Radiation Hazard Analysis NYS Div. of Homeland Security and Emergency Services 2.4m Ku-Band Earth Station in Newark, 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/cm²) 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/cm²) 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	2.4 meters
Antenna Surface Area	4.52 meters^2
Antenna Isotropic Gain	49 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	16 watts
Number of Carriers	1
Total Transmit Power	16 watts
W/G Loss from Transmitter to Feed	0.5 dB
Total Feed Input Power	14.26 watts
Near Field Limit	67.8 meters
Far Field Limit	162.72 meters
Transition Region	67.8 to 162.72 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:

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

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:

$$PD_{nf} = 0.651 \text{ mW/cm}^2$$

From 0 to 67.8 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:

$$\begin{split} PD_t &= (PD_{nf} * R_{nf})/R = \text{dependent on } R \ (1) \\ \text{Where: } PD_{nf} &= \text{near field power density} \\ R_{nf} &= \text{near field distance} \\ R &= \text{distance to point of interest} \\ \text{For: } & 67.8 < R < 162.72 \text{ meters} \end{split}$$

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

Uncontrolled Environment Safe Operating Distance, Rsafe,u:	44.1 meters
Controlled Environment Safe Operating Distance, Rsafe,c:	8.8 meters

4.0 On-Axis Far Field Region

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

$$\begin{split} PD_{\rm ff} &= (P^*G)/(4^*pi^*R^2) = \text{dependent on } R \\ Where: P &= \text{total power at feed} \\ G &= \text{numeric antenna gain in the direction of interest relative to isotropic radiator} \\ R &= \text{distance to point of interest} \\ For: R &> R_{\rm ff} = 162.72 \text{ meters} \end{split}$$

 $PD_{\rm ff} = 0.279 \text{ mW/cm}^2 \text{ at } R_{\rm ff}$

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:

$$\begin{split} G_{off} = 32 - 25*log(theta) \\ For \ 1 < theta < 48 \ degrees; \ -10 \ dBi \ from \ 48 < theta < 180 \ degrees \\ (Applicable \ for \ commonly \ used \ satellite \ transmit \ antennas) \end{split}$$

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 = 0.0056 mW/cm2

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:

 $PD_{nf}(off-axis) = PD_{nf}/100 = 0.00651 \text{ mW/cm}^2 \text{ at } D \text{ off-axis}$

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)/(2tan(alpha)) (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 = 2.4 meters		
	h = 2 m	eters	
Then:	alpha	S	
	8.7	7.99	
	15	4.79	
	20	3.72	
	25	3.11	
	35	2.47	

The operational area proposed for this terminal will not involve antenna elevation angles less than 8.7 degrees so the minimum separation distance between the terminal and the general public is 7.99 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 site 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 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 workers.

The following table summarizes all of the above calculations:

Dah # Hub Hub Datema Dimeter Df 2.4 meters Antema Centerline h 2.0 meters Antema Surface Area Sa 4.5 meters Antema Surface Area Sa 4.5 meters Frequency of Operation f 14.125 GHz Wavelength A 0.0212 meters $(/f T)^2 / 4$ HPA Output Power Pmp, 16.0 watts HPA O Antenna Loss L_a 0.05 dBW 10 * LogP ₁₀₀ > L_a Antenna Aperture Efficiency n 14.26 watts Reflector Surface Region Calculations Extent of Narr Field Calculations 2. On-Axis Near Field Calculations Extent of Narr Field Calculations 2. On-Axis Near Field Calculations Stand of Transition Region (max) <th>Parameter</th> <th>Abbr.</th> <th></th> <th>Units</th> <th>Formula</th>	Parameter	Abbr.		Units	Formula
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An one of the second	Near Field Power Density	PDnf	6.51	W/m ²	(16 * η * P)/ (π *D ²)
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Distance to the Far Field Region Rf 162.7 meters $(0.6 * D^2)/\lambda$ On-Axis Power Density in the Far Field PDff 2.79 W/m ² $(G_{es} * P) / (4 * \pi * Rf^2)$ On-Axis Power Density in the Far Field Limit and Beyond Meets Controlled Limits S. Off-Axis Levels at the Far Field Limit and Beyond Meets Controlled Limits Reflector Surface Power Density PDs 0.056 W/m ² $(G_{es} * P) / (4 * \pi * Rf^2)*(Goa/Ges)$ Goa/Ges at example angle θ 1 degree 0.0000 Goa = 32 · 25*log(θ) Meets Controlled Limits 6. Off-axis Power Density in the Near Field and Transitional Regions Calculations Meets Controlled Limits Meets Controlled Limits Power density 1/100 of Wn for one diameter removed PDs 0.0651 W/m ² ((16 * η * P) / (π *D ²))/100 7. Off-Axis Safe Distances from Earth Station S = (D / sin α) + (2h - D - 2)/(2 tan α) S = (D / sin α) + (2h - D - 2)/(2 tan α) α = minimum elevation angle of antenna 8.7 deg Meets Controlled Limits G = Ground Elevation Delta antenna-obstacle 1.0 m Ge $\alpha = 0.051$ 8.7 7.99 m 20 $\alpha = 0.051$ 3.11 m 20 <td>Controlled Environment Safe Operating Distance</td> <td>Rsc</td> <td>8.8</td> <td>m</td> <td>=(PDnf)*(Rnf)/Rsc</td>	Controlled Environment Safe Operating Distance	Rsc	8.8	m	=(PDnf)*(Rnf)/Rsc
On-Axis Power Density in the Far FieldPDff 533.72 feet0.79W/m²($G_{es} * P) / (4 * \pi * Rf²)$ 0.279mW/cm²Meets Controlled LimitsS. Off-Axis Levels at the Far Field Limit and BeyondMeets Controlled LimitsReflector Surface Power DensityPDs 0.056 W/m²($G_{es} * P) / (4 * \pi * Rf²)*(Goa/Ges)$ Goa/Ges at example angle θ 1 degree 0.020 Goa = $32 - 25*\log(\theta)$ Goa/Ges at example angle θ 1 degree 0.0056 mW/cm²Meets Controlled Limits6. Off-axis Power Density in the Near Field and Transitional Regions CalculationsMeets Controlled LimitsPower density 1/100 of Wn for one diameter removedPDs 0.0651 W/m²($(16 * \eta * P) / (\pi * D²))/100$ 7. Off-Axis Safe Distances from Earth Station $\alpha = minimum elevation angle of antenna8.7degh = maximum height of object to be cleared, meters2.0mGD = Ground Elevation Delta antenna-obstacle1.0melevation angle8.77.99m203.72m203.72m$	4. On-Axis Far Field Calculations				
On-Axis Power Density in the Far Field PDff 2.79 W/m^2 $(G_{es} * P) / (4 * \pi * Rf^2)$ Meets Controlled Limits Meets Controlled Limits S. Off-Axis Levels at the Far Field Limit and Beyond Meets Controlled Limits Reflector Surface Power Density PDs 0.056 W/m^2 $(G_{es} * P) / (4 * \pi * Rf^2)*(Goa/Ges)$ Goa/Ges at example angle θ 1 degree 0.0056 W/m^2 Goa = 32 - 25*log(θ) Goa/Ges at example angle θ 1 degree 0.0056 mW/cm ² Meets Controlled Limits 6. Off-axis Power Density in the Near Field and Transitional Regions Calculations Meets Controlled Limits Meets Controlled Limits 7. Off-Axis Safe Distances from Earth Station PDs 0.0651 W/m^2 $(16 * \eta * P) / (\pi * D^2) / 100$ $\alpha = minimum$ height of object to be cleared, meters 2.0 m $S = (D/ \sin \alpha) + (2h - D - 2)/(2 \tan \alpha)$ $GD = Ground Elevation Delta antenna-obstacle 1.0 m m elevation angle 8.7 7.99 m 20 3.72 m 20 3.72 $	Distance to the Far Field Region	Rf	162.7	meters	$(0.6 * D^2) / \lambda$
0.279mW/cm²Meets Controlled Limits5. Off-Axis Levels at the Far Field Limit and BeyondMeets Controlled Limits8. Reflector Surface Power DensityPDs 0.056 W/m² $(G_{es} * P) / (4 * \pi * Rf²)*(Goa/Ges)$ Goa/Ges at example angle θ 1 degree 0.020 Goa = 32 - 25*log(θ)Goa/Ges at example angle θ 1 degree 0.0056 mW/cm²Meets Controlled Limits6. Off-axis Power Density in the Near Field and Transitional Regions CalculationsMeets Controlled LimitsPower density 1/100 of Wn for one diameter removedPDs 0.0651 W/m² $((16 * \eta * P)/ (\pi * D²))/100$ 7. Off-Axis Safe Distances from Earth Station $\alpha = minimum elevation angle of antenna8.7degdegh = maximum height of object to be cleared, meters2.0mmGD = Ground Elevation Delta antenna-obstacle1.0mm203.72m203.72m203.72m203.72m$			533.72	feet	
S. Off-Axis Levels at the Far Field Limit and BeyondMeets Controlled LimitsReflector Surface Power DensityPDs 0.056 W/m² $(G_{es} * P) / (4 * \pi * Rf²)*(Goa/Ges)$ Goa/Ges at example angle θ 1 degree 0.020 Goa = 32 - 25*log(θ)Goa/Ges at example angle θ 1 degree 0.0056 mW/cm²Meets Controlled Limits6. Off-axis Power Density in the Near Field and Transitional Regions CalculationsMeets Controlled LimitsPower density 1/100 of Wn for one diameter removedPDs 0.0651 W/m² $((16 * \eta * P) / (\pi * D²))/100$ 7. Off-Axis Safe Distances from Earth Station a = minimum elevation angle of antenna8.7degh = maximum height of object to be cleared, meters 2.0 mGD = Ground Elevation Delta antenna-obstacle 1.0 melevation angle 8.7 7.99 m 20 3.72 m 20 3.72 m 25 3.11 m	On-Axis Power Density in the Far Field	PDff	2.79	W/m ²	
5. Off-Axis Levels at the Far Field Limit and Beyond PDs 0.056 W/m^2 $(G_{es} * P) / (4 * \pi * Rf^2)*(Goa/Ges)$ Goa/Ges at example angle θ 1 degree 0.020 Goa = 32 - 25*log(θ) Goa/Ges at example angle θ 1 degree 0.0056 mW/cm^2 Meets Controlled Limits 6. Off-axis Power Density in the Near Field and Transitional Regions Calculations POs 0.0051 W/m^2 $((16 * \eta * P) / (\pi * D^2))/100$ removed 0.00651 W/m^2 $((16 * \eta * P) / (\pi * D^2))/100$ Meets Controlled Limits 7. Off-Axis Safe Distances from Earth Station S = (D / sin α) + (2h - D - 2)/(2 tan α) S = (D / sin α) + (2h - D - 2)/(2 tan α) $\alpha = minimum$ height of object to be cleared, meters 2.0 m GD = Ground Elevation Delta antenna-obstacle 1.0 m elevation angle 8.7 7.99 m 15 4.79 m 20 3.72 m 20 3.72 m 20 3.72 m			0.279	mW/cm ²	
Reflector Surface Power DensityPDs 0.056 W/m^2 $(G_{es} * P) / (4 * \pi * Rf^2)*(Goa/Ges)$ Goa/Ges at example angle $\theta 1$ degree 0.020 Goa = 32 - 25*log(θ)Goa/Ges at example angle $\theta 1$ degree 0.0056 mW/cm^2 Meets Controlled Limits6. Off-axis Power Density in the Near Field and Transitional Regions CalculationsMeets Controlled LimitsPower density 1/100 of Wn for one diameter removedPDs 0.0651 W/m^2 $((16 * \eta * P) / (\pi * D^2))/100$ 7. Off-Axis Safe Distances from Earth Station a = minimum elevation angle of antenna 8.7 deg h = maximum height of object to be cleared, meters GD = Ground Elevation Delta antenna-obstacle 1.0 m15 4.79 m20 3.72 m20 3.72 m20 3.72 m20 3.71 m					Meets Controlled Limits
Goa/Ges at example angle θ 1 degree 0.020 Goa = 32 - 25*log(θ) Meets Controlled Limits Meets Controlled Limits 6. Off-axis Power Density in the Near Field and Transitional Regions Calculations PDs 0.0651 W/m ² ((16 * η * P)/ (π *D ²))/100 Power density 1/100 of Wn for one diameter removed PDs 0.0651 W/m ² ((16 * η * P)/ (π *D ²))/100 7. Off-Axis Safe Distances from Earth Station S = (D / sin α) + (2h - D - 2)/(2 tan α) α = minimum elevation angle of antenna 8.7 deg h = maximum height of object to be cleared, meters 2.0 m GD = Ground Elevation Delta antenna-obstacle 1.0 m elevation angle 8.7 7.99 m 20 3.72 m 20 3.72 m 20 3.72 m 25 3.11 m		ľ –			
0.0056 mW/cm ² Meets Controlled Limits 6. Off-axis Power Density in the Near Field and Transitional Regions Calculations PDs 0.0651 W/m ² $((16 * \eta * P)/(\pi * D^2))/100$ Power density 1/100 of Wn for one diameter removed PDs 0.0651 W/m ² $((16 * \eta * P)/(\pi * D^2))/100$ 7. Off-Axis Safe Distances from Earth Station S = (D/ sin α) + (2h - D - 2)/(2 tan α) S = (D/ sin α) + (2h - D - 2)/(2 tan α) α = minimum elevation angle of antenna 8.7 deg h = maximum height of object to be cleared, meters 2.0 m GD = Ground Elevation Delta antenna-obstacle 1.0 m elevation angle 8.7 7.99 m 20 3.72 m 20 25 3.11 m 1	Reflector Surface Power Density	PDs	0.056	W/m ²	
6. Off-axis Power Density in the Near Field and Transitional Regions Calculations Power density 1/100 of Wn for one diameter removed PDs 0.0651 W/m^2 $((16 * \eta * P)/(\pi * D^2))/100$ Received 0.00651 W/m^2 $((16 * \eta * P)/(\pi * D^2))/100$ Received 0.00651 mW/cm^2 Meets Controlled Limits 7. Off-Axis Safe Distances from Earth Station $S = (D/\sin \alpha) + (2h - D - 2)/(2 \tan \alpha)$ $\alpha =$ minimum elevation angle of antenna 8.7 deg h = maximum height of object to be cleared, meters 2.0 m GD = Ground Elevation Delta antenna-obstacle 1.0 m elevation angle 8.7 7.99 m 20 3.72 m 20 3.72 m 20 3.72 m 20 3.72 m	Goa/Ges at example angle θ 1 degree		0.020		$Goa = 32 - 25*log(\theta)$
Power density 1/100 of Wn for one diameter removed PDs 0.0651 W/m^2 $((16 * \eta * P)/(\pi * D^2))/100$ Rest Controlled Limits Meets Controlled Limits 7. Off-Axis Safe Distances from Earth Station $S = (D/\sin \alpha) + (2h - D - 2)/(2 \tan \alpha)$ $\alpha =$ minimum elevation angle of antenna 8.7 deg h = maximum height of object to be cleared, meters 2.0 m GD = Ground Elevation Delta antenna-obstacle 1.0 m elevation angle 8.7 7.99 m 20 3.72 m 20 3.72 m 20 3.72 m 20 3.71 m			0.0056	mW/cm ²	Meets Controlled Limits
removedNoneMeets Controlled Limits7. Off-Axis Safe Distances from Earth StationS = (D/ sin α) + (2h - D - 2)/(2 tan α) α = minimum elevation angle of antenna8.7degh = maximum height of object to be cleared, meters2.0mGD = Ground Elevation Delta antenna-obstacle1.0melevation angle8.77.99m154.79m203.72m253.11m		Transi	tional Regions Calculat	ions	
removed0.00651 mW/cm^2 Meets Controlled Limits7. Off-Axis Safe Distances from Earth Station $S = (D/\sin \alpha) + (2h - D - 2)/(2 \tan \alpha)$ $\alpha =$ minimum elevation angle of antenna8.7degh = maximum height of object to be cleared, meters2.0mGD = Ground Elevation Delta antenna-obstacle1.0melevation angle8.77.99m154.79m203.72m253.11m	Power density 1/100 of Wn for one diameter	PDs	0.0651	W/m ²	((16 * η * P)/ (π *D ²))/100
7. Off-Axis Safe Distances from Earth Station $S = (D/\sin \alpha) + (2h - D - 2)/(2 \tan \alpha)$ $\alpha = \min$ maximum levation angle of antenna 8.7 deg $h = \max$ maximum height of object to be cleared, meters 2.0 m GD = Ground Elevation Delta antenna-obstacle 1.0 m elevation angle 8.7 7.99 m 15 4.79 m 1.0 1.0 20 3.72 m 1.0 1.0 20 3.72 m 1.0 1.0 20 3.72 m 1.0 1.0 1.0	removed		0.00651	mW/cm ²	Meets Controlled Limits
h = maximum height of object to be cleared, meters 2.0 m GD = Ground Elevation Delta antenna-obstacle 1.0 m elevation angle 8.7 7.99 m 15 4.79 m 20 3.72 m 25 3.11 m	7. Off-Axis Safe Distances from Earth Station				
GD = Ground Elevation Delta antenna-obstacle 1.0 m elevation angle 8.7 7.99 m 15 4.79 m 20 3.72 m 25 3.11 m	α = minimum elevation angle of antenna		8.7	deg	
elevation angle 8.7 7.99 m 15 4.79 m 20 3.72 m 25 3.11 m	h = maximum height of object to be cleared, meter	s	2.0	m	
15 4.79 m 20 3.72 m 25 3.11 m	GD = Ground Elevation Delta antenna-obstacle		1.0	m	
20 3.72 m 25 3.11 m	elevation angle			m	
25 3.11 m			4.79	m	
			3.72	m	
35 2.47 m				m	
		35	2.47	m	