Determination of Transmission Coefficients from Finite Planar Composites Using Spatial Averaging

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Introduction

The transmission measurement through composite planar panels is important for the characterization of materials and for certain radome applications [1]. For design purposes it is important to have very accurate measurements that can be compared to predictions. In addition, it can enable the extraction of the electrical properties including the dielectric constant and/or the sheet impedance of a panel of material. Difficulties can arises for these comparisons due to errors incorporated during the experimental process. These errors range from effects due to scattering from the edges of a finite panel, scattering between the panel and the probe antenna and scattering due to items within the experimentation room. To improve the accuracy of the measurements, a technique is implemented which utilizes spatial averaging of the acquired data.

Similar techniques for antenna pattern measurements based on amplitude only [2], amplitude and phase [3] and for RCS [4] are well known. Usually, these methods are implemented using cross range samples. In this case for transmission and reflection coefficient measurements, down range spatial sampling has been utilized [5]. The goal of this paper is to determine useful guidelines for this method by analytically studying the mechanisms involved. Numerical data for this study comes from two electromagnetic codes: NEC-BSC [6] and ESP [7]. The NEC-Basic Scattering Code (NEC-BSC) is based on UTD. The Electromagnetic Surface Patch Code (ESP) is a moment method code. These codes are both used to determine the coupling between antennas with and without a dielectric planar panel between them.

Theoretical Approach

A technique to determine the transmission through a finite material planar panel is presented. The geometry is illustrated in Figure 1. The panel consists of a finite dielectric slab of relative permittivity of 2 and permeability of 1. It has dimensions along the x-axis of 3 wavelengths, y-axis of 3 wavelengths, and thickness along the z-axis of 0.1 wavelengths. The receiving antenna is moved from the dielectric slab panel at z equals 0 meters to 5 meters away from the panel. The transmitting antenna is 2 meters on the opposite side. Both, ESP and NEC-BSC, are used to obtain the two-port scattering parameter, S_{21}, between the two antennas with and without the panel. S_{21} represents all the fields traveling from port 2 to port 1. This includes the main beam through the panel as well as the scattering due to edges of the panel, scattering between the antenna and the panel, and could include scattering with objects potentially surrounding the setup. Since transmission through the composite planar panel is the only desired value for this

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purpose, the other scattered fields produce errors in the experimental data. Therefore it is advantageous to remove these errors from the data.

The fields are first normalized by using $\tau = S_{21,Panel} / S_{21,No\ Panel}$ where $S_{12,\text{Panel}}$ represents the S-parameter through the panel. $S_{12,\text{No Panel}}$ is the S-parameter without the panel. The theoretical value for the transmission coefficient for the infinite planar panel is calculated using standard method to be -0.3156 dB. Figure 2 represents the normalized data obtained from ESP and NEC-BSC using the above equation. It should be noted that the data for from the ESP and NEC-BSC codes agree about one wavelength away from the slab. In this vicinity, the deviation from the theoretical infinite plane solution is due to the diffraction from the finite panel edges. Since the NEC-BSC treats the antenna current distribution as being fixed relative to its position away from the panel and ESP does not, it is clear that their differences for positions closer to one wavelength are also due to antenna panel interactions. In addition, it should be noted that the total phase varies a little more than a 0.1 radian.

In the case of determining transmission coefficients, it is very difficult to hide the finite edges so that these fields will not affect the experiment. Other techniques such as using absorbers to try to cancel the panel's edges fail due to a large forward scatter shadow boundary. The spatial averaging technique on the other hand uses the fact that the direct path between the antennas will not vary much in phase, while the diffracted fields will. The set-up for the spatial averaging technique begins with two half-wave dipoles with sinusoidal current distribution on either side of the composite planar panel. By moving the receiving antenna in a straight line from the panel, multiple measurements of S_{21} at different spatial distances can be made for a single frequency. This data is normalized and then averaged over this range for each frequency, thereby averaging out the errors from the edges and potentially other scattering obstacles in the room. This leaves only the transmission coefficient for an infinite panel. The spatial averaging works because of the phase variation of the edge scattering waves. Since the receiver antenna is moving, the diffracted fields due to the four edges alternate between being in phase and out of phase with each other. If the end points of the spatial averaging are chosen correctly, the diffraction due to the edges will average out to zero leaving only the main beam. Figure 3 shows only the normalized diffracted fields calculated by NEC-BSC.

In Figure 3 it can be seen that the starting point for the spatial averaging should begin at 0.1245 meters and the ending point should be 4.23 meters to have a complete cycle of 2pi radians. By choosing these endpoints, the transmission coefficient after averaging for ESP is -0.3241 dB and NEC-BSC is -0.3643 dB. These values have very good agreement with the theoretical solution. Therefore the spatial averaging does a nice job of removing errors due to scattering from the edges of the panel and scattering due to interaction between the panel and the receiving antenna. Details about the number of samples needed and starting and ending points will be discussed in the presentation.

Conclusions

Spatial averaging is used in conjunction with the normalized data to remove errors in acquiring transmission coefficients from finite material panels. This is illustrated by data obtained from a UTD code, NEC-BSC, and a MM code, ESP. The errors from the scattering from the edges of the panel and scattering between the receiving antenna and the panel are effectively removed with this technique. The minimum size of the panel needed as well as the necessary starting, ending and number of samples points will be discussed.

References

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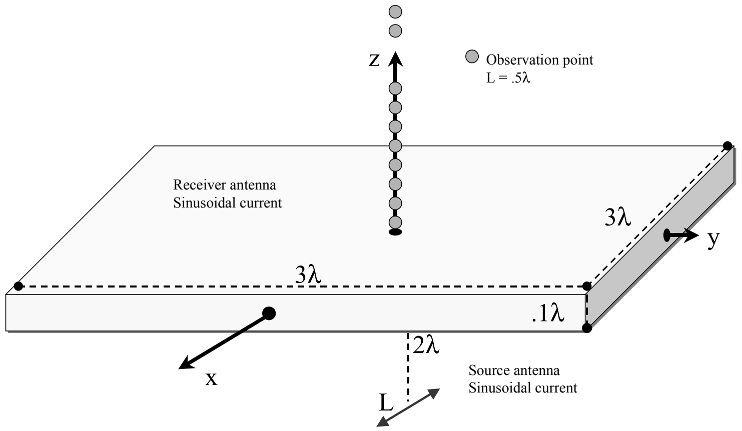

Figure 1. Geometry of a Dielectric Panel for Spatial Averaging

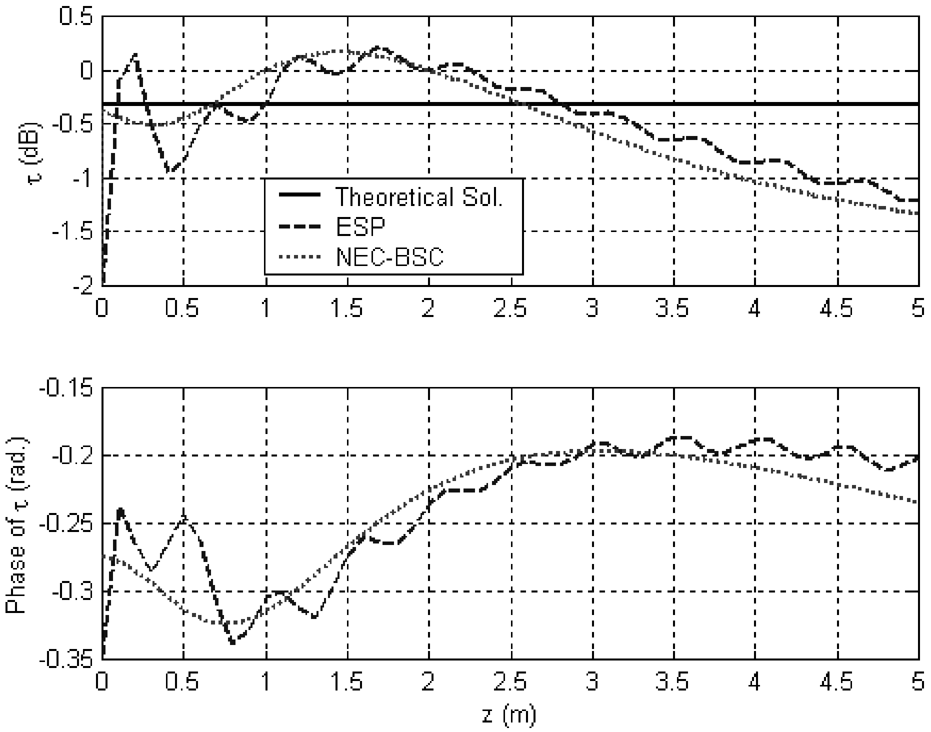

Figure 2. Transmission Coefficient for Spatial Averaging of Dielectric Panel

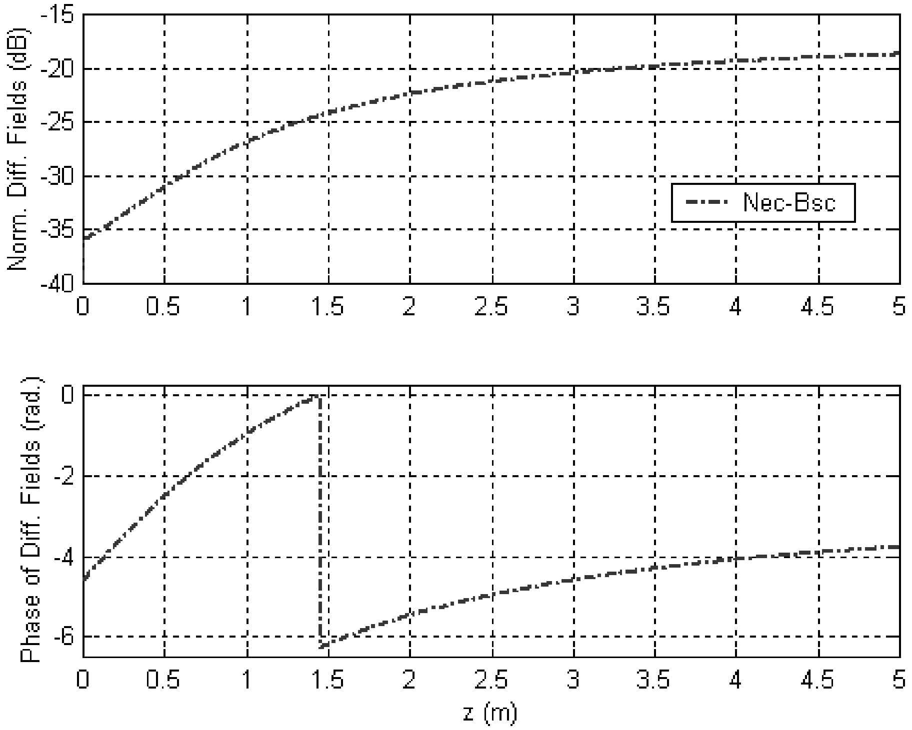

Figure 3. Normalized Diffracted Fields from Panel's Edges