Design of broadband microwave absorber utilizing FSS screen constructed with coupling configurations

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Abstract

The design of a frequency selective surface (FSS) screen constructed using a coupling configuration to implement a broadband microwave absorber is presented in this paper. The reflectivity representation recognizes the characterization of the absorber. Simulation and measurement results are presented and analyzed. A coupling FSS screen is introduced in order to obtain a better bandwidth and absorption. The bandwidth with the reflectivity below -10dB could get 5.45-18GHz, compared with the 6.28-18GHz of the absorber with square patches FSS, provided that the thickness of the absorber is 4mm.

1. Introduction

Microwave absorber is a kind of function material that can be used in stealth technology. The applications in areocraft such as battleplan and missile determine that the absorber must have broadband wave absorbing performance to reduce the probability of being explored. As a potential candidate of high performance wave absorber, the researches of the metamaterial absorber are mostly concentrating on the perfect and multi-bands absorption [1-5]. Usually the Jaumann screen and lossy frequency selective surface (FSS) could realize broadband radar absorber [6-9]. Because of the egregious thickness of the Jaumann screen [6], lossy FSS absorber, which is consist of resistive FSS and dielectric substrate, is the best choice of the broadband absorber [9].

The main means of study the FSS absorber are numeric method and equivalent circuit method [9-10], also some optimization method is necessary due to the parameters determining the wave absorbing performance [11-12]. As to the single layer lossy FSS absorber, broadband wave absorbing performance can be realized through any FSS patterns [8-9]. But the optimal bandwidths of the familiar FSS absorbers have not been reported up to now. On the other hand, unlike the numerous FSS patterns designed in the HIP (high impedance surface) field [13-16], the FSS patterns reported in the lossy FSS absorber by far are simple, such as square patch, crisscross, and ring, whose impedance are represented by series RLC circuit [9]. In this letter, based on the optimized results of the conventional absorber, we report a broadband lossy FSS absorber using crisscross and fractal square patch to form a compact single particle. The reflectivity of the absorber exhibits three apexes in the frequency range of 2-18GHz. Moreover, owing to symmetry geometry, the absorber is independent on the polarization of an incident wave.

2. Design

On the basis of the conventional square patches shape, a complex and coupling FSS structure is presented, as shown in Figure 1 (b).

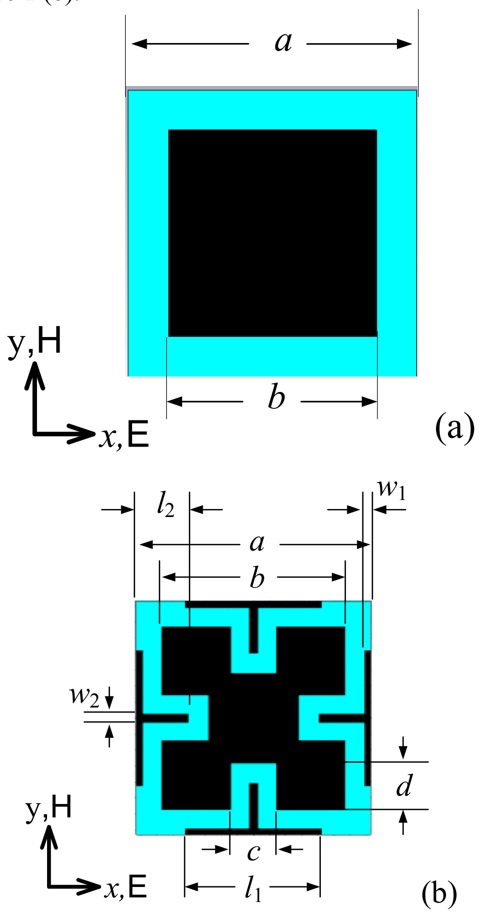


Figure.1 FSS screen of the absorber. The black represents the FSS and the blue indicates the dielectric substrate.

Compared with the square patches, the coupling structure has more optimizing parameters. The reflectivity properties, optimized by GA, are proposed for the coupling FSS absorbers and those of the square patches FSS absorber are also proposed for comparison, as shown in Figure 2. The results shown in Figure 2 indicate that the bandwidth is improved by using coupling FSS structure and there are three reflectivity nulls in the considerable frequency range.

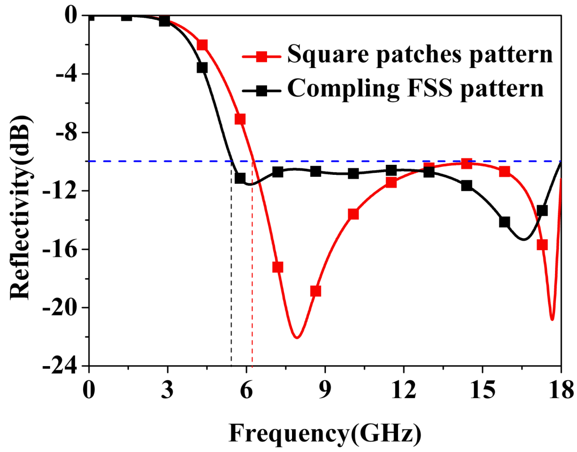
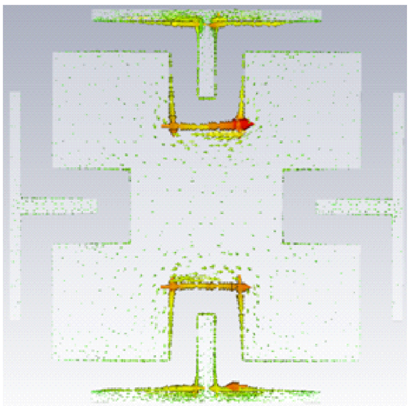
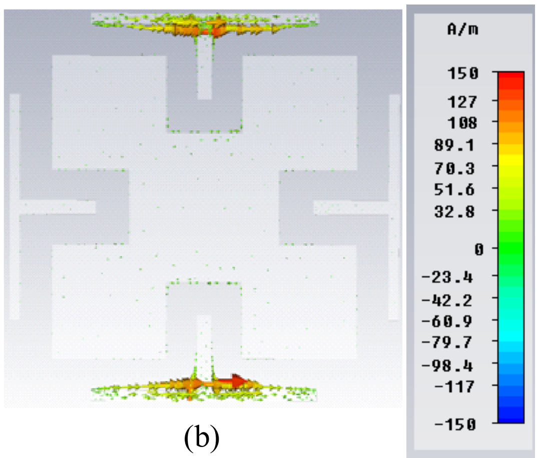


Figure 2: Modeled reflectivity of the absorber with different FSS pattern.

To get an insight into the origin of the bandwidth broadening, we monitor the surface current densities on the coupling FSS at resonance frequencies as shown in Figure 3.



(a)



(b)

Figure 3: Distribution of the surface currents on the FSS at the resonance frequencies

The current distribution shown in Figure 3 indicates that there are two resonances in the coupling FSS, one of which is due to the coupling between the crisscross and the fractal square patch along the magnetic field direction. The other occurs between the adjacent unit cells along the electric field direction. We can predict that the double resonances are the main factors bringing the broadening of the bandwidth.

The optimized parameters of the absorbers are list in Table.1.

Table.1 Optimized parameters of the designed absorber

FSS shape	*a* (mm)	*b* (mm)	*c* (mm)	*d* (mm)	l_1 (mm)	l_2 (mm)	w_1 (mm)	w_2 (mm)	ε_r	*Rs* (Ω/□)
Square patches	13.7	10.3	/	/	/	/	/	/	1.8	99.8
Coupling FSS	17.8	13.9	3.6	3.8	11.4	4.8	0.45	1	1	29.7

3. Experiment and Result

The feasibility of the broadband absorber was demonstrated by experimental prototype. The resistive patterns representing the lossy FSS have been manufactured by the silk printing technique through a photo etched frame. The commercial rigid polyurethane foam was used as the dielectric substrate. The pictures of 180mm×180mm broadband sample is shown in Figure 4

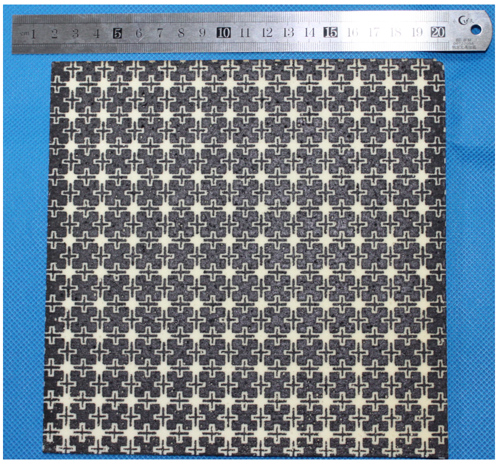


Figure 4: Fabricated sample of the 4mm broadband lossy FSS absorber

We verified the absorption performance of the broadband absorber in a microwave anechoic chamber. An Agilent 8720ET vector analyzer and two broadband double-ridged horn antennas are used to emit and receive the EM wave. Owing to the metal ground plane, the transmission is zero and the reflectivity represents the absorption. The measured reflectivity, compared with simulated result, is plotted in Figure 5

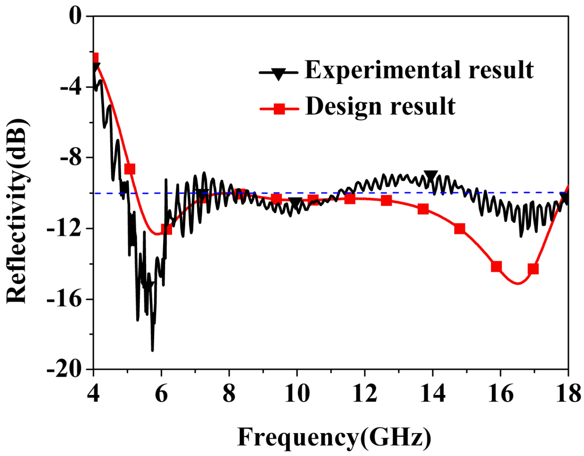


Figure 5: Comparison of the reflectivity of the broadband absorber between experimental (black curve) and simulated (red curve) results

Three absorption nulls exist in the considerable frequency range, which is consistent with the design result. The difference of the absorption intensity between the experiment and design is reasonably ascribed to the fabrication tolerances, such as the square resistance deviation of the lossy FSS. Both the simulation and experimental results indicate that the coupling in the FSS unit cell induces the absorption null in the low frequency, and lead to the enhancement of the bandwidth of the absorber.

In conclusion, a broadband metamaterial absorber with coupling FSS was design and fabricated. The design and experimental results show that the bandwidth with the reflectivity below -10dB of the 4mm thick absorber can get 5.27-18GHz, which is broader than 6.28-18GHz of the corresponding absorber with square FSS pattern.

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