Technical Appendix

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Analysis of Non-Ionizing Radiation for a 5.6-Meter Earth Station System

This report analyzes the non-ionizing radiation levels for a 5.6-meter earth station system. The analysis and calculations performed in this report comply with the methods described in the FCC Office of Engineering and Technology Bulletin, No. 65 first published in 1985 and revised in 1997 in Edition 97-01. The radiation safety limits used in the analysis are in conformance with the FCC R&O 96-326. Bulletin No. 65 and the FCC R&O specifies that there are two separate tiers of exposure limits that are dependant 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 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 minutes or less. The purpose of the analysis described in this report is to determine the power flux density levels of the earth station in the far-field, near-field, transition region, between the subreflector or feed and main reflector surface, at the main reflector surface, and between the antenna edge and the ground and to compare these levels to the specified MPEs.

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

Frequency Range (MHz)	Power Density (mW/cm^2)
30-300	0.2
300-1500	Frequency (MHz)*(0.8/1200)
1500-100,000	1.0

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

Frequency Range (MHz)	Power Density (mW/cm^2)
30-300	1.0
300-1500	Frequency (MHz)*(4.0/1200)
1500-100,000	5.0

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

Parameter	Symbol	Formula	Value	Units
Antenna Diameter	D	Input	5.6	m
Antenna Surface Area	$A_{surface}$	$\pi D^2 / 4$	24.63	m^2
Subreflector Diameter	D_{sr}	Input	56.0	cm
Area of Subreflector	A_{sr}	$\pi D_{sr}{}^2/4$	2463.01	cm^2
Frequency	F	Input	14250	MHz
Wavelength	λ	300 / F	0.021053	m
Transmit Power	P	Input	750.00	W
Antenna Gain (dBi)	G_{es}	Input	57.1	dBi
Antenna Gain (factor)	G	$10^{Ges/10}$	512861.4	n/a
Pi	π	Constant	3.1415927	n/a
Antenna Efficiency	η	$G\lambda^2/(\pi^2D^2)$	0.73	n/a

1. Far Field Distance Calculation

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

Distance to the Far Field Region $R_{ff} = 0.60\ D^2 / \lambda$ (1)
$= 893.8$ m

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

On-Axis Power Density in the Far Field $S_{ff} = G\ P / (4\ \pi\ R_{ff}^{\ 2})$ (2)
$= 38.319$ W/m^2
$= 3.832$ mW/cm^2

2. Near Field Calculation

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 diameter as the antenna. Past the boundary of the Near Field region, the power density from the antenna decreases linearly with respect to increasing distance.

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

Extent of the Near Field $R_{nf} = D^2 / (4\ \lambda)$ (3)
$= 372.4$ m

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

Near Field Power Density $S_{nf} = 16.0\ \eta\ P / (\pi\ D^2)$ (4)
$= 89.452$ W/m^2
$= 8.945$ mW/cm^2

3. Transition Region Calculation

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_t can be determined from the following equation:

Transition Region Power Density $S_t = S_{nf}\ R_{nf} / R_t$ (5)
$= 8.945$ mW/cm^2

4. Region between the Main Reflector and the Subreflector

Transmissions from the feed assembly are directed toward the subreflector surface, and are reflected back toward the main reflector. The most common feed assemblies are waveguide flanges, horns or subreflectors. The energy between the subreflector and the reflector surfaces can be calculated by determining the power density at the subreflector surface. This can be determined from the following equation:

Power Density at the Subreflector $S_{sr} = 4000\ P / A_{sr}$ (6)
$= 1218.023\ mW/cm^2$

5. Main Reflector Region

The power density in the main reflector is determined in the same manner as the power density at the subreflector. The area is now the area of the main reflector aperture and can be determined from the following equation:

Power Density at the Main Reflector Surface $S_{surface} = 4\ P / A_{surface}$ (7)
$= 121.802\ W/m^2$
$= 12.180\ mW/cm^2$

6. Region between the Main Reflector and the Ground

Assuming uniform illumination of the reflector surface, the power density between the antenna and the ground can be determined from the following equation:

Power Density between Reflector and Ground $S_g = P / A_{surface}$ (8)
$= 30.451\ W/m^2$
$= 3.045\ mW/cm^2$

7. Summary of Calculations

Table 4. Summary of Expected Radiation levels for Uncontrolled Environment

Region	Calculated Maximum Radiation Power Density Level (mW/cm^2)		Hazard Assessment
1. Far Field (R_{ff} = 893.8 m)	S_{ff}	3.832	Potential Hazard
2. Near Field (R_{nf} = 372.4 m)	S_{nf}	8.945	Potential Hazard
3. Transition Region ($R_{nf} < R_t < R_{ff}$)	S_t	8.945	Potential Hazard
4. Between Main Reflector and Subreflector	S_{sr}	1218.023	Potential Hazard
5. Main Reflector	$S_{surface}$	12.180	Potential Hazard
6. Between Main Reflector and Ground	S_g	3.045	Potential Hazard

Table 5. Summary of Expected Radiation levels for Controlled Environment

Region	Calculated Maximum Radiation Power Density Level (mW/cm^2)		Hazard Assessment
1. Far Field (R_{ff} = 893.8 m)	S_{ff}	3.832	Satisfies FCC MPE
2. Near Field (R_{nf} = 372.4 m)	S_{nf}	8.945	Potential Hazard
3. Transition Region ($R_{nf} < R_t < R_{ff}$)	S_t	8.945	Potential Hazard
4. Between Main Reflector and Subreflector	S_{sr}	1218.023	Potential Hazard
5. Main Reflector	$S_{surface}$	12.180	Potential Hazard
6. Between Main Reflector and Ground	S_g	3.045	Satisfies FCC MPE

It is the applicant's responsibility to ensure that the public and operational personnel are not exposed to harmful levels of radiation.

8. Conclusions

Based upon the above analysis, it is concluded that harmful levels of radiation may exist in those regions noted for the Uncontrolled (Table 4) and Controlled(Table 5) Environments.

The antenna is installed at Speedcast's teleport facility in Miami, Florida. The teleport is a gated and fenced facility with secured access in and around the existing antenna. The earth station is marked with the standard radiation hazard warnings, as well as the area in the vicinity of the earth station to inform those in the general population, who might be working or otherwise present in or near the direct path of the main beam.

The applicant will ensure that the main beam of the antenna will be pointed at least one diameter away from any building, or other obstacles in those areas that exceed the MPE levels. Since one diameter removed from the center of the main beam the levels are down at least 20 dB, or by a factor of 100, these potential hazards do not exist for either the public, or for earth station personnel.

Finally, the earth station's operating personnel will not have access to areas that exceed the MPE levels, while the earth station is in operation. The transmitter will be turned off during periods of maintenance, so that the MPE standard of 5.0 mw/cm**2 will be complied with for those regions in close proximity to the main reflector, which could be occupied by operating personnel.

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.*

RADIATION HAZARD STUDY

When applying for a license to construct and operate, modify, or renew an earth station, it is understood that licensees must certify whether grant of the application will have significant environmental impact as defined in the Federal Communications Commission's (FCC) rules, 47 C.F.R., Section 1.1307.

In this report Speedcast Communications, Inc. analyzes the maximum radiofrequency (RF) levels emitted from the satellite communications antenna described below. The reference document for this study is OET Bulletin No. 65, Edition 97-01, *Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields*, August 1997.

I. Antenna Near-Field Power Density Calculation

The extent of the near-field is defined by the following equation:

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

where:
R_{near} = extent of the near-field (in meters)
D_{ant} = diameter of the antenna main reflector (in meters)
λ = wavelength of the RF transmit frequency (in meters)

The maximum on-axis power density within near-field is defined by the following equation:

$$S_{near} = \{(16\eta P_{feed}) / [\pi(D_{ant})^2]\} / 10$$

where:
S_{near} = maximum on-axis power density within the near-field (in milliwatts per square centimeter)
η = antenna aperature efficiency
P_{feed} = maximum power into antenna feed flange (in watts)
D_{ant} = diameter of the antenna main reflector (in meters)

II. Antenna Far-Field Power Density Calculation

The distance to the beginning of the far-field region is defined by the following equation:

$$R_{far} = [0.6(D_{ant})^2] / \lambda$$

where:
R_{far} = distance to beginning of far-field (in meters)
D_{ant} = diameter of the antenna main reflector (in meters)
λ = wavelength of the RF transmit frequency in (meters)

The maximum on-axis power density within the far-field is defined by the following equation:

$$S_{far} = [(P_{feed}\ G_{ant}) / 4\pi(R_{far})^2] / 10$$

where:

S_{far} = maximum on-axis power density in the far-field (in milliwatts per square centimeter)
P_{feed} = maximum power into antenna feed flange (in watts)
G_{ant} = antenna main beam gain at RF transmit frequency (in watts)
R_{far} = distance to beginning of far-field (in meters)

III. Antenna Transition Region Power Density Calculation

By definition, the maximum on-axis power densitiy in the transition region will never be greater than the maximum on-axis power densities in the near-field:

$$S_{tr} \leq S_{near}$$

where:

S_{tr} = maximum on-axis power density in the transition region (in milliwatts per square centimeter)
S_{near} = maximum on-axis power density in the near-field (in milliwatts per square centimeter)

IV. Antenna Feed-Flange (or Subreflector) Power Density Calculation

The maximum power density at the antenna feed-flange (or subreflector surface) is defined by the following equation:

$$S_{feed(sub)} = 1000\ \{[2(P_{feed})] / \{[\pi(D_{feed(sub)})^2\ ] / 4\}\}$$

where:

$S_{feed(sub)}$ = maximum power density at the antenna feed-flange or subreflector surface (in milliwatts per square centimeter)
P_{feed} = maximum power into antenna feed flange (in watts)
$D_{feed(sub)}$ = diameter of the antenna feed-flange or subreflector (in centimeters)

V. Antenna Main Reflector Power Density Calculation

The maximum power density in the main reflector region of the antenna is defined by the following equation:

$$S_{ant} = \{[2(P_{feed})] / \{[\pi(D_{ant})^2\ ] / 4\}\} / 10$$

where:

S_{ant} = maximum power density in the antenna main reflector region (in milliwatts per square centimeter)
P_{feed} = maximum power into antenna feed flange (in watts)
D_{ant} = diameter of the antenna main reflector (in meters)

VI. Power Density Calculation between the Antenna Main Reflector and the Ground

The maximum power density between the antenna main reflector and the ground is defined by the following equation:

$$S_{ground} = \{P_{feed} / \{[\pi(D_{ant})^2] / 4\}\} / 10$$

where: S_{ground} = maximum power density between the antenna main reflector and the ground (in milliwatts per square centimeter)
P_{feed} = maximum power into antenna feed flange (in watts)
D_{ant} = diameter of the antenna main reflector (in meters)

VII. Summary of Calculated Radiation Levels

Speedcast Communications, Inc. understands the licensee must ensure people are not exposed to harmful levels of radiation.

Maximum permissible exposure (MPE) limits for general population/uncontrolled exposure were not considered in this analysis for several reasons. The main-beam orientation and height above ground of this highly directional antenna significantly limit exposure to the general population. Furthermore, access Speedcast station is limited to authorized personnel who have been appropriately briefed and advised.

MPE limits for occupational/controlled exposure, however, were considered in this analysis. It is standard practice for our technical staff to cease transmissions whenever maintenance is performed in close proximity to antenna reflector regions with potentially hazardous power density levels. Based on the results (see next page entitled "Radiation Hazard Calculations") and our standard practices within our controlled antenna environment, the earth station operators / technicians should not be exposed to radiation levels exceeding 5 mW/cm^2 power density over a six minute averaging time.

Antenna main reflector diameter	6.1	m
Feed flange (or subreflector) diameter	55.9	cm
RF transmit frequency	14.000	GHz
Maximum power into antenna feed-flange	660.00	W
Main-beam gain of antenna (at RF transmit frequency)	57.3	dBi
	538269.8	W
Antenna aperature efficiency	0.55	
Antenna main reflector surface area	29.22	m^2
Feed flange (or subreflector) surface area	2452.46	cm^2
Wavelength of the RF transmit frequency	0.021	m
Distance to beginning of far-field region	1042.58	m
Distance to extent of near-field region	434.41	m

Max. on-axis power density [far-field]	**2.60**	**mW/cm^2**	**SATISFIES MPE LIMITS**
Max. on-axis power density [near-field]	**4.97**	**mW/cm^2**	**SATISFIES MPE LIMITS**
Max. on-axis power density [transition region]	**4.97**	**mW/cm^2**	**SATISFIES MPE LIMITS**
Max. power density [feed-flange or subreflector]	**538.23**	**mW/cm^2**	**POTENTIAL HAZARD**
Max. power density [main reflector region]	**4.52**	**mW/cm^2**	**SATISFIES MPE LIMITS**
Max. power density [between main reflector and ground]	**2.26**	**mW/cm^2**	**SATISFIES MPE LIMITS**