Radiation Hazard Analysis – Isotropic Systems Ltd. 0.8m TB2/TB3 electrically-steered flat-panel antenna

Introduction

In compliance with the FCC's Rules and Regulations, a radiation hazard study has been completed for this prototype 0.8 m electrically-steered flat-panel VSAT antenna [ISL Antenna] for operation in the Ka SATCOM band. This study takes account of the FDCC's radiation hazard analysis as contained in OET Bulletin 65 issued in August 1997 and the ANSI radiation guidelines with respect to human exposure to radio frequency electromagnetic fields in the range 1500 MHz to 100 GHz. In this range the maximum power density is set at 1.0 mW/cm^2 for general population / uncontrolled exposure and 5.0 mW/cm^2 for occupational/controlled exposure.

Discussion

The ISL Antenna, as an electrically-steered antenna, can direct beams in a range +/- 70 deg from its zenith direction, but has a high gain in one direction at instantaneous moments in time. This significantly reduces the possibility of human exposure to RF radiation from what it would be in a broadcasting application. For this antenna, the power densities that might exist at locations where human exposure is possible are substantially less than the on-axis power of the antenna. Thus, operational guidelines by the antenna operator concerning the main beam orientation and relative location of the work and testing environment will lead to minimum exposure potential for the earth station being applied for in this application.

Technical discussion – Fresnel Zone

The ISL Antenna has a circular cross-section. The highest gain and power density for this antenna is located when the beam is steered to boresight, and the analysis uses that assumption. For antennas of this design, the near field, or Fresnel region, main beam power density can be described by the following equation:

$$R_{nf} = \frac{D^2}{4\lambda}$$

Where

- R_{nf} = distance to the near field (meters)
- D = diameter of the antenna (meters)
- λ = transmit frequency wavelength (meters)

For this application, D = 0.8 m and λ = 0.0107 m at 28.018 GHz; Thus, the distance to the end of the near field is

$$R_{nf} = \frac{(0.8m)^2}{4 \times 0.0107m} = 14.9\ m$$

The magnitude of the flux density of the beam (on-axis) will vary according to the location in the near field. The maximum value of the near-field on-axis power density (S_{nf}) is given by the following equation:

$$S_{nf} = \frac{16\eta P}{\pi D^2}$$

Where

- η = antenna efficiency
- P = power fed to antenna (Watts)
- D = antenna diameter (meters)

For this application, $\eta = 0.144$ (corresponding to a peak gain of 39 dBi from the transmit portion of the aperture and a 0.8 m overall aperture), P = 27.25 W (corresponding to all amplifiers being enabled at full power simultaneously, which is higher than standard operating conditions), and D = 0.8 m.

Then, the maximum near-field power density is

$$S_{nf} = \frac{16(0.144)(27.25\,W)}{\pi(0.8\,m)^2} = 31.3\frac{w}{m^2} = 3.13\,\frac{mW}{cm^2}$$

For off-axis calculations in the near-field, 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 10 (10 dB) less than the value calculated for the equivalent distance in the main beam.

The applicant agrees to prevent the presence of human beings in the entire area in front of the antenna in all directions except the backside of the antennas where the signal is further attenuated, through the installation of barriers, fencing, and signs, or other approaches to keeping people away during times of transmission.

Technical Discussion – Transition Region

Power density in the transition region decreases inversely with distance from the earth station antenna. On-axis power density in the transition region can be estimated by use of the following equation:

$$S_t = \frac{S_{nf}R_{nf}}{R}$$

Where

- S_t = power density in transition region (mW/cm^2)
- S_nf = Maximum power density in the near-field (mW/cm^2)
- R_{nf} = Extent of the near field (meters)
- R = Distance to point of interest

In this case, $S_{nf} = 3.13\frac{mW}{cm^2}$, $R_{nf} = 14.94\ m$, and R = 25.4 m (mean of the near-field and far-field limits).

Thus,

$$S_t = \frac{\left(3.13\frac{mW}{cm^2}\right)(14.94\ m)}{25.4\ m} = 1.84\frac{mW}{cm^2}$$

Technical Discussion – Fraunhofer Region

Power in the far-field or Fraunhofer region decreases inversely as the square of the distance. The distance to the beginning of the far-field region (R_{ff}) can be expressed by the following equation:

$$R_{ff} = 0.6D^2/\lambda$$

Where

- D = antenna diameter (meters)
- λ = transmit frequency wavelength (meters)

In this case, D = 0.8 m, and λ = 0.0107 m. Thus, the far-field will begin at:

$$R_{ff} = \frac{0.6(0.8\ m)^2}{0.0107\ m} = 35.9\ m$$

The power density of the far-field region is given by the following equation:

$$S_{ff} = \frac{GP}{4\pi\left(R_{ff}\right)^2}$$

Where

- S_{ff} = maximum power density in the far field
- G = gain of the antenna
- P = power into the antenna

In this case, G = 39 dBi = 7943, P = 27.25 W, R_{ff}=35.9 m. Then,

$$S_{ff} = \frac{(7943)(27.5\ W)}{4\pi(35.9\ m)^2} = 13.4\frac{W}{m^2} = 1.34\frac{mW}{cm^2}$$

Summary Table

Summary tables of Radiation Values for General Population/ Uncontrolled Exposure and Occupational/Controlled Exposure

		General Population/Uncontrolled Exposure Max Radiation Level: 1.0 mW/cm²	**Occupational/Controlled Exposure Max Radiation Level: 5.0 mW/cm²**
Region	**Radiation Level**	**Hazard Assessment**	**Hazard Assessment**
Near Field: R_{nf}=*14.9 m*	0.313 mW/cm² (off-axis – 10 dB reduced from peak)	Complies with Guidelines	Complies with Guidelines
Far Field: R_{ff}=*39.5 m*	0.134 mW/cm² (off-axis – 10 dB reduced from peak)	Complies with Guidelines	Complies with Guidelines

Transition Region: $R_{nf} < R_t < R_{ff}$	0.184 mW/cm^2 (off-axis – 10 dB reduced from peak)	Complies with Guidelines	Complies with Guidelines