Analysis of Non-Ionizing Radiation for a 2.4-Meter Mobile Ku Band Satellite Uplink

This report analyzes the non-ionizing radiation levels for a 2.4-meter mobile Ku Band satellite uplink. The analysis and calculations performed in this report comply with the methods described in the FCC Office of Engineering and Technology Bulletin, No. 65 first published in 1985 and 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. 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 General Population/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 Occupational 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 subreflector or 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 1. Limits for General Population/Uncontrolled Exposure (MPE)

Frequency Range (MHz)	Power Density (mW/cm^2)
30-300	0.2
300-1500	Frequency (MHz)*(0.8/1200)
1500-100,000	1.0

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

Frequency Range (MHz)	Power Density (mW/cm^2)
30-300	1.0
300-1500	Frequency (MHz)*(4.0/1200)
1500-100,000	5.0

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

Parameter	Symbol	Formula	Value	Units
Antenna Diameter	D	Input	2.35	m
Antenna Surface Area	$A_{surface}$	$\pi D^2 / 4$	4.34	m^2
Feed Flange Diameter	D_{fa}	Input	17.78	cm
Area of Feed Flange	A_{fa}	$\pi D_{fa}{}^2/4$	248.3	cm^2
Frequency	F	Input	14,250	MHz
Wavelength	λ	300 / F	0.021	m
Transmit Power	P	Input	339	W

Antenna Gain (dBi)	G_{es}	Input	49	dBi
Antenna Gain (factor)	G	$10^{Ges/10}$	79432.8	n/a
Pi	π	Constant	3.1415927	n/a
Antenna Efficiency	η	$G\lambda^2/(\pi^2 D^2)$	0.65	n/a

1. Far Field Distance Calculation

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

Distance to the Far Field Region $\quad R_{ff} = 0.60\ D^2 / \lambda$ $\quad$ (1)
$= 158$ m

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

On-Axis Power Density in the Far Field $\quad S_{ff} = G\ P / (4\ \pi\ R_{ff}{}^2)$ $\quad$ (2)
$= 85.837 W/m^2$
$= 8.58\ mW/cm^2$

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 can be determined from the following equation:

Extent of the Near Field $\quad R_{nf} = D^2 / (4\ \lambda)$ $\quad$ (3)
$= 65.7$ meters

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

Near Field Power Density $\quad S_{nf} = 16.0\ \eta\ P / (\pi\ D^2)$ $\quad$ (4)
$= 203.2\ W/m^2$
$= 20.32 mW/cm^2$

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 maximum power density in the Transition region will not exceed that calculated for the Near Field region. The power density calculated in Section 2 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 can be determined from the following equation:

Transition Region Power Density $$S_t = S_{nf} R_{nf} / R_t \quad (5)$$

The power density will run from a minimum of 8.58 mW/cm^2 to a maximum of 20.32 mW/cm^2.

4. Region between the Feed Assembly and the Antenna Reflector

Transmissions from the feed assembly are directed toward the antenna reflector surface, and are confined within a conical shape defined by the type of feed assembly. The most common feed assemblies are waveguide flanges, horns or subreflectors. The energy between the feed assembly and reflector surface can be calculated by determining the power density at the feed assembly surface. This can be determined from the following equation:

Power Density at the Feed Flange $$S_{fa} = 4000\ P / A_{fa} = 5461\ mW/cm^2 \quad (6)$$

5. Main Reflector Region

The power density in the main reflector is determined in the same manner as the power density at the feed assembly. The area is now the area of the reflector aperture and can be determined from the following equation:

Power Density at the Reflector Surface $$S_{surface} = 4\ P / A_{surface} = 245.54\ W/m^2 = 24.554\ mW/cm^2 \quad (7)$$

6. 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 Density between Reflector and Ground $$S_g = P / A_{surface} = 61.38\ W/m^2 = 6.138\ mW/cm^2 \quad (8)$$

The antenna is located on top of a mobile production truck and is 4 meters off the ground and is incapable of radiating at a depression angle below +5 degrees, therefore paragraph 2 on page 30 of the OET Bulletin 65 would be applicable in estimating the potential hazard at ground level.

"For off-axis calculations in the near-field and in the transition region it can be assumed that, if the point of interest is at least one antenna diameter removed from the center of the main beam, the power density at that point would be at least a factor of 100 (20dB) less than the value calculated for the equivalent distance in the main beam(see Reference [15])."

Therefore because ground level is greater than 1.175 meters below the edge of the antenna, signal densities can be reduced by a factor of 100 which would result in an anticipated signal density at ground level of .06138mW/cm^2

7. Summary of Calculations

Table 4. Summary of Expected Radiation levels for Uncontrolled Environment

Region	Calculated Maximum Radiation Power Density Level (mW/cm^2)		Hazard Assessment
1. Far Field (R_{ff} = 158 m)	S_{ff}	8.58	Potential Hazard
2. Near Field (R_{nf} = 65.7 m)	S_{nf}	20.32	Potential Hazard
3. Transition Region ($R_{nf} < R_t < R_{ff}$)	S_t	8.58 to 20.32	Potential Hazard
4. Between Feed Assembly and Antenna Reflector	S_{fa}	5461	Potential Hazard
5. Main Reflector	$S_{surface}$	24.55	Potential Hazard
6. Between Reflector and Ground	S_g	.06138	Satisfies FCC MPE

Table 5. Summary of Expected Radiation levels for Controlled Environment

Region	Calculated Maximum Radiation Power Density Level (mW/cm^2)		Hazard Assessment
1. Far Field (R_{ff} = 178.3 m)	S_{ff}	8.58	Potential Hazard
2. Near Field (R_{nf} = 74.3 m)	S_{nf}	20.32	Potential Hazard
3. Transition Region ($R_{nf} < R_t < R_{ff}$)	S_t	8.58 to 20.32	Potential Hazard
4. Between Feed Assembly and Antenna Reflector	S_{fa}	5461	Potential Hazard
5. Main Reflector	$S_{surface}$	24.55	Potential Hazard
6. Between Reflector and Ground	S_g	.06138	Satisfies FCC MPE

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

8. Conclusions

FCC OET Bulletin 65 , page 30, paragraph 3 indicates,

"For practical estimation of RF fields in the off-axis vicinity of aperture antennas, use of the radiation pattern envelope can be useful."

The attached manufacturers radiation patterns indicate that one degree removed from the center of the beam, energy densities are reduced by over 30 dB. With this said, we can draw the following conclusions:

Based on this analysis it is concluded that the FCC RF Guidelines have been exceeded in the specific regions of Tables 4 and 5. The applicant proposes to comply with the Maximum Permissible Exposure (MPE) limits of 1 mW/cm2 for the Uncontrolled areas and the MPE limits of 5 mW/cm2 for the Controlled areas by one or more of the following methods:

Means of Compliance Uncontrolled Areas:

Operation of the satellite uplink will be only under the supervision of a certified operator.

This antenna is located 4 meters off the ground on top of a mobile production unit.
Since one diameter removed from the main beam of the antenna or ½ diameter removed from the edge of the antenna (1.175 meter or 3.85 feet) the RF levels are reduced by a factor of 100 or 20 dB. None of the areas exceeding the MPE levels will be accessible by the general public.

Radiation hazard signs will be posted while this satellite uplink is in operation.

The applicant will ensure that no buildings or other obstacles will be in the areas that exceed the MPE levels.

Means of Compliance Controlled Areas

The earth station's operational personnel will not have access to the areas that exceed the MPE levels while the earth station is in operation.

The transmitters will be turned off during antenna maintenance.