Analysis of Non-Ionizing Radiation for a 5.0-Meter Earth Station System

This report analyzes the non-ionizing radiation levels for a 5.0-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 subreflector 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/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	Input	5.0	m
Antenna Surface Area	$A_{surface}$	$\pi D^2 / 4$	19.63	m^2
Diameter of feed	D_{sr}	Input	8.4	cm
Physical Area of feed flange	A_{sr}	$\pi D_{sr}^2/4$	55.4	cm^2
Frequency	F	Input	14,500	MHz
Wavelength	λ	300 / F	0.0207	m
Transmit Power	P	Input	162.00	W
Antenna Gain (dBi)	G_{es}	Input	55.0	dBi
Antenna Gain (factor)	G	$10^{Ges/10}$	316,228	n/a
Pi	π	Constant	3.1415927	n/a
Antenna Efficiency	η	$G\lambda^2/(\pi^2 D^2)$	0.55	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)
$= 724.6$ 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)
$= 7.76$ W/m^2
$= 0.776$ mW/cm^2

Off-axis power densities in the far-field region are reduced by at least 30 dB at angles of one degree or more for beam center. Therefore the far field off-axis power density will be less than:

$S_{ff} = (0.776$ mW/cm$^2) / 1000$
$= 0.000776$ 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)
$= 301.9$ m

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

Near Field Power Density $S_{nf} = 4.0\ \eta\ P / (\pi\ D^2)$ (4)
$= 18.16$ W/m^2
$= 1.816$ mW/cm^2

Conservative estimates of off-axis power density calculations in the near-field region can be made assuming a point of interest at least one antenna diameter from the center of the main beam. The resulting off-axis power density at any given distance from the antenna will be at least a factor of 100 (20 dB) less than the on-axis power density value at the same distance from the antenna.

Off-axis Near Field Power Density $S_{nf} = 1.816$mW/cm^2/100
$= 0.01816$ 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 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)
$< 1.816\ mW/cm^2$

Where R_t is a point of interest in meters with 302 meters < R_t < 725 meters. Estimates of off-axis calculations in the transition region can be made in the same fashion as for the near-field region by again assuming a point of interest at least one antenna diameter from the center of the main beam. The resulting off-axis power density at any given distance will be at least a factor of 100 (20dB) less than the on-axis power density value at the same distance from the center line axis of the antenna.

$S_{nf} = 1.816 mW/cm^2/100$
$< 0.01816\ mW/cm^2$

4. Region between the Main Reflector and the Feed

Transmissions from the feed assembly are directed toward the reflector surface. The energy between the feed and the reflector surfaces can be calculated by determining the power density at the reflector surface. This can be determined from the following equation:

Power Density at the Feed $S_{sr} = 4P / A_{sr}$ (6)
$= 116970\ W/m^2$
$= 11697\ mW/cm^2$

where "A_{sr}" is the surface area of the sub-reflector ($0.00554\ m^2$) and the factor of 4 results from the 6 dB tapered illumination level.

5. Main Reflector Region

The power density in the main reflector is determined in the same manner as the power density at the subreflector. 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)
$= 33\ W/m^2$
$= 3.3\ mW/cm^2$

6. Region between the Main Reflector and the Ground

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

Power Density between Reflector and Ground $S_g = P / A_{surface}$ (8)
$= 2.06\ W/m^2$
$= 0.206\ mW/cm^2$

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
1. Far Field (R_{ff} = 724.6 m)	S_{ff}	0.776	Satisfies FCC MPE
Off-axis Far Field		0.000776	Satisfies FCC MPE
2. Near Field (R_{nf} = 302 m)	S_{nf}	1.816	Potential Hazard
Off-axis Near Field		0.01816	Satisfies FCC MPE
3. Transition Region ($R_{nf} < R_t < R_{ff}$)	S_t	1.816	Potential Hazard
Off-axis Transition Region		<0.01816	Satisfies FCC MPE
4. Between Main Reflector and feed	S_{sr}	11697	Potential Hazard
4. Main Reflector	$S_{surface}$	3.3	Potential Hazard
5. Between Main Reflector and Ground	S_g	0.206	Satisfies FCC MPE

Table 5. Summary of Expected Radiation levels for Controlled Environment

Region		Calculated Maximum Radiation Power Density Level (mW/cm^2)	Hazard Assessment
6. Far Field (R_{ff} = 724.6 m)	S_{ff}	0.776	Satisfies FCC MPE
Off-axis Far Field		0.000776	Satisfies FCC MPE
7. Near Field (R_{nf} = 302 m)	S_{nf}	1.816	Potential Hazard
Off-axis Near Field		0.01816	Satisfies FCC MPE
8. Transition Region ($R_{nf} < R_t < R_{ff}$)	S_t	1.816	Potential Hazard
Off-axis Transition Region		<0.01816	Satisfies FCC MPE
4. Between Main Reflector and feed	S_{sr}	11697	Potential Hazard
9. Main Reflector	$S_{surface}$	3.3	Potential Hazard
10. Between Main Reflector and Ground	S_g	0.206	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 harmful levels of radiation will not exist in regions normally occupied by the public or the earth station's operating personnel. Because of the elevation angle of the antenna in transmitting in the domestic satellite arc the lower edge of the antenna will be at least 1 meter above the ground. Antenna geometry will make the transition region well out of reach of the general public or earth station personnel. The antenna is also located on a hill above the surrounding area and is in a fenced area preventing access from the general public to any of the potential hazard regions.

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.