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DESIGN OF DUAL-FEED DUAL-POLARIZED MICRO-STRIP ANTENNA WITH HIGH ISOLATION AND LOW CROSS POLARIZATION

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Abstract—A broadband dual-feed dual-polarized microstrip antenna with low cross polarization and high isolation is presented. The dual-orthogonal linearly polarized mode is excited by two different feed mechanisms from a single circular radiating patch. One of the two modes is excited by a pair of L-shaped probes with a 180° phase differences, and the other is excited by an H-shaped aperture. The proposed design has a very simple antenna structure with a wide input impedance bandwidth (23.25% for Port 1 and 35% for Port 2) and also its two input port isolation is found to be as low as −40 dB. Measured results of the fabricated antenna prototypes are also carried out to verify the simulation analysis.

1. INTRODUCTION

Dual-polarized antennas have been increasingly concerned for the wireless services and mobile subscribers due to the frequency reuse and polarization diversity [1]. Besides, the polarization sensitivity of the antenna is mitigated by utilizing the dual-polarized antennas. However, it is difficult to achieve high isolation between two input ports and low cross polarization for dual linear polarizations simultaneously [2]. Various techniques of the matching skills in microstrip antennas have been presented for dual-polarized applications in the last two decades, such as the L-probe [2, 3], and the aperture coupled feed methods [4–8]. Since the currents on the feeding probes may cause obvious cross-polarization radiations [9, 10], the discrimination between the two linear polarizations can thus be

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degraded. Several methods to reduce the cross polarization have been demonstrated. By utilizing L-probe feeds, a patch antenna with input impedance bandwidth of nearly 24% and isolation over 30 dB can be obtained [2]. With the use of aperture-coupled feeds, a high-isolation antenna with bandwidth of more than 14% is achieved [7]. If only the cross polarization at each port is suppressed, the isolations will certainly be improved. In addition, the isolation can be further improved by utilizing a two hybrid input ports structure [11].

In this paper, we use a circular patch as the dual-polarized radiator. The dual-orthogonal linear polarizations are generated by an L-shaped coupling probe and an H-shaped coupling aperture. As the L-shaped coupling probe provides additional capacitance between the probe and circular patch to compensate the large inductance associated with the probe feed [11]. It also increases the distance between the circular patch and ground, and reduces the value of radiation quality factor Q. Simultaneity, the H-shaped aperture has high resonant impedance implying large coupling, hence a smaller aperture can be used which will reduce the spurious back radiation through the aperture [12]. By further using a pair of L-shaped coupling probe feeds placed along the same resonant direction and at symmetric positions with respect to the patch center, some unwanted higher order modes that contribute to polarization impurity can be suppressed. The probe radiation can be further reduced if the straight probe is replaced by L-probe. By properly arranging the feed-lines, H-shaped aperture and L-probe, the radiation characteristics of wide band, high isolation can be achieved.

The isolation between the two feeding ports is less than 40 dB across an input impedance bandwidth of 23.25%, which is much better than [11] (14%). It is still worth pointing out that, although the proposed design has a very simple antenna structure, the other parameters such as cross polarization and gain are even better than [11]. As both feeding ports are operating at around 2.4 GHz with a wide impedance bandwidth, the proposed antenna structure is suitable for WLAN application or mobile wireless base stations. Details of the design consideration are described and discussed along with the analyses of surface current distributions and radiation characteristics.

2. ANTENNA DESIGN AND ANALYSIS

2.1. Single L-shape Probe Feeding Antenna

As is shown in Fig. 1(a), we initially design an antenna with H-shaped aperture and a single L-probe feeding for operation at around 2.4 GHz.

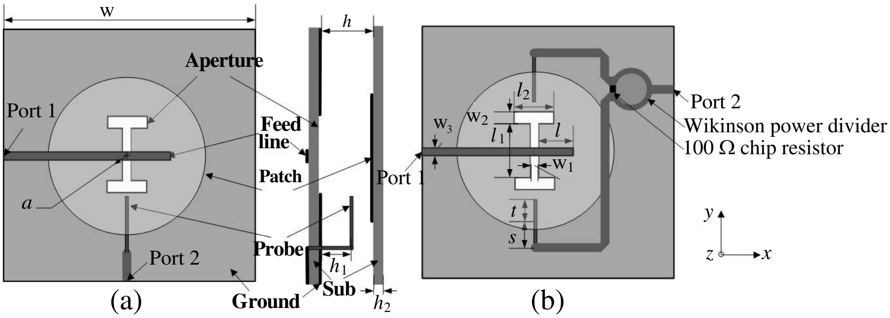


Figure 1. Geometry of the proposed dualpolarized antenna. (a) Bottom view and side view of single L-shaped probe feeding antenna; (b) Bottom view of differential feeding antenna.

The optimum performance of the proposed antenna is achieved by the parametric studies carried out by Ansoft HFSS version 12.

The feeding networks and input ports of the antenna are printed on one side of the bottom substrate, and on the other side is a ground plane embedded with H-shaped coupling aperture. The circular radiating patch printed under the top substrate is located 12 mm above the ground plane. All of them are fabricated on the same type of substrate with thickness $h_2 = 1\,\text{mm}$, relative loss tangent $\tan\delta = 0.001$ and permittivity $\varepsilon_r = 2.2$. An L-shaped probe which has vertical height h_1 and level length t is fixed between the radiating patch and ground plane. The rectangle feeding line of Port 1 and the coupling aperture in the ground plane form an aperture coupled feeding mechanism to excite a directed polarization mode. As for Port 2, its feeding network consists of a feeding line and a single L-shaped probe.

The proposed design has a wide impedance bandwidth, high isolation for both ports as illustrated in Fig. 3. Despite port 1 has obtained a low lever cross polarization, the cross polarization of port 2 in this arrangement becomes very poor at angles greater than 10° of broadside direction in the x-z plane as illustrated in Fig. 2. This is caused by the spatial phase delay ($\Delta\phi' = k_0 \Delta x \sin\theta$) formed between the symmetrical transverse currents at x-direction shown in Fig. 4. Consequently, the spatial phase delay resulted in the poor cross polarization quality at angles off broadside.

2.2. Differential Feeding Antenna

In order to reduce the cross polarization of port 2, we design another antenna with differential feeding as is shown in Fig. 1(b). A Wilkinson

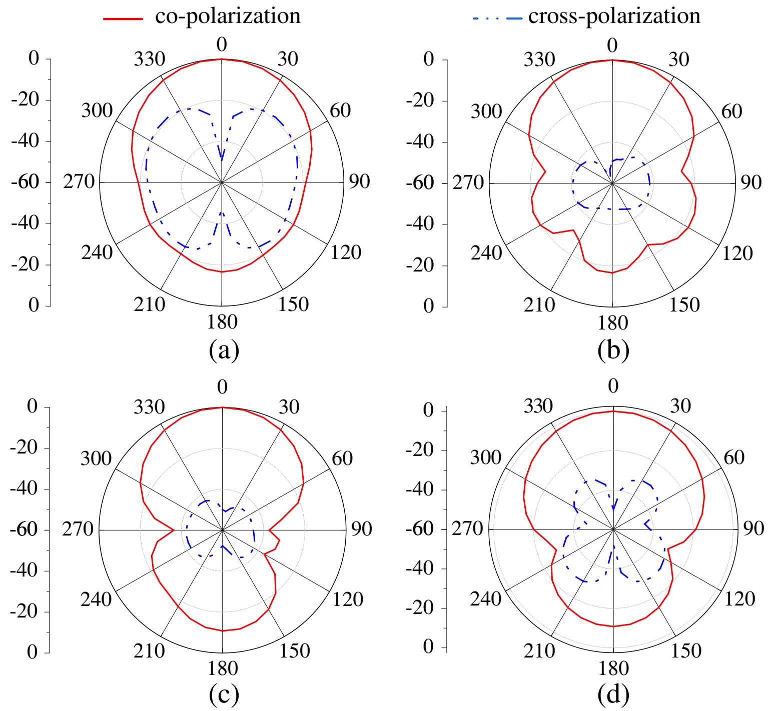


Figure 2. Simulated radiation patterns at 24 GHz for Port 1 and Port 2. (a) X-z plane for Port 2; (b) Y-z plane for Port 2; (c) X-z plane for Port 1; (d) Y-z plane for Port 1.

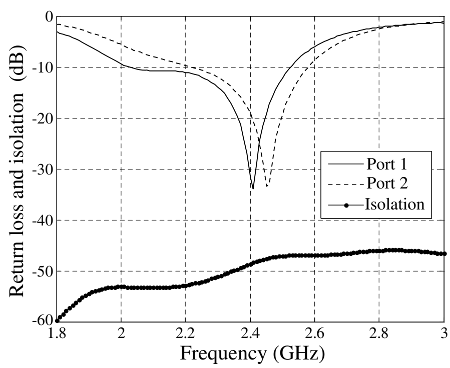


Figure 3. Simulated return loss, at Port 1 and Port 2, and isolation in (dB) of the single L-shaped probe feeding antenna.

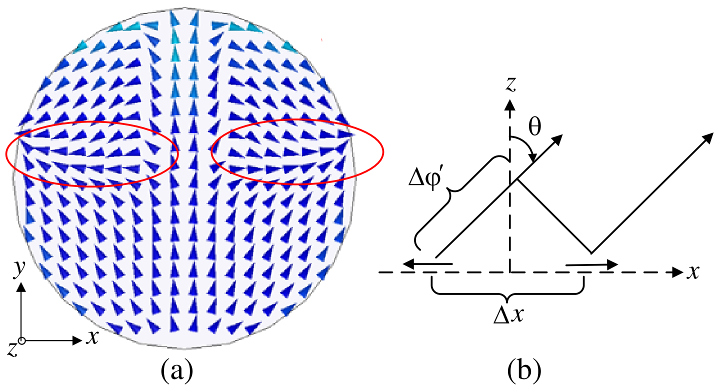


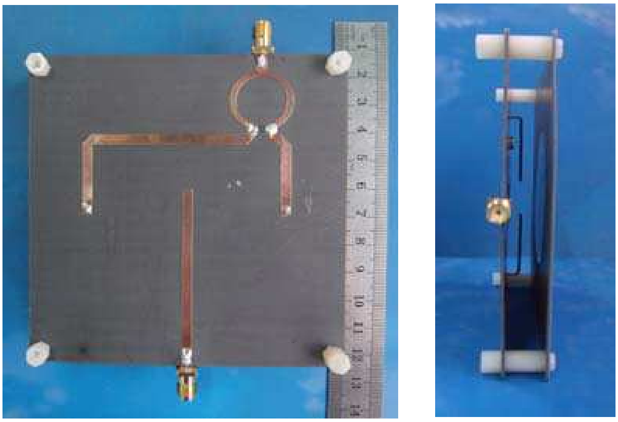
Figure 4. (a) Surface currents attributions of the radiating patch; (b) Spatial phase delay.

Table 1. Dimensions of the proposed antenna.

parameter	value	parameter	value
w	100 mm	w_3	3.1 mm
a	26 mm	s	5 mm
h_2	1 mm	W_1	1.5 mm
l_1	21 mm	h_1	3.7 mm
l_2	10 mm	t	20 mm
W_2	2 mm	h	12 mm
l	6 mm		

power divider and a half-wavelength delay line are employed in constructing the feed network to improve the cross polarization at x-z plane for port 2. Both the L-probes are fixed at the bottom substrate, and their positions are on y-axis and symmetrical with respect to x-axis, of which the detailed optimum geometrical parameters are given in Table 1. So that the signals in the two L-shaped probes will have equal amplitudes and 180° phase differences. Consequently, a y-directed polarization mode can be symmetrically excited through Port 2.

With the differential feeding structure, shown in Fig. 1, this spatial phase delay is canceled. This is because, within the symmetrical L-shaped probes, the spatial phase delay in one row or column is opposite to that of the other row or column and, consequently, they cancel each



(a) (b)

Figure 5. Photograph of the fabricated antenna. (a) Bottom view; (b) Side view.

other. As shown later, the cross polarization of port 2 at x-z plane is further enhanced, and other antenna performances are hardly affected by utilizing a pair of L-probes.

3. MEASUREMENT RESULTS AND DISCUSSION

The proposed differential feeding antenna was fabricated and tested. Fig. 5 shows the fabricated prototype of it. The reflection coefficients are measured using the Agilent N5230C vector network analyzer, and radiation characteristics are measured in the anechoic chamber. The isolation and return loss measured at the two feeding ports of the antenna are presented in Figs. 6 and 7, respectively, along with the simulated results.

The measured phase accuracy of the balanced feeding lines (Port 1) and a relative phase shift of exactly 180 degree at around 2.4 GHz are shown in Fig. 6. From the obtained results shown in Fig. 7, good excitation at around 2.4 GHz are exhibited by both the feeding ports for the fabricated antenna, and the impedance bandwidth measured at Port 1 and Port 2, with respect to the center frequency measured at 2.472 and 2.532 GHz, respectively, is 23.25% and 35%.

The isolation level between the two feeding ports of the prototype is shown in Fig. 6, and the isolation of more than 40 dB over the entire impedance bandwidths is demonstrated. There is a difference between the measured and simulated results, which could be due to the imperfect constructed feeding port. The radiation patterns

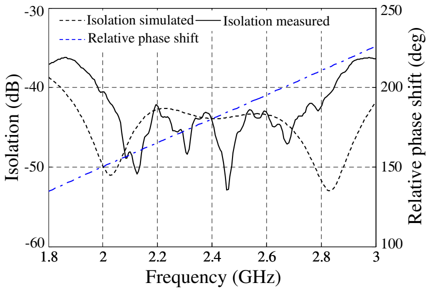


Figure 6. Measured and simulated isolation level, and measured relative phase shift.

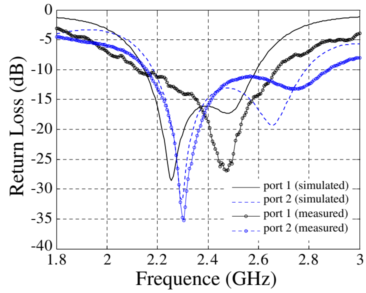


Figure 7. Simulated and measured return loss.

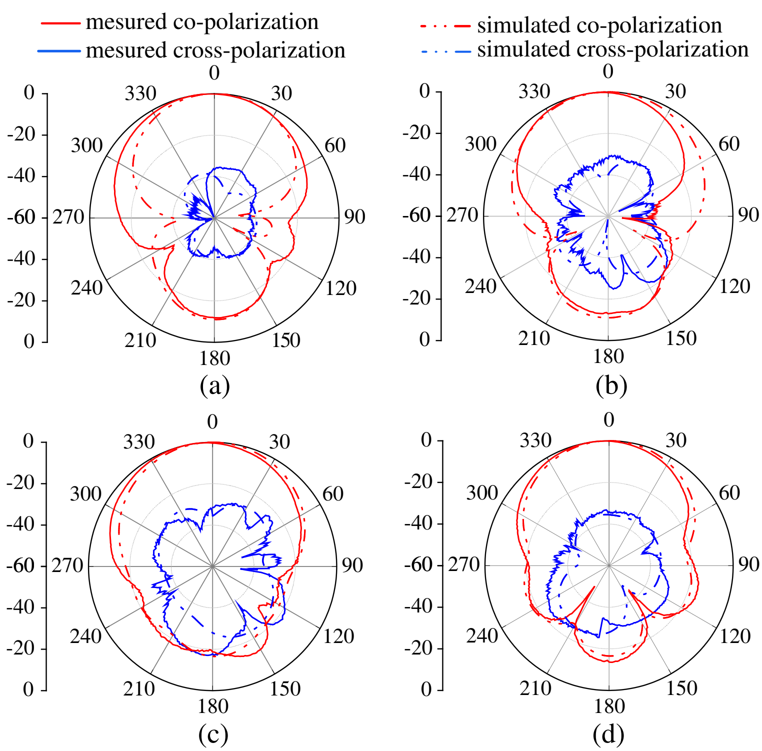


Figure 8. Measured and simulated radiation patterns at 2.4 GHz for Port 1 and Port 2. (a) X-z plane for Port 2; (b) Y-z plane for Port 2; (c) X-z plane for Port 1; (d) Y-z plane for Port 1.

measured at 2.4 GHz and 2.3 GHz for Port 1 and Port 2 are plotted in Figs. 8 and 9. Good broadside radiation patterns with low cross polarizations are observed in the two principal planes. For Port 1, the cross polarization level is −26 dB in the x-z plane and −31 dB in the y-z plane. As for Port 2, the cross polarization level is −23 dB in the y-z plane and −35 dB in the x-z plane. The measured and simulated gain of the antenna is shown in Fig. 10. The measured gain is more than 6.0 dBi from 2.1 GHz to 2.8 GHz, the peak gains measured at both ports are almost the same at around 9 dBi. The −3 dB gain bandwidth is about 29%. The difference between measured and simulated results of the gain could be attributed to fabrication tolerance and measurement errors.

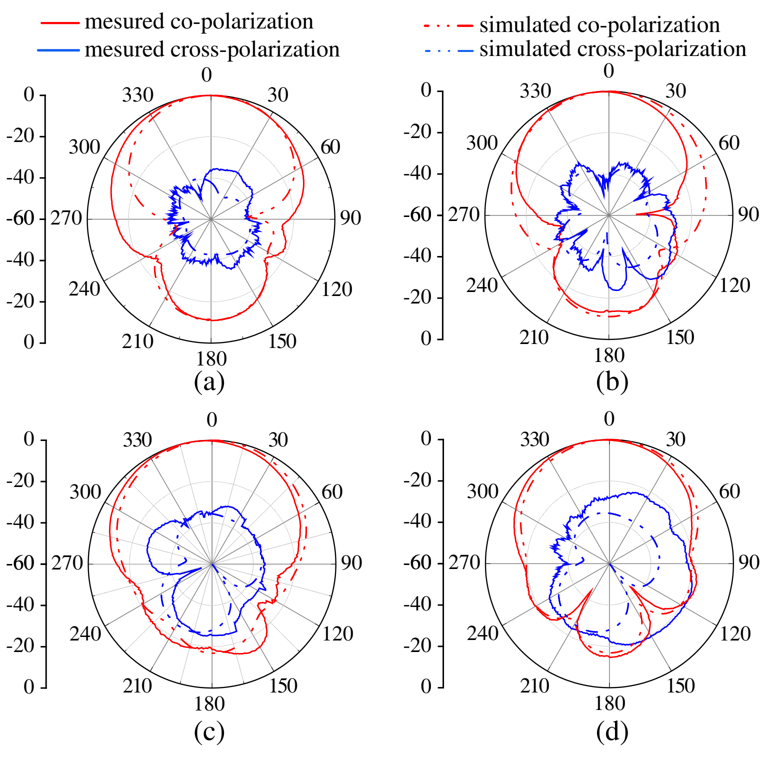


Figure 9. Measured and simulated radiation patterns at 2.3 GHz for Port 1 and Port 2. (a) X-z plane for Port 2; (b) Y-z plane for Port 2; (c) X-z plane for Port 1; (d) Y-z plane for Port 1.

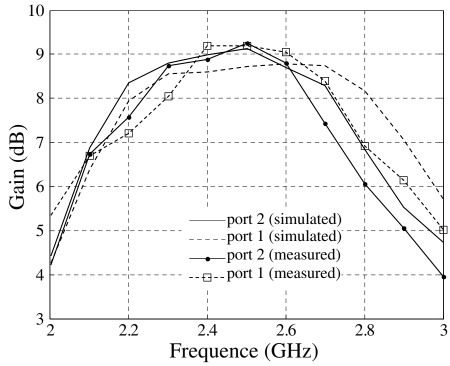


Figure 10. Simulated and measured gain.

4. CONCLUSION

A simple technique to design dual-feed dual linearly polarized circular microstrip patch antenna with broad bandwidth, low cross polarization and high isolation was presented. Two different feed mechanisms are designed to excite a dual-orthogonal linearly polarized mode from a single radiating patch for the operated frequency band at 2.4 GHz. The proposed design has a very simple antenna structure with a wide impedance bandwidth (23.25% for Port 1 and 35% for Port 2) and also its two input port isolation is found to be as low as −40 dB. Good broadside radiation patterns with low cross polarizations (Less than 23 dB) are observed in the two principal planes. From the measured results, it is found that the associated antenna parameters are in good agreement with simulation analysis.

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