Environmental Assessment
Boeing Proprietary

The Boeing Company

Submitted by:

Nathan A Miller
The Boeing Company
Frequency Management Service
Seattle, WA
(206) 544-6045

Per CFR 47, section 1.1307.b(1), Table 1, all applications for experimental operations with an ERP greater than 100 watts require evaluation for compliance with human exposure limits defined in section 1.1310, and if exceeded require submission of an Environmental Assessment as defined in section 1.1311.

This report presents an analysis of the non-ionizing radiation levels for a Prodelin 2.4 meter and Vertex 3.8 meter. The calculations used in this analysis were derived from and comply with the procedures outlined in the Federal Communication Commission, Office of Engineering and Technology Bulletin Number 65, which establishes guidelines for human exposure to Radio Frequency Electromagnetic Fields. Bulletin 65 defines exposure levels in two separate categories, the General Population/Uncontrolled Areas limits, and the Occupational/Controlled Area limits. The Maximum Permissible Exposure (MPE) limit of the General Population/Uncontrolled Area is defined in Table (1), and represents a maximum exposure limit averaged over a 30 minute period. The MPE limit of the Occupational/Controlled Area is defined in Table (2), and represents a maximum exposure limit averaged over a 6 minute period. The purpose of this report is to provide an analysis of the earth station power flux densities, and to compare those levels to the specified MPE's. This report provides predicted density levels in the near field, far field, transition region, main reflector surface area, area between the main reflector and sub reflector or feed assembly, as well as the area between the antenna edge and ground.

MPE Limits for General Population/Uncontrolled Area

Frequency Range (MHz)	*Power Density (mW/cm^2)*
1500 – 100,000	1.0

Table 1

MPE Limits for Occupational/Controlled Area

Frequency Range (MHz)	*Power Density (mW/cm^2)*
1500 – 100,000	5.0

Table 2

Prodelin 2.4 Meter

Table 3 contains formulas, equations and parameters that were used in determining the Power Flux Density levels for Prodelin 2.4 Meter:

Data Type	*Data Symbol*	*Data Formula*	*Data Value*	*Unit of Measure*
Power Input	P	Input	16	W
Antenna Size	D	Input	2.4	M
Antenna Area	A	$A = (\Pi D^2) \div 4$	4.52	M^2
Subreflector Size	Sub	Input	12.4	cm
Subreflector Area	A_{sub}	$A_{sub} = (\Pi Sub^2) \div 4$	120.76	cm^2
Gain dBi	G_{dbi}	Input	49.2	dBi
Gain Factor	G	$G = 10^{Gdbi/10}$	83176.38	Gain Factor
Frequency	f	Input	14250	MHz
Wavelength	λ	$299.79 / f$	0.021038	Meters
Aperture Efficiency	η	$\eta = [(G\lambda^2) \div (4\Pi)] \div A$	0.65	n/a
Pi	Π	Input	3.14159	Numeric
Constant	M/Sec	Input	299,792,458	Numeric
Conversion W to mW	mW	mW = $W \times 1000$	n/a	n/a
Conversion M to cm	cm	cm = $M \times 100$	n/a	n/a
Conversion M^2 to cm^2	cm^2	cm^2 = $M^2 \times 10000$	n/a	n/a
Conversion W/M^2 to mW/cm^2	mW/cm^2	mW/cm^2 = $W / M^2 \div 10$	n/a	n/a

Table 3

1. Far Field Analysis

The distance to the far field can be calculated using the following formula:

$$R_{ff} = \frac{0.6D^2}{\lambda} = \quad 164.27 \text{ Meters}$$

The power density in the far field can be calculated using the following formula. Note: this formula requires the use of power in milliwatts and far field distance in centimeters, or requires a post calculation conversion from W/M^2:

$$S_{ff} = \frac{PG}{4\Pi R_{ff}{}^2} = \quad 0.392 \text{ mW/cm}^2$$

2. Near Field Analysis

The extent of the Near Field region can be calculated using the following formula:

$$R_{nf} = \frac{D^2}{4\lambda} = \quad 68.45 \text{ Meters}$$

The power density of the near field can be calculated using the following formula. Note: this formula requires the use of power in milliwatts and diameter in centimeters, or requires a post calculation conversion from W/M^2:

$$S_{nf} = \frac{16\eta P}{\Pi D^2} = \quad 0.916 \text{ mW/cm}^2$$

3. Transition Region Analysis

The transition region extends from the end of the near field out to the beginning of the far field. The power density in the transition region decreases inversely with distance from the antenna, while power density in the far-field decreases inversely with the square of the distance. However the power density in the transition region will not exceed the density in the near field, and can be calculated for any point in the transition region (R), using the following formula. Note: This formula requires the use of distance in centimeters, or requires a post calculation conversion from W/M^2.

$$S_t = \frac{S_{nf}\, R_{nf}}{R} = \quad 0.916 \text{ mW/cm}^2$$

4. Main Reflector Surface Area Analysis

The maximum power density at the antenna surface area can be calculated using the following formula. Note: this formula requires the use of Power in milliwatts and Area in centimeters squared, or requires a post calculation conversion from W/M^2.

$$S_{surface} = \frac{4P}{A} = 1.415 \text{ mW/cm}^2$$

5. Subreflector Area Analysis

The area between the sub reflector and main reflector presents a potential hazard, with the highest density being located at the sub reflector area. The power density at the sub reflector can be calculated using the following formula. Note: this formula requires the use of Power in milliwatts and Area in centimeters squared, or requires a post calculation conversion from W/M^2.

$$Sub_{surface} = \frac{4P}{A_{sub}} = 529.964 \text{ mW/cm}^2$$

Tables 4 and 5 present a summary of the radiation hazard findings on the Prodelin 2.4 Meter for both the General Population/Uncontrolled Area, as well as the Occupational/Controlled area environments.

MPE Limits for General Population/Uncontrolled Area

Area	*Range Meters*	*Power Density (mW/cm^2)*	*Finding*
Far Field	164.27	0.392 mW/cm^2	Meets FCC Requirements
Near Field	68.45	0.916 mW/cm^2	Meets FCC Requirements
Transition Region	68.45 – 164.27	0.916 mW/cm^2	Meets FCC Requirements
Main Reflector Surface	N/A	1.415 mW/cm^2	Potential Hazard
Sub-reflector Surface	N/A	529.964 mW/cm^2	Potential Hazard

Table 4

MPE Limits for Occupational/Controlled Area

Area	***Range Meters***	***Power Density (mW/cm^2)***	***Finding***
Far Field	164.27	0.392 mW/cm^2	Meets FCC Requirements
Near Field	68.45	0.916 mW/cm^2	Meets FCC Requirements
Transition Region	68.45 – 164.27	0.916 mW/cm^2	Meets FCC Requirements
Main Reflector Surface	N/A	1.415 mW/cm^2	Meets FCC Requirements
Sub-reflector Surface	N/A	529.964 mW/cm^2	Potential Hazard

Table 5

Based on the above finding there is a potential hazard of radio frequency exposure with use of the Prodelin 2.4 Meter. In order to mitigate the risk of these hazards, this terminal will only be operated in a controlled area, which is confined to Boeing Property. The antenna beam will be directed into the target on the ground, or into the dirt hillside. During the experimental operation, the test area will be continuously monitored and controlled to prevent personnel entry into the hazard area. Additionally, the unit will be shut down prior to performing maintenance in any of the occupational hazard areas.

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Vertex 3.8 Meter

Table 3 contains formulas, equations and parameters that were used in determining the Power Flux Density levels for Vertex 3.8 Meter:

Data Type	*Data Symbol*	*Data Formula*	*Data Value*	*Unit of Measure*
Power Input	P	Input	16	W
Antenna Size	D	Input	3.8	M
Antenna Area	A	$A = (\Pi D^2) \div 4$	11.34	M^2
Subreflector Size	Sub	Input	12.4	cm
Subreflector Area	A_{sub}	$A_{sub} = (\Pi Sub^2) \div 4$	120.76	cm^2
Gain dBi	G_{dbi}	Input	53	dBi
Gain Factor	G	$G = 10^{Gdbi/10}$	199526.23	Gain Factor
Frequency	f	Input	14250	MHz
Wavelength	λ	$299.79 / f$	0.021038	Meters
Aperture Efficiency	η	$\eta = [(G\lambda^2) \div (4\Pi)] \div A$	0.62	n/a
Pi	Π	Input	3.14159	Numeric
Constant	M/Sec	Input	299,792,458	Numeric
Conversion W to mW	mW	$mW = W \times 1000$	n/a	n/a
Conversion M to cm	cm	$cm = M \times 100$	n/a	n/a
Conversion M^2 to cm^2	cm^2	$cm^2 = M^2 \times 10000$	n/a	n/a
Conversion W/M^2 to mW/cm^2	mW/cm^2	$mW/cm^2 = W / M^2 \div 10$	n/a	n/a

Table 6

1. Far Field Analysis

The distance to the far field can be calculated using the following formula:

$$R_{ff} = \frac{0.6D^2}{\lambda} = 411.82 \text{ Meters}$$

The power density in the far field can be calculated using the following formula. Note: this formula requires the use of power in milliwatts and far field distance in centimeters, or requires a post calculation conversion from W/M^2:

$$S_{ff} = \frac{PG}{4\Pi R_{ff}^2} = 0.150 \text{ mW/cm}^2$$

6. Near Field Analysis

The extent of the Near Field region can be calculated using the following formula:

$$R_{nf} = \frac{D^2}{4\lambda} = \quad 171.59 \text{ Meters}$$

The power density of the near field can be calculated using the following formula. Note: this formula requires the use of power in milliwatts and diameter in centimeters, or requires a post calculation conversion from W/M^2:

$$S_{nf} = \frac{16\eta P}{\Pi D^2} = \quad 0.350 \text{ mW/cm}^2$$

7. Transition Region Analysis

The transition region extends from the end of the near field out to the beginning of the far field. The power density in the transition region decreases inversely with distance from the antenna, while power density in the far-field decreases inversely with the square of the distance. However the power density in the transition region will not exceed the density in the near field, and can be calculated for any point in the transition region (R), using the following formula. Note: This formula requires the use of distance in centimeters, or requires a post calculation conversion from W/M^2.

$$S_t = \frac{S_{nf} R_{nf}}{R} = \quad 0.350 \text{ mW/cm}^2$$

8. Main Reflector Surface Area Analysis

The maximum power density at the antenna surface area can be calculated using the following formula. Note: this formula requires the use of Power in milliwatts and Area in centimeters squared, or requires a post calculation conversion from W/M^2.

$$S_{surface} = \frac{4P}{A} = \quad 0.564 \text{mW/cm}^2$$

9. Subreflector Area Analysis

The area between the sub reflector and main reflector presents a potential hazard, with the highest density being located at the sub reflector area. The power density at the sub reflector can be calculated using the following formula. Note: this formula requires the use of Power in milliwatts and Area in centimeters squared, or requires a post calculation conversion from W/M^2.

$$Sub_{surface} = \frac{4P}{A_{sub}} = 529.964 \text{ mW/cm}^2$$

Tables 7 and 8 present a summary of the radiation hazard findings on the Vertex 3.8 Meter for both the General Population/Uncontrolled Area, as well as the Occupational/Controlled area environments.

MPE Limits for General Population/Uncontrolled Area

Area	***Range Meters***	***Power Density (mW/cm^2)***	***Finding***
Far Field	411.82	0.150mW/cm^2	Meets FCC Requirements
Near Field	171.59	0.350 mW/cm^2	Meets FCC Requirements
Transition Region	171.59 – 411.82	0.350 mW/cm^2	Meets FCC Requirements
Main Reflector Surface	N/A	0.564 mW/cm^2	Potential Hazard
Sub-reflector Surface	N/A	529.964 mW/cm^2	Meets FCC Requirements

Table 7

MPE Limits for Occupational/Controlled Area

Area	***Range Meters***	***Power Density (mW/cm^2)***	***Finding***
Far Field	411.82	0.150mW/cm^2	Meets FCC Requirements
Near Field	171.59	0.350 mW/cm^2	Meets FCC Requirements
Transition Region	171.59 – 411.82	0.350 mW/cm^2	Meets FCC Requirements
Main Reflector Surface	N/A	0.564 mW/cm^2	Potential Hazard
Sub-reflector Surface	N/A	529.964 mW/cm^2	Meets FCC Requirements

Table 8

Based on the above finding there is a potential hazard of radio frequency exposure with use of the Vertex 3.8 Meter. In order to mitigate the risk of these hazards, this terminal will only be operated in a controlled area, which is confined to Boeing Property. The antenna beam will be directed into the target on the ground, or into the dirt hillside. During the experimental operation, the test area will be continuously monitored and controlled to prevent personnel entry into the hazard area. Additionally, the unit will be shut down prior to performing maintenance in any of the occupational hazard areas.