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X-Band Metamaterial Wideband Polarization Insensitive Thin Absorber using Lumped Resistors

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Abstract

A novel frequency selective surface (FSS) based absorber with broadband characteristics is presented in this paper. The absorber is designed for X band applications. The absorber presented here is thin broadband and polarization insensitive owing to its four fold symmetric nature. The simple design of the structure makes it more realizable and hence practically feasible.

1. Introduction

Microwave absorbers are not new and they have been in use since very early times. The radar absorbing materials have been used in many applications such as radar cross section (RCS) reduction, electromagnetic interference (EMI), electromagnetic compatibility (EMC), wireless communication and so forth [1]. The earliest reported among absorbers is Salisbury screen where a sheet is placed at $\lambda/4$ from the ground plane [2]. The drawback associated with the Salisbury screen is that it is very narrowband. The next in line came Jauman Absorber. It tried to overcome the drawback of Salisbury screen. In Jauman absorber multiple screens were kept each at a distance of $\lambda/4$ from the previous one [3]. The design overcame the drawback of narrow bandwidth but itself had a drawback of becoming bulky. The bulkiness of the absorber limited their application. To solve the above problem FSS based absorbers came into picture. FSS are periodic structures which shows filtering properties [4]. The FSS based absorbers are thin and lightweight. Here in this paper we have designed a FSS based absorber.

2. Design of the absorber

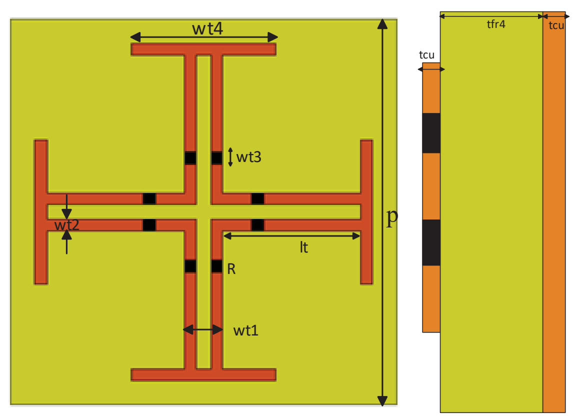
The absorbers are designed so as to get maximum possible absorption. The absorbers are characterized by S_{11} , S_{21} and absorption characteristics. The relation between the three is given by:

$$absorption = 1 - |S_{11}|^2 - |S_{21}|^2 \quad (1)$$

The FSS based absorber presented in this paper is a single layered structure. The structure is backed by copper as ground plane. Because the structure is backed by ground plane the structure does not allow any incident wave to pass through it hence, $S_{21} = 0$. Thus equation (1) reduces to:

$$absorption = 1 - |S_{11}|^2 \quad (2)$$

Looking at the above equation we are now interested in only two characteristics which are absorption and reflection coefficient characteristics. The design is printed on a FR-4 substrate. The top view, side view and the unit cell descriptions are shown in Figure.1. FR-4 substrate used in the design has a dielectric constant of 4.4 and loss tangent is 0.02. The thickness of the substrate is 3.2mm. The design consists of a patch made up of copper (thickness=0.035mm). It is in the shape of cross outline with elongated ends. The lumped resistors (R=250 ohm) are embedded in the design with the help of soldering. The unit cell dimension is 16mm X 16mm.



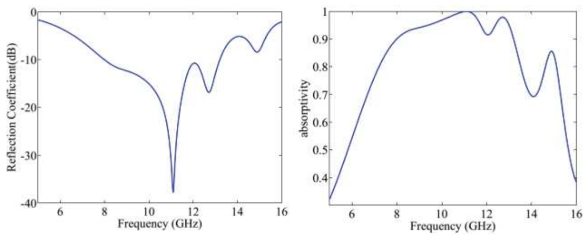
(a) (b)

Figure 1. (a) Top view and **(b)** side view of the proposed absorber.

Unit cell dimensions of the proposed structure is as: P= 16 mm, lt= 5.7 mm, wt1= 1.6 mm, wt2= 0.5 mm, wt3= 0.5 mm, wt4= 5 mm, R= 250 ohms, tcu= 0.035 mm, tfr4= 3.2 mm.

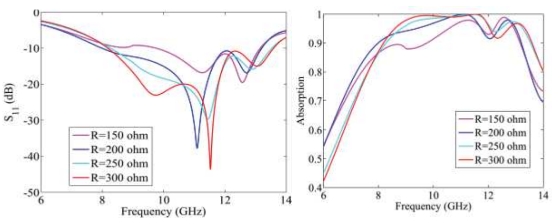
The full wave simulation was carried out in HFSS using periodic boundary conditions. To arrive at the desired result we have performed some parametric variations. Some results of parametric variation has been attached in the following section. The parametric analysis gives the optimum values of resistance to be used. The unit cell size, thickness of the substrate all were optimized using this parametric variation. The simulated results i.e. the reflection coefficient and the absorptivity is shown in Figure 2. For the above absorber.

The results of parametric variation of resistance and the substrate thickness is shown in Figure 3 and Figure 4 respectively.



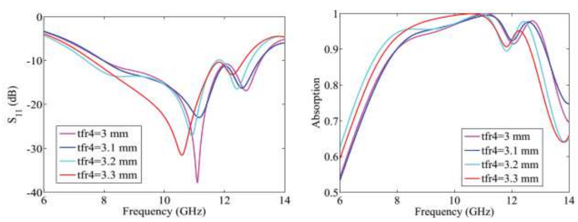
(a) (b)

Figure 2. (a) Simulated Reflection Coefficient and **(b)** absorptivity of the proposed absorber.



(a) (b)

Figure 3. Parametric variation of the lumped resistance used: **(a)** Reflection Coefficient and **(b)** Absorption



(a) (b)

Figure 4. Parametric variation of the substrate thickness of the FR-4 used: **(a)** Reflection Coefficient and **(b)** Absorption

The 10 dB reflection coefficient is obtained in between 8 GHz to 13.2 GHz thus covering the whole X band. The absorption of above 90 percent is also seen in the same frequency range.

3. Equivalent Circuit Model

The FSS based absorber presented in the paper is modeled using lumped components. The printed design is modeled into a series combination of series and parallel LC which is shown in Figure 5. The FR-4 substrate is modeled into a transmission line of length 3.2 mm. The copper as ground plane is being represented as a short circuit. The reflection coefficient obtained by simulation in HFSS and the circuit model in ADS are compared. Both the results although do not overlap but are in close approximation and is shown in Figure 6.

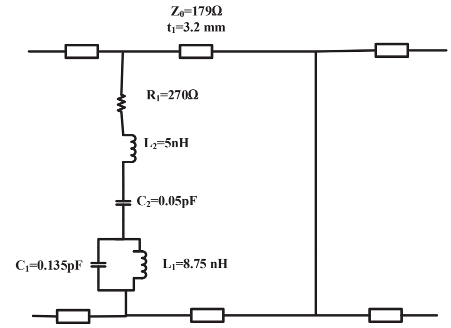


Figure 5. Equivalent Circuit Model of proposed absorber

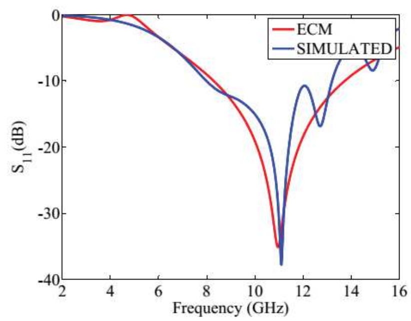


Figure 6. Comparison between the HFSS simulated response and the ADS simulated response.

4. Conclusion

In this paper, a wideband polarization-insensitive absorber using lumped resistors has been presented. The proposed structure is simple, symmetric and thin, which has negligible transmission coefficient and reflection coefficient above 90 percent in the whole range. The absorption mechanism of the designed absorber has been explained using parametric studies.

5. References

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