Design of A Wave-absorbing Frequency Selective Surface Unit

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Abstract—**In this paper, a wave-absorbing frequency selective surface (AFSS) with low frequency transmission/high frequency absorption is proposed. By reducing the RCS of the antenna system without affecting the radiation performance, the radar stealth effect can be improved. This unit adopts the method of proportionally loading the frequency selection structure on the metal reflection surface of the absorber unit, so that it has a frequency selection function without affecting the effect of the microwave absorption.**

Keywords—wave-absorbing frequency selective surface; RCS reduction; Radar Stealth; Absorber

I. Introduction

At present, the major measure to make radar system achieve frequency domain stealth is loading frequency selective surface on the radome, by reflecting the radar incident waves from the main threat direction to other directions, the antenna system can effectively achieve stealth in the face of single-base radar detection. However, this stealth pattern cannot realize all-round invisibility, and it may have a large RCS increase from some perspectives. during flight, a strong backscatter formed behind the nose cone of the aircraft. Which is the main area of radar detection, and the radar antenna system of the aircraft is one of the main scattering sources in this direction. Therefore, it is high time to reduce the RCS of the radar antenna system. The anti-stealth technology for defect of this stealth technology has been developed and a wave-absorbing frequency selective surface with inband transmission/out band absorption is one of them, but there are certain problems. Such as the insertion loss of the transmission band is too large, the transition band between the transmission band and the absorption band is too wide, and the narrow absorption bandwidth and poor absorption effect.

The wave-absorbing frequency selective surface proposed in this paper can transmit wave in 1GHz bandwidth, and absorb wave more than 10dB strong in the 4GHz-13.5GHz wide band, it performs well both in the receiving mode and the transmission mode and effectively reduces the RCS. Therefore, it has certain research significance.

II. Antenna Design And Working Principle

Since the wave-transmission band and the wave-absorbing band are not coincident in the frequency domain, the periodicity of the structure units of the layers resonating in different bands are generally inconsistent. To perform numerical simulation analysis on the AFSS unit, the unit period of each layer must be proportional, that is, the size ratio is a rational number. The ratio of period of the impedance surface in the AFSS unit designed in this paper and the bandpass FSS unit is 4:1. Figure 1 is the unit decomposition diagram. The master-slave boundary condition is set in the X and Y directions, and the Floquet port excitation is set in the Z direction to simulate the transmission and absorption characteristics of an infinite AFSS plane wave illumination. The structural parameters of antenna are shown in Table 1.

TABLE I. Parameters Of The Antenna Element

Parameters	***mm***	**Parameters**	***mm***
R_1	38	a_1	17
R_2	37	a_2	7
d	6	h	8
A	92	ε	2.65(No unit)

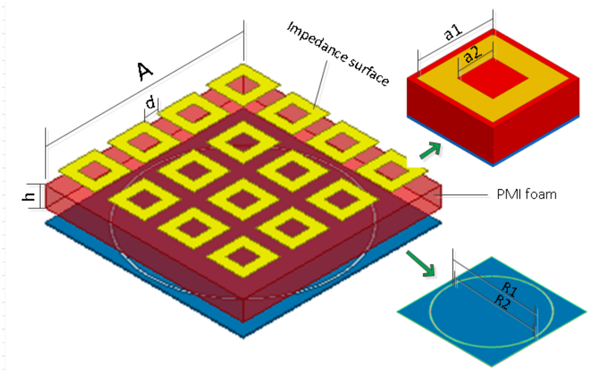


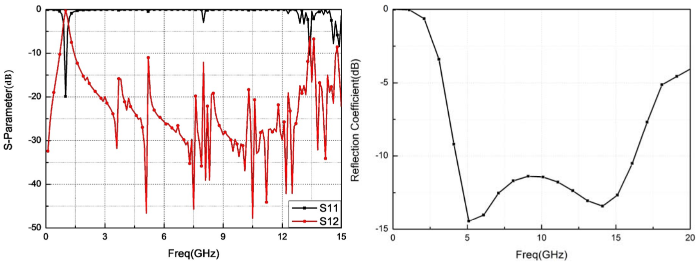
Fig. 1. The AFSS unit model.

The lower right corner of Fig. 1 is the absorber structure which composed of a resistive film pattern, the dielectric substrate in the middle layer and the metal floor. The structure size of the absorber is obtained by calculation, and the calculation result is basically consistent with the simulation result.

The lower left corner shows the frequency selection structure, using an aperture bandpass structure and the dielectric constant of the dielectric plate is 2.65. The reason why use an aperture-type ring unit is to achieve efficient transmission of intraband signals and total reflection of outband electromagnetic waves. The resonant wavelength of the ring is approximately the circumference of the ring. This structure makes the array more compact, has better polarization characteristics and incident angle stability.

III. SIMULATION RESULTS

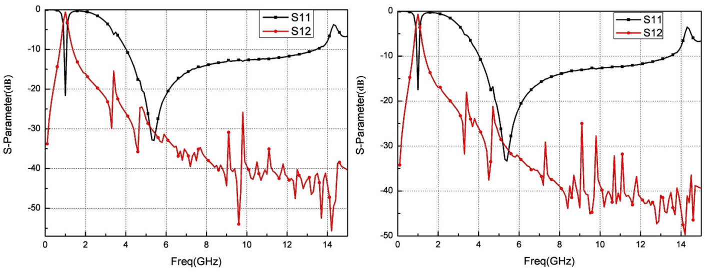
Simulation results of the frequency selective surface are shown in Figure 2(a). The bandpass FSS has an insertion loss of only 0.14dB in the 1GHz transmission band, its reflection coefficient is close to 1 in the 3-15GHz wide band, and the reflection phase is also substantially the same as the metal plane, so the bandpass FSS can be used as the metal ground plane of the absorber due to its 2-15GHz wide impedance band. The simulation result of the absorber structure unit shown as Fig. 2(b), the absorption effect is over 10dB in the wide band 4.15GHz-16.25GHz, and the absorption performance is good.



(a) (b)

Fig. 2. The component simulation results: (a)Simulation result of the frequency selective surface, (b)Simulation result of the absorber.

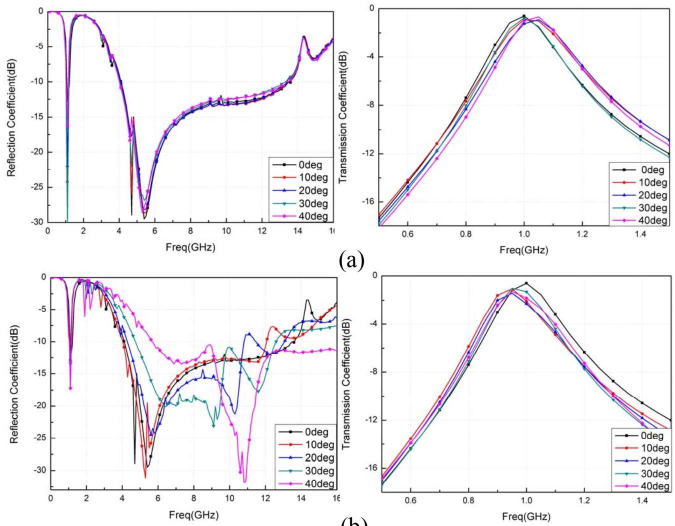
The result of complete unit are as follows: Under vertical incidence conditions, Fig. 3 shows the simulation results of the reflection and transmission coefficients of the AFSS in transmit mode and receive mode. The transmission mode has a transmission loss of 0.64 dB at 1 GHz, and it has a good transmission effect; at least 10 dB B can be achieved within a wide frequency range of 4-13.5 GHz.



(a) (b)

Fig. 3. The simulation results of the AFSS unit under vertical incidence conditions: (a) In transmiting mode, (b) In receiving mode.

The simulation results of the refection and transmission characteristics of the AFSS only in transmit mode under oblique incidence conditions are as Fig. 4 shows. For the absorption performance, the absorption effect is almost keep constant under TE polarization condition. Under the condition of TM polarization, the absorption bandwidth becomes narrower and the in-band absorption performance deteriorates. For the transmission performance, the insertion loss does not change much and the wave transmission is good. The difference in absorbing and transmitting performance under different polarization conditions is mainly because that the direction of the electric field is always parallel to the surface of the AFSS when the TE polarization is obliquely incident, and the angle between the electric field direction and the AFSS surface increases with the incident angle in TM polarization. Therefore, out-band absorption and in-band loss under TE polarization are greater than TM polarization. In general, compared to the existing research results, the insertion loss of the transmission band in this structure is less than 0.8dB, the absorption bandwidth increases about 3GHz, the stability under the oblique incident condition is obviously promoted, and the transmission effect is good. Absorption bandwidth can be widened around 3GHz and absorbing effect is good.



(b)

Fig. 4. The simulation results of the AFSS unit under oblique conditions: (a)TE polarizatoin, (b) TM polarization.

IV. CONCLUSION

In this paper, a wave-absorbing frequency selective surface (AFSS) with low frequency transmission/high frequency absorption is proposed. It can realize 1 GHz wave transmission and has more than 10dB wave absorbing effect in 4 GHz-13.5 GHz wide band, reducing RCS a lot. Since this work has simulated the transmission and absorption characteristics of the infinite AFSS under plane wave illumination, then it can be directly extended to the surface radome under normal incidence and applied to the project.

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