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DESIGN AND DEVELOPMENT OF CPW-FED MICROSTRIP ANTENNA FOR WLAN/WIMAX APPLICATIONS

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Abstract—In this paper, a novel broadband monopole antenna with an extended rectangular shaped slot based on coplanar waveguide (CPW)-fed is designed and presented. The antenna composed of a planar rectangular patch element embedded with slots, capable of generating two separate resonant modes with good impedance matching. The parametric study is performed to understand the characteristics of the proposed antenna. To verify the simulated design concept, a prototype antenna is designed and fabricated on the FR4 substrate, and characterized experimentally. The overall size of the antenna is 35.24 mm × 26.4 mm × 1.6 mm including the finite ground CPW feeding mechanism and total volume of the antenna is 1.49 cm^3. The antenna operates in broad frequency bands from 3.424 GHz to 6.274 GHz covering wireless local area network (WLAN) and worldwide interoperability for microwave access (WiMAX) bands. The maximum gain of the proposed antenna is 5.51 dBi at 4.78 GHz frequency band. The proposed antenna's radiation characteristics are also observed.

1. INTRODUCTION

Planar microstrip patch antennas are popular candidates for modern wireless communication systems due to their simple feeding, low profile, low manufacturing cost and easy-to-integrate features [1]. Moreover, fast growing field of wireless communications has spurred increasing

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possibility of using various service applications with different frequency bands in the same equipment and is demanding a small antenna for all application in single device. The size of the antenna has a great influence on the whole size of wireless systems and there is generally a tradeoff between the size and performance of antenna because the characteristics of the antenna are closely concerned with its size [2]. The rapid developments of wireless communication systems, especially the WLAN and WiMAX applications, which cover all the bands of 2.4/5.2/5.8 GHz and 2.5/3.5/5.5 GHz, have aroused much interest in the research of antennas with multiple bands or broadband [1–16]. Since these standards may be simultaneously used in many systems, there is a need for designing a single antenna that can cover all these bands [9]. Several papers has been published on various key design configurations for dual-band operation, including a monopole antenna fed with a meandered coplanar waveguide [4], CPW-fed tapered bent folded monopole antenna [5], printed monopole antenna with a trapezoid conductor-backed plane [6], CPW-fed monopole antenna with a cross-slot for WLAN operation [7], flared monopole antenna with a 'V' shape sleeve [8], CPW-fed Koch-fractal slot antenna [9], dual-band annular-ring slot antenna [11], compact disc slit monopole antenna [12] and a new non-uniform meandered and fork-type grounded antenna (NMFGA) for triple-band WLAN [15] etc..

A popular method of obtaining broad bandwidth to use parasitic patches, with either stacked geometry or coplanar geometry increases the thickness or area of the antenna respectively [10]. Recently, a simple structure of a single metallic layer monopole antenna with coplanar waveguide (CPW)-fed has become very popular in WLAN/WiMAX systems, owing to its many attractive features such as, wider bandwidth, light weight, low radiation loss, a simple structure of a single metallic layer and easy integration with WLAN/WiMAX integrated circuits [7].

In this paper, a single layer substrate antenna design with CPW-feed technology has been used to achieve dual-band operation for both WLAN and WiMAX bands. The proposed design is capable of providing enhanced bandwidth to cover WLAN operations at the 5.2 GHz and 5.8 GHz frequency bands and WiMAX operations at the 3.5 GHz and 5.5 GHz frequency bands. Slots are created in the radiating patch to control the current flow on the antenna surface. Slot dimensions are optimized to improve the various parameters like return loss, gain etc. across the targeted frequency bands. This paper also includes the comparisons between simulated and measured results. The proposed antenna's detailed dimensions are presented in the next section.

2. ANTENNA DESIGN

The geometry of the proposed dual-band antenna for WLAN/WiMAX applications with its parameter is depicted in Figure 1. The fabrication of the proposed antenna is done using a conventional FR4 substrate, often used to make printed circuit boards with thickness (h) of 1.6 mm and relative permittivity of 4.4, which makes it easy and inexpensive to manufacture. The 'FR4' is a fire electrical grade dielectric made with epoxy material reinforced with a woven fiberglass material. "FR4" means 'flame retardant' and type 4 indicates woven glass reinforced epoxy resin. Copper clad FR4 is available in a single side or double side sheets. The proposed antenna has a single layer metallic structure on one side of FR4 substrate layer whereas the other side is without any metallization. The FR4 substrate used in the proposed antenna has a uniform thickness of 0.02 mm. A CPW transmission line, consisting of a signal strip of width w_f and a gap distance of 'd' between the signal strip and the coplanar ground plane, is used for feeding the antenna. Two equal finite ground planes, each with dimensions of length L_g and width W_g, are placed symmetrically on each side of the CPW feed-line.

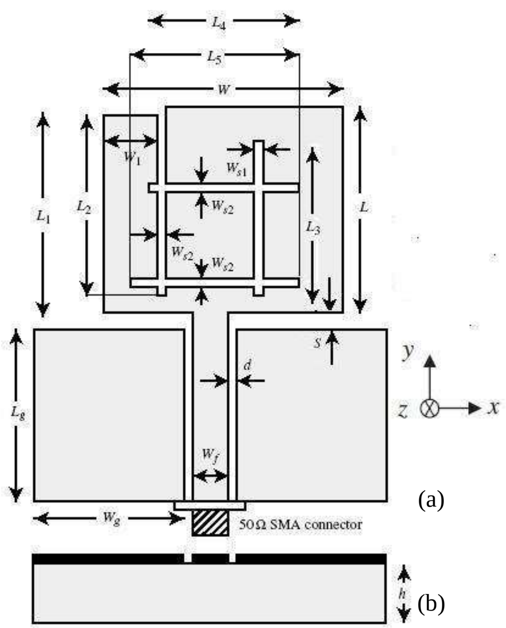

Figure 1. Geometry of the proposed antenna. (a) Top view, (b) front view.

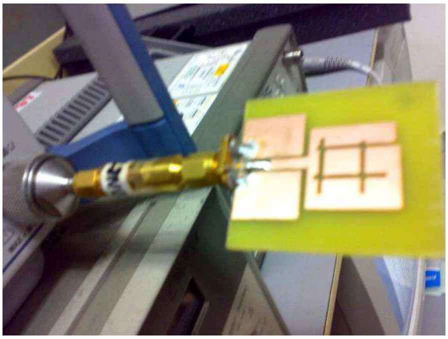

Figure 2. Fabricated antennas with proposed design.

The basis of the antenna structure is a rectangular patch monopole, which has dimensions of length L and width W, and connected at the end of the CPW feed line. The antenna performance is analyzed using method of moment based Zeland IE3D simulator.

The final optimized geometric parameters of the proposed antenna are: length of rectangular patch $L = 18.71$ mm, width of rectangular patch $W = 19.9$ mm, ground plane length $L_g = 15$ mm, ground plane width $W_g = 11.2$ mm, feed-line width $w_f = 2.6$ mm, slot length $L_2 = 17.57$ mm, slot length $L_3 = 14.63$ mm, slot length $L_4 = 12.75$ mm, slot length $L_5 = 14.2$ mm, slot width $w_{s1} = 1$ mm, slot width $w_{s2} = 1.2$ mm, arm width $W_1 = 4.92$ mm, arm length $L_1 = 18.22$ mm, spacing between ground plane and feed length $d = 0.7$ mm and spacing between rectangular patch and ground plane $s = 1.53$ mm. Total volume of the proposed antenna is $1.49\,\text{cm}^3$. Photograph of the fabricated prototype is shown in Figure 2.

3. SIMULATION RESULTS AND DISCUSSION

Simulated parametric study results and measured results for the proposed monopole antenna are also obtained. The simulated return loss is presented for the optimized set of antenna parameters in Figure 3. From simulated results, it is clear that antenna is resonant at two frequencies and two wideband operating bandwidths are obtained. The lower band (10 dB) impedance bandwidth is 19.44%, ranging from 3.4 GHz to 4.132 GHz, with respect to the central frequency of 3.77 GHz, and the bandwidth for the upper band is 1.716 GHz (4.312–6.028 GHz), or about 33.19%, referred to the central frequency at 5.17 GHz. The proposed antenna can operate over the bands which covers the required bandwidths of the IEEE 802.11 WLAN standards in the bands at 5.2 GHz (5150–5350 MHz) and 5.8 GHz (5725–5825 MHz) and WiMAX standards in the bands at 3.5 GHz (3.4–3.690 GHz) and 5.5 GHz (5.250–5.850 GHz). The antenna has a maximum gain of about 2.85 dBi with gain variations less than 0.6 dBi in lower frequency band, whereas in the higher frequency band, the antenna gain is within a range of 2.4–5.51 dBi as shown in Figure 4.

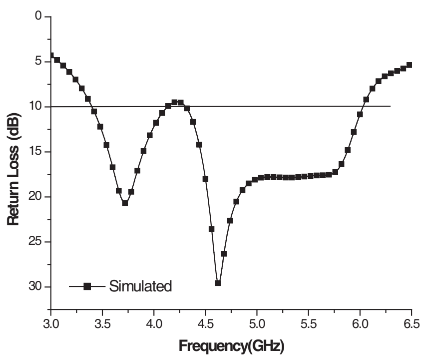

Figure 3. Simulated return-loss of proposed antenna.

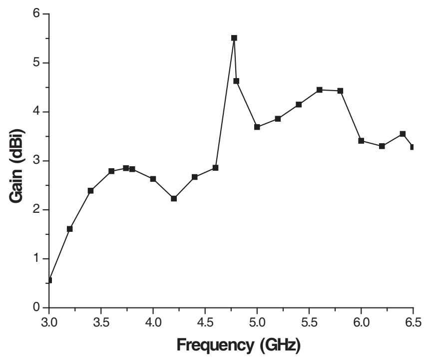

Figure 4. Simulated gain variation of the antenna against frequency.

A parametric study is investigated and it demonstrates that the following parameters influence on the performance of the proposed antenna in terms of bandwidth. Effect of variation of slot length L_3 along positive y-axis (upper-side of the patch) on proposed antenna return loss with respect to frequency is represented in Figure 5. The optimal performance is obtained for $L_3 = 14.63$ mm. It is observed from the figure that with decrease in the slot length (L_3) from the optimal value, the bandwidth of the lower frequency band increases significantly and that of upper frequency band decreases slightly and with increase in the slot length (L_3) from 14.63 mm to 16.23 mm, the bandwidth of lower-band decreases approximately by 60% whereas that of the upper frequency band increases by 20–25% from optimized value of bandwidth.

Figure 6 shows the simulated return loss of the proposed antenna as a function of frequency for different values of slot length L_4 along the positive x-axis (right-side of the patch). The optimal performance is obtained for $L_4 = 12.75$ mm. It is observed from the simulation results study that by decreasing the slot length (L_4) from optimal value, the two bands merge into a single wide-band and also there is slight increase in the bandwidth. It is also observed from simulation result that by increasing the slot length (L_4) from the optimal value, the lower-band shifts towards the lower frequency side with a loss in

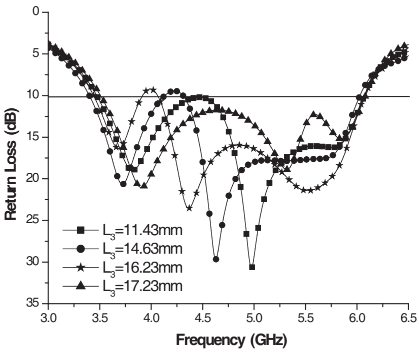

Figure 5. Effect of variaition of slot length L_3 on return loss.

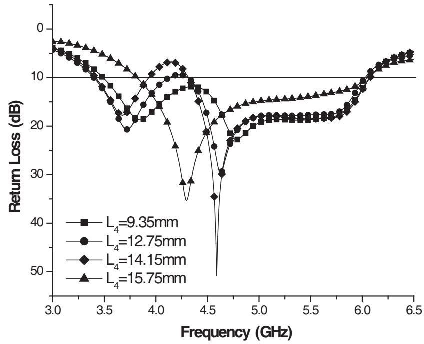

Figure 6. Effect of variaition of slot length L_4 on return loss.

the bandwidth approximately by 50% from the optimized value and increase in bandwidth in upper frequency band by 25–30%.

Effect of variation of slot length L_5 along positive x-axis (right-side of the patch) on the proposed antenna performance is shown in Figure 7. The optimal performance is obtained for $L_5 = 14.2\,\text{mm}$. It has been observed from the results that by decreasing the slot length (L_5) from the optimal value, the upper-band shift towards the higher frequency with a small loss in the bandwidth. By increasing the slot length L_5 from the optimal value, the two wide-bands merge into a single-band and there is shift in frequency towards the lower frequency with huge loss in the bandwidth. The lower frequency band remains unaffected by increase in slot length (L_5) up to 15.6 mm and increasing the slot length (L_5) beyond 15.6 mm results in huge loss in lower frequency band.

The patch current distributions are simulated using Zeland IE3D simulator. The current distributions at two resonant frequencies 3.74 GHz and 5.42 GHz are shown in Figures 8 and 9 respectively. Arrows indicate the direction of current flow. It can be clearly seen that the strong electric current flows near the edge of slot L_5, feed line and top edges of L_3 and L_4 at 3.74 GHz. This indicates that the embedded slot effectively provides the electrical current path for producing the lower mode. However, for higher mode at 5.42 GHz the surface currents mainly flow along the edges of arm L_1, feed-line and over the edges of the slots L_3, L_4 and L_5. This indicates that the arm L_1, slots L_3, L_4 and L_5 effectively provide the electrical current path for producing the higher modes. It is thus clearly seen that at different bands the current has different distributions along the antenna i.e., the current focuses along L_5 and feed-line at lower band and along L_5, L_3, L_4 and L_1 at higher band.

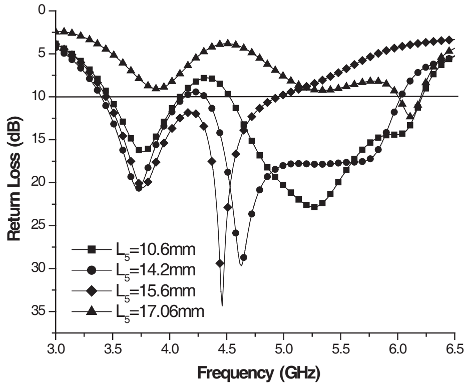

Figure 7. Effect of variaition of slot length L_5 on return loss.

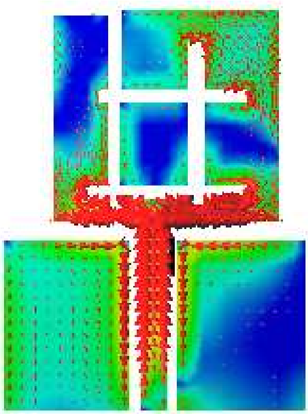

Figure 8. Current distributions at 3.74 GHz.

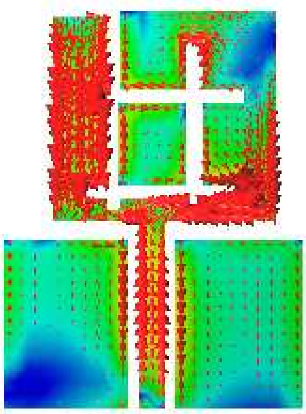

Figure 9. Current distributions at 5.42 GHz.

The simulated radiation patterns of the proposed CPW-fed extended rectangular-shape slot monopole antenna are presented in Figure 10 for different frequencies at 3.6 GHz and 5.5 GHz. The simulated radiation patterns of the proposed antenna in the azimuthal plane (x-y) and the elevation plane (y-z) are shown in Figure 10(a) and Figure 10(b) respectively for lower frequency of 3.6 GHz and higher frequency of 5.5 GHz. The radiation pattern obtained in the x-y plane is slightly close to omni-directional but at frequency 5.5 GHz, there is little bit directional radiation pattern is obtained as compared to omni-directional, and that in the elevation plane is similar to monopole kind

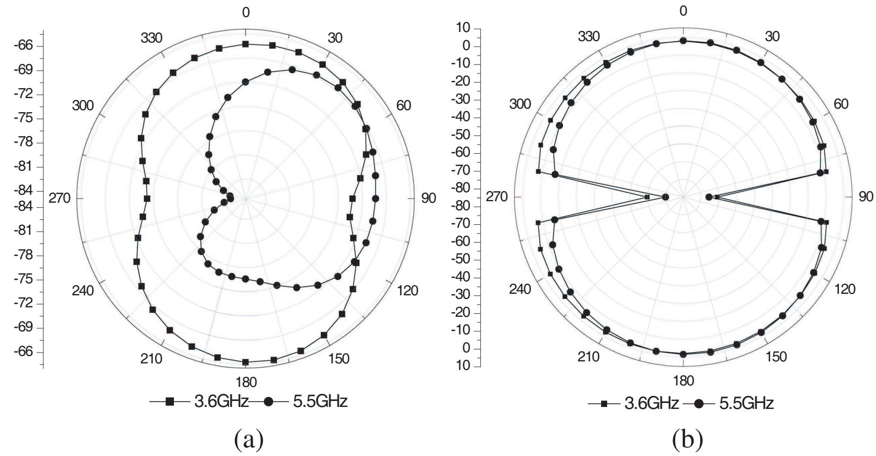

Figure 10. Radiation pattern plot of proposed antenna. (a) Azimuthal plane, (b) elevation plane.

of antenna at both the bands. Radiation performance of the antenna is acceptable at all the frequency bands. Simulation studies indicate that the maximum antenna radiation efficiency is approximately 90%. Measured radiation pattern of proposed design is to be carried out in future work and is not included in the manuscript.

3.1. Measured Results

A Prototype of proposed antenna with optimal dimension is fabricated on a substrate and its return loss parameter is measured. Simple screen printing and chemical etching process is used for printing the antenna pattern creation on the substrate. The measurement is carried out using Agilent N2283 vector network analyzer. In the measurement, the insertion loss and electrical length of the measurement probe from the PCB edge mount SMA connector to the network analyzer has been calibrated in advance. The measured and simulated return losses for the proposed antenna with an extended rectangular-shape slot are shown in Figure 11. The measured and simulated results show the satisfactory agreement over the entire operating band and a similar curve trend between the measured and simulated results is seen over the whole operating band. From the measured results, it is clear that single broadband results are obtained with total bandwidth of prototype antenna is 2.85 GHz (3.424–6.274 GHz) and it can cover the 5.15–5.35 GHz, and 5.725–5.825 GHz WLAN bands, and 3.4–3.69 GHz, and 5.25–5.85 GHz WiMAX bands of heterogeneous wireless

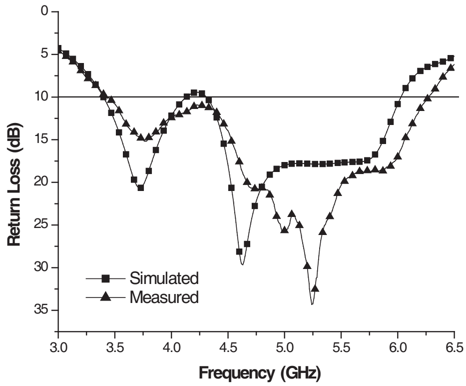

Figure 11. Simulated and measured return-losses of proposed antenna.

communication system. There is a very slight shift of peak resonant frequency towards higher frequency in the upper band when compared with simulated results and this discrepancy may be due to the slight dimensional error in the fabrication process and because of the effect of the cable connector in addition to errors in processing. The connector loading is not accounted for in the simulation but when used in the experiment provide loading with a variable reactance.

4. CONCLUSION

An optimal CPW fed monopole antenna with an extended rectangular-shape slot is proposed, simulated, fabricated and tested for WLAN/WiMAX operation. The simulated result shows a broad impedance bandwidth of 19.44%, ranging from 3.4 GHz to 4.132 GHz, with respect to the central frequency at 3.77 GHz for lower band, and a bandwidth of 1.716 GHz (4.312–6.028 GHz), or about 33.19%, referred to the central frequency at 5.17 GHz at upper band. The final measured result shows satisfactory agreement with the simulated results. The stable radiation patterns and good antenna gain over the operating bands has been obtained. Besides its wideband characteristics, the proposed antenna remains compact with volumetric size of 1.49 cm^3 which make it a good candidate for heterogeneous wireless communication systems.

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