A Compact Dual-band GCPW-fed Antenna for WLAN, WiMAX and Bluetooth Applications

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Abstract— In this study, a compact dual-band grounded coplanar waveguide fed printed planar monopole antenna (GCPW-PPMA) is designed and realized for Bluetooth, WLAN and WiMAX applications. Antenna is designed in two stages and a low-cost FR4 substrate is used. Firstly, a GCPW fed trapezoidal shape printed monopole radiator patch is designed at 5.8 GHz band and its bandwidth is improved by employing an inset. In the second phase, two different slot geometries are employed to excite 2.45 GHz band. Slot loadings, radiating patch and inset feeding are optimized and the dimensions of the resulting antenna are obtained as 25 mm × 27.5 mm. Simulated and measured results are in good agreement, and measured operating bands of the proposed antenna are 2.40 GHz–2.52 GHz and 3.76 GHz–5.875 GHz for $S_{11} < -10$ dB. The proposed GCPW-PPMA has dipole like radiation patterns in the operating bands. Its measured realized gains are 1 dB at 2.45 GHz and 2.5 dB at 5.8 GHz. The proposed antenna is suitable for space and weight limited portable devices.

1. INTRODUCTION

In recent years, the growth in wireless communication technologies has led to the development of various wireless systems such as Bluetooth, WLAN and WiMAX. Their most common frequency designations are presented in Table 1 for convenience. Todays space and weight limited devices require low-profile, compact and compatible antennas. Printed antennas are preferred for those purposes because of their low cost, easy fabrication and implementation in the applications [1–6]. A planar monopole antenna (PMA) is simply generated by replacing a monopole above the ground plane with a planar radiator sheet. Many different kinds of geometries of planar monopoles have been proposed for various applications since its first introduction by Dubost and Zisler [7]. PMAs provide wide bandwidth with very fine control and less degradation on the radiation pattern with an acceptable gain in the band. In addition to the useful properties of PMAs, printed planar monopole antennas (PPMA) have all advantages of printed antennas [8, 9]. Coplanar waveguide (CPW) feeding attracts more and more attention lately due to its advantages over microstrip feeding. It has wider bandwidth performance with lower dispersion and lower radiation leakage than microstrip feeding. Furthermore, its implementation for active and passive devices is easier. CPW structures with an additional ground plane on the back side of substrate achieve extra level of isolation and more electrical stability. Grounded CPW (GCPW) feeding also provides more readily mode suppression, when necessary [4–6, 10].

Therefore, in this study, it is intended to design and realize a compact, dual-band GCPW fed PPMA with slot loadings is aimed for Bluetooth, WLAN and WiMAX applications. Comprehensive numerical studies with parametric analysis are performed using HFSS to obtain the optimum designs before the fabrications and the measurements.

Table 1: Frequency designations.

Application	Frequency (GHz)	
Bluetooth	2.400–2.485	(802.15.1)
WLAN	2.412–2.472	(802.11/a-n)
	3.657–3.690	(802.11y)
	5.180–5.825	(802.11/a-n)
WiMAX	2.40, 5.80	(unlicensed)

Table 2: All dimensions of GCPW-PPMAs.

L_1 = 14.75 mm	L_6 = 2.25 mm	L_{13} = 5.00 mm	W_1 = 13.5 mm	W_6 = 0.25 mm
L_2 = 2.00 mm	L_7 = 5.90 mm	L_{14} = 1.60 mm	W_2 = 3.38 mm	W_7 = 1.00 mm
L_3 = 1.50 mm	L_8 = 6.60 mm	L_{15} = 0.90 mm	W_3 = 2.88 mm	W_8 = 4.00 mm
L_4 = 6.00 mm	L_9 = 0.50 mm	L_{16} = 0.75 mm	W_4 = 4.90 mm	W_9 = 4.00 mm
L_5 = 8.00 mm	L_{10} = 0.50 mm	L_{17} = 11.25 mm	W_5 = 0.41 mm	W_{10} = 0.75 mm
L_b = 2.00 mm	L_{11} = 0.575 mm		W_b = 13.5 mm	
L_t = 27.50 mm	L_{12} = 10.50 mm		W_t = 25.0 mm	

2. ANTENNA DESIGNS, RESULTS AND COMPARISONS

The antenna is designed in two stages and a low-cost FR4 substrate is used and its thickness and tangent loss are 1.5 mm and 0.02, respectively. Firstly, a printed planar monopole antenna (PPMA) is designed with GCPW feeding around 5.8 GHz. A trapezoidal geometry is employed as a radiating patch, and the dimensions of feeding line and ground planes are optimized to obtain a 50 Ω characteristic line impedance and an inset is employed for better matching performance. Illustration of the preliminary GCPW-PPMA is presented in Figure 1(a) and Figure 1(b) and all the dimensions of Figure 1 are given in Table 2. According to the simulated S_{11} results in Figure 2, the antenna with a bandwidth of 2.29 GHz operates between 3.71 GHz and 6 GHz and it covers 5.8 GHz band of WLAN and WiMAX. Implementation of proper slots having specific locations on an antenna is generally used for the excitation of additional operating frequencies, band stopping, antenna miniaturization, gain, and bandwidth enhancements [2, 4, 9]. In the second stage, two different slot structures are implemented on the preliminary GCPW-PPMA. The first slot located at the upper side of the radiating patch is mainly used to excite 2.45 GHz band. In Figure 1(c), the illustration of the slot loaded GCPW-PPMA is presented. The second slot

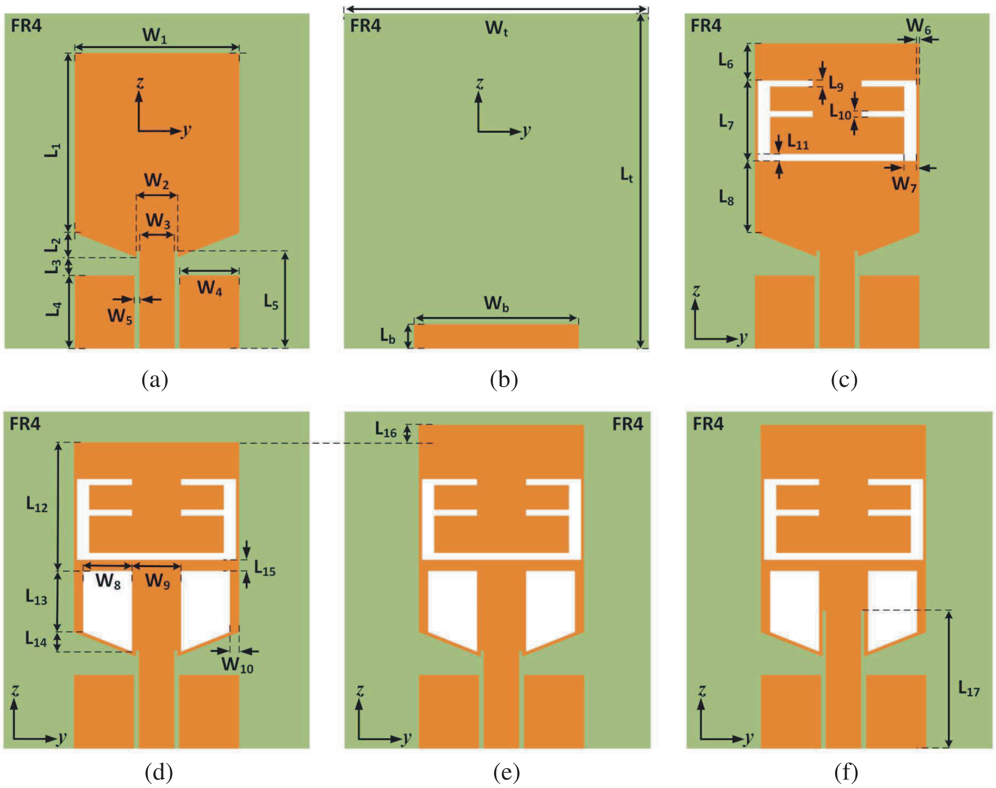


Figure 1: Illustration of GCPW-PPMAs, (a) front view of preliminary GCPW-PPMA without slots, (b) back view of GCPW-PPMAs, (c) front view of GCPW-PPMA with upper slot, (d) front view of GCPW-PPMA with slots, (e) front view of longer GCPW-PPMA with slots, (f) front view of proposed GCPW-PPMA.

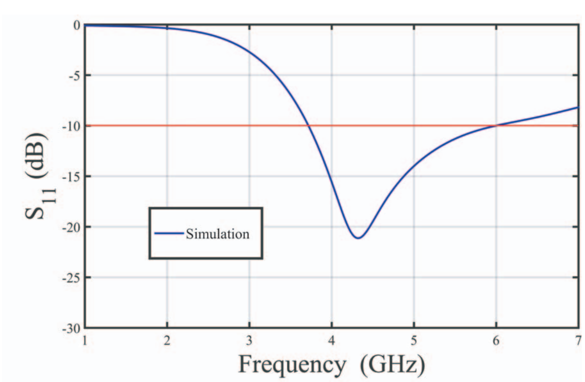


Figure 2: Simulated S_{11} results of preliminary GCPW-PPMA shown in Figure 1(a).

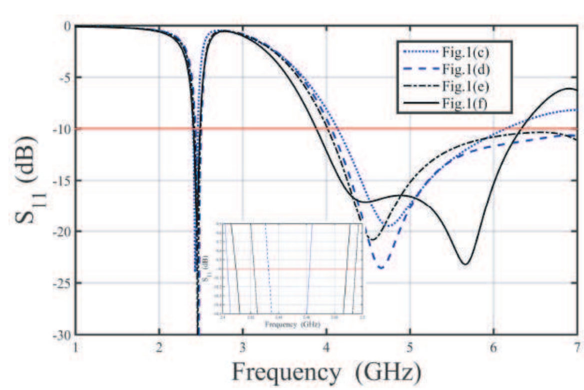
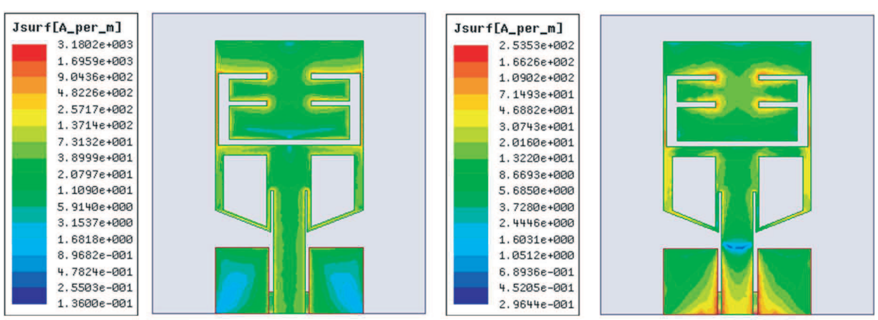


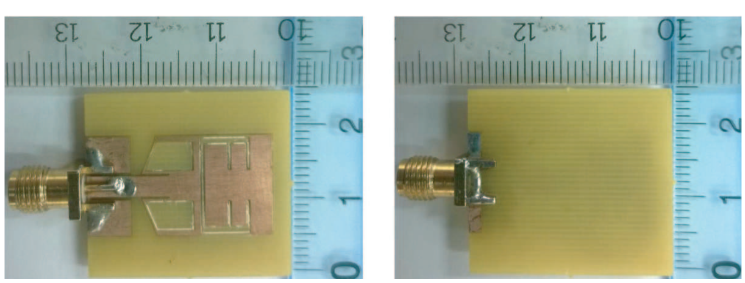
Figure 3: Comparisons of simulated S_{11} results of GCPW-PPMAs.

structure located at the lower side of the radiating patch and represented in Figure 1(d) is inserted into the antenna. Sizes, shapes and locations of the slots are optimized to obtain the necessary bandwidth at 2.45 GHz. Moreover, the length of radiating patch is increased 0.75 mm and it reaches to 15.50 mm. Inset feeding of GCPW-PPMA shown in Figure 1(e) is increased 3.25 mm and finally it reaches to 3.75 mm. The proposed GCPW-PPMA is represented in Figure 1(f). The comparisons of simulated results of GCPW-PPMAs are shown in Figure 3. As it is seen from the figure, the employment of upper slot excites frequencies around 2.45 GHz but it is not enough to obtain the required bandwidth. Insertion of the lower slots increases the bandwidths around 5.8 GHz and 2.45 GHz. However, this improvement is not very effective because the obtained bandwidth does not cover the frequency range given in Table 1 at 2.45 GHz band. The minimum operating frequency of the antenna is shifted to lower frequencies by increasing the length of the radiating patch and finally the required bandwidth is obtained by increasing the length of inset feeding. It is also seen from the figure that increase the length of inset feeding degrades the higher frequency bandwidth but these degradations are out of the 5.8 GHz band. According to the simulations, the proposed GCPW-PPMA operates at 2.41 GHz–2.49 GHz and 3.88 GHz–6.33 GHz bands. Its simulated realized gains are 0.82 dB at 2.45 GHz and 2.74 dB at 5.8 GHz. Current distributions of the antenna at the operating bands are shown in Figure 4(a) and Figure 4(b). According to the figure, the current concentrates on the surface between the upper slot loading and edges of radiating patch at 2.45 GHz. It concentrates at feeding line and ground planes at 5.8 GHz. The proposed antenna is fabricated by using MITS AutoLab milling machine. Front and back views of the fabricated antenna is given in Figure 5. S parameter measurements are carried out by HP 8720D vector network analyzer and, simulated and measured S_{11} results are compared in Figure 6. As it is obviously seen from the figure that the simulated and measured results are in good agreement. According to the measurements the proposed antenna operates at 2.40 GHz–2.52 GHz and 3.76 GHz–5.875 GHz bands. The difference between the simulated and measured results at higher frequencies might be due to the frequency dependence of FR4 substrate. Measured and simulated normalized radiation patterns of the proposed GCPW-PPMA are shown in Figure 7. According to the figure, the antenna has an omni-directional pattern in X-Y plane and figure-of-eight pattern in X-Z plane at 2.45 GHz and 5.8 GHz. Realized antenna gains are measured by using the two-antenna method presented in [11] and they are obtained as 1 dB and 2.5 dB at 2.45 GHz and 5.8 GHz, respectively.



(a) (b)

Figure 4: Surface currents at (a) 2.45 GHz, (b) 5.8 GHz.



(a) (b)

Figure 5: Fabricated antenna (a) front view, (b) back view.

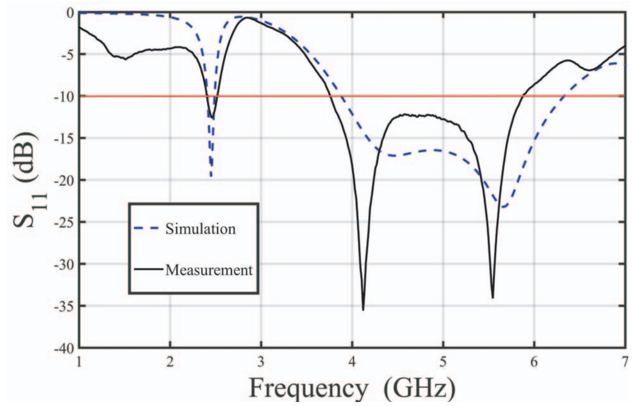


Figure 6: Comparison of simulated and measured S_{11} results of proposed GCPW-PPMA.

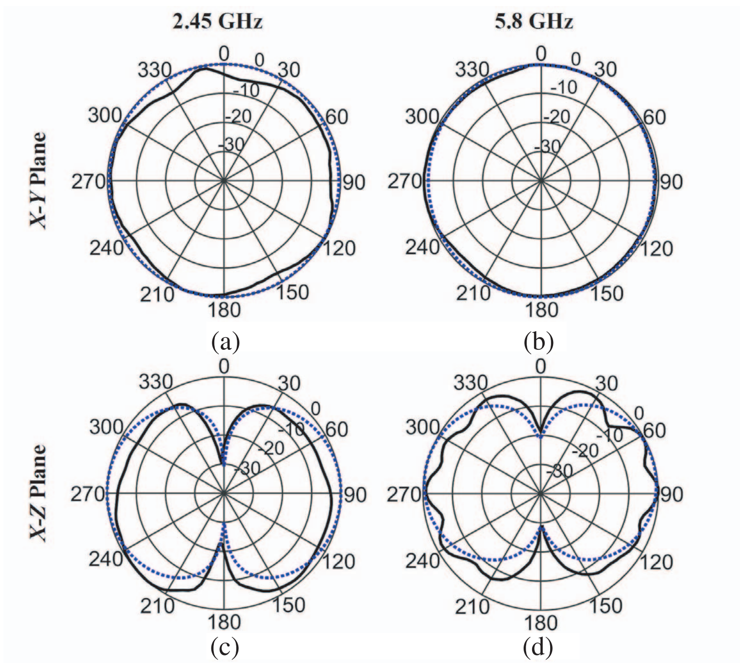


Figure 7: Radiation patterns of proposed GCPW-PPMA, (a) X-Y plane at 2.45 GHz, (b) X-Y plane at 5.8 GHz, (c) X-Z plane at 2.45 GHz, (d) X-Z plane at 5.8 GHz (Dotted: Simulation, Solid: Measurement).

3. CONCLUSION

In this study, a dual-band grounded coplanar waveguide fed planar printed monopole antenna has been designed and realized to for Bluetooth, WLAN and WiMAX applications at 2.45 GHz and 5.8 GHz bands. Firstly, a GCPW structure with inset is employed to feed a trapezoidal shape printed monopole radiator patch around 5.8 GHz. Then, two different slot loadings are inserted on the radiating patch. Shapes, sizes and dimensions of slots, radiating patch and inset feeding are optimized to excite 2.45 GHz band and obtain the necessary bandwidth. The resulting antenna whose total dimensions are 25 mm $\times$ 27.5 mm is fabricated and its performance is examined in terms of impedance matching, radiation pattern and realized gain. The proposed GCPW-PPMA operates in 2.40 GHz–2.52 GHz and 3.76 GHz–5.875 GHz bands. It has dipole like radiation pattern and its realized gains are measured as 1 dB and 2.5 dB at 2.45 GHz and 5.8 GHz, respectively. There is a good agreement between the simulated and measured results. Therefore, the proposed antenna is suitable for the integration and usage within portable devices. In future studies, 3 GHz band of WLAN and MIMO structures will be investigated to make the antenna fully compatible with WLAN and more convenient for smart portable devices.

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