Comparative Analysis of Microstrip Patch Antenna Coverage X Band Frequencies with Frequency Selective Surface

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ABSTRACT

In this paper, a design of a consolidated tuneable microstrip patch antenna using a ring-shaped frequency selective surface (FSS) is proposed. The designed antenna module (microstrip patch and FSS structure) operates in the X band cover frequencies of 8 GHz that incorporates a number of wireless communication systems applications. The proposed antenna module has been analyzed, designed, and simulated using CST. The material dielectric used for both antennas and FSS is Taconic TLX-8, with layer thickness 0.787 mm, relative permittivity $\varepsilon r = 2.55$, and loss tangent $\tan\delta = 0.0019$ Moreover, the proposed design has been compared with the traditional patch antenna. The proposed design has the advantage of the FSS for the same antenna to select the required frequency. Simulation results show enhancement gain of 5.68 dB to 7.16 dB, return loss (S11) of -13.7 dB to -32.33 dB and directivity of 7.67 dBi to 8.43 dBi. It has been seen that the rendering has been enhanced for FSS.

في هذا البحث ، تم اقتراح تصميم هوائي موحد موحد لشرائح ميكروستريب باستخدام سطح انتقائي للتردد على شكل حلقة (FSS). تعمل وحدة الهوائي المصممة (رقعة microstrip وهيكل FSS) في ترددات غطاء النطاق X البالغ 8 جيجاهرتز والتي تتضمن عددًا من تطبيقات أنظمة الاتصالات اللاسلكية. تم تحليل وتصميم ومحاكاة وحدة الهوائي المقترحة باستخدام CST. و المادة العازلة المستخدمة لكل من الهوائيات و FSS هي Taconic TLX-8بسمك طبقة 0.787 مم ، والسماحية النسبية εr = 2.55 ، وخسارة ظل الظل = 0.0019 علاوة على ذلك ، تمت مقارنة التصميم المقترح مع هوائي التصحيح التقليدي. يتمتع التصميم المقترح بميزة الخدمة الثابتة الساتلية (FSS) لنفس الهوائي لاختيار التردد المطلوب. تظهر نتائج المحاكاة كسب تعزيز من 5.68 ديسيبل إلى 7.16 ديسيبل وخسارة عودة (S11) من -13.7 ديسيبل إلى -32.33 ديسيبل واتجاهية من 7.67 ديسيبل إلى 8.43 ديسيبل. لقد لوحظ أن التقديم قد تم تحسينه للترددات السطحية.

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1. INTRODUCTION

The development of circuit technology for wireless communication systems is requiring the design of planar, compact, flexible, and reconfigurable structures. This demand applies to the development of new antennas, frequency selective surfaces (FSSs), materials, and fabrication techniques [1]. In order to meet these requirements, planar antenna and FSS structures need to be more versatile in their shapes and applications [1] Microstrip patch antennas are the most suitable for wireless communications and mobile applications because of having a low profile, lightweight and easy to fabricate. The antennas can be designed in a variety of shapes in order to obtain more gain and high bandwidth, dual-band, and circular polarization to even ultra-wideband operation [1].

Frequency Selective Surfaces (FSS) are resonant structures having either stopband [2, 3] or passband [4, 5] performance, due to which they are widely used as redoes, spatial filters, electromagnetic absorbers and shielding structures. FSS is also used in cavity resonant antenna to enhance the gain of the antenna. Fresnel zone plates are also used to improve focusing thereby achieving high directivity antennas [6, 7].

Many configurations of FSS structures are proposed to enhance the gain [7, 8]. The FSS has a wide range of applications in the microwave, infrared and visible light band. The FSS is also equipped on the flight weapon radar cover to realize the invisibility of the radar tank on flight weapon [9, 10]. The authors in [11] have improved the gain bandwidth production by utilizing FSS in Fabry-Perot radio antenna. In this regard, the authors in [12] have worked on three metallic ring-resonators, where these resonators are used for achieving triple band reflective FSS which is further used to improve the gain of the broadband triangular slot antenna. Also, in [4, 5] the transmission (passband) type of FSS is proposed in order to achieve a high band. However, the gain of an antenna has not taken into account, where the gain is quite significant in the antenna performance.

In [13], the gain of the dipole antenna is improved by combining the FSS with a dipole antenna, where the gain has reached up to 3 dB. The research paper in [14] describes an investigation of the possibility of using a new conductive ink, instead of copper clad laminates. In the manufacturing of microstrip patch antennas on glass and fibreglass substrates and of bioinspired FSSs on fibreglass substrates for wireless communication systems. The new conductive ink is developed using synthesized nitrocellulose which, in ethyl acetate solution, works as a bonding agent and carrier for the formation of a conductive film. The performance of the proposed design has shown a good performance by using FSS. In [15], the popular road to improve the gain of the microstrip antenna is to take advantage of the microstrip antenna array. In other word, it can be considered super material as substrate [16]. In [17], the gain of the microstrip antenna is improved by combining the FSS with microstrip antenna, where the gain has reached up to 4.61 dB. In [18], the gain of the microstrip antenna is enhanced by 4.54 dB. In [19], enhancement in the microstrip antennas has been designed and simulated with FSS, thus achieved a gain of 4.9 dB. In [20] enhancement of gain 5 dB using modified cross-shaped FSS constructed on Substrate Integrated Waveguide (SIW) a microstrip patch antenna working at ISM band (2.4 GHz). In this work, microstrip patch antennas with FSS is simulated and analysed using CST software. For comparison purposes, the proposed designed is compared with microstrip patch antenna without a ring-shaped frequency selective surface (FSS).

The rest of this paper as follows; Section II presents designs of the microstrip patch antenna and FSS. Section III provides results and discussion of the proposed antenna. Section IV shows the comparison between the patch antenna and the proposed antenna with FSS. Finally, Section V concludes this paper.

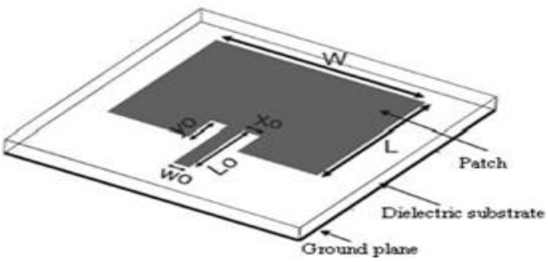
2. PROPOSED METHOD

In this section, we will present the simulation design in two phases. The first phase refers to the proposed patch antenna without FSS. The second phase presents the proposed antenna within FSS design. These two phases will be described respectively as follow:

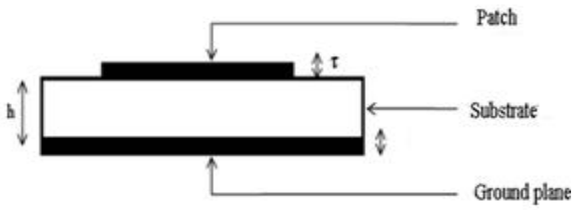
A- PROPOSED ANTENNA

The proposed antenna is a rectangular microstrip patch antenna which operate in the X band cover frequencies of 8 GHz. Classically, a rectangular microstrip patch antenna is composed of a conducting patch of width W and length L, printed on a dielectric substrate, of height h, relative permittivity εr, and loss tangent tanδ, which is mounted on a ground plane as illustrated in Fig. 1.

In this work, the inset-feed technique is used to improve the impedance matching between the microstrip line and the antenna input impedance. The inset-feed physical dimensions are length y0, slot width x0, and strip width W0, which is the same as the feeding microstrip line, as shown in Fig. 1. The overall feeding length as the microstrip line is L0. The patch antenna is designed on a double-sided substrate, where it is printed on 0.787 mm thickness Taconic TLX-8 substrates with a relative dielectric constant of 2.55. As shown in Fig 1, a copper plate with dimensions of 20.42 X 23.60mm^2 and thickness of 0.035 mm is used as the ground plane. The patch uses copper as a material with 0.035 thickness. A coaxial line with a characteristic impedance of 50 ohms is used as the feed of the traditional patch antenna. All dimensions of patch and substrate are given in Table 1.



(a)



(b)

Fig. 1. The geometry of a rectangular microstrip patch antenna. (a) 3D illustration and (b) cross-sectional view.

Table 1: Proposed antenna parameters (mm)

Variable	Patch (mm)	Substrate (mm)	Ground (mm)
W	20.50	23.60	23.60
L	11.00	20.42	20.42
W0	4.30	N/A	N/A
L0	5.45	N/A	N/A
x0	0.50	N/A	N/A
y0	0.75	N/A	N/A
material	Copper	Taconic TLX-8	Copper

B- CHARACTERISTICS OF UNIT CELL A RING-SHAPED FSS SUPERSTRATE

The FSS is a spatial electromagnetic filter, which is defined as one or two a dimensional cyclic array of patch elements. Fig 2 shows a ring-shaped FSS antenna composite and its unit cell structure. It consists of a 3 X 3 ring-shaped array. The proposed FSS is a 0.035 mm thick copper ring-shaped The thickness of Taconic TLX-8 substrates is 0.787mm with a relative dielectric constant of 2.55. Detailed dimensions of the hexagonal loops ring element are shown in Figure2.

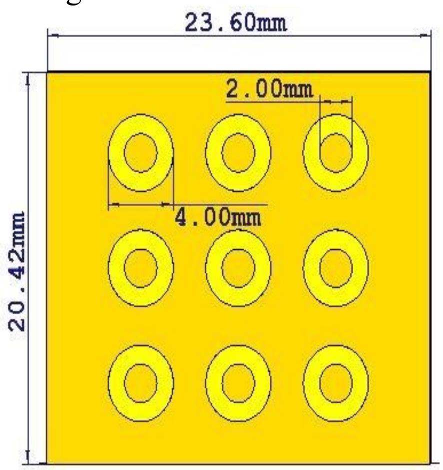


Fig. 2 FSS periodical structure (3x3 array)

3. RESULTS AND DISCUSSION

Rectangular micro strip patch antenna with FSS results, performance has been investigated and the simulation result as shown in Fig 3 (a), (b), (c), (d).

The rectangular microstrip patch antenna magnitude of the return loss s11 parameter was set down at an operating frequency of 8 GHz as illustrated in Figure 3 (a). It reached -13.70 dB at 8 GHz operating frequency after adding FSS the return loss s11 enhancement to -32.32. It can also be noted that the plan receives a good matching impedance which nearly equal to 50 Ω.

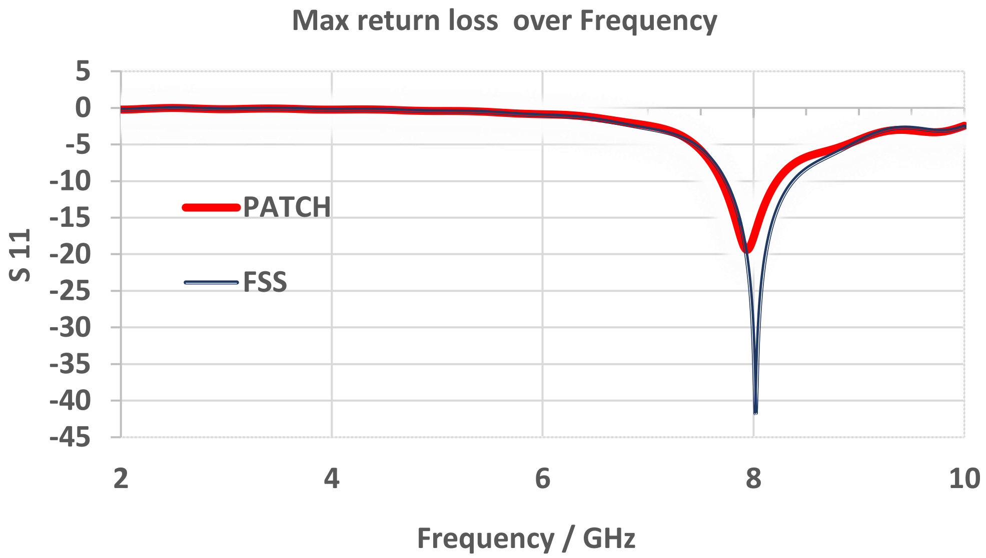


Fig 3 (a). The result shows the return loss at 8GHz

Shown in Figure 3 (b) the structure design of the microstrip patch antenna has achieved at 8 GHz maximum Gain 5.68 dB, after adding FSS structure of the patch antenna the gain enhancement and increased to 7.16dB at 8GHz operating frequency for this designed antenna.

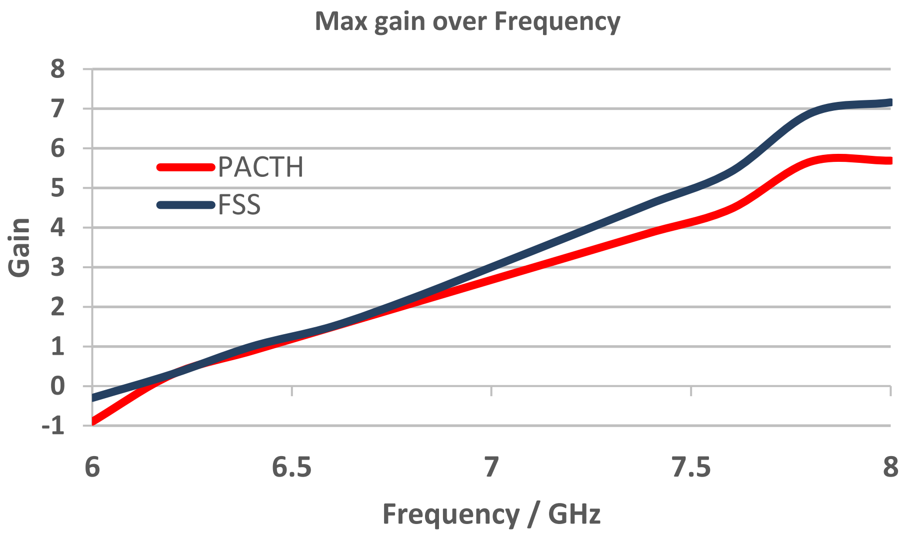


Fig 3 (b). The result shows the gain at 8GHz

The directionality of the designed antenna patterns achieves 7.67 dBi and with FSS patterns enhancement of directivity to 8.43 dBi for the same operating frequency as indicated in Figure 4 (c).

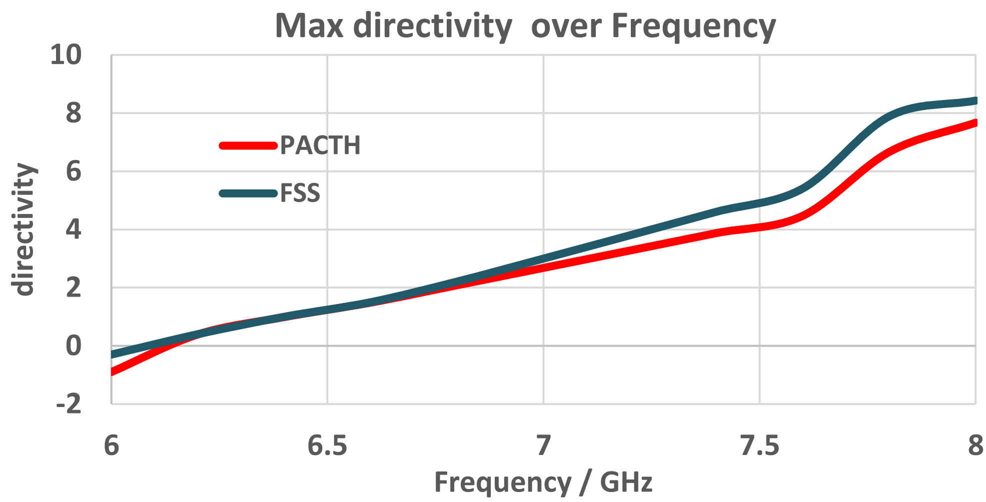


Fig 3 (c). The result of the directivity at 8GHz

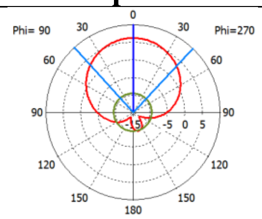
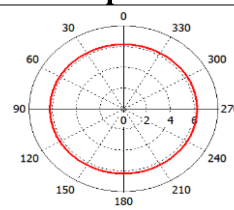
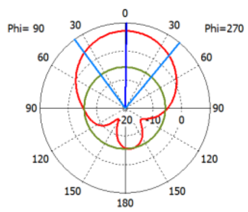
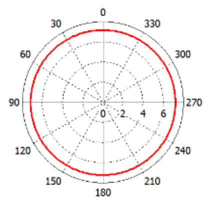
Rectangular Microstrip Patch Antena	
E-plane	**H-plane**
	
Rectangular Microstrip Patch Antena with FSS	
	

Fig 3 (d). The result shows radiation pattern E-plane and H-plane at 8GHz

4. COMPARISON OF RECTANGULAR PATCH ANTENNA APERTURES OF WITH FSS AND WITHOUT FSS STRUCTURES.

The simulated of the microstrip patch antenna and comparison with previous work the result with and without FSS periodical structure in figure 5 (3x3 array) shows shape design rectangular microstrip with FSS and all the comparison result in Table-2.

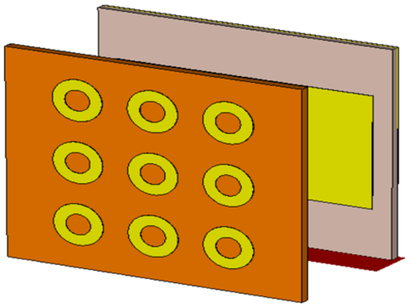


Fig 4. A rectangular microstrip patch antenna with FSS Structures (3x3 array)

Table 2: Comparison between Previous Work and Proposed Work.

References	Antenna structure	Material used	Resonant frequency	Result Without FSS			Result with FSS Structures		
				Gain (dB)	Return Loss (dB)	Directivity (dBi)	Gain (dB)	Return Loss (dB)	Directivity (dBi)
[7]	Microstrip patch Antenna	FR4	5.8GHz	1.84	-17.15	N/A	5.19	-11.39	N/A
[17]	Microstrip patch Antenna	FR4	Dual-Band 5-10.6 GHz	3.01	−23.6, −31.61	N/A	4.23,4.61	−23.6, −34.17	N/A
[18]	Microstrip Patch Antenna	FR4	5 GHz	N/A	-18	N/A	4.54	-25	N/A
[19]	Microstrip Patch Antenna	FR4	2.4GHz	1.9	-21	N/A	4.9	-18	N/A
[20]	microstrip patch antenna	FR4	2.4 GHz	3	-17	N/A	5	-25	N/A
PROPOSED	microstrip patch antenna	TLX-8	8 GHZ	5.688	- 13.7	7.67	7.14	- 32.32	8.43

5. CONCLISION

In this paper, we have designed and analyzed a rectangular microstrip antenna using a ring-shaped frequency selective surface (FSS). Operates in the X band cover frequencies of 8 GHz. the performance of the gain and return loss and directivity using without FSS and with FSS Structures. Simulation results show enhancement gain 6.21 dB to 7.19 dB, return loss (S11) -13.7 dB to -32.33 dB and directivity 7.67 dBi to 8.43 dBi. This has been seen that the rendering has been enhanced for FSS. In future works, we suggest using a different shape of FSS in several antenna designs in order to obtain a high gain, efficiency and more directivity.

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