Radiation Hazard Analysis

4.6m Transportable Hub

This analysis predicts the radiation levels around a proposed earth station complex, comprising of a 4.6m antenna with a 40W amplifier. 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	4.6m
Antenna Surface Area	16.6 sq. meters
Antenna Isotropic Gain	54.0 dBi
Number of Identical Adjacent Antennas	1
Nominal Antenna Efficiency (ε)	53%
Nominal Frequency	14.25GHz
Nominal Wavelength (λ)	0.0211 meters
Maximum Transmit Power / Carrier	40.0 Watts
Number of Carriers	1
Total Transmit Power	40.0 Watts
W/G Loss from Transmitter to Feed	1.0 dB
Total Feed Input Power	31.8 Watts
Radome Losses	0.0 dB
Near Field Limit	$R_{nf} = D^2/4\lambda$ = 251.3 meters
Far Field Limit	$R_{ff} = 0.6\ D^2/\lambda$ = 603.0 meters
Transition Region	R_{nf} to R_{ff} = 251.3 meters to 603.0 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_{as} = 4P/A = **0.76** mW/cm^2 (1)
Where: P = total power at feed, milliwatts
A = Total area of reflector, sq. cm

Evaluation
Controlled Environment: **Meets Controlled Limits**
Uncontrolled Environment: **Meets Uncontrolled Limits**

In general 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 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:

$PD_{nf} = (16\varepsilon P)/(\pi D^2) =$ **0.41** mW/cm² (3)
from 0 to 251.3 meters

Evaluation
Controlled Environment: **Meets Controlled Limits**
Uncontrolled Environment: **Meets Uncontrolled 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
$PD_{tr} =$ **0.41** mW/cm² to **0.17** mW/cm²
For: 251.3 m $< R <$ 603 m

Evaluation
Controlled Environment: **Meets Controlled Limits**
Uncontrolled Environment: **Meets Uncontrolled Limits**

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:

$PD_{ff} = PG/(4\pi R^2)$ and is dependent on R^2 ,(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: $R > R_{ff} =$ 603 meters
$PD_{ff} =$ **0.17** mW/cm^2 at R_{ff}

Evaluation
Controlled Environment: **Meets Controlled Limits**
Uncontrolled Environment: **Meets Uncontrolled Limits**

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)

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

$PD_{2\ deg\ off\text{-}axis} = PD_{ff}$x 280.2/G = **0.0002** mW/cm^2 **(6)**

Evaluation
Controlled Environment: **Meets Controlled Limits**
Uncontrolled Environment: **Meets Uncontrolled Limits**

6.0 Summary of Results

The calculation show the earth station meets all requirements for both controlled and uncontrolled access. However it is understood that the power density may exceed safe limits in areas such as the feed sand at the sub-reflector. In operation access to the antenna will be restricted to trained personnel.

The table below summarizes all of the above calculations.

Parameter	Abbr.		Units	Formula
Antenna Effective Diameter	Df	4.6	meters	
Antenna Centerline	h	2.4	meters	
Antenna Surface Area	Sa	16.6	$meter^2$	$(\pi * Df^2)/4$
Antenna Ground Elevation	GE	2.75	meters	
Frequency of Operation	f	14.3	GHz	
Wavelength	λ	0.0	meters	
HPA Output Power	P_{HPA}	40	watts	
HPA to Antenna Loss	L_{Tx}	1	dB	
Radome Loss	L_{Rad}	0	dB	
Transmit Power at Flange	P	31.8	watts	$P/10Log^{-1}(L_{Tx}/10)$
Effective Power after Radome		31.8	watts	$P/10Log^{-1}$(Radome Loss/10)
Antenna Gain	G_{es}	54	dBi	does not include radome loss
Antenna Aperature Efficiency	η	53%	n/a	
1. Reflector Surface Region Calculations				
Antenna Surface Power Density	Pdas	7.6	W/m^2	$(16 * P)/(\pi * D^2)$
		0.76	mW/cm^2	
Power at Radome Surface	Pdrad	7.6	W/m^2	$(16 * P)/(\pi * D^2)$
(outside radome)		0.76	mW/cm^2	**Meets controlled limits**
				Meets Uncontrolled limits
2. On Axis Near Field Calculations				
Extent of Near Field	Rn	251.3	meters	$D^2 / (4 * \lambda)$
		824.4	feet	
Near Field Power Density	PDnf	4.1	w/m^2	$(16 * \eta * P)/(\pi * D^2)$
		0.41	mW/cm^2	**Meets controlled limits**
				Meets Uncontrolled limits
3. On Axis Transition Region Calculations				
Extent of Transition Region (min)	R_{Tr}	251.3	meters	$D^2 / (4 * \lambda)$
Extent of Transition Region (min)		824.4	feet	
Extent of Transition Region (max)	R_{Tr}	603.0	meters	$0.6 * D^2 / \lambda$
Extent of Transition Region (max)		1978.5	feet	
Worst Case Transition Region Power Density	PD_{tr}	4.1	w/m^2	
		0.41	mW/cm^2	**Meets controlled limits**
				Meets Uncontrolled limits
4. On Axis Far Field Calculations				
Distance to Far Field Region	Rf	603.0	meters	$0.6 * D^2 / \lambda$
		1978.5	feet	
On Axis Power Density in the Far Field	PD_{ff}	1.7	W/m^2	$(G_{es} * P) / (4 * \pi * Rf^2)$
		0.17	mW/cm^2	**Meets controlled limits**
				Meets Uncontrolled limits
5. Off-axis Power Density in the Far Field Limit and Beyond				
Antenna Surface Power Density	PDs	0.0	W/m^2	$(G_{es} * P) / (4 * \pi * Rf^2) * (Goa/Ges)$
Goa/Ges at a sample angle of θ=2 degrees		0.001		Goa = 32 - 25*log(θ)
		0.0002	mW/cm^2	**Meets controlled limits**
				Meets Uncontrolled limits
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.				