ISSN: 2249-7862 (Print): 2455-877X (Online)
www.aureoleonline.in

Design And Implementation of A Dual-Band CPW-Fed Monopole Antenna For WLAN and WiMAX Applications

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Abstract

This study focuses on the design, fabrication, and characterization of a coplanar waveguide (CPW)-fed dual-band antenna suitable for Wireless Local Area Network (WLAN) and Worldwide Interoperability for Microwave Access (WiMAX) applications. The antenna, with compact dimensions of 60 × 60 × 1.6 mm^3, consists of a slotted radiating patch enclosed by a square ground plane, constructed on an FR4 substrate. Using CST Microwave Studio (Computer Simulation Technology), essential performance parameters such as radiation patterns, voltage standing wave ratio (VSWR), and return loss were thoroughly examined. The measured results show bandwidths of 0.71 GHz and 0.61 GHz in the upper frequency range, with resonant frequencies at 2.84 GHz and 4.17 GHz. These results make the antenna suitable for integration into compact portable devices operating in the ISM bands, establishing its effectiveness for WLAN and WiMAX applications.

Keywords *- CPW fed, patch antenna, ultra-wide band, WiMax, WLAN*

I. Introduction

Compact planar antennas are crucial in today's portable wireless communication devices. By supporting multiple frequency bands with a single antenna, these designs help minimize device dimensions and manufacturing costs, eliminating the necessity for various antennas. Ultra-wideband (UWB) technology, introduced as a practical solution for unlicensed wireless communication, enables high data transmission rates over short distances. To support such systems, the Federal Communications Commission (FCC) has designated the 3.1–10.6 GHz frequency range specifically for UWB communications [1]. Due to its low power requirements, cost-effectiveness, and strong communication security, UWB stands out as a key enabler for future wireless technologies [2–4].

In microwave and millimeter-wave technology, coplanar waveguide (CPW) antennas are widely preferred due to their broad bandwidth, low dispersion, minimal radiation losses, and cost-effective fabrication [5]. The electric field's placement outside the dielectric layer simplifies their design for microwave applications and ensures significantly reduced losses at higher frequencies compared to microstrip-fed counterparts [6]. Enhanced frequency band operation can be achieved by introducing slots into the patch and the ground plane [7]. Coupling in CPW-fed antennas is facilitated through a slot etched into the ground plane of the microstrip patch antenna [8]. Notably, a CPW-fed multiple-input multiple-output (MIMO) antenna capable of ultra-wideband (UWB) operation across the 3–11 GHz range has been presented for wireless communication applications [9]. These antennas omnidirectional radiation characteristics, lightweight configuration, and cost-efficiency render them highly suitable for compact wireless devices [10, 11].

Wideband planar antennas are increasingly being adopted in portable electronic devices [12]. For example, a dual-band monopole antenna with CPW feed, optimized for ISM band IoT applications, is presented in [13]. This work introduces a CPW-fed planar antenna, specifically designed for use in WLAN and WiMAX communication systems. CPW structures are favored in microwave and millimeter-wave applications due to their broad bandwidth, low dispersion, reduced radiation loss, and cost-effectiveness. The design methodology of the proposed antenna was explained in Section 2, followed by a parametric analysis in Section 3 to fine-tune its physical parameters. Section 4 details the fabrication and measurement process, while Section 5 discusses the results and outlines potential areas for future research.

II. Antenna Design and Construction

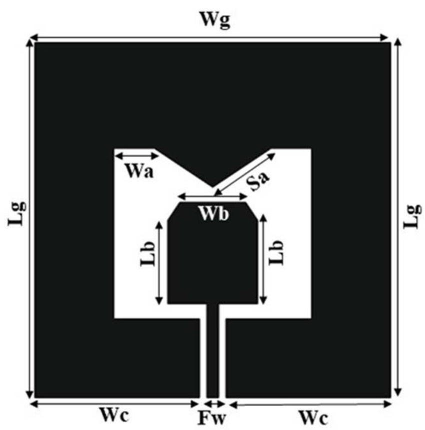

Fig. 1 Structure of CPW fed slotted antenna

Slots are incorporated into the antenna design to increase its bandwidth and enable operation across multiple frequency bands. The square FR4 substrate on which the antenna is built has compact measurements of 60 × 60 × 1.6 mm³. The main radiating element is a rectangular slotted conductive patch etched into the substrate. The square ground plane that maximizes the usage of available space encircles this area. This arrangement guarantees excellent performance and preserves the antenna's small size.

The synergy between the slotted radiating patch and the square ground plane enables wider bandwidth and multi-band functionality. The precise measurements of the patch and ground plane are shown in Figure 1, highlighting essential design elements supporting the antenna's increased operational effectiveness.

Table 1: Physical Dimensions of Antenna

Antenna Parameters	Units (mm)
Wg	60
Lg	60
Lb	28.5
Wa	6.
Sa	11.7
Wb	11
Fw	2
Wc	27.5
Substrate -FR4	1.6
Copper	0.035

III. Simulation And Analysis

CST Microwave Studio 2023 was used to conduct a parametric study in order to optimize the antenna's design parameters. The feed line width (Fw) has a significant impact on the antenna's performance, influencing bandwidth, resonant frequencies, and impedance matching, as illustrated in Fig. 2. A 50-ohm impedance match is achieved by centering the feed line because of the antenna's symmetrical construction. To assess how variations in antenna dimensions affect the resonant frequencies, a range of Fw values were investigated. The effect of changing the feed width Fw is shown in Fig. 2, where 2 mm produced two principal bands with return loss values of -20.31 dB at 2.84 GHz and -28.20 dB at 4.17 GHz. This is where optimal performance was recorded.

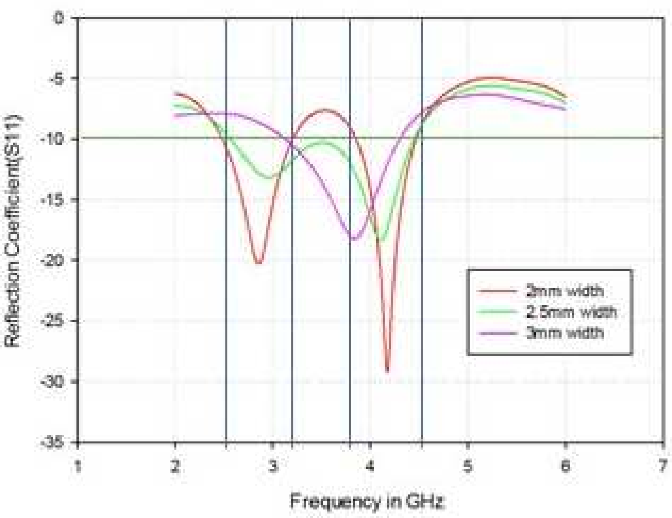

Fig. 2 Variation of return loss with a feed line width

As seen in Fig. 9, the antenna operates in dual-band mode when the optimal settings are used. Table 1 lists the substrate, radiating patch, and ground plane dimensions.

The simulation results demonstrate robust return loss characteristics, with values reaching approximately -20.31 dB at 2.84 GHz and an exceptional -28.20 dB at 4.17 GHz. The antenna achieves significant bandwidths of 0.71 GHz and 0.61 GHz for the lower and upper frequency bands, respectively. As depicted in Figure 5, the current distribution analysis reveals that at both operating frequencies, 2.84 GHz and 4.17 GHz, the current is predominantly concentrated around the feed point, the ground plane, and the side edges of the radiating patch. Conversely, the remaining radiating surface displays a relatively uniform current distribution, underscoring the efficiency of the antenna's design.

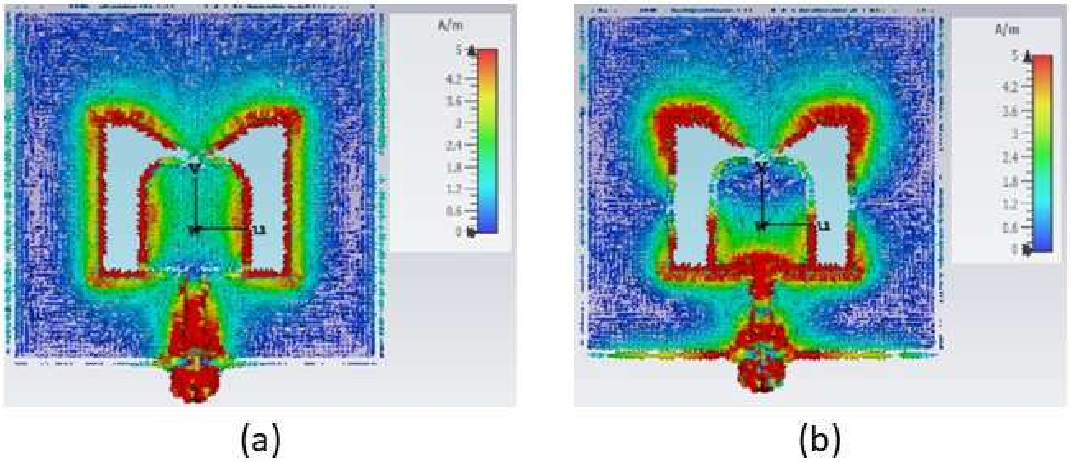

Fig. 5 Simulated Current density distribution curve (a) 2.84 GHz and (b) 4.17 GHz

IV. Fabrication and Experimental Results

The antenna was manufactured on an FR4 substrate, and an image of the completed antenna is shown in Fig 7.

Fig. 7 Fabricated antenna

The dual-band performance of the antenna was validated through return loss measurements conducted using a Vector Network Analyzer, as shown in Fig. 8. The measured results indicate bandwidths of 0.71 GHz in the lower band and 0.61 GHz in the upper band. Corresponding return loss values were observed at -18.21 dB at 2.84 GHz and -26.91 dB at 4.17 GHz, respectively. These findings affirm the antenna's effectiveness and its compatibility with WLAN and WiMAX applications.

Fig. 8 Measured return loss curve

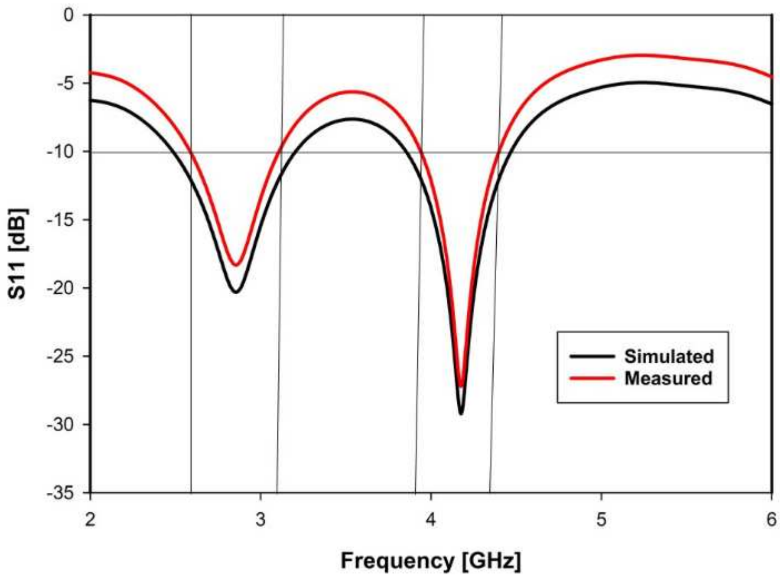

Fig. 9 Simulated and Measured return loss curve

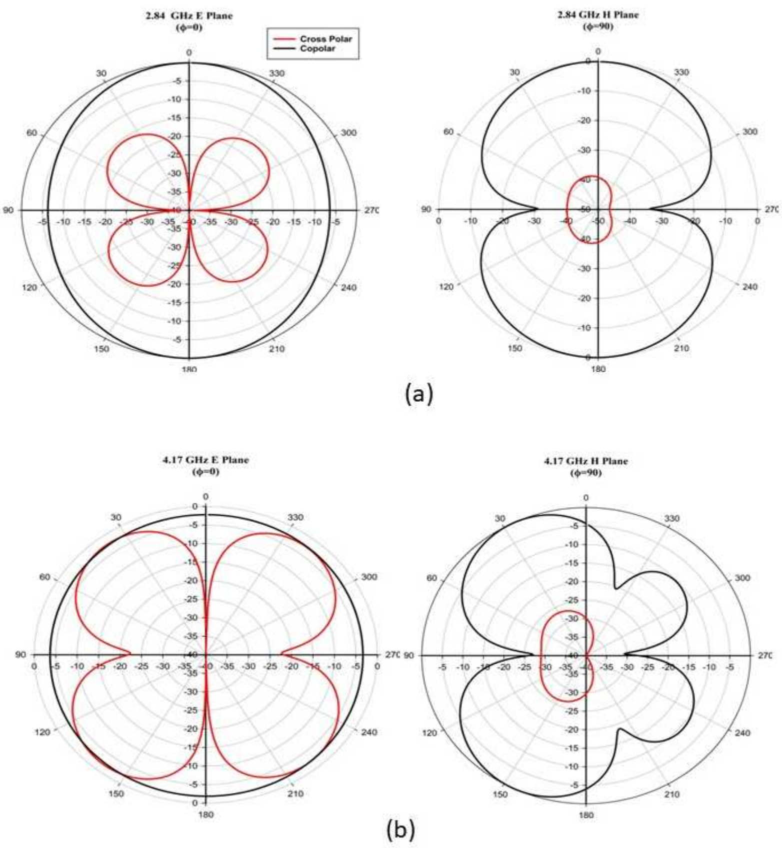

Fig. 11 2D radiation plot (a) 2.84 GHz E plane and H Plane, (b) 4.17 GHz E plane and H Plane

The radiation patterns generated by the proposed antenna exhibit a nearly omnidirectional behavior, rendering them highly suitable for mobile communication applications, as illustrated in Fig. 11. A comparative analysis with similar dual-band resonant antennas reported in the literature is presented in Table 2. Notably, the proposed antenna demonstrates superior performance, offering a more compact design and significantly broader bandwidth compared to its counterparts.

Table 2 Comparison of the Proposed Antenna with Prior Research

Ref	Area (mm)	Thickness (mm)	Resonating frequency	Bandwidth
[14]	97× 80	0.5	2.39 GHz	0.41 GHz
			3.77 GHz	0.60 GHz
[15]	15 ×30	1.6	2.63 GHz	0.14 GHz
			5.45 GHz	0.84 GHz
[16]	50 ×50	1.6	2.41 GHz	0.53 GHz
			5.80 GHz	0.20 GHz
[17]	44 ×41	1.6	2.40 GHz	0.59 GHz
			5.40 GHz	0.20 GHz
This work	**60 x60**	**1.6**	**2.84 GHz**	**0.71 GHz**
			4.17 GHz	**0.61 GHz**

V. Conclusion

The design, construction, and testing of a dual-band coplanar waveguide (CPW)-fed antenna are described in this study. It is designed to function at two distinct resonant frequencies, 2.84 GHz and 4.17 GHz, with corresponding bandwidths of 0.71 GHz and 0.61 GHz. Future advancements might concentrate on expanding the bandwidth of the antenna. The antenna is ideal for WLAN and WiMAX applications in portable devices because of its small size and powerful radiation performance.

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