Radiation Hazard Analysis
NYS Div. of Homeland Security and Emergency Services
3.8m Ku-Band Earth Station in Patroon Creek, NY

This analysis predicts the radiation levels around a proposed satellite terminal, comprised of one antenna which will be tested in a fixed environment. 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 9-01, 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 an 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.

Satellite Terminal Technical Parameter Table

Antenna Actual Diameter	3.8 meters
Antenna Surface Area	11.34 $meters^2$
Antenna Isotropic Gain	52.4 dBi
Number of Identical Adjacent Antennas	1
Nominal Antenna Efficiency	65%
Nominal Frequency	14.125 GHz
Nominal Wavelength	0.0212 meters
Maximum Transmit Power/Carrier	40 watts
Number of Carriers	1
Total Transmit Power	40 watts
W/G Loss from Transmitter to Feed	0.5 dB
Total Feed Input Power	35.65 watts
Near Field Limit	169.97 meters
Far Field Limit	407.93 meters
Transition Region	169.97 to 407.93 meters

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:

$PD_{refl} = 4P/A = 1.26$ mW/cm^2
Where: P = total power at feed in milliwatts
A = Total area of reflector in square centimeters

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. Operators and technicians shall receive training specifying this area as a high exposure area. Procedures will 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 R_{nf} above.

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

$PD_{nf} =$ 0.649 mW/cm^2
From 0 to 169.97 meters

Evaluation:

Uncontrolled Environment:	Meets Controlled Limits
Controlled Environment:	Meets 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:

$PD_t = (PD_{nf} * R_{nf})/R$ = dependent on R (1)
Where: PD_{nf} = near field power density
R_{nf} = near field distance
R = distance to point of interest
For: $169.97 < R < 407.93$ meters

We use Equation (1) to determine the safe on-axis distance required for the two occupancy conditions.

Uncontrolled Environment Safe Operating Distance, $R_{safe,u}$: 110.3 meters
Controlled Environment Safe Operating Distance, $R_{safe,c}$: 22.1 meters

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:

$PD_{ff} = (P*G)/(4*pi*R^2)$ = dependent on R
Where: P = total power at feed
G = numeric antenna gain in the direction of interest relative to isotropic radiator
R = distance to point of interest
For: $R > R_{ff} = 407.93$ meters

$PD_{ff} = 0.278\ mW/cm^2$ at R_{ff}

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 (side lobes) 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 1 < theta < 48 degrees; -10 dBi from 48 < theta < 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 1 degree off-axis at the far field limit we can calculate the power density as:

G_{off} = 32 - 25*log(theta) = 32 - 0 dBi = 1585 numeric
PD(1 deg. off-axis) = PD_{ff} * 1585/G = 0.0025 mW/cm^2

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 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-axis) = PD_{nf}/100 = 0.00649 mW/cm^2 at D off-axis

See Section 7 for the calculation for 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:

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

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

For distances equal to or greater than determined by Equation (2) the radiation hazard will be below safe levels.

For: D = 3.8 meters
h = 2 meters

Then:

alpha	S
6.5	16.92
15	7.59
20	5.89
25	4.92
35	3.91

The operational area proposed for this terminal will not involve antenna elevation angles less than 6.55 degrees so the minimum separation distance between the terminal and the general public is 16.92 meters. Suitable fencing or other barriers will be provided to prevent casual occupancy of the area in front of the antenna within the limits prescribed above at the lowest elevation angle required.

Summary

The earth station will be protected from uncontrolled access with suitable fencing and other barrier walls. 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 terminal. 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 workers.

The following table summarizes all of the above calculations:

Parameter	Abbr.		Units	Formula
Dish #		Hub		
Antenna Diameter	Df	3.8	meters	
Antenna Centerline	h	2.0	meters	
Antenna Surface Area	Sa	11.3	meters^2	$(\pi * Df^2)/4$
Antenna Ground Elevation	GE	0.0	meters	
Frequency of Operation	f	14.125	GHz	
Wavelength	λ	0.0212	meters	c / f
HPA Output Power	P_{HPA}	40.0	watts	
HPA to Antenna Loss	L_{tx}	0.50	dB	(! dB Radome Loss) P = 2.4 watts
Transmit Power at Flange	P	15.5	dBW	$10 * Log(P_{HPA}) - L_{tx}$
		35.65	watts	
Antenna Gain	G_{es}	52.4	dBi	
		205359.5	n/a	
PI	π	3.1415927	n/a	
Antenna Aperture Efficiency	η	65.00%	n/a	$G_{es} / (PI * Df / \lambda)^2$
1. Reflector Surface Region Calculations				
Reflector Surface Power Density	PDas	12.57	W/m^2	$(16 * P)/(\pi * D^2)$
		1.257	mW/cm^2	**Does Not Meet Uncontrolled Limits**
				Meets Controlled Limits
2. On-Axis Near Field Calculations				
Extent of Near Field	Rn	169.97	meters	$D^2 / (4 * \lambda)$
		557.50	feet	
Near Field Power Density	PDnf	6.49	W/m^2	$(16 * \eta * P) / (\pi * D^2)$
		0.649	mW/cm^2	**Meets Controlled Limits**
				Meets Controlled Limits
3. On-Axis Transition Region Calculations				
Extent of Transition Region (min)	Rtr	169.97	meters	$D^2 / (4 * \lambda)$
Extent of Transition Region (min)		557.50	feet	
Extent of Transition Region (max)	Rtr	407.93	meters	$(0.6 * D^2) / \lambda$
Extent of Transition Region (max)		1338.01	feet	
Worst Case Transition Region Power Density	PDtr	6.49	W/m^2	$(16 * \eta * P) / (\pi * D^2)$
		0.649	mW/cm^2	**Meets Controlled Limits**
				Meets Controlled Limits
Uncontrolled Environment Safe Operating Distanc	Rsu	110.3	m	=(PDnf)*(Rnf)/Rsu
Controlled Environment Safe Operating Distance	Rsc	22.1	m	=(PDnf)*(Rnf)/Rsc
4. On-Axis Far Field Calculations				
Distance to the Far Field Region	Rf	407.9	meters	$(0.6 * D^2) / \lambda$
		1338.01	feet	
On-Axis Power Density in the Far Field	PDff	2.78	W/m^2	$(G_{es} * P) / (4 * \pi * Rf^2)$
		0.278	mW/cm^2	**Meets Controlled Limits**
				Meets Controlled Limits
5. Off-Axis Levels at the Far Field Limit and Beyond				
Reflector Surface Power Density	PDs	0.025	W/m^2	$(G_{es} * P) / (4 * \pi * Rf^2) * (Goa/Ges)$
Goa/Ges at example angle θ 1 degree		0.009		Goa = 32 - 25*log(θ)
		0.0025	mW/cm^2	**Meets Controlled Limits**
6. Off-axis Power Density in the Near Field and Transitional Regions Calculations				
Power density 1/100 of Wn for one diameter removed	PDs	0.0649	W/m^2	$((16 * \eta * P) / (\pi * D^2))/100$
		0.00649	mW/cm^2	**Meets Controlled Limits**
7. Off-Axis Safe Distances from Earth Station				S = (D/ sin α) + (2h - D - 2)/(2 tan α)
α = minimum elevation angle of antenna		6.5	deg	
h = maximum height of object to be cleared, meters		2.0	m	
GD = Ground Elevation Delta antenna-obstacle		1.0	m	
elevation angle	6.5	16.92	m	
	15	7.59	m	
	20	5.89	m	
	25	4.92	m	
	35	**3.91**	m	