Analysis of Non-Ionizing Radiation for a 0.8-Meter Earth Station System

This report analyzes the non-ionizing radiation levels for a 0.8-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	0.8	m
Antenna Surface Area	$A_{surface}$	$\pi D^2 / 4$	0.44	m^2
Feed Flange Diameter	D_{fa}	Input	8.1	cm
Area of Feed Flange	A_{fa}	$\pi D_{fa}{}^2/4$	51.53	cm^2
Frequency	F	Input	14250	MHz
Wavelength	λ	300 / F	0.021053	m
Transmit Power	P	Input	11.20	W
Antenna Gain (dBi)	G_{es}	Input	39.0	dBi
Antenna Gain (factor)	G	$10^{Ges/10}$	7943.3	n/a
Pi	π	Constant	3.1415927	n/a
Antenna Efficiency	η	$G\lambda^2/(\pi^2 D^2)$	0.63	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)
$= 16.0$ 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)
$= 27.547\ W/m^2$
$= 2.755\ mW/cm^2$

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)
$= 6.7$ 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)
$= 64.307\ W/m^2$
$= 6.431\ mW/cm^2$

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)
$= 6.431\ mW/cm^2$

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 most common feed assemblies are waveguide flanges, horns or subreflectors. 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 from the following equation:

Power Density at the Feed Flange $S_{fa} = 4000\ P / A_{fa}$ (6)
$= 869.397\ mW/cm^2$

5. Main Reflector Region

The power density in the main reflector is determined in the same manner as the power density at the 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 $S_{surface} = 4\ P / A_{surface}$ (7)
$= 101.406\ W/m^2$
$= 10.141\ mW/cm^2$

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 $S_g = P / A_{surface}$ (8)
$= 25.352\ W/m^2$
$= 2.535\ mW/cm^2$

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} = 16.0 m)	S_{ff}	2.755	Potential Hazard
2. Near Field (R_{nf} = 6.7 m)	S_{nf}	6.431	Potential Hazard
3. Transition Region ($R_{nf} < R_t < R_{ff}$)	S_t	6.431	Potential Hazard
4. Between Feed Assembly and Antenna Reflector	S_{fa}	869.397	Potential Hazard
5. Main Reflector	$S_{surface}$	10.141	Potential Hazard
6. Between Reflector and Ground	S_g	2.535	Potential Hazard

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} = 16.0 m)	S_{ff}	2.755	Satisfies FCC MPE
2. Near Field (R_{nf} = 6.7 m)	S_{nf}	6.431	Potential Hazard
3. Transition Region ($R_{nf} < R_t < R_{ff}$)	S_t	6.431	Potential Hazard
4. Between Feed Assembly and Antenna Reflector	S_{fa}	869.397	Potential Hazard
5. Main Reflector	$S_{surface}$	10.141	Potential Hazard
6. Between Reflector and Ground	S_g	2.535	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 upon the above analysis, it is concluded that FCC RF Guidelines may have been exceeded in the specified region(s) of the Uncontrolled and Controlled Environments (Tables 4 and 5). The applicant proposes to comply with the Maximum Permissible Exposure (MPE) limits of 1.0 mW/cm**2 for the Uncontrolled Areas.

The area around the antenna, equal to one diameter removed from the main beam will be roped off, and public access will be denied. This restricted area will be at least 5 feet around the antenna, and radiation hazard signs will be posted during the operation of this earth station. Since one diameter removed from the center of the main beam the levels are down at least 20 dB, or by a factor of 100, these potential hazards do not exist for either the public, or for earth station personnel.

The applicant will ensure that the main beam of the antenna will be pointed at least one diameter away from any buildings or other obstacles in those areas that exceed the MPE levels.

Finally, the earth station's operating personnel will not have access to areas that exceed the MPE levels, while the earth station is in operation, and the transmitter(s) will be turned off during any antenna maintenance.

Analysis of Non-Ionizing Radiation for a 0.9-Meter Earth Station System

This report analyzes the non-ionizing radiation levels for a 0.9-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	0.9	m
Antenna Surface Area	$A_{surface}$	$\pi D^2 / 4$	0.64	m^2
Feed Flange Diameter	D_{fa}	Input	8.1	cm
Area of Feed Flange	A_{fa}	$\pi D_{fa}{}^2/4$	51.53	cm^2
Frequency	F	Input	14250	MHz
Wavelength	λ	$300 / F$	0.021053	m
Transmit Power	P	Input	11.20	W
Antenna Gain (dBi)	G_{es}	Input	40.1	dBi
Antenna Gain (factor)	G	$10^{Ges/10}$	10232.9	n/a
Pi	π	Constant	3.1415927	n/a
Antenna Efficiency	η	$G\lambda^2/(\pi^2 D^2)$	0.57	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)
$= 23.1$ 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)
$= 17.114\ W/m^2$
$= 1.711\ mW/cm^2$

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)
$= 9.6$ 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)
$= 39.951\ W/m^2$
$= 3.995\ mW/cm^2$

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)
$= 3.995\ mW/cm^2$

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 most common feed assemblies are waveguide flanges, horns or subreflectors. 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 from the following equation:

Power Density at the Feed Flange	$S_{fa} = 4000\ P / A_{fa}$ $= 869.397\ mW/cm^2$	(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	$S_{surface} = 4\ P / A_{surface}$ $= 70.421\ W/m^2$ $= 7.042\ mW/cm^2$	(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	$S_g = P / A_{surface}$ $= 17.605\ W/m^2$ $= 1.761\ mW/cm^2$	(8)

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} = 23.1 m)	S_{ff}	1.711	Potential Hazard
2. Near Field (R_{nf} = 9.6 m)	S_{nf}	3.995	Potential Hazard
3. Transition Region ($R_{nf} < R_t < R_{ff}$)	S_t	3.995	Potential Hazard
4. Between Feed Assembly and Antenna Reflector	S_{fa}	869.397	Potential Hazard
5. Main Reflector	$S_{surface}$	7.042	Potential Hazard
6. Between Reflector and Ground	S_g	1.761	Potential Hazard

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} = 23.1 m)	S_{ff}	1.711	Satisfies FCC MPE
2. Near Field (R_{nf} = 9.6 m)	S_{nf}	3.995	Satisfies FCC MPE
3. Transition Region ($R_{nf} < R_t < R_{ff}$)	S_t	3.995	Satisfies FCC MPE
4. Between Feed Assembly and Antenna Reflector	S_{fa}	869.397	Potential Hazard
5. Main Reflector	$S_{surface}$	7.042	Potential Hazard
6. Between Reflector and Ground	S_g	1.761	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 upon the above analysis, it is concluded that FCC RF Guidelines may have been exceeded in the specified region(s) of the Uncontrolled and Controlled Environments (Tables 4 and 5). The applicant proposes to comply with the Maximum Permissible Exposure (MPE) limits of 1.0 mW/cm**2 for the Uncontrolled Areas.

The area around the antenna, equal to one diameter removed from the main beam will be roped off, and public access will be denied. This restricted area will be at least 5 feet around the antenna, and radiation hazard signs will be posted during the operation of this earth station. Since one diameter removed from the center of the main beam the levels are down at least 20 dB, or by a factor of 100, these potential hazards do not exist for either the public, or for earth station personnel.

The applicant will ensure that the main beam of the antenna will be pointed at least one diameter away from any buildings or other obstacles in those areas that exceed the MPE levels.

Finally, the earth station's operating personnel will not have access to areas that exceed the MPE levels, while the earth station is in operation, and the transmitter(s) will be turned off during any antenna maintenance.

Analysis of Non-Ionizing Radiation for a 1.0-Meter Earth Station System

This report analyzes the non-ionizing radiation levels for a 1.0-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	1.0	m
Antenna Surface Area	$A_{surface}$	$\pi D^2 / 4$	0.72	m^2
Feed Flange Diameter	D_{fa}	Input	8.1	cm
Area of Feed Flange	A_{fa}	$\pi D_{fa}{}^2/4$	51.53	cm^2
Frequency	F	Input	14250	MHz
Wavelength	λ	300 / F	0.021053	m
Transmit Power	P	Input	11.20	W
Antenna Gain (dBi)	G_{es}	Input	41.2	dBi
Antenna Gain (factor)	G	$10^{Ges/10}$	13182.6	n/a
Pi	π	Constant	3.1415927	n/a
Antenna Efficiency	η	$G\lambda^2/(\pi^2 D^2)$	0.64	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)
$= 26.3$ 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)
$= 17.031$ W/m^2
$= 1.703$ 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)
$= 10.9$ 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)
$= 39.757$ W/m^2
$= 3.976$ 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)
$= 3.976$ mW/cm^2

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 most common feed assemblies are waveguide flanges, horns or subreflectors. 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 from the following equation:

Power Density at the Feed Flange $S_{fa} = 4000\ P / A_{fa}$ (6)
$= 869.397\ mW/cm^2$

5. Main Reflector Region

The power density in the main reflector is determined in the same manner as the power density at the 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 $S_{surface} = 4\ P / A_{surface}$ (7)
$= 61.894\ W/m^2$
$= 6.189\ mW/cm^2$

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 $S_g = P / A_{surface}$ (8)
$= 15.473\ W/m^2$
$= 1.547\ mW/cm^2$

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} = 26.3 m)	S_{ff}	1.703	Potential Hazard
2. Near Field (R_{nf} = 10.9 m)	S_{nf}	3.976	Potential Hazard
3. Transition Region ($R_{nf} < R_t < R_{ff}$)	S_t	3.976	Potential Hazard
4. Between Feed Assembly and Antenna Reflector	S_{fa}	869.397	Potential Hazard
5. Main Reflector	$S_{surface}$	6.189	Potential Hazard
6. Between Reflector and Ground	S_g	1.547	Potential Hazard

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} = 26.3 m)	S_{ff}	1.703	Satisfies FCC MPE
2. Near Field (R_{nf} = 10.9 m)	S_{nf}	3.976	Satisfies FCC MPE
3. Transition Region ($R_{nf} < R_t < R_{ff}$)	S_t	3.976	Satisfies FCC MPE
4. Between Feed Assembly and Antenna Reflector	S_{fa}	869.397	Potential Hazard
5. Main Reflector	$S_{surface}$	6.189	Potential Hazard
6. Between Reflector and Ground	S_g	1.547	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 upon the above analysis, it is concluded that FCC RF Guidelines may have been exceeded in the specified region(s) of the Uncontrolled Environment (Table 4). The applicant proposes to comply with the Maximum Permissible Exposure (MPE) limits of 1.0 mW/cm**2 for the Uncontrolled Areas.

The area around the antenna, equal to one diameter removed from the main beam will be roped off, and public access will be denied. This restricted area will be at least 5 feet around the antenna, and radiation hazard signs will be posted during the operation of this earth station. Since one diameter removed from the center of the main beam the levels are down at least 20 dB, or by a factor of 100, these potential hazards do not exist for either the public, or for earth station personnel.

The applicant will ensure that the main beam of the antenna will be pointed at least one diameter away from any buildings or other obstacles in those areas that exceed the MPE levels.

Finally, the earth station's operating personnel will not have access to areas that exceed the MPE levels, while the earth station is in operation, and the transmitter(s) will be turned off during any antenna maintenance.