

Experimental Investigation of 2-bit Active Frequency Selective Surface

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Abstract – A 2-bit active frequency selective surface (AFSS) is designed, fabricated and measured in this paper. This FSS structure loaded PIN diodes and biasing lines are designed carefully to realize four switchable states (2-bit): both TE polarization & TM polarization band-pass filter for code 00; TE band-pass filter or polarizer for code 01; TM band-pass filter or polarizer for code 10; both TE & TM reject for code 11. A finite AFSS prototype is manufactured and tested in a microwave anechoic chamber, which measured results show good performance realization and angle stability at 2.6GHz.

Index Terms — Active frequency selective surface, PIN diode, switchable, frequency selective surface.

1. Introduction

Frequency Selective Surfaces (FSSs) are spatial electromagnetic (EM) filter constituted by periodic metallic patch or aperture to transmit desired frequency signals and reflect the undesired [1]. A passive FSS (PFSS) has some limits because it offers no flexibility once fabricated, whereas an Active FSS (AFSS) allows the potentiality of control by changing the behavior of the surfaces [2-4].

In recent years, the ideas of coding, digital, programmable or multi-bit were proposed in fields of meta-material, meta-surface and other artificial electromagnetic periodic structure [5, 6]. If the coding idea is introduced into the AFSS, then a multi-functional AFSS can be realized, which can expand the applications of usual AFSSs.

In this paper, a real 2-bit switchable AFSS is presented, which has four working states: dual-polarization band-pass, TE polarizer, TM polarizer and dual-polarization shielding. This design shows potential applications on intelligent EMC, smart stealth radome, multiplex polarizers, EM architecture of buildings (EAoB) and so on.

2. Design and Fabrication of the AFSS

(1) Topological Structure of the AFSS Model

This 2-bit AFSS model is shown in Fig.1, consisting of one layer F4B-2 substrate with relative permittivity 2.65 and loss tangent 0.001 and thickness 1mm, and two orthogonal layers of meander metallic lines on two sides of the substrate. The dimensions of the unit cell specified in Fig.2 are $U=60\text{mm}$, $L=17.6\text{mm}$, $w=2.6\text{mm}$, and $g=1.5\text{mm}$.

Fig.1 also shows the PIN diodes arrangement and feeder topology of the 2-bit switchable AFSS. The PINs are distributed at intervals inside the elements, not each unit, for saving PINs. There are total four external feeder lines

numbered ①-④, which can form four types of combination: the first one is that ①-④ are all no biased so all PINs are OFF, which is Code-00; the second one is that ① provides positive voltage while ②③④ are all GND, so only PINs on the top layer are ON, which is Code-10; the third one is that ② provides positive voltage while ①③④ are GND, so only PINs on the bottom layer are ON, which is Code-01; the fourth one is that ①② give positive voltage while ③④ are GND so all PINs are ON, which is Code-11.

(2) Finite AFSS Prototype Manufacturing

The periodic boundary condition (PBC) was used in simulation to realize perfect infinite FSS. However, finite arrays are the only ones that really exist. Fig. 3(a) and (b) show the finite AFSS sample with 10×10 elements on each layer and overall dimension of $320\text{mm} \times 320\text{mm}$. The PIN diodes HSMP3862 from Avago Company are employed as RF switches with low resistance when forward biased and relative cheap price. The amount of PINs used in this sample is 290, which is bearable within the manufacturing cost range. This sample was produced by normal PCB technology and the PINs were welded onto the surface manually.

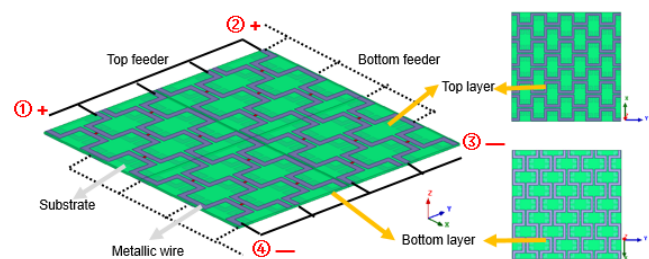


Fig. 1. 2-bit AFSS model with PINs and additional feeder.

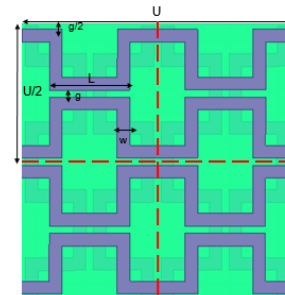


Fig. 2. The parameters of the FSS element.

3. Experimental Measurement and Results Analysis

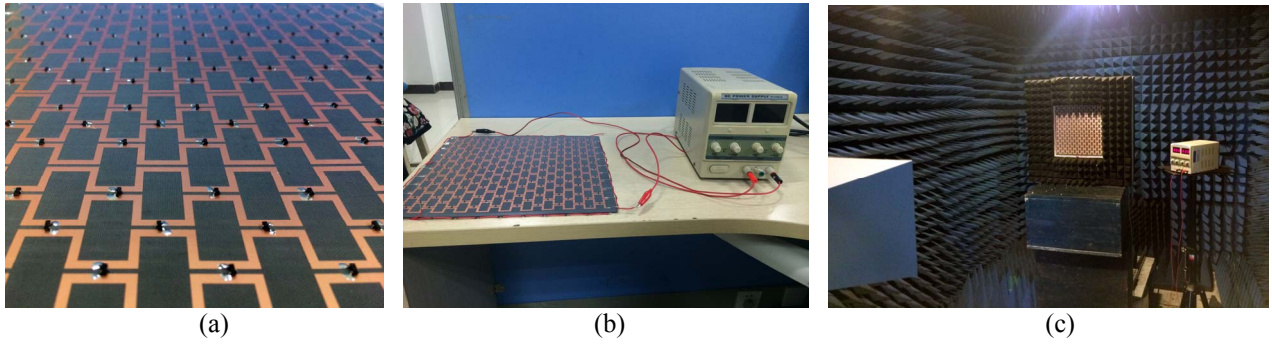


Fig. 3. The photos of (a) the AFSS prototype, (b) the biasing method and (c) the measurement setup for the AFSS

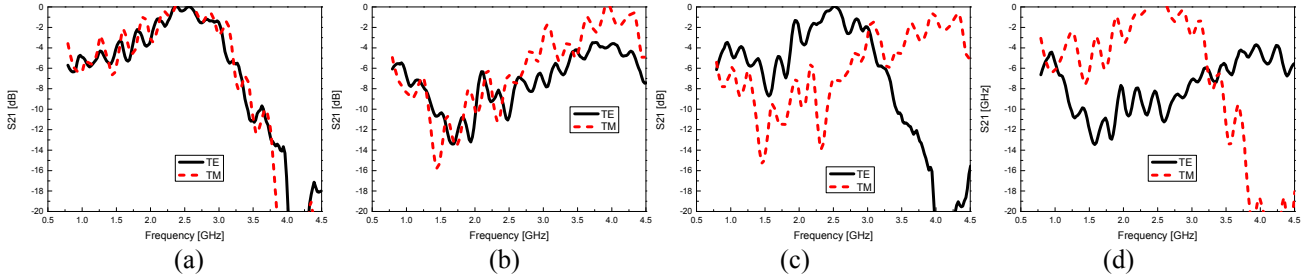


Fig. 4. Transmission coefficient of 2-bit AFSS under normal incidence, (a) “00” (OFF-OFF) state; (b) “11” (ON-ON) state; (c) “01” (OFF-ON) state; (d) “10” (ON-OFF) state.

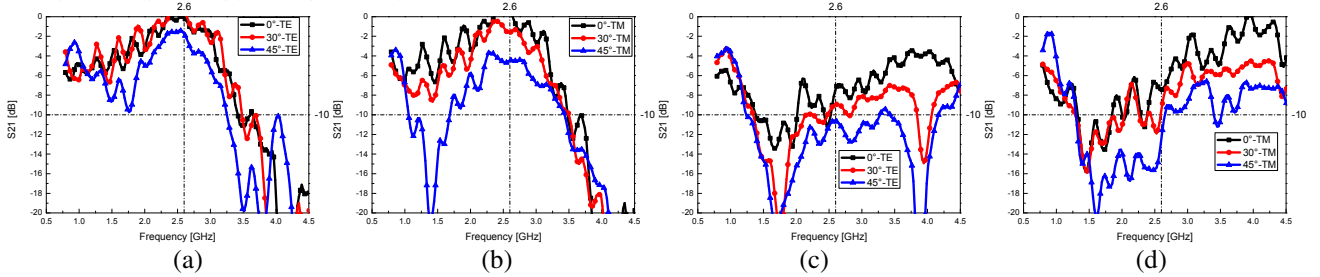


Fig. 5. The angle stability of 2-bit AFSS, (a) “00” (OFF-OFF) state of TE polarization; (b) “00” (OFF-OFF) state of TM polarization; (c) “11” (ON-ON) state of TE polarization; (d) “11” (ON-ON) state of TM polarization.

The measurement is carried out in a microwave anechoic chamber using two horn antennas (0.8-6GHz) system, which two antennas connected by an Agilent N5230C vector network analyzer (VNA), shown in Fig. 3(c). Considering the problem of background noise and normalization, two steps for the calibration are necessarily implemented: firstly, the transmission coefficient T_0 (dB) are measured without FSS; then transmission coefficient T_1 (dB) are measured with FSS. In the end, the transmission characteristic T (dB) of FSS can be calculated by $T = T_1 - T_0$.

A DC stabilized voltage source is used to provide bias voltage onto the AFSS. With no voltage, PIN diodes are at OFF state. When the voltage is 3.3V, the diodes are turned ON. The measured transmission coefficient under normal incidence are listed in Fig.4. For code-00, this surface is a dual-polarization band-pass filter near 2.6GHz; for code-11, this surface is transformed to dual-polarization shielding near 2.6GHz. For code-01 and code-10, this surface is TE selector (polarizer) and TM selector (polarizer), respectively. The measured transmission characteristic of the proposed structure under oblique incidence angles are depicted in Fig.5, which has displayed good angle stability till 45°.

4. Conclusion

In this paper, an experimental investigation of 2-bit AFSS with four switch modes is described, the 2-bit characteristic can be realized by appropriate structure and PINs and bias

method. The measured results have shown the preliminary 2-bit realization and good angle stability.

Acknowledgment

This work is supported by Jiangsu Industry-university-research cooperation innovation project under grant BY2014003-10 and Nanjing Industry-university-research cooperation innovation project under grant No.NBG0030113-1 and Natural Science Foundation of China under grant No. 61401199.

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