ATTACHMENT 1

Radiation Hazard Studies

This report presents an analysis of the non-ionizing radiation levels for a Boeing Phased Array antenna system.

The calculations used in this analysis were derived from and comply with the procedures outlined in the Federal Communications 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 aircraft station power flux densities, and to compare those levels to the specified MPE limits.

This report provides predicted density levels in the near field, far field, transition region, and main reflector surface area.

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

Table 3 contains formulas, equations and parameters that were used in determining the Power Flux Density levels for the Boeing Phased Array:

Data Type	Data Symbol	Data Formula	Data Value	Unit of Measure
Power Input	P	Input	42.7	W
Antenna Size	D	Input	0.381	m
Antenna Area	A	$A=\frac{\pi D^2}{4}$	0.1140	m^2
Subreflector Size	Sub	Input	N/A	cm
Subreflector Area	A_{sub}	$A_{sub}=\frac{\pi {D_{Sub}}^2}{4}$	N/A	cm^2
Gain dBi	G_{dbi}	Input	34.9	dBi
Gain Factor	G	$G = 10^{GdBi/10}$	3090.3	Gain Factor
Frequency	f	Input	14250	MHz
Wavelength	λ	$299.79/f$	0.021038	m
Aperture Efficiency	η	$\eta=\frac{G\lambda^2}{4\pi A}$	.95	n/a
Pi	π	Input	3.14159	Numeric
Speed of Light	C	Input	299,792,458	m/sec
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	$mW/cm^2 = \frac{W}{10m^2}$	n/a	n/a

Table 3

1. Far Field Analysis

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

$$R_{ff}=\frac{0.6D^2}{\lambda} = \text{ 4.14 Meters}$$

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: **For the purposes of this report we calculated the range where the occupational**

hazard limit of 5mW/cm² would be reached, thus establishing a keep out range for occupational workers.

$$S_{ff} = \frac{PG}{4\pi R_{ff}^{2}}$$ = 61.267 mW/cm² or at **5mW/cm² R = 14.5 m**

2. Near Field Analysis

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

$$R_{nf} = \frac{D^2}{4\lambda}$$ = 1.72 m

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:

$$S_{nf} = \frac{16\eta P}{\pi D^2}$$ = 143.024 mW/cm²

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.

$$S_t = \frac{S_{nf} R_{nf}}{R}$$

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.

$$S_{surface} = \frac{4P}{A}$$ = 149.812 mW/cm²

Tables 4 and 5 present a summary of the radiation hazard findings on the Boeing Phased Array terminal 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	4.14	61.267 mW/cm^2	Potential Hazard
Near Field	1.72	143.024 mW/cm^2	Potential Hazard
Transition Region	1.72 – 4.14	143.024 mW/cm^2	Potential Hazard
Main Reflector Surface	N/A	149.812 mW/cm^2	Potential Hazard

Table 4

MPE Limits for Occupational/Controlled Area

Area	Range Meters	Power Density (mW/cm^2)	Finding
Far Field	4.14	61.267 mW/cm^2	Potential Hazard
Near Field	1.72	143.024 mW/cm^2	Potential Hazard
Transition Region	5.02 – 12.05	143.024 mW/cm^2	Potential Hazard
Main Reflector Surface	N/A	149.812 mW/cm^2	Potential Hazard

Table 5

5. Summary

This document presents the radiation hazard for the Boeing Broadband System Network incorporating the Boeing Phased Array antenna and the maximum EIRP of 51.2 dBW. The radiation hazard is divided into two cases; General Public and Occupational. The General Public risk is mitigated by the placement of the antenna on the top of the aircraft, which is not accessible to the general public. The Occupational risk will be controlled by turning the system off prior to performing any antenna maintenance, accessing the top of the aircraft near the antenna, or operating personnel lifts or other similar equipment in the vicinity of the antenna hazard zone defined in this report.

This report presents an analysis of the non-ionizing radiation levels for a MELCO antenna system.

The calculations used in this analysis were derived from and comply with the procedures outlined in the Federal Communications 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 aircraft station power flux densities, and to compare those levels to the specified MPE limits.

This report provides predicted density levels in the near field, far field, transition region, and main reflector surface area.

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

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

Data Type	Data Symbol	Data Formula	Data Value	Unit of Measure
Power Input	P	Input	23	W
Antenna Size	D	Input	0.65	m
Antenna Area	A	$A = \frac{\pi D^2}{4}$	0.1274	m^2
Subreflector Size	Sub	Input	N/A	cm
Subreflector Area	A_{sub}	$A_{sub} = \frac{\pi D_{Sub}{}^2}{4}$	N/A	cm^2
Gain dBi	G_{dbi}	Input	33.1	dBi
Gain Factor	G	$G = 10^{GdBi/10}$	2041.74	Gain Factor
Frequency	f	Input	14250	MHz
Wavelength	λ	$299.79 / f$	0.021038	m
Aperture Efficiency	η	$\eta = \frac{G\lambda^2}{4\pi A}$	.56	n/a
Pi	π	Input	3.14159	Numeric
Speed of Light	C	Input	299,792,458	m/sec
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	$mW/cm^2 = \frac{W}{10m^2}$	n/a	n/a

Table 3

1. Far Field Analysis

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

$$R_{ff} = \frac{0.6D^2}{\lambda} = \text{ 12.05 Meters}$$

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:

$$S_{ff} = \frac{PG}{4\pi R_{ff}{}^{2}}$$ = 2.574 mW/cm^2

2. Near Field Analysis

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

$$R_{nf} = \frac{D^2}{4\lambda}$$ = 5.02 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:

$$S_{nf} = \frac{16\eta P}{\pi D^2}$$ = 15.650 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. **For the purposes of this analysis we calculated the transition region range where the occupational hazard limit of 5 mW/cm^2 would be reached, thus establishing a keep out range for occupational workers.**

$$S_t = \frac{S_{nf} R_{nf}}{R}$$ = **5 mW/cm^2 = 10.75 Meters**

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.

$$S_{surface} = \frac{4P}{A}$$ = 72.214 mW/cm^2

Tables 4 and 5 present a summary of the radiation hazard findings on the MELCO terminal 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	12.05	2.574 mW/cm^2	Potential Hazard
Near Field	5.02	15.650 mW/cm^2	Potential Hazard
Transition Region	5.02 – 12.05	15.650 mW/cm^2	Potential Hazard
Main Reflector Surface	N/A	72.214 mW/cm^2	Potential Hazard

Table 4

MPE Limits for Occupational/Controlled Area

Area	*Range Meters*	*Power Density (mW/cm^2)*	*Finding*
Far Field	12.05	2.574 mW/cm^2	Meets FCC Requirement
Near Field	5.02	15.650 mW/cm^2	Potential Hazard
Transition Region	5.02 – 12.05	15.650 mW/cm^2	Potential Hazard
Main Reflector Surface	N/A	72.214 mW/cm^2	Potential Hazard

Table 5

5. Summary

This document presents the radiation hazard for the Boeing Broadband System Network incorporating the MELCO antenna and the maximum EIRP of 46.7 dBW. The radiation hazard is divided into two cases; General Public and Occupational. The General Public risk is mitigated by the placement of the antenna on the top of the aircraft, which is not accessible to the general public. The Occupational risk will be controlled by turning the system off prior to performing any antenna maintenance, accessing the top of the aircraft near the antenna, or operating personnel lifts or other similar equipment in the vicinity of the antenna hazard zone defined in this report.

This report presents an analysis of the non-ionizing radiation levels for a TECOM antenna system.

The calculations used in this analysis were derived from and comply with the procedures outlined in the Federal Communications 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 aircraft station power flux densities, and to compare those levels to the specified MPE limits.

This report provides predicted density levels in the near field, far field, transition region, and main reflector surface area.

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

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

Data Type	Data Symbol	Data Formula	Data Value	Unit of Measure
Power Input	P	Input	17	W
Antenna Size	D	Input	0.65	m
Antenna Area	A	Input	0.1137	m^2
Subreflector Size	Sub	Input	N/A	cm
Subreflector Area	A_{sub}	$A_{sub} = \frac{\pi D_{Sub}^2}{4}$	N/A	cm^2
Gain dBi	G_{dbi}	Input	32.5	dBi
Gain Factor	G	$G = 10^{GdBi/10}$	1778.28	Gain Factor
Frequency	f	Input	14250	MHz
Wavelength	λ	$299.79 / f$	0.021038	m
Aperture Efficiency	η	$\eta = \frac{G\lambda^2}{4\pi A}$	.55	n/a
Pi	π	Input	3.14159	Numeric
Speed of Light	C	Input	299,792,458	m/sec
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	$mW/cm^2 = \frac{W}{10m^2}$	n/a	n/a

Table 3

1. Far Field Analysis

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

$$R_{ff} = \frac{0.6D^2}{\lambda} = 12.05 \text{ Meters}$$

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:

$$S_{ff} = \frac{PG}{4\pi R_{ff}^2} = 1.657 \text{ mW/cm}^2$$

2. Near Field Analysis

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

$$R_{nf} = \frac{D^2}{4\lambda} = \quad 5.02 \text{ Meters}$$

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:

$$S_{nf} = \frac{16\eta P}{\pi D^2} = \quad 11.288 \text{ mW/cm}^2$$

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. **For the purposes of this analysis we calculated the transition region range where the occupational hazard limit of 5 mW/cm^2 would be reached, thus establishing a keep out range for occupational workers.**

$$S_t = \frac{S_{nf} R_{nf}}{R}$$

at **5 mW/cm^2 R = 11.34 m**

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.

$$S_{surface} = \frac{4P}{A} = \quad 59.807 \text{ mW/cm}^2$$

Tables 4 and 5 present a summary of the radiation hazard findings on the TECOM terminal 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	12.05	1.657 mW/cm^2	Potential Hazard
Near Field	5.02	11.288 mW/cm^2	Potential Hazard
Transition Region	5.02 – 12.05	11.288 mW/cm^2	Potential Hazard
Main Reflector Surface	N/A	59.807 mW/cm^2	Potential Hazard

Table 4

MPE Limits for Occupational/Controlled Area

Area	Range Meters	Power Density (mW/cm^2)	Finding
Far Field	12.05	1.657 mW/cm^2	Meets FCC Requirement
Near Field	5.02	11.288 mW/cm^2	Potential Hazard
Transition Region	5.02 – 12.05	11.288 mW/cm^2	Potential Hazard
Main Reflector Surface	N/A	59.807 mW/cm^2	Potential Hazard

Table 5

5. Summary

This document presents the radiation hazard for the Boeing Broadband System Network incorporating the TECOM antenna and the maximum EIRP of 44.8 dBW. The radiation hazard is divided into two cases; General Public and Occupational. The General Public risk is mitigated by the placement of the antenna on the top of the aircraft, which is not accessible to the general public. The Occupational risk will be controlled by turning the system off prior to performing any antenna maintenance, accessing the top of the aircraft near the antenna, or operating personnel lifts or other similar equipment in the vicinity of the antenna hazard zone defined in this report.