Analysis of Non-Ionizing Radiation for a 3.14-Meter Earth Station System

This report analyzes the non-ionizing radiation levels for a 3.14-meter earth station system. The analysis and calculations performed in this report comply with the methods described in the Federal Communications Commission ("FCC") Office of Engineering and Technology Bulletin No. 65 ("Bulletin No. 65"), which was 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 Report and Order ("R&O") 96-326. Bulletin No. 65 and the FCC R&O (collectively "FCC RF Guidelines") 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, 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)	Determined Limit (mW/cm^2)
300-1500	Frequency (MHz)*(0.8/1200)	.3

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

Frequency Range (MHz)	Power Density (mW/cm^2)	Determined Limit (mW/cm^2)
300-1500	Frequency (MHz)*(4/1200)	1.5

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

Parameter	Symbol	Formula	Value	Units
Antenna Diameter	D	Input	3.14	m
Ant Equiv Surface Area	$A_{surface}$	13 elements	2.6*	m^2
Frequency	F	Input	399.96	MHz
Wavelength	λ	300 / F	0.75	m
Transmit Power	P	Input	.07	w
Antenna Gain (dBi)	G_{es}	Input	16.8	dBi
Antenna Gain (factor)	G	$10^{G_{es}/10}$	47.86	N/A
Pi	π	Constant	3.1415927	N/A
Antenna Efficiency	η	$(G*\lambda^2/(4*\pi))/A_{surface}$	0.74	N/A

* For a Yagi Antenna with 13 elements the surface area of each element is estimated to be 0.2 m^2. Total surface area is 2.6 m^2 .

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	$R_{ff} = 0.60\ D^2 / \lambda$ = 7.94 m	(1)

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	$S_{ff} = G\,P / (4\ \pi\ R_{ff}^2)$ $= .004\ W/m^2$ $= .0004\ mW/cm^2$	(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	$R_{nf} = D^2 / (4\ \lambda)$ $= 3.31\ m$	(3)

Based on FCC feedback, "For a Yagi antenna, unless more precise evaluation is known for their specific antenna design, and if a conservative approximation is sufficient, then we'd generally recommend using one of formulas (3)-(9) from OET Bulletin 65 (1997). These equations are generally accurate in an antenna's far field and when reflections either are insignificant or can be appropriately accounted for by simple modifications to the equation. For antennas that are not electrically short, these far-field equations will overestimate power density in the near field, and in that case the equations may be used regardless of separation distance to provide a conservative estimate.

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

Near Field Power Density	$S_{ff} = G\,P / (4\ \pi\ R_{nf}^2)$ $= .02\ W/m^2$ $= .002\ mW/cm^2$	(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 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_{tz} can be determined from the following equation:

Transition Region Power Density	$R_{tz} = S_{nf} * R_{nf} / R$ $= .014\ W/m^2$ $= .0014\ mW/cm^2$	

R above is given at a halfway point between the edge of the near field, and the beginning of the far field, but can be any value between R_{nf} and R_{ff} .

4. Region between the Antenna and the Ground

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

Power Density between Antenna and Ground	$S_g = P / A_{surface}$ $= .009\ W/m^2$ $= .0009 mW/cm^2$	(6)

5. 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}=7.94m)	S_{ff}	.0004	Satisfies FCC MPE
Near Field (R_{nf}=3.31m)	S_{nf}	.002	Satisfies FCC MPE
Transition Region ($R_{nf}<R_t<R_{ff}$)	S_t	.0014	Satisfies FCC MPE
Between Antenna and Ground	S_g	.0009	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**
Far Field (R_{ff}=7.94m)	S_{ff}	.0004	Satisfies FCC MPE
Near Field (R_{nf}=3.31m)	S_{nf}	.002	Satisfies FCC MPE
Transition Region (R_{nf}<R_t<R_{ff})	S_t	.0014	Satisfies FCC MPE
Between Antenna and Ground	S_g	.0009	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.

6. Exposure Summary

Based upon the above analysis, it is concluded that FCC RF Guidelines have not been exceeded in a worst case scenario approach of the near field phase of the Uncontrolled (Table 4) environment. In the Controlled (Table 5) environments, all regions comply with the FCC RF Guidelines.

7. Site Description and Mitigation

The site of installation for this system is a private rooftop located outside the downtown area of a small city. The closest occupied structure is outside of the far field boundary. Further, the earth station Yagi antenna will be mounted on a platform 12+ meters above ground, so the average person, standing around 2 meters shall still be outside the near field of this antenna's transmissions even when standing just under the system, and out of its near field. **The access controlled environment more than encompass the distance of the near and far fields in both the controlled and uncontrolled calculations above.** Non-assigned worker personnel and the general public must be accompanied by knowledgeable earth station personnel when they enter the earth station secured area.

Based on existing conditions of the site, the earth station will comply with category 2 of 47 CFR 1.1307(b)(4):

"(iii) Category Two—NOTICE: Mitigation actions are required in the form of signs and positive access control surrounding the boundary where the continuous exposure limit is exceeded for the general population, with the appropriate signal word "NOTICE" and associated color (blue) on the signs. Signs must contain the components discussed in paragraph (b)(4)(vi) of this section. Under certain controlled conditions, such as on a rooftop with limited access, a sign attached directly to the surface of an antenna will be considered sufficient if the sign specifies a minimum approach distance and is readable at this separation distance and at locations required for compliance with the general population exposure limit in § 1.1310 of this part. Appropriate training is required for any occupational personnel with access to controlled areas within restrictive barriers where the general population exposure limit is exceeded, and transient individuals must be supervised by trained occupational personnel upon entering any of these areas. Use of time averaging is required for transient individuals to ensure compliance with the general population exposure limit."

In conclusion, this antenna should pose no risk to the general public or those with access to the controlled environment that houses it who may have to work in its vicinity.