

A Novel ZOR Antenna with a Capability to Change Polarization and Diversity

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Abstract—In this paper, a novel zeroth-order resonator (ZOR) antenna by exciting two asymmetric coplanar strips (ACS) is reported. In order to attain ZOR resonance, the antenna has resorted to two annular ring resonators (ARRs) which control antenna characteristics at 2.7 GHz. In this frequency, antenna treats such as a planar dipole antenna with omnidirectional patterns and linear polarization. The proposed antenna by utilizing two ports can change circular polarization diversity at the second band region. The proposed miniaturized antenna covering more than 80% bandwidth overall two bands and a more than -15 dB isolation between two input ports can be used in portable systems.

1. INTRODUCTION

Recent investigations in the field of wireless communication systems have raised researchers' interest in users' demands. This causes the discovery of multipurpose microwave devices which offer multiple characteristics with more compactness. To enhance the transmission quality in multipath environments, Multiple-input Multiple-output (MIMO) technique employs multiple antennas in both receiver and transmitter. Therefore, adding up the MIMO technique into wireless systems can contribute to system consistency and transmission capacity [1, 2]. In order to have limited space in portable wireless devices, size reduction and isolation increment are two major challenges for MIMO antenna designs [3–5]. Metamaterials display unique electromagnetic features such as negative refractive index, zero propagation anti-parallel group, and phase velocities, which facilitate the realization of miniaturized devices with multiband, low isolation, high efficiency, and high gain [6–17].

The theory of ZOR permits miniaturization of the antenna, as ZOR frequency provides an infinite wavelength propagation at nonzero resonance frequency which makes it autonomous on the physical sizes of the antenna [6–8]. Though metamaterial antennas due to their compact size are preferred over conventional antennas, they suffer narrow bandwidth and often have circularly polarized (CP) signs, especially CP diversity [9, 10]. Hitherto, many works have outlined some bandwidth improvement techniques, utilizing asymmetrically fed coplanar waveguide (CPW) [11, 12] and integration the number of modes [13]. Short ended boundary condition is another method to increase bandwidth [14, 15]. In short ended boundary conditions, ZOR frequency is often controlled by series elements of the Composite Right/Left-Handed (CRLH) transmission line which helps designer shape ZOR frequency by adjusting the design dimensions involved in series distributed parameters. In such antennas, ZOR features depend on series parameters, thus bandwidth and resonant frequency can be controlled by using series capacitances. A triple-band MTM-inspired antenna is designed and verified using a finite difference time domain technique explained in [16]. Up to now, although many MIMO antennas with metamaterial structures have been reported [1–5], no CP diversity MIMO antenna using the ZOR technique is introduced. Some single port studies are available in the literature [18–21].

Received 19 April 2020, Accepted 31 August 2020, Scheduled 11 September 2020

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In this paper, a novel ZOR MIMO antenna is presented which has a narrow and a wide frequency operation bandwidth. It can support linearly polarized (LP) features at the first frequency band by resorting to CRLH elements. A wide frequency, bandwidth antenna changes circular polarization diversity by employing each of the input ports. In fact, it is capable of generating LP at the first band by selecting each of the input ports and changing CP diversity in the same direction by changing input ports.

2. ANTENNA THEORY AND GEOMETRY

Figure 1 shows the proposed antenna with an equivalent circuit model. Asymmetric coplanar strip (ACS)-fed structure planes are connected with the signal patch by a thin stripline in order to realize the

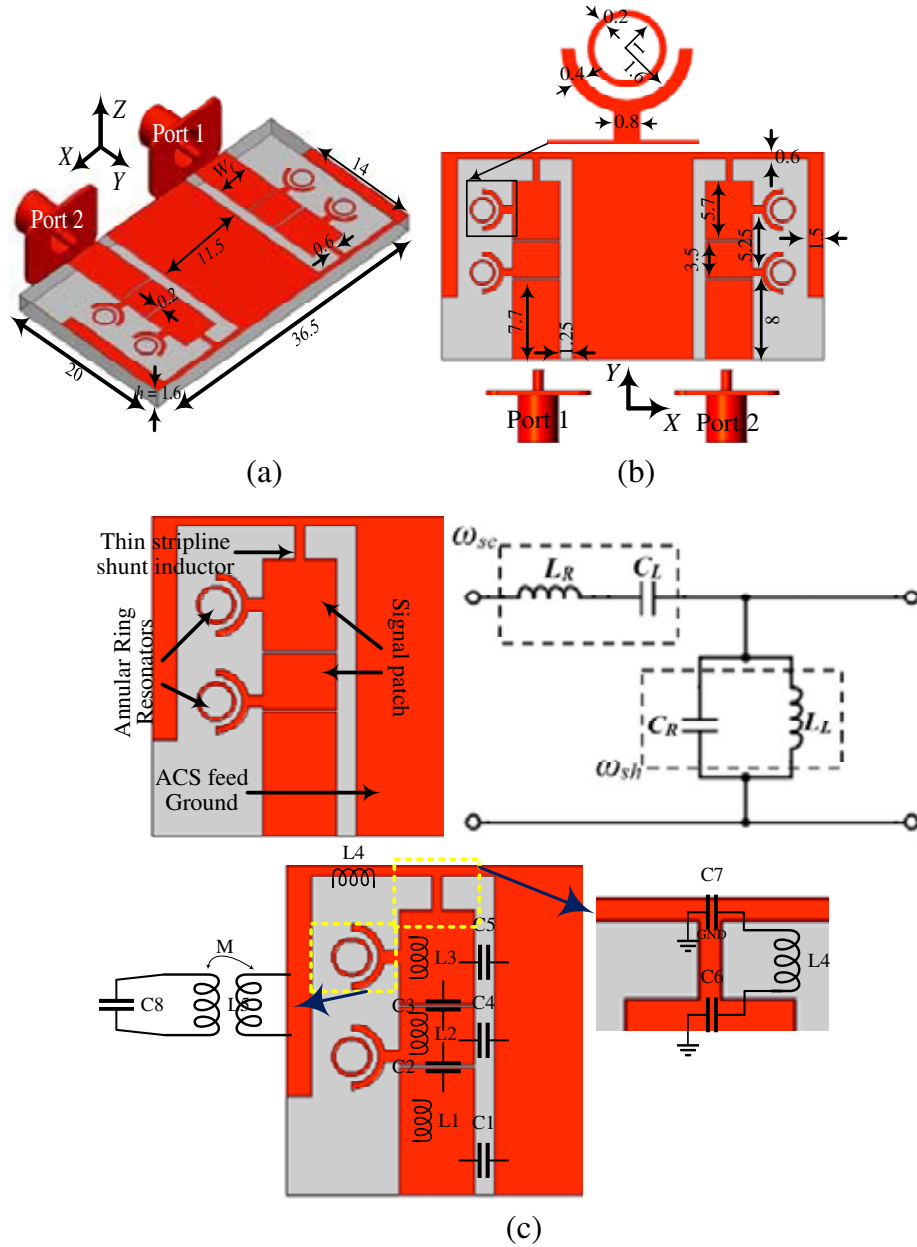


Figure 1. The configuration of proposed ZOR MIMO antenna; (a) perspective view, (b) top view, and (c) equivalent circuit.

CRLH transmission line [17,18] and to enable the short ended termination. Left-handed capacitance (C_L) is attained by introducing series gaps into the signal patch while shunt inductance (L_L) is designed by a thin stripline connecting the signal patch and ACS ground plane [22]. L_R is linked with the $50\ \Omega$ ACS line while the gap between the ACS line and ACS ground plane determines C_R . Note that ZOR frequency is adjusted by the series elements of CRLH TL because the proposed MIMO antenna is constructed on a short ended boundary condition. Based on the circuit model in Figure 1(b), ZOR frequency is given by [13].

$$\omega_{\text{ZOR}} = \omega_{\text{se}} = \frac{1}{\sqrt{L_R C_L}} \quad (1)$$

The structure is designed on an FR4 Glass Epoxy substrate ($\epsilon_r = 4.4$, $\tan \delta = 0.02$) with 1.6 mm thickness. The whole size of the proposed antenna is $36.5 \times 20\ \text{mm}^2$. Each port of the proposed MIMO antenna consists of a signal patch with two gaps, and a strip is connected between the signal patch and L-shaped stub of the ground plane. The ground planes are common between two ports. Besides, two annular ring resonators (ARRs) at each port are linked with the signal patch.

3. DESIGN METHODOLOGY AND RESULTS

Figure 2 displays simulated S_{11} , S_{22} , and S_{12} of the proposed antenna with and without ARR. The excitement of ARR create higher-order modes and consequently, a second band with a range of 75.8% fractional bandwidth attained. As illustrated in Figure 2, by embedding ARR on antenna isolation between two ports, S_{12} is reduced to less than $-15\ \text{dB}$ overall frequency bandwidth.

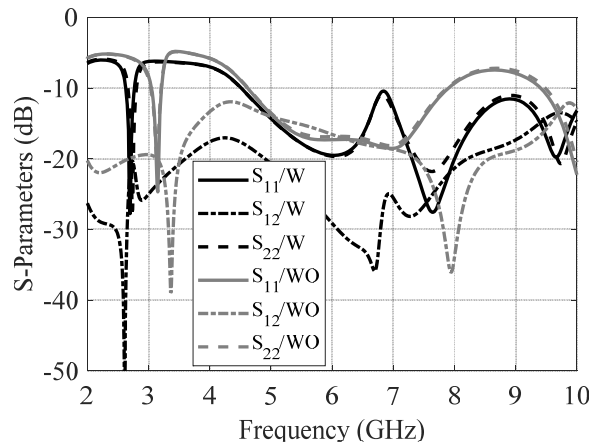


Figure 2. Simulated S_{11} , S_{22} , and S_{12} of the proposed antenna with and without ARR.

Current distributions of the proposed MIMO antenna are displayed with and without ARRs in Figures 3(a) and (b) at 2.7 GHz. As observed, more current is concentrated on ARR; therefore, the antenna can couple more power between the patch and L-shaped ground planes than the state without ARR. Figures 3(b) and (c) demonstrate current distributions at 2.7 (first mode) and 5.5 GHz (second mode), respectively. As seen in these figures, at the first mode (ZOR), the current concentrated on ARR elements while at the second mode, current distributed on the patch and L-shaped ground strip. Also, the current distributions on 5.5 GHz for two ports are displayed in Figures 4(a) and (b). As seen in Figure 4(a), by exciting port 1, antenna currents flow across a clockwise (RHCP) path, and by exciting port 2, this path is changed to an anticlockwise (LHCP) turn; thus by exciting each port CP diversity can be changed. The proposed antenna has been simulated and optimized using Ansoft HFSS. It has been fabricated and then measured by vector network analyzer (VNA) HP 8510. Figure 5 shows a photograph of the fabricated prototype. Figure 6 depicts the comparison between simulated and measured scattering parameters over frequency for two ports subjected to the permittivity tolerance of the substrate. The measured bandwidths for two ports are obtained as 7.4% (2.6–2.8 GHz) at the

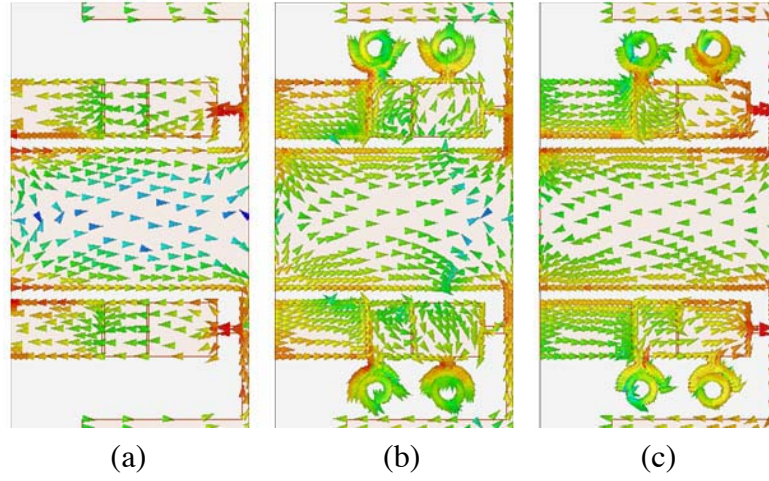


Figure 3. Distribution of proposed surface current at; (a) without ARR at 2.7 GHz, (b) with ARRs at 2.7 GHz and (c) with ARRs at 5.5 GHz.

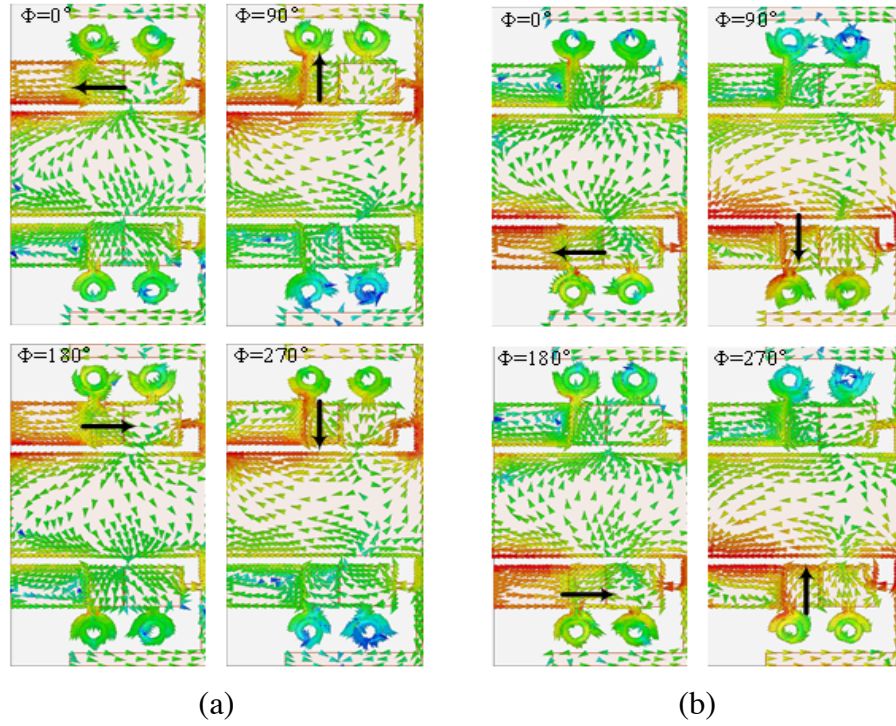


Figure 4. Current distribution on 5.5 GHz for two ports; (a) port 1 and (b) port 2.

first band and 75.8% (4.5–10 GHz) at the second band for port 1; 7.7% (2.5–2.7 GHz) at the first band and 75.8% (4.5–10 GHz) at the second band for port 2. Good isolation is expected of the antenna at all operation frequency bands with more than -15 dB.

The comparison between simulated and measured axial ratios (AR) for two ports are displayed in Figure 7. The findings indicated that there was a good agreement between simulated and measured results. The measured results for ports 1 and 2 are 5.21% (5.42–5.71 GHz) and 5.39% (5.41–5.71 GHz), respectively.

Figure 8 shows the measured radiation patterns of the proposed antenna at two operation bands.



Figure 5. Photograph of the fabricated antenna.

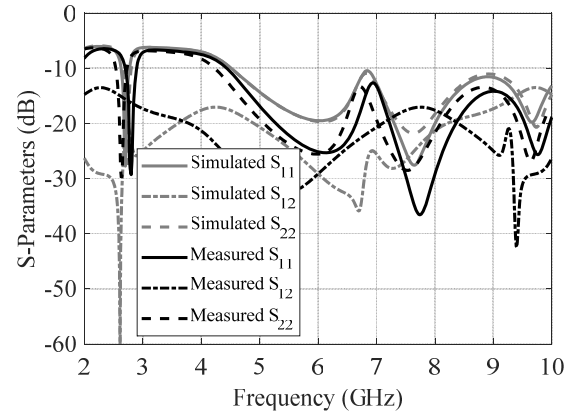


Figure 6. Comparison between simulated and measured scattering parameters S_{11} , S_{22} and S_{12} for two ports.

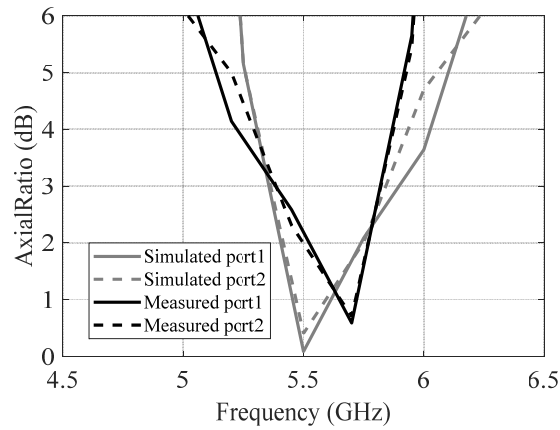


Figure 7. Comparison between simulated and measured axial ratio for two ports.

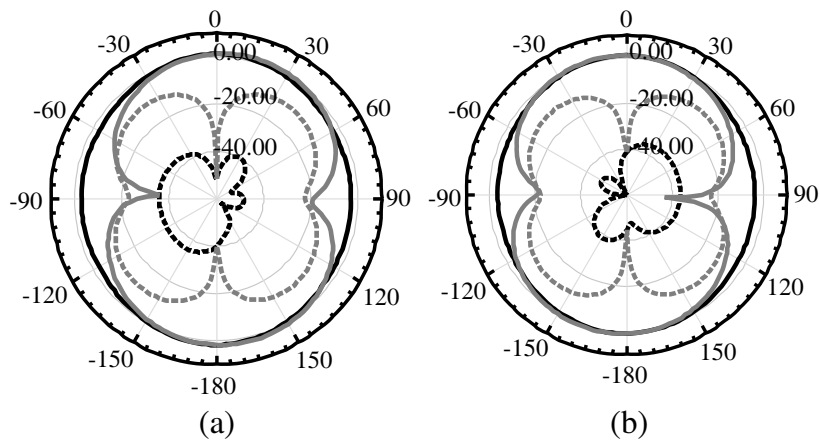


Figure 8. The measured radiation patterns of the proposed antenna at two 2.7 GHz for two ports; (a) port 1 and (b) port 2 (the grey color line is E -plane, the black line is H -plane, the solid line is Co-polarization and dash line is Cross-polarization).

The proposed antenna showed linear polarization at the first resonance and CP at the second one. The antenna has dipolar-type radiation patterns in xz -plane (E -plane) and omnidirectional radiation patterns in yz -plane (H -plane) at the first band for two ports.

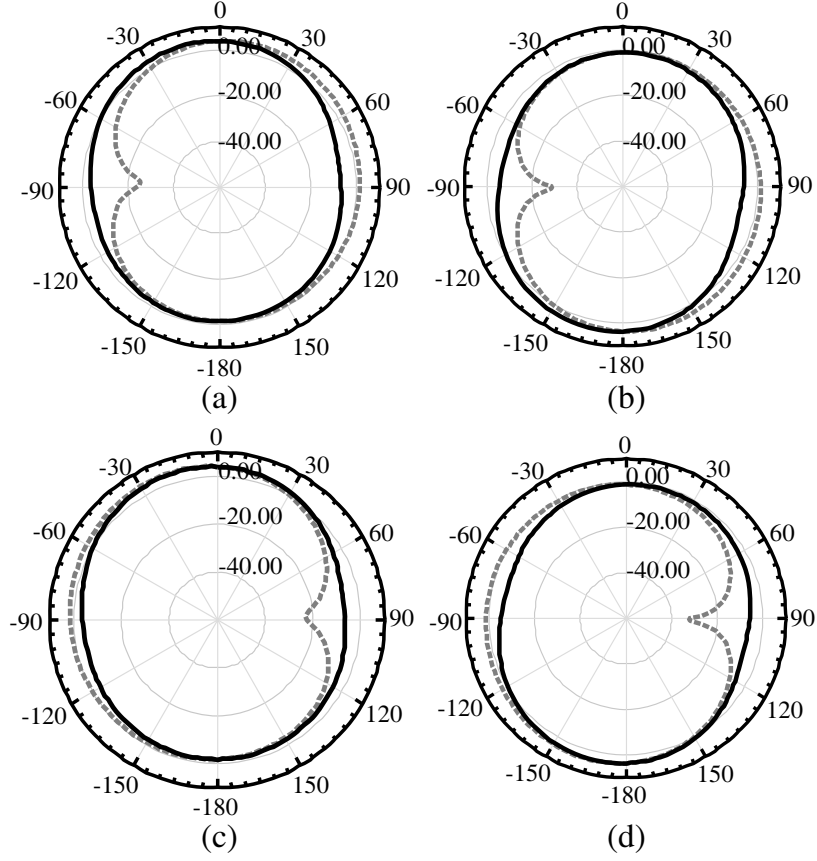


Figure 9. The measured radiation patterns of the proposed antenna at two 5.5 GHz for two ports; (a) port 1 (RHCP), (b) port 1 (LHCP), (c) port 2 (LHCP) and (d) port 2 (RHCP) (dash grey line is $\varphi = 90^\circ$ and the solid black line is $\varphi = 0^\circ$).

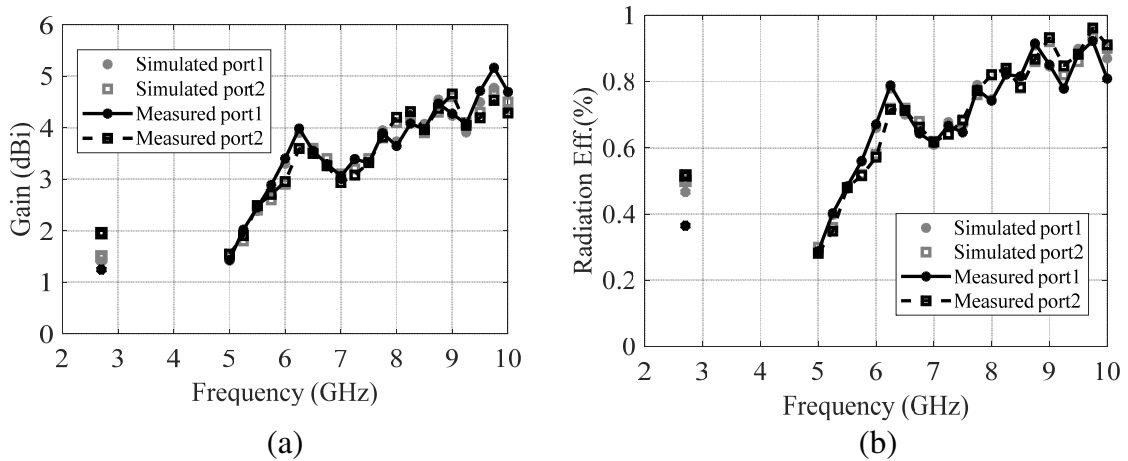


Figure 10. Comparison between simulated and measured for two ports (a) gain and (b) radiation efficiency for two ports.

Also, RHCP and LHCP for port 1 at $-z$ and $+z$, respectively, and vice versa for port 2 in planes $\varphi = 0$ and $\varphi = 90$ at 5.5 GHz are displayed in Figures 9(a) to (d). The peak gain and radiation efficiency of the proposed antenna are depicted in Figure 10. As indicated, at the first mode resonance frequency, a low gain antenna about 1.5 dBi was attained, and an acceptable matching was obtained between simulated and measured results for two ports. As mentioned in this antenna by radiating a relatively omnidirectional pattern, its radiation pattern is extremely dependent on to gain, and the directivity of the antenna is insignificant.

4. CONCLUSION

In this study, a dual-band and dual-polarized MIMO antenna with two ACS feeds has been presented. The proposed antenna treats a dipole pattern antenna at 2.7 GHz by resorting to CRLH elements (ARRs) which causes the generation of an omnidirectional pattern. Also, two L-shape arms have been used for generating the CP polarization which can change circular polarization diversity by selecting each of ports at 5.5 GHz. The proposed antenna is enabled to cover a frequency range of more than 80% and a 3-dB axial ratio bandwidth over 5%. Combining ZOR, ACS feed, and MIMO techniques in the present study produces a novel antenna which (as far as the authors of the present study are concerned) has not been reported in previous studies.

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