Attachment to Application

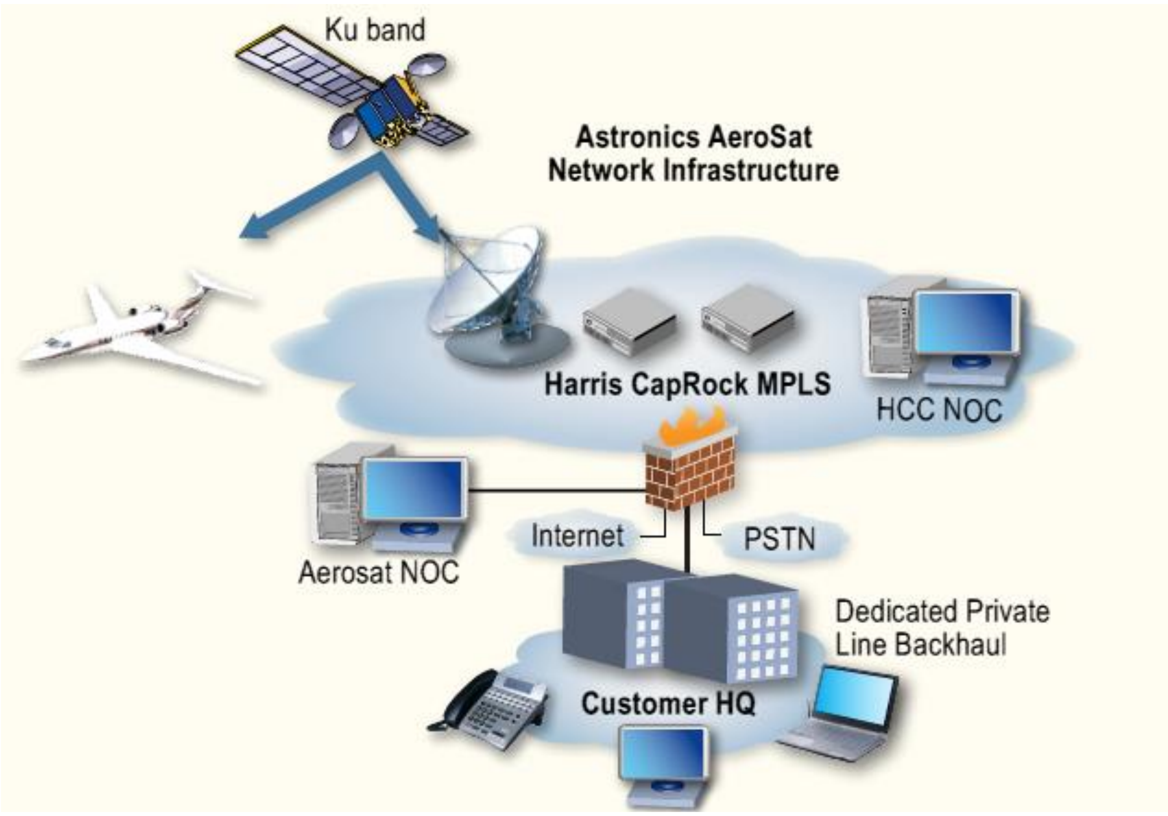
TECHNICAL APPENDIX

1 System Description

1.1 Overview

Astronics AeroSat's proposed Ku-band earth stations onboard aircraft ("ESAA") system is shown in figure 1. The system is comprised of aircraft earth station ("AES") equipment, leased capacity on a commercial Ku-band FSS satellite and associated ground segment.

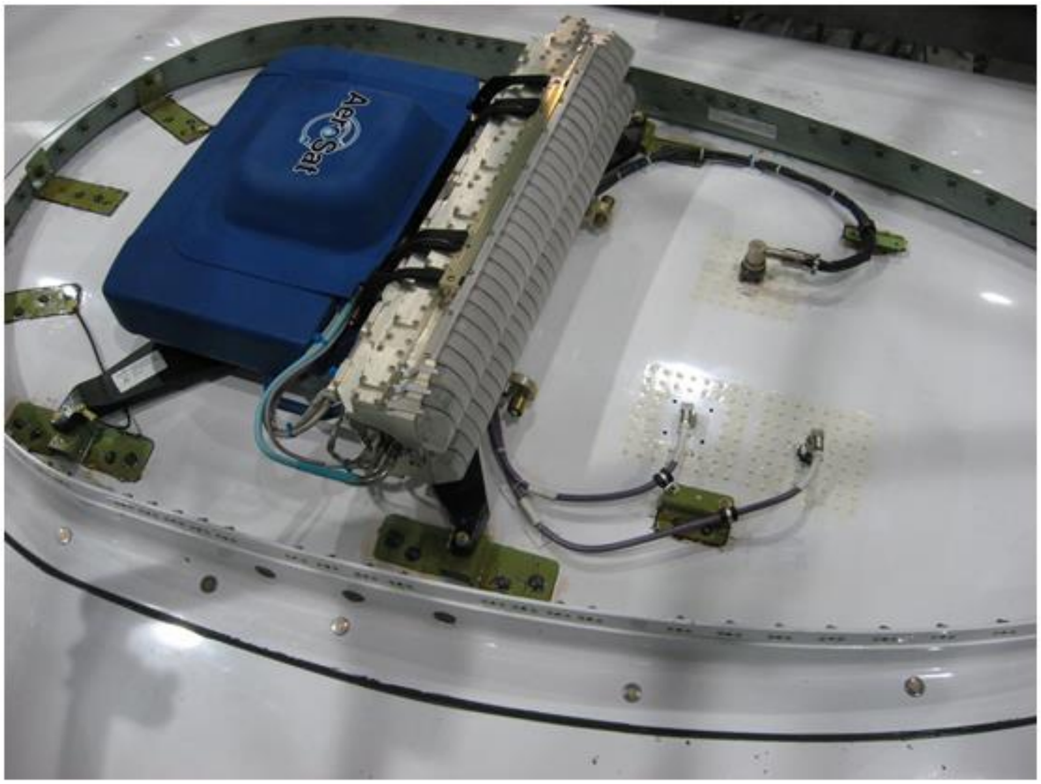
Figure 1: System Diagram



1.2 AES Equipment

Astronics AeroSat seeks to operate its HR6400 Ku-band terminal, which has been previously authorized by the Commission for experimental and commercial operations. In addition to the antenna subsystem mounted on the aircraft fuselage, an internally mounted Antenna Control Modem Unit ("ACMU") and a high power transceiver ("HPT") are mounted internally within the airframe of the aircraft, directly below the externally mounted equipment. Details related to the technical characteristics of the HR6400 terminal are in Section 3 - Technical Characteristics.

Figure 2: HR6400 Terminal (installed on an aircraft)



1.3 Satmex 6 Satellite

Astronics AeroSat will utilize commercial Ku-band Fixed Satellite Service ("FSS") capacity for its proposed experimental operations. Specifically, the HR6400 terminal will communicate with the Satmex 6 satellite located at the 113° W.L. orbital location.

Satélites Mexicanos S.A. de C.V ("Satmex") – the operator of Satmex 6 – has reviewed and confirmed that Astronics AeroSat's proposed experimental operations are consistent with Satmex's coordination agreements and will not result in unacceptable interference to other satellite operations within +/- 6 degrees of Satmex 6. *See* Section 6 - Coordination.

1.4 Gateway Earth Station and Network Operations Centers

The gateway earth station for the proposed experimental operations is located in Houston, Texas (Call Sign E030279). The hub earth station connects to licensed gateway earth stations, an iDirect hub, and an Astronics AeroSat's network control facilities. The iDirect hub will consist of a DVB-S2 modulator and an iDirect D-TDMA demodulator. Network control of Astronics AeroSat's proposed experimental operations will be provided pursuant to Astronics AeroSat's direction and control from a Network Operations Center ("NOC") in Amherst, New Hampshire, through its network control partner, Harris CapRock Corporation, who will provide managed network services to Astronics AeroSat.

Operation of the hub earth station will be controlled by a NOC subject to Astronics AeroSat's direction and control.

The NOC will be responsible for configuring, monitoring, controlling, and, if necessary, preventing transmissions from any HR6400 terminal. The NOC will be staffed at all times when experimental operations are underway, providing continuous supervision and monitoring of such operations. In addition, Astronics AeroSat personnel will be present and accessible via mobile phone during all experimental operations.

Primary Points of Contact:

Astronics AeroSat Test Site Supervisor
Mobile Phone Number: +1 (603) 400-2098

Networks Operations Center Coordinator
Office Phone Number: +1 (603) 879-0205
Facsimile Phone Number: +1 (603) 386-6488
Company Address:
Astronics AeroSat Corporation
Suite #2B 62 New Hampshire 101A
Amherst, NH 03031
Email Address: NOC@astronics.com

Secondary Point of Contact:

Harris CapRock Network Control Center
Managed Network Services 24x7 support
4400 S. Sam Houston Pkwy, E.
Houston, Texas 77046
(832) 668-2300

2 Network Technology

2.1 Satellite Access Techniques

Astronics AeroSat will lease capacity on a commercial Ku-band FSS satellite and utilize established waveforms – DVB-S2 and iDirect's Deterministic Time Division Multiple Access – for its proposed experimental operations. For the forward link, a hub earth station will broadcast a Time Division Multiplexed ("TDM") outbound channel from a central location shared by remote terminals within the airborne antenna equipment. For the return link, each remote terminal will transmit to the hub on a shared set of TDM access ("TDMA") inbound channels with dynamic timeslot assignments.

The forward link (hub-to-terminal) uses DVB-S2, and all of the traffic will be time division multiplexed on one carrier. DVB-S2 supports Adaptive Coding and Modulation ("ACM") with QPSK, 8PSK, and 16 APSK modulations and Low Density Parity Check Coding Rates between

0.25 and 0.9. Modulation and coding will be varied, and the airborne antenna equipment will determine which data are addressed to them by de-modulating all the frames they receive from the hub. The airborne antenna equipment then will transmit to the hub modems via the return link any information related to receive quality for the purpose of adapting future frame coding and modulation and ensuring acceptable performance.

The return link uses iDirect's Deterministic TDMA ("D-TDMA"), which supports multi-frequency ("MF") TDMA. The iDirect hub manages the frequency and timeslot assignments and ensures that no assignments are duplicated among the terminals. Timeslots and carriers are uniquely assigned, ensuring that only a single terminal can transmit in an assigned timeslot. Terminals will transmit a single carrier in each assigned time slots, and the hub will adjust the timeslot assignments as user demand varies with time on the return link.

The iDirect D-TDMA demodulator – which is located in the hub earth station – monitors the carrier-to-noise ratio ("*C/N*") of the signals transmitted from the airborne antenna to the hub. The iDirect demodulator issues power control corrections to terminals that are outside the target *C/N* range by adjusting the link power from the terminal to the target and maintaining the target level as return link characteristics change due to geographic position and operating environment. As detailed below in Section 3.3 - High Power Transceiver and Antenna Control Modem Unit, the HPT and ACMU in the airborne antenna equipment also help to control return link power.

2.2 Off-Axis EIRP Spectral Density

Off-axis EIRP spectral density emissions from the airborne antenna equipment will be controlled through the directivity of the antenna, limitations on the transmit power spectral density, control of pointing error, and control of skew angle relative to the orbital location of the serving satellite. Astronics AeroSat will control the off-axis EIRP spectral density emissions according to the values that the Commission applies to Earth Stations Aboard Aircraft ("ESAAs").[1]

Astronics AeroSat's HR6400 Ku-band Antenna System will limit off-axis EIRP spectral density to these values as follows:

- Limiting the transmit power spectral density by controlling the transmit power of the terminal and by selecting appropriate bandwidths for inbound channels
- Controlling the off-axis gain of the antenna along the GSO arc by preventing transmissions when the skew angle exceeds a certain threshold
- Controlling pointing error of less than 0.2° and preventing transmissions when the pointing error exceeds 0.5°

[1] *See* 47 C.F.R. § 25.227(a)(1)(i)(A)-(C).

Terminal transmit EIRP is controlled so that the minimum power is used to close the satellite link. D-TDMA supports BPSK, QPSK and 8PSK modulations, turbo code rates between 0.431 and 0.793, and spread spectrum factors between 1 and 16. The return link will operate at up to 4096 kbps under this experimental STA using occupied bandwidths between 160 kHz and 5.12 MHz (emissions designators 160KG7D to 5M12G7D).

3 Technical Characteristics of the Airborne Antenna Equipment

3.1 Radome and Radome Attachment Ring

The radome is transparent to the Ku-band radio waves and streamlines the HR6400 Ku-band antenna system by protecting the antenna from the outside environment and minimizing the impact of the system on the flight dynamics on the aircraft. The radome attachment ring provides structural support to the radome by distributing the structural load around the shell of the radome and securing the radome to the aircraft so the externally mounted equipment can withstand the forces applied to the radome and radome attachment ring during flight.

3.2 HR6400 Fuselage Mounted Unit Ku-band Antenna

The HR6400 FMU Ku-band antenna consists of the following components:

- A mechanically steered antenna array
- Low Noise Amplifier
- Polarization Converter Unit
- Antenna Driver
- Antenna Position Encoders

The antenna is mounted on a positioner with an elevation over azimuth gimbal. The positioner points the gimbaled antenna by controlling the antenna in azimuth, elevation and polarization and using received signal quality to assure that the positioner's reference system aligns with the aircraft inertial navigation system ("INS").

The antenna will not transmit until it receives the appropriate outbound signal from the satellite and it has validated antenna pointing within 0.2°. As noted in Section 3.3 - High Power Transceiver and Antenna Control MODEM Unit, the antenna will cease transmission immediately in certain instances to avoid causing interference.

SUMMARY OF TECHNICAL PARAMETERS - HR6400

Antenna diameter	24.375 in x 6.8 in
Type of Antenna	Horn antenna with lenses
Peak Power (SSPA)	35 watts
Transmit Bandwidth	160 kHz to 5.12 MHz
Transmit Gain	29 dBi
EIRP	44.4 dBW
Transmit Data Rate	Up to 4096 kbps
Transmit Polarization	Horizontal or Vertical
Transmit Max PSD	-16.3 dBW/4kHz
Transmit Beamwidth	1.5 degrees
Receive G/T	12.1 dB
Receive Bandwidth	500 MHz
Receive Polarization	Vertical or Horizontal (orthogonal to Transmit Polarization)

Antenna Control Parameters

Azimuth	Continuous, 360º
Elevation	-10º to 90º
Position accuracy	0.2º (in-motion)
Dynamic Tracking capability	Heading, pitch, roll vel. 7º/sec Heading, pitch, roll accel. 7º/sec^2

3.3 High Power Transceiver and Antenna Control Modem Unit

The High Power Transceiver ("HPT") includes a power detector and a power amplifier, as well as an interconnection with the antenna and the ACMU. The ACMU consists of an iDirect modem and its associated interconnections (*i.e.*, D-TDMA modulator and DVB-S2 de-modulator), an interconnection with the on-board Inertial Navigation System, an interconnection with the HPT.

The on-board Inertial Navigation System ("INS") provides information on the aircraft's position, attitude and related factors to the ACMU, and, using the aircraft navigational data, the ACMU controls the antenna's position. Specifically, the ACMU obtains data regarding the latitude, longitude, altitude, roll angle, pitch angle, heading, roll rate, pitch rate, yaw rate, and ground speed from the INS via the ARINC 429 data bus. Then, the iDirect modem selects the serving satellite based on the location of the aircraft and pre-loaded maps, and the ACMU controls the antenna's positioner to the correct azimuth, elevation, and polarization orientation relative to the aircraft position and orientation and points the antenna toward the target satellite. The aircraft latitude and longitude is updated every 200 milliseconds or less, the heading data are updated every 50 milliseconds or less, and the pitch and roll data are updated every 20 milliseconds or less. The ACMU updates the positioner controls continuously to maintain accurate pointing toward the target satellite.

The ACMU controls the antenna pointing accuracy to a pointing error of less than 0.2° between the target satellite and the axis of the antenna's main lobe.[2] The ACMU continuously monitors the pointing error and will mute the antenna transmitter if the pointing error exceeds 0.5°. All emissions automatically cease within 100 milliseconds if the angle between the orbital location of the target satellite and the axis of the main lobe of the antenna exceeds 0.5°, and transmission is not resumed until the pointing error is less than 0.2°.

The antenna transmitter also will cease transmissions automatically in the following instances:

- If the ACMU loses communication with the aircraft INS, or
- The MODEM looses receive signal, or
- If there is a failure of the ACMU itself, or
- If the reference oscillator fails.

The HPT allows accurate power control, and the ACMU ensures compliance with the Power Spectral Density ("PSD") limits in the Commission's Rules. The power detector within the HPT is stable over frequency and temperature and reports the Ku-band transmit power from the Power Amplifier ("PA"). In this way, Astronics AeroSat can maintain accurate power control at the PA output regardless of variations in PA gain over temperature and frequency. The iDirect modem within the ACMU calculates PSD.

The HPT is phase locked to a frequency stability of 10 MHz reference at ±0.01 parts per million, which is how the return link frequency stability is determined. If there is a loss of lock to the reference by either the HPT or the modem, the terminal ceases transmission immediately.

[2] This should satisfy the requirement in Section 25.227(a)(1)(ii)(A). *See* 47 C.F.R. § 25.227.

4 Link Budget

The link budgets for the HR6400 Ku-band Antenna terminal operation with the Satmex-6 satellite are provided below.

Forward Link Budet (Out-route)

Hub	Houston, TX
Required Eb/No	1.3 dB
Modulation	QPSK
Info Rate	18.354 Mbps
FEC Rate	26/85
Carrier Rolloff	1.2
Satellite SFD @ ES	-85.4 dBW/m2
Transpnder ID	Ku1
HUB Transmit	
Frequency	14.16 GHz
Satellite G/T @ ES	4.4 db/K
Antenna Diameter	6.1 m
Carrier EIRP	72.5 dBW
Ant. Input PSD	-23.73 dBW/4kHz
Path Loss	206.8 dB
Atm/Point/Pol Loss	0.6 dB
Aircraft Receive Terminal	
Frequency	11.86 GHz
Satellite EIRP	46.8 dBW
Downlink PFD @ Beam Peak	9.2 dBW/m2
Receive Gain	31.6 dB
Terminal G/T	12.1 dB/K
Path Loss	205.6 dB
Other Losses	0.6 dB
Transponder	
Total OPBO	3.5 dB
Carrier EIRP	43.3 dBW
C/No Thermal Up	98.12 dB-Hz
C/No Thermal Dn	77.81 dB-Hz
C/Io Total	82.37 dB-Hz
C/No+Io	76.48 dB-Hz
Add'l Link Margin	1 dB
% BW per cxr	99.96 %
% Power per cxr	99.88 %
Xpdr BW Alloc	36 MHz

Return Link Budet (In-route)

Terminal	
Required Eb/No	4.2 dB
Modulation	BPSK
Info Rate	270 Kbps
FEC Rate	1/2
Carrier Spacing	1.35
Carrier Spreading	4
Satellite SFD @ ES	-83 dBW/m2
Transpnder ID	Ku1
Aircraft Transmit Terminal	
Frequency	14.16 GHz
Satellite G/T @ ES	-0.9 db/K
Antenna Diameter	0.366 m
Carrier EIRP	41.1 dBW
Ant. Input PSD	-16.3 dBW/4kHz
Path Loss	207.1 dB
Atm/Point/Pol Loss	0.3 dB
Hub Receive	
Frequency	11.86 GHz
Satellite EIRP	50.2 dBW
Downlink PFD @ Beam Cente	-13.99 dBW/4kHz
Hub G/T	33.7 dB/K
Path Loss	207.1 dB
Other Losses	0.4 dB
Transponder	
Total OPBO	3.5 dB
Carrier EIRP	12.5 dBW
C/No Thermal Up	61.1 dB-Hz
C/No Thermal Dn	68.8 dB-Hz
C/Io Total	82.1 dB-Hz
C/No+Io	60.4 dB-Hz
Add'l Link Margin	1 dB
% BW per cxr	8.1 %
% Power per cxr	0.04 %
Xpdr BW Alloc	2.9 MHz

5 Off-Axis EIRP Spectral Density

The off-axis EIRP spectral density of the HR6400 Ku-band Antenna terminal complies with the FCC's two-degree spacing policies as set forth in Section 25.227 of the rules at all operational skew angles from 0-55º. The maximum input power into the antenna has been selected to ensure compliance at the maximum skew angle of 55º. (Lower skew angles are typical and would result in narrower beamwidth, thus lower off-axis EIRP spectral density.) Astronics AeroSat provides select 0-9º and 0-180º off-axis EIRP plots at for 0º and 55º skew angles, as well as summary plots showing compliance at all skew angles, below.

Figure 3: Co-Pol Off-Axis EIRP Spectral Density (14.25 GHz, 0° Skew)

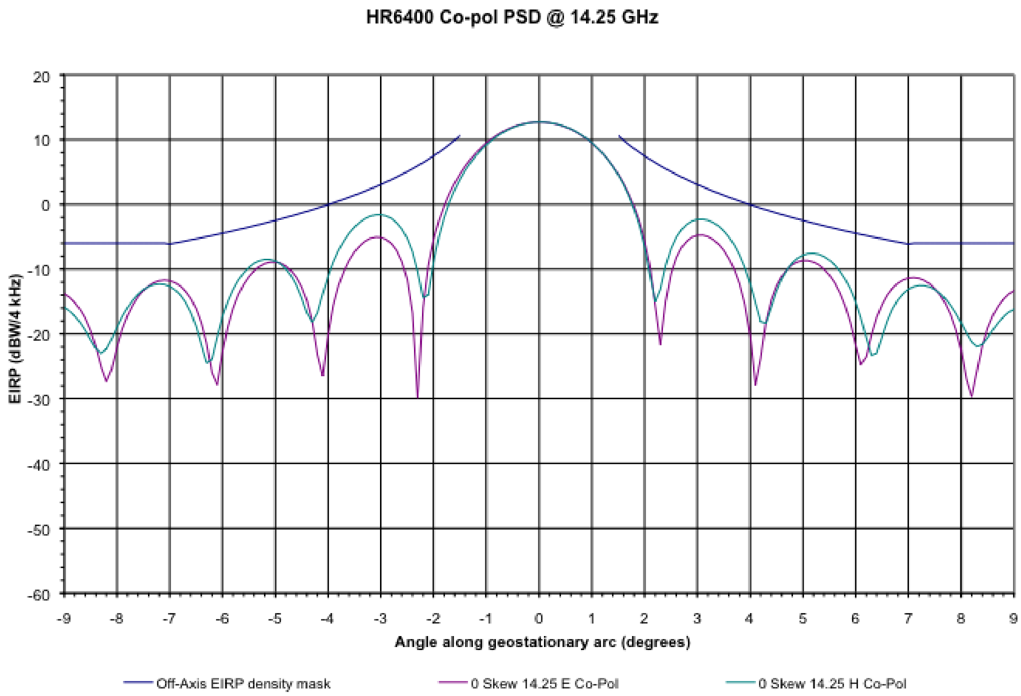


Figure 4: Co-Pol Off-Axis EIRP Spectral Density (14.25 GHz, 55° Skew)

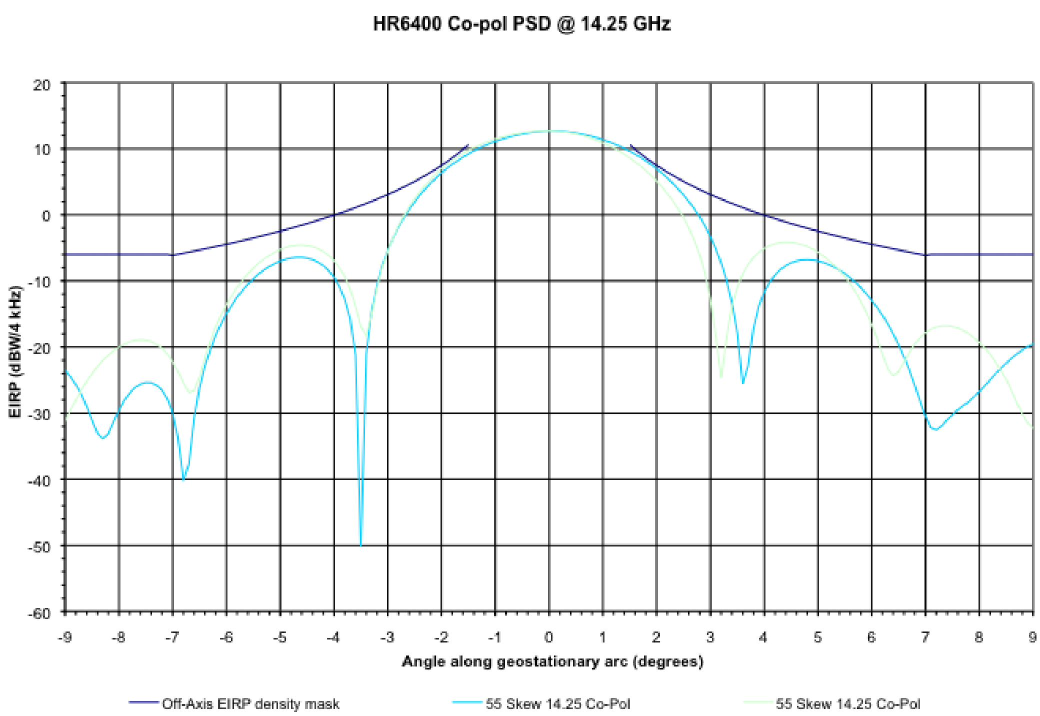


Figure 5: Co-Pol Off-Axis EIRP Spectral Density (14.25 GHz, 0° Skew)

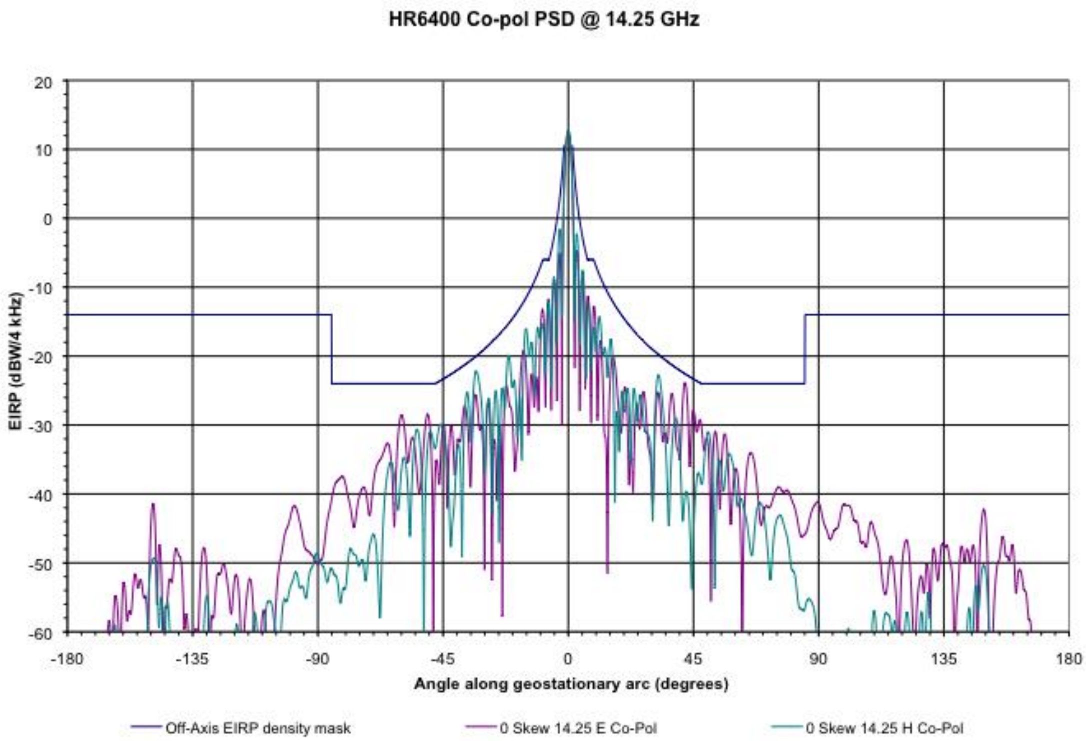


Figure 6: Co-Pol Off-Axis EIRP Spectral Density (14.25 GHz, 55° Skew)

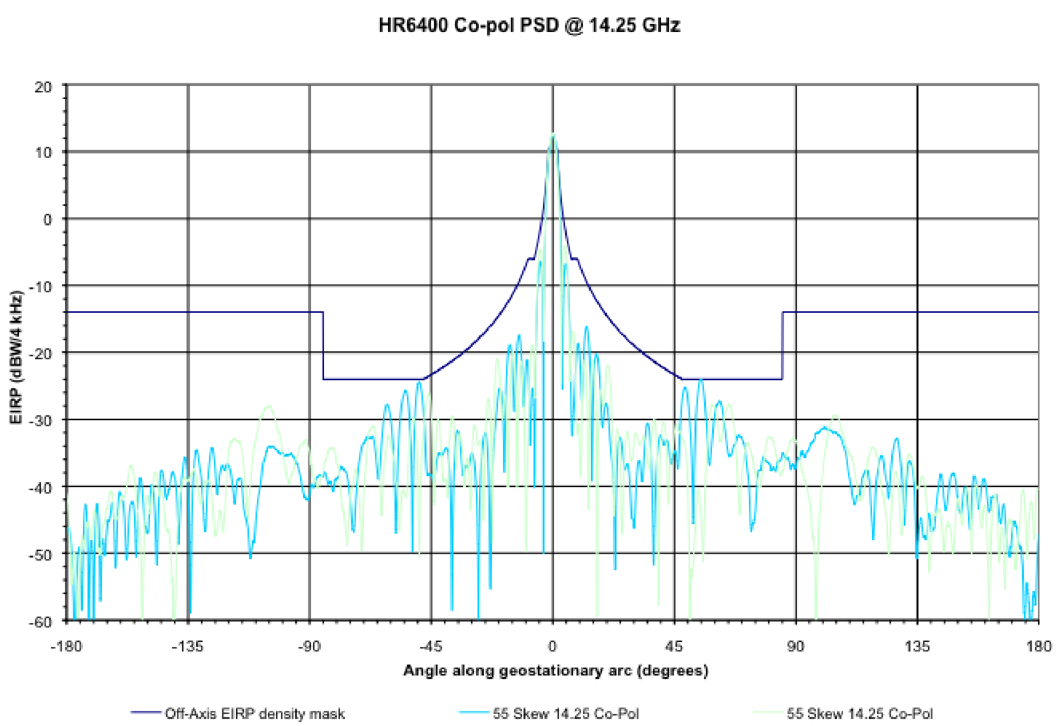


Figure 7: Co-Pol Off-Axis EIRP Spectral Density (14.25 GHz, All Skews)

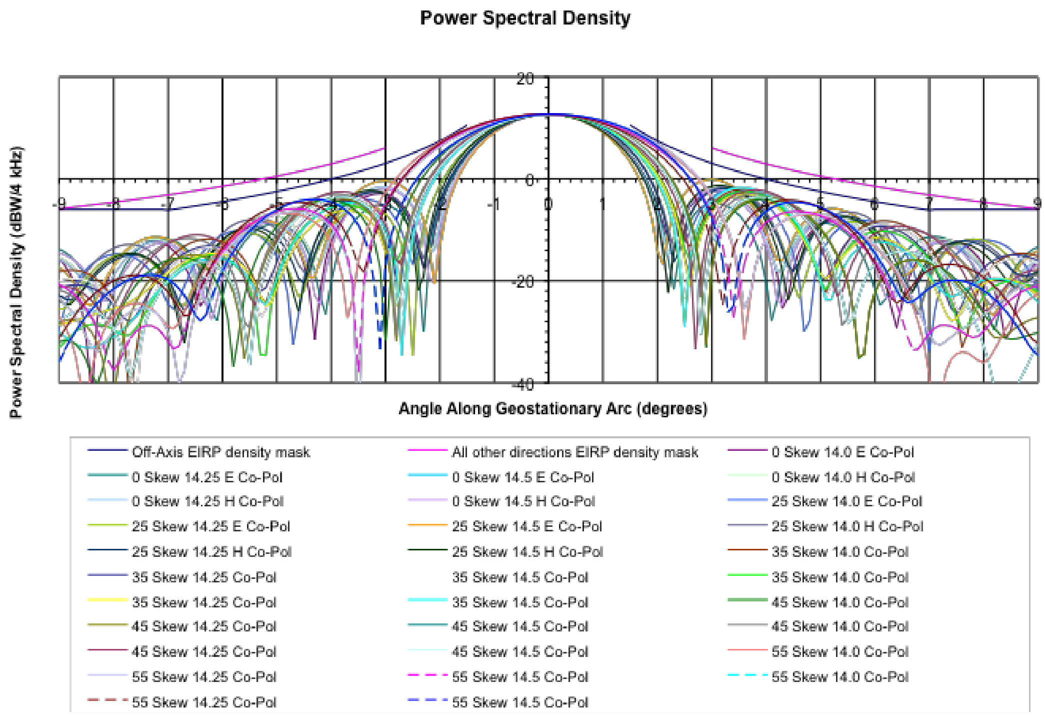


Figure 8: Co-Pol Off-Axis EIRP Spectral Density (14.25 GHz, All Skews)

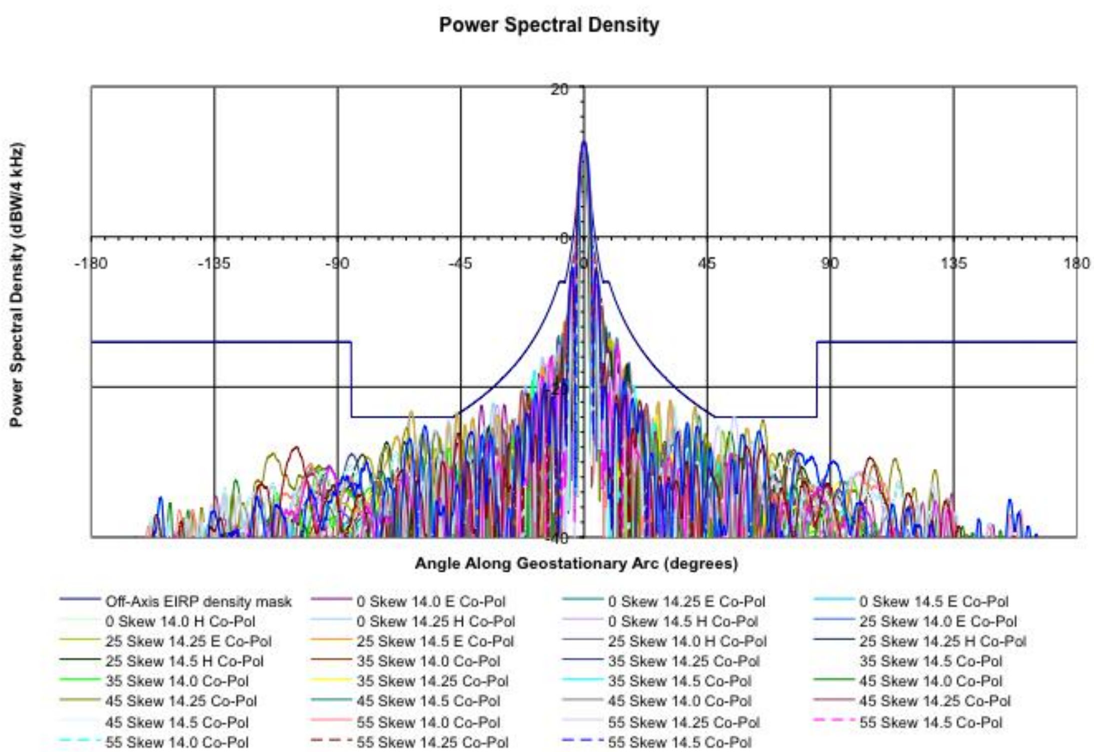


Figure 9: Cross-Pol Off-Axis EIRP Spectral Density (14.25 GHz, 0° Skew)

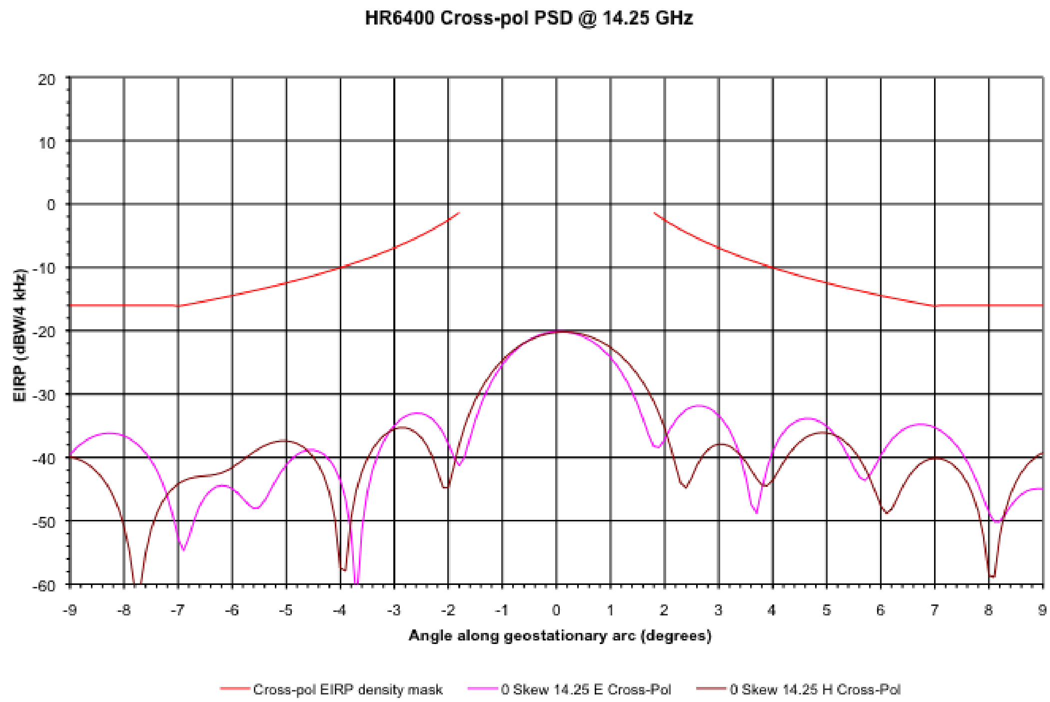


Figure 9: Cross-Pol Off-Axis EIRP Spectral Density (14.25 GHz, 55° Skew)

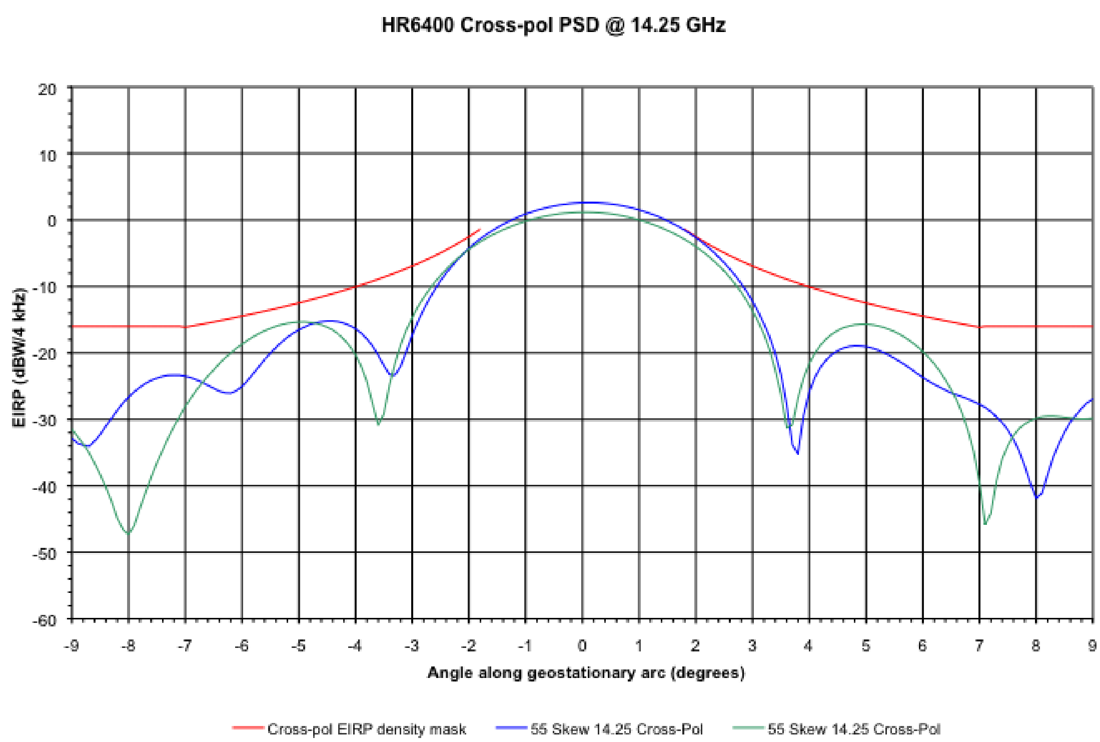
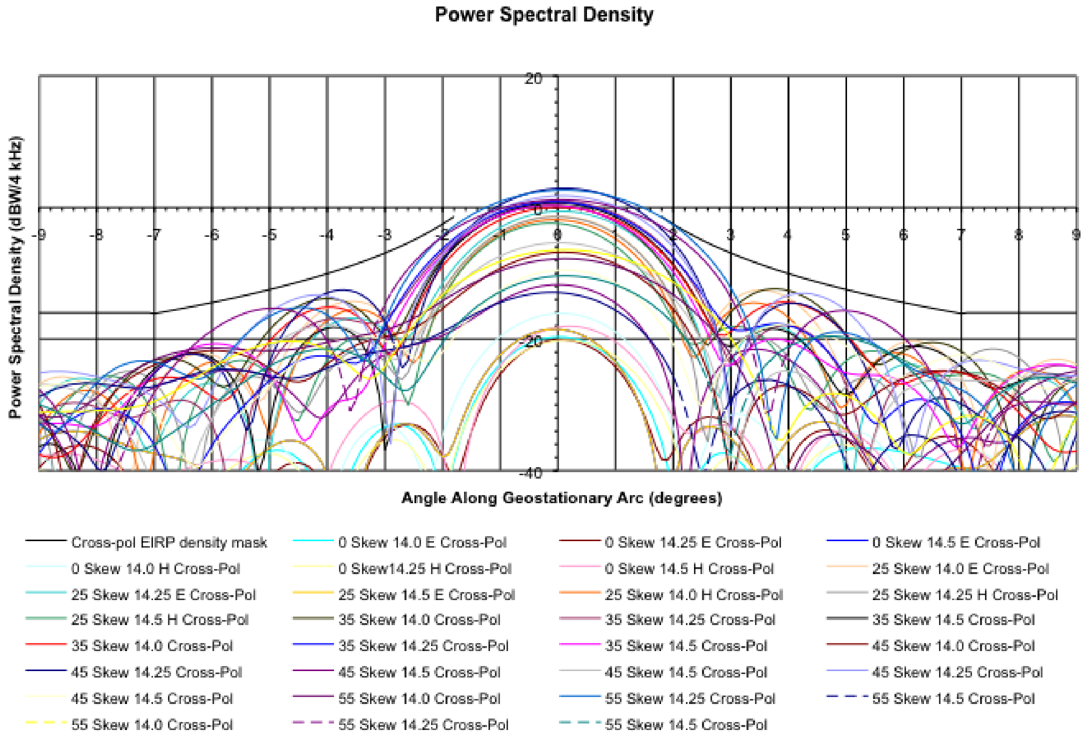


Figure 9: Cross-Pol Off-Axis EIRP Spectral Density (14.25 GHz, All Skews)



A large number of additional off-axis EIRP spectral density plots and tables for other transmit frequencies and skew angles, all of which demonstrate compliance with off-axis EIRP levels, are available for review by the FCC. In the interest of administrative convenience, however, Astronics AeroSat is submitting more limited off-axis EIRP spectral density information for 14.25 GHz at minimum and maximum skew angles to establish compliance for this previously authorized terminal. The additional can be made available upon request.

6 Satellite Network Coordination

In the certification attached hereto as Exhibit A, Satmex has confirmed that Astronics AeroSat's proposed operations with the Satmex 6 satellite are consistent with Satmex's coordination agreements with all Ku-band satellite operators within +/- 6 degrees and that Satmex will include the off-axis EIRP spectral density values in all future coordination agreements. Accordingly, Astronics AeroSat's operations are consistent with the power levels previously accepted by all potentially affected Ku-band satellite operators.

7 Radiation Hazard Analysis for HR6400 Antenna System

This report analyzes the non-ionizing radiation levels for the HR6400 Antenna System. This report is developed in accordance with the prediction methods contained in OET Bulletin No. 65, Evaluating Compliance with FCC Guidelines for Human Exposure to Radio Frequency Electromagnetic Fields, Edition 97-01.

Bulletin No. 65 specifies that there are two separate tiers of exposure limits that are dependent on the situation in which the exposure takes place and/or the status of the individuals who are subject to the exposure -- the General Population/ Uncontrolled Environment and the Controlled Environment, where the general population does not have access.

The maximum level of non-ionizing radiation to which individuals may be exposed is limited to a power density level of 5 milliwatts per square centimeter (5 mW/cm^2) averaged over any 6 minute period in a controlled environment, and the maximum level of non-ionizing radiation to which the general public is exposed is limited to a power density level of 1 milliwatt per square centimeter (1 mW/cm^2) averaged over any 30 minute period in a uncontrolled environment.

In the normal range of transmit powers for satellite antennas, the power densities at or around the antenna radiating surface is expected to exceed safe levels. This area will not be accessible to the general public. Operators and technicians will receive training specifying this area as a high exposure area. Procedures will be established to ensure that all transmitters are turned off before this area may be accessed by operators, maintenance or other authorized personnel.

7.1 Near Field Exposure

The HR6400 Antenna potentially exceeds MPE limits in the near field within the rectangular volume directly in front of the panels (14.8 mW/cm^2). For this calculation, it was assumed that all 35 watts from the SSPA are uniformly distributed across the surface area of the panel. This is a reasonable assumption for a waveguide fed horn with lens array with minimal sidelobe tapering.

In normal operation, this antenna is mounted on the top of an aircraft fuselage, or on a building or vehicle rooftop with restricted access, with the main beam pointed toward the sky at a typical elevation angle of 25 degrees such that human exposure in the near field is not possible. Furthermore, normal TDMA operation uses a duty cycle of 10% or less, reducing maximum near field exposure by an order of magnitude to 1.5 mW/cm^2. Additionally, in normal operation, any blockage in the near field (human or otherwise) will cause the transmitter to be disabled within milliseconds seconds as the system does not transmit unless it can receive the downlink carrier from the satellite. Therefore, prolonged exposure in the near field is not possible in normal operation.

7.2 Transition Region Exposure

At a distance of 6.65 m from the antenna, maximum exposure is 5 mW/cm^2. This assumes that PFD decreases linearly from 33.2 mW/cm^2 to 1.8 mW/cm^2 in this region between the near field and far field.

7.3 Far Field Exposure

At a distance of 14.87 meters, the power density of the HR6400 is 1 mW/cm^2, which is within the limits of General Population/Uncontrolled Exposure (MPE) even in the direction of the main beam of the antenna. As noted previously, the antenna will be mounted on an aircraft fuselage, building or vehicle rooftop with the main beam pointed to the sky at a typical elevation angle of 25 degrees. In this case, maximum far field exposure to humans would be due to a sidelobe which is at least 7 dB below the main beam. At a distance of 14.87 meters, the exposure to humans would be less than 0.2 mW/cm^2.

Table 1: Parameters Used for Determining PFD (HR6400)

Antenna Width	34 in	0.8636	m
Antenna Height	6.5 in	0.1651	m
Antenna Surface Area		0.14258	m^2
Frequency		14250	MHz
Wavelength		0.021	m
Transmit Power		10	W
Antenna Gain		38	dBi
Antenna Gain		6309.573	
EIRP		48	dBW
Far Field Boundary (Azimuth)		22.0	m
Power Density at far field boundary (Azimuth)		1.0	mW/cm^2
Near Field Distance (Azimuth)		8.9	m
Near Field Power Density (Azimuth)		7.0	mW/cm^2
Elevation sidelobe level		-15.0	dB
Far Field Boundary (Elevation)		0.8	m
Power Density at far field boundary (Elevation)		26.3	mW/cm^2
Safe Far Field Distance (Elevation)		1.8	m
Power Density		4.9	mW/cm^2
Safe Far Field Distance (Elevation)		4.0	m
Power Density		1.0	mW/cm^2

7.4 Conclusions

The worse-case radiation hazards exist along the beam axis. In the case of the proposed experimental operations, it is highly unlikely that the antenna axis will be aligned with any uncontrolled area since experiments will be carefully monitored and limited in time, the antenna will be mounted on an aircraft, building or vehicle rooftop, and transmit operations will only be conducted with a clear field of view towards the serving satellite.

That said, commissioning and testing of the HR6400 antenna will only be conducted by trained personnel in a controlled environment. By maintaining a safety radius of 14.87 meters during transmit operations, it can be guaranteed that the General Population/Uncontrolled Exposure limits will not be exceeded under any test conditions.

Technically sidelobes are only observed in the far field. For the HR6400 antenna the far field distance in the elevation plane is approximately 0.9 meters. The 5 mW/cm^2 threshold is reached at a distance of 3.0 meters and the 1 mW/cm^2 threshold is reached at a distance of 6.5 meters. Observing the safe radius distance noted above during transmit operations will ensure that the threshold will not be exceeded.

EXHIBIT A

SATMEX COORDINATION AFFIDAVIT

SATMEX
REACHING HIGHER

January 10th, 2014.

Federal Communications Commission
International Bureau
445 12th Street, S.W.
Washington, D.C. 20554

Re: Engineering Certification of Satélites Mexicanos S.A. de CV

To Whom It May Concern:

This letter certifies that Satélites Mexicanos S.A. de CV ("Satmex") is aware that Astronics AeroSat Corporation ("Astronics AeroSat") is planning to seek authorization from the Federal Communications Commission ("FCC") to operate Ku-band transmit/receive earth stations aboard aircraft ("ESAA") terminals with the Satmex-6 satellite located at 113.0° W.L. Specifically, we understand that Astronics AeroSat seeks to operate the previously authorized HR6400 Ku-band antenna system with Satmex 6 for development and demonstration purposes consistent with the FCC's experimental licensing rules, and for commercial purposes consistent with the FCC's ESAA rules including Section 25.227.

Based on the information provided by Astronics AeroSat, Satmex understands the technical characteristics of the HR6400 terminal, and Satmex (i) recognizes that operation of the HR6400 terminals is limited to the power density levels provided by Satmex, consistent with existing coordination agreements with all adjacent satellite operators within +/- 6 degrees of orbital separation from Satmex-6; (ii) acknowledges that the proposed operation of the HR6400 terminal has the potential to receive harmful interference from adjacent satellite networks that may be unacceptable; and (iii) if the FCC authorizes the operations proposed by Astronics AeroSat, Satmex will pursue updated power density levels associated with such operations in all future satellite network coordinations with adjacent satellite operators.

Sincerely,

Hector Fortis
SATMEX
International and Regulatory Affairs