Radiation Hazard Analysis Report
For the KuStream 5000 System

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Document Revision History

Pages in this document with Change Bars (||) on the margin indicate changes incorporated in the most recent revision; they do not reflect any changes made on previous revisions. Records of previous revisions can be obtained from Document Control.

Revision Letter	Change Description	Approval Date
A	Initial Release	
B	1. Add mask to each plot and add/label elevation and azimuth plots. (3 additional plots) 2. Page 9: Change 17.8 Watts to 43.7 Watts. 3. Change referenced figures on pages 4 and 9 to account for the additional figures added in #1 above. 4. Change all safe zone plots to account for reflector conditions. 5. Add paragraph on reflective environment conditions on page 9. 6. Update Table 1 and re-number as table 3; add table 1 (FCC requirements), and table 2 (field calculations). 7. Add field strength calculation discussion to “Results of Analysis” paragraph. 8. Page 9: Add Transition region definition. Delete “The near field power density can be used as worst case in the transition region” 9. Conclusion paragraph re-written. 10. Pare 10: Add paragraph on label requirements, and figure for labels. 11. Add Appendix A and B 12. Add paragraph on “FCC Limits on RF Radiation Intensity Levels”	

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Summary

This analysis calculates the non-ionizing radiation levels for a TECOM KuStream 5000 aeronautical mobile earth station (ESAA) terminal. The calculations performed in this analysis comply with the methods described in FCC Office of Engineering Technology (OET) Bulletin Number 65. This analysis demonstrates that the TECOM KuStream ESAA terminals are compliant and will not result in exposure levels exceeding the applicable radiation hazard limits when nominal safe zones are observed.

Introduction

The OET Bulletin 65 guidelines incorporate two separate tiers of exposure limits that are dependent on the situation in which the exposure takes place and/or the status of the individuals who are subject to exposure. Limits are determined for persons who are exposed due to their employment and who are made fully aware of the potential for exposure, and exposure limits are also set forth for the general population who may not be aware of the potential for exposure. TECOM ESAA terminals are typically installed on commercial airliners or business aircraft where access to the area around the aircraft is a controlled environment but not all personnel may be aware of the exposure risk. Accordingly, both exposure limits are discussed in this report.

ESAA Terminal Description

The KuStream 5000 ESAA terminal is similar to other small airborne terminals currently authorized with blanket license approval. The ESAA terminal uses transmitted power control to reduce uplink interference and improve system throughput. At maximum linear power, the ESAA terminal transmits with 17.8 watts. Operation can be up to 100% duty cycle, however the duty cycle is normally set to a fraction of this rate by the network loading conditions.

The ESAA incorporates a feature that limits the potential for human exposure. A condition for enabling transmitter operation is receiving the signal from the network satellite above a decoding threshold. The receive and transmit antenna patterns are collinear and any loss of connectivity in the receive path will shut down the transmitter within one second. Transmissions will not resume until downlink communications have been reestablished for approximately four seconds.

Gain plots for the aperture are shown in Figures 1 through 6 across ±180 degrees.

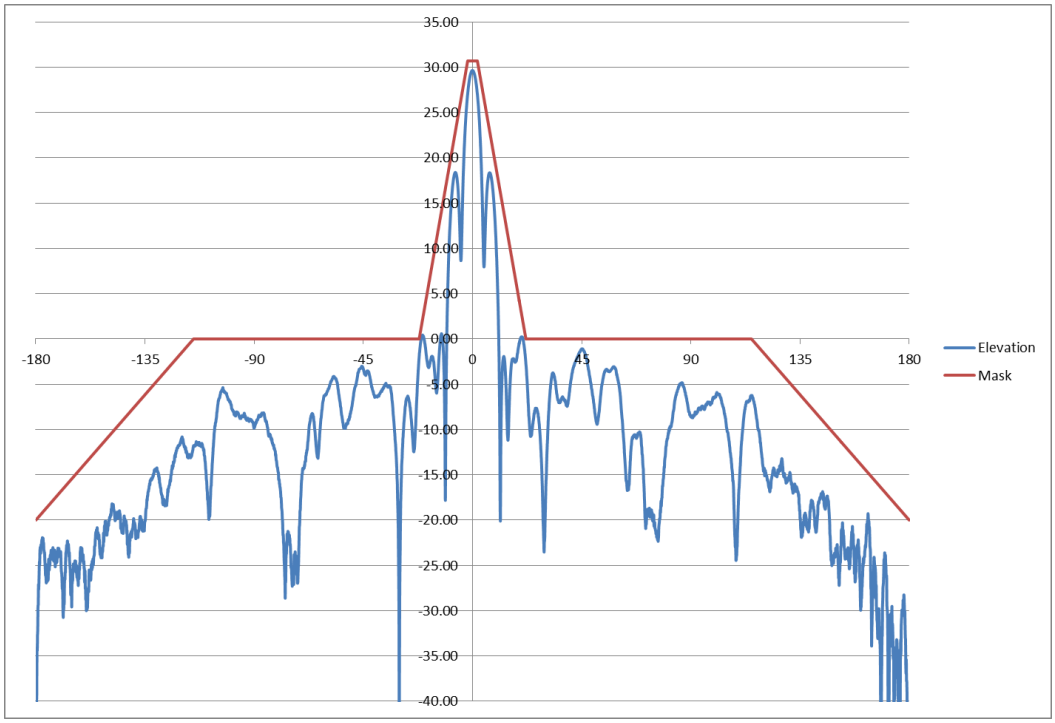

Figure 1: Ku-Band Antenna Elevation Gain at 13.75 GHz

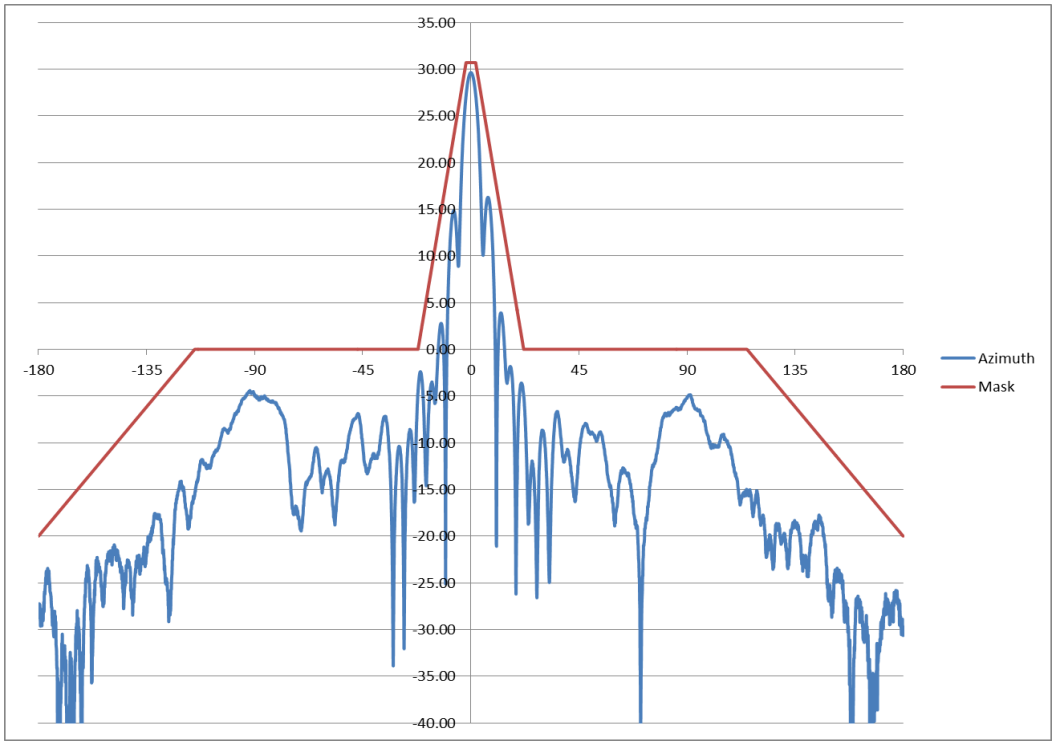

Figure 2: Ku-Band Antenna Azimuth Gain at 13.75 GHz

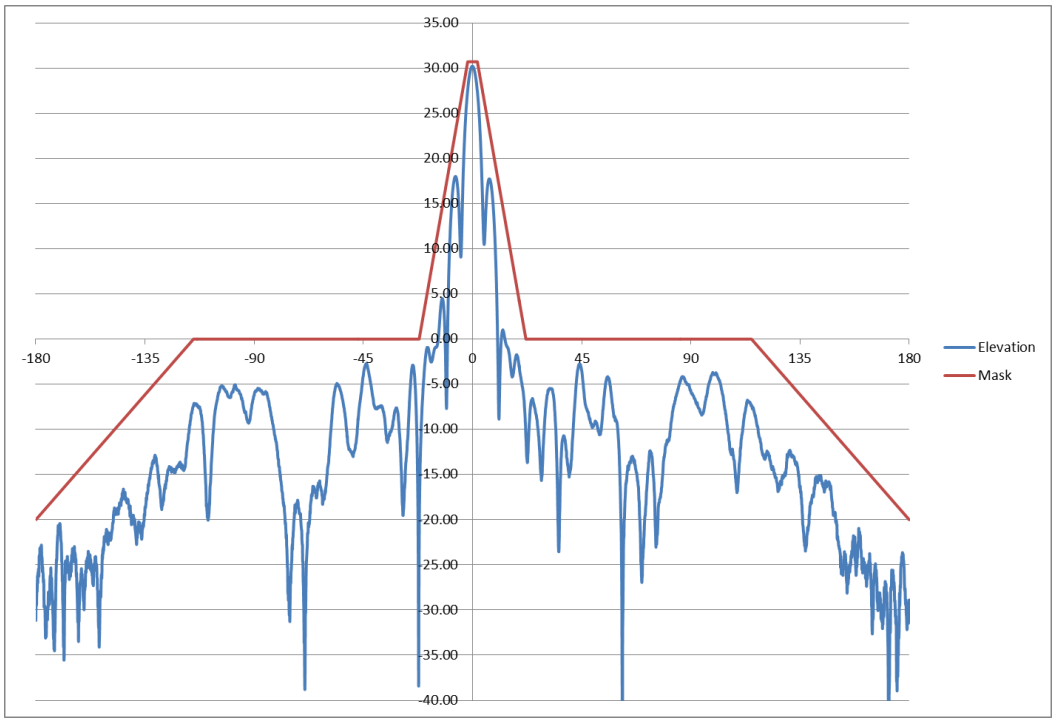

Figure 3: Ku-Band Antenna Elevation Gain at 14.125 GHz

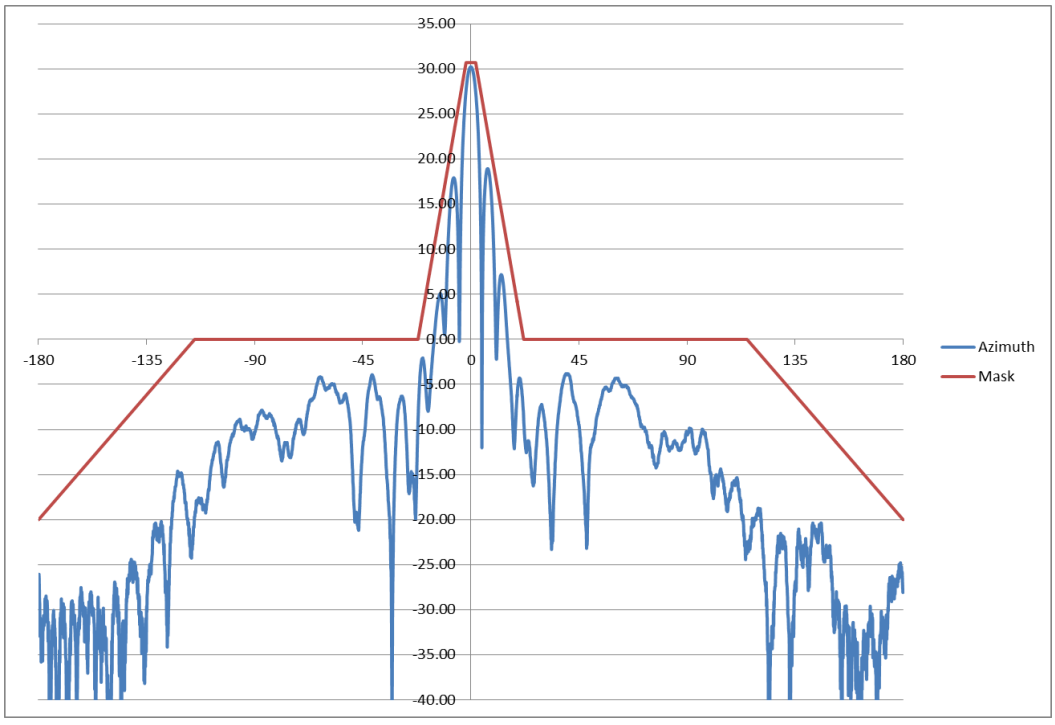

Figure 4: Ku-Band Antenna Azimuth Gain at 14.125 GHz

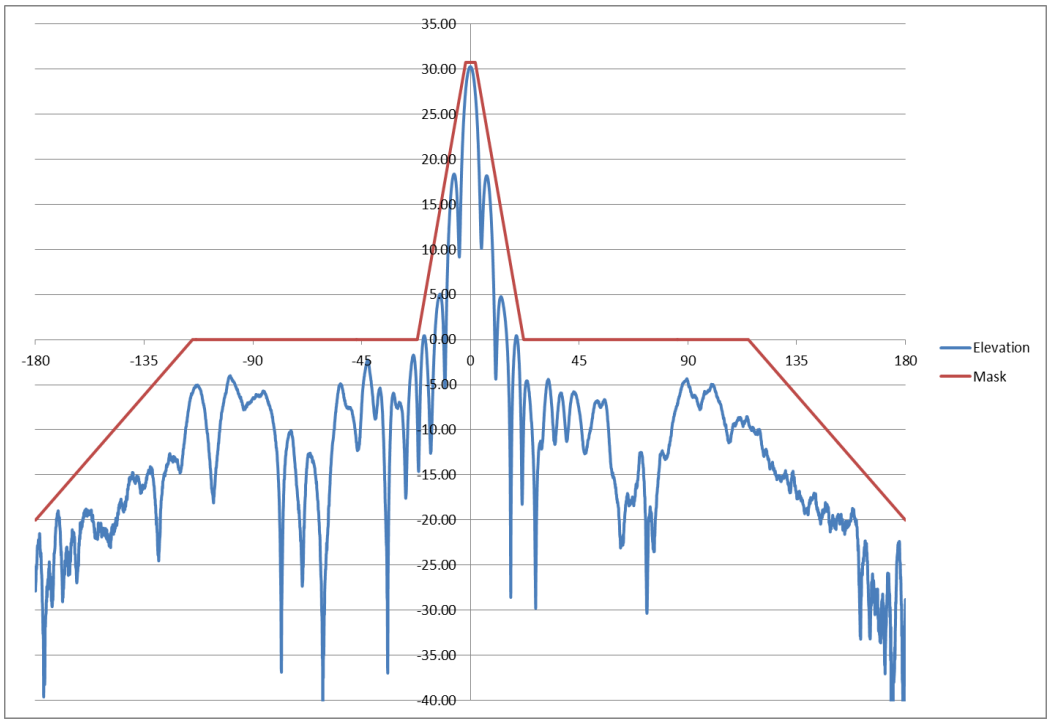

Figure 5: Ku-Band Antenna Elevation Gain at 14.50 GHz

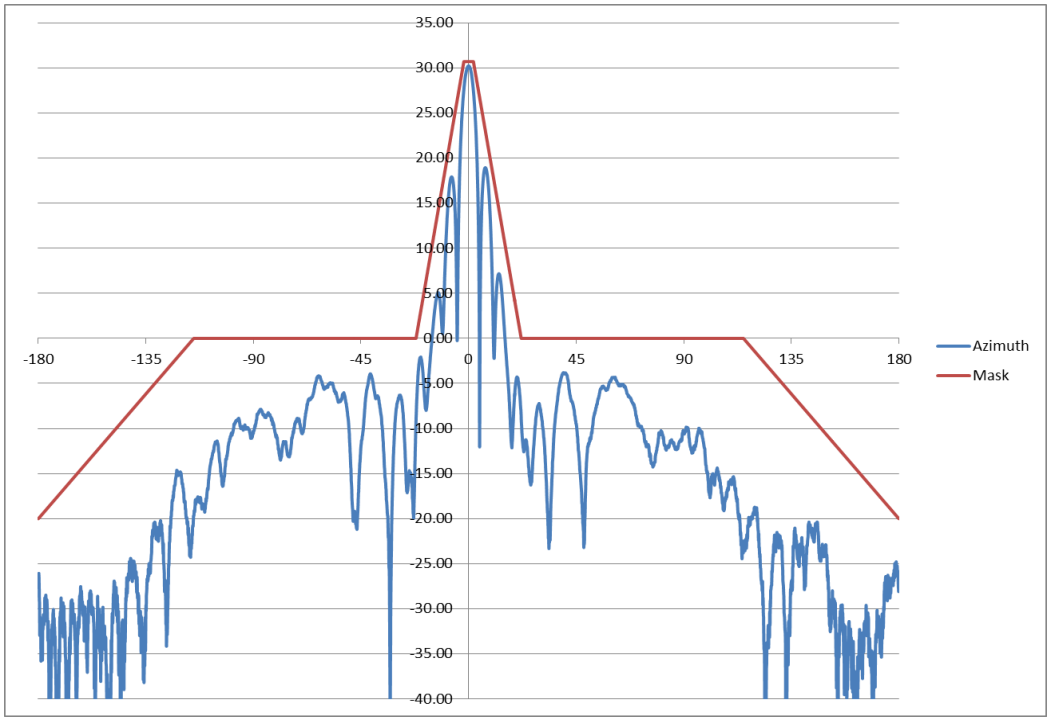

Figure 6: Ku-Band Antenna Azimuth Gain at 14.50 GHz

Explanation of the Exposure Calculation

OET Bulletin 65 provides equations for calculating the RF field power density with respect to the aperture location. The equations for near field radius and far field radius are:

$R_{near} = D^2 / (4\lambda)$

R near: = range for near field

D: = diameter of circular dish reflector antenna

λ: = wavelength

$R_{near} < R_{(Transition)} < R_{far}$; (The area between near field and far field is the transition field).

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

R far: = range for beginning of far field

D: = diameter of circular dish reflector antenna

λ: = wavelength

The equations for power density, near field and far field are:

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

S near: = Power Density in near field

P: = power input to antenna

D: = diameter of circular dish reflector antenna

η: = aperture efficiency

π = 3.1416

$S_{(Transition)} = (S_{near}) * (R_{near}) / R$

$S_{far} = P * G / (4\pi * R^2)$

S far: = Power Density in far field

P: = power input to antenna

G: = antenna gain (linear)

R: = distance from antenna

π = 3.1416

For the TECOM antenna, the following values are used:

Highest Transmit frequency: 14.5 GHz (wavelength (λ): 2.07 cm)

Aperture diameter: 29 cm (11.5 inches)

Aperture main beam gain: 30.7 dBic

Aperture side lobe gain: 18 dBic

Aperture back lobe gain: -22 dBic

Aperture Power Input: 43.7 Watts

Aperture efficiency (η): 0.75

A simplified conservative antenna gain mask plot for the KuStream 5000 is shown in each figure. The actual gain will always be below this level, and therefore provides a worst case value for the calculation of a safe distance for field tests, and for general population exposure. The mask has margin added to account for increased gains that will occur in production units.

In addition to the controlled and uncontrolled environments, the two cases to consider in ensuring public safety is 1) in an open environment, and 2) in front of a surface (e.g., aluminum hanger door) which acts as a reflector to the RF incident energy. The worst case is in the presence of a reflector, which depending on the distance in front of the reflector, could result in the effective RF power density being four times that present in a non-reflective environment. The safe zone plots included in this report are for the worst case reflective environment; all environments are presented in the tabular data shown in Table 3. For additional information on how a reflecting surface affects power density, see Section 2, "Equations for Predicting RF Fields" in the FCC document, OET Bulletin 65.

The actual value of the signal power density at a particular location will depend on the antenna gain, and on the location of the point of interest. Depending on how far the measurement point is from the antenna, the field strength will be estimated using near field, transition field, or far field equations.

Example:

Input power to aperture: 43.7 Watts = 43,700 mW

Antenna Gain = 30.7 dB (main beam) (power ratio = $10^{(30.7/10)}$ = 1174.9)

FCC maximum allowed power density for public exposure in front of a reflector = 0.25 mW/cm^2

Minimum allowed distance from antenna = SQRT [43700 x 1174.9/ (4xπx0.25)] = 4042.7 cm = 132.6 feet

FCC Limits on RF Radiation Intensity Levels

FCC regulations (FCC document, OET Bulletin 65) specify maximum RF radiation levels for occupational and general public exposure. The allowed limits are given in terms of a level and exposure time. A person in a certain designated category may be exposed to higher levels for shorter exposure times, as long as the time-averaged level is below the constant level allowed for the specified time interval. The levels allowed by the FCC are shown below in Table 1.

Table 1: FCC Limits for RF Radiation Intensity Levels (1.5 – 100 GHz)

Environment Type	Population Category	RF Level (mW/cm^2)
Reflection Free	Occupational	5
	General Public	1
Maximum Reflection	Occupational	1.25
	General Public	0.25

Results of Analysis

The hazard level can be considered for four regions defined by the orientation relative to the aperture: Main beam, First side lobes, forward off angle, and back lobes. The back lobes extend from the 180 degree position to +115 and -115 degrees relative to the main beam peak. Forward off angle covers the region between -22 to -115 and +22 to +115 degrees. The first sidelobes peak at ±7 degrees. The main beam -3 dB width is 4.2 degrees and reduces to -10 dB at 6.8 degrees width (± 3.4 degrees extent).

To simplify calculations, the far field calculations are used for all cases. The far field calculations always provide a conservative estimate of the field levels, except for a small zone between 202 cm and 247.4 cm (end of transition region). After the safe zone distances are calculated, all distances which are within this small zone (45.4 cm) are set to the far field distance of 247.4 cm (8.118 feet) at which point the far field calculations are accepted. Comparisons of the three sets of equations for the field strengths (mW/cm^2) are shown in Table 2 evaluated at all distances. Transition points are also indicated showing the distance at which one region stops and another region begins.

Polar plots of the safe zones are shown in Figures 8, 9, 10, and 11. Tabular data for the safe zone distance calculated using the simplified conservative antenna gain plot is shown in Table 3.

Label Requirements

The results of this report establishes that harmful levels of RF radiation are produced by the KuStream 5000 system, and that careful distance requirements for personnel and public exposure are important limits that must be controlled. In addition to the operating guidelines provided in Appendix A, warning labels will be displayed on the equipment, and on any radome covering the equipment to ensure that personnel and the general public are made aware of the dangers involved in close proximity to the immediate location and surrounding areas. Typical warning labels are shown in Figure 7 for both the equipment/radome, and for the safe zone boundary region.

Figure 7: Typical warning label for RF radiation conditions

Table 2: Zone Field Calculations for Near, Transition, and Far Field

(cm) Dist	$S_{ff} = \frac{PG}{4\pi R^2}$ (mW/cm^2) Far Field	$S_{nf} = \frac{16\eta P}{\pi D^2}$ (mW/cm^2) Near Field	$S_t = \frac{S_{nf}R_{nf}}{R}$ (mW/cm^2) Transition	
1	4.08E+06	195.19	20123.55	
2	1.02E+06	195.19	10061.78	
3	4.53E+05	195.19	6707.85	
4	2.55E+05	195.19	5030.89	
5	1.63E+05	195.19	4024.71	
6	1.13E+05	195.19	3353.93	
7	83191.80	195.19	2874.79	
8	63693.73	195.19	2515.44	
9	50325.91	195.19	2235.95	
10	40763.98	195.19	2012.36	
11	33689.24	195.19	1829.41	
12	28308.32	195.19	1676.96	
13	24120.70	195.19	1547.97	
14	20797.95	195.19	1437.40	
15	18117.33	195.19	1341.57	
98	424.45	195.19	205.34	
99	415.92	195.19	203.27	
100	407.64	195.19	201.24	
101	399.61	195.19	199.24	
102	391.81	195.19	197.29	
103	384.24	195.19	195.37	← End of Near Field Zone
104	376.89	195.19	193.50	
105	369.74	195.19	191.65	
106	362.80	195.19	189.84	
107	356.05	195.19	188.07	
202	99.90	195.19	99.62	← Beginning of modified equation zone
203	98.92	195.19	99.13	
204	97.95	195.19	98.64	
205	97.00	195.19	98.16	
206	96.06	195.19	97.69	
207	95.13	195.19	97.22	
242	69.61	195.19	83.16	
243	69.03	195.19	82.81	
244	68.47	195.19	82.47	
245	67.91	195.19	82.14	
246	67.36	195.19	81.80	
247	66.82	195.19	81.47	← End of Transition Zone (End of modified equation zone)
248	66.28	195.19	81.14	
249	65.75	195.19	80.82	
250	65.22	195.19	80.49	
251	64.70	195.19	80.17	
252	64.19	195.19	79.86	

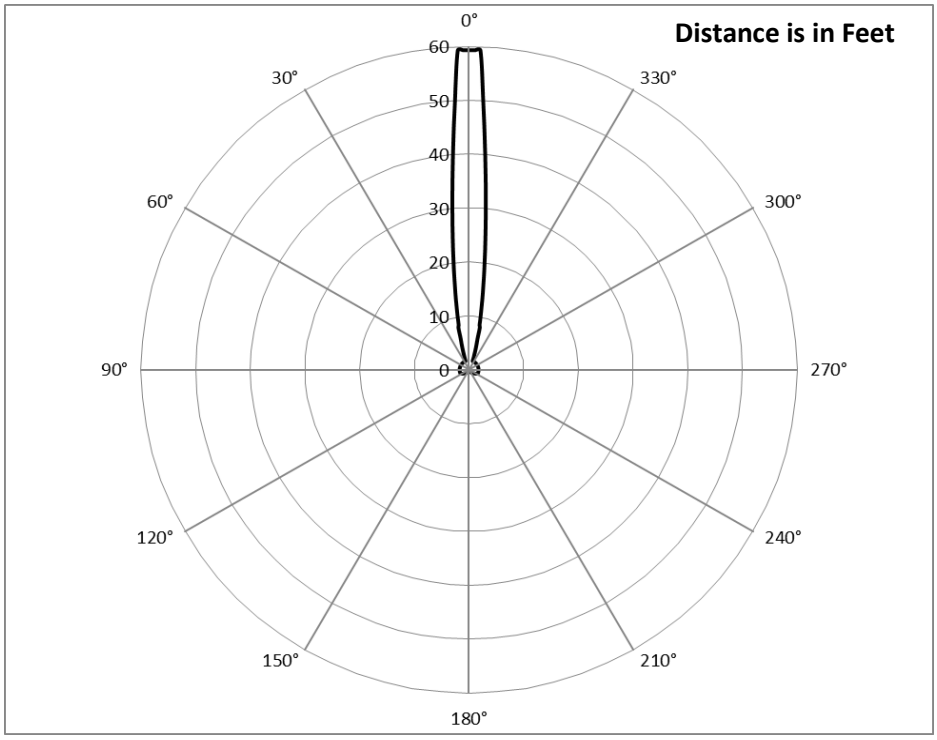

Figure 8: Safe zone distance requirements for the occupational access zone

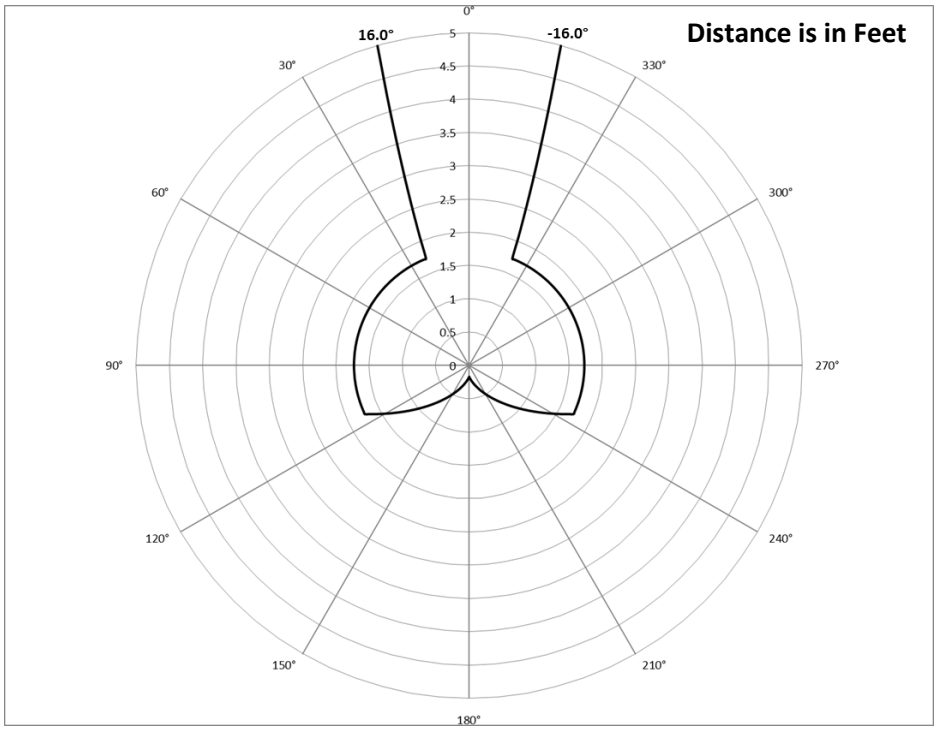

Figure 9: Expanded view of safe zone distance requirements for the occupational access zone

Figure 10: Safe zone distance requirements for the general public access zone

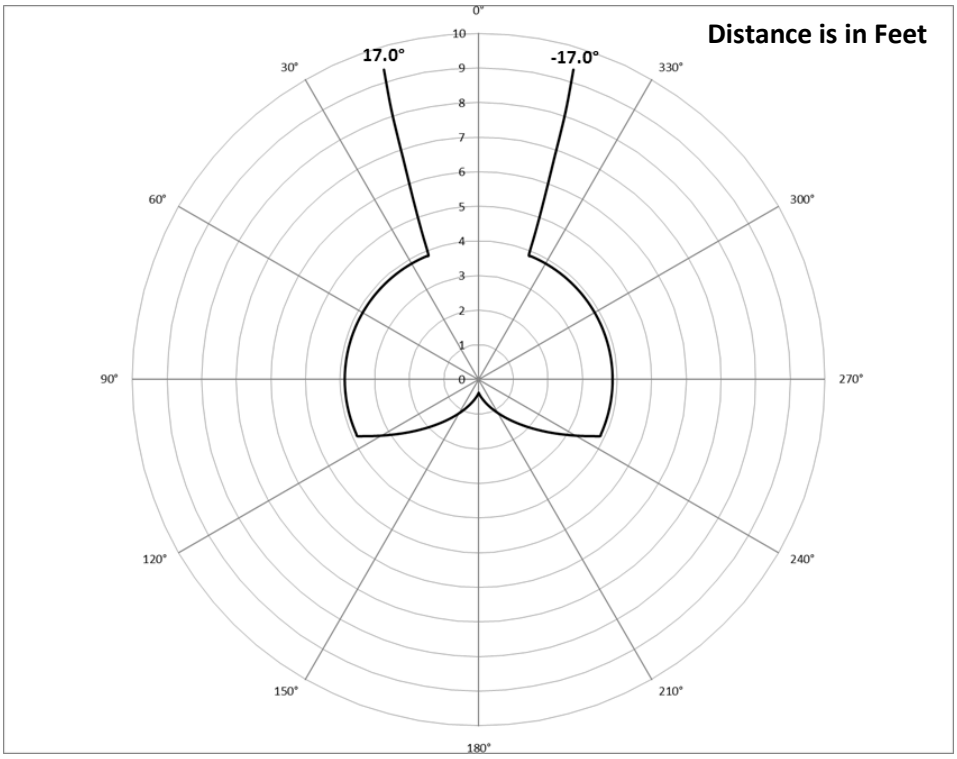

Figure 11: Expanded view of safe zone distance requirements for the general public access zone

Table 3: Tabular data of safe distance from antenna

Angle	Free Space Requirements		Standing in Front of a Reflector	
	Occupational/ Controlled Safe Distance (Ft)	General Population/ Uncontrolled Safe Distance (Ft)	Occupational/ Controlled Safe Distance (Ft)	General Population/ Uncontrolled Safe Distance (Ft)
-180	0.086	0.193	0.173	0.387
-175	0.103	0.231	0.206	0.462
-170	0.123	0.276	0.246	0.551
-165	0.147	0.329	0.294	0.658
-160	0.176	0.393	0.351	0.785
-155	0.210	0.469	0.419	0.938
-150	0.250	0.560	0.501	1.119
-145	0.299	0.668	0.598	1.336
-140	0.357	0.798	0.713	1.595
-135	0.426	0.952	0.852	1.904
-130	0.508	1.137	1.017	2.273
-125	0.607	1.357	1.214	2.714
-120	0.724	1.620	1.449	3.240
-115	0.865	1.934	1.730	3.867
-110	0.865	1.934	1.730	3.867
-105	0.865	1.934	1.730	3.867
-100	0.865	1.934	1.730	3.867
-95	0.865	1.934	1.730	3.867
-90	0.865	1.934	1.730	3.867
-85	0.865	1.934	1.730	3.867
-80	0.865	1.934	1.730	3.867
-75	0.865	1.934	1.730	3.867
-70	0.865	1.934	1.730	3.867
-65	0.865	1.934	1.730	3.867
-60	0.865	1.934	1.730	3.867
-55	0.865	1.934	1.730	3.867
-50	0.865	1.934	1.730	3.867
-45	0.865	1.934	1.730	3.867
-40	0.865	1.934	1.730	3.867
-35	0.865	1.934	1.730	3.867
-30	0.865	1.934	1.730	3.867
-25	0.865	1.934	1.730	3.867
-20	1.231	2.753	2.463	5.507
-15	2.980	8.100	5.959	16.200
-10	8.100	16.121	16.200	32.241
-5	17.444	39.006	34.888	78.012
0	29.641	66.280	59.282	132.559
5	17.444	39.006	34.89	78.012
10	8.100	16.121	16.200	32.241
15	2.980	8.100	5.959	16.200
20	1.231	2.753	2.463	5.507
25	0.865	1.934	1.730	3.867
30	0.865	1.934	1.730	3.867
35	0.865	1.934	1.730	3.867
40	0.865	1.934	1.730	3.867
45	0.865	1.934	1.730	3.867
50	0.865	1.934	1.730	3.867
55	0.865	1.934	1.730	3.867
60	0.865	1.934	1.730	3.867
65	0.865	1.934	1.730	3.867
70	0.865	1.934	1.730	3.867
75	0.865	1.934	1.730	3.867
80	0.865	1.934	1.730	3.867
85	0.865	1.934	1.730	3.867
90	0.865	1.934	1.730	3.867
95	0.865	1.934	1.730	3.867
100	0.865	1.934	1.730	3.867
105	0.865	1.934	1.730	3.867
110	0.865	1.934	1.730	3.867
115	0.865	1.934	1.730	3.867
120	0.724	1.620	1.449	3.240
125	0.607	1.357	1.214	2.714
130	0.508	1.137	1.017	2.273
135	0.426	0.952	0.852	1.904
140	0.357	0.798	0.713	1.595
145	0.299	0.668	0.598	1.336
150	0.250	0.560	0.501	1.119
155	0.210	0.469	0.419	0.938
160	0.176	0.393	0.351	0.785
165	0.147	0.329	0.294	0.658
170	0.123	0.276	0.246	0.551
175	0.103	0.231	0.206	0.462
180	0.086	0.193	0.173	0.387

Conclusion

The system when properly installed and operated will not subject personnel to excess RF energy. The analysis presented covers all possible environments during which personnel and/or the public will be exposed. Typical aircraft operation (tail mounted) will prevent direct exposure to the main beam of the aperture. Possible exposure may occur through antenna sidelobe emissions. An analysis of a typical operational scenario detailed in Appendix A, demonstrates that the RF radiation levels are well within the acceptable range for individuals walking around the aircraft.

A worst case transmit power (highest power level) analysis is shown below:

Example for tail mount:

Input power to aperture: 43.7 Watts = 43,700 mW

Distance from aircraft: 8 feet

Antenna mounted 14 feet above ground level.

Height of individual: 6' 2"

Antenna pointed at horizon

Angle off of antenna center beam: atan[(14-6.167)/8] = 44.4°

Distance to individual = SQRT(8^2+(14-6.167)^2) = 11.2 feet = 341.3 cm

Antenna Gain at exposure angle (using conservative mask) = 0 dB

FCC maximum allowed power density for public exposure in front of a reflector = 0.25 mW/cm^2

RF radiation power density = P*G / (4π*R^2) = 43700*1/(4π*341.3^2) = 0.0299 mW/cm^2 (Well within FCC Limits)

Operators and technicians working in and around the equipment will receive training specifying the areas of high exposure. Procedures will be established to ensure that all transmitters are turned off before this area may be accessed by operators, maintenance and/or other authorized personnel. A safety feature of the system turns off the transmitter within 100 milliseconds any time the aperture is blocked, thus preventing any more than brief exposure to the transmit radiation.

Commissioning and testing of the TECOM antenna will only be conducted by trained personnel in a controlled environment. In test and development the antenna testing area will be cordon off according to the safe zone areas presented in Figures 8 through 11. This will prevent the general public from being exposed to excessive levels of RF energy. Test personnel will be trained to establish a level of understanding and test protocol that will deter accidental exposure to excessive levels of RF energy.

Reference Documents

OET Bulletin No. 65, "Evaluating Compliance with FCC Guidelines for Human Exposure to Radio Frequency Electromagnetic Fields", Edition 97-01.

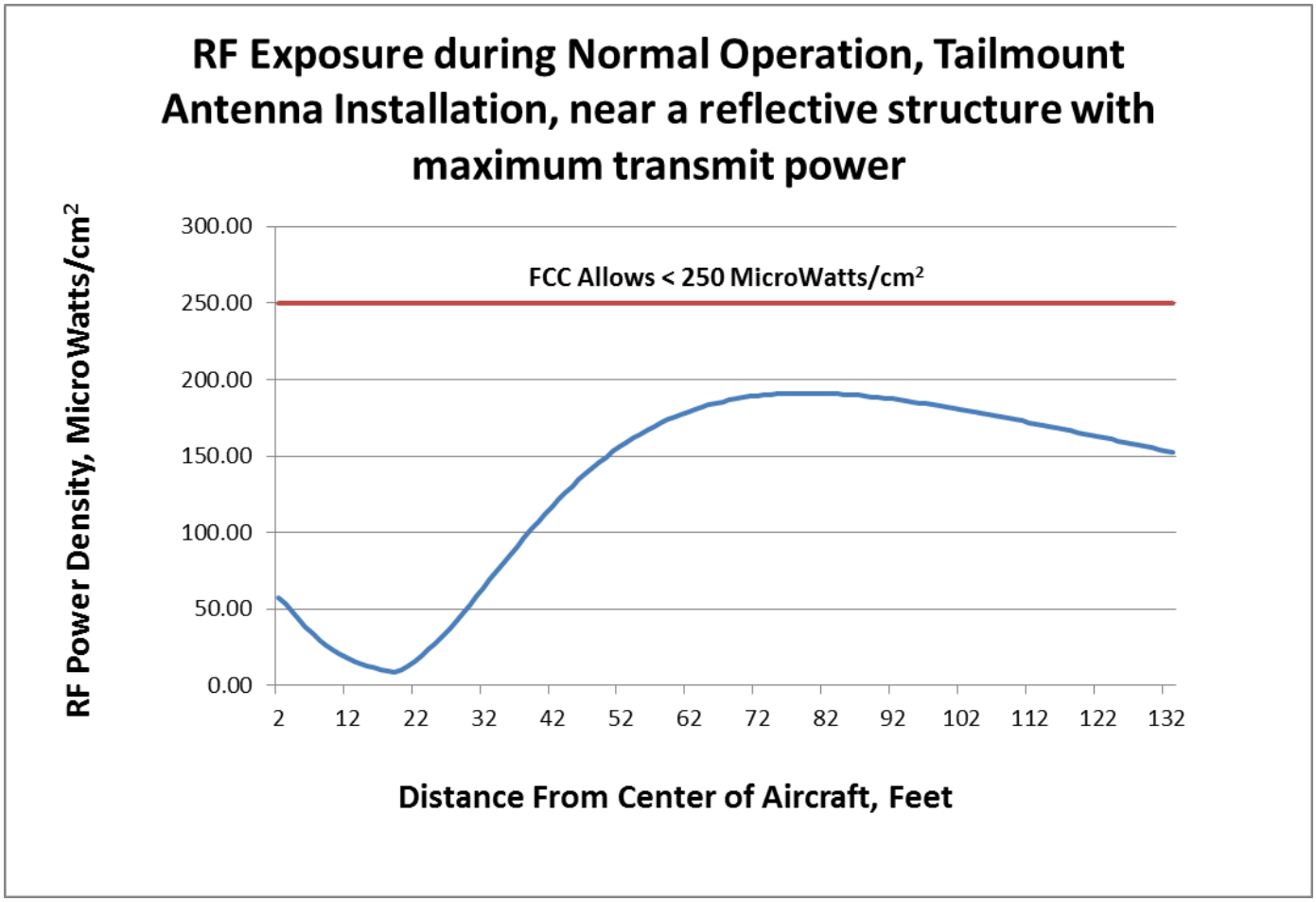

Figure 12: RF Radiation Intensity on the ground for maximum transmit power

APPENDIX A – RF Radiation Hazard for a Typical Tail Mount Application

Figure 13: Typical tail mount for SatCom satellite system.

For purposes of this typical tail mounted SatCom transceiver analysis, we will assume:

1. The top of the tail is 14 feet, 10 inches from the ground (Beechcraft King Air 250).
2. The lowest pointing angle is zero degrees (horizon).
3. Nominal RF power into antenna is 20 Watts.
4. Average height of personnel/general public working or walking around the aircraft is 6 ft., 2 in.

Using these conditions, the RF radiation intensity level will be within the allowed worst case scenario (general public, reflectors present) as shown in Figure 14. The allowed limit is 0.25 mW/cm^2, or equivalently, 250 microwatts/ cm^2. As shown in Figure 14, the actual levels are never close to the allowed level.

The case of nearby buildings being illuminated by the main beam of the antenna will be discussed next. According to FCC document, OET Bulletin 65, "it is also important to note that exposures inside a building can be expected to be reduced by at least 10-20 dB due to attenuation caused by building materials in the walls and roof". If there were reflective surfaces inside the building, the allowed RF level would be < 0.25 mW/ cm^2. Due to building material attenuation, we only need to achieve levels of < 2.5 mW/ cm^2 (a result of having 10 dB of building material attenuation) at the outside

surface of the building. This level is achieved with main beam illumination at a distance of 28.3 feet from the transmitter. We should also consider that for normal operation of the system, the main beam must be pointed at the satellite for transmission to occur. Any blockage or mis-pointing of the antenna will cause the transmitter to shut-down (mute) within 100 milliseconds after loss of a satellite signal.

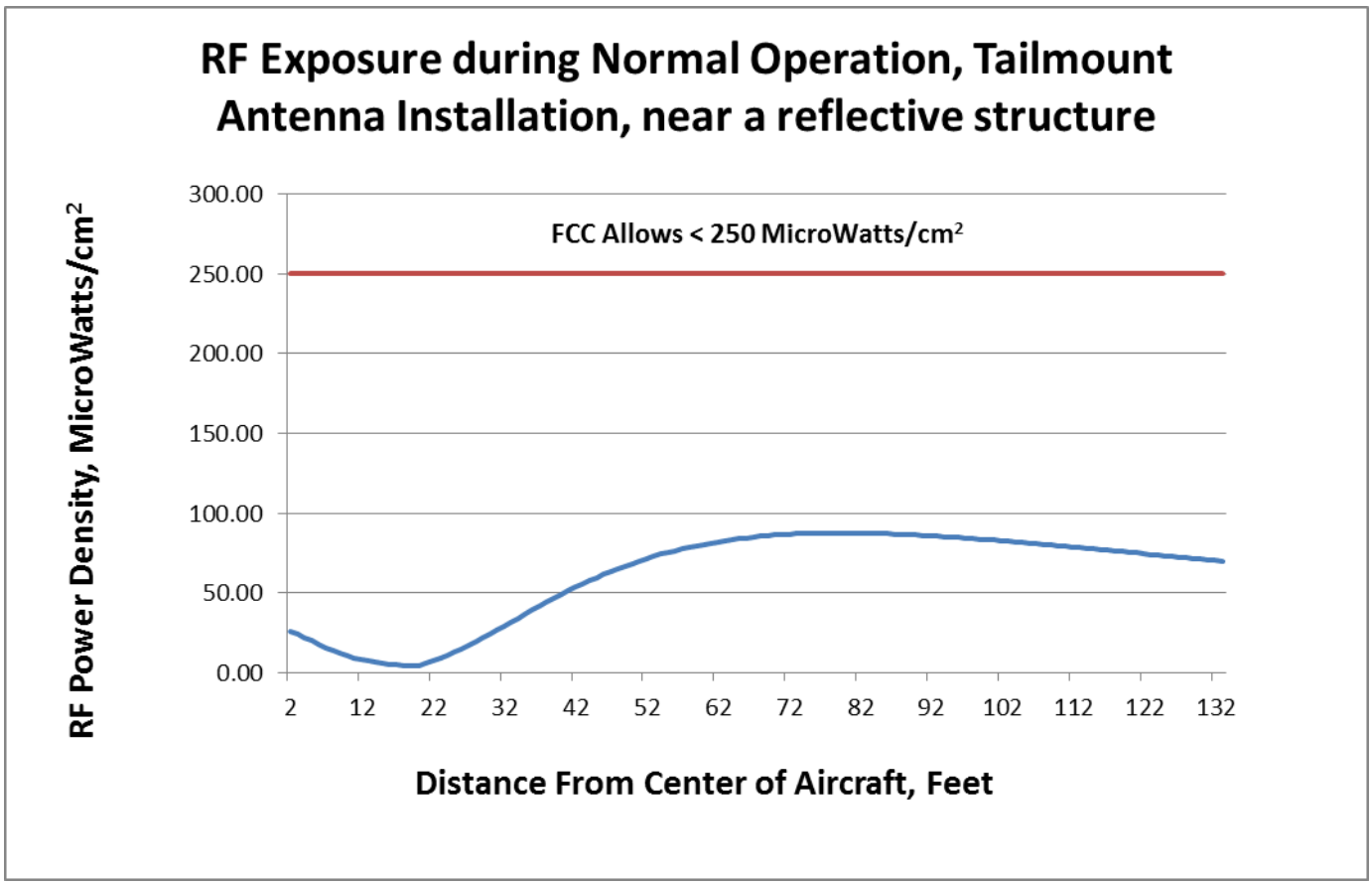

Figure 14: RF Radiation Intensity on the ground for a typical tail mount system.

APPENDIX B – Operational Safety Instructions

Note: This guide cannot cover all possible situations. The requirements set out in the Occupational Health and Safety Act must be complied with, and they should be referred to when this guideline is used.

Before Operation:

- Select the site for operation. If possible choose a location away from buildings and reflective structures. An area with restricted access by customers and untrained personnel is preferred. Determine the satellite that will be used and the pointing directions and angles. From these criteria, select the correct table to determine the safe approach distances.
- Train the operators and other maintenance personnel that will have access in safe operation and activity around an active transmitter. Read and understand the content of this report.
- Mark the hazardous area with notice of RF Radiation Hazard placards and/or keep-out ropes. Warning signs must be in clear view and of sufficient size to be easily legible.

During Operation:

- Restrict the operational area from access by untrained personnel.
- Assume the transmitter is active until it is positively secured.
- Terminate transmission if the safe area is accidently violated by any personnel.
- Terminate transmissions when the system is unattended.
- Terminate transmission when any fault is detected that may cause abnormal RF emissions.
- If instrumentation is available, check the RF level at the established perimeter to validate the safe zone.

After Operation:

- Secure the terminal to avoid operation by untrained personnel. The System power can be turned off at the system circuit breaker. Transmission can be further disabled by toggling the TX Enable switch to OFF.

During Other Maintenance:

- When maintenance personnel will be occupying the area above the fuselage / level with the antenna, secure the transmitter. The System power must be turned off at the system circuit breaker. Transmission must be further disabled by toggling the TX Enable switch to OFF. Transmission should be double disabled during aircraft washing, deicing, maintenance of upper antennas, removal of the terminal radome, or other activity that occupies areas where the antenna beam could be pointed while activated.

Note: The terminal requires the MODEM to be locked to the Satellite on Receive before activating Transmit. If the Receive path is interrupted, transmission will be disabled within 0.10 seconds.

In Case of Accidental Exposure:

First Aid

- Remove exposed worker from exposure area to a cool environment and provide cool drinking water.
- Apply cold water or ice to any burned areas.
- Seek immediate medical attention.
- Severe MW or RF overexposure may damage internal tissues without apparent skin injury, so a follow-up physical examination is advisable.