Tailoring the dielectric properties of Meta Materials

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***Abstract*—This paper presents the experimental investigations on the effect of metallic inclusions on a dielectric substrate for tailoring the properties of meta material. Dielectric properties of samples are measured with different metallic inclusions and the results are compared with and without inclusions. The designs of several samples leading to negative permittivity are presented along with their experimental results.**

I. INTRODUCTION

Recently, much attention has been given the materials with negative permittivity and permeability. It is well known that the most basic phenomena in electromagnetism are reflection, refraction and diffraction of waves. The refraction causes the angle of propagation at the interface between two media to alter, which depends on the indices of refraction of the two materials. All naturally occurring materials exhibit positive indices of refraction and the complex numbers of their electrical properties account for the wave dissipation.

Metamaterials are artificially made materials with electromagnetic properties different from that of its constituents, often leading to negative permittivity and permeability. These materials also possess negative refractive indices.

The theoretical possibility of negative permittivity is reported by inclusion of broken ring resonators [1], electric dipoles and small loop antennas [2], chiral inclusions [4-5]. The highly dispersive nature of the ring resonators near the resonance shows the opposite nature of the direction of phase velocity and the Poynting vector [1]. The study presented by Tretyakov [2] shows that real wideband negative permittivity is possible by loading with planar conducting wires or loaded with active circuits. In this paper, we present the experimental implementation of the negative dielectric materials using metallic inclusions like spirals, strips and wires inside a dielectric sample.

II. PREPARATION OF THE SAMPLE

Samples were made on materials with different dielectric constants. Figure 1 shows the schematic layout of the spirals sample made on RO3010 dielectric material from Rogers Corporation.

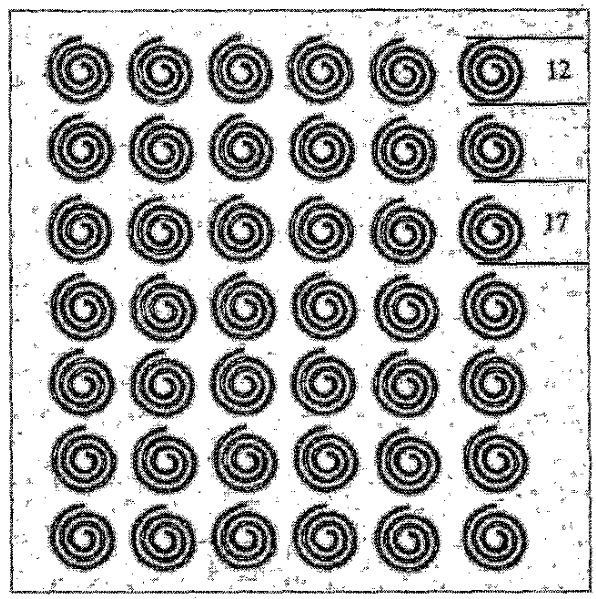

Figure 1. Schematic diagram of the spiral sample.

Thin metallic spirals of dimension 13 mm and width 1 mm are etched on the dielectric sheet with a period of 17 mm. The electrical properties were measured and compared for different samples with and without the spirals. Measurements were also repeated for samples with periodic metallic strips shown in figure 2. Samples were also made using thin wires with 20 μ diameter, fixed inside a Plexiglas sheet.

III. EXPERIMENTAL RESULTS

A. Measurement Setup

Measurements were carried out using free space spot focused antenna system [5]. The spot focusing horn lens system is a combination of two equal plano-convex dielectric lenses mounted back to back in a conical antenna. At the focal point, the electromagnetic wave has the properties of plane wave. Since the antenna dimensions determine the width and depth of the focus,

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the accuracy in evaluation of permittivity from the experimental values is determined by the design of an optimum focused beam at the focal plane. The measured focal length of the antenna is 30.5 cm with a spot size of 4.37cm x 3.2 cm at 9.1 GHz. The focused plane wave beam from the horn lens antenna system is incident on the sample positioned at the common focal plane of the two antennas. Using HP 8510C Network Analyzer, it could be possible to measure dielectric properties of the samples from 8 to 40 GHz. Free space TRL calibration along with time domain gating was used for accurate measurements.

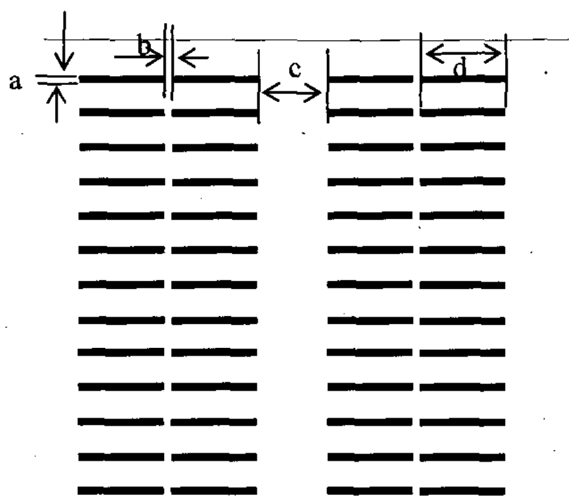

Figure 2. Schematic diagram of the sample 2

B. Spiral Metamaterials

Samples were made with periodic spiral strips etched on RO 3010 substrate from Rogers Corporation, as shown in figure 1. The sample is kept at the focus of the antenna system and S_{11} and S_{21} were measured. Figure 3 shows the measured results of the dielectric sheet with and without spirals.

C. Samples with thin metallic strips and thin wires

Samples were also made with thin metallic strips on a Teflon sheet of thickness 0.1 mm. with different dimensions are shown in Table I. Similarly samples were also prepared with thin metallic wires of diameter 20 μ, embedded in a Plexiglas sheet of thickness 3.3 mm

Fig. 4 (a) presents the measured results of a plane Teflon sheet of thickness 0.1 mm in X-band. Metallic strips of different dimensions are then periodically arranged on it and the effective dielectric properties of the samples are then measured. The dimensions of various metal strip configurations are tabulated in Table I. Figure 4 (b) presents the measured dielectric constant of these samples.

Table I. Metal strip dimensions

No	a (mm)	b (mm)	c (mm)	d (mm)
2	2	2	20	25
4	4	3	17	24
5	2	0	0	130

Figure 5 presents the measured results of the Plexiglas with and without metallic inclusions. Thin wires of 20 μ diameter with a spacing of 3 mm are embedded inside the Plexiglas (MM-1). It can be seen from these measurements that the real part of the permittivity is approaching negative values at lower frequencies. From these measurements, it can be concluded that desired permittivity tuning is possible using the metallic inclusions inside a dielectric medium

V. Conclusion

Preliminary results of the measurement on the dielectric tuning of meta materials are presented in this paper. Thin metallic inclusions inside a dielectric material can change its electrical properties and by varying the dimensions of inclusions like spirals and wires, the effective electrical properties can be controlled. Smart dielectric layers with negative dielectric properties can be easily realized using metallic inclusions.

References

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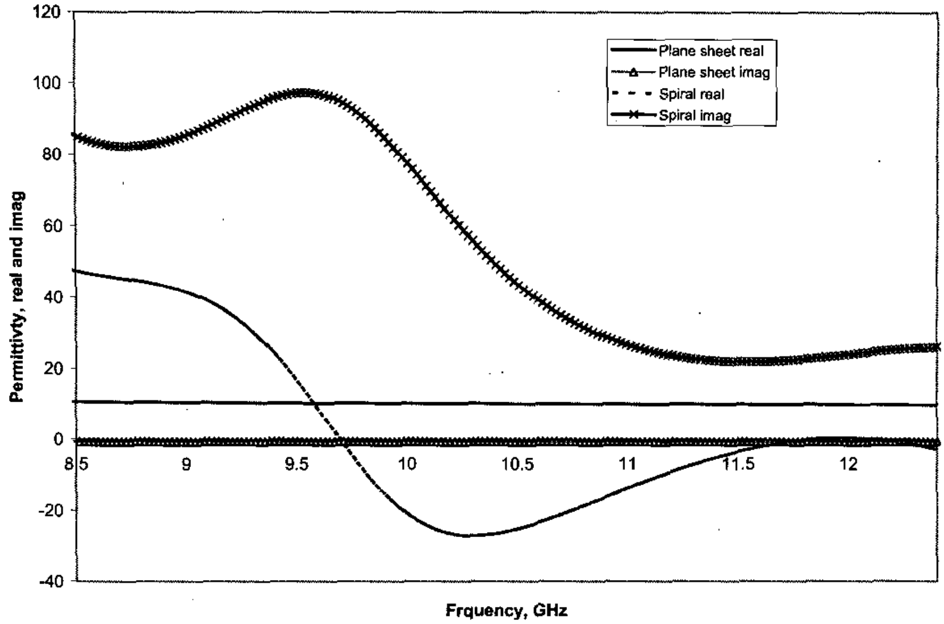

Fig. 3 Measured electrical properties of sample shown in figure 1. The sample is made on RO3010 dielectric substrate and the results are also shown for a plane sample of thickness 0.1 mm

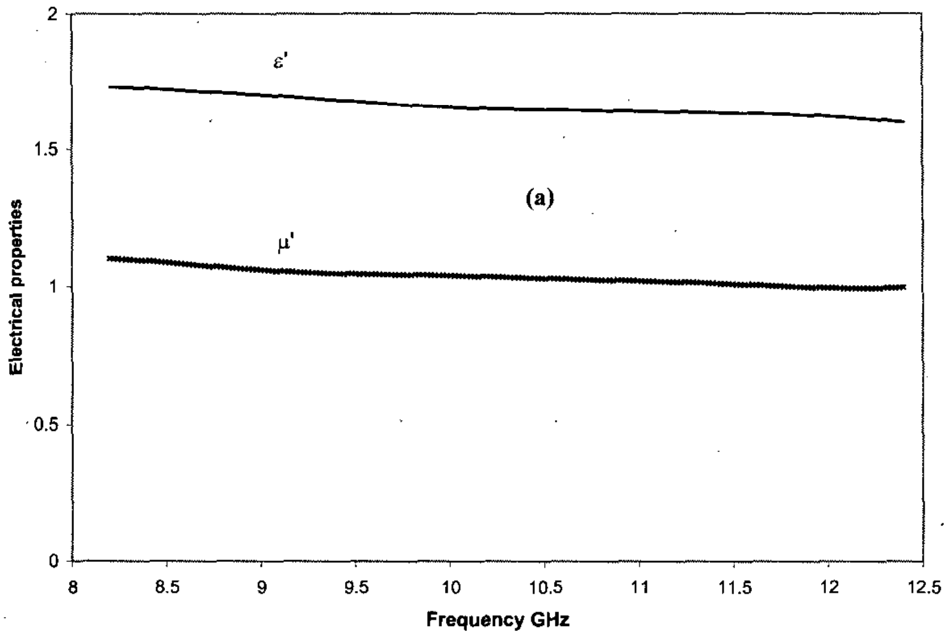

Figure 4 (a). Measured real part of the permittivity and permeability of a sheet of Teflon (t=0.1 mm)

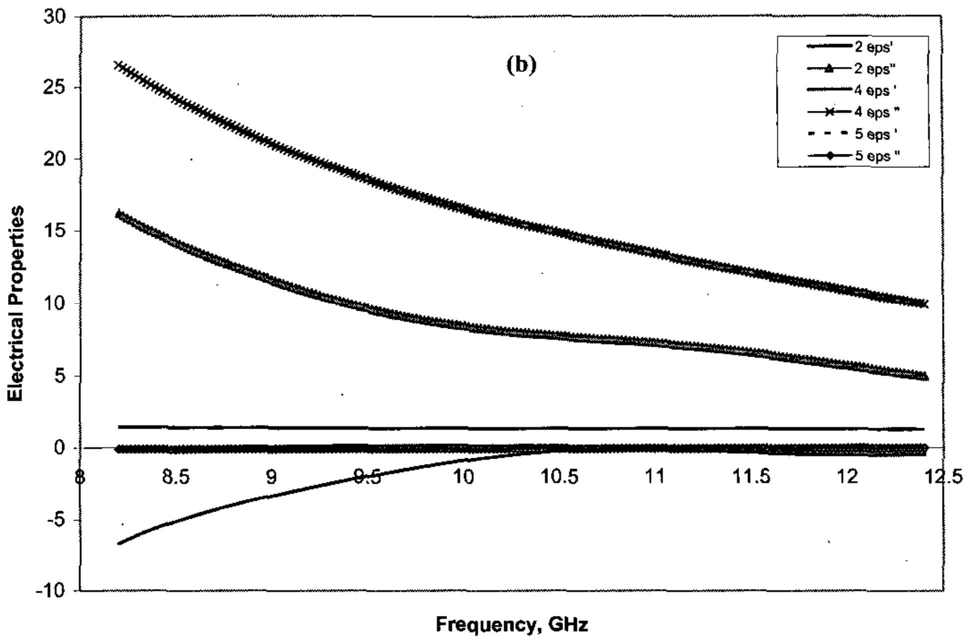

Figure 4 (b). Measured electrical properties of samples as shown in Table I.

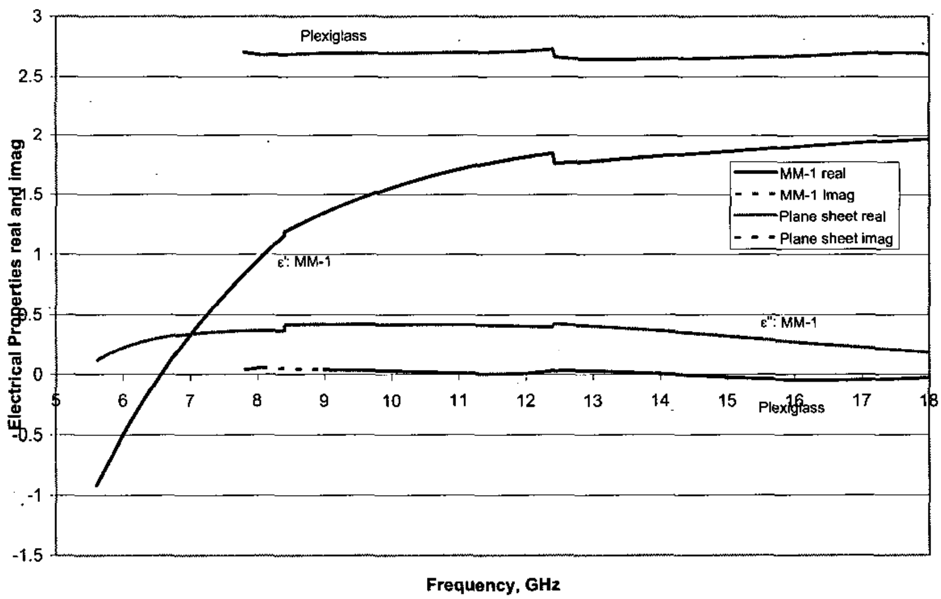

Figure 5. Measured dielectric properties of Plexiglas sheet embedded with thin wires (MM-1)and a plane sheet