Wide and Multi Band Fan Shaped Split Ring Resonator for Radar Absorber

M. Abdalla*, H. Elregealy, H. Hamza, M Fouad, M. Saber, A. Allam, and A. Mitkees

Department of Electronic Engineering, MTC University
Cairo, Egypt
email: nmaaabdallah@gmail.com

Abstract

The paper presents a new simple and ultra thin (5.6% λ_0) wide/ multi bands metamaterial radar absorber. The new metamaterial absorber is based on the use of fan shaped split ring resonator. The theoretical concepts have been validated using the electromagnetic full save simulations. The results illustrate that the proposed metamaterial absorber can achieve dual band of radar absorption. Both bands have wider bandwidth compared to conventional rectangular split ring resonator (four times wider in one band and eight times wider in the second band). Also, the proposed metamaterial absorber can achieve almost -20 dB reflection coefficient for both the cases of co polarized and cross polarized incidence fields at the center frequency.

1. Introduction

Since the first decade of 21st century, special interest has been focused by electromagnetic community on metamaterials. Owing to metamaterial unique electromagnetic features, they have been employed to solve many problems beyond conventional technological limitations. The need for electromagnetic absorption in many applications requires the radar absorbing materials (RAM) to be simple, thin, and wide band. Thanks to the unique metamaterials properties, they have been employed in designing radar absorber with properties beyond conventional physical limitations [1]. The simplest metamaterial radar absorber is an analogue to Salisbury screen and it is based on loading a lossy thin substrate with periodic split ring resonators (SRRs). This type of resonant type metamaterial absorber can be of ultra thin structure, but it suffers from narrow operating bandwidth.

The possibility of achieving wide band RAM is based on using multi-layered structure; first attempt was Jaumann absorber [2]. However, this technique results in thicker structure which may be not suitable for many applications. Since the properties of a metamaterial are usually determined from its geometrical structure and parameters, hence, the need for wide band absorber can be achieved by using non traditional SRRs geometries [3,4].

In this paper, we introduce the use of novel type of SRR configuration, named as a fan shaped SRR for achieving wide band metamaterial absorber. Comparison between the performances of the metamaterial absorber based on conventional rectangular SRR versus the proposed one are introduced. The results illustrate that the proposed absorber can achieve wide and multi bands. Both bands are wider in operation bandwidth compared to the conventional one.

2. RAM Structure:

Salisbury screen RAM is designed using a resistive absorber layer loading a (λ/4) grounded transmission line. This structure can achieve high impedance, an open circuit, for an incident electromagnetic wave. Metamaterials have been employed in designing ultra thin absorbers, lessλ/10 at the operating frequency, using different geometries of the periodic array unit cell and the design approach [5]. The common idea between the different approaches is to construct a high impedance ground plane by aid

ISBN 978-952-67611-0-7

of a periodic metal pattern surfaces. From circuit point of view, this is an equivalent to a tank circuit formed by an inductive load, the equivalent of the short circuited transmission line, and the capacitive load, equivalent to the resistive screen layer [6] as shown in Fig. 1 (a). An ultra thin transmission line metamaterial absorber has been achieved by using high capacitive metamaterial screen [6]. The simple capacitive load metamaterial absorber is based on the use of split ring resonator (SRR). In general SRRs may have different configurations whose equivalent circuits are mainly similar as shown in Fig. 1 (b) [7]. The simplest metamaterial absorber employs rectangular shaped SRR shown in Fig. 2 (a). However, this RAM structure is narrow band. The idea of increasing bandwidth of the resonator RAM is based on using SRR geometry that can enhance the parasitic effect so that the whole metamaterial RAM can resonate at different frequencies. Hence, wide/multi band absorber may be achieved. This concept can be fulfilled by proposing new resonator geometry, a fan shaped SRR shown in Fig. 2 (b).

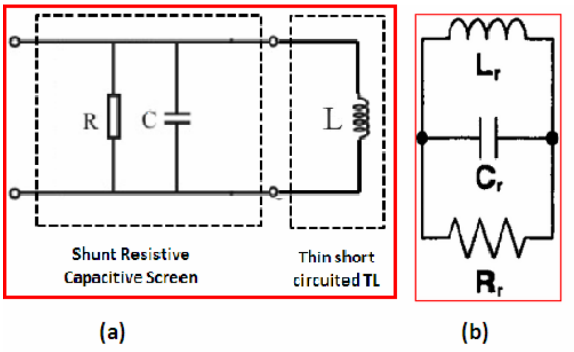

Fig.1:(a) An equivalent circuit of the metamaterial transmission line RAM. (b) A SRR equivalent circuit.

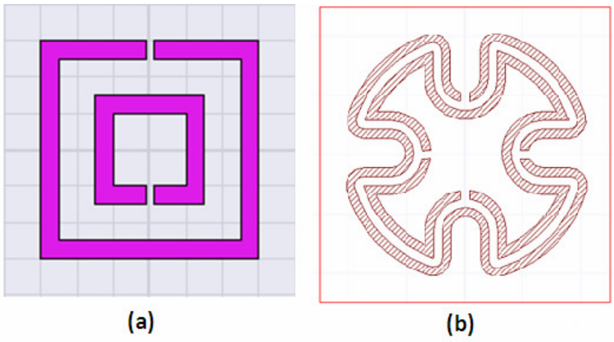

Fig.2) A unit cell geometry of (a) a rectangular SRR (b) a fan shaped SRR

3. Results and Discussions

The performance of the fan shaped SRR was compared versus the conventional rectangular SRR. Both radar absorbers were designed on a lossy FR4 substrate whose relative dielectric constant ε_r= 4.4, a dielectric loss tangent, tan δ = 0.02, and thickness, h = 1.6 mm. For both cases, the periodicity was set as 5mm. In both cases, the structure dimensions were selected to achieve radar absorption at X band. The results in all cases were obtained using the commercial full wave electromagnetic simulator (Ansoft-HFSS). The simulated conventional rectangular SRR has the following dimensions: an inner rectangular has an inner diameter (2a=1mm), the two rings separation is (d=0.3 mm), all the lines thicknesses are equal (w=0.25 mm), and the gap in both inner and outer ring is (g= 0.5 mm). The fan shaped SRR has an outer radius of 2.15 mm. All the lines thicknes and gaps are equal to 0.15 mm. Also, the U section length is 0.5 mm.

The simulated reflection coefficient for normal incidence of electromagnetic waves upon the metamaterial absorber implemented using rectangular SRR versus the fan shaped SRR are shown in Fig. 3 for the case of co polarized wave. As illustrated in the figure, the conventional rectangular SRR RAM can satisfy electromagnetic wave absorption at approximately 9.5 GHz with close to -15 dB reflection coefficient over a narrow bandwidth (10 dB fractional bandwidth is only 1%). On the other hand, the fan shaped SRR can demonstrate electromagnetic wave absorption centred at the same frequency 9.5 GHz with fractional 10 dB bandwidth of approximately 4.5%. Moreover, the fan shaped SRR absorber can demonstrate a second absorption band at approximately 11.7 GHz. The second band has better than -20 dB reflection coefficient over approximately 8 % bandwidth. This means that the fan shaped SRR metamaterial absorber can increase the bandwidth up to eight times compared to conventional SRR absorber.

ISBN 978-952-67611-0-7

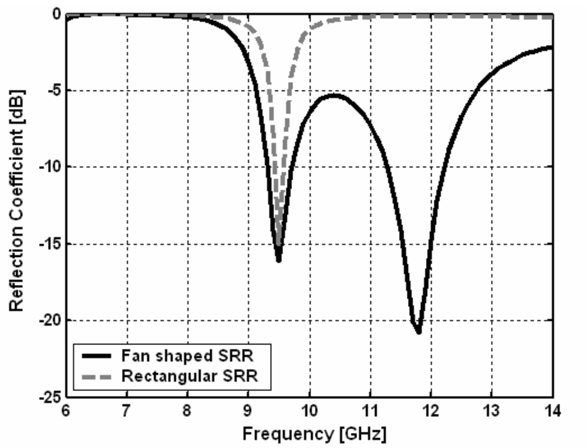

Fig.3 The simulated reflection coefficient of rectangular SRR and fan shaped SRR metamaterial absorber for co-polarized wave.

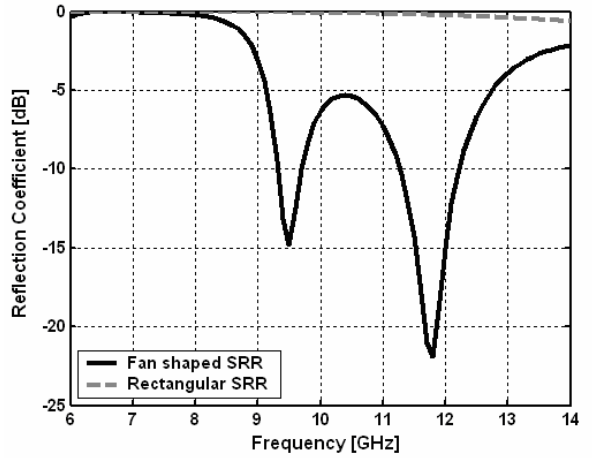

Fig.4 The simulated reflection coefficient of rectangular SRR and fan shaped SRR metamaterial absorber for cross-polarized wave.

Another advantage of the fan shaped is it can satisfy the electromagnetic absorption for either co polarized and cross polarized wave. For confirming of this point, the simulated reflection coefficients of both aforementioned absorbers assuming a cross polarized incident wave are shown in Figure 4. As shown in the figure, the fan shaped metamaterial absorber can demonstrate almost the same absorption for the two possible cases of co polarized and cross polarized electric field incidence. On contrast to fan shaped case, the conventional rectangular SRR failed to demonstrate any small reflection coefficient over the frequency band of interest as it is nearly 0 dB.

4. Conclusion

A new wide and multi band metamaterial radar absorber material using new type of split ring resonator, called fan shaped SRR, has been proposed. The performance of the proposed absorber was investigated and compared versus the conventional rectangular SRR absorber. The results confirm that the proposed new metamaterial absorber can introduce wide and multiple bands compared to rectangular SRR. The increase in the bandwidth reaches almost eight times the rectangular SRR absorber. Also, the proposed fan shaped absorber can sustain its performance for both co polarized and cross polarized waves. The absorber have achieved almost -20 dB reflection coefficient at center frequency.

References

[1] R. M. Fano, “Theoretical limitations on the broadband matching of arbitrary impedances,” J. Franklin Inst., vol. 249, no. 1–2, pp. 57–83,Jan 1950, 139–154.

[2] Du Toit, L.J.: ‘The design of Jauman absorbers’, IEEE Antennas Propag.Mag., 1994, 36, (6), pp. 17–25.

[3] D.Schurig, J.J.Mock, and D.R.Smith, “Electric-field-coupled resonators for negative permittivity metamaterials” Appl. Phys. Lett. 88, 041109 (2006)

[4] J. Zhang and Z. R. Hu, "A Novel Broadband Metamaterial Resonator with Negative Permittivity", PIERS Proceedings, Xi'an, China, March, 2010, pp/ 1346-1348

[5] Alireza Kazemzadeh and Anders Karlsson, “On the Absorption Mechanism of Ultra Thin Absorbers," IEEE Trans. Antennas Propag., 2101, VOL. 58, NO. 10, pp 3310-3315.

[6] Zhongxiang Shen and Hang Wang "On the optimum design of a thin absorbing screen", in Proc, Antennas and Propagation Society International Symposium, 2007 pp: 6039 – 6042.

[7] G. V. Eleftheriades and K. G. Balmain, Negative Refractive Metamaterials. New Jersey: John Wiey & Sons, 2005