A Dual-Polarization Slot Antenna Using a Compact CPW Feeding Structure

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

***Abstract*—A dual-polarization coplanar waveguide (CPW)-fed slot antenna is proposed in this letter. By exploiting the even and odd modes of a CPW structure, two orthogonal polarizations can be excited in a slot aperture by the same feeding CPW, which results in a compact dual-polarization antenna design with very good isolation between the ports. The -10-dB reflection coefficient bandwidths of two polarizations are 670 MHz (27.9%) for one polarization and 850 MHz (35.4%) for the other, and the isolation between the two ports in the WLAN band is better than -32.6 dB. The radiation pattern and efficiency of the proposed antenna are also measured, and radiation pattern data are compared with simulation results.**

***Index Terms*—Compact, dual polarization, isolation, slot antenna.**

I. Introduction

IN MANY multiple-antennas practical applications including those for diversity implementation and multiple-input–multiple-output (MIMO) systems applications, it is desirable to accommodate several antennas to increase the channel capability. One attractive solution is using multiple-polarization antennas [1]–[6], which can generate two or three orthogonal polarizations on a single antenna element, maintaining reasonable isolations between ports.

A tripolarization antenna was proposed in [1], but isolations between some ports were not sufficient and were hence unacceptable in high-performance applications. In resent research, several techniques have been published in [2]–[6] to improve isolations in similar antenna applications. Square patch antennas fed by a pair of coupled microstrip lines through a pair of crossed slots to excite two orthogonal modes for dual polarization were reported [2]. An air bridge, which is utilized in the cross part of two feedings for high isolation, was also proposed in [2], [3]. Different feed mechanisms, feed by probe and coupling through aperture, were used in [4] for high input isolation. In a study by Chen *et al.* [5], two vertical metallic sidewalls were used to provide multiple reflections for cross polarization, whose phases are altered by a modified feeding network and cancel each other. Another isosceles triangular slot antenna is proposed for wideband dual-polarization applications in [6]. TE_{10} and TE_{01} modes are excited by two orthogonally arranged microstrips. It should be emphasized that in much of the earlier work [2]–[6], dual feeding structures were used to excite dual-polarization, thus making the feed structure quite complex. Even the use of the air bridge in [2] and [3] brought insertion loss and occupied more space.

In order to simplify the feeding structure and save space, a coplanar waveguide (CPW) approach, which supports two orthogonal modes, was adopted in [7]. Two different radiators were utilized, one was a monopole and the other was an equivalent dipole. The isolation reported in this paper was -15 dB, which is sufficiently acceptable in some practical applications.

To meet the specification of wide bandwidth, simplicity, and high isolation, a dual-polarization CPW-fed slot antenna is proposed in this letter. Slot antennas are known to have wide bandwidth [8]. In the proposed design, the horizontal and vertical polarizations of a slot antenna are excited by the odd and even modes of a single CPW feed line. Measured performance of the developed antenna includes -10 dB reflection coefficient, with the bandwidths of 670 (27.9%) and 850 MHz (35.4%) for the two polarizations. The isolation between two ports in the WLAN band is better than -32.6 dB.

II. Antenna Configuration and Design

Fig. 1 shows the geometry of the proposed antenna. The overall dimensions of the antenna are 100×80 mm^2. The antenna is made of FR4 ($\varepsilon_\mathrm{r} = 4.4$, $\tan\delta = 0.01$), whose thickness is 1 mm. A 52×50 mm^2 slot, etched in the front side (light region), serves as the radiation aperture. In the back side (dark region), an L-shaped microstrip line is fed from port 1. The front-side metal serves as the ground plane of the microstrip line. The CPW is fed from port 2 in the front side.

It is well known that a square slot can support two independent modes, horizontal and vertical polarization modes, as shown in Fig. 2(a) and (b), respectively. To excite the two polarizations simultaneously, two orthogonal feedings must be used.

As shown in Fig. 3(a), when feeding from port 1, an odd mode is excited in the CPW structure, which generates a horizontal polarization mode inside the slot. When feeding from port 2, as

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Y. Li, Z. Zhang, W. Chen, and Z. Feng are with the State Key Lab of Microwave and Communications, Tsinghua National Laboratory for Information Science and Technology, Tsinghua University, Beijing, 100084, China (e-mail: zjzh@tsinghua.edu.cn).

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

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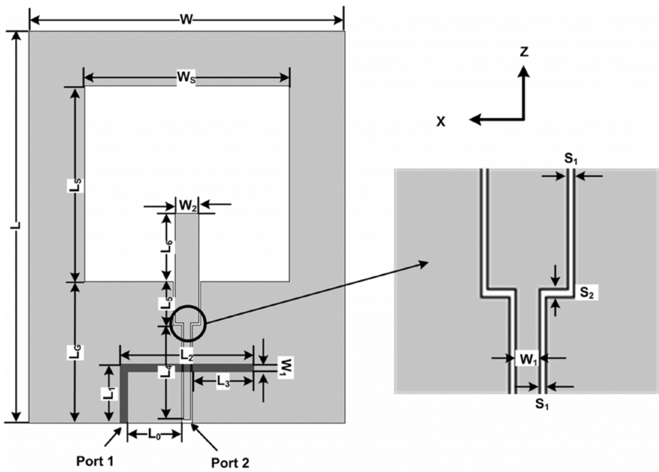

Fig. 1. Geometry and dimensions of the proposed antenna.

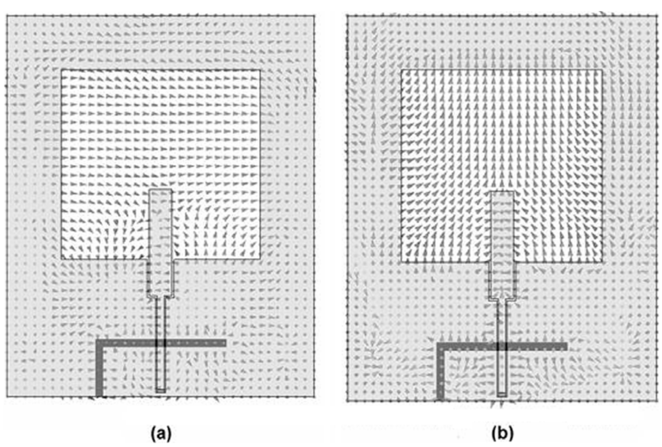

Fig. 2. Electric field distribution in slot: feeding in (a) port 1 and (b) port 2.

Fig. 3. Electric field distribution in CPW: feeding in (a) port 1 and (b) port 2.

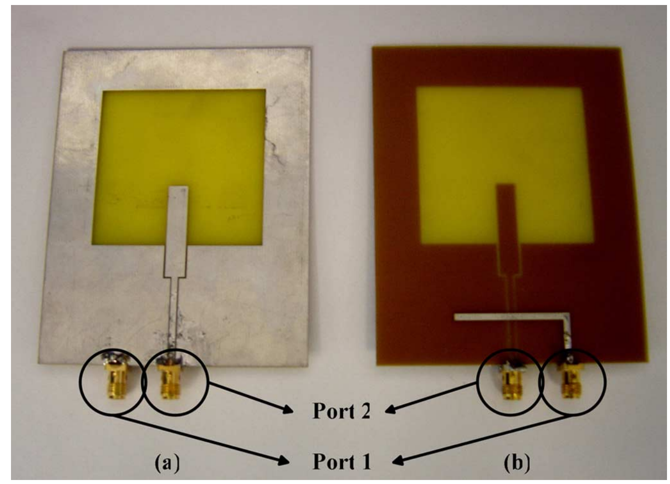

Fig. 4. Photograph of the proposed antenna: (a) front and (b) back.

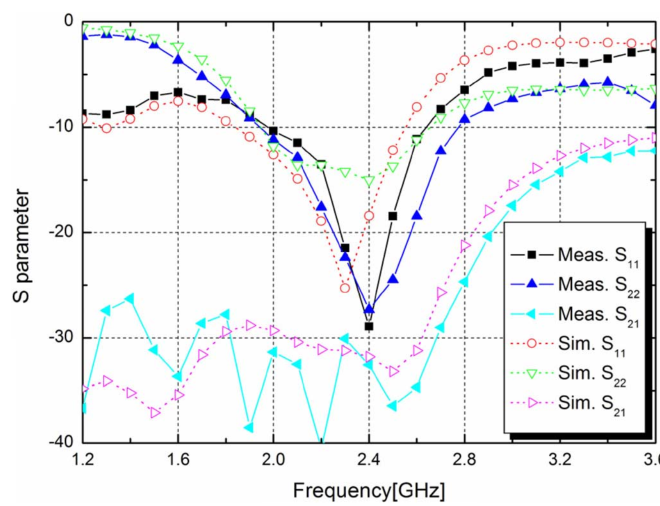

Fig. 5. Measured and simulated S-parameter of proposed antenna.

TABLE I
DETAILED DIMENSIONS OF THE PROPOSED ANTENNA

Parameter	L	L_S	L_G	L_0	L_1	L_2	L_3	L_4
Value(mm)	100	50	36	15	15	32	12.5	25.5
Parameter	L_5	L_6	W	W_S	W_1	W_2	S_1	S_2
Value(mm)	9.5	19	80	52	1.9	6	0.35	0.5

shown in Fig. 3(b), the mode in the CPW is a normal even mode, which can excite a vertical polarization mode inside the slot.

Dimensions of L_S and W_S determine the resonant frequencies of the vertical mode and horizontal mode, respectively. The L_3 is the tuning parameter for matching port 1. To match port 2, dimensions of W_2, L_5 and L_6 need to be optimized. The final values of each parameter are listed in Table I.

Due to the symmetric and antisymmetric characteristics of the two modes in CPW, high isolation can be achieved between two ports. As a result, the feeding structure is compact and can excite both polarization modes simultaneously and independently. The antenna is an attractive candidate for multiple antenna applications that require polarization diversity and also for some of the MIMO systems applications.

III. MEASUREMENT RESULTS

To validate the design, the S-parameters of the proposed antenna are simulated using Ansoft High Frequency Structure Simulator (HFSS). The antenna has also been fabricated and measured. The front and back views of the antenna prototype are shown in Fig. 4.

Fig. 5 shows the measured S-parameter of the proposed antenna (solid lines) compared to the simulated ones (dash lines). As shown in the figure, the center frequencies of the dual

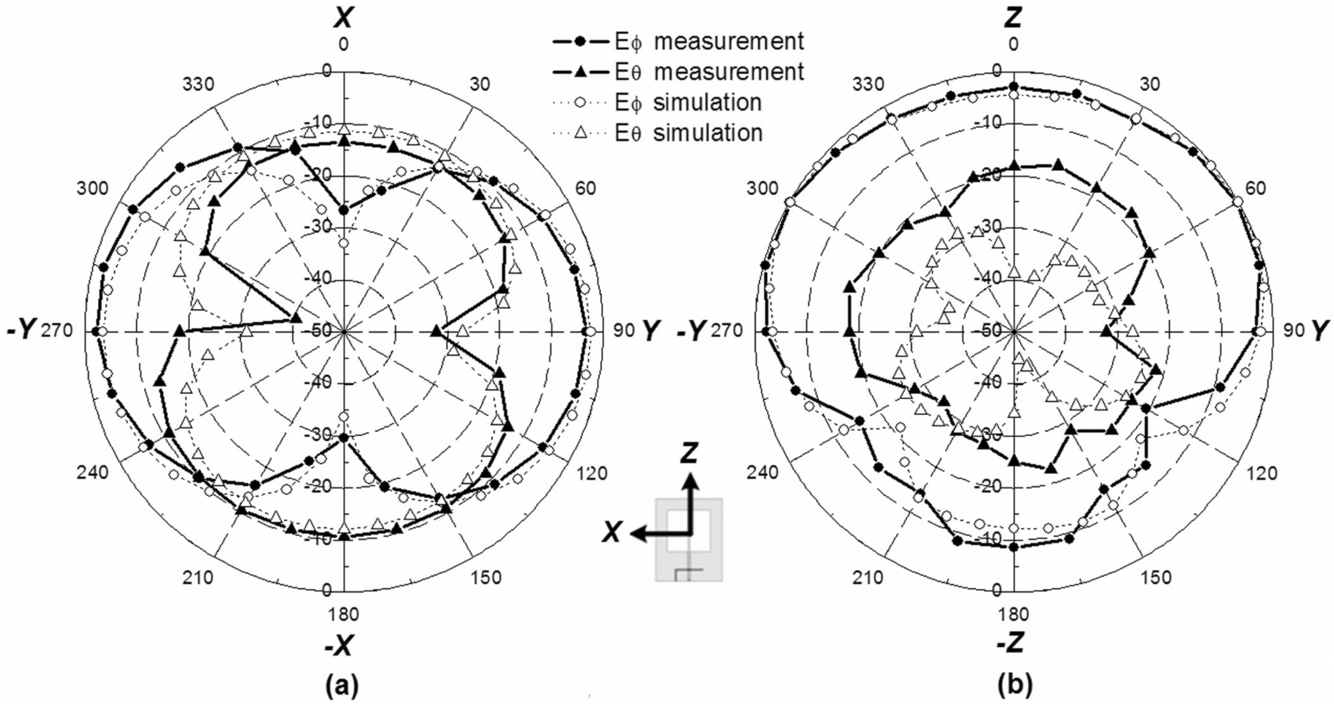

Fig. 6. Measured and simulated radiation patterns when feeding from port 1 at 2.4 GHz: (a) *xy* plane and (b) *yz* plane.

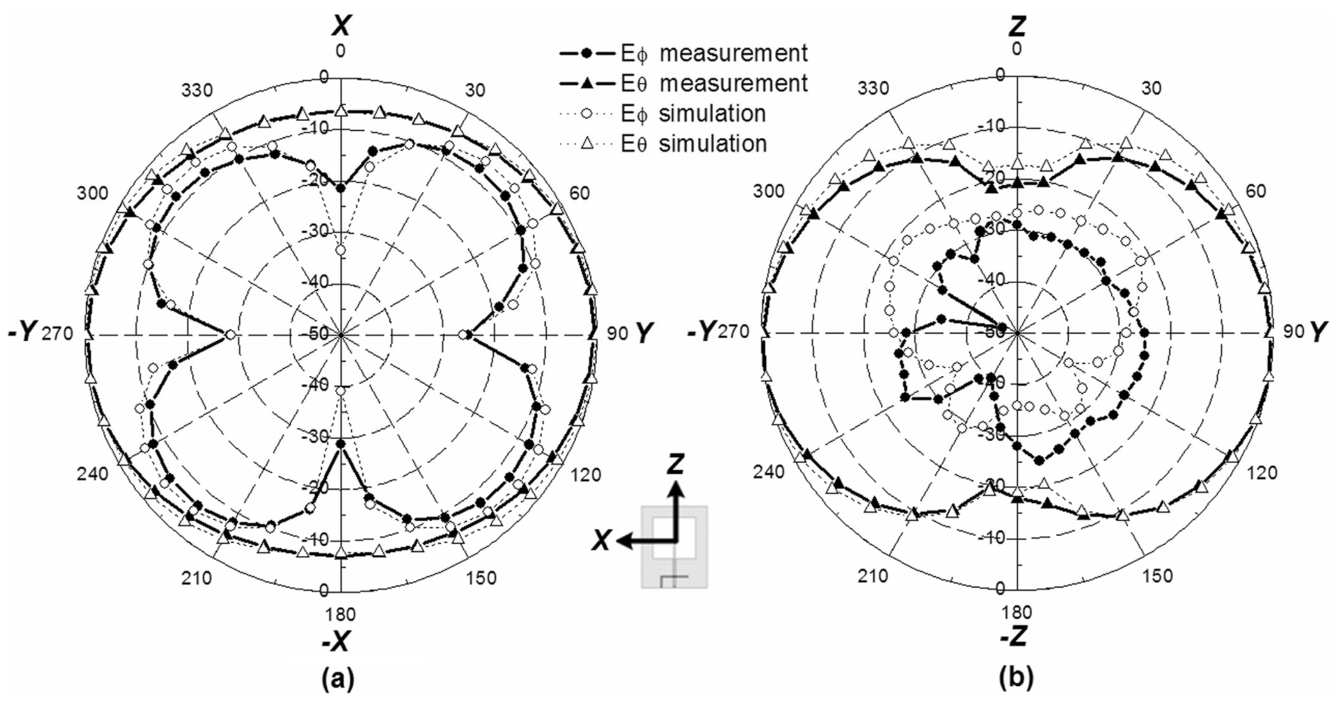

Fig. 7. Measured and simulated radiation patterns when feeding from port 2 at 2.4 GHz: (a) *xy* plane and (b) *yz* plane.

polarizations are both 2.4 GHz. The bandwidths of −10-dB reflection coefficient are 670 (1.96–2.63 GHz, 27.9%) and 850 MHz (1.93–2.75 GHz, 35.4%) for port 1 (horizontal polarization) and port 2 (vertical polarization), respectively. Throughout the WLAN frequency band (2.4–2.484 GHz), the worst case of reflection coefficient value for ports 1 and 2 is -19.2 dB. The isolation between two ports in the required band is lower than −32.6 dB. These results show that the proposed antenna has almost the same performance as the antennas in [2]–[6], but the structure is simpler and more compact, and higher isolation values were achieved.

The radiation patterns of the proposed antenna when feeding from ports 1 and 2 are shown in Figs. 6 and 7. For port 1, the horizontal polarization is the dominant polarization. The 3-dB beamwidths are 60° and 180° in E-plane (*xy* plane) and H-plane (*yz* plane), and cross-polarization levels are lower than 8.9 and

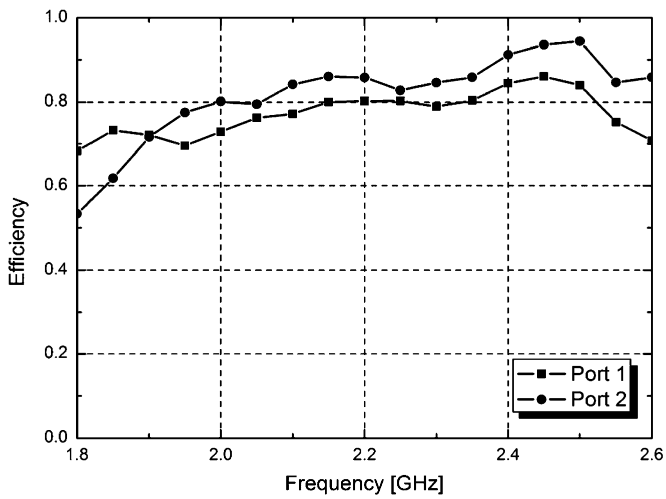

Fig. 8. Measured radiation efficiency of the proposed antenna.

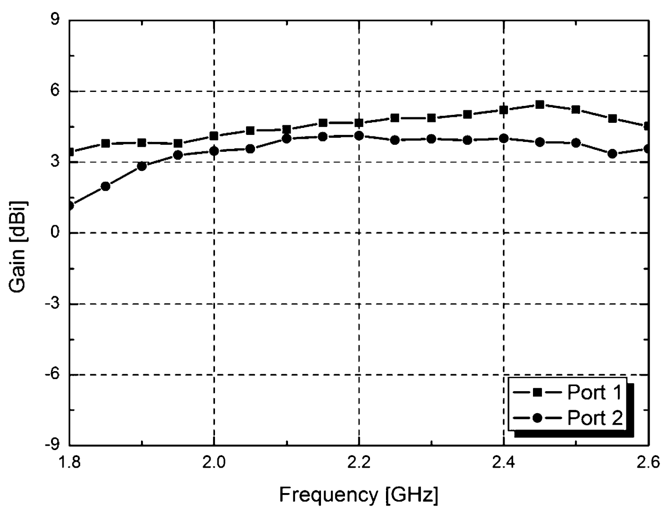

Fig. 9. Measured gain of the proposed antenna.

15.2 dB in E- and H-plane, respectively. For port 2, the vertical polarization case, the 3-dB beamwidths are 100° and 70° in E-plane (*yz* plane) and H-plane (*xy* plane), and cross-polarization levels are lower than 22.3 and 5.6 dB in E- and H-plane, respectively. From these results, it may be noted that the cross polarization in *xy* plane is worse than what was achieved in earlier designs as values for cross polarization are not lower than -15 dB. From the radiation patterns, however, we can observe that the poles of E_{φ} and E_{θ} are almost corresponding to the maximum of each other, which means the integration of the two patterns is close to zero. In other words, the signals of co- and cross polarizations are almost uncorrelated. In the *yz* plane, the cross-polarization level is sufficiently low to be ignored. From the above discussion, we may conclude that the signals received by the two ports are uncorrelated, so dual polarization in single antennas can be treated as two independent antennas.

The radiation efficiency and gain of the proposed antenna are also measured. The results are shown in Figs. 8 and 9, respectively. In the WLAN band of 2.4–2.484 GHz, the efficiency is better than 84.4% and 91.2% for ports 1 and 2; the gain is better than 5.21 and 3.85 dBi for ports 1 and 2. When exciting from port 1, the vertical strip inside the slot aperture does have some impact on the radiation pattern, which can be observed in Fig. 6(b). The radiation pattern slightly tilts toward the $+z$-direction, which explains why the horizontal mode has higher gain.

IV. CONCLUSION

In many multiple-antenna applications including those based on diversity implementation and MIMO systems, it is desirable to develop a one two-port dual-polarization antenna with wide bandwidth and high isolation between ports. To meet these specifications, this letter proposes a dual-polarization CPW-fed slot antenna. The dual-polarization radiation can be excited by the odd and even modes of the same CPW feed line. The antenna has been designed, and a prototype has been built and tested. Obtained results show bandwidths of the two polarizations are 670 (27.9%) and 850 MHz (35.4%) for both polarizations with reflection coefficient better than -10 dB. The isolation between two ports in the WLAN band is lower than -32.6 dB. From simulated and measured radiation patterns, the signals received by the two ports are proved to be uncorrelated. The radiation efficiency is better than 84.4% and 91.2%, and the gain is better than 5.21 and 3.85 dBi.

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