A Tripolarization Antenna Fed by Proximity Coupling and Probe

Hua Zhong, Zhijun Zhang, *Senior Member, IEEE*, Wenhua Chen, *Member, IEEE*, Zhenghe Feng, *Senior Member, IEEE*, and Magdy F. Iskander, *Fellow, IEEE*

***Abstract*—The design and characterization of a conformal tripolarization antenna with three independent ports and three orthogonal polarizations is presented. The antenna uses both proximity (slot) coupling and probe-fed ports to reduce isolation and improve polarization purity. The measured bandwidth of the -10-dB return loss is found to be 190 MHz (2.4–2.59 GHz). Measurements across the working bandwidth also show that the isolations among the three ports are better than -16, -30, and -40 dB, respectively. Design parameters and experimental results are presented.**

***Index Terms*—Probe, proximity coupling, tripolarization antenna.**

I. INTRODUCTION

THERE are normally two independent polarizations associated with uniform plane waves. However, in a multipath propagation environment, which is the default favorable condition of multiple-input–multiple-output (MIMO) systems, a specific location may be expected to be illuminated by plane waves from multiple directions. In such circumstances, there will be three independent polarizations, and hence, a tripolarization antenna will need to be used to receive all available information and take full advantage of the potential of a MIMO system in increasing channel capacity. Recently, there has been increasing interest in the design and characterization of multipolarization antennas. For example, a tripolarization antenna composed of a dual-polarization circular patch and a monopole wire antenna was adopted by Das *et al.* [1]. A tripolarization antenna constructed from two orthogonal slots and a monopole wire was reported by Itoh [2]. A tripolarization antenna formed by a dual-polarization dielectric resonator and a monopole wire was also introduced by Gray [3]. In these cases, a quarter-wavelength monopole antenna had been used for the vertically polarized element [1]–[3]. To help design a tripolarized antenna with a low profile that would be easier to integrate into commercial products (e.g., cell phones), Zhong proposed a new probe-feed conformal tripolarization antenna [4]. The port isolations of this conformal antenna [4], however, were unsatisfactory, and additional design changes were needed to improved the performance. Proximity coupling, which was used by Steven [5] to design a dual-polarization patch antenna, is adopted in the new design presented in this letter to improve the isolation in a conformal tripolarization antenna. The measured isolations among three ports of the proposed antenna are found to be better than -16, -30, and -40 dB, respectively. The total height of the antenna is 10.8 mm, and the area of the antenna is 94×94 mm^2.

Manuscript received December 22, 2008; revised January 19, 2009. First published April 07, 2009; current version published June 10, 2009. This work supported in part by the National Basic Research Program of China under Contract 2007CB310605, the National High Technology Research and Development Program of China (863 Program) under Contract 2007AA01Z284, and the National Natural Science Foundation of China under Contract 60771009.

H. Zhong, Z. Zhang, W. Chen, and Z. Feng are with the State Key Lab of Microwave and Communications, Department of Electronic Engineering, Tsinghua University, Beijing 100084, China (e-mail: zjzh@tsinghua.edu.cn).

M. F. Iskander is with the Hawaii Center for Advanced Communications, University of Hawaii at Manoa, Honolulu, HI 96822 USA (e-mail: Magdy.iskander@gmail.com, iskander@spectra.eng.hawaii.edu).

Color versions of one or more of the figures in this letter are available online at http://ieeexplore.ieee.org.

Digital Object Identifier 10.1109/LAWP.2009.2020185

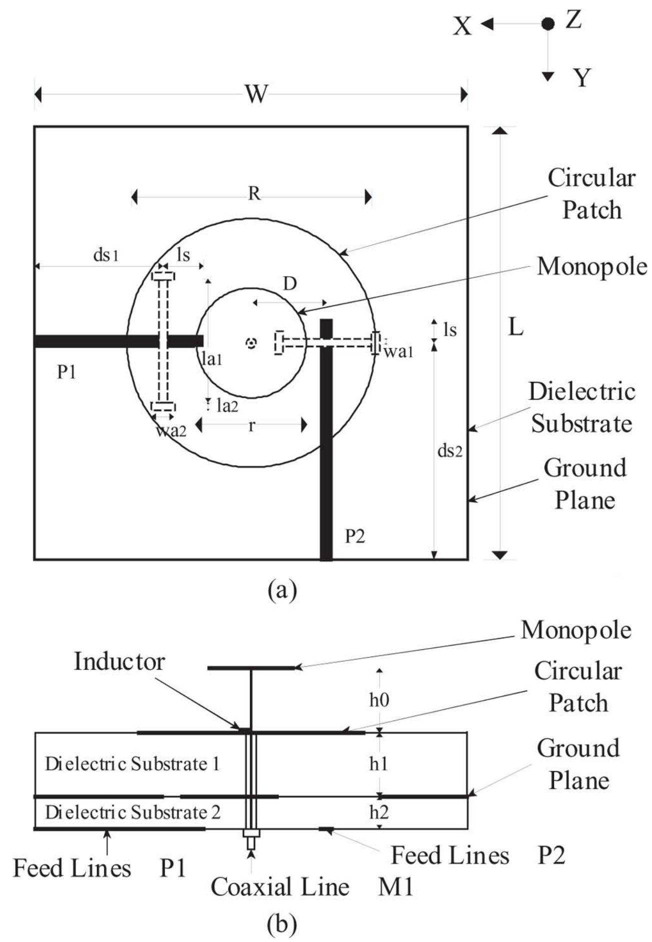
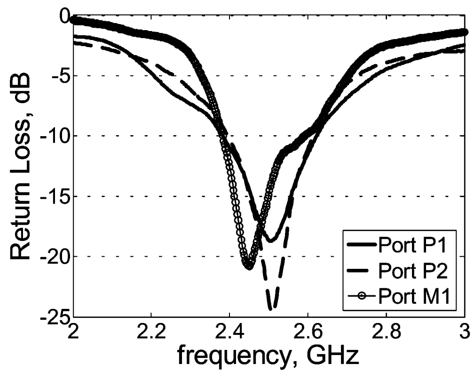


Fig. 1. Geometry of the tripolarization antenna. (a) Top view. (b) Side view.

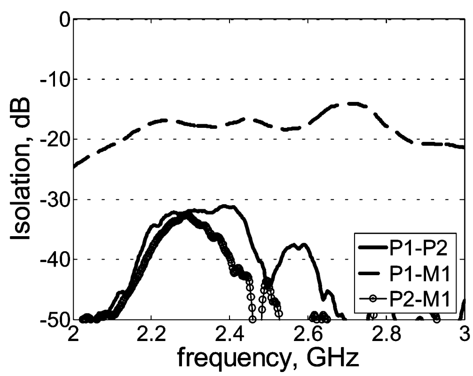
II. CONFIGURATION OF THE TRIPOLARIZATION ANTENNA

Fig. 1 shows the configuration of the tripolarization antenna. The substrate consists of two dielectric substrate layers

Fig. 2. Photograph of the tripolarization antenna.



(a)



(b)

Fig. 3. Measured S-parameters of the three antenna ports. (a) Return loss. (b) Isolation between each two ports.

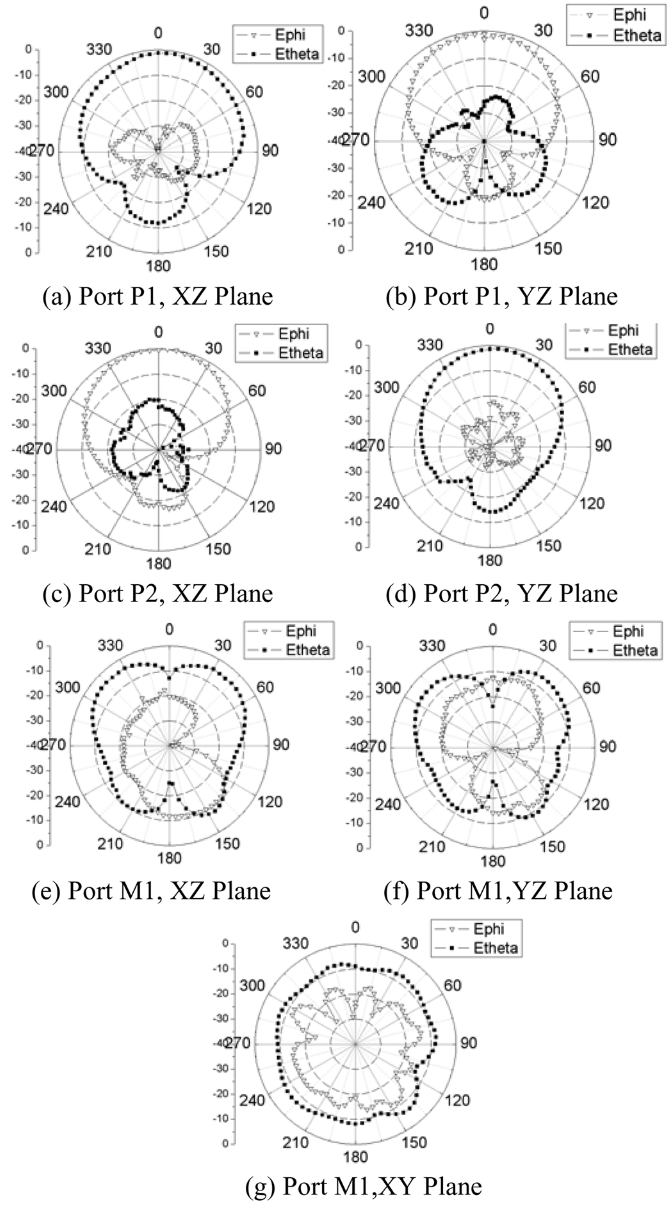


Fig. 4. Radiation patterns from the three ports.

(substrate 1 and 2, respectively). A dual-polarized circular microstrip patch sits on the top side of substrate 1. Two H-shaped slots, which provide the proximity coupling between feed lines and patches, are etched in the ground plane between substrates 1 and 2. Two microstrip feed lines are placed on the bottom side of substrate 2 below each slot for producing two orthogonally polarized radiation patterns. The two H-shaped slots are arranged in a "T" shape in order to improve the isolation between two polarizations. These two ports are marked as P1 and P2, respectively. In the center of the patch antenna, there is a grounded hole through two dielectric substrate layers orthogonally to the patch. A coaxial line passes through the hole and feeds a disk (capacitive)-loaded monopole antenna on the top of the patch. The inner conductor of the coaxial line is connected with the disk-loaded monopole antenna. The outer conductor of the coaxial line is connected with the patch antenna. The patch antenna acts as a ground for the monopole antenna. The monopole port is marked as M1. The height of the monopole antenna is 5 mm. The diameter of the monopole circular patch is 15.6 mm. With the height of the monopole antenna getting lower, the shunt capacitance between the disk and the patch antenna becomes higher. In order to improve impedance matching at port M1, a 1.5-nH shunt inductor is selected by experiment as a matching component to counteract the capacitance.

The dielectric constant is 2.6 for substrate 1 and 4.5 for substrate 2. The width of microstrip lines that feed P1 and P2 is 1.5 mm and designed as 50 Ω. The dimensions of two dielectric substrate layers are defined by the parameters W, L, R, h_1, and h_2. The dimensions of the "H" slot are defined by ds, ls, la_1, la_2, wa_1, wa_2, and D. The size of the monopole antenna is defined by h_0 and r. The prototype antenna designed has the following parameters: $W = L = 94$ mm, $R = 40$ mm, $h_1 =$

5 mm, $h_2 = 0.8$ mm, $h_0 = 5$ mm, and $r = 15.6$ mm. Port 1 has the following parameters: $ds1 = 32.5$ mm, ls = 7 mm, $la_1 = 17$ mm, $la_2 = 2$ mm, $wa_1 = 1$ mm, and$wa_2 = 4$ mm. Port 2 has the following parameters: $D = 12.3$ mm, $ds2 = 47$ mm, ls = 8.8 mm, $la_1 = 11.4$ mm, $la_2 = 2$ mm, $wa_1 = 1$ mm, and $wa_2 = 4$ mm.

The E-fields of the two orthogonal patch modes are parallel to the ground, and the monopole antenna radiates an E-field that is perpendicular to the ground plane. Thus, this antenna provides three orthogonal radiation modes.

III. Results

To verify the design, a prototype antenna is manufactured and measured. Fig. 2 shows a photograph of the tripolarization antenna. The measured return losses for all three ports are shown in Fig. 3(a). The -10-dB bandwidth of S_{11} (port P1), S_{22} (port P2), and S_{33} (port M1) are 2.38–2.62, 2.40–2.61, and 2.38–2.59 GHz, respectively. The isolations between any two ports are shown in Fig. 3(b). The isolation between ports P1 and M1 is below -16dB in the operational bandwidth. The isolations between ports P1 and P2 or P2 and M1 are better than -30 and -40 dB, respectively. These data represent significant improvements over the results given in the earlier attempt described in [4]. The much higher coupling between P1 and M1 than between P2 and M1 is due to the asymmetric layout of the feeding structure. If using the feeding pin of port M1 as a reference, all E-fields inside the slot of port P1 are along the same direction, thus generating higher coupling. All E-fields inside the slot of port P2 are perpendicular to the feeding pin. The fields on both sides of the symmetric line of the longer dimension are canceling each other, thus producing better isolation.

Fig. 4 shows the measured radiation patterns for each port. It clearly shows that the electric field excited by port P1 is parallel to the X-axis, the E-field excited by port P2 is parallel to the Y-axis, and the E-field excited by port M1 is parallel to the Z-axis. The designed antenna, therefore, has three orthogonally polarized modes.

IV. Conclusion

This letter describes the design and characterization of a compact tripolarization antenna whose total height is 10.8 mm. The isolation is below -16 dB between port P1 and port M2, below -30 dB between port P1 and P2, and below -40 dB between port P2 and M1. The operational bandwidth is 190 MHz.

References

[1] N. K. Das, T. Inoue, T. Taniguchi, and Y. Karasawa, “An experiment on MIMO system having three orthogonal polarization diversity branches in multipath-rich environment,” in *Proc. 60th IEEE Veh. Technol Conf.*, Sep. 2004, vol. 2, pp. 1528–1532.

[2] K. Itoh, R. Watanabe, and T. Matsumoto, “Slot-monopole antenna system for energy-density reception at UHF,” *IEEE Trans. Antennas Propag.*, vol. AP-27, no. 8, pp. 485–489, Jul. 1979.

[3] D. Gray and T. Watanabe, “Three orthogonal polarization DRA-monopole ensemble,” *Electron. Lett.*, vol. 39, no. 10, pp. 766–767, May 2003.

[4] H. Zhong, W. Chen, Z. Zhang, Z. Feng, and M. Iskander, “A conformal tri-polarization antenna,” in *Proc. IEEE Antennas Propag. Soc. Int. Symp.*, San Diego, CA, Jul. 2008, pp. 1–4.

[5] S. Gao and A. Sambell, “Dual-polarized broad-band microstrip antennas fed by proximity coupling,” *IEEE Trans. Antennas Propag.*, vol. 53, no. 1, pp. 526–530, Jan. 2005.