Circular Patch Antenna Inspired by the Use of Two Metamaterial Substrate Layers

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Performance optimization has been achieved for a circular patch antenna filled with two metamaterial layers. The first layer of metamaterial is obtained through complementary split-ring resonators patterned on the ground plane and the second metamaterial layer is patterned by small crossed strips located between two thin layers of the substrate. The proposed new model features three resonant frequencies and is observed an increased gain in the device. The results are provided by a commercial electromagnetic solver. The new model showed better efficiency when compared to a similar antenna composed with a metamaterial superstrate.

Index Terms— **Circular Patch, Metamaterial Substrate, Microstrip Patch Antenna, Parameters Optimization.**

I. INTRODUCTION

Microstrip patch antennas are one of the most commonly antennas used in practical applications due to its simple structure, easy integration into electronic circuits, low cost and ominidirectional radiation patterns [1], [2]. Metamaterials have been used in a variety of researches concerning various applications, as in antennas, in order to improve their performance [3], [4] and allow the development of more compact antennas [5].

In [3] a patch antenna was designed with a complementary split ring resonator (CSRR) array in the ground plane and the analysis of this antenna's parameters was done. In addition, another analysis with a different geometry including a metamaterial superstrate was conducted. New resonant frequencies were then generated and an improvement in the parameters values were obtained.

The objective of this study is to investigate the performance of a circular patch antenna with a dual-layer metamaterial, where each layer has a different structure. The first layer is located in the ground plane, and the second metamaterial layer is embedded in the substrate. Those two metamaterial structures are responsible for generating negative permeability and permittivity values [6]. Through modeling and simulations in CST 2014 software, optimizations of the new patch antenna are projected.

II. GEOMETRY OF THE PROPOSED ANTENNA

A microstrip circular patch antenna with two layers of metamaterial substrate is proposed in this paper. Fig. 1 shows the geometry of the proposed antenna. Fig.1(a) shows the circular patch antenna. Fig.1(b) shows the first metamaterial layer, the ground plane with CSRR array. Fig.1(c) shows the second layer of metamaterial. This layer is composed of small crossed strips located above the CSRRS's ground plane.

Between each of the metamaterial structures and the patch element, there is a layer of FR4 of 0.8 mm thick. Based on a FR4 of 1.6 mm, two FR4 layers are conceived with half the thickness each. Inserted between these media are the metamaterial structures, shown in Fig.1(c).

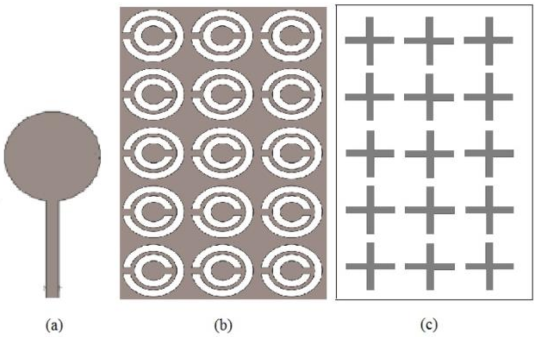

Fig. 1. Circular patch antenna geometry and two metamaterial structures.

The metamaterial layer inserted between the two FR4 media generates a medium with negative permittivity [6] and [7]; through this an optimization of the antenna is expected.

The structures of metamaterials considered in this article were modeled based on structures found in [8], where formulations regarding negative index media are presented. In [8] appears plasmonic type frequencies functions that describe the negative index effect for the permeability and permittivity.

III. RESULTS

Based on studies on antennas and concepts involving metamaterials, a simulation of a circular patch antenna with microstrip metamaterial substrate was developed. This new antenna designed with two layers of different metamaterial structures presented resonant frequencies equivalent to a CSRR grounded plane antenna [3], but with optimized values for the frequency 2.09 GHz. The resonant frequencies are 1.37 GHz, 2.09 GHz and 2.34 GHz. In Fig.2 it is seen the S11 parameters of the antenna.

The antenna had an impedance of 40.8 Ohms for all resonant frequencies.

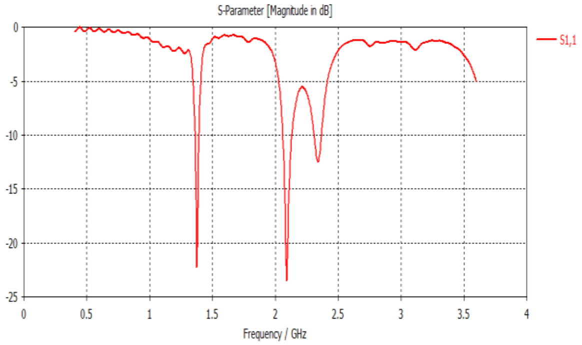

Fig. 2. Parameter S11 of the circular patch antenna with dual-layer metamaterial.

A comparison between the circular patch antenna with a single CSRR ground plane and the proposed dual layer metamaterial one is made in this paper. Figs. 3 and 4 show the efficiencies, radiation efficiency and total efficiency, of each of the configurations.

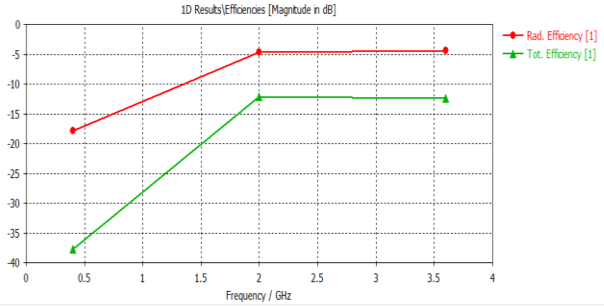

Fig. 3. Efficiency of circular patch antenna with CSRR ground plane.

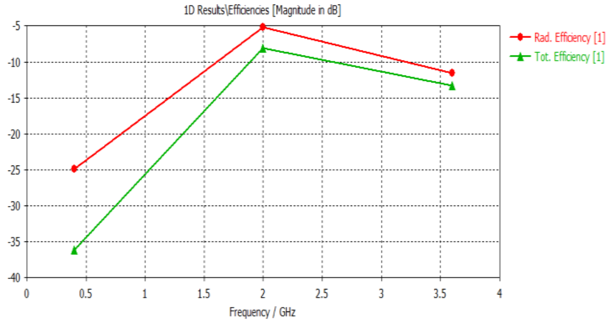

Fig. 4. Efficiency of the proposed dual-layer metamaterial antenna.

In Fig. 4 it can be seen that as the frequency increases, the radiation efficiency tends to the total efficiency.

For an ideal model of the designed antenna, where the second layer is immersed midst the FR4 substrate, would have the following efficiency, as seen in Fig. 5.

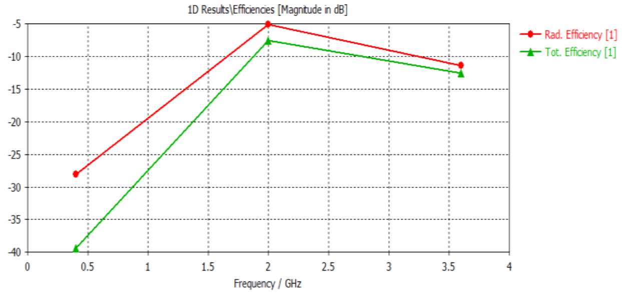

Fig. 5. Efficiency of the ideal antenna with dual-layer metamaterial.

IV. CONCLUSION

The microstrip circular patch antenna was investigated via simulation in CST software. Analyzing its efficiency and return loss, S11 parameter, the proposed dual-layer metamaterial antenna showed improvement in efficiency compared to a similar antenna that contains a metamaterial superstrate. Moreover, the radiation efficiency tends to the total efficiency for this new model, evidencing a superior performance.

The device designed in this article also showed a better gain in the frequency of 2.09 GHz, the second resonant frequency. Such result and other analyses will be presented in the full paper, including variations regarding the geometry of the patch elements and the second metamaterial layer, as well as a comparison with a conventional patch antenna.

V. ACKNOWLEDGMENT

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VI. REFERENCES

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