RADIATION HAZARD EVALUATION

For

Suman **3.7** **Site Id: Anthem_PWM**

Antenna Id: HUB3_7A

1 Overview

Determining the region around an antenna where radiation hazardous to human health is a consideration of many factors. With a parabolic dish antenna, the region is highly directional and the actual hazardous region is dependent on the antenna elevation angle. The following formulae are used to determine the near and far field regions. These regions are in the main beam of the radiation pattern, which we will assume consists of a conical angle extending +/- 3 degrees from the center axis of the antenna.

The analysis contained herein predicts the radiation levels around the proposed antenna. The calculations contained in this report are in accordance with FCC guidelines as contained in CFR 47 Part 1.1310 and OET Bulletin 65. The maximum level of non-ionizing radiation to which the general public is exposed is defined for controlled and uncontrolled environments as follows:

Environment	Exposure Limit: Power	Exposure Limit: Duration
Controlled - (applicable to system operators and technicians in the service area of the antenna):	**5 mW/cm^2**	**6 Minutes**
Uncontrolled - (applicable to general public in proximity of the antenna):	**1 mW/cm^2**	**30 Minutes**

2.1 Earth Station Technical Parameters - Input Data

1A	Antenna Diameter - Standard Parabola	3.7	meters
1B	Antenna Diameter - Elliptical Reflector		meters
1B1	Major Axis Diameter		meters
1B2	Minor Axis Diameter		meters
2	G = Antenna Isotropic Gain	52.3	dBi
3	h = Nominal Antenna Efficiency	68	Percent
4	Nominal Frequency	14.25	GHz
5	Maximum Transmit Power Amplifier Size	360.00	Watts
6	Number of Carriers	1	each
7	W/G Loss from Transmitter to Feed	0	dB
8	Multicarrier Fixed Backoff	0	dB
9	Desired Object Clearance Height	2	meters

2.2 Earth Station Technical Parameters - Calculated Data

10	A = Antenna Surface Area	10.75	sq meters		
10A	Standard Parabolic Reflector	10.75210086	sq meters		
10B	Elliptical Reflector	0.00	sq meters		
11	D = Effective Antenna Diameter	3.7	meters		
12	Total Transmit Power	360.00	Watts		
13	P = Total Feed Input Power (watts)	360.00	Watts		
14	E = Maximum E/S EIRP - Calculated	77.86	dBW		
15	λ = Wavelength (= c/f in m/GHz)	0.0210	m/GHz		
16	p = Pi	3.14159			
17	R_{nf} = Near Field Limit ($D^2/4\lambda$)	163	meters	535	feet
18	R_{ff} = Far Field Limit (R_{ff}=0.6D2/λ)	390	meters	1280	feet
19	R_{nf} to R_{ff} = Transition Region	163 to 390	meters	535 to 1280	feet

3 Power Density at the Antenna Surface

The power density at the reflector surface is expected to exceed the safe limits. The reflector is not accessible to the public and will not present a hazard. Terminal operators and technicians receive training identifying the area as presenting high exposure levels. Procedures are incorporated requiring that transmitters are not operating when access to the reflector surface is required.

The power density at the antenna reflector surface can be calculated by the expression:

PD_{REFL} = 4P/A = **13.39 mW/cm^2**

Where: P = Total power at the feed, milliwatts

A = Total area of reflector, sq cm

Evaluation:

Controlled Environment (less than 5 mW/cm^2 in 6 minutes): **HAZARD**

Uncontrolled environment (less than 1 mW/cm^2 in 30 minutes): **Mitigation Required**

4 On-Axis Power Density in the Near Field Region

The Radiating Near Field Region for a parabolic, circular reflector, is defined as extending from the reflector to a distance equal to the diameter squared divided by twice the wavelength. This distance is referred to as the Rayleigh distance. In this region the power is nearly all contained within a cylinder of radius 0.5D. As a safety measure the highest possible power density is applied to the whole of this region.

The power density in the Near Field Region of the antenna can be calculated by the expression:

$16*P*h/\pi*D^2$ = **9.11 mW/cm^2**

Where: P = Total power at the feed, milliwatts
h = Nominal antenna efficiency
D = Effective antenna diameter, meters

Evaluation:

Controlled Environment (less than 5 mW/cm^2 in 6 minutes): **HAZARD**

Uncontrolled environment (less than 1 mW/cm^2 in 30 minutes): **Mitigation Required**

5 On-Axis Power Density in the Transition Region

The transition region is located between the Near Field and Far Field regions. The power density begins to vary inversely with distance from the antenna in the transition region. The maximum power density in this region will not exceed the power density calculated for the Near Field region. Once again the power density figures are for the On-Axis and contained with a cylinder extending within +/- 1 degree of beam center. Where the antennas are normally operated at an elevation angle typically greater than 10°, the actual safe distance in front of the antenna may be found in paragraph 10. The formula for the calculation is used to evaluate the power density at any given distance in the transition as expressed below:

The power density in the On-Axis Transition Region can be calculated by the expression:

$PD_t=(PD_{nf})(R_{nf})/R$

Where: PD_{nf} = The Near Field power density, mW/cm^2
R_{nf} = Near Field maximum distance, meters
R = Distance to point of interest

For: 163 < R < 390 meters

Evaluation:

Controlled Environment Safe Operating Distance, meters: **297 meters**

Uncontrolled environment Safe Operating Distance, meters: **1485 meters**

6 On-Axis Power Density in the Far Field Region

The On-Axis power density in the far field region (PD_{ff}) varies inversely with the square of the distance. The calculation is performed below:

The Power Density at the start of the Far Field region can be calculated by the expression:

$E-10\log(4pR^2)$ 15.05 dBW/m^2

$\text{antilog}((E-10\log(4pR^2)/10)/10$ **3.20 mW/cm^2**

Evaluation:

Controlled Environment (less than 5 mW/cm^2 in 6 minutes): **SAFE**

Uncontrolled environment (less than 1 mW/cm^2 in 30 minutes): **Mitigation Required**

7 Off-Axis Power Density Levels at the Far Field Limit and Beyond

In the far field region, the power is distributed in a pattern of sidelobes as a function of the off-axis angle between the antenna center line and the point of interest. Off-axis power density in the far field can be estimated using the antenna radiation patterns prescribed for the antenna in use. Usually this will correspond to the antenna gain pattern envelope defined by the FCC or the ITU, which takes the form of:

$G_{off} = 32 - 25\log(\theta)$

for θ from 1 to 48 degrees; -10 dBi from 48 to 180 degrees
(Applicable for commonly used satellite transmit antennas)

For example: At one (1) degree off axis At the far-field limit, we can calculate the power density as:

$G_{off} = 32 - 25\log(1) = 32 - 0$ dBi = 1585 numeric

$PD_{1\ deg\ off\text{-}axis} = PD_{ff} \times 1585/G$ **0.0299 mW/cm^2**

Evaluation:

Considering that satellite antenna beams are aimed skyward, power density in the far field will usually not be a problem except at low look angles. In these cases, off axis gain reduction techniques may be used to further reduce the power density levels.

8 Off-Axis Power Density Levels at the Near Field and Transitional Regions

According to Bulletin 65, off-axis calculations in the near field may be performed as follows: assuming that the point of interest is at least one antenna diameter removed from the center of the main beam, the power density at that point is at least a factor of 100 (20 dB) less than the value calculated for the near field main beam power density. This may be calculated as follows:

$PD_{nf(off\text{-}axis)} = PD_{nf}/100$ = **0.0911 mW/cm^2**

9 Region Between the Feed Horn and Reflector/Sub-Reflector

Transmissions from the feed horn are directed toward the main reflector or the sub-reflector depending on the type of antenna (prime focus, Gregorian or Cassegrain). The transmission is confined within a conical shape defined by the

feed horn. The energy between the feedhorn and the reflector/sub-reflector is assumed to be in excess of any limit for permissible exposure. This region is not accessible to the general public, and operators and technicians should be suitable trained and procedures in place to preclude access to this region during active transmission.

10 Evaluation of Safe Occupancy Area in Front of the Antenna

The distance (L) from a vertical axis passing through the dish center to a safe off-axis point in front of the antenna can be determined based on the dish diameter. Assuming a flat terrain and a point on the horizontal plane with the center point of the antenna, the relationship is determined by the following formula:

L = (D/sin a) + (2h - D - 2)/(2 tan a)

Where: a = minimum elevation angle of antenna
D = Dish diameter in meters
h = Maximum height of object to be cleared, meters

For distances equal to or greater than determined by the equation above, the radiation hazard will be below safe levels

For: D = 3.7 meters
h= 2 meters

Safe distance for the following elevation angles (a):

a - Elevation Angle (degrees)	L - Safe Distance		
10	16.49	meters	
15	11.12	meters	
20	8.48	meters	
25	6.93	meters	
30	5.93	meters	
40	4.74	meters	
50	4.12	meters	
5.95	27.54	meters	Site Specific

11 Mitigation Analysis

Mitigation of accessibility to hazardous regions may take several forms depending on the antenna application and location. In instances such as mobile applications, the antenna may be located such that the hazardous region is not accessible during operation. An example may be in a mobile configuration where the antenna is located on top of a vehicle during operation. In other fixed installation instances the hazardous area may be fenced off to prevent access. In areas where only operators and technicians have access, training in safeguards and proper markings of hazardous areas may be sufficient. This analysis tool is designed to identify the hazardous exposure regions around an operating antenna system in accordance with the defined power density limits in CFR 47, part 1.1310 and OET bulletin 65.

12 Conclusion

Based upon the above analysis, it is concluded that harmful levles of radiation may exist in those regions noted for both the Controlled and Uncontrolled environment.

The antenna will either be installed on the roof of a buiding, the roof of a vehicle, or on the ground. A ground mounted antenna earth station will be surrounded by a fence, which will restrict any public access. All earth stations will be 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 might be working or otherwise present in or near the direct path of the main beam.

The applicant will ensure the main beam of the antenna will be pointed at least one diameter away from any building, or other obstacles in those areas that exceed the MPE levels. Since one diameter removed from the center of the main beam will lower levels by at least 20 dB, or by a factor of 100, these potential hazards do not exist for eihter the public, or for the earth station personnel.

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. The transmitter will be turned off during periods of maintenance, so that the MPE standard of 5.0 mW/cm² will be complied with for those regions in close proximity to the main reflector, which could be occupied by operating personnel.

RADIATION HAZARD EVALUATION

For

Suman **3.7** **Site Id: Anthem_STL**

Antenna Id: HUB3_7A

1 Overview

Determining the region around an antenna where radiation hazardous to human health is a consideration of many factors. With a parabolic dish antenna, the region is highly directional and the actual hazardous region is dependent on the antenna elevation angle. The following formulae are used to determine the near and far field regions. These regions are in the main beam of the radiation pattern, which we will assume consists of a conical angle extending +/- 3 degrees from the center axis of the antenna.

The analysis contained herein predicts the radiation levels around the proposed antenna. The calculations contained in this report are in accordance with FCC guidelines as contained in CFR 47 Part 1.1310 and OET Bulletin 65. The maximum level of non-ionizing radiation to which the general public is exposed is defined for controlled and uncontrolled environments as follows:

Environment	Exposure Limit Power	Exposure Limit Duration
Controlled - (applicable to system operators and technicians in the service area of the antenna):	**5 mW/cm^2**	**6 Minutes**
Uncontrolled - (applicable to general public in proximity of the antenna):	**1 mW/cm^2**	**30 Minutes**

2.1 Earth Station Technical Parameters - Input Data

1A	Antenna Diameter - Standard Parabola	3.7	meters
1B	Antenna Diameter - Elliptical Reflector		meters
1B1	Major Axis Diameter		meters
1B2	Minor Axis Diameter		meters
2	G = Antenna Isotropic Gain	52.3	dBi
3	h = Nominal Antenna Efficiency	68	Percent
4	Nominal Frequency	14.25	GHz
5	Maximum Transmit Power Amplifier Size	360.00	Watts
6	Number of Carriers	1	each
7	W/G Loss from Transmitter to Feed	0	dB
8	Multicarrier Fixed Backoff	0	dB
9	Desired Object Clearance Height	2	meters

2.2 Earth Station Technical Parameters - Calculated Data

10	A = Antenna Surface Area	10.75	sq meters		
10A	Standard Parabolic Reflector	10.75210086	sq meters		
10B	Elliptical Reflector	0.00	sq meters		
11	D = Effective Antenna Diameter	3.7	meters		
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13	P = Total Feed Input Power (watts)	360.00	Watts		
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15	λ = Wavelength (= c/f in m/GHz)	0.0210	m/GHz		
16	p = Pi	3.14159			
17	R_{nf} = Near Field Limit ($D^2/4\lambda$)	163	meters	535	feet
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The power density at the antenna reflector surface can be calculated by the expression:

PD_{REFL} = 4P/A = **13.39 mW/cm^2**

Where: P = Total power at the feed, milliwatts

A = Total area of reflector, sq cm

Evaluation:

Controlled Environment (less than 5 mW/cm^2 in 6 minutes): **HAZARD**

Uncontrolled environment (less than 1 mW/cm^2 in 30 minutes): **Mitigation Required**

4 On-Axis Power Density in the Near Field Region

The Radiating Near Field Region for a parabolic, circular reflector, is defined as extending from the reflector to a distance equal to the diameter squared divided by twice the wavelength. This distance is referred to as the Rayleigh distance. In this region the power is nearly all contained within a cylinder of radius 0.5D. As a safety measure the highest possible power density is applied to the whole of this region.

The power density in the Near Field Region of the antenna can be calculated by the expression:

$16 \cdot P \cdot h / \pi \cdot D^2$ = **9.11 mW/cm^2**

Where: P = Total power at the feed, milliwatts
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D = Effective antenna diameter, meters

Evaluation:

Controlled Environment (less than 5 mW/cm^2 in 6 minutes):	**HAZARD**
Uncontrolled environment (less than 1 mW/cm^2 in 30 minutes):	**Mitigation Required**

5 On-Axis Power Density in the Transition Region

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The power density in the On-Axis Transition Region can be calculated by the expression:

$PD_t = (PD_{nf})(R_{nf})/R$

Where: PD_{nf} = The Near Field power density, mW/cm^2
R_{nf} = Near Field maximum distance, meters
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For: 163 < R < 390 meters

Evaluation:

Controlled Environment Safe Operating Distance, meters:	**297 meters**
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$\text{antilog}((E-10\log(4pR^2)/10)/10$	**3.20 mW/cm^2**

Evaluation:

Controlled Environment (less than 5 mW/cm^2 in 6 minutes):	**SAFE**
Uncontrolled environment (less than 1 mW/cm^2 in 30 minutes):	**Mitigation Required**

7 Off-Axis Power Density Levels at the Far Field Limit and Beyond

In the far field region, the power is distributed in a pattern of sidelobes as a function of the off-axis angle between the antenna center line and the point of interest. Off-axis power density in the far field can be estimated using the antenna radiation patterns prescribed for the antenna in use. Usually this will correspond to the antenna gain pattern envelope defined by the FCC or the ITU, which takes the form of:

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for θ from 1 to 48 degrees; -10 dBi from 48 to 180 degrees
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For example: At one (1) degree off axis At the far-field limit, we can calculate the power density as:

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$PD_{1\ deg\ off\text{-}axis} = PD_{ff} \times 1585/G$	**0.0299 mW/cm^2**

Evaluation:

Considering that satellite antenna beams are aimed skyward, power density in the far field will usually not be a problem except at low look angles. In these cases, off axis gain reduction techniques may be used to further reduce the power density levels.

8 Off-Axis Power Density Levels at the Near Field and Transitional Regions

According to Bulletin 65, off-axis calculations in the near field may be performed as follows: assuming that the point of interest is at least one antenna diameter removed from the center of the main beam, the power density at that point is at least a factor of 100 (20 dB) less than the value calculated for the near field main beam power density. This may be calculated as follows:

$PD_{nf(off\text{-}axis)} = PD_{nf}/100$ = **0.0911 mW/cm^2**

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feed horn. The energy between the feedhorn and the reflector/sub-reflector is assumed to be in excess of any limit for permissible exposure. This region is not accessible to the general public, and operators and technicians should be suitable trained and procedures in place to preclude access to this region during active transmission.

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The distance (L) from a vertical axis passing through the dish center to a safe off-axis point in front of the antenna can be determined based on the dish diameter. Assuming a flat terrain and a point on the horizontal plane with the center point of the antenna, the relationship is determined by the following formula:

L = (D/sin a) + (2h - D - 2)/(2 tan a)

Where: a = minimum elevation angle of antenna
D = Dish diameter in meters
h = Maximum height of object to be cleared, meters

For distances equal to or greater than determined by the equation above, the radiation hazard will be below safe levels

For: D = 3.7 meters
h= 2 meters

Safe distance for the following elevation angles (a):

a - Elevation Angle (degrees)	L - Safe Distance		
10	16.49	meters	
15	11.12	meters	
20	8.48	meters	
25	6.93	meters	
30	5.93	meters	
40	4.74	meters	
50	4.12	meters	
5.95	27.54	meters	**Site Specific**

11 Mitigation Analysis

Mitigation of accessibility to hazardous regions may take several forms depending on the antenna application and location. In instances such as mobile applications, the antenna may be located such that the hazardous region is not accessible during operation. An example may be in a mobile configuration where the antenna is located on top of a vehicle during operation. In other fixed installation instances the hazardous area may be fenced off to prevent access. In areas where only operators and technicians have access, training in safeguards and proper markings of hazardous areas may be sufficient. This analysis tool is designed to identify the hazardous exposure regions around an operating antenna system in accordance with the defined power density limits in CFR 47, part 1.1310 and OET bulletin 65.

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Based upon the above analysis, it is concluded that harmful levles of radiation may exist in those regions noted for both the Controlled and Uncontrolled environment.

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The applicant will ensure the main beam of the antenna will be pointed at least one diameter away from any building, or other obstacles in those areas that exceed the MPE levels. Since one diameter removed from the center of the main beam will lower levels by at least 20 dB, or by a factor of 100, these potential hazards do not exist for eihter the public, or for the earth station personnel.

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. The transmitter will be turned off during periods of maintenance, so that the MPE standard of 5.0 mW/cm² will be complied with for those regions in close proximity to the main reflector, which could be occupied by operating personnel.

RADIATION HAZARD EVALUATION

For

GD Satcom **4.8** **Site Id: Anthem_SHD**
Antenna Id: HUB4_8A

1 Overview

Determining the region around an antenna where radiation hazardous to human health is a consideration of many factors. With a parabolic dish antenna, the region is highly directional and the actual hazardous region is dependent on the antenna elevation angle. The following formulae are used to determine the near and far field regions. These regions are in the main beam of the radiation pattern, which we will assume consists of a conical angle extending +/- 3 degrees from the center axis of the antenna.

The analysis contained herein predicts the radiation levels around the proposed antenna. The calculations contained in this report are in accordance with FCC guidelines as contained in CFR 47 Part 1.1310 and OET Bulletin 65. The maximum level of non-ionizing radiation to which the general public is exposed is defined for controlled and uncontrolled environments as follows:

Environment	Exposure Limit Power	Exposure Limit Duration
Controlled - (applicable to system operators and technicians in the service area of the antenna):	**5 mW/cm^2**	**6 Minutes**
Uncontrolled - (applicable to general public in proximity of the antenna):	**1 mW/cm^2**	**30 Minutes**

2.1 Earth Station Technical Parameters - Input Data

1A	Antenna Diameter - Standard Parabola	4.8	meters
1B	Antenna Diameter - Elliptical Reflector		meters
1B1	Major Axis Diameter		meters
1B2	Minor Axis Diameter		meters
2	G = Antenna Isotropic Gain	55.2	dBi
3	h = Nominal Antenna Efficiency	68	Percent
4	Nominal Frequency	14.25	GHz
5	Maximum Transmit Power Amplifier Size	360.00	Watts
6	Number of Carriers	1	each
7	W/G Loss from Transmitter to Feed	0	dB
8	Multicarrier Fixed Backoff	0	dB
9	Desired Object Clearance Height	2	meters

2.2 Earth Station Technical Parameters - Calculated Data

10	A = Antenna Surface Area	18.10	sq meters		
10A	Standard Parabolic Reflector	18.09557368	sq meters		
10B	Elliptical Reflector	0.00	sq meters		
11	D = Effective Antenna Diameter	4.8	meters		
12	Total Transmit Power	360.00	Watts		
13	P = Total Feed Input Power (watts)	360.00	Watts		
14	E = Maximum E/S EIRP - Calculated	80.76	dBW		
15	λ = Wavelength (= c/f in m/GHz)	0.0210	m/GHz		
16	p = Pi	3.14159			
17	R_{nf} = Near Field Limit ($D^2/4\lambda$)	274	meters	899	feet
18	R_{ff} = Far Field Limit (R_{ff}=0.6D2/λ)	657	meters	2156	feet
19	R_{nf} to R_{ff} = Transition Region	274 to 657	meters	899 to 2156	feet

3 Power Density at the Antenna Surface

The power density at the reflector surface is expected to exceed the safe limits. The reflector is not accessible to the public and will not present a hazard. Terminal operators and technicians receive training identifying the area as presenting high exposure levels. Procedures are incorporated requiring that transmitters are not operating when access to the reflector surface is required.

The power density at the antenna reflector surface can be calculated by the expression:

PD_{REFL} = 4P/A = **7.96 mW/cm^2**

Where: P = Total power at the feed, milliwatts
A = Total area of reflector, sq cm

Evaluation:

Controlled Environment (less than 5 mW/cm^2 in 6 minutes): **HAZARD**

Uncontrolled environment (less than 1 mW/cm^2 in 30 minutes): **Mitigation Required**

4 On-Axis Power Density in the Near Field Region

The Radiating Near Field Region for a parabolic, circular reflector, is defined as extending from the reflector to a distance equal to the diameter squared divided by twice the wavelength. This distance is referred to as the Rayleigh distance. In this region the power is nearly all contained within a cylinder of radius 0.5D. As a safety measure the highest possible power density is applied to the whole of this region.

The power density in the Near Field Region of the antenna can be calculated by the expression:

$16*P*h/\pi*D^2 =$ **5.41 mW/cm²**

Where: P = Total power at the feed, milliwatts
h = Nominal antenna efficiency
D = Effective antenna diameter, meters

Evaluation:

Controlled Environment (less than 5 mW/cm² in 6 minutes):	**HAZARD**
Uncontrolled environment (less than 1 mW/cm² in 30 minutes):	**Mitigation Required**

5 On-Axis Power Density in the Transition Region

The transition region is located between the Near Field and Far Field regions. The power density begins to vary inversely with distance from the antenna in the transition region. The maximum power density in this region will not exceed the power density calculated for the Near Field region. Once again the power density figures are for the On-Axis and contained with a cylinder extending within +/- 1 degree of beam center. Where the antennas are normally operated at an elevation angle typically greater than 10°, the actual safe distance in front of the antenna may be found in paragraph 10. The formula for the calculation is used to evaluate the power density at any given distance in the transition as expressed below:

The power density in the On-Axis Transition Region can be calculated by the expression:

$PD_t=(PD_{nf})(R_{nf})/R$

Where: PD_{nf} = The Near Field power density, mW/cm²
R_{nf} = Near Field maximum distance, meters
R = Distance to point of interest

For: 274 < R < 657 meters

Evaluation:

Controlled Environment Safe Operating Distance, meters:	**296 meters**
Uncontrolled environment Safe Operating Distance, meters:	**1482 meters**

6 On-Axis Power Density in the Far Field Region

The On-Axis power density in the far field region (PD_{ff}) varies inversely with the square of the distance. The calculation is performed below:

The Power Density at the start of the Far Field region can be calculated by the expression:

$E-10\log(4pR^2)$	13.42 dBW/m²
antilog((E-10log(4pR²)/10)/10	**2.20 mW/cm²**

Evaluation:

Controlled Environment (less than 5 mW/cm² in 6 minutes):	**SAFE**
Uncontrolled environment (less than 1 mW/cm² in 30 minutes):	**Mitigation Required**

7 Off-Axis Power Density Levels at the Far Field Limit and Beyond

In the far field region, the power is distributed in a pattern of sidelobes as a function of the off-axis angle between the antenna center line and the point of interest. Off-axis power density in the far field can be estimated using the antenna radiation patterns prescribed for the antenna in use. Usually this will correspond to the antenna gain pattern envelope defined by the FCC or the ITU, which takes the form of:

$G_{off} = 32 - 25\log(\theta)$

for θ from 1 to 48 degrees; -10 dBi from 48 to 180 degrees
(Applicable for commonly used satellite transmit antennas)

For example: At one (1) degree off axis At the far-field limit, we can calculate the power density as:

$G_{off} = 32 - 25\log(1) = 32 - 0$ dBi =	1585 numeric
$PD_{1\ deg\ off\text{-}axis} = PD_{ff} \times 1585/G$	**0.0105 mW/cm²**

Evaluation:

Considering that satellite antenna beams are aimed skyward, power density in the far field will usually not be a problem except at low look angles. In these cases, off axis gain reduction techniques may be used to further reduce the power density levels.

8 Off-Axis Power Density Levels at the Near Field and Transitional Regions

According to Bulletin 65, off-axis calculations in the near field may be performed as follows: assuming that the point of interest is at least one antenna diameter removed from the center of the main beam, the power density at that point is at least a factor of 100 (20 dB) less than the value calculated for the near field main beam power density. This may be calculated as follows:

$PD_{nf(off\text{-}axis)} = PD_{nf}/100 =$ **0.0541 mW/cm²**

9 Region Between the Feed Horn and Reflector/Sub-Reflector

Transmissions from the feed horn are directed toward the main reflector or the sub-reflector depending on the type of antenna (prime focus, Gregorian or Cassegrain). The transmission is confined within a conical shape defined by the

feed horn. The energy between the feedhorn and the reflector/sub-reflector is assumed to be in excess of any limit for permissible exposure. This region is not accessible to the general public, and operators and technicians should be suitable trained and procedures in place to preclude access to this region during active transmission.

10 Evaluation of Safe Occupancy Area in Front of the Antenna

The distance (L) from a vertical axis passing through the dish center to a safe off-axis point in front of the antenna can be determined based on the dish diameter. Assuming a flat terrain and a point on the horizontal plane with the center point of the antenna, the relationship is determined by the following formula:

L = (D/sin a) + (2h - D - 2)/(2 tan a)

Where: a = minimum elevation angle of antenna

D = Dish diameter in meters

h = Maximum height of object to be cleared, meters

For distances equal to or greater than determined by the equation above, the radiation hazard will be below safe levels

For:		
D =	4.8	meters
h=	2	meters

Safe distance for the following elevation angles (a):

a - Elevation Angle (degrees)	L - Safe Distance		
10	19.70	meters	
15	13.32	meters	
20	10.19	meters	
25	8.36	meters	
30	7.18	meters	
40	5.80	meters	
50	5.09	meters	
6.00	32.60	meters	**Site Specific**

11 Mitigation Analysis

Mitigation of accessibility to hazardous regions may take several forms depending on the antenna application and location. In instances such as mobile applications, the antenna may be located such that the hazardous region is not accessible during operation. An example may be in a mobile configuration where the antenna is located on top of a vehicle during operation. In other fixed installation instances the hazardous area may be fenced off to prevent access. In areas where only operators and technicians have access, training in safeguards and proper markings of hazardous areas may be sufficient. This analysis tool is designed to identify the hazardous exposure regions around an operating antenna system in accordance with the defined power density limits in CFR 47, part 1.1310 and OET bulletin 65.

12 Conclusion

Based upon the above analysis, it is concluded that harmful levles of radiation may exist in those regions noted for both the Controlled and Uncontrolled environment.

The antenna will either be installed on the roof of a buiding, the roof of a vehicle, or on the ground. A ground mounted antenna earth station will be surrounded by a fence, which will restrict any public access. All earth stations will be 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 might be working or otherwise present in or near the direct path of the main beam.

The applicant will ensure the main beam of the antenna will be pointed at least one diameter away from any building, or other obstacles in those areas that exceed the MPE levels. Since one diameter removed from the center of the main beam will lower levels by at least 20 dB, or by a factor of 100, these potential hazards do not exist for eihter the public, or for the earth station personnel.

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. The transmitter will be turned off during periods of maintenance, so that the MPE standard of 5.0 mW/cm² will be complied with for those regions in close proximity to the main reflector, which could be occupied by operating personnel.

RADIATION HAZARD EVALUATION

For

GD Satcom **1.2** **Site Id: Remote**
Antenna Id: REM1_2A

1 Overview

Determining the region around an antenna where radiation hazardous to human health is a consideration of many factors. With a parabolic dish antenna, the region is highly directional and the actual hazardous region is dependent on the antenna elevation angle. The following formulae are used to determine the near and far field regions. These regions are in the main beam of the radiation pattern, which we will assume consists of a conical angle extending +/- 3 degrees from the center axis of the antenna.

The analysis contained herein predicts the radiation levels around the proposed antenna. The calculations contained in this report are in accordance with FCC guidelines as contained in CFR 47 Part 1.1310 and OET Bulletin 65. The maximum level of non-ionizing radiation to which the general public is exposed is defined for controlled and uncontrolled environments as follows:

Environment	Exposure Limit Power	Exposure Limit Duration
Controlled - (applicable to system operators and technicians in the service area of the antenna):	**5 mW/cm^2**	**6 Minutes**
Uncontrolled - (applicable to general public in proximity of the antenna):	**1 mW/cm^2**	**30 Minutes**

2.1 Earth Station Technical Parameters - Input Data

1A	Antenna Diameter - Standard Parabola	1.2	meters
1B	Antenna Diameter - Elliptical Reflector		meters
1B1	Major Axis Diameter		meters
1B2	Minor Axis Diameter		meters
2	G = Antenna Isotropic Gain	43	dBi
3	h = Nominal Antenna Efficiency	68	Percent
4	Nominal Frequency	14.25	GHz
5	Maximum Transmit Power Amplifier Size	100.00	Watts
6	Number of Carriers	1	each
7	W/G Loss from Transmitter to Feed	0	dB
8	Multicarrier Fixed Backoff	0	dB
9	Desired Object Clearance Height	2	meters

2.2 Earth Station Technical Parameters - Calculated Data

10	A = Antenna Surface Area	1.13	sq meters		
10A	Standard Parabolic Reflector	1.130973355	sq meters		
10B	Elliptical Reflector	0.00	sq meters		
11	D = Effective Antenna Diameter	1.2	meters		
12	Total Transmit Power	100.00	Watts		
13	P = Total Feed Input Power (watts)	100.00	Watts		
14	E = Maximum E/S EIRP - Calculated	63.00	dBW		
15	λ = Wavelength (= c/f in m/GHz)	0.0210	m/GHz		
16	p = Pi	3.14159			
17	R_{nf} = Near Field Limit ($D^2/4\lambda$)	17	meters	56	feet
18	R_{ff} = Far Field Limit (R_{ff}=0.6D2/λ)	41	meters	135	feet
19	R_{nf} to R_{ff} = Transition Region	17 to 41	meters	56 to 135	feet

3 Power Density at the Antenna Surface

The power density at the reflector surface is expected to exceed the safe limits. The reflector is not accessible to the public and will not present a hazard. Terminal operators and technicians receive training identifying the area as presenting high exposure levels. Procedures are incorporated requiring that transmitters are not operating when access to the reflector surface is required.

The power density at the antenna reflector surface can be calculated by the expression:

PD_{REFL} = 4P/A = **35.37 mW/cm^2**

Where: P = Total power at the feed, milliwatts
A = Total area of reflector, sq cm

Evaluation:

Controlled Environment (less than 5 mW/cm^2 in 6 minutes): **HAZARD**

Uncontrolled environment (less than 1 mW/cm^2 in 30 minutes): **Mitigation Required**

4 On-Axis Power Density in the Near Field Region

The Radiating Near Field Region for a parabolic, circular reflector, is defined as extending from the reflector to a distance equal to the diameter squared divided by twice the wavelength. This distance is referred to as the Rayleigh distance. In this region the power is nearly all contained within a cylinder of radius 0.5D. As a safety measure the highest possible power density is applied to the whole of this region.

The power density in the Near Field Region of the antenna can be calculated by the expression:

$16*P*h/\pi*D^2 =$ **24.05 mW/cm²**

Where: P = Total power at the feed, milliwatts
h = Nominal antenna efficiency
D = Effective antenna diameter, meters

Evaluation:

Controlled Environment (less than 5 mW/cm² in 6 minutes):	**HAZARD**
Uncontrolled environment (less than 1 mW/cm² in 30 minutes):	**Mitigation Required**

5 On-Axis Power Density in the Transition Region

The transition region is located between the Near Field and Far Field regions. The power density begins to vary inversely with distance from the antenna in the transition region. The maximum power density in this region will not exceed the power density calculated for the Near Field region. Once again the power density figures are for the On-Axis and contained with a cylinder extending within +/- 1 degree of beam center. Where the antennas are normally operated at an elevation angle typically greater than 10°, the actual safe distance in front of the antenna may be found in paragraph 10. The formula for the calculation is used to evaluate the power density at any given distance in the transition as expressed below:

The power density in the On-Axis Transition Region can be calculated by the expression:

$PD_t=(PD_{nf})(R_{nf})/R$

Where: PD_{nf} = The Near Field power density, mW/cm²
R_{nf} = Near Field maximum distance, meters
R = Distance to point of interest

For: 17 < R < 41 meters

Evaluation:

Controlled Environment Safe Operating Distance, meters:	**82 meters**
Uncontrolled environment Safe Operating Distance, meters:	**409 meters**

6 On-Axis Power Density in the Far Field Region

The On-Axis power density in the far field region (PD_{ff}) varies inversely with the square of the distance. The calculation is performed below:

The Power Density at the start of the Far Field region can be calculated by the expression:

$E-10\log(4pR^2)$	19.75 dBW/m²
antilog((E-10log(4pR²)/10)/10	**9.45 mW/cm²**

Evaluation:

Controlled Environment (less than 5 mW/cm² in 6 minutes):	**HAZARD**
Uncontrolled environment (less than 1 mW/cm² in 30 minutes):	**Mitigation Required**

7 Off-Axis Power Density Levels at the Far Field Limit and Beyond

In the far field region, the power is distributed in a pattern of sidelobes as a function of the off-axis angle between the antenna center line and the point of interest. Off-axis power density in the far field can be estimated using the antenna radiation patterns prescribed for the antenna in use. Usually this will correspond to the antenna gain pattern envelope defined by the FCC or the ITU, which takes the form of:

$G_{off} = 32 - 25\log(\theta)$

for θ from 1 to 48 degrees; -10 dBi from 48 to 180 degrees
(Applicable for commonly used satellite transmit antennas)

For example: At one (1) degree off axis At the far-field limit, we can calculate the power density as:

$G_{off} = 32 - 25\log(1) = 32 - 0$ dBi =	1585 numeric
$PD_{1\ deg\ off\text{-}axis} = PD_{ff} \times 1585/G$	**0.7503 mW/cm²**

Evaluation:

Considering that satellite antenna beams are aimed skyward, power density in the far field will usually not be a problem except at low look angles. In these cases, off axis gain reduction techniques may be used to further reduce the power density levels.

8 Off-Axis Power Density Levels at the Near Field and Transitional Regions

According to Bulletin 65, off-axis calculations in the near field may be performed as follows: assuming that the point of interest is at least one antenna diameter removed from the center of the main beam, the power density at that point is at least a factor of 100 (20 dB) less than the value calculated for the near field main beam power density. This may be calculated as follows:

$PD_{nf(off\text{-}axis)} = PD_{nf}/100 =$ **0.2405 mW/cm²**

9 Region Between the Feed Horn and Reflector/Sub-Reflector

Transmissions from the feed horn are directed toward the main reflector or the sub-reflector depending on the type of antenna (prime focus, Gregorian or Cassegrain). The transmission is confined within a conical shape defined by the

feed horn. The energy between the feedhorn and the reflector/sub-reflector is assumed to be in excess of any limit for permissible exposure. This region is not accessible to the general public, and operators and technicians should be suitable trained and procedures in place to preclude access to this region during active transmission.

10 Evaluation of Safe Occupancy Area in Front of the Antenna

The distance (L) from a vertical axis passing through the dish center to a safe off-axis point in front of the antenna can be determined based on the dish diameter. Assuming a flat terrain and a point on the horizontal plane with the center point of the antenna, the relationship is determined by the following formula:

L = (D/sin a) + (2h - D - 2)/(2 tan a)

Where: a = minimum elevation angle of antenna

D = Dish diameter in meters

h = Maximum height of object to be cleared, meters

For distances equal to or greater than determined by the equation above, the radiation hazard will be below safe levels

For: D = 1.2 meters

h= 2 meters

Safe distance for the following elevation angles (a):

a - Elevation Angle (degrees)	L - Safe Distance		
10	**9.18**	**meters**	
15	**6.13**	**meters**	
20	**4.61**	**meters**	
25	**3.70**	**meters**	
30	**3.09**	**meters**	
40	**2.34**	**meters**	
50	**1.90**	**meters**	
5.00	**18.34**	**meters**	**Site Specific**

11 Mitigation Analysis

Mitigation of accessibility to hazardous regions may take several forms depending on the antenna application and location. In instances such as mobile applications, the antenna may be located such that the hazardous region is not accessible during operation. An example may be in a mobile configuration where the antenna is located on top of a vehicle during operation. In other fixed installation instances the hazardous area may be fenced off to prevent access. In areas where only operators and technicians have access, training in safeguards and proper markings of hazardous areas may be sufficient. This analysis tool is designed to identify the hazardous exposure regions around an operating antenna system in accordance with the defined power density limits in CFR 47, part 1.1310 and OET bulletin 65.

12 Conclusion

Based upon the above analysis, it is concluded that harmful levles of radiation may exist in those regions noted for both the Controlled and Uncontrolled environment.

The antenna will either be installed on the roof of a buiding, the roof of a vehicle, or on the ground. A ground mounted antenna earth station will be surrounded by a fence, which will restrict any public access. All earth stations will be 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 might be working or otherwise present in or near the direct path of the main beam.

The applicant will ensure the main beam of the antenna will be pointed at least one diameter away from any building, or other obstacles in those areas that exceed the MPE levels. Since one diameter removed from the center of the main beam will lower levels by at least 20 dB, or by a factor of 100, these potential hazards do not exist for eihter the public, or for the earth station personnel.

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. The transmitter will be turned off during periods of maintenance, so that the MPE standard of 5.0 mW/cm² will be complied with for those regions in close proximity to the main reflector, which could be occupied by operating personnel.

RADIATION HAZARD EVALUATION

For

GD Satcom **1.8** **Site Id: Remote**
Antenna Id: REM1_8A

1 Overview

Determining the region around an antenna where radiation hazardous to human health is a consideration of many factors. With a parabolic dish antenna, the region is highly directional and the actual hazardous region is dependent on the antenna elevation angle. The following formulae are used to determine the near and far field regions. These regions are in the main beam of the radiation pattern, which we will assume consists of a conical angle extending +/- 3 degrees from the center axis of the antenna.

The analysis contained herein predicts the radiation levels around the proposed antenna. The calculations contained in this report are in accordance with FCC guidelines as contained in CFR 47 Part 1.1310 and OET Bulletin 65. The maximum level of non-ionizing radiation to which the general public is exposed is defined for controlled and uncontrolled environments as follows:

Environment	Exposure Limit Power	Exposure Limit Duration
Controlled - (applicable to system operators and technicians in the service area of the antenna):	**5 mW/cm^2**	**6 Minutes**
Uncontrolled - (applicable to general public in proximity of the antenna):	**1 mW/cm^2**	**30 Minutes**

2.1 Earth Station Technical Parameters - Input Data

1A	Antenna Diameter - Standard Parabola	1.8	meters
1B	Antenna Diameter - Elliptical Reflector		meters
1B1	Major Axis Diameter		meters
1B2	Minor Axis Diameter		meters
2	G = Antenna Isotropic Gain	46.7	dBi
3	h = Nominal Antenna Efficiency	68	Percent
4	Nominal Frequency	14.25	GHz
5	Maximum Transmit Power Amplifier Size	200.00	Watts
6	Number of Carriers	1	each
7	W/G Loss from Transmitter to Feed	0	dB
8	Multicarrier Fixed Backoff	0	dB
9	Desired Object Clearance Height	2	meters

2.2 Earth Station Technical Parameters - Calculated Data

10	A = Antenna Surface Area	2.54	sq meters		
10A	Standard Parabolic Reflector	2.544690049	sq meters		
10B	Elliptical Reflector	0.00	sq meters		
11	D = Effective Antenna Diameter	1.8	meters		
12	Total Transmit Power	200.00	Watts		
13	P = Total Feed Input Power (watts)	200.00	Watts		
14	E = Maximum E/S EIRP - Calculated	69.71	dBW		
15	λ = Wavelength (= c/f in m/GHz)	0.0210	m/GHz		
16	p = Pi	3.14159			
17	R_{nf} = Near Field Limit ($D^2/4\lambda$)	39	meters	128	feet
18	R_{ff} = Far Field Limit (R_{ff}=0.6D2/λ)	92	meters	302	feet
19	R_{nf} to R_{ff} = Transition Region	39 to 92	meters	128 to 302	feet

3 Power Density at the Antenna Surface

The power density at the reflector surface is expected to exceed the safe limits. The reflector is not accessible to the public and will not present a hazard. Terminal operators and technicians receive training identifying the area as presenting high exposure levels. Procedures are incorporated requiring that transmitters are not operating when access to the reflector surface is required.

The power density at the antenna reflector surface can be calculated by the expression:

PD_{REFL} = 4P/A = **31.44 mW/cm^2**

Where: P = Total power at the feed, milliwatts
A = Total area of reflector, sq cm

Evaluation:

Controlled Environment (less than 5 mW/cm^2 in 6 minutes): **HAZARD**

Uncontrolled environment (less than 1 mW/cm^2 in 30 minutes): **Mitigation Required**

4 On-Axis Power Density in the Near Field Region

The Radiating Near Field Region for a parabolic, circular reflector, is defined as extending from the reflector to a distance equal to the diameter squared divided by twice the wavelength. This distance is referred to as the Rayleigh distance. In this region the power is nearly all contained within a cylinder of radius 0.5D. As a safety measure the highest possible power density is applied to the whole of this region.

The power density in the Near Field Region of the antenna can be calculated by the expression:

$16*P*h/\pi*D^2$ = **21.38 mW/cm^2**

Where: P = Total power at the feed, milliwatts
h = Nominal antenna efficiency
D = Effective antenna diameter, meters

Evaluation:

Controlled Environment (less than 5 mW/cm^2 in 6 minutes): **HAZARD**

Uncontrolled environment (less than 1 mW/cm^2 in 30 minutes): **Mitigation Required**

5 On-Axis Power Density in the Transition Region

The transition region is located between the Near Field and Far Field regions. The power density begins to vary inversely with distance from the antenna in the transition region. The maximum power density in this region will not exceed the power density calculated for the Near Field region. Once again the power density figures are for the On-Axis and contained with a cylinder extending within +/- 1 degree of beam center. Where the antennas are normally operated at an elevation angle typically greater than 10°, the actual safe distance in front of the antenna may be found in paragraph 10. The formula for the calculation is used to evaluate the power density at any given distance in the transition as expressed below:

The power density in the On-Axis Transition Region can be calculated by the expression:

$PD_t=(PD_{nf})(R_{nf})/R$

Where: PD_{nf} = The Near Field power density, mW/cm^2
R_{nf} = Near Field maximum distance, meters
R = Distance to point of interest

For: 39 < R < 92 meters

Evaluation:

Controlled Environment Safe Operating Distance, meters: **167 meters**

Uncontrolled environment Safe Operating Distance, meters: **834 meters**

6 On-Axis Power Density in the Far Field Region

The On-Axis power density in the far field region (PD_{ff}) varies inversely with the square of the distance. The calculation is performed below:

The Power Density at the start of the Far Field region can be calculated by the expression:

$E-10\log(4pR^2)$ 19.44 dBW/m^2

$\text{antilog}((E-10\log(4pR^2)/10)/10$ **8.80 mW/cm^2**

Evaluation:

Controlled Environment (less than 5 mW/cm^2 in 6 minutes): **HAZARD**

Uncontrolled environment (less than 1 mW/cm^2 in 30 minutes): **Mitigation Required**

7 Off-Axis Power Density Levels at the Far Field Limit and Beyond

In the far field region, the power is distributed in a pattern of sidelobes as a function of the off-axis angle between the antenna center line and the point of interest. Off-axis power density in the far field can be estimated using the antenna radiation patterns prescribed for the antenna in use. Usually this will correspond to the antenna gain pattern envelope defined by the FCC or the ITU, which takes the form of:

$G_{off} = 32 - 25\log(\theta)$

for θ from 1 to 48 degrees; -10 dBi from 48 to 180 degrees
(Applicable for commonly used satellite transmit antennas)

For example: At one (1) degree off axis At the far-field limit, we can calculate the power density as:

$G_{off} = 32 - 25\log(1) = 32 - 0$ dBi = 1585 numeric

$PD_{1\ deg\ off\text{-}axis} = PD_{ff} \times 1585/G$ **0.2980 mW/cm^2**

Evaluation:

Considering that satellite antenna beams are aimed skyward, power density in the far field will usually not be a problem except at low look angles. In these cases, off axis gain reduction techniques may be used to further reduce the power density levels.

8 Off-Axis Power Density Levels at the Near Field and Transitional Regions

According to Bulletin 65, off-axis calculations in the near field may be performed as follows: assuming that the point of interest is at least one antenna diameter removed from the center of the main beam, the power density at that point is at least a factor of 100 (20 dB) less than the value calculated for the near field main beam power density. This may be calculated as follows:

$PD_{nf(off\text{-}axis)} = PD_{nf}/100$ = **0.2138 mW/cm^2**

9 Region Between the Feed Horn and Reflector/Sub-Reflector

Transmissions from the feed horn are directed toward the main reflector or the sub-reflector depending on the type of antenna (prime focus, Gregorian or Cassegrain). The transmission is confined within a conical shape defined by the

feed horn. The energy between the feedhorn and the reflector/sub-reflector is assumed to be in excess of any limit for permissible exposure. This region is not accessible to the general public, and operators and technicians should be suitable trained and procedures in place to preclude access to this region during active transmission.

10 Evaluation of Safe Occupancy Area in Front of the Antenna

The distance (L) from a vertical axis passing through the dish center to a safe off-axis point in front of the antenna can be determined based on the dish diameter. Assuming a flat terrain and a point on the horizontal plane with the center point of the antenna, the relationship is determined by the following formula:

L = (D/sin a) + (2h - D - 2)/(2 tan a)

Where: a = minimum elevation angle of antenna
D = Dish diameter in meters
h = Maximum height of object to be cleared, meters

For distances equal to or greater than determined by the equation above, the radiation hazard will be below safe levels

For: D = 1.8 meters
h= 2 meters

Safe distance for the following elevation angles (a):

a - Elevation Angle (degrees)	L - Safe Distance		
10	10.93	meters	
15	7.33	meters	
20	5.54	meters	
25	4.47	meters	
30	3.77	meters	
40	2.92	meters	
50	2.43	meters	
5.00	21.80	meters	**Site Specific**

11 Mitigation Analysis

Mitigation of accessibility to hazardous regions may take several forms depending on the antenna application and location. In instances such as mobile applications, the antenna may be located such that the hazardous region is not accessible during operation. An example may be in a mobile configuration where the antenna is located on top of a vehicle during operation. In other fixed installation instances the hazardous area may be fenced off to prevent access. In areas where only operators and technicians have access, training in safeguards and proper markings of hazardous areas may be sufficient. This analysis tool is designed to identify the hazardous exposure regions around an operating antenna system in accordance with the defined power density limits in CFR 47, part 1.1310 and OET bulletin 65.

12 Conclusion

Based upon the above analysis, it is concluded that harmful levles of radiation may exist in those regions noted for both the Controlled and Uncontrolled environment.

The antenna will either be installed on the roof of a buiding, the roof of a vehicle, or on the ground. A ground mounted antenna earth station will be surrounded by a fence, which will restrict any public access. All earth stations will be 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 might be working or otherwise present in or near the direct path of the main beam.

The applicant will ensure the main beam of the antenna will be pointed at least one diameter away from any building, or other obstacles in those areas that exceed the MPE levels. Since one diameter removed from the center of the main beam will lower levels by at least 20 dB, or by a factor of 100, these potential hazards do not exist for eihter the public, or for the earth station personnel.

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. The transmitter will be turned off during periods of maintenance, so that the MPE standard of 5.0 mW/cm² will be complied with for those regions in close proximity to the main reflector, which could be occupied by operating personnel.

RADIATION HAZARD EVALUATION

For

AVL **1.8** **Site Id: Remote**
Antenna Id: REM1_8B

1 Overview

Determining the region around an antenna where radiation hazardous to human health is a consideration of many factors. With a parabolic dish antenna, the region is highly directional and the actual hazardous region is dependent on the antenna elevation angle. The following formulae are used to determine the near and far field regions. These regions are in the main beam of the radiation pattern, which we will assume consists of a conical angle extending +/- 3 degrees from the center axis of the antenna.

The analysis contained herein predicts the radiation levels around the proposed antenna. The calculations contained in this report are in accordance with FCC guidelines as contained in CFR 47 Part 1.1310 and OET Bulletin 65. The maximum level of non-ionizing radiation to which the general public is exposed is defined for controlled and uncontrolled environments as follows:

Environment	Exposure Limit: Power	Exposure Limit: Duration
Controlled - (applicable to system operators and technicians in the service area of the antenna):	**5 mW/cm^2**	**6 Minutes**
Uncontrolled - (applicable to general public in proximity of the antenna):	**1 mW/cm^2**	**30 Minutes**

2.1 Earth Station Technical Parameters - Input Data

1A	Antenna Diameter - Standard Parabola	1.8	meters
1B	Antenna Diameter - Elliptical Reflector		meters
1B1	Major Axis Diameter		meters
1B2	Minor Axis Diameter		meters
2	G = Antenna Isotropic Gain	46.8	dBi
3	h = Nominal Antenna Efficiency	68	Percent
4	Nominal Frequency	14.25	GHz
5	Maximum Transmit Power Amplifier Size	250.00	Watts
6	Number of Carriers	1	each
7	W/G Loss from Transmitter to Feed	0	dB
8	Multicarrier Fixed Backoff	0	dB
9	Desired Object Clearance Height	2	meters

2.2 Earth Station Technical Parameters - Calculated Data

10	A = Antenna Surface Area	2.54	sq meters		
10A	Standard Parabolic Reflector	2.544690049	sq meters		
10B	Elliptical Reflector	0.00	sq meters		
11	D = Effective Antenna Diameter	1.8	meters		
12	Total Transmit Power	250.00	Watts		
13	P = Total Feed Input Power (watts)	250.00	Watts		
14	E = Maximum E/S EIRP - Calculated	70.78	dBW		
15	λ = Wavelength (= c/f in m/GHz)	0.0210	m/GHz		
16	p = Pi	3.14159			
17	R_{nf} = Near Field Limit ($D^2/4\lambda$)	39	meters	128	feet
18	R_{ff} = Far Field Limit (R_{ff}=0.6D2/λ)	92	meters	302	feet
19	R_{nf} to R_{ff} = Transition Region	39 to 92	meters	128 to 302	feet

3 Power Density at the Antenna Surface

The power density at the reflector surface is expected to exceed the safe limits. The reflector is not accessible to the public and will not present a hazard. Terminal operators and technicians receive training identifying the area as presenting high exposure levels. Procedures are incorporated requiring that transmitters are not operating when access to the reflector surface is required.

The power density at the antenna reflector surface can be calculated by the expression:

PD_{REFL} = 4P/A = **39.3 mW/cm^2**

Where: P = Total power at the feed, milliwatts
A = Total area of reflector, sq cm

Evaluation:

Controlled Environment (less than 5 mW/cm^2 in 6 minutes): **HAZARD**

Uncontrolled environment (less than 1 mW/cm^2 in 30 minutes): **Mitigation Required**

4 On-Axis Power Density in the Near Field Region

The Radiating Near Field Region for a parabolic, circular reflector, is defined as extending from the reflector to a distance equal to the diameter squared divided by twice the wavelength. This distance is referred to as the Rayleigh distance. In this region the power is nearly all contained within a cylinder of radius 0.5D. As a safety measure the highest possible power density is applied to the whole of this region.

The power density in the Near Field Region of the antenna can be calculated by the expression:

$16*P*h/\pi*D^2$ = **26.72 mW/cm²**

Where: P = Total power at the feed, milliwatts
h = Nominal antenna efficiency
D = Effective antenna diameter, meters

Evaluation:

Controlled Environment (less than 5 mW/cm² in 6 minutes): **HAZARD**

Uncontrolled environment (less than 1 mW/cm² in 30 minutes): **Mitigation Required**

5 On-Axis Power Density in the Transition Region

The transition region is located between the Near Field and Far Field regions. The power density begins to vary inversely with distance from the antenna in the transition region. The maximum power density in this region will not exceed the power density calculated for the Near Field region. Once again the power density figures are for the On-Axis and contained with a cylinder extending within +/- 1 degree of beam center. Where the antennas are normally operated at an elevation angle typically greater than 10°, the actual safe distance in front of the antenna may be found in paragraph 10. The formula for the calculation is used to evaluate the power density at any given distance in the transition as expressed below:

The power density in the On-Axis Transition Region can be calculated by the expression:

$PD_t=(PD_{nf})(R_{nf})/R$

Where: PD_{nf} = The Near Field power density, mW/cm²
R_{nf} = Near Field maximum distance, meters
R = Distance to point of interest

For: 39 < R < 92 meters

Evaluation:

Controlled Environment Safe Operating Distance, meters: **208 meters**

Uncontrolled environment Safe Operating Distance, meters: **1042 meters**

6 On-Axis Power Density in the Far Field Region

The On-Axis power density in the far field region (PD_{ff}) varies inversely with the square of the distance. The calculation is performed below:

The Power Density at the start of the Far Field region can be calculated by the expression:

$E-10\log(4pR^2)$ 20.51 dBW/m²

$\text{antilog}((E-10\log(4pR^2)/10)/10$ **11.25 mW/cm²**

Evaluation:

Controlled Environment (less than 5 mW/cm² in 6 minutes): **HAZARD**

Uncontrolled environment (less than 1 mW/cm² in 30 minutes): **Mitigation Required**

7 Off-Axis Power Density Levels at the Far Field Limit and Beyond

In the far field region, the power is distributed in a pattern of sidelobes as a function of the off-axis angle between the antenna center line and the point of interest. Off-axis power density in the far field can be estimated using the antenna radiation patterns prescribed for the antenna in use. Usually this will correspond to the antenna gain pattern envelope defined by the FCC or the ITU, which takes the form of:

$G_{off} = 32 - 25\log(\theta)$

for θ from 1 to 48 degrees; -10 dBi from 48 to 180 degrees
(Applicable for commonly used satellite transmit antennas)

For example: At one (1) degree off axis At the far-field limit, we can calculate the power density as:

$G_{off} = 32 - 25\log(1) = 32 - 0$ dBi = 1585 numeric

$PD_{1\ deg\ off\text{-}axis} = PD_{ff} \times 1585/G$ **0.3725 mW/cm²**

Evaluation:

Considering that satellite antenna beams are aimed skyward, power density in the far field will usually not be a problem except at low look angles. In these cases, off axis gain reduction techniques may be used to further reduce the power density levels.

8 Off-Axis Power Density Levels at the Near Field and Transitional Regions

According to Bulletin 65, off-axis calculations in the near field may be performed as follows: assuming that the point of interest is at least one antenna diameter removed from the center of the main beam, the power density at that point is at least a factor of 100 (20 dB) less than the value calculated for the near field main beam power density. This may be calculated as follows:

$PD_{nf(off\text{-}axis)} = PD_{nf}/100$ = **0.2672 mW/cm²**

9 Region Between the Feed Horn and Reflector/Sub-Reflector

Transmissions from the feed horn are directed toward the main reflector or the sub-reflector depending on the type of antenna (prime focus, Gregorian or Cassegrain). The transmission is confined within a conical shape defined by the

feed horn. The energy between the feedhorn and the reflector/sub-reflector is assumed to be in excess of any limit for permissible exposure. This region is not accessible to the general public, and operators and technicians should be suitable trained and procedures in place to preclude access to this region during active transmission.

10 Evaluation of Safe Occupancy Area in Front of the Antenna

The distance (L) from a vertical axis passing through the dish center to a safe off-axis point in front of the antenna can be determined based on the dish diameter. Assuming a flat terrain and a point on the horizontal plane with the center point of the antenna, the relationship is determined by the following formula:

L = (D/sin a) + (2h - D - 2)/(2 tan a)

Where: a = minimum elevation angle of antenna
D = Dish diameter in meters
h = Maximum height of object to be cleared, meters

For distances equal to or greater than determined by the equation above, the radiation hazard will be below safe levels

For: D = 1.8 meters
h= 2 meters

Safe distance for the following elevation angles (a):

a - Elevation Angle (degrees)	L - Safe Distance		
10	10.93	meters	
15	7.33	meters	
20	5.54	meters	
25	4.47	meters	
30	3.77	meters	
40	2.92	meters	
50	2.43	meters	
5.00	21.80	meters	Site Specific

11 Mitigation Analysis

Mitigation of accessibility to hazardous regions may take several forms depending on the antenna application and location. In instances such as mobile applications, the antenna may be located such that the hazardous region is not accessible during operation. An example may be in a mobile configuration where the antenna is located on top of a vehicle during operation. In other fixed installation instances the hazardous area may be fenced off to prevent access. In areas where only operators and technicians have access, training in safeguards and proper markings of hazardous areas may be sufficient. This analysis tool is designed to identify the hazardous exposure regions around an operating antenna system in accordance with the defined power density limits in CFR 47, part 1.1310 and OET bulletin 65.

12 Conclusion

Based upon the above analysis, it is concluded that harmful levles of radiation may exist in those regions noted for both the Controlled and Uncontrolled environment.

The antenna will either be installed on the roof of a buiding, the roof of a vehicle, or on the ground. A ground mounted antenna earth station will be surrounded by a fence, which will restrict any public access. All earth stations will be 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 might be working or otherwise present in or near the direct path of the main beam.

The applicant will ensure the main beam of the antenna will be pointed at least one diameter away from any building, or other obstacles in those areas that exceed the MPE levels. Since one diameter removed from the center of the main beam will lower levels by at least 20 dB, or by a factor of 100, these potential hazards do not exist for eihter the public, or for the earth station personnel.

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. 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, which could be occupied by operating personnel.

RADIATION HAZARD EVALUATION

For

AVL **1.8** **Site Id: Remote**
Antenna Id: REM1_8C

1 Overview

Determining the region around an antenna where radiation hazardous to human health is a consideration of many factors. With a parabolic dish antenna, the region is highly directional and the actual hazardous region is dependent on the antenna elevation angle. The following formulae are used to determine the near and far field regions. These regions are in the main beam of the radiation pattern, which we will assume consists of a conical angle extending +/- 3 degrees from the center axis of the antenna.

The analysis contained herein predicts the radiation levels around the proposed antenna. The calculations contained in this report are in accordance with FCC guidelines as contained in CFR 47 Part 1.1310 and OET Bulletin 65. The maximum level of non-ionizing radiation to which the general public is exposed is defined for controlled and uncontrolled environments as follows:

Environment	Exposure Limit Power	Exposure Limit Duration
Controlled - (applicable to system operators and technicians in the service area of the antenna):	**5 mW/cm^2**	**6 Minutes**
Uncontrolled - (applicable to general public in proximity of the antenna):	**1 mW/cm^2**	**30 Minutes**

2.1 Earth Station Technical Parameters - Input Data

1A	Antenna Diameter - Standard Parabola	1.8	meters
1B	Antenna Diameter - Elliptical Reflector		meters
1B1	Major Axis Diameter		meters
1B2	Minor Axis Diameter		meters
2	G = Antenna Isotropic Gain	46.7	dBi
3	h = Nominal Antenna Efficiency	68	Percent
4	Nominal Frequency	14.25	GHz
5	Maximum Transmit Power Amplifier Size	250.00	Watts
6	Number of Carriers	1	each
7	W/G Loss from Transmitter to Feed	0	dB
8	Multicarrier Fixed Backoff	0	dB
9	Desired Object Clearance Height	2	meters

2.2 Earth Station Technical Parameters - Calculated Data

10	A = Antenna Surface Area	2.54	sq meters		
10A	Standard Parabolic Reflector	2.544690049	sq meters		
10B	Elliptical Reflector	0.00	sq meters		
11	D = Effective Antenna Diameter	1.8	meters		
12	Total Transmit Power	250.00	Watts		
13	P = Total Feed Input Power (watts)	250.00	Watts		
14	E = Maximum E/S EIRP - Calculated	70.68	dBW		
15	λ = Wavelength (= c/f in m/GHz)	0.0210	m/GHz		
16	p = Pi	3.14159			
17	R_{nf} = Near Field Limit ($D^2/4\lambda$)	39	meters	128	feet
18	R_{ff} = Far Field Limit (R_{ff}=0.6D2/λ)	92	meters	302	feet
19	R_{nf} to R_{ff} = Transition Region	39 to 92	meters	128 to 302	feet

3 Power Density at the Antenna Surface

The power density at the reflector surface is expected to exceed the safe limits. The reflector is not accessible to the public and will not present a hazard. Terminal operators and technicians receive training identifying the area as presenting high exposure levels. Procedures are incorporated requiring that transmitters are not operating when access to the reflector surface is required.

The power density at the antenna reflector surface can be calculated by the expression:

PD_{REFL} = 4P/A = **39.3 mW/cm^2**

Where: P = Total power at the feed, milliwatts
A = Total area of reflector, sq cm

Evaluation:

Controlled Environment (less than 5 mW/cm^2 in 6 minutes): **HAZARD**

Uncontrolled environment (less than 1 mW/cm^2 in 30 minutes): **Mitigation Required**

4 On-Axis Power Density in the Near Field Region

The Radiating Near Field Region for a parabolic, circular reflector, is defined as extending from the reflector to a distance equal to the diameter squared divided by twice the wavelength. This distance is referred to as the Rayleigh distance. In this region the power is nearly all contained within a cylinder of radius 0.5D. As a safety measure the highest possible power density is applied to the whole of this region.

The power density in the Near Field Region of the antenna can be calculated by the expression:

$16*P*h/\pi*D^2$ = **26.72 mW/cm²**

Where: P = Total power at the feed, milliwatts
h = Nominal antenna efficiency
D = Effective antenna diameter, meters

Evaluation:

Controlled Environment (less than 5 mW/cm² in 6 minutes): **HAZARD**

Uncontrolled environment (less than 1 mW/cm² in 30 minutes): **Mitigation Required**

5 On-Axis Power Density in the Transition Region

The transition region is located between the Near Field and Far Field regions. The power density begins to vary inversely with distance from the antenna in the transition region. The maximum power density in this region will not exceed the power density calculated for the Near Field region. Once again the power density figures are for the On-Axis and contained with a cylinder extending within +/- 1 degree of beam center. Where the antennas are normally operated at an elevation angle typically greater than 10°, the actual safe distance in front of the antenna may be found in paragraph 10. The formula for the calculation is used to evaluate the power density at any given distance in the transition as expressed below:

The power density in the On-Axis Transition Region can be calculated by the expression:

$PD_t=(PD_{nf})(R_{nf})/R$

Where: PD_{nf} = The Near Field power density, mW/cm²
R_{nf} = Near Field maximum distance, meters
R = Distance to point of interest

For: 39 < R < 92 meters

Evaluation:

Controlled Environment Safe Operating Distance, meters: **208 meters**

Uncontrolled environment Safe Operating Distance, meters: **1042 meters**

6 On-Axis Power Density in the Far Field Region

The On-Axis power density in the far field region (PD_{ff}) varies inversely with the square of the distance. The calculation is performed below:

The Power Density at the start of the Far Field region can be calculated by the expression:

E-10log(4pR²) 20.41 dBW/m²

antilog((E-10log(4pR²)/10)/10 **10.99 mW/cm²**

Evaluation:

Controlled Environment (less than 5 mW/cm² in 6 minutes): **HAZARD**

Uncontrolled environment (less than 1 mW/cm² in 30 minutes): **Mitigation Required**

7 Off-Axis Power Density Levels at the Far Field Limit and Beyond

In the far field region, the power is distributed in a pattern of sidelobes as a function of the off-axis angle between the antenna center line and the point of interest. Off-axis power density in the far field can be estimated using the antenna radiation patterns prescribed for the antenna in use. Usually this will correspond to the antenna gain pattern envelope defined by the FCC or the ITU, which takes the form of:

G_{off} = 32 - 25log(θ)

for θ from 1 to 48 degrees; -10 dBi from 48 to 180 degrees
(Applicable for commonly used satellite transmit antennas)

For example: At one (1) degree off axis At the far-field limit, we can calculate the power density as:

G_{off} = 32 - 25log(1) = 32 - 0 dBi = 1585 numeric

$PD_{1\ deg\ off\text{-}axis} = PD_{ff}$ x 1585/G **0.3725 mW/cm²**

Evaluation:

Considering that satellite antenna beams are aimed skyward, power density in the far field will usually not be a problem except at low look angles. In these cases, off axis gain reduction techniques may be used to further reduce the power density levels.

8 Off-Axis Power Density Levels at the Near Field and Transitional Regions

According to Bulletin 65, off-axis calculations in the near field may be performed as follows: assuming that the point of interest is at least one antenna diameter removed from the center of the main beam, the power density at that point is at least a factor of 100 (20 dB) less than the value calculated for the near field main beam power density. This may be calculated as follows:

$PD_{nf(off\text{-}axis)} = PD_{nf}/100$ = **0.2672 mW/cm²**

9 Region Between the Feed Horn and Reflector/Sub-Reflector

Transmissions from the feed horn are directed toward the main reflector or the sub-reflector depending on the type of antenna (prime focus, Gregorian or Cassegrain). The transmission is confined within a conical shape defined by the

feed horn. The energy between the feedhorn and the reflector/sub-reflector is assumed to be in excess of any limit for permissible exposure. This region is not accessible to the general public, and operators and technicians should be suitable trained and procedures in place to preclude access to this region during active transmission.

10 Evaluation of Safe Occupancy Area in Front of the Antenna

The distance (L) from a vertical axis passing through the dish center to a safe off-axis point in front of the antenna can be determined based on the dish diameter. Assuming a flat terrain and a point on the horizontal plane with the center point of the antenna, the relationship is determined by the following formula:

L = (D/sin a) + (2h - D - 2)/(2 tan a)

Where: a = minimum elevation angle of antenna
D = Dish diameter in meters
h = Maximum height of object to be cleared, meters

For distances equal to or greater than determined by the equation above, the radiation hazard will be below safe levels

For: D = 1.8 meters
h= 2 meters

Safe distance for the following elevation angles (a):

a - Elevation Angle (degrees)	L - Safe Distance		
10	10.93	meters	
15	7.33	meters	
20	5.54	meters	
25	4.47	meters	
30	3.77	meters	
40	2.92	meters	
50	2.43	meters	
5.00	21.80	meters	**Site Specific**

11 Mitigation Analysis

Mitigation of accessibility to hazardous regions may take several forms depending on the antenna application and location. In instances such as mobile applications, the antenna may be located such that the hazardous region is not accessible during operation. An example may be in a mobile configuration where the antenna is located on top of a vehicle during operation. In other fixed installation instances the hazardous area may be fenced off to prevent access. In areas where only operators and technicians have access, training in safeguards and proper markings of hazardous areas may be sufficient. This analysis tool is designed to identify the hazardous exposure regions around an operating antenna system in accordance with the defined power density limits in CFR 47, part 1.1310 and OET bulletin 65.

12 Conclusion

Based upon the above analysis, it is concluded that harmful levles of radiation may exist in those regions noted for both the Controlled and Uncontrolled environment.

The antenna will either be installed on the roof of a buiding, the roof of a vehicle, or on the ground. A ground mounted antenna earth station will be surrounded by a fence, which will restrict any public access. All earth stations will be 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 might be working or otherwise present in or near the direct path of the main beam.

The applicant will ensure the main beam of the antenna will be pointed at least one diameter away from any building, or other obstacles in those areas that exceed the MPE levels. Since one diameter removed from the center of the main beam will lower levels by at least 20 dB, or by a factor of 100, these potential hazards do not exist for eihter the public, or for the earth station personnel.

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. 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, which could be occupied by operating personnel.

RADIATION HAZARD EVALUATION

For

GD Satcom **2.4** **Site Id: Remote**
Antenna Id: REM2_4A

1 Overview

Determining the region around an antenna where radiation hazardous to human health is a consideration of many factors. With a parabolic dish antenna, the region is highly directional and the actual hazardous region is dependent on the antenna elevation angle. The following formulae are used to determine the near and far field regions. These regions are in the main beam of the radiation pattern, which we will assume consists of a conical angle extending +/- 3 degrees from the center axis of the antenna.

The analysis contained herein predicts the radiation levels around the proposed antenna. The calculations contained in this report are in accordance with FCC guidelines as contained in CFR 47 Part 1.1310 and OET Bulletin 65. The maximum level of non-ionizing radiation to which the general public is exposed is defined for controlled and uncontrolled environments as follows:

Environment	Exposure Limit Power	Exposure Limit Duration
Controlled - (applicable to system operators and technicians in the service area of the antenna):	**5 mW/cm^2**	**6 Minutes**
Uncontrolled - (applicable to general public in proximity of the antenna):	**1 mW/cm^2**	**30 Minutes**

2.1 Earth Station Technical Parameters - Input Data

1A	Antenna Diameter - Standard Parabola	2.4	meters
1B	Antenna Diameter - Elliptical Reflector		meters
1B1	Major Axis Diameter		meters
1B2	Minor Axis Diameter		meters
2	G = Antenna Isotropic Gain	49.2	dBi
3	h = Nominal Antenna Efficiency	68	Percent
4	Nominal Frequency	14.25	GHz
5	Maximum Transmit Power Amplifier Size	300.00	Watts
6	Number of Carriers	1	each
7	W/G Loss from Transmitter to Feed	0	dB
8	Multicarrier Fixed Backoff	0	dB
9	Desired Object Clearance Height	2	meters

2.2 Earth Station Technical Parameters - Calculated Data

10	A = Antenna Surface Area	4.52	sq meters		
10A	Standard Parabolic Reflector	4.523893421	sq meters		
10B	Elliptical Reflector	0.00	sq meters		
11	D = Effective Antenna Diameter	2.4	meters		
12	Total Transmit Power	300.00	Watts		
13	P = Total Feed Input Power (watts)	300.00	Watts		
14	E = Maximum E/S EIRP - Calculated	73.97	dBW		
15	λ = Wavelength (= c/f in m/GHz)	0.0210	m/GHz		
16	p = Pi	3.14159			
17	R_{nf} = Near Field Limit ($D^2/4\lambda$)	68	meters	223	feet
18	R_{ff} = Far Field Limit (R_{ff}=0.6D2/λ)	164	meters	538	feet
19	R_{nf} to R_{ff} = Transition Region	68 to 164	meters	223 to 538	feet

3 Power Density at the Antenna Surface

The power density at the reflector surface is expected to exceed the safe limits. The reflector is not accessible to the public and will not present a hazard. Terminal operators and technicians receive training identifying the area as presenting high exposure levels. Procedures are incorporated requiring that transmitters are not operating when access to the reflector surface is required.

The power density at the antenna reflector surface can be calculated by the expression:

PD_{REFL} = 4P/A = **26.53 mW/cm^2**

Where: P = Total power at the feed, milliwatts
A = Total area of reflector, sq cm

Evaluation:

Controlled Environment (less than 5 mW/cm^2 in 6 minutes):	**HAZARD**
Uncontrolled environment (less than 1 mW/cm^2 in 30 minutes):	**Mitigation Required**

4 On-Axis Power Density in the Near Field Region

The Radiating Near Field Region for a parabolic, circular reflector, is defined as extending from the reflector to a distance equal to the diameter squared divided by twice the wavelength. This distance is referred to as the Rayleigh distance. In this region the power is nearly all contained within a cylinder of radius 0.5D. As a safety measure the highest possible power density is applied to the whole of this region.

The power density in the Near Field Region of the antenna can be calculated by the expression:

$16*P*h/\pi*D^2$ = **18.04 mW/cm^2**

Where: P = Total power at the feed, milliwatts
h = Nominal antenna efficiency
D = Effective antenna diameter, meters

Evaluation:

Controlled Environment (less than 5 mW/cm^2 in 6 minutes): **HAZARD**

Uncontrolled environment (less than 1 mW/cm^2 in 30 minutes): **Mitigation Required**

5 On-Axis Power Density in the Transition Region

The transition region is located between the Near Field and Far Field regions. The power density begins to vary inversely with distance from the antenna in the transition region. The maximum power density in this region will not exceed the power density calculated for the Near Field region. Once again the power density figures are for the On-Axis and contained with a cylinder extending within +/- 1 degree of beam center. Where the antennas are normally operated at an elevation angle typically greater than 10°, the actual safe distance in front of the antenna may be found in paragraph 10. The formula for the calculation is used to evaluate the power density at any given distance in the transition as expressed below:

The power density in the On-Axis Transition Region can be calculated by the expression:

$PD_t=(PD_{nf})(R_{nf})/R$

Where: PD_{nf} = The Near Field power density, mW/cm^2
R_{nf} = Near Field maximum distance, meters
R = Distance to point of interest

For: 68 < R < 164 meters

Evaluation:

Controlled Environment Safe Operating Distance, meters: **245 meters**

Uncontrolled environment Safe Operating Distance, meters: **1227 meters**

6 On-Axis Power Density in the Far Field Region

The On-Axis power density in the far field region (PD_{ff}) varies inversely with the square of the distance. The calculation is performed below:

The Power Density at the start of the Far Field region can be calculated by the expression:

$E-10\log(4pR^2)$ 18.68 dBW/m^2

$antilog((E-10\log(4pR^2)/10)/10$ **7.38 mW/cm^2**

Evaluation:

Controlled Environment (less than 5 mW/cm^2 in 6 minutes): **HAZARD**

Uncontrolled environment (less than 1 mW/cm^2 in 30 minutes): **Mitigation Required**

7 Off-Axis Power Density Levels at the Far Field Limit and Beyond

In the far field region, the power is distributed in a pattern of sidelobes as a function of the off-axis angle between the antenna center line and the point of interest. Off-axis power density in the far field can be estimated using the antenna radiation patterns prescribed for the antenna in use. Usually this will correspond to the antenna gain pattern envelope defined by the FCC or the ITU, which takes the form of:

$G_{off} = 32 - 25\log(\theta)$

for θ from 1 to 48 degrees; -10 dBi from 48 to 180 degrees
(Applicable for commonly used satellite transmit antennas)

For example: At one (1) degree off axis At the far-field limit, we can calculate the power density as:

$G_{off} = 32 - 25\log(1) = 32 - 0$ dBi = 1585 numeric

$PD_{1\ deg\ off\text{-}axis} = PD_{ff} \times 1585/G$ **0.1407 mW/cm^2**

Evaluation:

Considering that satellite antenna beams are aimed skyward, power density in the far field will usually not be a problem except at low look angles. In these cases, off axis gain reduction techniques may be used to further reduce the power density levels.

8 Off-Axis Power Density Levels at the Near Field and Transitional Regions

According to Bulletin 65, off-axis calculations in the near field may be performed as follows: assuming that the point of interest is at least one antenna diameter removed from the center of the main beam, the power density at that point is at least a factor of 100 (20 dB) less than the value calculated for the near field main beam power density. This may be calculated as follows:

$PD_{nf(off\text{-}axis)} = PD_{nf}/100$ = **0.1804 mW/cm^2**

9 Region Between the Feed Horn and Reflector/Sub-Reflector

Transmissions from the feed horn are directed toward the main reflector or the sub-reflector depending on the type of antenna (prime focus, Gregorian or Cassegrain). The transmission is confined within a conical shape defined by the

feed horn. The energy between the feedhorn and the reflector/sub-reflector is assumed to be in excess of any limit for permissible exposure. This region is not accessible to the general public, and operators and technicians should be suitable trained and procedures in place to preclude access to this region during active transmission.

10 Evaluation of Safe Occupancy Area in Front of the Antenna

The distance (L) from a vertical axis passing through the dish center to a safe off-axis point in front of the antenna can be determined based on the dish diameter. Assuming a flat terrain and a point on the horizontal plane with the center point of the antenna, the relationship is determined by the following formula:

L = (D/sin a) + (2h - D - 2)/(2 tan a)

Where: a = minimum elevation angle of antenna

D = Dish diameter in meters

h = Maximum height of object to be cleared, meters

For distances equal to or greater than determined by the equation above, the radiation hazard will be below safe levels

For:			
	D =	2.4	meters
	h=	2	meters

Safe distance for the following elevation angles (a):

a - Elevation Angle (degrees)	L - Safe Distance		
10	**12.69**	**meters**	
15	**8.53**	**meters**	
20	**6.47**	**meters**	
25	**5.25**	**meters**	
30	**4.45**	**meters**	
40	**3.50**	**meters**	
50	**2.97**	**meters**	
5.00	**25.25**	**meters**	**Site Specific**

11 Mitigation Analysis

Mitigation of accessibility to hazardous regions may take several forms depending on the antenna application and location. In instances such as mobile applications, the antenna may be located such that the hazardous region is not accessible during operation. An example may be in a mobile configuration where the antenna is located on top of a vehicle during operation. In other fixed installation instances the hazardous area may be fenced off to prevent access. In areas where only operators and technicians have access, training in safeguards and proper markings of hazardous areas may be sufficient. This analysis tool is designed to identify the hazardous exposure regions around an operating antenna system in accordance with the defined power density limits in CFR 47, part 1.1310 and OET bulletin 65.

12 Conclusion

Based upon the above analysis, it is concluded that harmful levles of radiation may exist in those regions noted for both the Controlled and Uncontrolled environment.

The antenna will either be installed on the roof of a buiding, the roof of a vehicle, or on the ground. A ground mounted antenna earth station will be surrounded by a fence, which will restrict any public access. All earth stations will be 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 might be working or otherwise present in or near the direct path of the main beam.

The applicant will ensure the main beam of the antenna will be pointed at least one diameter away from any building, or other obstacles in those areas that exceed the MPE levels. Since one diameter removed from the center of the main beam will lower levels by at least 20 dB, or by a factor of 100, these potential hazards do not exist for eihter the public, or for the earth station personnel.

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. The transmitter will be turned off during periods of maintenance, so that the MPE standard of 5.0 mW/cm² will be complied with for those regions in close proximity to the main reflector, which could be occupied by operating personnel.

RADIATION HAZARD EVALUATION

For

Suman **3.7** **Site Id: Remote**

Antenna Id: REM3_7A

1 Overview

Determining the region around an antenna where radiation hazardous to human health is a consideration of many factors. With a parabolic dish antenna, the region is highly directional and the actual hazardous region is dependent on the antenna elevation angle. The following formulae are used to determine the near and far field regions. These regions are in the main beam of the radiation pattern, which we will assume consists of a conical angle extending +/- 3 degrees from the center axis of the antenna.

The analysis contained herein predicts the radiation levels around the proposed antenna. The calculations contained in this report are in accordance with FCC guidelines as contained in CFR 47 Part 1.1310 and OET Bulletin 65. The maximum level of non-ionizing radiation to which the general public is exposed is defined for controlled and uncontrolled environments as follows:

	Exposure Limit	
Environment	Power	Duration
Controlled - (applicable to system operators and technicians in the service area of the antenna):	**5 mW/cm^2**	**6 Minutes**
Uncontrolled - (applicable to general public in proximity of the antenna):	**1 mW/cm^2**	**30 Minutes**

2.1 Earth Station Technical Parameters - Input Data

1A	Antenna Diameter - Standard Parabola	3.7	meters
1B	Antenna Diameter - Elliptical Reflector		meters
1B1	Major Axis Diameter		meters
1B2	Minor Axis Diameter		meters
2	G = Antenna Isotropic Gain	52.3	dBi
3	h = Nominal Antenna Efficiency	68	Percent
4	Nominal Frequency	14.25	GHz
5	Maximum Transmit Power Amplifier Size	360.00	Watts
6	Number of Carriers	1	each
7	W/G Loss from Transmitter to Feed	0	dB
8	Multicarrier Fixed Backoff	0	dB
9	Desired Object Clearance Height	2	meters

2.2 Earth Station Technical Parameters - Calculated Data

10	A = Antenna Surface Area	10.75	sq meters		
10A	Standard Parabolic Reflector	10.75210086	sq meters		
10B	Elliptical Reflector	0.00	sq meters		
11	D = Effective Antenna Diameter	3.7	meters		
12	Total Transmit Power	360.00	Watts		
13	P = Total Feed Input Power (watts)	360.00	Watts		
14	E = Maximum E/S EIRP - Calculated	77.86	dBW		
15	λ = Wavelength (= c/f in m/GHz)	0.0210	m/GHz		
16	p = Pi	3.14159			
17	R_{nf} = Near Field Limit ($D^2/4\lambda$)	163	meters	535	feet
18	R_{ff} = Far Field Limit (R_{ff}=0.6D2/λ)	390	meters	1280	feet
19	R_{nf} to R_{ff} = Transition Region	163 to 390	meters	535 to 1280	feet

3 Power Density at the Antenna Surface

The power density at the reflector surface is expected to exceed the safe limits. The reflector is not accessible to the public and will not present a hazard. Terminal operators and technicians receive training identifying the area as presenting high exposure levels. Procedures are incorporated requiring that transmitters are not operating when access to the reflector surface is required.

The power density at the antenna reflector surface can be calculated by the expression:

PD_{REFL} = 4P/A = **13.39 mW/cm^2**

Where: P = Total power at the feed, milliwatts

A = Total area of reflector, sq cm

Evaluation:

Controlled Environment (less than 5 mW/cm^2 in 6 minutes): **HAZARD**

Uncontrolled environment (less than 1 mW/cm^2 in 30 minutes): **Mitigation Required**

4 On-Axis Power Density in the Near Field Region

The Radiating Near Field Region for a parabolic, circular reflector, is defined as extending from the reflector to a distance equal to the diameter squared divided by twice the wavelength. This distance is referred to as the Rayleigh distance. In this region the power is nearly all contained within a cylinder of radius 0.5D. As a safety measure the highest possible power density is applied to the whole of this region.

The power density in the Near Field Region of the antenna can be calculated by the expression:

$16*P*h/\pi*D^2 =$ **9.11 mW/cm^2**

Where: P = Total power at the feed, milliwatts
h = Nominal antenna efficiency
D = Effective antenna diameter, meters

Evaluation:

Controlled Environment (less than 5 mW/cm^2 in 6 minutes): **HAZARD**

Uncontrolled environment (less than 1 mW/cm^2 in 30 minutes): **Mitigation Required**

5 On-Axis Power Density in the Transition Region

The transition region is located between the Near Field and Far Field regions. The power density begins to vary inversely with distance from the antenna in the transition region. The maximum power density in this region will not exceed the power density calculated for the Near Field region. Once again the power density figures are for the On-Axis and contained with a cylinder extending within +/- 1 degree of beam center. Where the antennas are normally operated at an elevation angle typically greater than 10°, the actual safe distance in front of the antenna may be found in paragraph 10. The formula for the calculation is used to evaluate the power density at any given distance in the transition as expressed below:

The power density in the On-Axis Transition Region can be calculated by the expression:

$PD_t=(PD_{nf})(R_{nf})/R$

Where: PD_{nf} = The Near Field power density, mW/cm^2
R_{nf} = Near Field maximum distance, meters
R = Distance to point of interest

For: 163 < R < 390 meters

Evaluation:

Controlled Environment Safe Operating Distance, meters: **297 meters**

Uncontrolled environment Safe Operating Distance, meters: **1485 meters**

6 On-Axis Power Density in the Far Field Region

The On-Axis power density in the far field region (PD_{ff}) varies inversely with the square of the distance. The calculation is performed below:

The Power Density at the start of the Far Field region can be calculated by the expression:

$E-10\log(4pR^2)$ 15.05 dBW/m^2

$antilog((E-10\log(4pR^2)/10)/10$ **3.20 mW/cm^2**

Evaluation:

Controlled Environment (less than 5 $mW/cm^{2 \text{ in}}$ 6 minutes): **SAFE**

Uncontrolled environment (less than 1 mW/cm^2 in 30 minutes): **Mitigation Required**

7 Off-Axis Power Density Levels at the Far Field Limit and Beyond

In the far field region, the power is distributed in a pattern of sidelobes as a function of the off-axis angle between the antenna center line and the point of interest. Off-axis power density in the far field can be estimated using the antenna radiation patterns prescribed for the antenna in use. Usually this will correspond to the antenna gain pattern envelope defined by the FCC or the ITU, which takes the form of:

$G_{off} = 32 - 25\log(\theta)$

for θ from 1 to 48 degrees; -10 dBi from 48 to 180 degrees
(Applicable for commonly used satellite transmit antennas)

For example: At one (1) degree off axis At the far-field limit, we can calculate the power density as:

$G_{off} = 32 - 25\log(1) = 32 - 0$ dBi = 1585 numeric

$PD_{1\ deg\ off\text{-}axis} = PD_{ff} x\ 1585/G$ **0.0299 mW/cm^2**

Evaluation:

Considering that satellite antenna beams are aimed skyward, power density in the far field will usually not be a problem except at low look angles. In these cases, off axis gain reduction techniques may be used to further reduce the power density levels.

8 Off-Axis Power Density Levels at the Near Field and Transitional Regions

According to Bulletin 65, off-axis calculations in the near field may be performed as follows: assuming that the point of interest is at least one antenna diameter removed from the center of the main beam, the power density at that point is at least a factor of 100 (20 dB) less than the value calculated for the near field main beam power density. This may be calculated as follows:

$PD_{nf(off\text{-}axis)} = PD_{nf}/100 =$ **0.0911 mW/cm^2**

9 Region Between the Feed Horn and Reflector/Sub-Reflector

Transmissions from the feed horn are directed toward the main reflector or the sub-reflector depending on the type of antenna (prime focus, Gregorian or Cassegrain). The transmission is confined within a conical shape defined by the

feed horn. The energy between the feedhorn and the reflector/sub-reflector is assumed to be in excess of any limit for permissible exposure. This region is not accessible to the general public, and operators and technicians should be suitable trained and procedures in place to preclude access to this region during active transmission.

10 Evaluation of Safe Occupancy Area in Front of the Antenna

The distance (L) from a vertical axis passing through the dish center to a safe off-axis point in front of the antenna can be determined based on the dish diameter. Assuming a flat terrain and a point on the horizontal plane with the center point of the antenna, the relationship is determined by the following formula:

L = (D/sin a) + (2h - D - 2)/(2 tan a)

Where: a = minimum elevation angle of antenna
D = Dish diameter in meters
h = Maximum height of object to be cleared, meters

For distances equal to or greater than determined by the equation above, the radiation hazard will be below safe levels

For: D = 3.7 meters
h= 2 meters

Safe distance for the following elevation angles (a):

a - Elevation Angle (degrees)	L - Safe Distance		
10	**16.49**	**meters**	
15	**11.12**	**meters**	
20	**8.48**	**meters**	
25	**6.93**	**meters**	
30	**5.93**	**meters**	
40	**4.74**	**meters**	
50	**4.12**	**meters**	
5.00	**32.74**	**meters**	**Site Specific**

11 Mitigation Analysis

Mitigation of accessibility to hazardous regions may take several forms depending on the antenna application and location. In instances such as mobile applications, the antenna may be located such that the hazardous region is not accessible during operation. An example may be in a mobile configuration where the antenna is located on top of a vehicle during operation. In other fixed installation instances the hazardous area may be fenced off to prevent access. In areas where only operators and technicians have access, training in safeguards and proper markings of hazardous areas may be sufficient. This analysis tool is designed to identify the hazardous exposure regions around an operating antenna system in accordance with the defined power density limits in CFR 47, part 1.1310 and OET bulletin 65.

12 Conclusion

Based upon the above analysis, it is concluded that harmful levles of radiation may exist in those regions noted for both the Controlled and Uncontrolled environment.

The antenna will either be installed on the roof of a buiding, the roof of a vehicle, or on the ground. A ground mounted antenna earth station will be surrounded by a fence, which will restrict any public access. All earth stations will be 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 might be working or otherwise present in or near the direct path of the main beam.

The applicant will ensure the main beam of the antenna will be pointed at least one diameter away from any building, or other obstacles in those areas that exceed the MPE levels. Since one diameter removed from the center of the main beam will lower levels by at least 20 dB, or by a factor of 100, these potential hazards do not exist for eihter the public, or for the earth station personnel.

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. The transmitter will be turned off during periods of maintenance, so that the MPE standard of 5.0 mW/cm² will be complied with for those regions in close proximity to the main reflector, which could be occupied by operating personnel.