Astrobotic Technology, Inc.

RF Communications/Peregrine Mission 1

SCHEDULE S ANNEX 1

CERTIFICATION QUESTIONS COMPLIANCE

Eduardo Lugo/ RF Communications team

Annex 1 in support of X-Band frequency use request

Revision	C
Date	February 8, 2021
Officer	Eduardo Lugo

REVISION HISTORY

Revision	Date	Description	Author	Approval
A	2020.11.11	New format. ITU 22.5 reference	EL	EL
B	2020.11.21	Top LGA table	EL	EL
C	2021.02.08	Updated cable losses	EL	EL

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1 INTRODUCTION

Annex 1 provides proof of compliance for the Certification Questions on the Schedule S.

Questions 1, 4, 5, 6 and 7 would not apply due to the frequency that Peregrine Mission 1 X-Band transponder will be operating at.

The applicable certification questions for Astrobotic's Peregrine Mission 1 are questions 2 and 3:

2. Are the applicable frequency tolerances of 25.202(e) and out-of-band emission limits of 25.202(f)(1),(2), and (3) met?
3. Are the cessation of emissions requirements of 25.207 met?

2 ARE THE APPLICABLE FREQUENCY TOLERANCES OF 25.202(E) AND OUT-OF-BAND EMISSION LIMITS OF 25.202(F)(1),(2), AND (3) MET?

From FCC Part 25:

a) *25.202(e) frequency tolerance, space stations. the carrier frequency of each space station transmitter authorized in these services shall be maintained within 0.002 percent of the reference frequency.*

The transponder used by Peregrine's is Space Micro's X-Band transponder with a frequency stability of +/- 10 ppm (10 ppm is equivalent to 0.001%) as per the specification document SP99308-1 item 3.2.2.4.2 (attached as Annex 2).

b) *And out-of-band emission limits of 25.202(f)(1),(2), and (3) met?*

The bandwidth requested and assigned by DSN for Astrobotic's Peregrine Mission 1 (APM1) is 10 MHz. 25.202 (f) (1), (2) and (3) levels are shown in Figure 1 (blue line). Astrobotic's assigned bandwidth is shown in gold color.

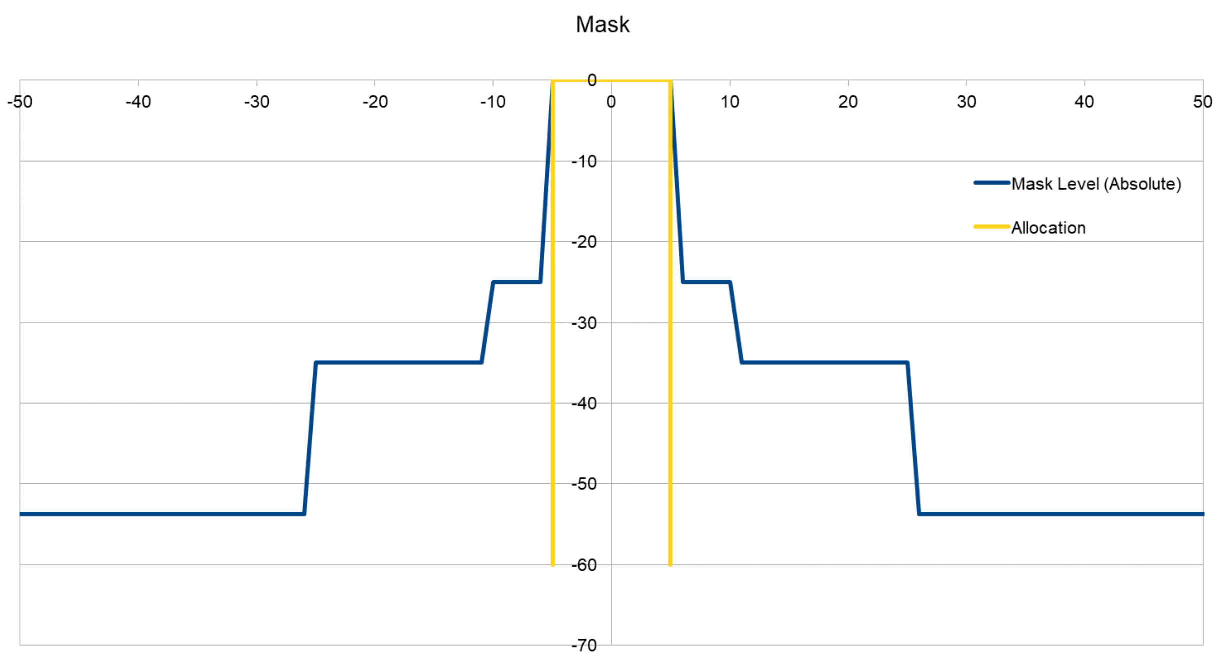

Figure 2-1: APM1's bandwidth allocation (gold line) and FCC 25.202 (f) mask

The spectrum for the two mod indices that Peregrine's transponder will used is shown on Figure 2.

From Figure 2 it can be seen that the mask on Figure 1 is met in all three ranges (50-200%, 10-200% and >250%

In addition, the spurious of the transponder as shown on the specification document SP99308-1 item 3.2.2.5.11.2

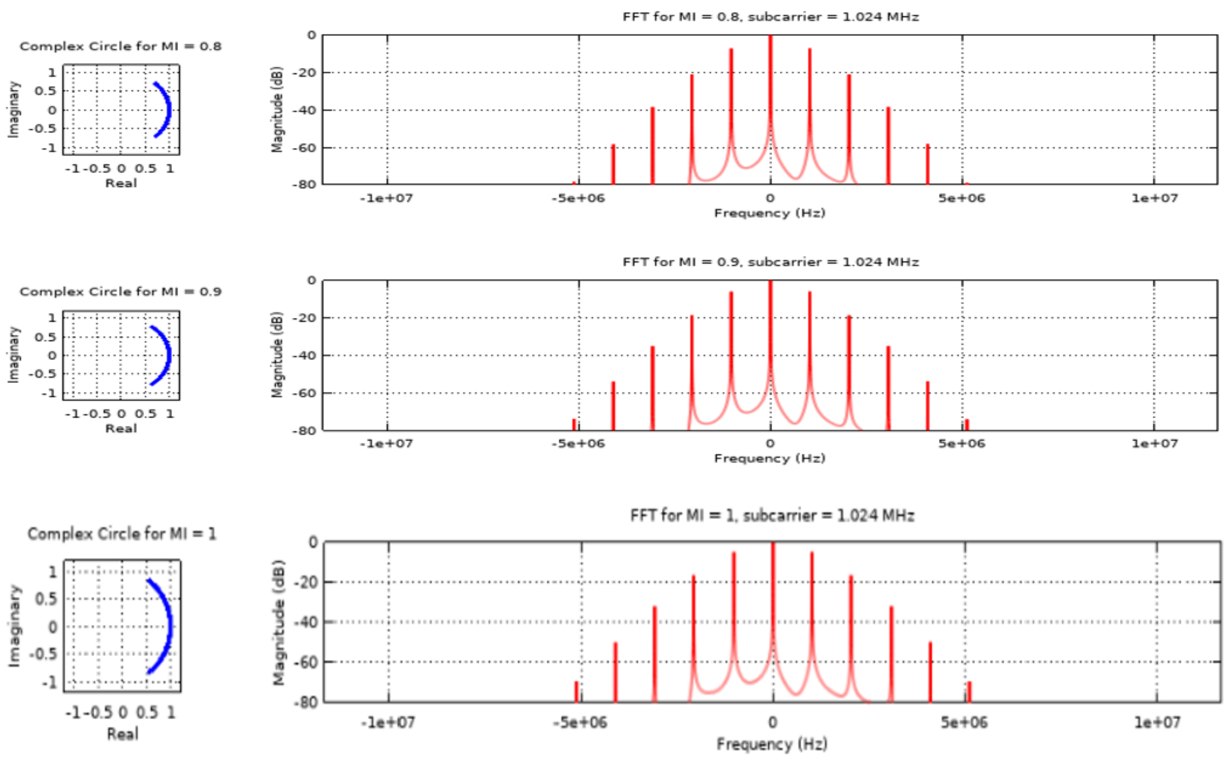

Figure 2-2: APM1's Spectrum for the three possible Mod Indices. (MI = 1.0 is unlikely to be used).

Frequency Range	Spur Level
Fc ± 5 MHz	-50 dBc
Fc ± 500 MHz to Fc ± 5 MHz	-60 dBc

Figure 2-3: APM1's transponder spurious expected performance.

3 ARE THE CESSATION OF EMISSIONS REQUIREMENTS OF 25.207 MET?

The receiver part of the X-Band transponder will be on as far as the transponder is powered on. The transmit part of the X-Band transponder can be muted on commands from the IAU (by schedule or mission phase) or by ground command.

In addition, Peregrine's Mission 1 will end after 192 hours of lunar surface operations with the arrival of lunar night. Peregrine, Astrobotic's lunar lander, is not designed to survive the lunar night. The battery and the solar panel will become inert will stop providing power to the lander, including the transponder.

In addition, the X-Band transponder is not designed to survive the lunar environment without the help of Peregrine thermal control system. Once the battery and solar panel stop providing power the transponder will also become inert.

4 POWER FLUX DENSITY

Peregrine's mission trajectory will take the distance of peregrine from the Earth from a projected perigee of 500 Km to an apogee of 406,400 Km (furthest moon distance from the earth).

ITU Radio Regulation No. 22.5 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) or the meteorological-satellite service (Earth-to-space), the maximum PFD produced at the geostationary satellite orbit ("GSO") by any EESS space station shall not exceed –174 dB(W/m2) in any 4 kHz band.

The RF output power on Peregrine's X-Band transponder is adjustable via command from the IAU or via ground command.

The RF output power on Peregrine's X-Band transponder will be adjusted according to the distance from Peregrine to Earth to produce a maximum Power Flux Density (PFD) at Earth's surface of -174 dBW/m^2 in any 4 KHz, although the frequency at which Peregrine's X-Band transponder will operate at will fall just outside of that range specified in ITU Radio Regulation No. 22.

4.1 CRUISE PHASE

Peregrine uses two Low Gain Antennas (LGA) antennas to provide 90 % spherical coverage during the cruise phase so that attitude adjustment is not required to establish the RF link to earth. The antenna gain for 90% coverage varies from -5 to 5 dBi.

The shown PFD was calculated using the highest gain point on the antenna (5 dBi which is the worst case for PFD).

Table 1, 2 and 3 show the PFD at Earth's surface for distances of 500, 370,000 and 406,400 Km respectively.

Table 4-1: Power Spectral Density at Vehicle Separation Stage (Perigee).

Distance of 500 Km (Perigee)	
Occupied Bandwidth (MHz)	10
LGA Antenna Gain (dBi)	5
Tx circuit losses (dB)	7.8
Amplifier Output Power (W)	0.06
Amplifier Output Power (dBW)	-14.1
EIRP (dBW)	-15.1
EIRP Density in assigned BW (dBW)	-85.05
EIRP Density 4 KHz (dBW)	-49.03
EIRP Density 1 MHz (dBW)	-25.05
Spreading Losses (dB)	-124.97
PFD in 4 KHz (dBW/m^2)	-174.0
PFD in 1 MHz (dBW/m^2)	-150.02

Table 4-2: Power Spectral Density during the Cruise Phase at 370,000 Km.

Distance of 370,000 Km	
Occupied Bandwidth (MHz)	10
LGA Antenna Gain (dBi)	5
Tx circuit losses (dB)	7.8
Amplifier Output Power (W)	6
Amplifier Output Power (dBW)	7.78
EIRP (dBW)	4.98
EIRP Density in assigned BW (dBW)	-65.02
EIRP Density 4 KHz (dBW)	-29.00
EIRP Density 1 MHz (dBW)	-5.02
Spreading Losses (dB)	-182.35
PFD in 4 KHz (dBW/m^2)	-211.35
PFD in 1 MHz (dBW/m^2)	-187.37

Table 4-3: Power Spectral Density during the Cruise Phase at 406,400 Km (worst case Apogee). This PFD is applicable for the Orbit and Descent phase.

Distance of 406,400 Km (Apogee/Moon Surface)	
Occupied Bandwidth (MHz)	10
LGA Antenna Gain (dBi)	5
Tx circuit losses (dB)	7.8
Amplifier Output Power (W)	12
Amplifier Output Power (dBW)	10.78
EIRP (dBW)	7.98
EIRP Density in assigned BW (dBW)	-62.02
EIRP Density 4 KHz (dBW)	-26.00
EIRP Density 1 MHz (dBW)	-2.02
Spreading Losses (dB)	-183.17
PFD in 4 KHz (dBW/m^2)	-209.17
PFD in 1 MHz (dBW/m^2)	-185.19

Table 4-4: Power Spectral Density at Moon surface (worst case Moon distance and using the Top LGA).

Distance of 406,400 Km (Apogee/Moon Surface)	
Occupied Bandwidth (MHz)	10
LGA Antenna Gain (dBi)	-2.0
Tx circuit losses (dB)	6.46
Amplifier Output Power (W)	12
Amplifier Output Power (dBW)	10.78
EIRP (dBW)	2.32
EIRP Density in assigned BW (dBW)	-67.68
EIRP Density 4 KHz (dBW)	-31.66
EIRP Density 1 MHz (dBW)	-7.68
Spreading Losses (dB)	-188.85
PFD in 4 KHz (dBW/m^2)	-214.83
PFD in 1 MHz (dBW/m^2)	-190.85

4.2 MOON SURFACVE OPERATIONS WITH THE MGA

During Moon surface operations Peregrine will deploy a gimballed Medium Gain Antenna (MGA). The use of the MGA will allow Peregrine to achieve data rates of 4 Mbps. Table 4 shows the PFD using the MGA.

Table 4-5: Power Spectral Density at 406,400 Km. Moon Surface operations using the Medium Gain Antenna.

Distance of 406,400 Km (Apogee/Moon Surface)	
Occupied Bandwidth (MHz)	10
LGA Antenna Gain (dBi)	26
Tx circuit losses (dB)	6.31
Amplifier Output Power (W)	3.55
Amplifier Output Power (dBW)	5.50
EIRP (dBW)	25.19
EIRP Density in assigned BW (dBW)	-44.81
EIRP Density 4 KHz (dBW)	-8.79
EIRP Density 1 MHz (dBW)	-15.19
Spreading Losses (dB)	-183.17
PFD in 4 KHz (dBW/m^2)	-191.96
PFD in 1 MHz (dBW/m^2)	-167.98