Analysis of Non-Ionizing Radiation associated with a 2.4 Meter Ku-band Earth Station Uplink System

Engineering statement concerning the application of the Aircraft Owners and Pilots Association (AOPA) for a transmit-receive Earth station.

Uplink Antenna designation: ______________

RADIATION HAZARD STUDY

Introduction

This study has been performed by United Media on behalf of the AOPA to estimate the potential radiation hazard that could exist in the vicinity of it's fixed satellite service Earth station in the 14 GHz band which employs a Prodelin model 1251 2.4 meter antenna. The power values employed in this study are the maximum that the station can generate. Typical operating values would be lower.

This study has been prepared in accord with the Commission's "OST Bulletin #65 Edition 97-01", this bulletin gives methods for predicting (and measuring) the expected power-density levels in the vicinity of an antenna, and has been used throughout this study. The safety limits employed in this study are in conformance with FCC R&O 96-326. Bulletin #65 and the R&O define two classes of Maximum Permissible Exposure (MPE). The first and most restrictive applies to persons in an uncontrolled / public environment This MPE is an average of 1 mW/cm^2 in any 30 minute period.

The second and less restrictive MPE applies to persons in a controlled / Occupational environment where the MPE is an average of 5 mW/cm^2 over any 6 minute period.

This study will report the maximum power flux densities in the far field, near field, and transition region of the Earth station's beam. The study will also report the maximum power flux densities between the feed and the main reflector, at the main reflector surface, and between the edge of the antenna and the ground.

Antenna Characteristics

The antenna employed by the Earth station in this study has the following Characteristics:

Antenna Diameter	(D)	=	2.4 meters		
Antenna surface area	(Sa)	=	$\pi (D/2)^2$	=	4.52 m^2
Feed diameter	(Df)	=	6.63 cm		
Feed area	(Fa)	=	$\pi (Df/2)^2$	=	34.5 cm^2
Wavelength at 14.25 GHz.	(l)	=	0.021 m		
Transmit power at feed	(P)	=	15.88 Watts		
Antenna Gain (As P ratio)	(G)	=	83176 at 14.25 GHz (49.2 dBi)		
Antenna aperture efficiency	(e)	=	0.65 (65 %)		
	π	=	3.1416		

Calculations and Results

The field in front of an antenna in this portion of the spectrum can be characterized by referring to two separate regions, the near-field or Fresnel region and the far-field or Fraunhofer region.

1. The Far Field region

The beginning of the far-field (Rf) can be calculated by:

$Rf = 0.6 D^2 / l$

Where: D = antenna diameter
l = wavelength

In this case the antenna is a Prodelin model 1251 2.4 meter antenna operating at a wavelength of 0.021 meters so the beginning of the far-field (Rf) is:

$= 0.6(2.4^2) / l$ or $3.456 / .021$

or 164.6 m

The maximum power density (Sf) on the main beam axis in the far-field region may be determined by calculating the power density at the beginning of the far field:

$Sf = PG / 4\pi R^2$

Where: P = Power fed to the antenna in Watts
G = antenna gain as a ratio relative to isotropic (83176 or 49.2 dB)
R = distance to the point of interest

Since this study concentrates on maximum potential exposure to humans (R) will be set to the beginning of the far-field (Rf) or 164.6 meters from above. So in this case the maximum intensity in the far field (Sf) will be:

$= 15.88\ (83176) / 4\ (3.1416)\ 164.6^2$

or $1.32 \times 10^6 / 3.4 \times 10^5$ or 3.87 Watts / m^2

Converting units, $Sf = 0.387$ mW / cm^2

2. The near field region

The extent of the near-field region (Rn) can be found by:

(1) $Rn = D^2 / 4(l)$

Where: D = antenna diameter
l = wavelength

In this case the antenna is a 2.4 Meter operating at a wavelength of .021 Meters so the extent of the near field (Rn) is:

$$= 2.4^2 / 4(.021) \text{ or } 5.76 / .084$$

$$\text{or } 68.57 \text{ m}$$

The value of the maximum near field power density (Sn) is given by:

$$S = 16eP / \pi D^2$$

Where:
P = Power fed to the antenna in Watts
e = Aperture efficiency (In this case 0.65)
D = Antenna diameter

In this case the maximum power reaching the antenna is 15.88 Watts, so the maximum near-field intensity (Sn) will be:

$$= 16(.65)15.88 \ / \ 3.1416(2.4^2) \text{ or } 165.15 \ / \ 18.09 \text{ or } 4.56 \text{ W/m}^2$$

Converting units, $S = 0.456 \text{ mW/cm}^2$

3. The transition region

The region between the near field and the far field is the transition region. It is in the transition region where the power density starts to decrease with distance, thus the maximum power density in the transition region will be equal to the maximum power density calculated above for the near field or

$$S = 0.456 \text{ mW/cm}^2.$$

4. The region between the feed and the reflector

Another region to be investigated is between the feed and the main reflector. This is an area with the shape of a cone extending from the feed horn to the main reflector. The power density will be highest at the feed end of this cone and can be calculated by:

$$S_{Fa} = 2P / Fa$$

Where:
P = Power fed to the antenna in Watts
Fa = Area of the feed aperture in cm

In this case the maximum power reaching the feed is 15.88 Watts, so the maximum power density at the feed aperture (S_{Fa}) will be:

$$S_{Fa} = 2P/Fa = 2(15.88)\text{W} / 34.5 \text{ cm}^2 \quad \text{or} \quad 0.92 \text{ W/cm}^2$$

5. The main reflector region

Another region to be investigated is at the main reflector. The power density (Sr) can be determined in the same manner as at the feed except that the area is now that area represented by the main reflector. This value can be found by:

$$Sr = 2P / Sa$$

Where: P = Power fed to the antenna in Watts
Sa = Area of the main reflector in $meters^2$

In this case the maximum power reaching the feed is 15.88 Watts, so the maximum power density at the main reflector (Sr) will be:

$$Sr = 2P/Sa = 2(15.88)W / 5.76\ m^2 = 31.76 / 5.76 \quad or \quad 5.51\ W / m^2$$

Converting units = $0.551\ mW / cm^2$

6. The region between the reflector edge and the ground

Another region to be investigated is between the edge of the main reflector and the ground. If the power were evenly distributed over the surface of the reflector, that is if the aperture illumination was uniform, the power density at the edge of the reflector (Sg) would be:

$$Sg = P/Sa = 15.88W / 5.76m^2 \quad or \quad 0.275\ mW/cm^2,$$

Summary Table 1

For 5 mW / cm² MPE for Controlled / Occupational environments

Region	Power Density	Hazard Assessment
1. Far-field, Rf = 164.6m	0.387 mW / cm²	No Hazard
2. Near-field, Rn = 68.57m	0.456 mW / cm²	No Hazard
3. Transition region, Rt Rn < Rt < Rf	0.456-0.387 mW / cm²	No Hazard
4. Between main reflector and Feed	0.92 W / cm²	Potential Hazard
5. Reflector surface	0.551 mW / cm²	No Hazard
6. Between antenna and ground	0.275 mW / cm²	No Hazard

Note to #6 above: As is the case with all earth station antennas, the illumination is actually tapered to achieve lower sidelobe levels. Specifically, those required by the FCC Rules to achieve two-degree spacing. Tapers on the order of 10 dB or more are typical. With such an illumination taper, the power density at the edge of the antenna will be considerably below this value.

United Media has considerable experience in building, testing and maintaining satellite communication facilities of this type, and our experience testing high efficiency antennas of this type suggest an edge taper of at least 10dB will exist on this antenna.

Summary Table 2

For 1 mW / cm² MPE for Uncontrolled / Public environments

Region	Power Density	Hazard Assessment
1. Far-field, Rf = 164.6m	0.387 mW / cm²	No Hazard
2. Near-field, Rn = 68.57m	0.456 mW / cm²	No Hazard
3. Transition region, Rt Rn < Rt < Rf	0.456-0.387 mW / cm²	No Hazard
4. Between main reflector and Feed	0.92 W / cm²	Potential Hazard
5. Reflector surface	0.551 mW / cm²	No Hazard
6. Between antenna and ground	0.275 mW / cm²	No Hazard

7. Conclusion:

This relatively low power digital uplink does not represent a radiation hazard since the only potential hazard is inside the antenna structure near the feedhorn. This is an easy area to control access to, and the transmitter will not be operational during any required antenna maintenance

This station will be located on the secured roof of the AOPA building located at the Frederick, MD airport. The antenna will be mounted to an existing steel structure above the roof that would preclude access to radiation with out the use of a ladder or lift of some type.

Based on the above analysis and operating practices it is concluded that humans cannot come close enough to the Earth station antenna itself to be a hazard to members of the public or station personnel

The Earth station antenna will be marked with standard radiation hazard warning signs including one placed on the surface of the antenna, thus warning individuals to avoid the area in front of the antenna.

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