Multiband Star Shape Slotted Micro-Strip Patch Antenna Design for Wireless Application

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Abstract—**In this paper a Seljuk star shape slotted microstrip patch antenna is presented on a rectangular shape glass epoxy FR4 substrate having thickness of 1.6mm. Probe feed technique is used in this slotted antenna for multiband behavior. The multiband behavior is analyzed using two slotted iterations. The proposed antenna covers multiband frequencies in the range from 1.6 to 5.9GHz. It is simulated using IE3D simulator. Electrical parameters of the antenna like return loss; radiation pattern & VSWR exc. are investigated. The relationship between geometric sizes of the patch and the electrical parameter specifications of the antenna is researched.**

Index Terms—**seljuk, slotted, multiband and IE3D**

I. Introduction

A microstrip patch antenna has a conducting patch that made of metals such as copper or gold, printed on a grounded dielectric substrate [1]. These antennas are low profile, light weight, easy fabrication, conformable to planar and nonplanar surfaces compatible with MMIC design [2]. A conventional microstrip patch antenna have the disadvantage of narrow bandwidth this poses a challenging task for the microstrip antenna designer to meet the broadband technique [3], [4]. A large number of microstrip patches have been developed that is used in wireless application. Some shapes are square, rectangle, ring, ellipse, pentagon, kite shape are introduced. In comparison to patch configuration the antenna with slot gives enhanced characteristics including wider band width and low conductor loss and better isolation [5]. Wireless local area network (WLAN) is rising its application in wireless communications. Antennas for portable WLAN device require broad band, high gain and compact design. As a result of these parameters multiband antenna techniques have attracted more attentions. Recently many new technologies have been proposed for multiband antenna design [6]-[10]. In this paper, slotted microstrip patch antennas are designed in a shape of Seljuk star which is one of the basic shapes of Seljuk culture. A Seljuk star has eight corners that can be easily obtained by combining two same dimension squares located 45^o relative to each other. Calculating all its geometric characteristics easily make this shape usage advantageous in microstrip patch antenna design [11]. Although many star shape patch designs are available, but the eight corner star is different. In other star shape antenna studies, rather than a simple, single layer design with a single coaxial feed line, aperture-coupled feed, stacked geometry exc. different and more complex techniques are preferred. In addition, except [12], there isn't any design formulation study for star shape patches, only geometric associations are examined [11]. Performance simulations of antenna are performed on IE3D software, which is based on the method of moments [13].

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II. Antenna Geomrtry

The basic structure of microstrip patch antenna is given through the rectangular patch and runs though several slotted iterations to generate multiband characteristics. The initial dimension of the patch is taken at 2.4GHz by taking the FR4/glass epoxy substrate and the height of substrate is 1.6mm, loss tangent 0.02 and the dielectric constants is 4.4. The basic formulae for length and width are given below [2].

$$w = \frac{c}{2f_0}\sqrt{\frac{2}{\varepsilon_r+1}} \quad (1)$$

$$\varepsilon_{reff} = \frac{(\varepsilon_r+1)}{2} + \frac{(\varepsilon_r-1)}{2}\left(1+\frac{12h}{w}\right)^{-\frac{1}{2}} \quad (2)$$

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{eff}}} \quad (3)$$

$$\Delta L = 0.412h\frac{(\varepsilon_{reff}+0.3))\left(\frac{w}{h}+0.264\right)}{(\varepsilon_{reff}-0.258)\left(\frac{w}{h}+0.8\right)} \quad (4)$$

$$L = L_{eff} - 2\Delta L \quad (5)$$

where
c = Velocity of light in free space
f_0 = Operating resonant frequency
ε_r = Relative dielectric constant
ε_{reff} = Effective dielectric constant of the substrate
h = Height of the substrate
w = Width of the substrate

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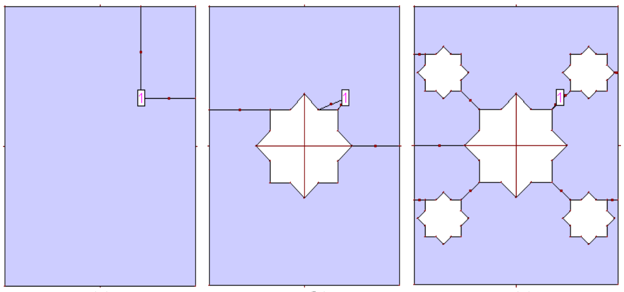


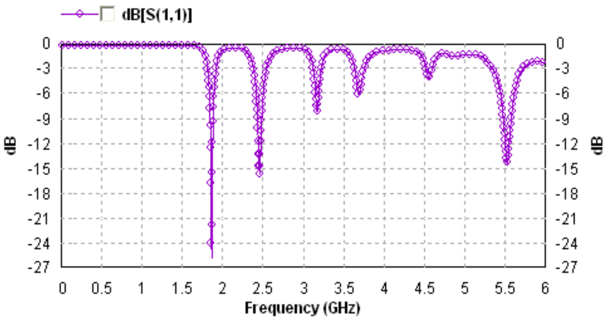
Figure 1. Simulated antenna designs (a) Zero slot (b) Single slot (c) Five slots

Fig. 1 shows the three designs of rectangular patch antenna one is simple rectangular patch another is a rectangular patch with a single slot and another one is rectangular patch with five slots. Length and width of the rectangular patch is 28mm and 38 mm respectively. The single slotted geometry is found making a slot in the rectangular patch in form of Seljuk star, this shape is designed by taking the two square of dimension 10mm, centered at (0, 0). In the five slotted geometry four additional Seljuk star slots is made symmetrically by taking the square dimension of 5cm cetered at coordinates (10, 10), (10, -10), (-10, 10) and (-10, -10). In this study all the designs is probe fed. The location of the probe is same in all three antenna designs.

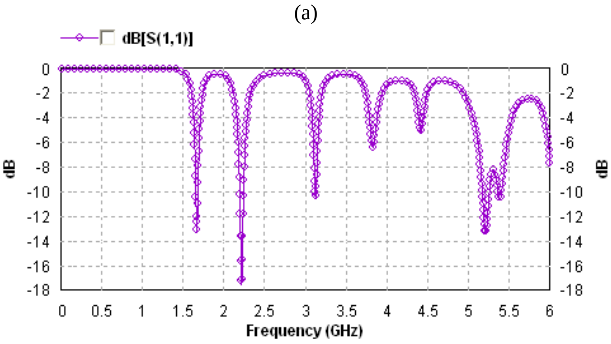
III. Results and Discussions

Fig. 2 shows the variation of return loss with the frequency for the zero, single and five slotted form of microstrip patch antenna.

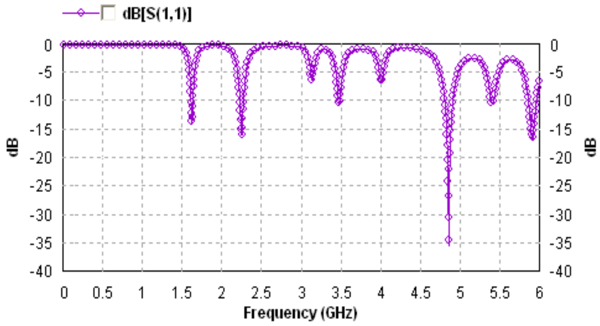
The return loss curve shows that the resonating band for the zero slotted patch antenna is three, for the single slotted patch antenna is five and for the five slotted patch antenna is six. This shows that designed patch antennas show the multiband behavior.



(a)



(b)



(c)

Figure 2. Return loss (a) Zero slot (b) Single slot (c) Five slots

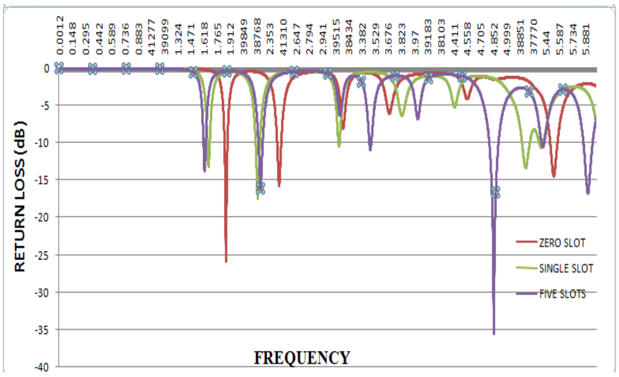


Figure 3. Comparison curve for return loss S_{11} (dB) vs frequency for zero slot, single slot and five slots patch antenna.

From the Fig. 3, which shows the combined comparative curve for the return loss for zero slot, single slot and five slots, in zero slotted form there are three bands with return loss less than -10dB and minimum value of return loss is less than -15dB, in single slotted form there are five bands with return loss less than -10dB and minimum return loss is approximately -17dB and in five slotted form there are six bands with return loss less than -10dB and the minimum value of return loss approaches nearly up to -35dB. So the return loss minimizes as increasing the slots in the patch antenna.

TABLE I. Comparison of Return Loss for Zero Slot, Singe Slot and Five Slots

Zero Slot		Single Slot		Five Slots	
Frequency (GHz)	Return Loss (dB)	Frequency (GHz)	Return Loss (dB)	Frequency (GHz)	Return Loss (dB)
1.86	-23.19	1.67	-13.12	1.62	-13.71
2.46	-15.6	2.21	-16.98	2.25	-16.09
5.52	-14.4	3.12	-10.60	3.47	-10.92
		5.2	-13.35	4.85	-35.23
		5.38	-10.65	5.40	-10.50
				5.90	-16.70

Table I has the values of Return Loss for different frequency points, from the table values it is quite clear that the antenna suits for various commercially available frequency range applications such as for GSM (1.86GHz), ISM band (5GHz), Wi-Fi IEEE 802.11 (2.4-2.5GHz for 802.11 b, g, n) and (5.7-5.9 for 802.11 a and n), this shows that the proposed antenna has wide application range for commercial application.

Other important parameters such as Directivity, Gain and Antenna efficiency are also simulated for the designed antennas. From Fig. 4, the curve is drawn in between Directivity and frequency and it is noticeable that average value of directivity stands at 8dBi and approaches up 10.5dBi for the zero slotted form of the antenna. Fig. 5 shows the curve between the total field gain and frequency. Fig. 6 shows the curve between radiation efficiency and frequency (Green color for zero slot, black color for single slot and violet color for five slots). In Fig. 7, Fig. 8 and Fig. 9 shows the curve between VSWR and frequency for zero, single and five slots respectively, in all the cases 1<VSWR<2 at all the resonating frequency, which shows the good impedance matching condition. Fig. 10 shows the 3-dimensional radiation pattern for all the geometries of patch antenna.

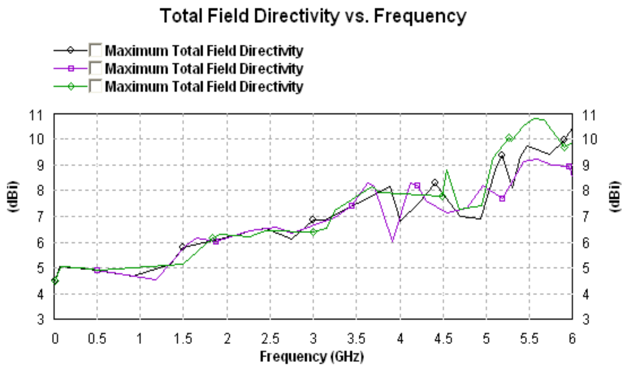


Figure 4. Antenna directivity comparison curve for zero slot, single slot and five slots

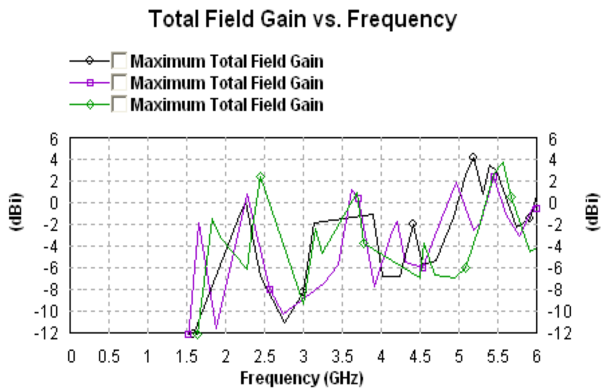


Figure 5. Antenna total field gain comparison curve for zero slot, single slot and five slots

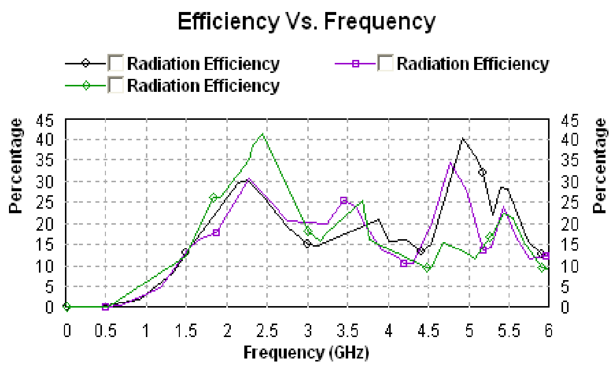


Figure 6. Radiation efficiency comparison curve for zero slot, single slot and five slots

The radiation efficiency of the three designs is not so high because the material FR4/glass epoxy is a lossy material, the loss tangent is high 0.02, and this material is easily available and less costly.

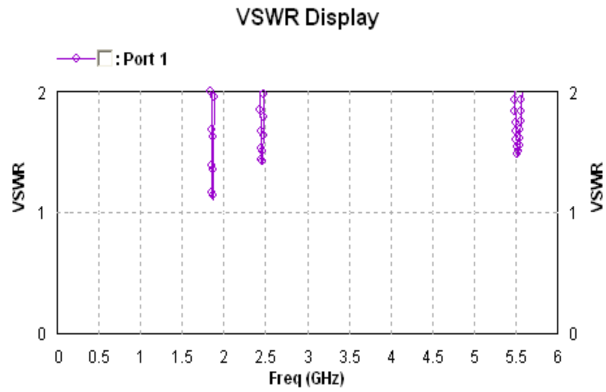


Figure 7. VSWR for zero slotted form at the frequency at frequency at 1.86GHz, 2.46GHz and 5.52GHz.

From Fig. 7 we can see that there are three resonating band in zero slot design that have the voltage standing wave ratio between one to two. This shows that reflecting energy is less at these frequencies, so matching is perfect at these points.

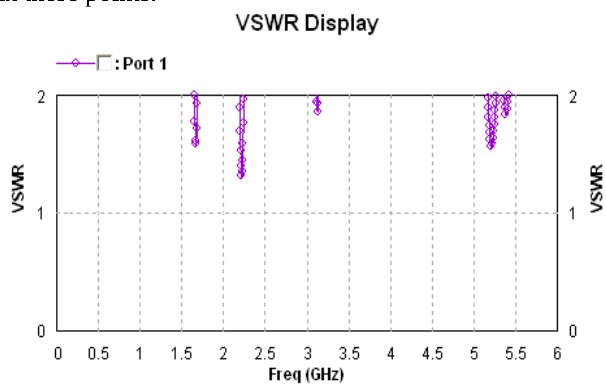


Figure 8. VSWR for the single slotted form at the frequency at frequency at 1.67GHz, 2.21GHz, 3.12GHz, 5.2GHz and 5.38GHz.

Fig. 8 shows that the resonating frequency bands for the single slot patch antenna for which the voltage standing wave ratio is vary from one to two is five. So these five frequencies support the good matching condition in single slotted patch antenna.

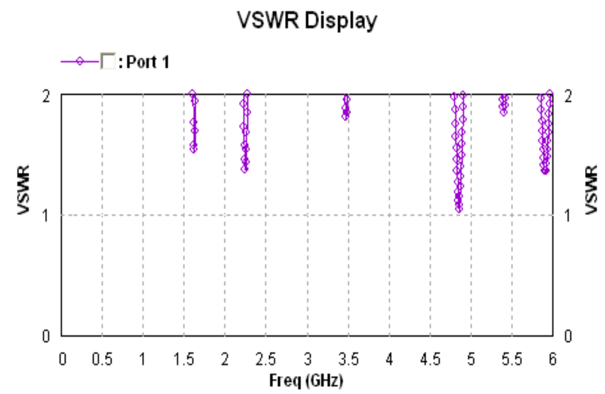
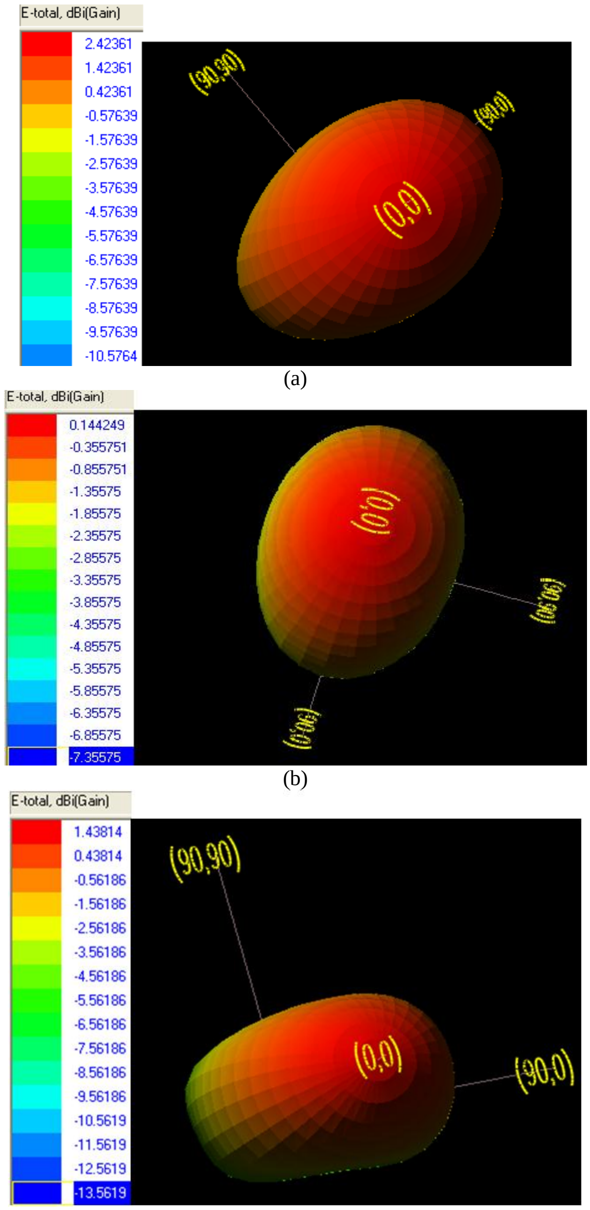


Figure 9. VSWR for the five slotted form at the frequency at frequency at 1.62GHz, 2.25GHz, 3.47GHz, 4.85GHz, 5.40GHz and 5.90GHz.

From Fig. 9 the six resonating band occurs for the five slotted patch antenna for which the VSWR varies from one to two. These frequencies show the good matching between the patch and coaxial probe.



(a)

(b)

(c)

Figure 10. Radiation patterns (a) Zero slot (at 2.445GHz) (b) Single slot (at 2.264GHz) (c) Five slots (at 4.848GHz)

Fig. 10(a), Fig. 10(b) and Fig. 10(c) show the 3-D radiation pattern for zero slot single slot and five slots rectangular patch at the frequency 2.445GHz, 2.264GHz and 4.848GHz respectively, in all the three design the pattern are nearly Omni directional and shows the positive gain, or we can say the antenna can be used as a transmitting as well as receiving antenna.

IV. Conclusions

In this paper a Seljuk star shape multiband microstrip patch antennas is simulated. The proposed antennas have slotted geometry. The performances of the said antenna are studied for different number of slots. It is found that the as the number of slots are increased, the operational frequency band also increases. For zero slot three resonant frequency bands occur, for single slot five resonant bands occurs and for five slots six resonant frequency bands occurs. These antenna can be used at various application such as GSM and WLAN-IEEE-802.11 (a, b, g and n). Therefore the proposed antennas have satisfactory performance for use as a multiband communication antenna.

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