MSU 21-Meter Tri-Band Radiation Hazard Report

Space Science Center
Morehead State University
235 Martindale Drive
Morehead, KY 40351

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Prepared by: Emily Walter

Reviewed by: Reviewer #1 Benjamin Malphrus
Reviewer #2 TBD

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1.0 REPORT AND STANDARDS OVERVIEW

1.1 Document Scope

This document is intended to show the compliance of Morehead State University's 21-meter satellite tracking antenna to the FCC OET Bulletin 65. OET 65 outlines standards, best practices, and methods of analysis/measurement of radiated emissions that humans may encounter from transmitter devices. In Appendix A, the limits for both controlled and uncontrolled exposure are given as functions of power density, electric field strength, or magnetic field strength depending on the range of frequencies being analyzed. This document will compare the analyses against the exposure values given for frequencies greater than 1500MHz, as these are the frequencies that will be utilized by MSU's aperture for transmit. Below is a table showing the controlled and uncontrolled exposure ratings as shown in FCC OET Bulletin 65 Appendix A.

Table 1: Exposure Limits

FCC OET Bulletin 65 Exposure Limits		
Exposure Type	Exposure Limit	Time of Exposure
Controlled Exposure	5mW/cm^2	6 minutes
Uncontrolled Exposure	1mW/cm^2	30 minutes

The difference between controlled and uncontrolled exposure lies in the knowledge that one is being exposed to RF radiation. These are also respectively called occupational and general exposure. Controlled exposure refers to exposure that a person is properly informed about as part of their work duties and that they have knowledge of how to mitigate or avoid. Uncontrolled exposure refers to exposure experienced by people who are not aware of the radiation and can include workers who are not informed/trained on dealing with RF hazards or the general public.

2.0 MSU 21-METER ANTENNA SPECIFICATION

2.1 21-Meter Operations Overview

The 21-meter at Morehead State University is a satellite tracking antenna that has been used for lunar and deep space operations at both S-band and X-band in the FCC designated deep space communications bands. Currently, the 21-meter is undergoing system and performance upgrades in order to reach compatibility for NASA's LEGS standards at S-band, X-band, and Ka-band. These upgrades include expanding the system to a new frequency as well as improving EIRP and G/T for each frequency band through upgraded amplifier systems. As part of the compliance evaluation, the new transmit powers and feed design will be analyzed against the exposure standards put in place by the FCC. This analysis will then inform any operational constraints or safety precautions that must be taken on site when the antenna is transmitting.

2.2 21-Meter Frequencies and Anticipated Performance

The 21-meter, as part of the upgrade to become LEGS compliant, will be able to transmit at S-band, X-band, or Ka-band in the FCC designated deep space frequency bands. For the analysis of exposure limits, each frequency will be analyzed at the low, mid, and high point of the bands of interest. This will verify that throughout the band the antenna is compliant or has appropriate safeguards in place to prevent excessive radiation exposure.

Table 2: 21-Meter Reflector Size Definitions

Tri-Band Antenna Mechanical Specifications		
Parameter	Symbol	Value
Main Reflector Diameter	D	21.0 m
Subreflector Diameter	D_{sub}	1.96 m
Main Reflector Area	A_{main}	346.4 m^2
Subreflector Area	A_{sub}	3.02 m^2

Table 3: 21-Meter Frequency Specific Parameters

	Tri-Band Configurations Under Analysis				
Frequency Band	Frequency [GHz]	Gain [dBi]	Gain [unitless]	Transmit Power [W]	EIRP [dBW]
S	2.025 – 2.120	49.2	8.31×10^4	1500	81.0
X	7.145 – 7.235	60.3	$1.07e10^6$	1200	91.1
Ka	22.55 – 23.15	69.0	7.94×10^6	250	93.0

In the table above, the analysis frequencies, gains, and the maximum transmit output power is shown. The analysis will evaluate the worst-case scenario of the highest output power of the power amplifier, even though all amplifiers will be backed off during operations.

3.0 EQUATIONS AND ANALYSIS

Below, each of the equations used for the analysis is documented in detail. All of these equations are directly pulled from or derived from the equations recommended for analysis in the FCC OET Bulletin 65.

3.1 Far-Field Exposure

A transmitting antenna will have three areas of interest around it, the near-field, transition region, and far-field. These different areas will exhibit different power density levels and must be analyzed using different equations. Below is an equation that determines the far-field boundary. When the distance is greater than this boundary, the antenna can be treated as radiating in the far-field.

$$R_{ff} = 0.6\left(\frac{D^2}{\lambda}\right)$$

In the far-field, power density decreases inversely with the square of distance from the antenna. This equation finds the power density in the main lobe of the antenna, meaning that this is the maximum possible power that would be seen (the power if the antenna was pointed directly at the point of interest).

$$S = \frac{P * G}{4\pi R^2}$$

3.2 Near-Field Exposure

The near-field experiences the maximum power density before it begins decreasing. The near-field has a similar equation to determine its boundary, shown below. When the distance is less than the boundary distance, the antenna is treated as if it is radiating in the near-field.

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

The equation called out below for the near-field is given below. This equation finds the maximum near-field power density for a given aperture.

$$S = \frac{16\eta P}{\pi D^2}$$

3.3 Transition Exposure

Any distance between the near-field boundary and far-field boundary are considered to be in the transition region of the antenna, also known as the Fresnel region. The power density in this region can be found by the equation shown below.

$$S_t = \frac{S_{nf} * R_{nf}}{R}$$

3.4 Between Main and Subreflector Exposure

From the FCC OET Bulletin 65, the power density at the reflecting surface is given by the following equation. This equation is an approximation of the maximum power density at the subreflector surface.

$$S_{subreflector} = \frac{4P}{A_{sub}}$$

3.5 Main Reflector Surface Exposure

From the FCC OET Bulletin 65, the power density at the surface of the antenna is given by the following equation. This equation is an approximation of the maximum power density directly in front of an antenna.

$$S_{surface} = \frac{4P}{A_{main}}$$

3.6 Ground Level Exposure

Ground level exposure can be represented as the power of the antenna transmitter illuminating the main reflector completely. This can be found by the following equation.

$$S_{ground} = \frac{P}{A_{main}}$$

4.0 ANALYSIS EXPOSURE RESULTS

4.1 S-Band Analysis

Table 4: S-Band Summary of Expected Exposure Levels

S-Band Analysis Results						
Analyzed Situation	Value [W/m²]	Value [mW/cm²]	Controlled Limit [mW/cm²]	Controlled Pass/Fail	Uncontrolled Limit [mW/cm²]	Uncontrolled Pass/Fail
Far-Field (1,828m)	2.971359136	0.297135914	5	Pass	1	Pass
Near-Field (762m)	43.26210862	4.326210862	5	Pass	1	Potential Hazard
Transition	43.26210862	4.326210862	5	Pass	1	Potential Hazard
Between Main and Subreflector	1988.608202	198.8608202	5	Potential Hazard	1	Potential Hazard
Main Reflector Surface	17.322987	1.7322987	5	Pass	1	Potential Hazard
Ground Beneath Main Reflector	4.330746751	0.433074675	5	Pass	1	Pass

4.2 X-Band Analysis

Table 5: X-Band Summary of Expected Exposure Levels

X-Band Analysis Results						
Analyzed Situation	Value [W/m^2]	Value [mW/cm^2]	Controlled Limit [mW/cm^2]	Controlled Pass/Fail	Uncontrolled Limit [mW/cm^2]	Uncontrolled Pass/Fail
Far-Field (6,342m)	2.544347531	0.254434753	5	Pass	1	Pass
Near-Field (2,642m)	32.33451661	3.233451661	5	Pass	1	Potential Hazard
Transition	32.33451661	3.233451661	5	Pass	1	Potential Hazard
Between Main and Subreflector	1590.886562	159.0886562	5	Potential Hazard	1	Potential Hazard
Main Reflector Surface	13.8583896	1.38583896	5	Pass	1	Potential Hazard
Ground Beneath Main Reflector	3.464597401	0.34645974	5	Pass	1	Pass

4.3 Ka-Band Analysis

Table 6: Ka-Band Summary of Expected Exposure Levels

Ka-Band Analysis Results						
Analyzed Situation	Value [W/m^2]	Value [mW/cm^2]	Controlled Limit [mW/cm^2]	Controlled Pass/Fail	Uncontrolled Limit [mW/cm^2]	Uncontrolled Pass/Fail
Far-Field (20,154m)	0.389063568	0.038906357	5	Pass	1	Pass
Near-Field (8,397m)	9.177824809	0.917782481	5	Pass	1	Pass
Transition	9.177824809	0.917782481	5	Pass	1	Pass
Between Main and Subreflector	331.4347003	33.14347003	5	Potential Hazard	1	Potential Hazard
Main Reflector Surface	2.887164501	0.28871645	5	Pass	1	Pass
Ground Beneath Main Reflector	0.721791125	0.072179113	5	Pass	1	Pass

5.0 CONCLUSION AND OPERATIONAL IMPACTS

Based on the evidence provided above, the ground station does exceed the FCC MPE potential hazard limit under certain conditions. The ground station requests the following mitigations be considered as reasonable and acceptable for the proposed scenarios.

In Tables 4 and 5, for the near-field and transition scenarios, the general public will not have access to the areas of the antenna that exhibit these power densities. The antenna in question is located in a remote area, on the top of a ridgeline with an elevation of 360 meters. The antenna also has an elevation mask of 5˚, meaning that it will never be pointing towards the ground during operations, preventing anyone without knowledge of the environment from entering.

In Tables 4, 5, and 6, the scenario between the main and subreflector exceeds both the controlled and uncontrolled FCC MPE. The antenna will never have people, knowing or otherwise, in this section of the structure when the dish is operational.