A BIDIRECTIONAL LEFT-HAND CIRCULARLY POLARIZED ANTENNA USING DUAL ROTATED PATCHES

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ABSTRACT: *In this article, we have proposed a multilayer bidirectional circularly polarized antenna for underground communications. The proposed antenna consists of two slot-coupled back-to-back arranged rotated patches and a microstrip feed-line. Identical left-hand circular polarization is achieved in both front and back directions to avoid the undesired polarization mismatch for point-to-point connection. A prototype of the proposed antenna is built to validate the design strategy. The measured data, including S-parameter, axial ratio, radiation pattern, and gain, agree well with the simulation results.* Microwave Opt Technol Lett 55:2044–2047, 2013; View this article online at wileyonlinelibrary.com. DOI 10.1002/mop.27800

Key words: *bidirectional pattern; identical circular polarization; underground communication; multilayer patch antenna*

1. INTRODUCTION

There is a growing interest in wireless communication systems for underground environments, such as mines, tunnels, and subways. The special environment of the underground, which features severe multipath fading and high attenuation rate, requires the antenna to have polarization diversity, low profile, and simple structure [1]. Circularly polarized (CP) antenna is an attractive candidate to overcome the multipath effect as it is relatively insensitive to the polarization loss caused by the misalignment between the transmitter and receiver orientations [2].

Various CP patch antennas have been proposed [3–10]. For example, the perturbation method is used in Refs. [3–5] to achieve circular polarization. Perturbations, caused by truncated corners at the circular patch edge [3,4] or asymmetric F-shaped slot at the rectangular patch [5], split the fundamental resonant mode into two near-degenerate modes. In Refs. [6–10], cross-slot is used for CP operation. The cross-slot, fed by an inclined microstrip feed-line [6–8] or a series microstrip feed-line [9,10], excites two orthogonal linearly polarized modes with equal amplitude and a 90° phase difference. In point-to-point communication systems for underground environments, identical circular polarization in the front and back of the radiating antenna is important in avoiding the undesired polarization mismatch. In all the designs mentioned earlier, the radiation patterns are unidirectional and cannot be easily modified into bidirectional radiation patterns. Slot antenna [11,12] has a bidirectional radiation pattern, and is widely adopted in circular polarization designs for its merit of wide axial-ratio (AR) bandwidth. However, the rotation of circular polarization in the front and back of the slot antenna is inversed. In Ref. [13], identical circular polarization is achieved in both front and back directions by arranging two back-to-back truncated patches fed by a coplanar waveguide. However, the AR bandwidth is only about 0.5%.

A novel CP antenna with AR bandwidth of 4% is designed in Ref. [14]. The CP operation is generated by rotating a dipole above the feeding slot. Based on this structure, in this article, the rotated dipole is replaced with a rotated patch at first. Two orthogonal modes are excited along the broad and narrow edges of the patch. Then, the rotated patch is copied and flipped along the slotted ground. As the rotation of the front patch and the back patch is mirrored with respect to the slot, identical circular polarization is achieved in both front and back directions.

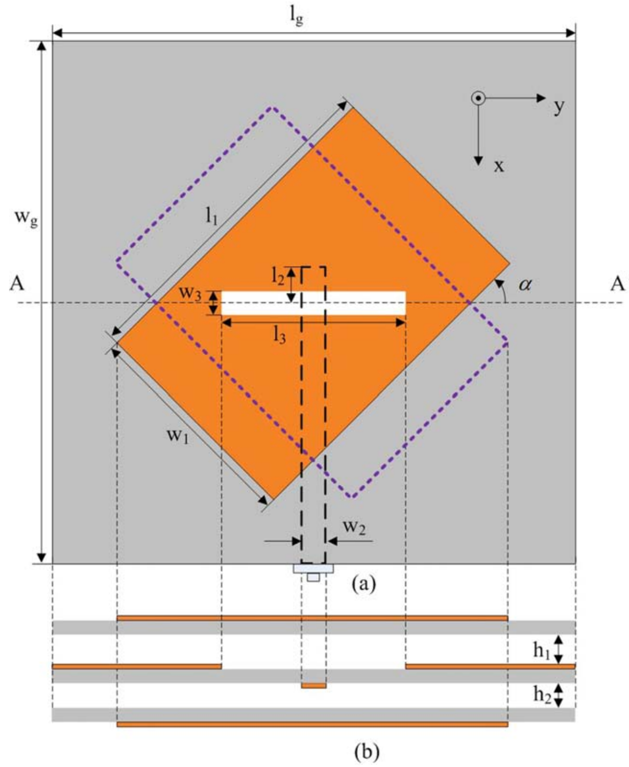

Figure 1 Geometry of the proposed antenna. (a) Top view and (b) cross-sectional view of *A-A'* plane. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com]

2. ANTENNA DESIGN

Figure 1 shows the geometry of the proposed antenna, which is composed of three layers of FR4 substrate with the same thickness $h = 0.8$ mm, relative permittivity $\varepsilon_r = 4.0$ and tan $\delta = 0.02$. Every two layers of substrate are separated by an air gap. On the front layer, a rectangular patch with an area of $l_1 \times w_1$ is rotated α degree with respect to y-axis in an anticlockwise direction. Accordingly, the rectangular patch on the back layer has the same area of $l_1 \times w_1$ with a mirror rotation angle of α degree with respect to y-axis in a clockwise direction to achieve identical circular polarization in the back direction. The center layer is a feed-network. A ground plane of 80 × 80 mm^2 and a 50-Ω open-circuited stub are arranged on the front and back of the center layer. An aperture with length l_3 and width w_3 is etched on the ground plane along y-axis. The offset part of the microstrip feed-line is l_2 from the center of the aperture. The detailed values of each parameter are listed in Table 1.

Due to the rotation, two orthogonal fundamental modes are excited along the broad and narrow edges of the patches. As the rotated angles of the front patch and back patch are mirrored

TABLE 1 Detailed Dimensions (unit: mm)

l_1	w_1	l_2	w_2	l_3	w_3	h_1	h_2	αα
44	35	6.5	1.6	29	3	10	8	42°

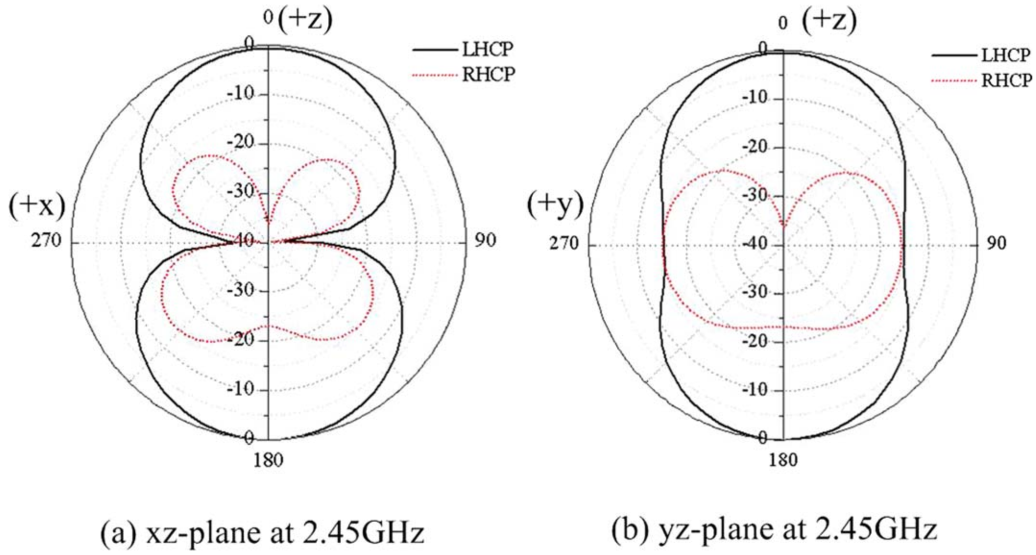

Figure 2 Simulated normalized radiation pattern of the proposed antenna at 2.45 GHz in (a) *xz*-plane and (b) *yz*-plane. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com]

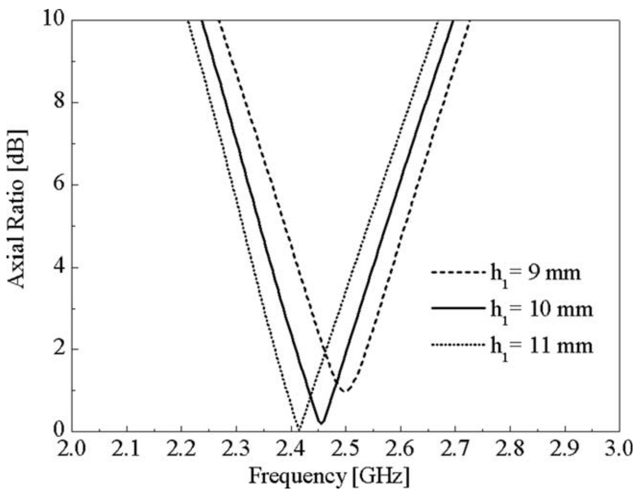

Figure 3 Simulated AR with different h_1

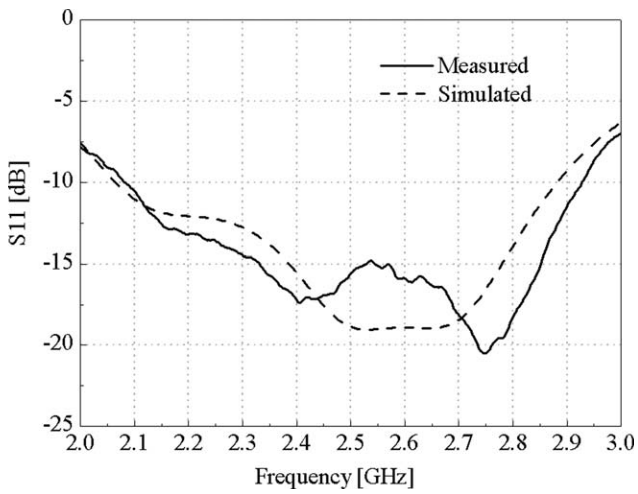

Figure 5 Simulated and measured reflection coefficient

with respect to *y*-axis, identical left-hand circular polarization (LHCP) is generated in both front and back direction along *z*-axis. Simulated radiation patterns at 2.45 GHz are illustrated in Figure 2. It can be observed that in both *xz*-plane and *yz*-plane,

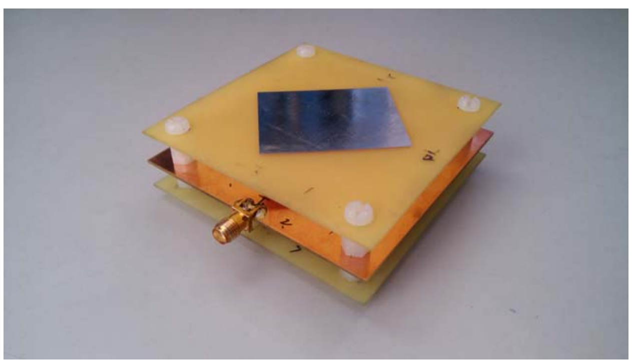

Figure 4 The fabricated prototype of the proposed antenna. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com]

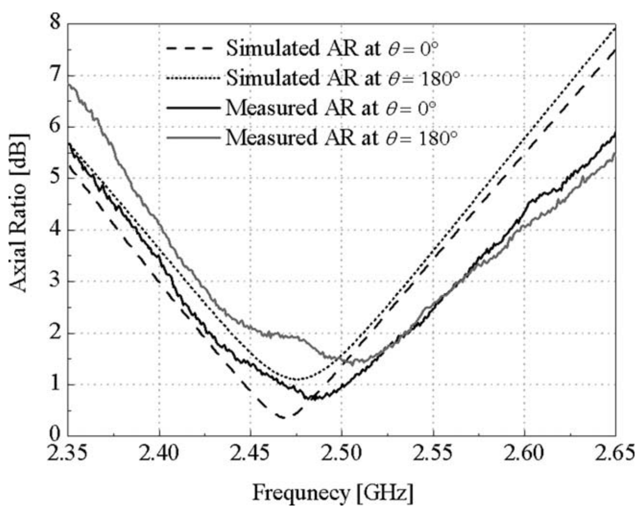

Figure 6 Simulated and measured AR

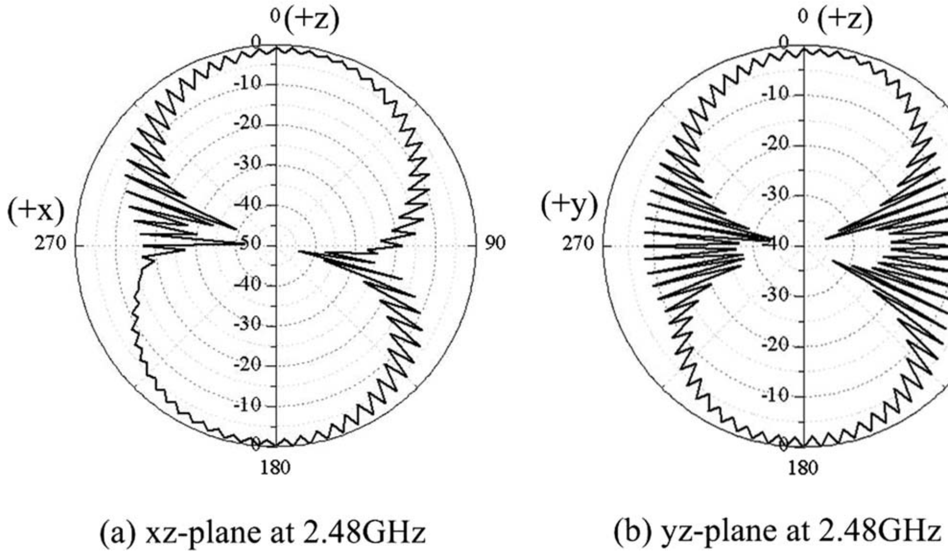

Figure 7 Measured normalized radiation patterns. (a) 2480 MHz at *xz*-plane. (b) 2480 MHz at *yz*-plane

the crosspolarization is more than 20 dB below the copolarization at the broadsides (+*z*-direction and −*z*-direction).

A parametric study is carried out to understand the effect of h_1 on the performance of CP operation. Figure 3 shows the effect of h_1 on circular polarization. As h_1 increases, the minimum value of AR in the front direction shifts to the lower frequency. Similarly, as h_2 increases, the minimum value of AR in the back direction will also shift to the lower frequency. By tuning h_1 and h_2, the coincided AR bandwidth in both front and back directions can be optimized.

3. MEASUREMENT RESULTS

The designed antenna is fabricated and measured. Figure 4 shows the photograph of the fabricated antenna. Four parasitic screws are used to fix the three layers of FR4 substrate. Figure 5 shows the measured reflection coefficient of the proposed antenna, which agrees well with the simulated results. The measured reflection coefficient bandwidth of −10 dB is 845 MHz, or 34.5% corresponding to 2.45 GHz. Figure 6 compares the measured and the simulated AR at the broadsides. It is observed that the measured results, when compared with the simulated results, exhibit a shift to slightly higher frequencies. This shift can be caused by fabricated error and uncertain permittivity of the substrate. The measured 3-dB AR bandwidths are 6.37% (2.408–2.564 GHz) in the front direction and 5.84% (2.422–2.565 GHz) in the back direction. The coincided 3-dB AR bandwidth in both the directions (+*z*-direction and −*z*-direction) is 5.8% (2.422–2.564 GHz), which is within the reflection coefficient bandwidth.

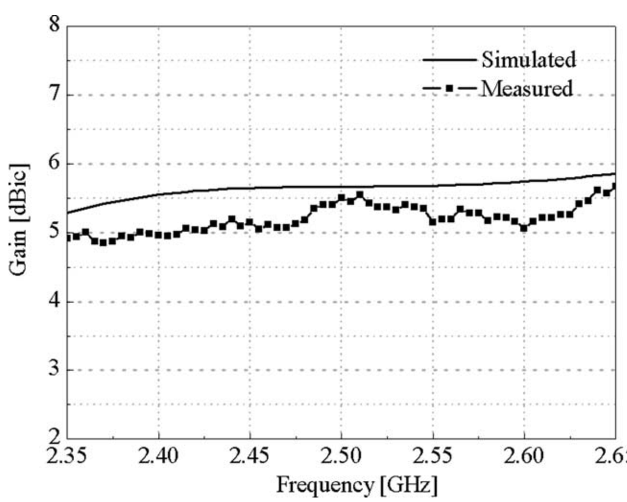

Figure 8 Simulated and measured gain

Figure 7 shows the measured normalized radiation patterns at 2.48 GHz in principal planes (*xz*-plane and *yz*-plane). Good AR is achieved at the broadsides (+*z*-direction and −*z*-direction). The measured gain is shown in Figure 8 and comparing with the simulated result. The measured gain is greater than 5 dBic and the peak gain is 5.6 dBic. The gain variation is less than 1 dB over the concided 3-dB AR bandwidth.

4. CONCLUSION

In this article, a multilayer bidirectional CP antenna has been proposed for underground communications. Identical LHCP is achieved in both front and back directions by arranging two slot-coupled back-to-back rotated patches. Experimental results show that the measured −10-dB reflection coefficient bandwidth is 34.5% corresponding to 2.45 GHz. The coincided 3-dB AR bandwidth in both front and back directions is 5.8%, which is within the reflection coefficient bandwidth. A value of crosspolarization ratio less than 20 dB can be obtained over the concerned bandwidth.

ACKNOWLEDGMENTS

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UWB BANDPASS FILTER BASED ON RING RESONATOR

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ABSTRACT: *A new ultra-wideband bandpass filter is proposed, with a ring resonator and two stepped-impedance stubs to provide good wideband filtering performance and sharp rejection skirts. Interdigital coupled lines are placed at both ends of the ring resonator as input and output feed lines. The use of interdigital coupled lines makes it possible for the first three resonances of the ring resonator to be closer to wideband characteristics. By cutting apertures in the ground plane under the interdigital coupled lines, the coupling effect between the feed lines and the ring resonator can be increased, so that the passband characteristics can be improved. By adding two stepped-impedance stubs to the ring resonator, sharp rejection skirts can be obtained in the passband.* © 2013 Wiley Periodicals, Inc. Microwave Opt Technol Lett 55:2047–2051, 2013; View this article online at wileyonlinelibrary.com. DOI 10.1002/mop.27780

Key words: *bandpass filters; resonator filters; ultra wide band; wideband; ring resonator*

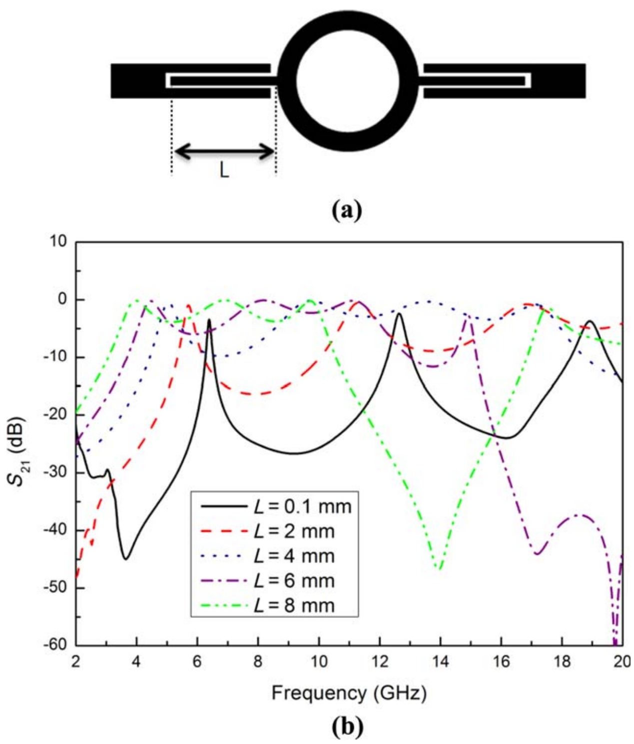

Figure 1 (a) A ring resonator with interdigital coupled feed lines. (b) *S*-parameters of the ring resonator for various values of coupling length *L*. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com]

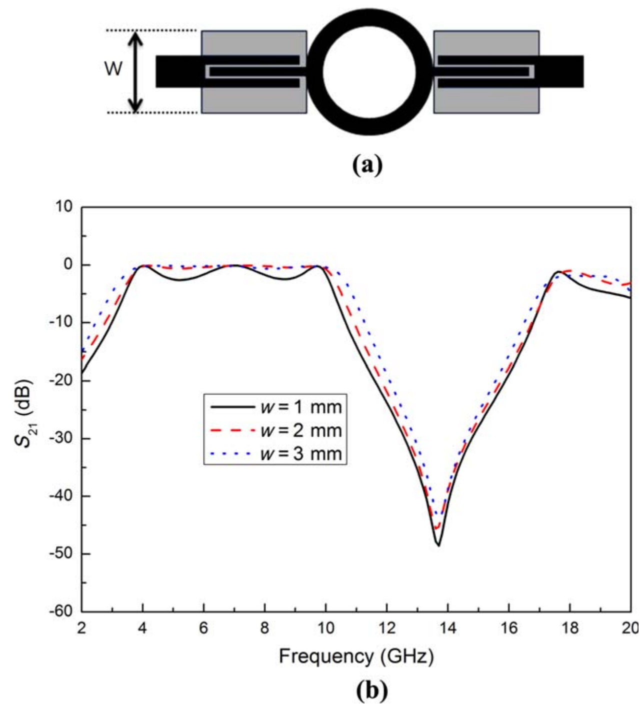

Figure 2 (a) A ring resonator with aperture-backed interdigital coupled feed lines. (b) *S*-parameters for various aperture widths. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com]

1. INTRODUCTION

In order to make effective use of frequency resources, new wireless communication systems have been researched. Recently,