

A Novel Frequency Selective Surface for Ultra Wideband Antenna Performance Improvement

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Abstract- A novel frequency selective surface (FSS) is proposed in this paper. The FSS has four layers on both sides of two separate substrates with a distance 8 mm, which is much smaller than the wavelength. The FSS has wide bandwidth, ranging from 2.7 GHz to 13.2 GHz. The FSS cell for Electromagnetic Band Gap (EBG) is used as a reflector for ultra wideband antenna to improve its front-to-back ratio. Compared the performance for the reference antenna with and without the proposed reflector, the average improvement of the front-to-back ratio of the UWB antenna with designed FSS reflector is 15 dB from 3.1 GHz to 10.6 GHz and the peak even can get to 30 dB at 5 GHz.

I. INTRODUCTION

Rigorous research by academics and industries has focused on exploiting the EBG properties best suited for respective applications. Their shape, periods and number of layers as well as the substrate characteristics determine the performance of frequency selective surfaces (FSS) [1]-[3]. FSS are widely used as polarizer, space filter, reflector in dual frequency antennas and as a random for radar cross section (RCS) controlling as well as front-to-back ratio improvement [4]-[7].

In this paper, a frequency selective surface (FSS) cell is proposed. The FSS has four layers on two substrates with a distance 8 mm, which is smaller than the wavelength. The FSS has wide bandwidth, ranging from 2.7 GHz to 13.2 GHz. Then a reflector with the proposed EBG cells for ultra wideband antenna is developed. Compared the performance for the reference antenna with and without the proposed reflector, the average improvement of the front-to-back ratio of the UWB antenna with designed FSS reflector is 15 dB from 3.1 GHz to 10.6 GHz and the peak even can get to 30 dB at 5 GHz. The rest of the paper is organized as follows. Section II is the designed frequency FSS cell. Section III is the proposed reflector with the developed EBG cells for ultra band antenna. Section IV is conclusion.

II. FREQUENCY SELECTIVE SURFACE DESIGN

A. Equivalent Circuit for the Frequency Selective Surface

Fig. 1 is the designed FSS cell and its equivalent circuit. The parameters d_1 , d_2 , g_1 , g_2 , a , b , n , w , s , are marked in Table I. The FSS is constructed on the FR-4 substrate with dielectric constant of 4.4, loss tangent 0.02, thickness of 1.5 mm.

TABLE I
PARAMETERS OF THE PROPOSED FSS (UNITS: MM)

d_1	d_2	g_1	g_2	a	b	n	w	s
15	15	14	14	1.5	2	4	2	6

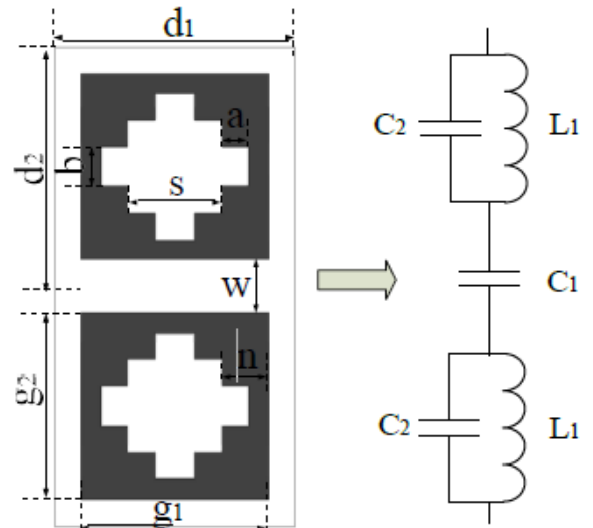


Figure 1. The corresponding equivalent circuits of the designed FSS element.

From the equivalent circuits of the FSS in Fig.1, C_1 , C_2 , L_1 are the equivalent inductive and capacitive. The gap w between the squares forms the capacitance C_1 , and the capacitance C_2 is formed by the gap b in the square as shown in Fig. 1. The capacitance value C_1 is determined by the patch length g_2 , the gap width w between the two adjacent patches and the effective dielectric constant of the substrate. The inductance value L_1 is determined by the length g_1 and the width n of the metallic strip [8]-[9].

The bandwidth of monolayer FSS is very narrow and didn't meet the requirements of ultra bandwidth application. Wide stop band filters can be realized by cascading two or more layers of periodic arrays. A four layer FSS structures with the same FSS cell shape in each layer and the equivalent circuit for the four layer FSS structure is shown in Fig. 2. The dielectric substrates between the metallic layers are modeled as short transmission lines with characteristic impedances Z_1 , $Z_1 = Z_0/\epsilon$, $Z_0=377 \Omega$, d is the thickness of FR4.

B. Simulated Results for the Designed FSS Cell

The ultra wide stop band FSS structure is designed by Ansoft HFSS software. The simulated transmission coefficients

are in Fig. 3. It is observed that the proposed FSS has wider bandwidth, ranging from 2.7 GHz to 13.2 GHz.

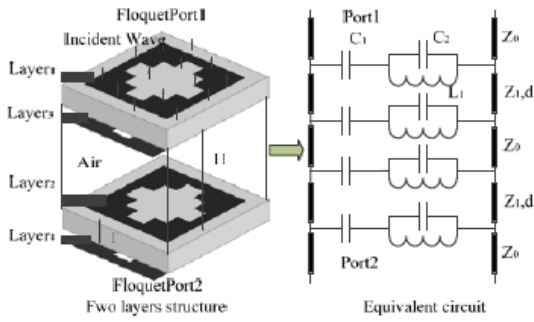


Figure 2. Structures and Equivalent circuit of the designed layer FSS, $T=1.5\text{ mm}, H=8\text{ mm}$.

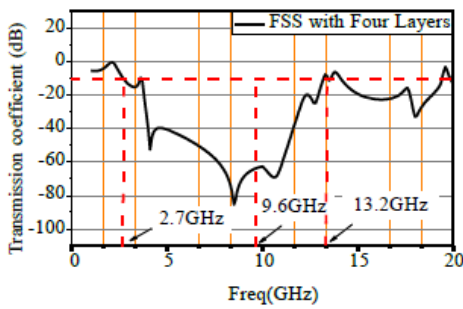


Fig.3. Transmission coefficient for FSS.

III. REFLECTOR WITH THE DESIGNED FSS CELLS FOR ULTRA WIDEBAND ANTENNA

The performance for the ultra-wideband antenna with the four layers FSS reflector has been simulated. The structure for the antenna with the designed FSS is in Fig. 4, and Fig. 5 is the prototype of the antenna [11]. The size for the four layers FSS is $108\text{ mm} \times 108\text{ mm}$ and the distance K between the antenna and FSS is 10 mm , which is approximately $\lambda / 4$ at the central frequency 6 GHz .

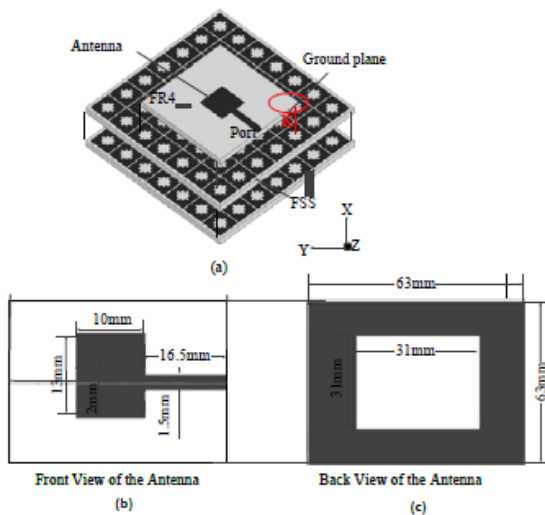
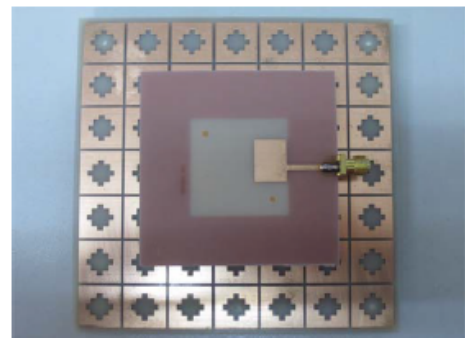


Fig.4. The antenna with FSS reflector

The four layers FSS acts as a reflector for the UWB antenna and is able to get low-backlobe level and high front-to-back ratio over ultra wideband from 3.1 GHz to 10.6 GHz . The prototype of the proposed antenna is fabricated and measured. S_{11} of the antenna with FSS is measured by using an Advantest R3770 network analyzer. Fig. 6 shows the simulated and measured S_{11} and Fig.7 shows the front-to-back ratio of the antenna. The FSS reflector has small effect on the impedance bandwidth, and the front-to-back ratio is significantly improved by the designed FSS reflector. The average improvement of the front-to-back ratio of the UWB antenna with FSS reflector is 15 dB from 3.1 GHz to 10.6 GHz and the peak even can get to 35 dB at 5 GHz . The discrepancy between the measured and simulated results is due to fabrication and measurement deviation.



(a)



(b)

Fig.5. The fabricated antenna with FSS (a) Top view (b) bottom view.

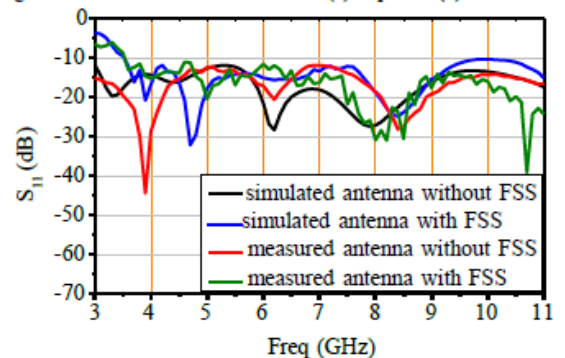


Fig.6. The simulated and measured S_{11} of the UWB antenna with and without FSS.

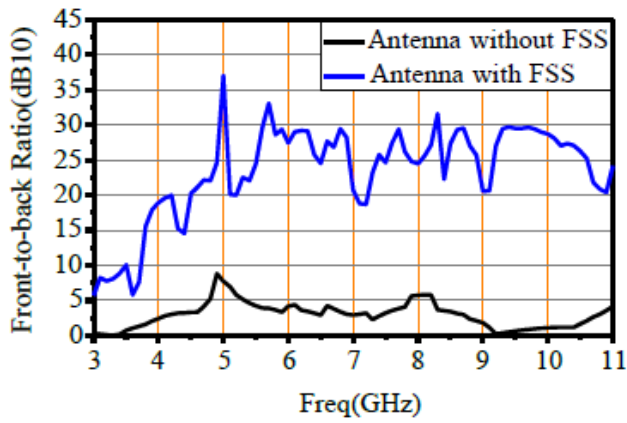


Fig.7. The front-to-back ratio of the UWB antenna with and without FSS

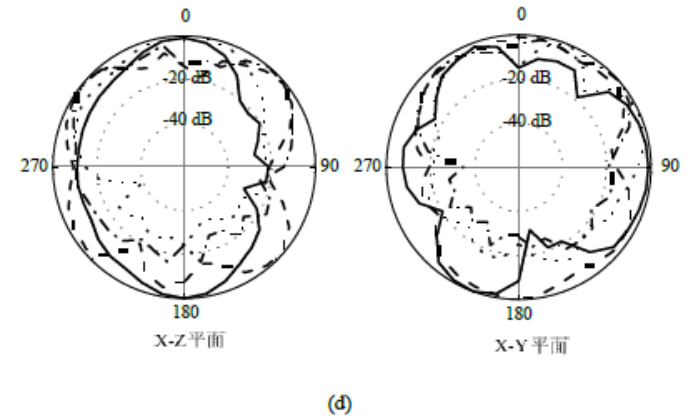
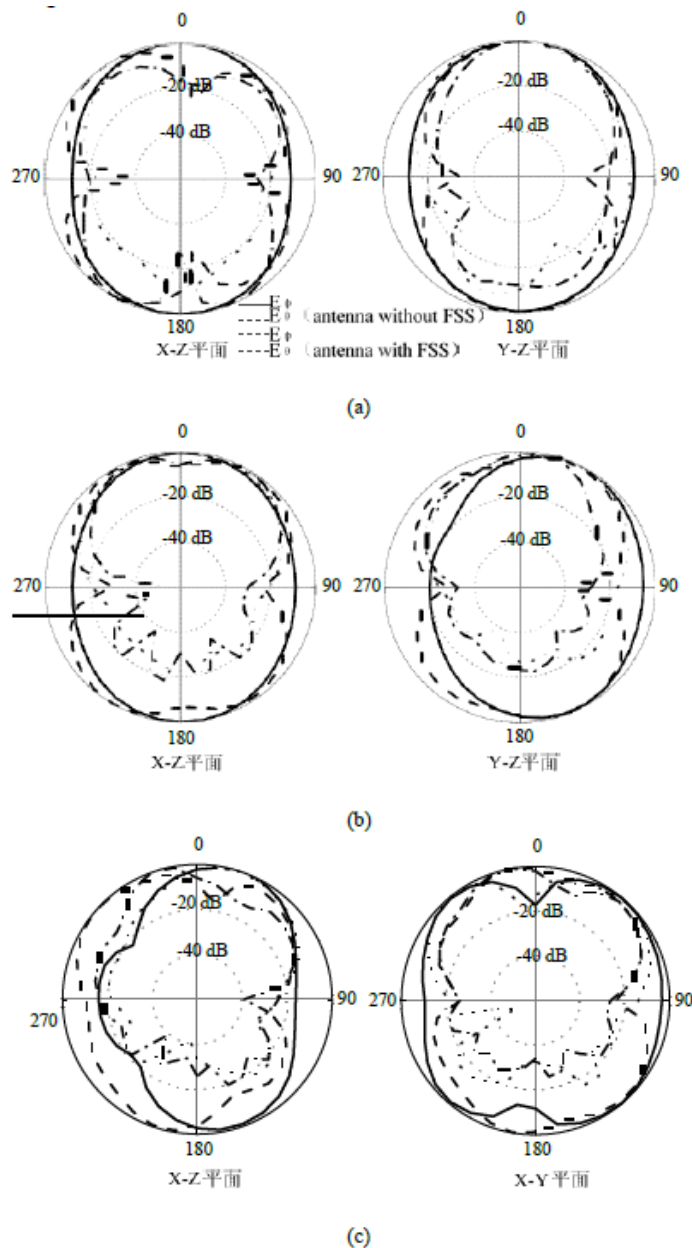


Fig.8. Radiation patterns on x-z plane and y-z plane (a) 3.5 GHz, (b) 5.3 GHz, (c) 7.9GHz, (d)10GHz

The far-field radiation characteristics for the antenna with FSS at the frequencies of 3.5, 5.3, 7.9 and 10 GHz are shown in Fig. 7 (a)–(d). Compared to the reference antenna [11], the antenna with the FSS reflector obviously reduces backward wave level from 3.1 to 10.6 GHz. It observed that the FSS reflector is an effective way to improve the front-to-back ratio of antenna.

IV. CONCLUSION

In this paper, the four layer FSS structure with the proposed cells has wider bandwidth from 2.7 GHz to 13.2 GHz. The FSS is used as a reflector for an ultra band antenna. Compared the reference antenna with and without the proposed reflector, the average improvement of the front-to-back ratio of the UWB antenna with FSS reflector is 15 dB from 3.1 GHz to 10.6 GHz and the peak even can get to 30 dB at 5 GHz. The designed FSS can be used as a reflector to improve the antenna performance.

ACKNOWLEDGMENT

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