Viasat, Inc.

Radiation Hazard Analysis

75 cm, 1.8 m Fixed and Temporary Earth Stations
Global Mantarray M40 Mobile Earth Station

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Contents

1 Introduction

This analysis calculates the non-ionizing radiation levels for three types of Viasat, Inc, (“Viasat") earth station terminals (“ES terminal") namely, 75 cm and 180 cm fixed and temporary fixed ES terminals and the Global Mantarray M40, or GM40 aeronautical earth stations in motion (“ESIM”). These three types represent typical antenna performance for terminals used under this experimental license operating on ViaSat-2 located at 69.9 W.L. 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 ES terminals are compliant and will not result in exposure levels exceeding the applicable radiation exposure 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 ES terminals in General Population/Uncontrolled Environments (though in many cases the 1.8 m class ES terminal will be installed in an enterprise environment with controlled access). 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 this document, this report analyzes the maximum power density levels in the vicinity of a ES 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 Table 1 and Table 2, which identify the potential exposure under nominal operating conditions and worst-case conditions, respectively.

2 ES Terminal Description

The ES terminals 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 ES terminal's traffic requirements. In normal operation, the ES terminal transmits burst traffic to the network with a nominal duty cycle of less than 6.25%.

The ES terminal incorporates two “fail safe" features that limit the potential for human exposure. First, the transmitter is not enabled until the receive 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. This includes the case where human interference causes degradation in the link. 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 ES 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 briefly then resume normal operation after an internal reset has occurred.

3 Explanation of the Analysis

The “Calculated Values" in Table 1, Table 2 and Table 3 show the exposure rates calculated using the formulae 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 ES terminal, the terminal’s transmitter duty cycle has been used to adjust the values calculated in accordance with Bulletin Number 65. To do this, the average power during the averaging period is calculated as the maximum transmitter peak transmit power output adjusted by the duty cycle of 6.25%.

The MPE level calculations for the area labeled “Between feed and reflector" are calculated based on the “fail safe" features of the Viasat ES Terminal. When the receive signal is lost due to signal blockage, the transmitter is shut down until the receive downlink 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 in the area between the feed and reflector. 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 ES 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. Accordingly, the average power value would be multiplied by 0.004 because the transmitter cannot transmit more than 0.4% of any rolling 30 minute period (the period over which the power density is averaged) with significant blockage near the sub reflector and between the sub-reflector and the feed.

4 Results of Analysis

This analysis demonstrates that the Viasat ES terminals satisfy Commission requirements because neither terminal would exceed the MPE limit of 1 milliwatt per centimeter squared averaged over a thirty minute period when operated in the network as designed. In particular, a fail-safe feature greatly reduces the chance of human exposure between the feed and the reflector surface: a small blockage in this area is sufficient to cause transmissions to cease. If the down link (receive signal) is interrupted by an object in this area, 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 the non-continuous operation, ensures that the general population will not be exposed to harmful levels of radiation that exceed Commission standards.

5 Conclusion

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

6 Analysis

Definitions

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 is $D_{maj}^2/(4\lambda)$ meters. The larger dimension $\left(D_{maj}\right)$ 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.

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.

Far Field Region

The far field region extends outward from the main reflector, beginning at a distance of $\left(0.6 \cdot D_{maj}^2\right)/\lambda$ 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.

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. Note: as described above, automatic transmit inhibit will activate when blockage between the reflector and feed occurs.

Power Density on the Antenna Surface.

The maximum power density directly in front of an antenna (e.g., at the antenna surface) can be approximated as four times the transmit power divided by the area of the antenna surface. Note: as described above, automatic transmit inhibit will activate when blockage between the reflector and feed occurs.

Table 1
Radiation from 75 cm ES Terminal

Input Parameters

Antenna Aperture Major Axis:	D_{maj} := 77 cm
Antenna Aperture Minor Axis:	D_{min} := 72 cm
Diameter of Feed Mouth	D_{feed} := 5.46 cm
Frequency of Operation:	F := 30 GHz
Max Power into Antenna:	P := 25 W
Aperture Efficiency:	η := 0.515

Calculated Values

Wavelength:	$\lambda \coloneqq \frac{c}{F}$	$\lambda = 0.999\ cm$
Area of Reflector:	$A_{ref} \coloneqq \frac{\pi D_{maj} D_{min}}{4}$	$A_{ref} = 0.435\ m^2$
Area of Feed Mouth:	$A_{feed} \coloneqq \frac{\pi D_{feed}^2}{4}$	$A_{feed} = 23.42\ cm^2$
Antenna Gain:	$G \coloneqq \frac{4\eta\pi A_{ref}}{\lambda^2}$	$G = 2.822 \times 10^4$ $G = 44.5\ dBi$
Length of Near Field:	$R_{nf} \coloneqq \frac{D_{maj}^2}{4\lambda}$	$R_{nf} = 14.8\ m$
EIRP:	$EIRP \coloneqq PG$	$EIRP = 58.0\ dBW$
Beginning of Far Field:	$R_{ff} \coloneqq 0.6\left(\frac{D_{maj}^2}{\lambda}\right)$	$R_{ff} = 36.0\ m$

Power Density Calculations

Far Field:

$S_{ff} \coloneqq \frac{PG}{4\pi R_{ff}^2}$ $6.25\% S_{ff} = 0.277 \ \frac{mW}{cm^2}$

Near Field:

$S_{nf} \coloneqq \frac{16\eta P}{\pi D_{maj}^2}$ $6.25\% S_{nf} = 0.691 \ \frac{mW}{cm^2}$

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

Area between Main Reflector and Feed:

$S_{ref} \coloneqq \frac{4P}{A_{ref}}$ $6.25\% \ x \ 0.4\% S_{ref} = 0.006 \ \frac{mW}{cm^2}$

Thus, the power density in each region is below the MPE limit for General Population/Uncontrolled Environments of 1.0 $\frac{mW}{cm^2}$.

Table 2
Radiation from 180 cm ES Terminal

Input Parameters

Antenna Aperture Major Axis:	D_{maj} := 189.6 cm
Antenna Aperture Minor Axis:	D_{min} := 181.0 cm
Diameter of Feed Mouth	D_{feed} := 5:46 cm
Frequency of Operation:	F := 30 GHz
Max Power into Antenna:	P := 25 W
Aperture Efficiency:	η := 0.515 cm

Calculated Values

Wavelength:	$\lambda := \frac{c}{F}$	$\lambda = 0.999\ cm$
Area of Reflector:	$A_{ref} := \frac{\pi D_{maj} D_{min}}{4}$	$A_{ref} = 2.7\ m^2$
Area of Feed Mouth:	$A_{feed} := \frac{\pi D_{feed}^2}{4}$	$A_{feed} = 23.42\ cm^2$
Antenna Gain:	$G := \frac{4\eta\pi A_{ref}}{\lambda^2}$	$G = 1.747 \times 10^5$ $G = 52.4\ dBi$
Length of Near Field:	R_{nf}	$R_{nf} = 89.9\ m$
EIRP:	$EIRP := PG$	$EIRP = 65.9\ dBW$
Beginning of Far Field:	$R_{ff} := 0.6\left(\frac{D_{maj}^2}{\lambda}\right)$	$R_{ff} = 215.8\ m$

Power Density Calculations

Far Field:

$S_{ff} \coloneqq \frac{PG}{4\pi R_{ff}^2}$ $6.25\% S_{ff} = 0.047\ \frac{mW}{cm^2}$

Near Field:

$S_{nf} \coloneqq \frac{16\eta P}{\pi D_{maj}^2}$ $6.25\% S_{nf} = 0.114\ \frac{mW}{cm^2}$

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

Area between Main Reflector and Feed:

$S_{ref} \coloneqq \frac{4P}{A_{ref}}$ $6.25\%\ x\ 0.4\% S_{ref} = 0.0009\ \frac{mW}{cm^2}$

Thus, the power density in each region is below the MPE limit for General Population/Uncontrolled Environments of 1.0 $\frac{mW}{cm^2}$.

Table 3
Radiation from GM40 ES Terminal

Input Parameters

Antenna Aperture Major Axis:	D_{maj} := 76.7 cm
Antenna Aperture Minor Axis:	D_{min} := 15.3 cm
Frequency of Operation:	F := 30 GHz
Max Power into Antenna:	P := 31.6 W
Aperture Efficiency:	η := 0.75

Calculated Values

Wavelength:	$\lambda \coloneqq \frac{c}{F}$	$\lambda = 0.999\ cm$
Area of Reflector:	$A_{ref} \coloneqq D_{maj} D_{min}$	$A_{ref} = 0.118\ m^2$
Antenna Gain:	$G \coloneqq \frac{4\eta\pi A_{ref}}{\lambda^2}$	$G = 1.029 \times 10^4$ $G = 40.5\ dBi$
Length of Near Field:	$R_{nf} \coloneqq \frac{D_{maj}^2}{4\lambda}$	$R_{nf} = 14.7\ m$
EIRP:	$EIRP \coloneqq PG$	$EIRP = 58.0\ dBW$
Beginning of Far Field:	$R_{ff} \coloneqq 0.6\left(\frac{D_{maj}^2}{\lambda}\right)$	$R_{ff} = 35.3\ m$

Power Density Calculations

Far Field:

$S_{ff} \coloneqq \frac{PG}{4\pi R_{ff}^2}$ $6.25\% S_{ff} = 0.13 \frac{mW}{cm^2}$

Near Field:

$S_{nf} \coloneqq \frac{16\eta P}{\pi D_{maj}^2}$ $6.25\% S_{nf} = 1.3 \frac{mW}{cm^2}$

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

Aperature:

$S_{apr} \coloneqq \frac{4P}{A_{apr}}$ $6.25\%\ x\ 0.4\% S_{apr} = 0.03 \frac{mW}{cm^2}$