International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 06, June-2016

Design of Star Shaped Slotted Rectangular Microstrip Patch Antenna for Multiband Applications

Manjit Kaur
Dept. of Electronics and Communication Engineering
Guru Nanak Dev University, Regional Campus
Gurdaspur (Punjab), India

Shashi B. Rana
Dept. of Electronics and Communication Engineering
Guru Nanak Dev University, Regional Campus
Gurdaspur (Punjab), India

***Abstract*—In today's world of wireless communication there is need of antennas having multiband characteristics. This paper presents the design of star shaped slotted rectangular microstrip patch antenna for multiband applications. The star slots are introduced in the geometry of rectangular patch antenna to increase the operating frequency bands to make it a multiband antenna. Proposed antenna is designed on FR4 epoxy substrate having relative permittivity 4.4 and 1.6mm thickness. The resonant frequency used for designing the proposed antenna is 3.2GHz. The proposed antenna works on seven frequency bands such as 3.08GHz, 4.68GHz, 5.67GHz, 5.93GHz, 8.14GHz, 8.46GHz and 9.93GHz. HFSS 13 software is used for designing, simulating and analyzing the different parameters of proposed antenna. The antenna is fabricated and tested. The experimental results are compared with simulated results which are in good agreement with each other**

Keywords*—*Multiband; Wireless Communications, Star Slots

I. INTRODUCTION

Microstrip antenna was introduced in 1970 and from there the microstrip antenna technology becomes the most rapidly developing [12] in the field of wireless communication because of their many tremendous features and advantages [1]. The main advantages of microstrip antennas which increase the interest of researchers in this field are its low profile, low cost, compact size, ease of fabrication and installation etc [2, 7]. Microstrip patch antennas are extremely compatible in hand held devices such as cellular phones and pagers [3]. Due to the increase in the demand of wireless applications, the need of compact microstrip antenna with dual and tri-band characteristics and the antenna with multiband characteristics also increases day by day [4]. To achieve the multiband characteristics many efforts has been made by the researchers in recent years. The methods such as notch technique, slots technique and fractal method are used to design multiband antennas [13]. By introducing these different types of methods and techniques in the geometry of microstrip patch antenna and proper selection of feeding technique helps to achieve the multiband characteristics easily [1]. A multiband characteristic helps the antenna to be used in various wireless applications such as Wi-Max (World Interoperability for Microwave Access) frequency band ranges are 2.5GHz (2.5-2.69GHz), 3.5GHz (3.4-3.69GHz) and 5.8 GHz (5.25-5.82 GHz), WLAN (Wireless Local Area Network) frequency band ranges are 2.4GHz (2.4-2.48GHz), 5.2GHz (5.15-5.35GHz) and 5.8GHz (5.725-5.825GHz) and Bluetooth at 2.4GHz [6, 8, 14]. FCC allocated the frequency range of 3.1 to 10.6GHz for UWB applications [9] and the microstrip antenna and slotted patch antenna is a good candidate for these wireless applications [10, 11]. On the other hand microstrip patch antennas with printed slots fed by different feeding techniques have several advantages over conventional microstrip patch antennas. Slotted patch antenna exhibit low radiation loss, low dispersion and wider bandwidth as compared to conventional microstrip patch antenna [5].

In the work a unique modification has been done in the geometry of rectangular microstrip patch antenna by introducing the star shaped slots. The main purpose of these slots is to increase the number of operating frequency bands. The proposed antenna have been successfully designed and fabricated. The good radiation characteristics and impedance bandwidth in the operating frequency bands have been achieved. The effect of various design parameters are also studied and discussed in this paper. Such type of antenna can be used for UWB applications, radar communication, fixed satellite communication, WLAN and Wi-Max applications etc.

II. ANTEENA DESIGN AND CONFIGURATION

The proposed antenna is developed on FR-4 glass epoxy substrate with dielectric constant 4.4, thickness h=1.6mm and resonant frequency taken as 3.2GHz. Initially the length and width of rectangular patch antenna is calculated by using equation (1) to (5), which comes to be 21.92mm and 28.52mm respectively. The base geometry of proposed antenna is shown in Fig. 1 and the parametric values are shown in Table 1.

$$w = \frac{c}{2\,fo\sqrt{\frac{\varepsilon_r + 1}{2}}} \tag{1}$$

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{w}\right]^{\frac{1}{2}} \tag{2}$$

$$L_{efff} = \frac{c}{2\,fo\sqrt{\varepsilon_{reff}}} \tag{3}$$

$$\Delta L = 0.412h \frac{(\varepsilon_{reff} + 0.3)\left(\frac{w}{h} + 0.246\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{w}{h} + 0.8\right)} \quad (4)$$

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

Where,
c = Velocity of light in free space.
h = Substrate height.
$\mathcal{E}r$ = Relative permittivity of the substrate.
W = Width of patch.
L = Actual Length of patch.
$Leff$ = Effective length
ΔL = Length extension.
$\mathcal{E}eff$ = Effective dielectric constant.

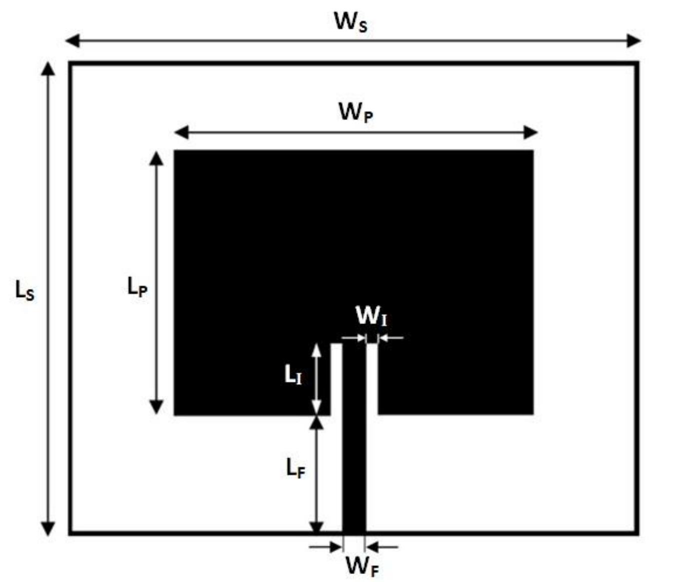

Fig. 1. Base geometry of proposed antenna

TABLE I. PARAMETRIC VALUES OF PROPOSED ANTENNA

S.No.	Parameters	Description	Values
1.	L_S	Length of substrate	38.92mm
2.	W_S	Width of substrate	45mm
3.	L_P	Length of patch	21.92mm
4.	W_P	Width of patch	28.52mm
5.	L_F	Length of feed line	9.89mm
6.	W_F	Width of feed line	1.8mm
7.	L_I	Length of inset cut	6mm
8.	W_I	Width of inset cut	1mm

The length and width of the ground plane of proposed antenna is same as the length and width of the substrate as shown in Table 1. To improve the antenna performance parameters further the star shaped slots has been introduced in the base geometry of proposed antenna. These slots are extracted from the rectangular patch of proposed antenna by taking all the other dimensions same as the base geometry. The star slots are designed by taking two equilateral triangle with side length X=5.75mm and by adjusting these triangles make the star shape with side length as X/3=1.91mm as shown in Fig 2. After making the star shaped slots extract these slots from the base geometry of proposed antenna to obtain the final geometry of antenna as shown in Fig 3. The proposed antenna is physically fabricated on FR4 epoxy substrate and the fabricated structure of proposed antenna is shown in Fig 4.

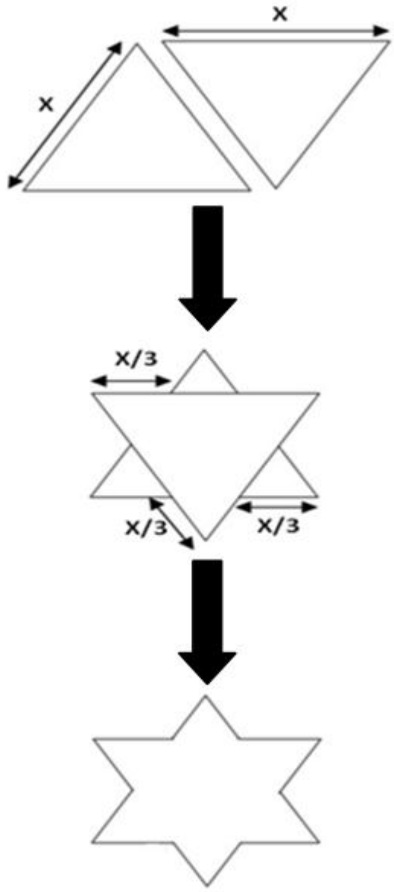

Fig. 2. Procedure for making Star shaped slots

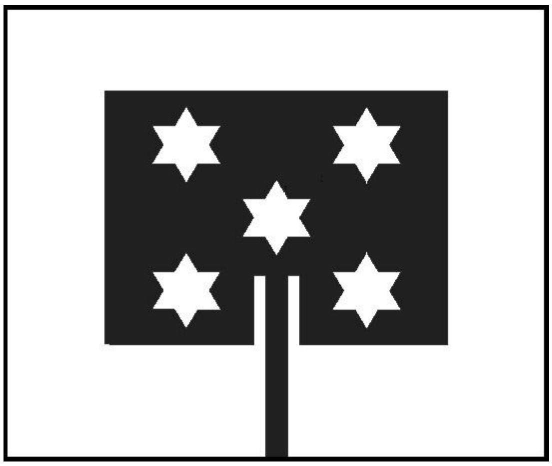
Fig. 3. Final Geometry of Proposed Antenna

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 06, June-2016

III. RESULTS AND DISCUSSIONS

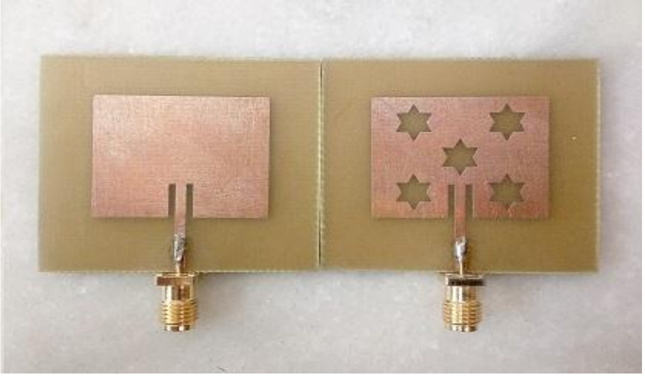

Fig. 4. Fabricated structure of proposed antennas

A. Return loss and VSWR

Simulations of proposed antenna are carried out using EM simulator based on Finite Element Method (FEM), Ansys/Ansoft High Frequency Structure Simulator (HFSS) V13 and the physically fabricated antennas are tested using Anritsu (MS46322A, 20GHz) Vector Network Analyzer (VNA). Figure 5 shows the simulated and measured result of return for the base geometry of proposed antenna and exhibits only three frequency bands of operations. The star shaped slots are introduced in the base geometry to enhance the performance parameters further. The fabricated structures of proposed antennas are shown in Figure 4. As seen in Figure 6 the antenna with star slots exhibits six frequency bands of operation. Due to good impedance matching the measured results of proposed antenna shows the bandwidth enhancement at the frequency ranging from 5.6 to 5.94GHz and 8.15 to 8.61GHz as shown in Figure 6. The return loss and VSWR of proposed antenna for both the geometries are at acceptable and are in good agreement with each other as shown in Fig 5, 6, 7 and 8. Table 2 shows the detailed values of simulated and measured results of proposed antenna with star slots such as return loss, bandwidth, VSWR and resonant frequency.

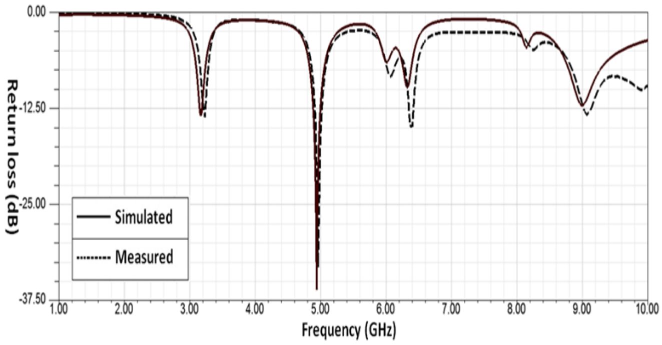

Fig. 5. Return loss v/s frequency plot for basic geometry of proposed antenna

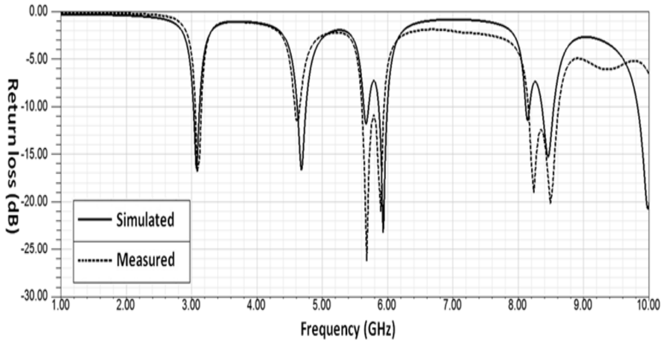

Fig. 6. Return loss v/s frequency plot for proposed antenna with slots

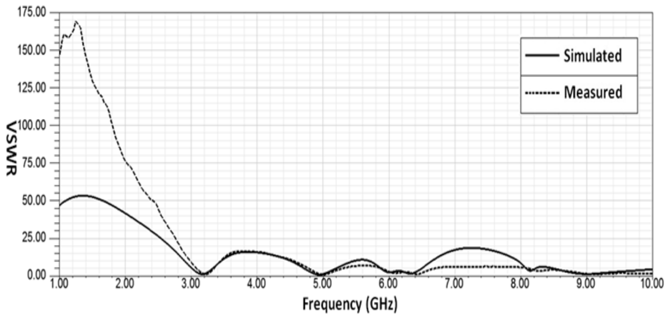

Fig. 7. VSWR v/s frequency plot for basic geometry of proposed antenna

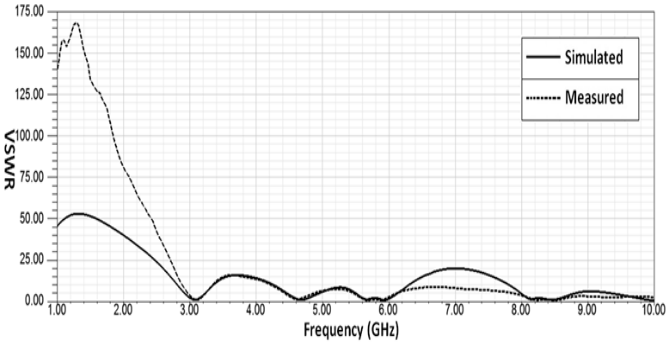

Fig. 7. VSWR v/s frequency plot for proposed antenna with slots

TABLE II. COMPARISON OF SIMULATED AND MEASURED RESULTS OF PROPOSED ANTENNA

Proposed Antenna	Resonant Frequency (GHz)	Return loss (dB)	VSWR	Bandwidth (MHz)
Simulated	3.08	-16.58	1.34	90
	4.68	-16.68	1.34	140
	5.67	-11.82	1.68	80
	5.93	-23.20	1.14	131
	8.14	-11.46	1.72	58
	8.46	-15.21	1.41	180
Measured	3.08	-16.84	1.51	100
	4.63	-11.34	1.73	80
	5.68	-26.13	1.10	340
	5.89	-21.00	1.21	
	8.23	-19.02	1.26	460
	8.48	-20.20	1.23	

B. Equations

Radiation pattern is the graphical representation which shows the directivity nature of the antenna in both elevation and azimuth plane. The elevation plane for phi=90 degree and phi=0 degree is useful for these patterns. 2D far-field radiation pattern for each frequency band like 3.08, 4.68, 5.67, 5.93, 8.14 and 8.46GHz is shown in Fig. 9a-f respectively. The gain of proposed antenna is also at acceptable level and the proposed antenna has maximum gain of 7.31dB at 8.46GHz frequency. The 3D gain plot at 8.46GHz frequency is shown in Fig. 9g.

IV. CONCLUSION

A rectangular patch microstrip antenna with star shaped slots is designed, simulated and fabricated for validating the experimental results. The proposed antenna resonates at the frequency of 3.08, 4.68, 5.67, 5.93, 8.14 and 8.46GHz which meets the different wireless standards such as mobile and satellite communication. The maximum value of gain is 7.31dB at the frequency band of 8.46GHz. All the simulated and measured values of proposed antenna are at acceptable level.

REFERENCES

[1] V. V. Reddy and N. V. S. N. Sarma, "Triband circularly polarized Koch fractal boundary microstrip antenna," IEEE Antenna and Wireless Propagation Letters, Vol. 13, pp. 1057-1060, 2014.

[2] S. Behera and D Barad, "A novel design of microstrip fractal antenna for wireless sensor network," International Conference on Computation of Power, Energy, Information and Communication, pp. 470-473, 2015.

[3] D. Kumar, M. Sharma and S. Bansal, "Novel design of key-shaped fractal antenna for UWB applications," IEEE 6th International Conference on Computational Intelligence and Communication networks, pp. 87-91, 2014.

[4] M. K. Khandelwal, B. K. Kanaujia, S. Dwari, S. Kumar and A. K. Gautam, "Analysis and design of dual band compact stacked microstrip patch antenna with defected ground structure for WLAN/WiMax applications," International Journal of Electronics and Communications (AEU), Vol. 69, pp. 39-47, 2015.

[5] T. Shanmuganantham, K. Balamanikandan and S. Raghavan, "CPW-Fed antenna for wideband applications," International Journal of Antenna and Propagation, Hindawi, pp. 1-4, 2008.

[6] S. Yadav, R. Choudhary, U. Soni, A. Dadhich and M. M. Sharma, "A Dual band star fractal antenna with slot for wireless applications," International Conference on Signal Propagation and Computer Technology (ICSPCT), pp. 738-740, 2014.

[7] W. Farooq, M. U. Rehman, Q. H. Abbasi, K. Q. Maqbool and K. Qaraqe, "Study of a microstrip patch antenna with multiband circular slots for portable devices," Proceedings of the 8th IEEE GCC Conference and Exhibition, 2015.

[8] X. Hu, W. Yang, S. Yu, R. Sun and W. H. Liao, "Triple band notched UWB antenna with tapered microstrip feed line and slot coupling for bandwidth enhancement," 16th International Conference on Electronic Packaging Technology, pp. 879-883, 2015.

[9] M. A. Abdalla, A. A. Ibrahim and A. Boutejdar, "Resonator switching techniques for notched UWB antenna in wireless applications," IET Microwaves, Antenna and Propagation, Vol. 9, pp. 1468-1477, 2015.

[10] R. R. Nithya, "Monopole Antenna C shape with a wide slot for UWB applications," IEEE Sponsored 2nd International Conference on Electronics and Communication System, pp. 850-853, 2015.

[11] G. Krishnaveni, B. Manimegalai and B. Saravanya, "A hexagonal monopole textile antenna for UWB applications," IEEE 2nd International Conference on Innovations in Information, Embedded and Communication Systems (ICIIECS), 2015.

[12] P. P. Chandran and S. Viswasom, "Gain and Bandwidth optimization of Novel Microstrip Patch Antenna," Fourth International Conference on Advances in Computing and Communications, IEEE, pp. 315-318, 2014.

[13] M. Rahimi, A. Keshtkar, F. B. Zarrabi and R. Ahmadian, "Design of compact patch antenna based on zeroth-order resonator for wireless and GSM applications with dual polarization," International Journal of Electronics and Communications (Elsevier), pp. 163-168, 2015.

[14] B. Roy, A. Bhatacharya, A. K. Bhattacharjee and S. K. Chowdhury, "UWB monopole antenna design in different substrate using sierpinski carpet fractal geometry," IEEE 2nd International Conference on Electronics and Communication System (ICECS), pp. 382-385, 2015.

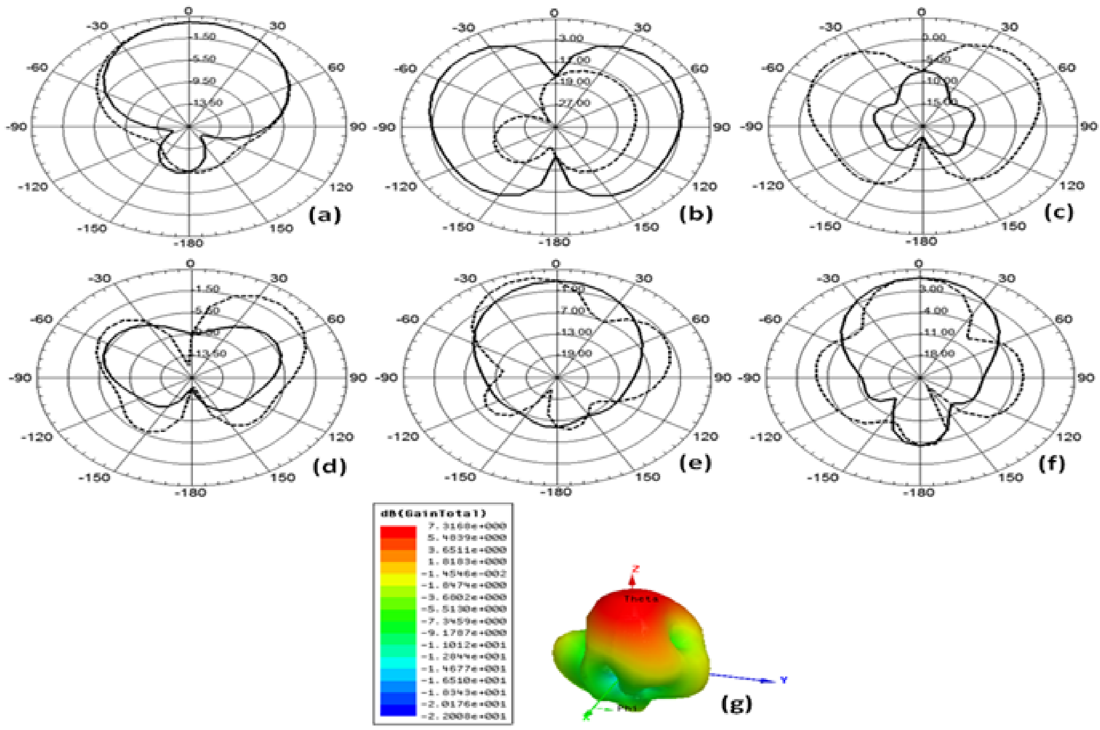

Fig. 9. (a-f) 2D far-field radiation pattern at respective frequency bands and (g) 3D gain plot at 8.46GHz frequency