ViaSat Arclight AMSS Network

Amended Technical Description

Exhibit 2

FCC License Application

Version 1.6 – Amended to Reflect Elimination of Contention Table
March 9, 2007

1 INTRODUCTION

In this application, ViaSat requests authorization to operate its two-way aeronautical mobile satellite service (AMSS) system within the continental United States and its territorial waters on a non-conforming, non-interference basis. ViaSat's waiver request is set forth in Section 1.1 and is supported by the descriptions and explanations in this Technical Description. The ViaSat system will be fully compliant with the Commission's non-interference protection rules.

ViaSat develops and produces advanced digital wireless products for military and commercial markets. ViaSat is a major producer of very small aperture terminal (VSAT) satellite communications systems and it designs and supplies major components of the aeronautical earth stations (AES) used in the Connexion by Boeing℠ Ku-band AMSS system. ViaSat also designed and produces the AES and ground earth station (GES) components of the ARINC SKYLink AMSS system.[1]

ViaSat's AMSS system uses a modified version of ViaSat's Arclight® VSAT technology. Figure 1-1 is a block diagram depicting the two-way network with AES terminals, GES, connectivity to the Internet, and the network operations center (NOC). The AMSS service will operate using standard commercial Ku-band Fixed Satellite Service (FSS) transponders. Service is planned to commence using SES's AMC-6 satellite at 72° W.L.

[1] The ARINC SKYLink system currently operates under FCC license E030205 and uses ViaSat's GES, authorized under FCC license, E030131, to communicate with ARINC's AES terminals.

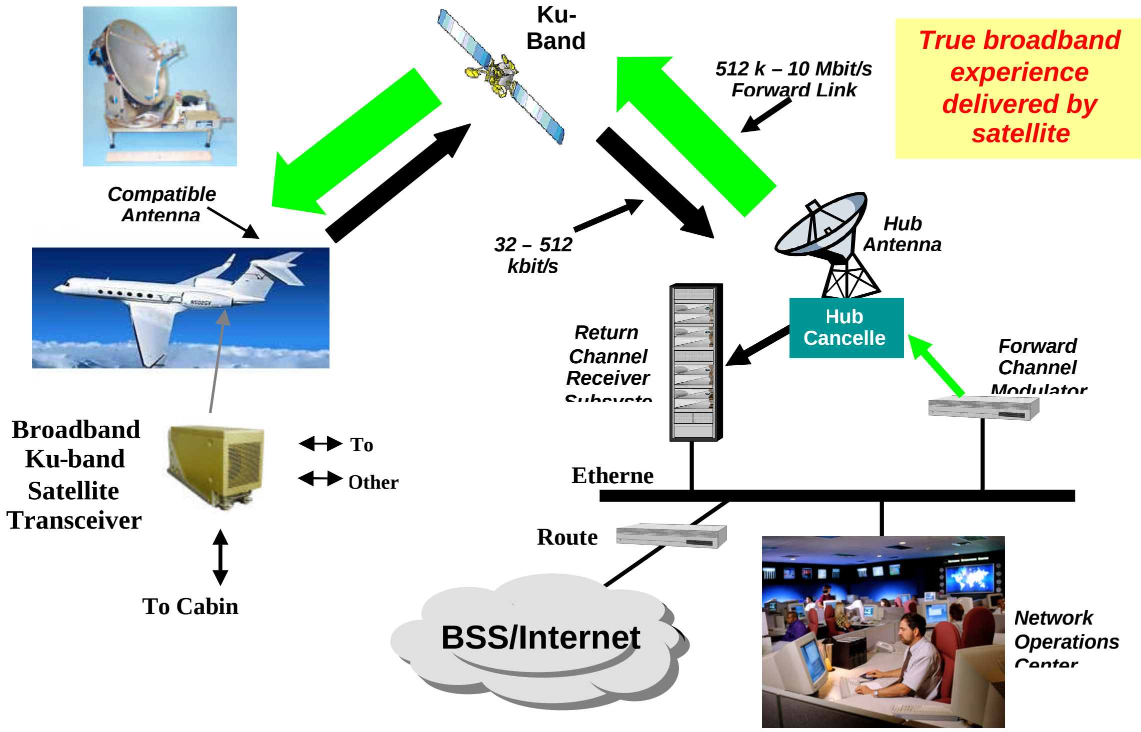

Figure 1-1 ViaSat AMSS System

The ViaSat AMSS system, provides a two-way, broadband communications link between multiple aircraft terminals and the Internet, via one or more ground stations. The service is targeted to aircraft such as regional jets and certain private business jets that are not served by other passenger data communications systems. The service will allow passengers and crew high speed access to e-mail, the World Wide Web, and corporate virtual private networks (VPN). Flight crews may also use the service for company access to facilitate flight and layover planning. The service is not an in-flight entertainment service and will not be used for air traffic control communications.

The Arclight system is uniquely designed to conserve the FSS Ku-band frequency spectrum in which it operates. One or more satellite transponders provide two-way service, to and from the aircraft. On a given transponder, the Forward and Return links[2] share the same uplink frequency in the 14.0-14.5 GHz range and the same downlink frequency in the 11.7–12.2 GHz range. This access technique that allows simultaneous transmission of two independent signals in a single bandwidth is referred to herein as Paired Carrier Multiple Access (PCMA). A piece of equipment described as the PCMA

[2] The communications channel from the ground station to the aircraft terminals is designated the Forward link, and the channel from the aircraft terminals to the ground is designated the Return link. Transmissions to the satellite are referred to as uplinks, and transmissions from the satellite are referred to as downlinks.

Hub Canceller at the GES separates Return downlinks from the Forward downlink and routes them to the demodulator for further processing.

This Technical Description describes ViaSat's application for authority for an AMSS system and provides details of the Arclight technology. ViaSat's waiver request and request to operate non-conforming antennas are set forth in this Section 1. Section 2 of this document provides a detailed description of the components that comprise the system. The spectral properties of the Forward and Return link waveforms are described in Section 3. Link budgets for the designated SES Americom satellite are provided in Section 4. The Spectrum Protection measures built into the system are described in Section 5. Appendix A provides a Glossary of terms. A Radiation Hazard Analysis of the ViaSat AMSS system is provided separately in Exhibit 1.

The Arclight technology has been designed, tested, and operated pursuant to several different licenses. Initially conceived as a VSAT product, testing of the Arclight technology was performed under ViaSat's Experimental License, call sign WD2XAQ, granted by the FCC to ViaSat on March 03, 2003.[3] Further, ARINC's SKYLink AMSS system incorporates ViaSat's Arclight technology. In connection with ARINC's system, ViaSat performed additional flight and operational testing under ARINC's Experimental License, call sign WC2XPE, granted by the FCC to Aeronautical Radio Inc., October 25, 2001, with a modification to authorize a Market Study issued on June 3, 2003. On April 6, 2005, the FCC granted to ARINC license E030205 for its SKYLink service.[4] ViaSat operates this service for ARINC out of ViaSat's Carlsbad, California headquarters facility.

In addition to the testing and commercial operation of the Arclight technology over the past two years in the U.S., ViaSat has also operated two Arclight hubs in Europe on Eutelsat spacecraft during 2005. One hub supports U.S. government comm-on-the-move (COTM) ground mobile applications (GMSS) and the other hub supports both commercial AMSS and GMSS operations.

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[3] ViaSat has made several modifications to that Experimental License to obtain authorization for additional test activities.

[4] *ARINC Incorporated, Application for Blanket Authority for Operation of Up to One Thousand Technically Identical Ku-Band Transmit/Receive Airborne Mobile Stations Aboard Aircraft Operating in the United States and Adjacent Waters*, File Nos. SES-LIC-20030910-01261, SES-AMD-20031223-01860, Order and Authorization, DA 05-1016 (rel. Apr. 6, 2005).

1.1 Request for Waiver of the Commission's Rules and for Authority to Operate Non-Conforming Antenna

1.1.1 Waiver of Domestic Allocation for Downlink Band

ViaSat respectfully requests a waiver of Section 2.106 of the Commission's rules to permit downlink operations for ViaSat's Arclight AMSS system on a non-conforming, non-interference basis. Although the U.S. Table of Allocations does not currently include a domestic allocation for AMSS in the 11.7-12.2 GHz band, the downlinks for the Arclight system will operate within the coordinated limits for the AMC-6 satellite, as agreed upon by SES Americom and the operators of adjacent satellites. Therefore, adjacent satellite operations would be protected from harmful interference. In addition, ViaSat requests a waiver of any other Commission rules deemed necessary for the grant of authority for ViaSat's system described in this Technical Description.

1.1.2 Off-Axis Gain and Power Density of Non-Conforming Antenna

In this application, ViaSat requests authorization to operate antennas that are not compliant with the Section 25.209 reference pattern. Due to the small diameter of ViaSat's AES terminals, the antenna does not meet the off-axis gain pattern provided in Section 25.209(a)(1). The antenna is thus not subject to routine processing; however, by limiting the input power density of individual antennas, the system will operate below the EIRP density mask defined by Sections 25.209(a)(1) and 25.134(a).

~~ViaSat further requests that the Commission grant authority to exceed this power density mask for short periods in accordance with the exceedance table set forth in Section 2.4 of this Technical Description. Grant of such authority would provide ViaSat with the certainty it needs to employ contention protocols in its AMSS system. However, the coordination requirements of Section 25.134(b) of the Commission's rules should not apply to the short periods for which the limits could be exceeded. Adjacent satellites will be protected from interference by the use of spread spectrum modulation techniques. Spreading of emissions across the spectrum results in low amplitude waveforms, which appear to adjacent satellites as noise.~~

Technical data and detailed descriptions of the system that support ViaSat's request to use a non-compliant antenna are provided in Sections 3.3 and 5 of this Technical Description.

2 SYSTEM DESCRIPTION

ViaSat's AMSS system provides two-way satellite data communications between AES terminals and a GES. The data entering and leaving the system is formatted in accordance with the TCP/IP protocol (Transmission Control Protocol/Internet Protocol). In a TCP/IP network, data is moved in datagrams that can be as large as 1500 bytes. Within the system, the TCP/IP datagrams are formatted for transmission over the satellite channel with additional overhead for error correction encoding and interleaving to provide a robust bi-directional channel. The Arclight system is a real-time (rather than a store-and- forward) system.

2.1 Satellite Network Overview

A Network Operations Center (NOC) at the GES authorizes AES terminals to connect to the system. To establish this connection, the aircraft terminal must first acquire the Forward link on the assigned satellite transponder and then wait for a periodic status message from the Network Control System (NCS) at the NOC. Once received, the terminal will initiate a login sequence as described in Section 2.4.2. The login process will prevent the use of unauthorized transmissions from terminals not authorized to enter the Arclight network.

The current Forward link modulator supports data rates between 512 kbit/s and 10.0 Mbit/s. The actual operating data rate is dependant upon link budget and leased bandwidth constraints. Prior to transmission, a robust Rate 1/3 Parallel Concatenated Convolutional Code (PCCC) forward error correcting (FEC) code is applied to the user data. The encoded data stream is direct sequence spread with a noise like pseudo-random spreading code (PN code) at an integer chip to bit ratio. The chip/bit ratio is configured as desired to insure that the Forward link fits within the available leased bandwidth. The spread signal is then applied to an Offset-Quadrature Phase Shift Keying (OQPSK) modulator and then upconverted for transmission over a standard FSS transponder.

The transmitted signal is up-linked from the GES antenna with sufficient power to reach a nominal output back-off (OBO) of 2 dB on the satellite transponder (see link budgets in Section 4). The use of OQPSK modulation allows the Forward link to operate near saturation without significant spectral re-growth. With the Forward link operating near saturation, the maximum outbound downlink effective isotropic radiated power (EIRP) spectral density for digitally modulated signals complies with the requirements of Section 25.202(f).

Return link data rates are established based on network capacity and requirements. Available data rates include 32, 64, and 128 kbit/s. All AES terminals default to 32 kbit/s unless authorized to use a higher data rate by the NOC after assessing the aggregate Return channel EIRP spectral density from all AES terminals operating on that particular transponder. The Arclight system will ensure that the maximum aggregate off-axis EIRP density of all terminals in the network complies with the proposed off-axis

EIRP density mask described by the combination of Section 25.134(a) and Section 25.209(a)(1).

The Return link waveform is direct sequence spread, Gaussian Minimum Shift Keyed (GMSK) with Rate 1/3 PCCC FEC encoding and interleaving. Individual AES terminals access the shared Return link using a random access burst Code Reuse Multiple Access (CRMA) protocol. As described previously, the Return channels occupy the same bandwidth as the Forward channel, and are recovered using PCMA technology.

2.2 Hardware Description

The ViaSat AMSS hardware consists of the aircraft terminal segment and the ground segment. The satellite segment, which is leased from a Satellite Service Provider, is described in Section 2.3.

2.2.1 Aircraft Terminal Segment

The aircraft terminal segment of the ViaSat AMSS system is comprised of three major sub-assemblies: an Airborne Integrated Transceiver Router (AITR), an Antenna Control Unit (ACU) and a Tail-Mount Antenna Subsystem (TMASS). These sub-assemblies are based on existing, proven Ku-band technology. The AES equipment has been certified to conform to applicable RCTA specifications by the Federal Aviation Administration. A block diagram of the AES is shown in Figure 2-1. Figure 2-2 shows the AES components: AITR, TMASS, and ACU from left to right.

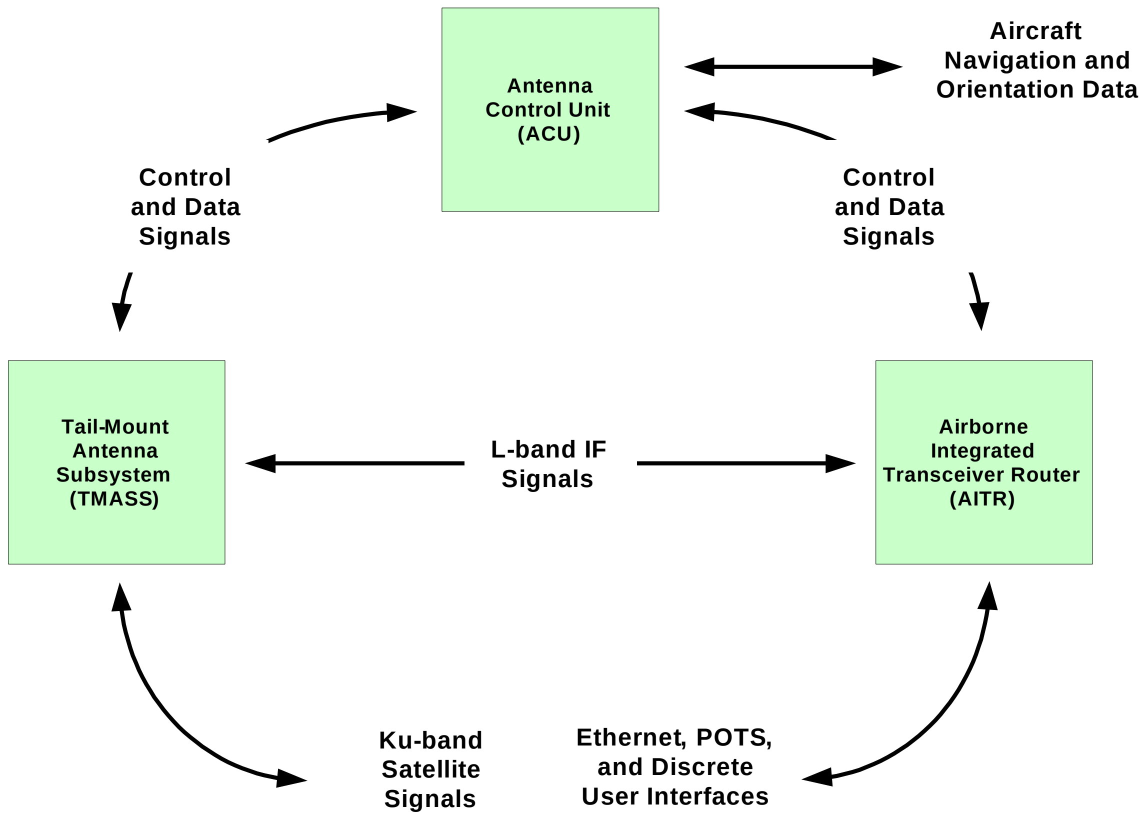

Figure 2-1 AES Block Diagram

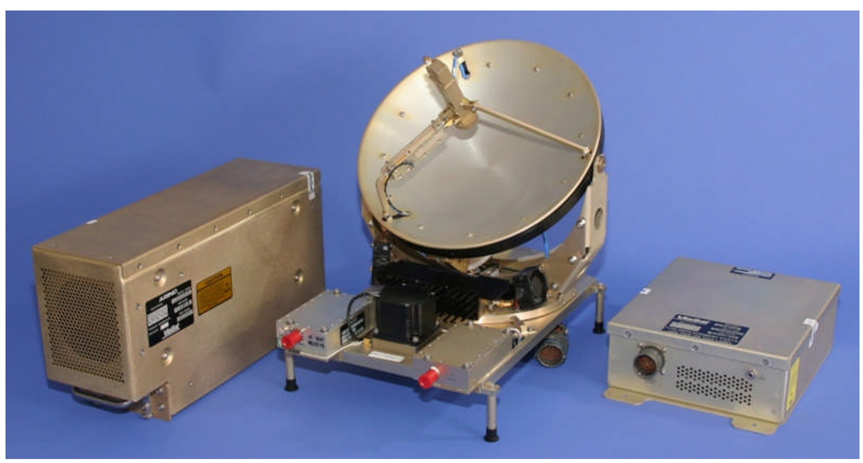

Figure 2-2 AES Components

2.2.1.1 Airborne Integrated Transceiver Router (AITR)

The AITR serves as the system controller for the AES. Its primary functions include the following:

- Packet routing at the local area network (LAN) Ethernet interface
- IP data encapsulation and recovery at the satellite interface

- Forward link continuous demodulation and decoding
- Return link encoding and burst modulation
- Implementation of power and frequency control algorithms
- Satellite network communications and control with the NOC
- Control of the ACU and indirectly the TMASS via the ACU
- User data transport
- Other miscellaneous functions

In addition, the AITR generates a precision reference frequency for the System and has multiple input and output discrete interfaces with the aircraft.

2.2.1.2 Tail-Mount Antenna Sub-System (TMASS)

The TMASS contains a steerable 0.2921 meter (11.5 inch) parabolic reflector antenna with dual-linear, prime focus feeds (transmit and receive). Under ACU control, the antenna rotates in three axes to obtain an optimal "look-angle" at the designated satellite through all normal flight altitudes of the aircraft. The TMASS includes the low noise amplifiers (LNAs) and downconverter for the receive functions and the upconverter and a class AB power amplifier for the transmit function. ViaSat developed the TMASS based on successful designs for systems deployed on oil drilling platforms and cruise ships, which also experience pitch, roll and yaw. ViaSat has refined those designs to work at altitude and temperature extremes typically experienced by aircraft.

The antenna steering provides continuous coverage of Azimuth angles (360°), 84º coverage of Elevation angles (6° to 90°), and 210º rotation for polarization. The TMASS is designed for mounting under a radome on top of the vertical stabilizer of an aircraft, but it can also be mounted under a radome on the crown of an aircraft fuselage. Figure 2-3 shows a larger view of the tail mounted antenna assembly.

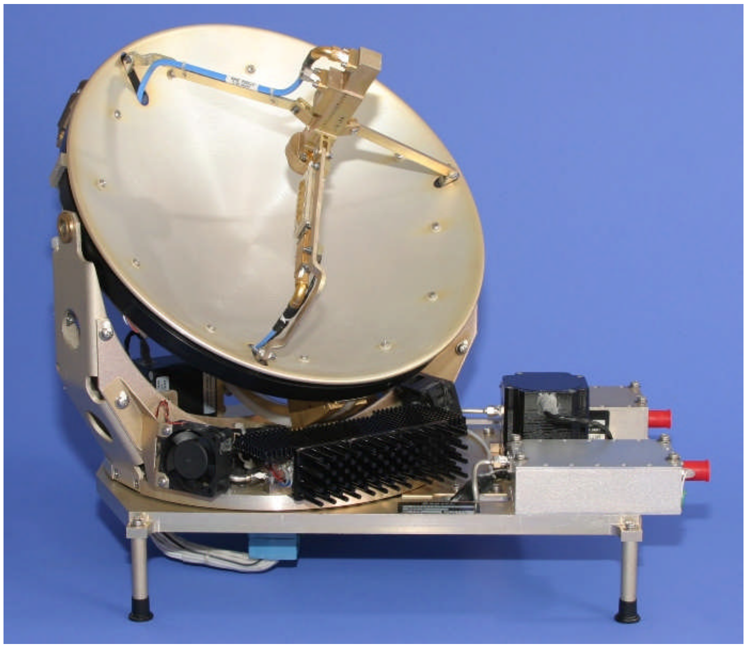

Figure 2-3 TMASS Assembly

The AES is capable of receiving in the frequency range of 11.7 to 12.2 GHz and 12.25 to 12.75 GHz, and simultaneously capable of transmitting from 14.0 to 14.5 GHz. Receive polarization choices are selectable as linear horizontal and linear vertical. Transmit polarization is linear and aligned to be orthogonal to the selected receive polarization. Technical details of the antenna including radiation patterns are provided in Section 3.1.

2.2.1.3 Antenna Control Unit (ACU)

The ACU is directed to steer the AES to a selected satellite by the AITR. The ACU uses aircraft position and attitude data received from the aircraft inertial navigation system (INS) to continuously determine how to position the antenna so that it points precisely at the selected satellite as the aircraft executes flight maneuvers. The ACU is directed by the AITR to the selected satellite and transponder. The pointing vector in space is determined from the instantaneous position and orientation of the aircraft and refined by the dynamic INS data, including Heading, Speed, Yaw and Yaw Rate, Pitch and Pitch Rate, Roll and Roll Rate, Latitude, Longitude, and altitude. Once the satellite is acquired, the ACU corrects for aircraft attitude changes based upon the INS data, without waiting for degradation in received signal strength. The ACU has successfully flown on experimental aircraft undergoing maneuvers outside of normal flight profiles and exhibited the ability to point the AES to the satellite throughout the extreme attitude changes encountered.

2.2.2 Ground Segment

2.2.2.1 Ground Earth Station

The primary GES for ViaSat's AMSS system is licensed under call sign E030131 and is located at a secure site in Carlsbad, California. This site has a number of domestic up and downlinks in operation. A 4.5 meter hub antenna and a Radio Frequency (RF) terminal currently provide the operational service for the ARINC's AMSS system. The GES is equipped with redundant 400 Watt high power amplifiers (HPA), of which approximately 50 Watts is needed to provide saturation of the transponder(s) assigned by SES Americom. The hub antenna has a receive G/T of 31.49 dB/K. The RF terminal is backed up with hot standby HPAs and low noise block converters.

2.2.2.2 Network Operations Center

The operation of the GES is monitored and controlled by a Network Management System (NMS) located in the NOC located in Carlsbad, California. The NOC is continuously staffed and monitors all RF transmissions and data flow through all assigned transponders. It is the responsibility of the NOC, using the NMS, to enable AITR-equipped aircraft to connect to the AMSS Network and to maintain control over their Return link transmissions.

2.3 Satellite Segment

SES Americom operates 16 geo-stationary orbit (GSO) satellites domestically and is planning to launch several more in the next two years. ViaSat previously utilized transponders from SES Americom for testing the performance and demonstrating the capability of the Arclight design under experimental authorization, WD2XAQ. For the initial rollout of the ViaSat AMSS Network on a commercial basis, transponder capacity on AMC-6 at 72º W.L. is being considered.

2.4 Network Management

The Arclight system has centrally controlled protocols for: (i) AES entry into the network; (ii) controlled authorization for the AES to transmit; (iii) controlled authorization to change transmit power or data rates; and (iv) the ability to terminate AES transmissions. As part of this control, the transmit power from each AES is monitored by the NMS and managed within a narrow range. The NMS is designed to ensure that the Arclight AMSS system operates in accordance with Commission's rules, including the power limits established in Sections 25.134(b), 25.202(f), 25.209(a)(1), and the transmitting antenna control requirements set forth in Section 25.271(c). Table 1 shows the effective mask defined by the combination of 25.134(b) and 25.209(a)(1).

Angle off-axis	Maximum EIRP Density in any 4 kHz band
$1.25° \leq \theta \leq 7°$	$15 – 25 \cdot \log_{10}\theta$
$7° < \theta \leq 9.2°$	-6
$9.2° < \theta \leq 48°$	$18 - 25 \cdot \log_{10}\theta$
$48° < \theta \leq 180°$	- 24

Table 1 Combined 25.209 and 25.134 Mask

Where: Θ is the angle in degrees from the axis of the main lobe.

The NMS will individually control the AES terminals in the network so as to ensure compliance on an aggregate basis. Aggregate EIRP density is managed by the NMS by a combination of Return link power control and ensuring that the number of simultaneous transmissions by AES terminals will not cause the aggregate off-axis EIRP density to exceed the mask in Table 1. ~~by more than the following levels for the corresponding amount of time:~~

~~Percentage of Time~~	~~Increase in Aggregate EIRP Allowed *~~
~~10% (10^{-1})~~	~~0 dB~~
~~1% (10^{-2})~~	~~2 dB~~
~~0.1% (10^{-3})~~	~~4 dB~~
~~0.01% (10^{-4})~~	~~6 dB~~
~~0.001% (10^{-5})~~	~~8 dB~~
~~0.0001% (10^{-6})~~	~~10 dB~~
~~0.00001% (10^{-7})~~	~~12 dB~~
~~0.000001% (10^{-8})~~	~~14 dB~~
~~0.0000001% (10^{-9})~~	~~16 dB~~

~~**Table 2 Exceedance Table**~~

2.4.1 Commissioning

Adding a new mobile AES terminal to the Arclight network starts with the installation of an AITR and TMASS on an aircraft. The AES will then be commissioned by the NOC before being granted access to the network. The NOC will exercise the built-in-test (BIT) functions and, when those have been successfully completed, will follow a written Test Plan to verify that transmissions from the AES fully comply with FCC regulations.

2.4.2 Log-in

The NMS at the GES has the responsibility for authorizing only commissioned AES terminals to "login" to the system. To accomplish login, the aircraft must be powered on and located in a position with a clear view to the satellite. The AES must acquire the assigned satellite transponder and subsequently receive and recognize the Forward data stream. The AES will seek authorization from the NOC to join the network each time the login sequence below commences. The NMS periodically broadcasts a configuration message over the Forward link that indicates to the AESs, among other things, the Return link assigned frequency and data rate. The NMS can be programmed to broadcast the message as often as once per second. Once acquired, the Forward link also provides the frequency reference for the Return link so that Return link login transmissions will be transmitted within a narrow frequency range for easier acquisition. The AES must recognize the NMS configuration message prior to transmitting on the Return link.

2.4.2.1 Log-in Sequence

Upon recognition of the NMS configuration message, the AES will transmit a login burst on the designated Return link. The initial login burst lasts approximately 16 ms and will be transmitted at a power level that is lower than normal transmissions to ensure that the login burst does not significantly affect the uplink aggregate EIRP density. The AES will wait approximately 10 seconds for a response from the NMS. If a response is received, the AES will adjust the transmit frequency and power of successive transmissions based on the response message from the NMS. If not received, the AES will increase power in 1 dB increments and send another login burst and wait for a response. Transmit power will only be increased up to a preconfigured maximum, which is well below the maximum transmit power for an AES antenna. If no response is received by the time the maximum power for login attempts is reached, the AES will drop the transmit power level back to the initial value, change frequency and continue login attempts. This cycle continues until the NMS recognizes the request.

Once login is successful, the AES can transmit user data and control messages as required and as allowed by the NMS. The Return uplink frequency and power will be under the positive control of the NMS. The Return link power control is described in Section 2.4.4 and Return link frequency control is described in Section 2.4.5.
The NMS can terminate successive login transmissions from individual AES as necessary, consistent with the requirements imposed by Section 25.271(c).

2.4.3 Return Link Transmission Authorization

An AES will transmit data bursts only when authorized by the NOC and only at a throughput rate authorized by the NOC. The NOC will authorize transmission if all of the following conditions are met:

- the AES has been commissioned;

- the AES has been logged in;
- the NOC has received no alarms from the AES;
- transponder bandwidth is available for the data rate requested; and
- transponder aggregate EIRP spectral density will remain below specified limits if the AES transmits.

Aircraft transmissions will cease immediately if any of the following occur:

- the NOC commands the AES to stop transmitting;
- the AES loses the Forward link from the GES for more than 1 second, typically;
- the ACU is unable to reliably track the satellite during rapid maneuvers;
- the AES detects a fault condition that may cause erroneous transmissions by the terminal (see Section 2.5); or
- the transmit frequency deviates from prescribed limits

The authorized throughput rate is different from the uplink data rate; the throughput rate is the allowable rate of data packets through the aircraft terminal and onto the satellite uplink. The Arclight System will implement a congestion control algorithm that will limit the number of simultaneous data packets on the Return link so as to control the aggregate Return link EIRP. The congestion control algorithm is described in more detail in Section 2.4.7.

2.4.4 Return Link Power Control

Maintaining the Return link aggregate EIRP spectral density below the EIRP spectral density envelope (see Section 5.1) requires that each AES sharing a Return link transponder be under transmit power control. The Arclight system utilizes "closed" power control to control uplink power on the Return link. The closed-loop power control will ensure that a constant EIRP towards the desired satellite is maintained during normal operation including aircraft attitude changes.

The "closed-loop" algorithm accounts for various signal losses and noise floor increases on both the Return link uplink to the satellite and Return link downlink to the GES. The NMS sends the adjustment parameter in accordance with the closed- loop algorithm. The GES estimates the received power and E_b/N_o (energy per bit divided by noise density) whenever a Return link transmission is received at the GES. The estimates are compared to a target level corresponding to the level desired at the NMS earth station.

The receive E_b/N_o at the NMS earth station can be used as a measure of the AES's EIRP directed towards the desired satellite because the Return link performance is determined by the link between the AES and the satellite, and also because the NMS tracks the location of the aircraft in relation to the G/T contour of the satellite antenna. The closed-loop power control algorithm also includes parameters for the current GES uplink power control settings and received beacon signal strength. To ensure that the closed-loop power control algorithm is updated on a sufficiently frequent basis, the NMS periodically polls the status of the AES terminals.

2.4.5 Return Link Frequency Control

Whenever the GES receives a transmission from an AES, a frequency error estimate is calculated. If the frequency error exceeds a predefined threshold, the NMS sends a correction message to the AES. This “closed-loop” frequency tracking capability allows for frequency drifting due to temperature and oscillator aging in the AES. In addition to frequency drift, frequency Doppler is pre-compensated on the Return link based on aircraft attitude information supplied by the aircraft INS.

As the aircraft travels toward or away from the satellite, the ACU utilizes data regarding the velocity relative to the satellite to accurately determine the Doppler frequency offset. The frequency is updated at a rate greater than once per second for the worst case frequency Doppler of ±16 kHz and a corresponding worst case frequency Doppler rate of change of about ±250 Hz/sec. For system protection, the Return link transmit frequency is monitored by the AES; and, if it deviates beyond prescribed limits, the AES will cease transmitting.

2.4.6 Data Rate Selection

The Arclight network architecture supports Return link data rates of 32, 64, 128, 256, and 512 kbit/s. The actual assigned Return link data rate is determined based on the link budget and network capacity and will be under the positive control of the NOC. The NOC uses positive control to assign the Return link data rate, and as such, an AES will only transmit at a rate determined by the NOC. Higher Return link transmit power is required to assure a positive link margin for higher data rates. Consequently, fewer AESs are allowed to transmit simultaneously at higher data rates to ensure that the aggregate EIRP density is not exceeded at adjacent satellites.

In addition, the NMS will have the capability to command all or individual AESs to change data rates for better control of network capacity. In all cases, the congestion control algorithm will ensure compliance with the maximum aggregate EIRP density.

The exact number of simultaneous transmissions at each data rate depends on the link budget; Table **2** ~~3~~ below provides a representative example of how the Return link data rate affects the number of allowed simultaneous transmissions by data rate. Typically, all of the AESs will operate at the same Return link data rate. However, the Return link data rate can be set on an individual AES basis to accommodate a higher data rate as a premium service offering.

32 kbit/s	64 kbit/s	128 kbit/s
136	0	0
0	68	0
0	0	34
68	0	17
52	26	8

Table 2 ~~3~~ Maximum Simultaneous Return Link Transmissions

The Arclight network supports Forward link data rates between 512 kbit/s and 10.0 Mbit/s. The higher the data rate, the more Forward link transmit power (satellite EIRP) is required to assure a positive link margin, and as a result the coverage area will be smaller. Typically, all of the AESs will operate at the same Forward link data rate, which, based on the link budgets and actual test results, is currently 3.5 Mbit/s.

2.4.7 Congestion Control

The NMS manages the aggregate EIRP density by implementing Return link power control and by ensuring that the total number of simultaneous transmissions by AESs will not exceed the maximum routinely authorized **aggregate** EIRP density ~~more than the values set forth in the proposed contention table~~. The number of simultaneous transmissions is managed using a congestion control algorithm.

The following definitions are applicable to the description of the congestion control mechanism:

- Capacity: The number of equivalent, simultaneous, minimum E_b/N_o transmissions allowed over the Return link.
- Transmit Duty Cycle: Percentage of time that the transmitter may be on while transmitting bursts to the NMS demodulator. The Transmit Duty Cycle can be set between 0 and 100%.
- P_{Sim} : Probability of Simultaneous Transmission: Return link data is divided into packets that are transmitted randomly. Packets can overlap and be recovered as long as the overlap of two packets is not within 2 spread spectrum chips of each other.
- P_{Col}: Probability of Packet Collision: Packet collisions occur when a Return link data packet is transmitted within 2 spread spectrum chips of another packet.

Congestion is controlled to manage the traffic generated by users logged into the system. The congestion control algorithm monitors the average number of simultaneous accesses, and maintains access to a level such that the peak number of simultaneous accesses is less than capacity ~~most of the time (see Table 2)~~. The congestion control algorithm includes as an input the estimated number of simultaneous Return link transmissions provided by the GES Return link demodulator. This estimate does not include packet collisions, however $P_{col} << P_{sim}$ for all cases of interest. This is because the packet length is significantly larger (>172,000 chips) than the number of chips required for a collision to occur (2 chips). For an IP network, it is difficult to accurately model the statistics of the data traffic due to the variety of uses, e.g., mouse clicks, ftp file transfers, voice over IP, etc. However, by monitoring the traffic load in real-time, the NMS can limit traffic over the channels by limiting transmissions as necessary from the terminals.

The Arclight congestion control algorithm limits transmissions of individual AESs by limiting the Transmit Duty Cycle of individual terminals. The NMS tracks the number of simultaneous transmissions over time and sends a traffic control parameter to the AESs in the NMS periodic status message. The traffic is limited at the LAN IP interface to the AES. By dropping packets at the IP interface, the congestion that would otherwise occur on the satellite network, instead occurs on the LAN that is connected to the AES on the user side. The TCP/IP protocol manages congestion on the LAN.

2.5 Fault Management

Fault Management has been designed into the AES as the controlling element of the AMSS platform, and into the ground support equipment in the Arclight system. The purpose of this Fault Management is to preclude any transmission that could interfere with other operations in the FSS spectrum due to anomalous behavior of any element in the Arclight system.

2.5.1 Aircraft Terminal Fault Management

The AESs in the Arclight network contain the following fault management controls:

- In the event of terminal hardware failures, including absence of the local oscillator (LO), loss of LO frequency lock and on-board processor failure, the AES will cease transmission.
- In the event of terminal failures that result in loss of communication between the antenna, antenna controller, or the transmit/receive sub-system, the AES will cease transmission.
- In the event of out-of-range temperature reporting, the AES will cease transmission.
- In the event of any other failure alarm or out-of-tolerance status notification that could result in an out of specification AES transmission, the AES will cease transmission.
- In the event that the NOC periodic status message is not received, the AES will cease transmission (even if the Forward link signal is still received).

2.5.2 Ground Earth Station Fault Management

The GES in the Arclight Network contain the following fault management controls:

- If the GES loses communications with the NOC, all AESs are commanded to cease transmissions within 820 ms, worst case.
- If an AES fails to properly respond to power control commands, that AES is commanded to cease transmissions within 250 ms.
- If an AES fails to properly respond to data rate change commands, that AES is commanded to cease transmissions within 250 ms.

In addition, transmission from the GES will cease when any of the following conditions occur:

- the satellite operator advises the NOC that harmful interference has been detected; or
- the NOC receives failure data from the GES.

3 SPECTRUM MANAGEMENT

Spectrum management includes managing the spatial distribution of energy emitted by elements of the Arclight system, which is determined by the antenna design, and the spectral distribution of that energy, which is determined by the transmit subsystem design and wavefoms.

3.1 AES Antenna Performance

In general, the AES antenna design determines how much of the Return link energy transmitted from the AES illuminates adjacent satellites. Antenna design also determines the Forward link performance.

3.1.1 Antenna Description

As described in Section 2.1.1.2, the AES antenna is a 0.2921 meter (11.5 in.) parabolic reflector with a prime focus mounted transmit/receive feed. The AES was designed to be mounted under a radome on top of the aircraft tail. The same antenna is used to transmit and receive orthogonally polarized signals simultaneously. It is continuously steered in azimuth, elevation and polarization to optimize the coupling between the antenna and the signal in space. The antenna performance is comprised of its receive and transmit patterns and pointing accuracy toward the satellite.

3.1.2 Antenna Patterns

One advantage of a mechanically steered parabolic reflector antenna is that its patterns are relatively constant as a function of its pointing angles. The effects of a non-isotropic radome and elements of the airframe impinging on the near field are measurable but do not result in enlarged sidelobes. Despite the co-linear transmit and receive feeds, the antenna's receive and transmit patterns are slightly different.

3.1.2.1 Receive Patterns

The parabolic reflector antenna receives the Forward link waveform. The receive characteristics of that AES determine the Forward link performance. The receive gain of the AES antenna was measured, without a radome, at 11.70 GHz, 12.225 GHz, and 12.75 GHz. The resulting E & H-Plane antenna patterns are plotted below in Figure 3-1.

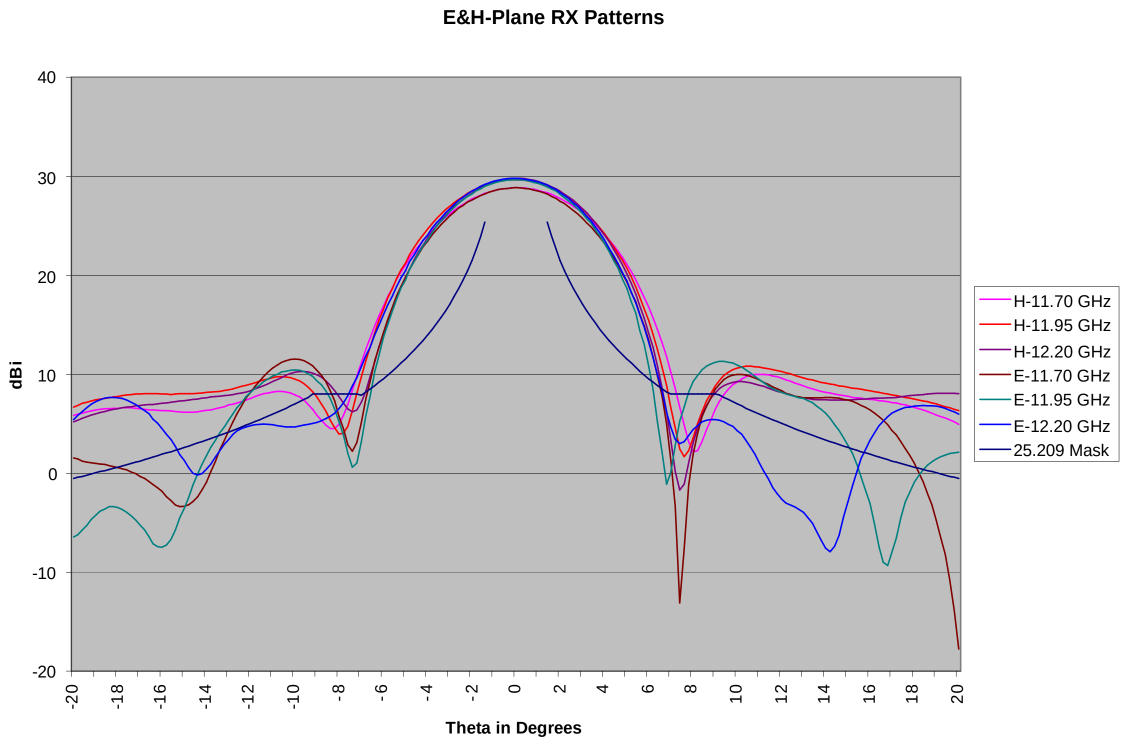

Figure 3-1 E&H-Plane Antenna Patterns

The measured receive antenna gain at the center of the beam is 28.94 dBi and is one of the key parameters in computing the Forward link budget (see Section 4.2).

Also, these patterns illustrate that the relative antenna gain at 2º off-axis is only about 1.3 dB less than the gain at boresight. This produces a significant co-channel interference component in the received Forward link spectrum. The Arclight system utilizes a spread spectrum Forward link waveform to mitigate the effect of the potential co-channel signals and, based on the processing gain, will recover the waveform with adequate margin.

3.1.2.2 Transmit Patterns

The parabolic reflector antenna transmits the Return link waveform. The transmit characteristics of this AES determine the Return link performance. In addition, the transmit characteristics determine the off-axis emissions. The transmit gain of the AES antenna was measured, without a radome, at 14.0 GHz, 14.25 GHz and at 14.5 GHz. The resulting antenna patterns are plotted below in the E and H-Planes in Figures 3-2 and 3-3. These plots include for reference the threshold defined in Section 25.209(a)(1) of the Commission's rules by the formulas:

$29 - 25 \cdot \log_{10}(\Theta)$	dBi	from	$1.25^\circ \leq \Theta \leq 7.0^\circ$
$+8$	dBi	from	$7.0^\circ < \Theta \leq 9.2^\circ$
$32 - 25 \cdot \log_{10}(\Theta)$	dBi	from	$9.2^\circ < \Theta \leq 48^\circ$
-10	dBi	from	$48^\circ < \Theta \leq 180^\circ$

The power density into the antenna input must be reduced to meet the spectral mask defined by Section 25.209(a)(1). This reduction, Δ, is accounted for in the link budgets by a reduction in the peak allowable antenna input power density, defined by 25.134(a). See Sections 3.3.1 for a detailed discussion.

In addition, the power density is further reduced due to the use of Rate 1/3 FEC encoding combined with Direct Sequence Spread Spectrum (DSSS) modulation. The spreading reduces the spectral density in proportion to the ratio of the spread bandwidth to the data bandwidth. For example, in the case of 128 kbit/s data transmissions, with the power density reductions mentioned above, the transmit EIRP density at the center of the beam is only -9 dBW/4 kHz. See Figure 3-4. Off-axis transmit antenna gain is one of the key parameters in computing the Return link budget (see Section 4.2).

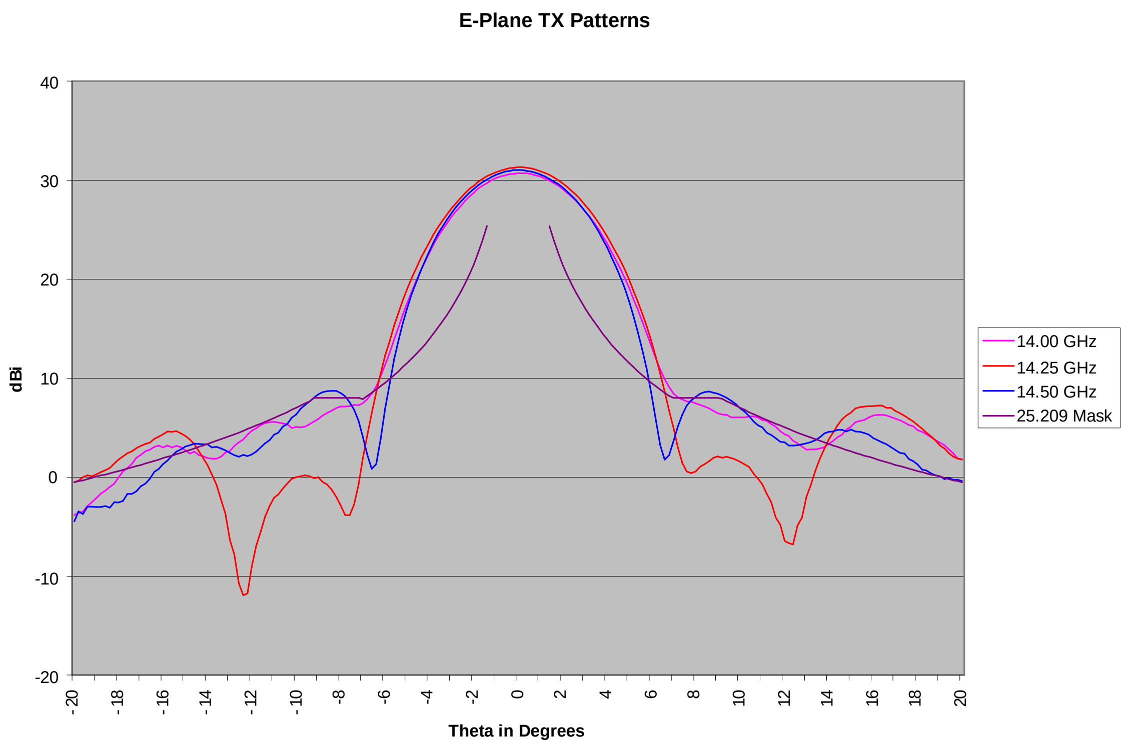

Figure 3-2 Measured Transmit E-Plane Pattern

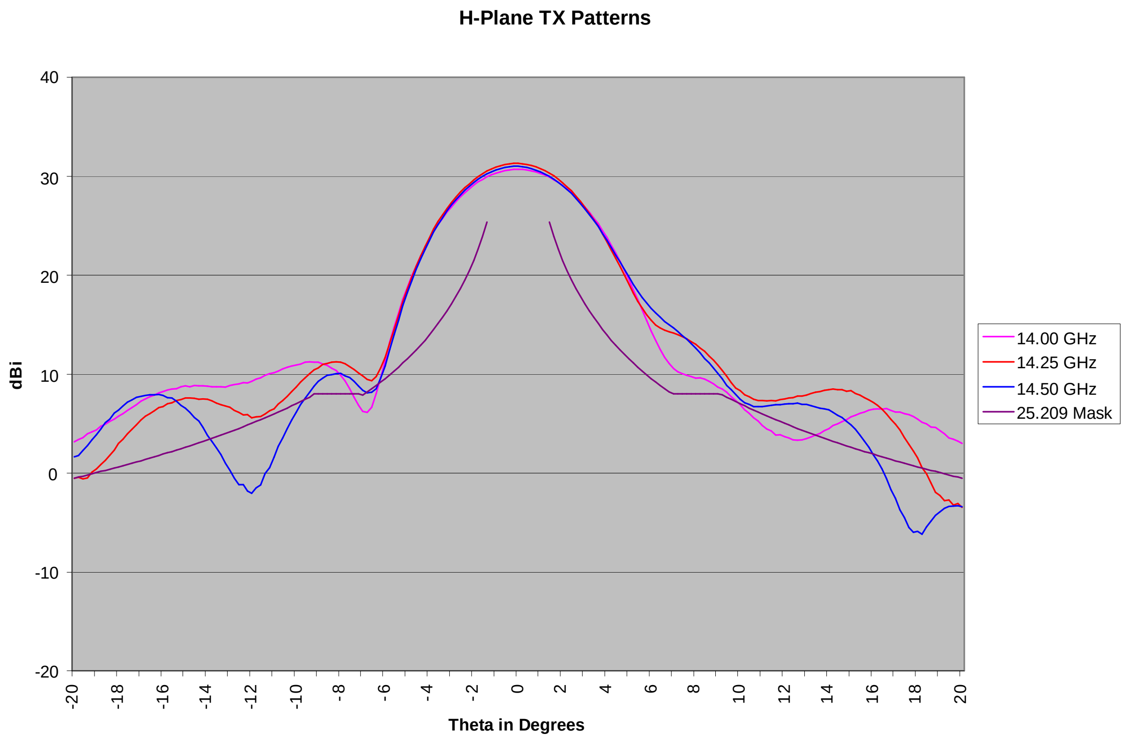

Figure 3-3 Measured Transmit H-Plane Pattern

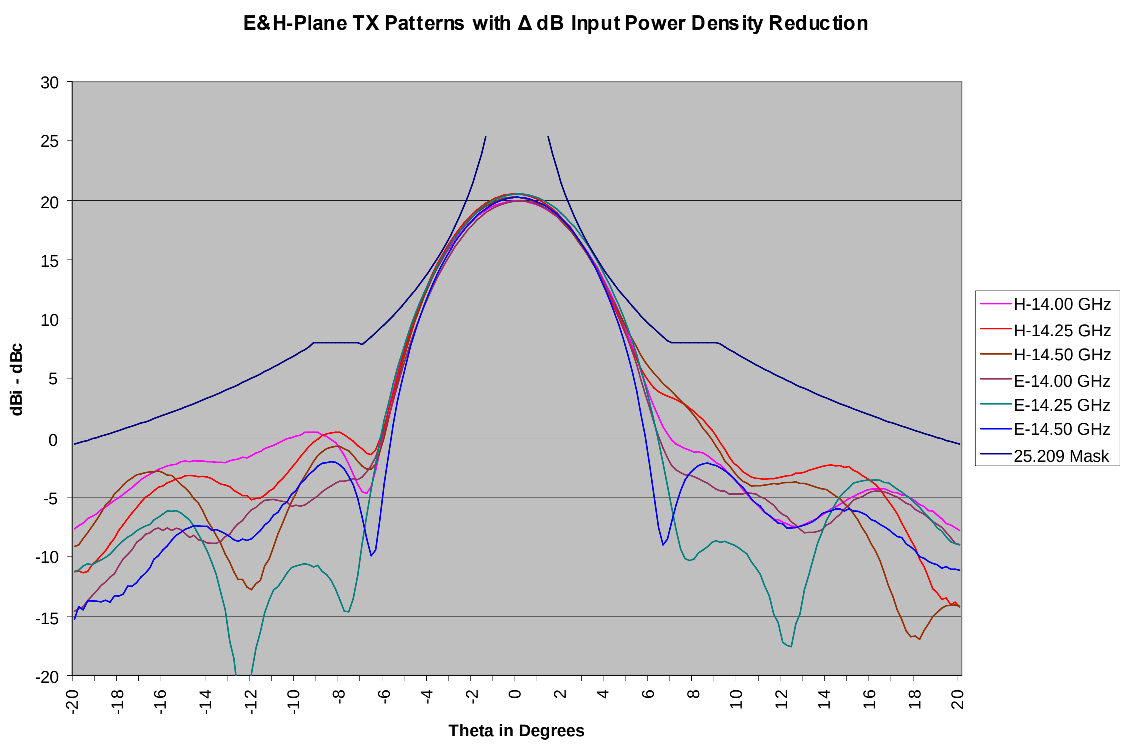

Figure 3-4 Measured E&H-Plane Patterns with Δ dB Input Power Density Reduction

3.1.3 Antenna Control

This section provides descriptions of the antenna pointing and polarization control of the Arclight AES. The system is designed to prevent transmission from a mispointed AES. The AES must be locked onto the correct transponder and actively receiving authorization to transmit. The AES uses data from the aircraft's INS to anticipate movement of the aircraft and to correct for attitude changes so that the AES maintains a lock on the transponder during flight. Any maneuver or navigational failure that prevents the antenna from properly pointing to the satellite will disrupt the received signal and shut down the transmitter within 1 second. Any airborne alarm condition that could cause an erroneous transmission, including off-axis, off-frequency, or off-power conditions, also terminates transmission until such condition is corrected.

3.1.3.1 Antenna Installation and Calibration

Prior to commissioning, the AES will be installed on the aircraft and calibrated. The AES is oriented during installation based on detailed installation drawings. Following installation, the antenna is calibrated under the control of the AES. The calibration is performed by moving the antenna off-axis around the expected beam center and then peaking the received Forward link power. Coherent power detection is used to mitigate the influence of adjacent satellites. Periodically, the NOC will initiate a calibration cycle of the antenna system.

3.1.3.2 Operational Antenna Pointing

Accurate pointing of the antenna is achieved under direction of the ACU described in Section 2.2.1.3. The ACU determines the desired antenna azimuth and elevation by executing an open loop pointing algorithm using:

- ephemeris data stored in the AES to determine the satellite location and polarization;
- stored constants to determine the antenna orientation relative to the airframe;
- Latitude, Longitude, and altitude data from the aircraft INS to determine the aircraft location;
- Heading, Yaw, Pitch, and Roll data from the aircraft INS to determine the aircraft
- orientation; and
- Speed, Yaw Rate, Pitch Rate, and Roll Rate data from the aircraft INS to predict changes in aircraft location and orientation.

Once the satellite is acquired, the ACU corrects for aircraft altitude changes based upon the INS data, without waiting for degradation of the received signal strength. The AESs access the INS data every 0.02 seconds, with a data resolution (least significant bit) of 0.05º. The ACU computes the desired antenna azimuth, elevation and polarization

1024 times every second (approximately once every millisecond). The antenna mechanical resolution is 0.09º. The antenna can slew in azimuth and elevation at more than 15º per second, which is sufficient to track aircraft motion within a normal flight envelope. The total root mean square pointing error for the antenna is calculated to be less than 0.1º, which is sufficient to satisfy the requirements for minimizing off-axis emissions, while maintaining the necessary gain for proper system operation.

The link quality measures of E_b/N_o and the packet loss rate will be used to determine when the Forward link has degraded to the point where loss of antenna pointing will be declared. The Return link transmission is terminated typically within 1 second of loss of the Forward link. Return link transmission resumes when the system lock is restored.

3.1.3.3 Polarization Control

The antenna receive polarization choices are selectable as linear horizontal, linear vertical, right-circular or left-circular. Transmit polarization is linear and aligned to be orthogonal to the selected receive polarization. The antenna reflector can be rotated 210º for fine control (0.25º) of the polarization. The ACU executes an open loop algorithm using the same inputs that it uses for antenna pointing to control the polarization.

3.2 Waveforms

3.2.1 Satellite Access Techniques

The Forward link and Return links will simultaneously share the same uplink and downlink spectrum by a technique previously described in the Introduction as PCMA. Return link signal recovery will be aided by the use of the PCMA Hub Canceller. The Return link is shared between multiple AESs using burst transmissions with the same or different spreading codes. The NOC assigns the Return links of AES terminals in use to particular frequencies to evenly distribute the Return links across the leased bandwidth. As additional new AESs log in to the network, the NOC reassigns the Return links as required to maintain an even distribution. The burst time intervals of transmitting AESs occur randomly, and thus, the GES demodulator recovers the transmissions based on the random arrival time. Based on this description, the Return link is best characterized as a Code Division Multiple Access (CDMA)/Aloha contention based protocol.

3.2.2 Out of Band Emissions

With respect to spurious emissions, the Forward link signal of the Arclight System meets the limits of Section 25.202(f). The Forward link waveform is DSSS, OQPSK with an underlying antipodal (BPSK) data stream. The Return link waveform is DSSS, GMSK. The Return link data rates are as described in Section 2.4.6. The Return link employs spectrum spreading, and thus, the Return link occupies either half of a transponder (18 MHz) or all of a transponder (36 MHz) depending upon Return link data rate. At 32 kbit/s, there will typically be two Return link frequencies per Forward link frequency, and the Forward link will occupy a full transponder. Return links operating at 64 kbit/s or higher will utilize the full transponder bandwidth, if available. Based on these link budgets and the use of PCMA, the Return link complies with the requirements of Section 25.202(f). The aggregate Return link spectrum will always be at least approximately 20 dB below the Forward link spectrum. Consequently, the spectral density of the aggregate Return links will be approximately 15dB-PSD below the level required at the authorized bandwidth and will satisfy Section 25.202(f).

3.3 Power Densities

Section 25.134(a) of the Commission's rules describes the maximum routinely authorized power densities at both the outbound uplink and outbound downlink. The outbound uplink power density described in this section is the on-axis density. The off-axis outbound uplink power density is discussed in Sections 5.2.

3.3.1 Outbound On-Axis Uplink Power Density

Section 25.134(a) of the Commission's rules specifies the maximum routinely authorized outbound uplink power density into an antenna to be –14 dBW/4 kHz. Including the antenna back-off, Δ, as described in Sections 3.1.2.2 and 5.1, the equation describing the maximum routinely authorized aggregate Return link uplink PSD is:

$PSD_{rul} = -14 - \Delta = -24.25$ dBW/4kHz (1)

Note that $\Delta = 10.25$ dB is necessary to satisfy off-axis emission requirements as described in Section 5.1.

The required AES transmit power is a function of the Return link data rate. The aggregate Return link power is computed as the sum of the contributions from all simultaneous transmissions in the network. This sum is calculated in accordance with the formula:

$PSD_{actual} = n32 * P32 + n64 * P64 + n128 * P128$ (2)

Where PSD_{actual} is the network aggregate uplink peak power spectral density (PSD), as it would appear at an antenna input. In equation (2), n32 is the number of AESs uplinking at 32 kbit/s and P32 is the required uplink power density for a 32 kbit/s link, and so forth for the remaining rates. The ViaSat NOC controls the AES data rates, transmit powers, and throughput to maintain aggregate Return link power below the threshold described by equation (1).

3.3.2 Outbound Downlink Power Density

Section 25.134(b) of the FCC Rules requires coordination of VSAT networks operating in the 12 GHz band using digital signals with an EIRP spectral density greater than +10.0 dBW/4 kHz. Based on the link budgets for the Arclight system, the maximum Forward link downlink EIRP density for the Forward link is 9.8 dBW/4 kHz.

While the Return link transmissions also share some of the transponder capacity and are present in the downlink signal, the power density contribution from these carriers is negligible in comparison to the Forward link's downlink EIRP density. From the link budgets, the composite downlink EIRP density for the Return links is -13.8 dBW/4 kHz and therefore coordination is not required for the space to earth downlink.

4 Link Budgets

4.1 CONUS Service Contours

The initial ViaSat AMSS service offering will utilize a Ku-band transponder on AMC-6, located at 72º West Longitude. Figures 4-1 and 4-2 show the EIRP and G/T contour for a representative transponder on AMC-6. Data for the Link Budgets, which follow the contour maps, have been developed from the contour data in these figures.

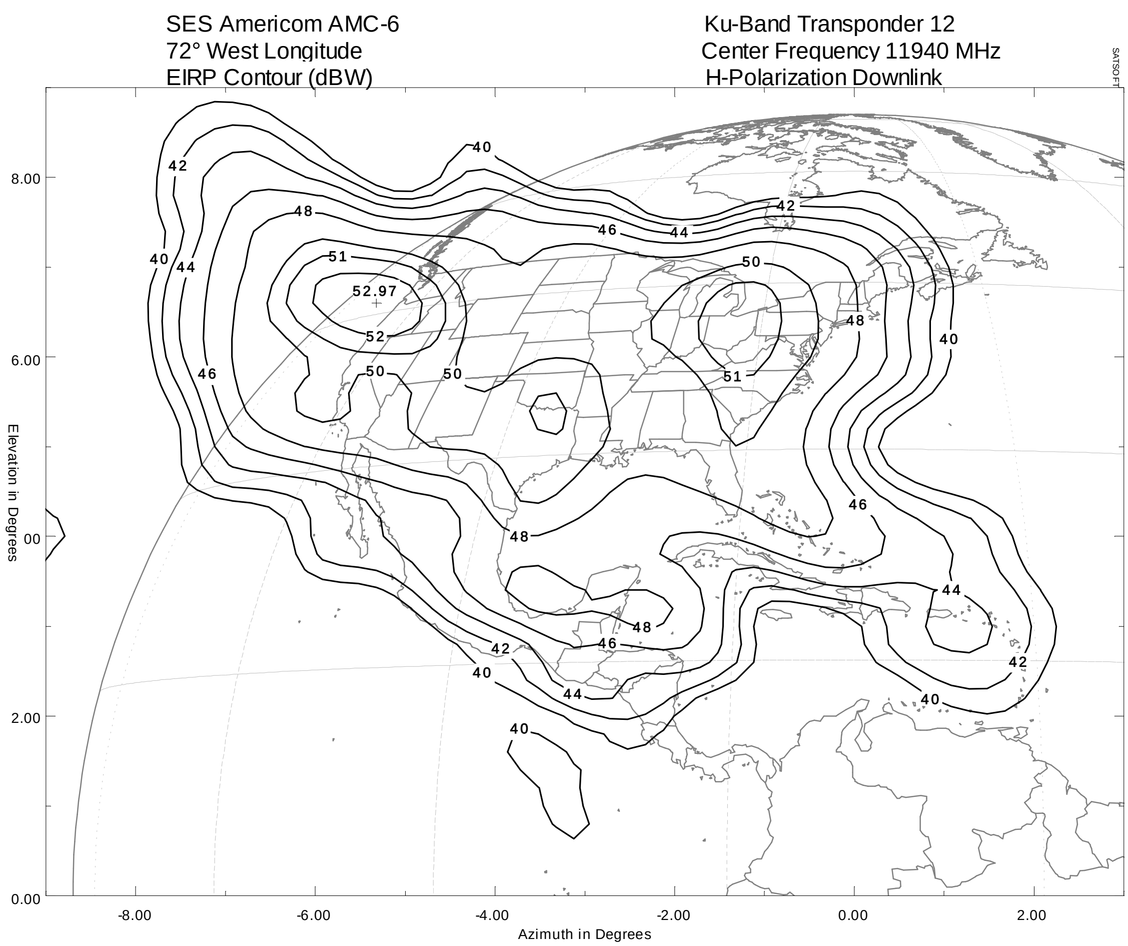

Figure 4-1

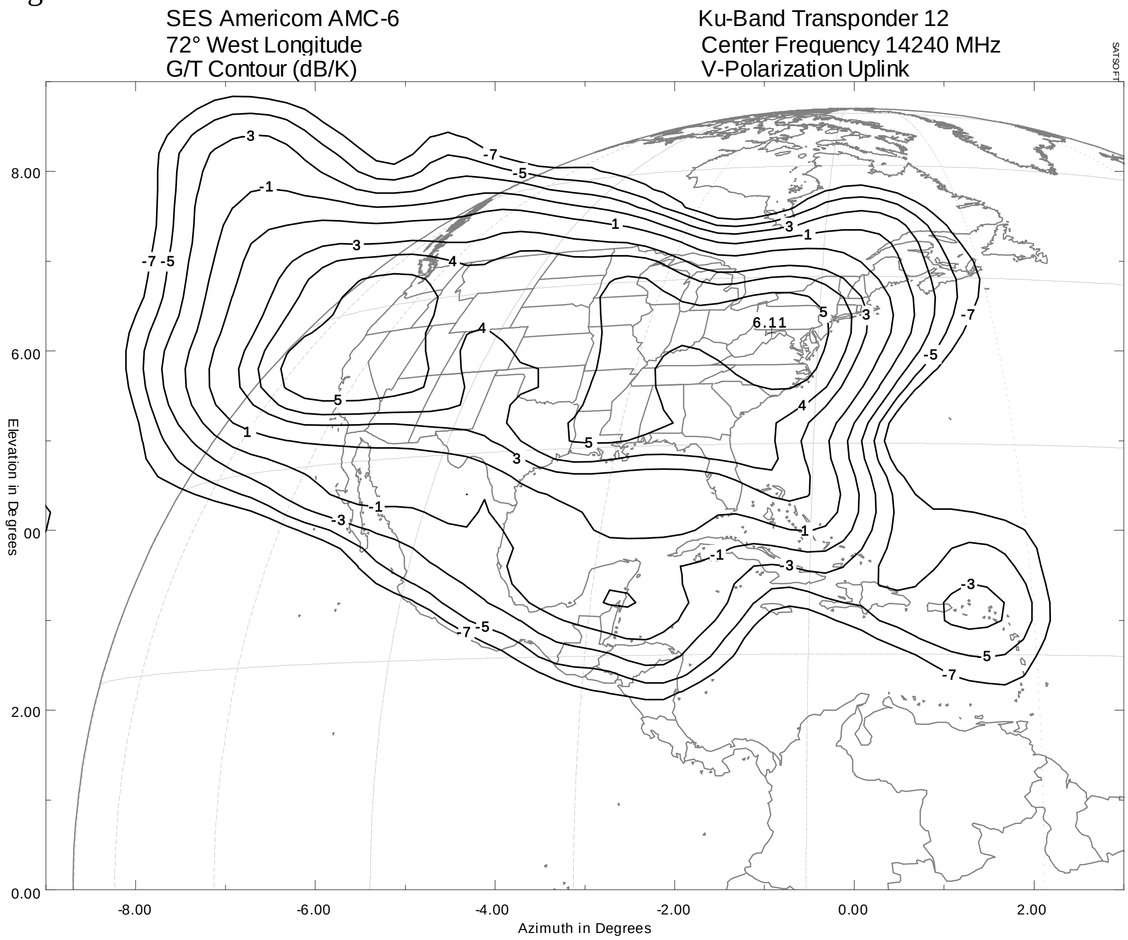

Figure 4-2

Figure 4-1 EIRP Contour

ViaSat Proprietary

Tail Mount Ant. Forward Link budget (hub to aircraft)

Satellite Name	AMC-6		Data Rate	3510000	bps		
Satellite Location	72.0	Deg W	Bit Error Rate	1 x 10E-7			
Satellite Center Beam EIRP	51.50	dBW	Eb/No Required	1.7	dB		
Satellite EIRP in direction of DL ES	49.00	dBW	C/No Required	67.15	dB-Hz		
Satellite SFD in direction of UL ES	-95.50	dBW/m^2	Availability Required	99.80%		Uplink	
Satellite Input Attenuator	6.0	dB	ITU Uplink Rain Zone	N/A			
Operating SFD (NCS value)	-89.50	dBW/m^2	ITU Downlink Rain Zone	N/A			
Satellite G/T in direction of UL ES	2.5	dB/K	Modulation Type	QPSK - DSSS			
Satellite Input Back Off	3.0	dB	FEC Factor	Rate 1/3 TC			
Satellite Output Back Off	1.0	dB	Spread Factor : Bandwidth	5.000		27000	kHz
Satellite Transponder BW	36	MHz	Carrier Spacing	1			
Satellite Translation Frequency	2,300	MHz	Spread Bandwidth : Signal Bandwidth	35100.0		5400.0	kHz

Uplink Name	Hub		Downlink Name	AMSS	
Uplink Location Latitude	33.1	Deg N	Downlink Location Latitude	40.0	Deg N
Uplink Location Longitude	117.2	Deg W	Downlink Location Longitude	95.0	Deg W
Uplink Frequency	14240.0	MHz	Downlink Frequency	11940.0	MHz
Uplink Antenna Size	4.5	m	Downlink Antenna Size	0.2921	m
Uplink Antenna Efficiency	0.59		Downlink Antenna Efficiency	0.58	
Uplink Antenna Gain	54.24	dBi	Downlink Antenna Gain	28.89	dBi
Uplink EIRP	71.01	dBW	Downlink Antenna LNA Temp	90	K
Uplink Output Circuit Loss	0.5	dB	Downlink Antenna Noise Temp	37	K
Uplink PA Output Power	53.274	Watts	Downlink Rain Noise	0.00	K
Uplink PA Output Power	17.27	dBW	Downlink Earth Station G/T	7.85	dB/K
Uplink Rain Attenuation	1.00	dB	Downlink Rain Attenuation	0.00	dB
Uplink Misc Losses	1	dB	Downlink Misc Losses	1.5	dB
Uplink Elevation Look Angle	28.52	Deg	Downlink Elevation Look Angle	38.02	Deg
Uplink Azimuth Look Angle	118.45	Deg	Downlink Azimuth Look Angle	146.56	Deg
Uplink Slant Range	38755.24	km	Downlink Slant Range	37947.14	km
Uplink m^2 Antenna Gain	44.52	dBi	Downlink m^2 Antenna Gain	42.99	dBi
Uplink Spreading Loss	162.76	dB(m^2)	Downlink Spreading Loss	162.58	dB(m^2)
Uplink Path Loss	207.28	dB	Downlink Path Loss	205.57	dB

Satellite Input level	-93.75	dBW/m^2	Satellite Input level	-138.27	dBW
Satellite Input Back Off	4.25	dB	Uplink C/No	92.83	dB-Hz
Satellite Output Back Off	2.25	dB	Uplink C/Io	95.44	dB-Hz
Satellite Downlink EIRP	46.75	dBW	Uplink C/(No+Io)	90.93	dB-Hz
			Uplink Margin	23.78	dB
Interference Calculations			Satellite Downlink EIRP	46.75	dBW
Adjacent Satellite Uplink	99.15	dB-Hz	Downlink C/No	76.13	dB-Hz
Adjacent Satellite Downlink	78.29	dB-Hz	Downlink C/Io	78.02	dB-Hz
Cross-Polarization Uplink	101.95	dB-Hz	Downlink C/(No+Io)	73.96	dB-Hz
Cross-Polarization Downlink	91.13	dB-Hz	Downlink Margin	6.81	dB
E.S. HPA Intermodulation	100.00	dB-Hz	Total Link C/(No+Io)	73.88	dB-Hz
Transponder Intermodulation	97.50	dB-Hz	Margin	6.72	dB

Calculate Interference Values?	Calculate Rain Fade For?
(•) Yes ( ) No	Neither

						FCC Limit:
C/Io Uplink	95.44	dB-Hz	Antenna Flange Power Density	-22.67	dBW/4 kHz	-14 dBW/4 kHz
C/Io Downlink	78.02	dB-Hz	Uplink Off-Axis EIRP Density @ 2º	-1.19	dBW/4 kHz	15 -25*log(Θ) dBW/
			Downlink EIRP Power Density	9.82	dBW/4 kHz	13 dBW/4 kHz

Transponder Bandwidth Utilization	97.50	%	Installed HPA Size	400.0	Watts
Transponder Bandwidth Utilization	35100.00	kHz	Installed HPA Size	26.02	dBW
Transponder Power Utilization	74.99	%	Required HPA Power	17.27	dBW
Transponder Power Equiv. Bandwidth	26996.19	kHz	Operating HPA Single Carrier OBO	8.76	dB

Duplex Bandwidth Required	35100.00	kHz	
Duplex Power Equiv. Bandwidth	27000.96	kHz	
Lease Bandwidth Required	35100.00	kHz	CRMA in Use

ViaSat Proprietary — Tail Mount Ant. Return Link budget (aircraft to hub)

Satellite Name	AMC-6		Data Rate	128000	bps	
Satellite Location	72	Deg W	Packet Error Rate	1 x 10E-3		
Satellite Center Beam EIRP	51.50	dBW	Eb/No Required	2.25	dB	
Satellite EIRP in direction of DL ES	49.50	dBW	C/No Required	53.32	dB-Hz	
Satellite SFD in direction of UL ES	-97.00	dBW/m^2	Availability Required	99.80%		1052
Satellite Input Attenuator	6	dB	ITU Uplink Rain Zone	N/A		
Operating SFD (NCS Value)	-91.00	dBW/m^2	ITU Downlink Rain Zone	N/A		
Satellite G/T in direction of UL ES	4.00	dB/K	Modulation Type	CRMA-GMSK		
Satellite Input Back Off	3	dB	FEC Factor	Rate 1/3 TC		
Satellite Output Back Off	1	dB	Spread Factor : Chip Rate	92		35328 kchip/s
Transponder BW	36	MHz	Alpha	0.859		
Satellite Translation Frequency	2,300	MHz	Spread Bandwidth : Signal Bandwidth	30346.8		164.9 kHz

Uplink Name	AMSS		Downlink Name	Hub		
Uplink Location Latitude	40.00	Deg N	Downlink Location Latitude	33.12	Deg N	
Uplink Location Longitude	95.00	Deg W	Downlink Location Longitude	117.24	Deg W	
Uplink Frequency	14240	MHz	Downlink Frequency	11940.00	MHz	
Uplink Antenna Size	0.2921	m	Downlink Antenna Size	4.5	m	
Uplink Antenna Efficiency	0.71		Downlink Antenna Efficiency	0.65		
Uplink Antenna Gain	31.27	dBi	Downlink Antenna Gain	53.13	dBi	
Uplink EIRP	31.30	dBW	Downlink Antenna LNA Temp	70	K	
Uplink Output Circuit Loss	1.28	dB	Downlink Antenna Noise Temp	35	K	
Uplink PA Output Power	1.352	Watts	Downlink Rain Noise	36.30	K	
Uplink PA Output Power	1.31	dBW	Downlink Earth Station G/T	31.43	dB/K	
Uplink Rain Attenuation	0.00	dB	Downlink Rain Attenuation	0.65	dB	
Uplink Misc Losses	1.5	dB	Downlink Misc Losses	1	dB	
Uplink Elevation Look Angle	38.02	Deg	Downlink Elevation Look Angle	28.52	Deg	
Uplink Azimuth Look Angle	146.56	Deg	Downlink Azimuth Look Angle	118.45	Deg	
Uplink Slant Range	37947.14	km	Downlink Slant Range	38755.24	km	
Uplink m^2 Antenna Gain	44.52	dBi	Downlink m^2 Antenna Gain	42.99	dBi	
Uplink Spreading Loss	162.58	dB(m^2)	Downlink Spreading Loss	162.76	dB(m^2)	
Uplink Path Loss	207.10	dB	Downlink Path Loss	205.75	dB	

Satellite Input level	-132.78	dBW/m^2	Satellite Input level	-177.30	dBW
Satellite Input Back Off	41.78	dB	Uplink C/No	55.30	dB-Hz
Satellite Output Back Off	39.78	dB	Uplink C/Io	59.62	dB-Hz
Satellite Downlink EIRP	9.72	dBW	Uplink C/(No+Io)	53.94	dB-Hz
			Uplink Margin	0.61	dB
<u>Interference Calculations</u>			Satellite Downlink EIRP	9.72	dBW
Adjacent Satellite Uplink	84.93	dB-Hz	Downlink C/No	62.36	dB-Hz
Adjacent Satellite Downlink	96.16	dB-Hz	Downlink C/Io	86.49	dB-Hz
Cross-Polarization Uplink	87.73	dB-Hz	Downlink C/(No+Io)	62.34	dB-Hz
Cross-Polarization Downlink	87.73	dB-Hz	Downlink Margin	9.02	dB
E.S. HPA Intermodulation	95.00	dB-Hz	Total Link C/(No+Io)	53.35	dB-Hz
Transponder Intermodulation	95.00	dB-Hz	Final Margin (zero with UPC, See PA)	0.03	dB

Number of active CDMA carriers	34	N
Self interference contribution	59.64	dB-Hz
Antenna gain at 3.4 deg off-axis	26.09	dBi

						FCC Limit:
C/Io Uplink	59.62	dB-Hz	Antenna Flange Power Density	-38.77	dBW/4 kHz	-24.25 dBW/4 kHz
C/Io Downlink	86.49	dB-Hz	Ntwk Aggregate On-Axis EIRP Densit	6.31	dBW/4 kHz	15-25*log(Θ) dBW/4
			Ntwk Aggregate Off-Axis EIRP Densit	1.13	dBW/4 kHz	15-25*log(Θ) dBW/4
			Downlink EIRP Power Density	-27.08	dBW/4 kHz	10 dBW/4 kHz

Transponder Bandwidth Utilization	84.30	%	<u>PA Sizing Analysis</u>			
Transponder Bandwidth Utilization	30347.00	kHz	Installed PA Size	6.0	Watts	P1dB Minimum
Transponder Power Utilization	0.01	%	Installed PA Size	7.78	dBW	
Transponder Power Equiv. Bandwidth	4.77	kHz	Required PA Power	1.31	dBW	
Number of like carriers supported	7543.41		Operating PA Single Carrier OBO	6.47	dB	
Actual transponder Utilization for N	0.45	%	Margin available for power increase	6.47	dB	

5 Protection of Fixed Satellite Service Users

This section provides a summary of provisions to protect satellite receivers operating in the 11.7 to 12.2 GHz and 14.0 to 14.5 GHz FSS bands from interference by the ViaSat AMSS system.

5.1 Protection of Users of the 11.7-12.2 GHz Band

For the ViaSat AMSS system, the EIRP spectral density levels will be equal to or less than those previously coordinated for the AMC-6 satellite.

5.2 Protection of Users of the 14.0-14.5 GHz Band

5.2.1 Fixed Satellite Services

Based on the link budgets, the maximum Forward link downlink EIRP density dominates the transponder emissions compared to the Return link. Thus the Forward link emissions determine the EIRP density performance relative to 25.134(b). The worst case Forward link EIRP is 51.5 dBW. This power is spread over the noise bandwidth (B_n = *36.0 MHz*) of the Forward link signal with EIRP density of 9.8 dBW/4 kHz, as described in Section 3.3.2.

The International Telecommunications Union (ITU) 2003 World Radio Conference (WRC-03) adopted a draft new Recommendation—Recommendation-R M.1643—that specifies how AMSS operations should protect FSS networks. The Recommendation specifies that:

> AMSS networks should be designed, coordinated and operated in such a manner that the aggregate off-axis e.i.r.p. levels produced by all co-frequency [airborne earth stations (AES)] within AMSS networks are no greater than the interference levels that have been accepted by other satellite systems.[5]

The design of ViaSat's AMSS system conforms with this ITU requirement.

ViaSat will protect GSO FSS satellites by controlling the aggregate off-axis e.i.r.p. density along the GSO arc to the level required for routinely processed VSAT applications. ViaSat's research reveals that there are no NGSO FSS operational systems to protect.

[5] Recommendation ITU-R M. 1643, Annex 1, Part A, ¶ 1.

To avoid harmful interference to other FSS systems from the Return link, the ViaSat AMSS system will manage the aggregate EIRP spectral density of the AESs in the plane of the GSO arc to the levels required for a routinely processed VSAT network as described in Sections 25.134(a) and 25.209(a)(1) of the Commission's Rules. That is, the aggregate EIRP spectral density of all aircraft transmitting simultaneously on the same frequency will not exceed the mask defined by an input power density of -14 dBW/4 kHz into an antenna with the sidelobe levels of Section 25.209(a)(1). This EIRP mask is shown in Figure 5-1 below and is also described by Table 1 in Section 2.4 above.

The "Aggregate EIRP" antenna pattern shown in Figure 5-1 is the ViaSat TMASS antenna patterns for the E & H-Planes at 14.25 GHz for ±90º combined with the input power density from the maximum allowed number of simultaneously transmitting AES terminals.

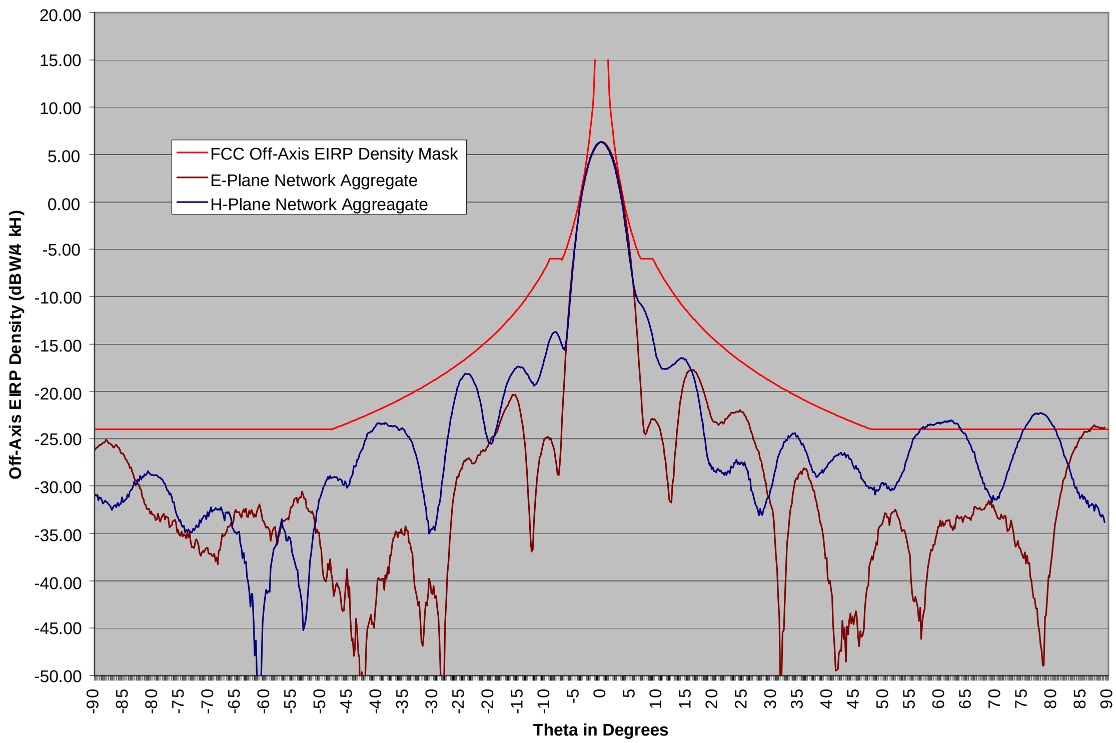

Figure 5-1 Off-Axis Aggregate EIRP Density and EIRP Density Mask

5.2.1.1 Off-Axis Antenna Gain Patterns

Off-axis emissions requirements are defined by Section 25.209(a)(1). The ViaSat AMSS system utilizes an 11.5" parabolic reflector for the Return link antenna. Due to the small diameter, the antenna by itself cannot meet the requirements of Section 25.209(a)(1). However, by limiting the on-axis aggregate EIRP density to 6.4 dBW/4 kHz, the system will operate below the EIRP mask and meet the intent of the requirement. The following Figure 5-2 expands the scale of Figure 5-1 to illustrate. The

AMSS antenna's sidelobe powers all remain below the mask. Figure 5-2 also includes a plot of the e.i.r.p. density of a typical AES for comparison

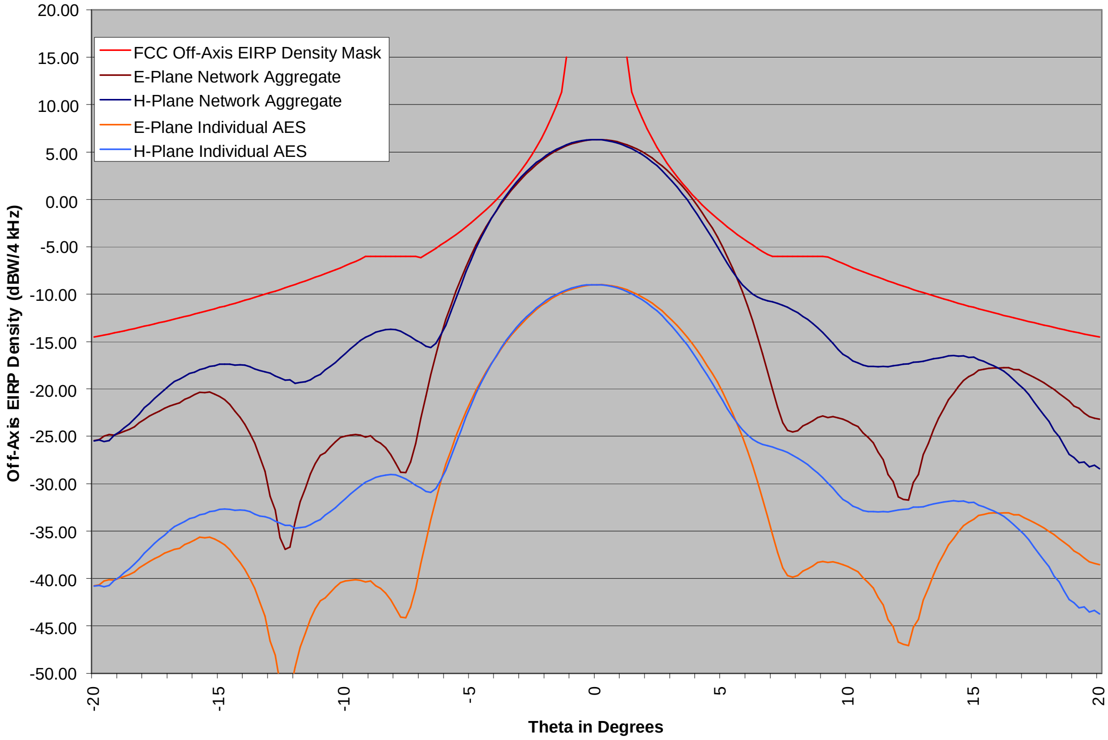

Figure 5-2 Expanded Off-Axis EIRP Density and Mask

In addition, as specified in the Recommendation, ViaSat has taken the various factors that can cause the aggregate off-axis e.i.r.p. levels to vary (*i.e.*, mispointing of AES antennas, variations in the antenna pattern of AES and variations in the transmit e.i.r.p. from AES) into account.[6] In terms of pointing accuracy, the ACU corrects for aircraft attitude changes based upon aircraft INS data, without waiting for degradation in received signal strength. *See* Sections 2.2.1.3 and 3.1.3.2. Variations in the antenna pattern of AES and variations in the transmit e.i.r.p. from AES are addressed by the AES transmit power back-off. *See* Section 3.3.1.

Further, as recommended, ViaSat's antennas, which use both open loop pointing to the satellite and a receive signal lock indication from the demodulator for pointing verification, are inherently resistant to capturing and tracking adjacent satellite signals and immediately will cease transmission if they detect that unintended satellite pointing has occurred or is about to occur.[7] *See* Sections 2.4.4 and 2.4.5. Finally, ViaSat has incorporated fault management into both the AESs and ground support equipment.[8] *See* Section 2.5.

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[6] Recommendation ITU-R M. 1643, Annex 1, Part A, ¶ 2.
[7] *Id.* at ¶ 3.
[8] *Id.* at ¶¶ 4, 5.

5.2.1.2 Off-Axis Aggregate EIRP Spectral Density Control

As described in Section 3.3.1 and repeated here for clarity, Section 25.134(a) describes the maximum on-axis return channel uplink power density into an antenna defined by Section 25.209(a)(1) as –14 dBW/4 kHz. As described in Section 3.3.1, the ViaSat AMSS system manages this aggregate return link power density to a level of 6.4 dBW/4 kHz to assure that the aggregate off- axis power density remains below the mask.

The EIRP from a given AES is determined primarily by its data rate (more specifically the E_b/N_o required to achieve an acceptable BER at that data rate) and its geographical location (more specifically, the slant range and satellite G/T in the direction of that location). The Arclight AMSS system uses a multi-tiered control system to manage the aggregate return link power density below the 6.4 dBW/4 kHz level established in Section 3.3.1. The first tier provides dynamic control of transmitted power. The GES monitors the number of active aircraft and number of simultaneous transmissions and adjusts transmitted power on airborne units (down to the minimum power consistent with their signaling rate) so that the aggregate EIRP remains below 6.4 dBW/4 kHz. The power output of an AES can be adjusted in 0.25 dB steps. Power adjustments are made over a period of seconds as the aircraft moves within the satellite's CONUS-wide footprint.

The second tier applies bandwidth control of the transmitted signal to reduce the signaling rate and thereby reduce the power required to maintain the minimum energy per bit. The signaling rate is adjustable from 128 kbit/s down to 32 kbit/s and may be used in conjunction with dynamic power control to assure adequate signal strength in the lowest G/T regions.

The third tier limits aggregate power by controlling the total number of users accessing the network. Usage statistics will be constantly monitored to validate the thresholds on transmitted power, signaling rate and the number of users to keep the system from exceeding the maximum allowable aggregate power. Additional transponders will be added when the user's service quality falls below the minimum acceptable level, i.e., when minimum guaranteed data rates are not being met.

The link budget in Section 4.2 show that a typical AES terminal operating at 128 kbit/s would require a nominal return link antenna input flange power density of -40.3 dBW/4 kHz (more or less antenna input flange power density could be required depending upon the satellite performance at the location of a given AES). The link budget also shows that this nominal input power density value will permit 33 simultaneous transmissions before the network aggregate power density level of 6.4 dBW/4 kHz is exceeded. The exact number of simultaneous transmissions supported depends upon the geographical distribution of the aircraft.

The probability of the aggregate on-axis return link power exceeding the 6.4 dBW/4 kHz level is essentially the probability that more than some number of AES (34 in this case) will transmit simultaneously. This probability depends upon the number of aircraft actually logged into the AMSS Network (active aircraft) and the probability that any given aircraft will be transmitting at any given time. ViaSat has designed the NMS to monitor the number of simultaneous transmissions and begin limiting the number of bursts AES terminals may send if the average number of transmissions exceeds a preset threshold. This enables the use of statistically based algorithms to manage the network and keep the aggregate off-axis EIRP density within the mask described by Table 1 in Section 2.4 herein~~, except as permitted by the exceedance factors in Table 2~~.

5.2.2 Terrestrial Services

ViaSat has conducted a search of the 14.0 to 14.5 GHz band to determine if there are any terrestrial services within North America licensed in this band and found none with which its AMSS Service would conflict. In any event, it is highly doubtful that aircraft that can transmit only when they are securely locked onto a GSO satellite would be able to transmit in the direction of a land-based service within the latitudes of CONUS. Nonetheless, ViaSat has ensured that its AESs comply with the maximum power-flux density (PFD) limits contained in Recommendation ITU-R M.1643.[9] These limits are: $-132 + 0.5 \cdot \Theta$ dB(W/m^2)/1 MHz for $\Theta < 40^\circ$; and -112 dB(W/m^2)/1 MHz for $40 < \Theta < 90^\circ$. The ViaSat AMSS system complies with the recommendation when the aircraft antenna is pointed 15º above horizontal (worst case for CONUS) and the aircraft is at 5,000 feet or higher.

5.2.3 Land and Maritime Mobile Satellite Services

Both the Land Mobile Satellite Service (LMSS) and Maritime Mobile Satellite Service (MMSS) use GSO FSS satellite transponders. ViaSat has evaluated its compliance with the requirements for protection of FSS networks to ensures that its AMSS system will not cause unacceptable interference to authorized LMSS and MMSS systems even if such systems employed co-frequency transponders on adjacent FSS satellites—which they do not. The CPM Report to WRC-03 supports ViaSat's conclusion. It concluded that sharing between an AMSS network and an MSS network "is feasible."[10]

Specifically, the forward link of the LMSS and MMSS systems employ a spread spectrum signal that is designed to prevent harmful interference to signals received by adjacent FSS satellites. Reciprocally, the mobile terminals of LMSS and MMSS systems must be able to tolerate interference from high power, wideband co-frequency signals of adjacent GSO FSS satellites. The forward link signal of the Arclight AMSS System is indistinguishable from a wideband, high power digital signal on an FSS satellite. Thus, ViaSat's forward link signal will not cause unacceptable interference to the receive

[9] Recommendation ITU-R M. 1643, Annex 1, Part B.

[10] Report of Conference Preparatory Meeting for WRC-203, § 2.4.1.3.4.

terminals of LMSS and MMSS systems in the U.S. even if such systems employed co-frequency transponders on adjacent FSS satellites—which they do not.

5.2.4 Government Services

ViaSat is aware that the 14.0 to 14.05 GHz segment of spectrum has been allocated to the U.S. Government for space research, and the 14.47 to 14.5 GHz segment has been allocated for radio astronomy. Recommendation ITU-R M.1643 specifies how AMSS should protect both of these services.

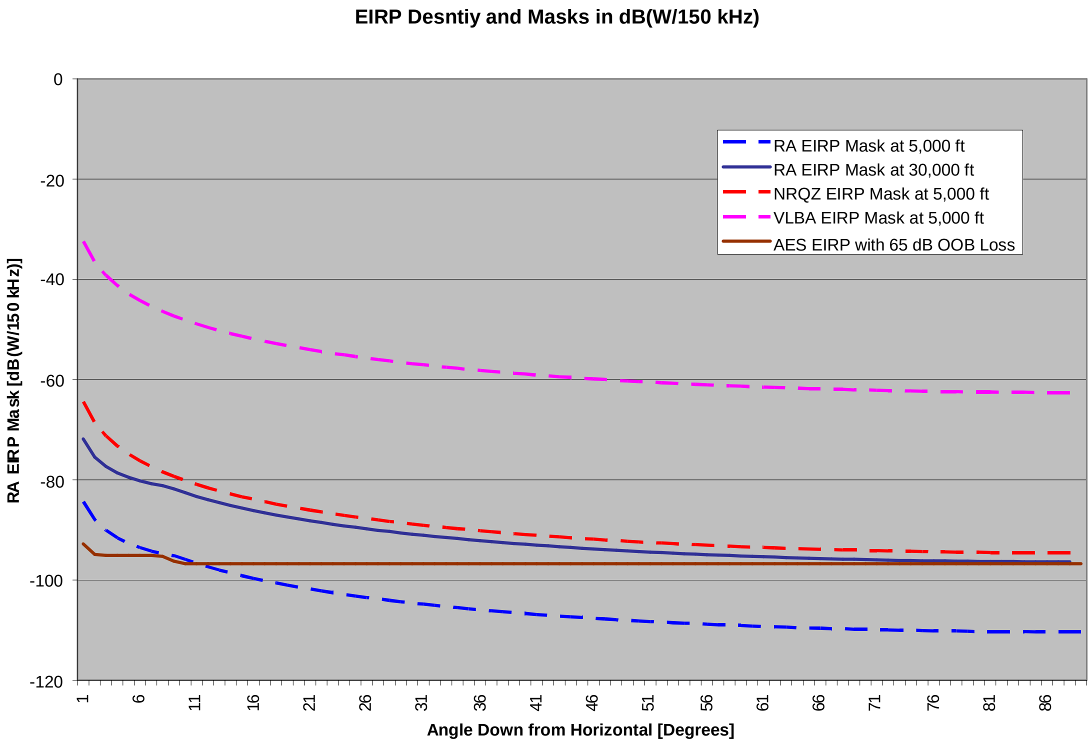
To protect radio astronomy, when operating on transponders with an uplink frequency above 14.44 GHz within the line-of-sight of a radio astronomy station operating in the 14.47 to 14.5 GHz band, the AESs will cease transmissions in this band during periods of scheduled radio astronomy observations. When operating on transponders with an uplink frequency at or below 14.44 GHz, ViaSat will ensure that emissions in the 14.0 to 14.47 GHz band meet the PFD limits set forth in the Recommendation.[11] These limits are:

$-190 + 0.5 \cdot \Theta$	$dB(W/(m^2 \cdot 150\ kHz))$	for	$\Theta < 10^\circ$
-185	$dB(W/(m^2 \cdot 150\ kHz))$	for	$10 < \Theta < 90^\circ$

The out-of-band emissions from an AES modulator are at least 60 dB down at frequencies more than 20 MHz removed from the band edge. With the antenna elevation adjusted down to 15.4º above horizontal (worst case for CONUS on AMC-6) and the aircraft operating above 30,000 feet, the ViaSat AMSS System, operating at or below 14.44 GHz, complies with the recommendation. See Figure 5-3, which includes only 10 dB of loss for the effects of airframe masking.

To protect the space research service, ViaSat will enter into coordination agreements with space research systems operation in the 14.0 to 14.5 GHz band.[12]

[11] Recommendation ITU-R M. 1643, Annex 1, Part C.
[12] *Id.* at Annex 1, Part D.



REVISED Figure 5-3 AES EIRP Flux Density Relative to ITU Rec. M.1643

5.2.5 Radionavigation

In taking the steps specified in the Recommendation to avoid interference to radioastronomy and the space research service, ViaSat will avoid interference to any existing maritime radionavigation services in the U.S. In any event, there are no records in the ITU Master Register indicating use of the radionavigation allocation in the 14.0 to 14.3 GHz band by any administration. Further, the CPM Report to WRC-03 found that "consideration of compatibility matters has not revealed a problem in the use of this band by AMSS with respect to RNS."[13]

[13] Report of Conference Preparatory Meeting for WRC-2003, § 2.4.1.2.2.

6 CONCLUSION

ViaSat demonstrates in this Technical Description that it will not cause interference to other licensees. ViaSat has carefully analyzed all aspects of the proposed Arclight AMSS service and, as fully demonstrated herein, can operate an AMSS service in the 11.7 to 12.2 and 14.0 to 14.5 GHz bands without causing harmful interference to other authorized users.

Appendix A Glossary

Term	Definition
dB	Decibel ($10 \log_{10} P_1/P_2$)
dBi	Gain relative to an isotropic source
dBW	Power ratio referenced to 1 Watt
dB/K	Ratio of gain in dB to noise temperature in Kelvin
E_b/N_o	Ratio of energy per bit to noise
EIRP	Effective Isotropic Radiated Power
e.i.r.p.	Effective Isotropic Radiated Power
GHz	GigaHertz (10^9 Hertz)
G/T	Ratio of antenna gain to receiver noise temperature
Hertz	Cycles per second
Hz	Hertz
kbit/s	Kilobits per second (10^3 bit/s)
Mbit/s	Megabits per second (10^6 bit/s)
MHz	MegaHertz (10^6 Hertz)

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