Analysis of Non-Ionizing Radiation for a 0.3 m Earth Station Antenna System

Introduction

This report analyzes the non-ionizing radiation levels for a 0.3 m earth station (ES) antenna system.

The FCC's Office of Engineering Technology's Bulletin No. 65 specifies that there are two separate tiers of exposure limits that are dependent upon the situation in which the exposure takes place and/or the status of the individuals who are subject to the exposure. The two tiers are General Population / Uncontrolled environment, and an Occupational / Controlled environment.

This ES antenna is mounted on the fuselage or vertical stabilizer on aircraft, well above head height of people working in the area and is covered by a radome which prevents access to the area between feed and reflector and reflector surface and which is clearly marked with RF warnings. Due to its location on top of the aircraft, the antenna is inaccessible to ground crew during normal gate operations when the antenna is active. The antenna will be turned off during maintenance windows where personnel may have access to areas near the antenna. Additionally, as discussed below, when maintenance occurs inside a hanger, the system will not transmit because receive communications (a precursor to transmit operations) with the satellite will be blocked.

Because the environment is controlled and any potential exposure is of a transitory nature, the limits for Occupational/Controlled Exposures are assumed to apply. Accordingly, this analysis discusses only the Maximum Permissible Exposure (MPE) limit for those types of exposures, which is a power density equal to five milliwatts per centimeter squared averaged over a six-minute period.

As described in the definitional section of this document, this report considers the maximum power density levels in the vicinity of an ES antenna in several regions: (1) the far field, (2) the near field, (3) the transition region between near field and far field, and (4) the surface of the radiating aperture. These radiation regions were analyzed using the definitions and formulas in Bulletin 65 for aperture antennas. The results of this analysis are summarized at the end of this document.

Terminal Description

The ES terminal transmits information at designated times that are assigned to the terminal by the network. The carrier frequency of each transmission burst depends on the ES terminal's traffic requirements. The duty cycle of the ES terminal can be set between 0 and 100% depending on the congestion of the network and the service plan. Dedicated channels allocated to ES terminals with duty cycle of 100% are a typically reserved for customers with high throughput, high service availability requirements.

The ES terminal incorporates a “fail safe" feature that limits the potential for human exposure. 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 link 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.

Analysis of Occupational/Controlled Environment

The calculated values in the analysis show the exposure rates calculated using the formulae from the Office of Engineering and Technology Bulletin Number 65 (Edition 97-01) for the peak RF power output during transmission as reduced by the effect of duty cycle. Because the Viasat network allows for duty cycles up to 100% this analysis will only consider the case of continuous transmissions as this represents the worst case with respect to exposure.

An important aspect of the Viasat ES terminal is the “fail safe" feature. 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 antenna aperture 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 power value would be multiplied by 0.004 because the transmitter cannot transmit more than 0.4% of any rolling six-minute period (the period over which the power density is averaged) with significant blockage near the aperture.

Summary of expected radiation levels for a Controlled environment

Region	Maximum Power Density	Hazard Assessment
Safe region range ≥ 5.3 m	5 mW/cm^2	Satisfies FCC MPE
Far field (R_{ff}) = 2.6 m	20.7 mW/cm^2	Exceeds FCC MPE
Near field (R_{nf}) = 1.1 m	48.4 mW/cm^2	Exceeds FCC MPE
Transition region (R_t) (R_t) = $R_{nf} < R_t < R_{ff}$	48.4 mW/cm^2	Exceeds FCC MPE
Main Reflector Surface ($S_{surface}$)	77.4 mW/cm^2	Exceeds FCC MPE*

*Note, that the power density level in the area between the feed and the reflector surface is greater than the reflector surface and is assumed to be a potential hazard. However, as discussed above, this region and the main reflector surface are covered by a radome, which prevents access to these areas.

Conclusion

Due to the 6º mechanical low elevation limit on the antenna and the mounting location on the aircraft fuselage or top of the tail (approximately 8 meters from the ground), persons on the ground in the vicinity of the aircraft are not likely to become exposed to the main beam projected by the antenna. While on-axis RF power density levels in the main beam do exceed the FCC MPE limits in some cases, only maintenance personnel are likely to be present in the regions within the main beam and the antenna will be turned off during maintenance windows where personnel may have access to areas near the antenna. Additionally, as discussed above, when maintenance occurs inside a hanger, the system will not transmit because receive communications (a precursor to transmit operations) with the satellite will be blocked.

The applicable exposure limit for the General Population / Uncontrolled environment, i.e., areas that people may enter freely, at this frequency of operation is 1 mW/cm^2 average power density over a 30-minute period. In the case of passengers and other members of the general public, no access is available near the antenna, and given the minimum operating elevation any area of uncontrolled access where general population may travel are well removed from the cylinder of RF projected by the antenna.

As required by 47 CFR 15.228 (d), ESIM terminals exhibiting radiation exposure levels exceeding 1.0 mW/cm2 in accessible areas, such as at the exterior surface of the radome, will have a label attached to the surface of the terminal warning about the radiation hazard and will include thereon a diagram showing the regions around the terminal where the radiation levels could exceed the maximum radiation exposure.

Analysis

The analysis and calculations that follow in this report are performed in compliance with the methods described in the OET Bulletin No. 65.

Definition of terms

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

$S_{surface}$ = maximum power density at the antenna surface
S_{nf} = maximum near-field power density
S_t = power density in the transition region
S_{ff} = power density (on axis)
R_{nf} = extent of near-field
R_{ff} = distance to the beginning of the far-field
R = distance to point of interest

P_a = 20 W	maximum power amplifier output
L_{fs} = 1.65 dB	loss between power amplifier and antenna feed
P = 13.68 W	power fed to the antenna in Watts
A = 0.071 m^2	physical area of the aperture antenna
G = 1298.7	power gain relative to an isotropic radiator
D = 0.3 m	diameter of antenna in meters
F = 14.5	frequency in GHz
λ = 0.02 m	wavelength in meters ($300/F_{MHz}$)
η = 0.625	aperture efficiency

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:

$$S_{surface} = (4 * P) / A \qquad (1.1)$$

$$= (4 * 13.68 \text{ W}) / 0.071 \text{ m}^2$$

$$= 77.4 \text{ mW/cm}^2$$

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 λ in same units):

$$R_{nf} = D^2 / (4 * \lambda) \qquad (1.2)$$

$$= (0.3 \text{ m})^2 / (4 * 0.02 \text{ m})$$

$$= 1.1 \text{ m}$$

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:

$S_{nf} = (16 * \eta * P) / (\pi * D^2)$ (1.3)

$= (16 * 0.625 * 13.68 \text{ W}) / (\pi * (0.3 \text{ m})^2)$

$= 48.38 \text{ mW/cm}^2$

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. 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:

$S_t = (S_{nf} * R_{nf}) / R$ (1.4)

$= (48.38 \text{ mW/cm}^2 * 1.1 \text{ m}) / R$

$= (53.22 \text{ m} * \text{mW/cm}^2) / R$ where R is the location of interest in meters

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 distance to the start of the far field can be calculated by the following equation:

$R_{ff} = (0.6 * D^2) / \lambda$ (1.5)

$= (0.6 * (0.3 \text{ m})^2) / 0.02 \text{ m}$

$= 2.6 \text{ m}$

The power density at the start of the far-field region of the radiation pattern can be estimated by the equation:

$S_{ff} = (P * G) / (4 * \pi * R_{ff}^2)$ (1.6)

$= (13.68 \text{ W} * 1298.7) / (4 * \pi * (2.6 \text{ m})^2)$

$= 20.72 \text{ mW/cm}^2$

Safe Region for Controlled Access. As given above, the power density in the far field region of the antenna pattern decreases inversely as the square of the distance. The distance to the point where the power density equals the 5 mW/cm^2 level can be determined by the equation:

$$R_{5\,mW} = ((P * G) / (4 * \pi * 5\ mW/cm^2 * 10))^{0.5} \quad (1.7)$$

$$= ((13.68\ W * 1298.7) / (62.8\ mW/cm^{\wedge}2))^{0.5}$$

$$= 5.3\ m$$

Analysis of Non-Ionizing Radiation for a 0.45 m Earth Station Antenna System

Introduction

This report analyzes the non-ionizing radiation levels for a 0.45 m earth station (ES) antenna system.

The FCC's Office of Engineering Technology's Bulletin No. 65 specifies that there are two separate tiers of exposure limits that are dependent upon the situation in which the exposure takes place and/or the status of the individuals who are subject to the exposure. The two tiers are General Population / Uncontrolled environment, and an Occupational / Controlled environment.

This ES antenna is mounted on the fuselage or vertical stabilizer on aircraft, well above head height of people working in the area and is covered by a radome which prevents access to the area between feed and reflector and reflector surface and which is clearly marked with RF warnings. Due to its location on top of the aircraft, the antenna is inaccessible to ground crew during normal gate operations when the antenna is active. The antenna will be turned off during maintenance windows where personnel may have access to areas near the antenna. Additionally, as discussed below, when maintenance occurs inside a hanger, the system will not transmit because receive communications (a precursor to transmit operations) with the satellite will be blocked.

Because the environment is controlled and any potential exposure is of a transitory nature, the limits for Occupational/Controlled Exposures are assumed to apply. Accordingly, this analysis discusses only the Maximum Permissible Exposure (MPE) limit for those types of exposures, which is a power density equal to five milliwatts per centimeter squared averaged over a six-minute period.

As described in the definitional section of this document, this report considers the maximum power density levels in the vicinity of an ES antenna in several regions: (1) the far field, (2) the near field, (3) the transition region between near field and far field, and (4) the surface of the radiating aperture. These radiation regions were analyzed using the definitions and formulas in Bulletin 65 for aperture antennas. The results of this analysis are summarized at the end of this document.

Terminal Description

The ES terminal transmits information at designated times that are assigned to the terminal by the network. The carrier frequency of each transmission burst depends on the ES terminal's traffic requirements. The duty cycle of the ES terminal can be set between 0 and 100% depending on the congestion of the network and the service plan. Dedicated channels allocated to ES terminals with duty cycle of 100% are a typically reserved for customers with high throughput, high service availability requirements.

The ES terminal incorporates a “fail safe" feature that limits the potential for human exposure. 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 link 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.

Analysis of Occupational/Controlled Environment

The calculated values in the analysis show the exposure rates calculated using the formulae from the Office of Engineering and Technology Bulletin Number 65 (Edition 97-01) for the peak RF power output during transmission as reduced by the effect of duty cycle. Because the Viasat network allows for duty cycles up to 100% this analysis will only consider the case of continuous transmissions as this represents the worst case with respect to exposure.

An important aspect of the Viasat ES terminal is the “fail safe" feature. 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 antenna aperture 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 power value would be multiplied by 0.004 because the transmitter cannot transmit more than 0.4% of any rolling six-minute period (the period over which the power density is averaged) with significant blockage near the aperture.

Summary of expected radiation levels for a Controlled environment

Region	**Maximum Power Density**	**Hazard Assessment**
Safe region range ≥ 8 m	5 mW/cm^2	Satisfies FCC MPE
Far field (R_{ff}) = 5.9 m	10.3 mW/cm^2	Exceeds FCC MPE
Near field (R_{nf}) = 2.4 m	24.1 mW/cm^2	Exceeds FCC MPE
Transition region (R_t) (R_t) = $R_{nf} < R_t < R_{ff}$	24.1 mW/cm^2	Exceeds FCC MPE
Main Reflector Surface ($S_{surface}$)	37.3 mW/cm^2	Exceeds FCC MPE*

*Note, that the power density level in the area between the feed and the reflector surface is greater than the reflector surface and is assumed to be a potential hazard. However, as discussed above, this region and the main reflector surface are covered by a radome, which prevents access to these areas.

Conclusion

Due to the 6º mechanical low elevation limit on the antenna and the mounting location on the aircraft fuselage or top of the tail (approximately 8 meters from the ground), persons on the ground in the vicinity of the aircraft are not likely to become exposed to the main beam projected by the antenna. While on-axis RF power density levels in the main beam do exceed the FCC MPE limits in some cases, only maintenance personnel are likely to be present in the regions within the main beam and the antenna will be turned off during maintenance windows where personnel may have access to areas near the antenna. Additionally, as discussed above, when maintenance occurs inside a hanger, the system will not transmit because receive communications (a precursor to transmit operations) with the satellite will be blocked.

The applicable exposure limit for the General Population / Uncontrolled environment, i.e., areas that people may enter freely, at this frequency of operation is 1 mW/cm^2 average power density over a 30-minute period. In the case of passengers and other members of the general public, no access is available near the antenna, and given the minimum operating elevation any area of uncontrolled access where general population may travel are well removed from the cylinder of RF projected by the antenna.

As required by 47 CFR 15.228 (d), ESIM terminals exhibiting radiation exposure levels exceeding 1.0 mW/cm2 in accessible areas, such as at the exterior surface of the radome, will have a label attached to the surface of the terminal warning about the radiation hazard and will include thereon a diagram showing the regions around the terminal where the radiation levels could exceed the maximum radiation exposure.

Analysis

The analysis and calculations that follow in this report are performed in compliance with the methods described in the OET Bulletin No. 65.

Definition of terms

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

$S_{surface}$ = maximum power density at the antenna surface
S_{nf} = maximum near-field power density
S_t = power density in the transition region
S_{ff} = power density (on axis)
R_{nf} = extent of near-field
R_{ff} = distance to the beginning of the far-field
R = distance to point of interest

P_a = 20 W	maximum power amplifier output
L_{fs} = 1.35 dB	loss between power amplifier and antenna feed
P = 14.83 W	power fed to the antenna in Watts
A = 0.159 m^2	physical area of the aperture antenna
G = 3015.6	power gain relative to an isotropic radiator
D = 0.45 m	diameter of antenna in meters
F = 14.5	frequency in GHz
λ = 0.02 m	wavelength in meters (300/F_{MHz})
η = 0.645	aperture efficiency

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:

$$S_{surface} = (4 * P) / A \quad (1.1)$$

$$= (4 * 14.83 \text{ W}) / 0.159 \text{ m}^2$$

$$= 37.29 \text{ mW/cm}^2$$

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 λ in same units):

$$R_{nf} = D^2 / (4 * \lambda) \quad (1.2)$$

$$= (0.45 \text{ m})^2 / (4 * 0.02 \text{ m})$$

$$= 2.4 \text{ m}$$

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:

$S_{nf} = (16 * \eta * P) / (\pi * D^2)$ (1.3)

$= (16 * 0.645 * 14.83\ W) / (\pi * (0.45\ m)^2)$

$= 24.05\ mW/cm^2$

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. 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:

$S_t = (S_{nf} * R_{nf}) / R$ (1.4)

$= (24.05\ mW/cm^2 * 2.4\ m) / R$

$= (48.38\ m * mW/cm^2) / R$ where R is the location of interest in meters

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 distance to the start of the far field can be calculated by the following equation:

$R_{ff} = (0.6 * D^2) / \lambda$ (1.5)

$= (0.6 * (0.45\ m)^2) / 0.02\ m$

$= 5.88\ m$

The power density at the start of the far-field region of the radiation pattern can be estimated by the equation:

$S_{ff} = (P * G) / (4 * \pi * R_{ff}^2)$ (1.6)

$= (14.83\ W * 3015.6) / (4 * \pi * (5.9\ m)^2)$

$= 10.30\ mW/cm^2$

Safe Region for Controlled Access. As given above, the power density in the far field region of the antenna pattern decreases inversely as the square of the distance. The distance to the point where the power density equals the 5 mW/cm^2 level can be determined by the equation:

$$R_{5\ mW} = ((P * G) / (4 * \pi * 5\ mW/cm^2 * 10))^{0.5} \quad (1.7)$$

$$= ((14.83\ W * 3015.6) / (62.8\ mW/cm\text{\^{}}2))^{0.5}$$

$$= 8.4\ m$$

Analysis of Non-Ionizing Radiation for the KuKarray Earth Station Antenna System

Introduction

This report analyzes the non-ionizing radiation levels for the KuKarray earth station (ES) antenna system in the Ku band.

The FCC's Office of Engineering Technology's Bulletin No. 65 specifies that there are two separate tiers of exposure limits that are dependent upon the situation in which the exposure takes place and/or the status of the individuals who are subject to the exposure. The two tiers are General Population / Uncontrolled environment, and an Occupational / Controlled environment.

The KuKarray is a Ku/Ka-band dual aperture ES antenna. This ES antenna is mounted on the fuselage of comercial aircraft such as the Boeing 737 and 787, and the Airbus A320 and A380, well above head height of people working in the area and is covered by a radome which prevents access to the area between feed and reflector and reflector surface and which is clearly marked with RF warnings. Due to its location on top of the aircraft, the antenna is inaccessible to ground crew during normal gate operations when the antenna is active. The antenna will be turned off during maintenance windows where personnel may have access to areas near the antenna. Additionally, as discussed below, when maintenance occurs inside a hanger, the system will not transmit because receive communications (a precursor to transmit operations) with the satellite will be blocked.

Because the environment is controlled and any potential exposure is of a transitory nature, the limits for Occupational/Controlled Exposures are assumed to apply. Accordingly, this analysis discusses only the Maximum Permissible Exposure (MPE) limit for those types of exposures, which is a power density equal to five milliwatts per centimeter squared averaged over a six-minute period.

As described in the definitional section of this document, this report considers the maximum power density levels in the vicinity of an ES antenna in several regions: (1) the far field, (2) the near field, (3) the transition region between near field and far field, and (4) the surface of the radiating aperture. These radiation regions were analyzed using the definitions and formulas in Bulletin 65 for aperture antennas. The results of this analysis are summarized at the end of this document.

Terminal Description

The ES terminal transmits information at designated times that are assigned to the terminal by the network. The carrier frequency of each transmission burst depends on the ES terminal's traffic requirements. The duty cycle of the ES terminal can be set between 0 and 100% depending on the congestion of the network and the service plan. Dedicated channels allocated to ES terminals with duty cycle of 100% are a typically reserved for customers with high throughput, high service availability requirements.

The ES terminal incorporates a “fail safe" feature that limits the potential for human exposure. 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 link 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.

Analysis of Occupational/Controlled Environment

The calculated values in the analysis show the exposure rates calculated using the formulae from the Office of Engineering and Technology Bulletin Number 65 (Edition 97-01) for the peak RF power output during transmission as reduced by the effect of duty cycle. Because the Viasat network allows for duty cycles up to 100% this analysis will only consider the case of continuous transmissions as this represents the worst case with respect to exposure.

An important aspect of the Viasat ES terminal is the “fail safe" feature. 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 antenna aperture 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 power value would be multiplied by 0.004 because the transmitter cannot transmit more than 0.4% of any rolling six-minute period (the period over which the power density is averaged) with significant blockage near the aperture.

Summary of expected radiation levels for a Controlled environment

Region	**Maximum Power Density**	**Hazard Assessment**
Safe region range ≥ 8.39 m	5 mW/cm^2	Satisfies FCC MPE
Far field (R_{ff}) = 16.9 m	1.39 mW/cm^2	Satisfies FCC MPE
Near field (R_{nf}) = 7.0 m	12.77 mW/cm^2	Exceeds FCC MPE
Transition region (R_t) (R_t) = $R_{nf} < R_t < R_{ff}$	12.77 mW/cm^2	Exceeds FCC MPE
Main Reflector Surface ($S_{surface}$)	65.62 mW/cm^2	Exceeds FCC MPE*

*Note, that the power density level in the area between the feed and the reflector surface is greater than the reflector surface and is assumed to be a potential hazard. However, as discussed above, this region and the main reflector surface are covered by a radome, which prevents access to these areas.

Conclusion

Due to the 6º mechanical low elevation limit on the antenna and the mounting location on the aircraft fuselage or top of the tail (approximately 8 meters from the ground), persons on the ground in the vicinity of the aircraft are not likely to become exposed to the main beam projected by the antenna. While on-axis RF power density levels in the main beam do exceed the FCC MPE limits in some cases, only maintenance personnel are likely to be present in the regions within the main beam and the antenna will be turned off during maintenance windows where personnel may have access to areas near the antenna. Additionally, as discussed above, when maintenance occurs inside a hanger, the system will not transmit because receive communications (a precursor to transmit operations) with the satellite will be blocked.

The applicable exposure limit for the General Population / Uncontrolled environment, i.e., areas that people may enter freely, at this frequency of operation is 1 mW/cm^2 average power density over a 30-minute period. In the case of passengers and other members of the general public, no access is available near the antenna, and given the minimum operating elevation any area of uncontrolled access where general population may travel are well removed from the cylinder of RF projected by the antenna.

As required by 47 CFR 15.228 (d), ESIM terminals exhibiting radiation exposure levels exceeding 1.0 mW/cm2 in accessible areas, such as at the exterior surface of the radome, will have a label attached to the surface of the terminal warning about the radiation hazard and will include thereon a diagram showing the regions around the terminal where the radiation levels could exceed the maximum radiation exposure.

Analysis

The analysis and calculations that follow in this report are performed in compliance with the methods described in the OET Bulletin No. 65.

Definition of terms

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

$S_{surface}$ = maximum power density at the antenna surface
S_{nf} = maximum near-field power density
S_t = power density in the transition region
S_{ff} = power density (on axis)
R_{nf} = extent of near-field
R_{ff} = distance to the beginning of the far-field
R = distance to point of interest

P_a = 25 W	maximum power amplifier output
L_{fs} = 1.18 dB	loss between power amplifier and antenna feed
P = 19.05 W	power fed to the antenna in Watts
A = 0.116 m^2	physical area of the aperture antenna
G = 2608.2	power gain relative to an isotropic radiator
D = 0.762 m	major diameter of antenna in meters
H = 0.1524 m	minor diameter of antenna in meters
F = 14.5	frequency in GHz
λ = 0.02 m	wavelength in meters ($300/F_{MHz}$)
η = 0.764	aperture efficiency

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:

$$S_{surface} = (4 * P) / A \quad (1.1)$$

$$= (4 * 14.83 \text{ W}) / 0.159 \text{ m}^2$$

$$= 65.62 \text{ mW/cm}^2$$

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 λ in same units):

$$R_{nf} = D^2 / (4 * \lambda) \quad (1.2)$$

$$= (0.116 \text{ m})^2 / (4 * 0.02 \text{ m})$$

$$= 7 \text{ m}$$

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:

$$S_{nf} = (16 * \eta * P) / (\pi * D^2) \qquad (1.3)$$

$$= (16 * 0.764 * 19.05 \text{ W}) / (\pi * (0.762 \text{ m})^2)$$

$$= 12.77 \text{ mW/cm}^2$$

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. 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:

$$S_t = (S_{nf} * R_{nf}) / R \qquad (1.4)$$

$$= (12.77 \text{ mW/cm}^2 * 7 \text{ m}) / R$$

$$= (89.36 \text{ m} * \text{mW/cm}^2) / R$$ where R is the location of interest in meters

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 distance to the start of the far field can be calculated by the following equation:

$$R_{ff} = (0.6 * D^2) / \lambda \qquad (1.5)$$

$$= (0.6 * (0.762 \text{ m})^2) / 0.02 \text{ m}$$

$$= 16.9 \text{ m}$$

The power density at the start of the far-field region of the radiation pattern can be estimated by the equation:

$$S_{ff} = (P * G) / (4 * \pi * R_{ff}^2) \qquad (1.6)$$

$$= (19.05 \text{ W} * 2608.2) / (4 * \pi * (16.9 \text{ m})^2)$$

$$= 1.39 \text{ mW/cm}^2$$

Safe Region for Controlled Access. As given above, the power density in the far field region of the antenna pattern decreases inversely as the square of the distance. The distance to the point where the power density equals the 5 mW/cm^2 level can be determined by the equation:

$$R_{5\ mW} = ((P * G) / (4 * \pi * 5\ mW/cm^2 * 10))^{0.5} \qquad (1.7)$$

$$= ((19.05\ W * 2608.2) / (1.39\ mW/cm^{\wedge}2))^{0.5}$$

$$= 8.9\ m$$