting modulated signals on any two carriers.	
S_{UW}	Maximum level of undesired wideband noise from interfering sources external to the AES that can be accepted within the designated receive band. (Outside the active receive channel)	AES6: -108.1 AES7: -114.1 AES4: -117.6 (Based on -95 dBW/m^2 and nominal antenna gain of 12, 6 and 2.5 dB for HGA, IGA and ELGA respectively)	dBW
S_{UN}	Maximum level of undesired interference from interfering sources external to the AES that can be accepted within the designated receive band.	1) Two adjacent similar carriers each at +6dBc (also faded along with the wanted channel), F80T0.25Q-1B : 11.25 kHz frequency spacing F80T1Q-4B : 45 kHz frequency spacing F80T1X-4B : 45kHz frequency spacing F80T4.5X-8B : 200 kHz frequency spacing. 2) Two adjacent carriers at 0 dBc (also faded along with the wanted channel) F80T1Q-1B : 45 kHz frequency spacing FR80T2.5X4/16-5B, FR80T2.5X16-5B, FR80T2.5X32-6B, FR80T2.5X64-7B : 95 kHz frequency spacing FR80T5X4/16-9B, FR80T5X16-9B, FR80T5X32-11B, FR80T5X64-13B: 200 kHz frequency spacing	dBc
S_{VS}	Minimum voice channel carrier level for sensitivity test.	N/A. (Data bearers are also used for voice)	
Θ_{SA}	Minimum separation angle between the line of sight to two satellites within the NGSS constellation.	N/A	degrees
A_{RA}	Maximum axial ratio for AES antenna.	6 dB This may be exceeded if compensated for by excess antenna gain. See Section 2.2.3.1.2.1.1 and subsections.	dB
D/U	Minimum pattern discrimination between two potential satellite positions above the minimum elevation angle, Θ_{MIN}	AES6: 13 dB, AES7: 7 dB, for 85% of all geostationary arc locations spaced 80 deg or more in longitude from the wanted satellite. AES4: N/A	
$\Delta\phi$	Maximum phase discontinuity permitted between beam positions of a steered AES antenna. If the system design does not require steered antennas, this value may be set to "not applicable" (n/a).	AES6 & AES7: < 8 deg for 90% of combinations of adjacent beams. AES4: N/A. Phase jumps shall be minimized by hysteresis.	
G_{MAX}	Maximum gain of the aeronautical antenna pattern in the upper hemisphere above the minimum elevation angle Θ_{MIN}	AES6: 17 AES7: 12 AES4: N/A (EIRP limit of 15 dBW applies)	dBic
G_{NOM}	Minimum gain of the aeronautical antenna pattern in the declared coverage volume.	The key requirements for the AES are G/T and EIRP, hence there is no minimum gain requirement for any of the antenna types. Typical minimum gain numbers, for information only, are: AES6: 12 dB AES7: 6 dB AES4: 2.5 dB	dBic

Symbol	Parameter	Value	Units
G/T	Minimum G/T performance of the AES based on antenna performance, associated equipment and installation parameters	AES6: -13 AES7: -19 AES4: See table in Section 2.2.3.1.2.1.1.3.	dB/K
L_{MAX}	Maximum cable loss between the connector of the antenna and the diplexer.	AES6 & AES7: 0.3 dB AES4: The typical maximum loss between antenna and DLNA = 0.3 to 0.5 dB. Integrated Class 4 antenna (containing HPA and DLNA): Not applicable. (Loss is internal to the antenna.)	dB
L_{MSG}	Maximum length in octets of user data sequence using ACARS transmissions.	220	Octets
L_{SNDP}	Maximum length in octets of user data contained in a maximum length sub-network dependent protocol data block.	N/A	Octets
N_D	Maximum number of simultaneous data carriers which are permitted in the maximum number of simultaneous carriers, N. For single-carrier systems, this term is not applicable. (3)	N/A. Voice and data services are time-shared on common carriers. See N below.	
N_V	Maximum number of simultaneous voice carriers which are permitted, N. For single-carrier systems, this term is not applicable. (3)	N/A. Voice and data services are time-shared on common carriers. See N below.	
N	Maximum number of simultaneous data and voice carriers. For a single carrier system, N = 1. (3)	AES6: 4 AES7: 4 AES4: 1	
$EIRP_{NOM}$	Nominal single carrier power for each of N_D data carriers in a multi-carrier capable AES, with no back-off.	AES6: 20 dBW EIRP AES7: 15.1 dBW EIRP AES4: 10 dBW EIRP for elevation = 5 to 70 degrees, and 8 dBW for elevation = 70 to 90 degrees.	dBW
P_{RNG}	Range over which the AES transmit power must be controlled	10	dB
TOL_{LOW}	Tolerance of EIRP control – lower EIRP limit.	AES6: 3.5 AES7: 2.0 AES4: 1.5	dB
TOL_{HIGH}	Tolerance of EIRP control – upper EIRP limit.	AES6: 2.0 AES7: 3.5 AES4, 5 to 70^{o} elevation : 3.5 AES4, 70 to 90^{o} elevation : 5.5	dB
$P_{SC\text{-}SC}$	Maximum burst output power of single carrier AES.	AES6: 20 dBW EIRP AES7: 15.1 dBW EIRP AES4: 10 dBW EIRP	dBW
P_{STEP}	Maximum acceptable step size for controlling AES transmit power.	1	dB
P_V	Maximum single carrier power for each of N_V voice carriers in a multi-carrier capable AES.	N/A. No separate voice carriers.	W dBm
$R_{SC\text{-}UD}$	Minimum average single channel user data rate sustainable at a residual ACARS packet error rate of 10^{-6}.	32	kb/s

Symbol	Parameter	Value	Units
Θ_{MIN}	Minimum elevation angle for satellite coverage.	5	deg
τ_{SW}	Maximum switching time between electronically steered antenna patterns. For systems that do not require steered antennas, value may be declared as "n/a".	50	µs
ρ_{RA}	Minimum exclusion zone radius necessary for protection of Radio Astronomy.	N/A	km
C/M	Carrier-to-multipath discrimination ratio measured at the minimum elevation angle, given in decibels	5^{o} elevation: 10 20^{o} elevation: 12 Median sea state as defined in SDM [1] Vol.5 Ch.3 Section 2.2.5.	dB
V_{SWR}	Maximum Voltage Standing Wave Ratio measured at a single input port of the AES antenna.	1.5:1	

Notes

30. *1660.5 to 1668 MHz is not used by this system. (Radio astronomy band)*
31. *AES6 and AES7 equipment are required to support operation in the Standard L-band only. AES4 equipment shall support operation over the full Extended L-band (XL) plus Standard L-Band.*
32. *Only the lowest bearer sub-type is listed, as this gives the lowest sensitivity levels. These numbers are intended to enable interference calculations between systems on an aircraft. Numbers assume that noise bandwidth = symbol rate and system noise temperature T = 240 Kelvin (or NF = 1.2 dB). Ambient temperature ≤ 25 deg C. Based on Packet Error Rate (PER) < 1E-3.*

2.2.3 Detailed Requirements

2.2.3.1 AES Application Requirements

This section and its subsections contain requirements for an AMS(R)S terminal and subsystems. Where possible, reference is made to the Inmarsat System Definition Manual (SDM) [1] and Mandatory Test Requirements (MTRs). The aim is to achieve commonality between requirements and test methods in this appendix and those required to obtain access to the Inmarsat network through the Inmarsat Type Approval process.

2.2.3.1.1 Inmarsat and Service Provider Type Approval

Type Approval (TA) of a system by Inmarsat is required before a terminal can access the Inmarsat network.
The objectives of Type Approval are two fold; to ensure that the system does not interfere with either the Inmarsat network, other users or other systems - “non-

interference" and also to ensure (to the maximum reasonable extent) that the system is 'Fit for Purpose' for its intended application (availability, reliability, performance).

The Type Approval process consists of the following elements, each of which has its own test requirements and pass/fail criteria:

- Physical Layer 1 MTR testing
- Protocol Layer 2/3 MTR Testing
- Functional testing
- System testing
- Environmental MTR testing
- On-air Performance benchmark testing (Alpha)
- Flight Trial (Beta)

Note: The MTRs listed in Table 1-3 constitute Inmarsat Type Approval / Type Assessment as required in the succeeding paragraphs.

The diagram below illustrates how all of the testing elements come together to form an Inmarsat Type Approval.

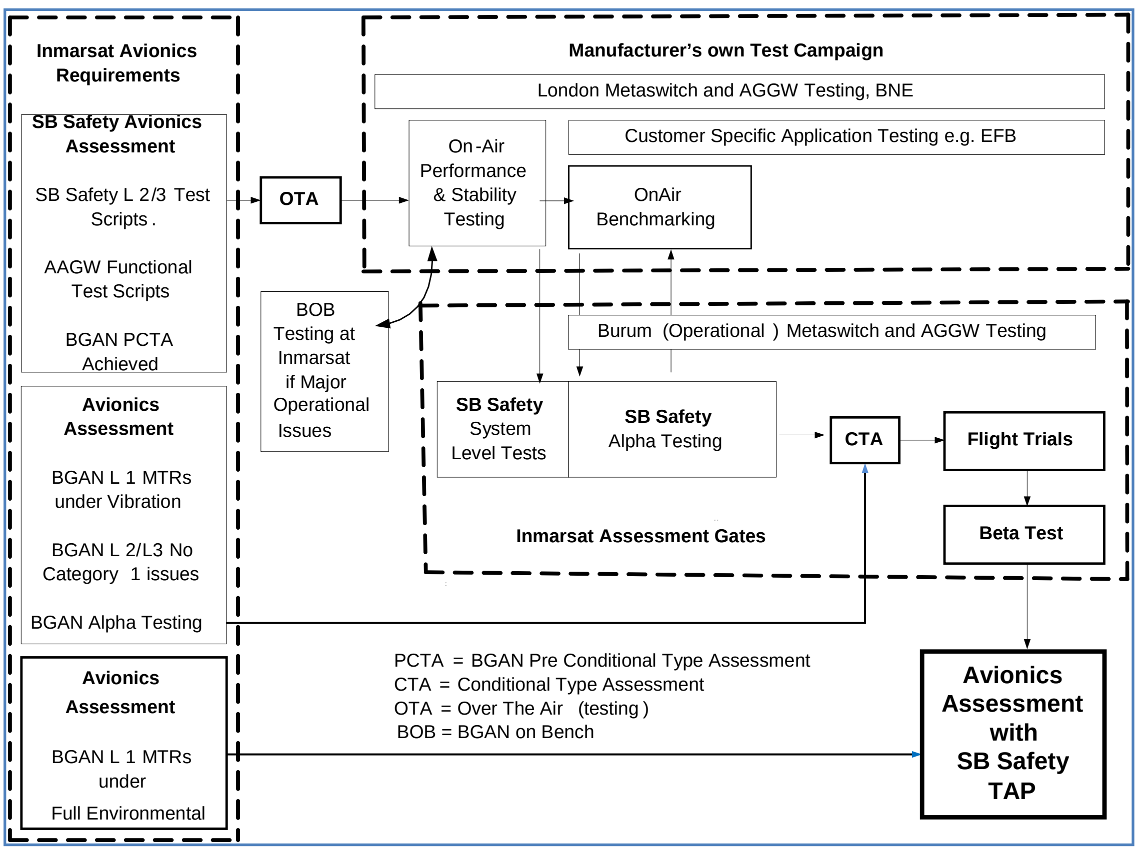

Figure 2-4 Overview of Inmarsat Type Approval Process

2.2.3.1.1.1 Complete AES Systems

In addition to any other requirements stated in this appendix, any complete AES seeking to demonstrate compliance with this MOPS shall achieve Inmarsat Type Approval as evidenced by a Type Approval Certificate issued by Inmarsat. Furthermore the AES shall be approved, in writing, by a relevant Communication Network Provider as being fit for use on their network (e.g. ARINC AQP or SITA VAQ testing).

2.2.3.1.1.2 Separately Approved Antenna Subsystems

In addition to any other requirements stated in this appendix, any HGA, IGA, DMA or DF equipment seeking to demonstrate compliance with this MOPS shall achieve a successful Inmarsat Type Assessment as evidenced by a Type Assessment Letter issued by Inmarsat.

2.2.3.1.1.3 Separately Approved Transceiver Systems

In addition to any other requirements stated in this appendix, any 6MA, 6F, 7MA or 7F transceiver seeking to demonstrate compliance with this MOPS shall achieve a successful Inmarsat Type Assessment as evidenced by a Type Assessment Letter issued by Inmarsat. In addition it shall achieve Inmarsat Type Approval as part of a complete AES6 or AES7, as evidenced by a Type Approval Letter issued by Inmarsat for an AES which includes the particular transceiver. Furthermore the transceiver shall be approved as part of at least one AES combination, in writing, by a relevant Communication Network Provider as being fit for use on their network (e.g. ARINC AQP or SITA VAQ testing).

2.2.3.1.2 Antenna

This section covers the requirements for the HGA and IGA antenna, as well as antenna-related characteristics for an AES4.
There is a large similarity between requirements in this appendix for the HGA and IGA and corresponding requirements in DO-210D. The main differences are

- For HGA and IGA antennas used in systems capable of transmitting on more than one carrier at a time, there are increased PIM requirements.
- A new single channel ELGA antenna with extended frequency of operation has been created.

Antenna types which have previously been accepted as meeting the requirements of DO-210D, may therefore be accepted as meeting the requirements of this appendix by only preforming additional tests related to the new passive intermodulation requirement in Section 2.2.3.1.2.6 and its subsections.
Note: HGA and IGA antennas, in the context of this appendix, are expected to be suitable for use in multi-channel systems. Extended L-band operation is therefore not required, and PIM requirements apply. HGA and IGA antennas may also be capable of extended L-band operation for single-channel use, thereby exceeding the requirements of this appendix. AES4 systems are restricted to single-channel

operation and therefore are not subject to PIM requirements, and operation over the Extended L-band and Standard L-Band is required.

2.2.3.1.2.1 Coverage Volume, Polarization and Antenna

2.2.3.1.2.1.1 Coverage Volume

The coverage volume of an antenna type represents the percentage of the solid angle contained in the sub-hemisphere above the antenna from 5° elevation (above the horizontal in level flight) to the zenith (90° or broadside to the antenna) over which the antenna being tested meets its requirements. The requirements and the percentage of the hemisphere which must be compliant vary from one antenna type to another.

2.2.3.1.2.1.1.1 HGA Coverage Volume

The HGA shall simultaneously satisfy the requirements for *G/T*, *EIRP*, A_{RA} and *D/U* for at least 75% of the solid angle of the sub-hemisphere described above.
The gain used to compute the coverage performance requirements shall be right hand circularly polarized per ITU-R Recommendation 573.
When computed with the maximum cable losses given in Table 2-2 and the DLNA noise figure given in Section 2.2.3.1.4.2, an HGA intended for operation in an AES6 shall achieve a G/T of not less than -13 dB/K within its declared coverage volume.
If a DLNA with a noise figure better than that listed in Section 2.2.3.1.3.2 is required to meet the minimum coverage volume, this shall be declared as a limitation of the equipment under test.
Note: For example, such a declaration might be a part of an application for a TSO.

The G/T performance shall include the effects of IM/PIM products generated by the antenna by converting the intermodulation product level to an equivalent noise temperature (T). For this purpose it shall be assumed that the power of the CW intermodulation product will be spread over a bandwidth of 172 kHz for 7th order intermodulation products and 192 kHz for 9th order intermodulation products during normal operation.
When computed with the maximum cable losses given in Table 2-2 and the characteristics of the appropriate high power amplifier (HPA), an HGA intended for operation in an AES6 shall achieve an EIRP of not less than $EIRP_{NOM}$ - TOL_{LOW} dBW as given in Table 2-3 for an AES6.
The axial ratio of the HGA (A_{RA}) shall be less than 6dB when referenced to a right hand circularly polarized source.
If the axial ratio exceeds 6 dB, it may be compensated for with excess gain with the following assumptions:

- the satellite axial ratio (A_{RSV}) is per Table 2-3
- the polarization ellipses are orthogonal

The satellite discrimination (*D/U*) shall be greater than 13dB for geostationary arc locations spaced 45° or more in longitude from the wanted satellite.

The coverage volume, as declared by the antenna manufacturer shall include all effects of:

- installation on a surface representative of the mounting surface on which it is intended to operate the antenna,
- beam-pointing errors within the antenna subsystem including those due to implementation of the beam steering algorithm, and
- the radome and/or other protective devices such as rain erosion coatings or lightning diversion systems.

The maximum gain of the HGA shall not exceed G_{MAX} for any steering angle.

2.2.3.1.2.1.1.2 IGA Coverage Volume

The IGA shall simultaneously satisfy the requirements for *G/T*, *EIRP* and, A_{RA} for at least 85% of the solid angle contained in the sub-hemisphere above 5 degrees elevation.

The gain used to compute the coverage performance requirements shall be right hand circularly polarized gain per ITU-R Recommendation 573.

When computed with the maximum cable losses given in Table 2-2 and the DLNA noise figure in Section 2.2.3.1.4.2, an IGA intended for operation in an AES7 shall achieve a G/T of not less than -19 dB/K. If a non-standard DLNA with a noise figure better than that listed in Section 2.2.3.1.4.2 is required, this shall be declared as a limitation of the equipment under test.

Note: For example, such a declaration might be a part of an application for a TSO.

The G/T performance shall include the effects of IM/PIM products generated by the antenna by converting the intermodulation product level to an equivalent noise temperature (T). For this purpose it shall be assumed that the power of the CW intermodulation product will be spread over a bandwidth of 172 kHz for 7^{th} order intermodulation products and 192 kHz for 9^{th} order intermodulation products during normal operation.

When computed with the maximum cable losses given in Table 2-2 and the characteristics of the appropriate high power amplifier (HPA), an IGA intended for operation in an AES7 shall achieve an EIRP of not less than $EIRP_{NOM}$ - TOL_{LOW} dBW as given in Table 2-3 for an AES7.

The axial ratio of the IGA (A_{RA}) shall be less than 6dB when referenced to a right hand circularly polarized source.

If the axial ratio exceeds 6 dB it may be compensated for with excess gain with the following assumptions:

- the satellite axial ratio (A_{RSV}) is per Table 2-3.
- the polarization ellipses are orthogonal.

The satellite discrimination (*D/U*) shall be greater than 7 dB for geostationary arc locations spaced 80° or more in longitude from the wanted satellite for 85% of the solid angle of the sub-hemisphere above 5 degrees elevation.

The coverage volume, as declared by the antenna manufacturer shall include all effects of:

- installation on a surface representative of the mounting surface on which it is intended to operate the antenna,
- beam-pointing errors within the antenna subsystem including those due to implementation of the beam steering algorithm, and
- the radome and/or other protective devices such as rain erosion coatings or lightning diversion systems.

The maximum gain of the IGA shall not exceed G_{MAX} for any steering angle.

2.2.3.1.2.1.1.3 AES4 Coverage Volume

The AES4 shall simultaneously satisfy the requirements for G/T and EIRP for at least 98% of the solid angle of the sub-hemisphere above 5 degrees elevation.
The following data shall be used to calculate the coverage volume:

- Measured antenna characteristics.
- Measured characteristics of the rest of the system. The system may be subdivided further as required, e.g. the diplexer may be measured separately from the transceiver, and the measurements then combined mathematically.
- An integrated AES4 antenna (containing an HPA and DLNA) may be separated internally in order to characterize the antenna portion for gain and noise temperature and to characterize the rest of the electronics for transmit power and noise figure.

Note: The measurements referenced in the previous bullet points may not be possible on an assembled production antenna. Special test items may therefore be required for this purpose. Such special test items are permitted when necessary.

The gain used to compute the coverage performance requirements shall be right hand circularly polarized per ITU-R Recommendation 573.
The antenna shall be characterized for radiation pattern performance using measurements in the sub-hemisphere above the antenna from 5° elevation up to 90° elevation.
The AES4 shall meet the following requirements over its declared coverage volume, under conditions specified in SDM [1] Vol.5 Ch.3 Sections 2.3.1 and 2.4.1:

Table 2-4 Class 4 G/T and EIRP requirements

Parameter	Requirement
Gain to noise temperature ratio (G/T)	≥ -22 dBK for Elevation = 70-90^o ≥ -21 dBK for Elevation = 60-70^o ≥ -20 dBK for Elevation = 20-60^o ≥ -21 dBK for Elevation = 15-20^o ≥ -22 dBK for Elevation = 5-15^o
Achievable EIRP	≥ 10.0 dBW for Elevation = 5-70^o ≥ 8.0 dBW for Elevation = 70-90^o

Notes:

33. *The antenna gain of the ELGA used in an AES4 is not specified. Instead the performance of the complete system is specified in terms of EIRP and G/T. Nominally the antenna gain is 2.5 dB.*
34. *Unlike the LGA specified in DO-210D, the ELGA typically implements a means of beam steering, allowing better gain and coverage volume than the LGA.*

When computed with the installation losses as specified by the manufacturer an AES4 shall achieve an EIRP of not less than $EIRP_{NOM}$ - TOL_{LOW} dBW as given in Table 2-3 for a Class 4 system.
The axial ratio of the AES4 shall be less than 6dB when referenced to a right hand circularly polarized source.
If the axial ratio exceeds 6 dB it may be compensated for with excess gain with the following assumptions:

- the satellite axial ratio (A_{RSV}) is per Table 2-3.
- the polarization ellipses are orthogonal.

except that over any 8% of the 98%, a further relaxation of no more than 2 dB in both G/T and EIRP is permitted.
The EIRP shall not exceed 15 dBW in any direction.

2.2.3.1.2.1.2 Polarization

Refer to Section 2.2.3.1.2.1.1 and its subsections.

2.2.3.1.2.1.3 Antenna Gain

Refer to Section 2.2.3.1.2.1.1 and its subsections.

2.2.3.1.2.2 Axial Ratio

Refer to Section 2.2.3.1.2.1.1 and its subsections.

2.2.3.1.2.3 Power Handling Capabilities

2.2.3.1.2.3.1 Single Carrier Antennas

An ELGA shall achieve all single-carrier specifications when handling a carrier having average power equal to the maximum average RF power rating of the antenna in the transmit band at maximum operational altitude.
NOTE: The term "maximum average RF power rating" is defined as the maximum transmitter output power that the antenna subsystem is rated to accept.

2.2.3.1.2.3.2 Multi-carrier Antennas

An HGA or IGA shall not sustain damage while handling two simultaneous in-band CW carriers, each at half the maximum rated power of the antenna.

2.2.3.1.2.4 Passband

The antenna shall meet its requirements over the following frequency bands:
An HGA or an IGA shall meet its requirements over at least the standard L-band. Manufacturers may optionally declare the capability of operating with a single channel over the Extended L-band.
AES4 shall meet its requirements over the Extended plus Standard L-band.
Note: The Standard L-band and Extended L-band are defined in Table 2-3.

2.2.3.1.2.5 Antenna Voltage Standing Wave Ratio

When measured at the single RF port of an HGA or IGA, the Voltage Standing Wave Ratio (VSWR) shall not exceed 1.5:1 when correctly mated with the appropriate connector for any selected beam. The nominal characteristic impedance shall be 50 ohms.
There is no VSWR requirement for the AES4 antenna, as its effect is internal to the system.

2.2.3.1.2.6 Antenna Intermodulation Products

The following sub-sections are applicable to multi-channel systems only.

2.2.3.1.2.6.1 Radiated Antenna Intermodulation Products in the GNSS Band

For multi-carrier operation, when operating two unmodulated carriers, each with a power of 8 dBW (HGA) or 9.1 dBW (IGA), anywhere in the antenna’s declared transmit band, the antenna shall not generate intermodulation products with levels and frequencies as follows:
In the frequency range 1559 to 1585 MHz, the level of the intermodulation product shall not exceed -158.5 dBW.
In the frequency range 1585 to 1605 MHz, the level of the intermodulation product shall not exceed -157 dBW.
Intermodulation levels should be referenced to the output port of an external 1/4-wave monopole GNSS antenna mounted on a common ground plane with the HGA under test. The isolation between the monopole and the HGA shall be 40 dB or other declared antenna isolation applicable to GPS and GLONASS respectively, or suitable compensation to the measurement shall be applied.

2.2.3.1.2.6.2 Antenna Intermodulation Products in the AMS(R)S Bands

The antenna intermodulation products of 9th order or higher shall be taken into account when calculating G/T for the purpose of calculating coverage, as described in sections 2.2.3.1.2.1.1.1 and 2.2.3.1.2.1.1.2 for HGA and IGA respectively.

Note: Guidance related to installations and selection of cables is given in ARINC 781 Section 2.3.6.

2.2.3.1.2.7 Carrier-to-Multipath Discrimination

With the aircraft in horizontal flight over sea in median sea condition (see note below), the AES antenna shall attenuate the reflected signal from the sea surface relative to the main signal in the direction of the satellite, so as to achieve a minimum C/M of 10 dB at 5^o elevation and 12 dB at 20^o elevation.

Note: The C/M over median sea (C/Mmed) is defined on the basis of the C/M for rough sea (C/Mrough corresponding to sea states with Beaufort Number 3 or higher) and on the C/M for smooth sea (C/Msmooth corresponding to the sea state with Beaufort Number 0), by C/Mmed = (0.3 x C/Msmooth) + (0.7 x C/Mrough) (all values in dB).

This agrees with the methodology used in the SDM and DO-210D.

2.2.3.1.2.8 Pattern Discrimination

Not applicable. See Section 2.2.3.1.2.9.4.

2.2.3.1.2.9 Steered Antenna Requirements

2.2.3.1.2.9.1 Phase Discontinuity

An HGA or IGA antenna shall meet the requirements of the SDM [1] Vol.5 Ch.3 Section 2.2.9.
There is no requirement for the AES4 antenna.

2.2.3.1.2.9.2 Beam Switching Time

The antenna shall meet the requirements of the SDM [1] Vol.5 Ch.3 Section 2.2.9.

2.2.3.1.2.9.3 Steering Rate

The antenna shall be capable of pointing to its commanded main beam steering direction (± 0.5dB of gain) within six seconds from any other initial main beam steering direction.

2.2.3.1.2.9.4 Pattern Discrimination

Refer to Section 2.2.3.1.2.1.1 and its subsections.

2.2.3.1.2.10 Manufacturer-defined Antenna Tests

For the purposes of environmental qualification the manufacturer shall define test procedures which do the following:

- Stimulate the antenna under test in such a manner that the beam steering and operational control interface are exercised and BITE responses monitored during the DO-160G environmental exposures listed in Table 2-25 as is required for tests which require that the antenna under test be powered and active. This is intended to be a design qualification test.
- Test the antenna's RF performance and control/BITE interfaces to the degree that the manufacturer can say with a high degree of confidence that the antenna performance/behavior is unchanged after the environmental exposure in Table 2-25. This assumes that the antenna under test was a properly functioning antenna before environmental exposure. This is intended to be a production test.

Results from this test (summary RF performance measurements or BITE response data) should be included with the antenna environmental qualification data.

2.2.3.1.3 Transceiver Subsystem

2.2.3.1.3.1 Transmitter Function

The transmitter shall meet all its requirements over the following frequency bands:
AES6, AES7, 6MA, 6F, 7MA, 7F: 1626.5 to 1660.5 MHz.
AES4: 1626.5 to 1660.5 MHz and 1668 to 1675 MHz.

2.2.3.1.3.1.1 Minimum Power Output

The levels derived in this section are based upon the $EIRP_{NOM}$ value for the system class being qualified (taken from SDM [1] Vol.5 Ch.3 Section 2.4.1) and the tolerance requirements (taken from SDM [1] Vol.5 Ch.3 Section 2.4.1.4) and the values of other system components as shown in Table 2-2 and Table 2-3.

2.2.3.1.3.1.1.1 AES4

For an AES4, at minimum antenna gain of the antenna in the declared coverage volume and in the elevation range 5 - 70°, the AES system shall emit an EIRP towards the satellite of not less than:

$$EIRP_{MIN} \geq EIRP_{NOM}\ [5 - 70°]\ - TOL_{LOW}$$

$$EIRP_{MIN} \geq 10\ dBW - 1.5\ dB\ = 8.5\ dBW$$

For an AES4, at minimum antenna gain of the antenna in the declared coverage volume and in the elevation range 70 - 90°, the AES system shall emit an EIRP towards the satellite of not less than:

$$EIRP_{MIN} \geq EIRP_{NOM}\,[70 - 90°] - TOL_{LOW}$$

$$EIRP_{MIN} \geq 8\ dBW - 1.5dB = 6.5\ dBW$$

2.2.3.1.3.1.1.2 Categories 6D and 7D

The power output from a 6D system, measured at the connector of the antenna, shall not be less than:

$$P_{OUT} \geq EIRP_{NOM} - G_{NOM} - TOL_{LOW} + 10\log(N)$$

$$P_{OUT} \geq 20.0 - 12 - 3.5 + 10\log(N) = 4.5 + 10\log(N)\ dBW$$

The power output from a 7D system, measured at the connector of the antenna, shall not be less than:

$$P_{OUT} \geq EIRP_{NOM\_Cl7} - G_{NOM} - TOL_{LOW} + 10\log(N)$$

$$P_{OUT} \geq 15.1 - 6 - 2 + 10\log(N) = 7.1 + 10\log(N)\ dBW$$

N is the number of simultaneous SBB carriers; only 1 carrier will be providing priority services. The value of N should be declared by the manufacturer for the system being certified, but may not exceed the value of N in Table 2-3. If a manufacturer has a mechanism to preempt non-priority channels in the event of lack of HPA power then the value of N can be made 1 for this test, however the manufacturer is required to prove the power preemption using the optional test defined in Section 2.4.2.3 and its subsections.
The maximum cable loss between the Class 6D / 7D transceiver and the antenna, as specified in Table 2-2, shall be included in this measurement, or compensated for by calculation.

2.2.3.1.3.1.1.3 Categories 7MA, 7F, 6MA, 6F

The power output from a 6MA or 6F transceiver, measured at the HPA output, shall not be less than:

$$P_{OUT} \geq EIRP_{NOM} - G_{NOM} - TOL_{LOW} + DLNA\ to\ Antenna + DLNA\ Transmit\ path + Transceiver\ to\ DLNA + 10\log(N)$$

$$P_{OUT} \geq 20.0 - 12 - 3.5 + 0.3 + 0.8 + 1.4 + 10\log(N) = 7 + 10\log(N)\ dBW$$

The power output from a 7MA or 7F transceiver, measured at the HPA output, shall not be less than:

$$P_{OUT} \geq EIRP_{NOM} - G_{NOM} - TOL_{LOW} + DLNA\ to\ Antenna + DLNA\ Transmit\ path + Transceiver\ to\ DLNA + 10\log(N)$$

$$P_{OUT} \geq 15.1 - 6 - 2 + 0.3 + 0.8 + 1.4 + 10\log(N) = 9.6 + 10\log(N)\ dBW$$

N is the number of simultaneous SBB carriers operating; only 1 carrier will be providing priority services. The value of N should be declared by the manufacturer for the system being certified, but may not exceed the value of *N* in Table 2-3. If a manufacturer has a mechanism to preempt non-priority services in the event of lack HPA power then the value of *N* shall be made 1 for this test, however the manufacturer is required to prove the power preemption using the optional test defined in Section 2.2.3.3.
The cable between the Class 6MA/6F/7MA/7F transceiver and the DLNA, the insertion loss of the DLNA and the cable between the DLNA and antenna are accounted for in the calculations based upon the maximum cable losses in Table 2-2 and the DLNA filter responses detailed in sections 2.2.3.1.4.3.2 and 2.2.3.1.4.3.3.

2.2.3.1.3.1.2 Maximum Individual Carrier Output

Note: The levels derived in this section are based on the EIRP value (taken from [1] Vol.5 Ch.3 Section 2.4.1) for the system class being qualified and the tolerance requirements (taken from SDM [1] Vol.5 Ch.3 Section 2.4.1.4) and the values of other system components as shown in Table 2-3.

2.2.3.1.3.1.2.1 AES4

For an AES4 system, at maximum antenna gain of the antenna in the elevation range 5 - 70°, the AES system shall not exceed the maximum EIRP towards the satellite, which is derived as follows:

$$EIRP_{MAX} \leq EIRP_{NOM} + TOL_{HIGH}$$

$$EIRP_{MAX} \leq 10\ dBW + 3.5\ dB = 13.5\ dBW$$

For an AES4 system, at maximum antenna gain of the antenna in the elevation range 70 - 90°, the AES system shall not exceed the maximum EIRP towards the satellite, which is derived as follows:

$$EIRP_{MAX} \leq EIRP_{NOM} + TOL_{HIGH}$$

$$EIRP_{MAX} \leq 8\ dBW + 5.5\ dB = 13.5\ dBW$$

2.2.3.1.3.1.2.2 Categories 6D and 7D

For a Class 6D subsystem the maximum power output measured at the connector of the antenna shall be limited to the maximum value derived as follows:

$$P_{OUT} \leq EIRP_{NOM} - G_{NOM} + TOL_{HIGH}$$

$$P_{OUT} \leq 20.0 - 12 + 2 = 10 \text{ dBW}$$

For a Class 7D subsystem the maximum power output measured at the input to the antenna port shall be limited to the maximum value derived as follows:

$$P_{OUT} \leq EIRP_{NOM} - G_{NOM} + TOL_{HIGH}$$

$P_{OUT} \leq 15.1 - 6 + 3.5 = 12.6$ dBW

The maximum cable between the Class 6D /7D subsystem and the antenna, as specified in Table 2-2, shall be included in this measurement, or compensated for by calculation.

2.2.3.1.3.1.2.3 Categories 7MA, 7F, 6MA, 6F

For a Class 6MA and 6F transceiver the maximum power output measured at the Transceiver HPA output port shall be limited to the maximum value derived as follows:

$P_{OUT} \leq EIRP_{NOM} - G_{NOM} + TOL_{HIGH} + \mathit{DLNA\ to\ Antenna} + \mathit{DLNA\ Transmit\ path} + \mathit{Transceiver\ to\ DLNA}$

$P_{OUT} \leq 20.0 - 12 + 2 + 0.3 + 0.8 + 1.4 = 12.5$ dBW

For a Class 7MA and 7F transceiver the maximum power output measured at the Transceiver HPA output port shall be limited to the maximum value derived as follows:

$P_{OUT} \leq EIRP_{NOM} - G_{NOM} + TOL_{HIGH} + \mathit{DLNA\ to\ Antenna} + \mathit{DLNA\ Transmit\ path} + \mathit{Transceiver\ to\ DLNA} + 10\log(N)$

$P_{OUT} \leq 15.1 - 6 + 3.5 + 0.3 + 0.8 + 1.4 = 15.1\ dBW$

The cable between the Class 6MA/6F/7MA/7F transceiver and the DLNA, the insertion loss of the DLNA and the cable between the DLNA and antenna are accounted for in the calculations based upon the maximum cable losses in Table 2-2 and the DLNA filter responses detailed in Sections 2.2.3.1.4.3.2 and 2.2.3.1.4.3.3.

2.2.3.1.3.1.3 Maximum Total Transmitter Output Power

The maximum total average transmit power from all channels of an AES shall be limited to no more than 18 dBW (63 W), referenced to the connector of the antenna. This is based on 40 dB isolation between the AES antenna and the GNSS antenna. If a different isolation level is declared by the manufacturer the maximum total average transmit power limit shall be adjusted accordingly. All channels shall be assumed to be transmitting with the maximum duty cycle.

Where an AES offers non-SBB services (e.g. Aero H+) simultaneously with SBB, this limit shall apply to the total power of all channels from all services which can transmit simultaneously.

Note: This requirement maintains compatibility with GNSS susceptibility requirements as stated in the ICAO GNSS SARPs.

A Class 6F or 6MA transceiver shall be capable of limiting its transmit power to below 17.8 dBW (60 W) average power, referenced to the connector of the antenna.

A Class 7F or 7MA transceiver shall be capable of limiting its transmit power to below 14.8 dBW (30 W) average power, referenced to the connector of the antenna.

Note: This requirement maintains compatibility with the power handling of an ARINC 741 or ARINC 781 antenna. If the antenna and installation allow a higher power level, this limit may be set to a different value for that installation.

2.2.3.1.3.1.4 Transmitter Intermodulation Performance.

A multi-channel AES shall meet the requirements of the SDM [1] Vol.5 Ch.3 sections 2.4.8.1, 2.4.8.2, 2.4.8.3 and 2.4.8.5.
Class 6MA, 7MA, 6F or 7F sub-systems may rely on the specified rejection provided by the applicable DLNA (Type MA or F). Derived requirements for the transceiver are listed in Table 2-31.

2.2.3.1.3.1.5 Transmitter Harmonics, Discrete Spurious and Noise Density

Note: This section excludes the requirements for intermodulation products in multi-channel AESs, which are covered in Section 2.2.3.1.3.1.4. This section also excludes requirements for emissions in the transmit band, which are covered in Section 2.2.3.1.3.1.9.

Harmonics, discrete spurious and noise emitted by an AES4 outside of its transmit band shall be at or below the limits in Table 2-5.
Harmonics, discrete spurious and noise emitted by an AES6 or AES7 outside of its transmit band shall be at or below the limits in Table 2-6.

Table 2-5 Harmonics, discrete spurious and noise density limits for AES4

Lower (MHz)	Upper (MHz)	EIRP limit (dBW)	Transmit Power Limit (dBW)	Measurement Bandwidth (kHz)
0.01	1518.0		-118	10
1518.0	1559		-186	10
1559	1605		-118 -125	1000 1
1605	1610		-115 -125	500 1
1610	1614		-78	10, averaged over 2000 seconds
1614.0	1621.5	-46		1000
1621.5	1624.5	-60		30
1624.5	1625.125	-60 to -57 linear		30
1625.125	1626	-57 to -47 linear		30
1626.0	1626.2	-47 to -40 linear		30
1626.2	1626.5	-40		30
1626.5	1662.5	See Section 2.2.3.1.3.1.9		
1662.5	1666		-52.5 -39.5	10 1000
1666	1677	See Section 2.2.3.1.3.1.9		
1677	1680	-60		30
1680	1685	-60		300
1685	1705	-60		1000
1735.0	18000	-60		3000

Notes to Table 2-5.

35. *Sections marked "linear" are linearly interpolated in dB vs. frequency.*
36. *The values in the "Transmit Power Limit" column refer to power at the connector of the antenna. For Class 4 antennas with integrated DLNA this physical connector does not necessarily exist. In this case the equivalent measurement may be performed using a specially prepared unit, or by measuring at a different point and calculating the equivalent levels.*
37. *The values in the "EIRP Limit" column shall be converted to equivalent Transmit Power Limits, referred to the connector of the antenna, using the appropriate antenna gain as described in the test procedure in Section 2.4.3.1.2.1.5.*
38. *All measurements shall use an averaging detector.*
39. *In the band 3 253.0 MHz to 3 321.0 MHz the maximum EIRP in one, and only one, 300 kHz measurement bandwidth shall not exceed -38 dBW. Elsewhere in this band the power limit in Table 2-5 shall be applied.*
40. *In the bands 4 879.5 MHz to 4 981.5 MHz and 5 004.0 MHz to 5 025.0 MHz the maximum EIRP in one, and only one, 3 MHz measurement bandwidth shall not exceed -48 dBW. Elsewhere in these bands the power limit in Table 2-5 shall be applied.*
41. *In the bands 6 506.0 MHz to 6 642.0 MHz and 6 672.0 MHz to 6 700.0 MHz the maximum EIRP in one, and only one, 3 MHz measurement bandwidth shall not exceed -48 dBW. Elsewhere in these bands the power limit in Table 2-5 shall be applied.*
42. *In the bands 8 132.5 MHz to 8 302.5 MHz and 8 340.0 MHz to 8 375.0 MHz the maximum EIRP in one, and only one, 3 MHz measurement bandwidth shall not exceed -48 dBW. Elsewhere in these bands the power limit in Table 2-5 shall be applied.*
43. *In the bands 9 759.0 MHz to 9 963.0 MHz and 10 008.0 MHz to 10 050.0 MHz the maximum EIRP in one, and only one, 3 MHz measurement bandwidth shall not exceed -59 dBW. Elsewhere in these bands the power limit in Table 2-5 shall be applied.*

Table 2-6 Harmonics, Discrete Spurious and Noise Density Limits for AES6 and AES7

Lower (MHz)	Upper (MHz)	EIRP limit (dBW)	Transmit Power Limit (dBW)	Measurement Bandwidth (kHz)
0.01	1518		-118	10
1518	1525		-146	10
1525	1559		-186	10
1559	1605		-122 -125	1000 1
1605	1610		-119 -125	500 1
1610	1614		-78 (See note 8)	10, averaged over 2000 seconds

1614	1621.5	-52 to -46 (See note 8)		1000
1621.5	1624.5	-60 (See note 8)		30
1624.5	1625.125	-60 to -57 linear (See note 8)		30
1625.125	1626.0	-57 to -47 linear (See note 8)		30
1626.0	1626.2	-47 to -41 linear		30
1626.2	1626.5	-41		30
1626.5	1662.5	See Section 2.2.3.1.3.1.9.		
1662.5	1670		-56 (See note 8) -39.5 (See note 8)	10 1000
1670	1690	-36		1000
1690	12000	-61		1000
12000	18000	-49		1000

Notes to Table 2-6.

44. *Sections marked "linear" are linearly interpolated in dB vs. frequency.*
45. *The values in the "Transmit Power Limit" column refer to power at the connector of the antenna.*
46. *The values in the "EIRP Limit" column shall be converted to equivalent Transmit Power Limits, referred to the connector of the antenna, using the appropriate antenna gain as described in the test procedure in Section 2.4.3.1.2.1.5.*
47. *All measurements shall use an averaging detector.*
48. *In the band 3253.0 MHz to 3321.0 MHz the maximum EIRP in one, and only one, 300 kHz measurement bandwidth shall not exceed -38 dBW. Elsewhere in this band the power limit in Table 2-6 shall be applied.*
49. *In each of the bands 4 879.5 MHz to 4 981.5 MHz, 6 506.0 MHz to 6 642.0 MHz and 8 132.5 MHz to 8 302.5 MHz the maximum EIRP in one, and only one, 300 kHz measurement bandwidth shall not exceed -48 dBW. Elsewhere in this band the power limit in Table 2-6 shall be applied.*
50. *In the band 9 759.0 MHz to 9 963.0 MHz the maximum EIRP in one, and only one, 300 kHz measurement bandwidth shall not exceed -59 dBW. Elsewhere in this band the power limit in Table 2-6 shall be applied.*
51. *If measured on one channel of a multi-channel system, this level shall be reduced by 10*log(N) dB, where N is the number of channels the system is capable of transmitting on simultaneously.*

2.2.3.1.3.1.6 Protection of Radio Astronomy

Requirements for protection of the radio astronomy bands are included in Section 2.2.3.1.3.1.5.
Note: It may be assumed that the BGAN network will not allocate transmit frequencies to the transmitter of an AES in or adjacent to the radio astronomy

band in geographic areas which are sensitive to emissions in the Radio Astronomy band.

2.2.3.1.3.1.7 Carrier-Off Level

After the transmitter has not transmitted for more than two seconds, the transmitted EIRP, referred to the connector of the antenna, shall be below the levels specified in Table 2-7 and Table 2-8**.**

Note: The tables are consolidated from applicable sections of ETSI EN 301 473 [9], including protection of GNSS bands and protection of Radio Astronomy bands. Requirements for interoperability of on-aircraft systems were added from DO210D change 3 as applicable.

Table 2-7. AES4 Unwanted Emissions Limits with Carrier Off

Lower (MHz)	Upper (MHz)	EIRP limit (dBW)	Transmit Power Limit (dBW)	Measurement Bandwidth (kHz) & detector
0.01	1000		-118	10, average
1000	1518		-118	10, peak hold
1518	1559		-186	10 average
1559	1605		-122 -128	1000, average over 20 ms 1, average over 20 ms
1605	1610		-106 to -91 -116 to -101	1000, average over 20 ms 1, average over 20 ms
1610	1626.5		-90	10, average over 2000 sec
1626.5	1662.5	-77		100, peak hold
1662.5	1666	-77		100, peak hold
1666	1677	-77		100, peak hold
1677	18000	-77		100, peak hold

Table 2-8. AES6 and AES7 Unwanted Emissions Limits with Carrier Off

Lower (MHz)	Upper (MHz)	EIRP limit (dBW)	Transmit Power Limit (dBW)	Measurement Bandwidth (kHz) & detector
0.01	1000		-118	10, average
1000	1518		-118	10, peak hold
1518	1525		-146	10, peak hold
1525	1559		-186	10 average
1559	1605		-122 [1] -128 [1]	1000, average over 20 ms 1, average over 20 ms

1605	1610		-106 to -91 [2] -116 to -101 [2]	1000, average over 20 ms 1, average over 20 ms
1610	1626.5		-94	10, peak hold
1626.5	1662.5	-63		3, peak hold
1662.5	10700	-72		100, peak hold
10700	18000	-76		100, peak hold

Notes to Table 2-7 and Table 2-8

52. *In the band 1559 to 1605 MHz, isolation of 40 dB is assumed between the AES antenna and a GNSS antenna on the same aircraft. Where different antenna isolation is declared, these limits may be adjusted accordingly.*
53. *The specified levels between 1605 and 1610 MHz provides for protection of GLONASS on the same aircraft, with an antenna isolation of 55 dB assumed. Where different antenna isolation is declared, these limits may be adjusted accordingly.*
54. *The values in the "EIRP Limit" column shall be converted to equivalent Transmit Power Limits, referred to the connector of the antenna using the appropriate antenna gain as described in the test procedure in Section 2.4.3.1.2.1.7.*

2.2.3.1.3.1.8 Power Control

The AES shall meet the requirements of the SDM [1] Vol.5 Ch.3 Section 2.4.1.4.

2.2.3.1.3.1.9 On-Channel Output Spectrum

2.2.3.1.3.1.9.1 AES4

The maximum EIRP spectral density of the unwanted emissions from an AES4 in any 3 kHz band within the band 1626.5 to 1662.5 MHz, but outside the nominated bandwidth given in Table 2-12, shall comply with the limits of either Table 2-9 or Table 2-10. The same table shall be applied to all bearer types transmitted by the same AES.
In addition, an AES4 shall simultaneously meet the requirements of the SDM [1] Vol.5 Ch.3 Section 2.4.2.

Table 2-9 Limits for In-band Emissions for AES4

Offset from the edge of the band of the nominated bandwidth (kHz)	Maximum EIRP (dBW) (see note 1)
0 to 25	0 to -15
25 to 125	-15 to -50
125 to 425	-50
425 to 1 500	-50 to -65
1500 to 36 000	-65

Note 1: The limits in this table may be exceeded provided that the sum in watts of the spectrum components exceeding the limits of the table does not exceed -30 dBW.

Table 2-10 Alternative Limits for In-band Emissions for AES4

Offset from the edge of the band of the nominated bandwidth (kHz) (see notes 1, 3)	**Maximum EIRP (dBW)** (see note 2)
0 to 25	0 to -15
25 to 55	-15 to -30
55 to AB	-30
AB to (AB + 0.35 x B3dB)	-30 to -40
(AB + 0.35 x B3dB) to CD	-40
CD to (CD + 0.25 x B3dB)	-40 to -50
(CD + 0.25 x B3dB) to EF	-50
EF to 1 500	-50 to -65
1 500 to 36 000	-65
NOTE 1: Frequency offset is determined from the edge of the nominated bandwidth. See Table 2-12. *NOTE 2: Linearly interpolated in dBW vs. Frequency offset.* *NOTE 3: The parameters AB, CD, EF are defined below.* *NOTE 4: B3dB (3 dB Bandwidth) is total width of the signal spectrum 3 dB below the maximum in-band density.*	

2.2.3.1.3.1.9.2 AES6 / AES7.

The maximum EIRP spectral density of the unwanted emissions from an AES6 or AES7 in any 3 kHz band within the band 1626.5 to 1662.5 MHz, but outside the nominated bandwidth, shall not exceed the limits of Table 2-11.
In addition, an AES6 or AES7 shall simultaneously meet the requirements of the SDM [1] Vol.5 Ch.3 Section 2.4.2.

Table 2-11 Limits for In-band Emissions for AES6 and AES7

Offset from the edge of the band of Nominated Bandwidth (kHz)	**Maximum EIRP (dBW) (see notes 1 and 2)**
0 to 25	5 to -15
25 to 125	-15 to (-50 + E)
125 to 425	-50 + E
425 to 1 500	(-50 + E) to -60
1500 to 36 000	-60
Note 1: The limits in this table may be exceeded provided that the sum in watts of the spectrum components exceeding the limits of the table does not exceed -30 dBW. *Note 2: E (in dB) is the excess EIRP of the AES compared with 15 dBW. In cases*	

where the antenna directivity of the AES is greater than 15 dBi then the factor E shall be limited to a maximum value of +15 dB. In all other cases, the factor E shall be limited to a maximum value of +10 dB.

The parameters AB, CD and EF are defined as a proportion of the 3dB Bandwidth as follows:
AB = (55 kHz) or (100 % of the B3dB), whichever is the greater;
CD = (95 kHz) or (200 % of the B3dB), whichever is the greater;
EF = (125 kHz) or (300 % of the B3dB), whichever is the greater.

The nominated bandwidths for the transmit bearers are given in Table 2-12.

Table 2-12 Nominated Bandwidth of Transmit Bearers

Bearer Type Prefix	Nominated Bandwidth (kHz)
RT0.5	25
RT1	50
RT2	100
RT2.5	100
RT4.5	200
RT5	200

2.2.3.1.3.1.10 Transmitter Operation in Moving Aircraft

The AES shall meet the requirements of the SDM [1] Vol.5 Ch.3 Section 2.4.10.1.

2.2.3.1.3.1.11 Transmitter Phase Noise

The AES shall meet the requirements of the SDM [1] Vol.5 Ch.3 Section 2.4.6

2.2.3.1.3.1.12 Frequency Accuracy

The AES shall meet the requirements of the SDM [1] Vol.5 Ch.3 Section 2.4.10.

2.2.3.1.3.1.13 Transmitter Tuning

The AES shall meet the requirements of the SDM [1] Vol.5 Ch.3 Section 2.4.9.

2.2.3.1.3.1.14 Manufacturer-defined Transmitter Test

The manufacturer shall define a test that will verify the correct operation of the transmit sub-systems. The test will then be used to verify the Transceiver operates correctly over a wide range of DO-160G [3] categories without adding excessive test time or cost that may have been incurred if many of the other tests were required to be repeated over environment. The aim is to detect degradation

in performance during or after (depending on the environmental category) environmental tests.
Measuring error vector magnitude (EVM) is one possible method to achieve this.
Measuring only one fast bearer type (e.g. T4.5) should suffice.

2.2.3.1.3.2 Receiver Function

2.2.3.1.3.2.1 Receiver Sensitivity

The AES shall meet the requirements of the SDM [1] Vol.5 Ch.3 Section 2.3.12.1.

2.2.3.1.3.2.1.1 Data

No separate requirement. Refer to Section 2.2.3.1.3.2.1.
Note: Data and voice are multiplexed onto the same SBB bearers.

2.2.3.1.3.2.1.2 Voice

No separate requirement. Refer to Section 2.2.3.1.3.2.1
Note: Data and voice are multiplexed onto the same SBB bearers.

2.2.3.1.3.2.2 Receiver Bandwidth

The tuning bandwidth of the receiver shall meet the requirements of the SDM [1] Vol.5 Ch.3 Section 2.3.4.

2.2.3.1.3.2.3 Rejection of Signals Outside the NGSS Receive Band

AES6 or AES7
The receiver shall acquire and track a satellite downlink signal with a minimum signal level given by the minimum of S_V and S_D in the presence of a CW interference signal of +3 dBm in the frequency range 470 to 18,000 MHz, excluding the band: 1449 to 1626.5 MHz.
Within the excluded band, the level of the CW interference signal shall be reduced linearly, in dB, from +3 dBm at 1449 MHz to –72 dBm at 1524 MHz and from +3 dBm at 1626.5 MHz to –72 dBm at 1560 MHz.
Note: Frequencies between 1524 and 1560 MHz are considered "in band" for the purpose of this section. Performance is subject to the requirements of Section 2.2.3.1.3.2.1.

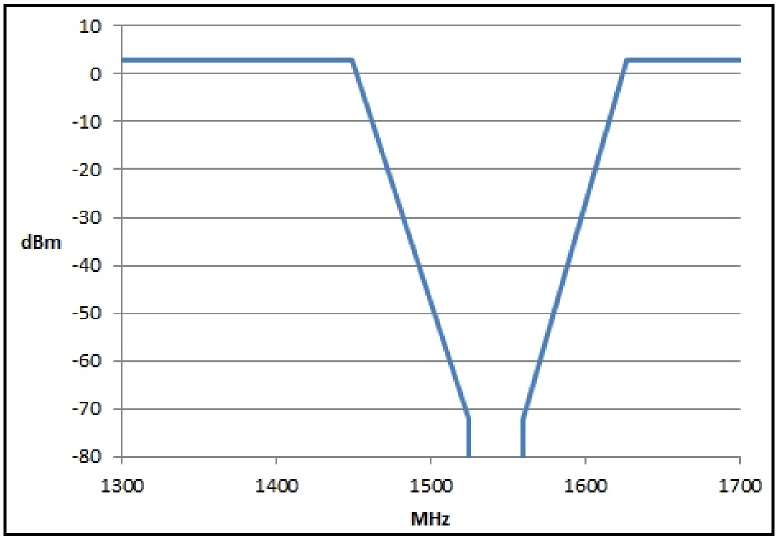

Figure 2-5 Class 6 & 7 Interferer Levels

Class 4

The receiver shall acquire and track a satellite downlink signal with a minimum signal level given by the minimum of S_V and S_D in the presence of a CW interference signal of -6.5 dBm in the frequency range 470 to 18,000 MHz, excluding the band: 1400 to 1626.5 MHz. The signal level is referred to the connector of the antenna array.

Within the excluded band, the level of the CW interference signal shall be reduced linearly, in dB, from -6.5 dBm at 1400 MHz to –72 dBm at 1517 MHz and from -6.5 dBm at 1626.5 MHz to –72 dBm at 1560 MHz.

Note: Frequencies between 1524 and 1560 MHz are considered "in band" for the purpose of this section. Performance is subject to the requirements of Section 2.2.3.1.3.2.1.

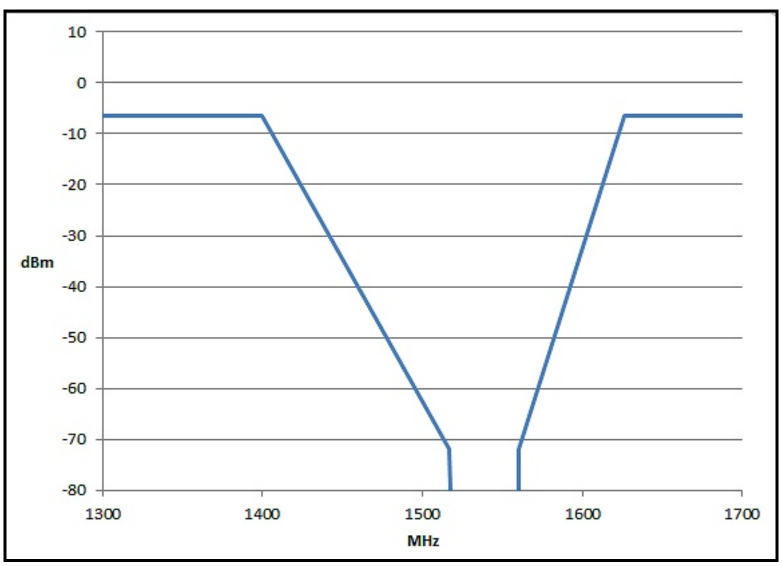

Figure 2-6 Interferer Level Class 4

2.2.3.1.3.2.4 Rejection of Carrier Signals Generated by Other AMS(R)S Equipment

Not applicable.
Note: This is not applicable because this requirement is already addressed by the following two factors:

- *Transmissions in the SBB transmit band are much lower than the SBB AES' own transmitted signal. The definition for coverage volume is already determined while transmitting at full power.*
- *Transmissions outside of the SBB transmit band are covered by section 2.2.3.1.3.2.3.*

2.2.3.1.3.2.5 Receiver Operation in Moving Aircraft

The receiver shall meet its requirements with a Doppler shift on the received signal of up to ± 2.5 kHz and peak rate of change of up to ± 30 Hz/s. (Reference: SDM [1] Vol.5 Ch.3 Section 2.3.5.)

2.2.3.1.3.2.6 Receiver Susceptibility

The receiver shall properly acquire and track the required signals and shall output data at the specified rate when subjected to wideband interference noise of level S_{UW} across the designated receive band.
The receiver shall properly acquire and track the required signals and shall output data at the specified rate when subjected to CW interference of level S_{UN} on any assignable channel within the designated receive band.
The receiver shall meet its performance requirements when subjected to channel impairments according to the requirements of the SDM [1] Vol.5 Ch.3 Section 2.3.10.2.

2.2.3.1.3.2.7 Acquisition

All transceivers shall meet the requirements of SDM [1] Volume 5, Chapter 3 Section 2.3.11.

2.2.3.1.3.2.8 Carrier-to-Noise Level Accuracy

All transceivers shall meet the requirements of SDM [1] Volume 5, Chapter 3 Sections 2.3.9.1 and 2.3.9.2.

2.2.3.1.4 DLNA (Diplexer / Low Noise Amplifier)

NOTE: Although there is no corresponding section in the main body of the DO-262 document, this additional section covers the requirements for the DLNA.

This section describes the requirements for two types of DLNA. These broadly correspond to two DLNA types described in ARINC 741 and 781 as follows:

Table 2-13 DLNA Types

Equipment Class Identifier	ARINC 741 Type	ARINC 781 Type
DMA	Modified Type A DLNA	
DF		Type F DLNA

Notes:

55. *Differences between diplexer requirements in this appendix and the ARINC 741 and 781 documents include the extension of the receive frequency range of the 'DMA' down to 1525 MHz, and adding a PIM requirement for the DMA.*
56. *The DLNAs are both intended for use in multi-channel systems. The requirements therefore exclude the Extended L-band.*

2.2.3.1.4.1 DLNA VSWR

The DLNA's Antenna, Receive and Transmit ports shall have a nominal impedance of 50 ohms. The DLNA Antenna and Transmit ports' VSWR shall be 1.3:1 maximum. The LNA output port (receive port) VSWR shall be 1.5:1 maximum. During any measurement the other two RF ports shall be terminated into 50 ohms.

2.2.3.1.4.2 DLNA Noise Figure

The noise figure of the receive path of the DLNA shall be less than 1.2 dB at temperatures up to 25 degrees C. It may increase at higher temperatures to a maximum of 1.6 dB at 70°C.

2.2.3.1.4.3 DLNA Gain / Filter Response

2.2.3.1.4.3.1 DLNA Gain

The gain of the receive path of the DLNA shall be between 53 and 60 dB.

2.2.3.1.4.3.2 Filter Response for 'DMA' DLNA

Antenna Port to Receive Port
The rejection from the antenna port to the receive port, relative to the maximum gain in the receive passband shall be:

Table 2-14 DMA Antenna Port to Receive Port Rejection

Frequency (MHz)	Rejection
0.0 to 1450.0	> 75 dB
1626.5 to 1660.5	> 120 dB
1660.5 to 18000.0	> 75 dB

Transmit Port to Antenna Port
The path from the transmit port to the antenna port shall have the following characteristics:

Table 2-15 DMA Transmit Port to Antenna Port Rejection

Frequency (MHz)	Rejection
0.0 to 1525.0	> 80 dB
1525.0 to 1559.0	> 120 dB
1559.0 to 1585.0	> 100 dB
1585.0 to 1605.0	> 88 dB
1605.0 to 1610.0	> 62 dB
1610.0 to 1614.0	> 40 dB
1614.0 to 1626.5	(Decreasing) [1]
1626.5 to 1631.5	< 2.3 dB
1631.5 to 1660.5	< 0.8 dB
1660.5 to 1735.0	(Increasing) [1]
1735.0 to 12000.0	> 50 dB
12000.0 to 18000.0	> 15 dB

Note 1: Although the diplexer response is not strictly constrained in this frequency segment, for the purposes of deriving the requirements of the transceiver, a linear slope in dB, on a logarithmic frequency scale shall be assumed. This is not intended to place a further requirement on the diplexer.

Transmit Port to LNA Output Port
The path from the transmit port to the receive port shall have the following characteristics:

Table 2-16 DMA Transmit Port to LNA Output Port Rejection

Frequency (MHz)	Rejection
0.0 to 1350.0	> 100 dB
1350.0 to 1530.0	> 80 dB
1530.0 to 1559.0	> 120 dB
1559.0 to 1565.0	> 80 dB
1565.0 to 1585.0	> 100 dB
1585.0 to 1626.5	> 40 dB
1626.5 to 1660.5	> 120 dB
1660.5 to 2000.0	> 80 dB
2000.0 to 18000.0	> 50 dB

2.2.3.1.4.3.3 Filter Response for 'DF' DLNA

Antenna Port to Receive Port

The rejection from the antenna port to the receive port, relative to the maximum gain in the receive passband shall be:

Table 2-17 DF Antenna Port to Receive Port Rejection

Frequency (MHz)	Rejection
0.0 to 1459.0	> 75 dB
1626.5 to 1660.5	> 120 dB
1660.5 to 18000.0	> 75 dB

Transmit Port to Antenna Port

The path from the transmit port to the antenna port shall have the following characteristics:

Table 2-18 DF Transmit Port to Antenna Port Rejection

Frequency (MHz)	Rejection
0.0 to 1525.0	> 80 dB
1525.0 to 1559.0	> 120 dB
1559.0 to 1585.0	> 111 dB
1585.0 to 1605.0	> 95 dB
1605.0 to 1610.0	> 62 dB
1610.0 to 1614.0	> 40 dB
1614.0 to 1620	> 30 dB
1620 to 1624.5	> 20 dB
1624.5 to 1625.5	> 10 dB (See exception below)
1625.5 to 1626.5	(Decreasing) [1]
1626.5 to 1633	< 1.3 dB
1633 to 1660.5	< 0.8 dB
1660.5 to 1735.0	(Increasing) [1]
1735.0 to 1865.0	> 50 dB
1865.0 to 3250.0	> 20 dB
3250.0 to 3330.0	> 50 dB
3330.0 to 4000.0	> 40 dB
4000.0 to 12000.0	> 50 dB
12000.0 to 18000.0	> 15 dB

Note 1: Although the diplexer response is not strictly constrained in this frequency segment, for the purposes of deriving the requirements of the transceiver, a linear slope in dB, on a logarithmic frequency scale shall be assumed. This is not intended to place a further requirement on the diplexer.

Despite the requirements above, the following relaxation is allowed above 55 degrees C:
Between 1525 and 1525.5 MHz the rejection shall be > 2.5 dB.

Transmit Port to LNA Output Port
The path from the transmit port to the receive port shall have the following characteristics, relative to the passband:

Table 2-19 DF Transmit Port to Receive Port Rejection

Frequency (MHz)	Insertion Loss
0.0 to 2000.0	> 125 dB
2000.0 to 18000.0	> 50 dB

2.2.3.1.4.4 DLNA Passive Intermodulation

2.2.3.1.4.4.1 DLNA Intermodulation Products in Satcom Receive Band

With two CW carriers, each of power 10.2 dBW anywhere in the band 1626.5 to 1660.5 MHz, the 7th and higher intermodulation product shall be less than -133 dBm in the band 1525 to 1559 MHz as measured at the receive port, but with the power level referenced to the antenna port.
Note: Levels are explained in ARINC 781 Section 2.2.4.5.1

2.2.3.1.4.4.2 Type F - DLNA Intermodulation Products in the GNSS Band

With two CW carriers, each of power 10.2 dBW anywhere in the band 1626.5 to 1660.5 MHz, the 5th and higher intermodulation products shall each be less than -100 dBm in the band 1555 to 1595.42 MHz as measured at the antenna port.
Note: Levels are explained in ARINC 781 Section 2.2.4.5.2

2.2.3.1.4.5 DLNA Maximum Transmit Power

With two CW carriers, each of power 16 dBW anywhere in the band 1626.5 to 1660.5 MHz, the insertion loss in the transmit path of the diplexer shall be within its specification.
Note: This requirement is to verify that no arcing occurs at maximum transmit power. Arcing is expected to cause a severe increase in insertion loss.

2.2.3.1.4.6 DLNA Receive Port Output Power

The DLNA receive port shall have a 1 dB compression point of at least 10 dBm.

2.2.3.1.4.7 Manufacturer Defined DLNA Test

The manufacturer may define a test to test for gross failures during environmental testing.

2.2.3.1.5 Required Aircraft Interfaces

The AES shall make provision for the following interfaces to connect to surrounding equipment on the aircraft:

- Interfaces required for ACARS, Voice and IP services (as described in other sections).
- Interface or interfaces to receive position and attitude data from the aircraft avionics. This data shall be used to select the correct satellite, steer the antenna and report the geographic position of the aircraft. Data shall be updated at least once per second. The data required is:
    - Latitude and longitude, to a precision of 1 second of arc or better.
    - Altitude. Absolute altitude is preferred although pressure altitude is acceptable.
    - Track angle.
    - Speed over ground.
    - Aircraft attitude. Roll pitch and yaw, to a precision of no more than one degree.
- Interface to receive the 24-bit ICAO address of the aircraft (as used for the Mode S transponder) from the aircraft. The ICAO address is used in conjunction with the IMSI and MSISDN as the addressing mechanism for the AES within the SBB system. While the AES is required to make provision for this, the use of this input in a specific installation is not compulsory where the aircraft does not have this information available on a suitable data bus, provided that other means is provided to enter this data into the configuration settings of the AES.

All these interfaces shall operate without degradation over the declared environmental specification of the AES.

2.2.3.2 User Link Modulation and Signal in Space (Physical Layer)

The AES receiver chain, from after the antenna connector, shall accept a signal-in-space with signal characteristics and receiver performance as specified in the Inmarsat SDM [1] Vol.5 Ch.3 sections 2.3.2 to 2.3.14.
The transmitter chain, up to before the antenna connector, shall transmit a signal with the signal format and transmitter performance as specified in the Inmarsat SDM [1] Vol.5 Ch.3 sections 2.4.1 to 2.4.8 and 2.4.8.2 to 2.4.11.

2.2.3.3 Priority, Precedence and Preemption

The SB-Safety service is designed principally for the elements in the ACD (Aircraft Control Domain), but with proper segregation other domains may be served (see Section 2.2.3.10).
The AES shall provide mechanisms to enable prioritization of priority-related communications over lower priority and non-priority communications. The diagram in Figure 2-7 shows the key logical elements in the data path for both voice and data communications in an SB-Safety AES. It also shows the three primary points of contention that need to be considered when applying the rules

of priority, precedence and preemption. Each AES shall have a mechanism to detect when contention - in at least each of these three areas - is likely or has occurred and to favor the higher priority communications over lower priority communications. Specific requirements are listed the following subsections.

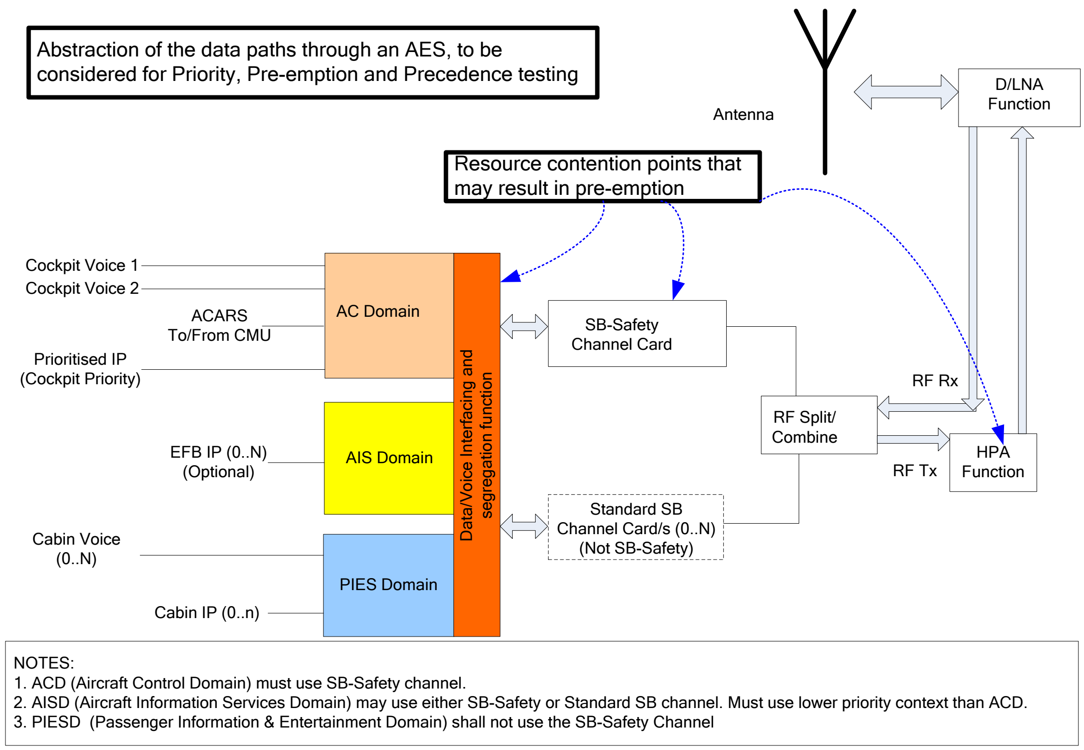

Figure 2-7 Logical functional elements to be considered for Priority, Precedence and Pre-emption

2.2.3.3.1 Packet Data

The APN for each function or IP port (e.g. ACARS, priority VoIP, Priority IP and non-priority IP Ethernet ports) shall be configurable at installation time.
The AES shall ensure that data to and from the various data sources (e.g. priority IP port, EFB, ACARS, VoIP) are transferred to and from the BGAN Protocol Stack in such a way that higher priority data is not affected by lower priority data.
Note: This requirement is considered a subset of the requirements for protection from a Denial-Of-Service (DOS) attack. This requirement is more thoroughly covered in the Information Security Section 2.2.3.10.

The level of network priority associated with individual PDP contexts is governed by the APN being utilized. The AES has no involvement in requesting or modifying the priority of a PDP context; it is only responsible for the initial establishment of the PDP context with the appropriate APN identifier. The AES *must be authorized for use against any APN that it attempts to access to obtain the relevant network resource.*

The BGAN network utilizes the 3G concept of Allocation/Retention Priority (ARP) in providing the priority and pre-emption of network resources. Each APN has an associated ARP value which translates to a priority level on the physical radio access bearers. The BGAN RAN is capable of providing 15 different levels of priority and therefore scope for introducing future priority cockpit IP services can be accommodated without affecting ACARS traffic.

Once PDP contexts have been set up by the AES, the BGAN network is wholly responsible for prioritizing the IP data across the air interface, including in the AES' transmit direction by using the correct priorities when allocating network resources. Defining this functionality is therefore not included in this section.

2.2.3.3.2 Circuit Mode Communications (Voice)

The AES shall apply priority and preemption mechanisms to air-to-ground and ground-to-air voice calls. Each call shall be assigned one of four levels of priority as follows:

Table 2-20 Voice call priority identifiers

Call Application	Priority Identifier
Distress	1 (High)
Air Traffic Service	2
Airline Operational Control	3
Airline Administrative Control	3
Airline Passenger Communications	4 (Low)

System resources (e.g. available voice circuits) shall be assigned to calls with a higher priority (lower priority identifier) in preference to calls of a lower priority, even if this means prematurely terminating a lower priority call.
Note : A configuration setting may be provided to disable prioritization of voice calls. In this case all calls shall be treated as non-priority (level 4). This option is intended for installations where priority voice is not required.

If an AES provides voice interfaces to the cabin, (e.g. 2-wire POTS for cabin crew or passengers), calls to or from these interfaces shall be assigned a priority level of 3 or 4 as appropriate for the application. In multi-channel systems such calls may also be serviced through an independent non-priority channel in the same AES.
Notes:

57. *The priority identifiers in the table above agree with ARINC 741, ARINC 781 and ICAO SVGM. These identifiers should therefore be used in the interface to the flight crew if compatibility with existing Classic Aero systems is to be preserved. The generic section of this appendix shows an opposite numbering scheme in Table 2-7, which is intended as a logical scheme only.*

58. *For Ground-To-Air calls: The Inmarsat Oceanic Safety SDM [1] defines the four level priority scheme for voice calls dialed from the ground side. It provides a table mapping the digits to be dialed to the corresponding Call Application.*

59. *For Air-To-Ground Calls: The interface to the pilot is User Terminal dependent and the naming and or numerical priority level convention is not intended to be standardized by this appendix. Nonetheless, a conformant implementation shall enable the user to specify these four logical call priorities when initiating an A2G call.*

60. *BGAN Emergency Calls as defined in SDM V1Ch4 are not part of the SBB-Safety system. These calls are detected by the BGAN terminal when the user dials one of a specific predefined set of emergency numbers (e.g., 999, 911, etc). The BGAN terminal sets an emergency tag to the call and the BGAN network diverts the call based on the location. SwiftBroadband priority service provides a more rigorously defined system for dealing with emergency situations; therefore it is not a requirement for this approval. Further the capability to make one of these emergency calls when no USIM is present is not applicable to the installation environment on an aircraft and is not required to be implemented.*

2.2.3.3.3 ACARS Communications

The AES shall allocate its own resources in a way that prioritizes ACARS messaging over non-safety data.
A facility shall be provided to configure the APN of the PDP context for the ACARS service at installation time.
All ACARS messages shall be handled by the AES at the same priority level.
Note: ACARS messaging is affected by two different prioritization mechanisms:

Prioritization between ACARS messages, e.g. ATC vs. AOC messages.

The ACARS protocol itself does not capture or convey priority information, therefore the AES and the SwiftBroadband network both handle all ACARS messages transparently at the same priority level. Connected avionics (e.g. CMU) and ground routing equipment may provide their own level of prioritizing, but such prioritization is beyond the scope of this AES MOPS.

Prioritization between ACARS data and other data on the network.

The ACARS protocol itself does not capture or convey priority information, therefore the AES and the SwiftBroadband network both handle all ACARS messages transparently at the same priority level. Connected avionics (e.g. CMU) and ground routing equipment may provide their own level of prioritizing, but such prioritization is beyond the scope of this AES MOPS.

The level of priority access to system resources in the AES and in the BGAN network is such that ACARS messages are assured of obtaining a communications path regardless of congestion caused by lower-priority communication services.

To assign the appropriate priority to the ACARS service, the BGAN network distinguishes the ACARS data from other network traffic on the basis of the APN *of the PDP context used for ACARS data. The AES is responsible for setting up the PDP context using the correct APN. The BGAN network is responsible for the allocation of system resources based on the APN name. This mechanism is described in Section 2.2.3.3.1.*

2.2.3.4 Satellite Subnetwork Data Protocol

The AES shall implement all functionality required to interact with the Inmarsat SwiftBroadband network protocol. This shall include (but not be limited to):

- AES acquiring and registering on the satellite network.
- Dynamically negotiating appropriate bearers.
- Dynamically negotiate FEC parameters to maximize throughput while maintaining target packet error rate.
- Negotiating spot-beam handovers.
- Connecting to circuit-switched services (voice).
- Connecting to packet-switched services.
- Creating PDP contexts.

Note: The SwiftBroadband protocol and control mechanisms aim to maintain a packet error rate of 10^{-3} after error correction. This is followed by a 16-bit CRC which will reject almost all packets with errors, giving a residual packet error rate of 16×10^{-9}. This exceeds the requirement of 10^{-6} in the generic part of this appendix. A packet in this context is an FEC block. A standard 128 octet message is typically contained in an FEC block. The lost packet rate of 10^{-3} after the CRC is improved to 10^{-12} by the retry mechanism used with background connections.

2.2.3.4.1 ATN-compliant Protocol Requirements

Not applicable. ATN is not supported.

2.2.3.4.2 ACARS Protocol Requirements

The AES shall implement an ACARS Airborne Gateway (AAGW) function and support ACARS communications as described in the Inmarsat SDM [1] V3C03, Section 2. The failover function to Classic Aero is, however, not a mandatory function.

If the AES is configured to handle ACARS, the AAGW shall automatically register with the AGGW after start-up.

Messages shall be passed transparently as binary payload data, independent of their content.

2.2.3.5 Voice Protocol

The AES shall implement all protocol features to set up and maintain two voice calls, one through the AMBE+2 vocoder, and one using VoIP, in accordance with the Inmarsat SDM [1].

2.2.3.5.1 Vocoder Interoperability with Satellite Subnetwork

The AES shall implement an AMBE+2 vocoder and associated CS voice protocols as specified in the Inmarsat SDM [1] V5C02 .
In addition, the AES shall implement a G729A vocoder and associated VoIP protocols as specified in the Inmarsat SDM [1] V3C02.
Digital test ports, either physical or virtual, shall be provided to test each voice codec with the Voice Codec Test Set (VCTS) or a functionally equivalent test using test vectors to verify that each voice codec executes it algorithm correctly as designed.

2.2.3.5.2 Vocoder Performance in an Aeronautical Environment

Note: The two vocoders (or voice codecs) are specified in the Inmarsat SDM [1]. AES designers have no choice regarding the vocoder algorithms, but should ensure correct implementation and functioning of these algorithms (e.g. by using known test vector sets). Attention should be paid to effects of aircraft acoustic noise during integration on the aircraft. See Section 3.4.6.3.

2.2.3.6 User Data Interfaces

2.2.3.6.1 ATN-Compliant Service Interface

Not applicable.

2.2.3.6.2 ACARS Interface

The AES shall provide transmit and receive ports to interface to at least one CMU (optionally two CMUs) or equivalent function in the aircraft.
ACARS interface shall provide ACARS service through the ACARS Airborne Gateway (AAGW) function as defined in Section 2.2.3.4.2.
Note: A typical interface implementation uses an ARINC 429 port to connect to at least one CMU. Alternate implementations achieving the same functionality (e.g. ARINC 664) are acceptable.

The AES shall contribute negligible delay to ACARS messages (air-to-ground and ground-to-air).
Note: No formal allocation of the allowable delay has been done. However, end-to-end through the network, delays of less than 10 seconds are expected. The delay in the AES should be less than 0.5 seconds. Only the end-to-end delay will be verified. It is important that separate data queues are implemented to allow proper prioritization of air-to-ground ACARS data.

2.2.3.6.3 External Physical and Data Link Layer Requirements

Not applicable.

2.2.3.6.4 Avionics Subnetwork Interface Requirements for ISO-8208 Service

Not applicable.

2.2.3.6.5 Alternative ATN-compliant Subnetwork Access Protocols

Not applicable.

2.2.3.6.6 IP Data Interface

The AES may optionally provide one or more interfaces to on-board computer equipment supporting Internet Protocol (IP).
If an IP interface is provided, facilities shall be provided for the AES to establish, either automatically or otherwise, a connection (PDP context) with a required APN on the ground to handle traffic to and from the IP interface.
Note: Information security requirements related to this interface are given in Section 2.2.3.10.

2.2.3.7 Circuit Mode Service Requirements

2.2.3.7.1 Required Services

The AES shall provide interfaces for at least two priority-service voice calls.
The priority of the voice calls shall be selectable, using four priority levels, similar to those in Table 2-20.
The AES shall provide for both air-to-ground and ground-to-air voice calls.
If a new voice call is established while no other calls are in progress, it shall use the AMBE+2 voice codec and the SBB CS connection. If a second voice call is established while another voice call is in progress it shall use the G729A vocoder and a VoIP connection, through a special PDP connection.
The AES shall have the ability, when so configured, to block all incoming non-priority calls. (ref. MASPS V130)
The AES shall have the ability, when so configured, to display the priority and calling line identity (CLI) to the flight crew. The CLI shall be displayed as a phone number or a name looked up from an on-board phone book. (ref. MASPS V140).

2.2.3.7.2 Voice Quality

The AES shall provide digital test ports, either physical or virtual, to allow testing of the processing of the voice signal paths from the analogue input port of the AES to the input of the voice codec, and the path from the output port of the voice codec to the analogue output port of the AES. A typical configuration is shown in Figure 2-8.

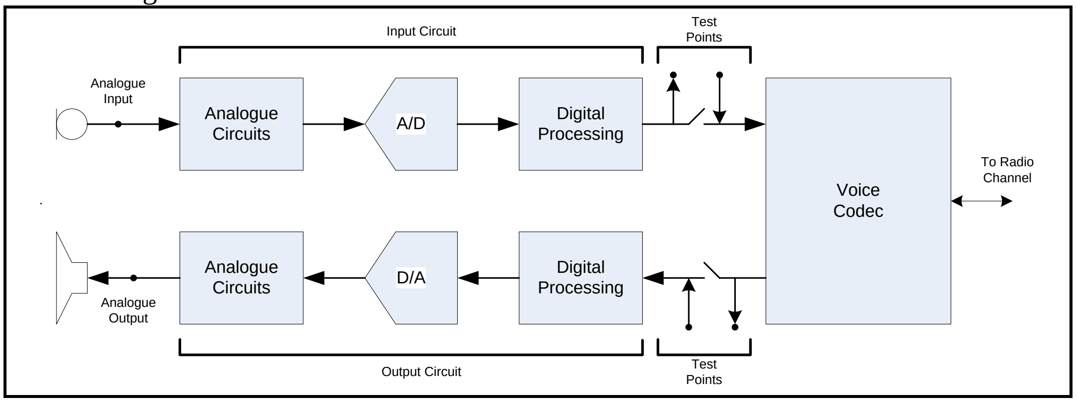

Figure 2-8 Typical voice circuits with test points

The AES shall furthermore provide for a digital loopback at the digital test points above to enable measurement of the characteristics of the voice input circuit and output circuit in cascade.
The input and output voice circuits shall each meet the following criteria:

2.2.3.7.2.1 Audio Frequency Response

The relative attenuation shall fall within the following mask.

Table 2-21 Relative attenuation of voice port

Frequency	Relative attenuation (dB)	
	Minimum	Maximum
300 to 400	-2.0	+4.4
400 to 600	-1.2	+2.6
600 to 2400	-1.2	+1.2
2400 to 2700	-1.2	+2.6
2700 to 3400	-1.2	+4.4

2.2.3.7.2.2 Total Audio Noise Including Quantization Noise

With a sinusoidal frequency of 1020 Hz applied to the input port, the overall baseband signal to noise power ratio, measured with psophometric noise weighting (according to ITU-T O.41), shall be above the following values.

Table 2-22 Total voice distortion limits

Input level (dBm0)	Baseband Signal to Noise Ratio (dB)
0	> 27
-10	> 26
-20	> 26

2.2.3.7.2.3 Spurious In-band Audio Signals

With the input and output ports terminated in their nominal impedance, the sum of all the in-band spurious and noise (including any 400 Hz and other in-band spurious signals), measured through a psophometric filter (according to ITU-T O.41), shall not exceed -64 dBm0.

2.2.3.7.2.4 Spurious and Image Audio Signals

With a sinusoidal signal in the range 300 to 3400 Hz applied to the digital input port of the audio output path at a level of 0 dBm0, the level of any resultant spurious out-of-band signal above 4 kHz (e.g. image) appearing at any audio output port shall not exceed -30 dBm0.
With a sinusoidal signal in the range 20 Hz to 20 kHz applied to the analogue input of the audio input path, at a level corresponding to 0 dBm0 in the digital domain at 1 kHz, the level of any resultant spurious product at the digital output shall not exceed -30 dBm0.

2.2.3.7.2.5 Audio Amplitude Jitter

With a sinusoidal signal of 1020 Hz applied to any input port at any level between 0 dBm0 and -20 dBm0, the overall baseband amplitude jitter shall not exceed 13% peak-to-peak (i.e. amplitude jitter < 0.13 * Vp-p).

2.2.3.7.2.6 Audio Phase Jitter

With a sinusoidal signal of 1020 Hz applied to any input port at any level between 0 dBm0 and -20 dBm0, the overall baseband phase jitter shall not exceed 10% peak to peak. (i.e. phase uncertainty < +/- 18 degrees from phase center).

2.2.3.7.2.7 Voice Latency

The sum of the latencies in the forward and return directions, which an AES adds to a voice call, shall not exceed the following values:

- CS or VoIP call over AES6 or AES7: 300 ms.
- CS or VoIP call over AES4, using bearers having 80 ms interleaving: 460 ms.

These values are measured from the time the first symbol of a frame is received through the antenna to the time the first symbol of a frame is transmitted through the antenna. Self-imposed delay (SID) is included. (ref. MASPS V80).

2.2.3.7.2.8 Call Setup Time

The AES shall not add more than 1 second to the call setup time for a new air-to-ground or ground-to-air call. This shall be achieved for 99% of calls. (ref. MASPS V30 & V40).

2.2.3.8 Recovery from Primary Power Interruption

The AES shall conform to the following requirements after encountering primary power interruptions from any cause.

- Power interruptions of less than five milliseconds duration shall cause data or voice interruptions of less than 180 ms in either direction.
- For power interruptions from 5 to 200 milliseconds duration the AES shall meet the following performance criteria:

    - The AES shall require no more than five seconds recovery time, beginning from when primary power has been restored. “Recovery” is defined as automatically returning to the previous operating state (without user intervention) such that priority voice and data services resume in the same configuration they were in before the power interruption occurred. This assumes stable transmit and receive bearers with at least the minimum quality characteristics with channel impairments specified in the SDM [1] Vol.5 Ch.3 Section 2.3.10, as well as established priority services.
    - In-transit data service packets which have been acknowledged on either the DTE or DCE interface, but not yet transferred to the opposite interface, may be lost. Non-AES higher-layer entities that employ end-to-end acknowledgement protocols may choose to retransmit such lost data.
    - Synchronization and RF output power may be lost during the power interruption and recovery time.
    - Calls and PDP contexts which are in the process of being set up may be lost.
    - There shall be no more than a momentary effect on cockpit displays.

- For power interruptions longer than 200 milliseconds duration the AES shall recover to an operational state without manual reset. The equipment shall register on the network for voice, data and ACARS service (as applicable) automatically.

2.2.3.9 Failure/Status Indication

The AES equipment shall provide, independent of any operator action, an indication of the AES resulting in

- loss of data communications
- loss of voice communications

Note: An industry-standard method for reporting these failures may be implemented by transmitting Label 270 on an ARINC 429 output port, as described in ARINC 741, part 2, Section 4.7.3.1.

2.2.3.10 Information Security

The AES shall provide adequate domain segregation to prevent the data stream to or from any IP interface from influencing the data streams used for the ACARS or priority voice functions.
An Information Security Risk Assessment shall be performed in accordance with the methodology provided in DO-326 Section 3.2.
With respect to the influence of any IP interface on the ACARS service at least the following threats (as identified in ARINC 781 Attachment 8 Section 4.5) shall be mitigated in the design of the AES:

Threat Condition	**Impact Level**
Undetected corruption of FANS messages (includes spoofing)	III (major) Spoofed FANS messages could result in false CPDLC messages instructing the flight crew to change heading or flight level, causing a reduction in safety margins.
Loss of availability of services	IV (minor) Loss of ACARS over SBB is mitigated via fallback to ACARS over Classic Aero Inmarsat service or HF radio in oceanic regions.

Notes:

61. *The aim of this requirement is to enable passing the ACARS, voice and IP data streams through a single modem. This would probably require that the IP data be handled transparently in the modem, so that it cannot influence the behavior of the modem in any way. This implies that the IP data shall not be able to control PDP contexts in the modem. It also implies that IP data shall be treated with a lower priority and be queued and throttled by the segregation function in favor of the ACARS and voice data streams.*

62. *RTCA DO-326[10] Section 3.3 provides guidance on how the Information Security Risk Assessment should influence the design.*

63. *ARINC 781-6 Attachment 8 describes a reference design which is likely to fulfill these requirements if implemented correctly, as well as an analysis showing how the requirements are fulfilled. Actual design details of any AES will probably differ from the reference design. Other independent solutions may also be possible. An analysis using the methodology in RTCA DO-326[10] will be required to determine if a specific design fulfills the requirements.*

2.3 Equipment Performance - Environmental Conditions

2.3.1 General Requirements

The environmental tests and their associated performance requirements described in this Section are intended to provide a laboratory means of determining the overall performance characteristics of the equipment under environmental conditions representative of those which may be encountered in actual operations.

Unless otherwise specified, the test procedures applicable to a determination of equipment performance under environmental test conditions are contained in RTCA Document DO-160G [3], Environmental Conditions and Test Procedures for Airborne Equipment. General information regarding the use of the procedures in RTCA DO-160G [3] is contained in Sections 1.0 through 3.0 of that document. Also, a method of identifying which environmental tests were conducted and other amplifying information on the conduct of the tests is contained in Appendix A of RTCA DO-160G [3].

DO-160G frequently gives different levels of environmental conditions. The equipment manufacturer is required to select the environmental categories suitable for intended airframes and installation environment.

Some of the minimum performance requirements in Section 2.2 of this normative appendix are not required to be qualified to all of the conditions contained in RTCA DO-160G [3]. Judgment and experience have indicated that these particular performance parameters are not susceptible to certain environmental conditions and that the level of performance specified in Section 2.2 will not be measurably degraded by exposure to these conditions. In those cases it is sufficient to verify compliance at ambient conditions for many requirements, and then continued compliance is inferred by successfully meeting the requirements.

Table 2-9 is a compliance matrix that cross-references the RTCA DO-160G [3] environmental test requirements with the performance requirements listed in Section 2.2.3 of this appendix. Only those tests specifically identified by "X" or by a numerically referenced footnote need be repeated in the various environments. Furthermore, unless otherwise noted successful verification of compliance to a requirement section implies compliance to all lesser sections as well.

In addition to the exceptions above, certain environmental tests contained in this section are not required for minimum performance equipment unless the manufacturer wishes to qualify the equipment for additional environmental conditions. If the manufacturer wishes to qualify the equipment to these additional conditions, then these tests shall be performed.

2.3.2 Equipment Configurations

The procedures in this appendix may be used to establish conformance of complete AES systems or major components of an AES, as listed in Section 2.2.1. However, even when a complete system is tested, it is allowable to demonstrate conformance by performing tests on individual major components, and then obtaining final results by calculation. Specifically, the filter characteristics of the DLNA may be measured separately from the rest of the

transmitter function and the total result obtained by calculation. This avoids the very high dynamic range required for the spurious and harmonics measurements. Similarly, the antenna's characteristics may be measured separately.
Measuring major components individually also allows measurement results to be reused where performance of different combinations of major components is to be established.

2.3.3 Configuration Control

Nominal environment testing, followed by extreme environment testing, shall be conducted on the AES with the operational flight software installed according to the correct software version number as specified in the equipment configuration documentation. Hardware shall conform to the configuration of the hardware version number specified in the equipment configuration documentation.

2.3.4 Specific Environmental Test Conditions

In addition to the specific functional tests to be repeated in various operational environments, the equipment as a whole shall be subjected to the test conditions as specified in RTCA DO-160G [3], in the sections identified in Table 2-23 and Table 2-24. By performing (and passing) those tests, the corresponding requirements of this standard shall be met.

2.3.5 Performance vs. Environmental Requirements Matrix

Table 2-23 DO-160G Performance vs. Environmental Requirements Matrix

ANTENNA SUBSYSTEM		**DO-160G Section**																						
Section	Title	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
		TEMPERATURE / ALTITUDE	TEMP VARIATION	HUMIDITY	OPERATIONAL SHOCKS /CRASH SAFETY	VIBRATION	EXPLOSIVE ATMOSPHERE	WATERPROOFNESS	FLUIDS SUSCEPTIBILTY	SAND AND DUST	FUNGUS RESISTANCE	SALT FOG	MAGNETIC EFFECT	POWER INPUT	VOLTAGE SPIKE	AUDIO FREQ. CONDUCTED SUSC.	INDUCED SIGNAL SUSCEPTIBILITY	RADIO FREQ. SUSC. (CONDUCTED. & RADIATED)	EMISSION OF RADIO FREQUENCY ENERGY	LIGHTNING INDUCED TRANSIENT SUSC.	LIGHTNING DIRECT EFFECTS	ICING	ESD	FIRE/FLAMMABILITY
HGA and IGA Antennas																								
2.2.3.1.2.1.1 including 2.2.3.1.2.1.1.1, 2.2.3.1.2.1.1.2, 2.2.3.1.2.4, 2.2.3.1.2.5	Coverage Volume (general RF performance of the antenna including VSWR)	1 18	2	2	2	2	-	2	2	2	2	2	-	2	2	2	2	1	-	2 14	2 23	2	2	-
2.2.3.1.2.3.2	Power Handling Capabilities	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.1.2.6	Antenna Intermodulation Products	18	-	-	19	19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.1.2.6.1	Radiated Antenna Intermodulation Products in the GNSS Band	18	-	-	19	19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.1.2.6.2	Antenna Intermodulation Products in the AMS(R)S Bands	18	-	-	19	19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

2.2.3.1.2.7	Carrier-to-Multipath Discrimination	1 18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.1.2.9.1	Phase Discontinuity	1 18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.1.2.9.2	Beam Switching Time	1 18	1	1	1	1	-	-	-	-	-	-	1	1	1	1	1	1	1	1 14	-	-	-	-
2.2.3.1.2.9.3	Steering Rate	1 18	1	1	1	1	-	-	-	-	-	-	1	1	1	1	1	1	1	1 14	-	-	-	-
ELGA Antenna																								
2.2.3.1.2.1.1 including 2.2.3.1.2.1.1.3, 2.2.3.1.2.4	Coverage Volume (general RF performance of the antenna including VSWR)	1 18	2	2	2	2	-	2	2	2	2	2	-	2	2	2	2	1	-	2 14	2 23	2	2	-
2.2.3.1.2.3.1	Power Handling Capabilities	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.1.2.7	Carrier-to-Multipath Discrimination	1 18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.1.2.9.2	Beam Switching Time	1 18	1	1	1	1	-	-	-	-	-	-	1	1	1	1	1	1	1	1 14	-	-	-	-
2.2.3.1.2.9.3	Steering Rate	1 18	1	1	1	1	-	-	-	-	-	-	1	1	1	1	1	1	1	1 14	-	-	-	-

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TRANSMITTER SUBSYSTEM		**DO-160G Section**																						
Section	Title	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
2.2.3.1.3.1.1	Minimum Power Output	X	X	X	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-
2.2.3.1.3.1.2	Maximum Individual Carrier Output	X	X	X	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-
2.2.3.1.3.1.3	Maximum Total Transmitter Output	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.1.3.1.4	Transmitter Intermodulation Performance.	18	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.1.3.1.5	Transmitter Harmonics, Discrete Spurious and Noise Density	18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.1.3.1.6	Protection of Radio Astronomy	18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.1.3.1.7	Carrier-Off Level	18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.1.3.1.8	Power Control	18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.1.3.1.9	On-Channel Output Spectrum	18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.1.3.1.10	Transmitter Operation in Moving Aircraft	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.1.3.1.11	Transmitter Phase Noise	18	-	-	-	X	-	-	-	-	-	-	-	13	-	X	-	-	-	-	-	-	-	-
2.2.3.1.3.1.12	Frequency Accuracy	X	X	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.1.3.1.13	Transmitter Tuning	18	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.1.3.1.14	Manufacturer-defined Transmitter Test	-	-	-	-	-	-	-	-	-	-	-	X	-	X	-	X	X	X	X 14	-	-	X	-

(continued)

RECEIVER SUBSYSTEM		DO-160G Section																					
Section	Title	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
2.2.3.1.3.2.1	Receiver Sensitivity	18	-	-	20	X	-	-	-	-	-	-	-	20	-	20	20	20	-	20 14	-	-	-	-
2.2.3.1.3.2.2	Receiver Bandwidth	18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-
2.2.3.1.3.2.3	Rejection of Signals Outside the NGSS Receive Band	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.1.3.2.5	Receiver Operation in Moving Aircraft	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.1.3.2.6	Receiver Susceptibility	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.1.3.2.7	Acquisition	18	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.1.3.2.8	Carrier-to-Noise Level Accuracy	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

DLNA SUBSYSTEM		DO-160G Section																					
Section	Title	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
2.2.3.1.4.1	DLNA VSWR	-	X	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.1.4.2	DLNA Noise Figure	18	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.1.4.3	DLNA Gain / Filter Response	18	22	-	22	22	-	-	-	-	-	-	-	22	22	22	22	22	-	22 14	-	-	22	-
2.2.3.1.4.4	DLNA Passive Intermodulation	18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.1.4.5	DLNA Maximum Transmit Power	21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.1.4.6	DLNA Receive Port Output Power	18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.1.4.7	Manufacturer Defined DLNA Test	X	X	X	X	X	-	-	-	-	-	-	-	X	X	X	X	X	-	X 14	-	-	X	-

OTHER REQUIREMENTS		DO-160G Section																						
Section	Title	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
2.2.3.1.5	Required Aircraft Interfaces	18	-	X	-	X	-	-	-	-	-	-	-	X	X	X	X	X	X	X 14	-	-	X	-
2.2.3.2	User link Modulation and Signal in Space	18	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.3	Priority, Precedence and Preemption	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Satellite Subnet work Data Protocol	Satellite Subnetwork Data Protocol	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.5	Voice Protocol	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.6	User Data Interfaces	18	-	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.7	Circuit Mode Service Requirements	24 18	-	24	-	24	-	-	-	-	-	-	-	24	-	24	24	24	24	-	-	-	-	-
2.2.3.8	Recovery from Primary Power Interruption	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-
2.2.3.9	Failure/Status Indication	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.2.3.10	Information Security	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 2-24 DO-160G Sections Applicable to the AES

DO-160G Section	Environment
4	Temperature and Altitude (See Note 1)
4.5	Temperature Tests
4.5.1	Ground Survival Low Temperature Test and Short-time Operating Low Temperature Test
4.5.2	Operating Low Temperature Test
4.5.3	Ground Survival High Temperature Test and Short-time Operating High Temperature Test
4.5.4	Operating High Temperature Test
4.5.5	In-flight Loss of Cooling Test (See Note 16)
4.6.1	Altitude Test
4.6.2	Decompression Test (See Note 3)
4.6.3	Overpressure Test (See Note 3)
5	Temperature Variation
6	Humidity
7	Operational Shocks and Crash Safety
7.2	Operational Shock (See Note 17, 25)
7.3	Crash Safety Test (See Notes 3, 4)
8	Vibration
9	Explosion Proofness (See Note 3)
10	Waterproofness (See Note 3)
10.3.1	Condensing Water Drip Proof Test (See Note 3)
10.3.2	Drip proof test (See Note 3)
10.3.3	Spray Proof Test (See Notes 3, 5)
10.3.4	Continuous Stream Proof Test (See Notes 3, 5)
11	Fluids Susceptibility (See Notes 3, 6)
11.4.1	Spray Test (See Note 3)
11.4.2	Immersion Test (See Note 3)
12	Sand and Dust (See Note 3)
13	Fungus Resistance (See Note 3)
14	Salt Fog (See Note 3)
15	Magnetic Effect
16	Power Input
16.5.1	Normal Operating Conditions (AC) (See Notes 7, 12)
16.5.2	Abnormal Operating Conditions (AC) (See Notes 7)
16.6.1	Normal Operating Conditions (DC) (See Notes 7, 12)
16.6.2	Abnormal Operating Conditions (DC) (See Notes 7, 8)
16.7	Load Equipment Influence on Aircraft Electrical Power System (AC and DC) (See Note 7)
17	Voltage Spike (See Note 9)
18	Audio Frequency Conducted Susceptibility – Power Inputs
19	Induced Signal Susceptibility
20	Radio Frequency Susceptibility (Radiated and Conducted) (See Notes 10, 11)
21	Emission of Radio Frequency Energy
22	Lightning Induced Transient Susceptibility (See Note 14)

23	Lightning Direct Effects (See Note 15)
24	Icing
25	Electrostatic Discharge (ESD)
26	Fire, Flammability

Notes to Table 2-23 and Table 2-24:

64. *Due to the difficulties in performing radiating measurements while changing the environmental conditions of the antenna, acceptable alternative test procedures may be implemented. Portions of the antenna subsystem may be measured over the required range of operating environmental conditions. The measurement data thus obtained may be used in an analysis to show that the specified antenna performance is achieved under the declared operating environmental conditions. This analysis shall include the effects of materials and construction of the individual radiating elements and account for the effects of beam pointing errors versus environmental conditions on other specification requirements within the declared coverage volume.*

65. *Performance parameters of the antenna subsystem will not be measured during these environmental tests. These environmental tests are for survivability and apply only to equipment which is mounted on the outside of the aircraft. Testing of the antenna RF performance properties to determine the serviceability of the antenna after exposure is acceptable. This test could take the form of a production test procedure or other test and shall verify the antenna RF and control functionality has not degraded compared to any baseline testing performed prior to environmental exposure (within test accuracy limits).*

66. *These tests are not listed for the receiver and transmitter subsystems and need not be performed unless the manufacturer wishes to qualify the equipment for the particular environmental condition. For example: An antenna intended for use under an additional radome (e.g. tail-mounted antennas) may only need to meet the drip-proof category of waterproofness.*

67. *The application of the Crash Safety Shock test may result in damage to the equipment under test. Therefore, this test may be conducted after the other tests have been completed. In this case, Section 2.1.7, "Effects of Test" does not apply.*

68. *This test shall be conducted with the spray directed perpendicular to the equipment.*

69. *Applicable requirements:*

    a) *At the end of the 24-hour exposure period, the equipment shall function.*

    b) *Following the 2-hour operation period at ambient temperature after the 160-hour exposure period at elevated temperature, the performance requirements shall be met.*

70. *The appropriate test will depend upon whether the equipment is AC or DC powered.*

71. *The application of the Low Voltage Conditions (DC) (Category B equipment) test may result in damage to the equipment under test. Therefore, this test may be conducted after the other tests have been completed. Section 2.1.7, "Effects of Test," does not apply.*

72. *Select Category A (high degree of protection against voltage spikes required) or Category B (lower standard of protection acceptable) as applicable for the equipment under test.*

73. *Excluding frequency to which receiver is tuned and the response within its resonant pass band.*

74. *Equipment is not required to meet performance specifications during the application of HIRF, (Category U, 20 v/m). The equipment must meet all requirements following the application.*
75. *Meet requirements of DO-160G [3] except as noted by Section 2.2.3.8.*
76. *Phase Noise (Section 2.2.3.1.3.1.11) performed under normal conditions only.*
77. *Not required for systems certified to Design Assurance Level D. For systems certified to Design Assurance Level C or higher, equipment is not required to meet performance specifications during the period of application of the Lightning Induced Transient test, but must meet all requirements following the test. (Ref AC 20-136B)*
78. *Only required for AMSS antennas.*
79. *Applicable to equipment requiring cooling. Modify test length to three hours. Verify no smoke or fire. Only essential services, namely one voice channel plus ACARS at 8 kb/s minimum, are required to be provided.*
80. *Not used*
81. *The Altitude tests in DO-160G sections 4.6.1, 4.6.2 and 4.6.3 are not applicable.*
82. *The antenna equipment shall be subjected to vibration and operational shock testing exposure equivalent to the qualification levels for which the antenna is being certified prior to subjecting the antenna to intermodulation testing.*
83. *A reduced subset of receiver sensitivity tests may be conducted under indicated environmental conditions. See Section 2.4.3.1.2.2.1.1. During the RF Susceptibility tests the receiver frequency is stepped through the full receive band. For Induced Lightning category, test is performed only after subjecting to environment. For Temperature and Altitude category (DO-160G Section 4) the reduced receiver sensitivity test does not apply, as the Inmarsat MTRs require a full Packet Error Rate test. Regardless of this table the mandatory test in the MTRs need to be executed for Inmarsat type approval.*
84. *Not used.*
85. *Only response between 1.5 and 1.7 GHz needs to be monitored.*
86. *After the Lightning Direct Effects test the antenna under test shall be functional if the manufacturer specifies this in the product's performance specification. In all cases it is a requirement that the antenna does not pose a danger to the aircraft after such exposure. If the antenna is limited to installation in positions on the aircraft where lightning strikes are not expected (e.g. under another radome which provides protection) this shall be declared as a limitation.*
87. *Circuit mode service. Perform test for Total Noise Including Quantization Noise test as in Section 2.4.3.7.2. For DO-160G Section 4, only testing over temperature is required, not altitude.*
88. *Operational shocks (DO-160G Section 7): Performance is only verified after (not during) exposure to shocks.*

An "X" in Table 2-23 indicates that testing of performance is required before/during/after exposure to the environmental tests as specified in DO-160G [3].
A "-" in Table 2-23 indicates that no testing of performance is required before/during/after exposure to the environmental tests in DO-160G [3].

If an antenna has previously been approved for Classic Aero operation in terms of TSO-C132 and DO-210D, then only the following tests (as applicable to the Class of antenna) in the Antenna Subsystem section of Table 2-23 are required to be performed: Sections 2.2.3.1.2.6, 2.2.3.1.2.6.1 and 2.2.3.1.2.6.2. The other antenna tests are then not applicable.

2.4 Equipment Performance Verification Procedures

The following procedures provide guidelines for tests to ensure compliance with the MOPS performance requirements. Except for Section 3.4.5, these do not require flight testing. Regarding secondary references from this section, any reference to "flight tests" in lower level documents should be ignored.

Some of the following tests may require additional test equipment not shown in the test setup figures. Such equipment would be associated with the interface between the satellite system emulator and the AES or radio channel unit.

2.4.1 Definitions of Terms and Conditions of Test

The following are definitions of terms and the conditions under which the tests described in this Section should be conducted:

a. 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 input terminals of the equipment under test.

b. Power Input Frequency

(1) In the case of equipment designed for operation from an AC source of essentially constant frequency (e.g., 400 Hz), the input frequency shall be adjusted to design frequency +2%.

(2) In the case of equipment designed for operation from an AC source of variable frequency (e.g., 300 to 1,000 Hz), unless otherwise specified, tests shall be conducted with the input frequency adjusted to within 5% of a selected frequency and within the range for which the equipment is designed.

c. Adjustment of Equipment

The circuits of the equipment under test shall be properly aligned and otherwise adjusted in accordance with the manufacturer's recommended practices prior to application of the specified tests.

d. Test Equipment

All equipment used in the performance of the tests should be identified by make, model and serial number where appropriate, and its latest calibration date. When appropriate, all test equipment calibration standards should be traceable to national and/or international standards.

e. Test Instrument Precautions

Due precautions shall be taken during the tests to prevent the introduction of errors resulting from the connection of voltmeters, oscilloscopes and other test instruments across the input and output impedances of the equipment under test.

f. Ambient Conditions

Unless otherwise specified, all tests shall be made within the following ambient conditions:

(1) Temperature: +15 to +35 degrees C (+59 to +95 degrees F)
(2) Relative Humidity: Not greater than 85%
(3) Ambient Pressure: 84 to 107 kPa (equivalent to +5,000 to -1,500 ft) (+1,525 to -460 m)

When tests are conducted at ambient conditions which differ from the above values, allowances shall be made and the differences recorded.

g. 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.

h. EMI Testing

Only the AES (not the test equipment) need be subjected to the electromagnetic environment as specified in Table 2-24. For the antenna subsystem, a matched load should be connected, and the antenna subsystem performance verified to requirements after application of HIRF.

Note: For specific airframes, the aircraft manufacturer may require the interconnecting wiring to be included in the specified electromagnetic environment.

i. Warm-up and Stabilization Requirements

Unless otherwise specified, all tests shall be conducted after a minimum equipment warm up period of not less than five minutes. In addition, the frequency reference source shall have completed its warm up cycle, if any, and any power on self-test(s) shall have been completed prior to testing.

j. Special Cooling Requirements

The manufacturer shall specify any special cooling requirements for any of the specified tests.

2.4.1.1 AES Application Test Conditions

2.4.1.1.1 Antenna Subsystem Test Conditions

Unless otherwise noted in Section 2.3.5, the antenna subsystem detailed verification procedures are assumed to be performed at normal laboratory ambient temperature and humidity, as defined in Section 2.4.1.

2.4.1.1.1.1 Antenna Under Test

The antenna under test shall not include the LNA, HPA, or front end filter(s) associated with the RF Front End subsystem. For steered antennas, or active antennas requiring any other type of control, a suitable control unit shall be included in the test. If a radome forms part of the antenna, this shall also be installed during the measurements. The antenna test installation shall also include any adapter plates, where used, or other hardware used to interface the antenna to the fuselage in a flight installation.

2.4.1.1.2 Transceiver Subsystem Test Conditions

Unless otherwise noted in Section 2.3.5, the transceiver subsystem (6D, 7D, 6F, 7F, 6MF, 7MF, AES transceiver functions) detailed verification procedures are assumed to be performed at normal laboratory ambient temperature and humidity, as defined in Section 2.4.1.

2.4.1.1.2.1 Transceiver Under Test

The AES shall be tested at the test frequencies shown in Table 2-25 and Table 2-26 unless otherwise specified.

Table 2-25 Transmit Test Frequencies

Designator	Standard L- Band	Extended plus Standard L-Band
TX_{F1}	1626.5 MHz	1626.5 MHz
TX_{F2}	1635.0 MHz	1635.0 MHz
TX_{F3}	1643.5 MHz	1643.5 MHz
TX_{F4}	1652.0 MHz	1652.0 MHz
TX_{F5}	1660.5 MHz	1660.5 MHz
TX_{F6}	N/A	1668.0 MHz
TX_{F7}	N/A	1675.0 MHz

Table 2-26 Receive Test Frequencies

Designator	Standard L- Band	Extended plus Standard L-Band
RX_{F1}	N/A	1518.0 MHz
RX_{F2}	1525.0 MHz	1525.0 MHz
RX_{F3}	1533.5 MHz	1533.5 MHz
RX_{F4}	1542.0 MHz	1542.0 MHz
RX_{F5}	1550.5 MHz	1550.5 MHz
RX_{F6}	1559.0 MHz	1559.0 MHz

For AES4 the Extended plus Standard L-Band test frequencies shall be used. For AES6 and AES7 the normal frequency band shall be used, except if a manufacturer is specifying a single channel AES6 or AES7 system, in which case they may elect to also qualify the product for Extended L-Band operation. This shall be declared in the system test plan.

2.4.1.1.3 DLNA Test Conditions

Unless otherwise noted in Section 2.3.5, the DLNA subsystem (DF, DMA) detailed verification procedures shall be performed at normal laboratory ambient temperature and humidity, as defined in Section 2.4.1.
The DLNA shall be tested at the test frequencies shown in Table 2-25 and Table 2-26 unless otherwise specified.

2.4.1.1.4 Required Aircraft Interfaces Test Conditions

Unless otherwise noted in Section 2.3.5 the required aircraft interfaces shall be tested with the AES operating under normal laboratory ambient temperature and humidity conditions noted in Section 2.4.1.

2.4.1.2 User Link Modulation and Signal in Space Test Conditions

Unless otherwise noted in Section 2.3.5 the interaction of the AES with the satellite sub-network shall be tested with the AES operating under normal laboratory ambient temperature and humidity conditions noted in Section 2.4.1.

2.4.1.3 Priority, Precedence and Preemption Test Conditions

The Priority, Precedence and Preemption performance shall be tested with the AES operating under normal laboratory ambient temperature and humidity conditions noted in Section 2.4.1.
These tests may be performed using the actual satellite constellation or against a network simulator, provided that the conditions of Section 2.4.2 are satisfied.

2.4.1.4 Satellite Sub-network Data Protocol Test Conditions

The Satellite Subnetwork Data Protocol shall be tested as part of the Inmarsat Type Approval process.

2.4.1.5 Voice Protocol Test Conditions

The voice protocol compliance shall be tested with the AES operating under normal laboratory ambient temperature and humidity conditions noted in Section 2.4.1.

2.4.1.6 User Data Interfaces Test Conditions

Unless otherwise noted in Section 2.3.5 the User Data Interface shall be tested with the AES operating under normal laboratory ambient temperature and humidity conditions noted in Section 2.4.1.

2.4.1.7 Circuit Mode Service Test Conditions

Unless otherwise noted in Section 2.3.5 the Circuit Mode Services, if provided, shall be tested with the AES operating under the standard conditions noted in Section 2.4.1. The performance of any voice services, if provided, shall be tested under the ambient audio noise test environments specified in Section 2.4.1.5.

2.4.1.8 Recovery from Primary Power Failure Test Conditions

Unless otherwise noted in Section 2.3.5 Recovery from Primary Power Failure shall be tested with the AES operating under the standard conditions noted in Section 2.4.1, with the exception that the power input to the AES shall be as described in the specific tests.

2.4.1.9 Failure/Status Indication Test Conditions

Failure/Status Indications shall be tested with the AES operating under the standard conditions noted in Section 2.4.1.

2.4.1.10 Information Security

Network security mechanisms shall be tested with the AES operating under the standard conditions noted in Section 2.4.1, unless otherwise indicated as a result of the plan for a Security Verification in accordance with DO-262 [10] Section 3.3.4

2.4.2 Required Test Equipment

2.4.2.1 AES Application

2.4.2.1.1 Antenna Subsystem Required Test Equipment

2.4.2.1.1.1 Standard Test Equipment

Testing shall be performed in accordance with the Institute of Electrical and Electronics Engineers (IEEE) St 169, 1983. It is suggested than an antenna test range with a minimum path length of 14 meters (40 feet) be used, having a reflectivity level less than or equal to –25 dB within a quiet zone containing the antenna under test and ground plane. “Compact” ranges and/or near-field probing techniques may also be employed if analysis shows that an equivalent accuracy may be obtained.
Other items of standard test equipment include:

- Range instrumentation, including a 2-axis (minimum) positioner, positioner controller, L-band transmitter, receiver, pattern recorder and polarization measurement instrumentation.
- Reference standard gain antenna(s) of the appropriate, technique-specific polarization with gain calibration traceable to National Institute for Standards and Technology (NIST) or other national standards.
- Components of the receive and transmit systems are necessary to perform system level verifications in conjunction with the antenna system verifications. These include the LNA, HPA, splitter/combiner, and front end filters.

2.4.2.1.1.2 Special Test Equipment

An antenna ground plane shall be used to simulate the conductive mounting surface on the intended aircraft. The ground plane shall extend at least 0.5 m beyond any active portion of the antenna under test, and shall extend beyond any radome employed. The ground plane shall be curved with a radius of approximately 100 inches to simulate an aircraft fuselage. Where the antenna is to be installed on an aircraft with a radius of curvature which differs by more than 30% from that used in the antenna tests, the validity of the results shall be justified by analysis and/or measurement.
Antenna Test Set: A means of steering the antenna to a required beam is required. This may be specific to the antenna type.

2.4.2.1.2 Transceiver Subsystem Required Test Equipment

2.4.2.1.2.1 Standard Test Equipment

The test procedures assume access to a variety of standardized test equipment, including directional couplers, high power loads, spectrum analyzers and oscilloscopes. Wherever possible, specific model numbers are identified. It is permissible to substitute alternate items of standard test equipment provided that the equivalent performance is maintained.

2.4.2.1.2.2 Special Test Equipment

The test procedures assume that the following special test equipment may be required.

- Satellite System Emulator –Inmarsat BGAN Physical Layer Tester (BPLT)
- Transceiver Test Controller – This device may be required to initialize the AES or to induce the AES to a certain state, or to initialize a certain condition. It is permissible for the transceiver test controller to use existing AES interfaces for this purpose.

2.4.2.1.3 DLNA Subsystem Required Test Equipment

2.4.2.1.3.1 Standard Test Equipment

The test procedures assume access to a variety of standardized RF test equipment, including directional couplers, high power loads, spectrum analyzers, network analyzer and noise figure meters. Wherever possible, specific model numbers are identified. It is permissible to substitute alternate items of standard test equipment provided that the equivalent performance is maintained.

2.4.2.1.4 Required Aircraft Interfaces Required Test Equipment

2.4.2.1.4.1 Standard Test Equipment

The test procedures assume access to a variety of standardized test equipment, including ARINC 429 simulators.

2.4.2.2 Modulation and Signal in Space Required Test Equipment

The test procedures assume that the following special test equipment may be required.

- Satellite System Emulator –BGAN Physical Layer Tester (BPLT) manufactured by Square Peg Communication Inc
- Transceiver Test Controller – This device may be required to initialize the AES or to induce the AES to a certain state, or to initialize a certain condition. It is permissible for the transceiver test controller to use existing AES interfaces for this purpose.

2.4.2.3 Priority, Precedence and Preemption Test Equipment

2.4.2.3.1 Packet Data

The manufacturer shall define test equipment to be used.

2.4.2.3.2 Circuit Mode Communications

This test requires the ability to initiate and terminate N simultaneous circuit-mode calls through the satellite network. Depending on the specific sub-network, this may require N telephone lines or N satellite network channels. This test makes no assumptions about the capabilities of these circuit-originating and circuit-terminating devices. It is permissible to utilize a separate AES, independent of the AES under test, in this role.
This test is not intended to verify the ability of the satellite network or the satellite sub-network as a whole, to satisfy the Priority, Precedence and Preemption requirements of the MASPS. This test should be coordinated with the satellite network operator to ensure that appropriate satellite capacity exists for the completion of the test. Such coordination may require that the test be performed in off-peak traffic hours.

2.4.2.3.3 ACARS Communications

A test setup is required which will allow simultaneous transmission and reception of ACARS messages as well as UDP data through an Ethernet port.
For ACARS messages a computer with an ARINC 429 interface (or alternative interface, as appropriate to the equipment under test) is recommended, with software simulating CMU behavior. For UDP communications a computer with suitable software (e.g. IPERF) is required.

2.4.2.4 Satellite Sub-network Data Protocol Test Equipment

The Satellite Subnetwork Data Protocol shall be tested as part of the Inmarsat Type Approval process, according to Inmarsat MTRs. The Square Peg ACARS Test Tool referenced in the MTR document (or a functional equivalent) will be required.

2.4.2.5 Voice Protocol Required Test Equipment

The test procedures assume that the following special test equipment may be required.

- Equipment to set up N_v simultaneous voice calls. Automated or manual methods may be used.
- Protocol Analyzer– Inmarsat BGAN Protocol Tester (BPT)
- Transceiver Test Controller – This device may be required to initialize the AES or to induce the AES to a certain state, or to initialize a certain condition. It is permissible for the transceiver test controller to use existing AES interfaces for this purpose.
- BGAN Voice Codec Test Set (BGAN VCTS)
- The ability to test over the satellite. An antenna with visibility to an I4 satellite and the necessary control for antenna steering is required.

Compliance with the requirements of Section 2.2.3.5.2 requires special test equipment capable of accurately reproducing the required environments. The tests are complex, and are typically carried out by organizations with expertise in the evaluation of vocoder or voice modem capabilities.

2.4.2.6 User Data Interface Required Test Equipment

The manufacturer shall define test equipment to test the ACARS and IP physical interfaces functionally under environmental conditions.

2.4.2.7 Circuit Mode Service Test Equipment

The following test equipment is required:

- Equipment to generate audio sine waves of controllable amplitude and frequency in the digital domain.
- Oscilloscope with FFT capability at audio frequencies or audio analyzer.
- Analogue audio signal generator.
- The ability to capture and analyze digital audio samples from the test port of the SDU.

2.4.2.8 Recovery from Primary Power Interruption Test Equipment

The test procedures assume that the following test equipment may be required:

- An AC and/or DC Power Supply capable of providing momentary power interrupts as prescribed in DO-160G [3].
- Audio signal generator
- Oscilloscope.

2.4.2.9 Failure/Status Indication Test Equipment

No special test equipment is required to verify these requirements.

2.4.2.10 Information Security

The plan for Security Verification, required under Section 2.4.3.10, shall identify any special test equipment required.

2.4.3 Detailed Test Procedures

2.4.3.1 AES Application Requirements

Reference: 2.2.3.1 Evidence of Inmarsat Type Approval and approval from a Communication Network Provider shall be provided, as detailed in Section 2.2.3.1.

2.4.3.1.1 Antenna Test Requirements

Test Frequencies: Antenna test shall be performed at the following test frequencies, unless otherwise specified in individual sections:

Table 2-27 Transmit Test Frequencies for Antennas

Designator	Standard L- Band	Extended plus Standard L-Band
TX_{F1}	1626.5 MHz	1626.5 MHz
TX_{F2}	1643.5 MHz	1643.5 MHz
TX_{F3}	1660.5 MHz	1660.5 MHz
TX_{F4}	N/A	1668.0 MHz
TX_{F5}	N/A	1675.0 MHz

Table 2-28 Receive Test Frequencies for Antennas

Designator	Standard L- Band	Extended plus Standard L-Band
RX_{F1}	N/A	1518.0 MHz
RX_{F2}	1525.0 MHz	1525.0 MHz
RX_{F3}	1542.0 MHz	1542.0 MHz
RX_{F4}	1559.0 MHz	1559.0 MHz

Standard L-band frequencies apply to HGA and IGA antennas.
Extended plus Standard L-band frequencies apply to AES4 antennas.

2.4.3.1.1.1 AES6 and AES7 Antenna Test Requirements

2.4.3.1.1.1.1 Coverage Volume

Reference: 2.2.3.1.2.1.1, 2.2.3.1.2.1.1.1 or 2.2.3.1.2.1.1.2
This requirement shall be tested using the procedure defined in the Inmarsat MTR [2]; DFL A1; Section 7.10. (This appendix also defines the test frequencies) The maximum antenna gain measured during this test shall also be recorded.

2.4.3.1.1.1.2 Polarization

Reference: 2.2.3.1.2.1.2
Polarization is covered by the tests in Section 2.4.3.1.1.1.1. No additional test is required.

2.4.3.1.1.1.3 Antenna Gain

Reference: 2.2.3.1.2.1.1; 2.2.3.1.2.1.1.1; 2.2.3.1.2.1.1.2;
Antenna gain is measured as part of the tests in Section 2.4.3.1.1.1.1. The maximum boresight gain shall also be recorded for use in Section 2.4.3.1.2.1.5. No additional test is required.

2.4.3.1.1.1.4 Antenna Axial Ratio

Reference: 2.2.3.1.2.2
Axial ratio is covered by the tests in Section 2.4.3.1.1.1.1. No additional tests are required.

2.4.3.1.1.1.5 Power Handling

Reference: 2.2.3.1.2.3; 2.2.3.1.2.3.1; 2.2.3.1.2.3.2
Equipment Required
Altitude environmental chamber
Vacuum pump / vacuum gauge
RF absorber panels
Dual directional coupler
RF attenuator (NARDA 757C-20 or appropriate equivalent)
Dual RF power meter (HP438)

Antenna test set. Refer to Section 2.4.2.1.1.2
RF power source
Measurement Required
This is an altitude test only, performed at ambient temperature. Pressure tolerances in DO-160G [3] apply.
Radio-absorbent foam should be used in the environmental chamber.

1. Connect the equipment as shown in Figure 2-9.
2. Pump down the environmental chamber and maintain the pressure at the level corresponding to the declared altitude category to which the antenna is to be certified.
3. After achieving temperature and pressure stability, apply an RF signal as specified in Sections 2.2.3.1.2.3.1 or 2.2.3.1.2.3.2 as applicable, and maintain for 1 hour. During this hour, switch between 10 arbitrarily selected beams. For antennas with less than 10 beams, use all beams. The incident and reflected power at the antenna input shall be monitored for the duration of the power handling test and compared to previously obtained measurements. Any changes shall be noted to detect changes in the antenna.

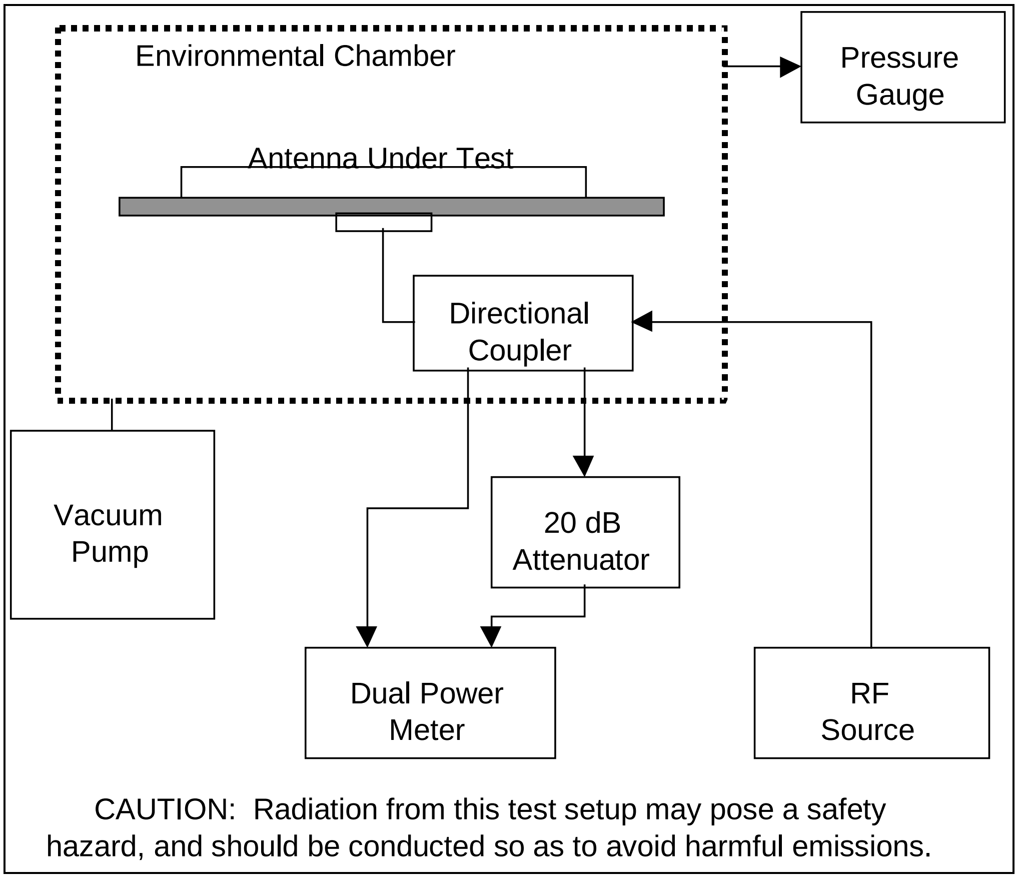

Figure 2-9 Power Handling Test Setup

4. Remove the RF signal. Remove the antenna from the environmental chamber.

5. Measure the gain performance in an anechoic chamber or equivalent at ambient temperature and altitude. Repeat at ten arbitrary beam positions (or all beams).
6. Compare to prior measurements and verify that gain performance has not degraded materially.
7. Inspect the antenna for signs of arcing or melting. No permanent damage is permissible.

2.4.3.1.1.1.6 Antenna Passband

Reference: 2.2.3.1.2.4
The antenna passband is covered by the tests in Section 2.4.3.1.1.1.1 and other sections. No additional tests are required.

2.4.3.1.1.1.7 Antenna VSWR

Reference: 2.2.3.1.2.5
Equipment Required
Ground Plane - refer to Section 2.4.2.1.1.2.
Automatic Network Analyzer (Hewlett-Packard 8753, 8720, 8510, or equivalent).Calibration kit (50Ω) Hewlett Packard 85032 (Type N), 85052 (3.5mm) or equivalent. It is acceptable to use adaptors to connect to the antenna under test if the connector on the antenna is not the same series as the calibration kit used.
Antenna test set. Refer to Section 2.4.2.1.1.2.
Anechoic or semi-anechoic room or an outdoor test range.

Measurement Requirements

8. Connect the equipment as shown in Figure 2-10.
9. For all antennas, measure the VSWR at the single RF port of the antenna subsystem. For switched or steered beam antenna types, measure the VSWR for a minimum of 10 beams evenly distributed over the declared coverage. For antenna types with fewer than 10 beams; measure all beams.

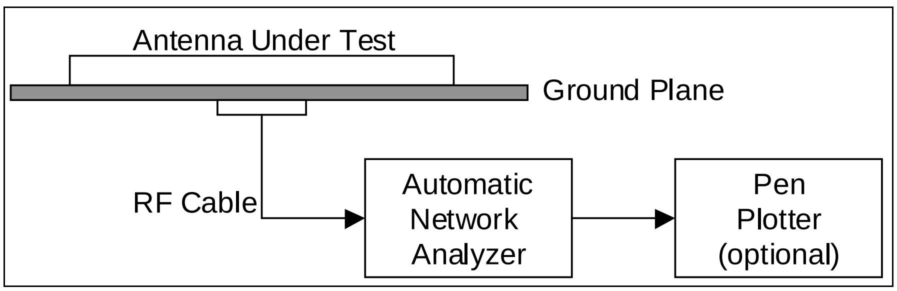

Figure 2-10 VSWR Test Setup

2.4.3.1.1.1.8 Radiated Antenna Intermodulation Products

2.4.3.1.1.1.9 Antenna Intermodulation in the GNSS Band

Reference: 2.4.3.1.1.1.9

Equipment Required:

Test ground plane suitable for mounting both the AUT and the GNSS monopole with at least 60” separation and with a roll plane radius of curvature equal to that of the radiation pattern certification ground plane ±30%.

50Ω terminations suitable for use on the DLNA receive port and hybrid coupler.

50Ω coaxial cable suitable for use at L-Band. The cable used to connect the ANT port of the DLNA to the AUT should be a low PIM type.

Spectrum Analyzer System such as HP70000B or HP8566 which can produce or accept an external frequency reference.

Two synthesized signal generators capable of operation in the 1.6-1.7GHz band and which can produce or accept an external frequency reference, e.g. HP8642B, Marconi Instruments 2032 etc.

RF power meter such as an HP438B or similar and compatible power sensor such as an HP8481.

Coaxially connected quadrature hybrid such as an ANAREN 3A0055 or equivalent.

Coaxial directional coupler such as an HP778B.

Type F DLNA.

AC Power Supply or DC power supply to power the AUT, DLNA and GNSS LNA.

50-100 Watt linear RF power Amplifier suitable for operation in the 1.6-1.7GHz band such as a ITS PA-1A6-49-DC-28 or equivalent.

Network Analyzer such as an HP8720D, HP8753C etc.

GNSS MOPS Test Filter/Amplifier with the following properties:

GNSS band-pass filter with < 1 dB insertion loss at 1610 MHz and >65 dB isolation from 1638.5 MHz to 1660.5 MHz.

GNSS amplifier, 1610 MHz, with gain > 50 dB and NF < 1.3 dB.

GNSS Test Monopole ($\lambda/4$) tuned to 1610MHz with a VSWR of <1.5:1.

Antenna test set. Refer to Section 2.4.2.1.1.2.

Measurement Requirements

10. Measure the losses of the DLNA transmit filter, the directional coupler and interconnect cables from the **HPA output to the AUT**. These losses must be used to adjust the reading on the power meter so that power into the AUT is correct for the class of AES for which testing is being performed.
11. Measure the gain and loss of the GNSS LNA and filter respectively. These values must be used to scale the measured IM product levels so that the level on the spectrum analyzer may be related back to the GNSS monopole connector.
12. Mount the AUT and the GNSS monopole on the ground plane with at least 60” of separation.
13. Connect the equipment as shown in Figure 2-11.
14. With the AUT elevation angle set to 5 degrees, steer the AUT in the direction of the GNSS antenna.
15. Use a spectrum analyzer to measure the isolation, in dB, between the two antennas ($ANTISO_{dB}$) at 1610 MHz.
16. Set RF synthesizer 1 (f1) to 1638.5 MHz.
17. The radiated IM is to be measured for 40 different antenna beam locations, equally spaced in solid angle in the region defined by an elevation angle greater than or equal to 20 degrees. Steer the antenna to each of the 40 beam locations

and perform the following steps 6-10. Note that if the AUT has less than 40 beams measure all beams. To start, set the antenna beam to point to the GNSS antenna (or as close as possible).

18. The RF Synthesizer number 2 (f2) frequency set is defined by the following:

for the IM order N = {7, 9, 11}, the frequency is calculated as:

$$f_2 = \frac{(N+1)\times f_1 - 2\times 1610}{(N-1)}$$

This yields the following set of frequency pairs:

Intermodulation Product Order N	F1 (MHz)	F2 (MHz)
7	1638.5	1648
9	1638.5	1645.625
11	1638.5	1644.2

To start, set the RF synthesizer number 2 (f2) for N = 7.

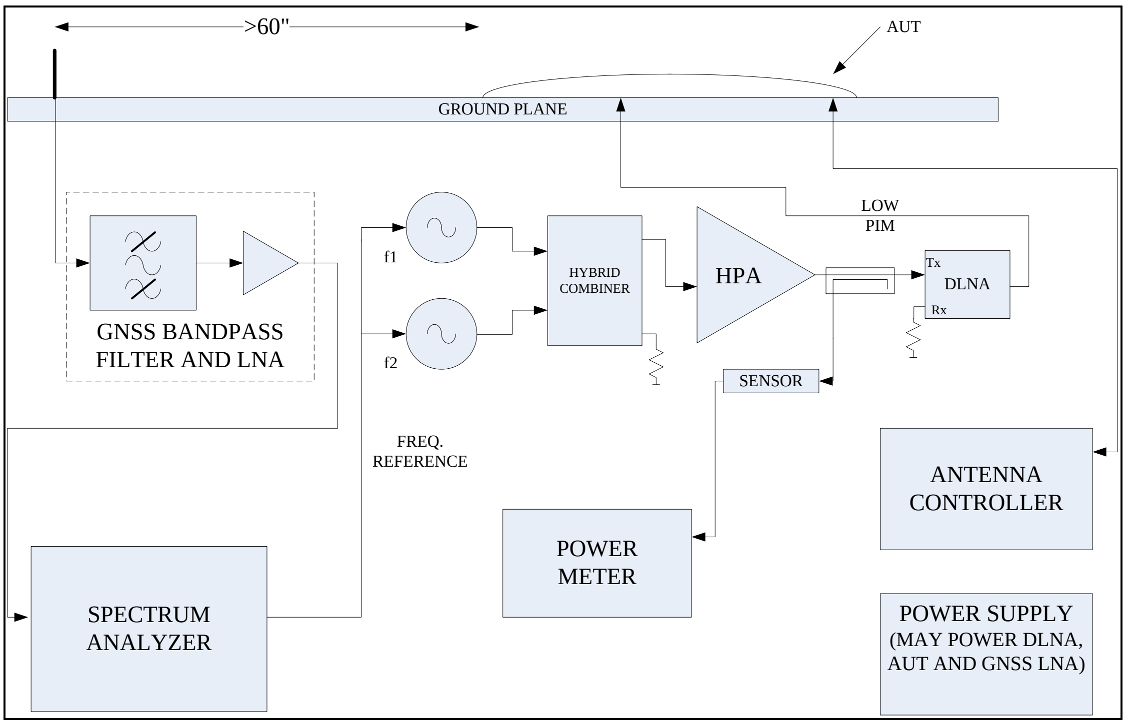

Figure 2-11 Block Diagram of Radiated IM in the GNSS Band Test Setup

19. Set up the power level of each carrier so that each of the carriers produced by the RF power amplifier (at the AUT) is equal to the required carrier power for a given AUT type (HGA = 8dBW, IGA=9.1dBW)

20. Measure the IM product level in dBm at the GNSS antenna using the spectrum analyzer at 1610 MHz and refer it back to the GNSS antenna output port ($IMGNSS_{dBm}$).

21. Normalize the IM product level to a 40 dB antenna isolation by performing the following calculation:

$$IMLEVEL = IMGNSS_{dBm} - 40\ dB + ANTISO_{dB}$$

22. Repeat steps 10 to 12 with RF synthesizer number 2 (f2) set for N = 9 and 11.
23. Repeat steps 10-13 with the antenna steered in the remaining beam directions..
24. Determine that the IM product levels determined in step 12 (IMLEVEL) do not exceed the values of Section 2.2.3.1.2.6.1.

2.4.3.1.1.1.10 Antenna Intermodulation in AMS(R)S Band(s)

Reference: 2.2.3.1.2.6.2
This requirement shall be tested using the procedure defined in the Inmarsat MTR [9]; DFL A1; Section 7.7. This applies to antenna intermodulation over temperature as well (Section 7.7.4). Prior to performing the IM test the AUT shall be subjected to 1 hour of vibration in each of the three principle axes (per DO-160G; Section 8) for the vibration category/curve to which the AUT is to be certified.

2.4.3.1.1.1.11 Carrier-to-Multipath Discrimination

Reference: 2.2.3.1.2.7
This requirement shall be tested using the procedure defined in the Inmarsat MTR [9]; DFL A1; Section 7.3. The antenna shall be tested at the frequencies defined in Section 2.4.3.1.1 based upon the declared antenna type.

2.4.3.1.1.1.12 Pattern Discrimination

Reference: 2.2.3.1.2.8
Not applicable. See Section 2.4.3.1.1.1.17.

2.4.3.1.1.1.13 Steered Antenna Requirements

2.4.3.1.1.1.14 Phase Discontinuity

Reference: 2.2.3.1.2.9.1
This requirement shall be tested using the procedure defined in the Inmarsat MTR [9]; DFL A1; Section 7.4. The antenna shall be tested at the frequencies defined in Section 2.4.3.1.1 based upon the declared antenna type.

2.4.3.1.1.1.15 Beam Switching Time

Reference: 2.2.3.1.2.9.2
This requirement shall be tested using the procedure defined in the Inmarsat MTR [9]; DFL A1; Section 7.1. The antenna shall be tested at the frequencies defined in Section 2.4.3.1.1 based upon the declared antenna type.

2.4.3.1.1.1.16 Steering Rate

Reference: 2.2.3.1.2.9.3
Equipment Required
AUT and a means of steering control

Source Antenna suitable for L-Band operation
Signal Generator (HP 8642 or similar)
Spectrum Analyzer (HP 8566B or similar)

Measurement Requirements

25. Connect the equipment as shown in Figure 8. The antenna controller should have a means of generating a trigger signal compatible with the spectrum analyzer in use when the steer beam command is issued to the AUT.
26. Set the frequency synthesizer and the spectrum analyzer to 1.645GHz.
27. Set the spectrum analyzer to zero span with a sweep time of 10s. A faster sweep time may be used for electronically steered antennas (≈0.5s or less).
28. Setup the AUT relative to the source antenna so that the AUT can be steered directly at the source antenna by steering the AUT to approximately 5° elevation.
29. Steer the AUT to the source horn. Note the azimuth and elevation or beam number of this beam.
30. Set a convenient level (approx. 80% of full scale) and record the marker level.
31. Steer the AUT to El=90°
32. Set the spectrum analyzer to external trigger, single sweep.
33. Steer the AUT back to the source horn co-ordinates recorded earlier.
34. Note the number of divisions on the spectrum analyzer before the signal level returned to the previous value. This shall be less than the maximum is Section 2.2.3.1.2.9.3.

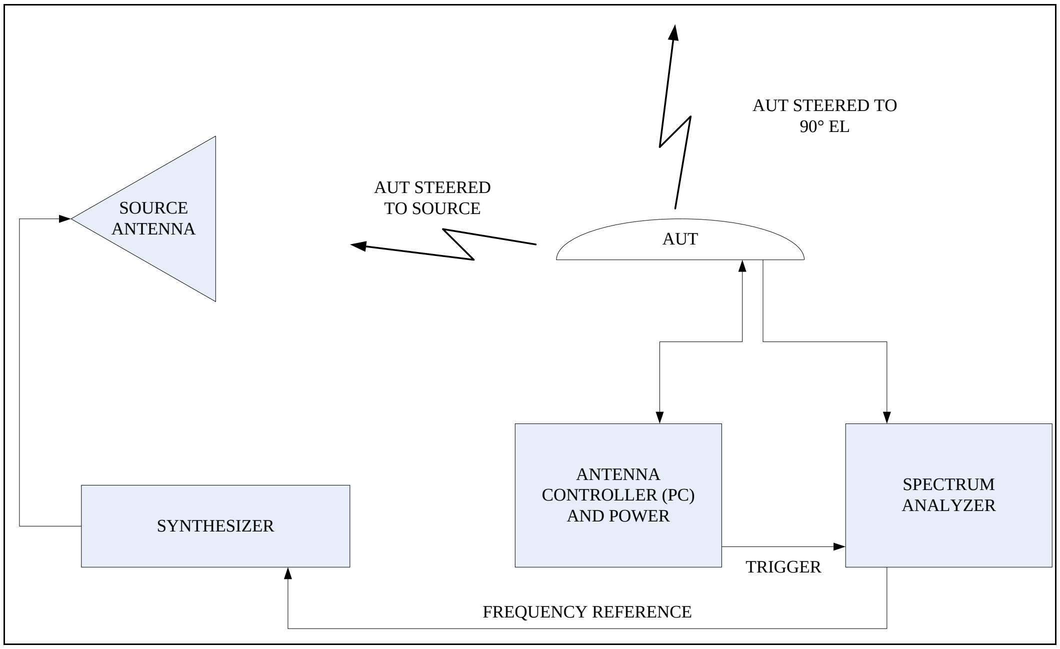

Figure 2-12 Antenna Steering Rate Test Setup

2.4.3.1.1.1.17 Pattern Discrimination

Reference: 2.2.3.1.2.9.4
This requirement shall be tested using the procedure defined in the Inmarsat MTR [9]; DFL A1; Section 7.1. The antenna shall be tested at the frequencies defined in Section 2.4.3.1.1 based upon the declared antenna type.

2.4.3.1.1.1.18 Antenna G/T

2.2.3.1.2.1.1; 2.2.3.1.2.1.1.1; 2.2.3.1.2.1.1.2; 2.2.3.1.2.1.1.3
This requirement shall be tested using the procedure defined in the Inmarsat MTR [9]; DFL A1; Section 7.2, 7.5 and 7.7. The antenna shall be tested at the frequencies defined in Section 2.4.3.1.1 based upon the declared antenna type.

2.4.3.1.1.2 AES4 Antenna Test Requirements

2.4.3.1.1.2.1 Radiation Pattern Measurements (Gain, Axial Ratio)

Reference: 2.2.3.1.2.1.1.3
Special Test Equipment
Test Range/Chamber and test positioner, compliant with Section 2.4.2.1.1.1 of this appendix.
Ground plane, compliant with Section 2.4.2.1.1.2 of this appendix.
Antenna controller (if required).
Antenna test set. Refer to Section 2.4.2.1.1.2.
All test equipment shall hold a valid calibration status. Cables, adaptors and other ancillary items need not be calibrated.
Definitions and conditions defined in Section 2.4.1 of this appendix apply.
Test Frequencies
The AES 4 antenna shall be characterized at the Extended plus Standard L-band frequencies listed in Table 2-25 and Table 2-26.
Test Facility
This test procedure assumes that a conventional far field range or anechoic chamber will be used to determine compliance of the AES 4 antenna. Equivalent compact range or near field techniques may also be used if they provide an equivalent level of accuracy and angular resolution. This shall be supported with measurement or analytical data as evidence.
Gain Standard Measurement
Prior to antenna radiation pattern measurements a measurement shall be conducted on a standard gain horn in the vertical and horizontal plane and the levels associated with the required test frequencies recorded for gain calibration of the test range. These should be retained as the gain standard should be re-measured at the end of the AES 4 antenna characterization to ensure that the test setup is stable and that no changes have occurred as a result of positioner movement, equipment drift, setup errors or cable damage.
Once the gain standard measurement has been completed it may be removed and the ground plane and AES 4 antenna (antenna under test or AUT) may be installed. Note that the center of rotation of the positioner shall be adjusted so that any parallax angle associated with the positioner rotation is removed. See Figure 2-13 for recommended typical setup details.
Radiation Pattern Measurement

The AUT shall be characterized over the INMARSAT sub-hemisphere extending from 5° elevation (above the plane associated with the plane of an aircraft in level flight) to 90° elevation (directly above the aircraft). The AUT shall be characterized at approximately 4820 points corresponding to grid of constant 2° elevation steps with the number of azimuth steps at each elevation angle being determined by

$$N_{steps}(elevation) = \text{ceil}(180*\cos(elevation))$$

This distributes the sampling evenly over the solid angle occupied by the measurement sub-hemisphere.

At each measurement point the complex (magnitude and phase) RF signals received by the AUT are measured for each of the two polarizations (H and V), at each of the nine test frequencies and for each beam to be tested. A typical test setup is in Figure 1. Note that the test setup is reciprocal and the AUT may transmit to the "source" horn in which case the H and V signals from the "source" horn are measured and recorded for each beam/frequency/measurement point.

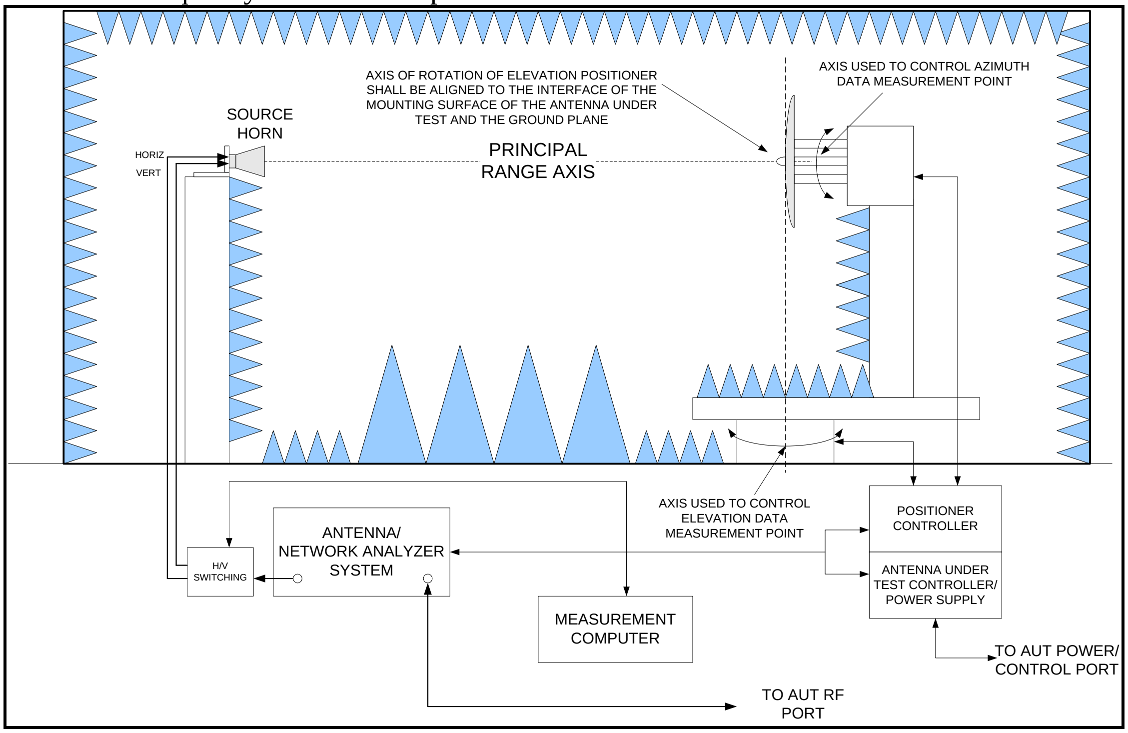

Figure 2-13 Typical Antenna Test Range

Once the data is collected it shall be organized for analysis for gain and axial ratio for each frequency, beam and measurement point. Right hand circularly polarized gain shall be computed and used to determine antenna compliance to the performance requirements in Section 2.2.3.1.2.1.3 for gain and axial ratio.

All differences in system/cable losses between the measurement of the gain standard and the measurement of the AUT shall be accounted for in the final antenna gain computation.

2.4.3.1.1.2.2 Carrier to Multipath (C/M) Ratio

Reference: 2.2.3.1.2.7

The anechoic chamber/far field range described in Section 2.4.3.1.1.2.1 shall be used for this measurements. A compact range or near field range (cylindrical or spherical) may be used if it can be shown that the same angular coverage accuracy can be achieved. Planar scanners are not suitable. Roll plane symmetry is assumed for this measurement. Data is collected from ϕb = 0° to 180° in 22.5° steps.
The requirement is for the C/M rejection of the antenna to be greater than 10dB at Θb = 5° elevation and 12dB at Θb = 20° elevation for a median sea state. Based on measurements this is computed as follows:

- C/M (smooth sea) is calculated for the specific specular point pattern measurement by using an equation.
- C/M (rough sea) is calculated by integration using the pattern measurements and multipath power densities.
- C/M (median sea) is calculated as the weighted average of C/M (smooth sea) and C/M (rough sea).

For a beam-pointing direction at elevation angle, θb = 5° and azimuth angle, ϕb = 0°, measure the elevation cuts for horizontal and vertical polarizations (Gh(θ,θb,ϕb) and Gv(θ,θb,ϕb) respectively) in the elevation range from θb to -45°. Measure the circular polarization gain at θb (Gc(θb,ϕb)). This is to be done for the test frequencies in Table 2-27 and Table 2-28.
The value of C/M for smooth sea state shall then be calculated as follows:

$$C/M_{smooth}(\theta_b,\phi_b) = \frac{\Gamma(\theta_b)\times G_c(\theta_b,\phi_b)}{G_h(-\theta_b,\theta_b,\phi_b)\times|k_h(\theta_b)|^2+G_v(-\theta_b,\theta_b,\phi_b)\times|k_v(\theta_b)|^2}$$

Where:

$\Gamma(\theta_b)$ is 1.59 for Θ_b = 5° elevation and 1.07 for Θ_b = 20°

$G_c(\theta_b,\phi_b)$ is the RCP power gain at Θ_b elevation (5° or 20° depending on the case) at the specific azimuth and frequency being evaluated

$G_h(-\theta_b,\theta_b\phi_b)$ is the horizontally polarized power gain at -Θ_b elevation when the beam is pointed to (Θ_b,ϕ_b) at the specific azimuth and frequency being evaluated

$G_v(-\theta_b,\theta_b\phi_b)$ is the vertically polarized power gain at -Θ_b elevation when the beam is pointed to (Θ_b,ϕ_b) at the specific azimuth and frequency being evaluated

$k_h(\theta_b)$ is the magnitude of the "horizontal" reflection coefficient of seawater at Θ_b incidence (0.983 at 5° and 0.932 at 20° elevation).

$k_v(\theta_b)$ is the magnitude of the "vertical" reflection coefficient of seawater at Θ_b incidence (0.15 at 5° and 0.55 at 20° elevation).

If the smooth sea result for a measured point complies with the limits in Section 2.2.3.1.2.7 then further analysis is not required.

The C/M computation in the rough sea case is computed using scattered power densities listed in Table 2-29 for elevation angles of 10° and 20°. The densities at 10° elevation angle shall be used for the computation of C/M at 5° elevation, i.e., $D_h(\theta,10°) \approx D_h(\theta,5°)$ and $D_v(\theta,10°) \approx D_v(\theta,5°)$.

Table 2-29 Scattering Power Densities for Rough Sea State Computation

Multipath Incidence Angle (Θ°)	Horiz. Pol. Density @ Θ_b = 10° Elevation ($D_h(\Theta,\Theta_b)$) in /°	Horiz. Pol. Density @ Θ_b = 20° Elevation ($D_h(\Theta,\Theta_b)$ in /°	Vert. Pol. Density @ Θ_b = 10° Elevation ($Dv(\Theta,\Theta_b)$) in /°	Vert. Pol. Density @ Θ_b = 20° Elevation ($D_v(\Theta,\Theta_b)$) in /°
0	45.0	8.0	0.5	1.0
5	33.0	26.3	1.1	2.8
10	24.0	24.1	2.1	4.0
15	18.0	22.1	2.8	6.1
20	16.5	22.0	3.7	7.5
25	10.0	18.9	2.8	7.5
30	4.0	15.8	1.3	7.3
35	1.5	8.7	0.8	4.8
40	1.0	5.4	0.5	3.4
45	0.0	4.8	0.0	3.2

C/M for Rough Sea: The carrier to multipath ratio for rough sea, C/M_{rough} can be calculated by the following method for a given pointing angle (θ_b,ϕ_b):

$$M_h(\theta_b,\phi_b) = \Delta\theta \times \sum_{\theta=-45°}^{0°} D_h(\theta,\theta_b) \times G_h(\theta,\theta_b,\phi_b) \times W_n(\theta)$$

And

$$M_v(\theta_b,\phi_b) = \Delta\theta \times \sum_{\theta=-45°}^{0°} D_v(\theta,\theta_b) \times G_v(\theta,\theta_b,\phi_b) \times W_n(\theta)$$

Where:

$M_h(\theta_b,\phi_b)$ is the computed horizontal multipath component for the AUT

$M_v(\theta_b,\phi_b)$ is the computed vertical multipath component for the AUT

Θ is the elevation angle being evaluated

ΔΘ is the elevation step angle (5° for Table 2-29)

$D_h(\theta,\theta_b)$ is the horizontally polarized scattered power density as given in Table 2-29

$D_v(\theta,\theta_b)$ is the vertically polarized scattered power density as given in Table 2-29

$G_h(\theta,\theta_b,\phi_b)$ is the horizontally polarized gain measured at the specific frequency and angle being evaluated

$G_v(\theta, \theta_{b,} \phi_b)$ is the vertically polarized gain measured at the specific frequency and angle being evaluated.

W_n are the trapezoidal rule weights as follows:

$W_n(\Theta) = 0.5$ for $\Theta = 0°$ and $-45°$. For all other values of Θ $W_n = 1.0$

Step 2: calculate the roll-off improvement factor relative to the omnidirectional reference by:

$$I(\theta_{b,} \phi_b) = \frac{G_c(\theta_b, \phi_b) \times \Delta\theta \times \Sigma_{omni}(\theta_b)}{M_h(\theta_b, \phi_b) + M_v(\theta_b, \phi_b)}$$

Where:
$I(\theta_{b,} \phi_b)$ is the roll-off improvement factor

$\Sigma_{omni}(\theta_b)$ is the standard summation or the omnidirectional antenna; 74.18 at 5° and 97.6 at 20° elevation respectively.

$G_c(\theta_b, \phi_b)$ is the RCP gain of the antenna at the frequency and angle under test..

$M_h(\theta_b, \phi_b)$ is the computed horizontal multipath component for the AUT in the previous step.

$M_v(\theta_b, \phi_b)$ is the computed vertical multipath component for the AUT in the previous step.

Step 3: Calculate C/M for the antenna under test by:

$$C/M_{rough}(\theta_b, \phi_b) = 10\log(I(\theta_b, \phi_b)) + 11.72$$

Where:
$I(\theta_b, \phi_b)$ was computed above in Step 2.

The median sea state value is then computed by:

$$C/M_{median} = 0.3 \times C/M_{smooth} + 0.7 \times C/M_{rough}$$

Step 4: Repeat Steps 1 to 3 for the other azimuth angles (ϕ_b) of 22.5°, 45°…to 180°.

Step 5: Repeat measurements and analysis for smooth, rough and median sea states for elevation (Θ_b) = 20°.

Table 2-30 Beam Directions to be Measured

Az (ϕ_b°)	El (°)	Az (°)	El (°)	Az (°)	El (°)	Az (°)	El (°)
0	5	112.5	5	0	20	112.5	20
22.5	5	135	5	22.5	20	135	20
45	5	157.5	5	45	20	157.5	20
67.5	5	180	5	67.5	20	180	20
90	5	-	-	90	20	-	-

For each beam direction measure the appropriate azimuth direction for elevations from -45° to +20° in 5° steps. Record the complex H and V signals for each measurement point at each frequency. Use this data to determine the RCP gain of the steered beams of the AUT at each azimuth at 5° and 20° elevation.

2.4.3.1.1.2.3 Constituent Component Characterization for EIRP and G/T

Reference: 2.2.3.1.2.1.1.3

These are measurements conducted on the internal interconnects and sub-assemblies within the AES 4 antenna and are used in the computation of the G/T of the integrated antenna. Assemblies expected to be measured in this procedure include but are not limited to:

- Baluns
- Switching networks
- Phase shifters
- Power splitters/combiners
- Coaxial interconnects or feed-throughs
- Filters
- LNA

Note that the filters and LNA together are referred to as the DLNA and may be characterized as one component. In that case the noise performance of the LNA will include the receive filter losses. They need not be characterized separately. The transmit filter losses must be characterized separately however for EIRP calculations.

Note that in general most of these components (baluns, feed etc.) are included in the antenna used for radiation pattern measurements since they are used to control the radiation pattern and to form the beam in space. Exceptions to this would likely be any coaxial feed-through/interconnects, the filters and the LNA which could be housed within the AES 4 antenna LRU. The effects of these components must be accounted for for EIRP and G/T computations. Note also that only ohmic loss contributes to Tsys; not mismatch loss.

This is not intended to be a detailed measurement procedure but a generalized guide to what must be taken into account. It is also assumed that the antenna manufacturer has qualified staff available to perform these types of measurements and to adjust the procedure for their specific equipment.

All measurements shall be conducted using a network analyzer and/or noise figure meter as applicable to the specific device under test. A typical equipment list and setup are given below. All test equipment shall hold a valid calibration status. Cables, adaptors and other ancillary items need not be calibrated, however where their loss performance is required they shall be measured with calibrated equipment.

Required Equipment:
Vector Network Analyzer: HP8753A/B/C, HP 8720D, Wiltron 360 or eq.
SMA/3.5mm Calibration Kit : HP85052 or eq.
SMA/3.5mm coaxial cables: various, 50Ω; Micro Coax, Aeroflex etc.
Miscellaneous 3.5mm PCB connectors and adaptors (if required).
Power Supply for active devices (LNA, switches, phase shifter): various
Noise Figure Meter (for LNA measurement): HP8970, 8973 or eq.
Noise Source: HP346B or eq. as required for the test instrument.
Groundplane.
Antenna test set. Refer to Section 2.4.2.1.1.2
Synthesized signal generator, spectrum analyzer, power meter, calibrated power attenuator rated at 5 to 10 times the HPA output power

Measurement Procedure for antenna components (cables, feed-throughs, filters)

35. Setup and calibrate the network analyzer (a full two port calibration) per the manufacturer's instructions for the frequency range to be tested (1.5 to 1.7GHz is a good range).

36. Insert the device under test (DUT) and measure the insertion loss and return loss for the DUT. If a power supply or bias voltage/current is required then the levels of bias shall be as per the design values used in the actual antenna. It is not recommended that the DLNA gain be measured with a network analyzer.

37. If the DUT is not a connectorized device such as a PCB assembly then the insertion loss associated with those connectors added may be subtracted from the measured data. This applies to adaptors as well. This may require a back-to-back measurement of a pair of connectors/adaptors or use of manufacturer's published data.

38. Record the insertion loss (dBS(21)) and return loss (dBS(11)) at all of the relevant frequencies in Table 2-27 and Table 2-28.

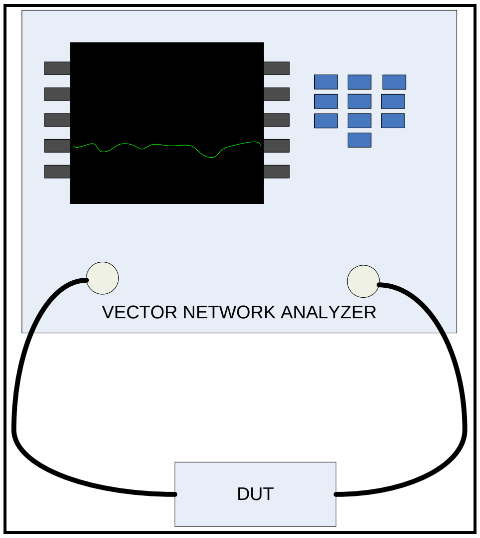

Figure 2-14 Typical Two-Port Device Measurement Setup

DLNA Measurement/Characterization Procedure

For characterization of the DLNA a noise source and noise figure test setup are typically used. These are used with the Y-Factor method and give acceptable accuracy for DLNA noise figure and gain. Some modern network analyzers have the capability of measuring noise as well. Noise figure and gain shall be collected for the receive band frequencies in Table 2-28.

Test Procedure

39. Calibrate the noise figure meter per the manufacturer's instructions. This may require that the user input the ENR (Excess Noise Ratio) values for the noise source into the instrument memory. The measurement averaging should be set to a convenient value (eg. 8 or 16).

40. Set the test frequency as follows:

    a. **START** = 1518MHz

    b. **STOP** = 1559 MHz

    c. **STEP** = 1MHz

Note that test data will not be taken at each 1MHz frequency step; this step size is required for the 8970A in order to allow all of the receive frequencies in Table 2-28 to be tested. Newer instruments may not require this.

41. Connect a suitable cable for connection to the DLNA to the RF input on the noise figure meter.

42. Connect the noise source to the RF input cable.

43. Push the **CALIBRATE** button on the 8970.

44. Verify the calibration state by checking that the direct connection of the noise source to the instrument yields a gain of 0.0 (±0.1) and a noise figure of 0.0 (±0.1.

45. Insert the DLNA and ensure that all connections are secure.

46. Power up the DLNA to the nominal power supply values used in the antenna.

47. Step through the receive band test frequencies and record the DLNA gain and noise figure at each frequency. Ensure that averaging is restarted and finished for each frequency.

48. Measurements may include the receive filter at the DLNA input.

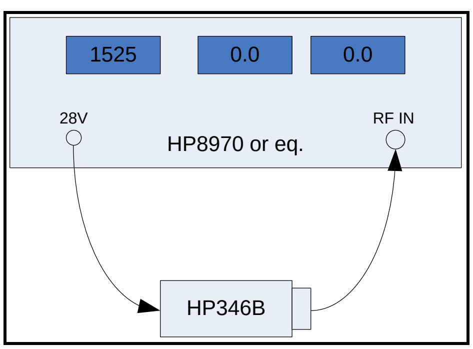

Figure 2-15 Typical Self Calibration Configuration for a Noise Figure Meter

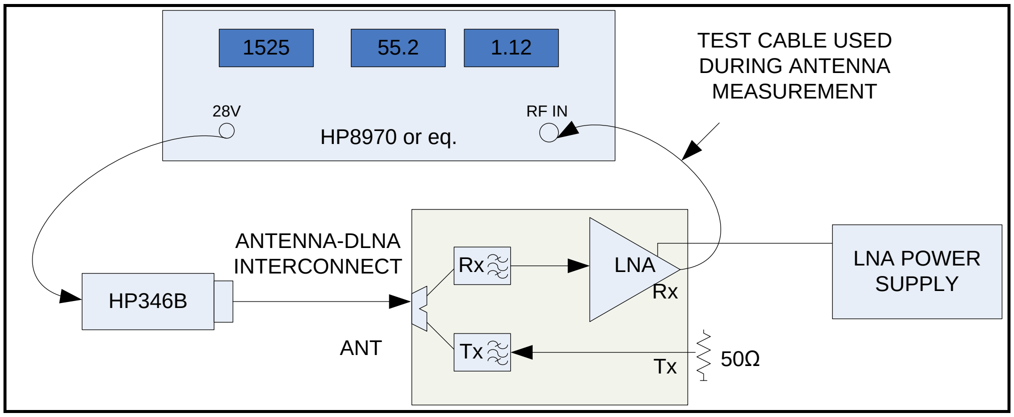

Figure 2-16 DLNA Measurement

HPA Measurements

Measurement of a built-in power amplifier (HPA) used in the AES 4 antenna shall be performed to determine the HPA gain and output power at the five transmit frequencies listed in Table 2-27. The test setup is shown below. The HPA output power should be measured using a spectrum analyzer protected with a high power attenuator of precisely known loss. The HPA output power should be measured at a level at which the HPA is still operating with acceptable linearity for use with the I-4/Alphasat system.

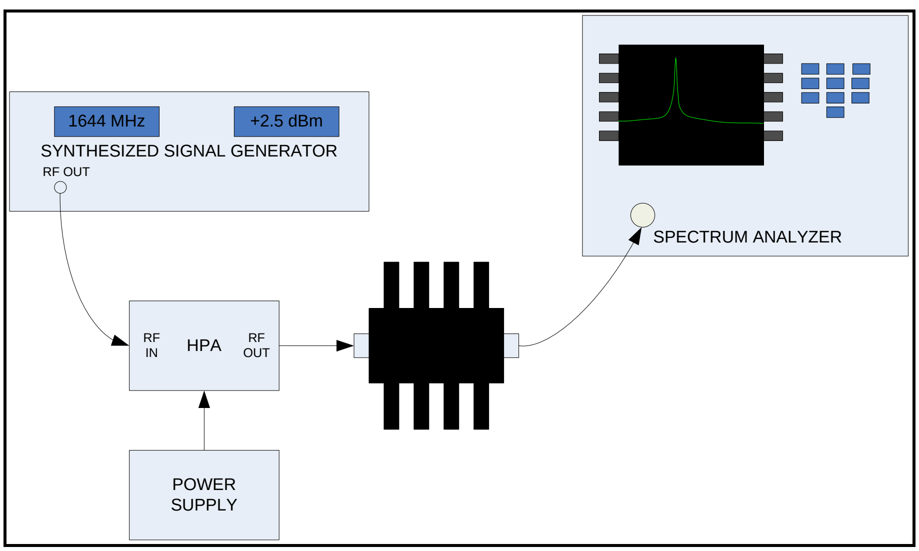

Figure 2-17 HPA Test Setup

Test Procedure

49. Measure the insertion loss of the attenuator at the transmit frequencies in Table 2-27 using a calibrated network analyzer. The attenuator shall be measured to a precision of 0.1dB at each test frequency. These values should be recorded as L_{ATTEN} for each frequency.

50. Connect the equipment as shown in Figure 5. Set the frequency of the signal generator to the first transmit frequency to be tested (1.6265 GHz). Set the output power of the signal generator to -30dBm. Ensure that the signal generator RF output is off.

51. Apply power to the HPA so that it is operating at its nominal power supply voltage.
52. Turn on the signal generator RF output and increase the power to the input of the HPA until the spectrum analyzer display indicates a power level such that the following is satisfied:

$$P_{DISP} = P_{HPA} - L_{ATTEN}$$

Where:

P_{DISP} is the displayed power on the spectrum analyzer.

L_{ATTEN} is the loss of the attenuator (in dB) recorded in Step 1.

P_{HPA} is the HPA output power to be recorded for use in EIRP computations.

As a target value; P_{HPA} should exceed that required to achieve the minimum EIRP for an AES4 terminal taking in to account installation losses. For example:

EIRP $\geq$10 dBW

$G_{ANT} \geq 2.5$dB

Installation Losses $\leq$ 2.5dB (A typical aircraft installation maximum)

$$P_{HPA} = EIRP - G_{ANT} + Installation\ Losses$$

From the above; the minimum amplifier power must be greater than 7.5dBW (5.62W) to meet the EIRP requirement of 10dBW. With a bit of margin one might decide that 7.1W (8.5dBW) is the minimum. If installation losses are known to be greater than 2.5dB due to cable type or run length or even transmit filter performance then the HPA target power shall be adjusted to maintain the 10dBW EIRP requirement.

53. Repeat for all remaining transmit frequencies. Record the HPA power for each test frequency for EIRP computation at each frequency.

2.4.3.1.1.2.4 Measurement and Computation of System Noise Temperature Tsys

The system noise temperature may be determined by one of three methods:

- The test procedure in DFL document MTR A.1; DFLD2253206, Issue A8, Section 7.5
- The test procedure in Inmarsat MTR 05; Issue 2, Section 6.5
- The method detailed below.

<u>CAUTION:</u> This test requires clear-sky radiation of RF energy and may require authorization from government agencies and/or relevant satellite operators.

The antenna gain and coverage volume requirements for AES4 antenna is to be satisfied by demonstrating that the overall AES4 system G/T requirement of Section 2.2.3.1.1.1.1.3 over the coverage volume as defined therein is met. In order to specify this in terms of performance at the single RF port of the antenna, it is necessary to use the temperature of the AES4 DLNA connected to this port.

In this G/T test, first the antenna noise temperature is measured at the test frequencies in Table 2-23. Then the receiver G/T is calculated using these temperatures together with the antenna gain values measured per the procedures in Section 2.4.3.1.1.2.1.

Equipment Required
Antenna Ground Plane
AES4 antenna under test with internal DLNA (access required to the internal DLNA input)
Noise Figure Meter (HP 8970B or equivalent).
Noise Source (HP 346C or equivalent)
RF Power Source (capable of maximum RF power for this test).

Measurement Requirements
The objective is to simulate as far as is practical the sky noise environment experienced during actual AES operation. The following conditions apply when performing antenna noise temperature measurements:

- The antenna shall be viewing a clear-sky condition (no or nearly no clouds) with a site that offers little or no obstruction of sky visibility over the upper hemisphere;
- The radome to be installed as part of the antenna shall be installed during the measurements;
- The antenna shall be mounted on the ground plane and positioned relative to the Earth in a manner that simulates nominally horizontal level aircraft flight;
- The ambient temperature shall be in the range of 290 ± 30 K, where (0° C = 273.15 K);
- The noise source and noise figure meter shall be operated within the temperature range for which their calibration is valid and that the correct ENR data from the noise source has been entered into the 8970B.

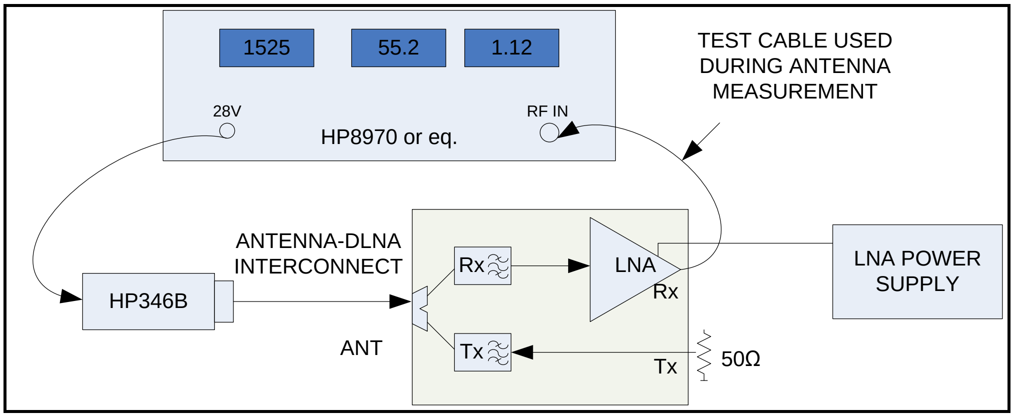

Figure 2-18 Measuring P_{Hot} and P_{Cold}

Step 1:

As shown in Figure 2-12, connect the HP346B Noise Source to the (test equipment) DLNA cable input using the interconnect normally used in the AES4 antenna, connect the DLNA output to the HP8970B Noise Figure Meter using the same test cable to be used for rooftop measurement, and record the ambient temperature at the antenna, load, and noise source, T_C.

If the RF Source is used for a diplexer transmit load, assure that it remains turned off during this test. The DLNA or LNA shall be the same unit built into the AES4 antenna under test.

Step 2:

Preset the HP8970B by pressing the "Preset" button.

Step 3:

Under “Smoothing” press "Increase" three times to increase the averaging from one sample to eight samples for smoothing. Press "Frequency" and enter the lowest receive test frequency by pressing "1518" on the numeric keypad followed by "Enter". Press "1.0" followed by the special function key "SP" to set up the test for measurement without an external oscillator.

Step 4:

Press "14.4 SP" to turn on the noise source, and "62 SP" and "72 SP" to hold the RF and IF attenuators during the measurement. Record the value displayed on the far-right display, which is proportional to power in decibels. This value is P_{Hot}.

Press "14.3 SP" to turn off the noise source. Record the value for cold source power, which is P_{Cold}.

Calculate:

$$Y_1 = P_{Hot} - P_{Cold} \tag{1}$$

Convert this dB value to a numerical factor and record it for use in equation (6).

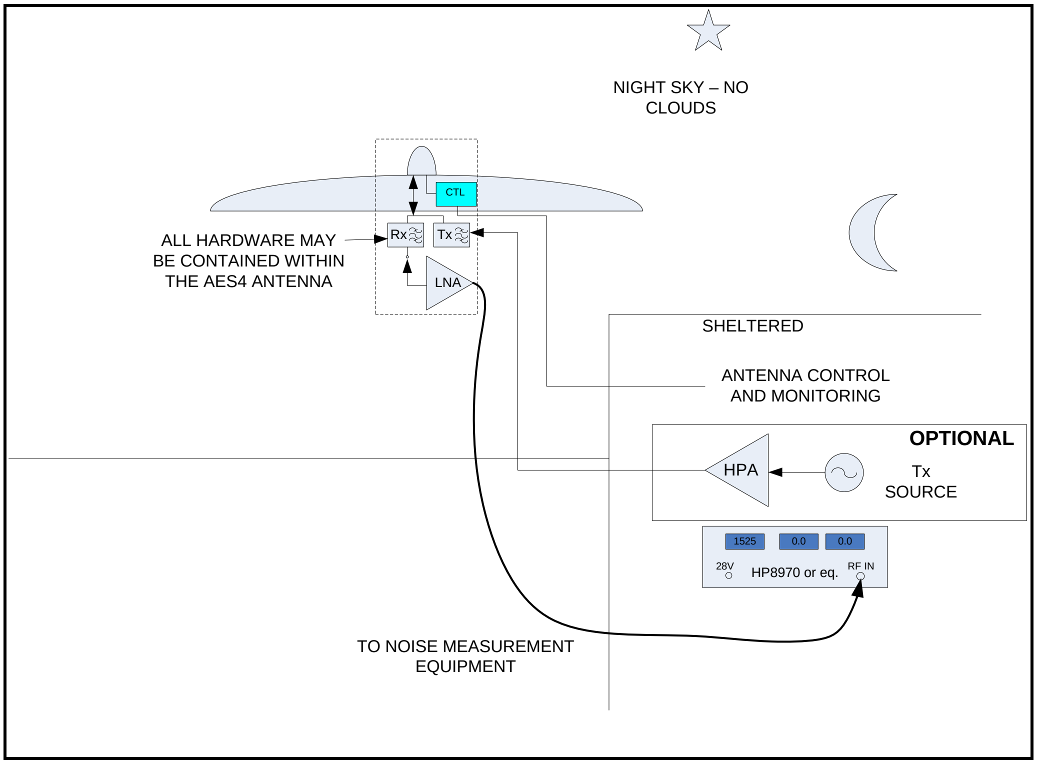

Figure 2-19 TAnt Measurement

Disconnect the HP346B Noise Source and attach the antenna output to the DLNA.

Terminate the transmit port of the DLNA or connect the RF power source to the transmit port of the DLNA.

Ensure that the source is tuned either to the mid-transmit band or whichever frequency was coordinated with authorities and operators and that there is a CW power level at the single RF port of the antenna that is equal to the maximum power handling capability of the AES4 antenna. Note that one of the previously agreed frequencies for PIMBIT may be used here as these are already reserved for testing.

P_{Ant} data shall be collected for the following beams to be used in the normal operation of the AES4 antenna. Symmetry of the antenna by quadrants is assumed and data shall be collected for Az = 0, 45 and 90° and for elevations of 5, 15, 30, 45, 60, 75 and 90°. This results in 19 test points for each frequency.

Record the value on the far-right display on the Noise Figure meter for each measurement. These values are defined as P_{Ant}. From these values, calculate:

$$Y_2 = P_{Cold} - P_{Ant} \tag{2}$$

Convert this dB value to a numerical factor and record it for use in equation (7).

Repeat Steps 1 and 4 to obtain P_{Hot}, P_{Cold}, and P_{Ant} at the nearest receive band frequencies in Table.

In the following analysis, the test receiver noise temperature (T_{Rx}) and the antenna noise temperature (T_{Ant}) are calculated from the basic definitions of the "Y" factors:

$$Y_1 = \frac{T_{Hot}+T_{Rx}}{T_{Cold}+T_{Rx}} \tag{3}$$

$$Y_2 = \frac{T_{Cold}+T_{Rx}}{T_{Ant}+T_{Rx}} \tag{4}$$

Calculate the system noise temperature in the following manner. Use the recorded ambient temperature for T_{Cold}. Find the value for T_{Hot} using:

$$T_{Hot} = T_0\left[10^{ENR}/_{10} - 1\right] \tag{5}$$

where T_0 is 290K and ENR is the Excess Noise Ratio of the noise source in dB.

Calculate the test receiver noise temperature T_{Rx} referred to its input, derived from Equation (3), as follows:

$$T_{Rx} = \frac{T_{Hot}-Y_1\times T_{Cold}}{Y_1-1} \tag{6}$$

Calculate the antenna noise temperature T_{A1}, derived from Equation (4), as follows:

$$T_{Ant} = {[T_{Cold} + T_{Rx}(1-Y_2)]}/{Y_2} \tag{7}$$

Step 5:

For the antenna under test, T_{Ant} shall be corrected for temperature by calculating the internal dissipation loss of the antenna by means of the expression:

$$L = {(T_{Cold} - T_{Sky})}/{(T_{Cold} - T_{Ant})} \tag{8}$$

Where L represents the internal dissipation loss of the AES4 antenna as a value > 1.

T_{Sky} is the external noise temperature, assumed to be 100K for this calculation.

T_{Ant} values are obtained from Equation (7).

From these values for L, corrected values of T_{Ant} may be obtained by using a value of 290K for T_{Cold} and substituting these values into Equation (9):

$$T_{AntCorr} = {T_{Sky}}/{\left(L + 290\left(1 - {1}/{L}\right)\right)} \tag{9}$$

Where $T_{AntCorr}$ are temperature-corrected values raw T_{Ant} values. Convert these values to dB.

Step 6:

Use the appropriate T_{Ant} values to the corresponding sectors and frequencies of the antenna measured gain.

$$\left({G}/{T}\right)_{Sector} = G_{Sector} - T_{Sector}$$

Perform this computation for each sector and verify compliance with Table 2-6 in Section 2.2.3.1.2.1.1.3.

EIRP Computation

EIRP shall be calculated as follows:

$$EIRP_{Sector} = P_{HPA} + G_{Antenna_{Sector}} - Ins.Loss$$

Where:

P_{HPA} is the HPA power in dBW

$G_{Antenna_{Sector}}$ is the RCP gain at the sector being evaluated at the specific frequency in dB.

Ins. Loss is any insertion loss in the transmit path which was not present when the antenna gain was measured (in dB).

Perform this computation for each sector and verify compliance with Table 2-6 in Section 2.2.3.1.2.1.1.3.

Max EIRP Determination for installed HPA Power

This is determined by evaluating all of the EIRP results (above) and verifying that none of them exceed the EIRP limit associated with G_{MAX} in Table 2-3.

2.4.3.1.1.3 Manufacturer-defined Antenna Tests

Reference: 2.2.3.1.2.10

The test procedure and pass/fail limits for this test shall be determined by the manufacturer.

2.4.3.1.2 Transceiver Subsystem Test Requirements

2.4.3.1.2.1 Transmitter Performance

2.4.3.1.2.1.1 Minimum Power Output

Reference: 2.2.3.1.3.1.1

This requirement shall be tested using the procedure defined in MTR 14, using test script MTR14b. An AES that is capable of supporting high data rate (HDR) services shall also be tested using test scripts MTR 14i. The required test frequencies are specified in the MTR. The test data for the maximum power case (zero dB back-off) shall be used for this purpose.

2.4.3.1.2.1.2 Maximum Individual Carrier Output

Reference: 2.2.3.1.3.1.2

This requirement shall be tested using the procedure defined in MTR 14, using test script MTR14b. An AES that is capable of supporting high data rate (HDR) services shall also be tested using test scripts MTR 14i. The required test frequencies are specified in the MTR. The test data for the maximum power case (zero dB back-off) shall be used for this purpose.

2.4.3.1.2.1.3 Maximum Total Transceiver Output Carrier Power

Reference: 2.2.3.1.3.1.3

Determine the sum of the results for the Maximum Individual Carrier Output for each individual channel as measured in Section 2.4.3.1.2.1.2. This shall be done by calculation.

2.4.3.1.2.1.4 Transmitter Intermodulation Products

Reference: 2.2.3.1.3.1.4

The requirement of Section 2.2.3.1.3.1.4 applies directly to equipment classes 6MA, 6F, 7MA, 7F, 6D and 7D. In these cases the measurement shall be referred to the connector of the antenna. The output from the transmitter may be measured without the diplexer, in which case the measured attenuation of the diplexer and cables shall be included in the final result by calculation.

In the case of equipment classes 6MA, 6F, 7MA and 7F the specified transmit port to antenna port rejection of the class DMA or DF diplexer, as appropriate, shall be taken into account by calculation. The values are specified in Sections 2.2.3.1.4.3.2 for DMA and 2.2.3.1.4.3.3 for DF.

In the case of equipment classes 6D and 7D the actual transmit port to antenna port rejection of the diplexer shall be taken into account by including the diplexer in the measurement, or by calculation after measuring the diplexer and transmitter performance separately.

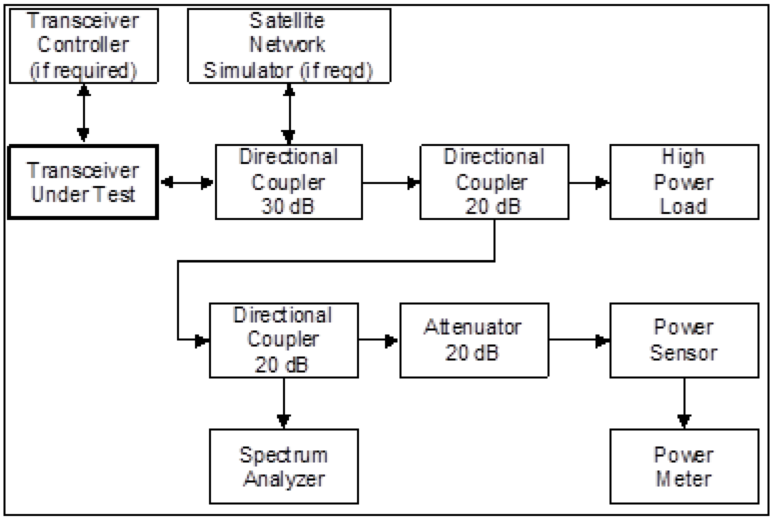

Figure 2-20 Transceiver Intermodulation Product Test Set Up

54. Connect the equipment as shown in Figure 2-20.
55. Command the transceiver to output a single unmodulated carrier at maximum individual output power level on frequency TX_{F1} (as defined in 2.4.1.1.2.1). Setup a second unmodulated carrier at maximum individual output power level on frequency TX_{F1} + 2 MHz.
56. Measure the inter-modulation products over the frequency band 1616 to 1660.5 MHz and compare the results with the limits in Table 2-31.
57. Repeated the test with the second carrier at TX_{F1} + 200kHz.
58. Repeat steps 2 to 4 for frequencies TX_{F2}, TX_{F3}, TX_{F4}.
59. Repeat steps 2 to 4 for frequencies TX_{F5}, with the second carrier at TX_{F5} – 2 MHz and TX_{F5} - 200 kHz respectively.

Derived limits for intermodulation products are given in Table 2-31. Interpolate between frequency points using straight lines in dB.

Table 2-31 Intermodulation Limits

Frequency	Limit
6MA, 7MA sub-system	
1616 -1626.5MHz	-5.1 dBc to -38.7 dBc
1626.5 – 1660.5 MHz	-29.5 dBc
6F and 7F sub-systems	
1616 – 1620 MHz	-8.7 dBc
1620 -1624.5 MHz	-18.7 dBc
1624.5 – 1625.5 MHz	-18.7 dBc to -28.7 dBc
1625.5 – 1626.5 MHz	-28.7 dBc to -38.7 dBc
1626.5 – 1660.5MHz	-29.5 dBc
6D and 7D sub-systems	
1616 -1626.5MHz	-38.7 dBc
1626.5 – 1660.5 MHz	-29.5 dBc

2.4.3.1.2.1.5 Transmitter Harmonics, Discrete Spurious and Noise Density

Reference: 2.2.3.1.3.1.5.
This requirement shall be tested using the test setup shown in the Inmarsat MTR [2], MTR 16 Section 3.2.1. The test shall be executed according to the test procedure defined in the Inmarsat MTR [2], MTR 16 sections 3.3.1, 3.3.2 and 3.3.3.1. The spectrum analyzer bandwidth and detector settings shall be according to Table 2-5 or Table 2-6, as appropriate for the equipment class. The required test frequencies are specified in the MTR.
Harmonic Spurious and Noise levels from the transmit chain shall all be referred to the connector port of the antenna.
Levels which are specified as EIRP in Table 2-6 shall be converted by calculation to a level referred to the antenna connector of the AES. This shall be done by subtracting the following antenna gain from the specified EIRP level:

- If the system being qualified includes an antenna, and the transceiver and DLNA will not be used with another antenna, then the maximum gain of the antenna, as measured in Section 2.4.3.1.1.1.1 shall be used.
- If the system excludes an antenna, the specified maximum gain (G_{MAX}) for an IGA from Table 2-3 shall be used.

Compliance shall be determined by calculation using the following data

- measured spectrum at the transmitter output, measured with a spectrum analyzer and
- insertion loss data for the transmit path of the DLNA as follows:
    - measured loss and isolation data of the DLNA, in the case of a Class 6D or 7D transceiver or an AES4, or
    - specified loss and isolation data of the DF DLNA as given in Section 2.2.3.1.4.3.3, in the case of a Class 6F or 7F transceiver, or
    - specified loss and isolation data of the DMA DLNA as given in Section 2.2.3.1.4.3.2, in the case of a Class 6MA or 7MA transceiver, and
- cable losses:
    - 0.3 dB for the DLNA to antenna cable, except for Equipment Class AES4
    - 1.4 dB loss for the transmitter to DLNA cable, except for Equipment Class AES4
    - Worst case cable losses in the range of losses specified by the manufacturer for an AES4.
    - If cables with different losses are used during the measurements, the difference in cable losses shall be compensated for by calculation.

Notwithstanding the above, it is permissible to measure the output spectrum of the transmitter and diplexer combined, provided the spectrum analyzer has the required dynamic range.

2.4.3.1.2.1.6 Protection of Radio Astronomy

Reference: 2.2.3.1.3.1.6.
Not applicable (included in the measurements in Section 2.4.3.1.2.1.5)

2.4.3.1.2.1.7 Carrier-off Level

Reference: 2.2.3.1.3.1.7

This requirement shall be tested using the test setup and procedure defined in the Inmarsat MTR [2], MTR 15. The transmitter shall be set up at the required test frequencies as specified in the MTR. Emissions shall be measured over the frequency bands listed in Table 2-7 or Table 2-8 (as appropriate to the AES class), using the measurement bandwidth and detector type in the same table.

For an AES4:

Measurements shall be made at the connector of the antenna (or equivalent improvised test point on a specially prepared unit), using the minimum cable length between antenna and diplexer specified by the manufacturer. Compliance shall be determined by calculation using the data measured during the test and the maximum boresight gain of the antenna as determined during the tests carried out in Section 2.4.3.1.1.1.1.

For an AES7:

If the Transceiver and DLNA are being qualified together (Class 7D subsystem), measurements shall be made at the DLNA antenna port and compliance shall be determined by calculation using the data measured during the test and the following fixed data points:

- Minimum DLNA to Antenna cable loss per Table 2-2.
- Maximum gain of an IGA antenna (GMAX_IGA) as per Table 2-3.

If a Transceiver is being qualified without a DLNA (Class 7F or 7MA transceiver), measurements shall be made at the Transceiver transmit port and the following assumed values included by calculation:

- minimum cable loss between the Transceiver and DLNA
- specified loss data of the DLNA as given in Section 2.2.3.1.4.3.2 for a 7MA system or Section 2.2.3.1.4.3.3 for a type 7F system.
- minimum cable loss between the DLNA and Antenna,
- maximum gain of an IGA antenna (GMAX_IGA) as per Table 2-3.

For an AES6:

If the Transceiver and DLNA are being qualified together (Class 6D subsystem), measurements shall be made at the antenna port of the DLNA. Compliance shall be determined by calculation using the data measured during the test and the following fixed data points:

- minimum DLNA to Antenna cable loss per Table 2-2.
- maximum gain of an IGA antenna (GMAX_HGA) as per Table 2-3.

If a Transceiver is being qualified without a DLNA (6F or 6MA), measurements shall be made at the Transceiver transmit port and assume:

- minimum cable loss between the Transceiver and DLNA
- specified loss data of the DLNA as given in Section 2.2.3.1.4.3.2 for a 6MA transceiver or Section 2.2.3.1.4.3.3 for a 6F transceiver.
- minimum cable loss between the DLNA and Antenna,
- maximum gain of an IGA antenna (GMAX_HGA) as per Table 2-3.

Note: For AES4, 7D and 6D systems, due to test equipment limitations it may not be possible to measure some of the very low levels of harmonics noise and spurious at the output of the DLNA. In these cases it is acceptable to make the performance *measurement prior to the diplexer and also measure the diplexer and demonstrate compliance by calculation.*

2.4.3.1.2.1.8 Power Control

Reference: 2.2.3.1.3.1.8
This requirement shall be tested using the procedure defined in the Inmarsat MTR [2], MTR 14b. The required test frequencies are specified in the MTR.

2.4.3.1.2.1.9 On-Channel Output Spectrum

Reference: 2.2.3.1.3.1.9
This requirement shall be tested using the procedure defined in the Inmarsat MTR [2], MTR 26. The required test frequencies and bearer types are specified in the MTR.

2.4.3.1.2.1.10 Transmitter Operation in Moving Aircraft

Reference: 2.2.3.1.3.1.10
This requirement shall be proven during the testing defined in Section 2.4.3.1.2.1.12.

2.4.3.1.2.1.11 Transmitter Phase Noise

Reference: 2.2.3.1.3.1.11
This requirement shall be tested using the procedure defined in the Inmarsat MTR [2], MTR 17. The required test frequencies and bearer types are specified in the MTR.

2.4.3.1.2.1.12 Frequency Accuracy

Reference: 2.2.3.1.3.1.12
This requirement shall be tested using the procedure defined in the Inmarsat MTR [2], MTR 19. The required test frequencies and bearer types are specified in the MTR.

2.4.3.1.2.1.13 Transmitter Tuning

Reference: 2.2.3.1.3.1.13
This requirement shall be tested using the procedure defined in the Inmarsat MTR [2], MTR 18. The required test frequencies and bearer types are specified in the MTR.

2.4.3.1.2.1.14 Manufacturer Specific Transmitter Test

Reference: 2.2.3.1.3.1.14
The test procedure and pass/fail limits for this test shall be determined by the manufacturer.

2.4.3.1.2.2 Receiver

Test frequencies for the receiver tests are given in the MTRs. However Class 6 and 7 equipment is not required to be tested over the extended portion of the L-band.

2.4.3.1.2.2.1 Receiver Sensitivity

Reference: 2.2.3.1.3.2.1; 2.2.3.1.3.2.2; 2.2.3.1.3.2.5
This test shall test receiver sensitivity, receiver bandwidth and receiver operation in a moving aircraft.
These requirements shall be tested using the procedure defined in the Inmarsat MTR [2]; MTR 8a, 8c, 8w, 10a, 10c, 10w. The system shall be tested at the frequencies defined in 0 based upon the declared system type.
For system types AES4, 6D and 7D the performance of the system (except for the antenna is measured. The receive antenna gain parameter, within the PLT shall be used to compensate for:

- G_{NOM} (from Table 2-3) based upon the defined system antenna type.

For system types 6MA, 6F 7MA and 7F the performance of the Transceiver only shall be measured. The receive antenna gain parameter, within the PLT shall be used to compensate for:

- G_{NOM} (from Table 2-3) based upon the defined system antenna type.
- Maximum cable loss – Antenna to DLNA (from Table 2-2).
- Minimum LNA gain 53 (from 2.2.3.1.4.2).
- Maximum Cable loss - DLNA to Transceiver (from Table 2-2).

When setting the noise figure on the PLT, for system types AES4, 6D and 7D the noise figure should be measured for the whole system from the antenna port.
For system types 6MA, 6F 7MA and 7F the noise figure shall be measured for the Transceiver only. The specified noise figure and gain of the intended DLNA, as well as the specified cable losses, shall then be used to calculate the system noise figure.

2.4.3.1.2.2.1.1 Test Methodology for Environmental Conditions

Receiver sensitivity testing is required to be repeated a large number of times over different environmental conditions (particularly in RF susceptibility and Induced signal susceptibility). To reduce the test burden only one modulation type and sub-type is required to be tested. This shall be F80T45X-8B at the H4 code rate under Additive White Gaussian Noise (AWGN) conditions.
The manufacturer may choose to further reduce the test time by measuring the equivalent channel error rate (pre-error correction) instead of the packet error rate. If the manufacturer wishes to implement this, then they shall provide measurement evidence linking channel error rate to packet error rate. A minimum of 200k data bits or 2000 bit errors must be tested for each channel error rate measurement.
For this test a fixed pattern for data bits (e.g. all zeroes) is acceptable as the channel scrambler is considered sufficient to ensure random symbols over the channel.

2.4.3.1.2.2.2 Receiver Bandwidth

Reference: 2.2.3.1.3.2.2
No separate test required.

Note: Receiver bandwidth is tested in other tests, e.g. by modulated adjacent channel interferers during receiver sensitivity tests in 2.4.3.1.2.2.1.

2.4.3.1.2.2.3 Rejection of Signals outside NGSS Receive Band

Reference: 2.2.3.1.3.2.3
The following equipment is required:

- BGAN Protocol Tester (BPLT) or equivalent source of BGAN modulated signals at a calibrated signal-to-noise ratio, suitable for PER or BER testing.
- CW signal generator, capable of the frequency range specified in Section 2.2.3.1.3.2.3.
- Directional coupler, with a frequency band covering the SBB receive band. A coupling factor of around 20 dB is recommended. If a different coupling factor is used it may be compensated for by adjusting the BPLT signal level.

2.4.3.1.2.2.3.1 Identification of Test Frequencies

The assessment of interfering frequencies shall be made for the following RF input frequencies:

	Lowest Frequency	Center Frequency	Highest Frequency
AES4	1518 MHz	1542 MHz	1559 MHz
AES6	1525 MHz	1542 MHz	1559 MHz
AES7	1525 MHz	1542 MHz	1559 MHz

2.4.3.1.2.2.3.2 Derivation of Test Levels

For AES4 and Class 6D and 7D transceiver and DLNA combinations, the test shall be conducted at the antenna connector using the interference levels defined in Section 2.2.3.1.3.2.3.
For Class 6MA and 7MA transceivers, the test shall be conducted at the transceiver's receive input port, and the interference levels, defined in Section 2.2.3.1.3.2.3. The levels shall also be modified by the parameters:

- 0.15dB antenna to DLNA cable (average loss as defined in Table 2-2)
- Modified type A DLNA Antenna port to receive port rejection (as defined in Table 2-13)
- 56.5dB DLNA gain as (average gain as defined in Section 2.2.3.1.4.2)
- Minimum DLNA to transceiver cable loss as (as given in Table 2-2)

For Class 6F and 7F transceivers, the test shall be conducted at the transceiver's receive input port, and the interference levels, defined in Section 2.2.3.1.3.2.3, shall be modified by the following parameters:

- 0.15dB antenna to DLNA cable (average loss as defined in Table 2-2)
- Type F DLNA Antenna port to Receive port rejection (as defined in Table 2-16)
- 56.5dB DLNA gain as (average gain as defined in Section 2.2.3.1.4.2)
- 15.5dB DLNA to transceiver cable as (average loss as defined in Table 2-2)

2.4.3.1.2.2.3.3 Test Method

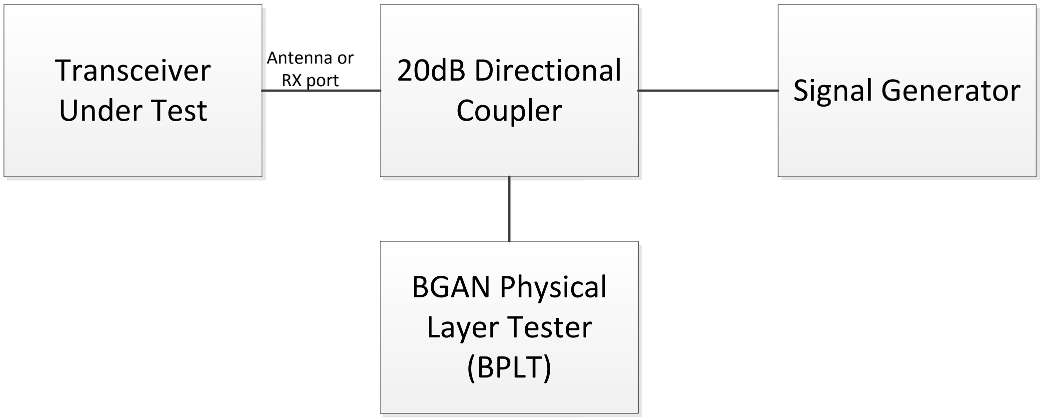

Figure 2-21 Test Setup for Rejection of Signals Outside the NGSS Receive Band

The test shall be carried out using the procedure defined in the Inmarsat MTR [2]; MTR 10a, although the scope shall be reduced to test the F80T45X bearer at the H4 coding rate. The test shall be run in the presence of all channel impairments and with the interference frequency and levels identified above. A minimum of 10,000 blocks shall be run for each test, and achieve a Packet Error Rate (PER) equal or better than $1x10^{-3}$.
Alternatively, the manufacturer may choose to use a faster test based on channel Bit Error Rate (BER) instead of post-FEC PER, as described in Section 2.4.3.1.2.2.1.1.
The interferer frequency shall be stepped in steps of 100 kHz or less with a dwell time of at least two measurement periods (for either PER or BER) per frequency. Marginal test cases (at individual problem frequencies) should be investigated by using finer frequency steps and longer measurements.

2.4.3.1.2.2.4 Rejection of Carrier Signals Generated by Other AMS(R)S Equipment

Reference: 2.2.3.1.3.2.4
Not applicable.

2.4.3.1.2.2.5 Receiver Operation in Moving Aircraft

Reference: 2.2.3.1.3.2.5

Not applicable.
Note: Doppler is already included as a signal impairment in Section 2.4.3.1.2.2.1

2.4.3.1.2.2.6 Receiver Susceptibility

Reference: 2.2.3.1.3.2.6
Testing of the wideband receiver susceptibility requirement is covered in this section. Testing of the narrow band receiver susceptibility requirement is covered as a channel impairment in the receiver sensitivity testing in Section 2.4.3.1.2.2.1.

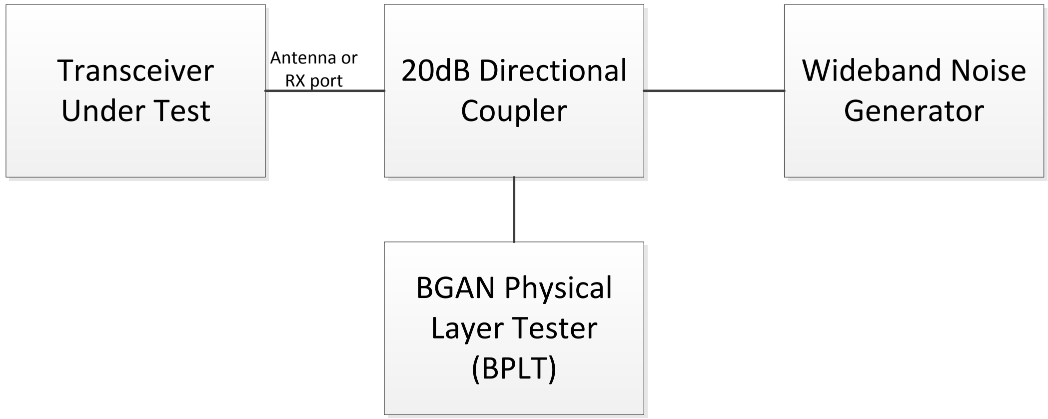

Figure 2-22 Receiver Susceptibility Test Setup

2.4.3.1.2.2.6.1 Noise Setup

The noise generation setup shown in Figure 2-22 generates a wideband (over the entire receiver band) noise-like signal with a narrow notch around the test frequency. This can be achieved by the programming of a vector signal generator. Suggested equipment:

- Agilent Vector Signal Generator, Model ESG E4438C-503
- Agilent Spectrum Analyzer, Model PSA E4440A
- Agilent Signal Studio, Model N7621

The wideband noise shall occupy the entire receiver band, with a 200kHz wide notch around the test frequency. The depth of the notch shall be at least 40dB, the 30dB bandwidth of the notch shall not exceed 220kHz.
The level of the wideband noise shall be at the level specified as SUW for AES4 and Class 6D and 7D subsystems. For Class 6F, 6MA, 7F and 7MA transceivers, the specified level shall be increased by:

- 0.0 dB antenna to DLNA cable (minimum cable loss as defined in Table 2-2)
- 60 dB DLNA gain as (maximum DLNA gain as defined in Section 2.2.3.1.4.2)
- 6 dB DLNA to transceiver cable as (minimum cable loss as defined in Table 2-2)

2.4.3.1.2.2.6.2 Test

This requirement shall be tested using the procedure defined in the Inmarsat MTR [2], MTR 8a. The test need only be conducted for the F80T0.25QL8 modulation type, and only needs to be conducted at one frequency. The frequency should be close to center band, but is left to the manufacturer's discretion to allow for tuning of the notch. For AES4 and Class 6D and 7D subsystems the wanted signal levels to be used are as per the MTR, with the test carried out at the antenna port.
For Class 6F, 6MA, 7F and 7MA transceivers, the test shall be conducted at the transceiver's receive input port, the wanted signal levels shall also be modified from the MTR by the parameters:

- 0.0 dB antenna to DLNA cable (minimum cable loss as defined in Table 2-2)
- 60 dB DLNA gain as (maximum DLNA gain as defined in Section 2.2.3.1.4.2)

- 6 dB DLNA to transceiver cable as (minimum cable loss as defined in Table 2-2)

The test shall be conducted with all the standard impairments, including adjacent carriers, but excluding fading and Doppler.

2.4.3.1.2.2.7 Acquisition

This requirement shall be tested using the procedure defined in the Inmarsat MTR [2], MTR 7 and 9. The required test frequencies and bearer types are specified in the MTR.
MTR7a, MTR7b, MTR7c, MTR7e, MTR9b, MTR9c, MTR9e shall be run at ambient and environmental conditions per Table 2-23. MTR7k, MTR7l, MTR7m, MTR7o, MTR9l, MTR9m, MTR9o need only be run at ambient, although the tests need to be repeated for medium and low elevation as detailed in the MTR.
For an AES4 and Class 6D and 7D subsystems the levels to be used in the test shall be as specified in the MTR, with the test carried out at the antenna port.
For Class 6F, 6MA, 7F and 7MA transceivers, the test shall be conducted at the transceiver's receive input port. The levels shall also be modified by the parameters:

- 0.3 dB antenna to DLNA cable (maximum cable loss as defined in table 2-4)
- 53 dB DLNA gain as (minimum DLNA gain as defined in Section 2.2.3.1.3.2)
- 25 dB DLNA to transceiver cable as (maximum cable loss as defined in table 2-4)

2.4.3.1.2.2.8 Carrier-to-Noise Level Accuracy

This requirement shall be tested using the procedure defined in the Inmarsat MTR [2], MTR 23. The required test frequencies and bearer types are specified in the MTR.
For an AES4 and Class 6D and 7D subsystems the levels to be used in the test shall be as specified in the MTR, with the test carried out at the connector of the antenna.
For Class 6F, 6MA, 7F and 7MA transceivers, the test shall be conducted at the transceiver's receive input port. The levels shall also be modified by the parameters:

- 0.15dB antenna to DLNA cable (average loss as defined in Table 2-2)
- 56.5dB DLNA gain as (average gain as defined in Section 2.2.3.1.4.2)
- 15.5dB DLNA to transceiver cable as (average loss as defined in Table 2-2)

2.4.3.1.3 DLNA Test Procedures

The environmental testing of the DLNA as identified in Section 2.3.5 shall be carried out in accordance with this Section which includes the description of the test setups and procedures used. All active tests (DUT powered up) will need to be performed at both 115 VAC, 400 Hz and +28 VDC.

- DLNA VSWR
- Noise Figure
- Gain/Filter Response
- DLNA Passive Intermodulation (PIM)
- DLNA Maximum Transmit Power
- DLNA Receiver Output Power

- Manufacturer Defined DLNA Tests

2.4.3.1.3.1 DLNA VSWR

Reference: 2.2.3.1.4.1
A typical test setup is shown in Figure 2-23.

Equipment Required
Network Analyzer – HP 8753, 8720 or equivalent
DLNA Control Box
True RMS Digital Multimeter – Agilent 34401A or equivalent
Single Phase 115 VAC, 400 Hz Power Supply
+28 VDC Power Supply
3.5 mm Calibration Kit – HP 85052D or equivalent

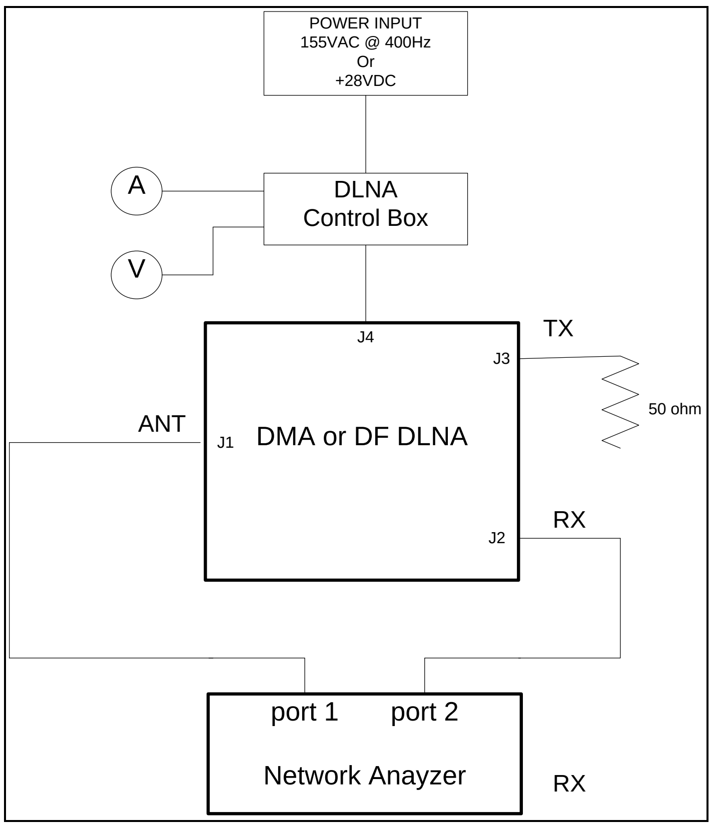

Figure 2-23 Typical DLNA Test Setup

Measurement Requirements

60. Connect the equipment as shown above in Figure 2-23. Unless otherwise specified the DLNA shall be powered at nominal voltage levels.
61. Set the output level of the network analyzer to be at least 5 dB below the input 1 dB compression point of the DLNA.
62. For all DLNAs, calibrate the network analyzer to sweep across the 1.5 to 1.7 GHz frequency range.

63. Perform an S11 measurement at each DLNA RF port, while other RF ports are terminated, either into the remaining port of the network analyzer or a 50 ohm load.

2.4.3.1.3.2 Noise Figure/Gain

Reference: 2.2.3.1.4.2

The noise figure of the receive path of the DLNA shall be less than 1.2 dB at temperatures up to 25°C. It may increase at higher temperatures to a maximum of 1.6 dB at 70°C.

Figure 2-24 contains a typical Noise Figure test setup.

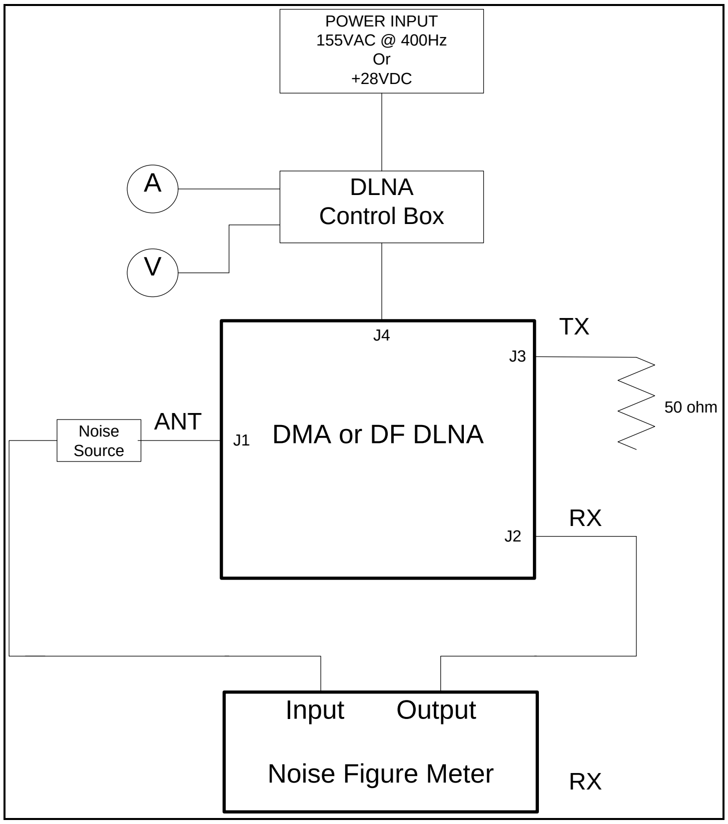

Figure 2-24 Typical DLNA Noise Figure Test Setup

Equipment Required

Noise Figure Meter – HP8970B or equivalent
Noise Source – HP346B or equivalent
DLNA Control Box
True RMS Digital Multimeter – Agilent 34401A or equivalent
Single Phase 115 VAC, 400 Hz Power Supply
+28 VDC Power Supply

Noise Figure Measurement Requirements

Noise Figure measurements are performed using a noise figure meter. The noise figure meter shall be swept across the frequency range 1.51 to 1.58 GHz. The setup shall be calibrated to correct for any path losses associated with cable loss. Measurements are performed at nominal voltage bias levels unless noted otherwise.

2.4.3.1.3.3 Gain / Filter Response

Reference: 2.2.3.1.4.3.2; 2.2.3.1.4.3.3
The gain of the receive path of the DLNA shall be between 53 and 60 dB.
S-parameter measurements as identified in Section 2.2.3.1.3.3 are performed using the typical DLNA test setup identified in Figure 2-24 and using the equipment identified in Section 2.4.3.1.3.1 with a 1.5 to 1.7 GHz. Table 2-32 provides the frequency ranges and required power levels for the S21 and S12 measurements.

Table 2-32 DLNA Receive Path Power Level and Measurement

Rejection Ant - Transmit	**Power Level (dBm)**	**S-Parameter**
1.6 to 1.7GHz	5	S21
Rejection Ant - receive		
1.5 to 1.6GHz	-50	S21

2.4.3.1.3.4 DLNA Passive Inter-modulation

Reference: 2.2.3.1.4.4; 2.2.3.1.4.4.1; 2.2.3.1.4.4.2
Equipment Required
Spectrum Analyzer Agilent – E4440A or equivalent
Two power amplifiers capable of producing 40W signal between 1.5 & 1.7 GHz – Amplifier Research AR-50S1G4A or equivalent
Two signal generators – HP 8657B or equivalent
Two 30 dB directional couplers
Two power meters – HP 437B or equivalent
Two power sensors – Agilent 8481A or equivalent
Combiner
PIM-free RF load
DLNA Control Box
True RMS Digital Multimeter – Agilent 34401A or equivalent
Single Phase 115 VAC, 400 Hz Power Supply
+28 VDC Power Supply

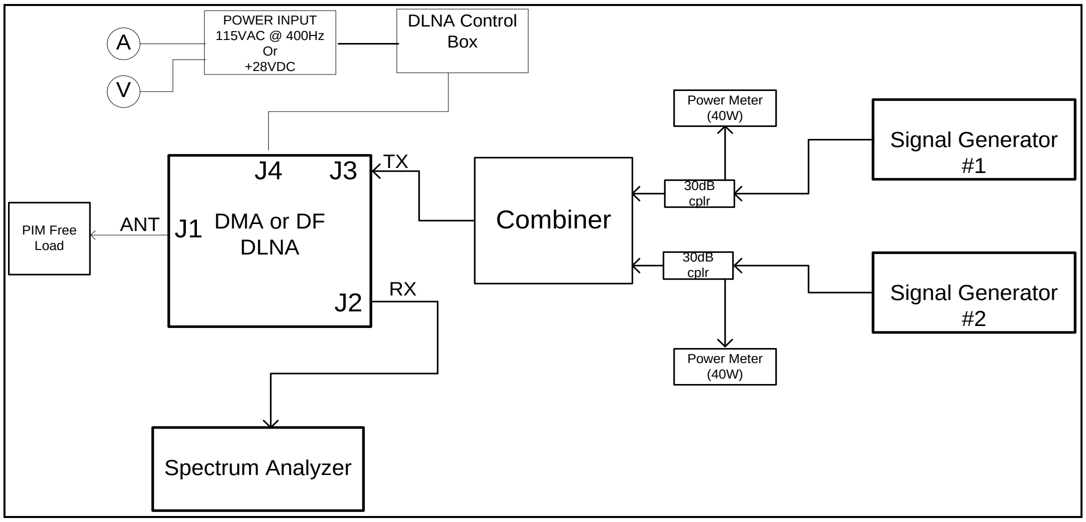

Figure 2-25 Typical PIM Test Setup

PIM Measurement

PIM measurements are performed using the test setup identified in Figure 2-25. Measure 5th and 7th order PIM using the following frequencies for each input:

Signal Input 1 = 40 W
5th order frequency = 1626.5 MHz
7th order frequency = 1630 MHz
Signal Input 2 = 40 W
5th order frequency = 1660.5 MHz
7th order frequency = 1654 MHz

The gain of the DLNA shall be subtracted from the value measured to obtain the correct PIM value.

2.4.3.1.3.5 DLNA Maximum Transmit Power

Reference: 2.2.3.1.4.5
Equipment Required
Power amplifier capable of producing an 80 W signal between 1.6 & 1.7 GHz
Signal generators – HP 8657B or equivalent
40 dB, 150 W power attenuator
Power meter – HP 437B or equivalent
Power sensor – Agilent 8481A or equivalent

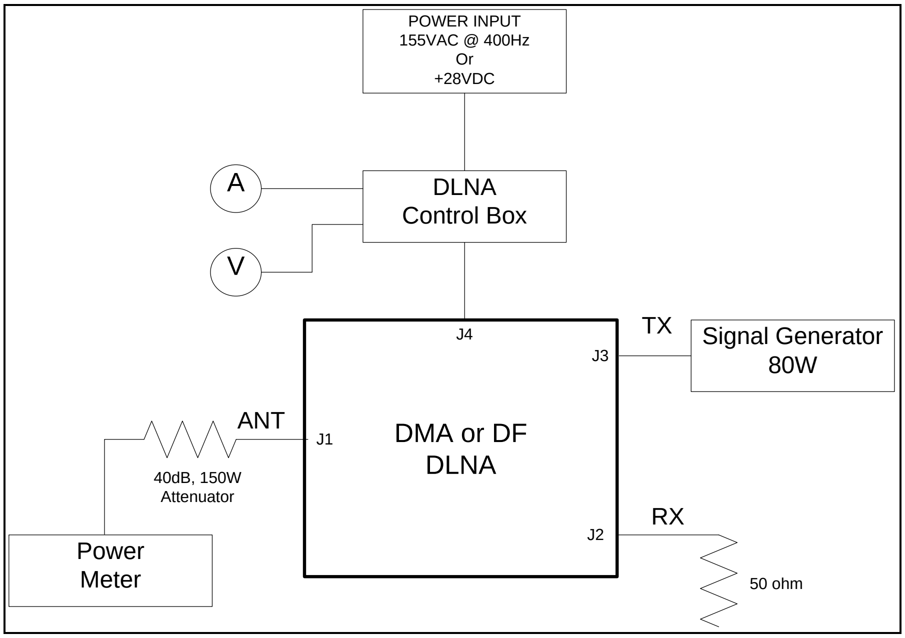

Figure 2-26 Typical Transmit Power Test Set-up

Transmit Power Measurement
The transmit power measurement is performed using the setup in Figure 2-26. The input signal shall be varied across 3 points of the transmit passband: 1626.5 MHz, 1643 MHz, and 1660.5 MHz.

2.4.3.1.3.6 DLNA Receiver Output Power

Reference: 2.2.3.1.4.6
Output power measurements are performed by sweeping the network analyzer at three frequency points centered at 1.5445 GHz using the typical DLNA test set-up identified in Figure 2-24and using the equipment identified in Section 2.4.3.1.3.1. A sweep shall be performed at multiple power levels. Response calibrations shall be performed for all paths to compensate for cable path losses. All measurements shall be performed at nominal voltage bias level unless noted otherwise. Table 2-32 provides the frequency ranges, required power levels and S-parameter to be measured.

2.4.3.1.3.7 Manufacturer Defined DLNA Test

Reference: 2.2.3.1.4.7
It is recommended that a complete test of the following electrical parameters be performed during testing to validate DLNA performance. Due to the duration and setups required for each parameter it is not possible to validate all parameters during all environment test conditions stated within DO-160G. As a minimum these should be validated prior to and upon completion of the environmental test requirements to ensure DLNA performance has remained stable.

- Noise Figure (Antenna to Receive Port)
- Gain (Antenna to Receive Port)
- Return Loss (Antenna, Receive, Transmit Ports)
- Insertion Loss (Transmit to Antenna Port)
- Rejection: Antenna Port to Receive Port
- Rejection: Transmit Port to Antenna Port

- Rejection: Transmit Port to Receive Port
- 1 dB Compression Point (Antenna to Receive Port)
- Output Third Order Intercept Point (Antenna to Receive Port)
- ON/OFF, BITE
- Spurious Outputs (Antenna to Receive Port)
- True RMS current consumption (115 VAC, 400 Hz power lines)
- DC current consumption (+28 VDC power lines)

2.4.3.1.4 Required Aircraft Interfaces

Reference: 2.2.3.1.5
The manufacturer shall define a test for the required aircraft interfaces.

2.4.3.2 User Link Modulation and Signal in Space (Physical Layer)

Reference: 2.2.3.2
No specific test. (These functions are verified section 2.4.3.1.2 and its subsections.)

2.4.3.3 Priority, Precedence and Preemption

2.4.3.3.1 Packet Data

Reference: 2.2.3.3.1
The manufacturer shall define a test to demonstrate the PDP contexts created for priority IP are created using the correct APN as per the configuration settings of the AES. It is not necessary to demonstrate that the air interface correctly prioritizes the data, as this is under the control of the BGAN network not the AES.
Note: The requirement to ensure segregation between the diverse sources of IP data is verified in Section 2.4.3.10.

2.4.3.3.2 Circuit Mode (Voice)

Reference: Section 2.2.3.3.2
Equipment and Setup Required
This test requires the ability to initiate and terminate N_v simultaneous circuit-mode voice calls through the satellite network, where N_v is the total number of safety voice circuits provided by the AES.
The scope of this test shall include all cockpit voice interfaces, as well as any additional interfaces aimed at priority or non-priority use.
This test is not intended to verify the ability of the satellite network or the satellite sub-network as a whole to satisfy the Priority, Precedence and Preemption of the MASPS.
Performing this test over the air requires significant co-ordination with Inmarsat Operations group and in some cases with the Service Provider for the following reasons:

- ensuring available capacity on the network,
- preparing the Satellite Network Operations group for the alarms automatically triggered when distress calls are made

- making a Mobile Terminated emergency call requires knowledge of special access codes not normally included in a subscription.

Test Procedure

64. Establish N voice calls at non-safety circuit-mode priority, Priority Level 4 (low), identified in Table 2-20.
65. While monitoring the Priority Level 4 (low) calls, attempt to establish an air-to-ground call at Circuit-Mode Priority 3. Verify that one of the non-safety circuits is terminated and made available for the safety call, and that the call is completed. This test is applicable only if the number of voice circuits N_v is less than the number of voice interfaces.
66. Repeat Step 2 until all channels are consumed by Priority 3 calls.
67. Repeat Steps 2 and 3 with Priority 2 calls.
68. Repeat Steps 2 and 3 with Priority 1 (high) calls.
69. At the completion of Step 5, there will be N Priority 1 (high) calls established. Attempt to initiate an air-to-ground call at Priority 2, and verify that the call is not accepted.
70. Attempt to initiate an air-to-ground call at Priority 3, and verify that the call is not accepted.
71. Attempt to initiate an air-to-ground call at Priority 4 (low), and verify that the call is not accepted. This step shall be performed for all equipment, including equipment that does not support Priority 4 (low) non-safety communications.
72. Terminate all calls, and re-establish Step 1 with Priority 4 (low) calls.
73. Repeat Steps 2 through 8 using ground-to-air calls and verify that the same results are obtained.

2.4.3.3.3 ACARS Communications

Reference: Section 2.2.3.3.3
The manufacturer shall define a test to verify that ACARS messaging is unaffected when UDP data transmission through the IP service is attempted at a rate which exceeds the available total channel capacity by at least 30%.

2.4.3.4 Satellite Subnetwork Data Protocol

Reference: 2.2.3.4
The Satellite Subnetwork Data Protocol shall be tested as part of the Inmarsat Type Approval process, according to the Inmarsat MTRs. An Inmarsat type approval certificate shall serve as evidence that the terminal interacts with the satellite subnetwork as required.

2.4.3.4.1 ATN-compliant Protocol

Reference: 2.2.3.4.1
Not applicable

2.4.3.4.2 ACARS Protocol

Reference: 2.2.3.4.2
The ACARS protocol shall be verified by executing the test cases in Section 3 of the document AAGW Test Case Descriptions [60]. The test setup shall be according to the Phase 3 test Architecture in Section 2.3 of the same document. If the user interface of the AES is not the standard ARINC 429 interface used in the test setup, a functionally-equivalent setup may be used, provided that the same protocol test cases can be executed.

2.4.3.5 Voice Protocol

2.4.3.5.1 Vocoder Interoperability with Satellite Subnetwork

Reference: 2.2.3.5.1 and 2.2.3.5.2
The vocoder function shall be verified according to MTR 43, using the BGAN Voice Codec Test Set (VCTS). A functionally equivalent test is acceptable. Bit-exact performance and end-to-end performance shall be verified.

2.4.3.5.2 Vocoder Performance in an Aeronautical Environment

Not applicable.

2.4.3.6 User Data Interfaces

2.4.3.6.1 ATN Interfaces

Not applicable.

2.4.3.6.2 ACARS Interface

Reference: 2.2.3.6.2

Under ambient conditions the ACARS interface is verified sufficiently as part of the ACARS protocol test in Section 2.4.3.4.2.
The manufacturer shall define a test to verify that the physical layer of the interface is functioning correctly (e.g. loop-back bit error rate test of ARINC 429 data words). This test shall be used to verify the interface under environmental conditions. The test data sent through the physical interface need not be ACARS messages.

2.4.3.6.3 IP Interfaces

The manufacturer shall define a test to verify that the physical layer of the IP interface is functioning correctly (e.g. loop-back bit error rate test). This test shall be used to verify the interface under environmental conditions.

2.4.3.7 Circuit Mode Service

Reference: Section 2.2.3.7.2.
In all tests in the following sub-sections the following applies:

- All levels, analogue and digital are RMS values.
- If the AES allows has a means to adjust the audio gain in the input and/or output voice circuits, the gain shall be set to the nominal gain.
- The AES' specified analogue levels at the voice input and output ports respectively, corresponding to 0 dBm0 in the digital domain shall be used as the analogue reference levels.
- The analogue voice input and output port shall be terminated into their specified termination impedances.

2.4.3.7.1 Audio Frequency Response

Reference: Section 2.2.3.7.2.1.
This test shall be performed at ambient conditions.

74. Set the audio input and output gain to the nominal level specified by the manufacturer.
75. Connect a resistive load at the nominal load impedance of the audio output of the voice circuit.
76. Enable the audio test mode as described in Section 2.2.3.7.2.
77. At the test point, insert a digital sine wave at a frequency of 300 Hz and at a level of 0 dBm0 into the audio output path.
78. Use an oscilloscope or suitable audio analyzer to measure the amplitude of the sine wave at the audio output.
79. Repeat steps 1 to 5 for at least each of the frequencies listed in Table 2-21.
80. Verify that the results comply with Table 2-21. Note that where a frequency is listed in the table twice, both constraints apply. The manufacturer's specified audio output level for a 0 dBm0 digital signal shall be used as the 0 dB reference point.
81. Repeat steps 1 to 7 for every voice output port.
82. Connect an audio signal generator to the audio input port of the AES, at the level which corresponds to -3 dBm0 in the digital domain, according the manufacturer's specifications.
83. With the signal generator set to each of the frequencies listed in Table 2-21, extract the audio samples from the voice port, and measure the signal amplitude in the digital domain.
84. Verify that the input voice circuit meets the requirements of Table 2-21. Note that where a frequency is listed in the table twice, both constraints apply.
85. Repeat steps 9 to 11 for every voice input port.
86.

2.4.3.7.2 Total Audio Noise Including Quantization Noise

Reference: Section 2.2.3.7.2.2.
This test shall be performed at ambient conditions, and environmental conditions as indicated in Table 2-23.

87. Insert a digital signal with a frequency of 1020 Hz into the voice output circuit at the digital test input port.
88. Measure the signal at the audio output of the AES using a suitable audio analyzer. A digital oscilloscope with suitable analysis software may be used as an alternative.
89. Determine the signal to noise ratio after psophometric weighting. (The method may differ according to the equipment available.)
90. Repeat steps 1 to 3 for each of the signal levels specified in Table 2-22, and verify that the requirements of Table 2-22 are met.
91. Repeat steps 1 to 4 for every voice output port of the AES.
92. Insert an analog signal with a frequency of 1020 Hz into the voice input port of the AES, with the level set to correspond to 0 dBm0 in the digital domain according the manufacturer's specification.
93. Extract the resulting digital signal at the test port.
94. Analyze the digital signal to determine the signal to noise ratio after psophometric filtering. (The method may vary according to the equipment available.)
95. Repeat steps 6 to 8 for every voice input port of the AES.

Note: As an alternative, the input and output voice circuits may be tested simultaneously by using a loop-back connection at either the analogue or the digital ports of the voice circuits. In this case the cascaded circuits shall together still meet the requirements of Table 2-22.

2.4.3.7.3 Spurious In-band Audio Signals

Reference: Section 2.2.3.7.2.3.
This test shall be performed at ambient conditions.

96. Terminate the voice input and output ports into their nominal impedance.
97. Measure the signal at the audio output of the AES using a suitable audio analyzer. A digital oscilloscope with suitable analysis software may be used as an alternative.
98. Determine the signal level after psophometric weighting. (The method may differ according to the equipment available.) Verify that the input voice circuit meets the requirements of Section 2.2.3.7.2.
99. Repeat steps 1 to 3 for every voice output port of the AES.
100. Extract the resulting digital signal resulting from the input voice circuit at the test port.
101. Analyze the digital signal to determine the signal level after psophometric filtering. (The method may vary according to the equipment

available.) Verify that the input voice circuit meets the requirements of Section 2.2.3.7.2.4.

102. Repeat steps 1 to 6 for every voice input port of the AES.

Note: As an alternative, the input and output voice circuits may be tested simultaneously by using a loop-back connection at either the analogue or the digital ports of the voice circuits. In this case the requirement may be relaxed by 3 dB.

2.4.3.7.4 Spurious and Image Audio Signals

Reference: Section 2.2.3.7.2.4.
This test shall be performed at ambient conditions.

103. Apply a sinusoidal digital signal to the digital input test port of the audio output circuit. The amplitude shall be 0 dBm0 and the initial frequency shall be 300 Hz.

104. Measure the analogue audio output signal using a spectrum analyzer with a resolution bandwidth of no more than 20 Hz.

105. Verify that, other than the wanted signal, no spectral products exist at a level higher than the level specified in Section 2.2.3.7.2.4 relative to the AES' specified analogue output level for a level of 0 dB0.

106. Repeat steps 1 to 3 for frequencies from 300 to 3400 Hz in steps of 100Hz.

107. Repeat steps 1 to 4 for all audio output ports.

108. Apply a sinusoidal analogue signal to the analogue voice input port of the AES. The level shall be the equipment's specified input level corresponding to a 0 dBm0 digital level. The initial frequency shall be 50 Hz.

109. Capture the digital output at the test port. Calculate the spectrum using an FFT (or equivalent technique) with a resolution bandwidth of no more than 20 Hz.

110. Verify that, other than the wanted signal, no spectral products exist at a level higher than that specified in Section 2.2.3.7.2.4.

111. Repeat steps 6 to 8 for the following frequencies:

- 50 Hz to 300Hz in steps of 50Hz
- 300 Hz to 20 000 Hz in steps of 100 Hz

112. Repeat steps 6 to 9 for all audio input ports.

2.4.3.7.5 Audio Amplitude Jitter

Reference: Section 2.2.3.7.2.5.This test shall be performed at ambient conditions.

113. Apply a digital sinusoidal signal with a frequency of approximately 1020 Hz to the digital test port of the voice output circuit. The initial level shall be 0 dBm0.

114. Measure the analogue output signal at the voice output port using a digital oscilloscope, which has been set up as follows:

- Set the trigger level to the average of the sine wave (typically zero volts).
- Set the horizontal scale to 0.1 ms per division.
- Set the vertical scale as required.
- Set the screen persistence to infinite.
- Clear the screen and wait ten seconds.
- Measure the peak-to-peak amplitude jitter at the peak of the sine wave on the oscilloscope. Verify that it is within the requirements of Section 2.2.3.7.2.5.

115. Repeat steps 1 to 2 with a level of -20 dBm0.

116. Repeat steps 1 to 3 for all audio output ports.

117. Create a digital loopback connection at the digital test point.

118. Connect a sinusoidal analogue signal to the voice input port. The initial level shall be the level corresponding to 0 dBm0 in the digital domain according to the AES' specifications. The frequency shall be 1020 Hz.

119. Repeat steps 5 to 6 for all voice input ports.

2.4.3.7.6 Audio Phase Jitter

Reference: Section 2.2.3.7.2.6.
This test shall be performed at ambient conditions.

120. Apply a digital sinusoidal signal with a frequency of approximately 1020 Hz to the digital test port of the voice output circuit. The initial level shall be 0 dBm0.

121. Measure the analogue output signal at the voice output port using a digital oscilloscope, which has been set up as follows:

- Set the trigger level to the average of the sine wave (typically zero volts).
- Set the horizontal scale to 0.1 ms per division
- Set a trigger delay of approximately 0.1 s.
- Set the screen persistence to infinite.
- Clear the screen and wait ten seconds.
- Measure the peak-to-peak phase jitter at the zero crossing of sine wave on the oscilloscope. Verify that it is within the requirements of Section 2.2.3.7.2.6.

122. Repeat steps 1 to 2 with a level of -20 dBm0.

123. Repeat steps 1 to 3 for all audio output ports.

124. Create a digital loopback connection at the digital test point.

125. Connect a sinusoidal analogue signal to the voice input port. The initial level shall be the level corresponding to 0 dBm0 in the digital domain according to the AES' specifications. The frequency shall be 1020 Hz.

126. Repeat steps 5 to 6 for all voice input ports.

2.4.3.7.7 Voice Latency

The manufacturer shall devise a test to determine the sum of the delays in the forward and return paths that voice samples incur in the AES during a voice call. The results may be obtained by a combination of measurement and analysis. Acceptable methods of verification include:

- Measuring processing delays and adding the delays in buffers and digital filters by analysis.
- Inserting a burst of a sine wave into the microphone circuit, looping the signal back in the digital domain at the physical layer, and measuring the delay at the headphone output.
- Inserting a burst of sine wave into the receiver using a BPLT (or similar equipment), looping the audio signal back from the headphone output to the microphone input, and measuring the delay at the BPLT (or similar suitable measurement point.

Delay errors caused by test setups and equipment may be compensated for by analysis, provided these delays are short (less than 15%) of the total delay.
The measurement shall be done separately for CS and VoIP calls.

2.4.3.7.8 Call Setup Time

The manufacturer shall devise a test to determine the sum of the delays in the AES during the call setup process. The results may be obtained by a combination of measurement and analysis. Acceptable methods of verification include:

- Demonstrating that the end-to-end requirements V30 and V40 in the MASPS are met when the AES operates over the live network.

Software tracing of time-stamped events related to the call setup process.Measurement results shall be based on the average of a minimum of 300 consecutive calls.
The test shall be done separately for CS calls and VoIP calls.
The test shall be done separately for mobile originated and mobile terminated calls.

2.4.3.8 Recovery from Primary Power Interruption Test Procedure

Subject the equipment to power interruptions, as described in DO-160G Section 16.5.1.4 or 16.6.1.3, as applicable for AC or DC powered equipment respectively. If equipment is intended for installation with either AC or DC supply, both cases shall be tested independently.
When conducting the test cases in DO-160G Table 16-1 (AC) or Table 16-3 (DC), the following power interruption cases shall be added, irrespective of the declared equipment category:

Test Condition	M1	M2	M3
T_f	20	50	5
T_i	400	800	1200
T_r	5	20	5
% V_{nom}	0	0	0

While subjecting the equipment to the power interruptions test cases, the following measurements shall be carried out on the equipment:

- Connect the AES to a BPLT and BNE and set it up to transfer data over a narrow beam bearer appropriate to its class of operation. A similar setup using the satellite network is also acceptable.
- Set up a computer connected to an IP port of the AES to exchange data over a background PDP context with another computer connected to the BNE (or a similar setup through the Inmarsat network).
- Use suitable software (e.g. IPERF) on the computers to send UDP packets from one computer to another while monitoring the successful packet transfers on each side of the link. Set the UDP packet sizes to represent no more than 1 ms of data on the radio bearer. Set the packet rate to at least one packet every 10 ms.
- Analyze the lost packets on the receiving end while applying the power interruption test cases up to 200ms duration, to determine that the amount of data lost meets the requirements.
- Repeat with the data sent in the opposite direction. If the setup allows, the test may also be performed in both directions simultaneously.
- Set up a phone call from the cockpit voice interface to a PSTN number and send an audio sine wave of between 0.9 and 2.5 kHz form one side of the call to the other.
- Monitor the output audio at the receiving end using an oscilloscope, while applying the power interruption test cases up to 200 ms. Use the oscilloscope data to verify that the interruption in the audio signal meets the requirements.
- Repeat with the audio sent in the opposite direction.

2.4.3.9 Failure/Status Indication Test Procedure

Reference: Section 2.2.3.9
The manufacturer shall specify a test to demonstrate that the fault reporting mechanisms implemented in the equipment perform as required.

2.4.3.10 Information Security Test Procedure

A plan for Security Verification in accordance with DO-262 [10] Section 3.3.4 shall be developed and executed to verify that the security countermeasures designed in as a result of the Security Risk Assessment are effective.
Verification shall include:

- Intended function tests for countermeasures
- Robustness tests
- Vulnerability tests

3 INSTALLED EQUIPMENT PERFORMANCE

This section is intended to be used when a new installation configuration is being planned, installed and verified, such as for a new type certification (TC) or supplementary type certification (STC).

3.1 Equipment Installation

3.1.1 Accessibility

Controls and monitors provided for in-flight operation shall be readily accessible from the appropriate operator's normal seated position. The operator/crew member(s) shall have an unobstructed view of the display(s) and controls when in the normal seated position.

3.1.2 Aircraft Environment

Equipment shall be compatible with the environmental conditions present in the specific location in the aircraft where the equipment is installed.

3.1.3 Display Visibility

All installed system displays shall be readily visible and readable from the operator's/-crew member's normal position in all ambient lighting conditions for which system use is required.
Note: Visors, glareshields, or filters may be an acceptable means of obtaining daylight visibility.

3.1.4 Inadvertent Turn-Off

Where controls for transceiver operation are provided, they shall be equipped with adequate protection against inadvertent turn off.

3.1.5 Failure Protection

Any probable failure of the equipment shall not degrade the normal operation of equipment or systems that are connected to it. Likewise, the failure of interfaced equipment or systems shall not induce failures of this equipment.

3.1.6 Interface Interference Effects

The equipment shall not be the source of harmful conducted or radiated interference, and shall not be affected by conducted or radiated interference from other equipment or systems installed in the aircraft.

3.1.7 Aircraft Power Source

The voltage and frequency tolerance characteristics of the equipment shall be compatible with the aircraft power source of appropriate category as specified in RTCA DO-160G [3].

3.1.8 Antenna Location/Installation

Isolation between the satcom antenna and any GNSS antennas shall be planned to be consistent with the isolation declared in Section 2.2.3.1.2.6.1. Isolation measurements may be required in marginal cases.
Isolation between the satcom antenna and antennas for other systems, such as radar transponders and ACAS/TCAS systems shall be considered carefully. Some measurements, analysis and additional information from manufacturers may be required to establish compatibility.
In installations where a second satcom system is installed on the same aircraft, potential radio interference between the systems shall be considered. In particular, interference-free operation of the satcom system used for priority services shall be ensured by the installation configuration.
Antenna placement shall take into account that part of the airframe, such as the wings or empennage, will obstruct the radio signals between the AES antenna and the satellite at some combinations of aircraft attitude and satellite position. While such obstruction is often not totally avoidable, the choice of antenna position should aim to minimize it, particularly for level flight.

3.1.9 RF Cable Requirements

Cable losses and intermodulation products require careful attention to ensure correct operation of the system. In a case where a TSO approval was issued for the complete system, the cables shall comply to the manufacturer's specifications.
Where the system consists of individual LRUs for which individual approvals were obtained, installed cable losses shall comply with Table 2-2.
For multicarrier systems, the cable between the DLNA and the antenna shall meet the requirements in Section 2.2.1.4.

3.1.10 Co-location with Other Inmarsat Satcom Systems

When co-locating more than one Inmarsat satcom system on one aircraft the following issues shall be considered

- Antennas should be spaced far enough apart so as to avoid distortion of the antenna beams due to mutual coupling between the antennas. Advice should be sought from the antenna manufacturers if the planned separation is less than approximately 18 inches.
- Potential intermodulation due to a signal from one system coupling in to the HPA of the other system should also be considered. An HPA designed for multi-channel operation normally represents a low risk in this regard, as it is designed to maintain intermodulation products within limits while transmitting multiple carriers. Adding an additional carrier at a substantially lower power level (due to the isolation between the antennas) should therefore be acceptable. The behavior

of single channel HPAs can vary greatly, and should therefore be measured, either in laboratory conditions or on the aircraft.

- Intermodulation products from a multi-channel system coupling into the receive path of a second system is normally not a concern, as intermodulation products have to be suppressed enough that the first system's own receiver is not affected.

3.1.11 Co-location of Dissimilar Satcom Systems

Installation of dissimilar satcom systems (e.g. a SwiftBroadband and an Iridium system) on the same aircraft may present specific problems. Particular attention should be paid to intermodulation products generated by multichannel systems. Refer to Section 3.2.1.

3.1.12 System Component Interoperability

Where components of the AES have been approved individually, installations shall only be made with valid combinations of equipment. Refer to Table 2-1.

As this appendix does not specify interface details, interoperability of AES components from different manufacturers is not ensured by conformance of components to this appendix alone. Verifying interoperability of new combinations of AES components is therefore strongly recommended before commencing a new installation configuration. Manufacturers should also be consulted.

3.1.13 Configuration of Priority for Data Services

The use of priority data services (ACARS and IP) shall be planned and configured for each new installation configuration.

To enable access to the ACARS and Priority IP APNs, it is required that the USIM of the priority service channel of the AES be activated with the service provider for Aeronautical Priority Services.

As part of the installation process the AES shall be configured to use the correct APN when setting up a PDP context for ACARS service. A ground test that confirms that ACARS messages can be sent and received by a specific aircraft is sufficient to ensure that ACARS messages also gets the right priority on the network. (ACARS messages cannot flow if the AES is accidentally configured for the wrong APN).

For IP services, care must be taken that the AES is configured to use the correct APN (priority or non-priority, as provided by the service provider) for each context. Unlike ACARS, it is possible to successfully test for interchange of IP data, while the AES might be configured the incorrect APN. In such a case the wrong priority level would be applied.

It is possible for an AES to simultaneously provide Priority and Non-priority IP services for different purposes through separate PDP contexts connected to separate APNs. The AES would typically distinguish between priority and non-priority IP data on the basis of the physical port through which the data flows, but details may differ depending on the AES design.

Example: The AES may be configured to handle all IP data to and from an EFB as either priority or non-priority data, depending whether the applications on the EFB are essential for the safety of the flight. The choice between priority or non-priority should be in line with the standard operating procedures of the aircraft operator.

Applications which do not contribute directly to flight safety should not be allowed to use Priority IP.

3.1.14 Configuration of Priority for Voice Calls

The priority of all voice services shall be planned and configured for each new installation. Priority calls shall only be allowed from appropriate ports.

3.2 Installed Equipment Performance Requirements

The installed equipment shall meet the requirements of Section 2.0 in addition to the requirements stated below. To meet the requirements of this section, test results supplied by the equipment manufacturer may be accepted in lieu of tests performed by the equipment installer.

However, performance characteristics that cannot be tested by the equipment manufacturer shall be tested by the installer. These include: (1) performance characteristics of equipment required for the transceiver installation that have not been tested or verified by the manufacturer, and (2) interactions with other equipment installed on the aircraft.

3.2.1 Radiated Antenna Intermodulation Products in AMS(R)S Bands

3.2.1.1 Self-interference by a Multi-channel SBB AES

While the AES components have individual requirements for intermodulation products, a new multi-channel installation can introduce new sources of intermodulation. The chief concern is intermodulation products appearing in the AES receive band, which may drastically reduce receiver sensitivity at specific receive frequencies. The affected receive frequencies are very dependent on the transmit frequencies allocated by the network. Intermodulation may be caused by poor antenna cables and metal structures near the antenna with intermittent contact.

Performing a multi-channel communication test over the satellite network (even if multi-channel) is a poor mitigation for this risk, as the combinations of transmit and receive frequencies may not reveal even major problems. An on-aircraft intermodulation test should be performed after every single aircraft installation. A “PIMBIT” function is included in a multi-channel SBB AES for this purpose. Following the manufacturer’s instructions is recommended.

3.2.1.2 Dissimilar AES Installations on the Same Aircraft

When installing more than one AES on the same aircraft, where AESs use different satellite networks, the following general requirement applies.

When transmitting two modulated carriers anywhere within the frequency band with each carrier f_{TMN} to f_{TMX} , each carrier having the maximum allowable single carrier power permitted by Section 2.2.3.1.3.1.2, and its subsections, of this appendix, the antenna subsystem shall not radiate internally generated intermodulation products in a direction toward a likely location(s) of antenna(s) on the same aircraft serving other AMS(R)S systems so as to cause an average power level that increases the effective noise

temperature of the other AMS(R)S system by more than 6%. In the absence of details of the second system, the other antenna may be assumed to be a quarter-wave monopole antenna matched to its load, and the isolation between the AES antenna and the second antenna is taken to be 40 dB, or different value as applicable to the specific installation.
When assessing the increase in noise temperature at the affected AES, two effects shall be taken into account separately:

- Intermodulation products when multiple carriers are transmitted
- Transmitter noise floor when one or more carriers are transmitted. (This may be particularly problematic when the SBB transmitter is transmitting near the lower edge of the transmit frequency band while an Iridium receiver is tuned to the upper end of its receive band.)
- This requirement shall be verified by analysis using

    - calculated or measured antenna isolation data for the specific installation configuration,
    - intermodulation performance of the transmitting AES, from the results previously measured for the transmitter,
    - calculated spreading factor, taking into account the worst case combination of transmitted waveform and receiver bandwidth and
    - previously measured transmitter noise floor, combined with the worst case of transmitting and receiving frequencies.

- This requirement shall specifically be verified by analysis, as it is possible that the potential problems will not be detected during an on-air test, when the combinations of frequencies cannot be easily controlled.

Note: Simultaneous operation of a SwiftBroadband AES and an Iridium AES on the same aircraft is a known to be problematic. Refer to Section 1.3.10.1. This phenomenon affects the Iridium AES receiver on the aircraft, operating in the band 1616 to 1626.5 MHz. This is independent of the Aireon service (hosted on Iridium satellites) which uses a different frequency band.

3.2.2 Declaration of Non-standard Antenna Isolation

If the AES design is based on a declaration of antenna isolation greater than 40 dB, as allowed by Section 2.2.3.1.3.1.3 or Section 3.2.1.2, then all installations shall provide at least the declared minimum isolation. This applies to isolation between the AES antenna and GNSS antennas, as well as between the AES antenna and the antenna of a second dissimilar satcom system.
The antenna isolation should be verified by measurement, either on the aircraft or on a suitable simulated installation.
For GNSS antennas the measurement shall be done in the GNSS frequency band.
For a second dissimilar AES, the measurement shall be made in the frequency band of the receiver which is likely to be interfered with (possibly therefore the frequency bands of the receivers of both AESs).

3.3 Conditions of Test

The following Sections define conditions under which the tests specified in Section 3.4 shall be conducted.

3.3.1 Power Input

Tests may be conducted either with the equipment powered by the aircraft's electrical power generation system or by an appropriate external power source connected to the aircraft.

3.3.2 Environment

During the tests, the equipment shall not be subjected to environmental conditions that exceed those in RTCA/DO-160G as specified by the equipment manufacturer.

3.3.3 Adjustment of Equipment

Circuits of the equipment under test shall be properly aligned and otherwise adjusted in accordance with the manufacturer's recommended practices prior to application of the specified tests.

3.3.4 Warm-up Period

Unless otherwise specified, tests shall be conducted after a warm-up (stabilization) period of twenty (20) minutes.

3.4 Test Procedures for Installed Equipment Performance

The following test procedures provide one means of determining installed equipment performance. Although specific test procedures are cited, it is recognized that the installing activity may prefer alternate procedures, which may be used if they provide at least equivalent information. In such cases, the procedures cited herein should be used as one criterion in evaluating the acceptability of the alternate procedures.

3.4.1 Conformity Inspection

Visually inspect the installed equipment to determine the use of acceptable workmanship and engineering practices. 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.

3.4.2 Interference Tests

3.4.2.1 Interference with General Aircraft Systems

This test is required to verify that the AES does not interfere with general aircraft systems, and that these systems do not interfere with the AES.

127. List all electrically-operated aircraft equipment which is considered potentially vulnerable to radio transmissions, as well as aircraft equipment that may potentially interfere with the AES.
128. Unless otherwise specified, all aircraft electrically-operated equipment and systems shall be switched on, using the aircraft's electrical power generating equipment, before conducting interference tests.

129. With the AES transceiver operating, including transmission of messages and voice calls and using all available channels, individually operate each of the other potentially vulnerable electrically-operated aircraft equipment and systems to determine that no significant conducted or radiated interference are caused to such equipment. Evaluate all reasonable combinations of control settings and operating modes. Operate communication and navigation equipment on at a minimum the low, high, and a mid-band, frequencies.

130. With all equipment which may potentially interfere with the AES powered off (where possible), operate the AES and establish a voice call to a nearby ground phone (such as a mobile). Monitor the voice quality of the call, both at the aircraft and at the ground phone. Power on all the equipment which may potentially interfere with the AES, and repeat the check on the voice quality, both on the aircraft and at the ground phone, and note any signs of impaired reception.

131. Operate the aircraft control surfaces (e.g. flaps, ailerons) through their range to activate all associated aircraft systems which may cause electrical power fluctuations (e.g. pumps or linear actuators).

The AES shall not be the source of unintentional harmful conducted or radiated interference, and shall not be affected by conducted or radiated interference from other equipment or systems installed in the aircraft.

3.4.2.2 Interference to GNSS

Adequate protection of on-board GNSS equipment from harmful interference shall be verified using this procedure.

132. Verify that the expected antenna isolation (between the AES and any GNSS antenna) is more than the required isolation declared in terms of Section 2.2.3.1.2.1.2,

133. If a margin of less than 10 dB is expected between the actual antenna isolation (between the AES and any GNSS antenna) and the required isolation declared in terms of Section 2.2.3.1.2.1.2, the installed isolation shall be measured for each new installation configuration.

134. Operate the AES while transmitting on all available channels. Verify that the operation of the GNSS equipment is not degraded by comparing the following parameters reported by the GNSS equipment, with transmission on and transmission off respectively:

- GNSS position
- Number satellites accessed
- C/No of received satellites

Notes:

1. In a typical installation, this should be achieved if:

- *the transceiver meets all requirements of Sections 2.2.3.1.2.1.2, 2.2.3.1.2.1.4, and 2.2.3.1.2.1.5;*
- *the isolation between AES and GNSS antennas is not less than the distance declared by the manufacturer in terms of Section 2.2.3.1.3.1.3.*

2. Interference problems noted upon installation of this 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. Compatibility between this equipment and previously installed equipment in the aircraft shall be ensured during the design of the specific installation configuration.

3.4.2.3 Interference between Dissimilar Satcom Systems

If the AES is installed on an airframe as part of a "dual-dissimilar" satellite communications suite, the test procedures in the following sub-sections shall be performed. In the following sections, "SATCOM A" refers to the SwiftBroadband AES covered by this MOPS, while "SATCOM B" refers to the other satellite communications system. It is possible that another technique-specific appendix of this appendix may apply to the SATCOM B system.
Although these on-aircraft tests are required, passing them shall not be acceptable motivation to waive the intermodulation requirements of Section 3.2.1.2, as the on-aircraft tests are unlikely to be done with the worst-case frequency combinations.

3.4.2.3.1 SATCOM B Interference to SATCOM A

Perform the following steps:

1. With SATCOM B inactive, establish a background class data connection and perform a TCP transfer on the SBB AES (SATCOM A), if appropriate (e.g. using a tool like IPERF). Verify that this session is maintained when SATCOM B is switched on and commanded to initiate a packet mode communications session, if appropriate. Verify that the SATCOM A communications session is maintained when the SATCOM B transfers a package message of 4000 octets containing random binary data. Terminate the SATCOM B packet mode communications session and verify that the SATCOM A communications session is maintained.
2. Repeat the process of Step 1 with SATCOM B circuit mode data communications, if appropriate.
3. Repeat the process of Step 1 with SATCOM B voice communications, if appropriate.
4. Repeat the process of Steps 1, 2, and 3, with SATCOM A maintaining two voice calls, instead of the data connection.
5. With SATCOM A inactive, initiate a SATCOM B packet mode communications session. Transmit a series of test messages of 4000 octets each. While the transmission is in progress, activate SATCOM A. Verify that SATCOM A can acquire the network. Verify that the SBB AES (SATCOM A) can initiate and sustain two voice calls for a period of 60 seconds during SATCOM B packet mode operations. Verify that the AES can properly terminate its voice call.
6. Repeat Step 5, but with SATCOM A transferring TCP data over a background class data connection instead of the two phone calls.

3.4.2.3.2 SATCOM A Interference to SATCOM B

Perform the following steps:

1. With SATCOM A inactive, establish a circuit-mode data communications session on SATCOM B, if appropriate. Verify that this session is maintained when SATCOM A is switched on and commanded to initiate TCP transfer over a background class data connection. Verify that the SATCOM B communications session is maintained when the SATCOM A transfers a package message of 4000 octets containing random binary data. Terminate the SATCOM A communications session and verify that the SATCOM B communications session is maintained.
2. Repeat Step 1 with SATCOM B maintaining packet-mode data communications session, if appropriate.
3. Repeat Step 1 with SATCOM B maintaining a circuit mode voice call, instead of the data connection.
4. With SATCOM B inactive, initiate a TCP transfer over a background data connection over SATCOM A. Transmit a series of test messages of 4000 octets each. While the transmission is in progress, activate SATCOM B. Verify that SATCOM B can acquire the network. Verify that the SATCOM B can initiate and sustain a voice call for a period of 60 seconds during SATCOM A data transfers. Verify that the SATCM B can properly terminate its voice call.
5. Repeat Step 4, but with SATCOM B operating in circuit data mode, if applicable. Verify that SATCOM B can initiate and complete a transaction by transmitting a 4000 octet message. Verify that the SATCOM B can properly terminate its circuit mode call.
6. Repeat Step 4, but with SATCOM B operating in packet data mode, if applicable. Verify that SATCOM B can initiate and complete a transaction by transmitting a 4000 octet message. Verify that the SATCOM B can properly terminate its packet data mode call.

3.4.3 Power Fluctuation Tests

Transceiver aircraft power sources shall be cycled through all normal configurations to verify that the transceiver performance for power interruption recovery during and after power changeover is satisfactory with no discernible abnormal operation.
In-transit data service packets which have been acknowledged on either the DTE or DCE interface, but not yet transferred to the opposite interface, may be lost. Non-transceiver higher layer entities which employ end-to-end acknowledgment protocols may choose to retransmit such lost data.

3.4.4 Ground Test Procedures

Perform the following minimum ground tests:

- With the aircraft parked within line-of-sight of the satellite, power on the AES. Verify that the AES logs onto the satellite. The aircraft's inertial reference system may need to be active.
- Verify that the AES logs onto the AGGW, indicated by "ACARS link available" indication.
- Send test ACARS messages in both directions. If the aircraft is FANS equipped, send FANS messages.
- If the AES can be controlled from multiple stations (e.g. multiple MCDUs) then verify operation of each of these.
- Make voice calls to and from the aircraft. Repeat from left seat and right seat.
- If the AES is capable of multiple channels, verify the passive intermodulation (PIM) performance of the installation. The AES' PIMBIT test should be used for this purpose.

- Verify IP connection operational (e.g. EFB connection and data transfer)

If the manufacturer’s manual prescribes any further ground tests, perform these as well.

3.4.5 Flight Test Procedures

Flight tests of installed systems are desirable to confirm or supplement bench and ground tests of installed performance.
The following points are recommended if a flight test is undertaken:

- Verify ACARS messaging in-flight.
- Verify phone calls in flight.
- Verify spot beam handover.
- Verify satellite handover.
- Verify coverage performance, particularly at low elevation.
- Verify GPS non-interference in flight.
- If automatic or manual fallback to Classic Aero services is offered by the AES, verify that performs as required.

Further in-flight tests may be defined in the manufacturer's installation instructions.

3.4.6 Installed System Performance Verification

3.4.6.1 Installed Functionality

Performance of the installed avionics, consisting of the Antenna Subsystem and the Transceiver Subsystem, should be verified in accordance with the manufacturer's instructions. The following general functional categories shall be validated:
Network Management Tests – Verify the ability of the AES to acquire and register with the BGAN network from a cold start. Verify the following items:

- The AES starts up, registers on the network and on the AGGW. Evidenced by “ACARS link available indication.
- ACARS messages can be sent and received
- FANS messages can be sent and received

IP Data Transfer Tests – Ensure that the AES can send and receive data and sustain communications using a background context. Transfer data of at least 100 KB each way.
Voice Services – Verify that the mechanisms for

- selecting, dialing, and releasing a circuit from aircraft side.
- accepting, and rejecting an incoming call through operator action.
- second voice channel operation.
- priority and preemption.

Subnetwork Physical Layer – Most of physical layer operation is verified by previous tests. Additionally the maximum capability of N_D simultaneous communications channels as declared by the manufacturer shall be verified.

3.4.6.2 Installed Antenna Coverage

The antenna tests of Section 2.4.3.1.1 and its subsections provide sufficient verification of coverage for top-mounted antenna installation using steered antennas and non-steered antennas with essentially hemispherical patterns. These installations are expected to be the common installation for most platforms.

3.4.6.3 Installed Audio System Functionality

Voice quality of phone calls shall be assessed under operational noise conditions applicable to the specific aircraft. Depending on the aircraft this may require an engine run-up on the ground, or in-flight testing. Attention should be paid to:

- Excessive background noise on the outgoing audio signal due to acoustic background noise. The successful integration of noise cancelling microphones and other audio cancellation techniques with the AES may be required to avoid this.
- Spurious audio interfering signals from electrical sources, such as hum or whine. Sources may be due to induced interference in wiring or inadequately cancelled ground voltage differences.
- Outgoing speech breaking up due the voice codec being unable to cope with environmental noise in the cockpit.
- Incoming audio levels being dissimilar from other radio sources, particularly when routed to a headset through an audio panel or audio management system.
- Outgoing audio level being unacceptably dissimilar from normal telephone voice.

Perform the following tests:

- Make air-to-ground calls.
- Make ground-to-air calls.
- Clear (end) calls from the ground side.
- Clear calls form the aircraft side.
- While a call is in progress, make a second call from the aircraft.
- While a call is in progress, make a second call from the ground.
- While two priority 3 calls are in progress, make a priority 2 call from the aircraft. Verify that one call is pre-empted (dropped) in favor of the new call.
- While two priority 2 calls are in progress, make a priority 1 call from the aircraft. Verify that one call is pre-empted (dropped) in favor of the new call.
- Repeat, with the last call made from the ground.

4 EQUIPMENT OPERATIONAL PERFORMANCE CHARACTERISTICS

This section is intended to verify correct operation of the AES on any aircraft. It provides guidance for ground testing after each installation on an individual aircraft, for pre-flight testing or for return-to-service testing after maintenance work.
AMS(R)S AES installations are expected to be accomplished in a variety of ways to fit the aircraft equipment and intended usage. This will also be the case with associated cockpit interfaces. The requirements of this section shall be suitably interpreted for the particular installation under consideration.

4.1 Operational Performance Requirements

The following sections identify requirements to ensure the operator that operations can be conducted safely and reliably in the expected operational environment.

4.1.1 Power Input

Prior to flight, the primary power shall be available for proper operation. Communications Displays
The required display(s) for the selection of various communication modes/functions of operation shall be accessible and available for use, both prior to and during flight.
Note: This may be accomplished with additional equipment connected to the AES, such as MCDUs.

4.1.2 Communications Controls

Cockpit control(s) required for proper operation of the equipment shall be available for use, prior to and during flight. These shall at least provide control for the following functions:

- Placing voice calls.
- Receiving incoming voice calls.
- Reading incoming ACARS messages.
- Compiling and transmitting ACARS messages.

4.1.3 System Operational Indication

Communication failure of degradation below minimum acceptable performance shall be readily discernible. These shall at least include indications for:

- ACARS service available (e.g. AAGW registered with AGGW, keep-alive messages are current)
- Voice service available (e.g. CS attached)

The following additional indications are recommended

- 2nd Voice channel available (e.g. registered on VoIP server)
- IP Data service available (e.g. PS attached and PDP context established for IP data)
- Satellite identity (or searching).

4.1.4 Equipment Operating Limitations

Equipment operating limitations of the AES shall be contained in the aircraft flight manual.

4.2 Test Procedures for Operational Performance Requirements

Operational equipment tests may be used after installation or return to service after maintenance.
A subset of operational equipment tests may be conducted as part of normal preflight tests. For those tests which can only be run in flight, procedures should be developed to perform these tests as early in the flight as possible to verify that the equipment is performing its intended function(s).

4.2.1 Power Input

With the aircraft's electrical power generating system operating, energize the equipment and verify that electrical power is available to the equipment.

4.2.2 Communications Displays

With the equipment operating, verify that the required display(s) are operational.
Example: Satcom status displayed on the MCDU.

4.2.3 Communications Controls

The communications control(s) shall be operated, as required, to verify satisfactory equipment response.
Example: Exercise MCDU menu tree.

4.2.4 System Operational Indication

System operational readiness shall be monitored either by means of Built-In-Test-Equipment (BITE) and/or by suitable preflight tests contained in a check list or flight manual. All equipment failure annunciators shall be tested during preflight tests to verify proper operation.
Examples:

- Built-in test
    - CMU indicates satcom link available
    - Satcom status indicates logged onto satellite
    - Satcom status indicates voice and ACARS available

- Pre-flight test
    - Make a test phone call
    - Send a test ACARS AOC message.

5 REQUIREMENTS CROSS-REFERENCE

This section indicates which requirements sections apply to each equipment class and sub-class.

Table 5-1 Requirements Cross-reference

Paragraph	Title	AES4	AES6	AES7	HGA	IGA	6MA	7MA	6F	7F	6D	7D	DMA	DF
2	Equipment performance requirements and test procedures													
2.1	General Requirements	X	X	X										
2.1.1	Airworthiness	X	X	X										
2.1.2	Intended Function	X	X	X										
2.1.3	Federal Communications Commission’s Rules	X	X	X										
2.1.4	Fire Protection	X	X	X										
2.1.5	Operation of Controls	X	X	X										
2.1.6	Accessibility of Controls	X	X	X										
2.1.7	Effects of Tests	X	X	X										
2.1.8	Performance in a Shared Environment	X	X	X										
2.1.9	AES Availability	X	X	X										
2.2	Equipment Performance Requirements – Standard Conditions													
2.2.1	SwiftBroadband AES classes, subsystem definitions and overall requirements	X	X	X										
2.2.1.1	Definition of SwiftBroadband AES classes	X	X	X										
2.2.1.2	Valid combinations of system components	X	X	X										
2.2.1.3	Services provided by an AMS(R)S AES	X	X	X										

Paragraph	Title	AES4	AES6	AES7	HGA	IGA	6MA	7MA	6F	7F	6D	7D	DMA	DF
2.2.1.4	RF Interconnecting Cables	X	X	X										
2.2.2	Definition of System-specific Parameters	X	X	X										
2.2.3	Detailed Requirements													
2.2.3.1	AES Application Requirements													
2.2.3.1.1	Inmarsat and Service Provider Type Approval	X	X	X										
2.2.3.1.1.1	Complete AES Systems	X	X	X										
2.2.3.1.1.2	Separately Approved Antenna Subsystems				X	X								
2.2.3.1.1.3	Separately Approved Transceiver Systems						X	X	X	X	X	X		
2.2.3.1.2	Antenna	X	X	X	X	X								
2.2.3.1.2.1	Coverage Volume, Polarization and Antenna	X	X	X	X	X								
2.2.3.1.2.1.1	Coverage Volume													
2.2.3.1.2.1.1.1	HGA Coverage Volume		X		X									
2.2.3.1.2.1.1.2	IGA Coverage Volume			X		X								
2.2.3.1.2.1.1.3	AES4 Coverage Volume	X												
2.2.3.1.2.1.2	Polarization	X	X	X	X	X								
2.2.3.1.2.1.3	Antenna Gain	X	X	X	X	X								
2.2.3.1.2.2	Axial Ratio	X	X	X	X	X								
2.2.3.1.2.3	Power handling capabilities													
2.2.3.1.2.3.1	Single Carrier Antennas	X												
2.2.3.1.2.3.2	Multi-carrier Antennas		X	X	X	X								
2.2.3.1.2.4	Passband	X	X	X	X	X								
2.2.3.1.2.5	Antenna Voltage Standing Wave Ratio		X	X	X	X								
2.2.3.1.2.6	Antenna Intermodulation Products													

Paragraph	Title	AES4	AES6	AES7	HGA	IGA	6MA	7MA	6F	7F	6D	7D	DMA	DF
2.2.3.1.2.6.1	Radiated Antenna Intermodulation Products in the GNSS Band		X	X	X	X								
2.2.3.1.2.6.2	Antenna Intermodulation Products in the AMS(R)S Bands		X	X	X	X								
2.2.3.1.2.7	Carrier-to-Multipath Discrimination	X	X	X	X	X								
2.2.3.1.2.8	Pattern Discrimination													
2.2.3.1.2.9	Steered Antenna Requirements													
2.2.3.1.2.9.1	Phase Discontinuity		X	X	X	X								
2.2.3.1.2.9.2	Beam Switching Time		X	X	X	X								
2.2.3.1.2.9.3	Steering Rate		X	X	X	X								
2.2.3.1.2.9.4	Pattern Discrimination		X	X	X	X								
2.2.3.1.2.10	Manufacturer-defined Antenna Tests	X	X	X	X	X								
2.2.3.1.3	Transceiver Subsystem													
2.2.3.1.3.1	Transmitter Function	X	X	X										
2.2.3.1.3.1.1	Minimum Power Output	X	X	X										
2.2.3.1.3.1.1.1	AES4	X												
2.2.3.1.3.1.1.2	Categories 6D and 7D		X	X							X	X		
2.2.3.1.3.1.1.3	Categories 7MA, 7F, 6MA, 6F			X			X	X	X	X				
2.2.3.1.3.1.2	Maximum Individual Carrier Output													
2.2.3.1.3.1.2.1	AES4	X												
2.2.3.1.3.1.2.2	Categories 6D and 7D		X	X							X	X		
2.2.3.1.3.1.2.3	Categories 7MA, 7F, 6MA, 6F		X	X			X	X	X	X				
2.2.3.1.3.1.3	Maximum Total Transmitter Output Power	X	X	X										
2.2.3.1.3.1.4	Transmitter Intermodulation Performance.		X	X			X	X	X	X	X	X		

Paragraph	Title	AES4	AES6	AES7	HGA	IGA	6MA	7MA	6F	7F	6D	7D	DMA	DF
2.2.3.1.3.1.5	Transmitter Harmonics, Discrete Spurious and Noise Density	X	X	X			X	X	X	X	X	X		
2.2.3.1.3.1.6	Protection of Radio Astronomy	X	X	X			X	X	X	X	X	X		
2.2.3.1.3.1.7	Carrier-Off Level	X	X	X			X	X	X	X	X	X		
2.2.3.1.3.1.8	Power Control	X	X	X			X	X	X	X	X	X		
2.2.3.1.3.1.9	On-Channel Output Spectrum													
2.2.3.1.3.1.9.1	AES4.	X												
2.2.3.1.3.1.9.2	AES6 / AES7.		X	X			X	X	X	X	X	X		
2.2.3.1.3.1.10	Transmitter Operation in Moving Aircraft	X	X	X			X	X	X	X	X	X		
2.2.3.1.3.1.11	Transmitter Phase Noise	X	X	X			X	X	X	X	X	X		
2.2.3.1.3.1.12	Frequency Accuracy	X	X	X			X	X	X	X	X	X		
2.2.3.1.3.1.13	Transmitter Tuning	X	X	X			X	X	X	X	X	X		
2.2.3.1.3.1.14	Manufacturer-defined Transmitter Test	X	X	X			X	X	X	X	X	X		
2.2.3.1.3.2	Receiver Function													
2.2.3.1.3.2.1	Receiver Sensitivity	X	X	X			X	X	X	X	X	X		
2.2.3.1.3.2.1.1	Data	X	X	X			X	X	X	X	X	X		
2.2.3.1.3.2.1.2	Voice	X	X	X			X	X	X	X	X	X		
2.2.3.1.3.2.2	Receiver Bandwidth	X	X	X			X	X	X	X	X	X		
2.2.3.1.3.2.3	Rejection of Signals outside the NGSS Receive Band	4	6/7	6/7			6/7	6/7	6/7	6/7	6/7	6/7		
2.2.3.1.3.2.4	Rejection of Carrier Signals Generated by Other AMS(R)S Equipment													
2.2.3.1.3.2.5	Receiver Operation in Moving Aircraft	X	X	X			X	X	X	X	X	X		
2.2.3.1.3.2.6	Receiver Susceptibility	X	X	X			X	X	X	X	X	X		
2.2.3.1.3.2.7	Acquisition	X	X	X			X	X	X	X	X	X		
2.2.3.1.3.2.8	Carrier-to-Noise Level Accuracy	X	X	X			X	X	X	X	X	X		

Paragraph	Title	AES4	AES6	AES7	HGA	IGA	6MA	7MA	6F	7F	6D	7D	DMA	DF
2.2.3.1.4	DLNA (Diplexer / Low Noise Amplifier)						MA	MA	F	F			X	X
2.2.3.1.4.1	DLNA VSWR												X	X
2.2.3.1.4.2	DLNA Noise Figure												X	X
2.2.3.1.4.3	DLNA Gain / Filter Response												X	X
2.2.3.1.4.3.1	DLNA Gain												X	X
2.2.3.1.4.3.2	Filter Response for 'DMA' DLNA												X	
2.2.3.1.4.3.3	Filter Response for 'DF' DLNA													X
2.2.3.1.4.4	DLNA Passive intermodulation												X	X
2.2.3.1.4.4.1	DLNA Intermodulation Products in Satcom Receive Band												X	X
2.2.3.1.4.4.2	Type F - DLNA Intermodulation Products in GNSS Band													X
2.2.3.1.4.5	DLNA maximum transmit power												X	X
2.2.3.1.4.6	DLNA Receive Port Output power												X	X
2.2.3.1.4.7	Manufacturer Defined DLNA Test													
2.2.3.1.5	Required Aircraft Interfaces	X	X	X			X	X	X	X	X	X		
2.2.3.2	User Link Modulation and Signal in Space (Physical Layer)	X	X	X			X	X	X	X	X	X		
2.2.3.3	Priority, Precedence and Preemption	X	X	X			X	X	X	X	X	X		
2.2.3.3.1	Packet Data	X	X	X			X	X	X	X	X	X		
2.2.3.3.2	Circuit Mode Communications (Voice)	X	X	X			X	X	X	X	X	X		
2.2.3.3.3	ACARS Communications	X	X	X			X	X	X	X	X	X		
2.2.3.4	Satellite Subnetwork Data Protocol	X	X	X			X	X	X	X	X	X		
2.2.3.4.1	ATN-compliant Protocol Requirements													
2.2.3.4.2	ACARS Protocol Requirements	X	X	X			X	X	X	X	X	X		

Paragraph	Title	AES4	AES6	AES7	HGA	IGA	6MA	7MA	6F	7F	6D	7D	DMA	DF
2.2.3.5	Voice Protocol	X	X	X			X	X	X	X	X	X		
2.2.3.5.1	Vocoder Interoperability with Satellite Subnetwork	X	X	X			X	X	X	X	X	X		
2.2.3.5.2	Vocoder Performance in an Aeronautical Environment	X	X	X			X	X	X	X	X	X		
2.2.3.6	User Data Interfaces													
2.2.3.6.1	ATN-Compliant Service Interface													
2.2.3.6.2	ACARS Interface	X	X	X			X	X	X	X	X	X		
2.2.3.6.3	External Physical and Data Link Layer Requirements													
2.2.3.6.4	Avionics Subnetwork Interface Requirements for ISO-8208 Service													
2.2.3.6.5	Alternative ATN-compliant Subnetwork Access Protocols													
2.2.3.6.6	IP Data Interface	X	X	X			X	X	X	X	X	X		
2.2.3.7	Circuit Mode Service Requirements													
2.2.3.7.1	Required services	X	X	X			X	X	X	X	X	X		
2.2.3.7.2	Voice quality	X	X	X			X	X	X	X	X	X		
2.2.3.7.2.1	Frequency Response	X	X	X			X	X	X	X	X	X		
2.2.3.7.2.2	Total noise including quantization noise	X	X	X			X	X	X	X	X	X		
2.2.3.7.2.3	Spurious in-band signals	X	X	X			X	X	X	X	X	X		
2.2.3.7.2.4	Spurious and Image signals.	X	X	X			X	X	X	X	X	X		
2.2.3.7.2.5	Amplitude jitter.	X	X	X			X	X	X	X	X	X		
2.2.3.7.2.6	Phase jitter.	X	X	X			X	X	X	X	X	X		
2.2.3.7.2.7	Voice latency	X	X	X			X	X	X	X	X	X		
2.2.3.7.2.8	Call setup time	X	X	X			X	X	X	X	X	X		
2.2.3.8	Recovery from Primary Power Interruption	X	X	X			X	X	X	X	X	X		
2.2.3.9	Failure/Status Indication	X	X	X			X	X	X	X	X	X		

Paragraph	Title	AES4	AES6	AES7	HGA	IGA	6MA	7MA	6F	7F	6D	7D	DMA	DF
2.2.3.10	Information Security	X	X	X			X	X	X	X	X	X		
3	INSTALLED EQUIPMENT PERFORMANCE & subsections	X	X	X										
4	EQUIPMENT OPERATIONAL PERFORMANCE CHARACTERISTICS & subsections	X	X	X										

6 ABBREVIATIONS

3G	3rd Generation
AAGW	ACARS Airborne Gateway
AC	Alternating Current
ACARS	Aircraft Communications and Reporting System
ACD	Aircraft Control Domain
ADS-C	Automatic Dependent Surveillance - Contract
AES	Aircraft Earth Station
AGGW	ACARS Ground Gateway
AISD	Aircraft Information Systems Domain
AMBE+2	Advanced Multi-Band Excitation +2
AMS(R)S	Aeronautical Mobile Satellite (Route) Services
AMSS	Aeronautical Mobile Satellite Services
AOC	Aeronautical Operational Control
APN	Access Point Name
ARINC	Aeronautical Radio Inc.
ATN	Air Traffic Network
ATS	Air Traffic Service
ATSP	Aeronautical Telecommunications Service Provider
AUT	Antenna Under Test
AWGN	Additive White Gaussian Noise
Az	Azimuth
BGAN	Broadband Global Area Network
BIT	Built In Test
BITE	Built In Test Equipment
BOB	BGAN on Bench (A BGAN testbench)
BNE	BGAN Network Emulator
BPLT	BGAN Physical Layer Tester
BPT	BGAN Protocol Tester
CER	Channel Error Rate
CMU	Communications Management Unit
C/M	Carrier to Multipath Ratio
CN	Change Notice
C/No	Carrier to Noise Density Ratio
CNP	Communication Network Provider
CPDLC	Controller-Pilot Datalink Communications
CRC	Cyclical Redundancy Check
CS	Circuit Switched
CSDU	Compact Satellite Data Unit
CW	Continuous Wave
°C	Degrees Celsius
dB	Decibel
dBm	Decibel referenced to 1 milliwatt
dBm0	dBm measured at a zero transmission level point
dBW	Decibel referenced to 1 watt
dBμV	Decibel referenced to 1 microvolt
DC	Direct Current
DCE	Data Communications Equipment
DFL	David Florida Laboratory
DLNA	Diplexer Low Noise Amplifier
DOS	Denial of Service
DSP	Digital Signal Processor
DTE	Data Terminal Equipment
DUT	Device Under Test

EFB	Electronic Flight Bag
EIRP	Effective Isotropic Radiated Power
El	Elevation
ELGA	Enhanced Low Gain Antenna
EMEA	Europe-Middle East-Africa
EMI	Electromagnetic Interference
eMLPP	Enhanced Multi-Level Priority and Pre-emption
ETSI	European Telecommunications Standards Institute
F	Fahrenheit
FAA	Federal Aviation Administration
FANS	Future Air Navigation System
FAR	Federal Airworthiness Regulations
FCC	Federal Communications Commission
FEC	Forward Error Correction
FFT	Fast Fourier Transform
FIR	Flight Information Region
FMHPA	Flange Mounted High Power Amplifier
GLONASS	Globalnaya Navigatsionnaya Sputnikovaya Sistema or Global Navigation Satellite System
GNSS	Global Navigation Satellite System
GOLD	Global Operational Data Link Document
GPS	Global Positioning System
G/T	Gain to Noise Temperature Ratio
HDR	High Data rate
HF	High Frequency
HGA	High Gain Antenna
HIRF	High Intensity Radiated Field
HLD	High Power Amplifier/Low Noise Amplifier/Diplexer
HPA	High Power Amplifier
IAI-2	Inmarsat Air Interface 2
ICAO	International Civil Aviation Organization
IEEE	Institute of Electrical and Electronic Engineers
IGA	Intermediate Gain Antenna
IM	Intermodulation
IMSI	International Mobile Subscriber Identity
IP	Internet Protocol
IPv4	Internet Protocol version 4 (4 byte address)
IRS	Inertial Reference System
ITU	International Telecommunications Union
K	Kelvins
kHz	Kilohertz
kPa	Kilopascals
kSym/s	Kilo symbols/second
LCP	Left circular Polarization
LGA	Low Gain Antenna
m	Meters
MAC	Media Access Control
MASPS	Minimum Aircraft System Performance Specification
MCDU	Multi-function Control Display Unit
MHz	Megahertz
mm	Millimeters
MMP	Meet Me Point
Modem	Modulator-Demodulator
MOPS	Minimum Operational Performance Standard
ms	Milliseconds
MSISDN	Mobile Subscriber Integrated Services Digital Network-Number
MSS	Mobile Satellite Service

MTR	Mandatory Test Requirements
MTBF	Mean Time Between Failures
MTTR	Mean Time to Repair
NF	Noise Figure (in dB)
NGSS	Next Generation Satellite Systems
NIST	National Institute for Standards and Technology
PDP	Packet Data Protocol
PER	Packet Error Rate
PIESD	Passenger Information and Entertainment System Domain
PIM	Passive Intermodulation
PIMBIT	Passive Intermodulation Built In Test
PIN	Personal Identification Number
PLC	Public Limited Company
PS	Packet Switched
PSAB	Primary Shared Access Bearer
PTT	Push to Talk
QAM	Quadrature Amplitude Modulation
QoS	Quality of Service
QPSK	Quadrature Phase Shift Keying
RA	Radio Astronomy
RAB	Radio Access Bearer
RAN	Radio Access Network
RCP	Right Circular Polarization
RF	Radio Frequency
RLC	Radio Link Controller
RMS	Root Mean Square
RNC	Radio Network Controller
RRC	Root Raised Cosine
RSP	Required Surveillance Performance
RTCA	Radio Technical Commission for Aeronautics
Rx	Receive
SARPs	Standards and Recommended Practices
SBB	Swift Broadband
SBBSS	Swift Broadband Safety Service
SCM	SDU Configuration Module
SDM	System Definition Manual
SDU	Satellite Data Unit
SITA	Formerly - Société Internationale de Télécommunications Aéronautiques
STC	Supplemental Type Certificate
SVGM	Satcom Voice Guidance Material
TBD	To Be Determined
TC	Type Certificate
TCP	Transmission Control Protocol
TDM	Time Division Multiplexed
TDMA	Time Division Multiple Access
TSO	Technical Standard Order
Tx	Transmit
UDP	User Datagram Protocol
UE	User Equipment
UMTS	Universal Mobile Telephone System
USIM	Universal Subscriber Identity Module
VAC	Volts Alternating Current
VCTS	Voice Codec Test Set
VDC	Volts Direct Current
VHF	Very High Frequency
VoIP	Voice over Internet Protocol
Vp-p	Volts peak to peak

VSWR	Voltage Standing Wave Ratio
Wi-Fi	Wireless Fidelity
XL	eXtended L-band

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