ANALYSIS OF NON-IONIZING RADIATION FOR A 5.5 METER EARTH STATION

This report analyzes the non-ionizing radiation levels for a 5.5 meter earth station. The Office of Engineering and Technology Bulletin, No. 65, Edition 97-01, specifies that there are two separate tiers of exposure limits that are dependent on the situation in which exposure takes place and/or the status of the individuals who are subject to the exposure. The Maximum Permissible Exposure (MPE) limit for persons in a Uncontrolled/Public environment to non-ionizing radiation over a thirty minute period is a power density equal to 1 mW/cm**2 (one milliwatts per centimeter squared). The Maximum Permissible Exposure (MPE) limit for persons in a Controlled/Occupational environment to non-ionizing radiation over a six minute period is a power density equal to 5 mW/cm**2 (five milliwatts per centimeter squared). It is the purpose of this report to determine the power flux densities of the earth station in the far field, near field, transition region, between the subreflector and main reflector surface, at the main reflector surface, and between the antenna edge and the ground.

The following parameters were used to calculate the various power flux densities for this earth station:

Antenna Diameter, (D)	= 5.5 meters		
Antenna surface area, (Sa)	= pi (D**2) / 4	= 23.76	m**2
Subreflector Diameter, (Ds)	= 88.9 cm		
Area of Subreflector, (As)	= pi (Ds**2)/ 4	= 6207.17	cm**2
Wavelength at 14.2500 GHz, (lambda)		= 0.021	meters
Transmit Power at Flange, (P)	= 100.00 Watts		
Antenna Gain, (Ges)	Antenna Gain at 14.2500 GHz Converted to a Power Ratio Given By: AntiLog (56.2 / 10)	= 4.169E+05 = 56.2	dBi
pi, (pi)	= 3.1415927		
Antenna aperture efficiency, (n)	= 0.55		

1. Far Field Calculations

The distance to the beginning of the far field region can be found by the following equation: (1)

Distance to the Far Field Region, (Rf) = 0.60(D**2) / lambda

= 862.1 m

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(1) Federal Communications Commission, Office of Engineering & Technology, Bulletin No. 65, pp. 17 & 18.

The maximum main beam power density in the far field can be calculated as follows: (1)

On-Axis Power Density in the Far Field, (Wf) = $\frac{(GES)\ (P)}{4(pi)(Rf^{**}2)}$

= 4.46 W/m**2

= 0.45 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 region. The region is contained within a cylindrical volume having the same diameter as the antenna. Past the extent of the near field region the power density decreases with distance from the transmitting antenna.

The distance to the end of the near field can be determined by the following equation: (1)

Extent of near field, (Rn) = D**2 / 4(lambda) = 359.22 m

The maximum power density in the near field is determined by: (1)

Near field Power Density, (Wn) = $\frac{16.0(n)P}{pi(D^{**}2)}$ mW/cm**2

= 9.26 W/m**2

= 0.93 mW/cm**2

3. Transition Region Calculations

The transition region is located between the near and far field regions. As stated above, the power density begins to decrease with 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 in the near field region, as shown above, will not exceed 0.93 mW/cm**2.

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4. Region Between Main Reflector and Subreflector

Transmissions from the feed horn are directed toward the subreflector surface, and are reflected back toward the main reflector. The energy between the subreflector and reflector surfaces can be calculated by determining the power density at the subreflector surface. This can be accomplished as follows:

Power Density at Subreflector, (Ws) = 4(P) / As

= 64.44 mW/cm**2

5. Main Reflector Region

The power density in the main reflector region is determined in the same manner as the power density at the subreflector, above, but the area is now the area of the main reflector aperture:

Power Density at Main Reflector Surface, (Wm) = (4(P) / Sa)

= 16.84 W/m**2

= 1.68 mW/cm**2

6. Region between Main Reflector and Ground

Assuming uniform illumination of the reflector surface, the power density between the antenna and ground can be calculated as follows:

Power density between Reflector and Ground, (Wg) = (P / Sa)

= 0.42 mW/cm**2

Table 1

Summary of Expected Radiation Levels

Based on (5 mW/cm**2) MPE for Controlled Environment

Region		Calculated Maximum Radiation Level (mW/cm**2)	Hazard Assessment
1. Far Field, (Rf)=	862.1 m	0.45	SATISFIES ANSI
2. Near Field, (Rn)=	359.22 m	0.93	SATISFIES ANSI
3. Transition Region, (Rt) Rn < Rt < Rf		0.93	SATISFIES ANSI
4. Between Main Reflector and subreflector		64.44	POTENTIAL HAZARD
5. Reflector Surface		1.68	SATISFIES ANSI
6. Between Antenna and Ground		0.42	SATISFIES ANSI

It is the applicants responsibility to ensure that the public and operational personnel are not exposed to harmful levels of radiation.

Table 2

Summary of Expected Radiation Levels

Based on (1 mW/cm**2) MPE for Uncontrolled Environment

Region	Calculated Maximum Radiation Level (mW/cm**2)	Hazard Assessment
1. Far Field, (Rf)= 862.1 m	0.45	SATISFIES ANSI
2. Near Field, (Rn)= 359.22 m	0.93	SATISFIES ANSI
3. Transition Region, (Rt) Rn < Rt < Rf	0.93	SATISFIES ANSI
4. Between Main Reflector and subreflector	64.44	POTENTIAL HAZARD
5. Reflector Surface	1.68	POTENTIAL HAZARD
6. Between Antenna and Ground	0.42	SATISFIES ANSI

It is the applicants responsibility to ensure that the public and operational personnel are not exposed to harmful levels of radiation.

7. Conclusions

Based on the above analysis it is concluded that the FCC RF Guidelines have been exceeded in the specified region(s) of Tables 1 and 2. The applicant proposes to comply with the Maximum Permissible Exposure (MPE) limits of 1 mW/cm2 for the Uncontrolled areas and the MPE limits of 5 mW/cm2 for the Controlled areas by one or more of the following methods:

Means of Compliance Uncontrolled Areas

_X_ Restrict Access: _X_ Fencing, _X_ Posting, ___ Secure Rooftop.

___ Remote Location: ___ Warning signs posted around area with minimal chance of public exposure.

___ Antenna Modifications: ___ Elevation of antenna on rooftop installations, ___ Shielding around antenna.

Means of Compliance Controlled Areas

_X_ Restrict Access: _X_ Fencing, _X_ Posting, ___ Secure Rooftop.

___ Time Averaging: ___ Limit time individuals have in areas where MPE is exceeded.

_X_ Transmitter Shut Off/Reduction: Transmitter power reduced or turned off.

___ Protective Clothing ___ Detection Device

Analysis of Non-Ionizing Radiation for a Satcom 6.4-Meter Earth Station System

This report analyzes the non-ionizing radiation levels for a 6.4-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	6.4	m
Antenna Surface Area	$A_{surface}$	$\pi D^2 / 4$	32.17	m^2
Subreflector Diameter	D_{sr}	Input	47.3	cm
Area of Subreflector	A_{sr}	$\pi D_{sr}{}^2/4$	1757.16	cm^2
Frequency	F	Input	14250	MHz
Wavelength	λ	$300 / F$	0.021053	m
Transmit Power	P	Input	225.00	W
Antenna Gain (dBi)	G_{es}	Input	57.4	dBi
Antenna Gain (factor)	G	$10^{Ges/10}$	549540.9	n/a
Pi	π	Constant	3.1415927	n/a
Antenna Efficiency	η	$G\lambda^2/(\pi^2 D^2)$	0.60	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)
$= 1167.4$ 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)
$= 7.220$ W/m^2
$= 0.722$ 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)
$= 486.4$ 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)
$= 16.856$ W/m^2
$= 1.686$ 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 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 $S_t = S_{nf}\ R_{nf} / R_t$ (5)
$= 1.686$ mW/cm^2

4. Region between the Main Reflector and the Subreflector

Transmissions from the feed assembly are directed toward the subreflector surface, and are reflected back toward the main reflector. The most common feed assemblies are waveguide flanges, horns or subreflectors. The energy between the subreflector and the reflector surfaces can be calculated by determining the power density at the subreflector surface. This can be determined from the following equation:

Power Density at the Subreflector $S_{sr} = 4000\ P / A_{sr}$ (6)
$= 512.189\ mW/cm^2$

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)
$= 27.976\ W/m^2$
$= 2.798\ mW/cm^2$

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)
$= 6.994\ W/m^2$
$= 0.699\ mW/cm^2$

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} = 1167.4 m)	S_{ff}	0.722	Satisfies FCC MPE
2. Near Field (R_{nf} = 486.4 m)	S_{nf}	1.686	Potential Hazard
3. Transition Region ($R_{nf} < R_t < R_{ff}$)	S_t	1.686	Potential Hazard
4. Between Main Reflector and Subreflector	S_{sr}	512.189	Potential Hazard
5. Main Reflector	$S_{surface}$	2.798	Potential Hazard
6. Between Main Reflector and Ground	S_g	0.699	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_{ff} = 1167.4 m)	S_{ff}	0.722	Satisfies FCC MPE
2. Near Field (R_{nf} = 486.4 m)	S_{nf}	1.686	Satisfies FCC MPE
3. Transition Region ($R_{nf} < R_t < R_{ff}$)	S_t	1.686	Satisfies FCC MPE
4. Between Main Reflector and Subreflector	S_{sr}	512.189	Potential Hazard
5. Main Reflector	$S_{surface}$	2.798	Satisfies FCC MPE
6. Between Main Reflector and Ground	S_g	0.699	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 the FCC MPE guidelines have been exceeded (or met) in the regions of Table 4 and 5. The applicant proposes to comply with the MPE limits by one or more of the following methods.

Means of Compliance Uncontrolled Areas

This antenna will be located in a fenced area. The fenced area will be sufficient to prohibit the general public from having access the areas that exceed the MPE limits

Since one diameter removed from the main beam of the antenna or ½ diameter removed from the edge of the antenna the RF levels are reduced by a factor of 100 or 20 dB. None of the areas exceeding the MPE levels will be accessible by the general public.

Radiation hazard signs will be posted while this earth station is in operation.

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.