Comparative Analysis between Trapezoidal Slot Antenna and High Gain Square Patch Antenna with FSS Structure for Wireless Application

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ABSTRACT:-

In this paper we provide a comparative analysis between trapezoidal slot antenna and square patch antenna with FSS (Frequency Selective Surface) structure for wireless applications, here the both patch antennas are designed by using HFSS software tool. This FSS and Trapezoidal slot are designed to have a band-pass property which could reduce the electromagnetic interference (EMI) and allow its signal wave radiated from the antenna. The Trapezoidal patch antenna operating frequency is 4GHz and it provides a gain of 5dB. But Square patch antenna with FSS structure provides a gain of 9dB at an operating frequency of 4GHz. The results indicates that square patch antenna with FSS structure provides a high gain (9dB) in comparison to the Trapezoidal slot antenna (5dB).

Keywords—FSS, Trapezoidal slot, patch antenna, EMI, polarization

I. INTRODUCTION

The FSS (Frequency Selective Surface)[1] technique providing a wireless communication to have high transmittance at the specified wireless-signal bands, high shielding effectiveness outside these bands, and minimal influence on the radiation characteristics of the internal antenna has been proposed and widely used.

The FSS [3]-[5] have a band-pass property of which could reduce the electromagnetic interference (EMI) of the FSS structure and allow its signal wave radiated from the internal antenna to pass through. When used as a band-pass filter in the waveguide, a conventional FSS may pass some higher order resonance frequencies that is not favorable. The unit cell size in a conventional FSS is large for low frequency bands. Hence a band-pass waveguide filter is designed using the presented FSS structure.

It could increase the performance of the internal antenna. This paper proposes applying the FSS technique, which has a property of Quarter-wave plate to transform the linearly-polarized (LP) wave radiated from a patch antenna to the circularly-polarized (CP) wave. In addition, the Frequency

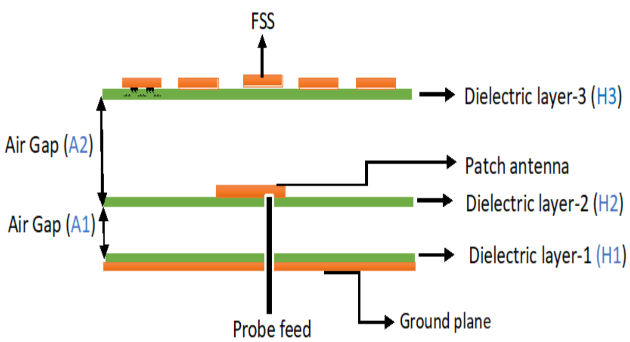
Selective Surface (FSS) will highly increase the antenna gain. The source antenna is simply a square patch antenna fed at its diagonal line, therefore, an linearly polarized wave is parallel to the 45-degree diagonal line, then the FSS structure used to transforms the linearly polarized (LP) wave into the circularly polarized (CP) wave.

The antenna has an impedance matching band from 3.86 to 4.16 GHz determined by a -25dB return loss. In this operation band, the axial ratio is below 4 dB, so it provides a circular polarization and the antenna gain is highly increased to 9dB.

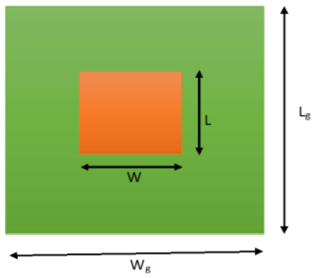
The radiation performance of a rectangular patch antenna having a trapezoidal slot at the center of the glass epoxy FR4. The resonant frequency lies in the higher band (4 to 5.85 GHz) allotted by IEEE 802.16 working group for Wi-MAX systems. The frequency band determined by a -5dB and gain are determined.

II. PROPOSED ANTENNA DESIGN

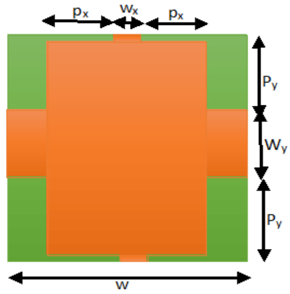
A. *Square patch antenna with FSS technique*



(a)



(b)



(c)

Fig 1 (a)Design of Square patch antenna with FSS structure, (b) top view of patc (c) top view of patch

B. Trapezoidal slot patch antenna

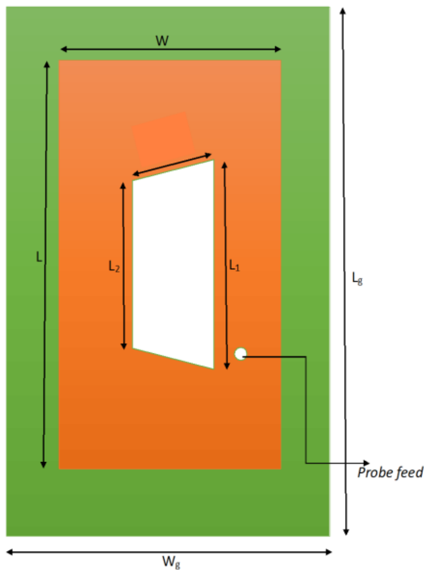


Fig 2 design of Trapezoidal slot patch antenna

III. ANTENNA DESIGNING EQUATIONS

$$\lambda = \frac{c}{f}$$

Where λ is the wavelength
C= speed of light
f= operating frequency

Width of the patch, $W = \frac{c}{2f_0\sqrt{\frac{\varepsilon_r+1}{2}}}$ ……….(1)

The effective dielectric constant (ε_{eff}) is less than (ε_r) because the fringing field around the periphery of the patch is not confined to the dielectric speared in the air also.

Here f_0 *is* resonant frequency and ϵ_r is the dielectric constant.

Length of the patch $L = L_{eff} - 2\Delta L$ ……..(2)

Here 'L_{eff}' is the effective length

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{eff}}}$$

Here 'ε_{eff}' effective dielectric constant
'ΔL' is the increased length.

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + \frac{12h}{W}\right]^{-1/2}$$

Here
'h' is the thickness of the substrate

$$h = \frac{0.0606\lambda}{\sqrt{\varepsilon_r}}$$

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

The minimum length of the substrate, $L_{sub} = 6h + L$
The minimum width of the substrate, $W_{sub} = 6h + W$

$$L = L_{eff} - 2\Delta L$$

IV. GAIN ENHANCEMENT TECHNIQUE

The configuration of the high-gain CP square patch antenna is shown in Fig 1(a). As the side view shown, a patch antenna is located between a top FSS and a bottom fully reflective ground plane, which planes form a resonant cavity. The square patch antenna shown in Fig 1(b) is an LP square patch antenna with its polarization parallel to the 45-degree diagonal line. The type of the FSS is band-pass with a unit cell shown in Fig1 (c). This FSS should act as a shielding and a PRS simultaneously. The well-designed FSS can reduce the EMI of the shielded system and it also can be a quarter-wave plate polarizer to transform the LP wave radiated from the antenna to CP. As the cavity resonating, the antenna gain will be highly increased.

V. DIMENSIONS OF ANTENNA DESIGN

A. Feeding consideration

In this paper we are using coaxial feeding technique for both the antenna designs because of good impedance matching.
The inner conductor of the SMA connector extends through the dielectric and is soldered to the radiating patch, while the outer conductor is connected to the ground plane.

B. Substrate selection

The first step in the design is to choose a suitable dielectric substrate of appropriate thickness (h=1) and loss tangent. A thicker substrate, besides being mechanically strong it will increase the radiated power, reduce the conductor loss and improve impedance bandwidth.
Here dielectric substrate is FR4 material with dielectric constant (ε_r= 4.4) used for both antenna designing.

C. Design considerations

In the square patch antenna with FSS structure uses three dielectric layers with thickness H1, H3 and H5, respectively. The FSS elements are printed on the top surface of dielectric layer (H5), the patch antenna is printed on the top surface of dielectric layer (H3), and a metal plane is printed in the bottom surface on the dielectric layer (H1). All the dielectric layers are the FR4 substrate with a dielectric constant 4.4 and a loss tangent 0.02. The corresponding dimensions: the thickness H1=0.4 mm, H3=1.6mm, H5=1.6 mm, and air gap dimensions are A1=2mm, A2=39.4. The antenna dimensions L1=170 mm, L2=22.5 mm, The feeding point X=Y=4.2 mm, The feeding hole radius is 0.75 mm; The FSS unit cell dimensions W=30 mm, Wx=0.9 mm, Px=12.3 mm, Wy= 7.1 mm, Py=10.45 mm.
And in trapezoidal slot patch antenna the dielectric material selected for this design is FR4 substrate which has a dielectric constant of ($\varepsilon_{r=4.4}$), and dielectric tangent of 0.025, the height of the dielectric substrate is (h=1.6mm).
The WI-MAX applications use the frequency range from (4-5.85) GHz. Resonant frequency selected for this design is 4GHz GHz. It includes calculation of width (W=25 mm). And actual length of the patch (L=40mm), ground plane dimensions (L_g=49.6 mm, and W_g=34.6 mm), feed point position is (xf, yf) = (10.02mm, 12.5mm).

D. Table- Dimensions of two designs

Designing parameter	**Square patch antenna with FSS technique**	**Trapezoidal slot patch antenna**
Patch length (L)	30mm	40mm
Patch width (W)	30mm	25mm
Substrate length (L_g)	170mm	49.6mm
Substrate width (W_g)	170mm	34.6mm
Substrate thickness (h)	1.6mm	1.6mm
Feed position (x_f,y_f)	(4.2,4.2,0)	(10.02,12.5,0)
Inner conductor diameter	0.325mm	0.6mm
Outer conductor diameter	0.75mm	1mm
Return loss (dB)	**-25dB**	**-4.6dB**
Gain (dB)	**9dB**	**5dB**
Axial ratio (dB)	**1**	**2**

VI) SIMULATION RESULTS

In this paper, the gain performance of the Square patch antenna with FSS structure fig 3(b) is compared with the gain performance of the Trapezoidal slot patch antenna fig 4(b). These two antennas are simulated using HFSS simulation software tool. The frequency band of square patch antenna determined by a -25dB return loss and obtained gain is 9dB and similarly trapezoidal slot patch antenna frequency band determined by a -5dB return loss and obtained gain is 5dB.

A) Results of Square patch antenna with FSS

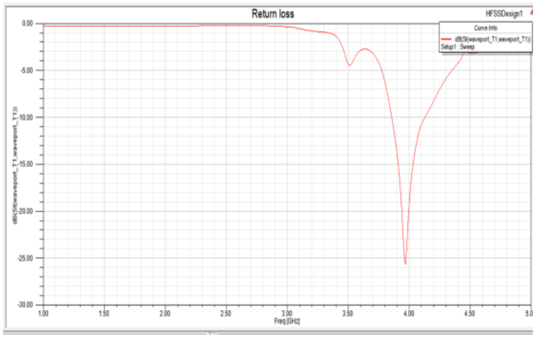


Fig 3(a) Return loss plot

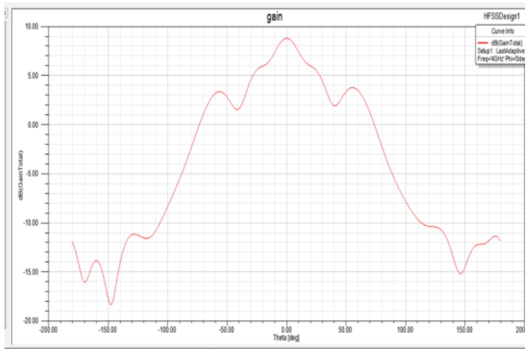


Fig 3(b) Gain plot

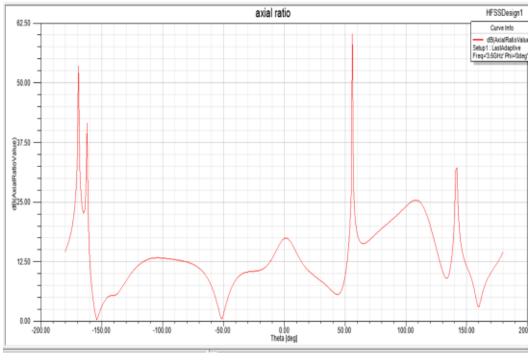


Fig 3(c) Axial ratio plot

B) Results of Trapezoidal slot patch antenna

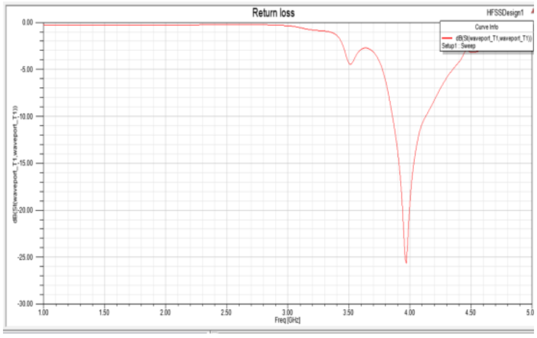


Fig 4(a) Return loss plot

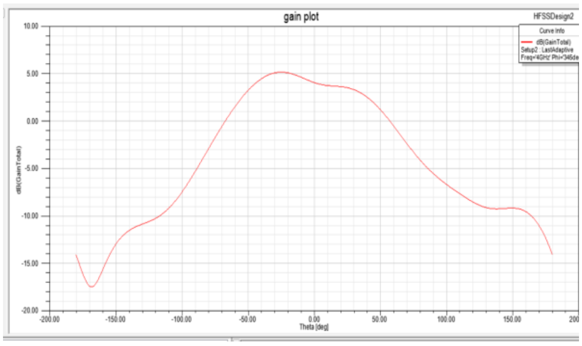
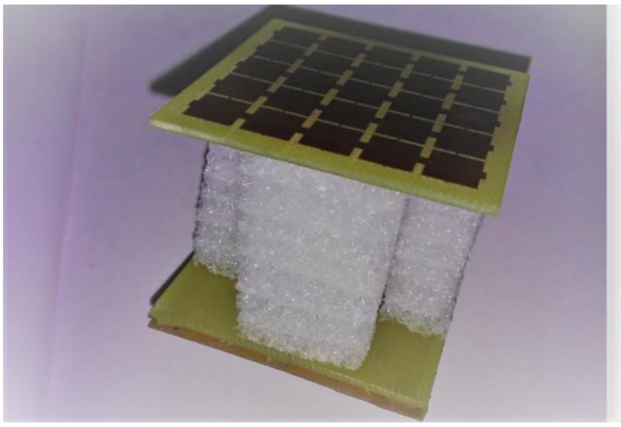
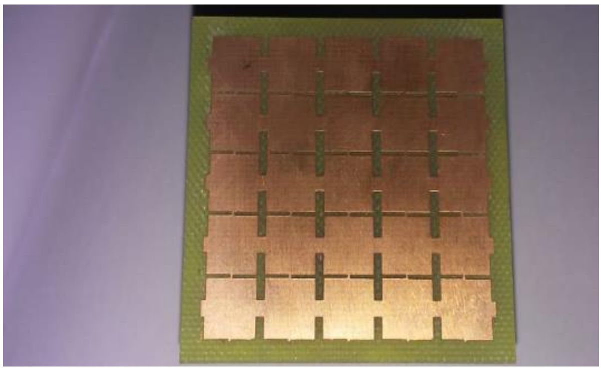


Fig 4(b) Gain plot

VII) FABRICATED DESIGN



(a)



(b)

Fig 5 Fabricated square patch antenna with FSS structure (a)Front view of antenna, (b) top view of antenna

VII) CONCLUSION

An advanced FSS technique has been applied for a high-gain CP antenna design. This shielding has high SE for stopping EMI radiated from the shielded FSS system and improving the system immunity to ambient noise. More importantly, it can transform an LP wave radiated from an internal patch antenna to CP wave. The square patch antenna with FSS provides a gain at 9dB, and the Trapezoidal slot patch antenna provides a gain at 5dB. From this we concluded that by using FSS technique the gain is increased to 4dB more when compared to Trapezoidal slot patch antenna then from this observation we concluded that the electromagnetic interference of radiated patch antenna is reduced.

VIII) REFERENCES

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