Radiation Hazard Analysis

Fixed Customer Premises Earth Station Terminal 75 cm Ka band Antenna

Introduction

This analysis calculates the non-ionizing radiation levels for a Viasat, Inc. (“Viasat”) fixed customer premises earth station terminal (“CP terminal”). 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 Viasat CP terminals are compliant and will not result in exposure levels exceeding the applicable radiation hazard limits.

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 when 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 when 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. Viasat will typically deploy its CP terminals in General Population/Uncontrolled Environments. Accordingly, this analysis discusses only the Maximum Permissible Exposure (“MPE”) limit for those types of exposures, which is a power density equal to 1 milliwatt per centimeter squared averaged over a thirty minute period.

As described in the definitional section of Appendix A, this report analyzes the maximum power density levels in the vicinity of a CP terminal antenna in five regions: (1) the far field, (2) the near field, (3) the transition region between near field and far field, (4) near the main reflector surface, and (5) between the main reflector and the feed. These radiation regions were analyzed using the definitions and formulas in Bulletin 65 for aperture antennas. The results of this analysis are summarized in Tables 1 and 2 in Appendix A, which identify the potential exposure under nominal operating conditions and worst-case conditions, respectively.

CP Terminal Description

The CP terminal transmits bursts of information at designated times that are assigned to the terminal by the network. The length and carrier frequency of each transmission burst depend on the CP terminal's mode of operation.

The CP Terminal does not support operation at 100% duty cycle and is limited to a maximum duty cycle of 50%. The nominal operating duty cycle during customer usage is typically 12% (Normal Mode) or less over a 30 minute averaging period (3 σ), and during periods of inactivity the duty cycle is 0.06% (Idle Mode).

Table 1 provides a summary of the radiation exposure analysis for both duty cycle values, 12% and 0.06%.

The CP terminal uses transmitter power control system to limit the transmitted power to that just necessary to operate at the desired S/N at the satellite. This reduces uplink interference in normal operation but allows for increased power output to mitigate the effects of changing atmospheric conditions. Under clear sky and cloudy conditions, all CP terminals will transmit at a nominal power level of 7.1 watts or less. This includes terminals at the edge of beam locations. In rainy conditions, a CP terminal typically adjusts its transmitted symbol rate, modulation, and forward error correction coding to maintain a robust link, but transmit power is not increased beyond the maximum power level of 7.1 watts.

The CP terminal incorporates two “fail safe” features that limit the potential for human exposure. First, the transmitter is not enabled until the received down link connection to the satellite has been established and an acceptable down link bit error rate has been achieved. The transmitter is disabled very quickly, in less than 40 milliseconds, if a loss of down connectivity occurs. Transmissions will not resume until approximately 10 seconds after downlink communications have been reestablished. Secondly, the terminal's transmitter is not capable of operating in a continuous transmit mode of operation. The CP terminal's outdoor unit incorporates a watchdog timer that will shut down the transmitter if it remains in a continuous transmit state for more than 10 seconds. Under these conditions, the transmitter will be turned off for 3 ms then resume normal operation after an internal reset has occurred.

Explanation of the Analysis

The “Calculated Values” in Table 1 are the exposure rates calculated using the formula from the Office of Engineering and Technology Bulletin Number 65 (Edition 97-01) for a system with continuous (100% transmit duty cycle) transmission. The Viasat network, however, is based on so-called “shared pipes”. Viasat terminals transmit short bursts of data periodically as instructed by the network and are neither designed for nor capable of continuous transmission. Therefore, in order to compute the effective radiated energy of a Viasat CP terminal, the terminals transmitter duty cycle has been used to adjust the values calculated from Bulletin Number 65.

The columns in the tables labeled “Idle Mode” and “Normal Mode” reflect the total potential for human exposure based on the length of time that the CP terminal transmits energy during a rolling 30 minute period. In Idle Mode, the maximum transmitter duty cycle is 0.06% and therefore the values in the column labeled “Idle Mode” are equal to the calculated values for 100% duty cycle multiplied by 0.0006. Similarly, in Normal Mode the maximum transmitter duty cycle is 12% and the values in the column labeled “Normal Mode” are equal to the calculated values for 100% multiplied by 0.12.

The MPE level calculations for each of the operating modes for conditions labeled “Between feed and reflector” are calculated based on the “fail safe” features of the Viasat CP Terminal. When the receive signal is lost due to signal blockage, the transmitter is shut down until the received down link is restored. The transmitter is shutdown in less than 40 milliseconds of the loss of the downlink. Since the areas of high field strength near the reflector and the feed are very sensitive to blockage of the down link, this “fail safe” feature minimizes the potential for human exposure. If the blockage due to human exposure occurs in these areas, the down link will be interrupted causing the transmitter to turn off almost immediately and it will remain off until the blockage is removed.

After the blockage is removed, the CP terminal will have to reacquire the receive downlink and wait to be invited back into the network before the transmitter will be enabled. The complete downlink recovery time is 10 seconds. The values in the column labeled “Idle”, “Normal”, and “Maximum Case” are multiplied by 0.004 because the transmitter cannot transmit more than 0.4% of any rolling 30 minute period with significant blockage near the sub reflector and between the sub-reflector and the feed.

Results of Analysis

This analysis demonstrates that this terminal is not a radiation hazard because the terminal does not exceed the MPE limit of 1 milliwatt per centimeter squared averaged over a thirty minute period. As demonstrated in Tables 1 and 2, the areas with the greatest field concentrations is between the feed and the reflector surface. The areas in which these high field concentrations exist are very small in size, which limits the risk of human exposure to a person's hands or arms. If the down link (receive signal) is interrupted by an object in an area of high field concentration, the uplink (transmit signal) is shut down in less than 40 milliseconds and the receiver down link recovery time is 10 seconds.

The uplink will remain off until the blockage is removed and the downlink recovery is complete. This feature, coupled with the terminal's use of uplink power control and non-continuous operation, ensures that the general population will not be exposed to harmful levels of radiation.

Conclusion

This radiation hazard analysis demonstrates that these CP terminals will not result in exposure levels exceeding the applicable radiation hazard limits.

Definitions

1) Far Field Region

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

2) Near Field Region

The near field region is an elliptical volume co-incident with the boresight of the main beam extending outward from the main reflector the length of the near field $\frac{D_{maj}^{2}}{4 \cdot \lambda}$ meters. The larger dimension (D_{maj}) of the elliptical antenna is used in place of the diameter of a circular antenna to calculate the worst-case length of the near field.

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 inversely with increasing distance. Therefore, the power density in the transition region will be less than the power density in the near field for the purpose of evaluating potential exposure.

4) Region Near the Main Reflector Surface

The power density near the main reflector surface can be estimated as equal to four times the the power divided by the area of the main reflector surface, assuming that the illumination is uniform and that it would be possible to intercept equal amounts of energy radiating towards and reflected from the antenna surface.

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.

OET 65 Definition of Terms and Formulas:

OET 65 Radiation Hazard Analysis

Definition of terms

The terms are used in the formulas here are defined as follows:

Ssurface = maximum power density at the antenna surface
Snf = maximum near-field power density
St = power density in the transition region
Sff = power density (on axis)
Rnf = extent of near-field
Rff = distance to the beginning of the far-field
R = distance to point of interest
P = power fed to the antenna
A = physical area of the aperture antenna
G = power gain in the direction of interest relative to an isotropic radiator
D = maximum dimension of antenna (diameter if circular)
λ = wavelength
η = aperture efficiency, typically 0.65 to 0.75

Formulas

Antenna Surface. The maximum power density directly in front of an antenna (e.g., at the antenna surface) can be approximated by the following equation:

$$f_{S.surface}(P,A) := \frac{4 \cdot P}{A}$$

Near-Field Region. In the near-field or Fresnel region,of the main beam, the power density can reach a maximum before it begins to decrease with distance. The extent of the near-field can be described by the following equation **(**D and l in same units):

$$f_{R.nf}(D,\lambda) := \frac{D^2}{4 \cdot \lambda}$$

The magnitude of the on-axis (main beam) power density varies according to location in the near-field. However, the maximum value of the near-field, on-axis, power density can be expressed by the following equation:

$$f_{S.nf}(P,D,\eta) := \frac{16 \cdot \eta \cdot P}{\pi \cdot D^2}$$

Aperture efficiency can be estimated, or a reasonable approximation for circular apertures
can be obtained from the ratio of the effective aperture area to the physical area as follows:

$$f_{\eta}(G,D,\lambda):=\frac{\left(\frac{G\cdot\lambda^2}{4\cdot\pi}\right)}{\left(\frac{\pi\cdot D^2}{4}\right)}$$

If the antenna gain is not known, it can be calculated from the following equation using
the actual or estimated value for aperture efficiency:

$$f_G(A,\lambda,\eta):=\frac{4\cdot\pi\cdot\eta\cdot A}{\lambda^2}$$

Transition Region. Power density in the transition region decreases inversely with distance from the antenna, while power density in the far-field (Fraunhofer region) of the antenna decreases inversely with the ***square*** of the distance. For purposes of evaluating RF exposure, the
distance to the beginning of the far-field region (farthest extent of the transition region) can be
approximated by the following equation:

$$f_{R.ff}(D,\lambda):=\frac{0.6\cdot D^2}{\lambda}$$

The transition region will then be the region extending from **R nf** to **R ff** . If the location of interest falls within this transition region, the on-axis power density can be determined from the following equation:

$$f_{S.t}(S_{nf},R_{nf},R):=\frac{S_{nf}\cdot R_{nf}}{R}$$

Far-Field Region. The power density in the far-field or Fraunhofer region of the antenna pattern
decreases inversely as the square of the distance. The power density in the far-field region of the
radiation pattern can be estimated by the general equation discussed earlier:

$$f_{S.ff}(P,G,R):=\frac{P\cdot G}{4\cdot\pi\cdot R^2}$$

Table 1

Table 1: Radiation from 0.745 m Fixed Terminal

Input Parameters

Antenna Aperture Major Axis:		$D_{maj} := 77 \cdot cm$
Antenna Aperture Minor Axis:		$D_{min} := 72 \cdot cm$
Diameter of Feed Mouth:		$D_{feed} := 5.461 \cdot cm$
Frequency of Operation:		$F := 30 \cdot GHz$
Max Power into Antenna:		$P := 7.1 \cdot W$
Aperture Efficiency:		$\eta := 0.515$

Calculated Values

Wavelength:	$\lambda := \frac{c}{F}$	$\lambda = 0.01\ m$
Area of Reflector:	$A_{ref} := \frac{\pi \cdot D_{maj} \cdot D_{min}}{4}$	$A_{ref} = 0.435\ m^2$
Equivalent Reflector Dia:	$Dia_{eq} := \sqrt{\frac{A_{ref} \cdot 4}{\pi}}$	$Dia_{eq} = 0.745\ m$
Area of Feed Mouth:	$A_{feed} := \pi \cdot \frac{D_{feed}^2}{4}$	$A_{feed} = ?\ m^2$
Antenna Gain:	$G := \frac{\eta \cdot 4 \cdot \pi \cdot A_{ref}}{\lambda^2}$	$G = 2.822 \cdot 10^4$ $10 \cdot \log(G) = 44.505$ dBi
Length of Near Field:	$R_{nf} := \frac{D_{maj}^2}{4 \cdot \lambda}$	$R_{nf} = 14.833\ m$
Beginning of Far Field:	$R_{ff} := 0.6 \cdot \frac{D_{maj}^2}{\lambda}$	$R_{ff} = 35.599\ m$

Power Density Calculations

Far Field: 100% Duty Cycle

$$S_{ff} := \frac{P \cdot G}{4 \cdot \pi \cdot {R_{ff}}^2} \qquad S_{ff} = 1.258 \ \frac{mW}{cm^2}$$

Idle Mode Normal Mode

$$S_{ff} \cdot 0.06\% = \left(7.549 \cdot 10^{-4}\right) \ \frac{mW}{cm^2} \qquad S_{ff} \cdot 12\% = 0.151 \ \frac{mW}{cm^2}$$

Near Field: 100% Duty Cycle

$$S_{nf} := \frac{4 \cdot \eta \cdot P}{A_{ref}} \qquad S_{nf} = 3.359 \ \frac{mW}{cm^2}$$

Idle Mode Normal Mode

$$S_{nf} \cdot 06\% = 0.202 \ \frac{mW}{cm^2} \qquad S_{nf} \cdot 12\% = 0.403 \ \frac{mW}{cm^2}$$

Transition Region: Power density is less than the maximum near field region power density and greater than the minimum far field region power density.

Main Reflector: 100% Duty Cycle

$$S_{ref} := \frac{4 \cdot P}{A_{ref}} \qquad S_{ref} = 6.522 \ \frac{mW}{cm^2}$$

Idle Mode Normal Mode

$$S_{ref} \cdot 0.06\% = 0.004 \ \frac{mW}{cm^2} \qquad S_{ref} \cdot 12\% = 0.783 \ \frac{mW}{cm^2}$$

Feed Mouth1: 100% Duty Cycle

$$S_{feed} := \frac{4 \cdot P}{A_{feed}} \qquad S_{feed} = \left(1.21 \cdot 10^{3}\right) \ \frac{mW}{cm^2}$$

Idle Mode Normal Mode

$$S_{feed} \cdot 0.06\% \cdot 0.004 = 0.003 \ \frac{mW}{cm^2} \qquad S_{feed} \cdot 12\% \cdot 0.004 = 0.582 \ \frac{mW}{cm^2}$$