Analysis of Non-Ionizing Radiation for a 13.2-Meter Earth Station System

This report analyzes the non-ionizing radiation levels for a 13.2-meter earth station system. The analysis and calculations performed in this report comply with the methods described in the FCC Office of Engineering and Technology Bulletin, No. 65 first published in 1985 and revised in 1997 in Edition 97-01. The radiation safety limits used in the analysis are in conformance with the FCC R&O 96-326. Bulletin No. 65 and the FCC R&O specifies that there are two separate tiers of exposure limits that are dependent on the situation in which the exposure takes place and/or the status of the individuals who are subject to the exposure. The Maximum Permissible Exposure (MPE) limits for persons in a General Population / Uncontrolled environment are shown in Table 1. The General Population / Uncontrolled MPE is a function of transmit frequency and is for an exposure period of thirty minutes or less. The MPE limits for persons in an Occupational/Controlled environment are shown in Table 2. The Occupational MPE is a function of transmit frequency and is for an exposure period of six minutes or less. The purpose of the analysis described in this report is to determine the power flux density levels of the earth station in the far-field, near-field, transition region, between the sub-reflector or feed and main reflector surface, at the main reflector surface, and between the antenna edge and the ground and to compare these levels to the specified MPEs.

Table 1. Limits for General Population/Uncontrolled Exposure (MPE)

Frequency Range (MHz)	**Power Density ($\frac{mW}{cm^2}$)**
30-300	0.2
300-1500	Frequency (MHz)*(0.8/1200)
1500-100,000	1.0

Table 2. Limits for Occupational/Controlled Exposure (MPE)

Frequency Range (MHz)	**Power Density ($\frac{mW}{cm^2}$)**
30-300	1.0
300-1500	Frequency (MHz)*(4.0/1200)
1500-100,000	5.0

Table 3. Formulas and Parameters Used for Determining Power Flux Densities

Parameter	**Symbol**	**Formula**	**Value**	**Units**
Antenna Diameter	D	Input	13.36	m
Antenna Surface Area	$A_{surface}$	$\frac{\pi D^2}{4}$	140.19	m^2
Subreflector Diameter	D_{sr}	Input	173.95	cm
Area of Subreflector	A_{sr}	$\frac{\pi D_{sr}^2}{4}$	23765.05	cm^2
Frequency	F	Input	30000	MHz
Wavelength	λ	300 / F	0.01000	m
Transmit Power	P	Input	300.00	W
Antenna Gain (dBi)	G_{es}	Input	69.3	dBi

Antenna Gain (factor)	G	$10^{\frac{Gei}{10}}$	8511380.4	n/a
Pi	π	Constant	3.1415927	n/a
Antenna Efficiency	η	$G\lambda^2/(\pi^2 D^2)$	0.48	n/a

1. Far Field Distance Calculation

The distance to the beginning of the far field can be determined from the following equation:

Distance to the Far Field Region R_{ff} $= 0.60\, D^2 / \lambda$ (1)
= 10709.4 m

The maximum main beam power density in the far field can be determined from the following equation:

On-Axis Power Density in the Far Field S_{ff} $= G P / (4 \pi R_{ff}^2)$ (2)

$= 1.77167 \frac{W}{m^2}$

$= 0.17717 \frac{mW}{cm^2}$

2. Near Field Calculation

Power flux density is considered to be at a maximum value throughout the entire length of thedefined Near Field region. The region is contained within a cylindrical volume having the samediameter as the antenna. Past the boundary of the Near Field region, the power density from theantenna decreases linearly with respect to increasing distance.

The distance to the end of the Near Field can be determined from the following equation:

Extent of the Near Field R_{nf} $= D^2 / (4 \lambda)$ (3)
= 4462.2 m

The maximum power density in the Near Field can be determined from the following equation:

Near Field Power Density S_{nf} $= 16.0\, \eta P / (\pi D^2)$ (4)

$= 4.136 \frac{W}{m^2}$

$= 0.414 \frac{mW}{cm^2}$

3. Transition Region Calculation

The Transition region is located between the Near and Far Field regions. The power density begins to decrease linearly with increasing distance in the Transition region. While the power density decreases inversely with distance in the Transition region, the power densitydecreasesinversely with the square of the distance in the Far Field region. The maximum power density inthe Transition region will not exceed that calculated for the Near Field region. The power densitycalculated in Section 1 is the highest power density the antenna can produce in any of the regionsaway from the antenna. The power density at a distance R_t can be determined from the followingequation:

Transition Region Power Density S_t $= S_{nf} R_{nf} / R_t$ (5)

$= 0.414 \frac{mW}{cm^2}$

4. Region between the Main Reflector and the Subreflector

Transmissions from the feed assembly are directed toward the subreflector surface, and are reflected back toward the main reflector. The most common feed assemblies are waveguide flanges, horns or subreflectors. The energy between the subreflector and the reflector surfacescan be calculated by determining the power density at the subreflector surface. This can bedetermined from the following equation:

Power Density at the Subreflector S_{sr} $= 4000\ P / A_{sr}$ (6)

$= 50.494 \frac{mW}{cm^2}$

5. Main Reflector Region

The power density in the main reflector is determined in the same manner as the power density atthe subreflector. The area is now the area of the main reflector aperture and can be determinedfrom the following equation:

Power Density at the Main Reflector Surface $S_{surface}$ $= 4\ P / A_{surface}$ (7)

$= 8.560 \frac{W}{m^2}$

$= 0.856 \frac{mW}{cm^2}$

6. Region between the Main Reflector and the Ground

Assuming uniform illumination of the reflector surface, the power density between the antenna andthe ground can be determined from the following equation:

Power Density between Reflector and Ground S_g $= P / A_{surface}$ (8)

$= 2.140 \frac{W}{m^2}$

$= 0.214 \frac{mW}{cm^2}$

7. Summary of Calculations

Table 4. Summary of Expected Radiation levels for Uncontrolled Environment

Region	Calculated Maximum Radiation Power Density Level $\left(\frac{mW}{cm^2}\right)$	Hazard Assessment
1. Far Field (R_{ff} = 10709.4 m)	S_{ff} 0.17717	Satisfies FCC MPE
2. Near Field (R_{nf} = 4462.2 m)	S_{nf} 0.414	Satisfies FCC MPE
3. Transition Region ($R_{nf} < R_t < R_{ff}$)	S_t 0.414	Satisfies FCC MPE
4. Between Main Reflector andSubreflector	S_{sr} 50.494	Potential Hazard
5. Main Reflector	$S_{surface}$ 0.856	Satisfies FCC MPE
6. Between Main Reflector and Ground	S_g 0.214	Satisfies FCC MPE

Table 5. Summary of Expected Radiation levels for Controlled Environment

Region	Calculated Maximum Radiation Power Density Level $\left(\frac{mW}{cm^2}\right)$	Hazard Assessment
1. Far Field (R_{ff} = 10709.4 m)	S_{ff} 0.17717	Satisfies FCC MPE
2. Near Field (R_{nf} = 4462.2 m)	S_{nf} 0.414	Satisfies FCC MPE
3. Transition Region ($R_{nf} < R_t < R_{ff}$)	S_t 0.414	Satisfies FCC MPE
4. Between Main Reflector and Subreflector	S_{sr} 50.494	Potential Hazard
5. Main Reflector	$S_{surface}$ 0.856	Satisfies FCC MPE
6. Between Main Reflector and Ground	S_g 0.214	Satisfies FCC MPE

It is the applicant's responsibility to ensure that the public and operational personnel are not exposed to harmful levels of radiation.

8. Conclusions

Based on the above analysis it is concluded that the FCC MPE guidelines have been met in most cases except one in the regions of Table 4 and 5. The applicant proposes to comply with the MPE limit for region 4 by placing proper emission warning signs at the antenna facility and ensuring that all operating personnel will be aware of the human exposure levels between the main reflector and the Sub-reflector of the Antenna. The antenna facility is located in an area that contains several other antennas and that is not accessible to the general population unless by prior arrangement with site operations staff and with a specific need to be on the site.

The applicant agrees to abide by the conditions specified in Condition 5208 provided below:

Condition 5208 - The licensee shall take all necessary measures to ensure that theantenna does not create potential exposure of humans to radiofrequency radiationin excess of the FCC exposure limits *defined in 47 CFR 1.1307(b) and 1.1310wherever such exposures might occur. Measures must be taken to ensurecompliance with limits for both occupational/controlled exposure and for general population/uncontrolled exposure, as defined in these rule sections. Compliancecan be accomplished in most cases by appropriate restrictions such as fencing.Requirements for restrictions can be determined by predictions based oncalculations, modeling or by field measurements. The FCC's OET Bulletin 65(available on-line at www.fcc.gov/oet/rfsafety) provides information on predictingexposure levels and on methods for ensuring compliance, including the use ofwarning and alerting signs and protective equipment for worker.*

Finally, occupational exposure will be limited, and the transmitter will be turned off during periods of maintenance, so that the MPE standard of 5.0 $\frac{mW}{cm^2}$ will be complied with for those regions in close proximity to the main reflector, and sub-reflector, which could be occupied by operating personnel.