Communications

Design of Dual-Polarized Monopole-Slot Antenna With Small Volume and High Isolation

Yue Li, Zhijun Zhang, Jianfeng Zheng, and Zhenghe Feng

***Abstract*—A compact monopole-slot antenna with polarization diversity is proposed for wireless local area network (WLAN) applications. Dual polarization is provided by a ground-folded monopole and a slot cut from the folded ground. The total volume of the proposed antenna is only 50 × 16 × 16 mm^3 ($0.4\lambda_0 \times 0.128\lambda_0 \times 0.128\lambda_0$). However, low mutual coupling is achieved due to the orthogonal modes of current distribution on the ground. A prototype of the proposed antenna is built and tested. The obtained results include the S parameters, radiation patterns and radiation gain. The results from our presentation match with the simulation and demonstrate an isolation better than −36 dB in the required band.**

***Index Terms*—Antenna diversity, monopole antennas, mutual coupling, slot antennas.**

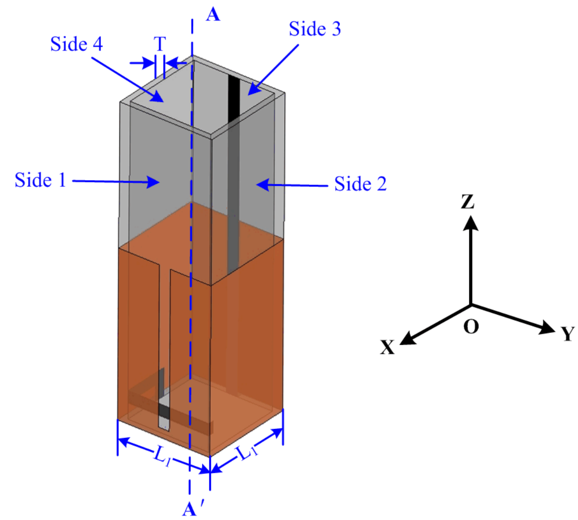

Fig. 1. 3-D Geometry of the proposed antenna.

I. Introduction

In modern wireless communication systems, the antennas providing polarization diversity are widely studied and adopted, especially for the multi-input multi-output (MIMO) application. Multi-polarization antennas with high isolation are able to mitigate multi-path fading and polarization mismatch between the transmitter and receiver. The benefit in special efficiency has already been validated by this type of antennas in many scenarios indoor and outdoor [1], [2].

To fulfill the increasing demand of channel capacity, several types of dual-polarization antennas have been designed and published in recent papers [3]–[10], including the patch antenna [3]–[6], slot antenna [7], [8], loop antenna [9] and patch-loop hybrid antenna [10]. All of the radiating elements can support two orthogonal modes with low mutual coupling. However, the ports isolation, the key issue of dual-polarization antennas, is also dictated by the feeding structure. For example, two orthogonal pairs of differential feed are used in [4]–[6]. And the even and odd modes of a compact CPW feeding are adopted in [7], [9] to reduce the mutual coupling between dual polarizations. Therefore, by appropriately designing the radiating element and the feeding structure, isolation better than 20 dB is realized in the [3]–[10].

In this communication, another design of high-isolation dual-polarized antenna is presented, built and tested for WLAN applications. The proposed antenna consists of a monopole with a folded ground and a slot cut from the folded ground, generating vertical and horizontal polarizations separately. The current distributions for dual polarizations on the shared ground are orthogonal with very low mutual coupling. The measured −10 dB bandwidths of dual polarizations both cover the required frequency band of 2.4–2.48 GHz, with the ports isolation lower than −36 dB. This communication aims to achieve high isolation in a relative small volume of 50 × 16 × 16 mm^3 ($0.4\lambda_0 \times 0.128\lambda_0 \times 0.128\lambda_0$, λ_0 is the wavelength in the free space). Due to this property, the proposed antenna is suitable for the space-limit systems, especially for portable access points, where the antennas of [3]–[10] are unable to mount.

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II. Antenna Design and Configuration

A. Antenna Configuration

Fig. 1 shows the geometry of the proposed dual-polarized antenna, a center-hollow cuboid made of FR4 substrate ($\varepsilon_r = 4.4, \tan\delta = 0.01$), with the thickness of $T = 1$ mm and expressed in gray color. The orange area is folded ground on the outer side of the substrate, and the black area shows the monopole and microstrip line on the inner side. The overall dimensions are 50 × 16 × 16 mm^3. A planer view of the proposed antenna cutting along the trace AA′ is shown in Fig. 2. The antenna is composed of a monopole with the ground folded and a slot cut from the ground on the opposite side of the monopole. The slot is fed through a 50 Ω open-ended microstrip line on the back side by capacitive coupling. When the antenna is fed through port 1, the monopole is excited for vertical polarization. When the antenna is fed through port 2, the slot is excited for horizontal polarization.

The operating frequency and the impedance matching are important issues for both polarizations. For the monopole mode, the frequency is determined by the length L_m, approximately a quarter of wavelength on the substrate. Wide bandwidth can be achieved by tuning the feeding microstrip line to 50 Ω. For the slot mode, the folded ground can be treated as a back cavity. The dimension of the ground and the length of slot determine the working frequency. Due to the cavity effect, the space L_1 also affects the bandwidth of slot mode. As discussed in [7],

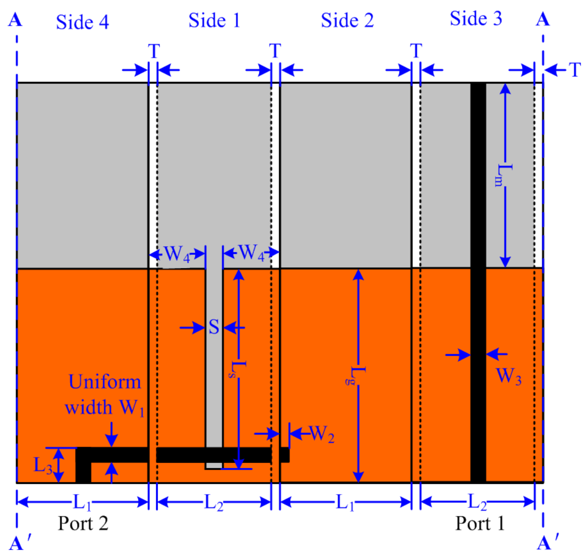

Fig. 2. Detailed dimensions in the planar view of the proposed antenna.

TABLE I
DETAILED DIMENSIONS OF THE PROPOSED ANTENNA

Parameter	L_1	L_2	L_3	L_m	L_g	L_s
Value (mm)	16	14	4.5	23	27	25.5
Parameter	S	W_1	W_2	W_3	W_4	T
Value (mm)	1.9	1.9	1	1.9	7.05	1

[9], the position and the length of the feeding microstrip line are also tuned for impedance matching. The key parameters are optimized by using the Ansoft High Frequency Structure Simulator (HFSS) software. And the detailed optimized values of each parameter are listed in Table I. If L_1 decreases for even smaller volume, the bandwidth of slot mode deteriorates and its operating frequency will also shift higher.

B. Isolation Analysis Between Working Modes

The isolation between the monopole mode and the slot mode will be discussed in this section. For two orthogonal modes, the mutual coupling is mainly derived from the shared ground. The current distributions for both modes are simulated and shown in Fig. 3. When the antenna is fed through port 2, the current of the slot mode is horizontal at the monopole located ground. When the antenna is fed through port 1, the current of the monopole mode is in phase on the opposite sides of the slot. The mutual coupling of two modes is very low. Another equivalent model is used to explain the good isolation between two modes. Seen from the Fig. 3, the current is concentrated on the edge of the ground and the slot. Therefore, the slot and the ground can be treated as a loop model with a narrow part and a wide part, as shown in the Fig. 4. The current distributions of the two modes on the loop model are totally orthogonal, illustrating good isolation property.

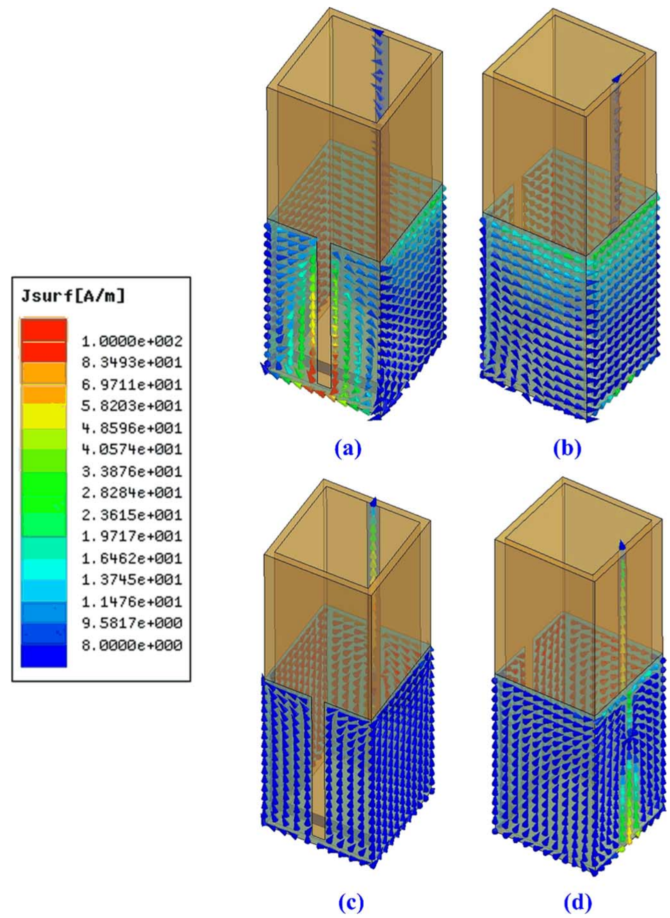

Fig. 3. Current distribution in the proposed antenna at 2.44 GHz: (a) front view fed through port 2, (b) back view fed through port 2, (c) front view fed through port 1, (d) back view fed through port 1.

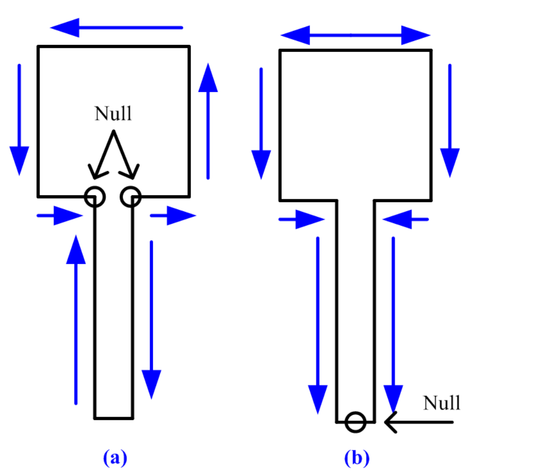

Fig. 4. Current distribution along the edge of ground of Fig. 3 fed through: (a) port 2, (b) port 1.

III. ANTENNA FABRICATION AND MEASUREMENT RESULTS

In order to demonstrate the validity of the design strategy, a prototype of the proposed antenna was built, as shown in Fig. 5. The measured S parameters are shown in Fig. 6, compared with the simulated results. For the simulation, the isolation is better than -45 dB in the desired band of 2.4–2.48 GHz. The measured isolation is lower than -36 dB. Once again, the high isolation has been achieved in very small volume of $50 \times 16 \times 16$ mm^3. The measured -10 dB bandwidth of reflection coefficients are 2.25–3.15 GHz and 2.37–2.53 GHz, both covering the WLAN band of 2.4–2.48 GHz.

In Fig. 6, the difference between simulated and measured results is mainly contributed from two fabrication factors. The first one is the symmetry of the structure and the other one is the usage of SMA. If the slot center is away from the center of side 1, the isolation will deteriorate. The soldered SMA can be treated as an extension of the ground, which will vary the impedance matching of the monopole mode.

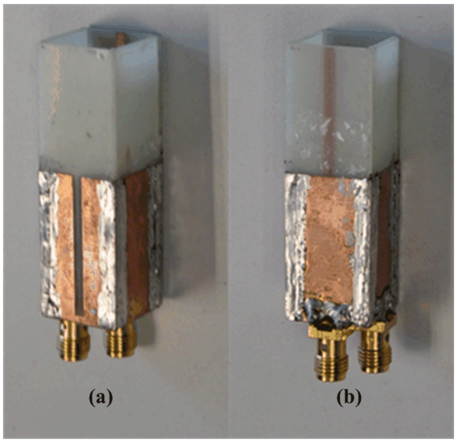

Fig. 5. Photo of the proposed antenna: (a) side 1 and 2, (b) side 3 and 4.

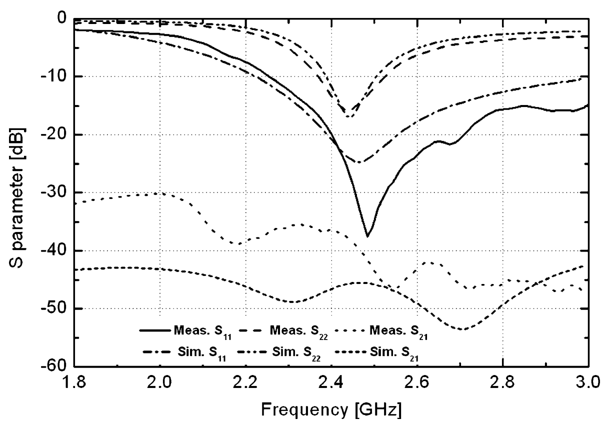

Fig. 6. Simulated and measured S parameters of the proposed antenna.

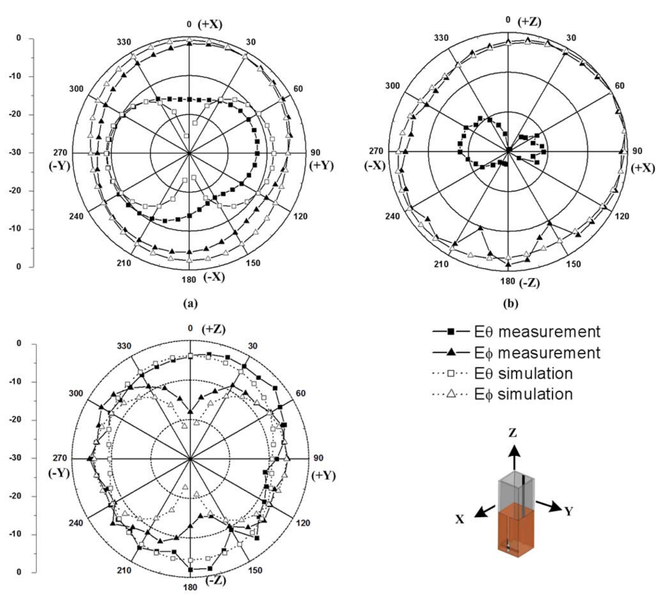

Fig. 7. Simulated and measured radiation patterns of the proposed antenna fed through port 1 at 2.44 GHz: (a) X-Y plane, (b) X-Z plane, (c) Y-Z plane.

The measured and simulated radiation patterns at 2.44 GHz are shown in Figs. 7 and 8. For the monopole mode in Fig. 7, a nearly

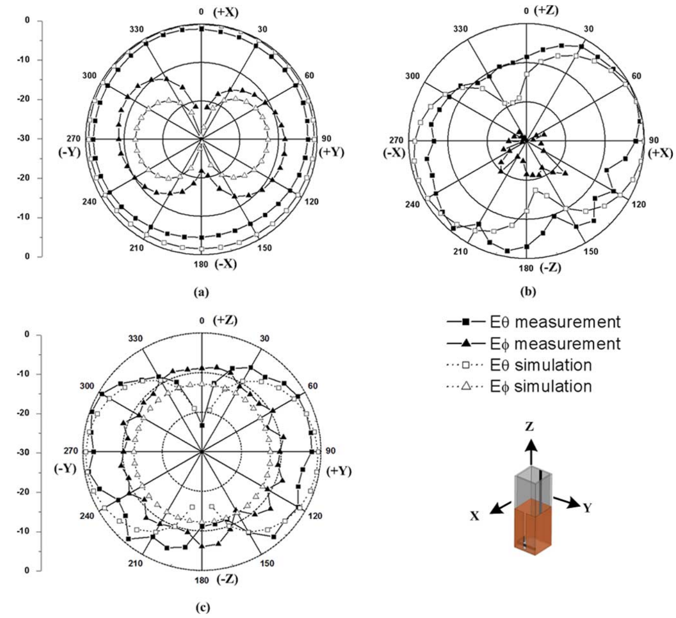

Fig. 8. Simulated and measured radiation patterns of the proposed antenna fed through port 2 at 2.44 GHz: (a) X-Y plane (b) X-Z plane (c) Y-Z plane.

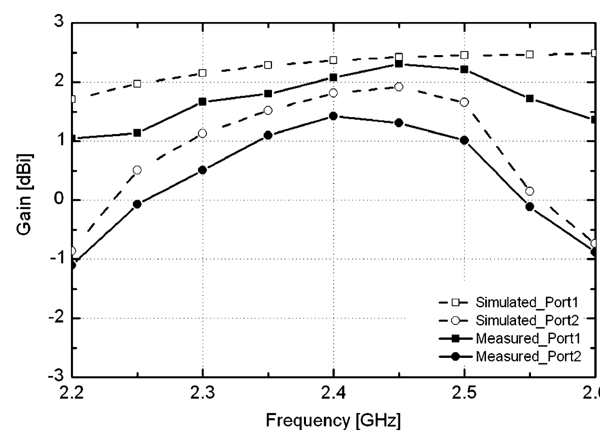

Fig. 9. Simulated and measured radiation gain of the proposed antenna.

omni-directional pattern appears in the H-plane (X-Y plane). A tilt appears in the E-plane (X-Z plane) due to the asymmetric structure of the monopole and the ground. As mention above, the soldered SMA in Fig. 5 can be treated as an extension of the ground, and results in the difference between the simulation and measurement. For the slot mode in Fig. 8, the measured results also agree well with the simulation. Due to folded ground, the electric field propagates along the metal to the back side. Compared with unidirectional radiation pattern of patch antenna in [3]–[6], [10] and bidirectional radiation pattern of no-ground slot or loop antenna in [7]–[9], there is no null in the azimuth plane (E-plane) of the proposed antenna for both polarizations.

The measured gains of dual polarization are shown in Fig. 9, together with the simulation results. In the required WLAN band of 2.4–2.48 GHz, the measured gains are better than 2.1 dBi and 1.1 dBi for vertical and horizontal polarizations, observed at $\theta = 70^\circ$ and $\theta = 60^\circ$ in the X-Z plane. The gain difference between dual polarizations is due the return loss. The gain difference between simulated and measured results mainly comes from the cable loss and fabrication error.

IV. Conclusion

A compact dual-polarized monopole-slot hybrid antenna is proposed for the WLAN application in this communication. The vertical polarization is provided by the monopole with folded ground, and the horizontal polarization is provided by the slot cut from the folded ground. Good isolation is analyzed based on the current distribution on the equivalent loop model. A prototype of the proposed antenna is built to validate the design idea. The required band of 2.4–2.48 GHz is covered with -10 dB reflection coefficient by both polarizations. And the -36 dB isolation is realized in very small volume of $50 \times 16 \times 16$ mm^3. Due to the merits of compact dimension and high isolation, the proposed dual-polarized antenna shows the potential use for the space-limiting systems.

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Printed Hybrid Lens Antenna

Nicolas Gagnon, Aldo Petosa, and Derek A. McNamara

***Abstract*—A novel printed hybrid lens antenna made of a 2-layer phase shifting surface (PSS) has been developed. It is a hybrid lens because the required operation is achieved by a combination of true phase correction (similar to a conventional lens, and previously reported PSS phase-correcting lenses) and amplitude-only correction (similar to a Fresnel zone plate). A prototype is fabricated and measured, revealing that the hybrid lens antenna has roughly twice the aperture efficiency of a Fresnel zone plate, and half that of a conventional lens. It provides an attractive compromise between performance, fabrication complexity and cost.**

***Index Terms*—Lens antennas, phase shifting surface.**

I. Introduction

Recently, techniques for realizing thin lenses have been the subject of several studies [1]–[8]. Among these techniques, the so-called phase shifting surface (PSS) concept is of particular interest since it allows for realizing relatively low-cost phase-correcting devices made of a few layers that are in total roughly one tenth of a free-space wavelength thick $(\lambda_0/10)$. A minimum of three conductive layers, resulting in a 3-layer PSS, have been shown to achieve a large enough phase shift range for realizing highly satisfactory lenses using this concept. Such a lens antenna has superior performance to a Fresnel zone plate (FZP) antenna. However, when compared to an FZP, the necessity of having to align and bond two separate dielectric layers makes the 3-layer PSS phase-correcting lens the more expensive option of the two. Nevertheless, it remains significantly inexpensive compared to a traditional shaped lens to which it has a similar performance [1].

If a PSS phase-correcting type lens antenna could be realized using only two conductive layers, the fabrication process would be simplified and less costly, merely requiring conductive patterns to be printed on the front and back of a single double-sided dielectric layer. However, since we have already shown [1], [3] that at least a 3-layer PSS is necessary to achieve a phase shift range close to 360°—which is the minimum requirement for a complete phase correction—a performance penalty is expected. To overcome the fact that a phase shift range of significantly less than 360° will be achieved with a PSS made of fewer than three conductive layers, this communication proposes to combine phase-only correction with amplitude-only correction in order to achieve a lens device based on a 2-layer PSS configuration. This concept leads to the design of what we have called a *hybrid lens*, where the term *hybrid* is selected to highlight the fact that a combination of two different concepts—namely phase correction and amplitude correction—are used for achieving the desired focusing/collimation function.

The communication is organized as follows. Section II presents the 2-layer phase shifting surface used to realize the hybrid lens.

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