TECHNICAL APPENDIX

RBC Signals LLC
Fixed Earth Station License Application Amendment

I. Radiation Hazard Study

400 MHz Earth Station

This study analyzes the non-ionizing radiation levels for a 400 MHz Yagi tracking earth station. 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 depending on the area of exposure 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 cannot access.

The maximum level of non-ionizing radiation to which individuals may be exposed is limited to a power density level of 1.33 milliwatts per square centimeter (1.33 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 0.27 milliwatt per square centimeter (0.27 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 surface are expected to exceed safe levels. The purpose of this study is to determine the power flux density levels for the earth station under study as compared with the MPE limits. This comparison is done in each of the following regions:

1. Far-field region
2. Near-field region
3. Transition region
4. The region between the antenna edge and the ground

Input Parameters

The following input parameters were used in the calculations:

Parameters:	Value	Unit	Symbol
Antenna Diameter	3.57	m	*D*
Antenna Transmit Gain	16.2	dBi	*G*
Transmit Frequency	400	MHz	*f*
Power Input to the Antenna	12.53	W	*P*

Calculated Parameters:

The following values were calculated using the above input parameters and the corresponding formulas:

Parameter	Value	Unit	Symbol	Formula
Antenna Surface Area	1.964	m^2	*A*	$G\lambda 2/(4\pi)/\lambda$
Antenna Efficiency	0.95		η	$G\lambda^2/(\pi^2 D^2)$
Gain Factor	41.7		*g*	$10^{G/10}$
Wavelength	0.75	m	λ	$300/f$

Behavior of EM Fields as a Function of Distance

The behavior of the characteristics of EM fields varies depending on the distance from the radiating antenna. These characteristics are analyzed in three primary regions: the near-field region, the far-field region and the transition region. Of interest also is the region between the antenna and ground.

For yagi antennas with circular cross sections, such as the antenna under study, the near-field, far-field and transition region distances are calculated as follows:

Parameter	Value	Unit	Formula
Near-Field Distance	4.25	m	$R_{nf} = D^2/(4\lambda)$
Distance to Far-Field	10.2	m	$R_{ff} = 0.60D^2/(\lambda)$
Distance of Transition Region	4.25	m	$R_t = R_{nf}$

The distance in the transition region is between the near and far fields. Thus, $R_{nf} \leq R_t \leq R_{ff}$. However, the power density in the transition region will not exceed the power density in the near-field. Therefore, for purposes of the present analysis, the distance of the transition region can equate the distance to the near-field.

Power Flux Density Calculations

The power flux density is considered to be at a maximum through the entire length of the near-field. This region is contained within a cylindrical volume with a diameter, D, equal to the diameter of the antenna. In the transition region and the far-field, the power density decreases inversely with the square of the distance. The following equations are used to calculate power density in these regions.

Parameter	Value	Unit	Symbol	Formula
Power Density in the Near-Field	2.42	mW/cm^2	S_{nf}	$16.0\ \eta\ P/(\pi D^2)$
Power Density in the Far-Field	0.04	mW/cm^2	S_{ff}	$GP/(4\pi\ Rff^2)$
Power Density in the Transition Region	2.42	mW/cm^2	S_t	$S_{nf}\ R_{nf}/(R_t)$

The power density between the antenna and ground, is calculated as follows:

Parameter	Value	Unit	Symbol	Formula
Power Density b/w Reflector and Ground	0.64	mW/cm^2	S_g	P / A

The below table summarizes the calculated power flux density values for each region. In a controlled environment, the only regions that exceed FCC limitations are shown below. These regions are only accessible by trained technicians who, as a matter of procedure, turn off transmit power before performing any work in these areas.

Power Density	Value	Unit	Controlled Environment
Far Field Calculation	0.04	mW/cm^2	Satisfies FCC MPE
Near Field Calculation	2.42	mW/cm^2	Exceeds Limits
Transition Region	2.42	mW/cm^2	Exceeds Limits
Region b/w Antenna & Ground	0.64	mW/cm^2	Satisfies FCC MPE

In conclusion, the results show that the antenna, in a controlled environment, may exist in the regions noted above and applicant will take the proper mitigation procedures to ensure it meets the guidelines specified in 47 C.F.R. § 1.1310.

The earth station will be marked with the standard radiation hazard warnings, as well as the area in the vicinity of the earth station to inform the general population, who might be working or otherwise present in or near the path of the main beam.

The applicant will ensure that the main beam of the antenna will be pointed at least one diameter away from any building, or other obstacles in those areas that exceed the MPE limits. Since one diameter removed from the center of the main beam the levels are down at least 20 dB, or by a factor of 100, public safety will be ensured.

Finally, the earth station's operational personnel will not have access to areas that exceed the MPE limits while the earth station is in operation. The transmitter will be turned off during periods of maintenance so that the MPE standard of 1.33 mW/cm^2 will be complied with for those regions in close proximity to the antenna, which could be occupied by operating personnel.

II. 3 Diamonds Satellites

A. Compliance with Orbital Debris and Deorbit Related Requirements

Assessment has been made for the Three Diamond Satellites for compliance with the requirements of §25.114(d)(14):

(i) The Three Diamonds satellite deployment planning and operational design was assessed to determine compliance with orbital debris release requirements. The Three Diamonds satellites are deployed from a qualified ISIS Quadpack system. The operational design of the Three Diamonds satellite does not include release of any debris during operations in any mission phase.

An assessment of the probability of the space station becoming a source of debris by collisions with small debris or meteoroids was performed using the NASA Debris Assessment Software (DAS), version 2.0.2. The Three Diamonds satellite was found to be compliant with the requirement (NS 8719.14 Requirement 4.5-2, Probability of Damage from Small Objects). Figure 1 below shows the DAS summary output screen.

(ii) The Three Diamonds satellite design has been assessed and found that the design limits the probability of accidental explosions during and after completion of mission operations. The only energy sources on board the satellite are the Li-Ion battery and the reaction wheel. Both are planned to be passivated at the end of mission. The Three Diamonds satellites have no propulsion systems, and hence have no residual fuel at end of mission.

(iii) The Three Diamonds satellite design has been assessed and found that the probability of the space station becoming a source of debris by collisions with large debris or other operational space stations is compliant with the requirement (NS 8719.14 Requirement 4.5-1, Probability of Collision with Large Objects). Figure 1 below shows the DAS summary output screen.

The anticipated evolution over time of the orbit of the Three Diamonds satellites has been assessed with DAS. The predicted orbital lifetime of the satellites is 5.3 years until re-entry into the atmosphere. The DAS orbital evolution is shown in Figure 2 below.

(iv) For the Three Diamonds satellites, the post-mission disposal plans at end of life are to rely on the natural orbital evolution, as shown in Figure 2 below, to culminate in atmospheric re-entry. As the satellites have no propulsion system, there is no fuel or other active propulsive means employed during deorbit.

For the Three Diamonds Satellites, a casualty risk assessment was performed because the planned post-mission disposal involves atmospheric re-entry. DAS analysis was performed as shows the satellites to be compliant with the requirement (NS 8719.14 Requirement 4.7-1, Casualty Risk from Reentry Debris).

Assessment of the Three Diamonds Satellites using DAS has shown the design and operational planning to be compliant with all requirements as shown in Figure 1 below. Note that compliance with Requirement 4.3-2, Mission-Related Debris Passing Near GEO, does not pertain to the Three Diamonds Satellites as they will not approach GEO orbits. Figure 1 also shows compliance with Requirement 4.4-3, Long Term Risk from Planned Breakups, because there are no planned breakups for these satellites. Compliance with Requirement 4.8-1, Collision Hazards with Space Tethers, does not pertain to the Three Diamonds Satellites as they do not employ tethers.

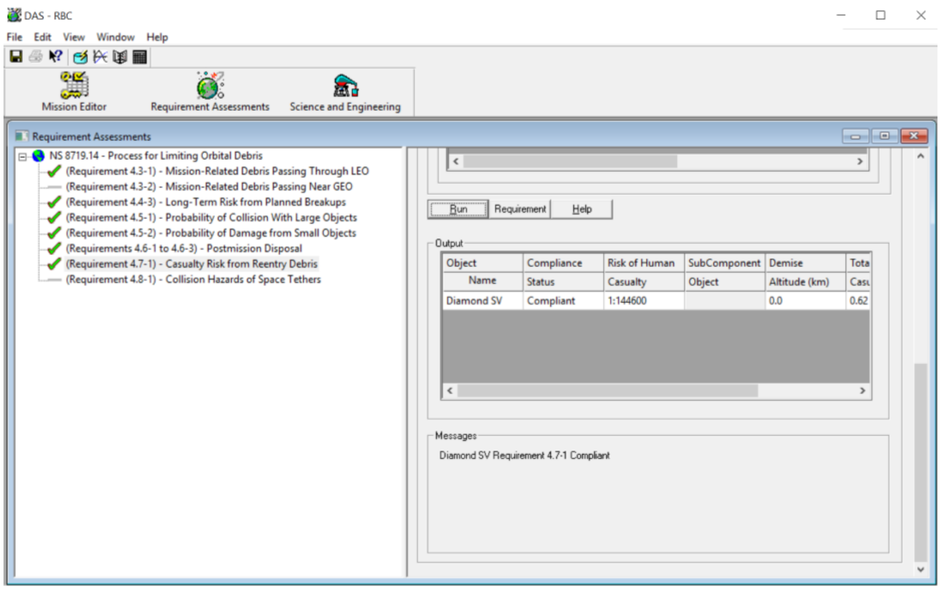


Figure 1 - Debris Assessment Software Requirements Compliance

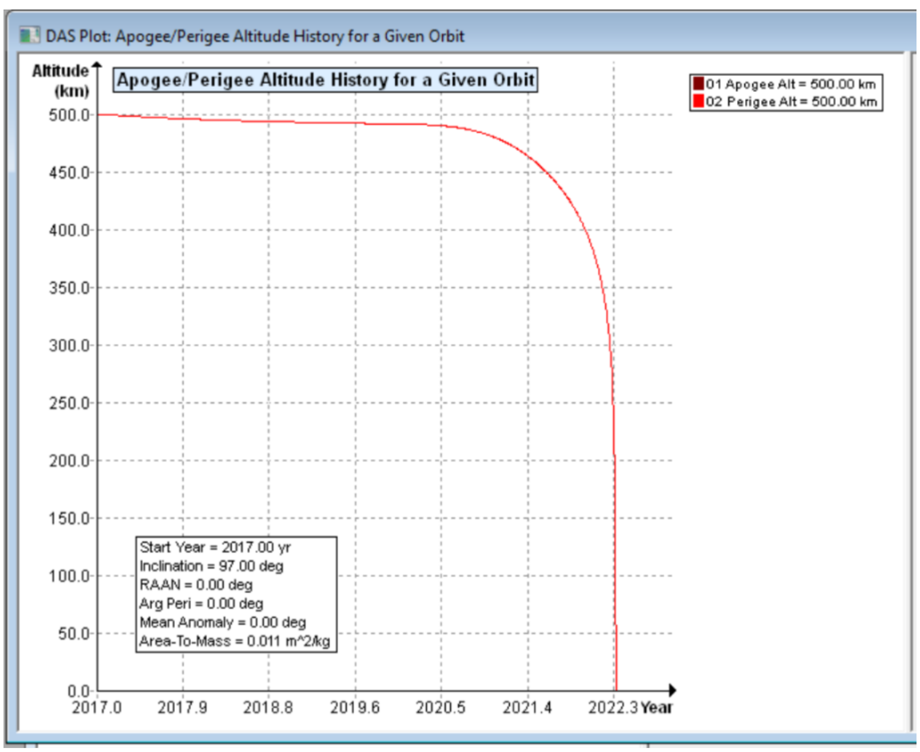


Figure 2 – DAS Orbit Evolution

B. Link Budgets

UHF Link - Uplink

Link parameters		**Unit**	**Notes**
Carrier Frequency	399.938	MHz	
Carrier wavelength	0.75	m	
Boltzmann constant	-228.6	dBW/K/Hz	
BASIC PARAMETERS			
Orbit height	500	km	
Earth radius	6371	km	
Horizon height	0	°	
Tx-Rx distance	**2573**	**km**	
Ground Segment			
Antenna Gain	17.0	dBi	*Dual Crossed Yagis*
Tx RF power	25.0	W	
Tx losses	1.6	dB	*Cable and connector*
Tx EIRP	**29.4**	**dBW**	
PROPAGATION			
GS antenna pointing loss	0.5	dB	
Polarization losses	3.0	dB	*Worst-case*
Free space losses	152.7	dB	
Atmospheric Losses	2.1	dB	
Ionospheric losses	0.4	dB	
Total Propagation Losses	**158.7**	**dB**	
Satellite Segment			
Satellite Antenna Pointing Loss	0.0	dB	
Antenna Gain	0.0	dBi	
Spacecraft Tx line losses	0.2	dB	
Antenna Temperature	150	K	*Earth is half of F.o.V.*
Satellite Noise Temperature	500	K	*Estimate*
System Noise Temperature	650.0	K	
System Noise Temperature	28.1	dBK	
Rx G/T	**-28.3**	**dB/K**	
Final C/No	**71.0**	**dBHz**	

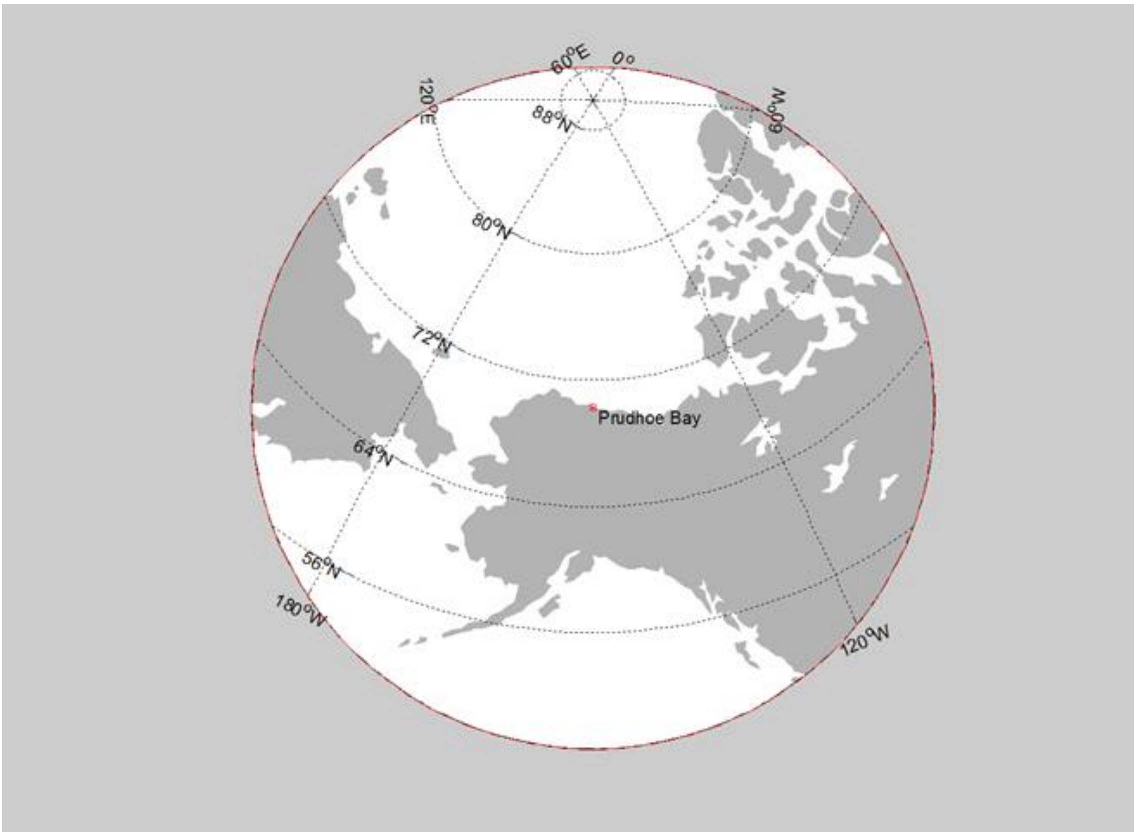
Receive Channel Bandwidth	7.2	kHz	*typically 1.5x bit rate*
Useful bitrate	4.8	kBit	
Required Eb/No	4.8	dB	*GMSK, Conv. R=1/2,K=7 & R.S. (255,223)*
Receiver Implementation Loss	3.0	dB	*Demodulator phase offset*
C/No required	**46.37**	**dBHz**	
MARGIN A --> B	**24.59**	**dB**	

UHF Link - Downlink

Link parameters		**Unit**	**Notes**
Carrier Frequency	401.50	MHz	*401 - 402 MHz*
Carrier wavelength	0.75	m	
Boltzmann constant	-228.6	dBW/K/Hz	
BASIC PARAMETERS			
Orbit height	500	km	
Earth radius	6371	km	
Horizon height	0	°	
Tx-Rx distance	**2573**	**km**	
Satellite Segment			
Tx antenna gain	0.0	dBi	
Tx RF power	1.0	W	
Tx losses	0.5	dB	*Cable and connector*
Tx EIRP	**-0.5**	**dBW**	
PROPAGATION			
Satellite Antenna Pointing Loss	0.0	dB	
Polarization Loss	3.0	dB	*Worst-case*
Free space losses	152.7	dB	
Atmospheric Loss	2.1	dB	
Ionospheric Loss	0.4	dB	
Total Propagation Losses	**158.2**	**dB**	
Ground Segment			
GS Antenna Pointing Loss	0.5	dB	
Antenna Gain	17.0	dBi	*Dual Crossed Yagis*
GS Transmission Line Losses	0.5	dB	
Antenna Temperature	170	K	*Worst-case at 0° elevation*
Ground Noise Temperature	300	K	*Estimate*
System Noise Temperature	470.0	K	
System Noise Temperature	26.7	dBK	
Rx G/T	**-10.7**	**dB/K**	
Final C/No	**59.2**	**dBHz**	

Receive Channel Bandwidth	28.8	kHz	*typically 1.5x bit rate*
Useful bitrate	19.2	kBit	
Required Eb/No	4.80	dB	*GMSK, Conv. R=1/2,K=7 & R.S. (255,223)*
Receiver Implementation Loss	3.00	dB	*Demodulator phase offset*
C/No required	**52.39**	**dBHz**	
MARGIN A --> B	**6.76**	**dB**	

C. TT&C Contours Map



Note that the contours at 2 dB below peak fall entirely beyond the edge of the visible Earth.

III. Technical Certification

I, David Morse, hereby certify that I am the technically qualified person responsible for the preparation of the technical information contained in the RBC Signals earth station license application and the accompanying Technical Appendix, that I am familiar with Part 25 of the Commission's Rules (47 C.F.R. Part 25), and that I have either prepared or reviewed the technical information submitted in this application and found it to be complete and accurate to the best of my knowledge and belief.

By: /s/David Morse

Title: VP, Communication Systems
Avaliant, LLC

Date: March 21, 2018