Enhanced Bandwidth Small Square Slot Antenna with Circular Polarization Characteristics for WLAN/WiMAX and C-Band Applications

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Abstract **─** This article proposes a novel printed slot antenna with circular polarization characteristics using an L-shaped slot in the ground plane and an L-shaped radiating stub with a pair of Γ-shaped slits for simultaneously satisfying wireless local area network (WLAN), worldwide interoperability for microwave access (WiMAX), and C-Band applications. The operating frequencies of the proposed antenna are 5.2/5.8 GHz, which covers WLAN system, 5.5 GHz for WiMAX system, and 4 GHz for C-Band system. The desired resonant frequencies are obtained by adjusting the length of Γ-shaped slits in the both sides of tapered microstrip feed-line. The measured results show good agreement with the numerical prediction. The designed antenna has a small size of 20 × 20 mm^2.

Index Terms **─** Circular polarization performance, Γ-shaped slit, and printed square slot antenna.

I. INTRODUCTION

Circular polarization is one of the common polarization schemes used in current wireless communication systems, such as radar and satellite systems. This is due to the fact that it can provide better mobility and weather penetration than linear polarization microstrip patch antenna [1], spiral antenna [2], dielectric resonator antenna [3], and slot antenna [4], which are some of the typical types of circularly polarized (CP) antennas. The operation principle of these CP antennas is to excite two orthogonal field components with equal amplitudes.

In this paper, a new printed square slot antenna with single-feed circular polarization characteristics, for WLAN/WiMAX and C-Band applications is presented. First by inserting an L-shaped slot on the ground plane, additional resonances are excited and the bandwidth is improved that achieves a fractional bandwidth with dual resonance performance of more than 45%. In the proposed structure, wide band circular polarization function is provided by cutting an L-shaped slot on the ground plane and a pair of Γ-shaped slits in the corners of the L-shaped radiating stub. The size of the designed antenna is smaller than the slot antennas with circular polarization function reported recently [1-4].

II. ANTENNA DESIGN

The proposed square slot antenna fed by a microstrip line is shown in Fig. 1, which is printed on an FR4 substrate of thickness 0.8 mm, and permittivity 4.4. By cutting a novel slot of suitable dimensions at the ground plane, circular polarization can be constructed. The truncated ground plane and L-shaped radiating stub with two Γ-shaped slits are playing an important role in the circular polarization characteristics of this antenna. This is because they can adjust the electromagnetic coupling effects between the feed-

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line and the ground plane, and improves its impedance bandwidth without any cost of size or expense [4]. Based on electromagnetic coupling, the modified L-shaped radiating stub with a pair of Γ-shaped slits act as an impedance matching element to control the impedance bandwidth of the proposed antenna. Because it can creates additional surface current paths in the antenna and thus additional resonances are excited and much wider impedance bandwidth can be produced [5].

In this work, we start by choosing the aperture length L_s+L_{s1}. We have a lot of flexibility in choosing this parameter. The length of the aperture mostly affects the antenna bandwidth. As L_s+L_{s1} decreases, so does the antenna BW and vice versa. At the next step, we have to determine the aperture width W_s+W_{s1}. The aperture width is approximately $\lambda_s/2$, where λ_s is the slot wavelength. The wavelength λ_s depends on a number of parameters such as the slot width as well as the thickness and dielectric constant of the substrate on which the slot is fabricated. The last and final step in the design is to choose the length of the Γ-shaped slits resonators. A good starting point is to choose it to be equal to $\lambda_m/4$, where λ_m is the guided wavelength in the microstrip line. In this design, the optimized length $L_{resonance}$ is set to resonate at $0.25\lambda_{resonance}$, where $L_{resonance1} = W_{L1} + W_{L2} + L_L$ and $L_{resonance2} = W_{L3} + W_{L4} + L_{L1} + L_f$. $\lambda_{resonance1}$ and $\lambda_{resonance2}$ correspond to the first resonance frequency (4 GHz) and the second resonance frequency (5.3 GHz), respectively. The final values of presented slot antenna design parameters are specified in Table 1.

Table 1: The final dimensions of the designed antenna.

Param.	mm	Param.	mm	Param.	mm
W_S	8	L_S	6	W_{S1}	8
L_{S1}	7	W_f	0.5	W_{f1}	2
W_L	4	L_L	8	W_{L1}	3
L_{L1}	2	W_{L2}	4	W_{L3}	2
W_{L4}	2	L_g	2	W_g	3

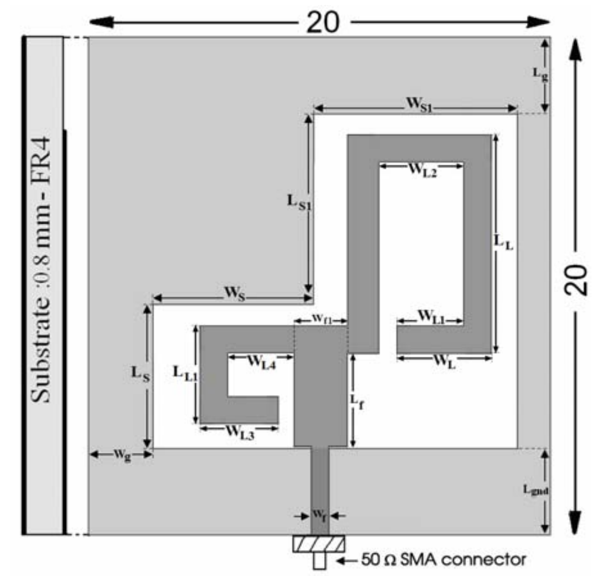
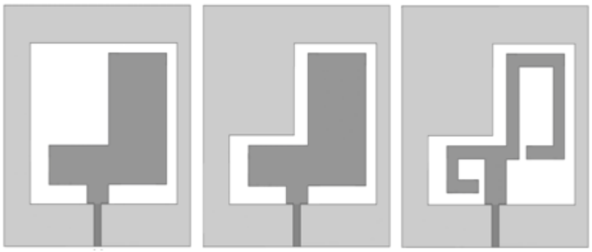


Fig. 1. Geometry of the proposed microstrip-fed slot antenna.

III. RESULTS AND DISCUSSIONS

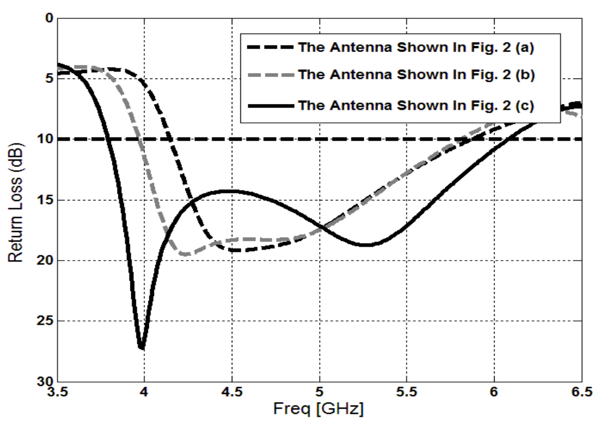
In this Section, the slot antenna with various design parameters were constructed, and the numerical and experimental results of the input impedance and axial ratio characteristics are presented and discussed. The parameters of this proposed antenna are studied by changing one parameter at a time and fixing the others. The simulated results are obtained using the Ansoft simulation software high-frequency structure simulator (HFSS) [6].

Figure 2 shows the structure of the various antennas used for wide-band impedance and circular polarization performance simulation studies. Return loss and axial ratio characteristics for ordinary square slot antenna with an L-shaped radiating stub and ground plane with a rectangular slot (Fig. 2 (a)), a ground plane with an L-shaped slot (Fig. 2 (b)), and L-shaped radiating stub with a pair of Γ-shaped slits and ground plane with an L-shaped slot (Fig. 2 (c)) are all compared in Fig. 3. As shown in Fig. 3 (a) and (b), in order to generate dual resonance characteristics (4/5.3 GHz), and to improve the circular polarization bandwidth, we use two L-shaped slits in the corners of the radiating stub. Also, by cutting an L-shaped slot in the ground plane a wide band circular polarization function is achieved that cover all the 5.2/5.8 GHz WLAN, 5.5 GHz WiMAX and 4-GHz C band.

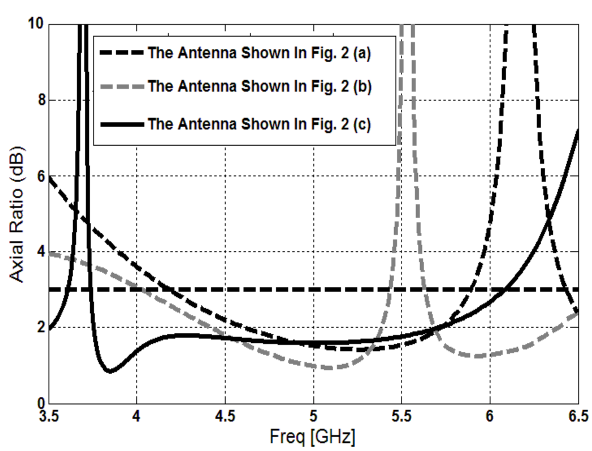


(a) (b) (c)

Fig. 2. The ordinary square slot antenna with an L-shaped radiating stub (a) and ground plane with a rectangular slot, (b) and ground plane with an L-shaped slot, (c) with a pair of Γ-shaped slits and ground plane with an L-shaped slot.



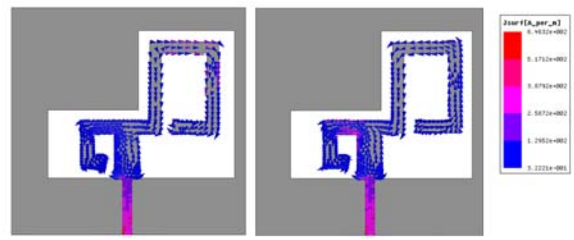
(a)



(b)

Fig. 3. Simulated (a) return loss characteristics and (b) axial ratio for the antennas shown in Fig. 2.

To understand the phenomenon behind this dual resonances performance, the simulated current distribution on the radiating stub for the proposed antenna at the new resonance frequencies of 4 GHz and 5.3 GHz are proposed at Fig. 4 (a) and (b), respectively. It can be observed from Fig. 4 (a) and (b) that the current is concentrated at these frequencies on the edges of the interior and exterior of the modified Γ-shaped folded microstrip arms. Therefore, the antenna impedance changes at these frequencies due to the resonance properties of the proposed structure.



(a) (b)

Fig. 4. Simulated surface current distributions for the proposed antenna shown in Fig. 1 at, (a) 4 GHz (first resonance frequency) and (b) 5.3 GHz (second resonance frequency).

In order to investigate the effects of Γ-shaped slits size on the proposed antenna, the simulated return curves with different values of Γ-shaped slits lengths are plotted in Fig. 5. As shown in Fig. 5, when W_L increases from 2 mm to 4.8 mm, the first resonance frequency is varied from 4.3 GHz to 3.8 GHz. From these results, we can conclude that the first resonance frequency is controllable by changing the W_L. Also, as the W_{L3} increases from 1.3 mm to 2.8 mm, the second resonance frequency is varied from 5.1 GHz to 5.5 GHz. Therefore, the second resonance frequency is controllable by changing the W_{L3}.

In this study, to achieve the circular polarization characteristics, we use two Γ-shaped folded microstrip arms in the radiating stub and an L-shaped slot on the ground plane, as displayed in Fig. 1. By changing the dimension of these open stub structures, we can achieve the RHCP and RLCP characteristics. The simulated RHCP and RLCP curves at 4 GHz and 5.3 GHz are presented in Fig. 6 (a) and (b), respectively. These figures confirm that the proposed antenna is capable of supporting both RHCP and RLCP modes at these frequencies. The proposed slot antenna with final design, as shown in Fig. 7, was built and tested.

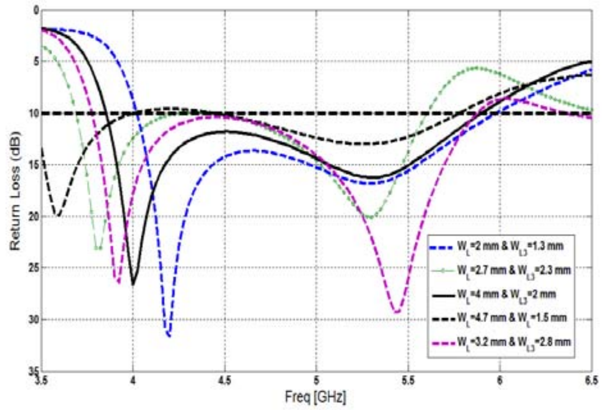
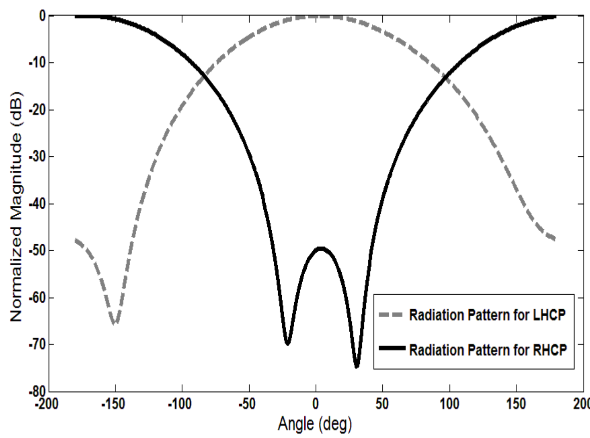
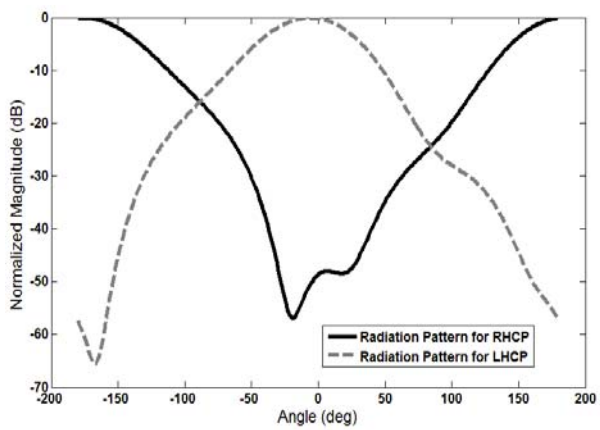


Fig. 5. Simulated return loss characteristics of the proposed antenna with different values of W_L and W_{L3}.



(a)



(b)

Fig. 6. Simulated circularly-polarized radiation patterns at (a) 4 GHz (first resonance frequency) and (b) 5.3 GHz (second resonance frequency).

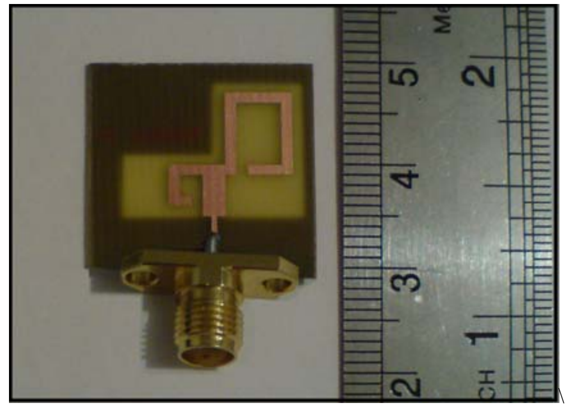
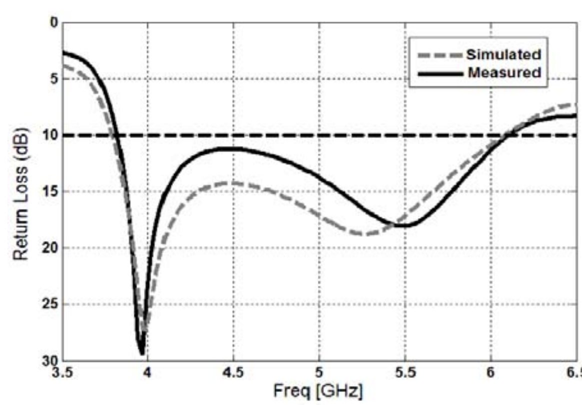


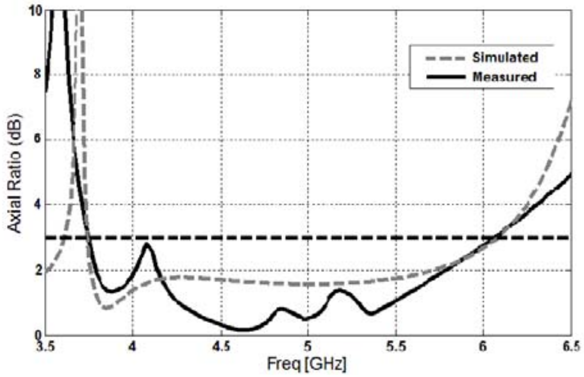
Fig. 7. Photograph of the realized printed slot antenna.

Figure 8 (a) and (b) shows the measured and simulated return loss and axial ratio characteristics of the proposed antenna, respectively. As shown in Fig. 8 (a) and (b), the fabricated antenna has the frequency band of 3.73 GHz to over 6.07 GHz with circular polarization characteristics 3.72 GHz - 6.05 GHz. As shown in Fig. 8, there exists a discrepancy between the measured data and the simulated results. This could be due to the effect of the SMA port. In order to confirm the accurate return loss and axial ratio characteristics for the designed antenna, it is recommended that the manufacturing and measurement process need to be performed carefully.

Figure 9 shows measured maximum gain of the designed antenna in dBi, in the Z-axis direction. A two-antenna technique is used to measure the radiation gain. As shown in Fig. 9, the measured maximum gain has a variation similar to other slot antennas gain at WLAN/ WiMAX and C-band frequencies [7].



(a)



(b)

Fig. 8. Measured and simulated (a) return loss characteristics and (b) axial ratio characteristics for the proposed antenna.

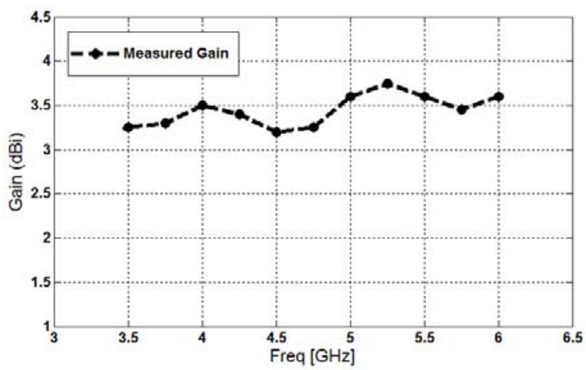


Fig. 9. Measured maximum gain of the proposed antenna.

IV. CONCLUSION

In this paper, a novel square slot antenna with circular polarization characteristics for WLAN/WiMAX and C-band applications is presented. The proposed antenna can operate from 3.73 GHz to 6.07 GHz with circular polarization characteristics around 3.72 GHz - 6.05 GHz. The designed antenna has a small size. Simulated and experimental results show that the proposed antenna could be a good candidate for WLAN/WiMAX and C-band applications.

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