1992

NASA/ASEE SUMMER FACULTY FELLOWSHIP PROGRAM

MARSHALL SPACE FLIGHT CENTER
THE UNIVERSITY OF ALABAMA

ANALYSIS OF WAVES IN SPACE PLASMA (WISP) NEAR FIELD SIMULATION AND EXPERIMENT

Prepared By:	James E. Richie, Ph.D.
Academic Rank:	Assistant Professor
Instution and Department:	Marquette University Department of Electrical and Computer Engineering
NASA/MSFC:	
Office:	Information and Electronic Systems Laboratory
Division:	Computers and Communications
Branch:	Communication Systems
MSFC Colleagues:	David P. Harris Hubert Gangl

The WISP payload scheduled for a 1995 space transportation system (shuttle flight) will include a large power transmitter on board at a wide range of frequencies. The levels of electromagnetic interference/electromagnetic compatibility (EMI/EMC) must be addressed to insure the safety of the shuttle crew. This report is concerned with the simulation and experimental verification of EMI/EMC for the WISP payload in the shuttle cargo bay. The simulations have been carried out using the method of moments for both thin wires and patches to simulate closed solids (2). Data obtained from simulation is compared with experimental results. An investigation of the accuracy of the modeling approach is also included.

The report begins with a description of the WISP experiment (4). A description of the model used to simulate the cargo bay follows. The results of the simulation are compared to experimental data on the input impedance of the WISP antenna with the cargo bay present. A discussion of the methods used to verify the accuracy of the model is shown to illustrate appropriate methods for obtaining this information. Finally, suggestions for future work are provided.

The WISP Experiment: EMI/EMC Issues

The specifics of the experiment that concern this investigation are as follows. First, a number of antenna lengths will be deployed: 5, 15, and 50 meters. Second, a frequency range from 100 KHz to 30 MHz will be transmitted in both a continuous wave and a pulsed fashion. Finally, the power transmitted will reach a maximum of 500 W (only in pulsed mode). These are the range of values that must be addressed to fully understand the near field strengths present at various components inside the cargo bay. A payload safety specification has not been written for these low frequencies; however, it is expected that 4 V/m will be chosen.

Cargo Bay Model

The cargo bay is modeled as a single, fully enclosed metallic object with infinite conductivity. The model is shown in figure 1. The model was broken into 5 inside panels, 5 outside panels, and a square O ring on the top to close the structure. The thickness of the box, α, is a paramater of the model. Each of the two sets of 5 panels is broken into 5 regions, as shown in figure 2. This was done to allow for a finer sampling of the current near the edges of the model. The value of γ is also a parameter called the corner dimension of the model and will be discussed later. Each of the 5 regions on each of the 5 panels on each of the two sets of open-box surfaces was then broken into rectangular patches that are inputs to the method of moments code NEC (1).

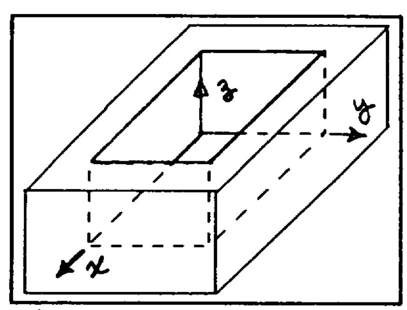

Figure 1

The model was constructed using guidelines concerning the total area of a patch and the aspect ratio of the rectangular patches. The aspect ratio of a single patch is defined to be the ratio of the large dimension divided by the small dimension. In summary, a shuttle cargo bay model has been developed that has four parameters: the thickness, the corner dimension, the maximum patch area, and the maximum aspect ratio.

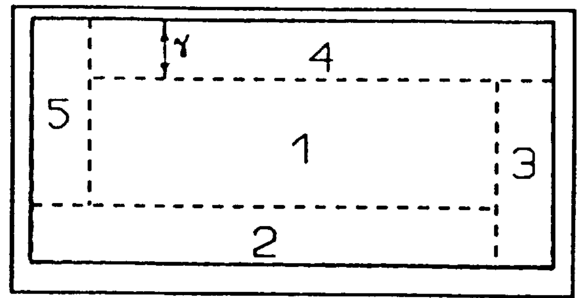

Figure 2

The corner dimension is a parameter of the model that recognizes the fact that the current must be sampled at a higher rate (or density) when compared with the center of a flat plate. This dimension allows the sections 2 through 5 to be broken into finer patches than section 1. Each of the five sections shown in figure 2 will be evenly broken into rectangular patches by specifying the number of patches in the length and the width of the section. Use of the corner dimension as a parameter allows the area near a corner and far from a corner to be different. This will help keep the number of patches (or unknowns) as low as practical.

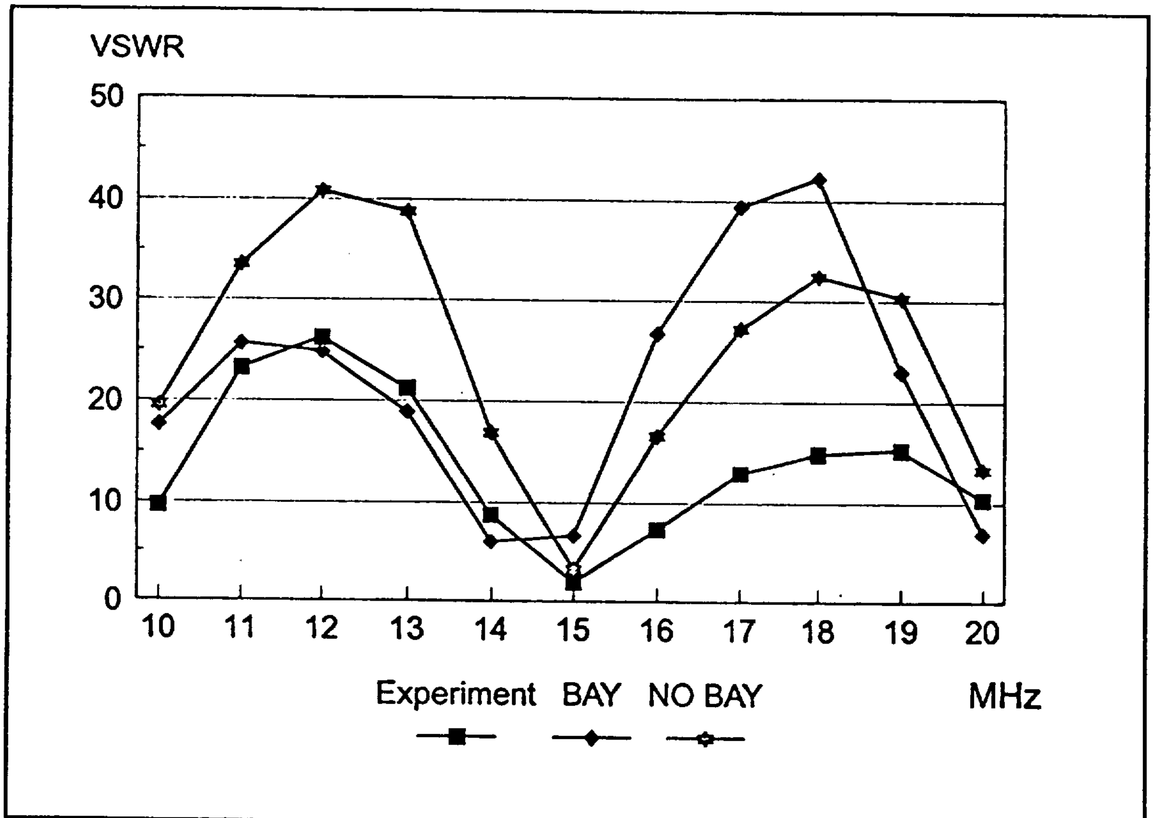

Figure 3

Results

Initial measurements necessary to continue the experiment are to find the antenna impedance and voltage standing wave ratio (VSWR) relative to 50 Ω. The VSWR is necessary to find the actual power that is emitted by the antenna. In the laboratory, a balun is used to convert from the unbalanced coaxial line to the balanced requirement of a dipole antenna. The impedance of the balun and the antenna in parallel can be found, and the impedance of the balun can be found alone using a network analyzer. The VSWR of the antenna can then be found by removing the effect of the balun from the impedance data. This has been accomplished for the case of a 50 meter WISP dipole at a set of frequencies ranging from 10 to 20 MHz, in steps of 1 MHz. A plot of the VSWR for the experiment and the NEC model is shown in figure 3. This graph also shows the VSWR for a 50 m antenna in free space to illustrate the effect of the cargo bay.

The simulation appears to accurately model the physical situation at the lower frequency end. Recall that the frequency range of operation is from 100 KHz to 30 MHz and the figure shows results only from 10 to 20 MHz. It is believed that the model would also be suitable at frequencies lower than 10 MHz. As the frequency increases in figure 3, it is apparent that the model is not adequate. A further refinement for the higher frequencies is necessary for accurate modeling of the effect of the cargo bay. These results also are consistent with similar codes (3).

Accuracy of the Model

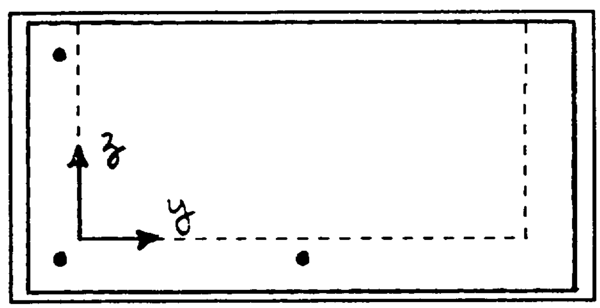

Figure 4

The hope of any numerical modeling procedure is that it accurately reflect what occurs in the laboratory. More often, however, it is found that a model is only partially acceptable. To quantify the accuracy of any electromagnetic model, it is appropriate to measure the degree that the boundary conditions have been satisfied. In this work, three lines parallel to the x axis inside the model have been used, as shown in figure 4. The electric and magnetic fields inside any metal box should be zero. Therefore, by requesting the field points inside the box, one can calculate the mean squared error inside the box and use this single number to measure how effectively the boundary conditions have been satisfied. Results for a particular model are given in table 1.

Model Parameters				Mean Squared Errors (Total)			
α	γ	Area(max)	Aspect Ratio (max)	30 MHz	20 MHz	10 MHz	No. Unknowns
1 m	1 m	$0.01\ \lambda^2$	1.33	0.154	0.473	0.572	733

Suggestions for Future Work

The extent that the method of moments and in particular the NEC code can model the cargo bay of the space shuttle for the WISP experiment has been investigated. It appears that careful choice of model parameters such as wall thickness, corner dimension, area and aspect ratio will lead to an appropriate model.

The model that accurately reflects the desired characteristics has not been found. The following suggestions for future work have been developed:

1. The NEC model should, of course be compared to other techniques of similar origin.

2. Comparison with near field data would more likely be within the range of the numerical models. It is generally true that the input impedance of an antenna is strongly dependent on higher order effects.

3. A modification of the NEC code could be performed that incorporates a more accurate patch model. This would not only cause the solutions to be more precise, but may significantly reduce the number of degrees of freedom necessary to solve.

Acknowledgment

The author would like to thank the EB33 team for their help and patience over the previous two summers. The many discussions on this and other topics have been very beneficial and greatly appreciated.

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