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Tri-band Microstrip Patch Antenna for Ku-band Application

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Abstract: **To overcome the challenges of multi-frequency operation a new scheme of multiband is proposed. This paper proposes a microstrip patch antenna for multiband operations. This antenna shows the three distinct frequency bands, centered at 12.5 GHz, 14.55 GHz and 16.7 GHz. The proposed antennas has compact size of 19 X 19 X 1.07 mm^3 including the ground plane and both antenna structures are designed on FR-4 substrate (ε_r= 4.5) of thickness h=1 mm. The proposed structure is simulated using the electromagnetic (EM) simulation software. The simulated return loss is less than -20dB at resonante frequencies. The presented antenna is suitable for multiband wireless communication systems.**

Keywords: **Multiband, microstrip feed line, resonance frequency, rod-shaped parasitic element, slit, slot.**

I. INTRODUCTION

Now a day's wireless communication devices needed more and more frequency bands because of increasing wireless service requirements. Recent developments in the field of wireless communication industry continue to drive the requirements for small, compatible, and affordable multiband antennas As these devices also wants smaller dimensions for the real estate, antennas need to smaller their dimensions and more than one operating frequency bands while maintaining their performance. Due to this specification the demand for multiband antenna design is increasing continuously.

Multiband antennas have derived rapidly increasing attention in modern wireless communication systems in which the downward compatibility and the roaming capability among multi-standards are demanded. For example, (i)The global system for mobile communication (GSM), (ii)The general packet radio service (GPRS), (iii)The wire-less local area networks (WLAN), (iv) The universal mobile telecommunications system (UMTS) are generally a dual band or multiband wireless standards communication devices [1].

A number of multiband antennas with notched band property have been proposed, and various techniques have been used to achieve the multiband operation. The mainly used methods are etching slots on the patch or on the ground plane, for examples H-shaped slot [2], U-shaped slot [3], C-shaped slot [4], etc. There are another technique is use of parasitic strips [5] near the radiation elements or the ground plane for achieving the notched band and multi-functionality.

Using DGS we can add an extra degree of freedom in microwave circuit design which opens the door to a wide range of applications [16]. DGS structure is realized by etching simple shape from the ground plane. DGS disturbs the shield current distribution in the ground plane cause the defect in the ground. Due to this disturbance there will be changes in characteristics of a transmission line such as capacitance and inductance [16].

Most of the previous researches have been adapted the single-notched-band design; few researches have been focused on dual-notched-bands design. Dual-notched-bands antennas designs have been explained in the papers [6]–[8]. In these above papers the dual- band have been achieved by adding the proper slits in the near of radiating patch element and the ground plane, by the inserting of slit, the desired two rejected bands have been obtained. Due to lack of low VSWR, some

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UWB planar antenna structures with dual notched bands are reported in the literature. The UWB planar antenna is reported that have a T-slit on the top of radiating patch and U-stub besides the feeding line and the dual bands are achieved by using T and U-shaped. In [9] and [10], different shapes of the slots like square, ring and folded trapezoid are used to obtain the desired band notched characteristics of antenna. Single and multiple [11] half-wavelength U-shaped is used for the frequency band-notch function and the modified planar slits are inserted in the radiation patch to achieve the single and multiple band-notched functions, respectively. Band-notch function is also achieved by using a T-shaped coupled parasitic element in the ground plane in [12].

Recently, many techniques have been used to increasing the antenna bandwidth with the truncated ground plane with use of an L-shaped notch in the lower corner [13], [14] and an inverted T-shaped notch in the middle [15].

In this paper, tri-band antenna is proposed for Ku-band wireless communication systems. A rectangular microstrip patch antenna with multiple slots in radiating element, and defective ground is proposed for tri-band. The designed antenna is small in size and compact. The structure is designed with microstrip technology and suitable for multiband wireless communication.

The organization of this paper is as follows. In Section 2, basic design of proposed tri-band antenna is described. In Section 3, the simulated results of proposed tri-band antenna design are presented and compared; finally, the paper is concluded in Section 4.

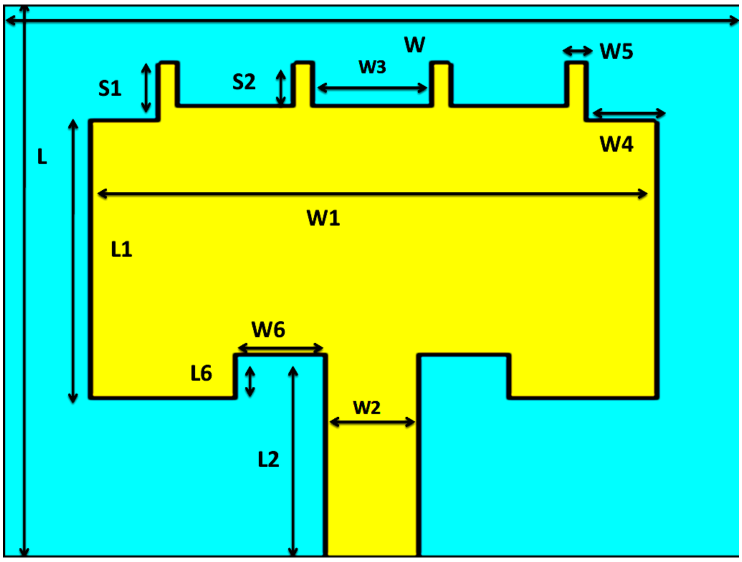
II. TRI-BAND ANTENNA DESIGN

An multiple slot rectangular patch antenna design structure is shown in Fig.1. In this structure five slots are cut in radiating patch to achieve the triple band operation, defective ground structure is introduced for improving the results.

This antenna is designed and simulated on FR-4 dielectric substrate that having dielectric constant (ε_r=4.5) and height of the substrate is 1 mm. The EM simulation software is used to design and optimize the antenna parameters to realize the proposed scheme for multiband operation.

The antenna has compact dimensions of 19 X 19 mm^2. In this antenna, for a better impendence matching over the full band, five slots with 1.5mm length are designed in the upper part of the patch. The patch is fed through a 50 ohm microstrip transmission line.

A partial ground plane with dimensions of 16.8 X 16.8 mm^2 is used for improving the results as shown in the Fig. 1(b). The width of the microstrip feed is fixed at W2=2.4 mm, and the length of that is L2=7 mm.



(a)

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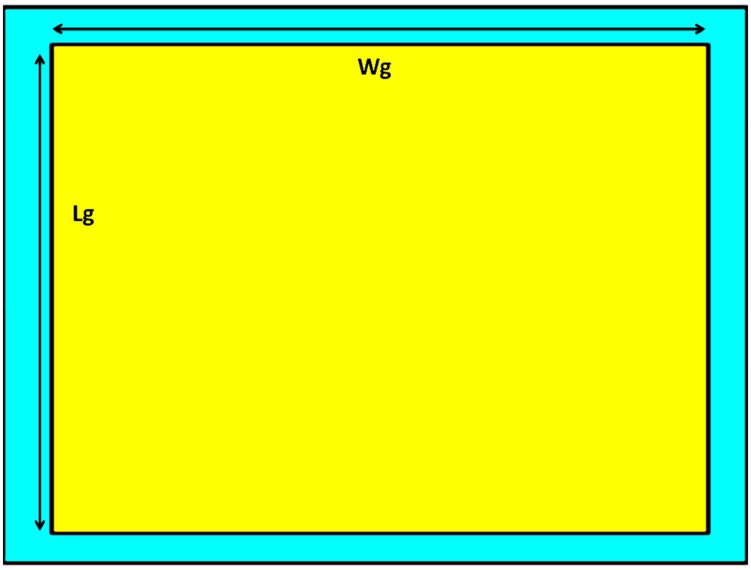

(b)

Fig 1. Proposed Tri-band antenna design (a) Front view (b) Back View

TABLE 1: KEY DIMENSIONS OF TRI-BAND ANTENNA DESIGN

Antenna parameter	Value	Antenna parameter	Value
W	19mm	W3	3mm
L	19mm	W4	1.8mm
L_1	9.5mm	W5	4mm
W1	14.6mm	L6	1.5mm
L2	7mm	W6	2.3mm
W2	2mm	S2	1.5mm
S1	2mm		

III. SIMULATION AND RESULTS

The software used to model and simulate the microstrip patch antenna is Electromagnetic (EM) simulation software. It has been widely used in the design of tunable filters, patch antennas, wire antennas, and other RF/wireless antennas. It can be used to calculate and plot the S-parameters, monostatic RCS, insertation loss, current distributions as well as the radiation patterns.

The simulation is done for various cases. Return loss is compared in various cases with slots, without slots and without DGS as in Fig.2.(a). Final return loss is shown in Fig.2. (b) As the figure shows antenna is working at three frequencies and all resonant frequencies have return loss -20dB. The VSWR of designed antenna is shown in figure Fig.2.(c) and at resonant frequencies VSWR is less than 2 which is required condition for antenna.

Current distribution of antenna at three different frequencies is shown in Fig.3 (a-c). as the current distribution shows a due to slots three resonant frequencies are achieved and their return loss is improved using DGS

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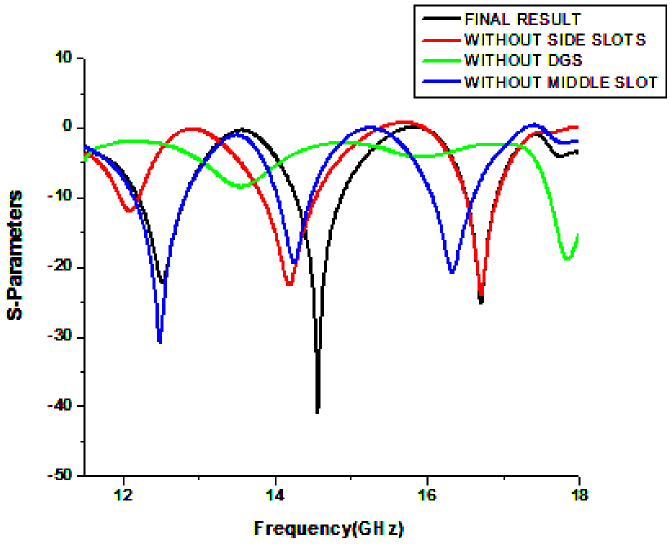
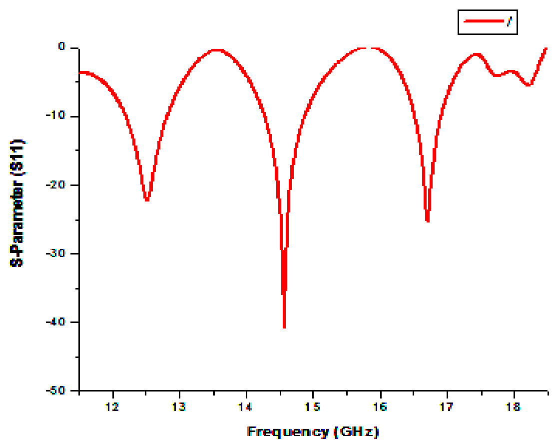


(a)



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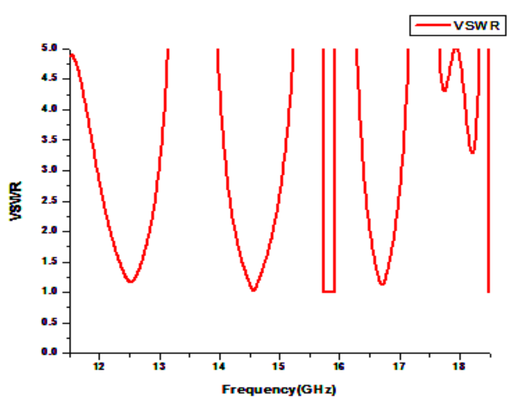

(c)

Fig. 2 Simulated results of Tri-band antenna structure (a) Comparison of Return loss (b) Return loss (c) VSWR

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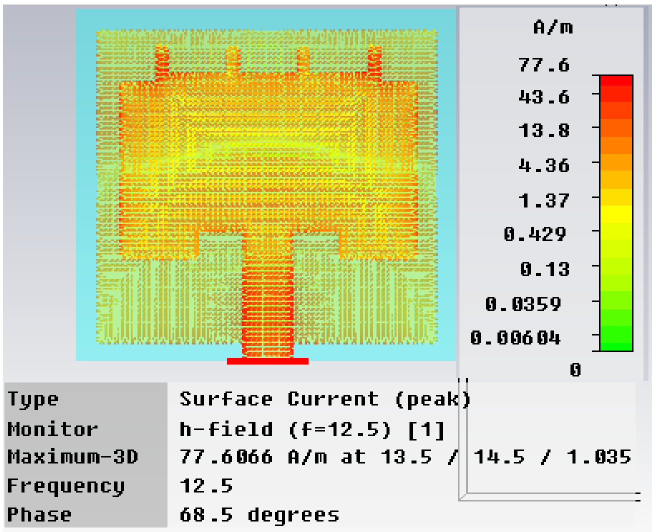

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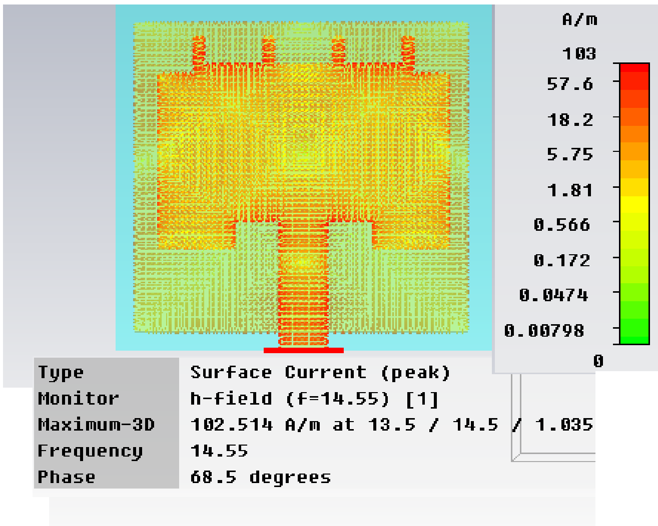

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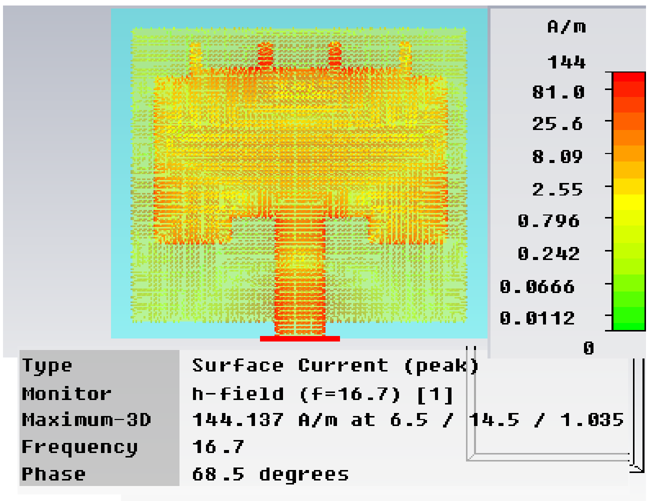

(c)

Fig.3 Surface current distribution of Tri-band antenna structure at (a) 12.5 GHz (b) 14.55GHz (c) 16.7GHz

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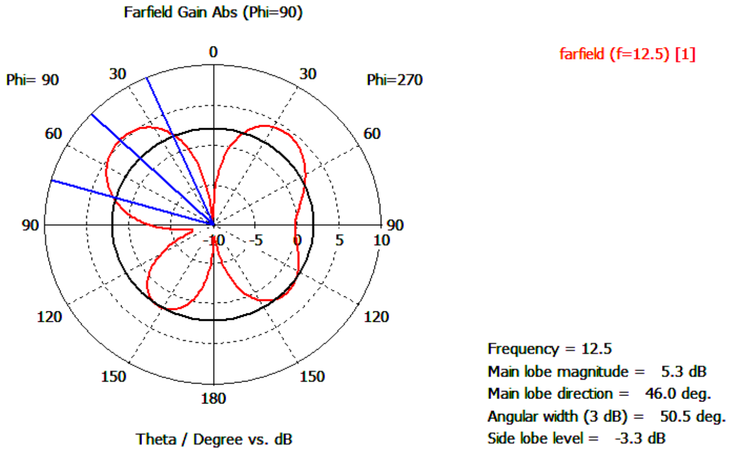
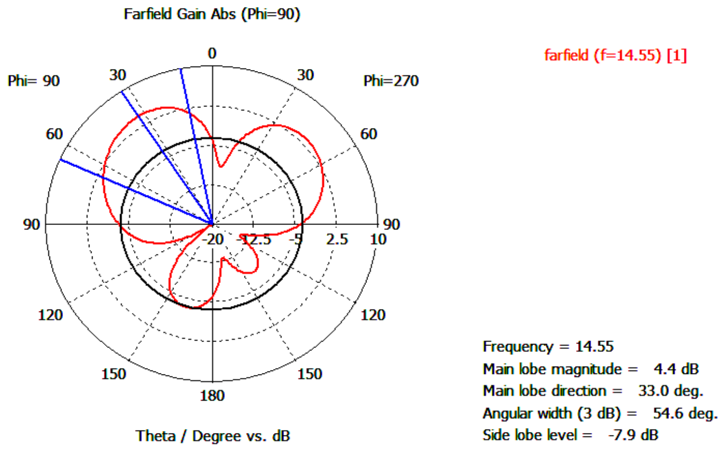
The radiation patterns of Tri-band antenna of directivity at theta is 90 degree for three resonance frequencies are shown in Fig. 4(a-c). The directivity of antenna is described by the shape of the radiation pattern. The radiation pattern shown in Fig.4 shows the pattern of resonant frequencies of 12.5 GHz, 14.55 GHz and 16.7 GHz respectively.

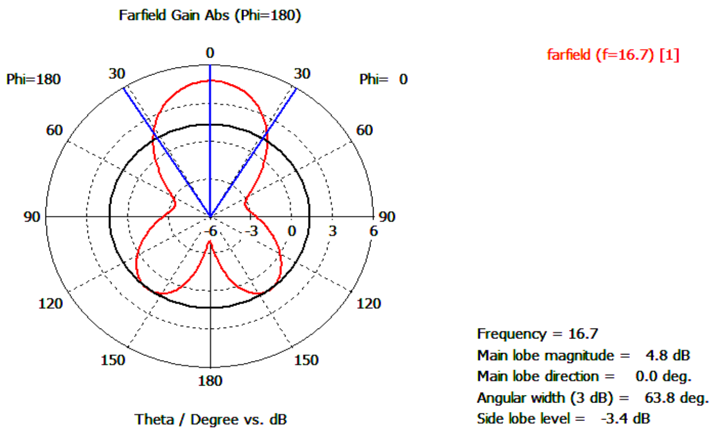
The radiation pattern of the antenna can be change by the varying the gap between the ground and the radiating patch of antenna. It is also depended on the dielectric loss of the substrate material.



(a)



(b)



(c)

Fig. 4 Radiation pattern of Tri-band antenna structure at (a) 12.5GHz (b) 14.55GHz (c) 16.7 GHz

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IV. CONCLUSIONS

In this paper, a new approach to multiband antenna structure is shown for increasing the number of operating frequency bands and improvement in return loss. The future aspect of this work is to increase the number of operating frequency bands by making changes in the size of slots or using different shaped structures like U-slits and L-slots. This structure can be further modified by increasing the switch-ability of radiating patch by connecting PIN diode or RF-MEMS switch in switchable slot. These proposed antennas can be used for multiband wireless communication applications.

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