Analysis of Non-Ionizing Radiation for a 2.4-Meter Earth Station System

Intellian v240MT C with 250W BUC

Document Version 1.0

Doc#2017-RH0724-1-V1_0

Contents

1. Introduction

This report analyzes the non-ionizing radiation levels for a 2.4-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 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, 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)*(1,500)
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)*(300)
1500-100,000	5.0

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

Parameter	Value	Units	Symbol	Formula
Antenna Diameter	2.4	m	D	Input
Antenna Transmit Gain	42.36	dBi	G	Input
Transmit Frequency	6,425	MHz	f	Input
Subreflector Diameter	46.7	cm	d	Input
Power Input to the Antenna	250	Watts	P	Input
Antenna Surface Area	4.5239	m^2	A	$\pi D^2/4$
Area of Subreflector	1712.8666	cm^2	a	$\pi d^2/4$
Antenna Efficiency	0.6604	real	η	$g\lambda^2/(\pi^2 D^2)$
Gain Factor	17218.6857	real	g	10^(G/10)
Wavelength	0.046692607	m	λ	300/f

2. 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 $R_{ff} = 0.60D^2 / \lambda$ (1)
  $= 74.016$ 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 $S_{ff} = gP / (4\pi R_{ff}^2)$ (2)
  $= 6.2529$ mW/cm^2

3. 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)
  $= 30.84$ 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)
  $= 14.5969$ mW/cm^2

4. 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)
  $= 14.5969$ mW/cm^2

5. Region between the Feed Assembly and the Main 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 Subreflector $S_{sr} = 4 P / a$ (6)
  $= 583.8166$ mW/cm^2

6. 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 $S_{surface} = 4\,P / A$ (7)
  $= 22.1049\ \mathrm{mW/cm^2}$

7. 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 $S_g = P / A$ (8)
  $= 5.5262\ \mathrm{mW/m^2}$

8. Summary of Calculations

Table 4. Summary of Expected Radiation levels for Uncontrolled Environment

Region	Calculated Maximum Radiation Power Density Level ($\mathrm{mW/cm^2}$)		Hazard Assessment
1. Far Field (R_{ff} = 74.016 m)	S_{ff}	6.2529	Potential Hazard
2. Near Field (R_{nf} = 30.84 m)	S_{nf}	14.5969	Potential Hazard
3. Transition Region ($R_{nf} < R_t < R_{ff}$)	S_t	14.5969	Potential Hazard
4. Between Feed Assembly and Main Reflector	S_{sr}	583.8166	Potential Hazard
5. Main Reflector	$S_{surface}$	22.1049	Potential Hazard
6. Between Reflector and Ground	S_g	5.5262	Potential Hazard

Table 5. Summary of Expected Radiation levels for Controlled Environment

Region	Calculated Maximum Radiation Power Density Level ($\mathrm{mW/cm^2}$)		Hazard Assessment
1. Far Field (R_{ff} = 74.016 m)	S_{ff}	6.2529	Potential Hazard
2. Near Field (R_{nf} = 30.84 m)	S_{nf}	14.5969	Potential Hazard
3. Transition Region ($R_{nf} < R_t < R_{ff}$)	S_t	14.5969	Potential Hazard
4. Between Feed Assembly and Main Reflector	S_{sr}	583.8166	Potential Hazard
5. Main Reflector	$S_{surface}$	22.1049	Potential Hazard
6. Between Reflector and Ground	S_g	5.5262	Potential Hazard

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

9. Conclusions

Based upon the above analysis, it is concluded that harmful levels of radiation may exist in those regions noted for the Uncontrolled (Table 4) environment.

The earth station will be mounted aboard a ship, and it is recommended that the lower edge of the antenna should be at least 2 meters above the deck. If this is not the case, additional procedures will be instituted to insure the safety of the Public in the vicinity of the antenna.

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. Since one diameter removed from the center of the main beam the levels are down at least 20dB, or by a factor of 100, public safety will be ensured.

The earth station will marked with the standard radiation hazard warnings, as well as the area in the vicinity of the earth station, to inform those in the general population, who may be working, or otherwise present on the roof, and in or near, the main beam of the antenna.

Finally, occupational exposure will be limited, and the transmitter will be turned off during periods of maintenance, so that the MPE standard of 5.0 mw/cm**2 will be complied with for those regions in close proximity to the main reflector, and subreflector, which could be occupied by operating personnel.

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 exposure 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 worker.

Analysis of Non-Ionizing Radiation for a 2.4-Meter Earth Station System

Intellian v240MT Ku with 125W BUC

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Contents

1. Introduction

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

Frequency Range (MHz)	Power Density (mW/ cm^2)
30-300	1.0
300-1500	Frequency (MHz)*(300)
1500-100,000	5.0

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

Parameter	Value	Units	Symbol	Formula
Antenna Diameter	2.4	m	D	Input
Antenna Transmit Gain	48.35	dBi	G	Input
Transmit Frequency	14,500	MHz	f	Input
Feed Flange Diameter	4.94	cm	d	Input
Power Input to the Antenna	125	Watts	P	Input
Antenna Surface Area	4.5239	m^2	A	$\pi D^2/4$
Area of Feed Flange	19.1665	cm^2	a	$\pi d^2/4$
Antenna Efficiency	0.515	real	η	$g\lambda^2/(\pi^2 D^2)$
Gain Factor	68391.1647	real	g	10^(G/10)
Wavelength	0.020689	m	λ	300/f

2. 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 $R_{ff} = 0.60D^2 / \lambda$ (1)
  $= 167.04$ 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 $S_{ff} = gP / (4\pi R_{ff}^2)$ (2)
  $= 2.4381$ mW/cm^2

3. 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)
  $= 69.6$ 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)
  $= 5.6917$ mW/cm^2

4. 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)
  $= 5.6917$ mW/cm^2

5. Region between the Feed Assembly and the Main 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 $S_{fa} = 4 P / a$ (6)
  $= 26087.1308$ mW/cm^2

6. 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 $S_{surface} = 4\ P\ /\ A$ (7)
  $= 11.0524\ mW/cm^2$

7. 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 $S_g = P\ /\ A$ (8)
  $= 2.7631\ mW/m^2$

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_{ff} = 167.04 m)	S_{ff}	2.4381	Potential Hazard
2. Near Field (R_{nf} = 69.6 m)	S_{nf}	5.6917	Potential Hazard
3. Transition Region ($R_{nf} < R_t < R_{ff}$)	S_t	5.6917	Potential Hazard
4. Between Feed Assembly and Main Reflector	S_{fa}	26087.1308	Potential Hazard
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6. Between Reflector and Ground	S_g	2.7631	Potential Hazard

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Region	Calculated Maximum Radiation Power Density Level (mW/cm^2)		Hazard Assessment
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It is the applicant's responsibility to ensure that the public and operational personnel are not exposed to harmful levels of radiation.

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Based upon the above analysis, it is concluded that harmful levels of radiation may exist in those regions noted for the Uncontrolled (Table 4) environment.

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Analysis of Non-Ionizing Radiation for a 2.4-Meter Earth Station System

Intellian v240MT Ka with 40W BUC

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300-1500	Frequency (MHz)*(1,500)
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)*(300)
1500-100,000	5.0

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

Parameter	Value	Units	Symbol	Formula
Antenna Diameter	2.4	m	D	Input
Antenna Transmit Gain	53.46	dBi	G	Input
Transmit Frequency	30,000	MHz	f	Input
Subreflector Diameter	17.8	cm	d	Input
Power Input to the Antenna	40	Watts	P	Input
Antenna Surface Area	4.5239	m^2	A	$\pi D^2/4$
Area of Subreflector	248.8455	cm^2	a	$\pi d^2/4$
Antenna Efficiency	0.3902	real	η	$g\lambda^2/(\pi^2 D^2)$
Gain Factor	221819.642	real	g	10^(G/10)
Wavelength	0.01	m	λ	300/f

2. 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 $R_{ff} = 0.60D^2 / \lambda$ (1)
  $= 345.6$ 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 $S_{ff} = gP / (4\pi R_{ff}^2)$ (2)
  $= 0.5912$ mW/cm^2

3. 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)
  $= 144$ 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)
  $= 1.38$ mW/cm^2

4. 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)
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5. Region between the Feed Assembly and the Main Reflector

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- Power Density at the Subreflector $S_{sr} = 4P / a$ (6)
  $= 642.9692$ mW/cm^2

6. 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 $S_{surface} = 4 P / A$ $= 3.5368 \text{ mW/cm}^2$ (7)

7. 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 $S_g = P / A$ $= 0.8842 \text{ mW/m}^2$ (8)

8. Summary of Calculations

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Region	Calculated Maximum Radiation Power Density Level (mW/cm^2)		Hazard Assessment
1. Far Field (R_{ff} = 345.6 m)	S_{ff}	0.5912	Satisfies FCC MPE
2. Near Field (R_{nf} = 144 m)	S_{nf}	1.38	Potential Hazard
3. Transition Region ($R_{nf} < R_t < R_{ff}$)	S_t	1.38	Potential Hazard
4. Between Feed Assembly and Main Reflector	S_{sr}	642.9692	Potential Hazard
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