

Wideband Circularly Polarized Printed Ring Slot Antenna for 5 GHz – 6 GHz

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Abstract. This paper presents the design of circularly polarized printed slot antenna operating at 5 – 6 GHz. The proposed antenna consists of L-shaped feedline on the top of structure and circular ring slot positioned at the ground plane underneath the substrate as a radiator. A radial and narrow slot in the ground plane provides coupling between the L-shaped feedline and circular ring slot. The circular polarization is realized by implementing the slits perturbation located diagonally to perturb the current flow on the slot structure. The antenna prototype is fabricated on FR4 substrate. The simulated and measured results are compared and analyzed to demonstrate the performance of the antenna. Good measured of simulated results are obtained at the targeted operating frequency. The simulated -10dB reflection coefficient bandwidths and axial ratio are 750 MHz and 165 MHz, respectively. The investigation on the affect of the important parameters towards the reflection coefficient and axial are also presented. The proposed antenna is highly potential to be used for wireless local area network (WLAN) and wireless power transfer (WPT).

1. Introduction

Wireless communication undergoes rapid changed in recent years. More peoples are using modern communication services, thus increases the demand on the used of the antenna that can covers a lot of communication services [1]. The utilization of the linear polarization (LP) is only capable to detect signals in one direction and will facing polarization mismatch loss - loss in signal strength when the signal is curving from different angles. Therefore, the used of circular polarization (CP) instead of the LP has overcome this problem by constantly receive a component of the signal due to the angular variation regardless of receiver orientation [2], thus making the CP antennas capable to send and receive signals in all angles.



The CP has the capability to enhance the system gain, cross polar discrimination and dealing with the multipath fading environment, consequently can enhance the system performances [3]. The polarization of the signal might change to orthogonal type of polarization when reflected with metallic objects, hence effect the polarization to be reverses and conversely will produced mostly orthogonal in polarized [4]. In addition, the CP is also preferable on penetrating the bend around the obstruction and have better resistance to the degradation of signals in bad weather conditions. Hence, CP is effective to be deployed for maintaining and establishing in communication systems, especially for unwanted and unpredicted propagation scenario. The ability of CP to reduce the mismatch polarization loss has made CP more attractive for some applications such as radia frequency identification, navigation and radar [5].

The CP antenna can be developed by different methods as reported in the literature. The CP antenna is successfully realized by arranging the LP antenna with controlling the feeding network [6] and the used of assymetric bowtie dipoles [7]. However, this approach taken will increased the complexity and the size of the structure. The conventional technique to produce a CP is by creating a perturbation segment on the radiator. Work done in [8-10] implemented perturbation segment on the rectangular patch either chamfering corner, L-slits or orthogonal assymmetric slots. Still, the perturbation technique on the patch has a drawback in term of narrow S_{11} and axial ratio (AR) bandwidth. Due to this drawback, slot antenna is gaining popular to fulfill the aim of wideband operation. Paper presented in [11, 12] shows the used of slot antenna to obtain wideband AR of more than 1 GHz. Therefore, the slot antenna is chosen due to its wideband characteristics and less sensitive to manufacturing tolerances than the conventional microstrip antennas.

In this paper, a circularly polarized circular ring slot antenna is proposed, which is capable to produce left-hand CP (LHCP) with wideband impedance and AR bandwidth. CP characteristics is achieved by implementing slits perturbation method located specifically on the circular ring slot antenna. Simulated and measured results indicate that the proposed antenna has successfully achieved the CP capability at 5-6 GHz frequency band with a maximum gain of 5 dBi.

2. Antennas Structure and Mechanism

The optimized structure of proposed CP slot antenna is indicated in Figure 1. It is composed of two parts : a feeding line with energy coupling and a circular ring slot as a radiator. The printed slot antenna is fabricated on a FR4 substrate with relative permittivity of 4.7 and a thickness of 1.6 mm. The dimension of the structure is $L_s \times W_s$. The front side of the antenna consists of L-shaped feedline with width of W_f and length of $L_{f1} + L_{f2}$.

The circular ring slot with a inner radius of a and outer radius of r_1 is etched on the opposite side of the substrate. Radial slot with diameter of r_2 and narrow slot with length of 5 mm are located at the y -axis below the ring slot. These slots are attached to the edge of the ring slot, and is positioned to be underneath and across by the feedline on the top. This is to ensure the good energy coupled between feedline and the ring slot. Two slits (length of L_{slit} and width of W_{slit}) are inserted diagonally -45° , connecting towards the inner radius. The slits and inner radius are separated with a gap of 0.3 mm. To obtain CP, the slits and the narrow feeding slot have to be 45° or 135° apart. The photograph of the fabricated CP slot antenna is shown in Figure 2.

The approach and mechanism of the proposed antenna is as follows. To achieve circular polarization, the antennas have to be excited by two orthogonal modes of the same magnitude and in phase quadrature. The existing of the slit will perturbed the flow of the current at the edge of the ring slot. This will lengthened the path of the current and drive it to travel along the slit. At the specific slit length, the proposed antenna fulfill the conditions to excite CP. Therefore, the length and width of the slits mostly determines the the response of AR and have to be optimized to ensure the AR value drop below than 3dB (CP is produced).

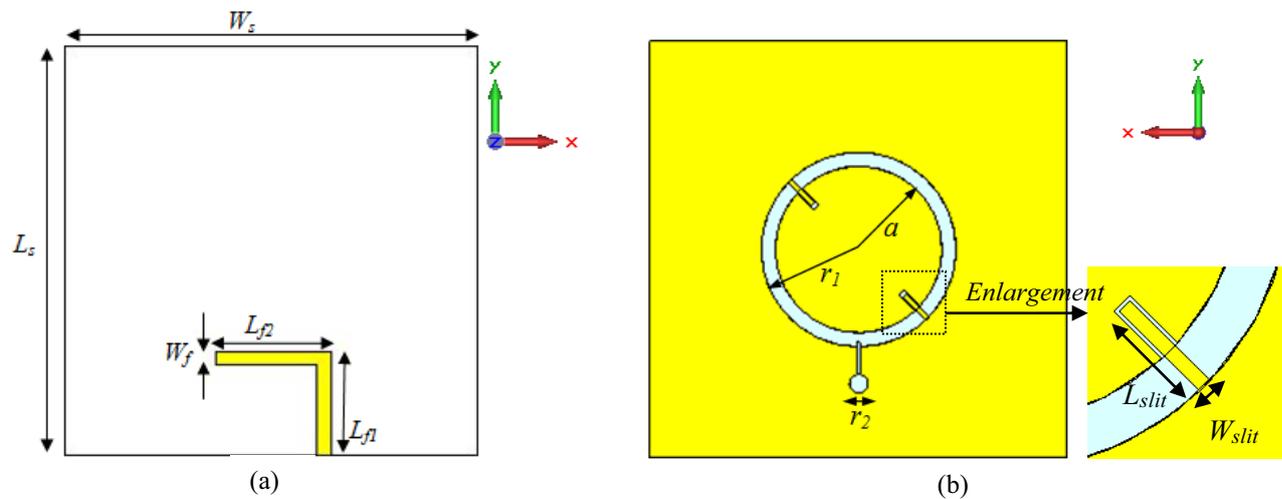


Figure 1. Geometry of the proposed antenna. (a) front view and (b) back view. (Dimensions in mm: $W_s=90$, $L_s=90$, $L_{f2}=25$, $W_f=3$, $L_{f1}=22$, $L_{slit}=7$, $a=17$, $r_1=20$, $r_2=2$, $L_{slit}=8$, $W_{slit}=1$)

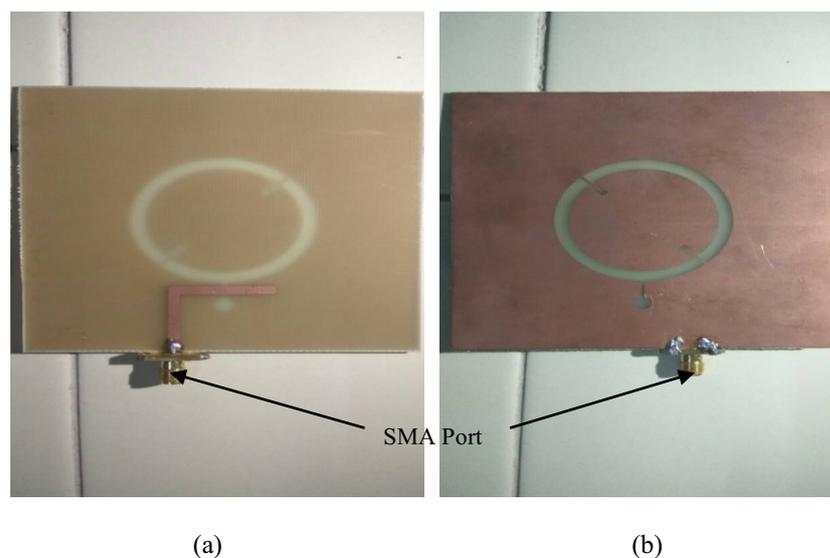


Figure 2. Fabricated CP printed slot antenna. (a) front structure and (b) back structure.

3. Parametric Studies

Figure 3 depicts the step of designing the proposed antenna. At first, the feedline and the circular ring slot is created, followed with radial slot at second stage. Here, the dimension of the feedline, radial slot and narrow slit is optimized to achieve good impedance matching when the energy is coupled to the circular ring slot. This have to be matched well with the width of the ring slot. At this condition, the antenna is excited with linear polarization. To achieve CP, the slit is introduced at the diagonal position (third step). Then, to obtain desired and optimized design, the parametric studies of the important parameters are conducted and investigated. This studies helped to identify the effect of the important parameters and provide useful informations to obtain optimized design. Thus, the affect towards S_{11} reflection coefficient and AR are presented.

Investigation began with the study on the effect of the radial slot. Fig. 4(a) shows the effect of size of the radial, r_2 to the S_{11} result when it is varies from 1mm to 5mm. Another important parameter that affect the impedance matching is the width of the feedline, W_f , as shown in Fig. 4(b). The

parameter W_f is varied from 2 mm to 6 mm. From the graph, it can be seen that good matching ($S_{11} < -10$ dB) is achieved when W_f is less than 3 mm. The S_{11} value is shift above the threshold -10dB when the width is greater than 3 mm. This proves that the dimension of the feedline and the radius of the radial slot affect on the coupling of the energy, thus give significant influence to the impedance matching of the proposed antenna.

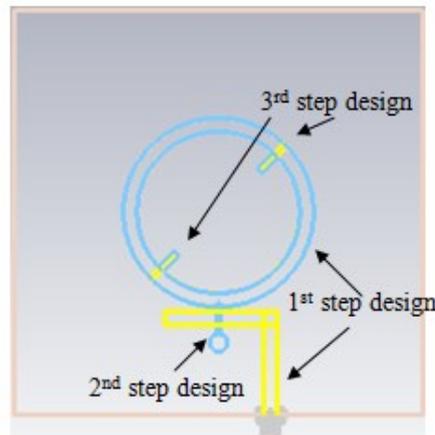


Figure 3. The step of designing CP printed slot antenna.

The investigation also has been carried out on the length of the slit, L_{slit} to the S_{11} and AR result, as shown in Figure 5(a) and Figure 5(b), respectively. For this analysis, the slit length is lengthened from 2 mm to 6 mm. From these figures, it proves that slit length is greatly affecting the CP characteristic and slightly influence the S_{11} response. When this length is further extended until 6 mm, the AR values is begun to fall. Therefore, based on this analysis, the value of AR is dropped below than threshold 3 dB when the slit length is between 3 mm to 4.2 mm. When the length is more than 4.2 mm, the AR value starts to increase, indicate CP is no longer excited.

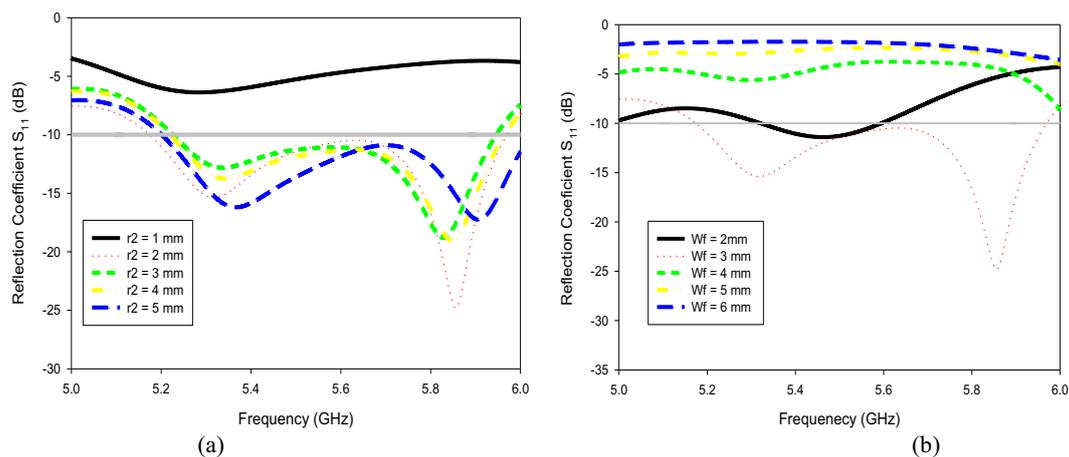


Figure 4. Effect towards S_{11} result for (a) small circular slot, r_2 and (b) width of the feedline,

W_f

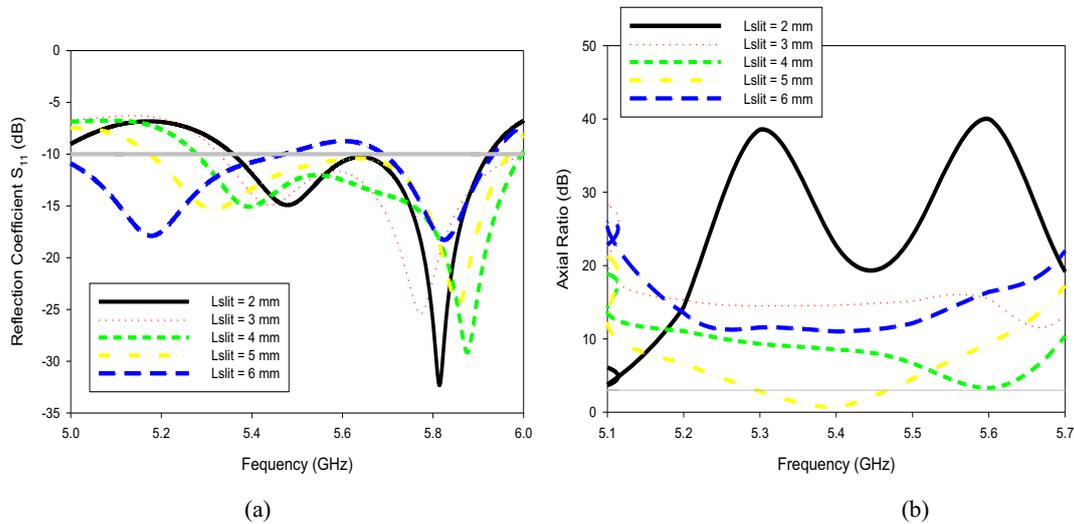


Figure 5. Effect of the slit length, L_{slit} to the (a) S_{11} and (b) axial ratio results

4. Result and discussion

Simulated and measured input reflection coefficient for CP printed slot antenna is shown in Figure 6. As shown in the figure, good agreement has been achieved between the simulated and measured. The measured impedance bandwidth of reflection coefficient, as referred to -10 dB is 514.9 MHz (5.5643 - 6.072 GHz). Slight discrepancies were occurred, which might be due to the fabrication tolerance. The etching process was done manually, which could make the slits slightly bigger or smaller than the actual size, thus affecting the antenna effective surface and resonance frequency.

Figure 7 plot the simulated AR curves over frequency. The simulated 3-dB AR bandwidth, BW_{AR} is 164.9 MHz (5.2952 – 5.4601 GHz). It can be noticed that the bandwidth of the AR lies within the targeted frequency band. Meanwhile, the simulated electric field at frequency 5.4 GHz is illustrated in Figure 8 and shown the proposed antenna produce LHCP when the slits are inserted at the -45° diagonal. Another type of orthogonal CP can be achieved if the position of the slits are changed to 45° diagonal (mirror at y-axis). By doing this, right hand CP can be produced.

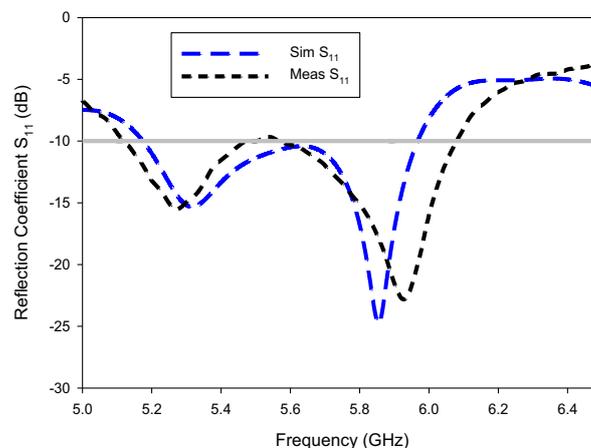


Figure 6. Comparison of simulated and measured reflection coefficient result.

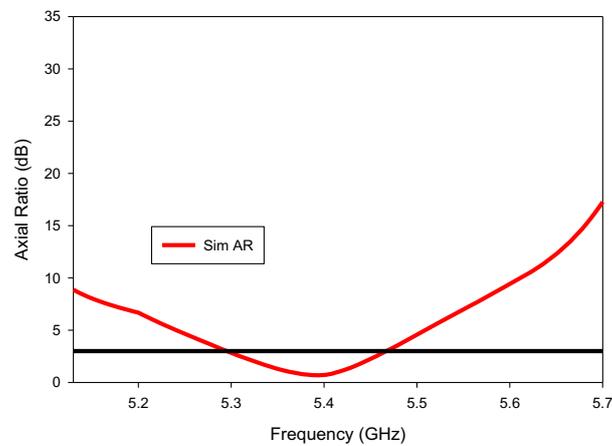


Figure 7. Simulated AR (dB) of the proposed antenna.

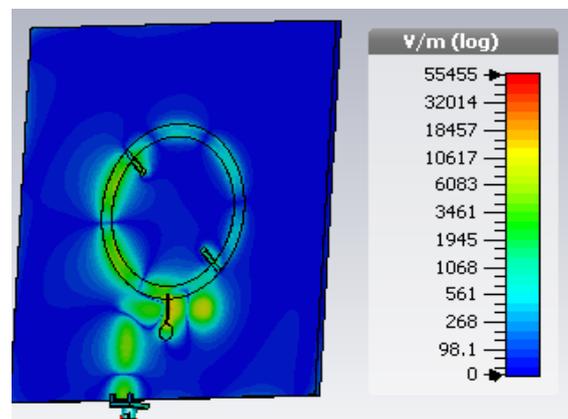


Figure 8. Simulated E-field for LHCP at 5.4 GHz.

5. Conclusion

A CP ring circular slot antenna having a wideband impedance and AR bandwidth has been presented. A circular ring slot antenna is used as a radiator. In this work, CP characteristic is developed using a simple method, which is by using slits perturbation. From the parametric studies conducted, the position and the length of the slits mainly influence the response of the AR. The simulated and measured results of the reflection coefficient and AR are presented. The results illustrate the proposed antenna is successfully achieved according to the desired specification. Compact in dimension, the proposed antenna is designed to be operated in the 5-6 GHz and potential suitable to be used in wireless power sensors application.

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