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SPACE STATION INTERNAL PROPAGATION

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I. Introduction

The Space Station Freedom (SSF) is planned with a wireless communication system in place for the transmission of information between crew members on board. The clarity of transmission is paramount to an effective system of communication. This report contains a short overview of the system including the requirements of interest, and a statement of the problem that was concentrated upon. The theory used to solve the problem is explored. The results given are for the experiments performed on a mockup of the proposed structure at the Marshall Space Flight Center.

The requirements on the signal level are that there is a 45 dB signal to noise ratio (SNR) from end to end, and that coverage over 99% of the volume be maintained. It is this last, 99% requirement that is addressed in the report.

II. Theory

The SSF wireless unit is operated inside a large cavity or waveguide that causes reflections. Because the number of modes is very large, it is not easily modeled using modal techniques. It is also filled with equipment that will increase the reflections. This is a formidable problem.

The point of attack will be to randomly sample the field strength inside the volume and estimate a probability distribution function (pdf) for the field strengths inside. Once a pdf is found, the requirement that 99% of the volume be covered can be re-designed and verified. The method for finding the 99% point shall be to find the location that insures that 99% of the area under the pdf is to the left. This is the power level obtained. The system power can be scaled to provide a 45 dB SNR.

The Rice-Nakagami or Rice distribution is a simple extension of the Rayleigh distribution where there is a significant line-of-sight path from the transmitter to the receiver (1). The line-of-sight path is a coherent component to the statistical distribution of the field strength inside the volume. For SSF, this distribution will correspond to the summation of a coherent line-of-sight path between the transmitter and the receiver and an incoherent portion. The incoherent portion is the sum of reflections from the walls and the equipment inside of the SSF. The distribution is given by:

$$p_R(A) = \frac{A}{\sigma_s^2} e^{-\left(\frac{A^2 + A_0^2}{2\sigma_s^2}\right)} I_0\left(\frac{A_0 A}{\sigma_s^2}\right) \quad [1]$$

where σ_s^2 is the variance (the subscript s is to differentiate this with the Rayleigh variance), A_0 is the strength of the coherent component, I_0 is the modified Bessel function of the first kind of order 0, and the subscript R on the pdf name is to denote a Rice distribution.

The Rice distribution, $p_R(A)$, has two estimated parameters to fit the data. The variance describes the spread of amplitudes similar to the Rayleigh variance. The value A_0 is proportional to the field strength of the line-of-sight component. It is important to note in passing that this distribution is ideal in cases of transmission over a rough surface.

The χ^2 test (2) has been used with much success to obtain the Rice distribution. A simple search routine was implemented to find the appropriate pdf parameters.

IV. Results

The experiments are detailed in (3,4). The experiments were performed on a 43 foot mockup with a diameter of 14 feet that was filled with demonstration equipment, and an empty mockup of the same diameter that was empty. The values of the parameters for each test were found and tabulated. A typical distribution with the Rice fit is shown in figure 1.

Conclusions reached from the results of the two tests are the shown in figure 2. The A_0 value is relatively independent of frequency. This was expected. The variance found should decrease slightly as the frequency increases. The results are ambiguous within this small frequency range. The average value of A_0 at 450 MHz was found to be 9.6 and the average variance was 18.2. If we compare the experiment 1 results (12.6 and 18.9), we see that the variance is much lower in the empty 27 foot mockup. It is believed the major contributor to this drop is the absence of the randomly placed scatterers in the second experiment.

V. Conclusions

The Rice pdf has been found to be the optimal distribution from theoretical and experimental results. This can been demonstrated quite convincingly.

VI. References

(1) Beckmann, P., and A. Spizzichino, The Scattering of Electromagnetic Waves from Rough Surfaces, Norwood, MA: Artech House, 1987.

(2) Guttman, I., et al, Introductory Engineering Statistics, 3rd Ed., New York: John Wiley, 1982, pp. 174-176.

(3) Bell, J.L., "Space Station Propagation Tests", internal memo, Lab. EB33, MSFC, Huntsville AL, Feb. 7, 1991.

(4) Bell, J.L., "Space Station Propagation Tests", internal memo, Lab. EB33, MSFC, Huntsville, AL, July 30, 1991.

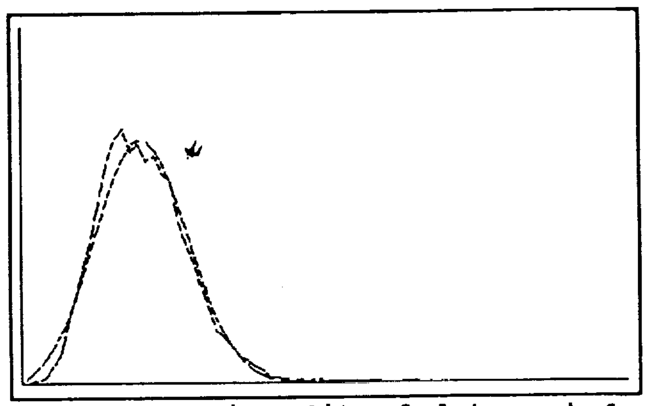

Figure 1. Rice fit of data set 1, experiment 1.

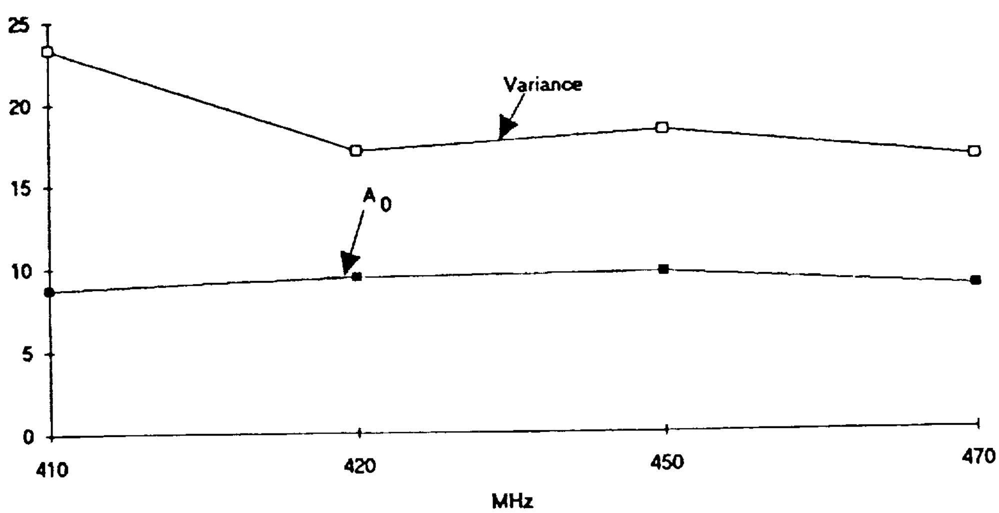

Figure 2. A_0, σ_s^2 vs. frequency over averaged test cases.