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Broadband Metamaterial Design Using Carbon Fiber and Resistive Sheet Materials

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***Abstract*— The objective of this paper is to compare experimental and simulated results of different broadband metamaterial absorber approaches. One such approach, which used a custom patterned fabricated board with resistive sheets, showed promising results in achieving broadband characteristics. In addition, quasi-isotropic carbon fiber patterns have been designed using genetic programming and simulated results have been obtained. We fabricate these carbon fiber designs and compare the measured results with the simulations, as well as compare with the resistive sheet design.**

I. Introduction

The objective of this research is to develop broadband metamaterial absorbers in the compact radar frequency band. In the companion paper [1] it was shown that this objective could be met by patterning advanced materials such as laser induced graphene, carbon fiber, and resistive sheets. The designs for these metamaterial patterns were developed using hybrid genetic programming with HFSS simulations. But fabricating these patterned metamaterial designs is challenging and in [1] an alternative method was explored: sandwiching resistive sheets in a multi-substrate arrangement. The resultant design has been fabricated and experimentally verified to produce broadband characteristics. In this paper we describe the fabrication procedure for patterning the metamaterial design using carbon fiber sheets. We will experimentally compare the results from the patterned carbon fiber design with the results obtained using the resistive sheet design.

II. Carbon Fiber Design

In the companion paper [1], a patterned design was developed for quasi-isotropic carbon fiber sheets. This design consists of the carbon fiber pattern that was developed by the method of genetic programming (GP), on top of FR4, and then backed with a copper backplane. The design for this approach, as well as the simulated results for absorptivity can be seen in Figure 1. The complex permittivity of these sheets was found using a novel approach described in [2]. This was then used to calculate the impedance of the carbon fiber sheets. The relative permittivity of the quasi-isotropic carbon fiber is $\varepsilon_r = 13$. The loss tangent is $\tan(\delta_e) = 0.08$. Then complex impedance was calculated to be $104.24 + i4.16\ \Omega/\square$. The details for this design were developed and then simulated in [1].

In this paper we will focus on fabricating this carbon fiber design, measuring the experimental results, and then comparing it with the simulated results. The design will be fabricated by adhering the carbon fiber sheets to the FR4 and copper backing, then using a milling machine to cut away portions of the carbon fiber layer, leaving only the patterned carbon fiber material behind. Then the absorptivity of this fabricated board can be measured and compared with the simulated results, as well as the results from the resistive sheet design that will be described further in the next section.

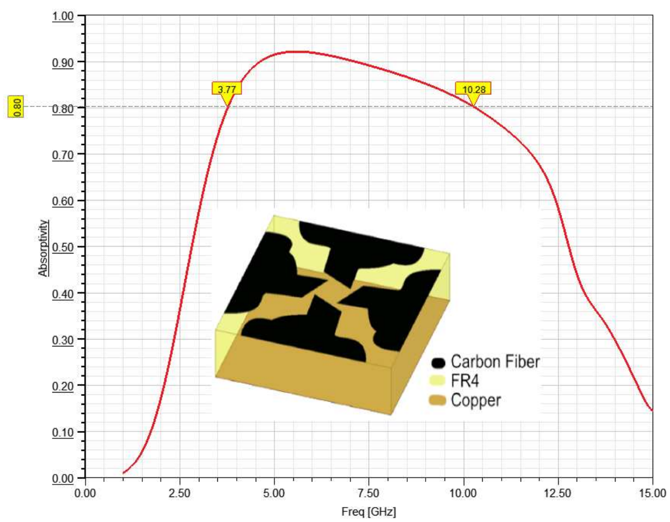

Figure 1. Quasi-isotropic carbon fiber pattern design and its corresponding simulated results for absorptivity.

III. Resistive Sheet Design

Due to the complexities of fabricating the carbon fiber boards in our custom pattern, another method was explored with more commercially available fabrication options. A metamaterial pattern design was found, and a custom board was fabricated according to this design. The pattern design and the absorptivity results are shown in figure 2. This pattern was from [3]. This fabricated board involved a copper pattern on top of FR4, backed with carbon-loaded polyethylene film, then a plexiglass sheet, finished with a copper backing. Experimental results were obtained by measuring the absorptivity of the fabricated board in the anechoic chamber. Two horn antennas were placed facing the board in order to measure the S parameters. This setup is shown in Figure 3. The measured data was then processed in MATLAB and compared with the simulated results. The comparison between the simulated and measured absorptivity is shown in Figure 4. It can be noted that the lack of smoothness in the experimentally obtained result compared with the simulated results is due to the limited dynamic range in reflection coefficient measurements when having highly absorbing materials. Regardless, this design demonstrated promising experimental results for obtaining broadband characteristics using this methodology. The results from this design can then be compared with the carbon fiber designs developed using genetic programming.

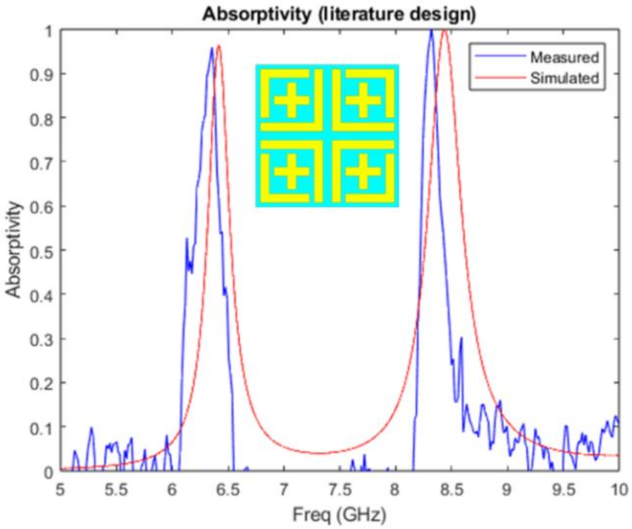

Figure 2. Measured absorptivity of fabricated metamaterial design compared with simulation results before adding the resistive sheets [3].

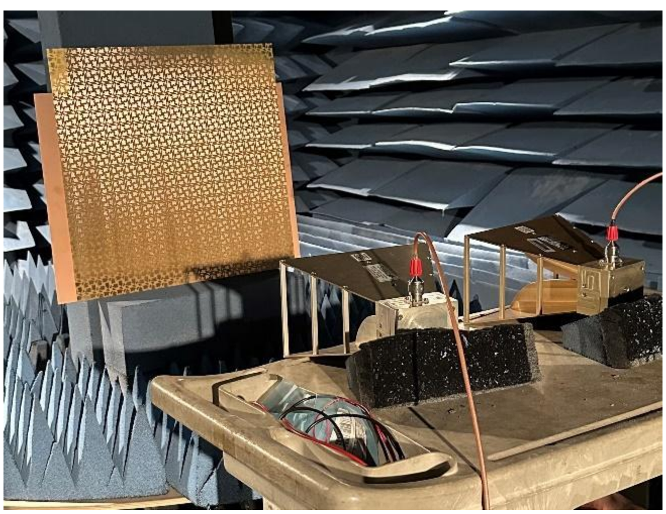

Figure 3: Measuring fabricated board in anechoic chamber.

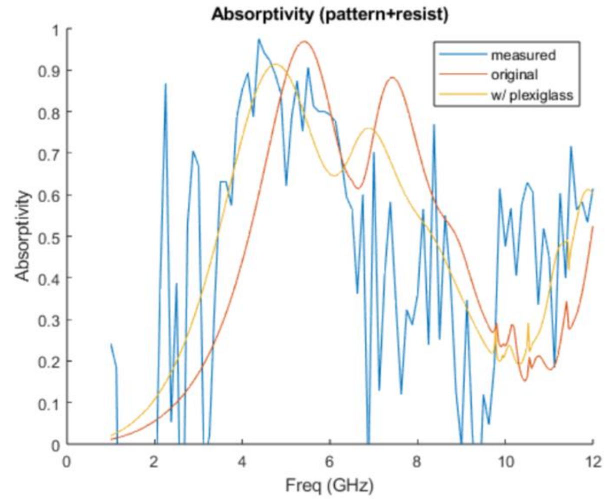

Figure 4: Measured absorptivity of fabricated board compared with simulated results after adding resistive sheets.

IV. Conclusion

This comparison between the experimentally measured and simulated results for the patterned resistive sheet design provides proof-of-concept for implementing patterned metamaterial absorber designs. In addition, preliminary attempts in patterning carbon fiber using an in-house milling machine shows that the simulated designs can be fabricated and measured. Finally, we compare the absorptivity of the fabricated carbon fiber-based design and the resistive sheet design.

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