



Compact Triple-Band CPW-Fed Monopole Antenna for Bluetooth/WiMAX/WLAN Applications

Kailash Chandra¹ · Mahendra Kumar² · Madhur Deo Upadhayay³

Received: 23 July 2018 / Accepted: 31 August 2019 / Published online: 17 September 2019
© Shiraz University 2019

Abstract

In this paper, a compact multiband CPW-fed monopole antenna is proposed. The designed antenna has a simple structure, which consists of a rectangular radiating patch with two symmetrically structured meandered line slots on both sides and a CPW-fed 50 Ω microstrip line. The designed antenna occupies only 23 × 23 mm² size on a FR-4 substrate sheet which makes it a good candidate for wireless mobile communications. Triple-band functionality is realized by making slots on patch to form a meandered strip on both sides of the rectangular radiating patch. These triple bands are suitable for Bluetooth, WiMAX, and WLAN applications, which are operating at 2.4 GHz, 3.5 GHz, and 5.5 GHz, respectively. The fabricated and characterized antenna prototype is having a good omnidirectional and directional radiation pattern in both H-plane and E-plane for the specified bands, respectively.

Keywords Coplanar waveguide (CPW) · Meandered line · Monopole antenna

1 Introduction

In recent years, the evolution of wireless communication has led to the increasing use of patch antennas due to its handful advantages such as low profile, low cost, light-weight, and miniaturization (Chakraborty et al. 2011). Moreover, the patch antennas are also very convenient for planar and non-planar surfaces to integrate with the RF/microwave circuits (Morghare and Sinha 2014). Rapid changes in wireless communication demand diverse antennas supporting more than one frequency band to

operate with single radiating element. Such antennas can be utilized to replace multiple antennas installed on different wireless handheld devices for making the wireless systems portable and more versatile (Srivastava et al. 2018). In recent years, focus has been laid on developing multiband operations that can cover various frequencies like 2.4–2.484 GHz (for Bluetooth), 5.15–5.35/5.75–5.825 GHz (for WLAN), 3.4–3.69 GHz bands (for WiMAX), and 8.025–8.5 GHz (for ITU Band) (Chen et al. 2014; Yadav et al. 2016; Khaldi 2017; Mansoul 2017). Various techniques have been reported in the literature to realize multiband antennas (Liua et al. 2012; Shinde and Shinde 2015; Ali et al. 2017; Lu and Huang 2010; Li et al. 2010; Fernandez and Sharma 2013; Bakariya et al. 2015; Zaman et al. 2018; Huang et al. 2015; Rajkumar and Kiran 2016). In (Liua et al. 2012; Shinde and Shinde 2015; Ali et al. 2017), slotted radiator/ground plane geometries are implemented for generating miniaturized multi-mode antennas. Parasitic strips have also been used which can provide different electrical paths to realize multi-frequency antennas (Lu and Huang 2010; Li et al. 2010). Besides these techniques, meandered structures are also implemented for procuring multiband performances (Fernandez and Sharma 2013; Bakariya et al. 2015; Zaman et al. 2018). In recent years, the unique characteristics of metamaterials

✉ Kailash Chandra
kailash22780@gmail.com

Mahendra Kumar
mahendra1812@gmail.com

Madhur Deo Upadhayay
madhur.upadhayay@snu.edu.in

¹ Department of Electronics and Communication Engineering, Sachdeva Institute of Technology, Mathura, Uttar Pradesh, India

² Department of Electronics and Communication Engineering, B.I.E.T., Jhansi, Uttar Pradesh, India

³ Department of Electrical Engineering, Shiv Nadar University, Gautam Buddha Nagar, Uttar Pradesh, India

have been utilized for generating multiple frequency bands in single antenna designs (Huang et al. 2015; Rajkumar and Kiran 2016; Ali et al. 2018).

Here in this work, we propose a very simple triple-band rectangular antenna design. Owing to its superiority in terms of simple configuration, enhanced impedance bandwidth, good radiation characteristics, and compact size, the proposed antenna can be a good candidate for the practical engineering applications. The proposed antenna occupies a very small volume, that is, only $23 \times 23 \times 1.6 \text{ mm}^3$ on FR-4 substrate. The structure consists of a compact monopole rectangular patch antenna with symmetrical meander strips on both sides and CPW ground plane. Meander strips are formed by etching open-ended slots on the radiating patch. The monopole antenna is operating at the frequency band from 2.7 to 7.9 GHz with -10 dB impedance bandwidth covering three different bands: Bluetooth, WiMAX, and WLAN bands applications, simultaneously. The organization of this article is done as follows: Sect. 2 includes description of the proposed design. The respective simulated performance is analyzed in Sect. 3. Section 4 includes the comparison of simulated result with experimentally obtained result and the fabricated prototype. The concluding remarks are presented in Sect. 5 followed by references.

2 Proposed Design and Description

Figure 1 shows the proposed configuration of triple-band CPW-fed microstrip monopole antenna. The structure is designed on a low-cost FR-4 substrate (loss $\tan 0.02$) with relative permittivity 4.4 using finite element method (FEM)-based HFSS simulator. The antenna consists of the

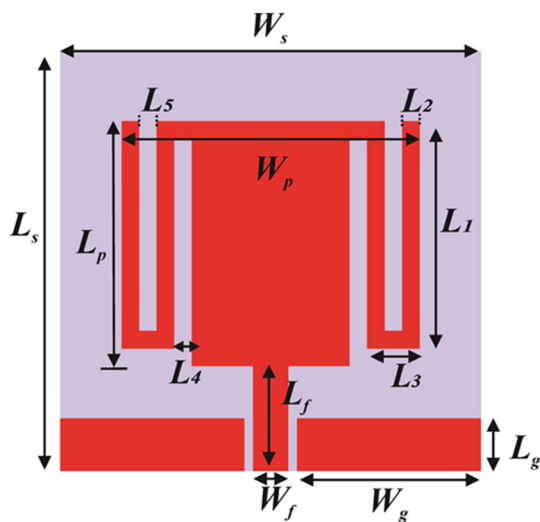


Fig. 1 Proposed antenna geometry

rectangular radiating patch, two symmetrical meandered line strips on both sides and connected with 50Ω CPW-fed microstrip line. These meandered line strips are used to generate multiple bands which are operating in three different bands such as Bluetooth, WiMAX, and WLAN. The meandered strips are realized by making slots on the rectangular radiation patch. These slots are etched to provide desired resonant frequencies by creating a longer current path. Further by virtue of inductive and capacitive coupling between the arms of meandered lines, the resonance frequencies can be tuned by changing the length of slots. In addition, because of symmetry in both sides of slots to form meander structure, can lead to a good omnidirectional radiation characteristics in the desired bands. The optimized dimensions for the geometry shown in Fig. 1 are as follows: $W_s = L_s = 23$, $W_p = 17$, $L_p = 13$, $W_g = 10$, $L_g = 3$, $L_f = 4$, $W_f = 2$, $L_1 = 12$, $L_2 = 1$, $L_3 = 3$, and $L_4 = L_5 = 1$. Here all dimensions are in mm.

A step-by-step procedure for designing antenna, shown in Fig. 1, is further explored in Fig. 2. The simple rectangular radiator without any slots, as shown in Fig. 2a, is considered as Antenna #1. Two open-ended slots are then inserted on both sides of the patch as shown in Fig. 2b for creating two bands operating at 2.4 GHz and 5.5 GHz. For achieving the third band operation at 3.5 GHz, another pair of slots added to the patch as shown in Fig. 2c.

3 Simulated Results and Performance Discussion

Figure 3 illustrates the simulated reflection coefficient of the proposed antenna operating at three different bands such as Bluetooth band at 2.4 GHz (2–2.6 GHz), WiMAX band at 3.5 GHz (3.28–3.7 GHz), and WLAN band at 5.5 GHz (4.8–6.5 GHz).

The effect of inserting slots on reflection coefficients is illustrated in Fig. 4a. It is observed here that a simple conventional radiator patch without any slots (Antenna #1) is operating over a frequency range from 2.7 to 7.9 GHz, whereas Antenna #2 with one pair of L-shaped slots generates two resonating modes at 2.4 GHz and 5.5 GHz. Third resonant mode at 3.5 GHz is generated by etching another pair of I-shaped slots (Antenna #3) on radiating surface. As displayed in Fig. 4b, the simulated performance of gain has enhanced from Antenna #1 to Antenna #3. The gain is positive and is more than 2.3 dBi in all the operating bands. The overall gain performance in the frequency range 1–8 GHz is acceptable from application point of view. The radiation efficiency is observed to be more than 85% in all the three operating bands, as displayed in Fig. 5.

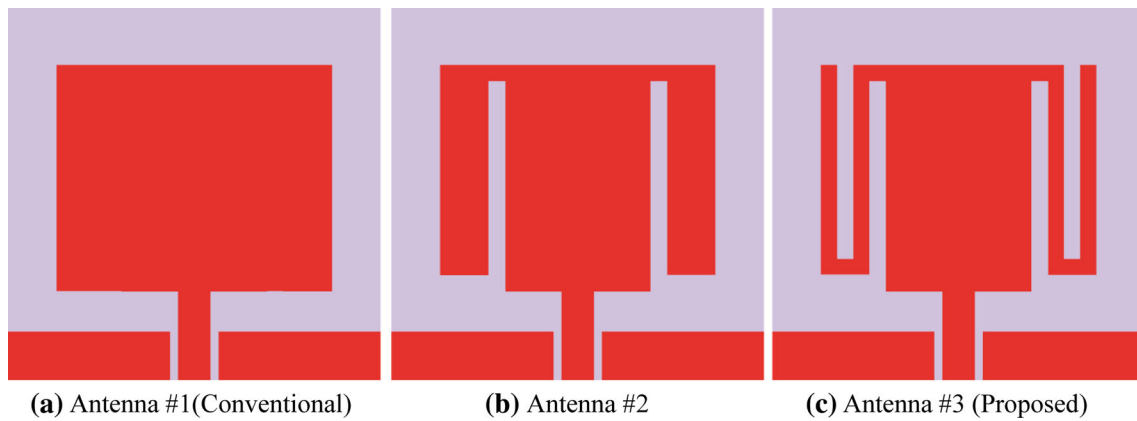


Fig. 2 Stepwise design procedure for achieving multiband

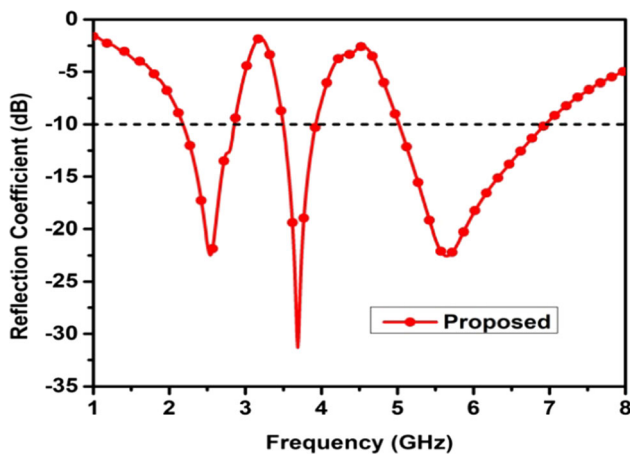


Fig. 3 Simulated reflection coefficient comparison

In order to describe the operating mechanism of the multiband antenna, simulated performance of surface current distribution for the optimized Antenna #3

configuration is obtained. The corresponding analysis is included in Fig. 6. As can be seen, the resonance at 2.37 GHz is contributed by the inner arm of the meandered line structure, whereas the outer arm of the loaded meandered line is responsible for procuring the second resonance at 3.48 GHz. The third resonance at 5.9 GHz is contributed by the coupling between the ground plane and the radiator of the antenna.

4 Fabrication and Characterization

For validating the proposed design, a prototype of Antenna #3 is fabricated using FR-4 dielectric substrate sheet. The photograph of the fabricated prototype is shown in Fig. 7a, whereas the measured and simulated reflection coefficients are compared in Fig. 7b. A very good agreement between measured and simulated results has been observed. The measured -10 dB frequency bands for the fabricated

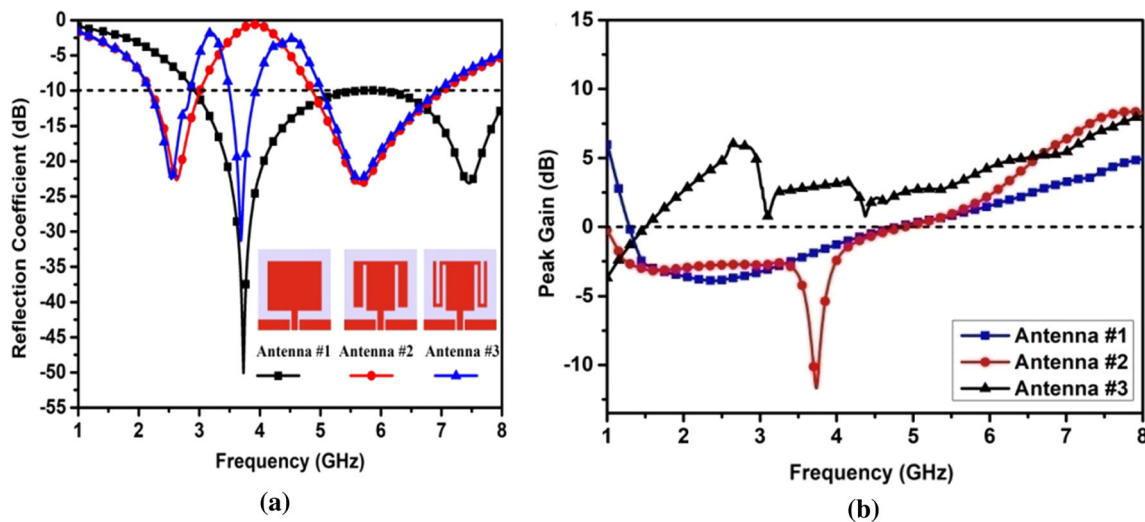


Fig. 4 a Effect of inserting slots and b simulated peak gain of Antenna #1, Antenna #2, and Antenna #3

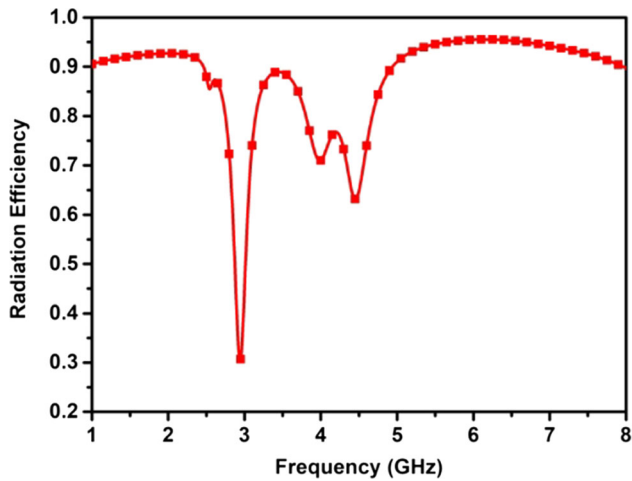


Fig. 5 Radiation efficiency of Antenna #3

antenna are observed from 2.06 to 2.69 GHz, 3.37 to 3.83 GHz, and 4.78 to 6.61 GHz. In both simulated and measured performance, these three bands are covering

Bluetooth (2–2.6 GHz), WiMAX (3.28–3.7 GHz), and WLAN (4.8–6.5 GHz) bands, respectively. A very small deviation between measured and simulated results is observed which may be due to the tolerances in the SMA connector and fabrication.

Further, in order to verify the radiation performance, radiation pattern measurement has also been taken in an anechoic chamber. Figure 8 shows the measured and simulated patterns at 2.4 GHz, 3.5 GHz, and 5.5 GHz in both H-plane and E-plane, respectively. The designed antenna shows an omnidirectional radiation patterns in the H-plane and dipole-like radiation pattern in the E-plane. Figure 9 plots the cross-polarization radiation performance at different frequencies for both E-plane and H-plane. The cross-polarization is observed to be very low for the case of both E-plane and H-plane.

Further, to establish the superiority of the suggested layout, a comparison between published multiband antennas and proposed work has been conducted and is listed in Table 1. The fractional bandwidth achieved is highest in

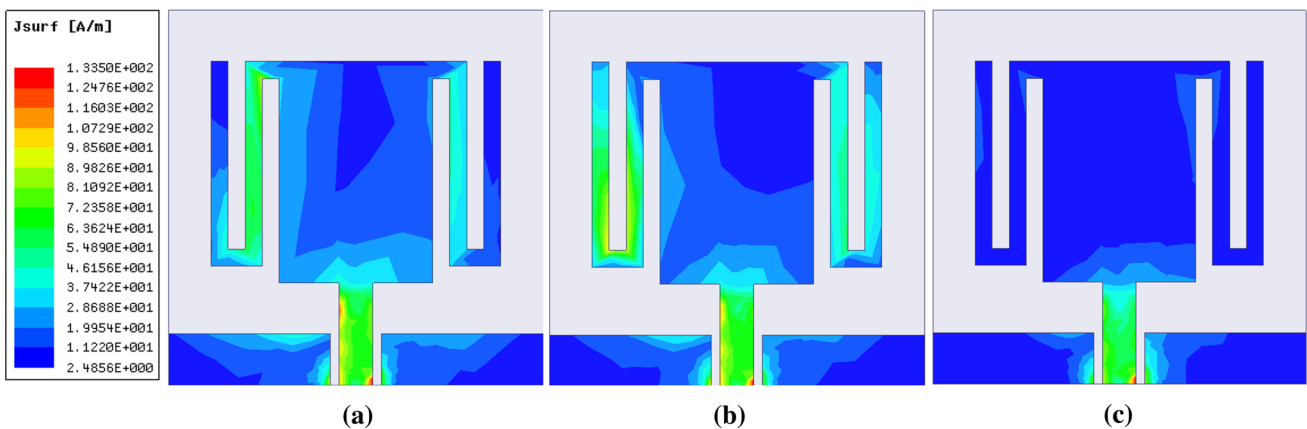


Fig. 6 Surface current distribution for Antenna #3 at a 2.37 GHz, b 3.48 GHz, and c 5.90 GHz

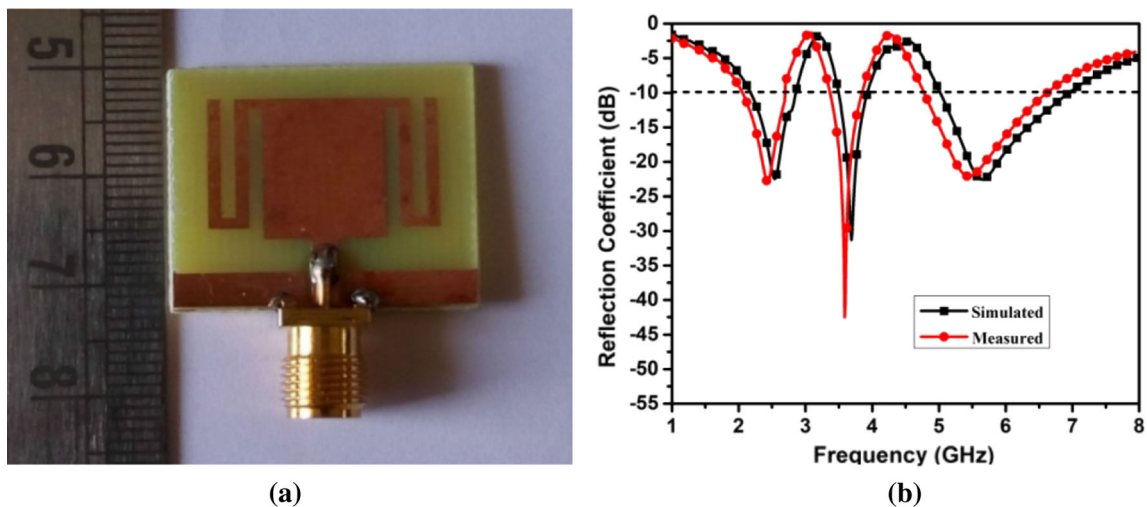


Fig. 7 a Photograph of fabricated prototype and b reflection coefficient comparison

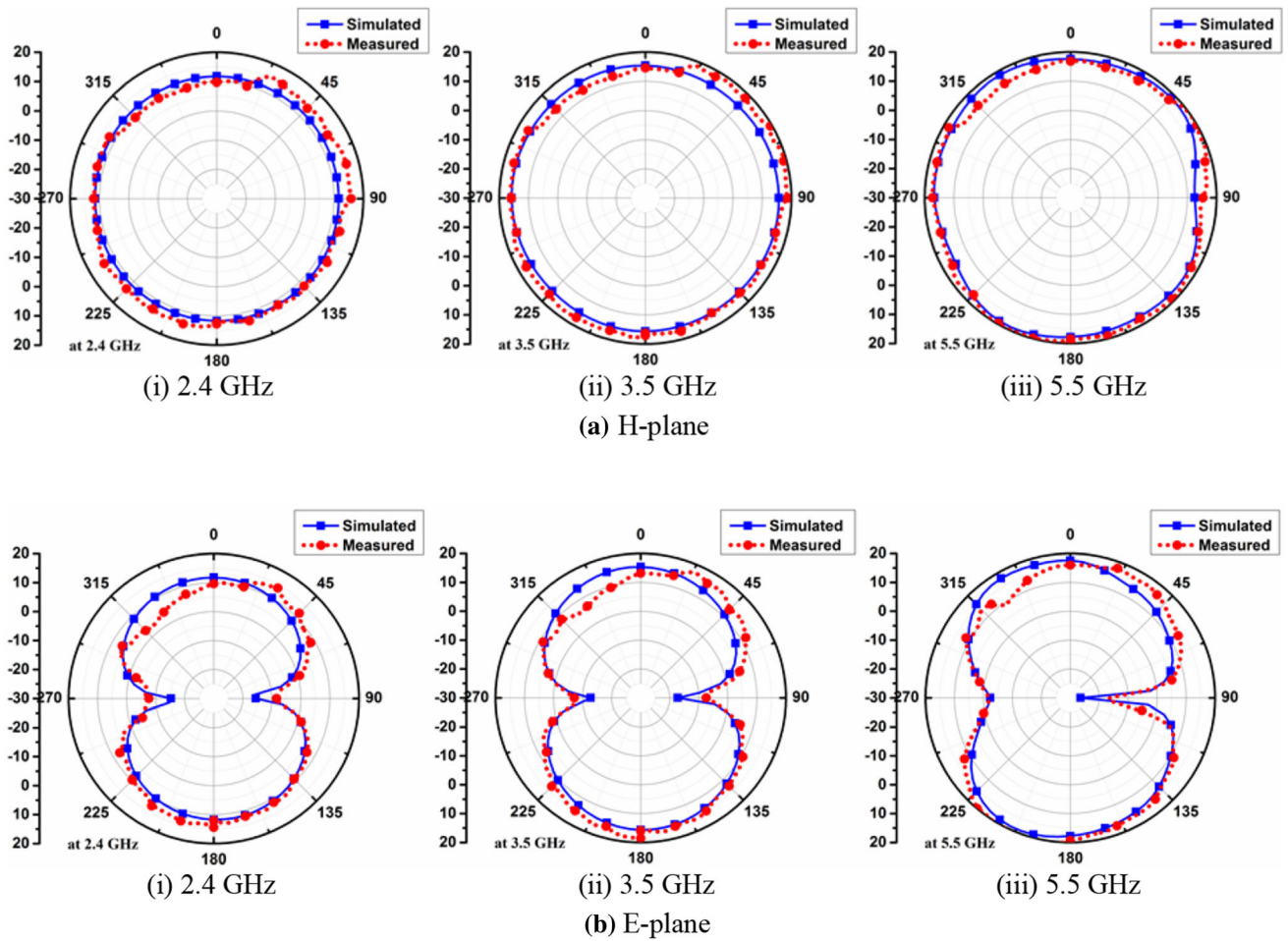


Fig. 8 Simulated and measured co-pol radiation pattern at different frequencies

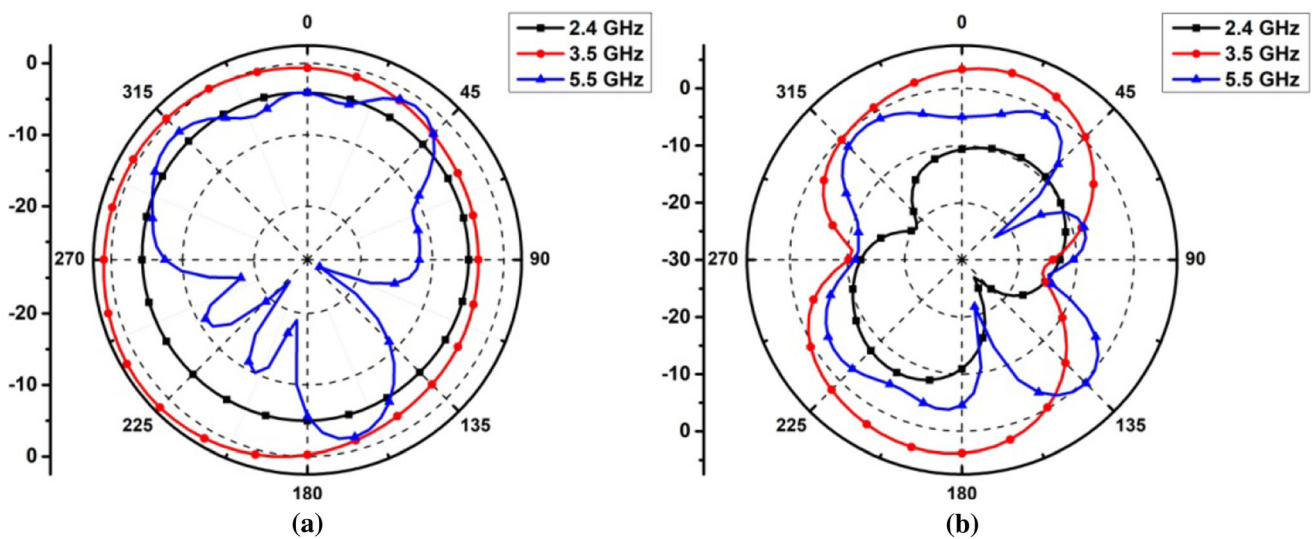


Fig. 9 Simulated cross-pol radiation pattern at different frequencies a E-Plane and b H-Plane

Table 1 Comparison of proposed and referenced works

References	Frequency bands	Bandwidth	FBW (%)	Size (L × W × h mm ³)
Lu and Huang (2010)	Bluetooth/WiMAX/ WLAN	NA	Band 1 10.40 Band 2 28.60 Band 3 22.70	30.0 × 25.0 × 1.6
Zaman et al. (2018)	Bluetooth/WiMAX/ WLAN	Band 1 2.38–2.50 GHz, Band 2 3.10–4.50 GHz, Band 3 5.09–6.65 GHz	Band 1 4.91 Band 2 36.84 Band 3 26.57	23.0 × 20.0 × 1.6
Huang et al. (2015)	WiMAX/WLAN	Band 1 2.3–4.0 GHz, Band 2 5.0–6.6 GHz	Band 1 53.96 Band 2 27.58	45.0 × 40.0 × 1.0
Rajkumar and Kiran (2016)	WiMAX/WLAN/ITU	NA	Band 1 9.28 Band 2 74.37 Band 3 5.34	25.2 × 23.7 × 1.6
This work	Bluetooth/WiMAX/ WLAN	Band 1 2–2.6 GHz, Band 2 3.28–3.7 GHz, Band 3 4.8–6.5 GHz	Band 1 26 Band 2 12 Band 3 30	23.0 × 23.0 × 1.6

case of the proposed work for the case of Bluetooth/WLAN bands. The comparison table also reveals that the suggested layout is compact in size in comparison with other existing designs.

5 Conclusion

In this paper, a compact multiband antenna for 2.4 GHz Bluetooth, 3.4 GHz WiMAX, and 5.5 GHz WLAN applications is introduced. The suggested antenna has a simple rectangular radiating structure with two symmetrical slots on patch to form like meandered lines for triple-band generation. This simple structure and small size can be used for cost-effective wireless mobile communications. This antenna has also good omnidirectional radiation patterns in H-plane with very low cross-polarization components.

References

- Ali T, Khaleeq MM, Fathima N, Biradar RC (2017) A slotted multiband antenna with wide-bandwidth operation at lower band for WLAN/WiMAX applications. In: 2017 International conference on smart technologies for smart nation (SmartTechCon), Bangalore, pp 158–162
- Ali T, Khaleeq MM, Pathan S, Biradar RC (2018) A multiband antenna loaded with metamaterial and slots for GPS/WLAN/WiMAX applications. *Microw Opt Technol Lett* 60(1):79–85
- Bakariya PS, Dwari S, Sarkar M, Mandal MK (2015) Proximity coupled multiband microstrip antenna for wireless applications. *IEEE Antennas Wirel Propag Lett* 14:646–649
- Chakraborty U, Chatterjee S, Chowdhury SK, Sarkar PP (2011) A compact microstrip patch antenna for wireless communication. *Prog Electromagn Res C* 18:211–220
- Chen S, Fang M, Dong D, Han M, Liu G (2014) Compact multiband antenna for GPS/WiMAX/WLAN applications. *Microw Opt Technol Lett* 57(8):1769–1773
- Fernandez SC, Sharma SK (2013) Multiband printed meandered loop antennas with MIMO implementations for wireless routers. *IEEE Antennas Wirel Propag Lett* 12:96–99
- Huang H, Liu Y, Zhang S, Gong S (2015) Multiband metamaterial-loaded monopole antenna for WLAN/WiMAX Applications. *IEEE Antennas Wirel Propag Lett* 14:662–665
- Khaldi MA (2017) A highly compact multiband antenna for Bluetooth/WLAN, WiMAX, and Wi-Fi applications. *Microw Opt Technol Lett* 59(1):77–80
- Li ZQ, Ruan CL, Peng L, Wu XH (2010) Design of a simple multiband antenna with a parasitic C-shaped strip. *J Electromagn Waves Appl* 24:1921–1929
- Liua WC, Wua CM, Chub NC (2012) A compact low profile-dual band antenna for WLAN and WAVE applications. *Int J Electron Commun* 66(6):467–471
- Lu JH, Huang BJ (2010) Planar multi-band monopole antenna with L-shaped parasitic strip for WiMAX application. *Electron Lett* 46(10):671–672
- Mansoul A (2017) Switchable multiband slot antenna for 2.4, 3.5, and 5.2 GHz applications. *Microw Opt Technol Lett* 59(11):2903–2907

- Morghare G, Sinha P (2014) Design of triband miniature microstrip antenna with modified resonating structure using CADFEKO. *Int J Sci Res Publ* 4(1):1–4
- Rajkumar R, Kiran KU (2016) A compact metamaterial multiband antenna for WLAN/WiMAX/ITU band applications. *Int J Electron Commun* 70(5):599–604
- Shinde PN, Shinde JP (2015) Design of compact pentagonal slot antenna with bandwidth enhancement for multi-band wireless applications. *Int J Electron Commun* 69(10):1489–1494
- Srivastava K, Kumar A, Kanaujia BK, Dwari S, Kumar S (2018) Multiband integrated wideband antenna for Bluetooth/WLAN applications. *Int J Electron Commun*. <https://doi.org/10.1016/j.aee.2018.03.027>
- Yadav A, Goyal S, Agarwal T, Yadav RP (2016) Multiband antenna for Bluetooth/ZigBee/Wi-Fi/WiMAX/WLAN/X-Band applications: partial ground with periodic structures and EBG. In: 2016 IEEE international conference on recent advances and innovations on engineering, Jaipur, pp 1–5
- Zaman W, Ahmad H, Mehmood H (2018) A miniaturized meandered printed monopole antenna for triband applications. *Microw Opt Technol Lett* 60(5):1265–1271