Analysis of Non-Ionizing Radiation for a 4.0-Meter Inflatable Earth Station Antenna System

This report analyzes the non-ionizing radiation levels for a 4.0-meter inflatable 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 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 reflector surface, at the reflector surface, between the antenna edge and the ground, and off-axis in the near-field, 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)	Averaging Time (minutes)
30 - 300	0.2	30
300 - 1500	Frequency [MHz] / 1500	30
1500 - 100000	1.0	30

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

Frequency Range (MHz)	Power Density (mW/cm²)	Averaging Time (minutes)
30 - 300	1.0	6
300 - 1500	Frequency [MHz] / 300	6
1500 - 100000	5.0	6

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

Parameter	Symbol	Formula	Value	Units
Antenna Diameter	D	Input	4.0	m
Antenna Surface Area	$A_{surface}$	$\pi \cdot D^2/4$	12.566	m²
Feed Flange Diameter	D_{fa}	Input	6.5	cm
Area of Feed Flange	A_{fa}	$\pi \cdot {D_{fa}}^2/4$	33.183	cm²
Frequency	F	Input	14250	MHz
Wavelength	λ	c/F	0.02104	m
Transmit Power	P	Input	100	Watts
Antenna Gain (dBi)	G_{es}	Input	53.6	dBi
Antenna Gain (factor)	G	$10^{G_{es}/10}$	$2.291 \cdot 10^5$	-
Antenna Efficiency	η	$G \cdot \lambda^2/(\pi^2 \cdot D^2)$	0.64208	-
Pi	π	Constant	3.14159265	-
Speed of Light	c	Constant	$2.9979 \cdot 10^8$	m/s

1. Far Field Calculation

The distance to the beginning of the Far Field can be determined from the following equation:

Distance to the Far Field Region $$R_{ff} = \frac{0.60 \cdot D^2}{\lambda} = 456.316 \text{ m} \quad (1)$$

The maximum main beam power density in the Far Field can be determined from the following equation:

On-Axis Far Field Power Density $$S_{ff} = \frac{G \cdot P}{4 \cdot \pi \cdot R_{ff}^2} = 8.755 \frac{W}{m^2} = 0.876 \frac{mW}{cm^2} \quad (2)$$

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 $$R_{nf} = \frac{D^2}{4 \cdot \lambda} = 190.132 \text{ m} \quad (3)$$

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

On-Axis Near Field Power Density $$S_{nf} = \frac{16.0 \cdot \eta \cdot P}{\pi \cdot D^2} = 20.438 \frac{W}{m^2} = 2.044 \frac{mW}{cm^2} \quad (4)$$

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:

Transition Region Power Density $$S_t = \frac{S_{nf} \cdot R_{nf}}{R_t} = 2.044 \frac{mW}{cm^2} \quad (5)$$

4. Region between the Feed Assembly and the Antenna Reflector

Transmissions from the feed assembly are directed toward the antenna reflector surface, and are confined within a conical shape defined by the type of feed assembly. The energy between the feed assembly and reflector surface can be calculated by determining the power density at the feed assembly surface. This can be determined form the following equation:

Power Density at the Feed Flange $$S_{fa} = \frac{4000 \cdot P}{A_{fa}} = 12054 \ \frac{mW}{cm^2} \quad (6)$$

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 $$S_{surface} = \frac{4 \cdot P}{A_{surface}} = 3.183 \ \frac{mW}{cm^2} \quad (7)$$

6. Region between the 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 $$S_g = \frac{P}{A_{surface}} = 0.796 \ \frac{mW}{cm^2} \quad (8)$$

7. Near Field Off-Axis Calculation

For off-axis calculations in the near-field and in the transition region, it can be assumed that, at distances of at least one diameter removed from the center of the main beam, the power density will be a least 20 dB less than the value calculated for the equivalent distance in the main beam. Therefore, for off-axis regions at least 4 meters away from the center of the main beam, the power density can be determined from the following equation:

Off-Axis Near Field Power Density $$S_{nf-offa} = S_{nf} - 20dB = 0.02044 \ \frac{mW}{cm^2} \quad (9)$$

8. 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 ($R_t \geq R_{ff} = 456.316$ m)	S_{ff}	0.876	Satisfies FCC MPE
2. Near Field ($R_t \leq R_{nf} = 190.132$ m)	S_{nf}	2.044	Potential Hazard
3. Transition Region ($R_{nf} < R_t < R_{ff}$)	S_t	2.044	Potential Hazard
4. Between Feed Assembly and Antenna Reflector	S_{fa}	12054.340	Potential Hazard
5. Main Reflector	$S_{surface}$	3.183	Potential Hazard
6. Between Reflector and Ground	S_g	0.796	Satisfies FCC MPE
7. Off-Axis Near Field	$S_{nf-offa}$	0.020	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
1. Far Field ($R_t \geq R_{ff} = 456.316$ m)	S_{ff}	0.876	Satisfies FCC MPE
2. Near Field ($R_t \leq R_{nf} = 190.132$ m)	S_{nf}	2.044	Satisfies FCC MPE
3. Transition Region ($R_{nf} < R_t < R_{ff}$)	S_t	2.044	Satisfies FCC MPE
4. Between Feed Assembly and Antenna Reflector	S_{fa}	12054.340	Potential Hazard
5. Main Reflector	$S_{surface}$	3.183	Satisfies FCC MPE
6. Between Reflector and Ground	S_g	0.796	Satisfies FCC MPE
7. Off-Axis Near Field	$S_{nf-offa}$	0.020	Satisfies FCC MPE

9. Conclusions

Based upon the above analysis, it is concluded that FCC RF Guidelines have been exceeded in the specified region(s) of Table 4 and Table 5. The applicant proposes to comply with the MPE limits by one or more of the following methods.

The applicant will ensure that the main beam of the antenna will be pointed at least one diameter (4 meters) away from any buildings or other obstacles in those areas that exceed the MPE levels. The area around the antenna equal to one diameter removed from the main beam will be secured off, and public access will be denied. This distance satisfies the FCC MPE for both Controlled and Uncontrolled Environments. In addition, radiation hazard decals attached to the antenna radome will further indicate to the general public the potential hazard associated closer to the antenna.

All operating personnel will be trained and made aware of the human exposure levels at and around the earth station. Specifically, concerning Region 4: due to the Antenna Reflector being confined to a radome on which the Feed Assembly rests, the region between the Feed Assembly and Antenna Reflector is only physically accessible between the Feed Assembly and radome surface, a gap of less than 3 inches. At a worst-case antenna elevation angle of 5°, the Feed Assembly will be approximately 7 feet above the ground. This confines the potential hazard to a very small area and only reachable in a limited number of circumstances. Furthermore, the earth station's operating personnel will not require access to this area while the earth station is in operation, and the transmitter will be turned off during any antenna maintenance.

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 the antenna does not create potential exposure of humans to radiofrequency radiation in excess of the FCC exposure limits defined in 47 CFR §§1.1307(b) and 1.1310 wherever such exposures might occur. Measures must be taken to ensure compliance with limits for both occupational/controlled exposure and for general population/uncontrolled exposure, as defined in these rule sections. Compliance can be accomplished in most cases by appropriate restrictions such as fencing. Requirements for restrictions can be determined by predictions based on calculations, modeling or by field measurements. The FCC's OET Bulletin 65 (available on-line at www.fcc.gov/oet/rfsafety) provides information on predicting exposure levels and on methods for ensuring compliance, including the use of warning and alerting signs and protective equipment for workers.*