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Coplanar Waveguide (CPW)-Fed Compact Dual Band Antenna for 2.5/5.7 GHz Applications

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Abstract—A novel coplanar waveguide fed compact dual-band antenna for 2.5/5.7 GHz applications is presented in this paper. The above characteristics are obtained by carefully optimizing the slotted ground planes and meander short placed between the signal strip and one of the lateral ground planes. The proposed antenna has been designed on a substrate with dielectric constant 4.4, thickness 1.6 mm, and it occupies a small area of $18.2 \times 20\,\text{mm}^2$. The experimental analysis shows 2 : 1 VSWR bandwidth up to 150 MHz and 370 MHz for 2.5 GHz and 5.7 GHz, respectively. Antenna radiation characteristics, including return loss, radiation pattern, radiation efficiency and gain are also validated with numerical simulation and experimental measurements.

1. INTRODUCTION

Coplanar waveguide (CPW) fed antennas are gaining great attention along with the growth in modern wireless communication systems due to their easy integration with MMIC circuits, lower radiation losses and less dispersion than microstrip antennas [1]. A basic open ended CPW transmission line can be transformed into an antenna by signal strip or ground plane modifications or both. The width of the lateral ground plane, signal strip and gap between ground and strip plays a vital role in determining the radiation characteristics of a CPW-fed antenna [2]. In recent years, various attractive dual-band antenna designs have been proposed.

In microstrip patch antenna so many techniques are used for achieving dual bands and compactness, such as triangular patch with two folding arms shorted to the ground plane [3], circular patch with curved slots on ground plane [4], an elliptical metallic patch [5], slotted patch with defected ground structure (DGS) [6], symmetric coupled lines [7], combination of the Jerusalem cross (JC) as a fractal load and fractal Minkowski slot antenna [8], half-mode substrate integrated waveguide with a row of shorting vias and slots [9], shorting pin and two arc-shaped slots in circular patch [10] stacked patch [11] and by slotted ground structure [12]. TE_{111} and TE_{113} modes of the rectangular dielectric resonator antenna (DRA) excited by a modified annular slot are reported in [13]. By using an irregular ring-shaped ground plane and a shared radiating element, dual resonances are achieved in MIMO antenna which is reported in [14]. Varactor diode using frequency reconfigurable bow-tie based single and dual-band mode antenna is proposed in [15]. In order to achieve dual resonances and desired bandwidth, superstrate stacking and slots in patch geometry are used in [16]. To analyze the radiation characteristics, semi-analytical techniques are reported for dipole in [17, 18], for loop antenna in [19] and for arbitrary curved geometries in [20]. The Cavity Model equivalent of optical patch antenna with an understanding of the operational mechanism and physical phenomena is reported in [21].

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A CPW-fed slot antenna is realized by embedding a vertical stub with the T-shaped strip and a slit to the ground plane as reported in [22] for realizing dual-band operations. Various dual-band antenna designs include symmetrically introducing four slot stubs on lateral arms [23], by an asymmetric slots in F-shaped end patch [24], by backed ground plane with radial stub on two identical elements [25], by using two parallel monopoles, one curved and one fork-shaped [26], by monopole structure with two inverted U-shaped, L-shaped lateral stubs [27], with two rectangular parasitic elements and an I-shape grounded stub [28], by printed log-periodic dipole array (LPDA) [29], by slots and monopole antenna [30], and by employing meander line technique in [31]. A theoretical and experimental study of twin-slot multilayer CPW-fed antenna is reported in [32], and highly selective behavior and regulation of sharp variations of a discontinuous parallel-plate waveguide with a narrow rectangular ridge filled with axially anisotropic material identified using mode matching technique is achieved in [33]. A study of modified short for improving impedance bandwidth in the wideband application is presented in [34] and for dual-band application in [35].

Available literature has addressed a few challenges of antenna compactness, gain and bandwidth. In this paper, we present a novel CPW-fed antenna by adding simple asymmetric slots and a meander short between the signal strip and ground plane for achieving dual-band resonance frequency. The advantage of this proposed antenna is not only a dual resonance frequency operation, but it can obtain compactness and favorable gain in the entire frequency bands. The geometry of the proposed dual-band antenna is shown in Figure 1. It consists of a signal patch, CPW ground planes with slots and a meander contact between the signal patch and one of the ground planes. Section 2 discusses the evolution of proposed antenna with geometric parameters. Simulated and experimental results of radiation characteristics are provided in Section 3, and in Section 4 a conclusion is given.

2. EVOLUTION AND GEOMETRY OF THE PROPOSED ANTENNA

Various stages of design evolution and their reflection characteristics are shown in Figures 1 and 2, respectively. The initial stage comprises an open-ended CPW transmission line designed for 50 Ω impedance, and the signal patch width W_2 and gap G of the CPW feed are designed to achieve 50 Ω impedance using general design equations [36], which is shown in Antenna 1.

From the evolution stages shown in Figure 1, it is clear that the proposed antenna evolves from

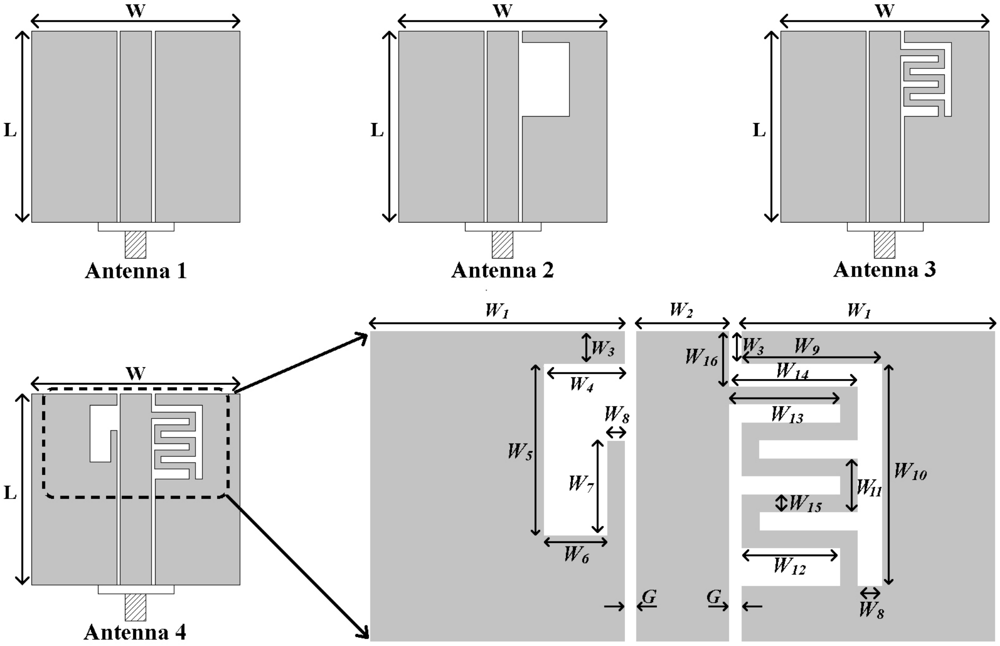


Figure 1. Evolution stages of proposed dual band CPW fed antenna.

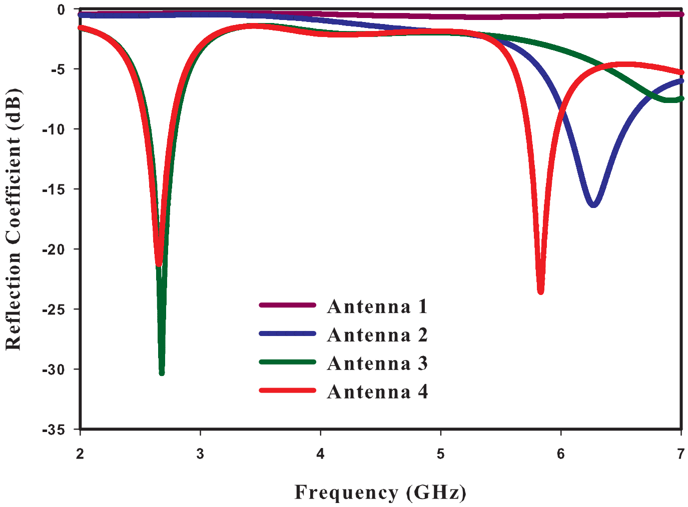


Figure 2. Simulated reflection coefficients (S_{11}) of antenna evolution.

an open-ended transmission line. The first stage of the antenna evolution comprises a slot etched out from the right side CPW ground plane, resulting in a resonance at 6.27 GHz, which is Antenna 2. In Antenna 3, there is a meander line which is short with signal strip and right half of ground plane through the slot. This novel technique brings a particular resonance to a lower value without compromising the overall dimensions of the antenna and also without the insertion of the passive circuit elements. The meander stub lowers the particular resonance of the antenna from 6.27 GHz to 2.67 GHz. A similar slot, with different dimensions, is etched out from the left half ground plane, results in the proposed antenna (Antenna 4) with dual resonances at 2.5 GHz and 5.7 GHz. The stub with length W_7 plays a vital role in the impedance matching of a particular resonance at 5.7 GHz caused by the slot.

The antenna parameters are optimized using Ansoft HFSS (High-Frequency Structure Simulator) based on the finite element method and get suitable behaviors of the designed antenna, and the detailed geometrical parameters are listed in Table 1.

Table 1. Geometrical parameters of the proposed antenna (unit: mm).

Parameters	L	W	G	W_1	W_2	W_3	W_4	W_5	W_6	W_7
Value	18.2	20	0.35	8.15	3	1.1	2	5.4	1.45	3
Parameters	W_8	W_9	W_{10}	W_{11}	W_{12}	W_{13}	W_{14}	W_{15}	W_{16}	
Value	0.55	3.5	7.7	1.8	2.35	2.7	3.3	0.6	1.6	

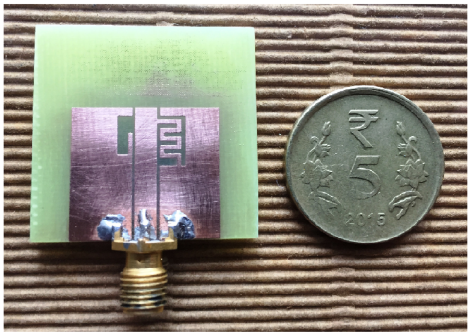


Figure 3. Fabricated prototype of dual band antenna.

The proposed antenna is excited by a 50 Ω coplanar waveguide line with strip width of W_2 and gap between the strip and the ground plane of G and is fabricated on a single layer FR4 epoxy dielectric substrate with a relative permittivity of 4.4, dielectric loss tangent of 0.02, and thickness of 1.6 mm. The prototype of the antenna with optimal dimensions is shown in Figure 3. The overall size of the antenna is $0.158\lambda_{01} \times 0.174\lambda_{01} \times 0.013\lambda_{01}$ ($18.2 \times 20 \times 1.6\,\mathrm{mm}^3$), where λ_{01} is the free space wavelength of the first resonance frequency 2.615 GHz. There is no metallization on the backside.

3. PARAMETRIC STUDIES

To investigate the effect of geometrical parameters on the performance of proposed antenna, parametric studies are carried out by numerical simulation. The first resonance is contributed by the meander strip length along with the slot dimensions in right half ground plane. The effects of parameters W_9 and W_{10} on S_{11} are shown in Figure 4 and Figure 5. When parameter W_9 or W_{10} is increased, the resonance at 2.5 GHz comes to a lower value without a change in the second resonance. As these parameter values are increased, the effective resonant length is increased which in turn results in lower shifting of the first resonant frequency.

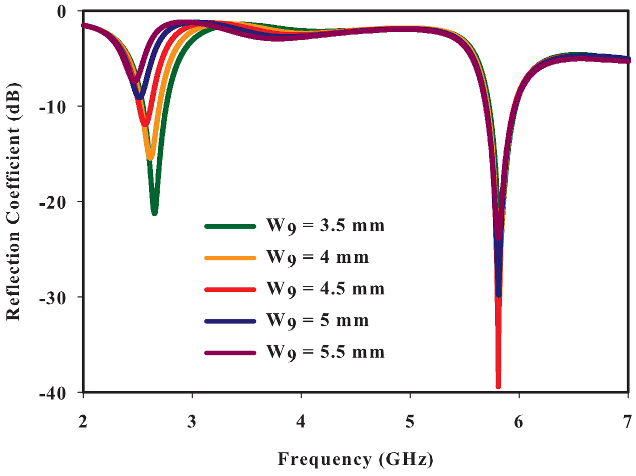


Figure 4. Simulated reflection coefficients for the proposed antenna with varying W_9.

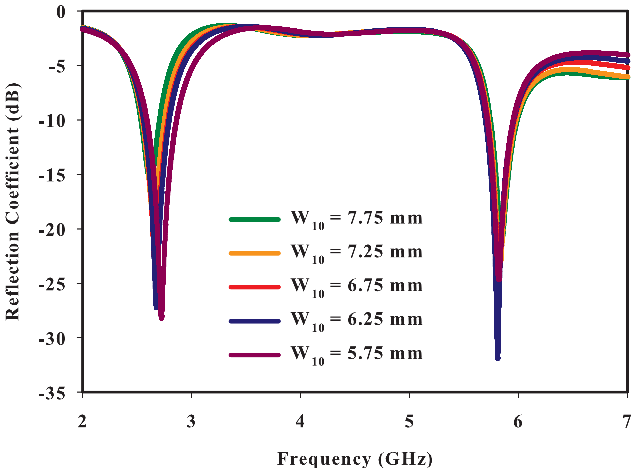


Figure 5. Simulated reflection coefficients for the proposed antenna with varying W_{10}.

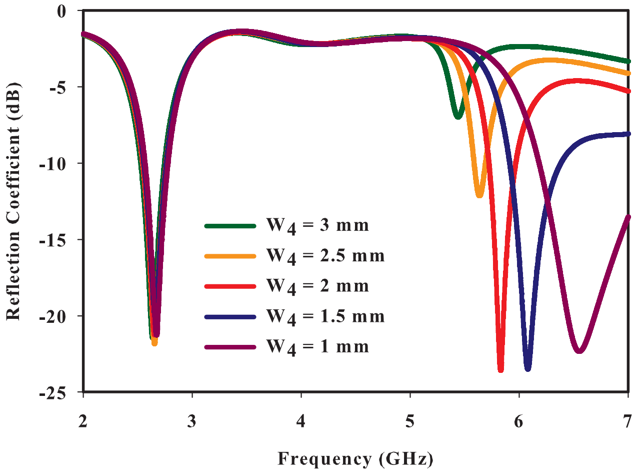


Figure 6. Simulated reflection coefficients for the proposed antenna with varying W_4.

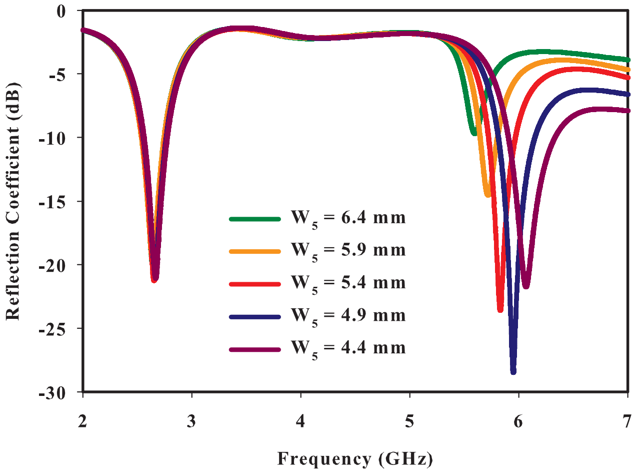


Figure 7. Simulated reflection coefficients for the proposed antenna with varying W_5.

The simulated reflection coefficients when the slot width W_4 varies from 1 mm to 3 mm are depicted in Figure 6. From the figure it is clear that when W_4 width is increased, the second resonance shifts to lower side due to the increase in current path length while the first resonance remains unchanged. Thus it is concluded that the second resonance depends on the slot width W_4, and it has no effect on the first resonance.

The effect of slot width W_5 on the performance of the antenna is exhibited in Figure 7, wherein W_5 is increased from 4.4 mm to 6.4 mm. As in the case of width W_4, the second resonance frequency comes down when width W_5 is increased and does not affect the first resonance. The above parametric studies demonstrate that the performance of the first resonant band in terms of resonant frequency, bandwidth, radiation pattern, and gain remains unchanged while changes are made in the above studied slot. This shows that the proposed antenna allows one to allocate the two operating resonance frequency bands independently.

4. EXPERIMENTAL RESULTS AND DISCUSSION

The experimental studies were done using Agilent PNA E8362B Vector Network Analyzer. Measured results are in good agreement with simulated ones. The simulated and measured input reflection coefficients (S_{11}) of the proposed antenna are depicted in Figure 8, and the small frequency shift in the first resonance is due to fabrication discrepancies. Experimental results show that the antenna exhibits two resonance frequencies with center frequencies 2.5 GHz and 5.7 GHz with a −10 dB impedance bandwidth of 150 MHz and 370 MHz, respectively.

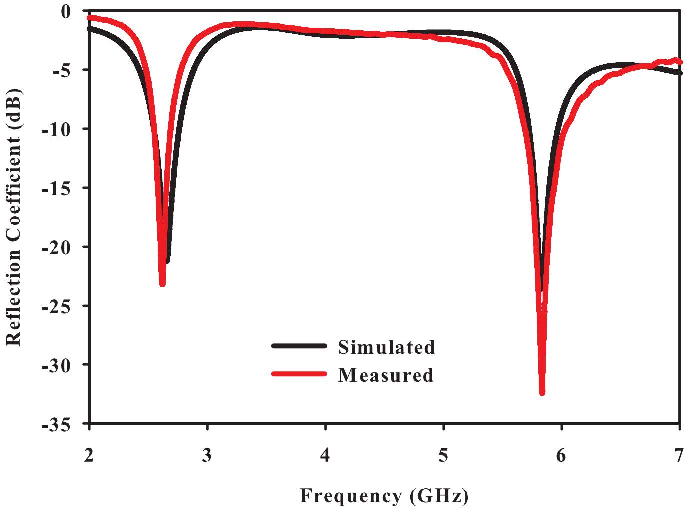


Figure 8. Measured and simulated reflection coefficient (S_{11}) of the proposed antenna.

The far-field measurements of antenna radiation characteristics were done in a microwave anechoic chamber. The two-dimensional radiation patterns of the antenna in E and H planes at both the resonant frequencies are shown in Figure 9. In E plane the obtained radiation patterns are omnidirectional at 2.5 GHz and nearly omnidirectional at 5.7 GHz as a conventional simple slot antenna. They are still stable to give slot like patterns. A figure of eight radiation pattern is obtained at 5.7 GHz and roughly close to same pattern at 2.5 GHz in the H plane.

The measured gain of the antenna is found to have a peak value of 5.30 dB for the first resonance and 3.44 dB for the second resonance, respectively, which is shown in Figure 10. The efficiency of the antenna measured using Wheeler cap method is found to be 60% for lower and higher resonances.

To conclude the advantages of proposed antenna compared with previous published dual-band antennas, a simple performance comparison is given in Table 2, where f_1 is the first resonant frequency and f_2 the second resonant frequency. When balanced with the antennas reported in [10, 16, 31], the proposed antenna shows compactness in size, much wider bandwidth and good gain in both the lower

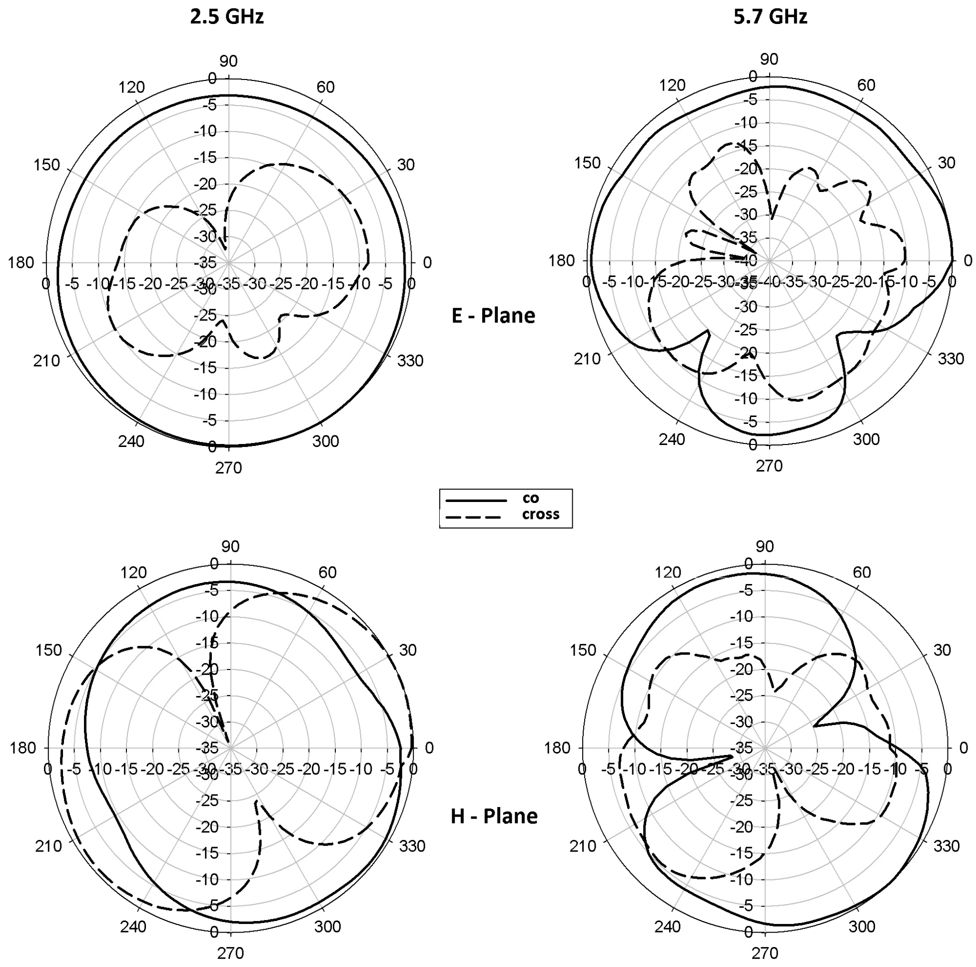
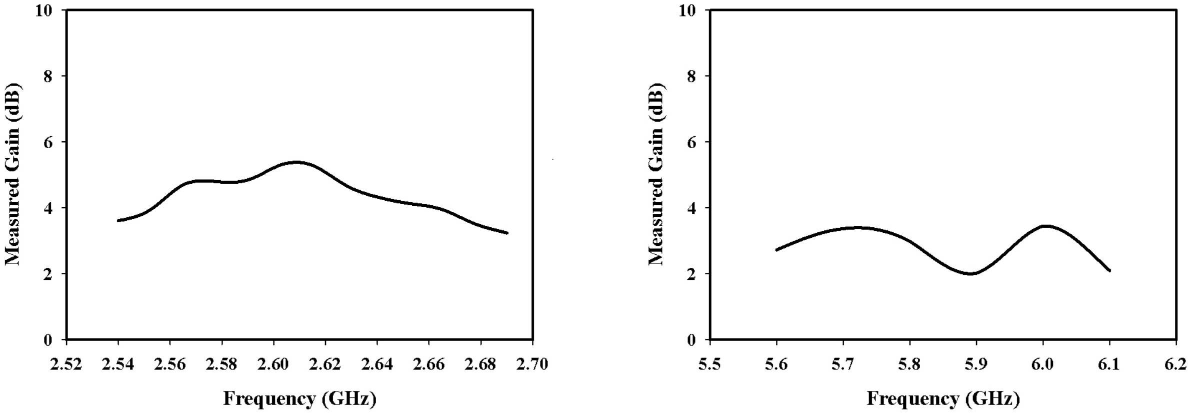


Figure 9. Measured radiation pattern of the proposed antenna at 2.5 GHz and 5.7 GHz.



(a) (b)

Figure 10. Measured gain response of the proposed antenna in (a) 2.5 GHz and (b) 5.7 GHz.

Table 2. Performance comparison of proposed antenna with the previous reported dual-band antennas.

Antenna	Size (mm^3)	f_1 (GHz)	f_2 (GHz)	Bandwidth (MHz)		Gain (dB)	
				f_1	f_2	f_1	f_2
Proposed antenna	$\mathbf{18.2 \times 20 \times 1.6}$	**2.50**	**5.70**	**150**	**370**	**5.30**	**3.44**
Ref. [10]	35×3	2.45	5.80	84	247	4.16	4.34
Ref. [16]	$30.18 \times 34.94 \times 5$	2.40	5.50	240	330	1.00	0.26
Ref. [31]	$50 \times 20 \times 0.1$	2.40	5.20	61	28	2.83	2.70

and upper bands. The novelty of this antenna lies in the design part with the combined use of slots and the meandered strip length from the center conductor to right half ground which results in dual-band operation without compromising the compactness of the antenna.

5. CONCLUSION

A compact CPW-fed dual-band antenna for 2.5 GHz (LTE 2500 and SDMB) and 5.7 GHz (WLAN) bands is designed and fabricated. Compactness and good radiation characteristics make the antenna suitable for wireless applications. The antenna offers reasonable dual impedance bandwidths ranging from 2.54 GHz to 2.69 GHz and 5.68 GHz to 6.05 GHz with moderate gain and efficiency.

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