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Stacked T-Shaped Strips Compact Antenna for WLAN and WiMAX Applications

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Abstract

A compact triple band antenna with stacked T-shaped strips inside a rectangular ring monopole has been proposed. This novel structure with a slot in the defected ground achieves triple band opration i.e. 2.47–2.77 GHz, 3.3–3.7 GHz and 5.10–6.62 GHz. These bands find application in important wireless communication standards like WiMAX (3.3–3.8 GHz, and 5.25–5.85 GHz, WLAN (2.4 G-2.5 GHz, 5.1–5.3 GHz, and 5.72–5.85 GHz). The antenna is printed on a FR-4 substrate with an overall dimension of $33 \times 17 \times 1.6\ mm^3$. An impedance bandwidth of 11% (2.47–2.77 GHz), 11% (3.3–3.7 GHz) and 25% (5.10–6.62 GHz) is obtained. A good conjunction between the simulated and measured results is inferred from the antenna design analysis.

Keywords Ring monopole · Slots · T shaped strips · WLAN · WiMAX

1 Introduction

Compact printed monopole antennas with multiband operation is gaining attention as a result of the tremendous development of compact devices for wireless applications [1, 2]. Antenna is the main component of wireless communication devices for adopting standards like WLAN, WiMAX etc. Now a days market demand for compact wireless portable

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device is increasing rapidly. Hence, in regard to this demand, design of miniaturized multi-band antenna has attracted many researchers [3–6]. Multiband antenna works for more than one standard is vital component for portable devices. Modified monopole antennas is considered as proficient among other antennas structures due to its simplest structures [7, 8].

The literature details various dual and multiband antennas [9–20]. In [9], a pair of L-shaped strips are combined to obtain triple band operation. However, large antenna dimension (i.e., 33×28 mm^2) is a major drawback. Two self similar ring radiator was designed in [10] for achieving triple band operation with a dimension of 38×25 mm^2. This antenna size is also large for compact devices. Li et al. [11] proposed a rectangular ring monopole antenna exhibiting triple band operation is designed using L-strips and inverted T-shaped stubs. In [12], L-Shaped strips on a 30×42 mm^2 substrate are used to obtain tri-band operation. Similarly, CPW fed slotted antenna with relatively larger dimension has been proposed in [13, 14]. Li et al. [15] proposed a triple band antenna that satisfies WLAN and WiMAX standards by employing fork shaped strips within a rectangular ring. The multiband operation is exhibited in [16] using fractal antenna using Koch iteration, however antenna size is considerably bigger i.e., 33.5×23.5 mm^2. Recently, in [17], using split ring resonator (SRR) a single narrowband at 1.1 GHz and ultra wide band (UWB) operation ranging from 2.3 to 6.1 GHz have been reported with an large antenna size of about 34×44 mm^2. A $\lambda/4$ rectangular stub loaded with metamaterial for 2.45, 3.5 and 5.8 GHz frequency bands has been designed in [18]. In [19], a fractal multiband antenna with Sierpinsiki triangle geometry with L-Shaped strips was reported. With a defected ground structure and compact slot, UWB antenna was presented in [20]. However, it exhibits less gain at operating frequencies. However, smaller antenna operational bandwidth and large size continues to remain the major loopholes in the aforementioned antenna designs.

In this research article, a compact tri-band antenna of 33×17 mm^2 dimensions with four T-shaped strips stacked one above another inside a rectangular ring monopole is proposed. The antenna operating bands are 2.47–2.77 GHz, 3.3–3.7 GHz and 5.10–6.62 GHz. The effect of adding strips on frequency and impedance matching are detailed. The parametric analysis are performed to justify the selection of antenna dimension.

The organization of the paper is briefed as follows: Section II details the methodology of the proposed design. The influence of various antenna parameters on performance has been explained in the third section. Section IV highlights the comparison between simulation and measured results. Section V concludes the paper.

2 Antenna Design

The development stages of the proposed antenna is depict in the Fig. 1. The first stage i.e., Antenna I consists of a rectangular ring ($w_1 \times h_1$), strip line ($w_8 \times h_6$), incremented strip line ($w_7 \times h_5$) and ground palne ($w \times h_7$). From [21], it is obvious that the tapered feed line gives better performance in terms of S_{11}. It is observed from the Fig. 2 that, a dual band operation at 2.5 and 5 GHz is produced by the Antenna I. Then four T-shaped strips are stacked one over another inside the rectangular ring to produce Antenna II. This results in triple band operation as can be seen from the Fig. 2. Further to enhance the impedence bandwidth, a rectangular slot has been etched in the ground. Finally, the proposed antenna is evolved with triple oprating bands with ranges 2.47–2.77 GHz, 3.3–3.7 GHz and 5.10–6.62 GHz. This range corresponds to WLAN and WiMAX applications. The Fig. 3

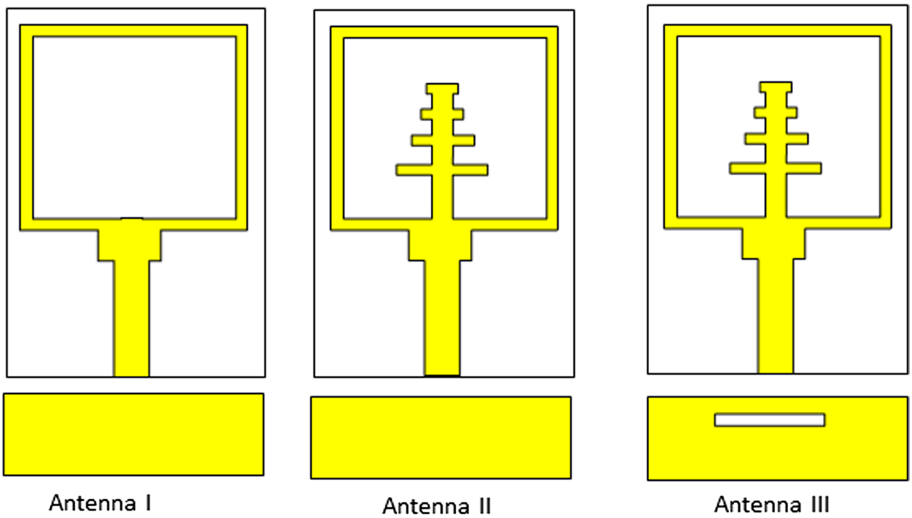
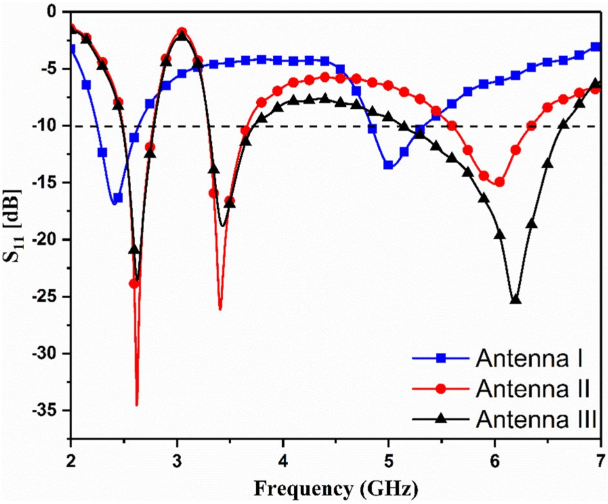


Fig. 1 Development stages of the proposed antenna

Fig. 2 S_{11} of various antenna in development stages



depicts a detailed dimension layout of Antenna III. Figure 4 shows the fabricated antenna. The final dimensions of the proposed antenna are presented in Table 1.

3 Parametric Analysis

The influence of various geometric parameters on the frequency parameter characteristics are detailed in parametric analysis. Initially, the effect of various stubs is analyzed. The Fig. 5 illustrates the different structures of the proposed design. The corresponding S_{11} performance is given in the Fig. 6. It is clear from the figure, the final shape marked *w*2

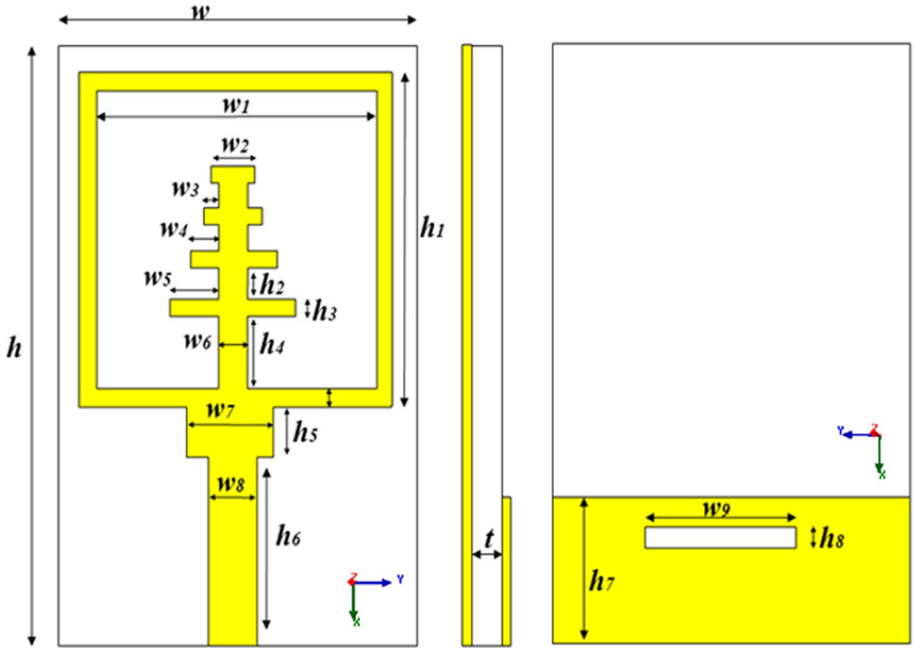
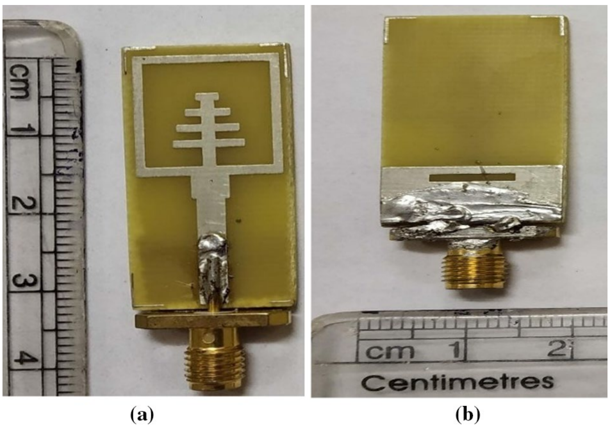


Fig. 3 Geometry of the proposed antenna

Fig. 4 **a** Front view and **b** Back view of the fabricated antenna



gives better performance in comparison with other structures. Additionally, it can be easily observed that on adding each stub the performance of the antenna gradually increases. After finalizing the structure, the effect of dimensions of the stubs are studied through parametric analysis.

First, we analyze the effect of variation in length of the ground slot on the S_{11} performance as described in Fig. 7. It can be inferred that $w_9 = 7.2$ mm produces only dual band operation, when w_9 is increased to 8.2 mm, the antenna operates at three bands. Hence, in the antenna design the ground slot width is chosen as 8.2 mm.

Table 1 Measurements of the proposed antenna

Parameter	Size (in mm)	Parameter	Size (in mm)
w	17	*h*	33
w1	13.5	*h1*	17.5
w2	2.5	*h2*	1
w3	1.7	*h3*	1
w4	2.7	*h4*	2.4
w5	3.1	*h5*	3
w6	1.4	*h6*	13.4
w7	4	*h7*	8.7
w8	3	*h8*	1.2
w9	8.2	*t*	1.6

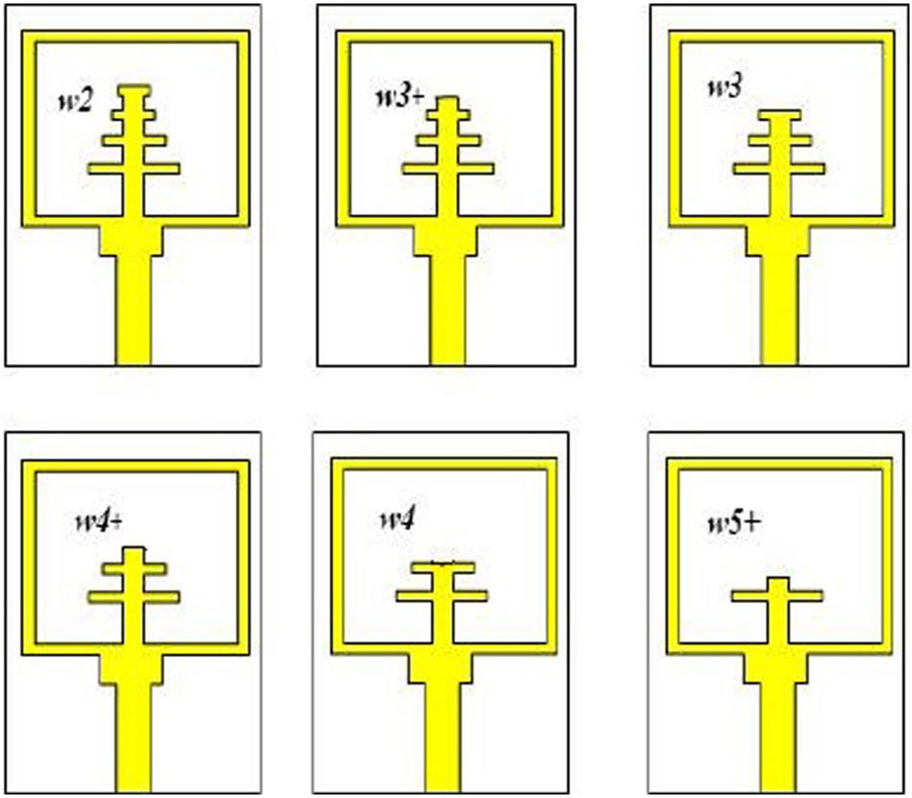


Fig. 5 Different structures of the proposed antenna

Next, to understand the effect of gap between the strips and ring monopole, the length of h_4 is differed from 1.4 to 3.4 mm. The various S_{11} performance corresponding to different *h*4 values are plotted in the Fig. 8.

It is obvious from Fig. 8 that the length of *h4* affects the second operating band at 3.5 GHz. This parameter gives the flexibility of tuning the antenna and set at any frequency

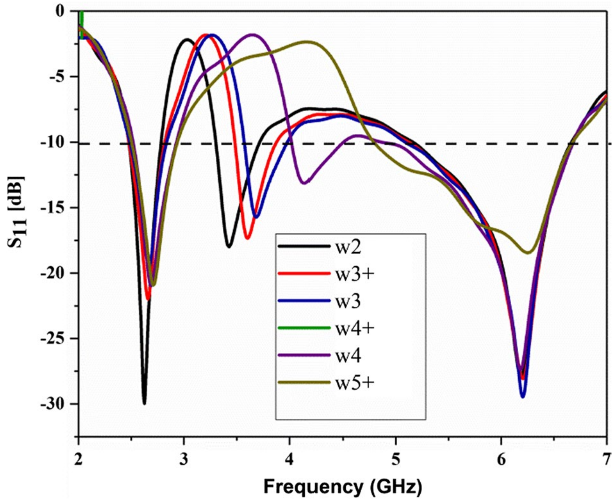


Fig. 6 S11 for different structures of the proposed antenna

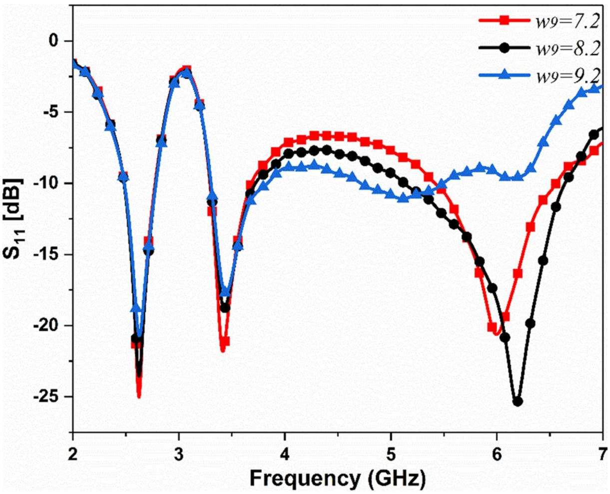


Fig. 7 Variation of S11 with respect to the variation in *w*9

between 3 and 4 GHz. Here, we fixed the length as 2.4 mm in order to get 3.5 GHz as the operating frequency.

The Fig. 9 shows the variation of S11 for the various values of w_5. To get the operating band at 3.5 GHz 3.1 mm has been chosen for the fabricated antenna. It is observed Fig. 9 that, the other values of w_5 shifts the operating band towards 3 GHz.

4 Measurement Results

Agilent N5230A vector network analyzer (VNA) is used to perform the proposed antenna design measurements. The Fig. 10 shows that there is minimal difference between measured and simulated results. Additionally, it can be inferred from the

Fig. 8 Variation of S11 with respect to the variation in *h*4

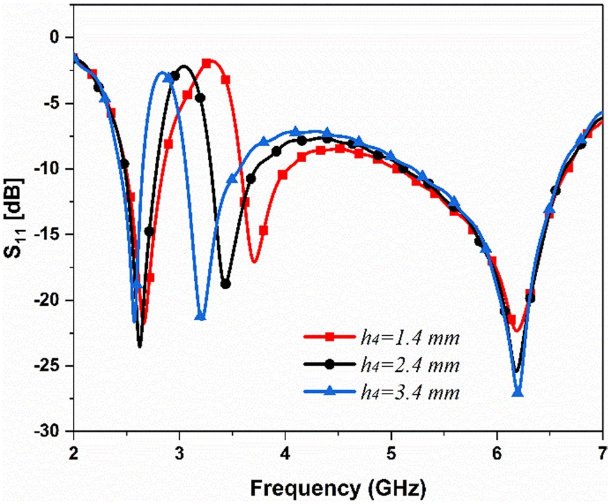


Fig. 9 Variation of S_{11} with respect to the variation in w_5

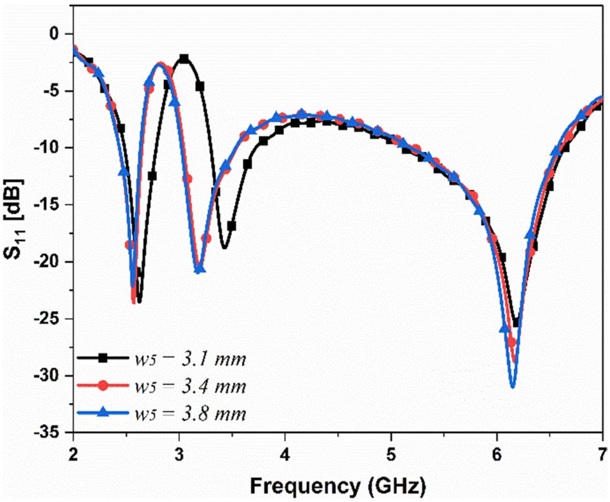


Fig. 10, that three bands of antenna operation are 2.47–2.77 GHz, 3.3–3.7 GHz and 5.10–6.62 GHz. These operating regions finds application in WLAN and WiMAX standards.

The surface current densities are given in Fig. 11. It is observed from figure that at 2.5 GHz, the current concentrates at the peripheral ring. The operating band at 3.5 GHz is due to the current at microstrip line. At 5.5 GHz, the current concentrates on ground slot as well as rectangular ring, thus validating the process of antenna design.

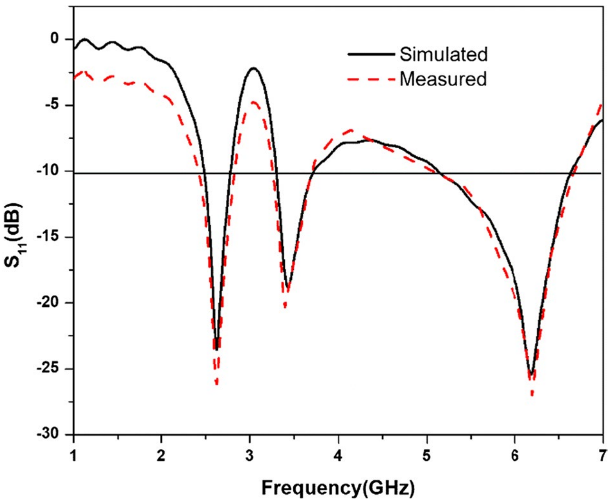


Fig. 10 Comparative analysis between the simulated and measured result

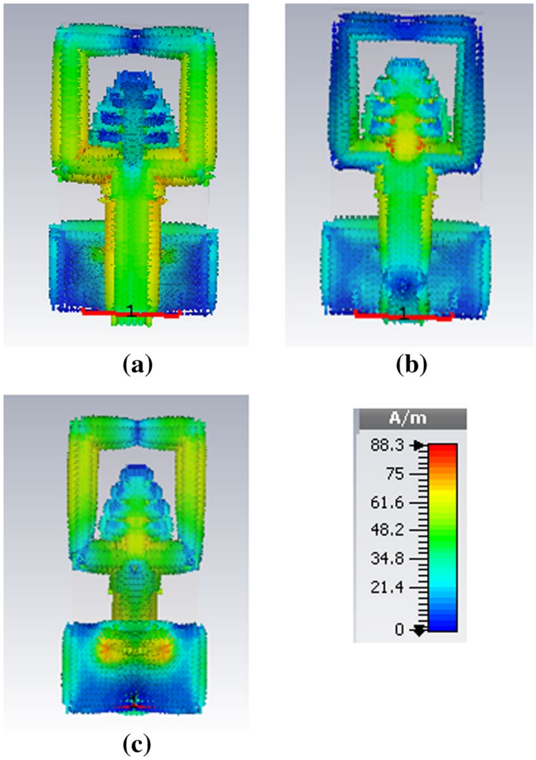


Fig. 11 Surface current density at **a** 2.5 GHz, **b** 3.5 GHz and **c** 5.5 GHz

Figure 12 shows the measured and simulated radiation pattern. The far field radiation pattern exhibits bidirectional pattern at center frequency, i.e., 2.5 GHz, 3.5 GHz and 5.5 GHz in E-Plane.

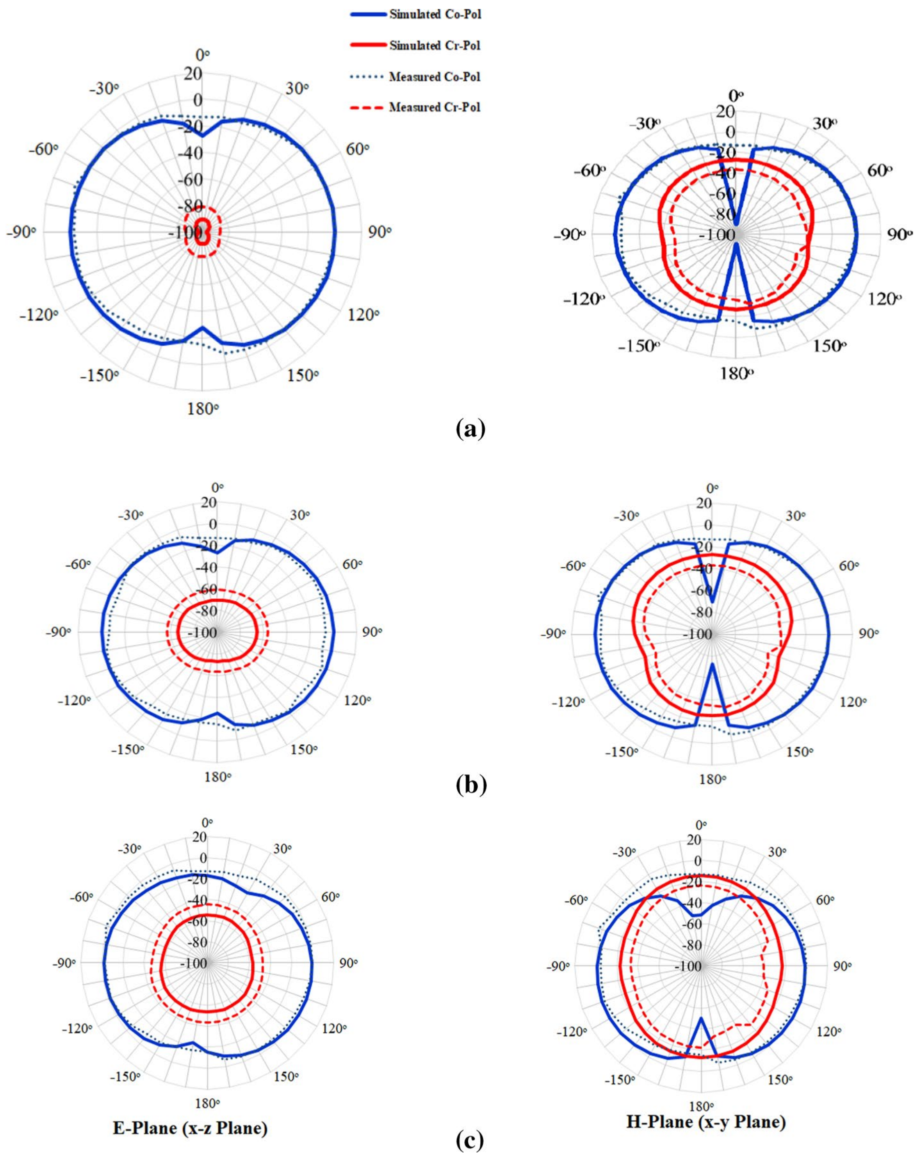


Fig. 12 Simulated and measured radiation patterns of the proposed antenna at **a** 2.5 GHz, **b** 3.5 GHz and **c** 5.5 GHz

Omni directional pattern is observed in the H-Plane. The antenna gains and radiation efficiency is simulated over the operating ranges. It can be seen from the Fig. 13 that the gain varies from 2 to 3.8 dB and the efficiency varies from 60 to 80% over the operating bands. Comparative analysis of the proposed antenna with the existing similar antenna designs is highlighted in Table 2, thus implying the superiority of the proposed design in terms of size, gain and bandwidth over its counterpart.

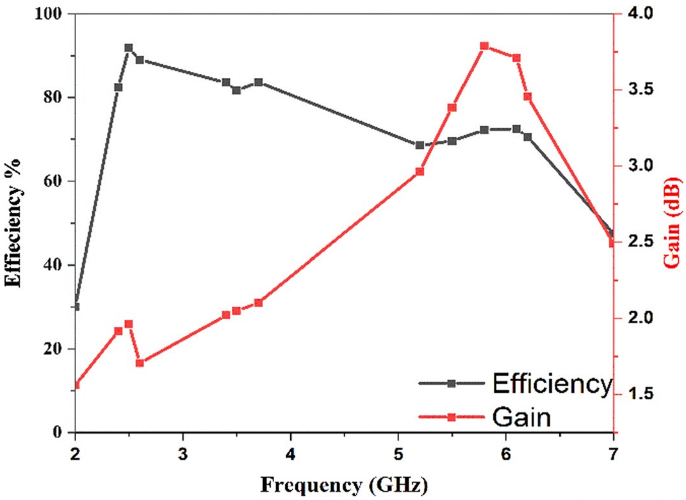


Fig. 13 Simulated gain and efficiency of the proposed antenna

Table 2 Comparison of proposed antenna with the existing designs

References	Operating bands (GHz)	Gain (dB)	Dimension ($L \times W$) in mm
[9]	2.34–2.74, 3.04–3.82, 5.03–6.05	2.36–4.0	33×28
[10]	2.35–2.8, 3.4–3.7 5.05–6.1	2.36–3.62	38×25
[11]	2.36–2.93, 3.34–3.77, 4.75–7.28	2–3.9	38×28
[12]	2.4–2.484, 3.4–3.69, 5.15–5.95	2–4	30×42
[15]	2.40–2.48, 5.15–5.30, 5.72–5.85	0–4	34×18
[21]	2.41–2.54, 3–6.65	1–2.3	33×17
Proposed work	2.47–2.77, 3.3–3.7, 5.10–6.62	2–3.9	33×17

5 Conclusion

A compact triple band antenna has been reported in this research article. The proposed design is compact in nature with dimension of $33 \times 17 \times 1.6$ mm^3. The printed monopole antenna exhibits triple band operation which supports important wireless communication standards like WLAN and WiMAX. The designed antenna achieves the omni-directional radiation pattern. It also achieves high gain and bandwidth. With these features and compact size, the proposed antenna could easily be adopted for real-time compact wireless communication devices.

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