A Tunable Microwave Absorber Based on Active Frequency Selective Surface

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Abstract— A novel microwave absorber is presented in this paper. The absorber is a single layer structure based on the topology of a Salisbury screen, but in which the conventional resistive layer is replaced by an active frequency selective surface (AFSS) controlled by PIN diodes. The reflectivity response of the tunable microwave absorber can be controlling by adjusting the current in PIN diodes. Experimental results are presented and prove the working mechanism of the new absorber, which show that the reflectivity response can be modulated over the frequency band from 10 GHz to 12 GHz.

1. INTRODUCTION

Stealth technology is one of the most important military technologies concerned by all the nations. Its essence is reducing radar cross section [1] (RCS) of targets. Radar absorbing materials (RAM) is the primary method of RCS reduction.

In the 1930s, there had been RAM that was used in the antenna field. After 1950s, there had been Salisbury screen [2], Dallenbach and Jaumann absorber [3] with fast development of radar technology. Passive radar absorbing material, once designed and manufactured, has fixed characteristics. If the environment of the battlefield changes the absorbing property of RAM is declined.

The tunable microwave absorber could control its reflectivity response according to threatened frequency, in order to obtain the optimal absorbing capability at its threatened frequency. In the 1990s, E. A. Parker [4] presented that the active frequency selective surface (FSS) was made by placing PIN diodes on the FSS, and the response of the active FSS could be controlled by adjusting the bias voltage or current in PIN diodes. In 2004, Barry Chambers and Alan Tennant [5] designed a single-layer tunable microwave absorber using an active FSS. Measured results proved that this absorber did well in 9–13 GHz, and the reflective response could be adjusted.

In this paper, a sample of tunable microwave absorber was designed and manufactured. At last, several microwave absorbers were optimized by genetic algorithm.

2. CONSTRUCTION

Passive radar absorbing structure involved Salisbury screen and Jaumann absorber. The tunable microwave absorber was developed based on them. The tunable absorber based on Salisbury screen was chosen through integrated advisement. Circuit analog (CA) absorber is made by adding reactance into the resistance layer of Salisbury screen. If the resistance or reactance of circuit analog absorber could be adjusted by the electricity, the tunable microwave absorber comes into being.

The tunable microwave absorber is made up of conducting plate, dielectric spacer and impedance sheet as shown schematically in Fig. 1(a). According to transmission line algorithm, the new absorber is equivalent to Fig. 1(b).

In Fig. 1(b), impedance sheet is replaced by resistance (R) and reactance (jX). So there are three methods for tuning impedance:

(1) X fixed, R adjusted. Loading PIN diodes on FSS array, R could be controlled by adjusting the current in PIN diodes.
(2) R fixed, X adjusted. Loading varactors on FSS array, X could be controlled by adjusting the voltage between varactors.
(3) R and X adjusted.

In this paper, we choose an impedance sheet scheme that combines FSS and PIN diodes. The resistance of PIN diode could be tuned by adjusting the current in PIN diode, so that the whole impedance of the sheet is controlled by this way. In addition, the response time of PIN diode is several nanoseconds.

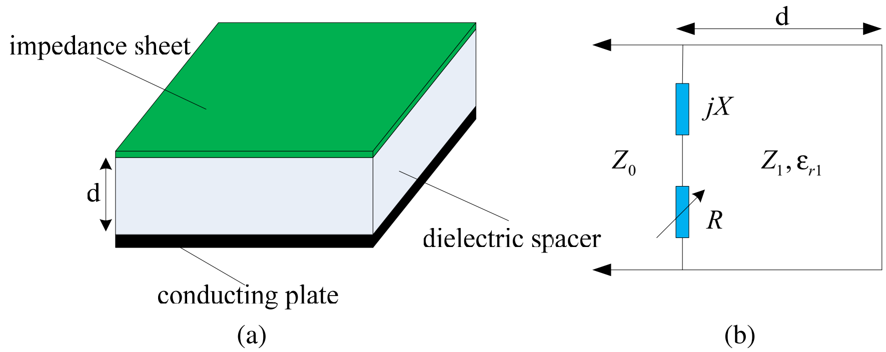

Figure 1: The tunable absorber construction and transmission line equivalent circuit model.

3. EXPERIMENTAL INVESTIGATIONS

In Fig. 2, a square ring FSS is designed to achieve a wide absorbing band, and there is a bias line between every two elements. Active control is achieved by loading a PIN diode on every leg of every element in vertical direction. To let the control current flow in the diodes, the elements are connected in parallel. In Fig. 2, the detail of an element is listed that the period is 9.44 mm, the gap between two elements is 2.76 mm, and the width of slot is 0.5 mm.

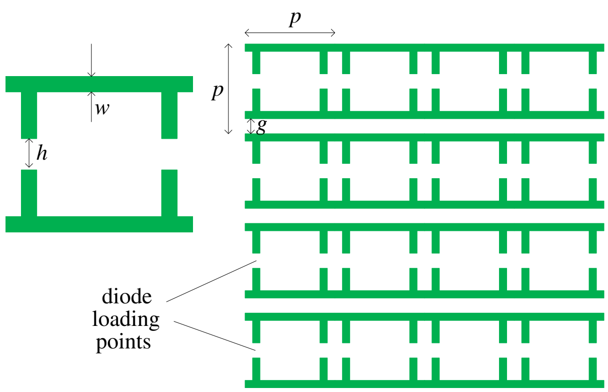

Figure 2: The geometry of FSS array.

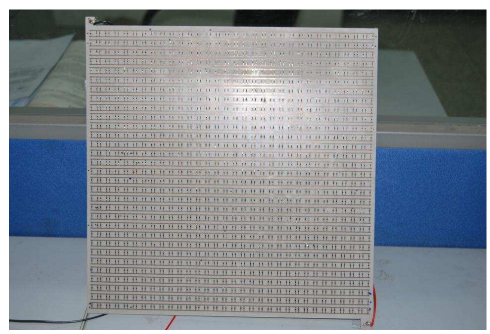

Figure 3: Manufacture of the active board.

Based on the design in Fig. 2, an active FSS is manufactured on a 1.5 mm thick dielectric board, the permittivity of which is 3.5. The board (Fig. 3) measures 300 mm by 300 mm and contains 1922 dipole elements which are loaded with commercially available surface-mount pin diodes using hand-soldering techniques.

A tunable microwave absorber is constructed by mounting the active FSS above a conducting back-plane using a 3 mm thick, foam dielectric spacer as shown in Fig. 1. The circuit surface of the board is lay downwards so that the diodes could be embedded into the foam spacer by a pressure, as a result that overall thickness is less than 5.0 mm.

The reflectivity of the absorber was measured over the frequency range of 6–18 GHz for various bias currents, and these data are presented in Fig. 4. For an applied bias current (0.02 A) the absorber is strongly reflecting. However, as the bias current is increased the reflectivity level reduces and the response frequency debases, showing a 2 GHz reflectivity bandwidth below −15 dB.

4. OPTIMIZATION

The design of tunable microwave absorber is an optimal problem. The reflectivity is a function of material parameter, thick of the spacer, shape and size of FSS element. The final intention of optimization is to search the optimal solution of all the parameters.

Genetic algorithm [6, 7] is used to an optimizing program for designing tunable microwave absorber. Applying this optimizing program, several tunable absorbers were designed. In this paper, a dual polarization tunable microwave absorber is presented. The element is cross dipole in order to achieve a dual polarization. In Fig. 5, the simulated results proved that the reflectivity response was

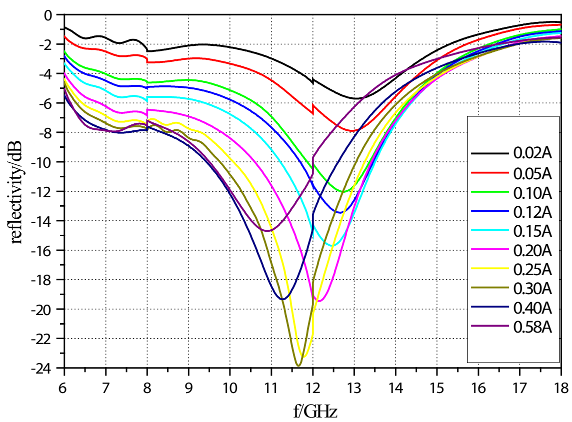

Figure 4: Measured data of the tunable absorber as various currents.

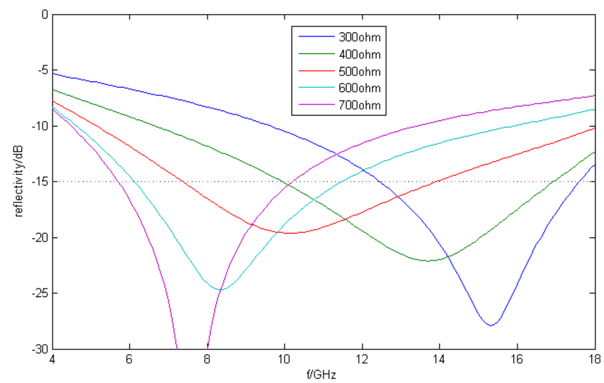

Figure 5: The simulated data of optimal result.

moved with the various resistances of the PIN diodes. From 5.6 GHz to 17.6 GHz, the reflectivity was below −15 dB, so that the absorber could achieve a 12 GHz bandwidth.

5. CONCLUSION

A new tunable microwave absorber which contains an active FSS layer has been presented. The active FSS is manufactured by loading PIN diodes onto the FSS array.

Measured data show that the absorber can be tuned to provide a variable reflectivity response over a band of frequencies from 10.6 to 12.6 GHz. A bias circuit was designed so that the PIN diodes were connected in parallel. In addition, the absorbing structure has a low weight and a thin thickness. At last, a dual polarization tunable absorber is optimized out by genetic algorithm with a 12 GHz bandwidth. And it provides an approach for a broadband, dual polarization and strongly absorbed RAM.

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