Lightweight 3-D Printed Metamaterial for Electromagnetic Wave Absorption

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Abstract **– In this paper, a broadband metamaterial absorber has been presented based on three-dimensional (3-D) printing technology. The proposed design comprises periodic arrays of hexagonal honeycombs, on which resistive ink has been deposited in square loop patterns. The novelty of the structure lies in its perforated geometry made from 3-D printing, which offers lightweight characteristic and mechanical stability to the design. The geometry also exhibits broadband absorption (above 90%) from 5.52 to 16.96 GHz under normal incidence, thus resulting in a fractional bandwidth of 101.78%. Finally, the structure has been fabricated using 3-D printing, and the ink has been painted through screen printing technique. The prototype, while measured, shows good agreement with the simulated response under normal incidence.**

Index Terms **— 3-D printing, metamaterial absorber, perforated structure, resistive ink.**

1. Introduction

Metamaterial absorber is an artificial composite structure [1], used to absorb electromagnetic (EM) wave owing to its attractive properties. Large absorption bandwidth, small thickness, and near unity absorption profile can be achieved by implementing various techniques in metamaterial absorber designs [2]-[4]. However, the structures also need to be lightweight as well as mechanically stable for deploying in practical applications. Earlier reported absorber designs have mostly used commercially available dielectric substrates, which are bulky, heavy, and difficult to install [5]-[7]. Therefore, broadband absorbers with high mechanical durability and light in weight are currently in great demand among the researchers.

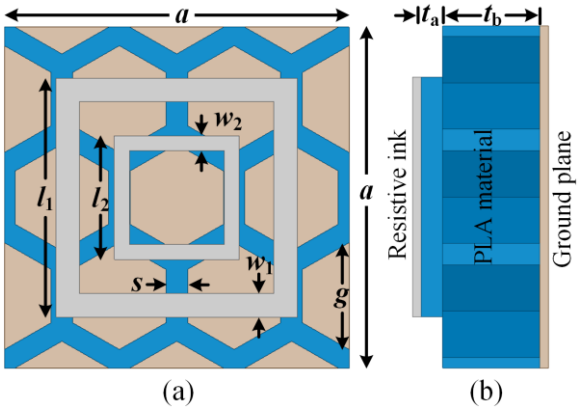

Fig. 1. Unit cell geometry of the proposed broadband metamaterial absorber. (a) Top view, and (b) side view.

In this paper, a metamaterial absorber has been presented based on 3-D printing technology. The proposed design is realized on a perforated substrate made from honeycomb geometry, thus resulting in a lightweight yet mechanically stable behavior. Moreover, resistive ink has been deposited on the geometry in square loop patterns, which leads to wideband absorption covering C, X, and Ku bands in the microwave spectrum. The design has also the notable advantage of exhibiting polarization-insensitive and angularly stable behavior. Finally, the proposed structure has been fabricated as well as experimentally validated.

2. Design and Analysis

Fig. 1 shows the unit cell geometry of the proposed metamaterial absorber that consists of a hexagonal honeycomb shaped dielectric substrate stacked with patterned resistive ink geometry. Commercially available polylactic acid (PLA) ($\varepsilon_r = 2.1$, and $tan\ \delta = 0.07$) is chosen as the constituent material for the dielectric substrate. Two concentric square loops are imprinted on the perforated honeycomb core, on which resistive ink has been uniformly deposited. The optimized dimensions of the structure are as follows: a = 16 mm, l_1 = 11.2 mm, w_1 = 1.1 mm, l_2 = 5.8 mm, w_2 = 0.7 mm, g = 2.5 mm, s = 1 mm, t_a =4.5 mm, and t_b = 1 mm. Y-shield resistive ink (σ = 2800 S/m) has been used in the design, while maintaining the ink thickness at 20 micron uniformly.

The structure, while simulated in Ansys HFSS software using periodic boundary conditions, exhibits broadband

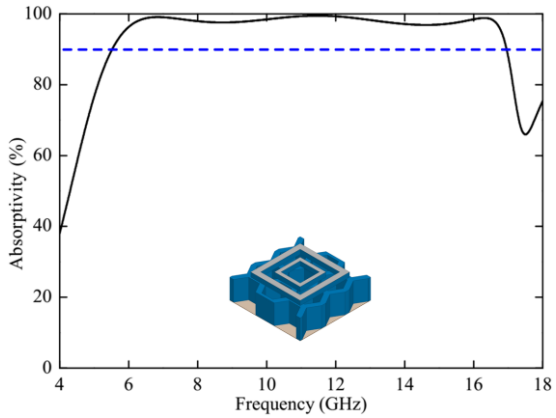

Fig. 2. Simulated absorptivity of the proposed broadband metamaterial absorber. Inset shows the perspective view of the unit cell topology.

absorption (above 90%) over the frequency range from 5.52 to 16.96 GHz. This leads to a fractional bandwidth of 101.78%, covering C, X, and Ku bands, as shown in Fig. 2.

Moreover, the proposed design is four-fold symmetrical and therefore displays identical absorption characteristics for any angle of polarization of the incident EM wave, as depicted in Fig. 3(a). Angular stability of the geometry has also been confirmed for transverse electric (TE) polarization and it is found to exhibit broadband absorption upto 45° angle of incidence, as observed from Fig. 3(b).

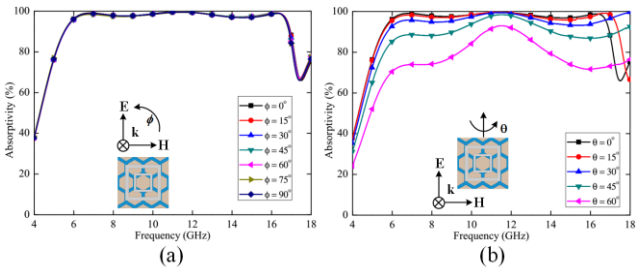

Fig. 3. Simulated absorptivity of the proposed broadband metamaterial absorber for (a) different polarization angles under normal incidence, and (b) different incident angles under TE polarization.

3. Experimental Verification

In order to experimentally verify the proposed design, a prototype has been fabricated. 3-D printing technology is used to construct the perforated honeycomb shaped dielectric substrate using PLA material, on which resistive ink has been deposited using screen printing technique. A thin copper tape has been pasted at the back side of the dielectric, to block the transmission through the sample. Fig. 4 shows the fabricated prototype, consisting of 9 × 9 unit cells in a 190 mm × 190 mm sample.

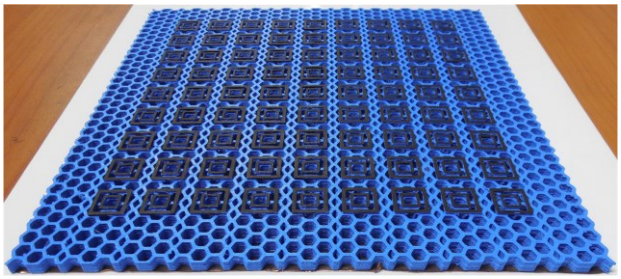

Fig. 4. Photograph of the fabricated prototype.

The prototype has been measured using free space technique and exhibits broadband absorption (above 90%) from 5.66 to 16.36 GHz, as depicted in Fig. 5. The measured result, while compared with the simulated response, shows good agreement under normal incidence. Slight deviation might be accounted to the fabrication error and tolerance in the constituent materials.

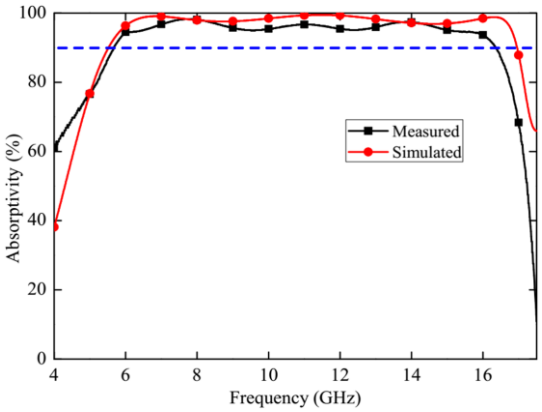

Fig. 5. Comparison of measure and simulated absorptivity responses of the proposed metamaterial absorber.

4. Conclusion

A broadband metamaterial absorber, based on hexagonal honeycomb as the substrate geometry, has been presented in this paper. The design exploits 3-D printing technique to construct the perforated dielectric, on which resistive ink has been painted to obtain broadband absorption. Mechanical stability as well as light weight properties of the geometry have made the proposed structure quite competitive for absorber applications.

Acknowledgment

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