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Dual-band Microstrip Patch Antenna Using Frequency Selective Surface for Satellite Communication Systems in S Band

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Abstract

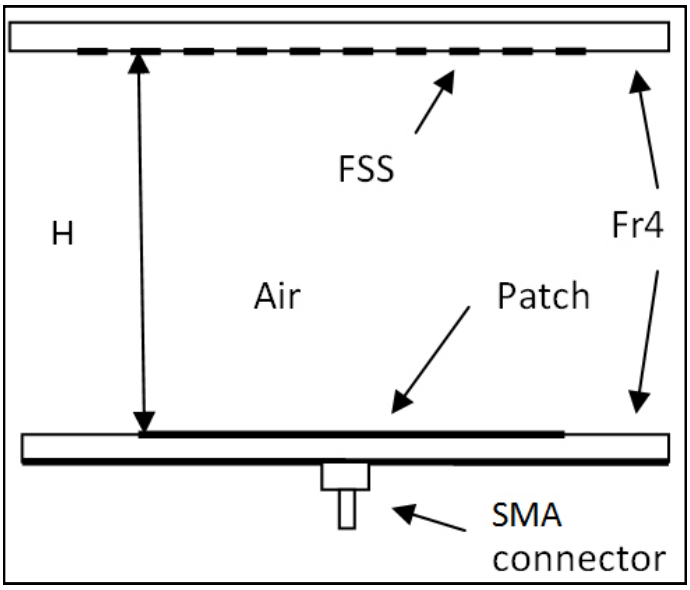
This paper presents E shaped microstrip patch antenna with multiple frequency selective surface (FSS). This proposed antenna reduce the return loss and enhance the bandwidth and gain in S band at resonance frequencies 2.25 and 3.78 GHz. S-band is the part of frequency spectrum between 2 and 4 GHz frequencies. Many satellites transmit at S-band frequency spectrums. The return loss is reduce from -5 to -14 dB and -14 dB to -21 dB at the resonant frequency of 2.25 GHz and 3.78 GHz, respectively After implanting the FSS in the E shaped patch antenna, It is found that the gain has been improved from 4.8 to 7.26 dB and 1.56 to 3.72 dB at resonant frequencies 2.25 GHz and 3.78 GHz, respectively.

Keyword

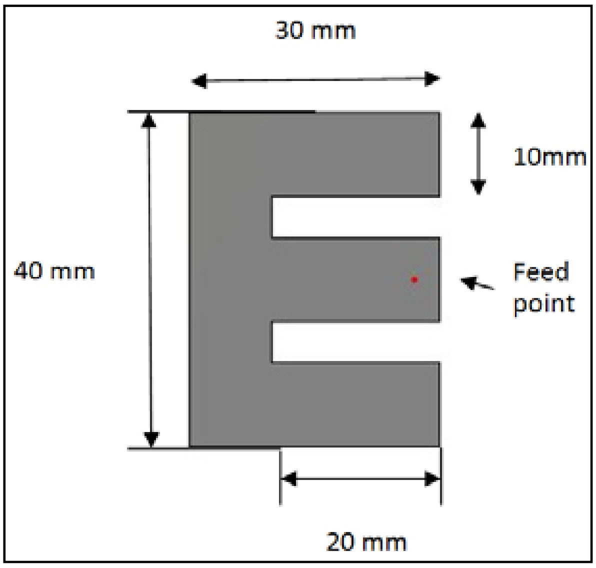
Return Loss, Bandwidth, Microstrip Patch Antenna, Frequency Selective Surface (FSS), Resonance Frequency, VSWR, Coaxial Probe Feed

I. Introduction

A patch antenna has inherent advantages of small size, low profile, lightweight, cost-effect, and its ease of integration with other circuits. It is very suitable for applications in wireless communication systems. For today's wireless communications multi-band and wide-band patch antennas will become the requirements for accurately transmitting the voice, data, video, and multimedia information. However, the most serious problem of a patch antenna is its narrow bandwidth because a patch antenna on a dielectric substrate has surface wave losses. Therefore, how to enhance the bandwidth and frequency bands of a patch antenna has become an important issue in the antenna design field. The frequency selective surface (FSS) structure has a phenomenon with high impedance surface that reflects the plane wave in-phase and suppresses surface wave.



(a)



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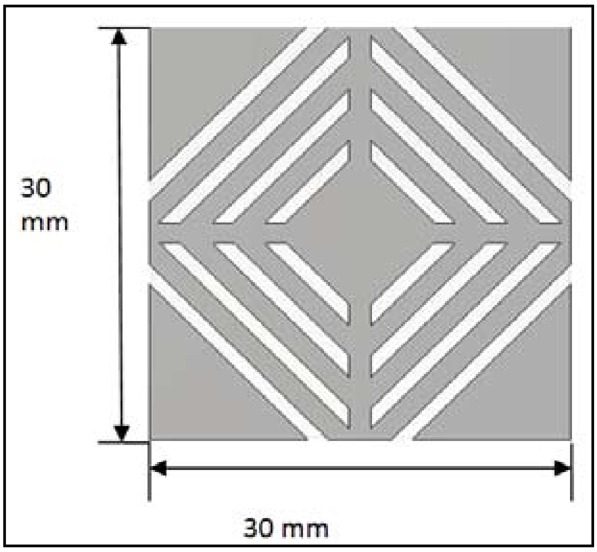


(c)

Fig. 1: Dual –Band Antenna (a) Antenna Geometry (b) E Shape Patch Antenna (c) FSS

A patch antenna with one FSS structure can improve its radiation efficiency, bandwidth, and gain, moreover, the FSS reduces the side lobe and back lobe level in its radiation pattern. The FSS has been widely applied in antennas, filters, reflectors, polarisers, absorbers, propagation, metamaterials, and artificial magnetic conductors (AMC) for more than four decades [1]-[6]. Typical FSS geometries are designed by dipoles, rings, square loops, fractal shapes, etc. The transmission or reflection characteristic of a FSS depends on the shape, size, periodicity, and geometrical structure of FSS elements.

In this paper, the dual-band FSS is used to study its impact on the bandwidths and resonant frequencies of E shape patch antenna operating at 2.25 GHz and 3.78 GHz. In simulations, the characteristics of E shaped patch antenna have been obtained by using the Computer simulator Technology (CST). Simulation results of the return loss, VSWR, radiation pattern, directivity and gain of proposed patch antenna have been presented in this paper.

II. The Proposed Antenna With FSS

Microstrip patch antenna consists of very thin metallic strip placed on ground plane where the thickness of metallic strip is restricted by t<< λ_0 and the height is restricted by$0.0003\lambda0 \leq .05\lambda_0$ [5-8] microstrip patch is designed so that its radiation pattern maximum is normal to the apatch. For a rectangular patch, the length l of the element is usually $\lambda_0/3 < L < \lambda_0/2$.There are numerous substrates that can be used for the design of microstrip antennas and their dielectric constants are usually in the range of $2.2 \leq \varepsilon_r \leq 12$. In this paper Fr-4 lossy (ε_r =4.33) is use to implement the rectangular microstrip patch antenna.

The proposed antenna is composed of E shaped patch antenna and FSS. E shaped patch antenna composed of a rectangular patch with two identical Rectangular shape cut slots, a rectangular ground plane and substrate, and a vertical probe connected to the patch. The thickness of the substrate with dielectric permittivity of 4.33 is 1.6mm. A copper plate with dimensions of 40mm*40mm and thickness of 0.038 mm is used as the ground plane. The dimensions of a patch antenna are 30mm*40mm and with two identical rectangular-shape slots are placed symmetrically with dimensions of 20mm*5mm, feed point lies in the central line of 12 mm. The patch uses copper as material and the thickness of it is 0.038 mm. A coaxial line with a characteristic impedance of 50 ohm has been used as the feed of the E shaped patch antenna. The inner conductor of the coaxial line is attached on the top patch going through the dielectric substrate, and the outer conductor is shorted to the metallic plate on the other side of the patch antenna. The FR4 material is used for the dielectric substrate with a thickness of 1.6 mm. The relative dielectric constant and electrical loss tangent of the substrate are adopted to be 4.33 and 0.02 at frequencies 2 to 4 GHz. Fig. 1(a) illustrates the geometry of the proposed patch antenna. The antenna has a very simple structure and thus it is easy to be manufactured. Fig. 1(b) shows the E shaped patch antenna along with probe feeding, contribute to the enhanced performance of the antenna.

In addition, the FSS composed of a metallic strip, dimensions of 30mm*30mm with cuts of 2 mm width square shape rings which are connected to their adjacent corner by 2 mm width metallic strip as shown in Fig. 1(c) which has thickness of 0.038mm, and 1.6 mm thick substrate of Fr4 lossy material with 40mm*40mm dimensions placed just above of patch. FSS placed above of patch antenna with 19 mm air gape which improve the bandwidths at resonant frequencies of the E shape patch antenna.

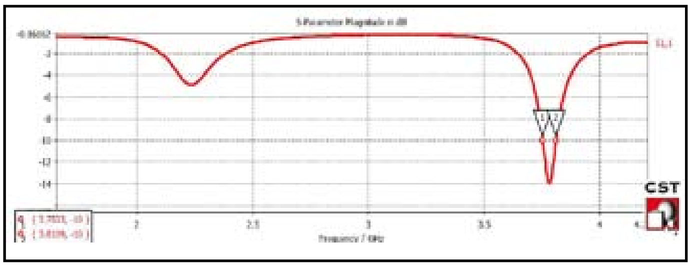
III. Results and Discussion

Simulation results for the E Shaped patch antenna implemented with and without a FSS are obtained from the Computer simulator Technology (CST). The return loss of E shaped patch antenna without FSS are -5 dB and -14 dB at 2.25 and 3.78 GHz resonant frequencies respectively, and with FSS are -14dB and -21dB respectively at same resonance frequencies. Gain, Directivity, VSWR, Bandwidth and radiation fields have been improved at the resonant frequencies of 2.25 GHz and 3.78 GHz for the E shaped patch antenna implanted with FSS. Simulation results of proposed antenna are shown in figures and have been comprised in table.

Table 1: Comparison of Simulated Results of Proposed Antenna With and Without FSS

Parameters	Patch Without FSS		Patch With FSS	
Frequency	2.25GHz	3.78GHz	2.25GHz	3.78GHz
Return loss	-5 dB	-14 dB	-14 db	-21 dB
VSWR	3.6	1.5	1.5	1.2
Bandwidth	0	67 MHz	104 MHz	77 MHz
Gain	4.8 dB	1.56 dB	7.26 dB	3.72 dB
Directivity	6.98 dB	6.93dB	8.12 dB	6.98 B

1. Return loss and VSWR of E shaped proposed patch antenna with and without FSS.



(a)

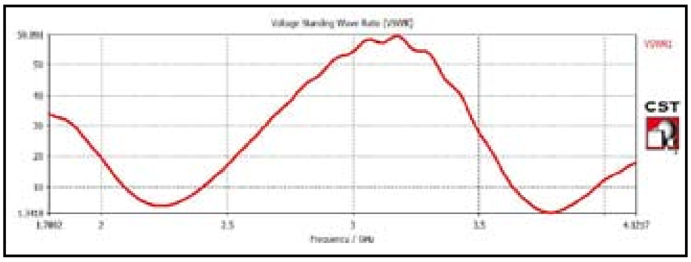


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Fig. 2: Without FSS (a) Return Loss (b) VSWR

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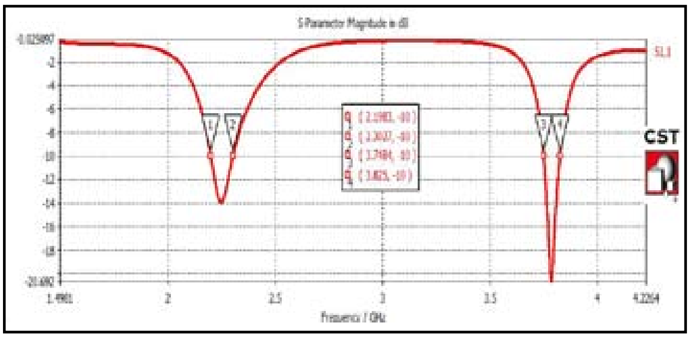
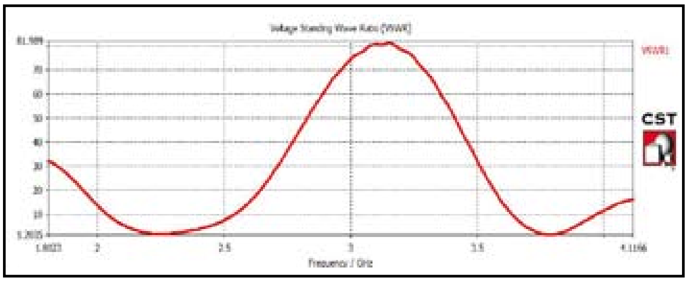


(a)

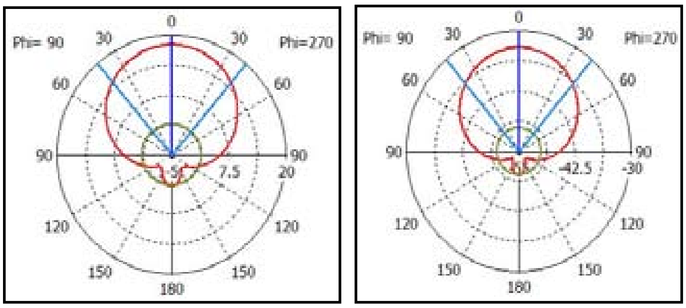


(b)

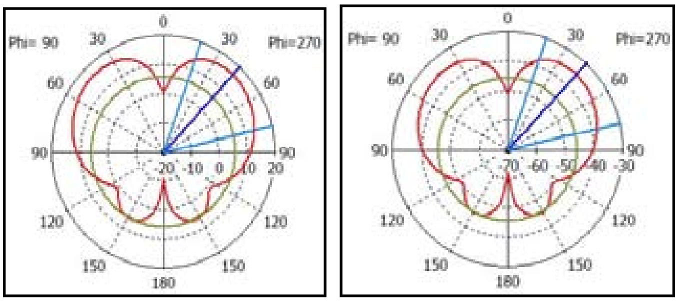
Fig. 3: With FSS (a) Return loss (b) VSWR

2. Electric(E) and Magnetic(H) field Radiation pattern of E shaped proposed patch antenna with and without FSS.

E-plane H-plane



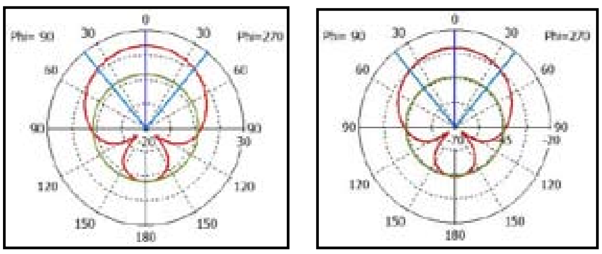
(a)



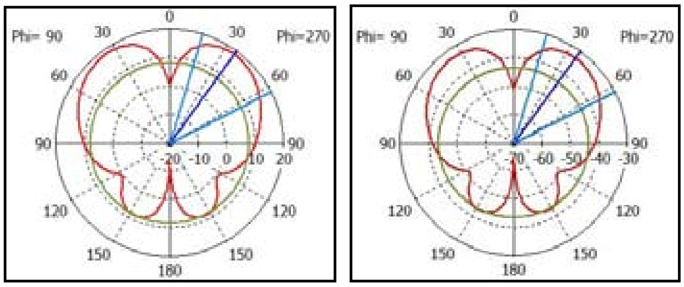
(b)

Fig. 4: Radiation Pattern Without FSS at (a) 2.25 GHz (b) 3.78 GHz

E-plane H-plane



(a)



(b)

Fig. 5: Radiation Pattern With FSS at (a) 2.25GHz (b) 3.78 GHz

The return loss and VSWR of E shaped patch antenna without and with FSS are shown in fig. 2, 3 respectively. From the simulation results, it is clear that the input impedance does not seriously affect the performance of the FSS antenna at H=19 mm and only the higher operating frequencies of the patch antenna slightly shift upward. Gain and directivity of proposed antenna have also been increased.

Fig. 4 shows the radiation patterns of the E shaped patch antenna without and with FSS at two operating frequencies (2.25 GHz and 3.78GHz). Main lobe magnitude of electric field with FSS have been increased from 17.8 to 21.8 dBV/m and 16.1 to 18.3 dBV/m at 2.25 GHz and 3.78 GHz, frequencies respectively. Main lobe magnitude of magnetic field increased from -33.6 to -29.7 dBA/m and -35.3 to -33.2 dBA/m respectively at 2.25 GHz and 3.78 GHz, frequencies respectively.

IV. Conclusion

In this paper, a dual-band E – shaped microstrip patch antenna with FSS has been designed and analyzed which improves the bandwidths and gain on sets of operating frequencies for a E shaped patch antenna. From simulation results, it is found that the Bandwidths, VSWR, Return loss, Gain and Directivity have been improved at the operating frequencies of 2.25 and 3.78 GHz for the E shaped patch antenna implanted with a FSS. This antenna cover most of frequency spectrum for satellite in S band.

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