iNTELLICOM

Radiation Safety Report for ThinSat300

August 21, 2012

ITC Document No:
201206073M01V09_RadiationReport.doc

Prepared by:
Intellicom Technologies, Inc.
and Thinkom Solutions, Inc.

Approved by:	
Paul Moller Vice-President, Intellicom Technologies Inc.	

iNTELLICOM Technologies, Inc.
PO Box 27056, San Diego, CA 92198
(858) 486-1115, www.ITCcom.net

Revision History

Revision History:	Date	Document Revision Description
V01-V02	Not recorded	Initial drafts
V03wb	Not recorded	Release to ThinKom
V04wb	2012 06 12	Updates
V05	2012 07 22	Updates
V06	2012 07 23	Updates
V07	2012 08 20	Updates
V08	2012 08 20	Updates
V09	2012 08 21	Release for FCC filing

1 TABLE OF CONTENTS

List of Figures

List of Tables

1.0 INTRODUCTION

This report is in response to the original 1985 FCC adoption of the 1982 American National Standards Institute (ANSI) guidelines and the further 1993 adoption of the 1992 ANSI and 1991 Institute of Electrical and Electronics Engineers (IEEE) guidelines[1] for evaluating exposure to RF transmitters licensed and authorized by the FCC. In 1996, the FCC adapted a modified version of its original proposal[2], which also fulfills the requirements of the Telecommunications Act of 1996 RF exposure guidelines[3]. The Maximum Permissible Exposure (MPE) radiation limit specifies two separate tiers as shown in Table 1:

- **(A) Occupational/Controlled Exposure**: The time-averaged exposure period is 6 minutes.
- **(B) General Population/Uncontrolled Exposure**: The time-averaged exposure period is 30 minutes.

Table 1 Maximum Permissible Exposure (MPE) Limits

(A) Controlled Exposure 6-Minute Average				(B) Uncontrolled Exposure 30-Minute Average		
Frequency Range (MHz)	***Electric Field Strength (E) (V/m)***	***Magnetic Field Strength (H) (A/m)***	***Power Density (S) (mW/cm^2)***	***Electric Field Strength (E) (V/m)***	***Magnetic Field Strength (H) (A/m)***	***Power Density (S) (mW/cm^2)***
0.3-3.0	614	1.63	(100)*			
3.0-30	1842/f	4.89/f	$(900/f^2)$*			
0.3-1.34				614	1.63	(100)*
1.34-30				824/f	2.19/f	$(180/f^2)$*
30-300	61.4	0.163	1.0	27.5	0.073	0.2
300-1500	--	--	f/300	--	--	f/1500
1,500-100,000	--	--	**5**	--	--	**1.0**

F = frequency in MHz
* = Plane Wave equivalent Power Density
-- = Not specified.

The satellite earth station being analyzed in this report is a ThinKom ***ThinSat® 300*** (phased array) antenna[4] that communicates with geosynchronous Ku band[5] satellites. It is designed to be mounted on the rooftop of vehicles and operate while the vehicle is in motion. Precision tracking methods using an Inertial Navigation Unit and GPS tracking maintain the antenna pointing accuracy to within a few tenths of a degree of boresight. The antenna is protected from the elements by an RF translucent radome.

Sophisticated software algorithms include the **automatic shutdown of RF transmissions** when the following conditions exist:

---

[1] ANSI/IEEE C95.1-1992 (IEEE Standard for Safety Levels with Respect to Human Exposure to RF Electromagnetic Fields, 3 kHz to 300 GHz)
[2] Refer to ET Docket 93-62 References 55 and 56, and FCC Office of Engineering (OET) Bulletin 65 Reference 57 Edition 97-01 for detailed information.
[3] See Section 704(b) of the Telecommunications Act of 1996, Pub. L No 104-104, Stat 56.
[4] A brochure of this antenna can be obtained by downloading http://www.thin-kom.com/brochures/ThinSAT300%20Brochure_04-12.pdf
[5] 13.75 to 14.50 GHz Transmit, 10.95 to 12.75 GHz Receive

1. When the antenna **pointing error** is greater than a several tenths of a degree. This error is in Azimuth or Elevation, or a combination of both. This is a settable parameter.
2. When the **elevation angle** goes below a preprogrammed value of 15^o or a mask.
3. When the **received signal** is no longer available (blocked) and the demodulator fails to lock onto the signal.

The purpose of this analysis is to determine the Power Flux Density (S) for the earth station and to compare these levels to the specified MPE's of Table 1.

1.1 Assumptions Used for this Analysis

Several formulas and parameters to be used for determining the Radiation Densities are provided in Table 2.

1.1.1 Near Field Power Density

The radiating area of the aperture is approximately 0.218m^2 (or 338 in^2). For this earth station filing, the ThinSat unit will be equipped with a 25W BUC. There is approximately 2 dB loss between the power amplifier and the aperture. This is a net power of 15.8 W. Over an area of 0.218m^2 (or 338 in^2), this is a **power density (P_{tot}/Area) of 7.3 mW/cm^2** (assuming a uniform power distribution over the aperture surface). Therefore, in the near field of the aperture, the radiation emitted from the ThinSat 300 exceeds the Maximum Permissible Exposure (MPE) limits.

Table 2 Formulas and Parameters Used in this Document

Parameter	Symbol	Formula	Value	Units
Transmit Frequency	F	Input	14,250	MHz
Wavelength	λ	C/F	0.0211	m
Antenna Diameter (inches) (equivalent to a parabolic antenna)				
Major (Azimuth)	D_1		26.0	inches
Minor (Elevation)	D_2		13.0	inches
Antenna Diameter (m)				
Major (Azimuth)	D_1		0.66	m
Minor (Elevation)	D_2		0.33	m
Antenna Radius				
Major (Azimuth)	R_1		0.33	m
Minor (Elevation)	R_2		0.17	m
Antenna Reflector				
Antenna Surface Area (plane)	$A_{surface}$	area of a rectangle,D^1 x D^2	0.22	m^2
	$A_{surface}$	area of a rectangle,D^1 x D^2	338	in^2
	$A_{surface}$	area of a rectangle,D^1 x D^2	2181	cm^2
Equivalent Diameter (as if circular)	De	2*sqrt($A_{surface}$/π)	0.53	m
Power Amplifier				
Transmit Power - saturated	P_{sat}	Measured	44	dBm
Line Losses between SSPA and feed	L	Measured	2.0	dB
Net Power Into Feed	P		42	dBm
Net Power Into Feed	P		15.8	Watts
Surface Power Density				
At antenna surface			7.3	mWatts/cm^2
EIRP Spectral Density (dBW/4kHz)				
14.05 GHz	$EIRP_{sat}$	Measured at 20° Elevation	13.7-17.5	dBW
14.25 GHz	$EIRP_{sat}$	Measured at 20° Elevation	14.2-17.6	dBW
14.45 GHz	$EIRP_{sat}$	Measured at 20° Elevation	14.5-17.8	dBW
RadiationCalculatons_v08pm.xls				

2 ANALYSIS

2.1 Exposure in the Transition Region and Far Field

In the **far field** the power density at the peak of the main beam is given[6] by:

$$Max\ Power\ Density = \frac{P_{tot} * Dir}{4\pi * R^2} \quad (1)$$

Where P_{tot} is the total power radiated, *Dir* is the antenna's directivity, and *R* is the distance from the aperture. In the **transition region** the peak power density is given approximately by:

$$Max\ Power\ Density = \frac{P_{tot}}{\pi * \left(R_{eff} + \frac{2*R}{\sqrt{Dir}}\right)^2} \quad (2)$$

Where R_{eff} is an effective radius of the antenna (defined by πR_{eff}^2 = Aperture Area). Note that when *R* is much greater than R_{eff}, R_{eff} in the denominator can be neglected and this equation becomes equal to the far-field expression of equation (1). Also, when the *R* is equal to zero, this equation gives the correct **near-field** value (= P_{tot}/Area).

Since the VICTS architecture employed by the ThinSat 300 antenna is essentially a mechanically scanned phased array antenna, its directivity varies with scan angle. Figure 1 shows the Tx antenna's directivity and is given approximately by 37 dBi + 10*log(sin(elev)), where elev is the elevation angle the mainbeam makes with respect to the horizon.

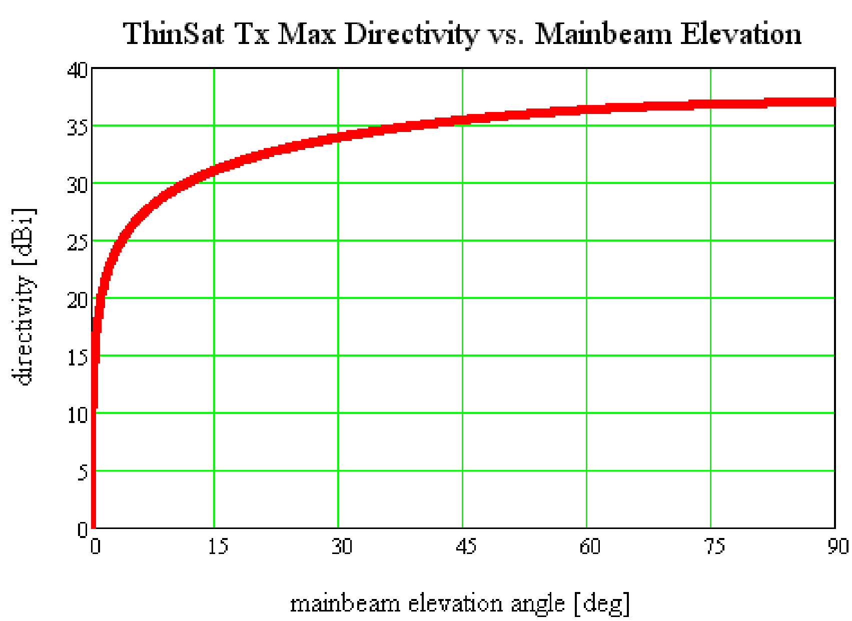

Figure 1 Maximum Directivity of the Tx Antenna vs. Mainbeam Elevation Angle

[6] OET Bulletin 65 Edition 97-01 dated August 1997, Formula (18).

2.2 Calculated & Measured Radiation Exposure

The values in Figure 1 were employed with equation (2) to calculate the power density values given in Table 3. This data is also plotted in Figure 2 along with some measured data points taken at distances of 1m and 5m away from the Tx antenna. The measured data shows good agreement with calculated values in Table 3 for mainbeam elevation angles away from the horizon. Although the Antenna Control Unit (ACU) will prohibit the antenna from pointing the mainbeam below an elev=15°, we have taken measurements for the case where the mainbeam is commanded to the horizon (elev=0°) out of an abundance of caution. At this particular elevation angle (on the horizon), the radiation density will be dictated by extraneous factors (ie. diffraction) not normally taken into account by a theoretical analysis.

Table 3 On-Axis Max Power Densities (in mW/cm^2) for 25W BUC

	Mainbeam Elevation Angle [deg]				
Distance [m]	**90**	**70**	**50**	**30**	**15**
0.5	6.5	6.5	6.4	6.1	5.9
1	5.9	5.8	5.6	5.2	4.9
2	4.9	4.8	4.5	3.9	3.6
3	4.1	4.0	3.7	3.0	2.7
4	3.5	3.4	3.1	2.4	2.1
5	3.1	2.9	2.6	2.0	1.7
10	1.7	1.6	1.3	0.9	0.7
15	1.1	1.0	0.8	0.5	0.4
20	0.7	0.7	0.5	0.3	0.3
30	0.4	0.4	0.3	0.2	0.1

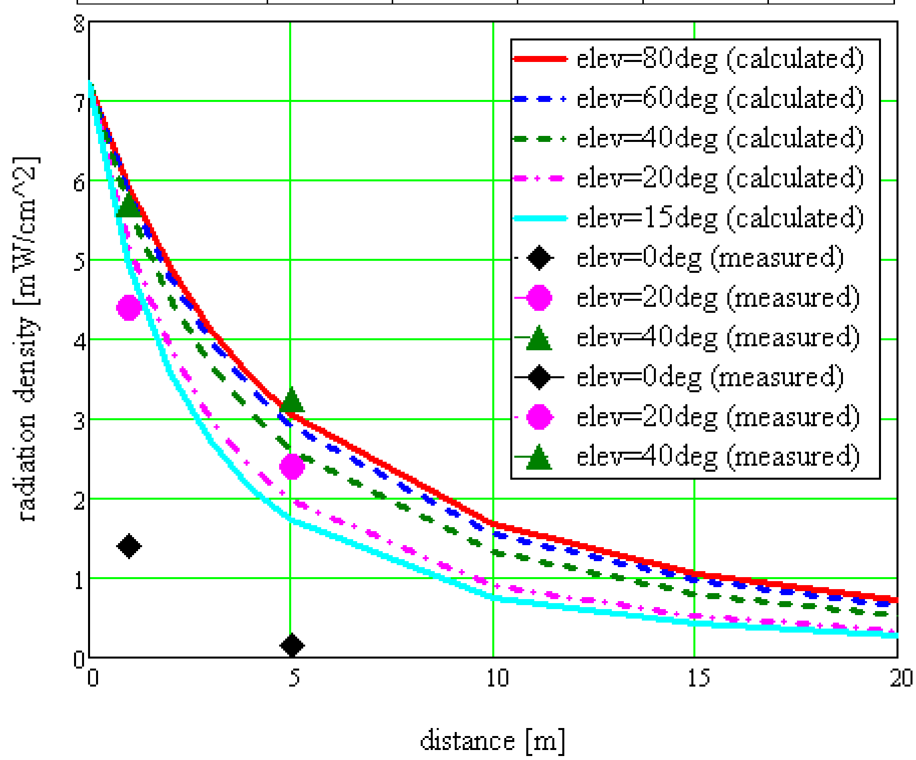

Figure 2 Calculated & Measured Radiation Densities vs. Distance

2.3 On-Axis Radiation Densities

For the case when the beam is scanned to **elev=90º** (the highest elevation angle the antenna will employ), the on-axis power density falls below the permissible levels for controlled (5 mW/cm^2) and uncontrolled (1 mW/cm^2) environments at distances of **1.9 and 15.7 meters** respectively.

For the case when the beam is scanned to **elev=15º** (the highest elevation angle the antenna will employ), the on-axis power density falls below the permissible levels for controlled (5 mW/cm^2) and uncontrolled (1 mW/cm^2) environments at distances of **1 and 8 meters** respectively.

A plot of the on-axis distances vs. mainbeam elevation angle for when the radiation falls below MPE controlled and uncontrolled exposure limits is shown in Figure 3.

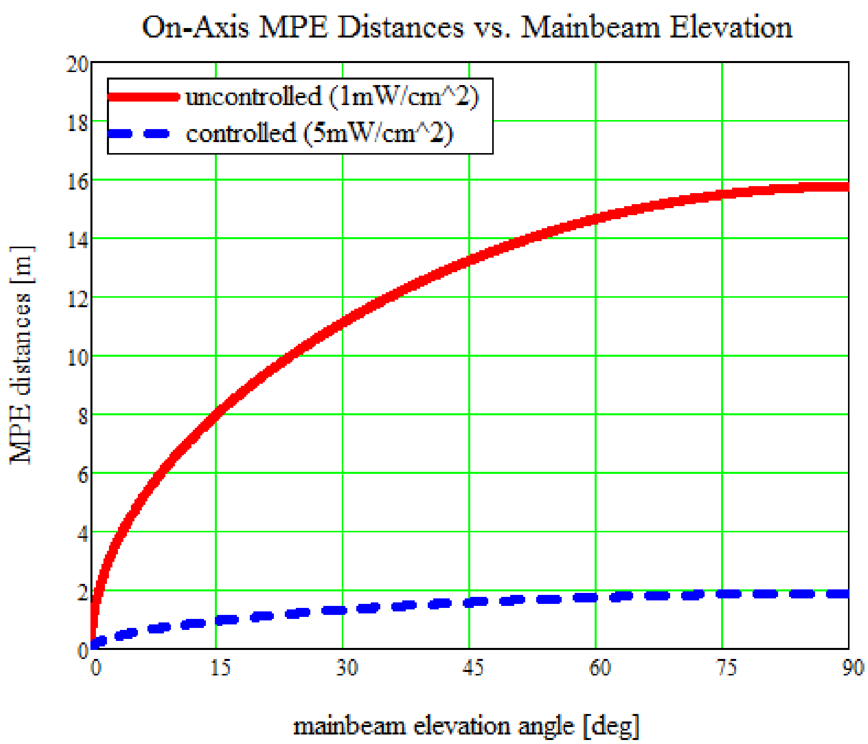

Figure 3 On-Axis MPE Distances vs. Mainbeam Elevation Angle

2.4 Alternate Near-Field Analysis for the Horizon

The ThinSat antenna will be deployed on the top of vehicles and buildings. The antenna mechanical boresight will be directed at or near zenith. Therefore, the radiation will be mainly confined to areas (above the antenna) that are typically not easily accessible to the general population.

It should also be noted that the ThinSat antenna does not suffer from the spillover phenomena (that occurs with reflector antennas). Therefore, the radiation levels will be extremely low in areas below the level at which the antenna is mounted. This was demonstrated in the measured data points in Figure 2.

We will further reinforce this by calculating the expected radiation densities using a more thorough analysis of the transition region fields. Figures 4 through 8 show (approximate) predicted normalized elevation patterns, “as seen” at various distances from the antenna for different scan angles in the antenna’s near-field.

The analysis used to generate the patterns is valid from boresight to 90 degrees from boresight (zenith to horizon assuming the antenna is pointed straight up). At angles more than 90 deg. from boresight, the radiation is further suppressed. This analysis does not take into account the fact that the antenna enclosure will also help further reduce near and below horizon radiation.

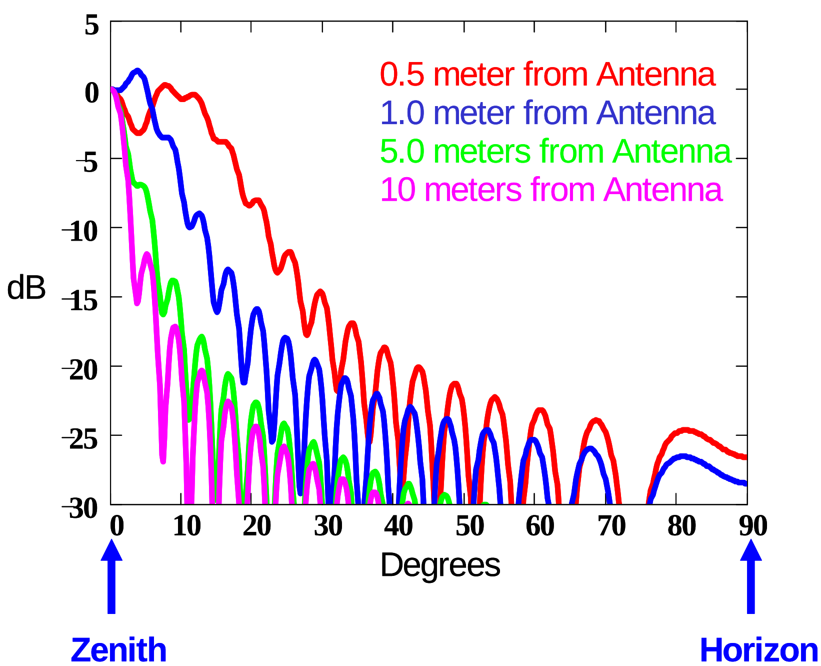

Figure 4 Elevation Radiation Patterns When Mainbeam Scanned to Elev=90º

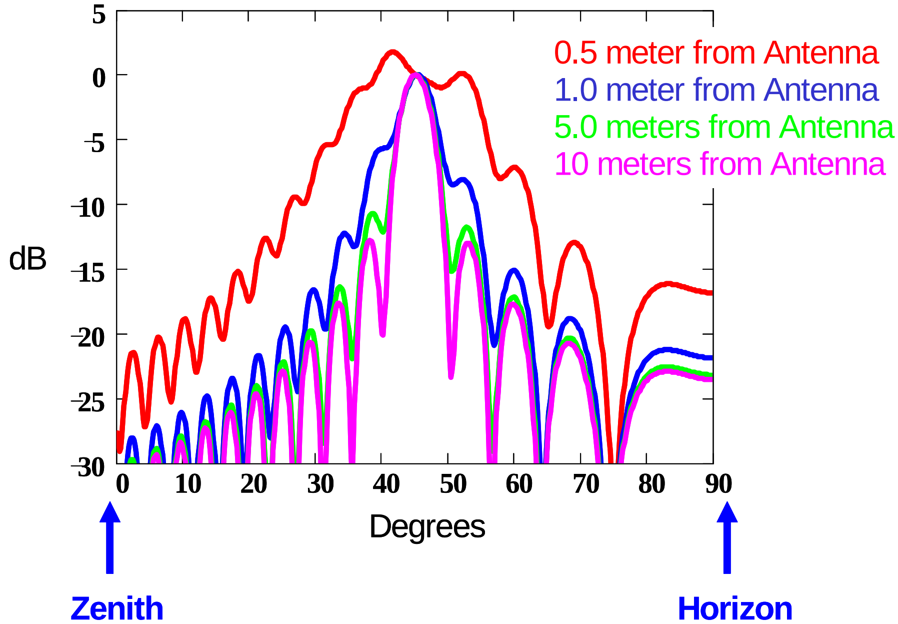

Figure 5 Elevation Radiation Patterns When Mainbeam Scanned to Elev=45º

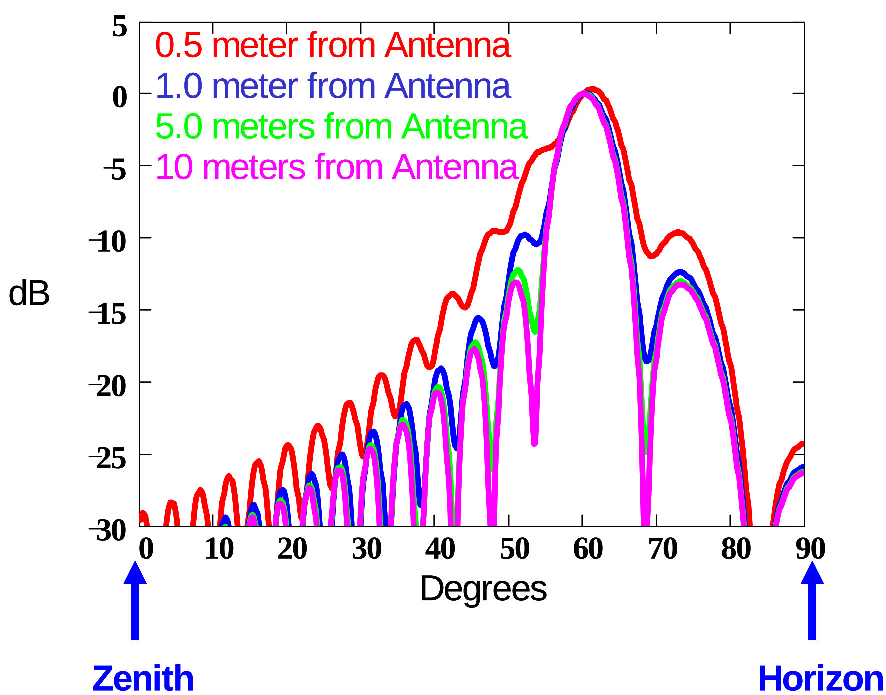

Figure 6 Elevation Radiation Patterns When Mainbeam Scanned to Elev=30º

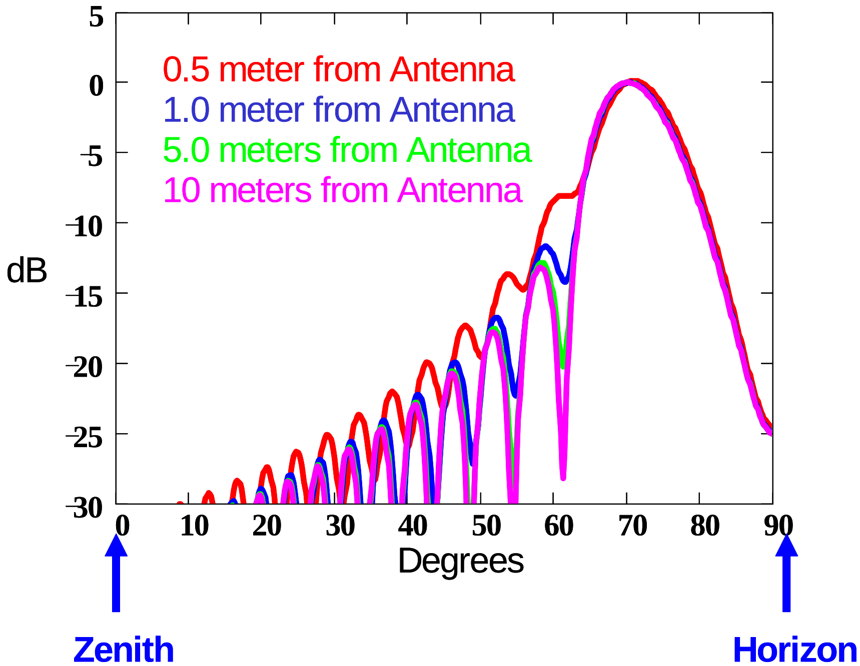

Figure 7 Elevation Radiation Patterns When Mainbeam Scanned to Elev=20º

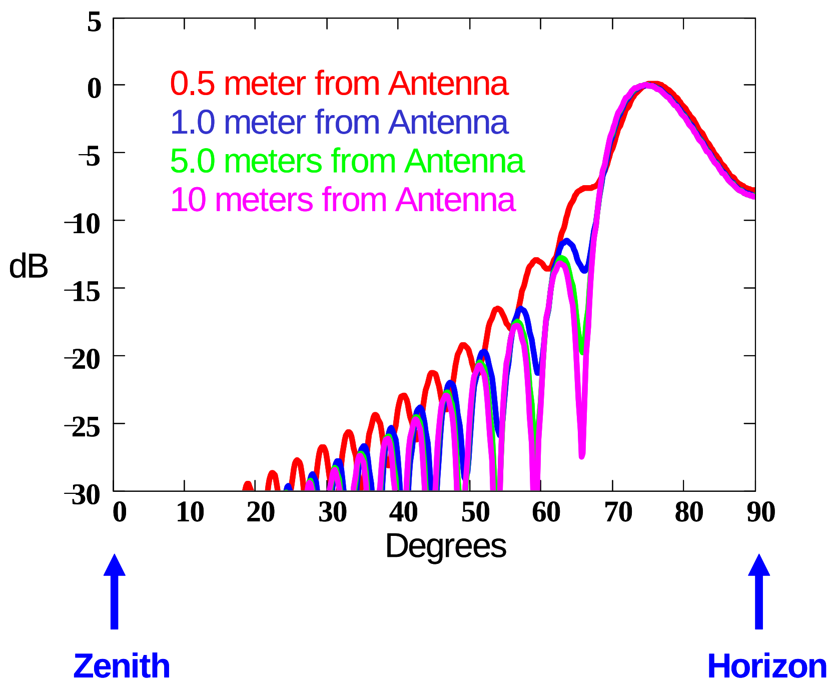

Figure 8 Elevation Radiation Patterns When Mainbeam Scanned to Elev=15º

As is shown by the figures, radiation in regions below the level of antenna will typically be very low, even at small distances. **For the (worst) case of an elev=15º** mainbeam angle, the on horizon radiation level is (at least) **8 dB** below the value for the mainbeam.

Since the peak/on-axis radiation value at a distance **1 meter** from the antenna for this scan angle (15° elevation) is about 5 mW/cm^2 (per Figure 2), at or below the level of the antenna the power density is at most 5 mW/cm^2 × 10^(-8/10) = **0.8 mW/cm^2** at this distance.

Alternatively, the calculated MPE distance for **uncontrolled exposure** (1 mW/cm^2) is **0.8m** at the horizon when the mainbeam is scanned to elev=15°. For controlled exposure (5 mW/cm^2), all distances are below the MPE limits if the operator stays below the plane of the antenna. At commanded elevation angles higher than elev=15°, the on-horizon radiation densities are expected to be much lower than 8 dB below the mainbeam peak as evidenced by the plots in Figures 4 through 7.

2.5 Case Studies – Vehicle Mounted Installations

2.5.1 Antenna Mounted on a Low Profile Vehicle

Figure 9 depicts a low profile Mini Cooper Clubman[7] with the antenna mounted on its rooftop. Two people are shown to give a prospective height to someone in close proximity to the vehicle. The Mini Cooper Clubman has a height of **56.1"** measured from ground to the rooftop. The total width of the vehicle is **75.3**", so the center of the rooftop to the vehicle edge is **37.65"**.

Antenna surface height 56.1" + 7" = 63", or ~ **5' 3"**

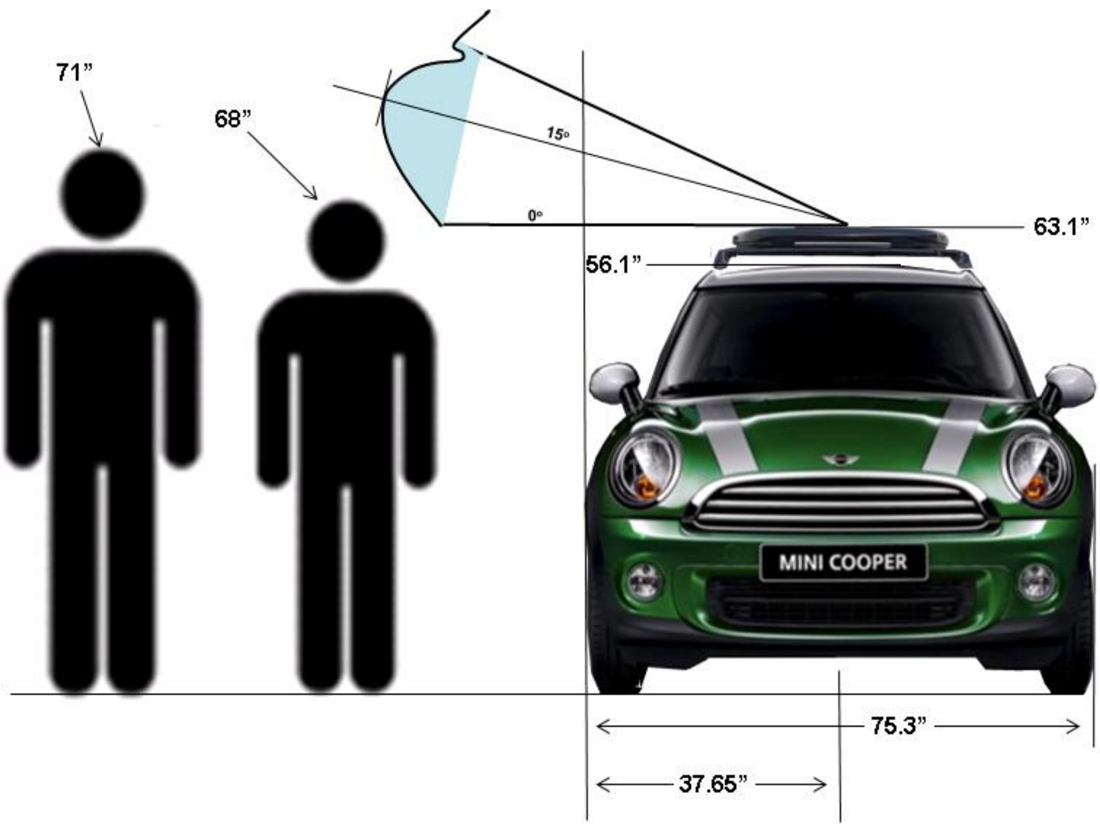

Figure 9 Antenna Rooftop Mount on a Low Profile Vehicle

A person standing right at the edge of the Mini-Cooper will be exposed to varying amounts of radiation depending on the person's height. Since the antenna will be limited to a minimum elevation of 15°, the maximum expected radiation exposure from Table 3 at a distance of 1 meter from the antenna is 4.9 mW/cm^2.

---

[7] A Mini Cooper Clubman was chosen for this artistic rendition due to its low profile and large rooftop surface area.

A person shorter than the top mounted surface of the antenna (~5'3") should expect to see no more than 0.8 mW/cm^2, safely below both MPE controlled and uncontrolled limits. Based on the data generated in Figure 8, we can calculate the expected exposure for a person standing at various distances away from the edge of the Mini Cooper. This data is presented in Figure 10 as a function of the person's height.

Note that we have assumed the mainbeam is pointed directly in azimuth at the subject person; in general this will not be the case but we have taken a very conservative approach out of an abundance of caution. **The data reveals radiation densities will always be below the controlled (5 mW/cm^2) MPE limits regardless of a person's height.** A taller person (ie. taller than 6') may need to stand farther away (>7m) to stay below the MPE uncontrolled exposure limit (1 mW/cm^2).

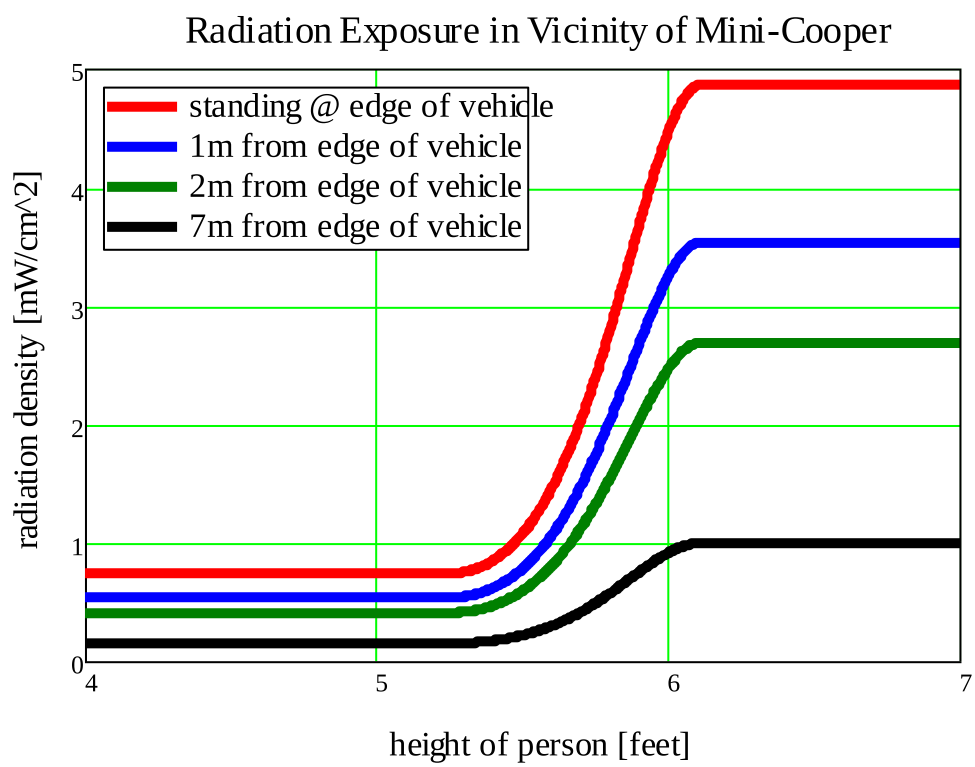

Figure 10 Worst-Case Radiation Exposure in Vicinity of Mini-Cooper Clubman

2.5.2 Antenna Mounted on a High Profile Vehicle

A more practical installation vehicle for ThinSat is the Chevy Suburban, whose cargo space provides more room for the electronics and equipment the antenna will be interfacing with. The Chevy Suburban installation is shown in Figure 11, which illustrates the antenna being mounted on the roof of the vehicle.

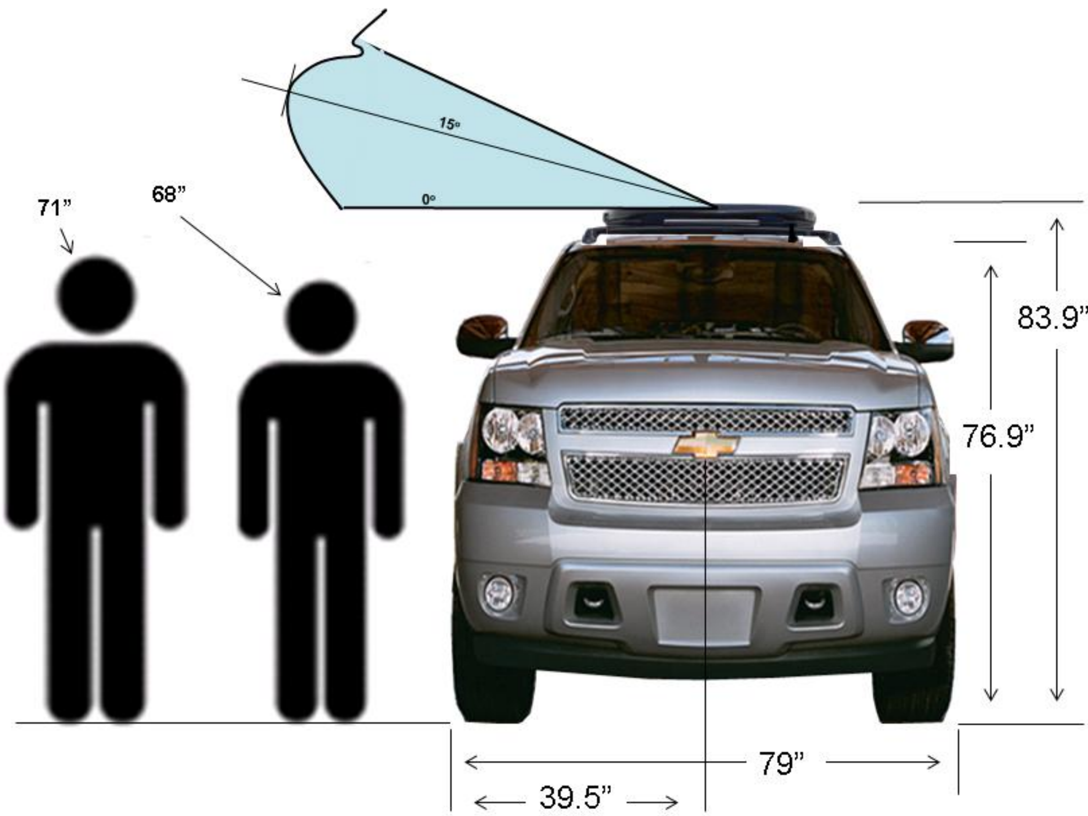

Figure 11 Antenna Rooftop Mount on a High Profile Vehicle

The height of the Suburban is **76.9"** measured from ground to the rooftop. The total width of the vehicle is **79**", so the center of the rooftop to the vehicle edge is **39.5"**.

Antenna surface height	76.9" + 7" = 83.9", or ~ **6' 11"**

The expected radiation exposure around the vicinity of the Suburban is shown in Figure 12. In all practical cases, the expected radiation exposure will fall safely below both the MPE controlled and uncontrolled exposure limits regardless of a person's height (up to 7 feet tall).

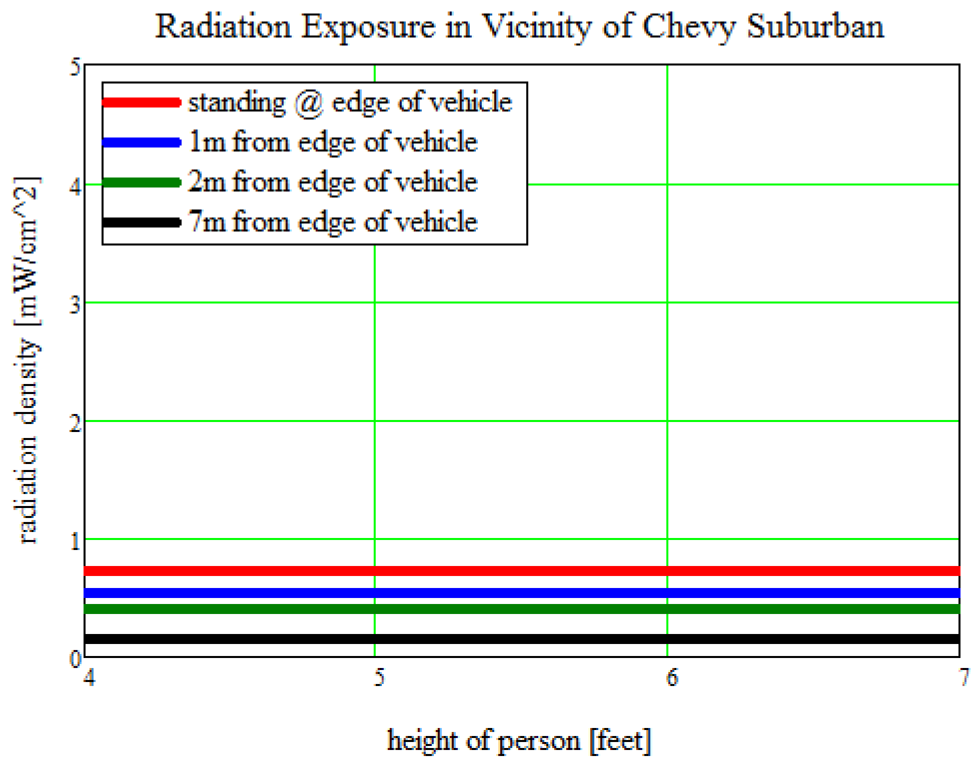

Figure 12 Worst-Case Radiation Exposure in the Vicinity of Chevy Suburban

3 SUMMARY AND CONCLUSIONS

3.1 Conclusions

Table 4 provides a summary of calculations and the expected radiation levels presented in the previous section.

Table 4 Summary of Radiation Exposure Levels/Distances

Mainbeam Scan	Power Density [mW/cm^2]	Distance [m]
All elevation angles	7.3	0
Mainbeam elev=**90°** (calculated on-axis)	1 (uncontrolled)	15.7
	5 (controlled)	1.9
Mainbeam elev=**15°** (calculated on-axis)	1 (uncontrolled)	8
	5 (controlled)	1
Mainbeam elev=**15°** (calculated @ horizon)	1 (uncontrolled)	0.8
	< 5mW/cm^2 at all distances	
Mainbeam elev=**0°** (measured @ horizon)	1.40	1
	1	2 (estimated, Figure 2)
	0.15	5

The table above contains a mixture of calculated and measured data. In the abundance of caution, recommendations will be given based on the more conservative of the two data sets.

Above the plane of the antenna:

- Based on the calculations presented in this report, the general public (**uncontrolled**) should always strive to stay below the plane of the antenna at all times if possible. Otherwise, Figure 3 can be used to determine recommended MPE distances if the commanded mainbeam elevation angle is known. If this elevation angle is unknown, the general public should stay at least **15.7 m away out of an abundance of caution**.
- Personnel working in the MPE **controlled** environment should stay at least **2 meters** away (time averaged over a 6-min span) to keep exposure levels below the MPE controlled threshold of 5 mW/cm^2.

Below the plane of the antenna:

- Measured data dictates the general population (**uncontrolled**) should stay at least **2 meters** away (time averaged over a 30-min span) from the antenna to keep exposure levels below the MPE uncontrolled threshold of 1 mW/cm^2.
- Below the plane of the antenna, radiation exposure will always be below the MPE **controlled** threshold of 5 mW/cm^2 regardless of distance.

It is recommended that the operator perform radiation flux density measurements around the antenna during typical operation to verify the area of hazard to personnel and ensure that personnel are restricted from entering the hazard area.

Table 5 Radiation Hazard Recommendations

Radiation Hazard Recommendations
• The earth station shall not transmit below 15º elevation. • The earth station shall mute transmission if there is no receive signal lock. • The earth station operator shall ensure that the general public (uncontrolled) stays below the plane of antenna.
Above the plane of the antenna: • The earth station operator shall ensure that the general public (uncontrolled) stays >16m away. • Controlled personnel shall stay > 2m away.
Below the plane of the antenna: • The earth station operator shall ensure that the general public (uncontrolled) stays >2m away. • Controlled personnel can work below the antenna surface at any distance.

3.2 Manufacturer Responsibility

1. The manufacturer shall advise the owner/operator to have or seek sufficient knowledge on the safe operation of radio transmitters.
2. The manufacturer shall be responsible for installing permanent RF hazard warning labels on the antenna housing, similar to the one in Figure 13.
3. Radiation hazard warnings signs shall be of sufficient size and in clear view of personnel nearby.
4. Labels shall provide a table (such as Table 5) showing the radiation hazard recommendations.
5. The manufacturer shall include warnings in the Operation, Installation, and Maintenance Manuals furnished with each antenna system regarding the potential hazard from RF radiation.
6. The manufacturer shall impose elevation restrictions that turns off the RF transmission should the mainbeam fall below an elevation of 15°.
7. The manufacturer shall pre-program the antenna system with elevation restrictions.
8. The manufacturer shall provide safety warnings to the operator regarding reducing or removing elevation restrictions.
9. The manufacturer shall maintain this document particularly if parameters of the transmission system change which could impact safety.
10. If a system is delivered that includes a modem and an antenna system, the manufacturer shall ensure that the system is muted within 3 seconds if it is not locked to a receive signal.
11. The manufacturer shall include warnings that an operational system shall include a modem that mutes its transmitter within 3 seconds if it is not locked to a receive signal.
12. The manufacturer shall provide updated labels and documentation to all customers if the safety information is revised.
13. The manufacturer shall recommend that the operator perform a **radiation safety test** of the areas in which personnel will be located during transmission. If radiation exceeds recommended levels, all transmission shall cease until radiation levels have been corrected.

Figure 13 Radiation Hazard Warning Label Sample

3.3 Operator Responsibility

1. The operator shall have sufficient knowledge or seek training on the safe operation of radio transmitters.
2. The operator shall adhere to the warnings provided by the manufacturer's labels, manuals, updates, or other documentation.
3. The operator shall keep the labels on the antenna platform in good shape and within clear view of anyone within close proximity.
4. The operator shall ensure that individuals will be prevented from straying within the hazard region by means of signs, fencing or caution tape, verbal warnings, and placement of the earth station or other appropriate means so as to minimize access to any hazardous region.
5. The operator shall perform a visual inspection of the area around the antenna within the hazard area to ensure that all personnel are below the antenna base and removed from the hazard area (Table 4) during transmission.
6. The operator shall ensure that the antenna system is configured with elevation restrictions that turn off the RF transmission when the antenna elevation falls below the above specified limits (Table 4).
7. The operator shall ensure that the system mutes its transmitter within 3 seconds if it is not locked to a receive signal.
8. The operator shall perform a **radiation safety test** of the areas in which personnel will be located during transmission. If radiation exceeds recommended levels, all transmission shall cease until radiation levels have been corrected.