Correlation Reduction in Closely-Spaced MIMO Antenna With Circular Polarization Diversity

Ubaid Ullah, Muath Al-Hasan, Ismail Ben Mabrouk
Networks and Communication Engineering department
Al Ain university
Abu Dhabi, United Arab Emirates
ubaid.ullah@aau.ac.ae, muath.alhasan@aau.ac.ae

Slawomir Koziel
Engineering Optimization and Modeling Center
Reykjavik University
Reykjavik, Iceland
koziel@ru.is

Qammer Abbasi
James Watt School of Engineering
University of Glasgow
United Kingdom
qammer.abbasi@glasgow.ac.uk

Akram Alomainy
School of Electronic Engineering and Computer Science
Queen Mary University of London
United Kingdom
a.alomainy@qmul.ac.uk

***Abstract*—Radiator correlation in multiple-input-multiple-output (MIMO) antenna has always been a serious concern for MIMO systems. In this paper, an antenna consisting of two parallel-placed coplanar waveguide (CPW)-fed radiators engineered on a common coplanar ground plane is presented. The antenna is designed with three parallel coplanar ground planes and two feed lines. The two outermost ground planes are systematically modified by etching a slot to form a quasi-loop, whereas the middle ground plane is made asymmetric along the feeding line. The current flowing on the edges of the quasi-loops generates opposite senses of circular polarization due to switched positioning of the slotted ground plane with respect to the feedline. This induces polarization diversity in the antenna. The proposed structure with circular polarization diversity features a low level of envelop correlation coefficient (ECC), < 0.005. Moreover, a wide impedance bandwidth ($|S_{11}| \leq -10$ dB) and axial ratio (AR) bandwidth of approximately 38.5 % from 4.7 GHz to 6.7 GHz. The average in-band isolation is $|S_{21}| \leq -15$ dB with the peak realized gain of 3.15 dBic when operated with the bi-directional radiation characteristics in the ±*z*-direction.**

Keywords—MIMO Antenna, Circular Polarization, Polarization Diversity

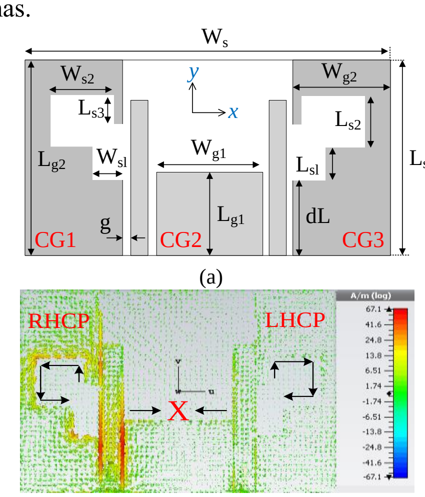
I. Introduction

Multiple-input-multiple-output (MIMO) technology is one of the key components of modern wireless communication systems. High data rates, improved channel capacity, data reliability, signal integrity, and improved spectral efficiency can be realized using MIMO technology [1]. As MIMO system employs multiple antennas, generally the correlation between the two radiators adversely affect the performance of the system by degrading the channel capacity [2]. To reduce the correlation, several isolation and decoupling techniques have been implemented [3]. The shortcomings of these techniques are added cost, circuit complexity and the requirement of external source. In contrast, polarization/pattern diversity seems to be a more effective solution for reducing the correlation between the closely spaced MIMO antennas [4]. It is well known that circularly polarized (CP) antennas have certain advantages over their linear counterparts [5]. Notwithstanding, the research on implementation of circular polarization diversity while ensuring wideband operation has been sparse in the literature so far.

In this paper, a topologically simple antenna of planar geometry is implemented with circular polarization diversity. The structure exhibits a very low level of (farfield-evaluated) envelop correlation coefficient (ECC) without using any external circuit elements. Moreover, the proposed antenna features a wide impedance and axial ratio bandwidth.

II. Antena Design And Operating Mechanism

The parametrized geometry and the surface current distribution of the proposed antenna design is shown in Fig. 1. The antenna is printed on FR4 substrate ($\varepsilon_r = 4.4$, $\tan\delta = 0.02$, thickness h = 1.5 mm) and fed by two parallel coplanar waveguides. A quasi-loop is formed in the outer coplanar ground planes CG1 and CG3 by etching an extended rectangular slot with mirrored geometry. The inner ground plane (CG2) is made asymmetric along the longitudinal y-axis. The mutual coupling is reduced due to the 180-degree phase-shifted current within the middle ground, which cancel out as depicted by X in Fig. 1(b). This topological configuration yields circularly polarized MIMO antenna with the opposite sense of polarization resulting in polarization diversity. This leads to a reduction of the far field correlation between the two closely space antennas.



(b)

Fig. 1. Geometry of the proposed CP MIMO antenna with polarization diversity (a) Parameterized simulation model (b) Surface current distribution at 5.5 GHz

III. Results And Discussion

The antenna is simulated using CST Microwave Studio. The antenna reflection coefficient shows a broad impedance bandwidth response from 4.7 GHz to 6.7 GHz as shown in Fig. 2. The isolation $|S_{12}|$ is shown in Fig. 3 with the reverence line is at –15 dB. It can be observed that the antenna isolation is well below –15 dB in more than 90% of the impedance bandwidth. The axial ratio response illustrated in Fig. 4 is covering almost the entire impedance bandwidth. This indicates 100-percent overlap between the impedance bandwidth and the axial ratio bandwidth. The ECC of the antenna evaluated using the simulated farfields is shown in Fig. 5, which demonstrates that the two antennas are almost uncorrelated (ECC < 0.005). The radiation pattern of the antenna is shown in the *xz*- and the *yz*-plane at four different frequency points. The radiation pattern of the port depicted in Fig. 6 shows RHCP in the +z-direction and LHCP in the –z-direction. Similarly, for the port 2 radiation pattern in Fig. 7, the LHCP is in the +z-direction and RHCP is in the –z-direction. A slight beam tilt from the broadside direction is due to the asymmetrical coplanar ground plane, which adds to the enhancement of ECC by bringing the pattern diversity into effect.

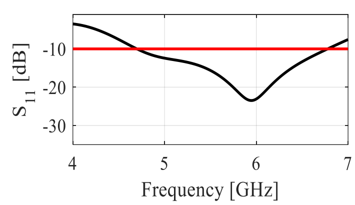


Fig. 2. Simulated reflection coefficient $|S_{11}|$.

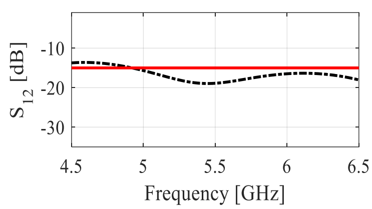


Fig. 3. Simulated isolation S-parameter $|S_{12}|$.

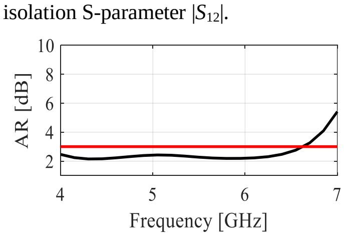


Fig. 4. Simulated Axial ratio.

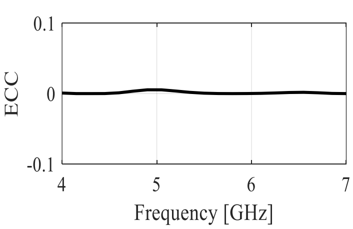
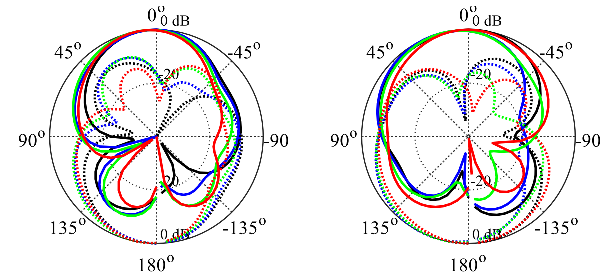
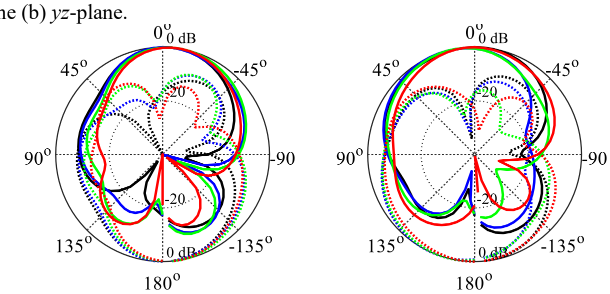


Fig. 5. Simulated envelop correlation coefficient.



(a) (b)

Fig. 6. Antenna Port 1 radiation pattern. RHCP (solid line) and LHCP (dotted line) 5 GHz (black), 5.5 GHz (blue), 6 GHz (green) and 6.5 GHz (red) (a) *xz*-plane (b) *yz*-plane.



(a) (b)

Fig. 7. Antenna Port 2 radiation pattern. LHCP (solid line) and RHCP (dotted line) 5 GHz (black), 5.5 GHz (blue), 6 GHz (green) and 6.5 GHz (red) (a) *xz*-plane (b) *yz*-plane.

IV. Conclusion

A MIMO antenna with circular polarization diversity has been presented. The antenna is designed with three parallel-placed coplanar waveguide ground planes. Circular polarization is induced in the antenna by modifying the geometry of the outermost ground planes and breaking symmetry of the middle ground plane. The opposite sense of polarization is realized due to the mirrored position of the slotted ground plane with respect to the microstrip feed line. The proposed antenna features low level of ECC and wide impedance and axial ratio bandwidth with acceptable isolation between the two antennas. The antenna is suitable for multiple WLAN and WiMAX indoor applications such as in tunnels and subways.

References

[1] M. A. Ul Haq and S. Koziel, “Ground plane alterations for design of high-isolation compact wideband MIMO antenna,” *IEEE Access*, vol. 6, pp. 48978-48983, 2018.

[2] H. T. Chattha, M. Nasir, Q. H. Abbasi, Y. Huang, and S. S. Alja’afreh, “Compact low-profile dual-port single wideband planar inverted-f MIMO antenna,” *IEEE Antennas Wireless Propag. Lett.*, vol. 12, pp. 1673–1675, 2013

[3] I. Nadeem and D. Choi, “Study on Mutual Coupling Reduction Technique for MIMO Antennas,” *IEEE Access*, vol. 7, pp. 563-586, 2019.

[4] M. Aziz ul Haq and S. Koziel, “Feedline alterations for optimization-based design of compact super-wideband MIMO antennas in parallel configuration,” *IEEE Antennas Wireless Propag. Lett.*, vol. 18, no. 10, pp. 1986-1990, Oct. 2019.

[5] U. Ullah, I. B. Mabrouk, and S. Koziel, “A compact circularly polarized antenna with directional pattern for wearable off-body communications,” *IEEE Ant. Wireless Propag. Lett.*, vol. 18, no. 12, pp. 2523-2527, Dec. 2019.