Radiation Hazard Report:

Analysis of Non-Ionizing Radiation for a 4 X 42 Element Yagi Antenna Array Earth Station System

This report analyzes the non-ionizing radiation levels for a 4 Yagi-Uda antenna earth station system. 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 dependent 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, 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	(MHz)*(0.8/1200) = 0.268
1500 – 100,000	1.0

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

Frequency Range (MHz):	Power Denstiy (mW/cm^2):
30 – 300	1.0
300 - 1500	(MHz)*(4.0/1200) = 1.34
1500 – 100,000	5.0

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

Parameter:	Symbol:	Formula:	Value:	Units:
Effective Aperture	A_e	$A_e = (\lambda^2 G)/(4\pi)$	11.06	m^2
Aperture Diameter	D	$D = 2 (A_e/\pi)^{1/2}$	5.38	m
Frequency	f	Input Value	402.6	MHz
Wavelength	λ	$\lambda = 300/f$	0.744	m
Transmit Power	P	Input Value	50	watts
Gain (logarithmic)	G	$G = 18.7 + 6.0 - L_a$ *	24.0	dBi
Gain (linear)	G	$G_l = 10^{(G/10)}$	251.2	none
Pi	π	Constant	3.14159	none
Aperture Efficiency	η	$\eta = [G \lambda^2)/4\pi]/ [\pi D^2]/4]$ **	0.490	none

Notes:
* Gain of 4 yagis in 2 over 2 configuration given the individual gain of each yagi is 18.7 dBi and the feed losses are 0.7 dB.

** Equation (14), OET Bulletin 65, Version 97-01

1. Far Field Distance and PFD Calculations:

The distance to the beginning of the far field from the center of the antennas can be given by:

$$R_{ff} = 0.60\ D^2/\lambda$$
$$R_{ff} = (0.60)\ (5.38)^2 / 0.744$$
$$R_{ff} = 23.30\ m$$

The maximum on-axis power flux density in the main beam at the far field boundary can be determined to be:

$$S_{ff} = PG/ 4\pi R_{ff}^2$$
$$S_{ff} = (50)*(251.2)/(4)(3.14159)(23.3)^2$$
$$S_{ff} = 1.841\ watts/m^2 = 0.18\ mW/cm^2$$

2. Near Field Distance and PFD Calculations:

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 surface area 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 as follows:

$$R_{nf} = D^2/4\lambda$$
$$R_{nf} = (5.38)^2/4(0.744) = 9.73 \text{ m}$$

The maximum power flux density of the Near Field can be determined from the following:

$$S_{nf} = 4\ \eta\ P/A_e$$
$$S_{nf} = 4\ (.490)\ (50)/\ (11.06)$$
$$S_{nf} = 8.86\ W/m^2 = 0.886\ mW/cm$$

3. Transition Region PFD Calculation:

The transition region will then be the region extending from R_{nf}, calculated from Equation (12)[1], to R_{ff}, calculated from Equation (16)[2]. If the location of interest falls within this transition region, the on-axis power density can be determined from the following equation:

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

Where R = Distance of interest from center of antenna, beyond the end of the Near Field. As an example, at a distance of 6.43 meters from the center of the antenna in the transition region the PFD would be approximately:

$$S_{6.43m} = [(0.886)(\ 9.73)]/(6.43)$$
$$S_{6.43m} = 1.34\ mW/cm^2$$

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[1] OET Bulletin 65, Version 97-01, Equation (12)
[2] *Ibid*, Equation (16)

4. PFD at Ground Level

The distance from the center of the antenna to the ground is approximately 9.1 m. However, the antenna is located in the middle of a flat surface roof on an industrial building. Then antenna center is approximately 4.8 meters above roof height and the roof surface is approximately 4.3 meters above ground surface. Given the antenna's position the closest line-of-sight distance from the center of the antenna to the ground surface is approximately 17 meters.

As our system uses a Yagi antenna array, an uniform surface illumination criteria (as is often used for parabolic surfaces) is not applicable. We have estimated that the transition region equation is more applicable for a Yagi and somewhat worst case for this situation. Applying the relationship as per Section 3, above:

$$S_g \approx S_t \approx (S_{nf} * R_{nf})/R$$
$$S_g \approx (0.886)(9.73)]/(17.0)$$
$$S_g \approx 0.51 \text{ mW/cm}^2$$

5. Summary of PFD Calculations:

The following summarizes the uncontrolled and controlled PFD levels exhibited by the Astro Digital's UHF Antenna System.

Table 4: Summary of Expected Radiation Levels for Uncontrolled Environment

Region:	Symbol:	Range: (meters)	PFD: (mW/cm^2)	Hazard Assessment:
Far Field:	S_{ff}	$R_{ff} \geq 23.3$	0.18	Satisfies FCC MPE
Near Field:	S_{nf}	$R_{nf} \leq 9.7$	0.89	Potential Hazard
Transition	S_t	$R_{nf} < R_t < R_{ff}$	1.34 @ R_t=6.43	Potential Hazard
Ground:	$S_g = S_t$	$R_g = R_t = 13.0$	0.51	Potential Hazard

Table 5: Summary of Expected Radiation Levels for Controlled Environment

Region:	Symbol:	Range: (meters)	PFD: (mW/cm^2)	Hazard Assessment:
Far Field:	S_{ff}	$R_{ff} \geq 23.3$	0.18	Satisfies FCC MPE
Near Field:	S_{nf}	$R_{nf} \leq 9.7$	0.89	Satisfies FCC MPE
Transition	S_t	$R_{nf} < R_t < R_{ff}$	1.34 @ R_t=6.43	Satisfies FCC MPE
Ground:	$S_g = S_t$	$R_g = R_t = 13.0$	0.51	Satisfies FCC MPE

The applicant takes the responsibility to ensure that the public and operational personnel are not exposed to harmful levels of radiation.

6. Conclusions

Based upon the above analysis, it is concluded that FCC RF Guidelines have been exceeded in the Near Field and a portion of the Transition Zone of the Uncontrolled (Table 4) environment. In the Controlled Environments (Table 5) none of the regions have levels that exceed the FCC RF Guidelines. The applicant will comply with the Maximum Permissible Exposure (MPE) limits of 0.268 mW/cm^2 for the Uncontrolled Areas, and the MPE limits of 1.34 mW/cm^2 for the Controlled Areas.

The earth station Yagi antenna will be mounted on a platform on the roof of the Astro Digital facility, well away from specific work and traffic areas. Thus, the applicant agrees that the antenna will be in an area secured from the public and worker personnel not familiar with the earth station system. Knowledgeable earth station personnel must accompany non-assigned worker personnel and the general public when they enter the earth station secured area.

The earth station's secured area will be marked with the required radiation hazard signs as described in the recent FCC R&0 13-39. The area in the vicinity of the earth station secured area will also have signs to inform those in the general population and those who may be working in the area or otherwise present that they are close to a RF System capable of producing hazardous levels.

The applicant agrees to abide by the conditions specified in Condition 5208 provided below:

Condition 5208 - *The licensee shall take all necessary measures to ensure that the antenna does not create potential exposure of humans to radio frequency 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 worker.*