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Compression of Surface Waves in a Microstrip Patch Antenna using Frequency Selective Surface

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***Abstract*---With the increasing modernization of wireless and mobile communication the use of microstrip patch antenna has become popular. The reason being its ease of analysis, negligible weight, economical and can be easily manufactured using Printed Circuit Board (PCB) technology. Despite of having so many advantages it has several drawbacks such as low gain, restricted bandwidth and low efficiency. In this paper, the Frequency Selective Surface (FSS) is used to improve the performance of microstrip patch antenna by compressing the surface waves. The comparison of proposed antenna is made with the conventional patch antenna in the same physical dimensions. The result in terms of bandwidth and return loss shows considerable improvement in the proposed microstrip patch antenna.**

Keywords---Frequency Selective Surface (FSS); Gain; Microstrip patch antenna; Return loss

I. INTRODUCTION

With the rapid development in the wireless field, microstrip patch antennas have become appealing prospect to the antenna community. In recent years microstrip patch antennas have been widely used in satellites, aerospace, radars, biomedical applications due to its properties like light weight, economical, robust, compatibility with integrated circuits. Despite its several advantages, they have several limitations such as low gain, low efficiency, less directivity and restricted bandwidth [1]. These limitations have been eliminated using a probe fed stacked antenna, slotted patch antenna, stacked shorted patches have been proposed and studied. Bandwidth can be improved using thicker substrate by cutting slots in the metallic patch by using aperture coupled stacked patch antenna. The limitation of using this antenna is that surface waves will be supported and results in mutual coupling in the antenna.To improve the performance of the antenna, a Frequency Selective Surface (FSS) structure can be used [2],[3].

Frequency Selective Surface consists ofeither radiating or non-radiating elements which act as a band stop or band pass filter respectively to electromagnetic waves [4]. FSS is a type of optical filter in which the filtering is achieved by the periodic pattern on its surface. The FSS helps in reducing the back lobe and side lobe level in the radiation pattern.The effect of an FSS on the performance of patch antenna depends on the periodicity of elements, geometry and the electrical properties of the substrate [5]. The application of FSS has beenwidely seen in reflectors, filters, antennas, polarizers, meta-materials, absorbers, propagation, and artificial magnetic conductors (AMC) for more than four decades [6]-[11].
Basically, there are two types of FSS designs which are used worldwide. The first type is known as inductive FSS which works similar to a high pass filter and the second type is capacitive FSS which works similar to a low pass filter.

II. DESIGN SPECIFICATIONS AND PARAMETERS OF MICROSTRIP PATCH ANTENNA

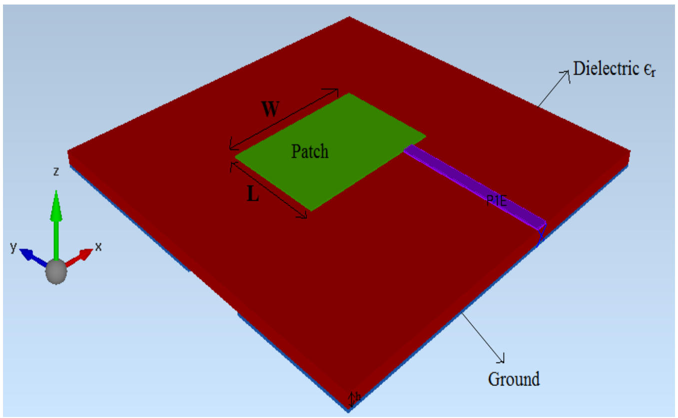

Fig. 1 . Microstrip patch antenna

The three important design specifications of Microstrip patch antenna are:

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A. Operating frequency (f_r): The operating frequency selected for proposed design is 9.5GHz.

B. Dielectric constant of the substrate (ε_r): The dielectric material selected for proposed design is having a dielectric constant of 4.4.

C. Height of dielectric substrate (h): The height of the dielectric substrate is selected as 0.8mm.

Calculation of parameters

A. Width (w)

The width of microstrip patch antenna depends on the operating frequency, the dielectric constant of the substrate and the height of the substrate. All these parameters are specified by the user. The equation to calculate the width of microstrip patch antenna is:

$$W = \frac{1}{2f_r\sqrt{\mu_0\epsilon_0}}\sqrt{\frac{2}{\epsilon_r + 1}} \qquad (1)$$

μ_0: Permeability of free space
ϵ_0: Permittivity of free space
ϵ_r: Dielectric constant
f_r : Resonant frequency
W: Width of substrate

B. The effective dielectric constant

Effective dielectric constant depends on the dielectric constant of substrate, height of substrate and the width of the antenna.

$$\epsilon_{eff} = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2} \times \frac{1}{\sqrt{1+\frac{12h}{W}}} \qquad (2)$$

ϵ_{eff}: Effective dielectric constant
h: Height of substrate

C. Calculation of Length Extension

Formula for the calculation of length extension is

$$\frac{\Delta L}{h} = 0.412\frac{(\epsilon_{eff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\epsilon_{eff}-0.258)\left(\frac{W}{h}+0.8\right)} \qquad (3)$$

ΔL: Length extension

D. Length (L)

The length of the patch depends on the operating frequency, effective dielectric constant, and width of the patch.

$$L = \frac{1}{2f_r\sqrt{\epsilon_{eff}\mu_0\epsilon_0}} - 2\Delta L = \frac{V_0}{2f_r\sqrt{\epsilon_{eff}}} - 2\Delta L \qquad (4)$$

L: Length of patch

III. ANTENNA DESIGN

In this paper, an open ended L slotted microstrip patch antenna is proposed. The open ended L-slot is combined with a rectangular patch fed by a microstrip feed line to form the required antenna. Due to the printed open-ended L-slot on asymmetric ground plate wideband impedance characteristic is produced and also the ground plate is greatly reduced in size [12]. The dimension of the antenna is 25 x 25 mm2having a dielectric substrate of thickness 0.8mm. The substrate used is FR4 Epoxy has a relative permittivity of 4.4. The ground plane has an L slot which is clearly shown in Fig.2.

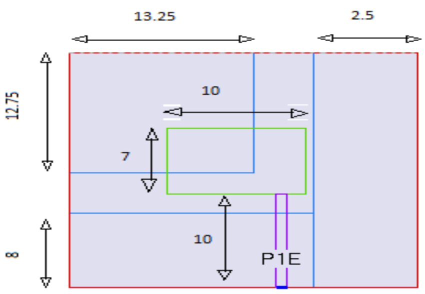

Fig. 2 . Dimensions of antenna in mm

IV. FSS DESIGN

The geometry of proposed FSS structure is clearly shown in the Fig.3. The FSS consists of two layers. One layer is made up of fractal cross elements supported by another layer made up of dielectric substrate FR4 Epoxy having a thickness of 0.4mm [13].

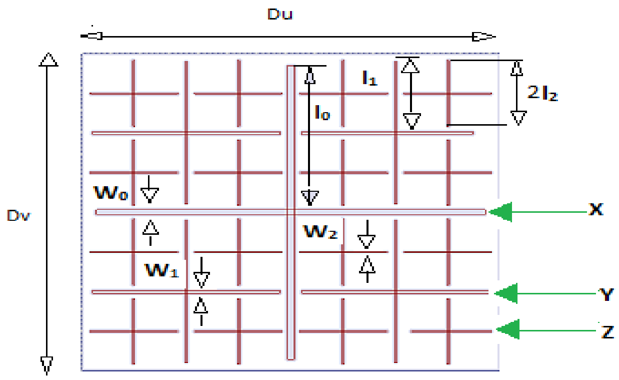

Fig. 3 . Dimensions of the FSS

X-FSS formed by the original crossed dipole
Y-FSS of elements generated in the first iteration
Z-FSS of elements generated in the second iteration.
The dimensions of FSS are:
l_0=11.4mm
l_1=5.5mm
$2l_2$=5.2mm
Width of fractal crosses are based on the relations
W_0=0.4mm
$W_{n+1}=0.5W_n$

V. EXPERIMENTAL RESULTS

EMPIRE XPU 7.03 is 3-D electromagnetic field simulator software which is used to obtain the simulation results of return losses for the microstrip patch antenna created with and without an FSS. It is based on the powerful Finite Difference Time Domain method (FDTD).

A comparative study of the microstrip patch antenna with and without an FSS is done. Simulation results were investigated by checking the impedance matching with better than 10 dB return loss [14].

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From the observation, the resonant frequency of patch antenna with and without FSS is found to be near 9.5GHz for the impedance matching with better than 10dB return loss. Though the result shows that bandwidth has been improved near the frequency 9.5GHz for the patch antenna with FSS.

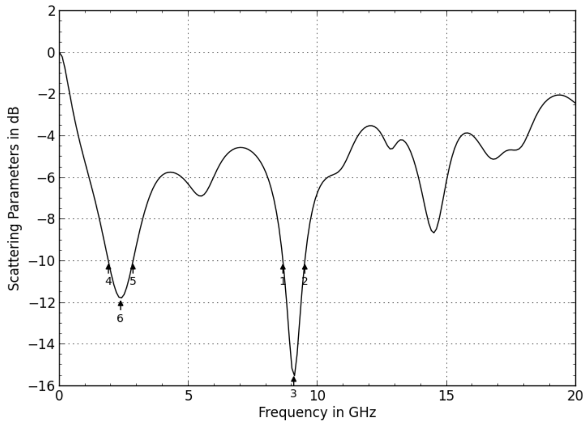

Fig. 4 . Antenna without FSS

The table below shows the results of patch antenna without FSS.

TABLE I

S.No	Resonant Frequency (f_r) (GHz)	Return Loss(dB)	Bandwidth (GHz)
1.	9.07	-15.397	0.847

Now let us examine the results of implanting FSS with the antenna. To find out the best result, it is necessary to find out the correct position of FSS from the patch.

VI. ANALYSIS OF PATCH ANTENNA WITH FSS

We have started with the FSS distance 1.1mm from the patch.

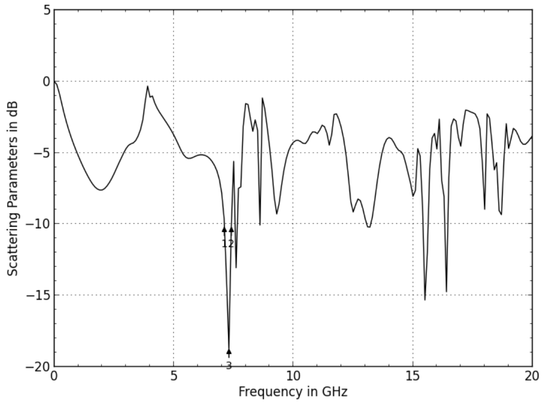

Fig. 5 . FSS distance 1.1mm from patch

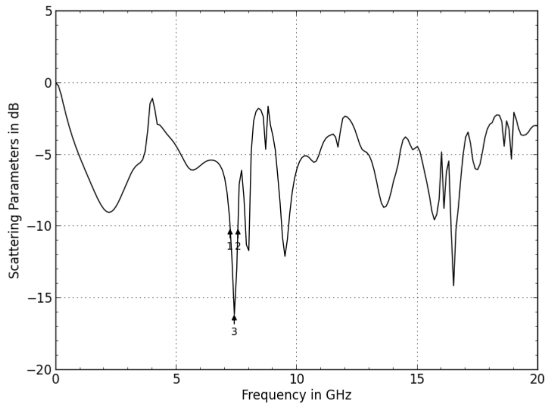

Fig. 6 . FSS distance 2.1mm from patch

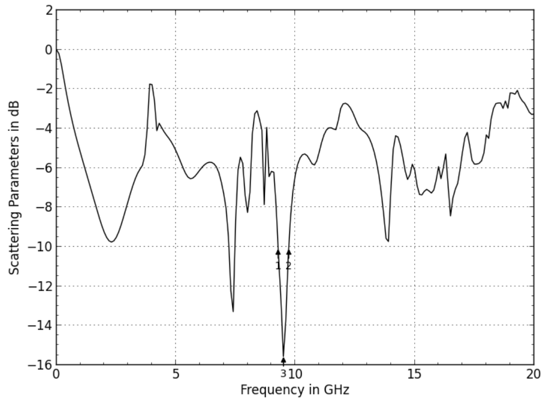

Fig. 7 . FSS distance 3.1mm from patch

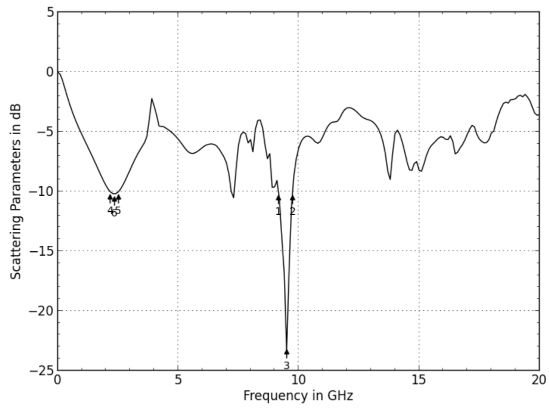

Fig. 8 . FSS distance 4.1mm from patch

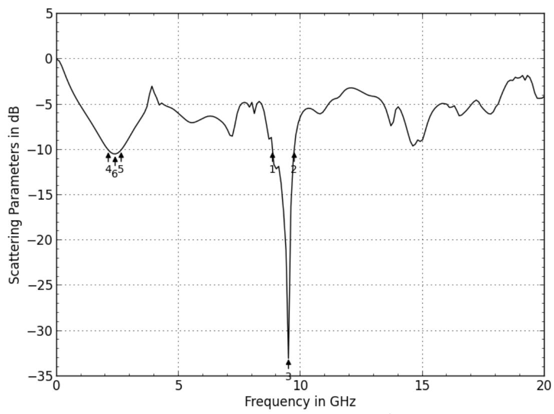

Fig. 9 . FSS distance 5.1mm from patch

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We see that till 3.1mm results are not very good, but from 4.1mm results begin to improve.We can show tabulated as,

TABLE II

S.No.	FSS Distance from Patch (mm)	Resonant Frequency (f_r) (GHz)	Return Loss (dB)	Bandwidth(GHz)
1.	1.1	7.3	-18.552	0.294
2.	2.1	7.3	-15.994	0.327
3.	3.1	9.5	-15.478	0.448
4.	4.1	9.5	-22.978	0.585
5.	5.1	9.5	-32.870	0.890

From the above results, it can be seen that the return loss and bandwidth begin to improve as we increase the distance of FSS from the patch.

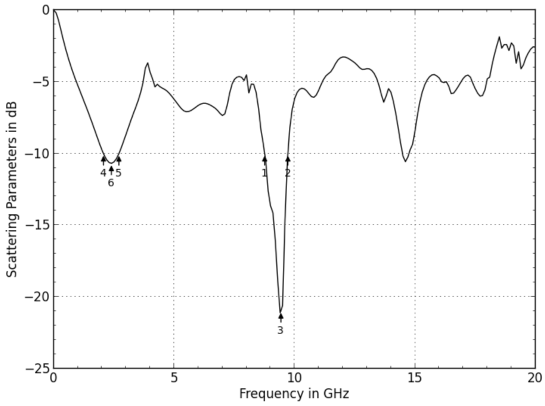

Fig. 10 . FSS distance 6.1mm from patch

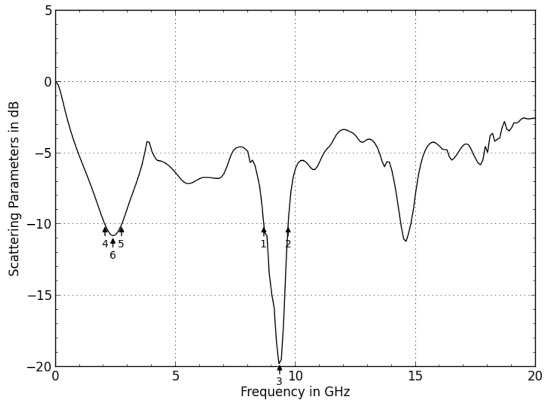

Fig. 11 . FSS distance 7.1mm from patch

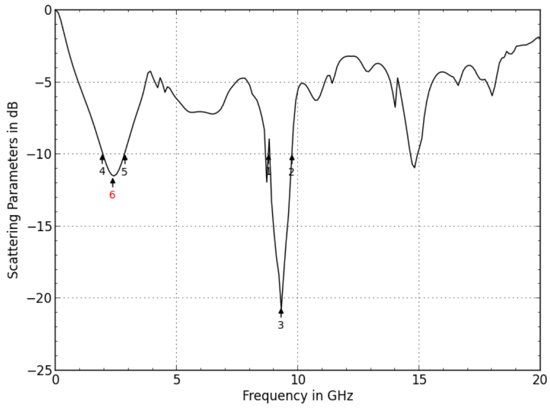

Fig. 12 . FSS distance 8.1mm from patch

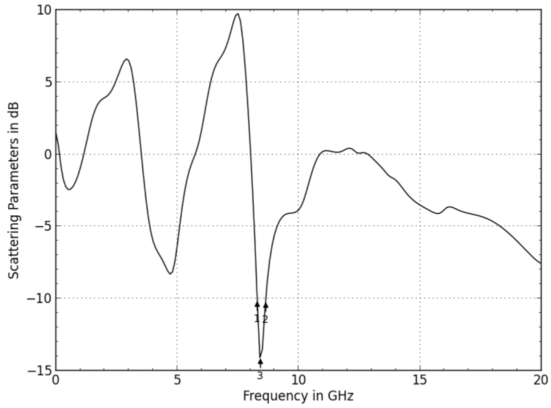

Fig. 13 . FSS distance 9.1mm from patch

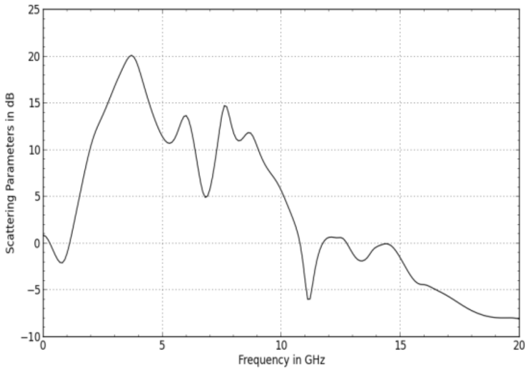

Fig. 14 . FSS distance 10.1mm from patch

S.No.	FSS Distance from Patch (mm)	Resonant Frequency (f_r) (GHz)	Return Loss (dB)	Bandwidth (GHz)
6.	6.1	9.4	-20.961	0.965
7.	7.1	9.3	-19.65	1.015
8.	8.1	9.3	-20.493	0.970
9.	9.1	8.4	-13.991	0.352
10.	10.1	-	-	-

Hence, by seeing all the above results we can conclude that two particular structures are of our interest.

1) When FSS is at a distance of 5.1mm from the patch, the return loss is maximized.
2) When FSS is at a distance of 7.1mm from the patch, the bandwidth is maximized.

VII. VSWR CHARACTERISTIC

For patch antenna with FSS at distance 5.1mm

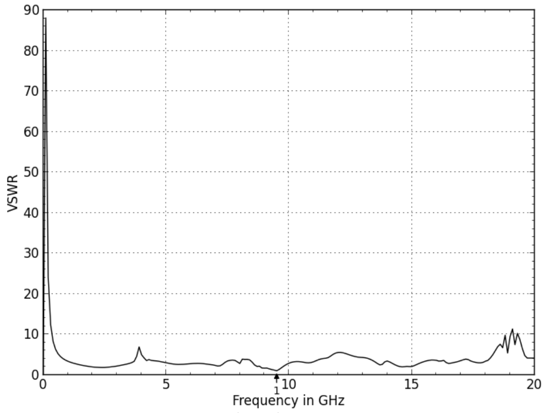

Fig. 15 . VSWR vsfreq for FSS at distance 5.1mm

The obtained value of VSWR is 1.035 at resonance frequency 9.5GHz,which is better for antenna performance as VSWR should be less than 2. This value of VSWR shows good impedance matching and less radiation loss.

For patch antenna with FSS at distance 7.1mm

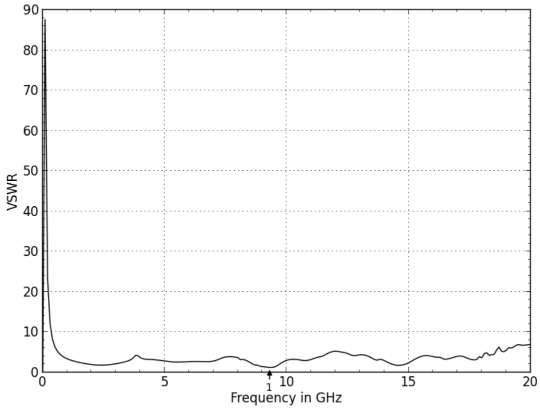

Fig. 16 . VSWR vsfreq for FSS at distance 7.1mm

The obtained value of VSWR is 1.22 at resonance frequency 9.3GHz,which is better for antenna performance as VSWR should be less than 2. This value of VSWR shows good impedance matching and less radiation loss.

VIII. CONCLUSION

The microstrip patch antennas are widely used in mobile communication systems. The basic aim of this paper is to design a conventional patch antenna and the patch antenna with FSS with same physical dimensions which can operate at 9.5GHz to study the performance of a microstrip patch antenna when FSS is added to it. Then from the simulated results, it can be seen that the performance is better with the patch antenna that is designed with FSS in comparison to the conventional patch antenna.

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