A Broadband Polarization-Insensitive Circuit Analog Absorber using Lumped Resistors

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***Abstract*— In this paper, a broadband circuit analog absorber has been presented based on lumped resistors, which exhibits 10 dB absorption bandwidth from 3.96 GHz to 8.16 GHz, covering entire C-band. The designed structure is polarization-insensitive and wide-angle absorptive. The effect of the lumped resistors has been studied to examine the absorption mechanism of the wideband absorber. The structure has also been fabricated, whose measured results are in good agreement with the simulated responses.**

Keywords*— *Circuit analog absorber; boradband absorber; lumped resistors; frequency selective surface.

I. INTRODUCTION

Radar absorbing materials are widely used in many applications such as radar cross section (RCS) reduction, electromagnetic interference (EMI), electromagnetic compatibility (EMC), wireless communication and so forth [1]. Salisbury screen, one of the oldest radar absorbers, is very simple in nature, but has limited absorption bandwidth [2]. Jaumann absorber has an extended bandwidth at the expense of large thickness [3]. Circuit analog (CA) absorbers are a perfect solution to this narrow bandwidth problem, where resistive components have been implemented on high impedance surfaces (HIS) [4-5].

In this paper, a metamaterial based CA absorber has been proposed, which is composed of a single square loop (SSL) loaded with chip resistors. The structure exhibits reflectivity below -10 dB in the frequency range from 3.96 GHz to 8.16 GHz under normal incidence. The proposed absorber is polarization-insensitive and wide-angle absorptive for TE polarization. In addition, the structure has also been fabricated and measured in anechoic chamber, which shows good agreement with the simulated results.

II. DESIGN OF THE STRUCTURE

Fig. 1 illustrates the unit cell of the proposed broadband absorber, where the top view and side view are shown in Fig. 1(a) and 1(b), respectively. The proposed structure comprises a periodic arrangement of a single square loop imprinted on a grounded dielectric substrate, where four chip resistors are soldered in each arm of the square loop. The top and bottom metallic patches are made of copper (thickness of 0.035 mm, conductivity of 5.8 x 10^7 S/m) and the dielectric substrate is FR-4 with relative permittivity of 4.4 and dielectric loss tangent of 0.02. The dimensions of the unit cell along with the field vector directions are also shown in Fig. 1.

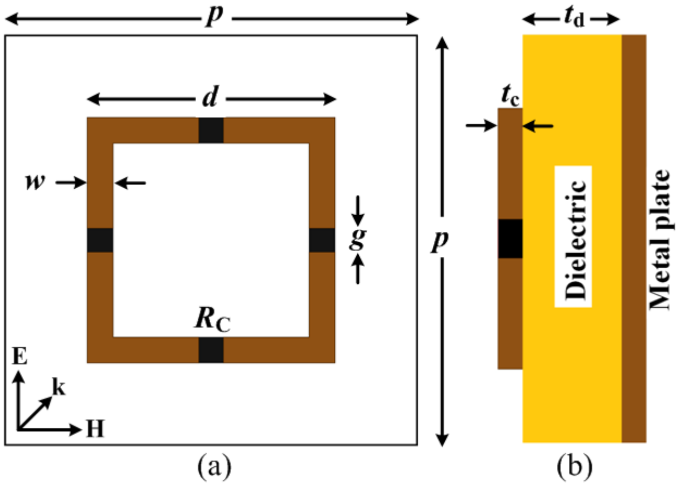


Fig. 1. Unit cell geometry of the proposed broadband absorber: (a) top view, and (b) side view. Geometrical dimensions are: p = 20 mm, d = 12 mm, w = 1.25 mm, g = 1.2 mm, t_d = 6 mm, t_c = 0.035 mm, and R_C = 150 Ω.

When the structure is simulated with HFSS by ANSYS using periodic boundary conditions, it is observed that the reflection coefficient is less than -10 dB over the frequency range of 3.96 GHz to 8.16 GHz as observed from Fig. 2(a). Since the transmission is zero due to complete metal backing, the absorptivity of the structure therefore can be calculated as: A = 1- $|S_{11}|^2$, and observed as above 90% for the above frequency range as shown in Fig. 2(b).

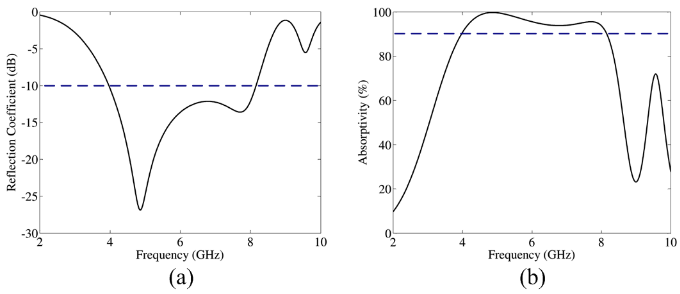
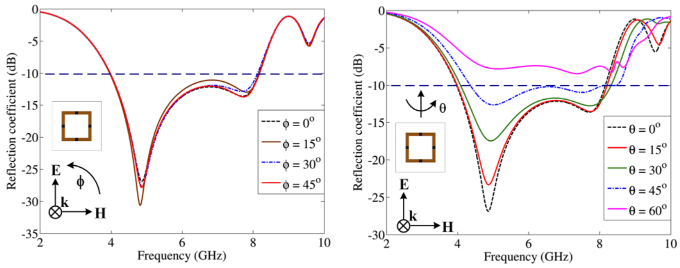


Fig. 2. Simulated (a) reflection coefficient, and (b) absorptivity of the proposed broadband absorber.

The proposed structure is polarization-insensitive due to four-fold symmetry as depicted in Fig. 3(a). The structure has also studied for different oblique incidence under TE polarization, where it sustains its broadband nature upto 45° angle of incidence as shown in Fig. 3(b).

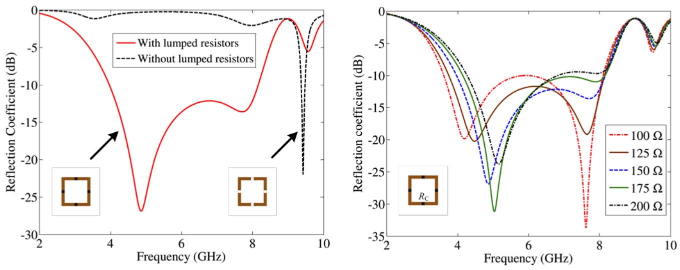


(a) (b)

Fig. 3. Simulated reflection coefficients of the proposed structure for (a) different polarization angles under normal incidence, and (b) different incident angles under TE polarization.

In order to explain the mechanism behind broadband absorption, the reflection coefficient of the structure has been compared under two different conditions. When the chip resistors are absent, the simulation shows a single narrow reflection dip at 9.42 GHz with reflectivity of -21.94 dB as observed from Fig. 4(a). This clearly validates that the narrow absorption peak of the proposed absorber is due to dielectric loss of the substrate, whereas the broadband absorption occurs owing to presence of lumped resistors.

The values of the chip resistors are also varied in order to further elucidate the absorption mechanism. It is observed from Fig. 4(b) that the 10 dB bandwidth gradually decreases while increasing value of resistance from 100 Ω to 200 Ω.



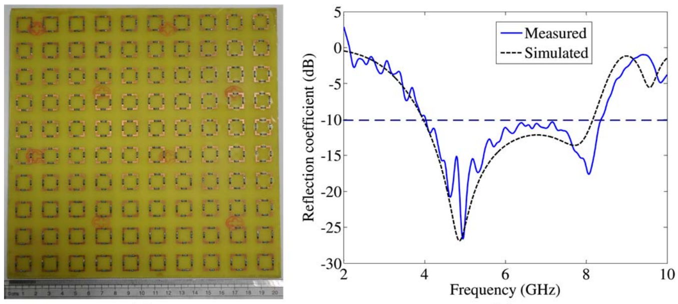
(a) (b)

Fig. 4. Reflection coefficients of the proposed broadband structure (a) with and without lumped resistors, and (b) for different resistor values (R_C).

III. Experimental Verification

In order to experimentally demonstrate the proposed absorber, the structure has been fabricated using printed circuit board (PCB) technique. The chip resistors are then soldered on the fabricated sample in a surface-mounting technology. The overall sample contains 10 × 10 unit cells, on which 400 resistors are soldered as shown in Fig. 5(a).

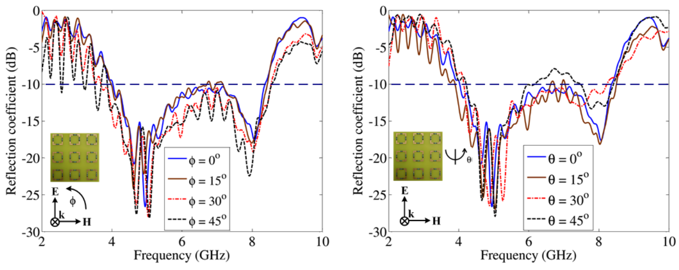
The fabricated sample is measured in an anechoic chamber using free space measurement technique [6]. It is observed from Fig. 5(b) that the measured reflection coefficient is less than -10 dB from 4.02 GHz to 8.37 GHz under normal incidence. A slight deviation between the simulated and measured results is observed, which may be due to small error in resistor values and fabrication tolerance.



(a) (b)

Fig. 5. (a) Fabricated structure, and (b) comparison of measured and simulated reflection coefficients of the proposed broadband structure.

The fabricated prototype has also examined for different angles of polarization as shown in Fig. 6(a), where it maintains 10 dB absorption bandwidth for all the angles. Fig. 6(b) shows the measured response for different incident angles under TE polarization, which also matches with the simulated response.



(a) (b)

Fig. 6. Measured reflection coefficients of the fabricated structure for (a) different polarization angles under normal incidence, and (b) different incident angles under TE polarization.

IV. Conclusion

In this paper, a broadband polarization-insensitive metamaterial absorber using lumped resistors has been presented. The proposed structure has reflection coefficient less than -10 dB from 3.96 GHz to 8.16 GHz, having bandwidth of 69.31% at 6.06 GHz. The absorption mechanism of the designed absorber has been explained using some parametric studies. Finally, the proposed absorber has also been fabricated, whose experimental results are validated with the simulated responses.

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