

Exhibit A-3 - Analysis of Non-Ionizing Radiation for Horn Antenna Earth Station (RADAR Calibration)

This report analyzes the non-ionizing radiation levels for a horn antenna (used for on-orbit calibration) earth station system. The analysis and calculations performed in this report show compliance with the methods described in the FCC Office of Engineering and Technology's General RF Exposure Guidance, 447498 D01 v05r02 and developed in accordance with the prediction methods contained in OET Bulletin No. 65, Evaluating Compliance with FCC Guidelines for Human Exposure to Radio Frequency Electromagnetic Fields, Edition 97-01, pp 26-30.

*** It is assumed for this analysis that a horn antenna is the same as an "Aperture Antennas".

The radiation safety limits used in the analysis are in conformance with Title 47 Chapter I, Subchapter A, Part 1, Subpart I, Section 1.1310. Section 1.1310 specifies that there are 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 the exposure.

The Maximum Permissible Exposure (MPE) limits for persons in a General Population/Uncontrolled environment are shown in Table 1. The General Population/Uncontrolled MPE is a function of transmit frequency and is for an exposure period of thirty (30) minutes or less. The MPE limits for persons in an Occupational/Controlled environment are shown in Table 2. The Occupational MPE is a function of transmit frequency and is for an exposure period of six (6) minutes or less.

Frequency Range (MHz)	Power Density (mW/cm ²)
0.3 - 1.34	100
1.34 - 30	$180/(\text{Frequency(MHz)})^2$
30-300	0.2
300-1500	$\text{Frequency(MHz)}/1500$
1500-100,000	1

Table 1. Limits for General Population/Uncontrolled Exposure (MPE)

Frequency Range (MHz)	Power Density (mW/cm ²)
0.3-3.0	100
3.0-30	$900/\text{Frequency(MHz)}^2$
30-300	1
300-1500	$\text{Frequency(MHz)}/300$
1500-100,000	5

Table 2. Limits for Occupational/Controlled Exposure (MPE)

Parameter	Symbol	Formula	Value	Units
Ant Largest Diameter	D	Input	0.127	m
Ant Equiv Surface Area	A_{Surface}	$\pi(D/2)^2$	0.013	m ²
Ant Surface Pwr Dens	S_{Surface}	$4P/A_{\text{Surface}}$	15067.7	W/m
Frequency (band center)*	F	Input	9800	MHz
Wavelength	λ	$300/F$ (MHz)	0.030	m
Transmit Power (at horn)**	P	Input	48.97	W
Antenna Gain (dBi)	G_{es}	Input (known)	20.00	dBi
Antenna Gain (factor)	G	$10^{(G_{\text{es}}/10)}$	100	n/a
Pi	π	Constant	3.14159	n/a
Antenna Efficiency	η	$(G\lambda^2/(4\pi))/A_{\text{Surface}}$	0.550	n/a

Table 3. Formulas and Parameters Used for Determining Power Flux Densities

***Note:** The horn antenna can transmit between 9200 MHz to 10400 MHz, so the center of the frequency band was chosen for the calculations. This is using the X-band horn calibration configuration (horn antenna).

****Note:** This assumes a CW (Continuous Wave) type of signal, not a pulsed (duty cycled) type waveform.

1. Near Field Calculations (On-Axis, Parabolic Antenna)

Power flux density is considered to be at a maximum value throughout the entire length of the defined Near Field region. The region is contained within a cylindrical volume having the same surface area as the antenna. Past the boundary of the Near Field region, the power density from the antenna decreases linearly with respect to increasing distance (until the far field is reached).

The distance to the end of the Near Field can be determined from the following equation:

$$\begin{aligned} \text{Extent of the Near Field:} \quad R_{\text{nf}} &= D^2/(4\lambda) \\ &= 0.134 \text{ m} \end{aligned} \quad (1)$$

The maximum power density in the Near Field can be determined from the following equation:

$$\begin{aligned} \text{Near Field Power Density :} \quad S_{\text{nf}} &= 16\eta P/\pi D^2 \\ &= 8504.6 \text{ W/m}^2 \\ &= 850.46 \text{ mW/cm}^2 \end{aligned} \quad (2)$$

2. Transition Region Calculation (On-Axis, Horn Antenna)

The Transition region is located between the Near and Far Field regions. The power density begins to decrease linearly with increasing distance in the Transition region. While the power density decreases inversely with distance in the Transition region, the power density decreases inversely with the square of the distance in the Far Field region. The maximum power density in the Transition region will not exceed that calculated for the Near Field region. The power density calculated in **Section 1** is the highest power density the antenna can produce in any of the regions away from the antenna.

The power density at a distance R_{tz} can be determined from the following equation:

$$\begin{aligned}\text{Transition Region Power Density:} \quad S_{tz} &= S_{nf}R_{nf}/R_{tz} \\ &= 8504.6 \text{ W/m}^2 \\ &= 850.46 \text{ mW/cm}^2\end{aligned}\tag{3}$$

R_{tz} is calculated at a distance of 0.134 meters from the antenna, which is the worst case; it is the edge of the near-field boundary, R_{nf} .

3. Far Field Calculations (On-Axis, Horn Antenna)

The distance to the beginning of the far field can be determined from the following equation:

$$\begin{aligned}\text{Distance to the Far Field Region:} \quad R_{ff} &= 0.60 (D^2)/\lambda \\ R_{ff} &= 0.323 \text{ m}\end{aligned}\tag{4}$$

The maximum main beam power density in the far field can be determined from the following equation:

$$\begin{aligned}\text{On-Axis (boresight) Power Density in the Far Field:} \quad S_{ff} &= PG/(4\pi R_{ff}^2) \\ &= 3735.2 \text{ W/m}^2 \\ &= 373.52 \text{ mW/cm}^2\end{aligned}\tag{5}$$

However, due to the shape of the aperture (horn antenna) and the high levels of exposure, the minimum safe distance to achieve 1.0 mW/cm² safe exposure levels for a Uncontrolled Environment is 6.26 m (or R_{ue}):

$$\begin{aligned}\text{On-Axis Power Density, safe distance (Far Field):} \quad S_{ue} &= PG/(4\pi R_{ue}^2) \\ &= 9.94 \text{ W/m}^2 \\ &= 0.994 \text{ mW/cm}^2\end{aligned}\tag{6}$$

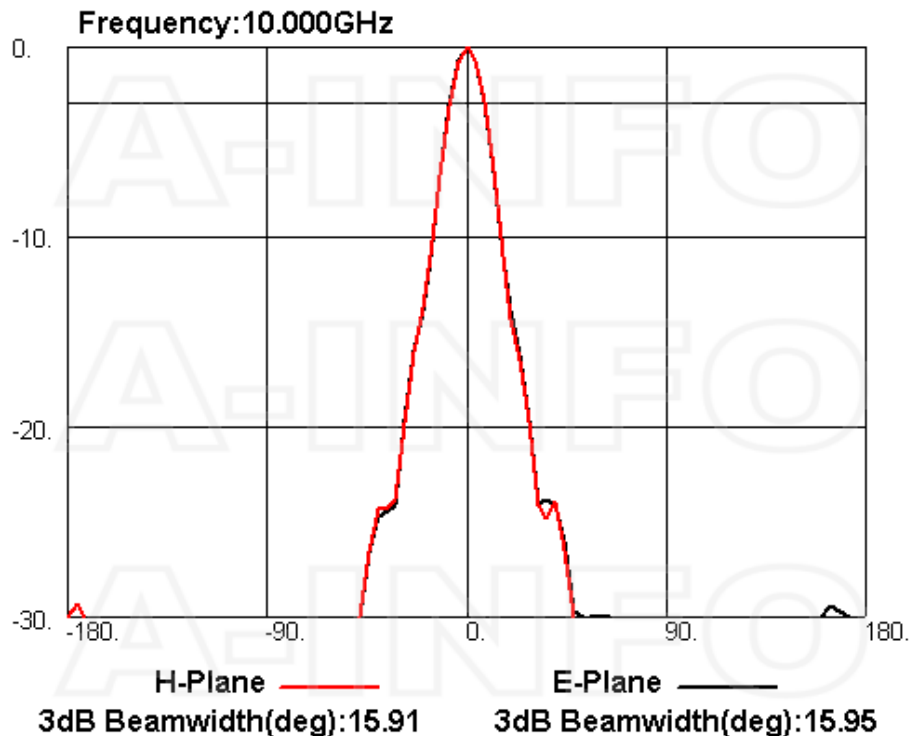
However, since the ground location is within a controlled area, the minimum safe distance to achieve 5.0 mW/cm² safe exposure levels for a Controlled Environment is 2.79 m (or R_{ce}):

$$\begin{aligned} \text{On-Axis Power Density, safe distance (Far Field):} \quad S_{ce} &= PG/(4\pi R_{ce}^2) \\ &= 50.0 \text{ W/m}^2 \\ &= 5.00 \text{ mW/cm}^2 \end{aligned} \quad (7)$$

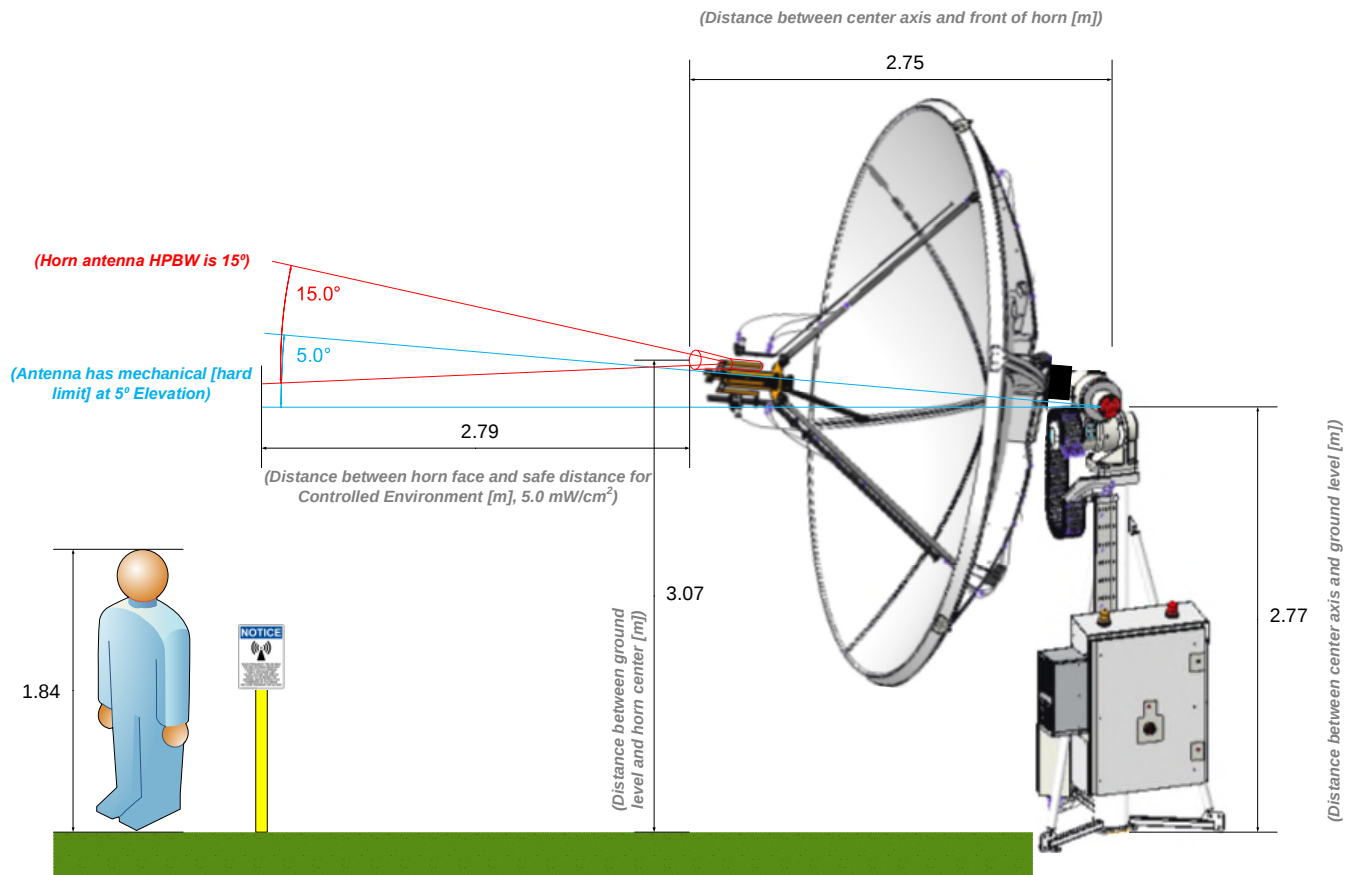
4. Off-Axis Levels at the Far Field Limit and Beyond (Horn Antenna)

In the far field region, the power is distributed in a pattern of maxima and minima (sidelobes) as a function of the off-axis angle between the antenna center line and the point of interest. Off-axis power density in the far field can be estimated using the antenna radiation patterns prescribed for the antenna in use, which happens to be a horn pattern, which tend to be wider than parabolic reflectors, thus the parabolic calculations will not be used for this part of the analysis.

Instead, we will consider pattern information provided by the horn manufacturer. In this case the horn manufacturer states the HPBW (-3dB beam width) is 15.95° for the E-plane and 15.91° for the H-plane (circular, pattern at 10.000 GHz).



There are several other considerations about the setup and geometry of the antenna on which the horn is mounted (and using as a Az/El positioner); below is a scaled figure to understand dimensional relationships:



- The antenna the horn is attached to (used as the positioner) has a 5° mechanical elevation limit (hard limit) which the antenna cannot go below
 - This means that the antenna can never point at ground level (0° elevation)
- The center of the horn vertex is approximately 3.07m (10.07 feet) above ground, thus an average height person of 1.84m (6 feet) will not be on boresight
- Even though there is RF energy in the gain pattern beyond the HPBW of the horn pattern, the gain (and thus the exposed power) is decreased as a function of the off boresight angle
 - This means that off boresight energy would still be below the occupational exposure limits at the distance of 2.79m (9.15 feet) in the far field and therefore safe for personnel
- Additional signage will be placed in a 5.54m (6m for a round number) radius around the Radome to warn personnel of the RF danger
- The horn and positioner are being utilized for LEO orbit tracking, therefore the direction of the beam will be constantly moving and will be mainly pointed up at the sky during normal operations.

- o When the system is not in use, the transmitter will be inhibited

Considering that the satellite antenna beams are aimed skyward and the site's minimum allowed TX elevation is 5° without additional site review and concurrence, power density in the off axis far field will usually not be a problem.

5. Summary of Calculations

Calculated Maximum Radiation Power Density Level Density Level - Uncontrolled Environment			
Region		(mW/cm ²)	Hazard Assessment
Far Field ($R_{ff} = 0.323$ m)	S_{ff}	373.52	Exceeds Uncontrolled
Near Field ($R_{nf} = 0.134$ m)	S_{nf}	850.46	Exceeds Uncontrolled
Transition Region ($R_{nf} < R_{tz} < R_{ff}$)	S_{tz}	850.46	Exceeds Uncontrolled
Further Than Far Field ($R_{ue} = 6.26$ m)	S_{ue}	0.994	Limit 1 mW/cm ² ; Satisfies FCC MPE

Table 4. Summary of Expected Radiation Levels for Uncontrolled Environment

Calculated Maximum Radiation Power Density Level Density Level - Controlled Environment			
Region		Level (mW/cm ²)	Hazard Assessment
Far Field ($R_{ff} = 0.323$ m)	S_{ff}	373.52	Exceeds Controlled
Near Field ($R_{nf} = 0.134$ m)	S_{nf}	850.46	Exceeds Controlled
Transition Region ($R_{nf} < R_{tz} < R_{ff}$)	S_{tz}	850.46	Exceeds Controlled
Further Than Far Field ($R_{ce} = 2.79$ m)	S_{ce}	5.00	Limit 5 mW/cm ² ; Satisfies FCC MPE (6 min)

Table 5. Summary of Expected Radiation Levels for Controlled Environment

6. Conclusions

Based upon the above analysis, it is concluded that FCC RF Maximum Permissible Exposure (MPE) Guidelines have not been exceeded for an occupational/controlled environment at the station location, if personnel are outside the designated border (signage and posts). The signage will be posted before X-band transmit operations take place and a visual sweep of the area will be completed to confirm no personnel are in danger of being exposed to high MPE levels.

The applicant proposes to comply with the MPE limits of 5.0 mW/cm^2 for occupational/controlled areas until an actual RF survey is performed to measure the actual exposure levels. This also aligns with the existing access posture at the station location, in which access at the proposed location is within not only a controlled environment (Lockheed Martin private property), but also an inner controlled area (restricted access) in where special existing training is required (for hazardous materials) and access is controlled through procedural check in and gated access for authorized personnel only.

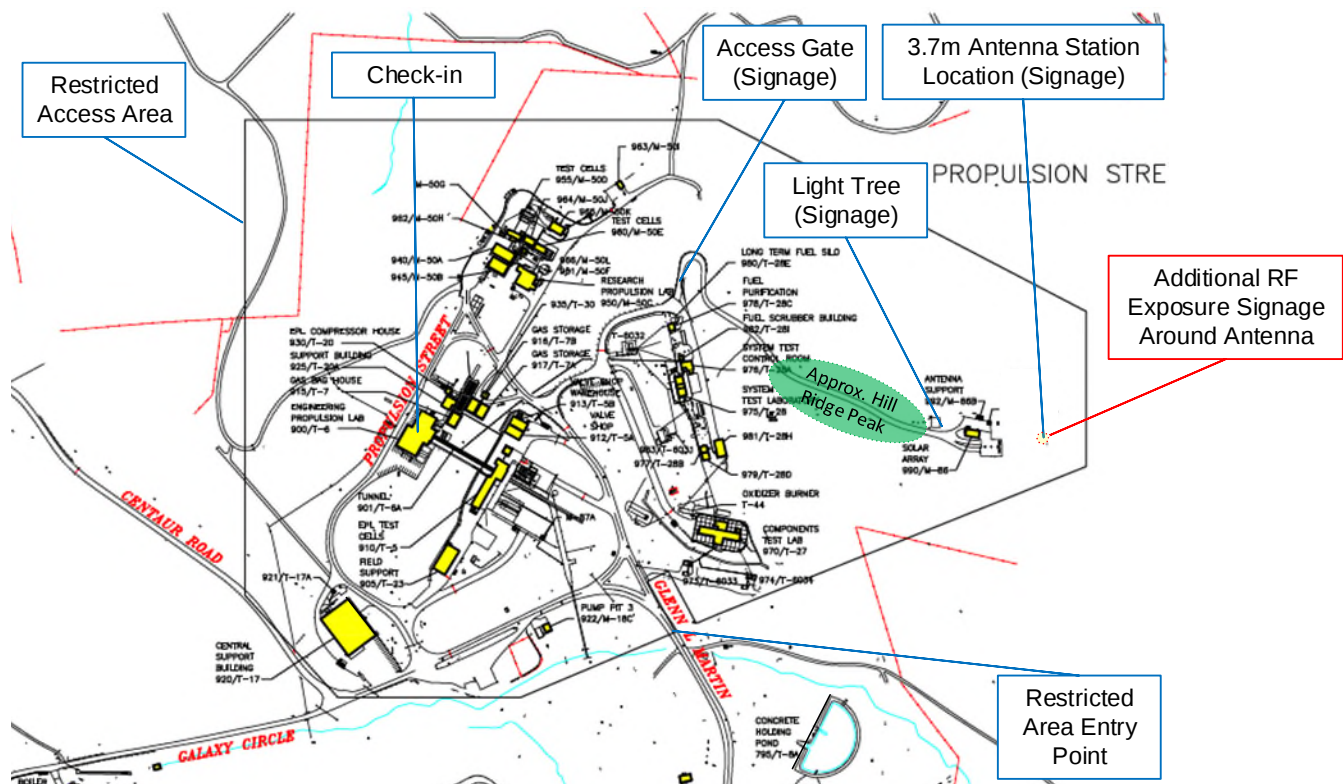
It is understood that it is the applicant's responsibility to ensure that the public and operational personnel are not exposed to harmful levels of non-ionizing radiation. In response, the applicant agrees to perform an RF Radiation Survey (after authorization to transmit has been approved) to measure and verify the Non-ionizing Radiation MPE exposure levels, using a calibrated Narda FCC shaped probe and PPE (Nardalert XT) along with certified RF radiation survey personnel. The RF survey will document the surrounding RF exposure levels measured in a report which will be made available to any interested parties upon request. Based on the actual measured values (in conjunction with the calculated values), mitigation steps will be taken to ensure personnel safety which may include (but not limited to) Radiation exposure warning postings, radiation light tree indication, area access training for personnel (at a minimum), limited access (occupational/controlled environment), PPE, etc.

Upon completion of the RF MPE survey, applicable protective measures will be taken to ensure personnel RF safety (as outlined above), compliance for all emitters at the site location, training will also be provided, as well as a RF safety zone (new, additional signage) will be clearly marked with signage at the station location, along with a radiation warning light tree indicator. In addition, contact information for the area will be provided to personnel to determine if the transmitters are active. An antenna power cutoff/lockout tagout will be accessible outside the exposure area for personnel to access in order to 'safe' the antenna area before occupation.

Example Of Signage:



Notional Station Location Information:



The applicant agrees to abide by the conditions specified in Condition 5208 provided below:

Condition 5208 - The licensee shall take all necessary measures to ensure that the antenna does not create potential exposure of humans to radiofrequency radiation in excess of the FCC exposure limits defined in 47 CFR 1.1307(b) and 1.1310 wherever such exposures might occur. Measures must be taken to ensure compliance with limits for both occupational/controlled exposure and for general population/uncontrolled exposure, as defined in these rule sections. Compliance can be accomplished in most cases by appropriate restrictions such as fencing.

Requirements for restrictions can be determined by predictions based on calculations, modeling or by field measurements. The FCC's OET Bulletin 65 (available on-line at www.fcc.gov/oet/rfsafety) provides information on predicting exposure levels and on methods for ensuring compliance, including the use of warning and alerting signs and protective equipment for worker.

Environmental Impacts Assessment:

- Reference Section 1.1307

Location Reference: 39°30'46.2"N 105°06'54.1"W - Lockheed Martin Space, 12257 South Wadsworth Blvd, Littleton, CO 80127

Response to Section 1.1307:

- (a) - No EA impacts have been identified at this station location.
 - This location is on Lockheed Martin property, no official wilderness or wildlife protection has been identified.
 - No threatened/endangered wildlife or habitat has been identified at this location.
 - No heritage/historic buildings or structures, nor religious sites have been identified at this location.
 - The location is on top of a mountain in the foothills, no flood plain threat identified.
 - Location is native grassland, no excessive land excavation has been identified.