Analysis of Non-Ionizing Radiation for a 1.35-Meter Earth Station System

This report analyzes the non-ionizing radiation levels for a 1.35-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 dependant 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 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/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 (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		1.35	m
Antenna Surface Area	$A_{surface}$	$\pi D^2 / 4$	1.4314	m^2
Frequency	F		14.25	GHz
Wavelength	λ	$300 / F$	0.0211	m
Transmit Power	P		350	W
Antenna Gain (dBi)	G_{es}		44.5	dBi
Antenna Gain (factor)	G	$10^{Ges/10}$	26915.3480	
Pi	π		3.1416	
Antenna Efficiency	η		0.65	

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)
$= 51.94$ 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)
$= 290.9601$ W/m^2
$= 29.0960$ 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:

Extent of the Near Field $R_{nf} = D^2 / (4\ \lambda)$ (3)
$= 21.6422$ 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)
$= 635.7465$ W/m^2
$= 63.5746$ 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 2 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:

Transition Region Power Density $S_t = S_{nf}\ R_{nf} / R_t$ (5)
≤ 63.5746 mW/cm^2

4. Distance to Safe Region Calculation

Since the power density decreases inversely with the square of the distance in the Far Field region, the distance to the On-axis Power Density of 5 mW/cm^2 can be determined from the following equation:

Distance to ANSI 5 mW/cm^2 $D_{safe} = R_{ff} ((S_{ff} / 5)^{0.5})$ (6)
$= 125.2980$ meters

5. Main Reflector Region

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

Power Density at the Reflector Surface $S_{surface} = 4\ P / A_{surface}$ (7)
$= 978.0715$ W/m^2
$= 97.8072$ mW/cm^2

6. Off-axis Evaluation

For off-axis calculations in the Near Field and in the Transition region, it can be assumed that, if the point of interest is at least one antenna diameter removed from the center of the main beam, the power density at that point would be at least a factor of 100 (20dB) less than the value calculated for the equivalent distance in the main beam. For off-axis calculations in the Far Field, the calculated main-beam power density can be multiplied by the appropriate relative power density factor obtained from the antenna gain pattern. Since the proposed antenna meets or exceeds the performance specifications under Part 25.209 of the FCC rules, the off-axis gain for this antenna is equal to or greater than 10dBi less than the on-axis gain in any direction of 48 degrees or more removed from the centerline of the main beam.

Near Field Off-axis Power Density $S_{nf(off)} = 0.01\ S_{nf}$ (8)
$= 0.6357$mW/cm^2

Far Field Off-axis Power Density $S_{ff(off)} = 0.1\ S_{ff}$ (9)
$= 2.9096$ mW/cm^2

7. Summary of Calculations

Table 4. Summary of Expected Radiation levels for Uncontrolled Environment

Region	Calculated Maximum Radiation Power Density Level (mW/cm^2)		Hazard Assessment
Far Field (R_{ff} = 51.94 m)	S_{ff}	29.0960	Potential Hazard
Near Field (R_{nf} = 21.642 m)	S_{nf}	63.5746	Potential Hazard
Transition Region ($R_{nf} < R_t < R_{ff}$)	S_t	63.5746	Potential Hazard
Safe Distance Region (D_{safe}=125.298m)			
Main Reflector Surface	$S_{surface}$	97.8072	Potential Hazard
Near Field Off-axis Region (Between reflector and ground)	$S_{nf(off)}$	0.6357	Potential Hazard
Far Field Off-axis Region	$S_{ff(off)}$	2.9096	Potential Hazard

Table 5. Summary of Expected Radiation levels for Controlled Environment

Region	Calculated Maximum Radiation Power Density Level (mW/cm^2)		Hazard Assessment
Far Field (R_{ff} = 51.94 m)	S_{ff}	29.0960	Potential Hazard
Near Field (R_{nf} = 21.642 m)	S_{nf}	63.5746	Potential Hazard
Transition Region ($R_{nf} < R_t < R_{ff}$)	S_t	63.5746	Potential Hazard
Safe Distance Region (D_{safe}=125.298m)			
Main Reflector Surface	$S_{surface}$	97.8072	Potential Hazard
Near Field Off-axis Region (Between reflector and ground)	$S_{nf(off)}$	0.6357	Potential Hazard
Far Field Off-axis Region	$S_{ff(off)}$	2.9096	Potential Hazard

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 this analysis it is concluded that the FCC RF Guidelines have been exceeded in the specific regions of Tables 4 and 5. The applicant proposes to comply with the Maximum Permissible Exposure (MPE) limits of 1 mW/cm^2 for the uncontrolled areas and the MPE limits of 5 mW/cm^2 for the controlled areas, by one or more of the following methods:

Means of Compliance - Uncontrolled Areas

This antenna will be located on a vehicle rooftop. The distance from the ground to the center of the antenna is approximately 4.0 meters. The location will be sufficient to prohibit access to the areas that exceed the MPE limits. The general public will not have access to areas within ½ diameter removed from the edge of the antenna.

Radiation hazard signs will be posted at any rooftop access location. The signs will be completely visible from the ground.

The applicant will ensure that no buildings or other obstacles will be in the areas that exceed the MPE levels.

Means of Compliance - Controlled Areas

The earth station's operational personnel will not have access to the areas that exceed the MPE levels while the earth station is in operation.

The transmitters will be turned off during antenna maintenance.

Means of Compliance – Safety in General

This antenna system is located on a mobile unit and conditions will vary from operating site to operating site. Because of this, the licensee will establish procedures for the operational personnel to verify that the antenna is not pointing in the direction of populated areas, and that access to hazardous areas are restricted while the unit is in operation.

In addition, the transmit power used in these calculations is greater than that which will typically be utilized by the earth station. During normal operation, the typical power level would generally not exceed more than 50 to 75 percent of the indicated transmitter power. Maximum transmit power would generally only occur in conditions of extreme inclement weather.