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

M. Karthikeyan· R. Sitharthan· Tanweer Ali· Sameena Pathan· Jaume Anguera· D. Shanmuga Sundar

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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 operation 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 $33 \times 17 \times 1.6 \text{ mm}^3$. 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
device is increasing rapidly. Hence, in regard to this demand, design of miniaturized multiband 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., $33 \times 28 \text{ mm}^2$) is a major drawback. Two self similar ring radiator was designed in [10] for achieving triple band operation with a dimension of $38 \times 25 \text{ mm}^2$. 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 $30 \times 42 \text{ mm}^2$ 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., $33.5 \times 23.5 \text{ mm}^2$. 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 $34 \times 44 \text{ mm}^2$. 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 $33 \times 17 \text{ mm}^2$ 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. This range corresponds to WLAN and WiMAX applications. The Fig. 3

## 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 ($w_8 \times h_8$), incremented strip line ($w_7 \times h_7$) 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 impedance bandwidth, a rectangular slot has been etched in the ground. Finally, the proposed antenna is evolved with triple operating 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
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 $w/2$
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.
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 $h_4$ affects the second operating band at 3.5 GHz. This parameter gives the flexibility of tuning the antenna and set at any frequency.
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. 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.
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.
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.
5 Conclusion

A compact triple band antenna has been reported in this research article. The proposed design is compact in nature with dimension of $33 \times 17 \times 1.6 \text{ mm}^3$. 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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**Dr. Madurakavi Karthikeyan** is working as an Assistant Professor Senior Grade in School of Electronics, VIT, Vellore. He received his BE degree in electronics and communication engineering from S.K.P Engineering College, Tiruvannamalai, India, in 2008 and his ME degree in communication systems from Mailam Engineering College, Mailam affiliated to Anna University, Tamilnadu, India, in 2011. He received his PhD in Department of Electronics and Communication Engineering from Pondicherry University, Puducherry, India. His current research area includes MIMO receiver design, wireless energy harvesting in IOT and cyber physical systems, antenna design etc.
R. Sitharthan is working as an Assistant Professor Senior Grade in School of Electrical Engineering, VIT, Vellore. His current research area includes Distributed generation systems, Artificial Intelligent, controller Power systems, microwave antenna design.

Tanweer Ali is working as an Assistant Professor in the Dept. of Electronics & Communication Engineering at Manipal Institute of Technology, Manipal Academy of Higher Education, Manipal. He is an active researcher in the field of microstrip antennas, wireless communication and microwave Imaging. He has published more than 120 papers in reputed peer reviewed international journal and conferences. He is a senior member IEEE (SMIEEE), and Associate Member of IETE India. He is on the board of reviewers of journals like the IEEE Transactions on Antennas and Propagation, IEEE Antennas and Wireless Propagation Letters, IET Microwaves, Antennas & Propagation, IET Electronics letter, Wireless Personal Communication (WPC), Springer, AEU-International Journal of Electronics and Communications, Microwave and optical Technology letters (MOTL), Wiley, International Journal of Antennas and Propagation, Hindawi., Advanced Electromagnetics, Progress in Electromagnetic Research (PIER), KSII Transaction of Engineering Science, Korea, International Journal of Microwave and Wireless Technologies, Frequenz, Radio engineering, IEEE Access etc.

Sameena Pathan has completed PhD at MIT, Manipal. Her research interest includes microwave imaging, dermoscopic image analysis and pattern recognition. She has many publications in reputed national/international journals and conferences. She is a reviewer of journals published by Springer.
Jaume Anguera  He is reviewer for several IEEE journals as well in others. He is associate editor at Electronics Letters, editor of International Journal on Antennas and Propagation (IJAP) and International Journal on Electronics and Communications. His biography is listed in Who’sWho in the World, Who’sWho in Science and Engineering, Who’sWho in Emerging Leaders and in IBC (International Biographical Center, Cambridge-England). His detailed information can be found at: http://users.salleurl.edu/~jaume.anguera.

D. Shanmuga Sundar  is an Investigator-Post doctorate, University of Chile, Chile, Santiago. His current research area includes Flexible Electronics, Optical Communication, Photonics, microwave antenna design.