Radiation Hazard Analysis

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This analysis predicts the radiation levels around a proposed earth station complex, comprised of one (reflector) type antenna. This report is developed in accordance with the prediction methods contained in OET Bulletin No. 65, Evaluating Compliance with FCC Guidelines for Human Exposure to Radio Frequency Electromagnetic Fields, Edition 97-01, pp 26-30. The maximum level of non-ionizing radiation to which employees may be exposed is limited to a power density level of 5 milliwatts per square centimeter (5 mW/cm^2) averaged over any 6 minute period in a controlled environment and the maximum level of non-ionizing radiation to which the general public is exposed is limited to a power density level of 1 milliwatt per square centimeter (1 mW/cm^2) averaged over any 30 minute period in a uncontrolled environment. Note that the worse-case radiation hazards exist along the beam axis. Under normal circumstances, it is highly unlikely that the antenna axis will be aligned with any occupied area since that would represent a blockage to the desired signals, thus rendering the link unusable.

Earth Station Technical Parameter Table

Antenna Aperture Size	0.152m x 0.152m
Antenna Effective Diameter	0.172 meters
Antenna Surface Area	0.023 sq. meters
Antenna Isotropic Gain	24.0 dBi
Number of Identical Adjacent Antennas	1
Nominal Antenna Efficiency (ε)	0.38
Nominal Frequency	14.25 GHz
Nominal Wavelength (λ)	0.0211 meters
Maximum Transmit Power / Carrier	8.0 Watts
Number of Carriers	1
Total Transmit Power	8.0 Watts
W/G Loss from Transmitter to Feed	0 dB
Total Feed Input Power	8.0 Watts
Radome Losses	0.5 dB
Effective RF Power at radome	7.13 Watts
Near Field Limit	$R_{nf} = D^2/4\lambda$ = 0.35 meters
Far Field Limit	$R_{ff} = 0.6\ D^2/\lambda$ = 0.84 meters
Transition Region	R_{nf} to R_{ff}

In the following sections, the power density in the above regions, as well as other critically important areas will be calculated and evaluated. The calculations are done in the order discussed in OET Bulletin 65.

1.0 At the Antenna Surface

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

PD_{as} = 4P/A = **138.504** mW/cm^2 (1)

Where: P = total power at feed, milliwatts

A = Total area of reflector, sq. cm

In the normal range of transmit powers for satellite antennas, the power densities at or around the reflector surface is expected to exceed safe levels. This area will not be accessible to the general public.

This antenna will incorporate a radome which has 0.5 dB of loss. The worst case power density at the surface of the radome is shown below:

$PD_{radome}=4P_{rad}/A$ = **123.442** mW/cm² (2)
Where: Prad = total power at feed less radome losses, milliwatts
A = Total area of reflector, sq. cm (this would represent worst case)

Operators and technicians should receive training specifying this area as a high exposure area. Procedures must be established that will assure that all transmitters are rerouted or turned off before access by maintenance personnel to this area is possible.

2.0 On-Axis Near Field Region

The geometrical limits of the radiated power in the near field approximate a cylindrical volume with a diameter equal to that of the antenna. In the near field, the power density is neither uniform nor does its value vary uniformly with distance from the antenna. For the purpose of considering radiation hazard it is assumed that the on-axis flux density is at its maximum value throughout the length of this region. The length of this region, i.e., the distance from the antenna to the end of the near field, is computed as Rnf above.

The maximum power density in the near field is given by:

$PD_{nf} = (16\varepsilon P)/(\pi D^2)$ = **47.334** mW/cm² (3)
from 0 to 0.35 meters

Evaluation
Uncontrolled Environment: **Does Not Meet Uncontrolled Limits**
Controlled Environment: **Does Not Meet Controlled Limits**

3.0 On-Axis Transition Region

The transition region is located between the near and far field regions. As stated in Bulletin 65, the power density begins to vary inversely with distance in the transition region. The maximum power density in the transition region will not exceed that calculated for the near field region, and the transition region begins at that value. The maximum value for a given distance within the transition region may be computed for the point of interest according to:

PD_{tr} = $(PD_{nf})(R_{nf})/R$ = dependent on R (4)
where: PD_{nf} = near field power density
R_{nf} = near field distance
R = distance to point of interest
PD_{tr} = **47.334** mW/cm²
For: 0.35 < R < 0.84 meters

We use Eq (4) to determine the safe on-axis distances required for the two occupancy conditions:

Evaluation

Uncontrolled Environment Safe Operating Distance, (meters), R_{safeu}: 16.5
Controlled Environment Safe Operating Distance, (meters), R_{safec}: 3.31

4.0 On-Axis Far-Field Region

The on- axis power density in the far field region (PD_{ff}) varies inversely with the square of the distance as follows:

PD_{ff} = $PG/(4\pi R^2)$ = dependent on R (5)
where: P = total power at feed
G = Numeric Antenna gain in the direction of interest relative to isotropic radiator
R = distance to the point of interest
For: $R > R_{ff}$ = 0.84 meters
PD_{ff} = **20.277** mW/cm² at R_{ff}

We use Eq (5) to determine the safe on-axis distances required for the two occupancy conditions:

Evaluation

Uncontrolled Environment Safe Operating Distance,(meters), R_{safeu} : See Section 3
Controlled Environment Safe Operating Distance,(meters), R_{safec} : See Section 3

5.0 Off-Axis Levels at the Far Field Limit and Beyond

In the far field region, the power is distributed in a pattern of maxima and minima (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)

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, the off axis gain reduction may be used to further reduce the power density levels.

For example: At two (2) degrees off axis At the far-field limit, we can calculate the power density as:

$G_{off} = 32 - 25\log(2) = 32 - 7.52$ dBi = 280.2 numeric

$PD_{2\ deg\ off\text{-}axis} = PD_{ff} \times 280.2/G$ = **22.616** mW/cm² **(6)**

6.0 Off-Axis power density in 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 equivalent on-axis power density in the main beam. Therefore, for regions at least D meters away from the center line of the dish, whether behind, below, or in front under of the antenna's main beam, the power density exposure is at least 20 dB below the main beam level as follows:

$PD_{nf(off\text{-}axis)} = PD_{nf} / 100 =$ **0.473** mW/cm^2 at D off axis (7)

See Section 7 for the calculation of the distance vs. elevation angle required to achieve this rule for a given object height.

7.0 Evaluation of Safe Occupancy Area in Front of Antenna

The distance (S) from a vertical axis passing through the dish center to a safe off axis location in front of the antenna can be determined based on the dish diameter rule (Item 6.0). Assuming a flat terrain in front of the antenna, the relationship is:

$S = (D/ \sin \alpha) + (2h - D - 2)/(2 \tan \alpha)$ (8)

Where: α = minimum elevation angle of antenna
D = dish diameter in meters
h = maximum height of object to be cleared, meters

For distances equal or greater than determined by equation (8), the radiation hazard will be below safe levels for all but the most powerful stations (> 4 kilowatts RF at the feed).

For	D =	0.172 meters
	h =	2.0 meters, delta between antenna and object >1 m
Then:		
	α	S
	10	0.5 meters
	15	0.3 meters
	20	0.3 meters
	25	0.2 meters
	30	0.2 meters

8.0 Summary of Results

The earth station site will be protected from uncontrolled access by virtue of the fact that it will be mounted on the roof of a vehicle. There will also be proper emission warning signs placed and all operating personnel will be aware of the human exposure levels at and around the earth station. The applicant agrees to abide by the conditions specified in Condition 5208 provided below:

> *Condition 5208 - The licensee shall take all necessary measures to ensure that the antenna does not create potential exposure of humans to radiofrequency radiation in excess of the FCC exposure limits defined in 47 CFR 1.1307(b) and 1.1310 wherever such exposures might occur. Measures must be taken to ensure compliance with limits for both occupational/controlled exposure and for general population/uncontrolled exposure, as defined in these rule sections. Compliance can be accomplished in most cases by appropriate restrictions such as fencing. Requirements for restrictions can be determined by predictions based on calculations, modeling or by field measurements. The FCC's OET Bulletin 65 (available on-line at www.fcc.gov/oet/rfsafety) provides information on predicting exposure levels and on methods for ensuring compliance, including the use of warning and alerting signs and protective equipment for worker.*

The table below summarizes all of the above calculations.

Parameter	Abbr.		Units	Formula
Antenna Diameter	Df	0.172	meters	
Antenna Centerline	h	2	meters	
Antenna Surface Area	Sa	0.023	$meter^2$	$(\pi * Df^2)/4$
Antenna Ground Elevation	GE	2	meters	
Frequency of Operation	f	14.25	GHz	
Wavelength	λ	0.0211	meters	
HPA Output Power	P_{HPA}	8	watts	
HPA to Antenna Loss	L_{Tx}	0	dB	
Transmit Power at Flange	P	8	watts	$P/10Log^{-1}(L_{Tx}/10)$
Effective Power after Radome		7.13	watts	$P/10Log^{-1}$(Radome Loss/10)
Antenna Gain	G_{es}	24	dBi	does not include radome loss
		251.2	n/a	
Antenna Aperature Efficiency	η	38%	n/a	
1. Reflector Surface Region Calculations				
Reflector Surface Power Density	Pdas	1385.0	W/m^2	$(16 * P)/(\pi * D^2)$
		138.50	mW/cm^2	
Power at Radome Surface	Pdrad	1234.4	W/m^2	$(16 * P)/(\pi * D^2)$
(outside radome)		123.44	mW/cm^2	**Does not meet controlled limits** **Does not meet uncontrolled limits**
2. On Axis Near Field Calculations				
Extent of Near Field	Rn	0.35	meters	$D^2 / (4 * \lambda)$
		1.15	feet	
Near Field Power Density	PDnf	473.3	w/m^2	$(16 * \eta * P)/(\pi * D^2)$
		47.33	mW/cm^2	**Does not meet controlled limits** **Does not meet uncontrolled limits**
3. On Axis Transition Region Calculations				
Extent of Transition Region (min)	R_{Tr}	0.35	meters	$D^2 / (4 * \lambda)$
Extent of Transition Region (min)		1.15	feet	
Extent of Transition Region (min)	R_{Tr}	0.84	meters	$0.6 * D^2 / \lambda$
Extent of Transition Region (max)		2.76	feet	
Worst Case Transition Region Power Density	PD_{tr}	473.3	w/m^2	
		47.33	mW/cm^2	**Does not meet controlled limits** **Does not meet uncontrolled limits**
Uncontrolled enviorment safe operating distanc	Rsu	16.54	meters	$(PD_{nf})/R_{nf})/Rsu$
Controlled enviorment safe operating distance	Rsc	3.31	meters	$(PD_{nf})/R_{nf})/Rsc$
4. On Axis Far Field Calculations				
Distance to Far Field Region	Rf	0.84	meters	$0.6 * D^2 / \lambda$
		2.76	feet	
On Axis Power Density in the Far Field	PD_{ff}	202.77	W/m^2	$(G_{es} * P) / (4 * \pi * Rf^2)$
		20.28	mW/cm^2	**Does not meet controlled limits** **Does not meet uncontrolled limits**
5. Off-axis Power Density in the Far Field Limit and Beyond				
Reflector Surface Power Density	PDs	226.16	W/m^2	$(G_{es} * P) / (4 * \pi * Rf^2) * (Goa/Ges)$
Goa/Ges at a sample angle of θ 2 degrees		0.498		Goa = 32 - 25*log(θ)
		22.62	mW/cm^2	**Does not meet uncontrolled limits**
6. Off Axis Power Density in the Near Field and Transitional Region Calculations				
Power Density of Wn/100 for 1 diameter	PDs	4.733	W/m^2	$[(16 * \eta * P)/(\pi * D^2)] / 100$
removed		0.473	mW/cm^2	**Meet uncontrolled limits**
7.0 Off-axis Safe Distances from Earth Station				
minimum elevation angle of antenna	α	10	degree	
hieght of object to be cleared	h	2	meter	
Groun elevation delta antenna-obstacle elevation ang	**GD**	**S**		
	10	0.5	meter	S=(D/sinα) + (2h - D- 2) / (2tanα)
	15	0.3	meter	
	20	0.3	meter	
	25	0.2	meter	
	30	0.2	meter	

Note: Maximum FCC power density limits for 6GHz is 1mW/cm2 for general population exposure as per FCC OS&T Bulletin No. 65, Edition 97-01 August 1997, Appendix A page 67.