High gain Patch Antenna using a Frequency Selective Surface (FSS)

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Abstract- A novel design of a New Frequency Selective Surface NFSS is presented, characterized and employed for the gain enhancement of a microstrip antenna operating at 5.2 GHz. The new FSS structure is then applied as a superstrate to a conventional microstrip patch antenna. The main goal of this work is to study low profile with compact size superstrate. Simulation and analysis results of the FSS design with CST Microwave studio are compared with results from the equivalent circuit of proposed FSS unit cell in ADS software to improve characteristics in terms of transmission and reflection responses. Analyse of the gain, input impedance and radiation pattern of the E and H-plane field are shown. Drastic gain increase of up to 9.4 dBi is obtained while maintaining a good matching level. The proposed NFSS antenna can be used for WLAN applications.

Keywords—Frequency Selective Surface (FSS), antenna resonant cavity, equivalent circuit, WLAN applications.

I. INTRODUCTION

With the appalling growth of wireless industry, antennas engineering has attracted the attention of many researchers[1-4]. These antennas are low cost and light weight. Moreover, improved directivity, gain and suppression of surface waves are the properties that can offer antennas with periodic elements. These periodic structures are electromagnetic band gap [5-7], meta-materials [8,9], or frequency selective surface [10,11] and even dielectric. These FSS structures are like a high reflective superstrate offering a better principal lobe with increased levels of radiation. Furthermore, these NFSS do not suffer from mutual coupling which can degrade the performance of the antenna [12].

For many years, the FSS are the subject of various studies [13,14] and one of the properties very used by FSS is frequency filtering.

After crossing of the electromagnetic wave through an FSS, some frequency are transmitted while others are reflected.; reaction of an FSS face is determined by the geometry of the periodic structure, its properties of dispersion and the step of lattice [11,15]. It results in the concentration of the electromagnetic energy, perpendicular to the surface FSS [9,18]. This unique property of FSS can be effectively used for the improvement of gain by putting FSS superstrate structure over conventional antennas, such as patch antennas. In this design, a new FSS form is proposed. The patterns are presented in a discontinuous circular shape combined with the FSS hybrid form, which is placed above the conventional microstrip patch antenna.The antenna is excited with SMA cable. The idea of this contribution is to minimize the number of FSS structures used in creating a directional antenna with high gain and low side lobe [16,17]. Compared to the existing designs, the proposed configuration provides a better gain enhancement with a single very small FSS superstrate layer configuration.

II. ANTENNA AND FSS CONFIGURATION

A. Proposed FSS unit cell

The new FSS structure is designed to act as a filter. It is a discontinuous circle combined with a hybrid FSS printed on the top of 0.381 mm thickness ROTMM6 substrate, with the dielectric constant is $\varepsilon_r=6$, as shown in Fig.1. The resonance frequency of the proposal FSS structure is determined by the unit cell dimension.The smaller size of the FSS, the higher the resonance frequency. Moreover, the permittivity of the substrate controls the resonance frequency and the bandwidth. Simulations were carried out using the CST Microwave Software. Finally, the unit cell length and spacing are evaluated and optimized, respectively. Table. I lists the optimized unit cell parameters.

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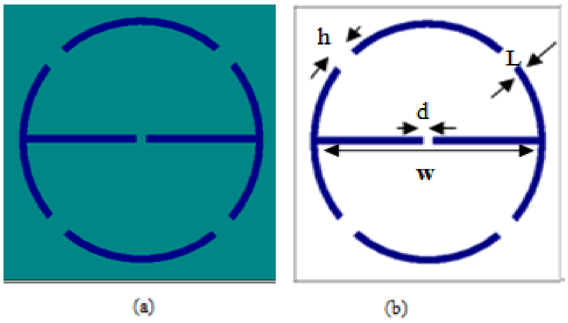


Fig.1 (a) Structure of unit cell FSS, (b)parameters of unit cell.

Table I. Optimized FSS unit cell parameters (MILLIMITERS)

Parameters	L	h	d	w
Values	1	3	1	30

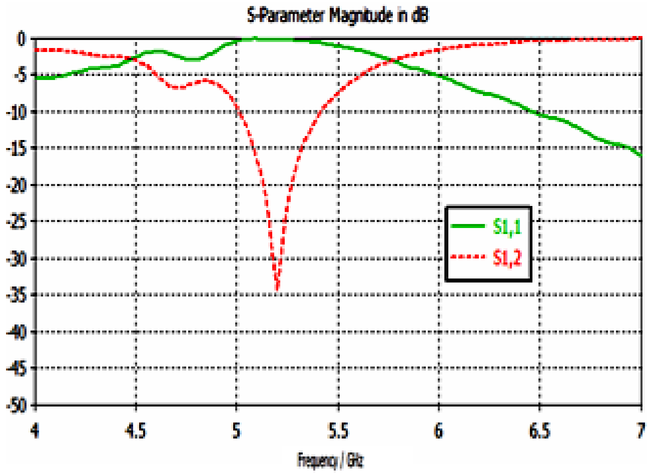


Fig.2 Simulated transmission and reflection responses of proposed FSS.

Fig.2 shows the transmittive and reflective coefficient characteristics of the proposed FSS unit cell. It has a non-conducting state at 5.2 GHz fielding filter operation. Therefore, a stop band with combined resonant circular ring with a discontinuous line is obtained over the frequency band from 5 to 5.4 GHz.

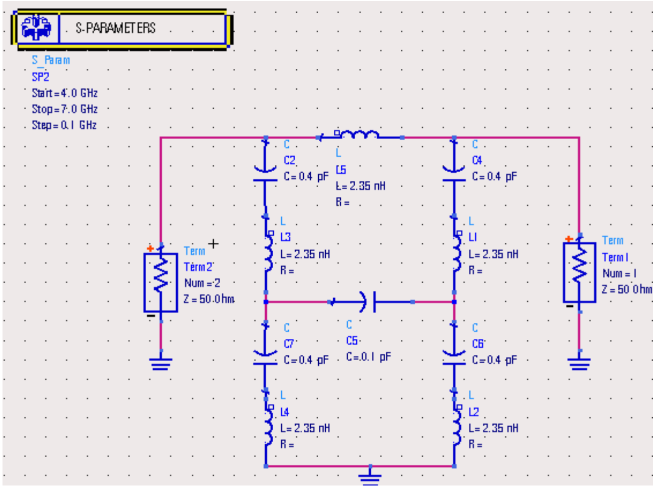


Fig.3 Simulated Equivalent circuit of proposed FSS in ADS.

The equivalent circuit of the proposed FSS unit cell with characteristic impedance Z is shown in Fig.3. The introduced capacitances represent the discontinuities in the FSS unit-cell, while the inductance represent the metallic parts forming the circular loop. For a given FSS unit cell geometry, a unique equivalent inductance and capacitance values exist. Therefore, by changing the values of the inductances and capacitances, the resonance frequency is changed. For WLAN applications, the optimal values of the capacitances and inductances are: C_1= C_2=C_3=C_4= 0.4 pF, C_5=0.1 pF and L_1 =L_2=L_3=L_4=L_5=2.35 nH.

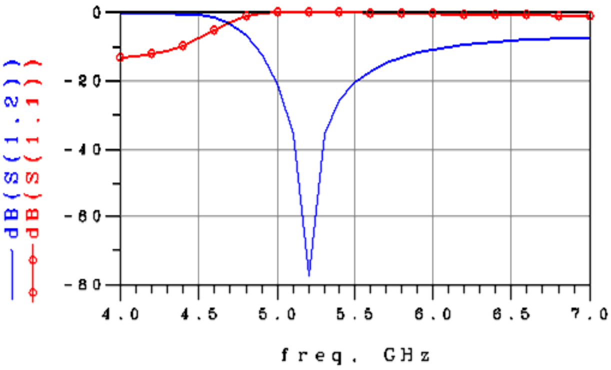


Fig.4 Simulated transmission and reflection responses of equivalent circuit in ADS.

Fig.4 shows the reflection and transmission characteristics of the equivalent lumped element circuit using ADS Software. Results show a good agreement with the simulated ones shown in Fig.2

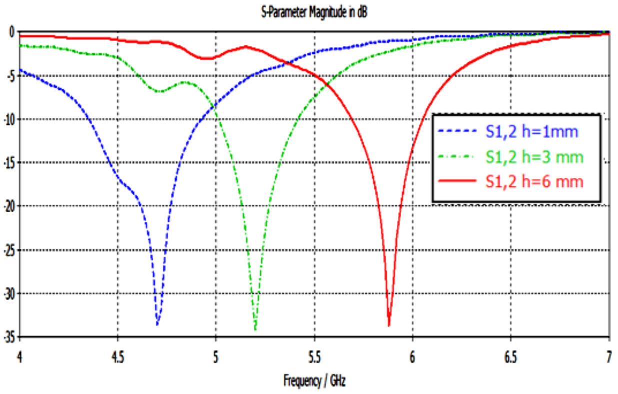


Fig.5 Effect of the length discontinuity h on the proposed NFSS on the transmission coefficient .

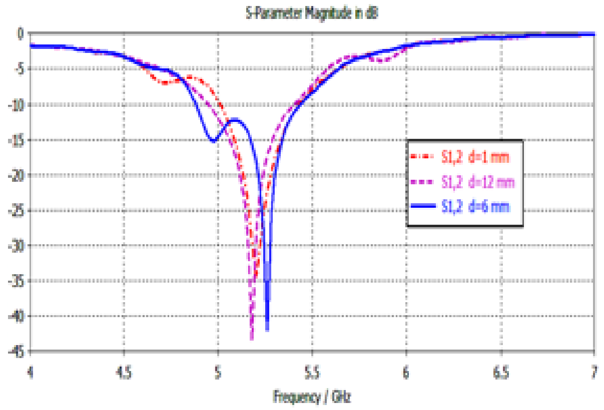


Fig.6 Effect of the length discontinuity d on the proposed NFSS on the transmission coefficient.

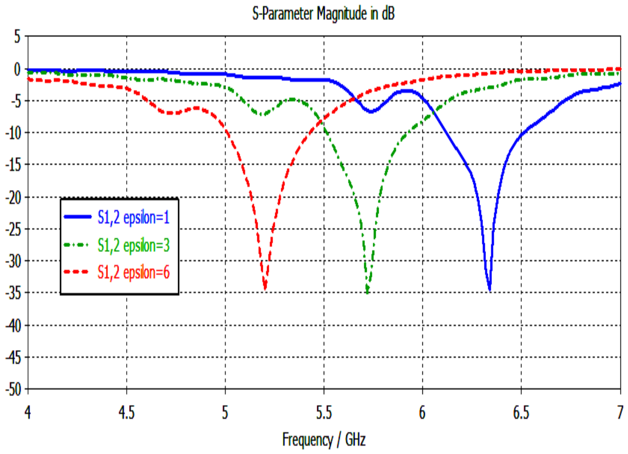


Fig.7 Effect of the permittivity on the proposed NFSS on the transmission coefficient.

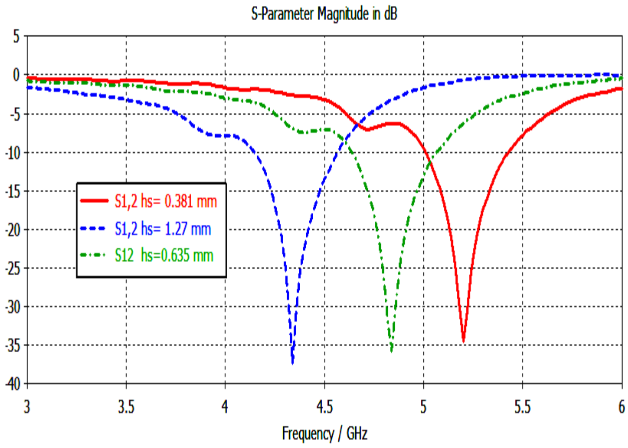


Fig.8 Effect of the height on the proposed NFSS on the transmission coefficient.

The Figs.5-8 show the transmission characteristics of the proposed FSS unit cell for different parameter value. The filtering operation is affected by the length of the discontinuity at the extreme of the NFSS loop. This effect can be clearly understood in Figs 5 and 6. By changing the length and spacing of the discontinuity, the transmission characteristics are changed. One aspect of the stop band filter is obtained at $h = 0.05\lambda$ at 5.2GHz.

The resonance frequency of the stop-band filter is also affected by the relative permittivity and thickness of the substrate, as illustrated in Figs 7 and 8. By increasing the substrate height and permittivity, the resonance frequency decreases.

B. *Proposed Antenna with NFSS*

To validate the operational principal of the proposal NFSS, a 3*3 FSS structure is placed on the top of probe-fed rectangular patch antenna printed on 1.575mm thickness RT/duroid 5870 substrate with the dielectric constant is ε_r=2.33. The FSS layer is placed at a distance of half of wavelength at 5.2 GHz.

Fig 9 shows the geometry of the proposed antenna incorporating the NFSS structure. Final antenna parameters are listed in Table. II .The NFSS structure is not only applied to imitate the opaque or transparent surface at 5.2GHz, but also to control the radiated power from the antenna.

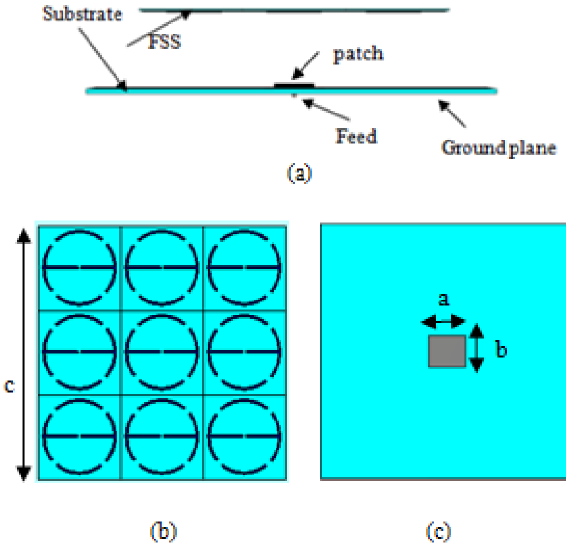


Fig.9 (a) Structure of the proposed antenna, (b) Proposed hybrid FSS screen and (c) Antenna patch.

Table II. Final dimensions of proposed antenna (MILLIMITERS)

Parameters	A	b	c	d	H
Values	20.995	17.403	108	140	1.575

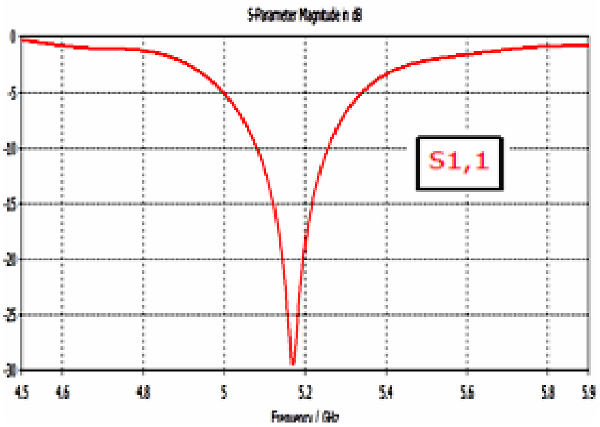
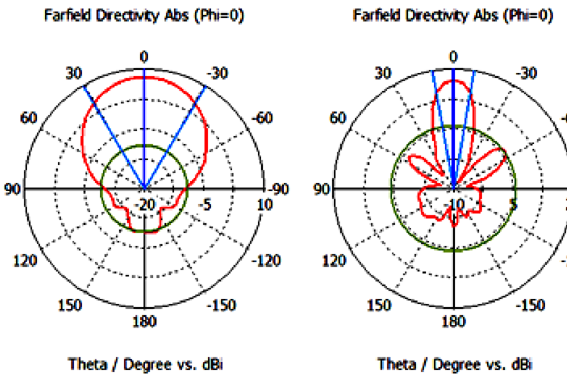


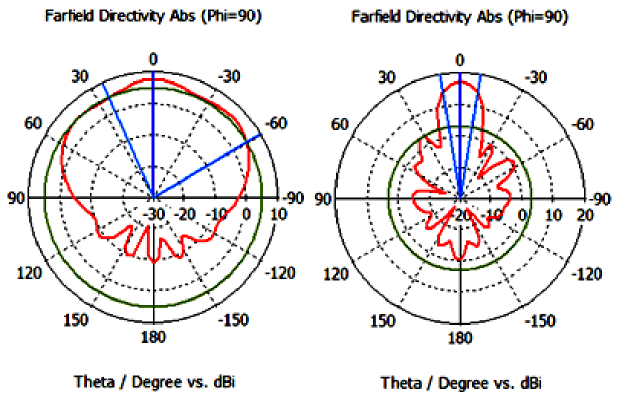
Fig.10 Antenna patch matching, simulation results.

The simulation result of the return Loss of the antenna shown in Fig.10. The final dimensions of the NFSS are used in the simulations are shown in the first part. Good matching is obtained over 5.08 to 5.25 GHz.



(a) (b)

Fig.11 Gain of the antenna: (a) without FSS and (b) with FSS for the E-plane



(a) (b)

Fig.12 Gain of the antenna: (a) without FSS and (b) with FSS for the H-plane

To study the influence brought up by the proposed antenna, the system is simulated. The simulated E- and H-plane radiation patterns at 5.2 Ghz are shown in Fig.11 and 12,respectively. A drastic gain increase is obtained of 17.4 dBi compared to 7.94 dBi form the antenna without FSS.

These results show the effectiveness of the proposed FSS structure in increasing the gain.

III. CONCLUSION

In this work, a new FSS unit cell has been designed, analyzed and simulated. Results have shown that the proposal FSS structure can be used as a stop band filter. The proposed NFSS has been then applied as a superstrate to a conventional patch antenna. A gain increase up to 9.4 dBi at 5.2 GHz achieved. With these characteristics, the proposed antenna incorporating the NFSS can be used in WLAN applications.

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