Analysis of RF Exposure for a 5.60 Meter Earth Station System

This report analyzes the radiofrequency exposure levels for a 5.60 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 Number 65 (OET65), which was published in 1985 and revised in 1997. Near-field exposure was calculated using an updated formula based on IEEE Std. C95.3-2021 and recommended by OET in August 2024.

The exposure limits used in the analysis conform with the FCC R&O 96-32 and OET65. There are two separate Maximum Permissible Exposure (MPE) limits that depend on the situation in which the exposure takes place and the status of the individuals who are subject to the exposure. The MPE limits for people in a General Population/Uncontrolled environment are shown in Table 1. The MPE limits for people in an Occupational/Controlled environment are shown in Table 2.

The purpose of the analysis described in this report is to determine the worst-case power flux density levels of the earth station in the far-field, near-field, transition region, at the main reflector surface, and at off-axis locations. Those levels are then compared to the following 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 to Determine Power Flux Densities

Parameter	Symbol	Formula	Value	Units
Antenna Diameter	D		5.60	m
Antenna Surface Area	$A_{surface}$	$\pi D^2 / 4$	24.63	m^2
Frequency	F		14.00	GHz
Wavelength	λ	300 / F	0.0214	m
Transmit Power	P		50.0	W
Antenna Gain (dBi)	G_{es}		57.0	dBi
Antenna Gain (factor)	G	$10^{Ges/10}$	501,187.23	
Antenna Efficiency	η		0.7416	

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 $R_{ff} = 0.60\ D^2 / \lambda$ (16)
$= 879.2523$ 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 $S_{ff} = G\ P / (4\ \pi\ R_{ff}^2)$ (18)
$= 2.5795\ W/m^2$
$= 0.2580\ mW/cm^2$

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. Beyond the Near Field region boundary, 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 $R_{nf} = D^2 / (4\ \lambda)$ (12)
$= 366.3551$ m

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

Field Power Density $S_{nf} = 16.0\ P / (\eta\ \pi\ D^2)$ (C95.3-20214)
$= 10.9495\ W/m^2$
$= 1.0950\ mW/cm^2$

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 region. The power density at a distance R_t can be determined from the following equation:

Transition Region Power Density $S_t = S_{nf}\ R_{nf} / R_t$ (17)
$\leq 1.0950\ mW/cm^2$

4. Distance to MPE Calculation

Since the power density decreases inversely with the square of the distance in the Far Field region, the distance to On-axis MPE limits can be determined from the following equations:

Distance to 1 mW/cm^2

$$D_{mpe1} = R_{ff} ((S_{ff} / 1)^{0.5})$$
$$= 446.56 \text{ meters}$$

Distance to 5 mW/cm^2

$$D_{mpe5} = R_{ff} ((S_{ff} / 5)^{0.5})$$
$$= 199.71 \text{ meters}$$

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

$$S_{surface} = 4 P / A_{surface} \quad (11)$$
$$= 8.1202 \text{ W/m}^2$$
$$= 0.8120 \text{ mW/cm}^2$$

6. Off-axis Evaluation

For off-axis calculations in the Near Field and in the Transition regions, 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 (20 dB) 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 10 dBi less than the on-axis gain in any direction 48 or more degrees removed from the centerline of the main beam.

Near Field Off-axis Power Density

$$S_{sn(off)} = 0.01 S_{nf}$$
$$= 0.0110 \text{ mW/cm}^2$$

Far Field Off-axis Power Density

$$S_{sn(off)} = 0.1 S_{ff}$$
$$= 0.0258 \text{ mW/cm}^2$$

7. Summary of Calculations

Table 4. Summary of Calculated RF Exposure Levels for an Uncontrolled Environment

Region	Calculated Maximum Power Density (mW/cm^2)		Assessment
Far Field (R_{ff} = 879.2523 m)	S_{ff}	0.2580	Meets Limit
Near Field (R_{nf} = 366.3551 m)	S_{nf}	1.0950	Exceeds Limit
Transition Region ($R_{nf} < R_t < R_{ff}$)	S_t	1.0950	Exceeds Limit
MPE Distance (D_{mpe1}= 446.56 m)			
Main Reflector Surface	$S_{surface}$	0.8120	Meets Limit
Near Field Off-axis Region	$S_{nf(off)}$	0.0110	Meets Limit
Far Field Off-axis Region	$S_{ff(off)}$	0.0258	Meets Limit

Table 5. Summary of Calculated RF Exposure Levels for a Controlled Environment

Region	Calculated Maximum Power Density (mW/cm^2)		Assessment
Far Field (R_{ff} = 879.2523 m)	S_{ff}	0.2580	Meets Limit
Near Field (R_{nf} = 366.3551 m)	S_{nf}	1.0950	Meets Limit
Transition Region ($R_{nf} < R_t < R_{ff}$)	S_t	1.0950	Meets Limit
MPE Distance (D_{mpe5}= 199.71 m)			
Main Reflector Surface	$S_{surface}$	0.8120	Meets Limit
Near Field Off-axis Region	$S_{nf(off)}$	0.0110	Meets Limit
Far Field Off-axis Region	$S_{ff(off)}$	0.0258	Meets Limit

It is the applicant's responsibility to ensure that the public and operational personnel are not exposed to excessive RF exposure levels.

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 uncontrolled areas and the MPE limits of 5 mW/cm^2 for controlled areas using one or more of the following methods:

Means of Compliance - Uncontrolled Areas

This antenna is located within a controlled, fenced area at ground level. Operational procedures permit operation of this antenna only when the antenna is off-axis to all uncontrolled, publicly accessible areas.

Means of Compliance - Controlled Areas

The earth station's operational personnel are not permitted to access areas predicted to exceed the MPE limits while the earth station is in operation. The transmitter will be turned off during antenna maintenance. Appropriate RF Exposure signs are posted at all access locations.

Means of Compliance – General

The licensee will establish procedures for the operational personnel to verify that the antenna is not pointed in the direction of populated areas predicted to have power density exceeding the MPE limits while the unit is in operation.