Radiation Hazard Analysis
Gateway Earth Station

Introduction

This analysis calculates the non-ionizing radiation levels for a SpaceX Services, Inc. ("SpaceX Services") gateway earth station. The calculations performed in this analysis comply with the methods described in FCC Office of Engineering and Technology Bulletin, Number 65 (Edition 97-01) ("Bulletin 65"). This analysis demonstrates that SpaceX Services gateways are generally compliant and will not result in exposure levels exceeding the applicable radiation hazard limits, and any radiation hazard that may exist will be mitigated by limited access and various protocols to ensure safe exposure levels.

Bulletin 65 and Section 1.1310 of the Commission's rules specify two separate tiers of exposure limits: one for Occupational/Controlled Exposures and one for General Population/Uncontrolled Exposures. Limits for Occupational/Controlled Exposures apply in situations where persons are exposed as a consequence of their employment and are fully aware of and can control their exposure. These limits also apply in situations where a person is transient through a location where such limits would otherwise apply provided the person is made aware of the potential for exposure. The limits for General Population/Uncontrolled Exposure apply in situations in which the general public may be exposed, or in which persons that are exposed as a consequence of their employment may not be fully aware of the potential for exposure or cannot exercise control over their exposure. SpaceX Services will deploy its gateways in Occupational/Controlled Exposures Environments. Accordingly, this analysis discusses only the Maximum Permissible Exposure ("MPE") limit for those types of exposures, which for the Ku-band frequencies used by these gateways is a power density equal to 5 mW/cm^2 averaged over a six-minute period.[1]

As described in the definitional section below, this report analyzes the maximum power density levels in the vicinity of a gateway antenna in four regions: (1) the far field, (2) the near field, (3) near the main reflector surface, and (4) between the main reflector and the feed mouth. These radiation regions were analyzed using the definitions and formulas in Bulletin 65 for aperture antennas. The results of this analysis are summarized in Table 1, which identifies the potential exposure under worst-case operating conditions.

Gateway Description

The gateway antenna is a one-meter parabolic dish capable of steering its beams to track NGSO satellites passing within its field of view. At the antenna flange, the maximum transmit power is 14.93W. Although unlikely in practice, for purposes of this analysis we have conservatively assumed that the gateway can transmit at 100% duty cycle.

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1 *See* 47 C.F.R. § 1.1310(e).

Explanation of the Analysis

The "Calculated Values" in Table 1 are the exposure rates calculated using the formulae from Bulletin 65 for a system with continuous (100% transmit duty cycle) transmission.

Results of Analysis

This analysis demonstrates that the SpaceX Services gateway is not a radiation hazard because it does not exceed the MPE limit of 5 mW/cm^2 averaged over a six-minute period in generally-accessible areas. These gateways will be located in an area clearly marked with Radiation Hazard signage with no access by the general public.[2] Only around the feed mouth (this measurement is taken at a point between the feed and the sub-reflector) and at the main reflector surface are the relevant radiation levels exceeded. Power to the transmitters will be turned off remotely whenever work needs to be performed in either of these regions. Signage will mark the area for Radiation Hazard and access by qualified personnel only, ensuring awareness and enhancing safety. Consequently, there is no risk of radiation exposure beyond the acceptable limits.

Conclusion

This radiation hazard analysis demonstrates that SpaceX Services gateways will not result in unacceptable radiation exposure levels.

[2] The near field region creates no concern for the general public as they lie behind signage where only authorized personnel may enter. Likewise, the far field region creates no concern for the general public because it develops 30 meters from the antenna at a minimum elevation angle of twenty-five degrees where the general public cannot access. Accordingly, there is no risk of radiation exposure beyond the acceptable limits.

Definitions

1) Far Field Region

The far field region extends outward from the antenna surface, beginning at a distance of $\frac{0.6D^2}{\lambda}$ meters where the D is the diameter of the antenna. The maximum power density is calculated using the equation recommended in Bulletin 65.

2) Near Field Region

The near field region is a volume co-incident with the direction of the main beam extending outward from the antenna surface the length of the near field $\frac{D^2}{4\lambda}$ meters.

3) Transition Region

The transition region is located between the near field region and the far field region. This region has a power density that decreases with increasing distance. Therefore, the power density in the transition region will be less than the maximum power density in the near field and more than the maximum power density in the far field for the purpose of evaluating potential exposure.

4) Region Near the Antenna Surface

The power density near the antenna surface can be estimated as equal to four times the power divided by the area of the main reflector surface (main reflector illumination is uniform).

5) Region between the Main Reflector and the Feed

The power radiated from the feed toward the reflector is conical in shape with the vertex at the feed. The maximum power is at the feed mouth and can be estimated as four times the transmit power divided by the area of the feed mouth.

TABLE 1: RADIATION FROM SPACEX SERVICES FIXED GATEWAY EARTH STATION

Input Parameters

Antenna Diameter	$D = 1.016$ m
Frequency	$f = 14.5$ GHz
Diameter of Feed Mouth	$D_{feed} = 5.77$ cm
Max Power into Antenna	$P_{max} = 14.93$ W
Aperture efficiency [%]	$\eta = 62.1\%$
Maximum Transmit Duty Cycle	$DTx = 100\ \%$

Calculated Values

Wavelength	$\lambda = \frac{c}{f} = 0.0207\ m$
Area of Reflector	$A = \frac{\pi D^2}{4} = 0.81\ m^2$
Area of Feed Mouth	$A_{feed} = \frac{\pi D_{feed}^2}{4} = 0.0026\ m^2$
Antenna Gain	$G_{max} = \frac{\eta 4\pi A}{\lambda^2} = 14779.93$ $10\log(G_{max}) = 41.7\ dB$
Length of Near Field	$R_{nf} = \frac{D^2}{4\lambda} = 12.47\ m$
Beginning of Far Field	$R_{ff} = 0.6\frac{D^2}{\lambda} = 29.94\ m$

Power Density Calculations

Power Density in Far Field	$S_{ff} = DTx\frac{P_{max}G_{max}}{4\pi R_{ff}^2} = 1.96\ \frac{mW}{cm^2}$
Power Density in Near Field	$S_{nf} = DTx\frac{4\eta P_{max}}{A} = 4.58\ \frac{mW}{cm^2}$
Power Density at Antenna Surface (Main Reflector)	$S_{ref} = DTx\frac{4P_{max}}{A} = 7.37\ \frac{mW}{cm^2}$
Power Density at Feed Mouth	$S_{feed} = DTx\frac{4P_{max}}{A_{feed}} = 2283.53\ \frac{mW}{cm^2}$