A Wideband High-Isolated Dual-Polarized Patch Antenna Using Two Different Balun Feedings

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***Abstract*—In this letter, a dual-polarized patch antenna with low profile and wide bandwidth is presented. The square patch, where a bow-tie slot is etched on, is excited by two different balance-to-unbalance feedings for dual polarization. One of the polarizations is excited by the central-placed transition, which transfers the unbalanced microstripline feed to the balanced slot feed. The other polarization is excited by a differential feed network, which contains two capacitively coupled probe feeds. By adopting the two balanced feedings, high isolation and low cross polarization are achieved. A prototype of the proposed antenna is built and tested. Measured results show that the −10-dB reflection coefficient bandwidth of the two polarizations is about 18.8%, with port isolation less than −28.5 dB.**

***Index Terms*—Baluns, dual-polarized antennas, microstrip antennas.**

I. Introduction

RECENTLY, dual-polarized antennas are being widely used as polarization diversity schemes in modern wireless communication systems [1]. The patch antenna is an attractive candidate for dual polarization owing to its characteristics of high gain and low cost. The basic idea of dual-polarized patch antennas is to excite two orthogonal modes of the patch with two different feed networks. In order to improve the impedance bandwidth, an air-gap layer is usually added between the radiated patch and the ground plane.

In the last decades, various dual-polarized patch antennas have been proposed [2]–[9]. Based on the operating principle of feed networks, these antennas can be categorized into different types: aperture-coupled feed [2]–[4], probe direct or coupled feed [5][6], or the hybrid feed of aperture and probe [7]–[9]. Among them, aperture-coupled feed is popular for its design flexibility. For example, the two feed networks can be two orthogonal H-shaped slots [2], a rectangular slot and a C-shaped slot [3], or a single square-ring slot [4]. However, the aperture-coupled feed has the drawback of high backlobe radiation. Good front-to-back (FB) ratio can be obtained by adopting a probe feed. For example, in [6], the square patch is excited by two pairs of L-shaped probes. The measured FB ratio is higher than 15 dB.

In order to further decrease cross-polarization levels (XPLs) and increase port isolation, balanced feed network is widely used. One typical balanced feed network is the differential feed system, which is adopted by most of the designs mentioned above. Designing two such differential feed networks in a single layer is complicated and will cause gain loss. A simple approach is to replace one of the differential feed networks with a single central-placed balanced feed network. For example, in [8], two capacitively coupled probe feeds and a central-placed slot-coupled feed are proposed.

In this letter, a novel balance-to-unbalance transition for cross-polarization suppression and broadband dual-polarized operation is proposed. The transition transfers an unbalanced microstripline feed to a balanced slot feed and is placed at the central part of the patch. Apart from the mode excited by the transition, another orthogonal mode of the patch is excited by a typically differential probe proximity feed network. The two-balun structure, bandwidth, isolation, radiation patterns, XPLs, gain, and FB ratio have been analyzed in detail.

II. Antenna design

Fig. 1 shows the geometry of the proposed dual-polarized patch antenna. The designed antenna consists of three FR4 substrates: the upper horizontal substrate (#1), the middle vertical substrate (#2), and the bottom horizontal substrate (#3). The air gap between substrates #1 and #3 is determined by the width of substrate #2. All the three substrates have the same thickness of 0.8 mm, also with the same property ($\varepsilon_{\rm r} = 4.4, \tan\delta = 0.02$). A microstrip-to-slot transition is printed on substrate #2, as shown in Fig. 1(b). Both the T-shaped slot and the folded microstripline have a uniform width of 1 mm, The vertical ground plane is connected with the horizontal ground plane on substrate #3, where a differential feed network is printed, as shown in Fig. 1(c). The length difference of the two feed arms is about $\lambda/2$. A square patch and two strips are printed on the two sides of substrate #1, as shown in Fig. 1(d). A bow-tie slot is etched on the patch, which is shorted to the vertical ground plane via two metal pins at the center. The two strips are connected with points B and b via two probes. The dimensions of the proposed antenna are optimized by Ansoft HFSS, and the values of the key parameters are listed in Table I.

The differential feed network of port 1 consists of a power divider and a half-wavelength delay line, so that the two signals at points B and b have equal amplitudes and a phase difference of 180°. A quarter-wavelength impedance transformer is used

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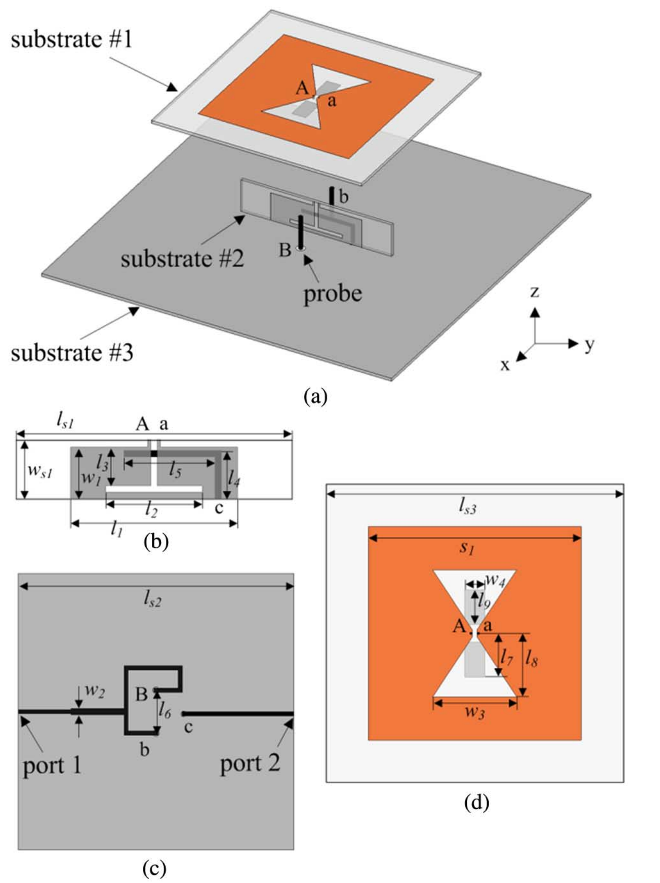

Fig. 1. (a) Geometry of the proposed antenna. (b) Dimensions of substrate #2. (c) Dimensions of substrate #3. (d) Dimensions of substrate #1.

TABLE I
DETAILED DIMENSIONS (UNIT: MILLIMETERS)

l_{s1}	w_{s1}	l_{s2}	l_{s3}	l_1	w_1	l_2	l_3	l_4
43	9.2	100	60	26	8	15	6	7.5
l_5	l_6	w_2	l_7	l_8	s_1	w_3	l_9	w_4
14.2	15.6	2.3	8.8	12.8	43	17	7	4

to achieve good impedance match. Consequently, an x-directed polarization of the radiated patch can be excited symmetrically through port 1, as shown in Fig. 2(a). Port 2 is extended by a 50-Ω microstripline and is connected to the feedline on substrate #2 via a hole in the horizontal ground plane. The feed network on substrate #2 is an unbalance-to-balance transition, where the unbalanced microstripline feed can be transferred into a balanced slot feed, which couples energy to the bow-tie slot on the patch. Consequently, a y-directed polarization of the radiated patch can be excited symmetrically through port 2, as shown in Fig. 2(b). Since the transition for port 2 is placed at the field null of the x-directed polarization and the two orthogonal polarizations are balance fed, high isolation and low cross polarization can be obtained.

III. EXPERIMENTAL RESULTS

Fig. 3 shows the photograph of the fabricated antenna. Four parasitic screws are used to fix the two horizontal substrate layers. The simulated and measured S-parameters of the

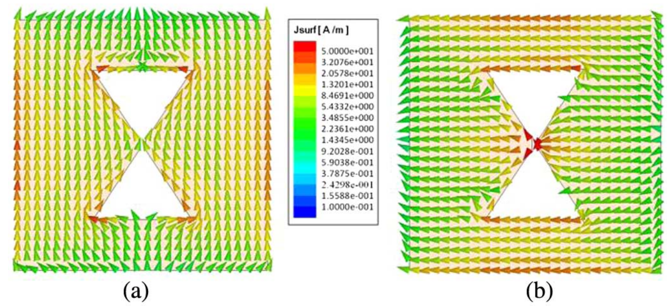

Fig. 2. Current distribution of the radiated patch at 2.4 GHz: fed from (a) port 1 and (b) port 2.

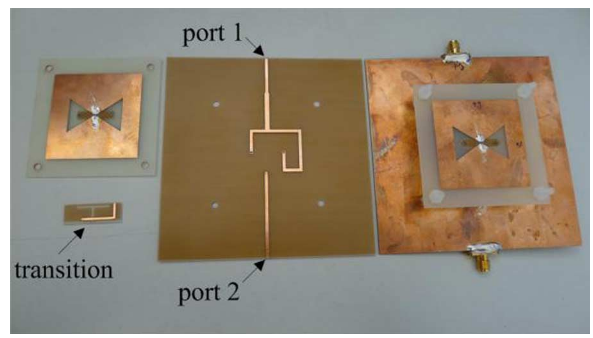

Fig. 3. Photograph of the proposed antenna.

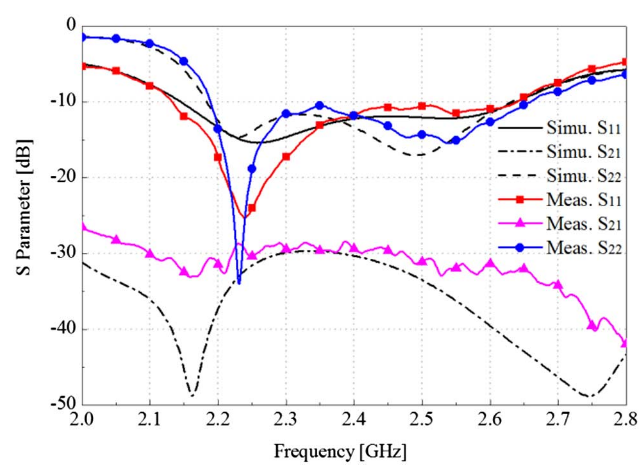

Fig. 4. Simulated and measured S-parameters.

proposed antenna are plotted in Fig. 4. It is shown that the measured -10-dB reflection coefficient bandwidth of port 1 is 506 MHz (2.133–2.639 GHz), or about 21.1% corresponding to 2.4 GHz. The measured -10-dB reflection coefficient bandwidth of port 2 is 471 MHz (2.189–2.66 GHz), or about 19.6%. Therefore, the overlapped bandwidth of ports 1 and 2 is about 18.8% (2.189–2.639 GHz). It is also observed that the measured isolation for frequencies across the concerned bandwidth is less than -28.5 dB.

Fig. 5 plots the simulated and measured normalized E-plane and H-plane radiation patterns at 2.4 GHz for port-1 and port-2 excitations. Symmetric radiation patterns with low XPLs are observed. The measured XPLs in yz-plane are a little higher than the simulated results. This difference mainly comes from the imperfect assemble of the proposed antenna. For port-1 excitation,

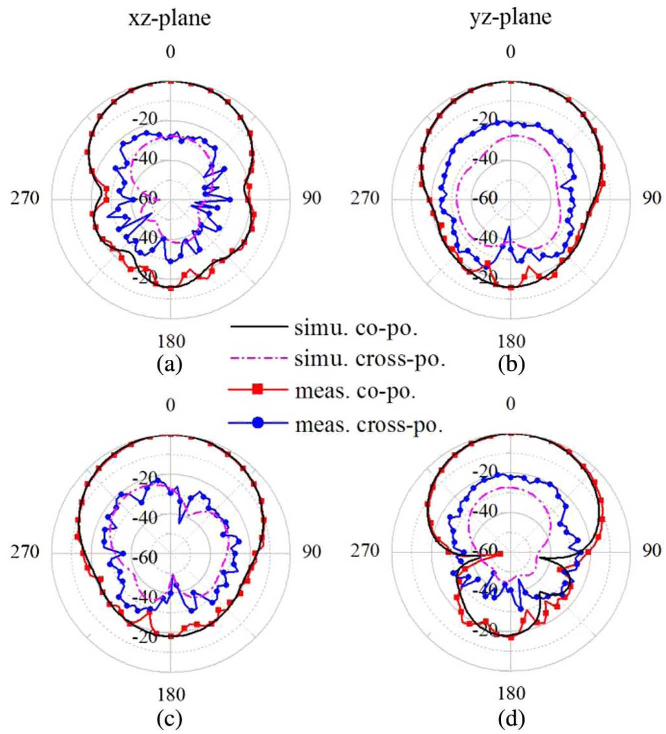

Fig. 5. Simulated and measured normalized radiation patterns at 2.4 GHz. (a) E-plane for port 1. (b) H-plane for port 1. (c) H-plane for port 2. (d) E-plane for port 2.

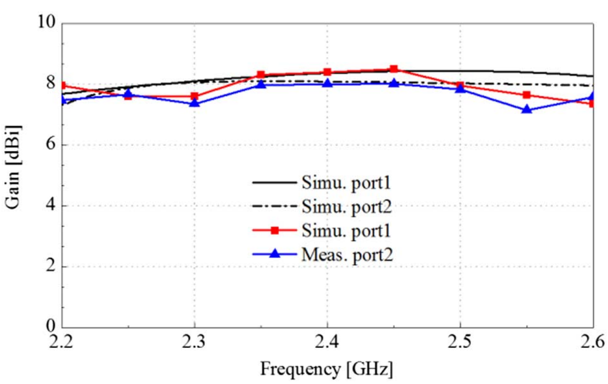

Fig. 6. Simulated and measured gain of the proposed antenna.

the measured XPLs in E-plane and H-plane are less than -23 and -20 dB, respectively. For port-2 excitation, the measured XPLs in H-plane and E-plane are less than -21 and -20 dB. The measured FB ratio of ports 1 and 2 is larger than 15 and 17 dB, respectively. Fig. 6 shows the simulated and measured gains for ports 1 and 2. The measured gain in the broadside direction for ports 1 and 2 excitation at 2.4 GHz is about 8.4 and 8.0 dBi, respectively, also with the gain variations of ports 1 and 2 less than 1 dBi. A comparison of the proposed antenna

TABLE II
COMPARISON OF DUAL-POLARIZED PATCH ANTENNAS

Antennas	$h_d(\lambda)$	bandwidth (%)	isolation (dB)
[2]	0.093	20	< -34
[6]	0.102	23.8	< -30
[7]	0.085	14.5	< -40
[8]	0.081	13.1	< -32
[9]	0.08	14	< -40
proposed	0.08	18.8	< -28.5

with other dual-polarized patch antennas is listed in Table II. It is shown that the proposed antenna has the merits of low profile and wide bandwidth. In addition, the isolation performance of the proposed antenna is sufficient in practical applications.

IV. CONCLUSION

A novel dual-polarized patch antenna design is presented in this letter. Two different baluns—one is a central-placed transition, and the other is a differential system—are adopted to excite the slot-etched patch orthogonally. The transition, which transfers the unbalanced microstripline feed to the balanced slot feed, is placed at the field null of the x-directed polarization for high isolation. Experimental results show that a -10-dB reflection coefficient bandwidth of 18.8% is achieved at both the two ports, with port isolation less than -28.5 dB. Symmetrical radiation patterns, low XPLs in both E- and H-planes, stable gain, and high FB ratio are also obtained.

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