Flexible Inkjet-Printed Metamaterial Paper Absorber

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***Abstract*—In this paper, a novel inkjet-printed metamaterial absorber is proposed for the first time. The proposed absorber consists of circular Jerusalem-Cross resonators and it is printed on a thin paper substrate. The performance of the proposed absorber is validated through EM simulation and measurement. Flexibility and high absorptivity are achieved in X-band.**

I. INTRODUCTION

Electromagnetic (EM) wave absorbers dissipate EM energy of an incident wave to prevent unwanted reflection and have been researched in various areas, such as electromagnetic interference (EMI), electromagnetic compatibility (EMC), bolometers, and radar cross section (RCS) reduction [1]. Especially, wedge-tapered and ferrite-compound absorbers show a good absorbing performance and are commonly used in most of anechoic chambers [2]. However, it is difficult for conventional absorbers to expand to numerous ranges of practical applications, because material-based absorbers are bulky, heavy and expensive.

To solve this problem, a metamaterial-based absorber is proposed and it has received a lot of attention for EM wave absorbing technology. The metamaterial is an artificial structure which has an exotic EM property that cannot exist in nature, such as negative index refraction and cloaking [3]–[7]. A metamaterial absorber, especially using a frequency selective surface (FSS) structure, consists of an array of conductive patterns on a planar dielectric substrate with fully metallic back [4]–[7]. Thus, it has a thinner geometry than conventional structures and features a lower cost by using cheap conductive plates. In addition, a FSS metamaterial absorber has high absorptivity despite of low profile, because of an array of conductive patterns which are composed of electric LC (ELC) resonators. At its resonant frequency, reflection is decreased by impedance matching between the metamaterial absorber and the air [4]. In order to actually fabricate a metamaterial absorber, a printed-circuit-board (PCB) process is typically necessary. Such a process is quite complicated and has various chemical processes which are still dangerous to human body. In addition, some conventional metamaterial absorbers are built on a hard dielectric substrate, so it can be applied on only flat surface.

In this paper, we propose a novel metamaterial absorber that is built on a cost-effective and flexible paper substrate by inkjet-printing technology. The proposed absorber has no need for chemical PCB process and can be fabricated by simple inkjet-printing with conductive inks on a paper. A paper is used for the proposed absorber's substrate, so its expense becomes cheaper than conventional metamaterial absorber. In addition, because a paper is soft enough to bend, the proposed absorber has flexibility.

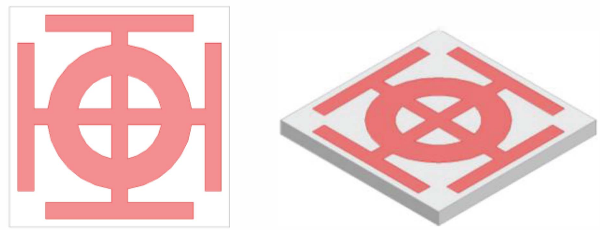

Fig. 1. Unit cell of the proposed absorber.

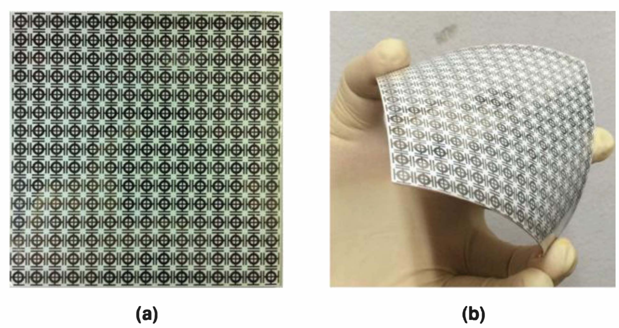

Fig. 2. Fabricated prototype of the proposed absorber.

II. DESIGN AND STRUCTURE

Fig. 1 shows the unit cell of the proposed absorber. The unit cell is composed of a Jerusalem-Cross with internal conductive ring on the top layer and a fully metallized on the bottom layer of a paper substrate. Since a modified Jerusalem-Cross pattern on the top layer is printed with conductive inks, it has inductive components and capacitive components which lead to electrical LC resonance. Therefore, the impedance of the proposed absorber is manipulated to match to impedance of an air at the resonance frequency and the proposed absorber can absorb incident wave without reflection. The bottom layer of the proposed absorber is completely conductive so that there is no transmitted EM energy.

Fig. 2 shows the fabricated paper metamaterial absorber prototype. The prototype is composed of 15×15 unit cells on a paper substrate, as shown in Fig 2(a). In order to print the top layer's pattern, a conductive ink which has surface resistance of 0.2-ohm/square is used at 10 GHz. Since a single paper has 0.254-mm thickness, two papers sheets are attached by an adhesive to realize 0.508mm-thickness for good absorbing performance. The thicker paper generates higher absorption because of transmitted EM energy can be more attenuated. However, the EM properties of the "composite" paper substrate are different from those of a single paper sheet, because of the presence of an adhesive layer in between the two paper layers. Therefore, the EM properties of a paper substrate are measured by using T-resonator [8]. The measured dielectric constant and loss tangent of a paper substrate is 2.75 and 0.035, respectively. In addition, the flexibility of the proposed metamaterial absorber can be observed in Fig. 2(b).

III. Result and Discussion

To demonstrate the performance of the proposed absorber, both full-wave simulations and measurements are performed. A commercial finite-element-method (FEM)-based simulator (ANSYS HFSS) is used for EM simulation and the measurement results for normal incidence are obtained using a space-wave method with a vector network analyzer (VNA) Anritsu MS2038C, a standard gain horn antenna. The fabricated absorber under test (AUT) is surrounded by wedge-tapered absorbers to prevent an unwanted reflection and placed at 1m apart from the horn antenna to satisfy a far-field condition. In order to eliminate external RF signals, a time gating method is applied to the VNA.

Fig. 3 shows simulated and measured absorptivity of the proposed absorber. The absorptivity can be obtained from the reflectivity ($|S_{11}|^2$) and the transmission ($|S_{21}|^2$) of the incident EM wave, as given by

$$A(\omega) = 1 - |S_{11}|^2 - |S_{21}|^2 \tag{1}$$

Since the bottom plane of the proposed absorber is completely conductive, transmission coefficient is zero. Therefore, the absorptivity can be calculated by measuring only the reflection coefficient [5]. As a result, the proposed absorber has 79.5% of absorptivity at 10.36 GHz. There are small differences in the absorptivity values between the simulation and the measurement results due to the surface roughness of the paper substrate.

IV. Conclusion

In this paper, a novel inkjet-printed metamaterial absorber is proposed. Since the proposed absorber can be simply fabricated by inkjet-printing on a thin and cheap paper substrate, there is no significant difficulty to expand for large area with lower expense. In addition, periodic ELC resonator patterns have enough conductivity to operate as an absorber by using conductive ink. The proposed absorber has 79.5% of absorptivity at 10.36 GHz and flexibility. Therefore, the proposed absorber can be used in various EM wave applications requiring flexible low-cost absorbers. The angular and polarization sensitivity of the proposed absorber will be presented in the conference.

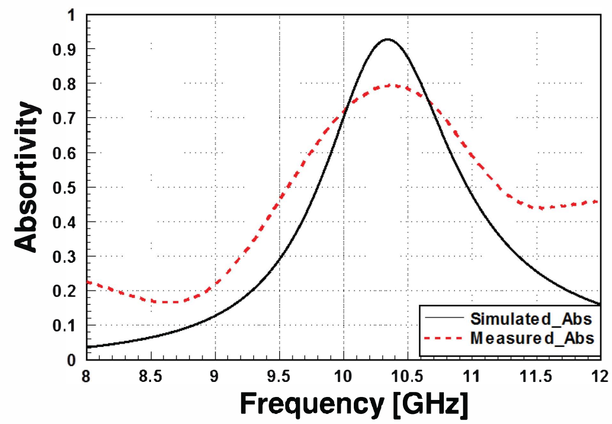

Fig. 3. Simulated and measured absorptivity of the proposed absorber.

Acknowledgement

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