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Engineering Notes

ENGINEERING NOTES are short manuscripts describing new developments or important results of a preliminary nature. These Notes cannot exceed 6 manuscript pages and 3 figures; a page of text may be substituted for a figure and vice versa. After informal review by the editors, they may be published within a few months of the date of receipt. Style requirements are the same as for regular contributions (see inside back cover).

International Space Station Electromagnetic Environment

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Introduction

ELECTROMAGNETIC environment analysis is important in space vehicle subsystem design and operation. Murphy and Cutler[1] analyzed Space Shuttle flight experiment data for determining the electromagnetic fields produced by the S- and Ku-band antennas. There are concerns about the levels of electric field strength radiated by the international space station (ISS) communication and tracking systems transmitters. Users of the ISS who are designing scientific experiment payloads need to know the levels of electromagnetic fields in the space station environment. Astronauts are required to assemble and maintain the space station. To ensure astronaut safety and mission success, the electromagnetic fields produced by the various transmitters need to be quantified.

The purpose of this study is to quantify and to present the electric field strengths radiated by the space station transmitting antennas (Fig. 1) using well-developed and readily available techniques. All antenna locations given in the following sections are in meters and are referenced to the origin of the ISS coordinate system. The antenna models used in the field computations were validated by measured far-field antenna radiation patterns.

Low-Gain Antennas

The space station has uhf and S-band low-gain transmitting antennas. Both the uhf and S-band antennas are fractional-turn resonant quadrifilar helices. A computer tool based on the method of moments (MoM) technique was used for the low-gain antenna analyses.[2] The space station structures, which are in the far-field range of the antenna, are not included in the field computations. The uhf and S-band helical antenna models used in the MoM field computations were validated by the anechoic-chamber-measured, far-field uhf and S-band antenna radiation patterns.

The uhf antenna transmit frequency is 417.5 MHz. There are four uhf antennas on the space station. The two antennas radiated in the $+X$-axis direction are located at (6.31, 3.42, 7.84) m and (2.2, −12.59, −3.32) m referenced to the ISS coordinate system. The two antennas radiated in the $-X$-axis direction are located at (4.91, 3.42, 7.84) m and (0.7, −12.59, −3.32) m. The uhf radio has the capability to transmit at two power levels. The high-power mode is for the communication between the ISS and Space Shuttle. The low-power mode is for the communication between the ISS and astronauts. The nominal transmitted power at the uhf radio output, including losses of the circulator, hybrid/splitter, cavity bandpass filter, is 6.3 W at the high-power mode.[3] The minimum cable loss calculated at the minimum operation temperature of −73.3°C is 2.5 dB for the uhf antennas mounted on the lab module. The antenna peak gain is 5 dB. Based on the 6.3-W transmitted power and 2.5-dB cable loss, the electric fields around the uhf antenna were computed. Figure 2 shows the contour curves of electric fields (volts per meter) produced by the uhf antenna. The rf exposure limit for the extravehicular mobility unit (EMU) on the space suit at the uhf frequency is 60 V/m. The keep-out zone, in which the electric fields are greater than the maximum permitted 60-V/m exposure level, for the EMU electronics is approximately a cylindrical region of 0.7 m in diameter and 0.6 m in length, extending forward from the antenna.

The S-band antenna transmit frequency is 2.265 GHz and is radiated in the $+X$-axis direction. There are three antenna locations at (−2.0, 0.09, −13.66) m, (0.8, 8.14, −3.59) m, and (0.8, −9.19, −3.59) m. The antenna peak gain is 3.5 dB. The maximum transmitted power referenced at the power amplifier output is 40 W. The nominal cable loss between the power amplifier output and antenna is 1 dB at the minimum operation temperature.[3] Figure 3 shows the electric fields (volts per meter) produced by the S-band low-gain antenna. The rf exposure limit for the EMU electronics at the S-band frequency is 106 V/m. The keep-out zone, in which the electric fields are greater than the maximum permitted 106-V/m exposure level, is approximately a cylindrical region of 0.9 m in diameter and 0.7 m in length, extending forward from the antenna.

High-Gain Antennas

The space station has S-band and Ku-band high-gain transmitting antennas. The S-band antenna is a conical horn with a 33-cm-diam aperture, and the Ku-band antenna is a reflector with a 1.83-m-diam aperture. Both the S-band and Ku-band high-gain antennas track the tracking data and relay satellite system in a field-of-view region

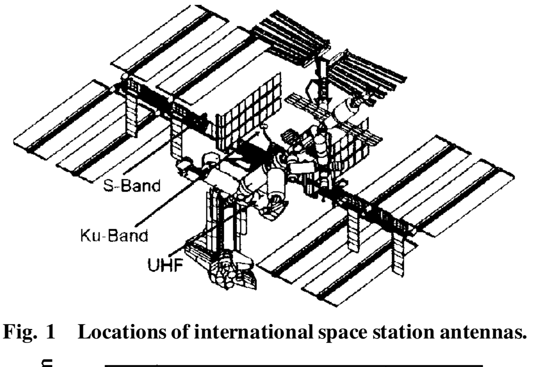

Fig. 1 Locations of international space station antennas.

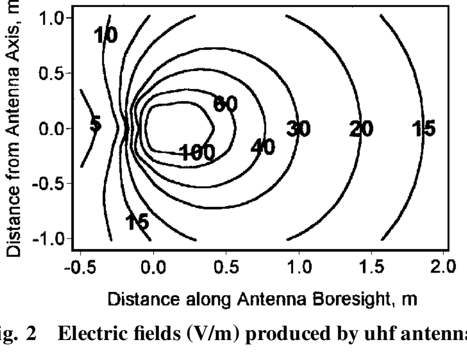

Fig. 2 Electric fields (V/m) produced by uhf antenna.

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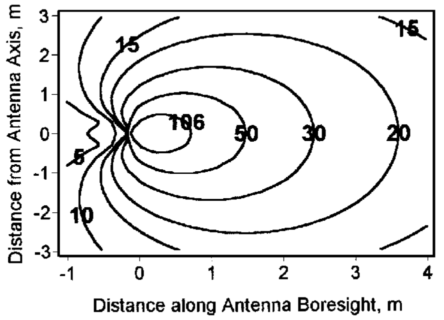

Fig. 3 Electric fields (V/m) produced by S-band low-gain antenna.

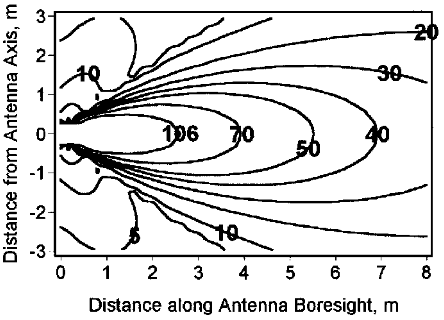

Fig. 4 Electric fields (V/m) produced by S-band high-gain antenna.

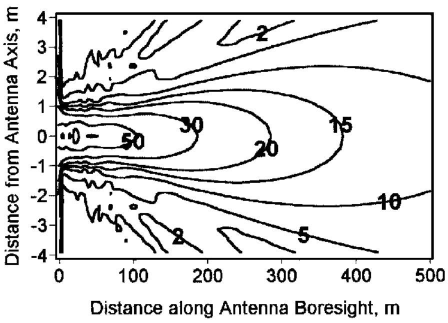

Fig. 5 Electric fields (V/m) produced by Ku-band antenna.

of $-120 \le \theta \le 120$ deg and $-60 \le \phi \le 60$ deg. The S-band antenna transmit frequency is 2.265 GHz, and the antennas are located at (−2.53, 0.09, −14.26) m, (0.26, 8.14, −4.19) m, and (0.26, −9.19, −4.19) m referenced to the ISS coordinate system. The peak gain is 16 dB. The maximum transmitted power referenced at the power amplifier output is 40 W. The nominal cable loss between the power amplifier output and antenna is 1 dB at the minimum operation temperature.[3] The aperture integration technique was used to compute the electric fields for this antenna.[4] The conical horn antenna model was validated by measured far-field S-band antenna radiation patterns.

Figure 4 shows the electric fields (volts per meter) produced by the S-band high-gain antenna. The radiated energy is spread mostly within a cone region. The keep-out zone, in which the electric fields are greater than the maximum permitted 106-V/m exposure level, for the EMU electronics is approximately a cylindrical region of 1 m in diameter and 2.6 m in length, extending forward from the antenna.

The Ku-band antenna transmit frequency is 15 GHz and is located at (−4.81, −4.17, −3.56) m in the ISS coordinate system. The peak gain is 48.4 dB. The maximum transmitted power referenced at the power amplifier output is 10 W. The nominal cable loss is 1 dB at the minimum operation temperature.[3] In the field computations for the Ku-band reflector antenna, the geometrical theory of diffraction (GTD) is used.[5] The GTD-computed field intensities were validated by the anechoic-chamber-measured, far-field Ku-band antenna radiation patterns.

Figure 5 shows the electric fields (volts per meter) produced by the Ku-band high-gain antenna. For a range distance less than 100 m from the aperture, the radiated energy is mainly confined within the aperture projected cylinder. The alternate electric field peaks and valleys of the Fresnel zone phenomenon are observed in close range distances less than 40 m. The rf exposure limit for the EMU electronics at the Ku-band frequency is 20 V/m. The keep-out zone, in which the electric fields are greater than the maximum permitted 20-V/m exposure level, is approximately a cylindrical region of 2.4 m in diameter and 290 m in length, extending forward from the antenna.

Conclusions

The electric fields around the various space station transmitting antennas are computed and presented. This information is important in assessing personnel and electronic equipment rf exposure hazards and is useful for the users of the space station who are designing scientific experiment payloads to be operated in the space station environment. As an example, the keep-out zones in which the electric fields exceed the specified maximum permitted rf exposure to the EMU electronics on the space suit were determined. Similarly, keep-out zones for other equipment can be determined using information presented in this Note.

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Efficient Approach for International Space Station Global Positioning System Multipath Analysis

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Introduction

THE international space station (ISS) is very large in terms of physical and electrical size and is a very complex space vehicle, as shown in Fig. 1. The solar panels and thermal radiators are rotated dynamically to maintain preferential orientation with respect to the sun. The Global Positioning System (GPS) antennas have to track the GPS satellites in a wide-field-of-view region and will encounter multipath interference from the ISS structures. Multipath is an important error source for attitude determination.[1,2]

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