Radiation Hazard Study

SW 75cm Offset Feed Earth Station ku-band Antenna with 500mW BUC

This analysis predicts the radiation levels around a earth station comprised of one aperture (reflector) type antenna. 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, Section 2 Prediction Methods, Aperture Antennas, 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 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 unuseable.

Earth Station Technical Parameters

Antenna diameter	**0.75 m**
Antenna Isotropic gain	**38 dBi**
Maximum Transmit Power	**0.5 Watts**
Number of carriers	**1**
Nominal Frequency	**14.25 GHz** *(frequency for the 38 dBi in FCC312 E42)*

In the following sections, the power density in the above regions, as well as other critically important areas will be calculated and evaluated.

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 given by the equation (1).

(1) $L_{nf} = D^2/(4\lambda)$

Where L_{nf} = length to end of the near field,

Where D = antenna diameter

Where λ = wavelength at **14.25** GHz = 21.0×10^{-3} meters or 21 mm

From equation (1) it is found that the distance to the end of the near field is **7** meters.

The maximum power flux density in the near field PD_{nf} is given by:

(2) $PD_{nf} = 16\, P_t\, \eta/(\pi D^2)$

Where P_t is the maximum power transmitted by the amplifier (**0.5** Watts).

Where η = Antenna Efficiency

Antenna efficiency can be estimated, or a reasonable approximation for circular apertures can be obtained from the ratio of the effective aperture area to the physical area as follows:

$$\eta = (G\lambda^2/4\pi)/(\pi D^2/4) = G\lambda^2/(\pi^2 D^2) = \mathbf{0.50}$$

Where G = the on-axis gain of the antenna (**38** dBi at **14.25** GHz)

From equation (2), we see that

$$PD_{nf} = \mathbf{0.23}\ \text{mW/cm}^2$$

Evaluation

Uncontrolled Environment	Complies with FCC Limit of 1 milliwatt per square centimeter
Controlled Environment	Complies with FCC Limit of 5 milliwatts per square centimeter

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 power density in the near field region, as shown above, will not exceed **0.23** mW/cm².

Evaluation

Uncontrolled Environment	Complies with FCC Limit of 1 milliwatt per square centimeter
Controlled Environment	Complies with FCC Limit of 5 milliwatts per square centimeter

On-axis Far-Field Region

Free-space power density is maximum on-axis, varies inversely with the square of the of the distance and may be calculated from equation (3).

(3) $PD_{ff} = GP_t/(4\pi R^2)$

Where PD_{ff} = the power flux density on-axis in the far field,

R = the distance to the far field region and is found from equation (4).

(4) $R = 0.6D^2/\lambda$

From equation (4) it is found that the distance to the far field is **16** meters.

And, PDff is found from equation (3) as follows:

PD_{ff} = **0.10** mW/cm²

Evaluation

Uncontrolled Environment	Complies with FCC Limit of 1 milliwatt per square centimeter
Controlled Environment	Complies with FCC Limit of 5 milliwatts per square centimeter

Region Between Feed Flange and Reflector

Transmissions from the feed horn are directed toward the reflector surface, and are confined within a conical shape defined by the feed. The energy between the feed and reflector surface can be calculated by determining the power density at the feed flange. This can be accomplished as follows:

Power Density at Feed Flange, $PD_{feed} = 4*P_t/Fa$

Where Fa = Area of Feed Window $= \pi * D_f^2/4$

Where D_f = **5** cm

Fa = **20** cm²

PD_{feed} = **102** mW/cm²

The energy between the feed horn and reflector 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 have received training specifying this area as a high exposure area. Procedures are established that assure that the transmitter is turned off before access by maintenance personnel to this area.

Main Reflector Region

The power density in the main reflector region is determined in the same manner as the power density at the feed flange, above, but the area is now the area of the reflector aperture:

Power Density at Reflector Surface, $PD_{reflector} = 4*P_t/Sa$

Where Sa = Surface Area of Reflector = **0.4** m²

$PD_{reflector}$ = **0.45** mW/cm²

Evaluation

Uncontrolled Environment	Complies with FCC Limit of 1 milliwatt per square centimeter
Controlled Environment	Complies with FCC Limit of 5 milliwatts per square centimeter

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 on-axis center line and the point of interest. The on-axis main-beam will be the location of the greatest of these maxima. The on-axis power density calculated above represent the maximum exposure levels that the system can produce. Off-axis power densities will be considerably less and hence comply with FCC limits.

Off-axis Levels at the Near Field and in the Transition Region

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 (20dB) 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:

PDnf(off-axis) = PDnf /100 = **0.002** mW/cm^2

Evaluation

Uncontrolled Environment	Complies with FCC Limit of 1 milliwatt per square centimeter
Controlled Environment	Complies with FCC Limit of 5 milliwatts per square centimeter

Evaluation of Safe Occupancy Area in Front of Antenna

As covered in the section above "Off-axis levels at the Near Field and in the Transition Region", the off-axis levels are well below the FCC limits. Therefore, no fencing or barrier is required to prevent access to the area in front of the antenna by employees. This area will not be accessible to the general public.

The area not to be accessed by maintenance personnel without the transmitter being turned off is the area between the feed horn and the reflector.

Conclusion

Based on the above analysis it is concluded that harmful levels of radiation will not exist in regions accessible to the general public or to the earth station's operating personnel.

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