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DESIGN OF NOVEL MULTIBAND RADAR ABSORBERS USING CYLINDRICAL FREQUENCY SELECTIVE SURFACES

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Abstract

In this paper, a novel ultra-thin and multi-band radar absorber structure using cylindrical frequency selective surfaces (FSS) is proposed. The unit cell of the structure consists of a curved square ring printed on a cylindrical dielectric spacer to realize strong resonance to achieve efficient absorption of the incident microwave energy. The use of novel cylindrical FSS coating results in a considerable decrease of the radar cross section of a perfect electric cylinder. Furthermore, our studies prove that the proposed absorbing structure can be easily scaled to desired frequencies, and extension to dual- and multiband performances is possible. Meanwhile, the operational principle of the proposed absorbers is briefly introduced.

Key words: frequency selective surface, absorber, wideband, conformal.

1. Introduction

The study of radar absorbers has attracted increasing attention over the years. The use of absorbers in various applications to hide objects from radar has been common since the past years.Salisbury and Jaumann screens are the oldest and simplest types of radar absorbers [1-6]. Recently, the use of metamaterial structures and frequency selective surfaces (FSS) as microwave absorbers has attracted considerable attentions to enhance their performance by adjusting the refraction index and impedance of the metamaterial to maximize the metamaterial losses and realize strong absorption [7-13]. Such absorbers utilize artificial structures with dimensions much smaller than the operation wavelength to get high absorption and exhibit attractive features, such as flexible design option, small and light structures**.** Various methods have been introduced to obtain wide and multi-band absorbers. So that both single-layer structures and multi-layer structures have been reported, each of which has its own advantages and disadvantages. [14-23].

The study of radar absorbers using planar FSS and metamaterials has been widely discussed in the literature, but the design of radar absorbers using cylindrical FSS structures is an almost untouched topic in such electromagnetic problems. This letter presents the design and simulation of single and multi-band cylindrical radar absorbers.

2. Absorber Configuration

The proposed cylindrical radar absorber structure comprises a single-layer FSS in the form of curved square metallic rings, an ultra-thin dielectric spacer, and a perfect electric conductor (PEC) cylinder with radius 19.5 mm. The absorber is a curved periodic structure. The parameters of a unit cell are shown in Fig. 1 (a). The rings are made of tantalum nitride material (σ = 7400 S/m) with a thickness of 0.02 mm separated from the PEC cylinder by a foam material with thickness 2 mm, which has air-like permittivity and permeability.

The physical mechanism of operation of the radar absorbing materials may be described as follows. In the case of common absorbers, such as Jaumann and Salisbury screens, the resistive plate above the ground plane should be placed at a distance of above the ground, since the impedance seen towards the ground at the bottom of resistive plate becomes infinity and the impedance at the top of plate is equal to that of the plate, which should be equal to that of free space for matched conditions. However, for the design of radar absorbers using FSS structures, which generate capacitances and inductance together with resistors, the distance between the plate and ground need not be equal to (Fig. 2). The reason is that the reactance at the bottom of FSS plate towards the ground (Zd) may be cancelled by those of FSS. Therefore, the impedance at the top of FSS plate (ZR) will become real. Consequently, the parameters of the structure may be determined in such a way that the resistance ZR become equal to that of free space. As a result, perfect matching conditions may be achieved so that the waves enter FSS and become dissipated in it.

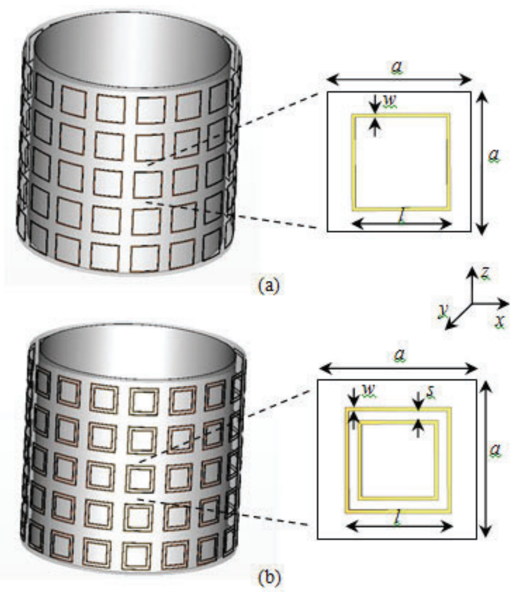

Fig. 1: The Geometry of (a) single band, and (b) dual-band cylindrical absorber structure. (a = 8mm, l = 5.7 mm, w = 0.2 mm, s = 0.5 mm).

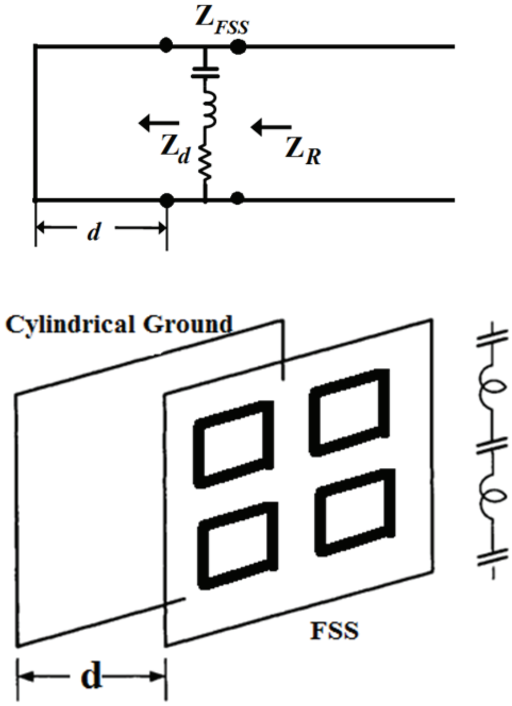

Fig. 2: Simulated monostatic RCS of the proposed single and dual-band cylindrical absorbers.

3. Discussion

The cylindrical FSS used in the proposed absorber is a periodic structure which can be idealized as infinitely long and analysed by commercial simulators. We performed computer simulations of the absorber using the CST Microwave Studio. A periodic boundary condition is set in the z directions, and an open boundary is defined in the x and y directions for the electromagnetic wave normal incidence.

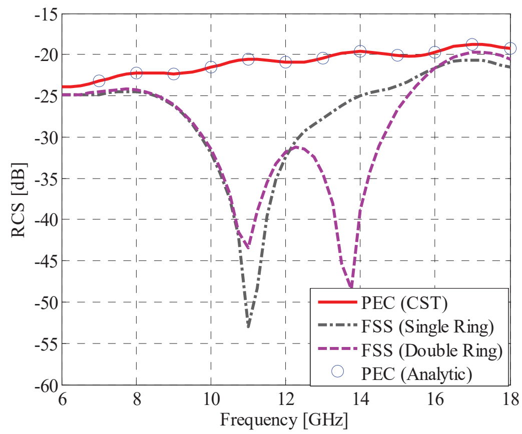

Fig. 3: Simulated monostatic RCS of the proposed single and dual-band cylindrical absorbers.

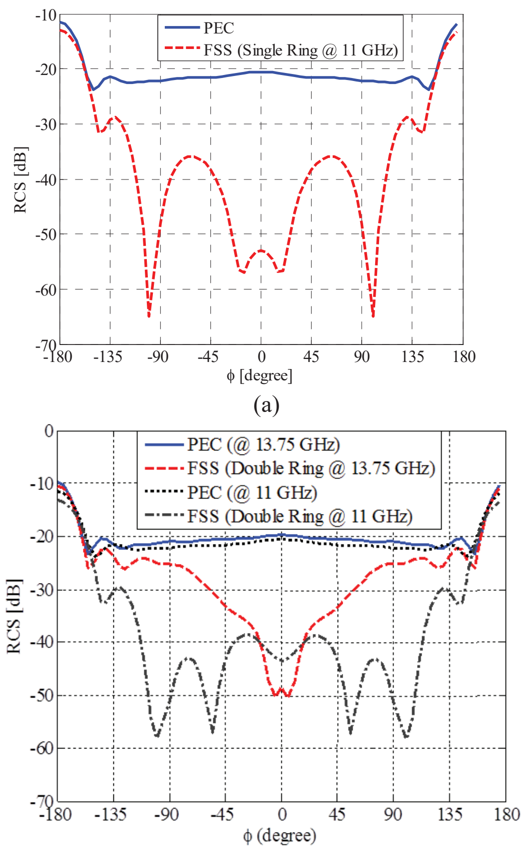

Fig. 4: Bistatic RCS of coated PEC cylinder at the resonant frequencies of (a) single band, and (b) dual-band absorbers.

In order to ensure the accuracy of CST results, the analytic RCS of PEC cylinder is compared with them in Fig. 3. Also, the simulated monostatic RCS of the coated cylinder by the proposed absorber based on single ring FSS structure for normal incidence ($\theta = 90°$ and $\varphi = 0°$) is given in Fig. 3. Observe that there is a resonance at 11 GHz, at which the RCS reduction level is almost 32 dB that is very significant.

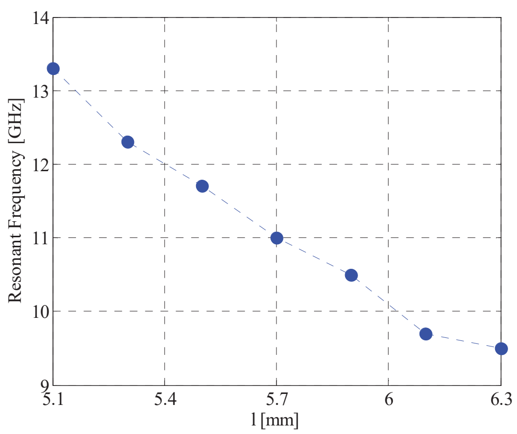

Fig. 5: The variations of resonant frequency of single band cylindrical absorber with parameter *l*.

Further studies show that by the extension of proposed structure, the realization of multiband cylindrical absorber is possible. For instance, the layout of a dual-band cylindrical absorber structure is shown in Fig. 1(b). Its unit cell consists of sets of concentric curved metallic rings with different dimensions. Every ring responds to one resonant frequency and is almost independent of others. The numerical simulations of the structure are performed in a frequency range of 6-18 GHz, and the results are presented in Fig. 3. It is seen that this structure has two resonant frequencies at 11 and 13.75 GHz, which achieve RCS reduction levels of almost 23 dB and 30 dB, respectively. Figure 4 shows the bistatic RCS of coated PEC cylinder at the resonant frequencies of the proposed single and dual-band absorbers. Observe that the performance of absorbers at the resonant frequencies is excellent.

As an interesting and applicable property of the proposed single band absorber, the dimensions of rings can be changed to adjust the resonant frequency. The variations of resonant frequency with parameter l are presented in Fig. 5. Observe that, by its variation from 5.1 to 6.7 mm, the resonant frequency changes from 6.4 to 9.5 GHz. The presented curves can be used to design desired absorbers.

(5). Conclusions

In summary, we have designed a radar absorber structure using a novel cylindrical FSS. The results show that the single band absorber structure can be used to decrease the RCS of a PEC cylinder in an adjustable frequency band. Afterwards, by extension to a dual-band structure, a dual-band radar absorber structure was obtained, and its performance was investigated. The proposed radar absorber structures can be scaled to other frequencies. In the future, it is expected to use this design to realize ultra-wideband cylindrical radar absorber structures.

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