Form 312

Analysis of Non-Ionizing Radiation for Universal Space Networks 13.0-Meter Earth Station Antenna

This report analyzes the non-ionizing radiation levels for Universal Space Networks Alaska #1 (AK01). This 13 meter antenna's transmits from the prime focus thru a transparent subreflector. The analysis and calculations performed in this report comply with the methods described in the FCC Office of Engineering and Technology Bulletin, No. 65 (oet65) first published in 1985 and revised in 1999 in 4^{th} Edition. The radiation safety limits used in the analysis are in conformance with the FCC R&O 96-326. Bulletin No. 65 and the FCC R&O specifies that there are two separate tiers of exposure limits that are dependant on the situation in which the exposure takes place and/or the status of the individuals who are subject to the exposure. The Maximum Permissible Exposure (MPE) limits for persons in a General Population/Uncontrolled environment are shown in Table 1. The uncontrolled MPE is a function of transmit frequency and is for an exposure period of thirty minutes or less.

The MPE limits for persons in an Occupational/Controlled environment are shown in Table 2. The controlled MPE is a function of transmit frequency and is for an exposure period of six minutes or less. The purpose of the analysis described in this report is to determine the power flux density levels of the earth station in the far-field, near-field, transition region, between the feed and main reflector surface, at the main reflector surface, and between the antenna edge and the ground and to compare these levels to the specified MPEs.

Table 3 contains the formulas and parameters used for determining the power flux densities.

Frequency Range (MHz)	Max Power Density (mW/cm^2)
1500 – 100,000	1.0

Table 1. Limits for General Population/Uncontrolled Exposure (MPE)

Frequency Range (MHz)	Max Power Density (mW/cm^2)
1500 – 100,000	5.0

Table 2. Limits for Occupational/Controlled Exposure (MPE)

Parameter	Symbol	Formula	Value	Units
Antenna Diameter	D	Input	13.0	meters
Antenna Surface Area	$A_{surface}$	$\pi D^2 / 4$	132.73	$meters^2$
Feed Radius	R	Input	.052	meters
Feed Aperture Area	$A_{aperture}$	πR^2	0.008494	$meters^2$
Frequency	F	Input	2050.0	MHz
Wavelength	λ	300 / F	0.146341	meters
Transmit Power	P	Input	200.0	Watts
Antenna Gain (dBi)	G_{es}	Input	46.5	dBi
Antenna Gain (scalar)	G	$10^{Ges/10}$	44688.4	n/a
Pi	π	Constant	3.1415927	n/a
Antenna Efficiency	η	$G\lambda^2 / (\pi^2 D^2)$	0.55	n/a

Table 3. Formulas and Parameters Used for Determining Power Flux Densities

Far Field Distance Calculation

At the Far Field region the angular field distribution is essentially independent of the distance from the antenna, and the field has a predominantly plane-wave character and has a uniform distribution of electric and magnetic field strength. The power flux density now decreases inversely with the square of the distance.

The distance to the beginning of the far field can be determined from the following equation:

Distance to the Far Field Region $\boldsymbol{Rff = 0.6\ D^2 \div \lambda}$ **= 692.9 meters** (1)

The maximum flux power density in the far field can be determined from the following equation:

On-axis power flux density $\boldsymbol{Sff = EIRP \div (4\,\pi\,Rff^2)}$ (2)

Where $\boldsymbol{EIRP = G\,P = 8933671.8}$

$\boldsymbol{Sff}$ **= 1.4807 W/m² = 0.1480 mW/cm²**

Near Field Calculation

Power flux density is considered to be worse case 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 aperture.

The distance to the end of the Near Field can be determined from the following equation:

Extent of the Near Field $\boldsymbol{Rnf} = \boldsymbol{D}^2 \div (4\lambda)$ **= 288.7 meters** (3)

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

Near Field Power Flux Density $\boldsymbol{Snf} = 16.0\, \boldsymbol{\eta}\, \boldsymbol{P} \div (\boldsymbol{\pi}\, \boldsymbol{D}^2)$ (4)

$\boldsymbol{Snf} =$ **3.3149 W/m² = 0.3314 mW/cm²**

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. The maximum power density in the Transition region will not exceed that calculated for the Near Field region.

The power flux density in the Transition Region at distance $\boldsymbol{Rt}$ can be determined from the following equation:

Transition Region Power Density $\boldsymbol{St} = \boldsymbol{Snf}\, \boldsymbol{Rnf} \div \boldsymbol{Rt}$ (5)

Where the given distance $\boldsymbol{Rnf} < Rt < Rff$

Maximum power density $\boldsymbol{St} =$ **0.3314 mW/cm² (**$\boldsymbol{Rt} =$ **288.7 meters)**

Directly in Front of Feed Assembly Calculation

Transmissions from the prime focus feed assembly are directed out of the feed towards the main reflector aperture. This calculation is defined as the power density directly in front of and touching the feed assembly aperture, completely blocking and absorbing all power from the transmission out of the feed assembly to the main reflector.

The power density at the feed assembly is determined by the following equation:

Power Density at the Feed $\boldsymbol{Sfeed} = 4\, \boldsymbol{P} \div \boldsymbol{Aaperture}$ (6)

$\boldsymbol{Sfeed}$ **= 94174.6 W/m² = 9417.4 mW/cm²**

Main Reflector Region Calculation

Transmissions from the prime focus feed assembly are directed towards the main reflector aperture which in turn reflects the power towards the boresight axis of the antenna out into space.

The power density in the reflector aperture is determined by the following equation:

Power Density at the Reflector $\boldsymbol{Ssurface} = 4\, \boldsymbol{P} \div \boldsymbol{Asurface}$ (7)

$\boldsymbol{Ssurface}$ **= 6.0272 W/m² = 0.6027 mW/cm²**

Region between the Reflector and the Ground

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

Power Flux Density to Ground $Sg = P \div Asurface$ (8)

$Sg =$ **1.5067 W/m² = 0.1506 mW/cm²**

Summary of Calculations

Tables 4 and 5 summarize the calculations of potential hazards.

Region	Variable	Calculated Maximum Power Flux Density (mW/cm²)	Hazard Assessment
Far Field (Rff = 692.9 m)	Sff	0.1480	Satisfies FCC MPE
Near Field (Rnf = 288.7 m)	Snf	0.3314	Satisfies FCC MPE
Transition Region ($Rnf < Rt < Rff$)	St	0.3314	Satisfies FCC MPE

Table 4 Summary of Expected Radiation Levels for Uncontrolled Environment (1 mW/cm² max)

Region	Variable	Calculated Maximum Power Flux Density (mW/cm²)	Hazard Assessment
Far Field (Rff = 692.9 m)	Sff	0.1480	Satisfies FCC MPE
Near Field (Rnf = 288.7 m)	Snf	0.3314	Satisfies FCC MPE
Transition Region ($Rnf < Rt < Rff$)	St	0.3314	Satisfies FCC MPE
Feed Aperture	$Sfeed$	9417.4	Potential Hazard
Reflector	$Ssurface$	0.6027	Satisfies FCC MPE
Between Reflector and Ground	Sg	0.1506	Satisfies FCC MPE

Table 5 Summary of Expected Radiation Levels for Controlled Environment (5 mW/cm² max)

Conclusions

Based on the analysis, it is concluded that the FCC RF Guidelines are exceeded only upon personnel being directly in-between the feed aperture and the reflector vertex as shown in figure 1. This potential hazard could only occur in the controlled environment during maintenance. This is based upon the need to use a telescoping man lift to elevate a person approximately 28 feet above the ground level to the potentially hazardous area.

Means of Compliance in Uncontrolled Areas

No hazard exists in the uncontrolled environment due to the antennas are in a locked fenced secure location. No uncontrolled person would have access to the antenna within a 50 meter distance without triggering security alarms.

Means of Compliance in Controlled Areas

The potential hazard that exists in the controlled environment is the applicant's responsibility to insure that operational personnel are not exposed to harmful levels of radiation. Appropriate RF hazard signage will alert operational personnel at the antenna base as well as illuminated red light indicator flashing at antenna base when the transmitter is active. The earth stations personnel will not have access to the area that exceeds the MPE levels while the earth station is in operation. The transmitters will be interlocked in the off position during antenna maintenance.

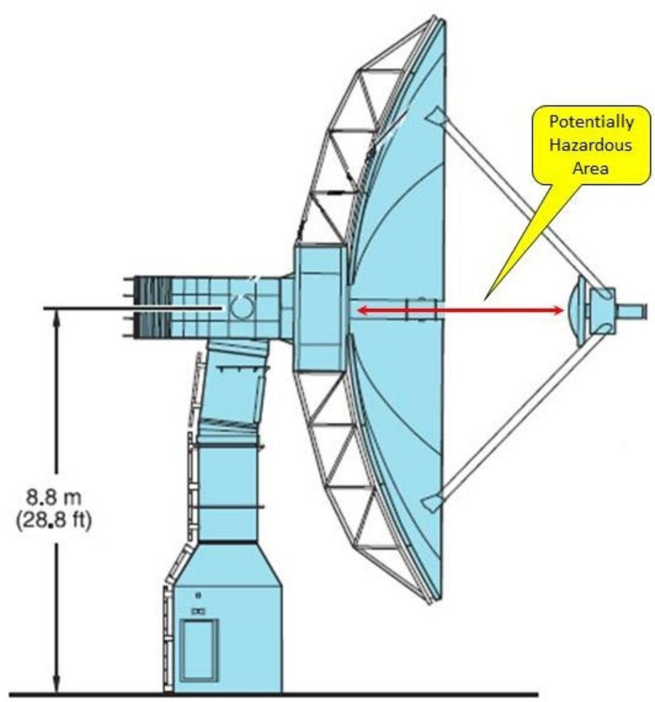

Figure 1 – Controlled access area of potential Radiation Hazard