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Analysis of Non-Ionizing Radiation for a 4.8-Meter Earth Station System

This report analyzes the non-ionizing radiation levels for a 4.8-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 (mW/cm2)
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 (mW/cm2)
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	4.8 m	m
Antenna Surface Area	$A_{surface}$	$(\pi/4)\cdot D^2$	18.10	m^2
Sub-reflector Diameter	D_{sr}	Input	36.6	cm
Area of Sub reflector	A_{sr}	$(\pi/4)\cdot Dsr^2$	1049.67	cm^2
Frequency	F	Input	14125	MHz
Wavelength	λ	300/F	2.122	cm
Transmit Power	P	Input	100.00	W
Antenna Gain (dBi)	G_{es}	Input	55	dBi
Antenna Gain (factor)	G	$10^{Ges/10}$	316227.7	n/a
Pi	π	Constant	3.1415927	n/a
Antenna Efficiency	η	$G\cdot(\lambda/(\pi\cdot D))^2$	0.627	n/a

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1. Far Field Distance Calculation

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

$$\text{Distance to the Far Field Region } R_{ff} = 0.60\ D^2/\lambda \quad (1)$$
$$= 650.9\ \text{m}$$

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

$$\text{On-Axis Power Density in the Far Field } S_{ff} = G\ P\ /\ (4\ \pi\ R_{ff}^{\ 2}) \quad (2)$$
$$= 5.93965\ \text{W/m}^2$$
$$= 0.5939\ \text{mW/cm}^2$$

2. Near Field Calculation

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

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

$$\text{Extent of the Near Field } R_{nf} = D^2/\ (4\ \lambda) \quad (3)$$
$$= 271.2\ \text{m}$$

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

$$\text{Near Field Power Density } S_{nf} = 16.0\ \eta\ P\ /\ (\pi\ D^2) \quad (4)$$
$$= 13.847\ \text{W/m}^2$$
$$= 1.3847\ \text{mW/cm}^2$$

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 density decreases inversely with the square of the distance in the Far Field region. The maximum power density in the Transition region will not exceed that calculated for the Near Field region. The power density calculated in Section 1 is the highest power density the antenna can produce in any of the regions away from the antenna. The power density at a distance R_t can be determined from the following equation:

$$\text{Transition Region Power Density } S_t = S_{nf}\ R_{nf}\ /\ R_t \quad (5)$$
$$= 1.481\ \text{mW/cm}_2$$

4. Region between the Main Reflector and the Sub-reflector

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

Power Density at the Sub-reflector $S_{sr} = 4 \cdot P / Asr$ (6)
$= 0.381072\ W/cm^2$
$= 381.07\ mW/cm^2$

5. Main Reflector Region

The power density in the main reflector is determined in the same manner as the power density at the sub-reflector. The area is now the area of the main reflector aperture and can be determined from the following equation:

Power Density at the Main Reflector Surface $S_{surface} = 4\ P / A_{surface}$ (7)
$= 22.099\ W/m^2$
$= 2.209\ mW/cm^2$

6. Off-axis Levels at the Far Field Limit and Beyond

In the far field region, the power is distributed in a pattern of maxima and minima (sidelobes) as a function of the off-axis angle between the antenna on-axis center line and the point of interest. The on-axis main-beam will be the location of the greatest of these maxima. The on-axis power density calculated above represent the maximum exposure levels that the system can produce. Off-axis power densities will be considerably less and hence comply with FCC limits.

7. Off-axis Levels at the Near Field Limit and in the Transition Region

According to Bulletin 65, off-axis calculations in the near field may be performed as follows: assuming that the point of interest is at least one antenna diameter removed from the center of the main beam, the power density at that point is at least a factor of 100 (20dB) less than the value calculated for the equivalent on-axis power density in the main beam. Therefore, for regions at least D meters away from the center line of the dish, whether behind, below, or in front under of the antenna's main beam, the power density exposure is at least 20 dB below the main beam level as follows:

Power Density off-axis behind, below or in front under the antenna's main beam S_g =
$S_g = Snf/100 = 0.014\ mW/cm^2$

7. Summary of Calculations

Table 4. Summary of Expected Radiation levels for Uncontrolled Environment

Region		**Calculated Max. Radiation Power Density Level (mW/cm^2)**		**Hazard Assessment** ($\leq 1mW/cm^2$)
	Far Field (R_{ff} = 650.9 m)	S_{ff}	0.593	Satisfies FCC MPE
	Near Field (R_{nf} = 271.2 m)	S_{nf}	1.385	Potential Hazard
	Transition Region ($R_{nf} < R_t < R_{ff}$)	S_t	1.385	Potential Hazard
	Between Main Reflector and Sub-reflector	S_{sr}	381.072	Potential Hazard
	Main Reflector	$S_{surface}$	2.209	Potential Hazard
	Between Main Reflector and Ground	S_g	0.014	Satisfies FCC MPE

Table 5. Summary of Expected Radiation levels for Controlled Environment

Region		**Calculated Max. Radiation Power Density Level (mW/cm_2)**		**Hazard Assessment** ($\leq 5mW/cm^2$)
	Far Field (R_{ff} = 650.9 m)	S_{ff}	0.593	Satisfies FCC MPE
	Near Field (R_{nf} = 271.2 m)	S_{nf}	1.385	Satisfies FCC MPE
	Transition Region ($R_{nf} < R_t < R_{ff}$)	S_t	1.385	Satisfies FCC MPE
	Between Main Reflector and Sub-reflector	S_{sr}	381.072	Potential Hazard
	Main Reflector	$S_{surface}$	2.209	Satisfies FCC MPE
	Between Main Reflector and Ground	S_g	0.014	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. Evaluation of Safe Occupancy Area in Front of Antenna

As covered in the section above “Off-axis levels at the Near Field and in the Transition Region”, the off-axis levels are well below the FCC limit for a controlled environment. However, in an abundance of caution, a fence will be used to prevent employee and the general public access to the area surrounding the antenna. In addition, the area between the feed horn and the reflector will not be accessible by maintenance personnel without the proper training and the transmitter being turned off.

9. Conclusions

Based on the above analysis it is concluded that harmful levels of radiation will not exist in regions normally occupied by the public or the earth station's operating personnel. The transmitter will be turned off during antenna maintenance so that the FCC MPE of 5.0 mW/cm2 will be complied with for those regions with close proximity to the reflector that exceed acceptable levels.