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RESEARCH PAPER

# Double-ring multiband microstrip patch antenna with parasitic strip structure for heterogeneous wireless communication systems

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*In this paper, a novel design of compact Coplanar Waveguide-fed planar monopole antenna with enhanced bandwidth and multiband characteristics has been proposed. Two rectangular rings have been incorporated in a rectangular patch to obtain multiband operation for Wireless Local Area Network (WLAN) (2.4/5.2/5.8 GHz) and Worldwide Interoperability for Microwave Access (WiMAX) (2.3/2.5/5.5 GHz) bands. A parasitic strip and meandering along with double-ringed structure have been used to achieve enhanced impedance bandwidth in WLAN (from 2.26 to 3.03 GHz) and WiMAX (from 4.48 to 6.85 GHz) bands. The parametric analysis is carried out to study effect of varying dimensions on antenna performance. The proposed antenna is optimized and prototype is designed and fabricated. Simulated and measured radiation patterns in elevation and azimuthal planes are also observed. The antenna shows significant gain of 7.33 dBi at 6.54 GHz frequency.*

**Keywords:** , Antennas and propagation for wireless systems, Antenna design, Modeling and measurements

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## I. INTRODUCTION

With the advent of modern communication systems, with highly advanced features, there is a growing demand for compact, cost-effective, wide, and multiple band antennas for usage in viable wireless communication structures [1–3]. Rapidly developing wireless technologies mandate the incorporation of different Worldwide Interoperability for Microwave Access (WiMAX) standards and Wireless Local Area Network (WLAN) standards into a single unit. To facilitate the simultaneous use of these standards in a wireless system, there is a requirement to design a single antenna, which can cover these bands completely and can attain higher antenna impedance bandwidth [4–6]. Since the device size of the wireless systems is decreasing manifold, smaller antenna size is required for practical applications [4–6]. The growing demand in the field of wireless communication and its expanding applications has put a challenge for the antenna designers to accomplish the objectives set forth.

Microstrip antennas seem to be capable enough owing to their light weight, simplicity in design and fabrication, its cost-effectiveness, and its ability to integrate with printed circuits. But, they are confronted with some shortcomings which include constricted bandwidth, small gain, etc. Improving one parameter generally results in deterioration of other characteristics. So there has to be a tradeoff between various parameters to suit a particular application.

Several papers have been published on design of multiband antennas with enhanced bandwidth using different techniques. In [6], authors proposed Coplanar Waveguide (CPW)-fed triangle-shaped monopole antenna for WLAN and WiMAX bands, but sufficient bandwidth enhancement is not brought about in the lower band. In [7], authors suggested defected ground structure with cross-shaped stripline antenna for WLAN/IMT/Bluetooth/WIMAX applications, which involves working on the ground plane beneath the microstripline adding to the complexity of the design. Liu *et al.* designed a Triple-Frequency Meandered Monopole Antenna with Shorted Parasitic Strips for Personal Communications Service, Universal Mobile Telecommunications System and WLAN applications [8]. The authors used T-slot microstrip patch antenna for GPS, WLAN and WiMAX standards in [9], but the impedance bandwidth achieved in the bands is low. In [10], stacked-layered structures with aperture coupling have been implemented to design the dual-band antenna for WLAN and WiMAX standards, which achieves the desired characteristics at the cost of increased complexity and difficulty to achieve impedance matching using aperture coupling.

In this paper, a combination of CPW feed, parasitic strip, double-ringed structure with meandering have been used to obtain a simple, small-sized, multiband antenna with

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enhanced bandwidth in the covered bands. This CPW-fed planar monopole antenna design, consisting of two rectangular strip rings with a vertical branch strip and meandering operates in WLAN bands (2.4/5.2/5.8 GHz) and WiMAX bands (2.3/2.5/5.5 GHz). Simulation results demonstrate that the proposed antenna has good return loss ($S_{11}$ parameter), radiation characteristics, and impedance bandwidth across the desired bands. The other parameters of the antenna also comply with the standard results desirable for the performance of the antenna. This paper is divided into various sections as follows: in the Section II, the details of the antenna design along with its parametric study are presented. Section III discusses the corresponding simulated and measured results. Finally, the conclusions are presented in Section IV.

## II. ANTENNA DESIGN

### A) Geometry of proposed antenna

Figure 1 exhibits the geometry of the proposed CPW-fed planar monopole antenna for heterogeneous wireless applications with optimized dimensions. The designed antenna has a planar structure with one layer of copper arranged on one side of substrate while the opposite flank is devoid of any metallization. The antenna is designed and fabricated using screen printing and chemical etching procedure to create antenna pattern on the substrate. The antenna is printed on 1.6 mm-thick FR4 substrate sheet with dielectric constant of 4.4, which makes it easy and economical to manufacture.

The elementary design of the antenna structure consists of an arrangement of two rectangular rings and a vertical branch strip. The outer rectangular ring of the proposed antenna has a fixed strip width of '$S_w$'. An additional rectangular-shaped ring of same width but smaller in size is formed inside the larger ring by cutting the right-hand side of the larger ring. The main purpose of two rectangular ring antennas with a parasitic strip is to accomplish the multiband operation for mixed wireless applications. A fixed metal strip CPW transmission line is used to excite the antenna. The thickness of the CPW transmission line is designated as '$W_F$'. Two same sized finite ground planes of width 'Wg' and length '$L_g$' are positioned evenly on either side of the feed line. The gap between the CPW transmission line and ground planes is '$d$'.

The various optimized dimensions of the proposed antenna, after parametric analysis, have got the following geometric values: length and width of rectangular patch as $L = 29.10$ mm and $W = 19$ mm, respectively, length and width of ground plane as $L_g = 11.25$ mm and $W_g = 6$ mm respectively, feed-line width $W_F = 4.75$ mm, strip length $L_1 = 8.8$ mm, $L_2 = 5.3$ mm, strip length $L_3 = 5.3$ mm, strip width $S_{w1} = 3$ mm, strip width $S_{w2} = 2$ mm, width $W_1 = 6$ mm, spacing between feed length and ground plane $d = 1.35$ mm and gap between the main radiating patch and ground plane, $G = 3.6$ mm. The proposed antenna acquires a total volume of $1.35\ cm^3$. The performance of the designed antenna is analyzed using Zeland IE3D electromagnetic simulator based on MoM (Method of Moments) principle.

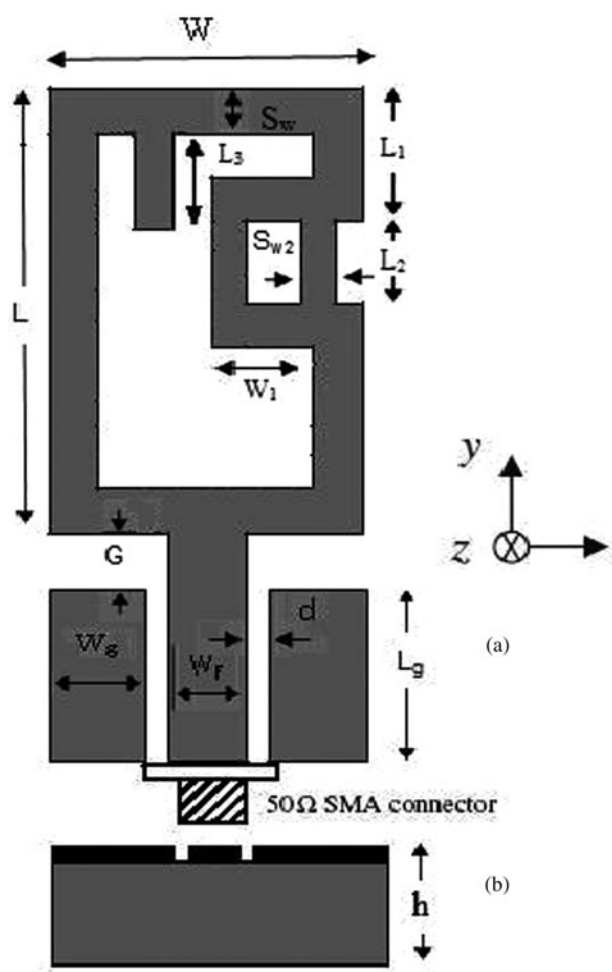


**Fig. 1.** Geometry of proposed antenna with multiband operation.

### B) Parametric study of antenna

This section shows the simulation results obtained after varying the various geometric parameters of the antenna on its return loss performance.

#### 1) EFFECT OF RECTANGULAR RINGS, PARASITIC STRIP, AND MEANDERING ON THE ANTENNA PERFORMANCE

The proposed antenna is designed in steps, each of which is shown in Figs. 2(a)–(d). Initially a single-rectangular ring structure is formed (Fig. 2(a)). Then an inner smaller ring inside the outer ring is formed at the right-hand side of larger ring (Fig. 2(b)). Further a vertical parasitic strip is added in the patch (Fig. 2(c)) along with incorporation of meandering at the boundary common to outer and inner

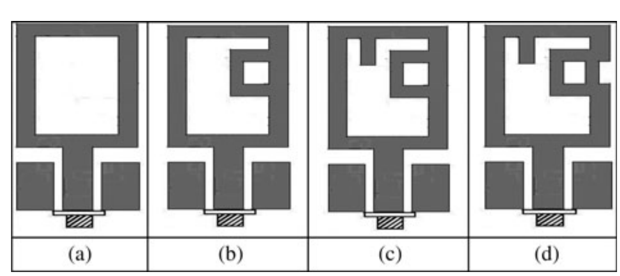


**Fig. 2.** Antenna with (a) outer ring only, (b) outer and inner ring, (c) outer and inner ring with parasitic strip, and (d) outer and inner ring with parasitic strip and meandering.

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ring (Fig. 2(d)). The effect of addition of small rectangular strip ring, vertical branch strip, and meandering of outer ring on $S_{11}$ parameter is shown in Fig. 3.

It is observed from Fig. 3 that when only outer ring (Fig. 2(a)) is used, two resonant bands appear in the return loss curve one from 6.2 to 6.9 GHz in upper frequency band another from 2.26 to 3.03 GHz in lower frequency band. When, an inner ring (Fig. 2(b)) is added to outer ring the bandwidth in upper band increases with a shift in resonant frequency to lower side in upper band. The lower band is not affected by addition of inner ring. With addition of parasitic strip (Fig. 2(c)) to above structure there is no change in the bandwidth of lower band whereas there is a slight improvement in the bandwidth at upper band along with increase in return loss at peak resonant frequency. Introducing meandering (Fig. 2(d)) in the patch causes significant increase in the bandwidth at upper frequency band and improves the return loss at peak resonant frequency. Meandering negligibly affects the lower frequency band.

#### 2) Effect of variation in parasitic strip length ($L_3$)

The length of parasitic strip ($L_3$) is varied to demonstrate its effect of on the performance of the proposed antenna. Figure 4 shows the effect of varying parasitic strip length $L_3$ on $S_{11}$ parameter with reference to frequency.

It is clear from Fig. 4 that increase in the vertical strip length ($L_3$) along the negative $y$-axis, causes an increase in bandwidth in the upper band till an optimized value of $L_3 =$ 5.93 mm is reached. There after bandwidth decreases on further increase in the length of $L_3$ from its optimal value. It is seen in simulation results that change in the branch strip length ($L_3$), mainly affects the upper frequency band and has negligible effect on the lower frequency band.

#### 3) Effect of variation of gap space ($G$) between the radiating patch and ground plane

Figure 5 represents the effect of varying gap space ($G$) between the radiating patch and ground plane on $S_{11}$ parameter. It is seen that the increase in the gap distance ($G$) along the positive $Y$-axis, first increases the bandwidth in the both lower and upper frequency bands up to the optimum value of $G =$ 3.6 mm and further increase in $G$ after that decreases the bandwidth in both the bands. It can be well interpreted from the return loss curve that an increase in the gap distance '$G$' moves the peak resonant frequency toward lower side in both resonant bands. The photograph of the fabricated antenna is shown in Fig. 6.

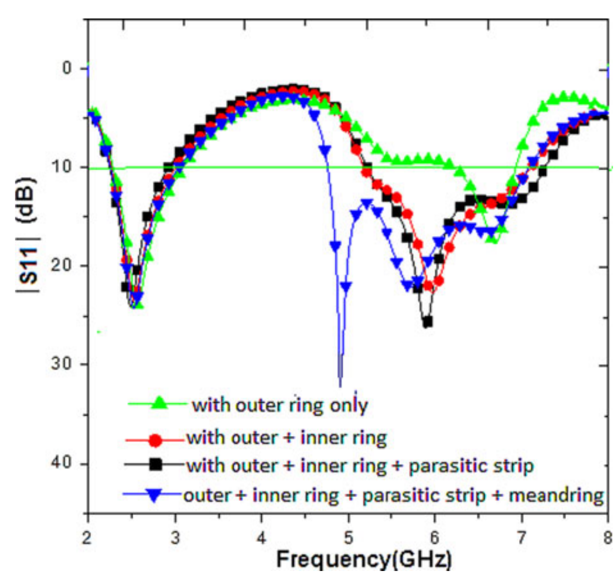


**Fig. 3.** Effect of rectangular rings, parasitic strip and meandering on the antenna performance.

## III. RESULTS AND DISCUSSION

The fabricated prototype was tested for return loss measurements for validation of impedance bandwidth results on Agilent's vector network analyzer (VNA) model no. E5071C. The simulated and measured results for the proposed antenna have been observed and compared in Fig. 7. Figure 7 shows a close proximity between the simulated and measured results of the proposed antenna. Return loss ($S_{11}$ parameter) curve shows that, two resonant bands with wide operating bandwidths are obtained. A small variation in 10 dB down bandwidth between measured and simulated results is seen at the upper frequency band. The main reason for variation in the results can be attributed to the inaccuracies imported while constructing the antenna using wet etching technique and also because of the alignment issues associated while connecting the antenna to the VNA using a Sub Miniature version A connector.

It is observed from measured results that (10 dB) impedance bandwidth of 28.52% at lower frequency band, extending from 2.26 to 3.03 GHz, with respect to the resonant frequency of 2.652 GHz, and the bandwidth of about 38.82%, for the upper band extending from 4.766 to 7.062 GHz with reference to the central frequency at 5.91 GHz is achieved. The projected antenna is capable of operating at IEEE 802.11 WLAN bands at 2.4/5.2/5.8 GHz and IEEE 802.16 WiMAX bands at 2.3/2.5/5.5 GHz.

The gain of the proposed antenna, at upper and lower bands of operation, has a significant value as shown in Fig. 8. In lower frequency band (2.26–3.03 GHz), the measured gain of antenna lie in the range 1–2.89 dBi, while in the upper band (4.766–7.062 GHz), the gain lies between 3.14 and 7.33 dBi.

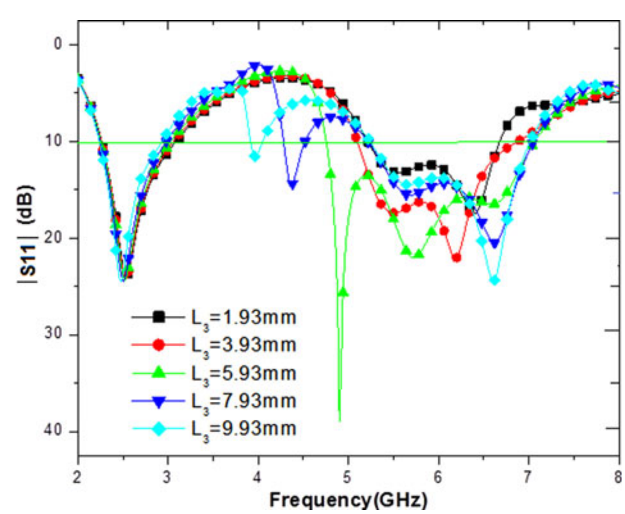


**Fig. 4.** Effect of variation in parasitic strip length ($L_3$).

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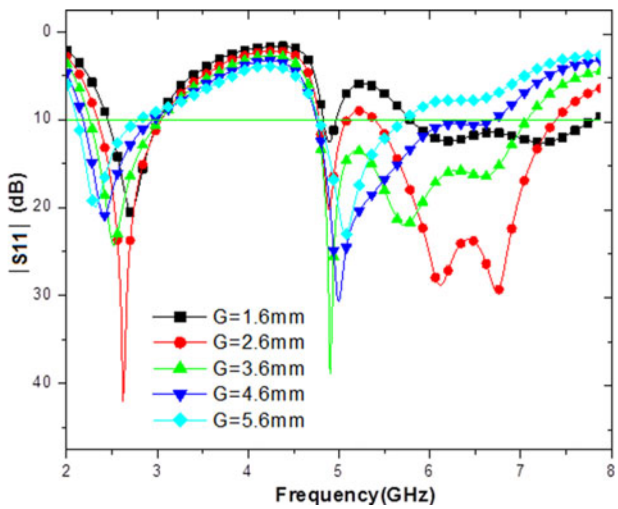


**Fig. 5.** Effect of variation of gap space (*G*) between the radiating patch and ground plane.

The comparative gain curve of simulated and measured values is plotted in Fig. 8 in which the measured gain shows slight variations from the simulated values, which may be due to equipment error in VNA. The summary of results of the proposed antenna is given in Table 1.

The radiation pattern of the antenna is measured at three different frequencies viz. 2.5, 5.0 and 6.54 GHz as shown in Fig. 9. The radiation pattern of the fabricated antenna is measured in an anechoic chamber which works over a frequency range of 800 MHz to 12 GHz with the size of quiet zone to be 20 × 20 × 20 $cm^3$. The antenna under test (AUT) is placed at

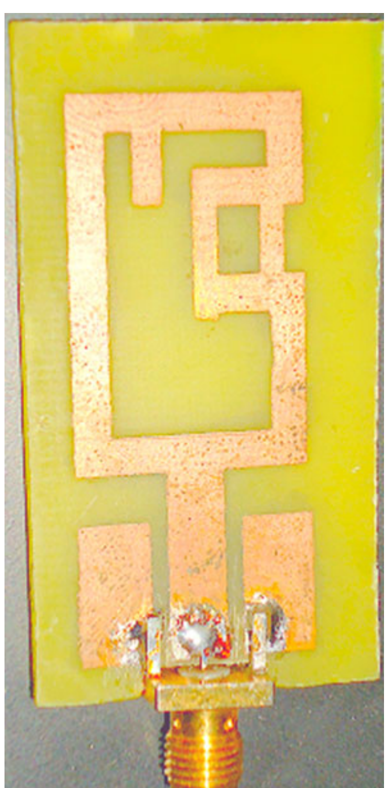

**Fig. 6.** Photograph of the fabricated antenna.

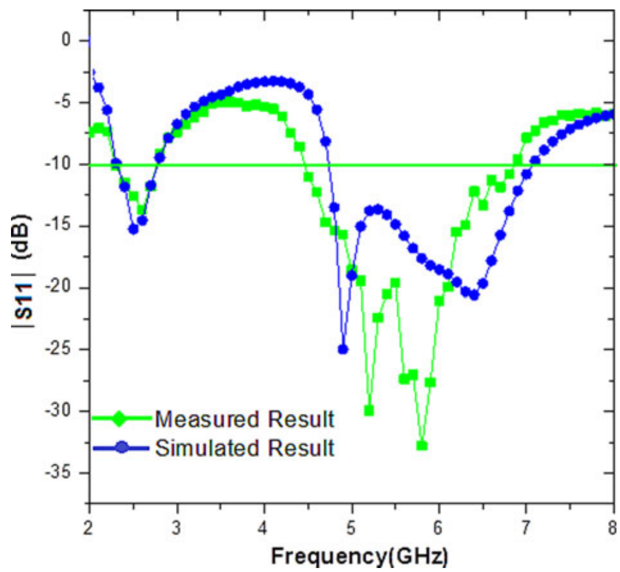


**Fig. 7.** Simulated and measured return loss curves of the proposed antenna.

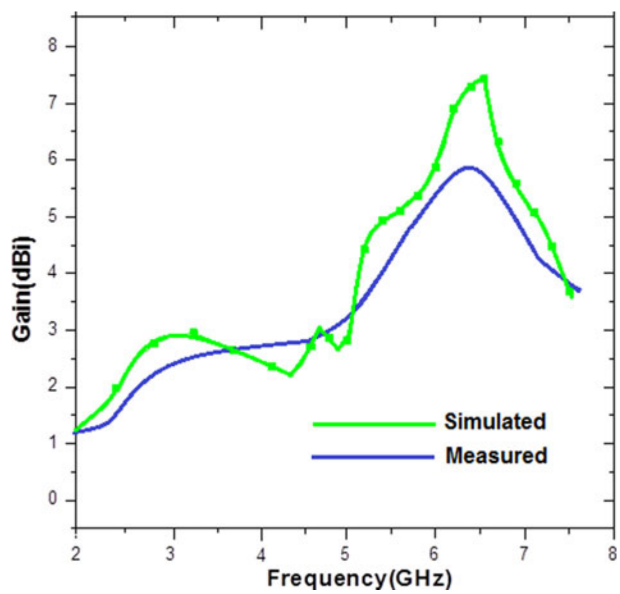


**Fig. 8.** Simulated and measured gain curves of the proposed antenna.

distance of 7.2 m to be in far field even at 12 GHz from a standard Horn antenna at the transmitter side. The gain of AUT is measured with respect to the standard horn antenna, which has 12 dBi calibrated gain value. Then graph is plotted using gain substitution/transfer technique. The

**Table 1.** Summary of the measured and simulated results of the proposed antenna.

| Parameter→ band↓ | Band covered measured (simulated) (in GHz) | Percentage bandwidth measured (simulated) (in %) | Maximum gain measured (simulated) (in dBi) |
|---|---|---|---|
| Lower band | 2.26–3.03 (2.26–3.03) | 28.52 (28.52) | 2.61 (2.61) |
| Upper band | 4.48–6.85 (4.76–7.062) | 41.87 (38.82) | 5.86 (7.33) |

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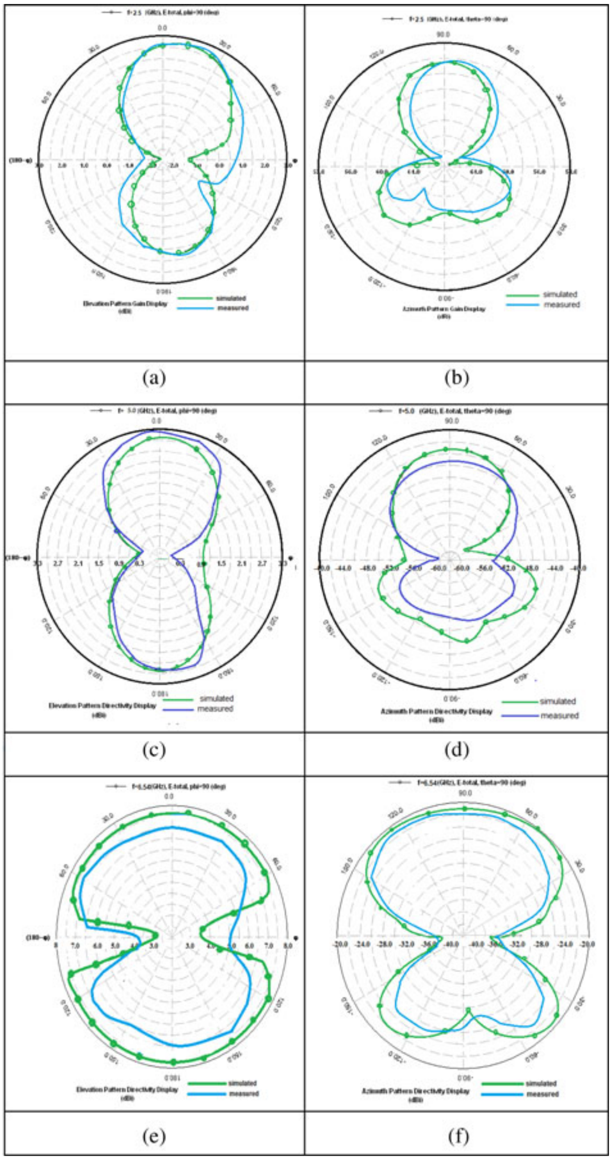

**Fig. 9.** Simulated and measured radiation pattern plots of the designed CPW-fed planar antenna at: (a) 2.5 GHz in elevation plane, (b) 2.5 GHz in azimuth plane (c) 5 GHz in elevation plane, (d) 5 GHz in azimuth plane (e) 6.54 GHz in elevation plane, and (f) 6.54 GHz in azimuth plane.

validation of its results is done on Agilent's E5071C VNA operating in the frequency range of 9 kHz to 8 GHz.

In the azimuthal plane, radiation pattern of the antenna is almost omni-directional in upper half plane and in the elevation plane it is equivalent to that of monopole antenna at all frequencies of measurement. The measured radiation pattern plots are in agreement with the simulated patterns, with small variations in the exact values. The proposed antenna exhibits a good radiation performance over all the desired frequencies.

## IV. CONCLUSION

In this paper, a CPW-fed compact planar microstrip patch antenna consisting of two rectangular rings, a parasitic strip and meandering has been proposed, designed, fabricated and tested for multiband operation. The various parameters of the proposed antenna are tested for $S_{11}$ parameter, gain, and radiation pattern. The measured results for the antenna show an impedance bandwidth of 28.52% for the lower band, ranging from 2.26 to 3.03 GHz, at the central frequency of 2.652 GHz. In the upper band, it attains a significant impedance bandwidth of about 41.87% (4.48–6.85) GHz at a central refrequency of 5.91 GHz. The maximum measured gain of 5.86 dB achieved by the antenna at its upper band and stable radiation patterns over the required functional bands, make the designed antenna appropriate for heterogeneous wireless networks.

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