

Radiation Hazard Analysis
New York Department of Homeland Security
Vehicle-Mounted 1.2m Antenna and 16W HPA

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 | 1.2 meters |
| Antenna Surface Area | 1.13 meters ² |
| Antenna Isotropic Gain | 43.5 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 | 16.95 meters |
| Far Field Limit | 40.68 meters |
| Transition Region | 16.95 to 40.68 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:

$$PD_{\text{refl}} = 4P/A = 5.04 \text{ mW/cm}^2$$

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:

$$PD_{\text{nf}} = 2.604 \text{ mW/cm}^2$$

From 0 to 16.95 meters

Evaluation:

| | |
|---------------------------|-----------------------------------|
| Uncontrolled Environment: | Does Not Meet Uncontrolled 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:

$$PD_t = (PD_{nf} * R_{nf})/R = \text{dependent on } R \text{ (1)}$$

Where: PD_{nf} = near field power density

R_{nf} = near field distance

R = distance to point of interest

For: $16.95 < R < 40.68$ meters

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

Uncontrolled Environment Safe Operating Distance, $R_{safe,u}$: 44.1 meters

Controlled Environment Safe Operating Distance, $R_{safe,c}$: 8.8 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:

$$PD_{ff} = (P * G)/(4 * \pi * R^2) = \text{dependent on } R$$

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: $R > R_{ff} = 40.68$ meters

$$PD_{ff} = 1.115 \text{ mW/cm}^2 \text{ at } R_{ff}$$

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:

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

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:

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

$$PD(1 \text{ deg. off-axis}) = PD_{\text{ff}} * 1585/G = 0.079 \text{ mW/cm}^2$$

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:

$$PD_{\text{nf}}(\text{off-axis}) = PD_{\text{nf}}/100 = 0.02604 \text{ mW/cm}^2 \text{ at } D \text{ off-axis}$$

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:

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

Where: α = 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 = 1.2 meters

h = 2 meters

| Then: | α | S |
|-------|----------|------|
| | 5 | 6.91 |
| | 15 | 2.4 |
| | 20 | 1.86 |
| | 25 | 1.55 |
| | 35 | 1.24 |

The operational area proposed for this temporary fixed terminal will not involve antenna elevation angles less than 5 degrees so the minimum separation distance between the terminal and the general public is 6.91 meters. When in operation the terminal will maintain the appropriate safe distance through the use of fencing or other barriers to preclude harmful uncontrolled environment interference. The area near the terminal will not be accessible to the general public and all operating personnel will be aware of the minimum safe distances.

Summary

The satellite terminal will be protected from uncontrolled access while in operation. 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 | 1.2 | meters | |
| Antenna Centerline | h | 2.0 | meters | |
| Antenna Surface Area | Sa | 1.1 | 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} | 16.0 | watts | |
| HPA to Antenna Loss | L _{tx} | 0.50 | dB | (! dB Radome Loss) P = 2.4 watts |
| Transmit Power at Flange | P | 11.5 | dBW | $10 * \text{Log}(P_{HPA}) - L_{tx}$ |
| | | 14.26 | watts | |
| Antenna Gain | G _{es} | 43.5 | dB | |
| | | 20479.1 | 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 | PD _{as} | 50.43 | W/m ² | $(16 * P) / (\pi * D^2)$ |
| | | 5.043 | mW/cm ² | Does Not Meet Uncontrolled Limits |
| | | | | Does Not Meet Controlled Limits |
| 2. On-Axis Near Field Calculations | | | | |
| Extent of Near Field | R _n | 16.95 | meters | $D^2 / (4 * \lambda)$ |
| | | 55.60 | feet | |
| Near Field Power Density | PD _{nf} | 26.04 | W/m ² | $(16 * \eta * P) / (\pi * D^2)$ |
| | | 2.604 | mW/cm ² | Does Not Meet Uncontrolled Limits |
| | | | | Meets Controlled Limits |
| 3. On-Axis Transition Region Calculations | | | | |
| Extent of Transition Region (min) | R _{tr} | 16.95 | meters | $D^2 / (4 * \lambda)$ |
| Extent of Transition Region (min) | | 55.60 | feet | |
| Extent of Transition Region (max) | R _{tr} | 40.68 | meters | $(0.6 * D^2) / \lambda$ |
| Extent of Transition Region (max) | | 133.43 | feet | |
| Worst Case Transition Region Power Density | PD _{tr} | 26.04 | W/m ² | $(16 * \eta * P) / (\pi * D^2)$ |
| | | 2.604 | mW/cm ² | Does Not Meet Uncontrolled Limits |
| | | | | Meets Controlled Limits |
| Uncontrolled Environment Safe Operating Distance | R _{su} | 44.1 | m | $= (PD_{nf}) * (R_{nf}) / R_{su}$ |
| Controlled Environment Safe Operating Distance | R _{sc} | 8.8 | m | $= (PD_{nf}) * (R_{nf}) / R_{sc}$ |
| 4. On-Axis Far Field Calculations | | | | |
| Distance to the Far Field Region | R _f | 40.7 | meters | $(0.6 * D^2) / \lambda$ |
| | | 133.43 | feet | |
| On-Axis Power Density in the Far Field | PD _{ff} | 11.15 | W/m ² | $(G_{es} * P) / (4 * \pi * R_f^2)$ |
| | | 1.115 | mW/cm ² | Does Not Meet Uncontrolled Limits |
| | | | | Meets Controlled Limits |
| 5. Off-Axis Levels at the Far Field Limit and Beyond | | | | |
| Reflector Surface Power Density | PD _s | 0.790 | W/m ² | $(G_{es} * P) / (4 * \pi * R_f^2) * (Goa / Ges)$ |
| Goa/Ges at example angle θ 1 degree | | 0.071 | | $Goa = 32 - 25 * \log(\theta)$ |
| | | 0.0790 | 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 | PD _s | 0.2604 | W/m ² | $((16 * \eta * P) / (\pi * D^2)) / 100$ |
| | | 0.02604 | mW/cm ² | Meets Controlled Limits |
| 7. Off-Axis Safe Distances from Earth Station | | | | |
| | | | | $S = (D / \sin \alpha) + (2h - D - 2) / (2 \tan \alpha)$ |
| α = minimum elevation angle of antenna | | 5.0 | deg | |
| h = maximum height of object to be cleared, meters | | 2.0 | m | |
| GD = Ground Elevation Delta antenna-obstacle | | 1.0 | m | |
| elevation angle | 5.0 | 6.91 | m | |
| | 15 | 2.40 | m | |
| | 20 | 1.86 | m | |
| | 25 | 1.55 | m | |
| | 35 | 1.24 | m | |