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Design of High Gain Compact Microstrip Patch Antenna at ISM Band

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A Frequency-Selective Surface (FSS) is any thin, repetitive metal surface designed to reflect, transmit, or absorb electromagnetic radiation according on the frequency of the wave. The entering plane wave will either be transmitted (passband) or reflected back (stopband) depending on the characteristics of the unit cell. This happens when the frequency of an electromagnetic (EM) wave coincides with the resonance frequency of the FSS components. As a result, an FSS is a spatial filter capable of allowing or inhibiting EM waves of a certain frequency range in free space. FSSs have now been widely investigated, and great progress is being made in the field of their design and implementation for a wide range of practical applications, from microwave to optical frequencies. The Frequency Selective Surface attached to the new center-fed circular patch antenna is presented. A wide band from 5 GHz to 6.2 GHz is achieved with a monopole-like radiation pattern. According to simulation results of the proposed antenna structure, it can be applied in ISM band applications, wireless audio and video systems and other wireless communications at 5.8 GHz. It has a simulated maximum gain of 5.36 dBi and a bandwidth of 31.1 %. Throughout the operational band, the omnidirectional radiation pattern is fairly constant. The overall dimensions of the antenna are 27.34 × 27.34 mm^2 including FSS structure thus makes a compactable wideband system at 5.8 GHz. A circular patch antenna with diamond slot at center initialize first resonance at 5.8 GHz with a dimension of 20 × 20 mm^2 and performance parameter is further improved by appending FSS Structure.

Keywords: Frequency Selective Surface (FSS), Broadband, Industrial Scientific Medical (ISM) band, High efficiency.

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1. INTRODUCTION

The technology had now moved to their advanced level where the size and the working of the device need not to be proportional. In the fast-moving world, Antennas are the most important thing that we come across in our day-to-day life. Antennas are the devices which are used to receive and transmit the signals and it is a device that transforms electrical power into electromagnetic waves and the other way around. Among all the antenna, the most simple and basic form of antennas are microstrip patch antenna. They are simple in construction. This antenna has the radiating patch at one end and the ground at another end in between the ground and patch there is a dielectric substrate. The dielectric substrate may vary based on the application of the antenna. Substrate provides mechanical support for the antenna. Choosing the substrate should satisfy both the occasionally challenging electrical and mechanical requirements. We should use the substrate that meets conformability, machinability, solderability, weight, elasticity, cost etc. Some commonly used dielectric substrates are Duroid, Benzocyclo butane, Roger 4350, FR4-epoxy, Bakelite. Substrate with high dielectric must be used to reduce the size of the antenna.

The main parameter in the design of the antenna is the structure and shape of the substrate, like the loss tangent and dielectric constant. Over the years, FR 4 substrate plays an important role in increasing the bandwidth of the antenna. This substrate is very low in cost and has good mechanical properties and has relative mechanical and electrical stability. So, we used FR4 Substrate in our Antenna and Frequency Selective Surface (FSS).

Nowadays, in order to improve the characteristics like power consumption, transmission reception characteristics and marketability in wireless communications miniaturization and high data rate with bandwidth is needed [1] but the microstrip patch antenna straggle for bandwidth and gain. One of the ways in order to obtain the appropriate radiation properties, gain, and directivity is using Frequency Selective Surface at back of the antenna [2]. Frequency Selective Surface is periodic Structures made of 2 or 3 dimensional structures that displays filtering abilities [3-6]. FSS is used to improve radiation efficiency of metal-surface of the antenna. Coplanar waveguide (CPW) line is the most effective method to improve the antenna's bandwidth. To intensify the gain, directivity and to reflect the back radiations of the antenna, FSS is used as reflective surface [7]. For high selectivity and for compactness, Substrate integrated waveguide Technology is used [8]. The important thing of using fractal structures is to aid self-similarity and space-filling properties are important for designing compact structures. [9-12].

2. ANTENNA DESIGN

2.1 Antenna Design without FSS

The design configuration of the proposed antenna consists of a circular patch coplanar waveguide (CPW) fed monopole antenna with a rhombic slot etched at the centre

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of the circular patch which is depicted in Fig. 1. The substrate is FR4, which has a 4.4 dielectric constant and a tanδ = 0.02. The metal patch used is made of the conducting element Copper with a thickness of 0.035 mm.

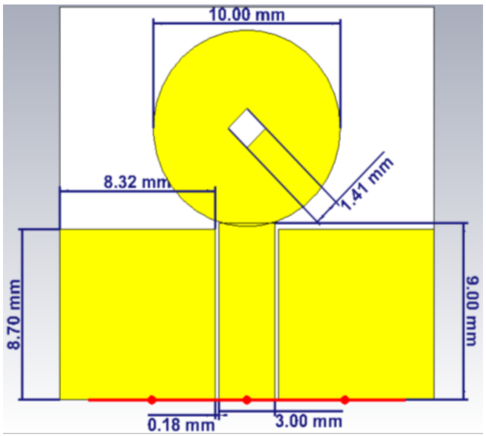


Fig. 1 – Proposed antenna design without FSS structure

2.2 Antenna Design with FSS

The design configuration of the proposed antenna consists of a circular patch coplanar waveguide (CPW) fed monopole antenna with a rhombic slot etched at the centre of the circular patch along with FSS structure at the back of antenna which is shown in Fig. 3. The substrate is FR4, which has a 4.4 dielectric constant and a tanδ = 0.02. The metal patch used is made of the conducting element Copper with a thickness of 0.035 mm. The Minkowski structured Frequency Selective Surface shown in Fig. 2 is kept at the backside of the antenna. The unit cell's overall thickness is 1.635 mm. The unit cell dimension of FSS structure is 13.67 × 13.67 mm^2 and the dimension of FSS structure is 27.34 × 27.34 mm^2. The topmost layer of FSS is copper consisting thickness of 0.035 mm and the bottom layer is made up of FR4 substrate with a 1.6 mm thickness. The separation of distance between the antenna and this FSS structure is 1.8 mm. current distribution along patch with FSS shown in Fig. 4 and current distribution along patch without FSS shown in Fig. 5.

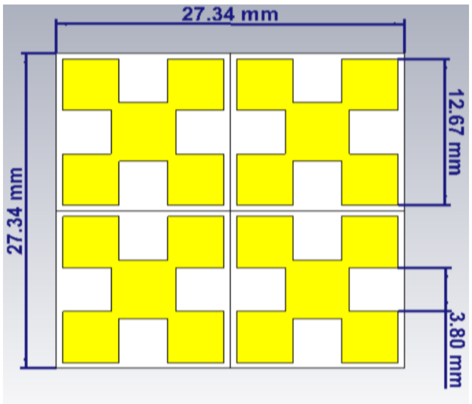


Fig. 2 – FSS structure

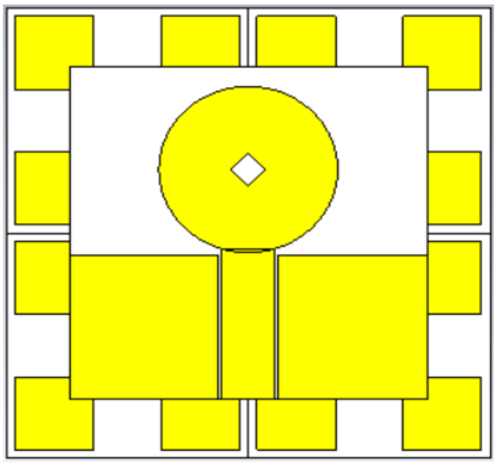


Fig. 3 – Proposed antenna design FSS structure

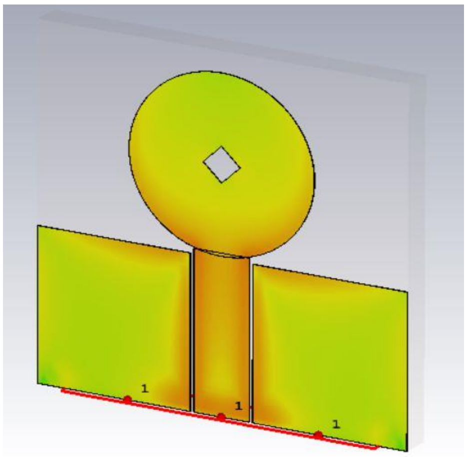


Fig. 4 – Current distribution without FSS

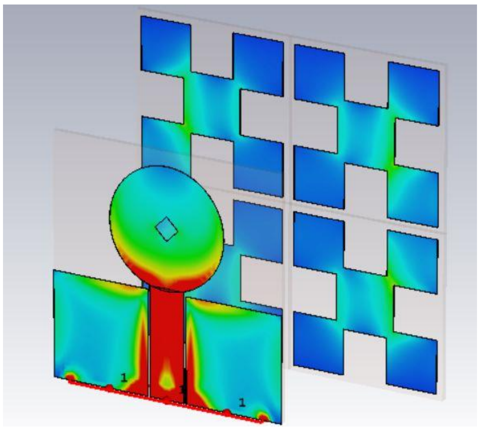


Fig. 5 – Current distribution with FSS

3. RESULT AND DISCUSSION

The simulation of this design is done using CST microwave studio. The return loss (S_{11}) of the suggested antenna design at 5.8 GHz was – 12.522 dB without FSS structure depicted in Fig. 6 and – 17.634 with the FSS structure in shown in Fig. 7 placed at the back of the antenna. The return loss was comparatively increased on keeping the FSS structure at the back of the antenna design. The gain and directivity of the antenna without FSS structure is 2.17 and 2.54 dBi respectively as shown in the Fig. 8. Similarly, antenna's gain and directivity with FSS structure is 5.36 dB and 5.85 dB respectively as in the Fig. 9. The bandwidth of the proposed antenna

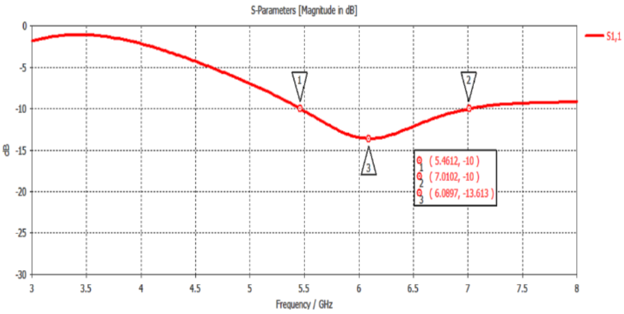


Fig. 6 – Return loss and bandwidth without FSS structure

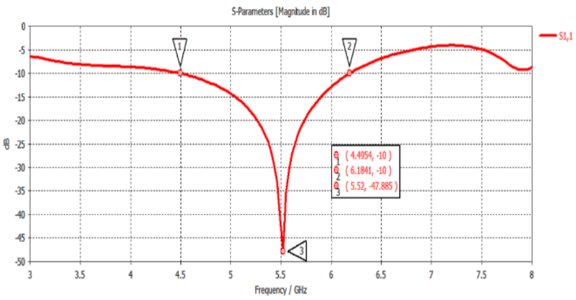
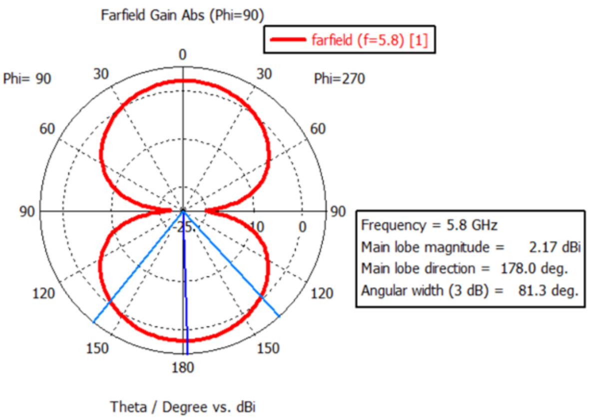
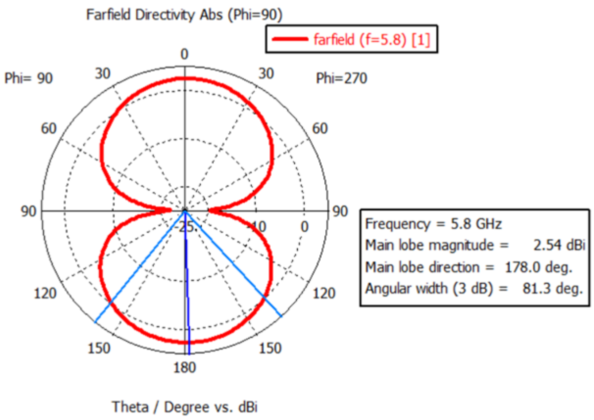


Fig. 7 – Return loss and bandwidth with FSS structure



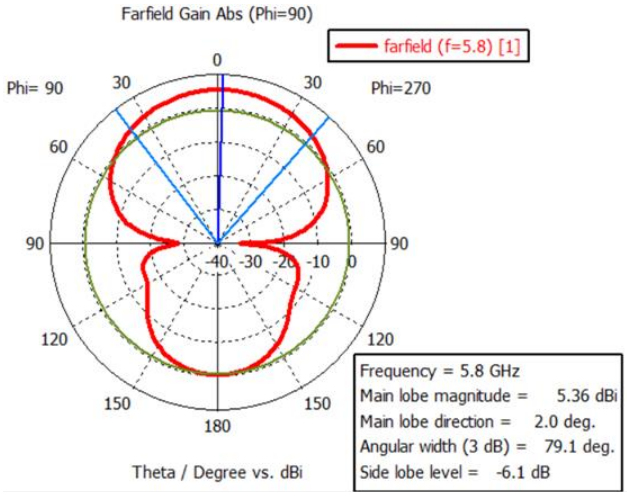
(a)



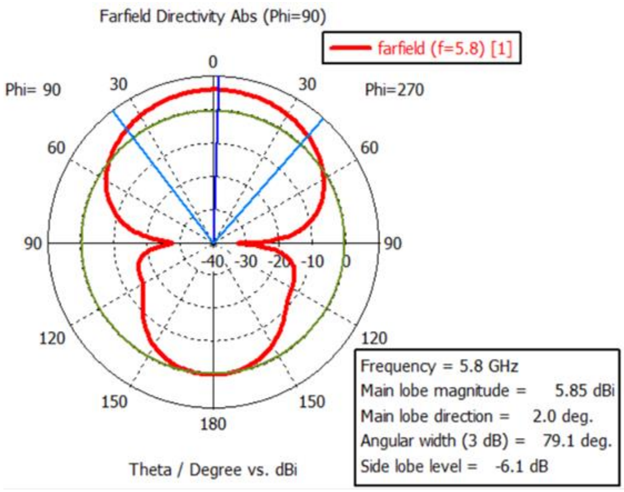
(b)

Fig. 6 – (a) Gain and (b) Directivity without FSS structure

design without FSS ranges from 5.5 to 7 GHz and with FSS bandwidth ranges from 4.5 to 6.2 GHz. The radiation efficiency of the antenna without FSS is 85.433 % and with FSS is 91.623 %. There was a drastic improvement in the radiation efficiency after using the FSS structure at the back of the antenna.



(a)



(b)

Fig. 7 – (a) Gain and (b) Directivity with FSS structure

Table 1 – Parameters of the antenna without and with FSS structure from simulation

Parameters	Antenna without FSS at 5.8 GHz	Antenna with FSS at 5.8 GHz
Return loss (S_{11})	– 12.522 dB	– 17.634 dB
Gain	2.17 dBi	5.36 dBi
Directivity	2.54 dBi	5.85 dBi
Radiation efficiency	85.433 %	91.623 %
Bandwidth	5.5 to 7 GHz	4.5 to 6.2 GHz

4. CONCLUSION

The proposed antenna structure is applied in ISM applications, wireless audio and video systems and other wireless communications at 5.8 GHz. The proposed antenna was simulated using the waveguide port mode available in the CST microwave studio software and the parameters of the antenna were analyzed. We used 4 individual FSS unit cell to improvise the gain, directivity and radiation efficiency and better results were obtained from the CST microwave studio simulation. Here a minkowski structure with iteration is formed as FSS. The antenna's specifications were improved by the band stop nature of novel FSS. The antenna's Frequency Selective Surface is kept at the back. The antenna's bandwidth was enhanced by the single layer FSS about 1.7 GHz with good impedance matching. The proposed antenna is suitable for broadband applications at 5.8 GHz ISM band.

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Дизайн компактної мікросмужкової патч-антени з високим коефіцієнтом підсилення в діапазоні ISM

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Частотно-селективна поверхня (FSS) — це будь-яка тонка повторювана металева поверхня, призначена для відображення, пропускання або поглинання електромагнітного випромінювання відповідно до частоти хвилі. Вхідна плоска хвиля буде передана (смуга пропускання) або відбита назад (смуга зупинки) залежно від характеристик елементарної комірки. Це відбувається, коли частота електромагнітної (ЕМ) хвилі збігається з резонансною частотою компонентів FSS. Таким чином, FSS є просторовим фільтром, здатним пропускати або гальмувати електромагнітні хвилі певного діапазону частот у вільному просторі. Зараз FSS широко досліджені, і досягнуто значного прогресу в області їх проектування та реалізації для широкого спектру практичних застосувань, від мікрохвильових до оптичних частот. Представлена частотно-селективна поверхня, приєднана до нової круглої патч-антени з центральним живленням. Широка смуга від 5 ГГц до 6,2 ГГц досягається за допомогою монопольної діаграми спрямованості. Згідно з результатами моделювання запропонованої структури антени, її можна застосовувати в додатках діапазону ISM, бездротових аудіо- та відеосистемах та інших бездротових комунікаціях на частоті 5,8 ГГц. Він має симульоване максимальне підсилення 5,36 дБі та смугу пропускання 31,1%. У всьому робочому діапазоні всенаправлена діаграма спрямованості досить постійна. Загальні розміри антени становлять 27,34 × 27,34 мм^2, включаючи структуру FSS, що робить компактну широкосмугову систему на 5,8 ГГц. Кругла патч-антена з ромбоподібним отвором у центрі ініціалізує перший резонанс на частоті 5,8 ГГц із розміром 20 × 20 мм^2, а параметр продуктивності додатково покращується шляхом додавання структури FSS.

Ключові слова: Частотно-селективна поверхня (FSS), Широкосмуговий діапазон, Промислово-науковий медичний діапазон (ISM), Висока ефективність.