ACKNOWLEDGMENT

The authors acknowledge the financial support of CAPES, FAPERN and CNPq, beyond the CITEd/UFERSA laboratories, laboratory telecommunications of UFRN, laboratory mechanical tests of UFERSA, the physics laboratory of UERN.

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BIDIRECTIONAL SAME-SENSE CIRCULARLY POLARIZED ANTENNA USING SLOT-COUPLED BACK-TO-BACK PATCHES

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Received 18 August 2016

ABSTRACT: *In this letter, a dual-patch antenna with bidirectional circular polarization of the same sense is proposed for coal mine and tunnel communications and positioning systems. The proposed antenna consists of two back-to-back patches with a common ground plane. We only feed one patch on the front side by microstrip feeding line, and the energy is coupled to the other patch on the back side through a slot, which is etched on the common ground. By properly truncating the corners of the dual patches, bidirectional radiation pattern is achieved with the right-hand circular polarization on both front and back sides. Compared to previous designs for the same purpose, the proposed antenna is with a compact structure using only two layers of substrate and without using complex feeding networks, benefiting from the merits of small dimension, low cost, and easy fabrication. We have built the antenna prototype and taken the measurement. The measured impedance bandwidth for S11<−10 dB is 90 MHz (2.44–2.53 GHz), and the measured 3-dB axial-ratio bandwidth is 20 MHz (2.455–2.475 GHz), agreeing well with the simulated results. The measured peak right hand circularly polarization gains are 3.70 dBic and 3.09 dBic for front and back directions.* © 2017 Wiley Periodicals, Inc. Microwave Opt Technol Lett 59:645–648, 2017; View this article online at wileyonlinelibrary.com. DOI 10.1002/mop.30368

Key words: *bidirectional pattern; circularly polarized; same sense*

1. INTRODUCTION

For the communication systems in coal mine, tunnel with long and narrow spaces, the antennas with bidirectional radiation pattern are attractive candidates for relay base stations [1–4]. Compared to the linearly polarized antennas, circularly polarized (CP) antennas are adopted due to their good performance in reducing the polarization mismatch, which is due to the multipath diffraction and reflection [5–8]. However, in such applications, the CP antennas with different sense for bidirectional patterns usually mismatch the polarizations between two antennas, e.g., one antenna of left hand circularly polarization (LHCP) with another antenna of right hand circularly polarization (RHCP).

In order to simplify the installation and maintenance, it is a good idea to realize the bidirectional CP antennas with the same sense, and there are many designs available in the literature [9–13]. For example, a back-to-back rotated microstrip antenna is proposed in Ref. [9] with three substrate layers. In Refs. [10,11], a square-aperture metallic waveguide antenna is presented for same-sense CP due to space 90 degree difference between two feeding monopoles. In Ref. [12], an array consisting of eight dipoles is presented with end-fire same-sense CP patterns. A bidirectional CP antenna is realized in Ref. [13] by using an asymmetric frequency selective surface (FSS) to change the sense of the CP wave.

In this letter, we proposed another design method for bidirectional CP antenna with the same sense. Back-to-back slot-coupled patches are utilized for same-sense CP pattern in front and back sides. Compared to previous designs for the same purpose, the proposed antenna is with the merits of simple structure (e.g., integrated with only two substrate layers), simple feeding (e.g., we only feed one patch, and the energy can be coupled to another one), and compact dimensions. The reflection coefficient, axial ratio (AR), and radiation patterns are measured to verify the design strategy.

2. ANTENNA DESIGN AND CONFIGURATION

Figure 1 shows the geometry and the dimensions of the proposed bidirectional antenna with the same-sensed RHCP. As illustrated by the layer-separated view in Figure 1, the overall dimensions of the antenna are 90 × 90 mm^2. The antenna consists of three metallic layers, which are separated by two layers of low-loss F4B substrates ($\varepsilon_r = 2.5$ and $\tan\delta = 0.001$) with the

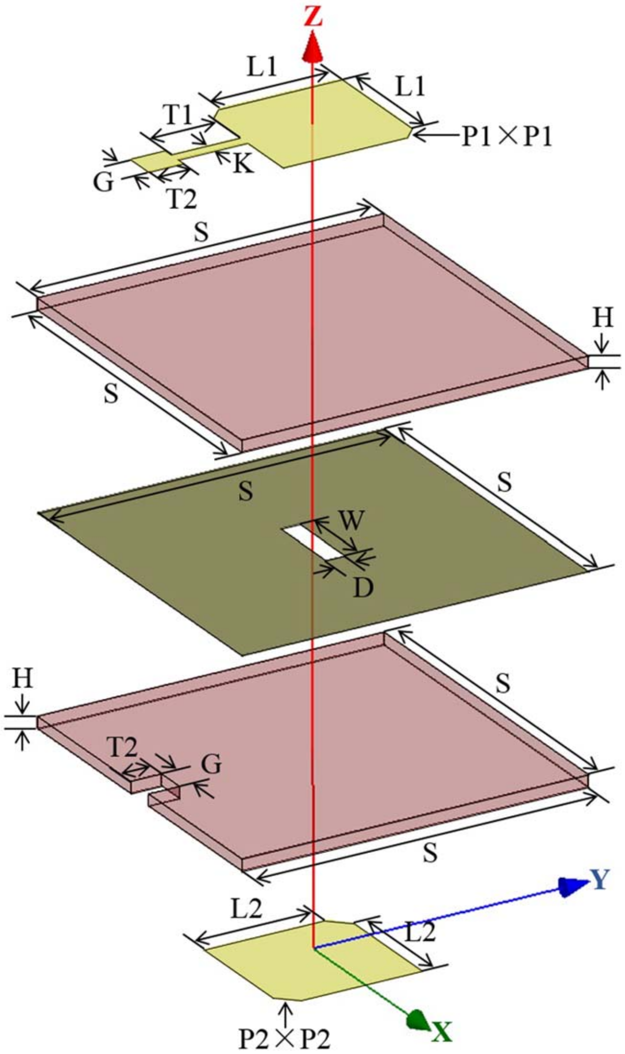
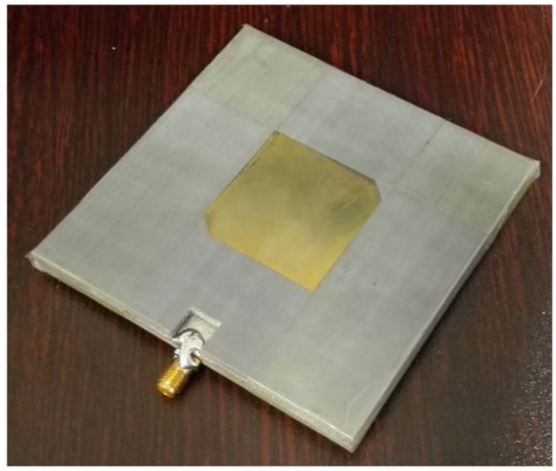
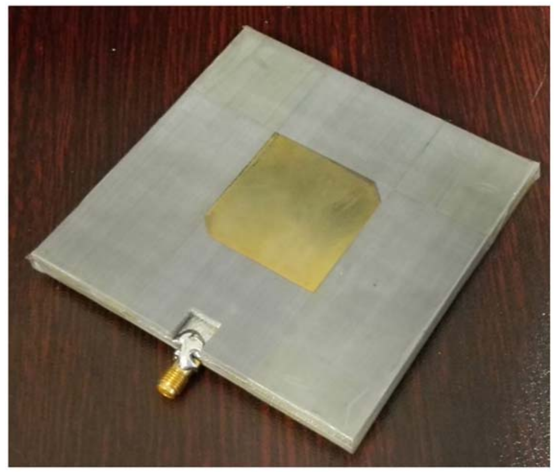


Figure 1 Configuration of proposed antenna. [Color figure can be viewed at wileyonlinelibrary.com]



(a)



(b)

Figure 3 Photograph of the proposed antenna: (a) front and (b) back. [Color figure can be viewed at wileyonlinelibrary.com]

same thickness of 3 mm. The front and back metallic layers are two square patches, but with different dimensions. The dimension difference is due to the asymmetric feeding structures for the two back-to-back patches, with only single feed ports in the front. As indicated in Figure 1, the front and back square patches are sharing the same ground, i.e., middle metallic layer, where a slot is etched for energy coupling between the dual

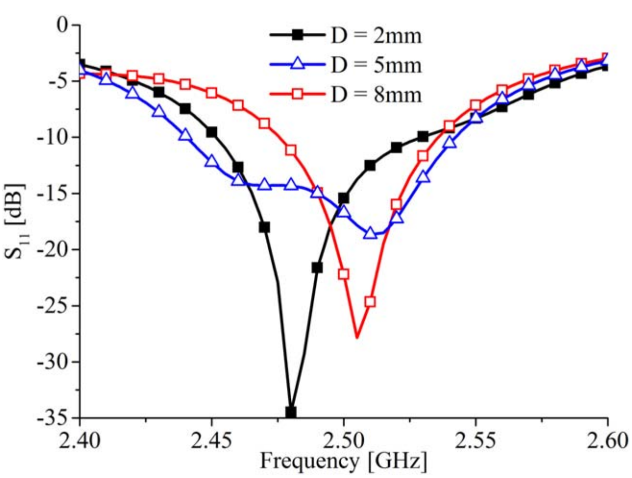


Figure 2 Simulated reflection coefficients varying with parameter *D*. [Color figure can be viewed at wileyonlinelibrary.com]

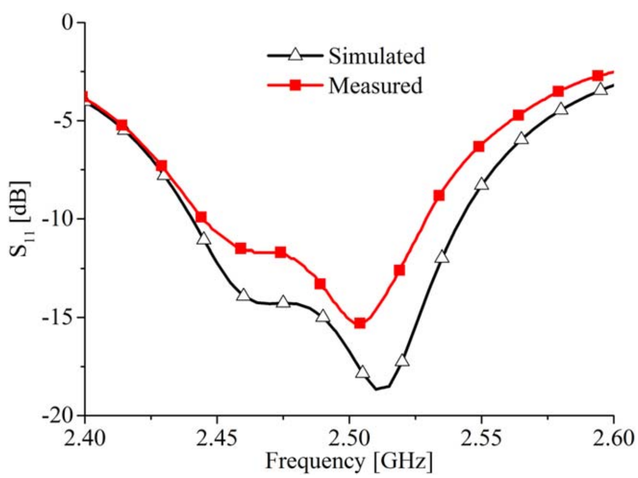


Figure 4 Simulated and measured S_{11} of proposed antenna. [Color figure can be viewed at wileyonlinelibrary.com]

TABLE 1 Detailed Dimensions of Proposed Antenna

Parameter	S	H	$T1$	$T2$	K	G
Value (mm)	90	3	18	9	3	8
Parameter	$L1$	$L2$	$P1$	$P2$	W	D
Value (mm)	32	31.5	4	4.5	20	5

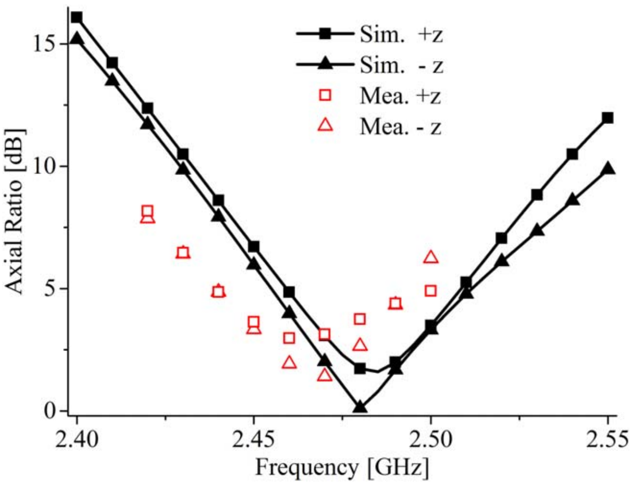


Figure 5 Simulated and measured axial ratio of proposed antenna. [Color figure can be viewed at wileyonlinelibrary.com]

patches. The proposed feeding structure in Figure 1 is with the merits of easy fabrication, especially for the multiple layered structures. The back-to-back patches are with perturbation segments appropriately cut at the corners, providing bidirectional radiation pattern with RHCP on both front and back sides. The basic operating principle is described as following: first, the patch on the front side is fed by a stepped microstrip feeding line (i.e., for impedance matching), and then, the energy is coupled to the other patch on the back side through the coupled slot on the common ground. As mentioned above, with the different feeding method, the dimension of the two patches and segments

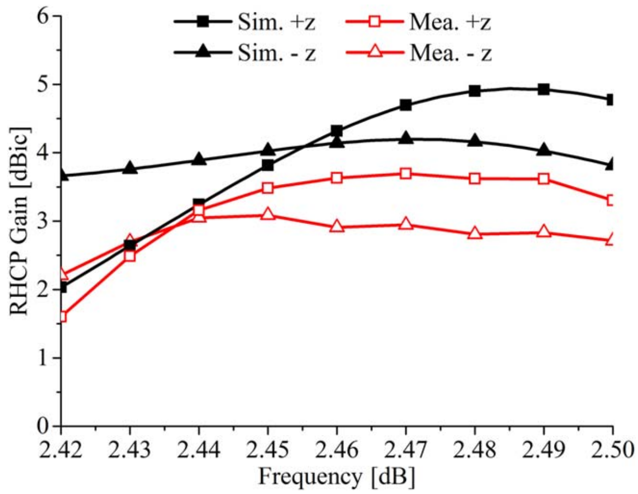


Figure 7 Simulated and measured RHCP Gain of proposed antenna. [Color figure can be viewed at wileyonlinelibrary.com]

have a slight difference of 0.5 mm, where $P1 = 4$ mm and $P2 = 4.5$ mm. Compared to previous designs of the bidirectional CP antennas with the same sense, the proposed antenna in Figure 1 is with a compact structure and simple feeding networks with only two layers of substrates.

For proposed feeding structures, the coupled slot determines the overall performance of the dual directional radiation patterns. The slot-coupled dual patches can be treated as two coupled cavities, and the dimensions of the coupled slot are affecting the coupling of the cavities. Figure 2 shows the reflection coefficients for different widths, i.e., D, of the rectangular slots on the common ground. Based on the analysis mentioned above, the variation of the width D changes the energy coupled from one patch to the other patch. By properly tuning the value of D, we can find an optimized width of the coupled slot with widest -10 dB bandwidth ($S_{11} \leq -10$ dB) from 2.440 GHz to 2.542 GHz with the value of $D = 5$ mm. When the coupling is strong (i.e., larger value of D) or weak (i.e., smaller value of D), the bandwidths are not at the maximum. For the other

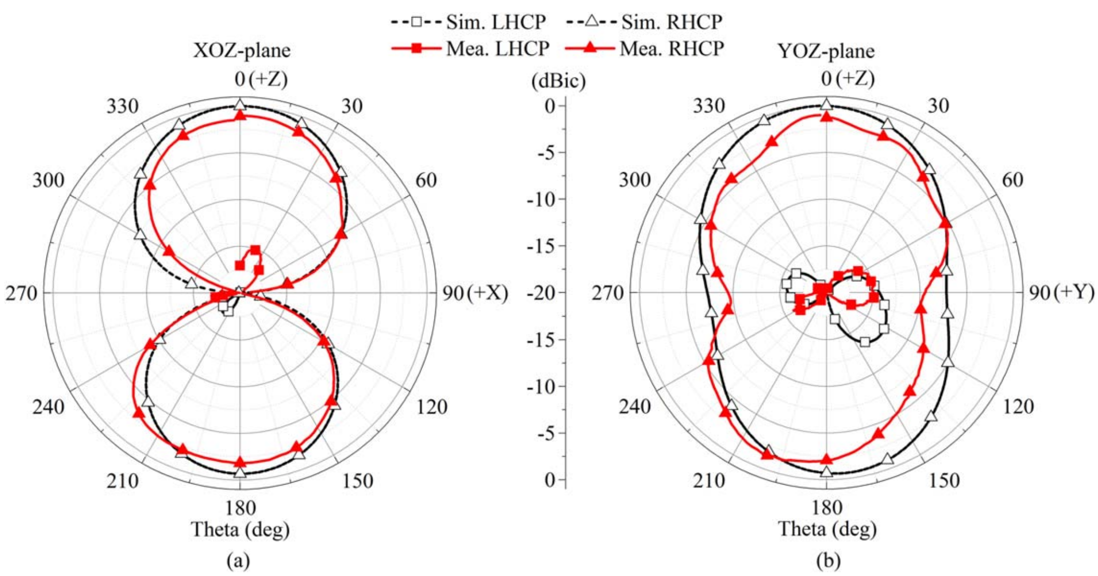


Figure 6 Simulated and measured normalized radiation patterns at the frequency of 2.48 GHz: (a) *XOZ*-plane, (b) *YOZ*-plane. [Color figure can be viewed at wileyonlinelibrary.com]

parameters, the detailed optimized values are listed in Table 1 by using the ANSYS HFSS software.

3. EXPERIMENTAL RESULTS

To demonstrate the validity of the presented design strategy, the proposed antenna has been fabricated and tested. The front view and the back view of the fabricated prototype are shown in Figures 3(a) and 3(b). The reflection coefficient is measured using a N5071B vector network analyser, and the AR, gain, and radiation pattern are measured in a far field anechoic chamber.

The simulated and measured magnitude of the reflection coefficients are shown in Figure 4. It is well known that a square patch can support two independent modes, horizontal and vertical polarization modes. With perturbation segments appropriately cutting at the diagonal corners of the patch and two linearly polarizations are excited at 2.51 and 2.46 GHz, as indicated in Figure 4. The -10 dB bandwidth covers from 2.44 to 2.53 GHz in measurement, which is about 3.63% with respect to the center frequency at 2.48 GHz.

Figure 5 shows the measured axial ratio, compared with the simulated result. The best performance of circularly polarization is at the frequency of 2.484 GHz. The simulated axial ratio curve in the $\pm Z$ directions are nearly overlapped, with the 3 dB AR bandwidth in the $+Z$ and $-Z$ directions are about 26 MHz (from 2.471 to 2.497 GHz) and 33 MHz (from 2.465 to 2.498 GHz). However, the measured ones have slightly differences: in the $+Z$ direction, the bandwidth is about 20 MHz (from 2.455 to 2.475 GHz); whereas in the $-Z$ direction, it is 35 MHz (from 2.45 to 2.485 GHz). However, the characteristic of AR is acceptable for realistic application.

The measured radiation patterns in *XOZ*- and *YOZ*-planes at 2.48 GHz for both RHCP (i.e., co-polarization) and LHCP (i.e., cross-polarization) are presented in Figure 6, with clear bidirectional patterns and low cross-polarization. It can be observed that the measured results fit the simulation quite well, bidirectional patterns and nearly omnidirectional shapes are observed in the *XOZ* and *YOZ* planes, respectively. The radiation pattern in *YOZ*-plane is slightly asymmetrical due to the existence of the feeding structure.

The simulated and measured gain at broadside of the antenna is shown in Figure 7. The measured gains is more than 3.50 dBic in the operation band and the peak gain is about 3.70 dBic in the $+Z$ direction, and more than 2.80 dBic in the operation band and the peak gain is about 3.09 dBic in the $-Z$ direction. However, the measured gain is slightly lower than the simulated gain. The difference is due to fabrication tolerance and measurement errors, but acceptable for practical use.

4. CONCLUSION

A bidirectional same-sense circularly polarized antenna using slot-coupled back-to-back patches is developed in this letter. The proposed antenna has a compact structure with only two layers of substrate and without using complex feeding networks. Based on the experimental results of the impedance and radiation characteristic, the proposed antenna is exhibiting the potential for practical applications in coal mine and tunnel communications and positioning systems.

ACKNOWLEDGMENT

This work is supported by the National Natural Science Foundation of China under Contract 61301001, and the China Postdoctoral Science Foundation funded project 2015T80084.

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A DUAL BAND STACKED APERTURE COUPLED ANTENNA ARRAY FOR WLAN APPLICATIONS

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Received 27 July 2016

ABSTRACT: *In this article, a dual band stacked micostrip antenna array is presented for wireless local area network. The antenna is designed and simulated using CST MWSv'14. Stacking of the patches is done to achieve dual band. Further resonant slots are cut on the patch to achieve greater bandwidth. The antenna uses aperture coupled feed with defected ground structure on reduced ground. The antenna is fabricated on FR4 substrate with a dielectric constant of 4.4. The simulated antenna shows a bandwidth of 228.3 MHz from 3.63 to 3.86 GHz and 232 MHz from 5.15 to 5.38 GHz. The simulated gain and envelope correlation coefficient was found to be 6.11 dB and 0.14. The testing of the prototype antenna (to measure S_{11}) is done using vector network analyser. The measured results are matching to the simulated ones. The simulated and the measured results are presented in the article.* © 2017 Wiley Periodicals, Inc. Microwave Opt Technol Lett 59:648–654, 2017;