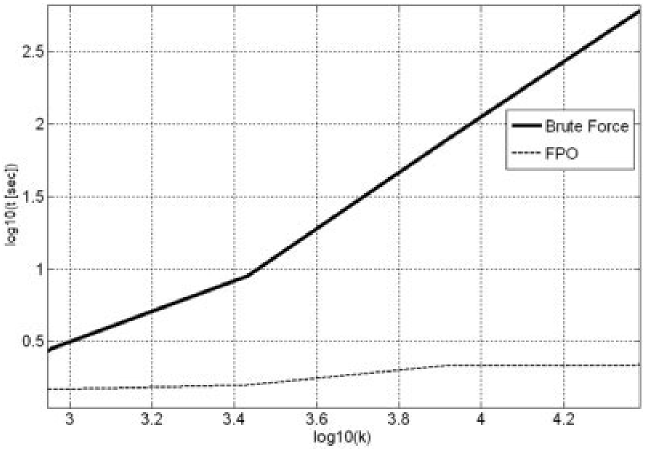

Figure 8 Computation time of the whole radiation pattern. Brute force versus FPO

O(k) for each integral and a number of incident angles φ O(k) gives O(k^2). With the FPO proposed, the computation time for all incident angles is nearly O(1).

5. Conclusions

A method for the efficient calculation of the whole radar cross-section pattern of infinite cylindrical shells with arbitrary cross section is presented. It has been shown that the computation time is independent of frequency. Accuracy is also good for all frequencies and incident angles.

ACKNOWLEDGMENTS

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APPENDIX

The UGO used to compare the method presented in this article is as follows:

$$\int_{x_1}^{x_2} f(x)\exp(jkg(x))dx = \frac{f(x_1)}{jkg'(x_1)} - \frac{f(x_2)}{jkg'(x_2)} + \sqrt{\frac{2\pi}{kg''(x_0)}} f(x_0)\exp(ikg(x_0)), \quad \text{(A1)}$$

where the first two terms give the contribution of the endpoints, the third term gives the contribution of the reflection point.

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A CIRCULAR CPW-FED SLOT ANTENNA RESONATED BY THE CIRCULAR LOOP FOR BROADBAND CIRCULARLY POLARIZED RADIATION

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ABSTRACT: *The coplanar waveguide (CPW) fed circular slot antenna, resonated by the circular loop with a narrow opening, is designed for obtaining broadband circularly polarized (CP) radiation. The length of protruded signal strip (L_S) is utilized to adjust the phase difference between two orthogonal field components in the circularly polarized waves. In this design, the proposed antenna has the minimum return loss of −56.5 dB at the frequency of 2.403 GHz. The impedance and 3 dB axial-ratio bandwidths can reach up to 740 MHz or 33.3% and 390 MHz or 16.6%, respectively. In addition, the simulated results are about as good as those of the measured ones.* © 2008 Wiley Periodicals, Inc. Microwave Opt Technol Lett 50: 1423–1426, 2008; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.23359

Key words: *circular polarization; CPW-fed; circular loop*

1. INTRODUCTION

The microstrip-fed antennas suffer from the need for careful alignment of the etchings on the two sides of the PC board. Also, the use of a microstrip line is not compatible with the monolithic microwave integrated circuits (MMIC) fabrication and, therefore, an easier integration with device is not possible [1, 2]. Furthermore, when the same substrate is used, the slot antennas usually have a much wider circular polarization (CP) bandwidth than the conventional single-fed CP microstrip antenna the CP bandwidth of which is usually less than 2% [1]. Coplanar waveguide (CPW) fed printed slot antennas have not only relatively much wider impedance bandwidth than the design with a microstrip line fed, but also easily integrated with integrated circuits by using a single metallic layer [3]. The designs of the CPW-fed slot antennas have recently motivated the present study.

This article presents a simple design of a CPW-fed circular slot antenna with broadband CP radiation. To generate a CP wave, the circular loop is slit into two arms. The CP wave is radiated when two standing-wave current distributions are of equal amplitude and quarter-wave length difference [4, 5]. The length of the two arms is used to adjust two standing-wave current. A protruded strip connects the CPW feed line and the circular loop to resonate a frequency of 2.45 GHz. Furthermore, by adjusting the length of the protruded strip and the circumference of the circular loop, a good impedance matching and excellent characteristics of axial ratio (AR) can be achieved.

Both the return loss and the radiation patterns are given in this article.

2. ANTENNA STRUCTURE

The antenna geometry is shown in Figure 1. This antenna is realized on an inexpensive FR4 dielectric substrate with a thickness of 1.6 mm (h) and a relative permittivity of 4.4 (ε_r). In these suggested antennas, a 50-Ω coplanar waveguide with a protruded signal strip (length = L_S) is used to feed the antenna. The width of signal feed line (W_f) is 6.37 mm with a gap g_1 = 0.5 mm, which is between the signal feed line and the ground plane. From the empirical experiences, the circumference of the circular loop is about 1.125 λ_{eff} (λ_{eff} is the wavelength of the operational frequency in FR4 substrate). To radiate an axial ratio (AR) wave, a small gap g_2 = 1.4 mm is inserted into the circular loop (radius is R_{in}) and two arms are thus formed. Moreover, the long arm of the circular loop is about 1 λ_{eff} and the short one is about 0.125 λ_{eff}. Both widths of the protruded strip and the circular loop are fixed to be 1 mm. Furthermore, the radius of R_{out} is fixed to 19 mm, and the width of circular ground (W_1) is chosen to be 9 mm. Although the ground size has less influence on the characteristics of the antenna, the asymmetrical ground is still used for improving the 3 dB AR bandwidth and the AR space distribution [6, 7]. The widths of W_3 and W_4 are fixed to be 16 and 13 mm, respectively.

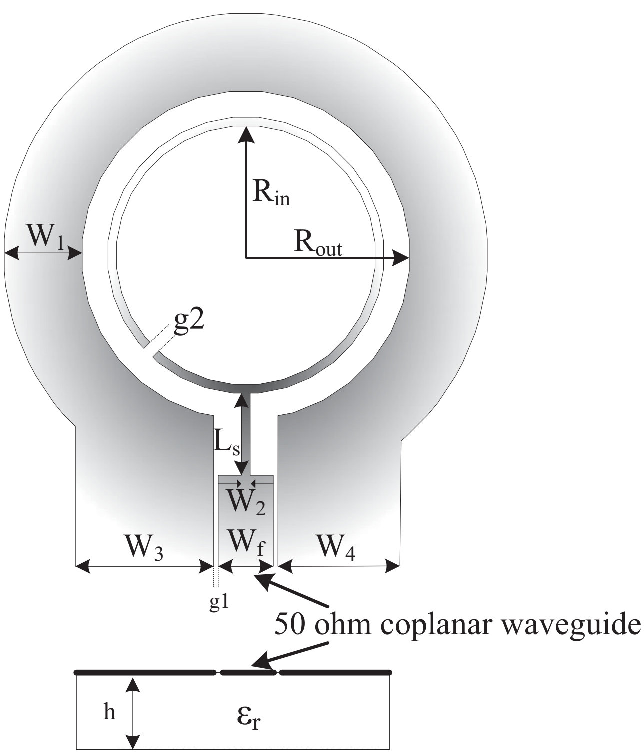


Figure 1 Geometry of the circular CPW-fed slot antenna resonated by the circular loop

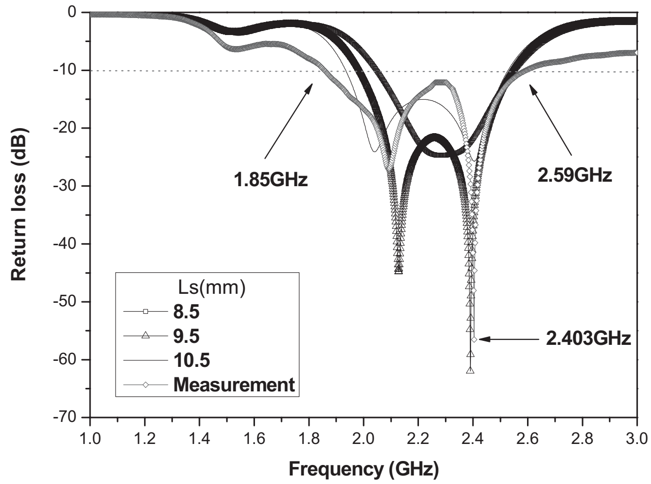


Figure 2 Simulated and measured return loss of proposed antenna during the various frequencies for different signal strip lengths of 8.5, 9.5, and 10.5 mm

3. EXPERIMENTAL RESULTS AND DISCUSSION

The effects of the length of the protruded signal strip (L_S) of the proposed antenna on the impedance matching and the AR value have been investigated. By varying the lengths of L_S, the widest impedance bandwidth of 556 MHz (from 1.987 GHz to 2.543 GHz) has been achieved. Figure 2 shows the simulated return ratio against the frequency of the proposed antenna with different signal strip lengths (L_S) of 8.5, 9.5, and 10.5 mm. It is apparent that as the length of L_S increases, the center frequency of the return ratio shifts toward the lower frequency. When the signal strip length of L_S is 9.5 mm, the resonant frequency of 2.4 GHz and the minimum return ratio of −62 dB are obtained. Moreover, the measured return loss (S_{11}) of the proposed antenna (L_S = 9.5 mm), with a minimum return ratio of −56.5 dB at the resonant frequency of 2.4 GHz, is also shown in Figure 2. Both results of the simulation and the measurement show good agreement.

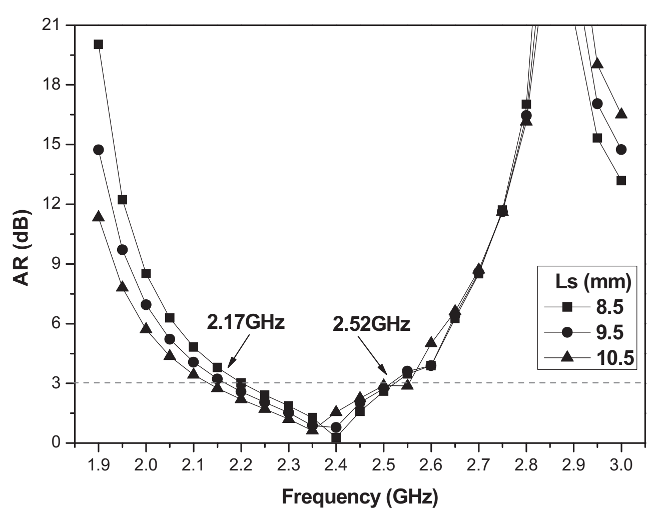
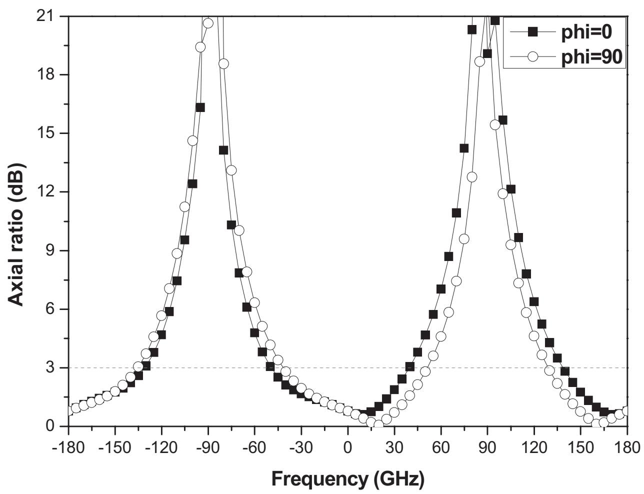
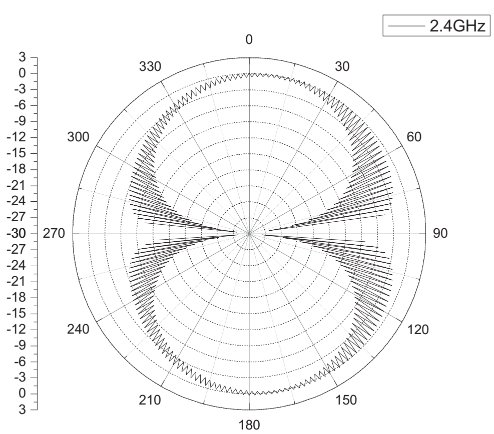


Figure 3 Simulated axial ratios of proposed antenna during the various frequencies for different signal strip lengths of 8.5, 9.5, and 10.5 mm

To achieve a CP wave, the circular loop is slit into two arms and thus it generated two orthogonal field components with an equal amplitude but in phase quadrature. The radius of the circular loop (R_{in}), the position of the gap between the two arms, and the size of the gap (g_2) can be used to tune the amplitude and the phase of two orthogonal field components. The R_{in} is determined by the length of the protruded strip L_S because the circular loop must be kept in the center of the circular slot. Therefore, the major key parameter, which influences the CP operation, is L_S and g_2. To simplify the design, from our experiences, the position of the gap, with a fixed size of 1.4 mm on the circular loop, is chosen to be located at about 45 degree referring to the protruded signal strip. A quite wide AR bandwidth may be obtained by properly adjusting the length of L_S. Figure 3 shows the simulated AR value of the proposed antenna during various frequencies. Although the proposed antenna can achieve wider bandwidth when the length of L_S is 10.5 mm, we still choose 9.5 mm as the length of L_S to gain the lowest AR value at 2.4 GHz (same as the resonant frequency).

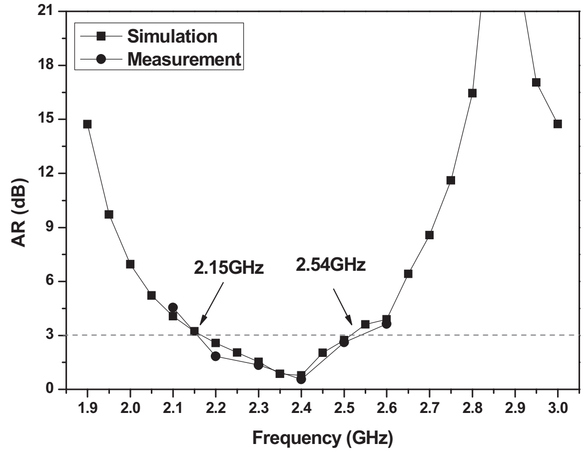


(a)

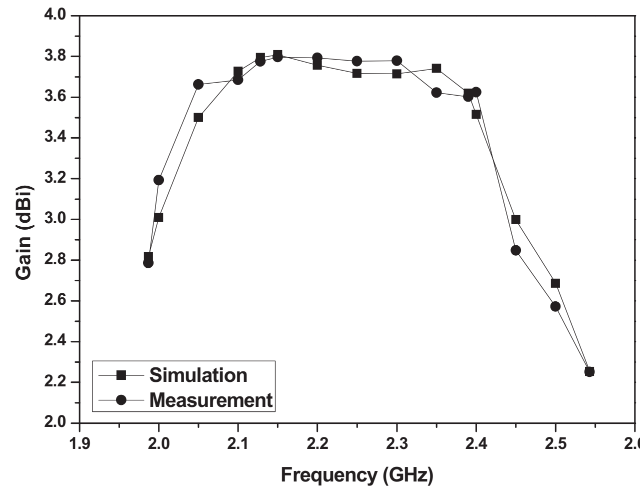


(b)

Figure 4 (a) Simulated axial ratio against elevation angle (θ) with different azimuthal angels of $\phi = 0$ and 90 degrees at 2.45 GHz. (b) Measured polarization patterns with different azimuthal angels of $\phi = 0$ at 2.45 GHz



(a)



(b)

Figure 5 Simulated and measured (a) axial ratios and (b) antenna gain for proposed during the various frequencies

Figure 4(a) shows the simulated AR value of the proposed antenna against the elevation angle (θ) at the azimuthal angles of $\phi = 0°$ and 90°, with the frequency set at 2.4 GHz. When the elevation angles range from $-50°$ to 40° at $\phi = 0°$ (square line), the AR value is lower than 3 dB. Correspondingly, as ϕ is at 90° (circle line) and θ ranges from $-40°$ to 50°, we found that the AR value is less than 3 dB. Therefore, we conclude that the proposed antenna demonstrates a good CP characteristic in space distribution. Figure 4(b) reveals the measured AR value of the proposed antenna against the elevation angle (θ) at 2.4 GHz. Moreover, the radiation pattern of the proposed antenna is measured and its AR values are lower than 3 dB, whereas the elevated angles range from $-46°$ to 36° at +z direction, and a mirror pattern is measured at $-$z direction. Comparing with the measured result in Figure 4(a) at $\phi = 0$ degree, the simulation one in Figure 4(b) shows very good agreement and the small difference can be thus explained from the fabricated tolerance, the measurement error, and the environmental interference.

The AR value and the antenna gain are measured and are simulated at different frequencies as shown in Figure 5. Figure 5(a) shows that the CP bandwidth, determined by 3 dB AR, is about

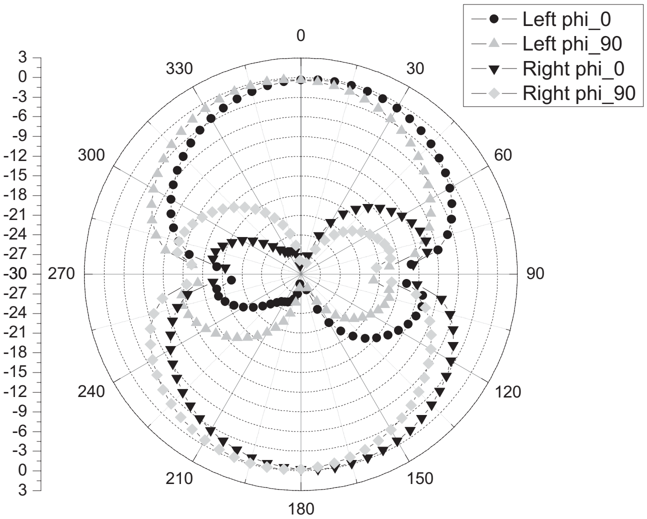


Figure 6 Radiation patterns of the proposed antenna on the elevation plane at the resonant frequency of 2.4 GHz

370 MHz or 15.8% (from 2.15 GHz to 2.52 GHz) and 390 MHz or 16.6% (from 2.15 GHz to 2.54 GHz), respectively, for simulated and measured results. The variations of the antenna gain are only 0.2 dBi from 2.1 GHz to 2.4 GHz, and the maximum antenna gain is 3.8 dBi at 2.15 GHz. Figure 6 shows the simulated radiation patterns in two orthogonal planes at 2.4 GHz. Therefore, this figure clearly reveals that our proposed antenna radiates a good LHCP wave in wide elevation angles, including the directions of $+z$ and $-z$.

4. CONCLUSION

A single layer circularly polarized CPW-fed circular slot antenna has been successfully demonstrated. Even fabricated on the inexpensive FR4 substrate, this antenna still reveals excellent performance at 2.4 GHz. To sum up, by properly adjusting the length of the protruded signal strip, the proposed antenna can be designed to have an impedance bandwidth of 740 MHz (33.3%) and a 3 dB AR bandwidth of 390 MHz (16.6%), good broadside LHCP radiation patterns over a wide elevation angle range, and the maximum antenna gain of 3.8. To conclude, our proposed antenna could provide good CP radiation for wide bandwidth transmitting and receiving applications.

ACKNOWLEDGMENTS

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BANDPASS FILTER WITH IMPROVED SPURIOUS PERFORMANCE USING MODIFIED RING DIELECTRIC RESONATOR IN MIC ENVIRONMENT

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ABSTRACT: *A C-band bandpass filter is designed using modified ring dielectric resonator in microwave integrated circuit (MIC) environment for improved spurious response. The dielectric resonator (DR) filters are generally made in cavity environment because of its good spurious response in cavity environment, but its spurious performance degrades as the filter is designed in MIC environment. In MIC environment, the smaller substrate thickness makes DR closer to ground plane and affects its resonance mode spectrum which, in turn, affects closely spaced resonant frequencies. The dense resonant mode spectrum of DR in MIC environment limits its application for filter designing. This article introduces a comparative study on filter realization with modified ring DR and conventional ring DR to show the improvement of spurious response in MIC environment. The simulated and measured results of these filters are presented to demonstrate the validity of the design procedure and improvement of spurious response.* © 2008 Wiley Periodicals, Inc.
Microwave Opt Technol Lett 50: 1426–1431, 2008; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.23391

Key words: *dielectric resonator (DR); dielectric resonator filter; modified ring dielectric resonator; spurious response; resonator mode separation*

1. INTRODUCTION

The role of dielectric resonator (DR) in miniaturization of microwave filter and oscillators is well recognized [1, 2]. The microwave filters consist of dielectric resonators that have good in-band performance, but the crowded mode spectrum of dielectric resonator gives poor out-of-band response. To get good out-of-band response, mode suppressor [3], and irises [4] have been suggested earlier to filter out the spurious modes. Further, the air-filled cylindrical cavities at the input [5], application of $TM_{01\delta}$ mode for bandpass filter [6], mixed mode filter design [7], combine filter [8], and sandwiched conductors DR [9] are the well recognized approaches for improving the spurious performance of dielectric resonator filters. But in all these filters, the attentions are mostly paid to cavity filters, where the dielectric resonators are placed within rectangular or cylindrical metal enclosures (cavity), and it has been found that very limited studies are available on dielectric resonator filters in microwave integrated circuit (MIC) environment [10, 11]. The reason for using the DR in cavity environment is that when DR is placed at the center of cavity, maximum mode separation can be achieved [12], whereas in MIC environment, the