Electromagnetic Response from a Two-Dimensional Array of Conducting Strips Inter-Connected with Columns of Silver-Coated Micron-Sized Particles

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***Abstract*—Controlling the propagation of electromagnetic (EM) waves through a dielectric medium has applications in antenna miniaturization and beam-forming. One method of controlling EM propagation is to use a two-dimensional array of conducting strips printed on one side of a dielectric layer. The work presented in this paper demonstrates a new way to implement these conducting strips. More specifically, conducting micron-sized particles are embedded into the design of the conducting strips and are used to control the EM response of the overall host dielectric. This control occurs through the response of the particles to a magneto-static field. When a field is applied, the particles within a dielectric cavity form columns in the direction of the field lines. Since the particles are conducting, this results in conducting columns that connect various conducting strips. The advantage of using these particles is that a directly connected biasing circuit is not required and allows for the placement of these particles in very complex geometries. Finally, theory and simulations are shown to agree and validate the overall results.**

***Index Terms*—Scattering, Propagation**

I. INTRODUCTION

Controlling the electromagnetic (EM) wave propagation through various dielectric materials has been studied extensively [1]-[2] in the past. Much of this foundational work was theoretically rigorous and usually assumed a fixed structure. One method that was developed to control the EM propagation of a host dielectric medium was to print a two-dimensional array of conducting strips on one of the planar surfaces [1]. This technique then led to the study of many different shapes of printed conductors and for improving the performance of various antenna geometries using frequency selective structures (FSS) [3]. Though much of this earlier work uses fixed conductors to control propagation. This paper presents an alternative to controlling the EM propagation through a dielectric layer using embedded micron-sized particles, as shown in Figs. 1 and 2. The topology consists of conducting strips on both the top and bottom surfaces of a t thick dielectric layer. Then, if a propagating EM wave is incident on the top surface (i.e., propagating in the -z-direction), the conducting strips mainly interact with the x-component. Therefore, one method to control the propagation is to change the x-dimensions of the conducting strips on both the top and bottom layers.

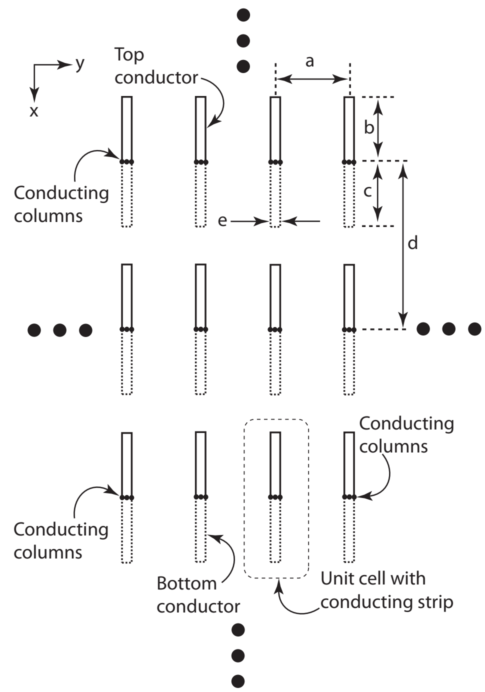

Fig. 1. An illustration of the two-dimensional array of conducting strips with embedded conducting particles.

II. FUNCTIONALITY

This paper illustrates the use of the micron-sized particles in Fig. 2 as a method of changing the lengths of the conducting strips. Initially, to implement these particles, a cylindrical cavity between points A and B in Fig. 2 is defined and several micron-sized particles are placed into this cavity. Then, to manipulate the particles, a magneto-static field is applied and the particles form columns in the directions of the field lines, as shown in Fig. 2. Therefore, if the field is applied in the z-direction the two conducting plates on the top and bottom layers can be connected to change the EM response of the overall host dielectric.

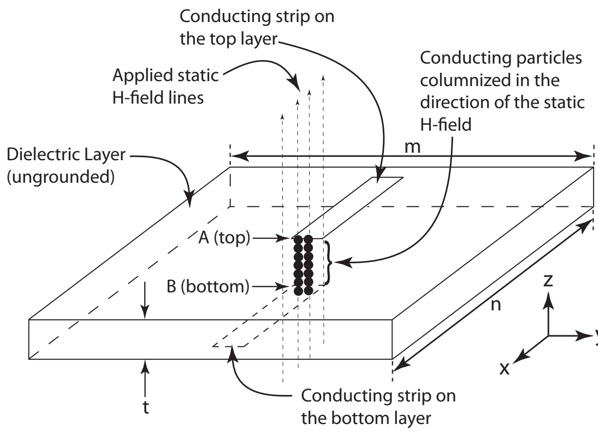

Fig. 2. A drawing of the individual unit cell shown in Fig. 1 (a = 5.0 mm, b = 5.0 mm, c = 5.0 mm, d = 15.0 mm, e = 1.0 mm, m = 5.0 mm, n = 5.0 mm and t = 1.54 mm).

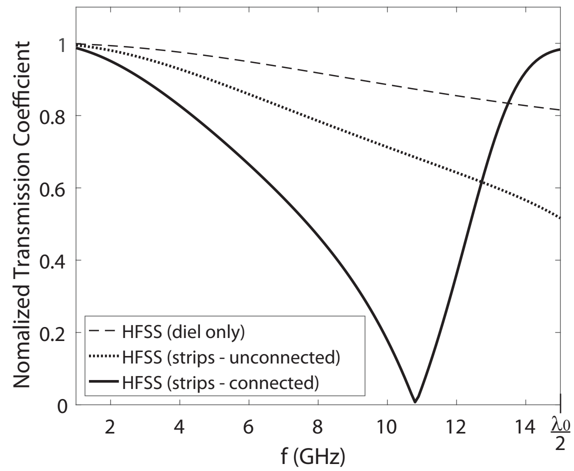

Fig. 3. Transmission through the dielectric layer with the conducting strips.

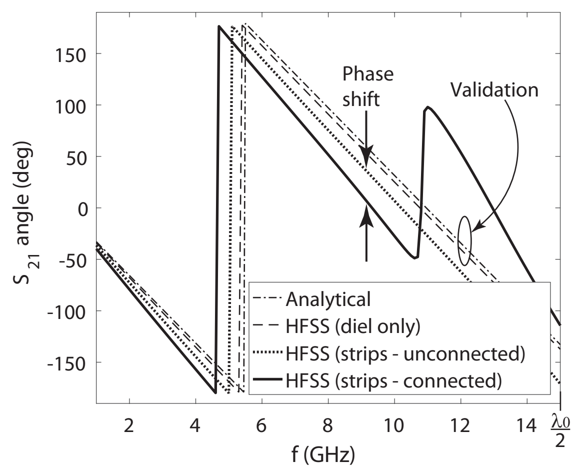

Fig. 4. Angle of the propagating wave through the dielectric layer with the conducting strips.

III. THEORETICAL AND SIMULATION RESULTS

The response of the two-dimensional array shown in Fig. 1 was modeled in HFSS [5]. The particles chosen for this work were manufactured by Potters Industries [4] and are silver coated with a magnetite core. The size of the particles vary from 10 to 40 microns. Though, to reduce simulation time it has been shown in [6] that conducting cylindrical columns with a radius of 20 microns can be used to model the columns formed by the micron-sized particles. Furthermore, to reduce computation time, the unit cell in Fig. 1 was modeled using periodic boundary conditions and Floque ports in HFSS. This resulted in the dimensions shown in Fig. 2. Finally, the dielectric chosen for the simulations was a t = 1.54 mm thick TMM4 (ε_r = 4.5 and $\tan\delta$ = 0.0009) substrate manufactured by Rogers Corporation [7].

The simulated transmission coefficients and phase of an EM wave propagating through the array is shown in Figs. 3 and 4, respectively. Furthermore, for analytical validation the phase introduced by the dielectric layer on the propagating EM wave is shown in Fig. 4. Similarly, the overall length of the conducting strips is 10 mm (top and bottom). This results in a free-space half-wavelength at 15 GHz. This point is also shown in Figs. 3 and 4, and is denoted at $\lambda_0/2$. Because the conducting strips are dielectrically loaded, the transmission coefficient and phase change should be below this point, as illustrated in [1].

IV. CONCLUSION

A method to control the EM properties of a host dielectric with a printed two-dimensional array of conducting strips was presented here. This included the used of conducting micron-sized particles with a magnetite core that respond to magneto-static fields by forming columns in the directions of the field lines. It was shown that the length of the conducting strips could be changed by embedding cavities with these particles into the host dielectric between the conducting strips. For validation, simulations were compared to theoretical wave propagation equations and published half-wavelength resonant computations.

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