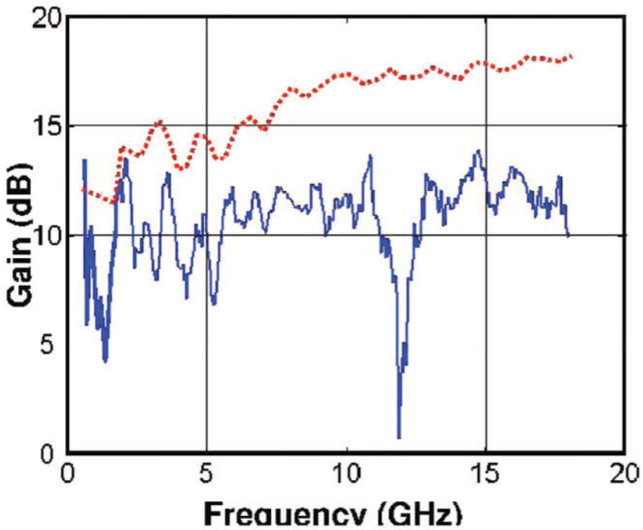

Figure 5 Response of Gain versus frequency. ____ Measured . . . . Calculated. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

that the construction of the horn is far from ideal, the deviations from the predicted values are to be expected. While the width curvature of the horn is easy to manufacture, obtaining the precise separation curvature and maintaining the correct plate separation is problematic. This would account for the deviations seen in VSWR and sidelobes at the higher frequencies.

6. CONCLUSION

The performance of an extreme bandwidth horn has been described. By making use of the parallel plate waveguide equations to model the characteristic impedance of a radial line, and combined with an elliptic plate separation and Hecken near optimal impedance function, a "TEM" horn of extreme bandwidth was designed. The VSWR remains below 2 from 250 MHz to 17.5 GHz, and the radiation pattern is stable, with sidelobes generally below -10 dB.

Because of the thin metal gauge, it is virtually impossible to construct the area around the apex accurately, and a profile machined from much thicker and inherently stable material would exhibit a much more uniform gain response. It is also expected that the deep dip in gain, most probably caused by a higher order mode being generated, would be evened out.

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DUAL-FREQUENCY CIRCULARLY-POLARIZED MICROSTRIP ANTENNA WITH SWITCHABLE POLARIZATION SENSE

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ABSTRACT: *A dual-frequency circularly-polarized (CP) microstrip antenna capable of switching polarization sense is presented. The antenna is fed by a microstrip line through aperture coupling. First, it is found that a CP mode can be excited when the radiating patch is square and an open-ring slot is used as the coupling aperture. Then, by truncating the radiating patch, another CP mode can be obtained. The two CP modes have reversed polarization senses, and their operating frequencies are different. For the proposed dual-frequency CP microstrip antenna, two prototypes with frequency ratios of 1.07 and 1.23 were constructed, and voltage-controlled diodes are employed to achieve the electrical switching between the two CP modes.* © 2008 Wiley Periodicals, Inc. Microwave Opt Technol Lett 50: 2125–2128, 2008; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.23569

Key words: *microstrip antenna; dual-frequency operation; switchable polarization*

1. INTRODUCTION

It is well-known that circular polarization (CP) radiations can be produced from a linearly-polarized (LP) microstrip antenna by the method of truncating patch corners, and the polarization sense of the obtained CP is determined by the position of the truncated corners. On the basis of the method, several designs for the microstrip antenna with the polarization switching between LP and CP or between right-hand circular polarization (RHCP) and left-hand circular polarization (LHCP) have been presented [1–3]. For these reported designs, PIN diodes or other electrical devices are used to reconfigure the truncated corners, and the antennas are operated at the same frequency while the polarization is switched. To simultaneously obtain frequency diversity, a U-shaped slot is embedded to the radiating patch with the reconfigurable truncated corners, and the antenna can provide CP and LP radiations at two different frequencies [4]. In addition, by cutting a reconfigurable thin slot in a nearly square patch, the microstrip antenna that is capable to operate at two distinct frequencies with reversed CPs has also been realized [5].

In this article, a new design for the dual-frequency microstrip antenna with switchable CP is proposed. The antenna is single-fed and excited through slot coupling. When the radiating patch is square and an open-ring slot is used as the coupling aperture, a LHCP radiation of the antenna can be generated. The polarization sense can be reversed to RHCP by properly truncating the radiating patch. Consequently, when the antenna is operated at the RHCP and LHCP modes, the size of the radiating patch is obviously different, which leads to a dual-frequency operation. Details of the design concept are described and the experimental results of constructed prototypes are also exhibited.

2. ANTENNA CONFIGURATION AND ANALYSIS

Figure 1 shows the geometry of the proposed antenna. A square radiating patch with truncated corners of equal side length l is etched on a FR4 substrate. The antenna is excited by an aperture-coupled feed mechanism in which the microstrip feed line and open-ring slot are fabricated on the opposite sides of another FR4 substrate. Both the FR4 substrates are with the thickness of 1.6 mm and relative permittivity 4.4, and a foam material of thickness 5 mm is inserted between them. The microstrip feed line is composed of an open stub and an impedance transformer. The shorted section of the open-ring slot is subtended by an angle of α.

For the antenna shown in Figure 1, it is first found that, when the radiating patch is not truncated (l = 0 mm), a LHCP radiation can be excited through the coupling of the open-ring slot with a specific α, and its CP axial ratio is varied with increasing l. The example of the open-ring slot with $\alpha = 15°$ is selected to show the effects of various l on the axial ratio. Figure 2 presents the simulation results carried out by IE3D. Observing the results, it is clearly seen that, when l = 0 mm, the antenna has a CP radiation with an axial ratio of less than 1 dB; however, the axial ratio is more than 16 dB when l is increased to 9 mm. It implies that the original CP radiation can be converted to a LP radiation by truncating the corners of the square patch. As l is further increased, the axial ratio is dramatically decreased, and another CP mode appears at l = 14 mm case. For the two CP modes (corresponding to the cases of l = 0 and 14 mm), the operating frequencies are located around 2600 and 2990 MHz, and the polarization senses are found to be LHCP and RHCP, respectively. It has to be mentioned that the similar simulation results are also observed for other α, but the frequency ratio of the two CP operating frequencies would be changed with the increasing of α. According to the above discussions, the antenna polarization can be switched between LHCP and RHCP by reconfiguring the truncated corners, and the frequency ratio of the two CP operating frequencies could be controlled by α.

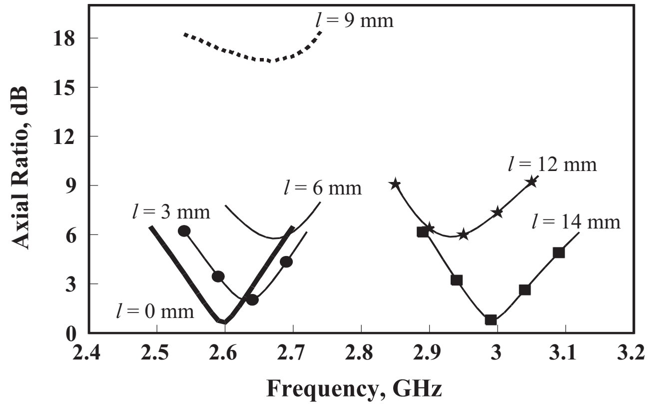

Figure 2 Simulated results for the effects of various l on the axial ratio

3. EXPERIMENTAL RESULTS

For the proposed antenna design, two prototypes with $\alpha = 15°$ and 142° were constructed and measured. Details of the antenna layout and dimensions are shown in Figure 3. Theses prototypes use a pair of voltage-controlled diodes to connect the radiating patch and truncated corners, and consequently the prototypes can produce the LHCP and RHCP radiations when the diodes are ON and OFF, respectively. The measured results of the two

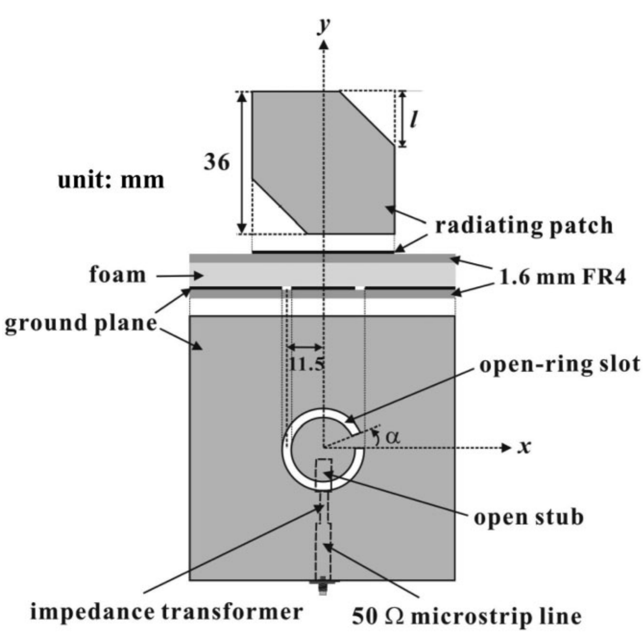

Figure 1 Geometry of the proposed reconfigurable microstrip antenna

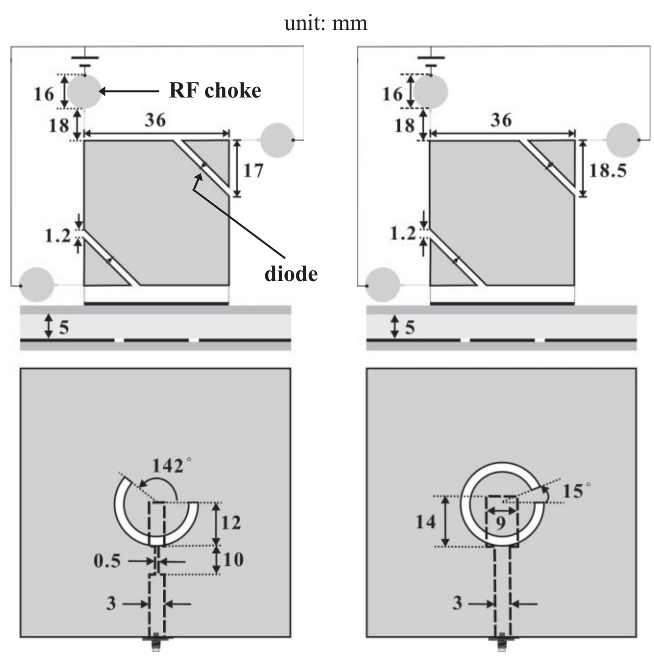

Figure 3 Designs of the two constructed prototypes

is partly due to the ohmic loss of the diodes. The experimental results of Prototype A and B are also summarized in Table 1.

4. CONCLUSIONS

The design of a dual-frequency microstrip patch antenna with switchable CP sense has been presented. The polarization switching is achieved using a pair of diodes to reconfigure truncated corners of the radiating patch of an open-ring-slot-coupled microstrip antenna. Moreover, the reconfigurable CP antenna has different operating frequencies when the polarization is switched. From the obtained simulation results, it is found that the frequency ratio of the two CP operating frequencies could be related to the angle subtended by the shorted section of the open-ring slot. Two prototypes at different CP senses are presented in Figure 4. For the prototype of $\alpha = 15°$ (Prototype A), the LHCP operating bandwidth, referred to 3 dB axial ratio, is 1.6% with respect to the center frequency 2430 MHz, and the RHCP operating bandwidth is 3.5% with respect to the center frequency 3000 MHz. Because the diodes and slits between the radiating patch and truncated corners are not considered in the numerical analyses, therefore the simulation and experiment have some differences in the dimensions of the truncated corners and the CP operating frequencies. As regards the prototype of $\alpha = 142°$ (Prototype B), the LHCP and RHCP operating bandwidths are centered at 2560 and 2740 MHz with CP operating bandwidths of 1.1% and 2.1%, respectively. The frequency ratio of the two CP operating frequencies is 1.23 for Prototype A, and it is decreased to 1.07 for Prototype B. Moreover, Figure 4(a) shows that the return loss within all CP operating frequencies is less than 10 dB. The impedance matching is achieved by tuning the dimensions of the open stub and impedance transformer.

The radiation characteristics of the constructed prototypes operated at each CP mode are also investigated, and it is found that the radiation patterns are similar to that of a traditional microstrip antenna operated at the fundamental mode. Only the radiation patterns of Prototype A measured at 2430 and 3000 MHz are shown, and the results are plotted in Figures 5 and 6, respectively. Broadside radiations with good axial ratio are observed for each CP sense. The measured peak gain is 4.5 dBi for the LHCP radiation and 7.3 dBi for the RHCP radiation. The gain difference

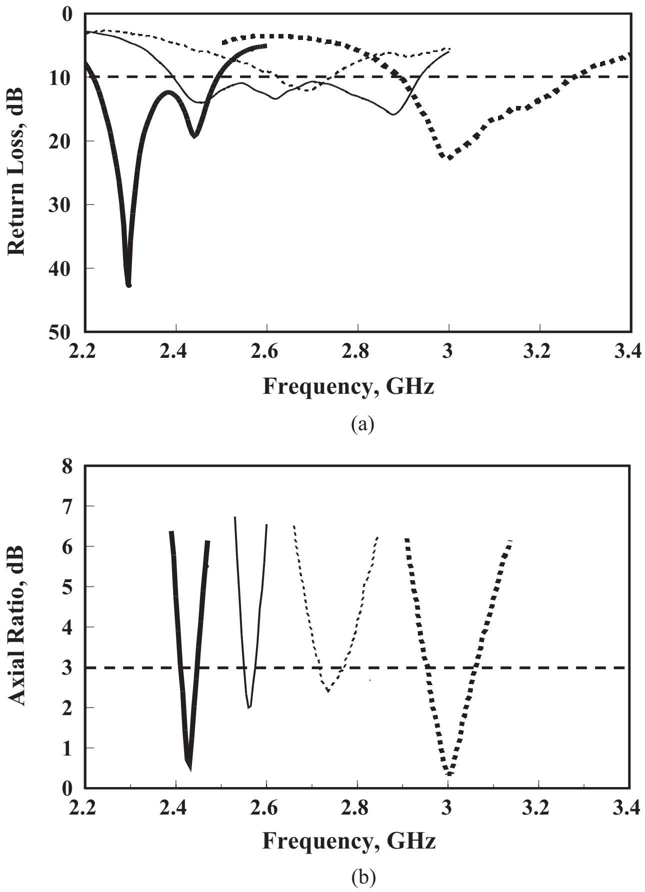

Figure 4 Measured results for the prototypes operated at different CP senses. (a) return loss (b) axial ratio ___ LHCP, Prototype A, — LHCP, Prototype B, ▬ RHCP, Prototype A, ... RHCP, Prototype B

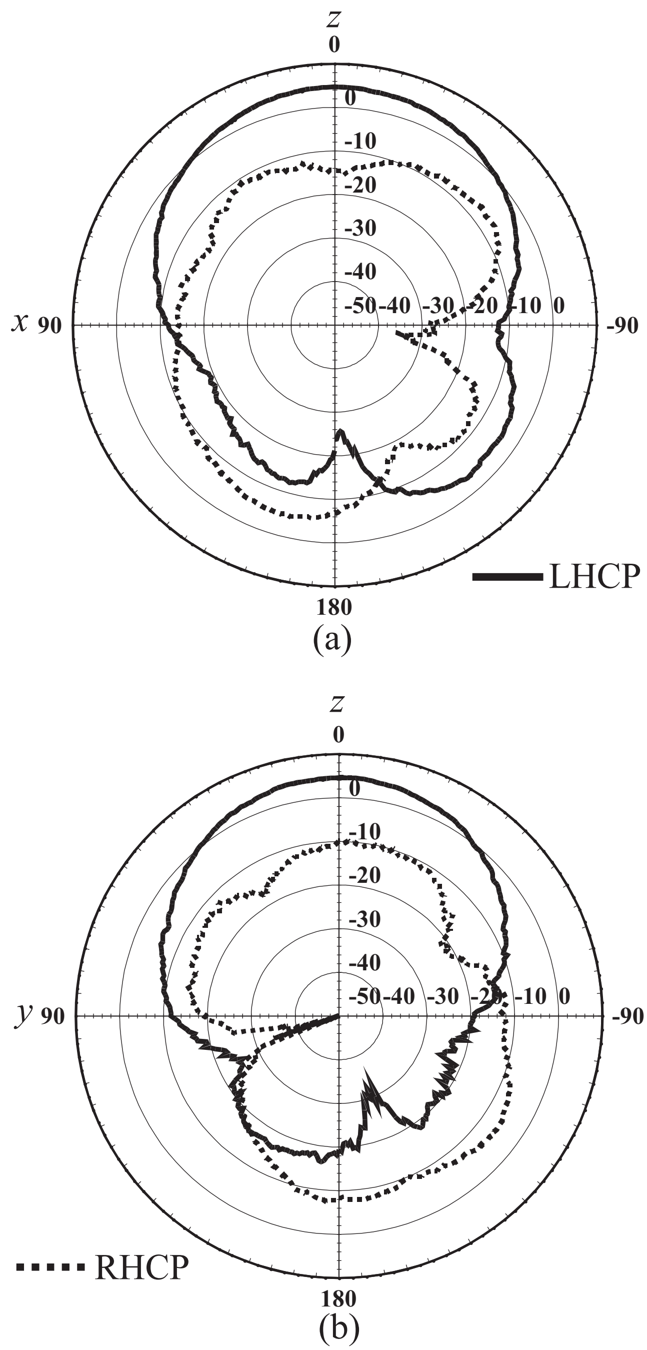

Figure 5 Radiation patterns of the LHCP mode of Prototype A measured at 2430 MHz. (a) *x*-*z* plane (b) *y*-*z* plane

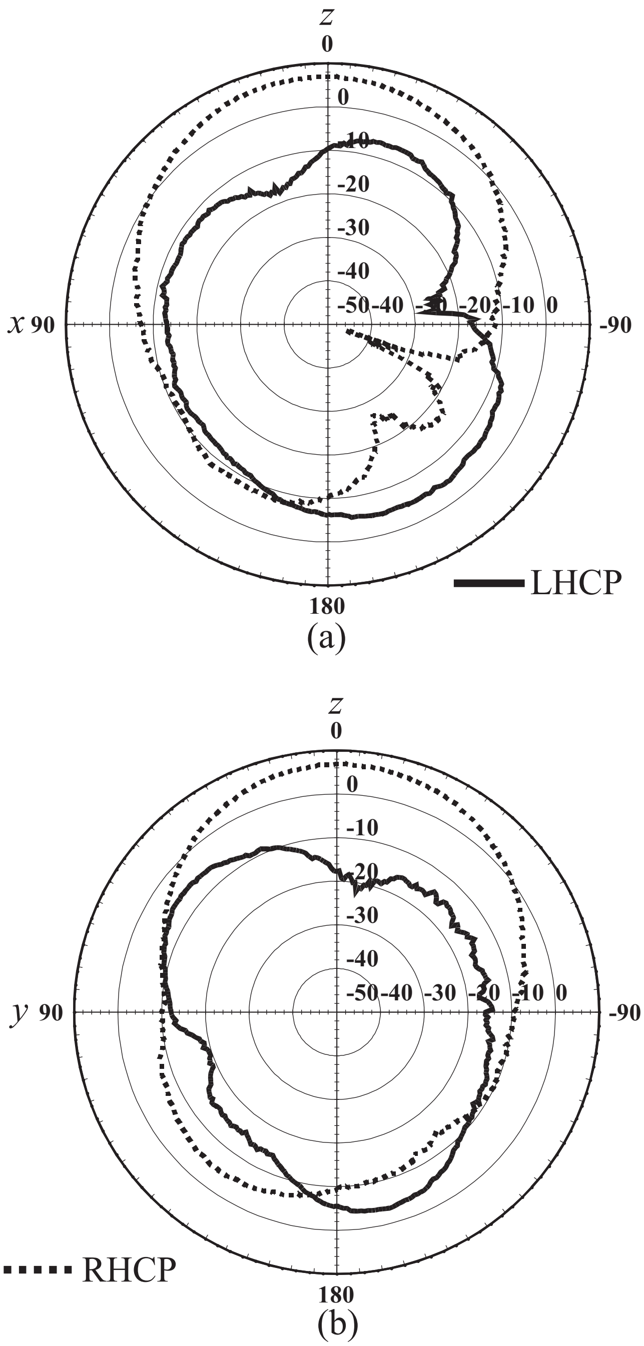

Figure 6 Radiation patterns of the RHCP mode of Prototype A measured at 3000 MHz. (a) *x-z* plane (b) *y-z* plane

totypes with frequency ratios of 1.07 and 1.23 have been successfully implemented, and the measured results show that the antenna can provide broadside radiation patterns at each CP operation.

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A GSM SIGNALS-BASED POSITIONING TECHNIQUE FOR MOBILE APPLICATIONS

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ABSTRACT: *A mobile positioning system based on GSM signals analysis and on a cooperative stochastic optimization algorithm is presented. The proposed technique is intended as a backup solution in those applicative scenarios where the GPS system fails to work (*e.g., *urban canyons). The hardware architecture of the system and the positioning algorithm are described and validated by means of a numerical assessment.* © 2008 Wiley Periodicals, Inc. Microwave Opt Technol Lett 50: 2128–2130, 2008; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.23568

Key words: *positioning; GSM; mobile applications*

1. INTRODUCTION

Global system for mobile communications (GSM) [1] is the most widespread mobile phone standard. It operates in the 900- and 1800-MHz frequency bands. Each assigned band is subdivided into 200-kHz radio channels by using the FDMA (frequency division multiple access). Every GSM Base Transceiver Station (BTS) has a special Broadcast Control Channel (BCCH) used to transmit its own identification data and the identities of neighboring cells, which are monitored by the mobile stations to guarantee a suitable quality-of-service (QoS) of the communication link. Since the propagation properties of the BCCH depend on the spatial positions of the mobile stations, they can be profitably exploited to develop a positioning system. As a matter of fact, the

TABLE 1 Measured Results for the Constructed Prototypes

		LHCP			RHCP		
Prototype	α	f_c (MHz)	CPBW (%)	Gain (dBi)	f_c (MHz)	CPBW (%)	Gain (dBi)
Prototype A	15°	2430	1.6	4.5	3000	3.5	7.3
Prototype B	142°	2560	1.1	4.7	2740	2.1	7.6

CPBW, CP operating bandwidth; f_c, Center frequency of CPBW.