

Radiation Hazard Analysis
KVH Industries
H90 ESV

This analysis predicts the radiation levels around a proposed earth station complex, comprised of one (reflector) type antennas. 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/cm²) averaged over any 6 minutes 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 minutes 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.

Earth Station Technical Parameter Table

Antenna Actual Diameter	1.067 meters
Antenna Surface Area	0.894 sq. meters
Antenna Isotropic Gain	42.0 dBi
Number of Identical Adjacent Antennas	1
Nominal Antenna Efficiency (ϵ)	62.4%
Nominal Frequency	14.25 GHz
Nominal Wavelength (λ)	0.0211 meters
Maximum Transmit Power / Carrier	6.0 Watts
Number of Carriers	1
Total Transmit Power	6.0 Watts
W/G Loss from Transmitter to Feed	0.1 dB
Radome Loss	0.7 dB
Total Feed Input Power	5.86 Watts
Near Field Limit	$R_{nf} = D^2/4\lambda = 13.5$ meters
Far Field Limit	$R_{ff} = 0.6 D^2/\lambda = 32.5$ 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:

$$PD_{refl} = 4P/A = 2.6 \text{ mW/cm}^2 \quad (1)$$

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. 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:

$$PD_{nf} = (16\pi P)/(\pi D^2) = \mathbf{1.363 \text{ mW/cm}^2} \quad (2)$$

from 0 to 13.5meters

Evaluation

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

$$PD_t = (PD_{nf})(R_{nf})/R = \text{dependent on } R \quad (3)$$

where: PD_{nf} = near field power density
 R_{nf} = near field distance
 R = distance to point of interest
 For: $13.5 < R < 32.5$ meters

We use Eq (3) to determine the safe on-axis distances required for the two occupancy conditions:

Evaluation

Uncontrolled Environment Safe Operating Distance,(meters), R_{safeu} : 18.4
 Controlled Environment Safe Operating Distance,(meters), R_{safec} : 13.5

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:

$$PD_{ff} = PG/(4\pi R^2) = \text{dependent on } R \quad (4)$$

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: $R > R_{ff} = 32.5$ meters
 $PD_{ff} = 0.584 \text{ mW/cm}^2$ at R_{ff}

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

Evaluation

Uncontrolled Environment Safe Operating Distance (meters), $R_{safeu} = 32.5$ meters
 See Section 3
 Controlled Environment Safe Operating Distance (meters), $R_{safec} = 32.5$ meters
 See Section 3

5.0 Off-Axis Levels at the FarField 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 one (1) degree off axis At the far-field limit, we can calculate the power density as:

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

$$PD_{1 \text{ deg off-axis}} = PD_{ff} \times 1585/G = \mathbf{0.058 \text{ mW/cm}^2} \text{ (5)}$$

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:

$$PD_{nf(off-axis)} = PD_{nf} / 100 = \mathbf{0.014 \text{ mW/cm}^2} \text{ at D off axis (6)}$$

See Section 8 for the calculation of the distance vs. elevation angle required to achieve this rule for a given object height.

7.0 Region Between the Feed Horn and Sub-reflector

Transmissions from the feed horn are directed toward the subreflector surface, and are confined within a conical shape defined by the feed horn. The energy between the feed horn and subreflector is conceded to be in excess of any limits for maximum permissible exposure. 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.

8.0 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:

$$S = (D / \sin \alpha) + (2h - D - 2) / (2 \tan \alpha) \quad (7)$$

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 (7), the radiation hazard will be below safe levels for all but the most powerful stations (> 4 kilowatts RF at the feed).

For D = 1.067 meters

 h = 2.0 meters

Then:

α	S
10	3.1 meters
15	2.1 meters
20	1.7 meters
25	1.4 meters
30	1.2 meters

Suitable fencing or other barrier may 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 worker.

The following table summarizes all the above calculations:

Table: Summary of All RadHaz Parameters			H90 ESV
Parameters		Units	Comments
Dish #	Hub		
Antenna Diameter	1.000	meters	
Antenna Centerline	0.600	meters	
Antenna Surface Area	0.785	m^2	
Antenna Ground Elevation	2.000	meters	
Frequency of Operation	14.250	GHz	
Wavelength	0.021	meters	
HPA Power Output	6.000	Watts	
HPA to Antenna Loss	0.100	dB	(0.7dB Radome Loss)
Transmit Power at Flange	7.68	dBi	
	5.86	Watts	
Antenna Gain	42.0	dBi	
	15848.93		
π	3.141593		
Antenna Aperture Efficiency	71.1	%	
Near Field Limit	11.884	meters	Rnf
Far Field Limit	28.522	meters	Rff
Transition Region			Rnf to Rff
1. Reflector Surface Region Calculations			
Reflector Surface Power Density	29.9	W/m^2	
	3.0	mW/cm^2	Does Meet Controlled Limits
			Does Not Meet Uncontrolled Limits
2. On-Axis Near Field Calculations			
Extent of Near Field	11.884	meters	
	38.990	feet	
Near Field Power Density	17.651	W/m^2	
	1.765	mW/cm^2	Does Meet Controlled Limits
			Does Not Meet Uncontrolled Limits
3. On-Axis Transition Region Calculations			
Extent of Transition Region(min)	11.884	meters	
Extent of Transition Region(min)	38.990	feet	
Extent of Transition Region(max)	28.522	meters	
Extent of Transition Region(max)	93.575	feet	
Worst Case Transition Region Power Density	17.651	W/m^2	
	1.765	mW/cm^2	Does Meet Controlled Limits
			Does Meet Uncontrolled Limits
Rsafeu (distance for 5mW/cm^2)	4.2	meters	
Rsafeu (distance for 1mW/cm^2)	21.0	meters	
4. On-Axis Far Field Calculations			
Distance to the Far Field Region	28.522	meters	
	93.575	feet	
On-Axis Power Density in the Far Field	7.561149	W/m^2	
	0.756	mW/cm^2	Does Meet Controlled Limits
			Does Meet Uncontrolled Limits
Rsafeu (distance for 1mW/cm^2)	24.8	meters	
5. Off-Axis Levels at the Far Field Limit and Beyond			
Reflector Surface Power Density	0.756	W/m^2	at start of far field
Goa/Ges at example angle 1 degree	0.100007		
	0.075617	mW/cm^2	Does Meet Uncontrolled Limits
6. Off-Axis Power Density in the Near Field and Transitional Regions Calculations			
Power density 1/100th of the near field power density for one antenna diameter removed	0.17651	W/m^2	
	0.017651	mW/cm^2	
7. Region Between the Feed Horn and Sub-reflector			
8. Off Axis Safe Distance from Earth Station			
Minimum elevation angle of antenna	10	deg	
Maximum height of object to be cleared	2	meters	
Ground Elevation Delta: antenna-obstacle	1	meters	
Elevation angle(deg)	10	2.9	meters
	15	2.0	meters
	20	1.6	meters
	25	1.3	meters
	30	1.1	meters