Analysis of Non-Ionizing Radiation for an 13 m Earth Station Antenna System

This report analyzes the non-ionizing radiation levels for a 13 m earth station antenna system. This antenna system is operated at two different frequencies and power levels. Both are examined in this document.

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 when operating at 7.075 GHz and 243 W of input power

Region	**Maximum Power Density**	**Hazard Assessment**
Far field (R_{ff}) = 2393 m	0.176 mW/cm^2	Satisfies FCC MPE
Near field (R_{nf}) = 997.1 m	0.411 mW/cm^2	Satisfies FCC MPE
Transition region (R_t) $(R_t) = R_{nf} < R_t < R_{ff}$	0.411 mW/cm^2	Satisfies FCC MPE
Main Reflector Surface ($S_{surface}$)	0.735 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.

Because expected radiation levels satisfy MPE for an Uncontrolled environment when operating at 7.075 GHz, the levels for a controlled environment are therefore also satisfied and not shown.

Summary of expected radiation levels for an Uncontrolled environment when operating at 1.842 GHz and 1321 W of input power

Region	**Maximum Power Density**	**Hazard Assessment**
Far field (R_{ff}) = 623 m	0.875 mW/cm^2	Satisfies FCC MPE
Near field (R_{nf}) = 260 m	2.043 mW/cm^2	Potential Hazard
Transition region (R_t) (R_t) = $R_{nf} < R_t < R_{ff}$	2.043 mW/cm^2	Potential Hazard
Main Reflector Surface ($S_{surface}$)	3.982 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**
Far field (R_{ff}) = 623 m	0.875 mW/cm^2	Satisfies FCC MPE
Near field (R_{nf}) = 260 m	2.043 mW/cm^2	Satisfies FCC MPE
Transition region (R_t) (R_t) = $R_{nf} < R_t < R_{ff}$	2.043 mW/cm^2	Satisfies FCC MPE
Main Reflector Surface ($S_{surface}$)	3.982 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

The proposed earth station system will be located in an environment with controlled access and will be serviced by trained personnel. Only trained personnel will operate the transmitting system during testing. No access to the reflector/feed area will be permitted when the transmitter is turned on. Based on the above analysis it is concluded that no hazard exists for the public when the system is operated at either 7.075 GHz or 1.842 GHz

Analysis for operation at 7.075 GHz

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

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 = 300 W	maximum power amplifier output
L_{fs} = 0.9 dB	loss between power amplifier and antenna feed
P = 243 W	power fed to the antenna in Watts
A = 132.732 m^2	physical area of the aperture antenna
G = 520218	power gain relative to an isotropic radiator
D = 13 m	diameter of antenna in meters
F = 7075	frequency in MHz
λ = 0.042 m	wavelength in meters ($300/F_{MHz}$)
η = 0.56	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:

$$S_{surface} = (4 * P) / A \qquad (1.1)$$

$$= (4 * 243\ W) / 132.732\ m^2$$

$$= 0.735\ mW/cm^2$$

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):

$$R_{nf} = D^2 / (4 * \lambda) \qquad (1.2)$$

$$= (13\ m)^2 / (4 * 0.042\ m)$$

$$= 997.086\ m$$

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} = $(16 * \eta * P) / (\pi * D^2)$ (1.3)

= $(16 * 0.6 * 243\ W) / (\pi * (13\ m)^2)$

= $0.412\ mW/cm^2$

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 = $(S_{nf} * R_{nf}) / R$ (1.4)

= $(0.412\ mW/cm^2 * 997.086\ m) / R$

= $(410.332\ m * mW/cm^2) / R$ 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} = $(0.6 * D^2) / \lambda$ (1.5)

= $(0.6 * (13\ m)^2) / 0.042\ m$

= 2393 m

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

S_{ff} = $(P * G) / (4 * \pi * R_{ff}^2)$ (1.6)

= $(243\ W * 520218) / (4 * \pi * (2393\ m)^2)$

= $0.176\ mW/cm^2$

Analysis for operation at 1.842 GHz

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

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 = 2000 W	maximum power amplifier output
L_{fs} = 1.8 dB	loss between power amplifier and antenna feed
P = 1321 W	power fed to the antenna in Watts
A = 132.732 m^2	physical area of the aperture antenna
G = 32302.9	power gain relative to an isotropic radiator
D = 13 m	diameter of antenna in meters
F = 1842	frequency in MHz
λ = 0.163 m	wavelength in meters ($300/F_{MHz}$)
η = 0.513	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:

$$S_{surface} = (4 * P) / A \quad (1.1)$$

$$= (4 * 1321 \text{ W}) / 132.732 \text{ m}^2$$

$$= 3.982 \text{ mW/cm}^2$$

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):

$$R_{nf} = D^2 / (4 * \lambda) \quad (1.2)$$

$$= (13 \text{ m})^2 / (4 * 0.163 \text{ m})$$

$$= 259.595 \text{ m}$$

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:

$$S_{nf} = (16 * \eta * P) / (\pi * D^2) \qquad (1.3)$$

$$= (16 * 0.6 * 1321\ W) / (\pi * (13\ m)^2)$$

$$= 2.043\ mW/cm^2$$

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:

$$S_t = (S_{nf} * R_{nf}) / R \qquad (1.4)$$

$$= (2.043\ mW/cm^2 * 259.595\ m) / R$$

$$= (530.306\ m * mW/cm^2) / R$$ 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:

$$R_{ff} = (0.6 * D^2) / \lambda \qquad (1.5)$$

$$= (0.6 * (13\ m)^2) / 0.163\ m$$

$$= 623.027\ m$$

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

$$S_{ff} = (P * G) / (4 * \pi * R_{ff}^2) \qquad (1.6)$$

$$= (1321\ W * 32302.911) / (4 * \pi * (623.027\ m)^2)$$

$$= 0.875\ mW/cm^2$$