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REQUEST FOR LM400 EXPERIMENTAL AUTHORIZATION

Lockheed Martin Corporation ("Lockheed Martin") hereby seeks authority under Part 5 of the Federal Communications Commission's rules to conduct experimental satellite operations of one LM 400 Radar Pathfinder (RPF) Satellite and RF Payload in support of an exercise conducted for the benefit of U.S. Government agencies defining the Administration's Golden Dome capabilities and under contract to the National Reconnaissance Office (NRO). Contract # CRADA NRO000-25-Z-0077.

The LM 400 RPF mission is currently projected for launch around 2nd quarter 2027 from Wallops Island with a maximum operational duration of 12 months. RPF will utilize a combination of ground stations owned by Lockheed Martin and KSAT.

Lockheed Martin is herein seeking full experimental authority for up to 2 years to account for any potential shifts in the deployment schedule of the launch or mission activities once in flight.

Mission Overview

The Lockheed Martin LM 400 RPF project mission goals and objectives are to increase the Technology Readiness Level (TRL) of the LM 400 Bus with Payload Interfaces and demonstrate RF X-band Electronically Steered Array (ESA) Synthetic Aperture Radar (SAR) Payload capabilities.

The RPF spacecraft will launch as the primary payload on a Firefly Alpha launch vehicle from Wallops Island. Once deployed, the RPF spacecraft will fly a circular orbit at 450 km altitude and 42° inclination to maximize the ground contact time of the spacecraft with the Lockheed Martin Ignite Ground Station (IGS) located at Lockheed Martin's Waterton Campus in Littleton, CO and access to SAR calibration arrays in the CONUS.

During radar operation, the radar will transmit and receive X-band energy over the CONUS or OCONUS site. For comm contacts, the spacecraft will transmit and receive either S-Band or X-band energy between the spacecraft and the Ignite Ground Stations when over CONUS and KSAT GSaaS stations when OCONUS.

For its nominal CONOP, the program will have 1-3 space-ground communication contacts per revolution and 1-3 imaging operations per day, either communication or imaging can be CONUS or OCONUS. When passing over CONUS, the program will either perform TT&C over the X-band or S-band communication system to a Lockheed Martin Ignite Ground Station or exercise the SAR (X-band payload) system to collect data over a CONUS site but will not do both in a single pass. TT&C operations can be conducted over S or X-band. Radar data will only be downloaded via X-band. In Safe State, only S-band will be available to the vehicle for repair and recovery.

After the end of the mission, the RPF spacecraft will be de-orbited in a controlled operation.

Ground station segment.

The Lockheed Martin spacecraft will be under the primary TT&C control at the operation center facility in Waterton, Colorado. Additional control stations from Kongsberg Satellite Services (KSAT) will be contracted for TT&C control. The location details of those facilities follows: (The Lockheed Martin Waterton and Valley Forge Facilities are included in this application.)

Receive Ground Stations				
Network	**Location**	**Frequency Band**	**Lat. (N)**	**Long. (E)**
LM	Littleton, CO, USA	S	39.513	-105.115
		X	39.513	-105.115
	Valley Forge	X	40.090	-75.403
KSAT	Athens, Greece	S	37.845	22.623
		X	37.845	22.623
	Awarua, New Zealand	S	-46.529	168.380
		X	-46.529	168.380
	Hawaii, US	S	20.817	-156.455
		X	20.817	-156.455
	Jeju, South Korea	S	33.387	126.317
		X	33.387	126.317
	Mauritius	S	-20.501	57.451
		X	-20.501	57.451
	Mingenew, Australia	S	-29.010	115.342
		X	-29.010	115.342
	Puertollano, Spain	S	38.673	-4.162
		X	38.673	-4.162
	Hartebeesthoek, South Africa	S	-25.886	27.706
		X	-25.886	27.706

Transmit Ground Stations				
Network	**Location**	**Frequency Band**	**Lat. (N)**	**Long. (E)**
LM	Littleton, CO	S	39.513	-105.115
		X	39.513	-105.115
KSAT	Athens, Greece	S	37.845	22.623
	Awarua, New Zealand	S	-46.529	168.380
	Hawaii, US	S	20.817	-156.455
	Jeju, South Korea	S	33.387	126.317
	Maspalomas, Spain	S	27.767	-15.636
	Mauritius	S	-20.501	57.451
	Mingenew, Australia	S	-29.010	115.342
	Puertollano, Spain	S	38.673	-4.162
	Hartebeesthoek, South Africa	S	-25.886	27.706

Table 1: Ground Station Locations

Additional technical details.

Lockheed Martin supplements the details on its Form 442 with these details related to the LM 400 RPF mission:

S-band Comm

The primary purposes of the S-band omni antennae are TT&C operations and Safe-state troubleshooting/recovery operations. For Safe-state, it is our only communication path available. We plan to operate in three data rates: **Nominal (Max and pointed), Critical Events Safe-state (Min, no pointing, maximum margin), Post Critical Events Safe-state (no pointing, 3dB of margin)**. All three are detailed below. We do not plan to operate at the peak gain, but included it for reference.

Spacecraft TT&C Frequencies:

- Downlink (Satellite) 2242.5 MHz
- Uplink (Ground) 2064.96875 MHz

Spacecraft Antenna Gain and Modulation:

- Antenna Gain (Max Array Gain) 6.424 dBi
- Polarization:
  - Uplink RHCP
  - Downlink RHCP
- Modulation:
  - Uplink BPSK
  - Downlink BPSK

Uplink Signal Characteristics (Ground):

Data Rate Use	Max Data Rate (kbps)	Necessary Bandwidth (kHz)	Maximum EIRP (dBm)	Maximum ERP (W)
Nominal	128 kbps	256	81	76,736.15
Safe states	64 kbps	128	81	76,736.15

Table 2: S-band Uplink Signal Characteristics by data rate

Downlink Signal Characteristics (Satellite):

Data Rate Name	Max Data Rate (kbps)	Necessary Bandwidth (kHz)	EIRP (dBm) @90% FOV	ERP (W)
Nominal (peak)	2000 @ 90 deg Elev	8000*	35.77	2.3
Nominal (operational)	2000 @ 90 deg Elev	8000*	29.31	0.52
Critical Events Safe State	303	1212*	23.88	0.15
Post Critical Events Safe State	833	3332*	23.88	0.15

(*) Null-Null Bandwidth

Table 3: S-band Downlink Signal Characteristics by data rate

X-band Comm

The X-Band communication subsystem intends to operate over 8025-8250 MHz for satellite-to-ground (downlink) and 7190-7250 MHz for ground-to-satellite (uplink). The two purposes of the X-Band communication subsystem are to support downlinking data that has been collected by the SAR payload, and perform TT&C. The planned center frequencies of downlink and uplink operation are detailed below, along with additional details about the downlink and uplink RF characteristics.

Spacecraft Frequencies:

- Downlink (Satellite) 8137 MHz
- Uplink (Ground) 7212 MHz

Spacecraft Antenna Gain:

- Antenna Gain (Peak) 17.8 dBic
- Polarization:
  - Uplink LHCP
  - Downlink RHCP

Uplink Signal Characteristics (Ground):

- Modulation BPSK
- Max Data Rate 228 kbps
- Occupied Bandwidth 512 kHz
- Maximum EIRP 59.23 dBW
- Maximum ERP 510688.59 W

Downlink Signal Characteristics (Satellite):

- Modulation QPSK
- Max Data Rate 93.3 Mbps
- Occupied Bandwidth 66.96 MHz
- Operational EIRP 40.9 dBm
- Operational ERP 7.5 W

X-Band Radar

To collect radar imagery, Lockheed Martin has developed antenna technology to demonstrate the capability to achieve Synthetic Aperture Radar (SAR) images. The radar configuration, including bandwidth, pulse repetition frequency, and duty cycle, will be varied as required based on the desired resolution of the SAR images.

Lockheed Martin is requesting the use of frequency bands for testing to demonstrate SAR capabilities from 9200 MHz to 10400 MHz The spacecraft can be commanded to collect SAR images utilizing any of the frequencies specified below.

Allocations for Earth Exploration-Satellite (active) exist on a non-interference basis, in accordance with notes 5.427, 5.469A, 5.474, 5.474A, 5.474B, 5.474C, 5.474D, 5.475A, 5.475B, 5.476A, 5.478A, 5.478B, 5.479, 5.480, US67, US71, and US476A, for bands:

- 9200 – 9300 MHz
- 9300 – 9500 MHz
- 9500 – 9800 MHz
- 9800 – 9900 MHz
- 9900 – 10000 MHz
- 10000 – 10400 MHz

Lockheed Martin will be demonstrating SAR capabilities on a non-interfering basis.

During these demonstrations, Lockheed Martin will have a 24-hour contact that will have the ability to cease operations if a complaint of harmful interference is received.

Program Manager: Josh McGarry
Mobile: 1-720 731-1531

Test Frequency Bands

- 9200 – 10400 MHz for SAR Imaging
  - Bandwidth can vary between 10 MHz and 1200 MHz but will always remain within the 9200MHz to 10400MHz band.
  - Because this is the first-time on orbit for this radar, we will be sampling performance across the bandwidth requested, most frequently in 140 MHz, 280 MHz, 1120 MHz steps.

Payload Antenna Gain:

- Antenna Tx Gain (Peak) 43.7 dBi
- Antenna Tx Gain (Average) 43.1 dBi
- Average EIRP 78.3 dBW
- Polarization
  - Horizontal - Horizontal
  - Vertical – Vertical
  - Dual Polarization – Horizontal and Vertical
- Linear Frequency Modulation

Average vs. Max EIRP:

- RPF's EIRP is tied to the frequency in which we are transmitting as shown in Figure 9 below.
- Center frequencies will vary between 9225 - 10375 MHz, but EIRP will not exceed the max EIRP shown at 9210 MHz of 79.3 dBW EIRP
- Individual radar collections will last a maximum of 10 seconds with a maximum transmit duty factor of 20%, so the maximum EIRP will be reached for 2 seconds of each 10 second task at 9210 MHz. 10 second tasks are not expected to be routine, nor is transmitting at 9210 MHz.
- We can only perform radar collections during a single collection window over the United States per revolution and 3 collection windows per day. The max number of individual radar collections we will do in a single window is 10. If we did 10 collects in a single window all at center frequency of 9225MHz we would transmit 79.3 dBW for a total of 20 seconds per rev, 60 seconds per day. This is a scenario we may perform 0-1 times.
- Because of the low duty cycle and the infrequency with which we would be transmitting at our maximum EIRP, we felt it more representative of our mission's CONOP to provide an Average EIRP.

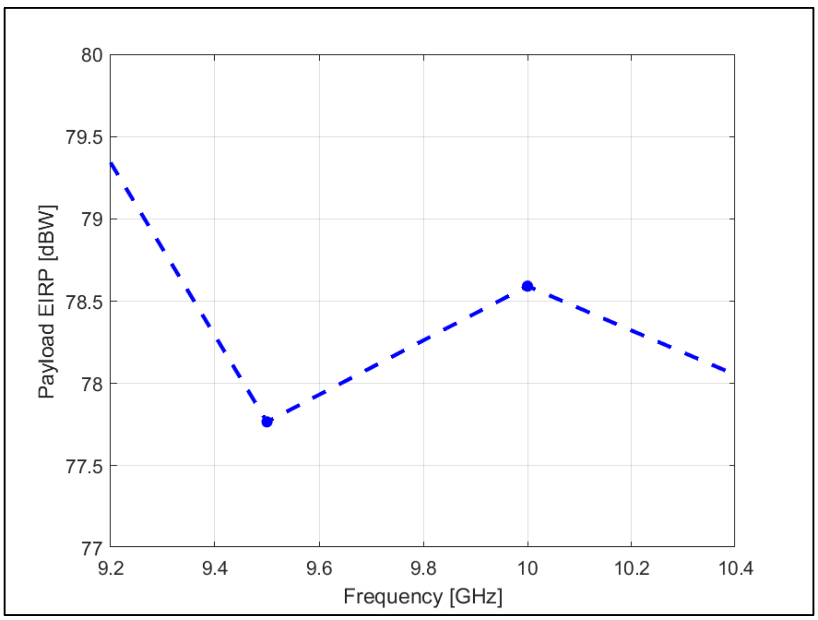

Figure 1: Frequency to EIRP of SAR

Beam Profiles

S-Band Downlink (2200-2290 MHz) Beam Profile

The antenna transmit beam profile is shown in Figure 3.

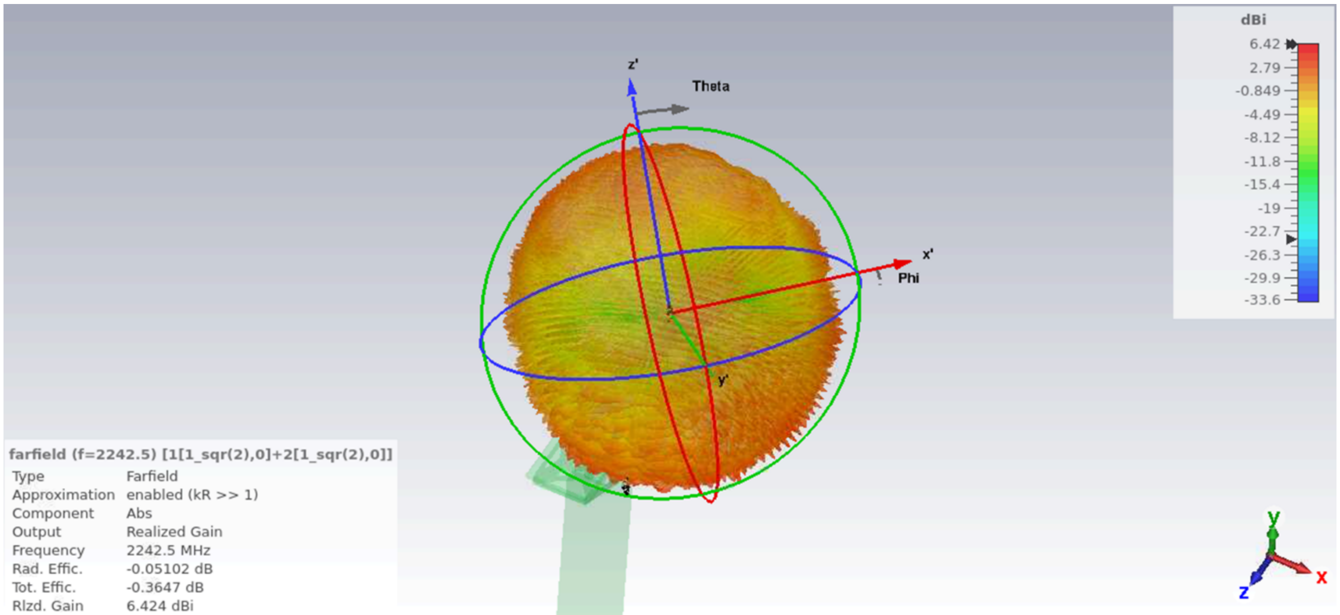

Figure 2: Arrayed Omni Patterns

RPF, Combined Omni, Nadir Deck Omni Boresight (+Z), Pointed				
Coverage Area	**Frequency (MHz)**	**Max Gain (dB)**	**Min Gain (dB) at 90%**	**Min Gain (dB)**
+/- 1°	2064.969	1.31	0.92	0.89
	2242.5	0.53	-0.04	-0.09

Table 4: Realized Gain Omni Combined Pattern Performance (SV Pointed to Ground Station)

RPF, Combined Omni, Whole Sphere, Nadir Deck Omni Boresight +Z, Baseline	
Frequency (MHz)	**Min Gain (dB) at 90%**
2064.969	-5.72
2242.5	-5.47

Table 5: Realized Gain Omni Combined Pattern Performance (SV Not Pointed Ground Station)

X-Band Downlink Beam Profile (8025-8275 MHz)

The antenna beam profile is shown in Figure 4.

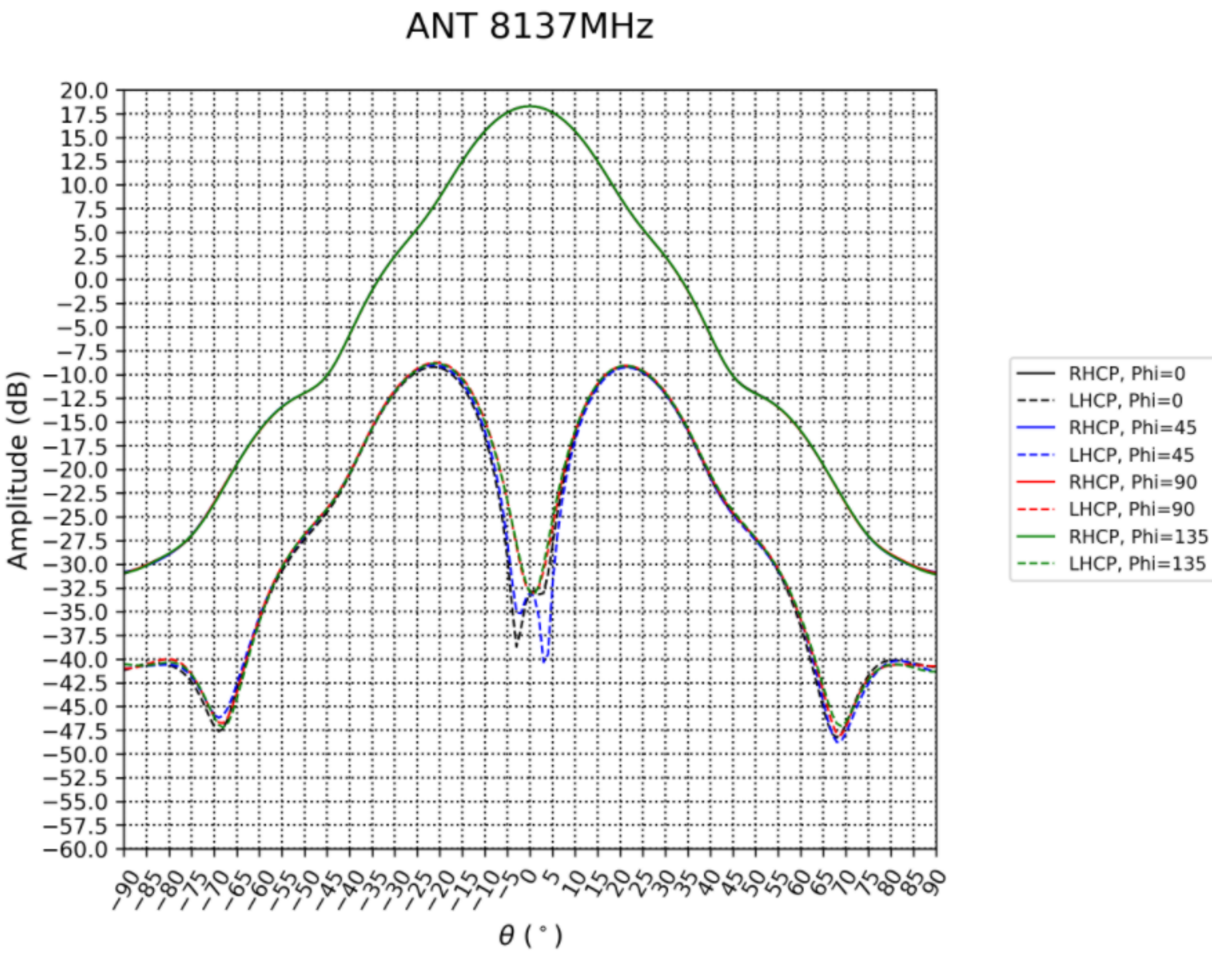

Figure 3: X-band Communication Beam Profile

X-Band SAR Radar Beam Profile (9200-10400 MHz)

The antenna beam profile is shown in Figures 5 & 6.

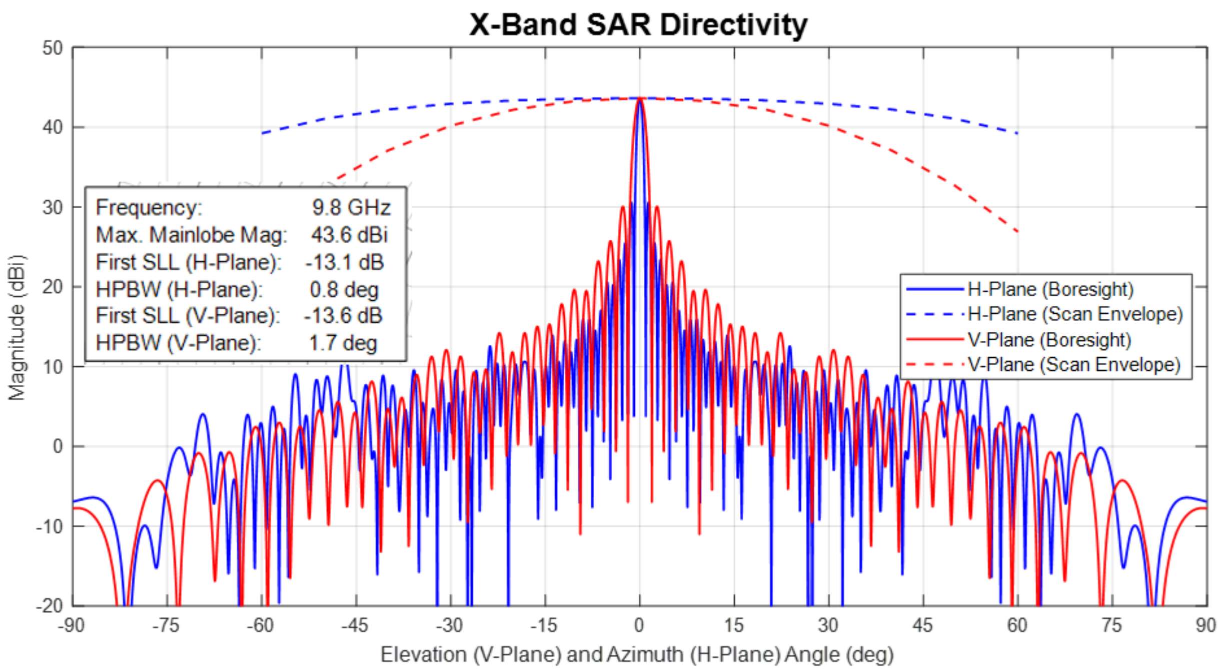

Figure 4: X-band SAR Directivity-1

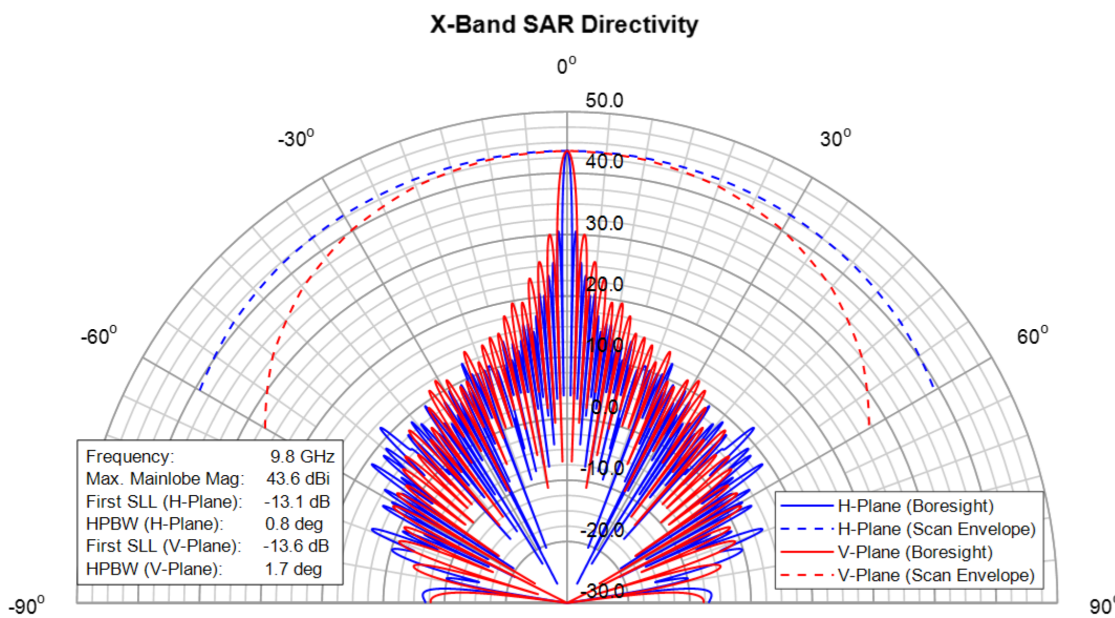

Figure 5: X-band SAR Directivity - 2

Power Flux Density Analysis

This section demonstrates the Satellite will operate with power flux-density (PFD) below specified limits. For each band shown a worst-case approach was taken to show compliance in even the most outlying case.

Power Flux Density in the band 2200 – 2290 MHz

In accordance with note US303 within the FCC Table of Frequency Allocations the power flux-density at Earth-s surface from non-Federal stations shall not exceed -144 to -155 dBw/m2/kHz, depending on the angle of arrival, in accordance with ITU Radio Regulation 21.16.

Figure 7 shows the Satellite complies with the power flux-density of ITU radio Regulation 21.16 at all angles of arrival. Further, the onboard radio power may be adjusted to further reduce power as required to mitigate interference.

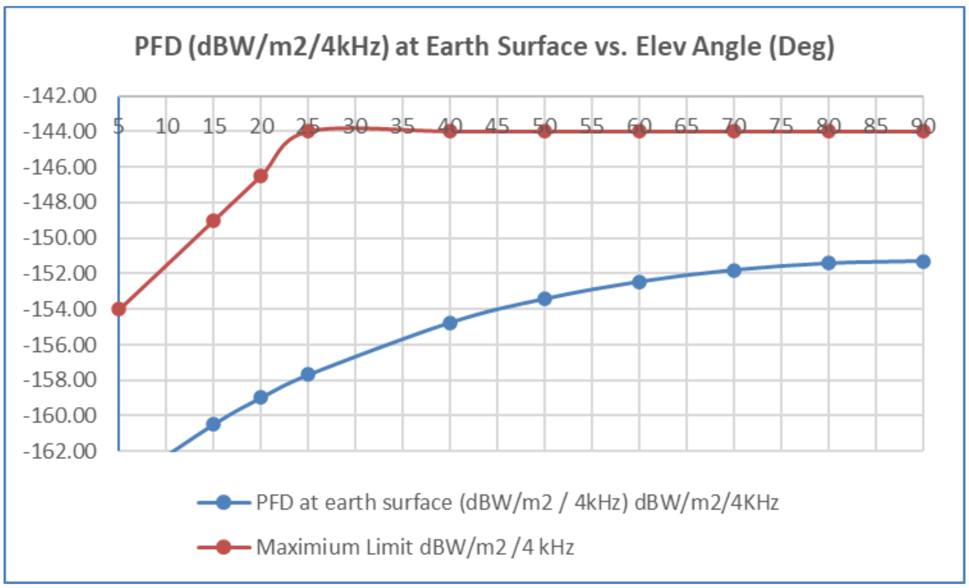

Figure 6: Downlink PFD for S-band Communications

S-Band PFD Calculations

S-Band TTC Ground–to-Satellite (Uplink)

S-Band Tx TTC Uplink 2064.96875 MHz	Unit	Min Ground Elevation to LEO Satellite	Max Ground Elevation to LEO Satellite	Notes
Equivalent Isotropic Radiated Power (EIRP), Max	dBW	51	51	Verge Ground Terminal
Max Supported Uplink Data Rate for CXS-1000	kbps	128	128	
RF Operational BW	MHz	0.256	0.256	Symbol Rate Rs=Rb/(m x r) where m=1 for BPSK, r=1/2 BW=Rs(1+α); where α is filter roll-off (1 for conservative null-null BW)
Satellite Altitude	km	450	450	
Ground Elevation Angle	deg	10	90	
Slant Range	km	1569.57	450.00	
Free-Space Path Loss ($4\pi/R^2$)	dB	134.91	124.06	
Total Power Flux Density (PFD) at Satellite	dBW/m^2	-83.91	-73.06	
Fraction of power flux density in 256 kHz	%	100%	100%	This factors how much of the whole energy is captured in 100% (i.e. α =1) of the trasmission BW of 256 kHz
PFD at Satellite (dBW/m^2 / 256 kHz)	dBW/m^2 / 256 kHz	-83.91	-73.06	If Transmission BW is 256kHz for the total EIRP, and filtering captures 100% of the energy; So Unit reference is given per 256kHz
Fraction of power flux density in 4 kHz (dB)	**dB**	-18.1	-18.1	**BW Scaling to 4KHz**
PFD at satellite (dBW/m^2 / 4kHz)	**dBW/m2/4KHz**	**-102.0**	**-91.1**	

Table 6: S-band Uplink PFD Calculations

S-Band TT&C Satellite–to-Ground (Downlink)

S-Band Tx TTC Downlink 2242.5 MHZ	Unit	Worst Case Min Angle of Arrival	Worst Case Max Angle of Arrival	Notes
Equivalent Isotropic Radiated Power (EIRP), Max	dBW	5.77	5.77	Tx Power=6.5W Simulated Max Array Gain Gt = 6.424 dBi Line Losses= 8.75 dB
Tx Data Rate (Supported Max for Link closure)	kbps	2000.0	2000.0	Rb
BPSK Modulation Index (m)	BPSK	1.0	1.0	m (m=1 for BPSK)
FEC rate (r)	BPS	0.5	0.5	r=1/2
Transmit Symbol Rate RS=Rb/(m x r) (with FEC rate 1/2, and BPSK)	ksps	4000	4000	Symbol Rate Rs=Rb/(m x r) where m=1 for BPSK, r=1/2 BW=Rs(1+α); where α is filter roll-off (1 for conservative null-null BW)
Null-Null BW	kHz	8000.0	8000.0	BW=Rs(1+α); where α is filter roll-off (1 for conservative null-null BW)
Tx Filter Roll-off Factor α		1	1	Effect of CIC filter to limit BW to 4 MHz
TX Bandwidth	kHz	8000	8000	With Tx Filtering where α=1 for 100% of nul-null energy is captured,
Satellite Altitude	km	450	450	
Ground Elevation Angle	deg	10	90	
Slant Range	km	1569.57	450.00	
Free-Space Path Loss ($4\pi/R^2$)	dB	134.91	124.06	
Satellite Total Power Flux Density (PFD)	**dBW/m^2**	**-129.14**	**-118.29**	in 8 MHz Tx Null-Null BW
% Power flux density captured with Tx filtering		100%	100%	Obtained from (1+α)/2 = 100% Pls note that when α=1, we capture 100% of null-null energy
Reduction from Null-Null Power	dB	0.00	0.00	
Power flux density in 4 MHz (dB)	**dBW/m^2**	**-129.14**	**-118.29**	in 8 MHz Tx Null-Null BW
Fraction of Power in 4 kHz	**dB**	**-33.01**	**-33.01**	
PFD at earth surface (dBW/m^2 / 4kHz)	**dBW/m2/4KHz**	**-162.1**	**-151.30**	Scaled for 4 kHz
Maximum Limit	**dBW/m^2 /4 kHz**	**-151.5**	**-144.0**	
Margin	**dB**	**10.65**	**7.30**	

Table 7: S-band Downlink PFD Calculations

Power Flux Density in the band 8025 – 8400 MHz

To ensure that interference with any Deep Space Research communications within the adjacent frequency spectrum at 8400-8450 MHz remains below -221 dB(W/(m2 Hz)), per ITU-R SA.1157-1, RPF plans to operate such that the highest band edge within the operating frequency (8250 MHz) is more than 125-MHz below the lower edge of the DSN band. Figure 8 shows the Satellite complies with the power flux-density of ITU radio Regulation 1157-1.

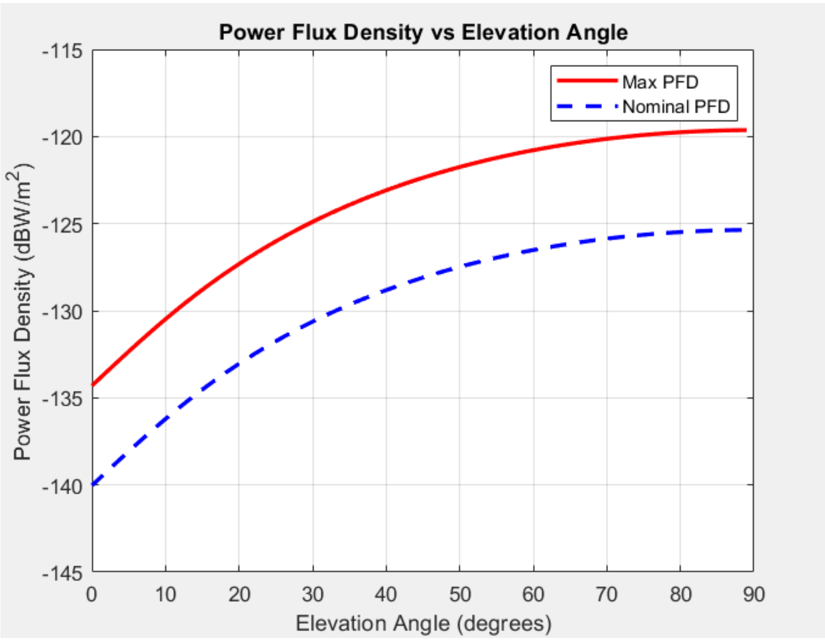

Figure 7: PFD for X-band Communication Antenna

X-Band PFD Calculations

8137 MHz X-Band Satellite Uplink Transmission

X-Band Tx Uplink 7212 MHz	**Unit**	**Worst Case PFD Min Angle of Arrival**	**Worst Case PFD Max Angle of Arrival**
Ground Equivalent Isotropic Radiated Power (EIRP), Max	dBW	59.23	59.23
RF Operation BW (7190-7250 MHz)	MHz	60	60
Transmitted Data Rate	Msymbols/s	0.228	0.228
Transmitted Bandwidth	kHz	512	512
Satellite Altitude	km	450	450
Earth Radius	km	6371	6371
Ground Elevation Angle	deg	15	90
Slant Range	km	1293.07	450.00
Spreading Loss	dB	133.22	124.06
Satellite Total Power Flux Density (PFD)	dBW/m^2	-73.99	-64.83

Table 8: X-band Comms Uplink PFD Calculations

8137 MHz X-Band Satellite Downlink Transmission

X-Band Tx Downlink 8137 MHz	**Unit**	**Worst Case PFD at ground Min Angle of Arrival**	**Worst Case PFD at ground Max Angle of Arrival**	**Worst Case PFD @ GSO***
Equivalent Isotropic Radiated Power (EIRP), Max	dBW	16.60	16.60	-1.40
RF Operation BW (8025-8250 MHz)	MHz	225	225	225
Transmitted Data Rate	Msymbols/s	55	55	55
Transmitted Bandwidth	kHz	66000	66000	66000
Satellite Altitude	km	450	450	35,336
Earth Radius	km	6371	6371	N/A
Ground Elevation Angle	deg	5	90	N/A
Slant Range	km	1943.68	450.00	35,336
Spreading Loss	dB	136.76	124.06	161.96
Satellite Total Power Flux Density (PFD)	dBW/m^2	-120.16	-107.46	-163.36
Fraction of power flux density in 4 kHz (dB)	**dB**	-42.2	-42.2	-42.2
PFD (dBW/m^2 / 4 kHz)	dBW/m^2 /4 kHz	-162.3	-149.6	-205.5
Maximum Limit	dBW/m^2 /4 kHz	-150.0	-140.0	-174.0
Margin	dB	12.3	9.6	31.5
*** GSO Orbit Received PFD from the single LEO RF Payload (Worst Case)**				

Table 9: X-band Comms Downlink PFD Calculations

Power Flux Density in 9900 – 10400 MHz Band

PFD limits between 9900 - 10400 MHz were identified within ITU Radio Regulation 21.16 and WRC-15 Table 21-4. Figure 9 shows the simulated limits of power flux-density for Earth Exploration-Satellite (active) in the 9900 – 10400 MHz frequency band.

SAR Imaging will be performed at grazing angles greater than or equal to 10°. The figure below shows the simulated worst-case power flux density for grazing angles greater than 10°, compared to the allowable limits specified in Table 21-4 (Rev WRC-15).

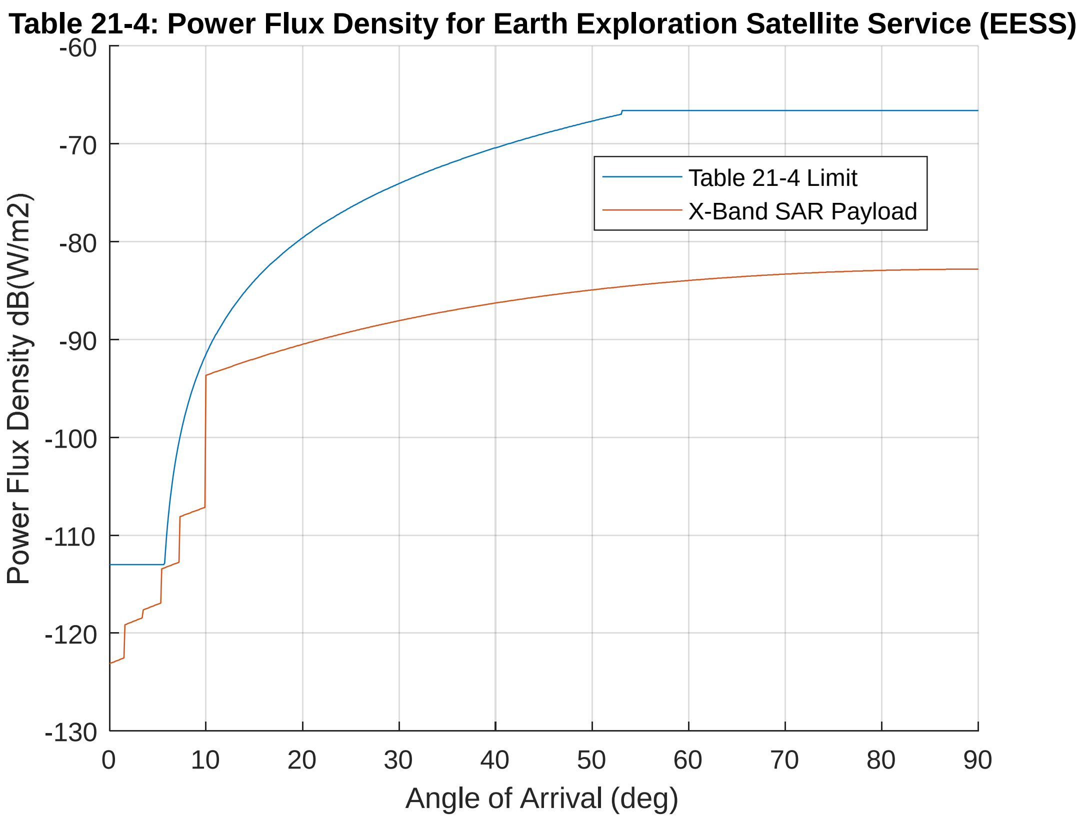

Figure 8: PFD for X-band SAR

PFD Calculations for interference with GSO

No. 22.5 of the ITU Radio Regulations specifies that in the frequency band 8025-8400 MHz, which the EESS (using non-geostationary satellites) shares with the fixed-satellite service (Earth-to-space) and the meteorological-satellite service (Earth-to-space), the maximum power flux-density produced at the geostationary satellite orbit ("GSO") by any EESS space station shall not exceed –174 dBW/m2 in any 4 kHz band.

The calculation below shows that the PFD produced by the transmissions from the proposed RPF SAR satellites does not exceed the limit in No. 22.5, even in the worst possible hypothetical case.
The PFD at the GSO produced by the Satellite transmission is:

PFD [dBW/m2 /4 kHz] = EIRP (dBW) - 71 - 20log10(D) - 10log10(BW) – 24

Where:

- EIRP is the Maximum EIRP of the transmission, in dBW;
- D is distance between the Satellite and GSO, in km;
- BW is the symbol bandwidth of the transmission, in MHz.

The minimum possible distance between the Satellite and the GSO is 35,786 - 450 = 35,336 km.

Under a hypothetical assumption that the Satellite antenna is radiating at its peak EIRP toward the GSO, with the peak EIRP = 17 dBW and BW = 67 MHz produces a PFD at the GSO of:

-187 dBW/m2/4 kHz

Though we cannot imagine a scenario where our X-band communications antenna would be radiating at a GSO, should this highly unlikely event occur, the PFD is 13 dB below the specified maximum.

Protection of the Radio Astronomy Service

Recommendation ITU-R RS.2066-0 provides an operational procedure to avoid main-beam to main-beam coupling between Earth Exploration Service (EESS) (active) SAR systems when transmitting near 9600 MHz and radio astronomy services (RAS) stations performing observations in the band 10.6 – 10.7 GHz in order to avoid damage to the sensitive RAS low noise amplifier.

The RPF SAR Payload test site is located within CONUS, and SAR Imaging will not occur within the protection areas around any RAS stations defined in ITU-R RS.2066.0.