Inkjet-Printed Cylindrical EBG for Low-Cost, Omnidirectional Antennas using Split-Ring Resonators

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***Abstract*—In this paper, a low-cost, inkjet-printed, cylindrical electromagnetic bandgap structure has been designed, fabricated, and measured for increased directivity. For the EBG structure, a split-ring resonator array has been used, and increase in gain by 3dB has been achieved. This is the first ever cylindrical EBG structure that has been inkjet-printed on paper substrate, and shows promise for low-cost, omni-directional, high gain antennas for applications such as vehicular antennas, telecommunications, radar, and RFID.**

I. Introduction

With the proliferation of wireless communications devices, there is a growing need for omni-directional high gain antennas. Fulfilling these needs would lead to increased range and reliability for many different devices such as vehicular antennas, base station antennas for telecommunication, and RFID applications. To accomplish this goal many methods have been used to try to achieve this outcome. One such method is the use of metamaterials.

Metamaterials have been of interest to researchers for quite some time. They are materials that exhibit a negative permittivity and permeability. They have found recent use in acting as electromagnetic bandgap (EBG) structures in rejecting certain frequencies of antennas. [1,2] Other researchers have shown that if the EBG is arranged in a cylindrical fashion one can create a cylindrical electromagnetic bandgap (CEBG) structure which substantially increases the gain of an antenna. These structures rely upon partial reflecting surfaces to obtain both an omni-directional pattern and high gain. It accomplishes this by allowing most of the energy to pass through. The energy that is reflected will be symmetric around the cylinder, creating a spike in the E-field. This then causes a high directivity for the antenna. [3]

In addition to investigations of its uses, many new ideas have been introduced to implement EBGs. There has emerged a relatively new periodic structure that creates negative permittivity and permeability called Split Ring Resonator. [4,5] These resonators use a small gap between elements to create substantial capacitances. This in turn lowers the resonant frequency and allows for miniaturization in the production of EBGs.

This paper deals with applying all of these advances using ink-jet printing technology to implement them. It will discuss the advantages of printing the EBG and its effect on performance.

II. Design and Fabrication

When designing an EBG structure, an optimum solution that is both simple and cost-efficient. In pursuit of that ideal, the antenna was designed to have a basic sma connector to feed the antenna. This antenna launches the EM waves that interact with the CEBG. Next, the split ring resonators are designed for specific frequencies of operation, and are placed at a given radius around the antenna. These resonators are excited by the EM waves from the antenna, in this case the monopole antenna. With multiple resonators excited, higher directivity can be achieved. Figure 1 shows the simulated design of the CEBG with the monopole in the center, and a rectangular ground plane.

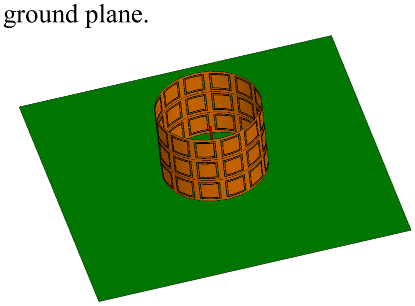

Figure 1. Design of CEBG antenna using HFSS.

The fabrication of this antenna was done using a Dimatix inkjet materials printer, which printed silver nano-particles onto photopaper. The photopaper has been characterized to have a dielectric constant of 3.3 and loss tangent of 0.07. [6] After the array of SRR was printed on the photopaper, it was wrapped around a piece of highly porous foam to maintain its cylindrical symmetry. The dielectric can be approximated to be 1, due to its high porosity. Next, the wire was mounted onto a rectangular piece of aluminum metal sheet with a sma

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connector on the bottom. Figure 2 shows the picture of the fabricated inkjet-printed CEBG antenna.

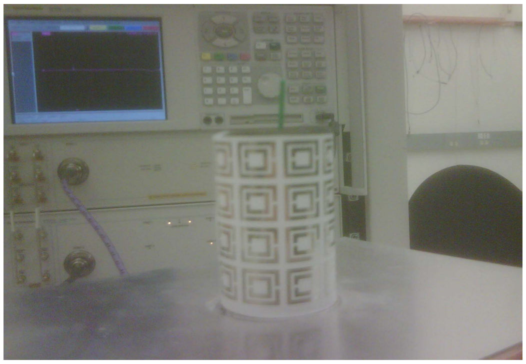

Figure 2. Fabrication of CEBG antenna using Dimatix materials printer.

III. Measurements

Measurements were conducted using an Agilent VNA and an ancechoic chamber. The return loss of the CEBG is shown in figure 3, showing a small deviation with and without the EBG shell around the monopole at 1.82GHz.

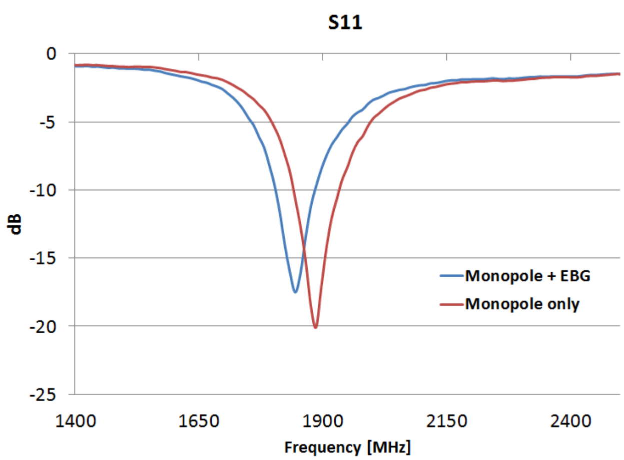

Figure 3. S11 measurement versus simulation comparison.

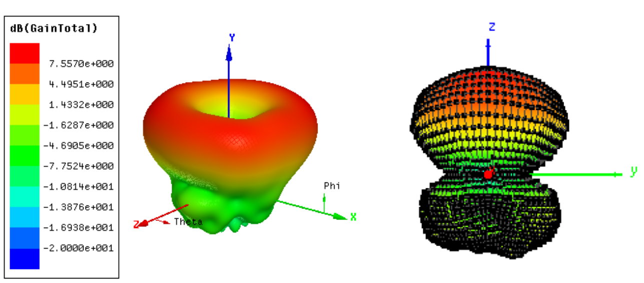

Figure 4. Simulation vs. measurement of radiation pattern with measured gain of max 5.9dB at 1.7 GHz.

Directivity gain measurements were taken using an ETS-Lindgren AMS-8050 chamber. Figure 4 shows the radiation pattern measurements closely match the simulation results.

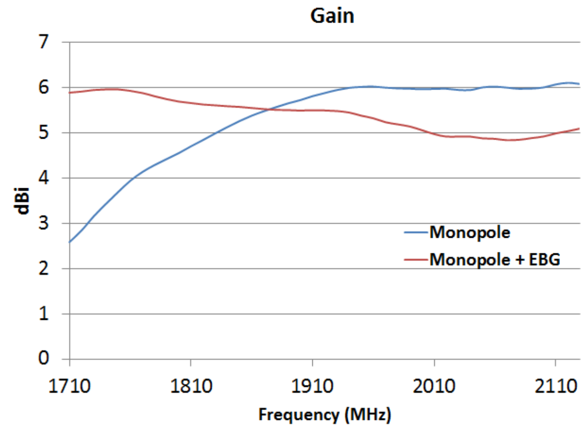

Figure 5. Gain measurements with and without the EBG shell around the monopole antenna.

These measurement results in figure 5 show that there is a 3dB increase in gain at 1710MHz when using the EBG shell. However, as frequency increases, the effect of the EBG shell decreases, and this is to be expected because the EBG has higher directivity and thus narrower beam at the resonance.

IV. Results

The gain measurements clearly show that the EBG shell increases the directivity gain of the monopole antenna by 3dB. In future designs, low loss substrates such as LCP or Kapton can be used to increase the efficiency compared to paper. Also, by tuning the split ring resonantors and the monopole, it is possible to tune this CEBG to applications such as vehicular antennas, base stations for telecommunication or RFID applications.

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