GLOBAL
EAGLE
ENTERTAINMENT
1050 OAK CREEK DRIVE
LOMBARD IL 60148
PHONE: (630) 620-0472
www.globaleagleent.com

Ku GSAA FCC Experimental Filing Narrative

Document Number:	RWD11-0032-00	Rev.:	2.0

	Name / Title	DATE
Prepared By:	Darshan Shah/ Sr. Systems Engineer	12/21/2016
Reviewed By:	David Keir / Consultant	12/21/2016
Approved By:	Atul Dhuria / Director Systems Engineering	12/21/2016

THIS PAGE INTENTIONALLY LEFT BLANK

REVISION HISTORY

ECO Number	Revision level	Approval Initial	Date Changed	Comments
1499	1.0	A. Dhuria	12/21/2016	Initial Release
1555	2.0	A. Dhuria	12/21/2016	Technical RF Performance has been updated due to FCC requirement changes

Table of Contents

List of Figures

List of Tables

List of Equations

1 Purpose of Experiment

Row 44[1] is seeking a license in the Experimental Radio Service for a one year period to operate up to four Aircraft Earth Stations (AESs) in North America pursuant to Sections 5.3 (e), (h) and (j) of the Commission's Rules. Reference 47 Code of Federal Regulations (CFR) Part 5.3(e), (h) and (j) for specific filing requirements. The purpose of this operation is to test and evaluate the terminal antenna for provision of commercial service under the Commission's rules governing Earth Stations Aboard Aircraft (ESAA). Reference 47 CFR Part 25.227 for specific filing requirements. Row 44 understands that experimental operation must operate on a non-interference basis with respect to primary users in the band, and must accept any interference caused by these licensees. To facilitate processing of this request, Row 44 is submitting the information provided in this attachment in addition to a completed FCC Form 442. This attachment describes the general scope of Row 44's planned experimental operations, the research to be performed, the complete technical details of the operations proposed, the program objectives, and the performance evaluation of these operations.

1.1 Overview of Row 44's Row 44 ESAA System

Row 44 currently offers a broadband Internet data service to passengers and crew abroad commercial aircraft traveling in North American airspace, consistent with the framework that the Commission has adopted for ESAA. The service includes IP data services, IP voice and IPTV. The purpose of the proposed experimental program is to test a new, next generation remote terminal for introduction to the existing Row 44/Row 44 ESAA network (Call Sign E080100). Row 44 notes that its transmission will comply with Part 25.227(a)(1)(i)(A) of the FCC's rules for the uplink Radio Frequency (RF) transmit power density will not exceed as indicated in Table 1 and Table 2 for each skew/elevation combination. A summary of principal transmission parameters is provided in Table 3

Table 1: – GSAA Maximum Spectral Density at the Antenna Flange to Comply with 47 CFR Part 25.227(a)(1)(i)(A)

GSAA MAXIMUM SPECTRAL DENSITY AT THE ANTENNA FLANGE (dBW/4kHz)

Elevation[deg]\Skew[deg]	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90
0	-15.6	-15.6	-15.7	-15.9	-16.2	-16.6	-17.1	-17.7	-18.2	-18.9	-19.6	-20.5	-21.6	-22.7	-24	-25.3	-26.6	-27.7	-28.4
5	-15.6	-15.6	-15.7	-15.9	-16.2	-16.6	-17.1	-17.7	-18.2	-18.9	-19.6	-20.5	-21.6	-22.7	-24	-25.3	-26.6	-27.7	-28.4
10	-15.6	-15.6	-15.7	-15.9	-16.2	-16.6	-17.1	-17.7	-18.2	-18.9	-19.6	-20.5	-21.6	-22.7	-24	-25.3	-26.6	-27.7	-28.4
15	-15.6	-15.6	-15.7	-15.8	-16.1	-16.4	-16.9	-17.4	-17.9	-18.5	-19.2	-20.1	-21.1	-22.1	-23.3	-24.6	-26	-27.2	-28.2
20	-15.6	-15.6	-15.7	-15.8	-16.1	-16.4	-16.9	-17.4	-17.9	-18.5	-19.2	-20.1	-21.1	-22.1	-23.3	-24.6	-26	-27.2	-28.2
25	-15.6	-15.6	-15.6	-15.7	-15.9	-16.2	-16.6	-17.1	-17.7	-18.2	-18.9	-19.6	-20.5	-21.6	-22.7	-24	-25.3	-26.6	-27.7
30	-15.6	-15.6	-15.6	-15.7	-15.9	-16.2	-16.6	-17.1	-17.7	-18.2	-18.9	-19.6	-20.5	-21.6	-22.7	-24	-25.3	-26.6	-27.7
35	-15.6	-15.6	-15.6	-15.7	-15.8	-16.1	-16.4	-16.9	-17.4	-17.9	-18.5	-19.2	-20.1	-21.1	-22.1	-23.3	-24.6	-26	-27.2
40	-15.6	-15.6	-15.6	-15.7	-15.8	-16.1	-16.4	-16.9	-17.4	-17.9	-18.5	-19.2	-20.1	-21.1	-22.1	-23.3	-24.6	-26	-27.2
45	-15.6	-15.6	-15.6	-15.6	-15.7	-15.9	-16.2	-16.6	-17.1	-17.7	-18.2	-18.9	-19.6	-20.5	-21.6	-22.7	-24	-25.3	-26.6
50	-15.6	-15.6	-15.6	-15.6	-15.7	-15.8	-16.1	-16.4	-16.9	-17.4	-17.9	-18.5	-19.2	-20.1	-21.1	-22.1	-23.3	-24.6	-26
55	-15.6	-15.6	-15.6	-15.6	-15.6	-15.7	-15.9	-16.2	-16.6	-17.1	-17.7	-18.2	-18.9	-19.6	-20.5	-21.6	-22.7	-24	-25.3
60	-15.6	-15.6	-15.6	-15.6	-15.6	-15.7	-15.8	-16.1	-16.4	-16.9	-17.4	-17.9	-18.5	-19.2	-20.1	-21.1	-22.1	-23.3	-24.6
65	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6	-15.7	-15.9	-16.2	-16.6	-17.1	-17.7	-18.2	-18.9	-19.6	-20.5	-21.6	-22.7
70	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6	-15.7	-15.8	-16.1	-16.4	-16.6	-17.4	-17.9	-18.2	-19.2	-20.1	-21.1
75	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6	-15.7	-15.9	-16.2	-16.6	-17.1	-17.7	-18.2
80	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6
85	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6
90	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6

[1]The in-flight connectivity business established by Row 44 now operates under the name Global Eagle Entertainment, which is the parent company of Row 44 (see IBFS File No. SES-T/C-20121203-01063). As Row 44 remains the name of the FCC licensee, that designation is used in this application.

Table 2:~~ –~~ GSAA Maximum EIRP Spectral Density to Comply with 47 CFR Part 25.227(a)(1)(i)(A)

GSAA MAXIMUM EIRP SPECTRAL DENSITY (dBW/4kHz)

Elevation[deg]\Skew[deg]	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90
0	18.3	18.3	18.2	18	17.7	17.3	16.8	16.2	15.7	15	14.3	13.4	12.3	11.2	9.9	8.6	7.3	6.2	5.5
5	18.3	18.3	18.2	18	17.7	17.3	16.8	16.2	15.7	15	14.3	13.4	12.3	11.2	9.9	8.6	7.3	6.2	5.5
10	18.3	18.3	18.2	18	17.7	17.3	16.8	16.2	15.7	15	14.3	13.4	12.3	11.2	9.9	8.6	7.3	6.2	5.5
15	18.3	18.3	18.2	18.1	17.8	17.5	17	16.5	16	15.4	14.7	13.8	12.8	11.8	10.6	9.3	7.9	6.7	5.7
20	18.3	18.3	18.2	18.1	17.8	17.5	17	16.5	16	15.4	14.7	13.8	12.8	11.8	10.6	9.3	7.9	6.7	5.7
25	18.3	18.3	18.3	18.2	18	17.7	17.3	16.8	16.2	15.7	15	14.3	13.4	12.3	11.2	9.9	8.6	7.3	6.2
30	18.3	18.3	18.3	18.2	18	17.7	17.3	16.8	16.2	15.7	15	14.3	13.4	12.3	11.2	9.9	8.6	7.3	6.2
35	18.3	18.3	18.3	18.2	18.1	17.8	17.5	17	16.5	16	15.4	14.7	13.8	12.8	11.8	10.6	9.3	7.9	6.7
40	18.3	18.3	18.3	18.2	18.1	17.8	17.5	17	16.5	16	15.4	14.7	13.8	12.8	11.8	10.6	9.3	7.9	6.7
45	18.3	18.3	18.3	18.3	18.2	18	17.7	17.3	16.8	16.2	15.7	15	14.3	13.4	12.3	11.2	9.9	8.6	7.3
50	18.3	18.3	18.3	18.3	18.2	18.1	17.8	17.5	17	16.5	16	15.4	14.7	13.8	12.8	11.8	10.6	9.3	7.9
55	18.3	18.3	18.3	18.3	18.3	18.2	18	17.7	17.3	16.8	16.2	15.7	15	14.3	13.4	12.3	11.2	9.9	8.6
60	18.3	18.3	18.3	18.3	18.3	18.2	18.1	17.8	17.5	17	16.5	16	15.4	14.7	13.8	12.8	11.8	10.6	9.3
65	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.2	18	17.7	17.3	16.8	16.2	15.7	15	14.3	13.4	12.3	11.2
70	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.2	18.1	17.8	17.5	17.3	16.5	16	15.7	14.7	13.8	12.8
75	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.2	18	17.7	17.3	16.8	16.2	15.7
80	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3
85	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3
90	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3

Table 3:~~ –~~ Row 44 Transmission Parameters for GSAA

Antenna Manufacturer	QEST
Antenna Model Number	GSAA RF Subsystem
Transmitter frequencies	14.05-14.47 GHz ± 10^{-5}%
Modulating waveform	DVB-S2, DVB-S2X, QPSK, 8-PSK
Boresight Gain	33.6 dBi (at 14.25 GHz)
Antenna Off-~~axis~~ Axis ~~gain~~ Gain ~~performance~~Performance	Partially complies with §25.209
High Power Amplifier Maximum	25 watts
Peak power ~~density~~ Density at the ~~flange~~Flange	-15.6 dBW/4kHz
Carrier Bandwidth	1.024 MHz (1M02G7D)
Peak Boresight EIRP (~~after~~ After ~~cable~~ Cable and ~~radome~~ Radome ~~losses~~Losses)	41.3 dBW (Carrier Bandwidth at 14.25 GHz)
Off-axis EIRP Co-~~pol~~ Pol Spectral Density	Complies with §25.227

Formatted Table

Approval of the requested authority will serve the public interest by completely characterizing the performance and non-interference with existing Fixed Satellite Service operations and will permit Row 44 to continue its preparation to upgrade and expand its in-flight mobile broadband service. Row 44's provision of ESAA services is already providing high-speed broadband internet access, interactive entertainment, and also facilitates access by flight crews to important weather updates, and security information. The addition of the proposed Global Satellite Antenna Assembly (GSAA) antenna to Row 44's current operations will promote both improved and expanded service to the traveling public. Accordingly, Row 44 requests that the FCC grant its application for a license in the Experimental Radio Service. Row 44 is able to commence testing immediately.

1.2 Overview of Row 44's ESAA Antenna Experimental Plan

The Ku band AESs used by Row 44 provide two-way broadband communications services to passengers and flight crews, allowing in-flight, real-time access to e-mail, the Internet and virtual private networks. The AESs will operate in conjunction with a Very Small Aperture Terminal (VSAT) network hub station that is licensed to Hughes Network Systems (HNS).

The Row 44 ESAA system provides two-way, broadband communications between multiple aircraft terminals and the Internet via multiple satellite gateways under the control of a Network Operations Center (NOC). Satellite gateways are procured from HNS based on the existing Hughes HX as well as HT architecture. A key element of the HNS's satellite system is a VSAT HX/HT broadband terminal that provides Internet Protocol (IP) connectivity via geostationary satellites, augmented with a mobility feature to offer airborne users broadband IP data service. The airborne platform is comprised of GSAA, a Ku-Band RF Unit (KRFU), a Modem Data Unit (MDU), a Cabin Wireless Local Area Network (LAN) Unit (CWLU), and a Server Management Unit (SMU). The system supports reception and transmission in the 11.70 GHz to 12.20 GHz and 14.05 GHz to 14.47 GHz band respectively, utilizing independent linearly polarized array antennas for communication to and from a geostationary satellite in space. The GSAA supports an elevation range from 90° to 0° of continuous coverage while the azimuth coverage will be continuous over 360°.

Space segment capacity for experimental operations will consist of transponders on AMC-1 (129° W.L.), AMC-9 (83° W.L.), and SES-1 (101° W.L.). The Ground Earth Station (GES) is licensed to Hughes Network Systems under the call sign E940460 and is located in North Las Vegas, Nevada (Latitude: 36°14'11.0"N; Longitude: 115°7'4.0"W – 83-NAD) as well as SES at Woodbine, MD (Latitude: 38°40'3.36"N; Longitude: 77°26'24.0"W – 83-NAD) under the call sign E900448 and E140059. The aircraft used for experimental testing is a HU-16B Albatross test aircraft (US registration N44HQ) outfitted with the Row 44 Broadband System and a Honeywell Aircraft Data Inertial Reference Unit (ADIRU). There will also be units tested at a testing facility in Lombard, IL on a laboratory cart.

Multiple users access the 36 MHz satellite transponder bandwidth using Time Division Multiple Access (TDMA). The 1.024 MHz bandwidth waveform supports adaptive coding and modulation and will be using the latest generation transmission standard Digital Video Broadcasting (DVB-S2 and DVB-S2X). The modulation from the satellite to the AES is either Quadrature Phase Shift Keying (QPSK) or Octal Phase Shift Keying (PSK) at a maximum transmitted signaling rate of 30 mega-symbols/second.

The modulation from the AES to the satellite is offset QPSK with a transmitted signaling rate of 2048, 1024, 512, or 256 kilo-bits/second (kbps). In cases where the baseband modulated signal is not of a 1.024 Msps rate, the transmitter shall employ spreading to convert baseband 256 ksps or 512 ksps signals to occupy the 1.024 MHz bandwidth, thereby maintaining compliance with the 1.024 MHz channel allocation. For robust operation, transmit encoding utilizes multi-rate 1/2, 2/3, 4/5, and 9/10 turbo-coding. Received encoding incorporates a BCH (Bose, Chaudhuri, and Hocquenghem) code with a low density parity check code at rates ranging from 1/4, 1/3, 2/5, 9/20, 1/2, 11/20, 3/5, 2/3, 3/4, 4/5, 5/6, 8/9, and 9/10 for QPSK and 1/2, 3/5, 23/36, 2/3, 25/36, 3/4, 4/5, 5/6, 8/9, and 9/10 for 8PSK. These waveforms are modulated/ demodulated in the MDU. For the uplink signal, the Ku KRFU provides the frequency up-conversion from the intermediate L-Band frequencies of 950 to 1450 MHz to the transmit frequency, and the subsequent signal amplification. When the antenna gain is included in the AES link budget, the transmitter emits a maximum effective isotropic radiated power (EIRP) of +41.3 dBW.

Row 44's GSAA antenna is not compliant with the off-axis antenna gain envelope established in 47 CFR Part 25.209(a)(2) and 25.209(a)(5), as illustrated in Table 4 and Table 5 which shows compliance by skew and elevation ("1" indicates the antenna is compliant and "0" indicates the antenna is not compliant to the requirement indicated in the caption).

Table 4:~~ –~~ 47 CFR Part 25.209(a)(2) Azimuth Co-Polarization Gain Envelope Compliance ~~across~~ Across ~~all~~ All Skew ~~&~~ and Elevation as well as Frequency (14.05– 14.47GHz) ~~&~~ and Linear Polarization

Elevation[deg]\Skew[deg]	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90
0	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0
5	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0
10	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0
15	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0
20	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0
25	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0
30	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0
35	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0
40	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0
45	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
50	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
55	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0
60	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0
65	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0
70	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0
75	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
80	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
85	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
90	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Table 5:~~ –~~ 47 CFR Part 25.209(a)(5) Elevation Co-Polarization Gain Envelope Compliance ~~across~~ Across ~~all~~ All Skew ~~&~~ and Elevation as well as Frequency (14.05– 14.47GHz) ~~&~~ and Linear Polarization

Elevation[deg]\Skew[deg]	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90
0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
5	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
10	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
15	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
20	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
25	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
30	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
35	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
40	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
45	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1
50	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1
55	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1
60	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1
65	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1
70	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1
75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1
80	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
85	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

However, the AES transmitter shall still be comply with the FCC EIRP spectral density limits as indicated in 47 CFR Part 25.227(a)(1)(i)(A) and is illustrated in Table 1 which indicates the maximum uplink flange densities capable of satisfying the FCC maximum EIRP spectral density limit across all frequency and polarization (Note: the antenna performance is best at 14.50 GHz; it is the performance at this frequency which determines the maximum EIRP spectral density). Table 2 indicates the maximum EIRP spectral density to meet the FCC requirement. Row 44 has obtained the required coordination letters for this antenna pursuant to 47 CFR Part 25.227(b) with SES Americom, the satellite space segment provider. Copies of these letters are attached in Exhibit B. All operations will also be subject to existing coordination agreements executed in 2008 with the National Aeronautics and Space Administration (NASA) and the National Science Foundation (NSF) covering the transmit band operations of Row 44's license ESAA network.

A radiation hazard study for this antenna is provided as Appendix C ~~**Error! Reference source not found.**~~ hereto.

1.3 Antenna Characteristics

1.3.1 Transmit Patterns

Antenna EIRP spectral density plots for the transmit band at 14.00 GHz, 14.25 GHz, and 14.50 GHz are attached as Exhibit A in conformance with 47 CFR Part 25.227 and as required under 47 CFR Part 25.225(g)(1). Patterns are provided for vertical and horizontal polarization, each for a given range of elevation and/or skew values. Each plot demonstrates compliance with the off-axis EIRP density limits for one of a variety of conditions where the aircraft's location, not being of the same longitude as the target satellite, invokes a skew of the antenna's orientation relative to that of the satellite.

EIRP spectral density plots are shown in Exhibit A. These plots depict the antenna's compliance to 47 CFR Part 25.227. The specific skew and elevation combinations were selected so as to associate with the best-case and worst-case off-axis scenarios relating to compliance. Please note that the GSAA EIRP spectral density performance in the plane perpendicular to the GSO plane (i.e. the FCC mask as required under 47 CFR Part 25.227(a)(1)(i)(B)) is not fully compliant to the same EIRP spectral density levels in the plane tangent to the GSO plane (i.e. the FCC mask as required under 47 CFR Part 25.227(a)(1)(i)(A)). This is well understood with the satellite space segment provider and has been coordinated with the adjacent satellites.

The vertical and horizontal polarizations off-axis gain characteristics indicate the antenna can support the EIRP spectral densities as described in section 1.1 while being compliant to 47 CFR Part 25.227, the transmit power being set to values being respectively compatible with the prevailing values of the antenna skew and elevation.

In practice, during aircraft movement, the skew angle value is monitored by the GSAA. The aircraft transmitter shall be muted in the event that the skew angle exceeds a specific limit, corresponding to that beyond which, the off-axis EIRP density would otherwise exceed the 47 CFR Part 25.227 EIRP density consistent with those of Row 44's current authorization.

1.3.2 Antenna Control

The experimental configuration operates the same way as the existing, licensed configuration. The Antenna Control Unit (ACU), a separate device connected to the existing Satellite Antenna Assembly (SAA) is now integrated within the GSAA. Compensating for the aircraft motion, the GSAA adjusts the antenna's azimuth, elevation, and polarization in maintain the pointing of the antenna toward the target satellite.

The GSAA obtains information on the aircraft's location, velocity, and orientation from the on-board Inertial Navigation System (INS) via either an ARINC 429, ARINC 629, or ARINC 664 data bus. The GSAA antenna is gimbaled, which permits the directing of the transmission beam in azimuth, elevation, and polarization according to the received signal quality and aircraft position data. As with the licensed implementation with the current SAA antenna, the combination of the aircraft's inertial navigation data and measured Es/N0 data (provided to the GSAA from the (MDU)) allow the 0.2° peak error to be maintained under the variety of aircraft motion and orientation scenarios.

1.3.3 Antenna Pointing Accuracy and Tracking

In compliance with 47 CFR Part 25.227(a)(1)(ii)(A), as well as ITU-R M.1643, Annex 1, Part A, Section 2, antenna pointing accuracy is controlled by the GSAA to a pointing error of less than 0.2° peak between the orbital location of the target satellite and the axis of the main lobe of the antenna. Row 44 has designed its system so that all emissions shall 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 is projected to exceed ±0.2°. This provides ample margin to ensure satisfaction of the requirement of 47 CFR Part 25.227(a)(1)(iii)(A) that transmissions cease in the event this angle exceeds ±0.5°.

If, under rare circumstances such as extreme turbulence, the GSAA is incapable of maintaining its pointing towards the satellite, the transmitter shall be muted as mentioned, and only resumed upon the pointing error assuming a value less than 0.2°.

1.3.4 Interference Protection-Terrestrial Sites

Row 44 complies with the out–of-band emissions requirements in 47 CFR Part 25.202(f). Row 44 is also cognizant of FCC rules for fixed satellite services and will operate on a non-interfering basis. For purposes of protecting Radio Astronomy sites, consistent with ITU Recommendation M.1643, Part C, Row 44 will limit aggregate power flux density (pfd) in the band 14.47 GHz to 14.5 GHz as follows:

- -221 dBW/m^2/Hz (for protection of Green Bank, Arecibo, and Socorro)
- -189 dBW/m^2/Hz (for protection of 10 Very Long Baseline Array sites)

Row 44 has executed a coordination agreement with the NSF that establishes non-interfering operation with radio observations (see Exhibit B).

Row 44 also acknowledges the utilization of the frequency band from 14.0 GHz to 14.05 GHz and the possible use of the band from 14.05 GHz to 14.2 GHz allocated to NASA Tracking and Data Relay Satellite System (TDRSS) for space research. NASA's protection limits specify that the interference threshold limit is -100 dBW/MHz in the 14.05 GHz to 14.4 GHz band, -146 dBW/MHz in the 14.0 GHz to 14.05 GHz band, and -176 dBW/MHz in the 13.4 GHz to 14.0 GHz band. Row 44 has discussed its planned operation with NASA and by terminating AES transmission in the vicinity of NASA sites located at White Sands, New Mexico and Blossom Point, Maryland. Row 44 will comply with the limits near these earth stations. In the event that Row 44 begins operation in the vicinity of Guam, it will also coordinate this operation with NASA to avoid unacceptable interference. Consistent with the requirements of ITU Recommendation M.1643, Part D, a coordination agreement between Row 44 and NASA has been executed (see Exhibit B).

Finally, Row 44 recognizes that the FCC maintains multiple monitoring stations throughout the US where the received field strength at the monitoring stations must not exceed 10mV/m^2 in the authorized bandwidth.

In summary, Row 44 will mute transmission at a range that would otherwise have the potential to cause interference with any of the above identified terrestrial sites.

1.3.5 Interference protection-Adjacent Satellites

Adjacent Satellite Interference (ASI) is mitigated by the sidelobe performance of the GSAA antenna (Satellites at 2° spacing have the greatest potential exposure to interference. It is unlikely that interference occurs for satellites with a spacing that is greater than 2° from the target satellite).

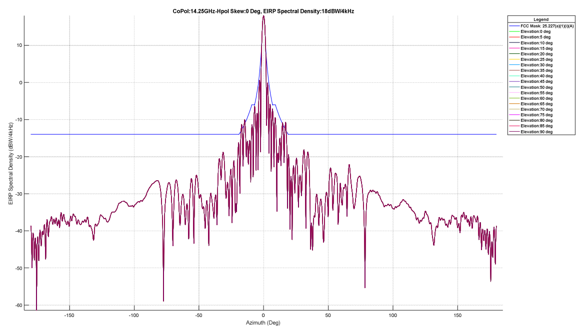
Row 44 shall ensure that:

- GSAA movement and pointing accuracy is accomplished such that the interference to adjacent satellites and/or adjacent transponders within the same satellite does not occur during the more-demanding instances during aircraft taxiing, take-off, in-flight, and landing;

- Under conditions of extreme and abrupt aircraft movement, where the GSAA hardware is incapable of immediately responding, and the pointing error temporarily exceeds 0.2°, that the transmitter is muted.

1.3.6 Maximum EIRP

Row 44's maximum power spectral density at the antenna flange is -15.6 dBW/4kHz resulting in a maximum EIRP of 41.3 dBW in a 1.024 MHz bandwidth (cable and radome losses are accounted for). A plot of the EIRP density in a 4 kHz band for horizontal and vertical polarizations at 14.25 GHz at 0 degree skew (with traces covering the range of 0° to 90° elevation) is shown in Figure 1 per 47 CFR Part 25.227(a)(1).



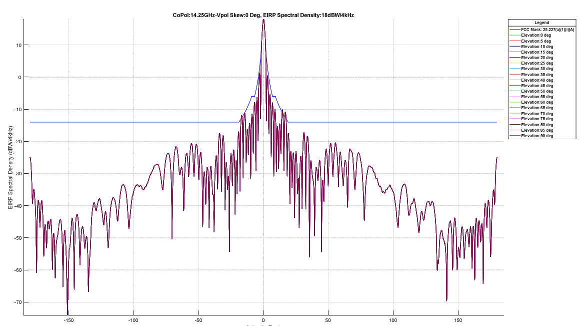


Figure 1 – EIRP Density for Horizontal and Vertical Polarization with 0° Skew (and 0° to 90° elevation) at 14.25 GHz to Show 47 CFR Part 25.227(a)(1)(i)(A) ~~compliance~~Compliance

1.4 Program Objectives

Row 44's GSAA system has several challenges to be met in order to most effectively attain optimal performance. Thus the following issues need to be evaluated under controlled conditions:

1. Maintaining the antenna pointing accuracy during aircraft taxi, take-off, in-flight, and landing, and assuring the 'time-to-mute' (if the 0.5° accuracy is exceeded) is within requirements.
2. Eliminating the potential of adjacent satellite interference for satellites within 2° to 6° spacing of the target satellite, while operating the transmitter at its maximum, authorized level.
3. Assessing the extent of geographic RF coverage regions, performing satellite 'handoffs' as needed, considering prevailing skew angle and GSAA pointing elevation angles
4. Evaluating ~~bit~~ Bit ~~error~~ Error ~~rate~~ Rate (BER) performance both in clear and severe weather conditions
5. Verifying Doppler compensation performance during moments of rapid aircraft acceleration and high velocity
6. Determining the necessary ranges for avoiding interference to terrestrial locations such as NASA TDRSS sites, NSF Radio Astronomy site, and FCC monitoring sites

1.5 Contributions to the Development of Radio Art

Operation of airborne internet service is a burgeoning field, where airlines anticipate significant increases in passenger traffic as long as satisfactory user experience is maintained. To ensure that users are offered reliable service at speeds commensurate with their expectations, extensive evaluation must be conducted prior to full scale commercial deployment of any enhanced new transmit/receive terminals.

High speed service aboard a commercial aircraft via satellite is markedly dependent on the radio link performance, aircraft motion, and airborne antenna dynamics and characteristics. In addition, this performance must not interfere with existing satellite and ground services making it imperative to identify any situations where interference might occur that require transmitter muting.

Appendix A EIRP Spectral Density Plots

EIRP Spectral Density Plots

Appendix B Coordination Letters

Coordination Letters

Appendix C Radiation Hazard Analysis

C.1 GSAA Antenna

C.1.1 Introduction

This exhibit constitutes the radiation hazard analysis for Row 44's transmitter using the FCC procedure outlined in FCC Bulletin #65. The limit for exposure to RF energy, for frequencies greater than 1.5 GHz, is 5 mW/cm^2 for up to a six minute duration (occupational/controlled exposure) and a 1 mW/cm^2 for up to 30 minute duration (categorized as general population/ uncontrolled exposure).[1]

Analysis for exposure to radiation is presented for the near field, far field, and the transition region. Appropriate separation-distances are provided for the controlled and uncontrolled exposure scenarios considering individuals located in the direction of either the antenna's main beam or its side lobes.

C.1.2 Analysis

The extent of the near field region for the main beam is defined in terms of the radius R_{nf} according to the relation

Equation 1 – Near Field Region Radius

$$R_{nf} = \frac{D^2}{4\lambda}$$

where D is the maximum dimension of the antenna panel, and λ is the transmit signal's wavelength.

The near field maximum power density, S_{nf}, is determined from

Equation 2 – Near Field Maximum Power Density

$$S_{nf} = 0.1\,\eta\,\frac{P_{PA}}{A}\left(\frac{in\ mW}{cm^2}\right)$$

where P_{PA} is the transmit power (after cable losses are accounted for) and A is the surface area of the antenna aperture, and η is the efficiency of the antenna aperture.

The far field region for the main beam is defined as beginning and continuing out-from a radius R_{ff}, given by

Equation 3 – Far Field Region Radius

$$R_{ff} = 0.60\left(\frac{D^2}{\lambda}\right)$$

The far field power density S_{ff} at the minimum far field radius and farther is given in terms of the EIRP denoted by P_{EIRP} according to

Equation 4 – Far Field Power Density

$$S_{ff} = \frac{P_{ERIP}}{(4\pi)\left(R_{ff}^2\right)}$$

(The value of P_{EIRP} should already consider coax losses and aperture efficiency.)
Note that when the radius is expressed in meters, the Power Density is in units of W/m^2. The results are converted to units consistent with the FCC limits (mW/cm^2) by multiplying values in W/m^2 by 0.1.

C.1.2.1 Near Field Exposure from Main Antenna Beam

The GSAA antenna has the "quasi-oval" dimensions of D=0.627 m (24.7 inches) and h=0.198 m (7.8 inches). However, all considered, the adjusted surface area "A" equals 0.1019 m^2.

At the highest frequency of 14.5 GHz, the wavelength is 0.0207 m. The near field radius is then R_{nf} = 4.75 m

The antenna aperture efficiency factor, η, is 0.77 and losses attributable to various hardware is 4.21 dB. Based on the wavelength and the panel-width given farther above, the Far Field radius is then R_{ff} = 11.41 m

In the operation of GEE's system, the antenna may be fed with ten different signal levels, as provided in Table 6~~Error! Reference source not found.~~ and Table 7~~Error! Reference source not found.~~. The associated Near Field radius Power Density Values are:

Field Code Changed

Field Code Changed

~~Table 6: HPA Transmit Power, EIRP, and Near Field Power Density as a Distance R_{nf}~~

Table 6: HPA Transmit Power, EIRP, and Near Field Power Density as a Distance R_{nf}

Formatted: Caption, Keep with next

HPA Transmit Power (Watts)	HPA Transmit Power (dBm)	Transmit Power (dBm)*	S_{nf} (mW/cm^2)*
25.00	43.98	39.77	7.17
22.28	43.48	39.27	6.39
19.86	42.98	38.77	5.69
17.70	42.48	38.27	5.07
15.77	41.98	37.77	4.52
14.06	41.48	37.27	4.03
12.53	40.98	36.77	3.59
11.17	40.48	36.27	3.20
9.95	39.98	35.77	2.85
8.87	39.48	35.27	2.54
7.91	38.98	34.77	2.27
7.05	38.48	34.27	2.02
6.28	37.98	33.77	1.80
5.60	37.48	33.27	1.60
4.99	36.98	32.77	1.43
4.45	36.48	32.27	1.27
3.96	35.98	31.77	1.14
3.53	35.48	31.27	1.01
3.15	34.98	30.77	0.902
2.81	34.48	30.27	0.804
2.50	33.98	29.77	0.717

*Incorporates hardware losses

(**Note:** ~~that~~ the equation for the maximum Power Density in the Near Field considers a given radiated signal/power confined-to and passing-through a physical area corresponding to that of the antenna aperture. Along these lines, the S_{nf} values cannot be assumed to vary with distance from the antenna, for locations within the Near Field.)

Formatted: Justified

Formatted: Font: Bold, Underline

The associated Far Field radius Power density values are ~~as well~~illustrated in Table 7~~Table 7~~:

~~Table 7: HPA Transmit Power, EIRP, and Far Field Power Density at Distance R_{ff}~~

Table 7: HPA Transmit Power, EIRP, and Far Field Power Density at Distance R_{ff}

Formatted: Caption, Keep with next

HPA Transmit Power (Watts)	HPA Transmit Power (dBm)	EIRP (dBm)*	Sff (mW/cm2)*
25.00	43.98	73.37	1.33

HPA Transmit Power (Watts)	HPA Transmit Power (dBm)	EIRP (dBm)*	Sff (mW/cm2)*
22.28	43.48	72.87	1.19
19.86	42.98	72.37	1.06
17.70	42.48	71.87	0.942
15.77	41.98	71.37	0.839
14.06	41.48	70.87	0.748
12.53	40.98	70.37	0.667
11.17	40.48	69.87	0.594
9.95	39.98	69.37	0.530
8.87	39.48	68.87	0.472
7.91	38.98	68.37	0.421
7.05	38.48	67.87	0.375
6.28	37.98	67.37	0.334
5.60	37.48	66.87	0.298
4.99	36.98	66.37	0.265
4.45	36.48	65.87	0.237
3.96	35.98	65.37	0.211
3.53	35.48	64.87	0.188
3.15	34.98	64.37	0.167
2.81	34.48	63.87	0.149
2.50	33.98	63.37	0.133

* Incorporates hardware losses

Comment [OJ271961]: This is not a dish antenna.

Row 44 is considering exposure to two values of Power Density: 5 mW/cm^2 and 1 mW/cm^2.

C.1.2.2 5 mW/cm^2 Analysis

Some of the S_{nf} values in Table 6~~Error! Reference source not found.~~ are greater than 5 mW/cm^2, and some are less than 5 mW/cm^2. As the Near Field analysis assumes that the Power Density in the Near Field does not vary with distance, for cases where S_{nf} values are less than 5 mW/cm^2, there is no location in the Near Field where the Power Density is higher. No individual located in the Near Field anywhere whatsoever will be subjected to a 5 mW/cm^2 exposure level.

Field Code Changed

For the S_{nf} values in Table 6~~Error! Reference source not found.~~ which are greater than 5 mW/cm^2, we'll assume that the Power Density decreases linearly between the Near Field radius and the Far Field radius. Interpolating the respective Power Density values, Table 8~~Error! Reference source not found.~~ lists the distances where the Power Density will equal 5 mW/cm^2 (for the selected TX powers).

Field Code Changed

~~Table 8: Separation for Controlled Exposure Limit (Main Beam)~~

Table 8: Separation for Controlled Exposure Limit (Main Beam)

HPA Transmit Power (dBm)	Separation for Controlled Limit (5 mW/cm^2)	
	Meters	Feet
43.98	7.22	23.7
43.48	6.52	21.4
42.98	5.74	18.8
42.48	4.87	16.0

As mentioned previously, if for S_{nf} values less than 5 mW/cm^2, in attempting to determine the location at which the Power Density may equal 5 mW/cm^2, we cannot project a location closer than R_{nf}.

For such cases, and for these power levels, a conservative approach will be adopted. Table 9~~Error! Reference source not found.~~ therefore designates the Near Field radius of 4.75 meters (15.6 feet) as the minimum physical separation guaranteeing an exposure no greater than 5 mW/cm^2.

~~Table 9: Separation for Controlled Exposure Limit (Main Beam)~~

Table 9: Separation for Controlled Exposure Limit (Main Beam)

HPA Transmit Power (dBm)	Separation for Controlled Limit (5 mW/cm^2)	
	Meters	Feet
41.98	4.75	15.6
41.48	4.75	15.6
40.98	4.75	15.6
40.48	4.75	15.6
39.98	4.75	15.6
39.48	4.75	15.6
38.98	4.75	15.6
38.48	4.75	15.6
37.98	4.75	15.6
37.48	4.75	15.6
36.98	4.75	15.6
36.48	4.75	15.6
35.98	4.75	15.6
35.48	4.75	15.6
34.98	4.75	15.6
34.48	4.75	15.6
33.98	4.75	15.6

C.1.2.3 1 mW/cm^2 Analysis

For the cases in Table 7~~**Error! Reference source not found.**~~ where the S_{ff} values are greater than 1 mW/cm^2, the distance of separation will be calculated by inverse-squared analysis. For the cases in Table 7~~**Error! Reference source not found.**~~ where the S_{ff} values are less than 1 mW/cm^2, linear interpolation will be used to identify the location between R_{nf} and R_{ff} where the 1 mW/cm^2 value will be encountered. For the cases in Table 6~~**Error! Reference source not found.**~~ where the S_{nf} values are less than 1 mW/cm^2, a distance of R_{nf} will apply.

Formatted: Caption, Keep with next

Formatted: Caption, Keep with next

For the TX levels where S_{ff} values exceed 1 mW/cm^2, standard inverse-squared analysis has been used to identify the necessary separations listed in **Error! Reference source not found.** ~~**Error! Reference source not found.**~~.

Table 10: Separation for Uncontrolled Exposure Limit (Main Beam)

HPA Transmit Power (dBm)	Separation for Uncontrolled Limit (1 mW/cm^2)	
	Meters	Feet
43.98	13.1	43.1
43.48	12.4	40.7
42.98	11.7	38.4

For the TX levels where S_{ff} values are less than 1 mW/cm^2, linear interpolation will be employed (considering the Power Density values at R_{nf} and R_{ff}) in order to project the location at which a 1 mW/cm^2 exposure exists.

Assuming that the Power Density decreases linearly between the Near Field radius and the Far Field radius, the distances at which the Power Density equals 1 mW/cm^2 are listed in Table 10 ~~Error! Reference source not found.~~.

~~**Table 6: Separation for Uncontrolled Exposure Limit (Main Beam)**~~

Table 10: Separation for Uncontrolled Exposure Limit (Main Beam)

Formatted: Caption, Keep with next

HPA Transmit Power (dBm)	Separation for Uncontrolled Limit (1 mW/cm^2)	
	Meters	Feet
42.48	11.3	37.1
41.98	11.1	36.5
41.48	10.9	35.7
40.98	10.6	34.9
40.48	10.4	34.0
39.98	10.1	33.0
39.48	9.71	31.8
38.98	9.31	30.6
38.48	8.87	29.1
37.98	8.38	27.5
37.48	7.83	25.7
36.98	7.21	23.6
36.48	6.51	21.4
35.98	5.73	18.8
35.48	4.85	15.9

For TX levels where S_{nf} values are less than 1 mW/cm^2, a conservative approach will be adopted. Table 11~~Table 7~~ therefore references the Near Field radius of 4.75 meters (15.6 feet) as the minimum physical separation to facilitate an exposure no greater than 1 mW/cm^2 for the respective power levels.

~~Table 7: Separation for Uncontrolled Exposure Limit (Main Beam)~~

Table 11: Separation for Uncontrolled Exposure Limit (Main Beam)

Formatted: Caption, Keep with next

HPA Transmit Power (dBm)	Separation for Uncontrolled Limit (1 mW/cm^2)	
	Meters	Feet
34.98	4.75	15.6
34.48	4.75	15.6
33.98	4.75	15.6

C.1.2.4 Exposure from Antenna Beam Side-Lobes

The previous calculations assumed the individual was located in the sight of the main antenna beam (The main antenna beam is less than 10 degrees beam-width in azimuth). The following analysis provides insight into the exposure when an individual is located to the side of or behind the antenna.

Table 12~~Error! Reference source not found.~~ provides Power Density values at distances R_{nf} and R_{ff} when an individual is located in the direction of the highest antenna side-lobe (which corresponds to a 17 dB gain reduction from the main beam).

Formatted: Font: Not Bold

~~Table 8: Transmit Power, EIRP, and Far Field Power Density at Distance R_{ff}~~

Table 12: Transmit Power, EIRP, and Far Field Power Density at Distance R_{ff}

Formatted: Caption, Keep with next

HPA Transmit Power (dBm)	Sidelobe (dB)	Sidelobe Transmit Power (dBm)*	Sidelobe EIRP (dBm)*	S_{nf} (mW/cm^2)	S_{ff} (mW/cm^2)
43.98	-17	22.77	52.16	0.0542	0.0265
43.48	-17	22.27	51.66	0.0483	0.0237
42.98	-17	21.77	51.16	0.0431	0.0211
42.48	-17	21.27	50.66	0.0384	0.0188
41.98	-17	20.77	50.16	0.0342	0.0167
41.48	-17	20.27	49.66	0.0305	0.0149
40.98	-17	19.77	49.16	0.0272	0.0133
40.48	-17	19.27	48.66	0.0242	0.0119
39.98	-17	18.77	48.16	0.0216	0.0106
39.48	-17	18.27	47.66	0.0192	0.00942
38.98	-17	17.77	47.16	0.0171	0.00839
38.48	-17	17.27	46.66	0.0152	0.00748
37.98	-17	16.77	46.16	0.0136	0.00667
37.48	-17	16.27	45.66	0.0121	0.00594
36.98	-17	15.77	45.16	0.0108	0.00530
36.48	-17	15.27	44.66	0.00965	0.00472
35.98	-17	14.77	44.16	0.00860	0.00421
35.48	-17	14.27	43.66	0.00766	0.00375
34.98	-17	13.77	43.16	0.00683	0.00334
34.48	-17	13.27	42.66	0.00609	0.00298
33.98	-17	12.77	42.16	0.00542	0.00265

*Incorporates Coax Feeder Loss

As is obvious, neither the S_{nf} or S_{ff} values (at distances R_{nf} or R_{ff}) exceed even the uncontrolled limit of 1 mW/cm^2. Therefore, no minimum distance criteria of separation will apply for individuals located in directions outside the antenna's main beam.

C.1.3 Summary

This exhibit presents the radiation hazard analysis for Row 44 's GSAA transmitter transmitting at HPT output/transmit power levels of 33.98 to 43.98 dBW in increments of 0.5 dB. Considering the worst-cases, individuals positioned in the direction of the main beam of the antenna, and in the controlled exposure environment should be at least 7.22 meters (23.7 feet) away from the antenna aperture (for a 6 minute duration). Under the same circumstance, individuals in an uncontrolled exposure environment should be at least 13.1 meters (43.1 feet) away from the antenna aperture (for a 30 minute duration).

For individuals located in directions which are outside the antenna's main beam, no minimum distance of separation is applicable.