

Analysis of Non-Ionizing Radiation for a 0.23 m Earth Station

This analysis provides the calculated non-ionizing radiation levels for a 0.23-meter earth station system.

The methods and calculations performed in this analysis are based on the FCC Office of Engineering and Technology Bulletin, No.65, October 1985 as revised in 1997 in Edition 97-01. The radiation safety limits used in the analysis are in conformance with the FCC R&O 96-326 (Summarized in Annex 1). There are separate exposure limits applicable to the General Population/Uncontrolled Environment and the Occupational/Controlled Environment. The Maximum Permissible Exposure (MPE) limits for persons in a General Population/Uncontrolled environment for the frequency band of this antenna, is 1 mW/cm² for a 30 minute or lower time period as shown in Annex 1 (a). The MPE limit for persons in an Occupational/Controlled environment for the frequency band of this antenna is 5 mW/cm² for a 6 minute time or lower period as shown in Annex 1 (b). The purpose of this analysis described is to determine the power flux density levels of the earth station at the main reflector surface, the near-field, transition region, far-field, between the sub-reflector or feed and, at the main reflector surface, and between the antenna edge and the ground and to compare these levels to the specified MPEs.

The parameters of the antenna that is the subject of this analysis are shown in Table 1. Intermediate calculated values and constants are provided in Table 2.

Table 1. Input Parameters Used for Determining Power Flux Densities

Parameter	Symbol	Formula	Value	Units
Antenna Diameter	D	Input	0.23	m
Frequency	F	Input	14250	MHz
Transmit Power	P	Input	25	W
Antenna Gain (dBi)	G _{es}	Input	30.4	dBi

Table 2. Calculated Values and Constants

Parameter	Symbol	Formula	Value	Units
Antenna Surface Area	A _{surface}	$\pi D^2/4$	0.04	m ²
Wavelength	λ	300/F	0.021053	m
Antenna Gain (factor)	G	$10^{G_{es}/10}$	1096.48	n/a
Pi	π	Constant	3.1415927	n/a
Antenna Efficiency	η	$G\lambda^2/(\pi^2 D^2)$	0.93	n/a

1. Antenna Main Reflector Surface

The power density in the main reflector is determined from the Power level and the area of the main reflector aperture. This is determined from the following equation:

Power Density at the Main Reflector Surface:

$$\begin{aligned} S_{\text{surface}} &= 4P/A_{\text{surface}} & (1) \\ &= 2406.880 \text{ W/m}^2 \\ &= 240.688 \text{ mW/cm}^2 \end{aligned}$$

2. Near Field Calculation

Power Flux density is considered to be at a maximum value throughout the entire length of the defined Near Field region. The region is contained within a cylindrical volume having the same diameter as the antenna. Past the boundary of the Near Field region, the power density from the antenna decreases linearly with respect to increasing distance. The distance to the end of the Near Field is determined from the following equation:

Extent of the Near Field:

$$\begin{aligned} R_{\text{nf}} &= D^2 / (4\lambda) & (2) \\ &= 0.63 \text{ m} \end{aligned}$$

The maximum power density in the Near Field is determined from the following equation:

Near Field Density:

$$\begin{aligned} S_{\text{nf}} &= 16.0 \eta P / (\pi D^2) & (3) \\ &= 224.033 \text{ mW/cm}^2 \end{aligned}$$

3. Transition Region Calculation

The Transition Region is located between the Near and Far Field regions. The power density begins to decrease linearly with increasing distance in the Transition region. While the power density decreases inversely with distance in the Transition region, the power density decreases inversely with the square of the distance in the Far Field region. The power density calculated in Section 1 is the highest power density the antenna can produce in any of the regions away from the antenna. The power density at a distance R_t is determined from the following equation:

Transition Region Power Density:

$$\begin{aligned} S_t &= S_{\text{nf}} R_{\text{nf}} / R_t & (4) \\ &= 224.033 \text{ mW/cm}^2 \end{aligned}$$

4. Far Field Distance Calculation

The distance to the Far Field Region is calculated using the following equation:

Distance to Far Field Region:

$$\begin{aligned} R_{ff} &= 0.6 D^2 / \lambda \\ &= 1.508 \quad \text{m} \end{aligned} \quad (5)$$

The maximum main beam power density in the far field is determined from the following equation:

On-axis Power Density in the Far Field:

$$\begin{aligned} S_{ff} &= G P / (4 \pi R_{ff}^2) \\ &= 95.969 \quad \text{mW/cm}^2 \end{aligned} \quad (6)$$

5. Region between the Main Reflector and the Ground

Assuming uniform illumination of the reflector surface, the power density between the antenna and the ground is determined from the following equation:

Power Density between Reflector and Ground:

$$\begin{aligned} S_g &= P / A_{\text{surface}} \\ &= 60.172 \quad \text{mW/cm}^2 \end{aligned} \quad (7)$$

7. Summary of Calculations

Table 3. Summary of Expected Radiation levels for Uncontrolled Environment

Region	Symbol	Calculated Maximum Radiation Power Density Level (mW/cm ²)	Hazard Assessment
1. Main Reflector	S _{surface}	240.688	Potential Hazard
2. Near Field (R _{nf} = 0.63 m)	S _{nf}	224.033	Potential Hazard
3. Transition Region (R _{nf} < R _t < R _{ff})	S _t	224.033	Potential Hazard
4. Far Field (R _{ff} = 1.51 m)	S _{ff}	95.969	Potential Hazard
5. Between Main Reflector and Ground	S _g	60.172	Potential Hazard

Table 4. Summary of Expected Radiation levels for Controlled Environment

Region	Symbol	Calculated Maximum Radiation Power Density Level (mW/cm ²)	Hazard Assessment
1. Main Reflector	S _{surface}	240.688	Potential Hazard
2. Near Field (R _{nf} = 0.63 m)	S _{nf}	224.033	Potential Hazard
3. Transition Region (R _{nf} < R _t < R _{ff})	S _t	224.033	Potential Hazard
4. Far Field (R _{ff} = 1.51 m)	S _{ff}	95.969	Potential Hazard
5. Between Main Reflector and Ground	S _g	60.172	Potential Hazard

It is the applicant's responsibility to ensure that the public and operational personnel are not exposed to harmful levels of radiation.

8. Conclusion

Based upon the above analysis, it is concluded that harmful levels of radiation may exist in those regions noted for the Uncontrolled (Table 3) Environment and the Controlled Environment (Table 4).

SD-ATMA is a 0.23 m Ku-band ESAA terminal that will be mounted on an aircraft tail typically 25 ft above the ground.

The main beam of the terminal points toward the geostationary arc at a typical elevation angle of 25 degrees such that human exposure is not possible in the main beam. Additionally, any blockage (human or otherwise) will cause the transmitter to be disabled within milliseconds as the system does not transmit unless it can receive the downlink carrier from the satellite. Normal TDMA operation uses a duty cycle of 10% or less, reducing maximum near field exposure by an order of magnitude. Therefore, prolonged exposure will not occur.

Finally, neither trained personnel nor general population will have access to the areas that exceed the MPE levels while the ESAA terminal is in operation. The transmitter will also be switched off during periods of maintenance while the operating personnel are in close proximity to the main reflector.

The aircraft will be marked with the standard radiation hazard warnings, as well as the area in the vicinity of the terminal to inform those in the general population, who might be working or otherwise present near the aircraft.

“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 workers.”

ANNEX 1
(MPE Levels)

a) Limits for General Population/Uncontrolled Exposure (MPE)

Frequency Range (MHz)	Power Density (mW/cm²)
30-300	0.2
300-1500	Frequency(MHz)*(4.0/1200)
1500-100,000	1

b) Limits for Occupational/Controlled Exposure (MPE)

Frequency Range (MHz)	Power Density (mW/cm²)
30-300	1
300-1500	Frequency(MHz)*(4.0/1200)
1500-100,000	5