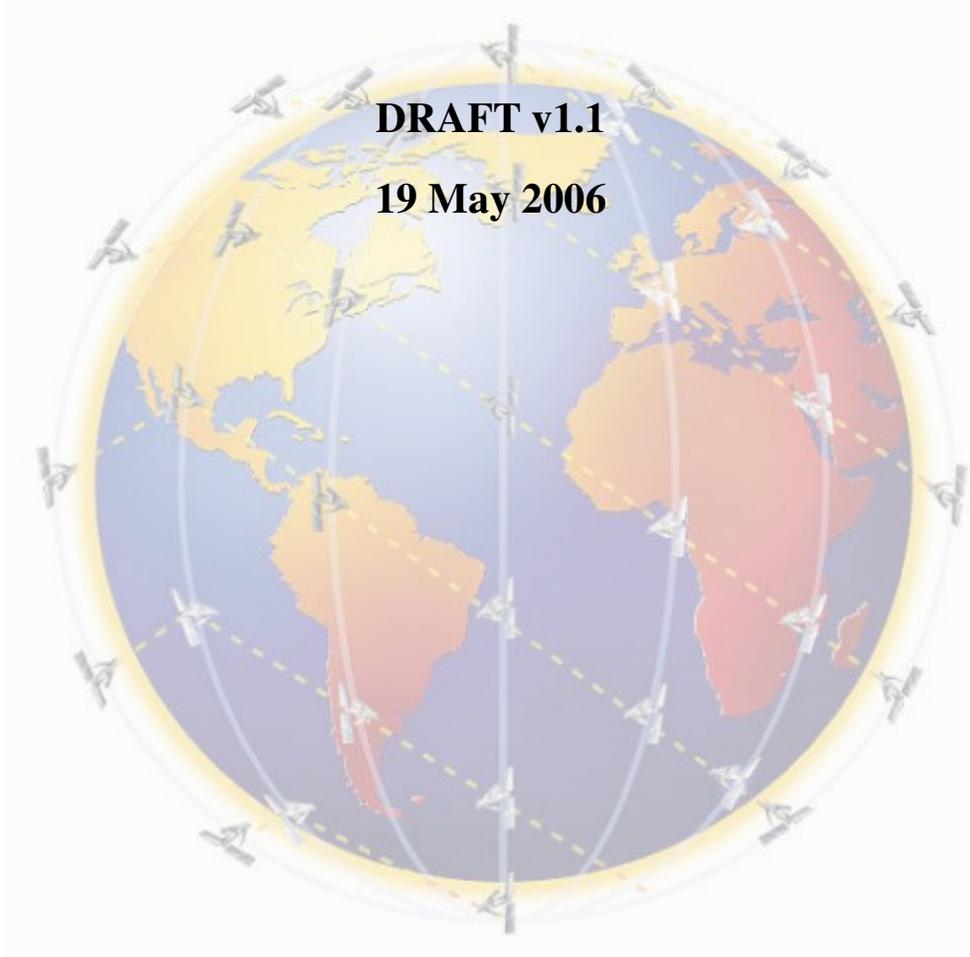


**ICAO TECHNICAL MANUAL FOR
IRIDIUM
AERONAUTICAL MOBILE SATELLITE (ROUTE) SERVICE**



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Table of Contents

ICAO TECHNICAL MANUAL FOR.....	I
IRIDIUM	I
AERONAUTICAL MOBILE SATELLITE (ROUTE) SERVICE	i
DRAFT V1.1	I
19 MAY 2006	I
1 INTRODUCTION	1
1.1 Scope.....	2
1.2 Iridium AMS(R)S	2
1.3 Applicable Documents.....	3
2 IRIDIUM SATELLITE NETWORK OVERVIEW	5
2.1 System Architecture.....	5
2.1.1 Space Segment	6
2.1.2 Terrestrial Segment.....	8
2.2 Channel Classifications.....	9
2.2.1 Overhead Channels	9
2.2.2 Bearer Service Channels	10
2.3 Channel Multiplexing	10
2.3.1 TDMA Frame Structure.....	11
2.3.2 FDMA Frequency Plan	11
2.3.3 Duplex Channel Band	11
2.3.4 Simplex Channel Band	13
2.4 L-Band (1616-1626.5 MHz) Transmission Characteristics.....	14
2.4.1 Signal Format.....	14
2.4.2 Power Control	15
2.5 Call Processing.....	15
2.5.1 Acquisition.....	15
2.5.2 Access	17
2.5.3 Registration and Auto-Registration	17
2.5.4 Telephony	18
2.5.5 Handoff	19
2.6 Voice and Data Traffic Channel	20
2.7 Iridium Data Services – RUDICS and SBD	21
2.7.1 Iridium RUDICS Service.....	21
2.7.2 Iridium SBD Service.....	23
3 AMS(R)S SARPS COMPLIANCE	25
3.1 RF Characteristics.....	25
3.1.1 Frequency Bands.....	25
3.1.2 Emissions	25
3.1.3 Susceptibility.....	26
3.2 Priority and Preemptive Access	26
3.3 Signal Acquisition and Tracking	27
3.4 Performance Requirements.....	28
3.4.1 Designated Operational Coverage	28

3.4.2 Failure Notification	28
3.4.3 AES Requirements.....	29
3.4.4 Packet Data Service Performance	29
3.4.5 Voice Service Performance.....	31
3.4.6 Security	32
3.5 System Interfaces	34
APPENDIX A: AIRCRAFT EARTH STATION RF CHARACTERISTICS	39
APPENDIX B: ACRONYMS	43

1 INTRODUCTION

The use of satellite telecommunications for aeronautical communication service is an emerging technology. The current aeronautical communication systems are primarily High Frequency (HF), Very High Frequency (VHF) radio links to ground stations. Systems using these radio links have been traditionally known as Aeronautical Mobile Services (AMS) in general. When used in commercial aircraft, the services are identified with the term “Route”, usually by adding “(R)” to the acronym, indicating that the services apply to air traffic in the commercial air routes. The term “Off Route” applies to military aircraft, which do not fly in the commercial air lanes. The term AM(R)S thus refers to aeronautical mobile communications in the commercial air routes. The addition of the term “Satellite” refers to the emerging use of Satellite Communications for aeronautical communications, hence Aeronautical Mobile-Satellite (R) Service, AMS(R)S.

Satellite communications fit into the current radio link infrastructure because they provide services that traditional radio link communications cannot provide reliably. Excluding the possibility of “bouncing” HF signals off of the ionosphere, traditional radio communications are “line of sight” which limits aeronautical communications to a range of approximately 500 km even over “flat” terrain such as the ocean. Currently commercial air carriers are using satellite communications to provide AMS(R)S services in areas not covered by radio communications such as transoceanic flights. The present AMS(R)S technology is dependent on a geosynchronous satellite communications infrastructure which can only be accessed at lower latitudes (<70 degrees).

Iridium Satellite Network, with its constellation of 66 low Earth orbit (LEO) satellites, is the only global mobile satellite communication network in the world, with complete coverage of the entire Earth, including oceans, airways, and Polar regions, offering reliable voice and data service to and from remote areas where no other form of communication is available. Iridium Satellite Network is well suited for AMS(R)S offering capabilities where no other communication systems in the world provide.

Back in the late ‘90s, Iridium and its business partners were involved in various ICAO Working Groups dialoguing with working group members and assessing the acceptability of Iridium Satellite Network for AMS(R)S offering. The consensus was that Iridium met the Acceptability Criteria of AMS(R)S offering after AMCP WGA/14 and WP-599 submission in January 1999. This was before the AMS(R)S SARPs was written and was before the launch of the Iridium commercial service.

Now in its sixth year of successful operation with hundreds of thousands of subscribers all over the world and its user terminals installed on numerous type of aircrafts, Iridium Satellite LLC, the new Iridium company, is working with its service providers and aircraft equipment manufacturers in planning for the Iridium AMS(R)S offering. Iridium Satellite LLC is also working with ICAO and its working groups to ensure the future Iridium AMS(R)S offering is in compliance with the newly drafted AMS(R)S SARPs.

1.1 Scope

The objective of this technical manual is to provide guidance to States on their consideration of the Iridium Satellite Network as a platform to offer AMS(R)S. The scope of this document contains the Iridium service provider portion of an end-to-end AMS(R)S system. This document also reflects the change in ICAO policy, as decided in the last assembly meeting (reference), to have a performance based SARPs as compared to an implementation based SARPs.

Chapter 1 of this document provides an overview of how Iridium Satellite Network can support AMS(R)S. It is followed by a system overview of the Iridium Satellite Network in Chapter 2. Chapter 3 provides Iridium Satellite Network performance information in light of the AMS(R)S SARPs. Appendix A provides a table of Iridium specific performance parameters pertaining to minimum operation performance standard for avionics supporting next generation satellite system as specified in RTCA DO-262.

Given that the performance of the future Iridium AMS(R)S system will highly depend on the performance of the underlying Iridium satellite subnetwork, we believe that this technical manual will provide valuable insight as guidance material of the performance of the future Iridium AMS(R)S system.

It is not the objective of this technical manual to serve as a verification report. Once the end-to-end Iridium AMS(R)S is designed, built, and tested, ISLLC, its AMS(R)S service providers, and its avionics manufacturers will submit certification and regulatory type approval material to Civil Aviation Administrator and other regulatory agencies of individual State for Iridium AMS(R)S certification.

1.2 Iridium AMS(R)S

AMS(R)S is designated 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.

Iridium AMS(R)S will comprise safety and non-safety communications. Safety communications refer to communications for Air Traffic Services (ATS) and Aeronautical Operational Control (AOC) to the cockpit or flightdeck. Non-safety communications to the cabin crew and passengers are known as Aeronautical Administrative Communications (AAC) and Aeronautical Public Correspondence (APC), respectively. Aeronautical Public Correspondence is also known as Aeronautical Passenger Communications. The aeronautical services to be offered therefore fall into four major categories:

- Air Traffic Services (ATS) - which includes air traffic control, and weather information provided by civil aviation administrations; e.g., the FAA;
- Aeronautical Operational Control (AOC) - primarily communications from an airline's operational control center that affect the safety and regularity of flight;
- Aeronautical Administrative Communications (AAC) - for example ticketing, special orders, passenger related information;
- Aeronautical Public Correspondence (APC) - personal communications by/for passengers.

An Iridium AMS(R)S communications link comprises of three principal elements –Aircraft Earth Station (AES), Iridium satellite network, and AMS(R)S Ground Subsystem (AGS).

An AES serves as the interface equipment between the voice/data network on an aircraft and the Iridium satellite network. An AES will comprise of multiple Iridium Subscriber Units (ISU). The embedded ISUs will serve as radio transceivers that provide RF path connectivity with the Iridium Satellite Network while other AES electronics interface with voice/data user subsystems onboard the aircraft. The RF characteristics of the AES are essentially those of the ISU. The ISU will provide the actual modem and signal processing function as well as Iridium satellite subnetwork protocol management including circuit-switched voice/data management. The AES developer will provide the interworking functions between the Iridium voice/data channels and the end users/applications/services.

An AGS will provide the interface between the Iridium Gateway and aeronautical unique terrestrial users, such as Air Traffic Controllers, airline operations, etc. The voice/data traffic will traverse either a Public Switch Voice/Data Network or leased lines from the Iridium Gateway to the ground user facilities. The AGS supports flight deck safety services as defined by AMS(R)S and provides packet data interfaces with aeronautical datalink service providers, such as ARINC, SITA, Honeywell, and others. For the purpose of this document, we use the term Ground Earth Station (GES) to encompass both the Iridium Gateway and the AGS.

The Iridium Satellite Network supports primarily the transmission of circuit switched data. Discussions regarding packet switched data in the AMS(R)S context presume that the packet data is sent by an external application that is utilizing the Iridium Satellite Network as a transmission medium. All Circuit Switch Packet Data (CSPD) calls require terminal applications which format packets compatible with peer level packet applications in the terrestrial networks being addressed. For Iridium AMS(R)S, the AES and the GES provide the packet switching peer at the aircraft side and at the ground side of the Iridium Satellite Network, respectively.

1.3 Applicable Documents

Detailed descriptions of the design and operation of Iridium Satellite Network are contained in the *Iridium Air Interface Specification* (AIS). The AIS is an Iridium proprietary and confidential document and will require special approval for release. Request for AIS shall be forwarded to ISLLC; detailed contact information can be found at <http://www.iridium.com>.

The following documents are also referenced in this technical manual.

- Draft *ICAO Core AMS(R)S SARPs* for core specification of NGSS supporting AMS(R)S;
- RTCA DO-262, *Minimum Operational Performance Standards for Avionics Supporting Next Generation Satellite Systems (NGSS)*, for minimum performance standard of NGSS AMS(R)S;
- RTCA DO-270, *Minimum Aviation System Performance Standards (MASPS) for the Aeronautical Mobile-Satellite (R) Service (AMS(R)S) as Used in Aeronautical Data Links*, for requirement and specification for the data link;
- RTCA DO-215A and RTCA DO-231 for guidance on overall data and voice performance requirements;

- ICAO IRD-SWG03-WP08, “WP599 from AMCP WGA Meeting, Phoenix, January 1999”, regarding acceptability of Iridium for AMS(R)S.

Copies of RTCA document may be obtained from RTCA, Inc., <http://www.rtca.org>. Copies of ICAO document may be obtained from ICAO, <http://www.icao.int>.

2 IRIDIUM SATELLITE NETWORK OVERVIEW

Iridium Satellite Network is a truly global mobile satellite voice and data solutions. With complete coverage of the Earth's oceans, airspace, and Polar Regions, Iridium delivers essential services to users around the globe.

Iridium Satellite launched service in December 2000. Iridium World Data Services were launched in June 2001; this service includes Dial-Up Data with a throughput rate of up to 2.4 Kbps, Direct Internet Data with a throughput rate of up to 10 Kbps, and the Router-Based Unrestricted Digital Interworking Connectivity Solution (RUDICS). Iridium Short Burst Data (SBD) service was added to the data service offering in June 2003.

Iridium Satellite operates its Satellite Network Operations Center (SNOC) in Virginia, USA, gateways in Arizona, Alaska, and Hawaii, USA, TTAC facilities in Arizona, USA, Yellowknife and Iqaluit, Canada, and Iceland, as well as hot/cold backup facilities around the globe.

ISLLC has contracted with Boeing Corporation to operate and maintain its satellite constellation. The Iridium constellation, gateway facilities, telemetry and control facilities, as well as overall network and system health are being monitored around-the-clock every single day. ISLLC also has contracted with Celestica Inc., a world-class electronic equipment manufacturer, to manufacture its subscriber equipment. Iridium Subscriber Units (ISU) includes satellite handsets, L-band¹ Transceivers (LBT), and Short Burst Data (SBD) devices.

System improvements in the satellite and handset have been introduced, providing improved voice quality and subscriber equipment performance. Multiple analysis and tests had demonstrated the satellite constellation longevity as 2014. Plans are underway for the manufacturing and launch of the next generation constellation.

2.1 System Architecture

The Iridium Satellite Network is a satellite-based, wireless personal communications network providing a robust suite of voice and data services to virtually any destination anywhere on earth.

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 are relayed from one satellite to another until they reach the satellite above the ISU and the signal is relayed back to Earth.

The key elements of the Iridium communication system are illustrated in Figure 2-1.

¹ For the purpose of this document, the term "L-band" specifically refers to the band 1616-1626.5 MHz.

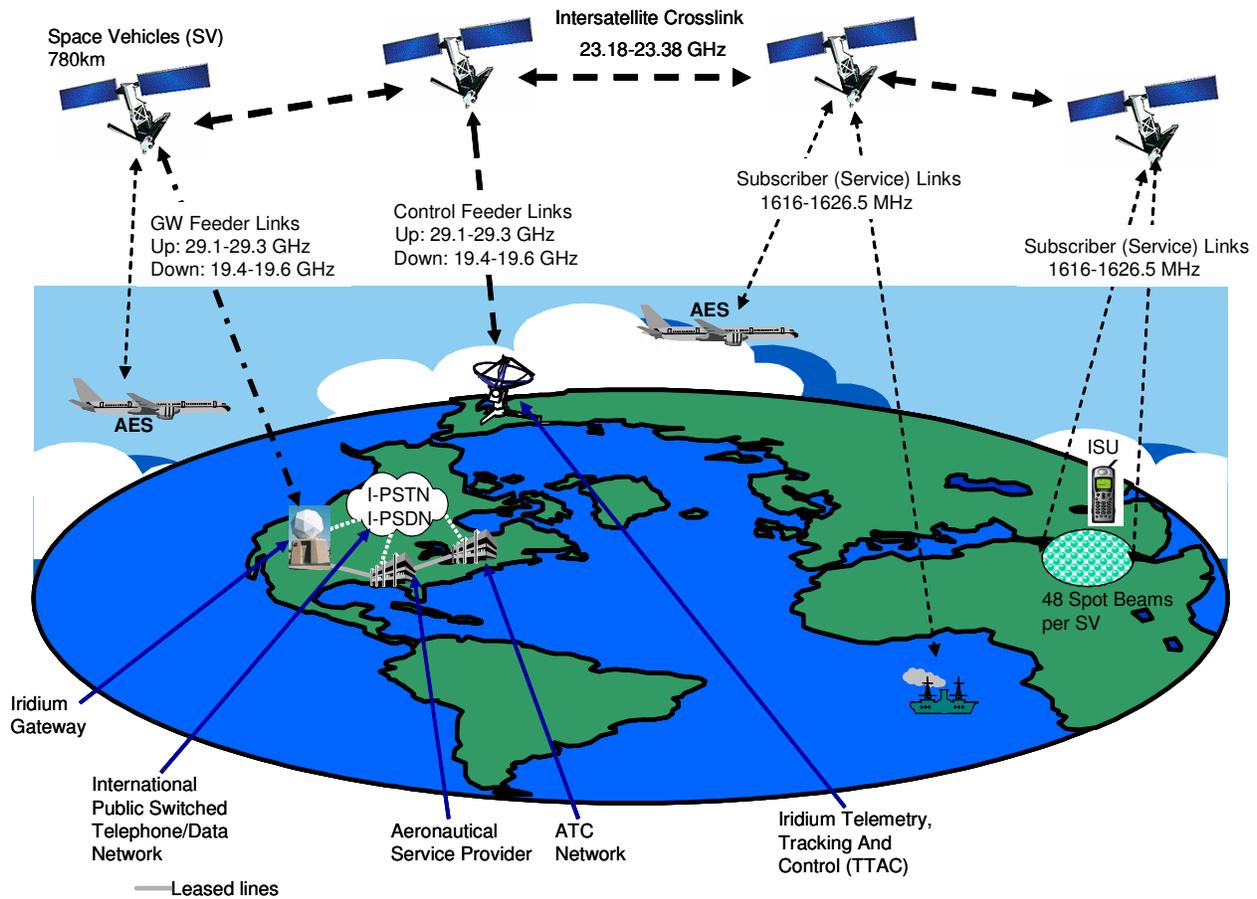


Figure 2-1 Key Elements of the Iridium AMS(R)S

2.1.1 Space Segment

The Iridium space segment utilizes a constellation of 66 operational satellites in low-Earth orbit, as shown in Figure 2-2. 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, which are evenly spaced within each plane, perform as nodes in the communication network. The six co-rotating planes are spaced 31.6° apart in longitude, resulting in a spacing of 22° between Plane 6 and the counter-rotating portion of Plane 1. 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. There are 10 additional satellites orbit as spares ready to replace any unserviceable satellite in case of a failure.

Each satellite communicates with subscriber units, including Aircraft Earth Stations (AESs) 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 2-3 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 space vehicles (SVs) cause the satellites to get closer together as the sub-satellite latitude increases, as illustrated in Figure 2-2. This orbital motion, in turn, causes the coverage of neighboring SVs 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 intersatellite interference and increased availability in high latitudes due to overlapping coverage.

The Iridium Satellite Network architecture incorporates certain characteristics, such as call hand-off, 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.

Each SV 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 neighboring 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 Ground Earth Stations required to provide global coverage to one.

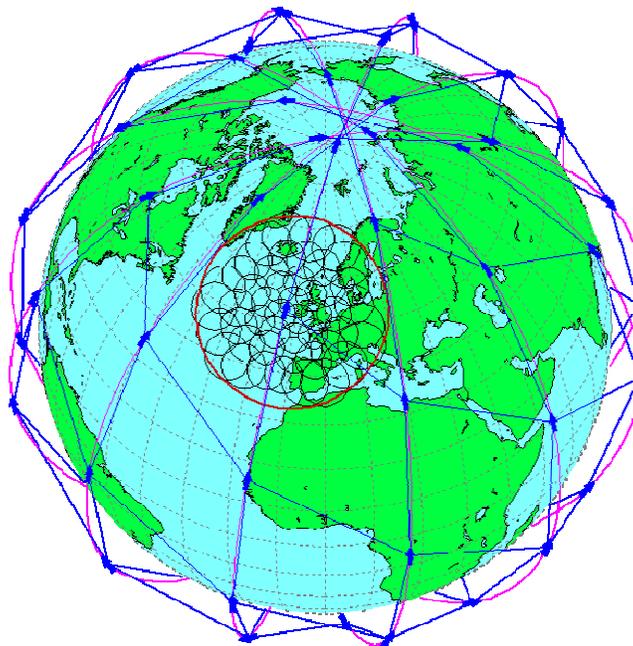


Figure 2-2 Iridium 66-Satellite Constellation

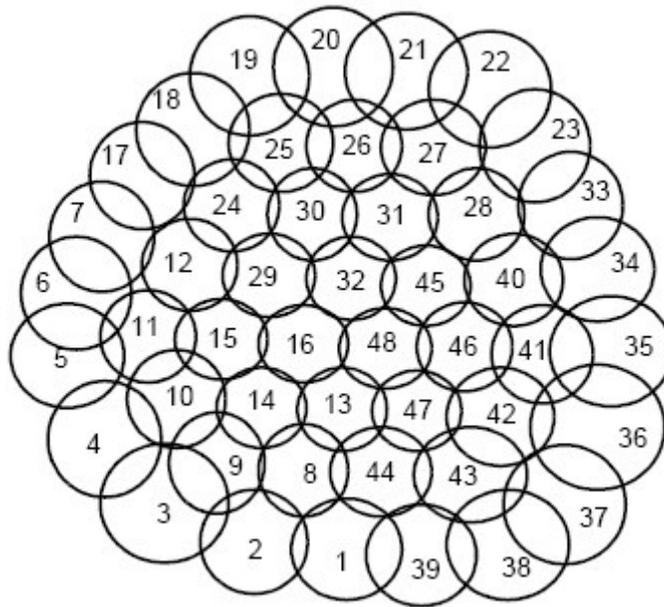


Figure 2-3 Iridium Spot-Beam Configuration

2.1.2 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: four Telemetry, Tracking, and Control (TTAC) sites, the Operational Support Network (OSN), and the Satellite Network Operation Center (SNOC). The primary linkage between the System Control Segment, the satellites, and the gateways is via control feeder links and intersatellite 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 the terrestrial Public Switched Telephone Networks (PSTNs) and Public Switched Data Networks (PSDNs); it communicates via the ground-based antennas with the gateway feederlink antennas on the satellite. 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.

2.2 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 2-4 illustrates the hierarchy of Iridium channel types. Iridium aeronautical services utilize only the indicated channel types.

In the discussions that follow, the term "channel" always refers to a time-slot-and-frequency combination. The terms "frequency" or "frequency access" will be used to denote the specific radio frequency of an individual channel.

2.2.1 Overhead Channels

The Iridium Satellite Network has four overhead channels; the overhead channels are Ring Channel, Broadcast Channel, Acquisition Channel, and Synchronization Channel.

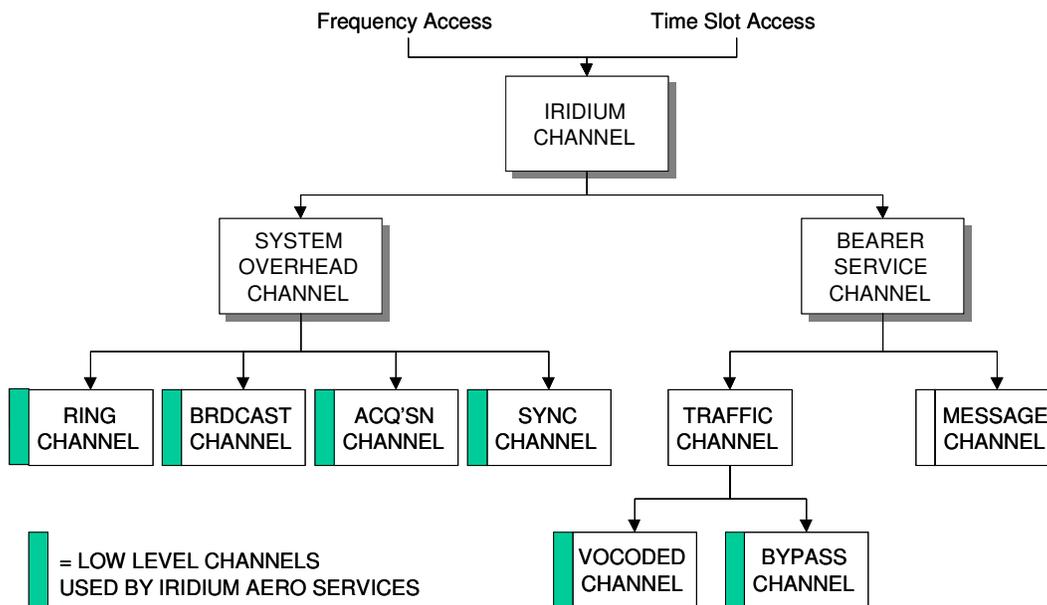


Figure 2-4 Iridium Channel Structure Hierarchy

The Ring Channel is a downlink-only channel used to send ring alert messages to individual subscriber units. Its downlink frequency is globally allocated 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 ISUs 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. ISUs determine which Acquisition Channels are active by monitoring the Broadcast Channel.

The Synchronization Channel is a duplex channel used by the ISU to achieve final synchronization with an SV 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 ISU will occupy when the sync process is complete. During the sync process, the SV measures the DTOA and DFOA of the uplink sync burst and sends correction information to the ISU in the downlink sync burst. A synchronization channel is assigned to an ISU by the SV. The synchronization procedure is accomplished by the ISU transmitting an uplink burst which the SV measures for time and frequency error relative to the assigned channel. The SV sends time and frequency corrections for the latest uplink burst over the downlink channel. This process is repeated until the SV determines that the ISU transmit time and frequency are within the tolerance for a traffic channel. When this occurs, the SV transmits a message to that effect to the ISU and reconfigures the channel for traffic channel operation.

2.2.2 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 such as Iridium pagers. The Iridium aeronautical service does not utilize the simplex messaging services.

Traffic channels support duplex services; these 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.

2.3 Channel Multiplexing

Channels are implemented in the Iridium Satellite Network using a hybrid TDMA/FDMA architecture based on TDD using a 90 msec frame. Channels are reused in different geographic locations by implementing acceptable co-channel interference constraints. A channel assignment comprises of both a frequency carrier and a time slot.

2.3.1 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 2-5. 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 ksp/s. A 2400 bps traffic channel uses one uplink and one downlink time-slot each frame.

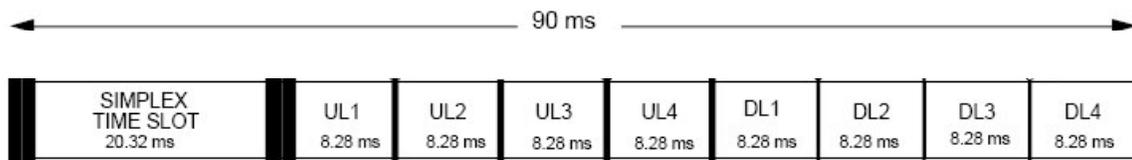


Figure 2-5 Iridium TDMA Structure

2.3.2 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.

2.3.3 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 subbands.

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. The minimum group of duplex channels that can be allocated to an antenna beam is called a reuse unit pair. 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. A reuse unit pair consists of an uplink reuse unit and a downlink reuse unit.

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, reclassified 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

2.3.4 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

2.4 L-Band (1616-1626.5 MHz) Transmission Characteristics

2.4.1 Signal Format

All L-Band uplink and downlink transmissions used in the Iridium Satellite Network employ variations of 25 kbps QPSK modulation, and are implemented with 40% square root raised cosine pulse shaping. The variations of QPSK used include differential encoding (DE-QPSK) and BPSK, which is treated as a special case of QPSK. Figure 2-6 illustrates the relevant FDMA frequency characteristics.

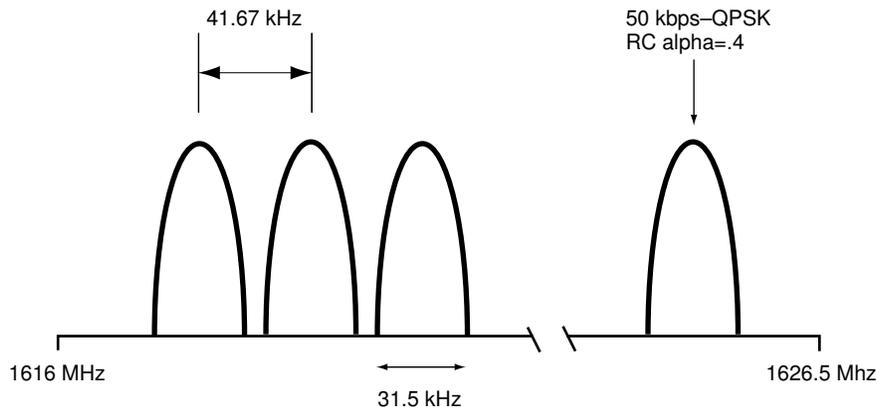


Figure 2-6 FDMA Frequency Plan

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 kbps and provides a burst data rate of 50 kbps.

Uplink traffic channels use DE-QPSK modulation with 40% square root raised cosine pulse shaping and burst transmission rates of 25 kbps, 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 kbps, or 25 kbps. BPSK is used because it provides a 3 dB link advantage, which improves the burst acquisition probability.

Certain signaling, control, and traffic applications implement error correction coding to improve the link bit error rate, with characteristics tailored for each application certain traffic and signaling 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 transmitted in every traffic burst containing a data payload (as opposed to a voice payload). If the

Frame Check Sequence 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 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 good voice and data quality.

2.4.2 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. This level is achieved at an $E_b/(N_o+I_o)$ of 6.1 dB in clear line of sight conditions. The basic Iridium Satellite Network will operate with an average link margin of 15.5 dB above this level, as required to mitigate fading due to the Rayleigh multipath and shadowing typical of handheld phone operation in urban environments. Under good channel conditions, this level is reduced by adaptive power control. Even under adaptive power control, link margin is maintained to mitigate fades that are too short in duration to be compensated for by the power control loop.

Adaptive power control uses a closed loop algorithm in which the space vehicle and AES receivers measure received E_b/N_o 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.

2.5 Call Processing

Call Processing in the Iridium Satellite Network consists of Acquisition, Access, Registration and Auto-Registration, Telephony, and Handoff.

2.5.1 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 SV and the ISU. Acquisition by an ISU 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 step in Acquisition is to achieve frame timing alignment, determine the correct downlink time slot, and detect the Doppler shift of the received signal. Then the ISU must pre-correct the transmitted signal so the received signal, at the SV, arrives during the correct receive time window and has at most a small Doppler offset.

To acquire the system, an ISU turns on its receiver and acquires the SV Broadcast Channel transmission for the beam in which the ISU is located. The Ring Channel includes the broadcast time/frequency for each beam, and the ISU can use this to determine which channel to use. The decoded SV broadcast (Broadcast Acquisition Information message) indicates to the ISU if Acquisition is permitted; this is 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 ISU extracts the beam ID and selects a random Acquisition Channel.

The ISU 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 SV on the Acquisition Channel. Upon receipt of the Acquisition Request message from the ISU, the SV calculates the time and frequency error of the received signal. It then sends a Channel Assignment message to the ISU along with time and frequency corrections.

After each transmission on the uplink Acquisition Channel, the ISU 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 ISU 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 ISU and other ISUs attempting to use the Acquisition Channel.

The ISU, 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 SV. The SV 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 SV will set Sync Status to Sync OK if the time and frequency errors are within the tolerance for Traffic Channel operation. If the SV sends a Repeat Burst in the Sync Status information element, the ISU adjusts its timing and frequency and retransmits a Sync Check message. If the SV sends Sync OK in the Sync Report message, the ISU acknowledges by sending a Sync Check message and waits for a Sync/Traffic Switch message from the SV. Upon receipt of the Sync/Traffic Switch message, the ISU exits the Acquisition process and initiates the Access process. The SV then switches the Sync Channel to a Traffic Channel.

2.5.1.1 Acquisition Control

Under certain circumstances it is 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 ISUs may attempt Acquisition. All subscribers are members of one out of 10 randomly allocated populations, referred to by Acquisition Class 0 to 9. The subscriber equipment reads the Acquisition Class from the SIM card that was programmed when it is initially provisioned. In addition, subscribers may be members of one or more special categories (Acquisition Class 11 to 15), also held in the ISU. 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 ISU proceeds with Acquisition.

2.5.2 Access

The Access process determines the ISU's location with respect to Service Control Areas defined in earth fixed coordinates. Based on the Service Control Area within which the ISU is found to be located and on the identity of the ISU's 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 ISU based on an external source such as Global Positioning System (GPS) or an aircraft navigation system, or it may be determined by the Geolocation function contained within the Access function.

2.5.3 Registration and Auto-Registration

Registration is the process of the ISU 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 ISU for a mobile terminated call). The ISU must be registered in the gateway serving its location to initiate or terminate a call. An ISU registration occurs for one of five reasons:

1. The ISU presently contains an invalid Temporary Mobile Subscriber Identification (TMSI) or Location Area Identity (LAI)
2. The TMSI presently assigned to an ISU expires
3. A call termination or origination is performed and, based on the new location, the ISU is told to re-register by the system
4. A mobile subscriber initiates a manual ISU registration procedure
5. The ISU's present location exceeds the re-registration distance from the point of its last registration.

The procedures used for ISU registration (Location Update) after acquisition and access, are standard GSM procedures with three exceptions:

1. The ciphering option is not used during the assignment of a new TMSI.

2. The option of using periodic ISU registration is also not used (instead, autoregistration is used on an as-needed basis).
3. Since connection has already been established during the Access process, the Location Update message no longer requires the special use of a Set Asynchronous Balanced Mode (SABM) message for transport.

Auto-registration refers to the capability of an ISU to reregister with the network only on an as needed basis. The ISU will automatically reregister 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 ISU passively estimates both its location and its positional error, based upon information gathered from the Ring Channel of the passing SVs.

2.5.4 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 an ISU of an incoming call.

Functions supporting Telephony are distributed between the ISU, SV and gateway components. The functions are partitioned so as to group like procedures together. The ISU 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 2-7 below.

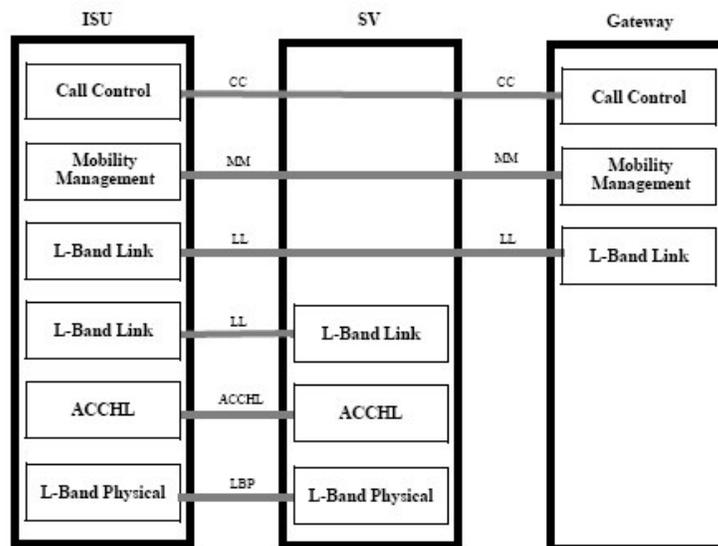


Figure 2-7 Protocol Partitions

Five protocol partitions are supported by the ISU:

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 GSM. This includes the Mobile Switching Center to Mobile Subscriber (MSC-MS) signaling in the GSM Mobile Radio Interface CC sublayer 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 signaling in the GSM Mobile Radio Interface MM sublayer 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 signaling associated with Mobile origination or termination and provides for the signaling 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 SV and the ISU. 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 SV and the ISU. The ACCHL protocol permits sharing the traffic channel burst with other protocols. The ACCHL Logical Channel is bi-directional, and uses the Link Control Word Part and the Payload Part of the Traffic Channel between the SV and the ISU. The ACCHL protocol will transport variable size messages on the ACCHL Logical Channel and is used to guarantee the delivery of messages between the SV and the ISU. It relies on LBP only in that LBP arbitrates the access to the physical layer when there is contention for the Physical Layer resources.

2.5.5 Handoff

The Iridium SVs, in low earth polar orbit, have highly directional antennas providing Iridium system access to ISUs. These antennas are configured to project multiple beams onto the surface of the earth. The beams move rapidly with respect to ISUs and with respect to other SVs. 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 SV movement in this highly mobile environment, is required in three situations. First, an ISU must be handed off between SVs as they move relative to the ISU (Inter-SV).

Second, an ISU must be handed off between beams on a SV as beam patterns move relative to the ISU (Intra-SV). Last, an ISU 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 ISU initiated.

As an SV moves away (for example, moves over the horizon) and a new SV approaches (for example comes into view over the horizon), an ISU must transfer from the current SV (the losing SV) to the new SV (the gaining SV). This Inter-SV 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 SVs move from the equator to a pole, the actual distance between adjacent SVs decreases to a few kilometers and then increases to several thousand kilometers as the SVs again approach the equator. To avoid radio interference, beams near the edges of an SV's coverage field are turned off as the SV approaches a pole, and then turned on again as it approaches the equator. Also, the same radio channels are never available in adjacent beams on a SV or between nearby SVs. Thus, as the SV and its beams pass by, an ISU must frequently transition to a new beam. This Intra-SV 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 ISU to be handed off to a different channel in the same beam. This is called Intra-beam handoff. An ISU 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 SV 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-SV or Intra-SV, but are initiated by the ISU (at the request of the Iridium system) rather than by the Iridium system itself.

2.6 Voice and Data Traffic Channel

Traffic channels provide two-way connections between space vehicles and subscriber equipment that support the Iridium services. These channels transport the system voice and data services along with the signaling 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 signaling 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 signaling messages.

The Link Control Word field provides a low rate signaling 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 forward error control (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 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 ensure good quality vocoded voice performance tailored for the Iridium communication channels. For data service, the L-band transport employs a frame check sequence to provide essentially error free data transport service.

The basic interface to the ISU and the circuit switched channel setup/teardown are provided at a modem application level using the Iridium AT command set. 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.

2.7 Iridium Data Services – RUDICS and SBD

2.7.1 Iridium RUDICS Service

The Iridium RUDICS service 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 AT Commands to control a circuit switched data capable ISU. Figure 2-8 illustrates the call set up process of a Mobile Originated (MO) data call. The remote application dials a customer specific Iridium number, which connects the call through the Siemens D900 telephony switch, to the RUDICS server. The customer specific number is assigned and provisioned by Iridium. Each ISU is authenticated using Calling Line Identification for the RUDICS customer specific number that it dialed. Once authenticated the call is routed over the terrestrial connection to a pre-configured Internet Protocol (IP) address and Port where the user host application server is. The RUDICS service supports the follow service transport types: TCP/IP encapsulation, PPP, and MLPP.

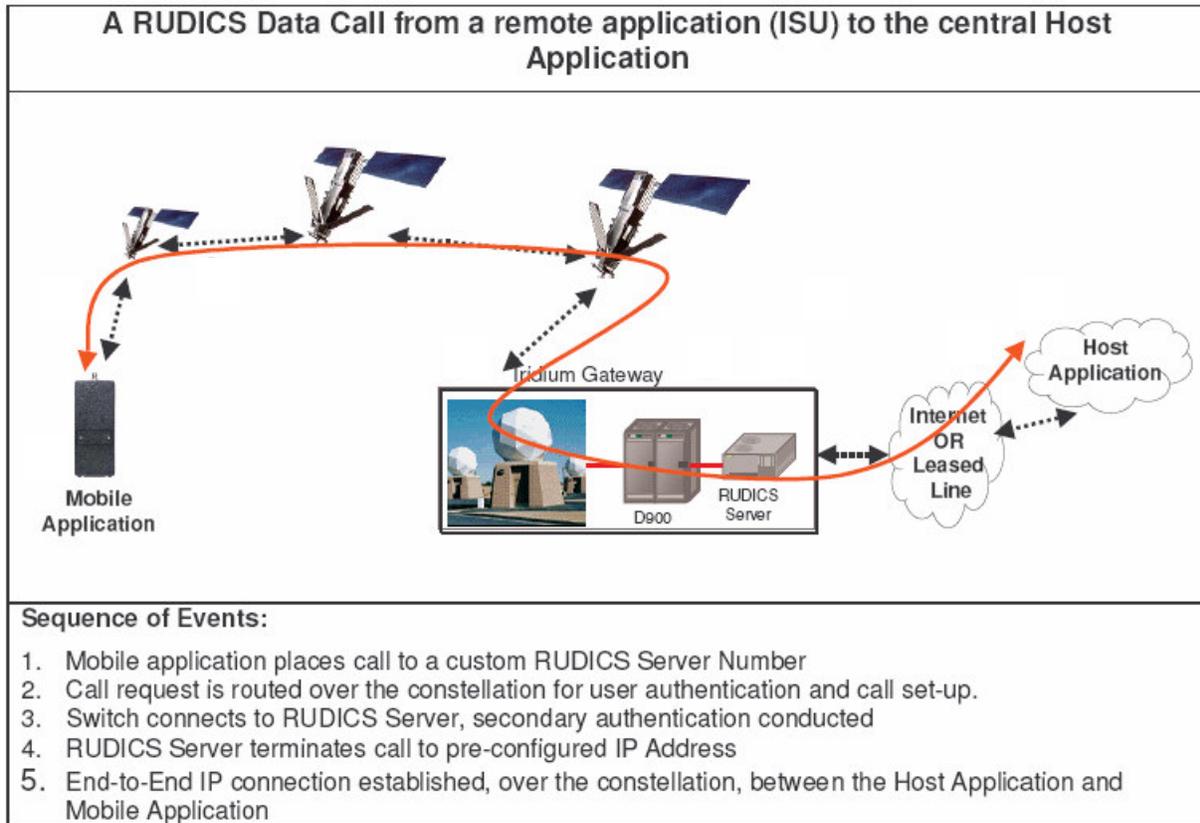


Figure 2-8 Iridium RUDICS Mobile Originated Data Call Setup

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 ISU 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 ISUs can be used to send data simultaneously and the data can be delivered in an N x 2400 bps PPP connection.

2.7.2 Iridium SBD Service

The Iridium Short Burst Data Service is a simple and efficient satellite network transport capability to transmit short data messages between field equipment and a centralized host computing system. A Mobile Originated SBD message can be up to 1960 bytes. A Mobile Terminated SBD message can be up to 1890 bytes.

Figure 2-9 shows the system architecture of the Iridium SBD service while Figure 2-10 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 ISU to notify it of the arrival of a new message. The ISU then initiated a MO call to the SBD Subsystem to pull down the message.

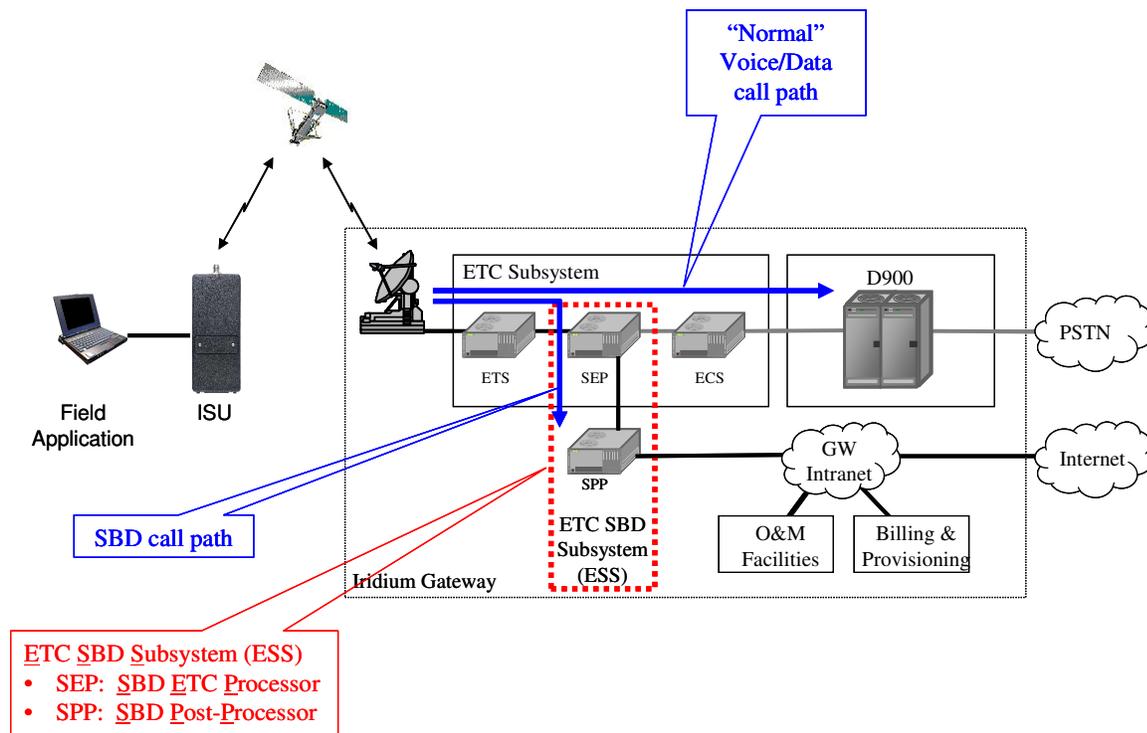
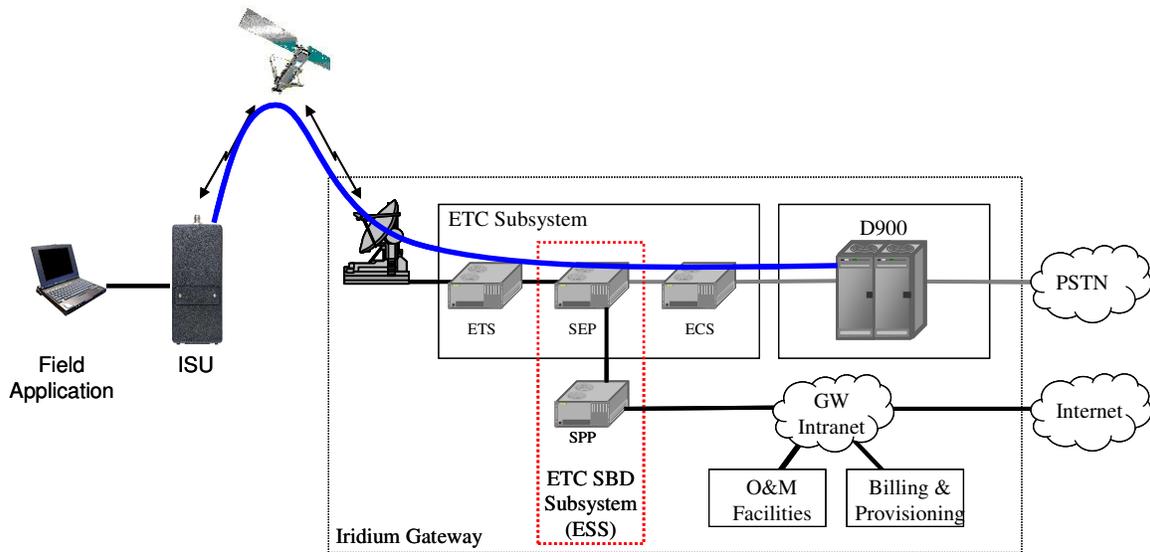
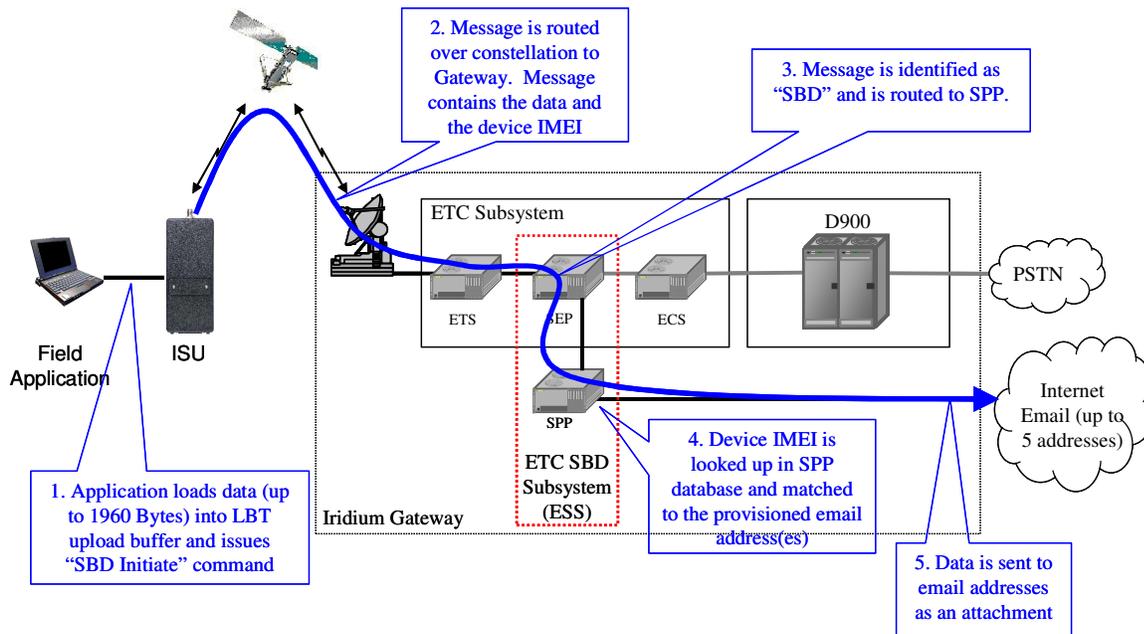


Figure 2-9 System Architecture of Iridium SBD Service

Since SBD message utilizes the Iridium signaling transport during the access phase of a circuit-switched voice call set up process, it has the benefits of additional FEC protection as well as a fast and efficient on-the-air off-the-air packet delivery service.



(a)



(b)

Figure 2-10 Setting Up a MO SBD Call (a) Registration (b) Message Delivery

3 AMS(R)S SARPS COMPLIANCE

This chapter provides additional supporting and guidance material regarding Iridium AMS(R)S service performance and AMS(R)S SARPs compliance. While this document mainly pertains to the Iridium satellite subnetwork, examples of typical numbers for end-to-end system is provided to show how the Iridium subnetwork fits within the overall compliance of the end-to-end AMS(R)S system. Table 3-1 tabulates the AMS(R)S SARPs requirements and the associated Iridium specific performance parameters.

The actual verification of the Iridium AMS(R)S service against the AMS(R)S SARPs is beyond the scope of this Technical Manual and will be coordinated by Iridium Satellite LLC, its AMS(R)S service providers and AES manufacturers, and the Civil Aviation Authorities (CAA) of States during the certification process for the States.

The following sections are organized in a similar fashion as the AMS(R)S SARPs.

3.1 RF Characteristics

The Iridium AMS(R)S AES should be designed and manufactured to meet the emission and susceptibility requirements of RTCA DO-262, which is currently required for certification by FAA's Technical Standard Order, TSO-C159, pertaining to Avionics Supporting Next Generation Satellite Systems (NGSS). [*AMS(R)S SARPs, 4.3*]

3.1.1 Frequency Bands

The Iridium subscriber links operate in the 1616-1626.5 MHz band, which is part of the Mobile Satellite Service (MSS) band allocated by the U.S. and international Radio Regulations (ITU Radio Regulations, No. 5.347A, No. 5.351A, No. 5.364, and No. 5.365).

This band is also allocated on a primary basis for AMS(R)S operation under ITU Radio Regulations No. 5.367. [*AMS(R)S SARPs, 4.3.1*]

The Iridium Satellite Network also uses satellite-to-satellite radio links in the 23.18-23.38 GHz band. The Iridium feeder link utilizes a 19.4-19.6 GHz downlink and a 29.1-29.3 GHz uplink for communications between the Iridium Satellite and the Iridium Gateway/TTAC. Given the critical functions of these high capacity links, they were designed to be highly reliable with superb data integrity performance.

3.1.2 Emissions

The Iridium AMS(R)S AES are designed to meet the emission requirements of RTCA DO-262 in order to ensure that it will not cause harmful interference to GNSS and other systems necessary to support safety and regularity of air navigation, installed on the same or other aircraft. [*AMS(R)S SARPs, 4.3.2*]

The Iridium ISU is designed to meet the emission limits set out in ITU-R Recommendation M.1343, "Essential technical requirements of mobile earth stations for global non-geostationary mobile-satellite service systems in the bands 1-3 GHz", as well as national/regional type-approval specifications such as FCC Part 2 and Part 25 and ETSI EN301 441 specifications. FCC

and ETSI regulatory testing of standard Iridium ISU shows that the Iridium ISU meets the specified emission performance.

Iridium ISUs have been installed in numerous types of aircrafts including commercial airliners by various Iridium AES manufacturers. Some CAAs have already approved installation of Iridium ISU on commercial airliners for non-AMS(R)S uses..

If needed for AMS(R)S, a bandpass filter with passband frequency of 1616-1626.5 MHz can be specified and placed at the output of an AMS(R)S AES equipment to provide additional emission protection.

3.1.3 Susceptibility

The Iridium AMS(R)S AES equipment will operate properly in an interference environment causing a cumulative relative change in its receiver noise temperature ($\Delta T/T$) of 25%. [*AMS(R)S SARPs, 4.3.3*]

25% increase in receiver noise temperature is equivalent to a 0.6 dB link margin degradation. This additional degradation due to interference is accounted for in the Iridium link budget calculation. Iridium operates with sufficient link margin to meet this requirement at all time.

3.2 Priority and Preemptive Access

The basis for Iridium AMS(R)S Priority, Precedence, and Pre-emption (PPP) is the set of mechanisms designed for, and already implemented in, the Iridium Satellite Network for signaling and system management purposes. The Iridium Satellite Network utilizes two resource management functions, Acquisition Class control and Priority Class control, to assure access to communication channels for priority users. [*AMS(R)S SARPs, 4.4*]

The acquisition process is one of several protocols completed between an ISU and the satellite constellation for each call set up regardless if the call is mobile originated (from aircraft) or mobile terminated (to aircraft). For mobile originated call, the ISU will start the acquisition process once the call is placed. For mobile terminated call, the ISU will start the acquisition process upon the reception of a RING, indicating an incoming call from the GES.

Each satellite beam broadcasts which Acquisition Classes are allowed to acquire satellite resource on that beam. Only ISUs with the proper Acquisition Class (AC) are allowed to start the acquisition process. Acquisition Class ranges from 0-15. Default non-safety Iridium terminals use an Acquisition Class in the range of 0-9. AMS(R)S safety traffic will be assigned Acquisition Class 14.

Acquisition Class is mainly use for SV load shedding. In a satellite beam with heavy traffic load, certain Acquisition Classes (e.g., AC0-9) will be shut down to prohibit further traffic load on the satellite. To ensure AMS(R)S safety traffic will get through, Iridium will not shut down AC14 for SV load shedding.

The Acquisition Class affects how calls initially gain access to the satellite constellation while Priority Class provides continued access for safety-related calls.

The Iridium Satellite Network allows for four levels of priority. Each satellite has priority queuing for both channel assignment of new calls and handoff order of in-progress calls. High priority calls, taking precedence, are queued before low priority calls.

The four Iridium priority levels are mapped to the four-level AMS(R)S priority structure as specified by Table 2-7 of RTCA DO-262.

- Iridium Priority 3 (AMS(R)S #4, Distress, Urgency, highest priority);
- Iridium Priority 2 (AMS(R)S #3, Direction finding, Flight Safety);
- Iridium Priority 1 (AMS(R)S #2, Other Safety and Regularity of Flight);
- Iridium Priority 0 (AMS(R)S #1, AMSS Non-Safety, lowest priority).

In case of extreme system resource shortage, on-going low priority calls will be pre-empted by the system to allow access for higher priority call.

While the Iridium Acquisition Class Control and Priority Class Control provide internal system controls for internal PPP management, the Iridium AMS(R)S AES manufacturers and AMS(R)S service providers will need to provide the input/output queuing for call/message priority function at the Iridium network interfaces. These capabilities are intrinsic to the protocol machines that interface Iridium AMS(R)S with its external users, and reside in the AMS(R)S AES and GES.

Currently both the Acquisition Class and Priority Class are encoded on a SIM card; hence the Acquisition Class and Priority Class are associated with a SIM card and an ISU that uses that SIM card. For AMS(R)S, the acquisition class and priority class will need to be associated with each AMS(R)S call (type) and will be controlled by the protocol software that sets up the call.

Iridium AMS(R)S AES and GES will support Priority, Precedence and Pre-emption to ensure that messages transmitted in accordance with Annex 10, Volume II, 5.1.8, including their order of priority, are not delayed by the transmission and/or reception of other types of messages.

[*AMS(R)S SARPs, 4.4.1*]

All AMS(R)S data packets and all AMS(R)S voice calls will be identified as to their associated priority. [*AMS(R)S SARPs, 4.4.2*]

Within the same message category, the Iridium AMS(R)S service will provide voice communications priority over data communications. [*AMS(R)S SARPs, 4.4.3*]

3.3 Signal Acquisition and Tracking

The Iridium Satellite Network consists of fast moving LEO SVs and is hence designed to handle large Doppler frequency shift and Doppler rate of change. The signal acquisition and tracking functions are handled internally within the Iridium Satellite Network by the ISU and the SVs and are transparent to the Iridium users.

Link synchronization is achieved by pre-correcting the ISU transmit timing and frequency so that uplink bursts arrive at the SV in the correct time slot and on the correct frequency access for the assigned channel. This pre-correction is accomplished by adjusting the ISU timing and frequency in accordance with error feedback which is sent in the downlink maintenance messages by the SV. The ISU will compensate for a maximum uplink carrier frequency Doppler shift of up to +/-

37.5 KHz to achieve the specified uplink frequency of arrival requirements. The ISU receiver will accommodate a carrier frequency Doppler shift of up to +/-37.5 KHz.

Since the Iridium Satellite Network became operational, the Iridium ISUs have been demonstrated to maintain link connectivity in numerous test flights onboard jets and research rockets. A recent test involved the NASA Sounding Rocket was conducted in April 2004. An Iridium flight modem, consisted of an Iridium ISU and other electronics, integrated and packaged by NASA, sent data successfully and continuously from lift-off through 2 rocket stage burns, reaching a peak velocity of to 1.5 km/sec (5400 km/h), and only cut out when the rocket tumbled at apogee (120 km). The flight modem reacquired after the first parachute deployed and data was sent until the rocket hit the ground with a reported force of 50 g's. The Iridium link was maintained on impact and the flight modem continued to transmit for another 25 minutes. This and other demonstrations show that Iridium communication links are robust for high speed flights with large Doppler offset and Doppler rate of change.

The Iridium AES, GES and satellites properly acquire and track service link signals when the aircraft is moving at a ground speed of up to 1500 km/h along any heading. [AMS(R)S SARPs, 4.5.1]

The Iridium AES, GES and satellites properly acquire and track service link signals when the component of the aircraft acceleration vector in the plane of the satellite orbit is up to 0.6 g. [AMS(R)S SARPs, 4.5.2]

The Iridium AES, GES and satellites should be able to properly acquire and track service link signals when the aircraft is moving at a ground speed of up to 2800 km/h along any heading and the component of the aircraft acceleration vector in the plane of the satellite orbit is up to 1.2 g. These will be further verified during Iridium AMS(R)S certification process. [AMS(R)S SARPs, 4.5.1.1, 4.5.2.1]

3.4 Performance Requirements

3.4.1 Designated Operational Coverage

Iridium Satellite Network provides mobile communication with operational Pole to Pole coverage of the entire earth.

Iridium plans to provide AMS(R)S as an alternative and/or redundant communications capability in oceanic/remote/polar (ORP) region with the ability to provide alternative and/or redundant communications capability for continental flights as appropriate. [AMS(R)S SARPs, 4.6.1.1]

3.4.2 Failure Notification

As an operational network serving hundreds of thousands of subscribers all over the globe, the Iridium Satellite Network is being monitored 24/7 by its Network Operation and Maintenance Contractor, the Boeing Corporation. There are methods and processes in place for network outage detection, prediction, reporting, warning, and remediation.

Iridium and its AMS(R)S service providers will ensure the AMS(R)S system, in the event of a service failure, will provide timely predictions of the time, location and duration of any resultant outages until full service is restored. [AMS(R)S SARP_s, 4.6.2.1]

Iridium and its AMS(R)S service providers will amend the current process to ensure the AMS(R)S system will announce a loss of communications capability within 30 seconds of the time when it detects such a loss. [AMS(R)S SARP_s, 4.6.2.2]

3.4.3 AES Requirements

The Iridium AMS(R)S AES should meet the relevant performance requirements contained in voice and data performance requirements of the AMS(R)S SARP_s for aircraft in straight and level flight throughout the designated operational coverage of the Iridium satellite system. These will be further verified during Iridium AMS(R)S certification process. [AMS(R)S SARP_s, 4.6.3.1]

The Iridium AMS(R)S AES should meet the relevant performance requirements contained in voice and data performance requirements of the AMS(R)S SARP_s for aircraft attitudes of +20/-5 degrees of pitch and +/- 25 degrees of roll throughout the designated operational coverage of the Iridium satellite system. These will be further verified during Iridium AMS(R)S certification process. [AMS(R)S SARP_s, 4.6.3.1.1]

3.4.4 Packet Data Service Performance

The Iridium Satellite Network provides AMS(R)S packet data service in accordance with the requirements stated in the AMS(R)S SARP_s. [AMS(R)S SARP_s 4.6.4.1]

As stated earlier, the Iridium Satellite Network should be treated as a transmission medium. The AES on the aircraft and the AMS(R)S Ground Subsystem (AGS) on the terrestrial side together with the Iridium satellite network constitute a mobile sub-network of the ATN or other data (e.g., Data-2) network. Iridium will work with its AES manufacturers and AMS(R)S service providers to ensure the Iridium AMS(R)S packet-data service will be capable of operating as a constituent mobile sub-network of the ATN. The AES and the AGS will provide ATN-compatible network interface. [AMS(R)S SARP_s 4.6.4.1.1]

Iridium offers a multitude of data services, of which the Iridium RUDICS and SBD services are well suited for AMS(R)S application. RUDICS offers the shortest call establishment time among all standard Iridium circuit-switch data services. SBD, though also based on circuit switch channel, offers a data transport service which looks more like a packet data call. The following performance parameters are based on statistics accumulated over many years of Iridium Satellite Network operation.

Traditional Iridium data service, like RUDICS, is based on circuit-switch mode. Data circuit is established and the channel stays up until the connection is torn down. The connection establishment time for a RUDICS call ranges from 10-14 sec. Once the circuit is established, the channel provides a reliable transport service of 2.4 kbps as a minimum with a more typical throughput around 2.6 kbps.

Since the Iridium SBD service utilizes only the Access phase of the normal Iridium call establishment, it does not traverse the full path of the Iridium Gateway to the GSM switch and

hence has a shorter call establishment delay. In fact, there is really no standard call set up for SBD. SBD call can send data immediately as soon as the Acquisition process is completed, which on average is about 1.5 sec. Therefore, the average call establishment time is about 1.5 sec for MO SBD and 3.6 sec for MT SBD, assuming an average RING alert duration of 2.1 sec in a typical operating environment. Since SBD utilizes the signalling channel payload (with FEC protection) rather than the normal traffic channel payload, its average throughput is less than that of standard Iridium data services such as RUDICS and is around 1.2 kbps.

3.4.4.1 Delay Parameters

Based on accumulated performance statistics, the connection establishment delay of a RUDICS based packet data call will be much less than 30 sec. and that the connection establishment delay of a SBD based packet data call will be much less than 8 sec. [AMS(R)S SARPs, 4.6.4.1.2.1]

Assuming a subnetwork service data unit (SNSDU) length of 128 octets, the Iridium satellite subnetwork will support the following transit delay values:

For RUDICS based packet data service, the transit delay (average transfer delay) of a 128-byte payload will be around $128 \times 8 / 2400 = 0.43$ sec. For SBD based packet data service, the transit delay of a 128-byte message will be around $128 \times 8 / 1200 = 0.86$ sec. Hence, the transit delay of the highest priority packet should be less than 5 sec. regardless if it is from AES or GES. [AMS(R)S SARPs, 4.6.4.1.2.3, 4.6.4.1.2.4]

Based on the earlier discussion and the average transfer delay value, therefore the 95th percentile transfer delay should be less than 15 seconds for the highest priority data service whether it is from-aircraft or to-aircraft. [AMS(R)S SARPs, 4.6.4.1.2.5, 4.6.4.1.2.6]

Based on operational experience and performance statistics, most calls are released within 2 sec. Hence, connection release delay for all calls should be less than 5 sec. [AMS(R)S SARPs, 4.6.4.1.2.7]

3.4.4.2 Integrity

The AMS(R)S SARPs specifies packet data service integrity by residual error rate and it further defines residual error rate as the combination of the probability of undetected error, the probability of undetected loss of an subnetwork service data unit (SNSDU) and the probability of an undetected duplicate SNSDU.

Regarding undetected loss and undetected duplicate, both the Iridium circuit switch data transport and the Iridium SBD protocol employs message sequence number and automatic repeat request (ARQ) retransmission at the Iridium PDU level. For SBD, message sequence number is also applied at the SNSDU level. Regardless of where the MSN is applied, it is impossible to have undetected loss and undetected duplicate of an SNSDU.

Probability of undetected error is simply the packet error rate.

For RUDICS based packet data service, part of the analysis provided in a previous working group paper, WGA/14 WP-599 Attachment 5, still applies. The reliable mode circuit-switch data employs a 24-bit frame check sequence and the user payload field in an Iridium PDU is 248 bits. To transport a 128-byte data packet, it will take 5 Iridium PDUs. WP-599 Attachment 5 shows

using simple analysis that the probability of a 128-byte data packet in error is about 3×10^{-7} . WP-599 continues to show that the packet error rate can be further reduced if additional protocol layer with additional error detection capability is employed. For the purpose of this technical manual, we will simply assume the packet error rate of 3×10^{-7} and do not further assume additional enhancement provided other protocol layer.

The SBD service uses the Iridium signalling channel for data transport and is a guaranteed delivery service with multiple layers of error protection. It employs forward error control in the form of BCH coding in addition to selective ARQ. By design, the SBD data transport will have better packet error rate performance than the circuit switch data transport.

The Iridium AMS(R)S packet data will have a residual error rate no greater than 10^{-6} per SNSDU, whether it is from-aircraft or to-aircraft. [AMS(R)S SARPs, 4.6.4.1.3.1, 4.6.4.1.3.2]

The probability of a subnetwork connection (SNC) provider-invoked SNC release will be less than 10^{-4} over any one-hour interval. [AMS(R)S SARPs, 4.6.4.1.3.3]

The probability of an SNC provider-invoked reset will be less than 10^{-1} over any one-hour interval. [AMS(R)S SARPs, 4.6.4.1.3.4]

The probability of provider-invoked SNC release and SNC reset will be verified for the Iridium AMS(R)S certification process.

3.4.5 Voice Service Performance

Iridium AMS(R)S will support both voice and data services and the Iridium AMS(R)S voice service will meet the requirement of the AMS(R)S SARPs. [AMS(R)S SARPs, 4.6.5.1]

3.4.5.1 Call Processing Delay

Based on past operational experience and performance statistics, most mobile-originated and mobile-terminated voice calls take 12 sec and 14 sec to set up, respectively.

For Iridium AMS(R)S, the 95th percentile of the time delay for a GES to present a call origination event to the terrestrial network interworking interface after a call origination event has arrived at the AES interface should not be greater than 20 seconds. In order to verify the 95th percentile number, additional data will need to be gathered to build the cumulative probability density function. This will be done as part of the Iridium AMS(R)S verification efforts. [AMS(R)S SARPs, 4.6.5.1.1.1]

For Iridium AMS(R)S, the 95th percentile of the time delay for an AES to present a call origination event at its aircraft interface after a call origination event has arrived at the terrestrial network interworking interface should not be greater than 20 seconds. In order to verify the 95th percentile number, additional data will need to be gathered to build the cumulative probability density function. This will be done as part of the Iridium AMS(R)S verification efforts. [AMS(R)S SARPs, 4.6.5.1.1.2]

3.4.5.2 Voice Quality

The Iridium ISU incorporates a 2.4 kbps Advanced Multi-Band Excitation (AMBE) vocoder developed by Digital Voice System Inc. (DVSI). This vocoder is tailored to the Iridium

communication channel and provides good quality audio performance with a nominal Mean Opinion Score (MOS) of 3.5 under typical operating and channel condition.

Even though voice quality of Iridium terminal operating in various aeronautical environments had not been quantified, Iridium terminals have been installed and used on various types of aircrafts including helicopter with good success. Iridium AMS(R)S voice quality will be measured and documented as part of the Iridium AMS(R)S certification efforts. [AMS(R)S SARPs, 4.6.5.1.2.1]

WGA/14 WP-599 Attachment 4 analysed the Iridium voice call delay. That analysis estimated a total one-way voice transfer delay over the Iridium network of about 374 msec based on the assumption therein; the material presented there still applies. That estimated delay value compares well with some of the test data seen. Additional data regarding Iridium voice call delay will be gathered and documented as part of the Iridium AMS(R)S verification efforts.

The Iridium AMS(R)S voice service will have a total voice call transfer delay within the AMS(R)S subnetwork no greater than 0.485 second. [AMS(R)S SARPs, 4.6.5.1.2.2]

3.4.5.3 Voice Capacity

Iridium AMS(R)S will have sufficient available voice traffic channel resources such that an AES- or GES-originated AMS(R)S voice call presented to the system shall experience a probability of blockage of no more than 10^{-2} . [AMS(R)S SARPs, 4.6.5.1.3.1]

An Iridium satellite beam has an average diameter of 400 km. In the current software system configuration, Iridium can support up to 252 voice circuits per beam. We believe this capacity will support the stated probability of blockage for the intended operational coverage of oceanic/remote/polar region.

3.4.6 Security

The Iridium Satellite Network being an operational satellite service employs various security measures against external attack and tampering.

Iridium Channel Security

The complexity of its air interfaces makes it very hard to be intercepted and to be tampered.

To successfully monitor an L-band channel, an eavesdropper must be located within the transmit range of the ISU being monitored, approximately 10 to 30 km from the transmitting ISU. ISU downlink L-Band transmissions could be received over a much wider area. A single SV beam covers an area of about 400 km in diameter.

The complexity of the Iridium air interface would make the challenge of developing an Iridium L-Band monitoring device very difficult. Among the complications are

- Large, continually changing Doppler shifts
- Frequent inter-beam and inter-SV handoffs
- Time-division multiplexed burst mode channels
- Complicated modulation, interleaving and coding

A sophisticated monitoring device would be needed in the general proximity of an Iridium gateway to receive the feederlink channel.

The complexity of the feederlink interface poses a formidable technical challenge for prospective eavesdroppers. Among the technical complications are

- Large, continually changing Doppler shifts
- High capacity, ~3 Mbps channels
- High-gain tracking antenna required
- Must reacquire new SV every 10 minutes

This security aspect of the Iridium Satellite Network provides protection against tampering of messages in transit. [AMS(R)S SARPs, 4.6.6.1]

Space Segment Security

The Iridium Satellite Network uses command authentication and encryption to safeguard critical commands to the satellite constellation. These features provide protection against unauthorized entry, spoofing, and “phantom controllers”.

This security aspect of the Iridium Satellite Network provides protection against unauthorized entry. [AMS(R)S SARPs, 4.6.6.3]

Physical Security

The Iridium Gateway, its Master Control Facility, and its Telemetry, Tracking And Control stations are all secured facilities.

This security aspect of the Iridium Satellite Network provides protection against unauthorized entry. [AMS(R)S SARPs, 4.6.6.3]

Authentication Security

The Iridium authentication process is adapted without change directly from the GSM specifications. The GSM algorithm A3 is used to encrypt authentication information transmitted over the air interface.

- Authentication encryption
 - Designed to prevent ISU cloning fraud
 - GSM encryption algorithm A3 is executed on SIM card to generate Signed Result (SRES) response based on the following inputs
 - Secret Ki parameter stored in SIM card
 - RAND parameter supplied by network

This security aspect of the Iridium Satellite Network provides protection against certain type of denial of service such as intentional flooding of traffic. [AMS(R)S SARPs, 4.6.6.2]

3.5 System Interfaces

Iridium will work with its AMS(R)S service providers and AES manufacturers to ensure that the Iridium AMS(R)S system will allow subnetwork users to address AMS(R)S communications to specific aircraft by means of the ICAO 24-bit aircraft address. [*AMS(R)S SARPs, 4.7.1*]

Iridium will work with its AMS(R)S service providers to ensure that the Iridium AMS(R)S system will provide an interface to the ATN as well as a connectivity notification (CN) function. [*AMS(R)S SARPs, 4.7.2.1, 4.7.2.2*]

Table 3-1 Iridium AMS(R)S System Parameters per ICAO AMS(R)S SARPs

AMS(R)S SARPs Reference	AMS(R)S SARP Contents	Iridium Subnetwork Value ²	Allocation to Network External to Iridium	Additional Comments on Performance
4.2.1	AMS(R)S shall conform to ICAO Chapter 4	Yes	Yes	-
4.2.1.1	Recommendation to ensure CNS protection by AMSS system	Yes	Yes	-
4.2.1.2	Support packet data, voice, or both	Yes; both	Yes	By design.
4.2.2	Mandatory equipage	N/A for service provider	-	-
4.2.3	2 year's notice	N/A for service provider	-	-
4.2.4	Recommendation consider worldwide implementation	Yes	Yes	-
4.3.1.1	Only in frequency bands allocated to AMS(R)S and protected by ITU RR	Yes; 1616-1626.5 MHz	-	-
4.3.2.1	Limit emissions to control harmful interference on same aircraft	Yes	-	(M) AES emission to be measured by AES equipment manufacturer per RTCA DO262.
4.3.2.2	Shall not cause harmful interference to AMS(R)S on other aircraft	Yes	-	(M) AES emission to be measured by AES equipment manufacturer per RTCA DO262.
4.3.3.1	Shall operate properly in cumulative $\Delta T/T$ of 25%	Yes	-	(M) AES emission to be measured by AES equipment manufacturer per RTCA DO262.
4.4.1	Priority and pre-emptive access	Yes	Yes	(I) To be verified by AES manufacturer per RTCA DO262.
4.4.2	All AMS(R)S packets and voice calls shall be identified by priority	Yes	Yes	(I) To be verified by AMS(R)S Service Providers (SP).
4.4.3	Within the same msg category, voice has priority over data	Yes	Yes	(I) To be verified by AMS(R)S SP.
4.5.1	Properly track signal for A/C at 800 kt. along any heading	Yes	-	Verified by operational experience.
4.5.1.1	Recommendation for 1500 kts.	TBD	-	(M) To be verified by AES manufacturer.
4.5.2	Properly track with 0.6 g acceleration in plane of orbit	Yes	-	Verified by operational experience.
4.5.2.1	Recommendation 1.2 g	TBD	-	(M) To be verified by AES manufacturer.

² Iridium supplied values.

AMS(R)S SARPs Reference	AMS(R)S SARP Contents	Iridium Subnetwork Value ²	Allocation to Network External to Iridium	Additional Comments on Performance
4.6.1.1	Provide AMS(R)S throughout Designated Operational Coverage	Oceanic / remote / Polar (ORP) region	-	Verified by operational experience.
4.6.2.1	Provide timely predictions of service failure-induced outages	Yes	Yes	(I) By process to be set up with AMS(R)S SP.
4.6.2.2	Within 30 s	Yes	Yes	(I) By process to be set up with AMS(R)S SP.
4.6.3.1	Meet performance in straight and level flight	Yes	-	(I) To be verified by AES manufacturer.
4.6.3.1.1	Recommendation for +20/-5 pitch ant +/-25 roll	TBD	-	(I) To be verified by AES manufacturer.
4.6.4.1	Requirements on AMS(R)S packet data	Yes	-	See subsections.
4.6.4.1.1	Capable of mobile subnetwork in ATN	Yes; ISO-8028	Yes	(I) To be verified by AMS(R)S SP when end-to-end system is implemented.
4.6.4.1.2.1	Connection establishment delay < 70 seconds	< 30s	TBD	Iridium subnetwork performance verified by current performance data. (M) End-to-end performance to be verified by AMS(R)S SP when end-to-end system is implemented.
4.6.4.1.2.1.1	Recommendation Connection establishment delay < 50 seconds	< 30s	TBD	Iridium subnetwork performance verified by current performance data. (M) End-to-end performance to be verified by AMS(R)S SP when end-to-end system is implemented.
4.6.4.1.2.2	Transit delay based on SNSDU of 128 octets and defined as average values	Yes	Yes	-
4.6.4.1.2.3	From A/C High priority < 23 seconds	< 5s	TBD	Iridium subnetwork performance verified by current performance data. (M) End-to-end performance to be verified by AMS(R)S SP when end-to-end system is implemented.
4.6.4.1.2.3.1	Recommendation from A/C Low priority < 28 seconds	< 10s	TBD	Iridium subnetwork performance verified by current performance data. (M) End-to-end performance to be verified by AMS(R)S SP when end-to-end system is implemented.
4.6.4.1.2.4	To A/C high priority < 12 seconds	< 5s	TBD	Iridium subnetwork performance verified by current performance data. (M) End-to-end performance to be verified by AMS(R)S SP when end-to-end system is implemented.

AMS(R)S SARPs Reference	AMS(R)S SARP Contents	Iridium Subnetwork Value ²	Allocation to Network External to Iridium	Additional Comments on Performance
4.6.4.1.2.4.1	Recommendation To A/C low priority < 28 seconds	< 10s	TBD	Iridium subnetwork performance verified by current performance data. (M) End-to-end performance to be verified by AMS(R)S SP when end-to-end system is implemented.
4.6.4.1.2.5	From A/C Data transfer delay 95%ile high priority < 40 seconds	< 15s	TBD	Iridium subnetwork performance verified by current performance data. (M) End-to-end 95%ile value requires CDF statistics. To be further verified by AMS(R)S SP when end-to-end system is implemented.
4.6.4.1.2.5.1	Recommendation From A/C Data transfer delay 95%ile low priority < 60 seconds	TBD	TBD	(M) End-to-end 95%ile value requires CDF statistics. To be further verified by AMS(R)S SP when end-to-end system is implemented.
4.6.4.1.2.6	To A/C Data transfer delay 95%ile high priority < 15 seconds	< 8s	TBD	Iridium subnetwork performance verified by current performance data. (M) End-to-end 95%ile value requires CDF statistics. To be further verified by AMS(R)S SP when end-to-end system is implemented.
4.6.4.1.2.6.1	Recommendation To A/C Data transfer delay 95%ile low priority < 30 seconds	TBD	TBD	(M) End-to-end 95%ile value requires CDF statistics. To be further verified by AMS(R)S SP when end-to-end system is implemented.
4.6.4.1.2.7	Connection release time 95%ile < 30 seconds	< 5s	TBD	Iridium subnetwork performance verified by current performance data. (M) End-to-end 95%ile value requires CDF statistics. To be further verified by AMS(R)S SP when end-to-end system is implemented.
4.6.4.1.2.7.1	Recommendation connection release time 95%ile < 25 seconds	< 5s	TBD	Iridium subnetwork performance verified by current performance data. (M) End-to-end 95%ile value requires CDF statistics. To be further verified by AMS(R)S SP when end-to-end system is implemented.
4.6.4.1.3.1	Residual error rate from A/C < 10 ⁻⁴ /SNSDU	< 10 ⁻⁶	-	Verified by current performance data. (M) To be further verified by AMS(R)S SP when end-to-end system is implemented.
4.6.4.1.3.1.1	Recommend RER from A/C < 10 ⁻⁶ /SNSDU	< 10 ⁻⁶	-	Verified by current performance data. (M) To be further verified by AMS(R)S SP when end-to-end system is implemented.
4.6.4.1.3.2	RER to A/C < 10 ⁻⁶ /SNSDU	< 10 ⁻⁶	-	Verified by current performance data. (M) To be further verified by AMS(R)S SP when end-to-end system is implemented.
4.6.4.1.3.3	Pr{SNC provider invoked release}< 10 ⁻⁴ /hr	< 10 ⁻⁴ /hr	TBD	(M) To be verified by AMS(R)S SP when end-to-end system is implemented.
4.6.4.1.3.4	Pr{SNC provider invoked reset}< 10 ⁻¹ /hr	< 10 ⁻¹ /hr	TBD	(M) To be verified by AMS(R)S SP when end-to-end system is implemented.
4.6.5.1	Requirements for AMS(R)S voice service	Yes	Yes	-

AMS(R)S SARPs Reference	AMS(R)S SARP Contents	Iridium Subnetwork Value ²	Allocation to Network External to Iridium	Additional Comments on Performance
4.6.5.1.1.1	AES call origination delay 95%ile < 20 seconds	< 20s	TBD	Iridium subnetwork performance verified by current performance data. (M) CDF statistics are needed for 95%ile value verification; to be further verified by AMS(R)S SP.
4.6.5.1.1.2	GES call origination delay 95%ile < 20 seconds	< 20s	TBD	Iridium subnetwork performance verified by current performance data. (M) CDF statistics are needed for 95%ile value verification; to be further verified by AMS(R)S SP.
4.6.5.1.2.1	Voice intelligibility suitable for intended operational and ambient noise environment	Yes	Yes	(M) To be verified by AES manufacturer.
4.6.5.1.2.2	Total allowable transfer delay within AMS(R)S subnetwork < 0.485 second	< 0.485s	-	Verified by current performance data. (M) To be further verified by AMS(R)S SP when end-to-end system is implemented.
4.6.5.1.2.3	Recommendation to consider effects of tandem vocoders	TBD	-	-
4.6.5.1.3.1	Sufficient voice traffic channel resources for Pr{blockage < 0.01} for AES or GES originated calls	< 0.01	-	(M) To be verified by AMS(R)S SP when end-to-end system is implemented.
4.6.6.1	Protect messages from tampering	Yes	Yes	-
4.6.6.2	Protect against denial of service, degradation, or reduction of capacity due to external attacks	Yes	Yes	-
4.6.6.3	Protect against unauthorized entry	Yes	Yes	-
4.7.1	Address AMS(R)S by means of 24 bit ICAO address	Yes	Yes	By design.
4.7.2.1	If the system provides packet data service, it shall provide an interface to the ATN	Yes	Yes	By design.
4.7.2.2	If the system provides packet data service, it shall provide an CN function	Yes	Yes	By design.

APPENDIX A: AIRCRAFT EARTH STATION RF CHARACTERISTICS

FAA's Technical Standard Order, TSO-C159, states that "Avionics Supporting Next Generation Satellite Systems (NGSS)" identified and manufactured on or after the effective date (20 September 2004) of the TSO must meet the minimum operational performance standards (MOPS) specified in RTCA DO-262.

RTCA DO-262 is a normative specification dealing mainly with RF characteristics and performance of AES supporting NGSS. Each NGSS is to provide system specific performance specification so that RF performance of AES built for that particular satellite system could be tested and verified.

Table A-1 tabulates some of the system specific performance parameters for the Iridium communication satellite system per RTCA DO-262. Iridium will work with its AES manufacturers in understanding the MOPS and the Iridium specific system parameters.

Table A-1 Iridium AMS(R)S System Parameters per RTCA DO-262

Symbol	Characteristics	System Specific Value	Paragraph Reference
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.	3.5 dB	DO-262 2.2.3.1.1.2
f_{RMX}	Maximum operating frequency for space vehicle transmissions (AES reception)	1626.5 MHz	DO-262 2.2.3.1.1.4
f_{RMN}	Minimum operating frequency for space vehicle transmissions (AES reception)	1616.0 MHz	DO-262 2.2.3.1.1.4
f_{TMX}	Maximum operating frequency for AES transmissions	1626.5 MHz	DO-262 2.2.3.1.1.4
f_{TMN}	Minimum operating frequency for AES transmissions	1616.0 MHz	DO-262 2.2.3.1.1.4
f_M	Channel modulation rate	50 kbps	DO-262
P	Nominal polarization of AES antenna	RHCP	DO-262 2.2.3.1.1.1.2
P_{NC}	Maximum output power allowed during intervals when no transceiver channel is transmitting	-77 dBW / 100 kHz	DO-262 2.2.3.1.2.1.7
S_D	Minimum data channel carrier level for sensitivity test	-114 dBm	DO-262 2.2.3.1.2.2.1.1
S_{HSNT}	Maximum level of harmonic, spurious and noise allowed within the designated transmit band	-35 dBW / 100 kHz	DO-262 2.2.3.1.2.1.5
S_{HSNR}	Maximum level of harmonic spurious and noise within the designated receive band	-35 dBW / 100 kHz	DO-262 2.2.3.1.2.1.5
S_{IMT}	Maximum level of 2-tone intermodulation products allowed within the designated transmit band	N/A, no multi-carrier IM expected	DO-262 2.2.3.1.2.1.4
S_{IMR}	Maximum level of 2-tone intermodulation products allowed within the designated receive band	N/A, no multi-carrier IM expected	DO-262 2.2.3.1.2.1.4
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	-174 dBm/Hz	DO-262 2.2.3.1.2.2.6

Symbol	Characteristics	System Specific Value	Paragraph Reference
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.	-128 dBm	DO-262 2.2.3.1.2.2.6
S_V	Minimum voice channel carrier level for sensitivity test	-114 dBm	DO-262 2.2.3.1.2.2.1.2
Θ_{SA}	Minimum separation angle between the line of sight to two satellites within the NGSS constellation	N/A ⁽¹⁾	DO-262 2.2.3.1.1.8
A_{RA}	Maximum axial ratio for AES antenna	4 dB at 8 deg. elevation; 3 dB at zenith	DO-262 2.2.3.1.1.2
D/U	Minimum pattern discrimination between two potential satellite positions above the minimum elevation angle, Θ_{MIN}	N/A	DO-262 2.2.3.1.1.8
ϕ_{Δ}	Maximum phase discontinuity permitted between beam positions of a steered AES antenna.	N/A	DO-262 2.2.3.1.1.9.1
G_{MAX}	Maximum gain of the aeronautical antenna pattern in the upper hemisphere above the minimum elevation angle Θ_{MIN}	3 dBic	DO-262 2.2.3.1.1.1.3
G_{MIN}	Minimum gain of the aeronautical antenna pattern in the upper hemisphere above minimum elevation angle Θ_{MIN}	-3.5 dBic	DO-262 2.2.3.1.1.1.3
L_{MAX}	Maximum cable loss between AES antenna port and the AES transceiver input port	3 dB	DO-262 2.2.3.1.2.2
L_{MSG}	Maximum length in octets of user data sequence using Data 2 transmissions	TBD	DO-262 2.2.3.6.2
L_{SNDP}	Maximum length in octets of user data contained in a maximum length sub-network dependent protocol data block	TBD	DO-262 2.2.3.3.1
N_D	Maximum number of simultaneous data carriers	2 ⁽²⁾	DO-262 2.2.3.1.2.1.1
N_V	Maximum number of simultaneous voice carriers	2 ⁽²⁾	DO-262 2.2.3.1.2.1.1

Symbol	Characteristics	System Specific Value	Paragraph Reference
P_D	Maximum single carrier power for each of N_D data carriers in a multi-carrier capable AES	5.5 W	DO-262 2.2.3.1.2.1.1
P_{RNG}	Range over which the AES transmit power must be controlled	+0 to -8 dB relative to P_D , Iridium internal controlled	DO-262 2.2.3.1.2.1.8
P_{SC-SC}	Maximum burst output power of single carrier AES	8.5 dBW	DO-262 2.2.3.1.2.1.2
P_{STEP}	Maximum acceptable step size for controlling AES transmit power	1 dB step, Iridium internal controlled	DO-262 2.2.3.1.2.1.8
P_V	Maximum single carrier power for each of N_V voice carriers in a multi-carrier capable AES	5.5 dBW	DO-262 2.2.3.1.2.1.1
R_{SC-UD}	Minimum average single channel user data rate sustainable at a residual packet error rate of 10^{-6}	2.4 kbps	DO-262 2.2.3.1.2.2.1.1
Θ_{MIN}	Minimum elevation angle for satellite coverage	8.2 deg.	DO-262 2.2.3.1.1.1.1
τ_{SW}	Maximum switching time between electronically steered antenna patterns.	N/A	DO-262 2.2.3.1.1.9.2
ρ_{RA}	Minimum exclusion zone radius necessary for protection of Radio Astronomy	N/A	DO-262 2.2.3.1.2.1.6.2
C/M	Carrier-to-multipath discrimination ratio measured at the minimum elevation angle	6 dB	DO-262 2.2.3.1.1.7
V_{SWR}	Maximum Voltage Standing Wave Ratio measured at a single input port of the AES antenna	1.8:1	DO-262 2.2.3.1.1.5

Notes:

- (1) Line of sight separation angle depends on latitude and specific location of the terminal.
- (2) In general, this is left to the AES manufacturer as long as other RF performance parameters are within specifications. Assuming a dual-carrier antenna unit, $N_D + N_V$ shall be less than or equal to 2.

APPENDIX B: ACRONYMS

AES	Aircraft Earth Station
AGS	AMS(R)S Ground Subsystem
ARQ	Automatic Repeat Request
ATC	AT Command
BCH	Bose, Ray-Chaudhuri, Hocquenghem (a type of error control code)
BER	Bit Error Rate
DL	Downlink
DFOA	Differential Frequency of Arrival
DTOA	Differential Time of Arrival
ECS	Earth Terminal Controller - Communication Subsystem
ET	Earth Terminal
ETC	Earth Terminal Controller
ETS	Earth Terminal Controller- Transmission Subsystem
FA	Field Application
FDD	Frequency Division Duplex
FDMA	Frequency Division Multiple Access
FEC	Forward Error Control
GES	Ground Earth Station
GSM	Global System for Mobile Communication (Groupe Special Mobile)
GSS	Gateway SBD Subsystem
ISC	International Switching Center
ISDN	Integrated Services Digital Network
ISLLC	Iridium Satellite LLC
ISU	IRIDIUM Subscriber Unit
ITU	International Telecommunications Union
kbps	Kilobits-per-second
ksps	Kilosymbols-per-second
LBT	L-band Transceiver
MCF	Master Control Facility
MMA	Main Mission Antenna
MO	Mobile Originated
MOC	Message Origination Controller
MOMSN	Mobile Originated Message Sequence Number
MSN	Message Sequence Number
MT	Mobile Terminated

MTMSN	Mobile Terminated Message Sequence Number
NGSS	Next Generation Satellite System
PLMN	Public Land Mobile Network
PSDN	Public Switched Data Network
PSTN	Public Switched Telephone Network
RUDICS	Router-Based Unrestricted Digital Interworking Connectivity Solution
SBD	Short Burst Data
SEP	SBD ETC Processor
SIM	Subscriber Information Module
SNOC	Satellite Network Operation Center
SNSDU	Subnetwork Service Data Unit
SPP	SBD Post Processor
SSD	SBD Subscriber Device
SSS	Switching Subsystem
SV	Space Vehicle
TDD	Time Division Duplex
TDMA	Time Division Multiple Access
TTAC	Telemetry Tracking and Control/Command
UL	Uplink
VA	Vendor Application