SpaceQuest, Ltd.
Earth Station License Application

Technical Appendix

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I. Radiation Hazard Study

UHF Yagi

This study analyzes the non-ionizing radiation levels for a 400 MHz Yagi tracking earth station. This report is 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.

Bulletin No. 65 specifies that there are two separate tiers of exposure limits that are depending on the area of exposure and/or the status of the individuals who are subject to the exposure -- the General Population/Uncontrolled Environment and the Controlled Environment, where the general population cannot access.

The maximum level of non-ionizing radiation to which individuals may be exposed is limited to a power density level of 1.33 milliwatts per square centimeter (1.33 mW/ cm^2) averaged over any 6 minute period in a controlled environment, and the maximum level of non-ionizing radiation to which the general public is exposed is limited to a power density level of 0.27 milliwatt per square centimeter (0.27 mW/cm^2) averaged over any 30 minute period in a uncontrolled environment.

In the normal range of transmit powers for satellite antennas, the power densities at or around the antenna surface are expected to exceed safe levels. The purpose of this study is to determine the power flux density levels for the earth station under study as compared with the MPE limits. This comparison is done in each of the following regions:

1. Far-field region
2. Near-field region
3. Transition region
4. The region between the antenna edge and the ground

Input Parameters

The following input parameters were used in the calculations:

Parameters:	Value	Unit	Symbol
Antenna Diameter	3.57	m	*D*
Antenna Transmit Gain	16.2	dBi	*G*
Transmit Frequency	400	MHz	*f*
Power Input to the Antenna	12.53	W	*P*

Calculated Parameters:

The following values were calculated using the above input parameters and the corresponding formulas:

Parameter	Value	Unit	Symbol	Formula
Antenna Surface Area	1.964	m^2	*A*	$G\lambda 2/(4\pi)/\lambda$
Antenna Efficiency	0.95		η	$G\lambda^2/(\pi^2D^2)$
Gain Factor	41.7		*g*	$10^{G/10}$
Wavelength	0.75	m	λ	$300/f$

Behavior of EM Fields as a Function of Distance

The behavior of the characteristics of EM fields varies depending on the distance from the radiating antenna. These characteristics are analyzed in three primary regions: the near-field region, the far-field region and the transition region. Of interest also is the region between the antenna and ground.

For yagi antennas with circular cross sections, such as the antenna under study, the near-field, far-field and transition region distances are calculated as follows:

Parameter	Value	Unit	Formula
Near-Field Distance	4.25	m	$R_{nf} = D^2/(4\lambda)$
Distance to Far-Field	10.2	m	$R_{ff} = 0.60D^2/(\lambda)$
Distance of Transition Region	4.25	m	$R_t = R_{nf}$

The distance in the transition region is between the near and far fields. Thus, $R_{nf} \leq R_t \leq R_{ff}$. However, the power density in the transition region will not exceed the power density in the near-field. Therefore, for purposes of the present analysis, the distance of the transition region can equate the distance to the near-field.

Power Flux Density Calculations

The power flux density is considered to be at a maximum through the entire length of the near-field. This region is contained within a cylindrical volume with a diameter, D, equal to the diameter of the antenna. In the transition region and the far-field, the power density decreases inversely with the square of the distance. The following equations are used to calculate power density in these regions.

Parameter	Value	Unit	Symbol	Formula
Power Density in the Near-Field	2.42	mW/cm^2	S_{nf}	$16.0\,\eta\,P/(\pi D^2)$
Power Density in the Far-Field	0.04	mW/cm^2	S_{ff}	$GP/(4\pi\,Rff^2)$
Power Density in the Transition Region	2.42	mW/cm^2	S_t	$S_{nf}\,R_{nf}/(R_t)$

The power density between the antenna and ground, is calculated as follows:

Parameter	Value	Unit	Symbol	Formula
Power Density b/w Reflector and Ground	0.64	mW/cm^2	S_g	P/A

The below table summarizes the calculated power flux density values for each region. In a controlled environment, the only regions that exceed FCC limitations are shown below. These regions are only accessible by trained technicians who, as a matter of procedure, turn off transmit power before performing any work in these areas.

Power Density	Value	Unit	Controlled Environment
Far Field Calculation	0.04	mW/cm^2	Satisfies FCC MPE
Near Field Calculation	2.42	mW/cm^2	Exceeds Limits
Transition Region	2.42	mW/cm^2	Exceeds Limits
Region b/w Antenna & Ground	0.64	mW/cm^2	Satisfies FCC MPE

The results show that the antenna, in a controlled environment, may exist in the regions noted above and applicant will take the proper mitigation procedures to ensure it meets the guidelines specified in 47 C.F.R. § 1.1310.

The earth station will be marked with the standard radiation hazard warnings, as well as the area in the vicinity of the earth station to inform any residents or guests who might be working or otherwise present in or near the path of the main beam. The earth station will be installed on private property and inaccessible to the general public. In addition, because power levels are down at least 20 dB (or by a factor of 100) one diameter removed away from the center of the main beam, public safety will be ensured by minimum elevation angles that result in upward pointing towards the satellite and away from inhabited areas.

Finally, because there is no potential for public access to the earth station site (on private property), the General Population/Uncontrolled Environment limits are not implicated. Furthermore, only operations and maintenance personnel will have access to areas that may potentially exceed the MPE limits and they will do so only while the earth station is not in operation. The transmitter will be turned off during periods of maintenance so that the Controlled Environment MPE standard will be satisfied.

II. Radiation Hazard Report

VHF Yagi

This report analyzes the non-ionizing radiation levels for a 3.02-meter Yagi antenna earth station system. The analysis and calculations performed in this report comply with the methods described in the FCC Office of Engineering and Technology's General RF Exposure Guidance, 447498 D01 v05r02. The radiation safety limits used in the analysis are in conformance with Title 47 Chapter I, Sub-chapter 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 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, 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)
0.3 - 1.34	100
1.34 - 30	180/Frequency(MHz)^2
30-300	0.2
300-1500	Frequency(MHz)/1500
1500-100,000	1

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

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

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

Parameter	Symbol	Formula	Value	Units
Ant Largest Dimension	D	Input	3.02	m
Frequency	F	Input	145.8	MHz
Wavelength	λ	$300/F$	2.06	m
Transmit Power	P	Input	25	W
Antenna Gain (dBi)	G_{es}	Input	12.34	dBi
Antenna Gain (factor)	G	$10^{G_{es}/10}$	17.14	n/a
Pi	π	Constant	3.141592654	n/a
Antenna Efficiency (Ideal)	η	Input	0.73	n/a
Ant Equiv Surface Area	$A_{Surface}$	$G\lambda^2/(4\pi\ \ )$	5.77	m^2

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)

$= 2.66\ \mathrm{m}$

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 $S_{ff} = GP/(4\pi R_{ff}{}^2)$ (2)

$= 4.82\ \mathrm{W/m^2}$

$= 0.482\ \mathrm{mW/cm^2}$

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 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.

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)

$= 1.12\ \mathrm{m}$

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

Near Field Power Density $S_{nf} = 4\eta P/A_{surface}$ (4)

$= 12.65\ \mathrm{W/m^2} =$
$1.265\ \mathrm{mW/cm^2}$

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 2 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:

Transition Region Power Density $S_{tz} = S_{nf}R_{nf}/R_{tz}$ (5)

$= 1.265\ \mathrm{mW/cm^2}$

R_{tz} is calculated at a distance of 1.12 meters from the antenna, which is the worst-case distance. This is the edge of the near-field, R_{nf}.

4. Region between the Antenna and the Ground

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

Power Density between Antenna and Ground $S_g = P/A_{surface}$ (6)

$$= 4.33\ \mathrm{W/m^2}$$
$$= 0.433\ \mathrm{mW/cm^2}$$

5. 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
Far Field (R_{ff} =2.66 m)	S_{ff}	0.482	Potential Hazard
Near Field (R_{nf} = 1.12 m)	S_{nf}	1.265	Potential Hazard
Transition Region ($R_{nf} < R_{tz} < R_{ff}$)	S_{tz}	1.265	Potential Hazard
Between Reflector and Ground	S_g	0.433	Potential Hazard

Table 5. Summary of Expected Radiation Levels for Controlled Environment

Region	Calculated Maximum Radiation Power Density Level (mW/cm^2		Hazard Assessment
Far Field (R_{ff} = 8.36 m)	S_{ff}	0.482	Satisfies FCC MPE
Near Field (R_{nf} = 3.48 m)	S_{nf}	1.265	Potential Hazard
Transition Region ($R_{nf} < R_{tz} < R_{ff}$)	S_{tz}	1.265	Potential Hazard
Between Reflector and Ground	S_g	0.433	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.

6. Conclusions

Based upon the above analysis, it is concluded that FCC RF Guidelines have been exceeded in the Far and Near Field, the Transition Zone, and the region between the Antenna and the Ground of the Uncontrolled (Table 4) environment. In the Controlled (Table 5) environments the near field and transition regions have levels that exceed the FCC RF Guidelines. The applicant proposes to comply with the Maximum Permissible Exposure (MPE) limits of 0.2 mW/cm^2 for the Uncontrolled Areas, and the MPE limits of 1 mW/cm^2 for the Controlled Areas.

The earth station Yagi antenna will be mounted on a secure facility roof; so the applicant agrees that the antenna will be in an area secured from the public and worker personnel not familiar with the earth station system. Non-assigned worker personnel and the general public must be accompanied by knowledgeable earth station personnel when they enter the earth station secured area. To ensure safe operation and eliminate transmission exposure, no personnel shall have access to the near field of the antenna when it is tasked for tracking or transmission.

The earth station's secured area will be marked with the required radiation hazard signs as described in the recent FCC R&O 13-39. The area in the vicinity of the earth station secured area will also have signs to inform those in the general population and those who may be working in the area or otherwise present that they are close to a RF System capable of producing hazardous levels.

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.*

III. Ownership, Directors, and Officers

The applicant, SpaceQuest, Ltd. is a Virginia corporation of which the principal place of business is 3554 Chain Bridge Road, Suite 400, Fairfax, VA 22030-2709.

The following individuals serve as officers and directors of SpaceQuest and can be contacted through the address listed above:

Name	Title	Nationality
Dino A. Lorenzini	CEO	U.S.A.

The names, addresses, and citizenship of stockholders of record directly or indirectly owning and/or voting 10 percent or more of SpaceQuest voting stock are:

Name	Nationality	Address	Ownership
AAC Clyde Space AB	Sweden	Uppsala Science Park Dag Hammarskjölds väg 48 Uppsal, SE-751 83 Sweden	100%

Dino A. Lorenzini, along with his wife, hold 16.3% of AAC Clyde Space AB. No other individuals or entities directly or indirectly hold a 10 percent or greater ownership or voting interest in SpaceQuest.