Analysis of Non-Ionizing Radiation for a 3.7 m Earth Station Antenna System

This report analyzes the non-ionizing radiation levels for a 3.7 m earth station antenna system. Note that while the system is equipped with an 80 W power amplifier, the amplifier is operated in a multi-carrier mode with a total output back off of 3 dB. Therefore the maximum combined power of all carriers is 40 watts.

The FCC's Office of Engineering Technology's Bulletin No. 65 specifies that there are two separate tiers of exposure limits that are dependant upon the situation in which the exposure takes place and/or the status of the individuals who are subject to the exposure. The two tiers are General Population / Uncontrolled environment, and an Occupational / Controlled environment.

The applicable exposure limit for the General Population / Uncontrolled environment, i.e., areas that people may enter freely, at this frequency of operation is 1 mW/cm^2 average power density over a 30 minute period.

The applicable exposure limit for the Occupational / Controlled environment, i.e., areas that only authorized / trained personnel have access to, at this frequency of operation is 5 mW/cm^2 average power density over a 6 minute period.

Summary of expected radiation levels for an Uncontrolled environment

Region	**Maximum Power Density**	**Hazard Assessment**
Safe region range ≥ 162.681 m	1.0 mW/cm^2	Satisfies FCC MPE
Far field (R_{ff}) = 390.435 m	0.369 mW/cm^2	Satisfies FCC MPE
Near field (R_{nf}) = 162.681 m	0.862 mW/cm^2	Satisfies FCC MPE
Transition region (R_t) (R_t) = $R_{nf} < R_t < R_{ff}$	0.862 mW/cm^2	Satisfies FCC MPE
Main Reflector Surface ($S_{surface}$)	1.326 mW/cm^2	Potential Hazard

Note, power density level in the area between the feed and the reflector surface is greater than the reflector surface and is assumed to be a potential hazard.

Summary of expected radiation levels for a Controlled environment

Region	Maximum Power Density	Hazard Assessment
Safe region range ≤ 1.0 m	1.326 mW/cm^2	Satisfies FCC MPE
Far field (R_{ff}) = 28.52 m	0.369 mW/cm^2	Satisfies FCC MPE
Near field (R_{nf}) = 11.883 m	0.862 mW/cm^2	Satisfies FCC MPE
Transition region (R_t) (R_t) = $R_{nf} < R_t < R_{ff}$	0.862 mW/cm^2	Satisfies FCC MPE
Main Reflector Surface ($S_{surface}$)	1.326 mW/cm^2	Satisfies FCC MPE

Note, power density level in the area between the feed and the reflector surface is greater than the reflector surface and is assumed to be a potential hazard.

Conclusions

Based on the analysis it is concluded that while radiation levels above the 1 mW/cm^2 threshold do potentially exist in close proximity to the antenna reflector, the power levels for foot traffic at distances greater than 3 m from the antenna satisfy the FCC MPE levels.

Analysis

The analysis and calculations that follow in this report are performed in compliance with the methods described in the OET Bulletin No. 65.

For the following calculations, operation at the maximum power output of the transmitting system was assumed in order to determine the worst case RF hazard. In normal operation however, the output power of the transmitting system will be reduced by several dB and transmits at a duty cycle less than 100%.

Definition of terms

The terms are used in the formulas here are defined as follows:

$S_{surface}$ = maximum power density at the antenna surface
S_{nf} = maximum near-field power density
S_t = power density in the transition region
S_{ff} = power density (on axis)
R_{nf} = extent of near-field
R_{ff} = distance to the beginning of the far-field
R = distance to point of interest

P_a = 40 W	maximum power amplifier output
L_{fs} = 0.5 dB	loss between power amplifier and antenna feed
P = 35.65 W	power fed to the antenna in Watts
A = 10.752 m^2	physical area of the aperture antenna
G = 198428.876	power gain relative to an isotropic radiator
D = 3.7 m	diameter of antenna in meters
F = 14,250	frequency in MHz
λ = 0.021 m	wavelength in meters ($300/F_{MHz}$)
η = 0.65	aperture efficiency

Antenna Surface. The maximum power density directly in front of an antenna (e.g., at the antenna surface) can be approximated by the following equation:

$$S_{surface} = (4 * P) / A$$

$$= (4 * 35.65\ W) / 10.752\ m^2$$

$$= 1.326\ mW/cm^2$$

Near Field Region. In the near-field or Fresnel region, of the main beam, the power density can reach a maximum before it begins to decrease with distance. The extent of the near field can be described by the following equation **(D** and λ in same units):

R_{nf} $= D^2 / (4 * \lambda)$

$= 3.7\ m^2 / (4 * 0.021\ m)$

$= 162.681\ m$

The magnitude of the on-axis (main beam) power density varies according to location in the near field. However, the maximum value of the near-field, on-axis, power density can be expressed by the following equation:

S_{nf} $= (16 * \eta * P) / (\pi * D^2)$

$= (16 * 0.65 * 35.65\ W) / (\pi * 3.7\ m^2)$

$= 0.862\ mW/cm^2$

Transition Region. Power density in the transition region decreases inversely with distance from the antenna, while power density in the far field (Fraunhofer region) of the antenna decreases inversely with the ***square*** of the distance. The transition region will then be the region extending from R_{nf} to R_{ff}. If the location of interest falls within this transition region, the on-axis power density can be determined from the following equation:

S_t $= (S_{nf} * R_{nf}) / R$

$= (0.862 * 162.681) / R$

$= (140.242\ m * mW/cm^2) / R$ where R is the location of interest in meters

Far-Field Region. The power density in the far-field or Fraunhofer region of the antenna pattern decreases inversely as the square of the distance. The distance to the start of the far field can be calculated by the following equation:

R_{ff} $= (0.6 * D^2) / \lambda$

$= (0.6 * 3.7\ m^2) / 0.021\ m$

$= 390.435\ m$

The power density at the start of the far-field region of the radiation pattern can be estimated by the equation:

$$S_{ff} = (P * G) / (4 * \pi * R_{ff}^2)$$

$$= (35.65 \text{ W} * 198428.876) / (4 * \pi * 390.435 \text{ m}^2)$$

$$= 0.369 \text{ mW/cm}^2$$

Safe Region for Uncontrolled Access. As given above, the power density at the end of the Near Field region is 0.862 mW/cm^2 and power density at the reflector surface is 1.326 mW/cm^2 so the safe region for uncontrolled access within the main beam of the reflector will be 162.681 m. However the antenna is pointing up at the geostationary satellite arc at a minimum elevation angle of 28.78º and therefore the main beam of the antenna will quickly above any nearby foot traffic. Power density levels are also assumed to be reduced by at least 20 dB at a distances one diameter or greater removed from the cylinder projected by the main beam of the antenna.

The height above the ground where the lower edge of the cylinder projected by the main beam of the antenna will be located for a given distance can be determined by the equation:

$$H = H_r + D * \tan(El^o)$$

$$= 1 \text{ m} + 3 \text{ m} * \tan(28.78)$$

$$= 2.58 \text{ m}$$

Where H is the height above the ground, H_r is the height of the lower edge of the antenna reflector, D is the distance from the antenna, and Elº is the operating elevation angle.

Safe Region for Controlled Access. As given above, the power density at the reflector's surface is 1.326 mW/cm^2 and less than the already less than the 5 mW/cm^2 criteria for controlled access. The area between the reflector surface and the feed is still considered to be a potential hazard.