

A COPLANAR-STRIP DIPOLE ANTENNA FOR BROADBAND CIRCULAR POLARIZATION OPERATION

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Abstract—A coplanar-strip dipole antenna with two enhanced features is presented for broadband circular polarization (CP) operation. The first feature of the proposed antenna is the replacement of a conventional thin dipole by a wide strip, resulting in two degenerated orthogonal modes to make CP operation possible. The second one is the use of two coplanar strips instead of two non-coplanar ones, thereby giving rise to the advantages of easy implement, good impedance matching, and wide axial ratio (AR) bandwidth. Two examples are given, one for the lower band around 1.8 GHz and the other for the ultra-wideband (UWB). For the lower band, the measured -10 dB return loss (RL) bandwidth is 119% (0.74 to 2.93 GHz), and the measured 3 dB AR bandwidth is 50% (1.45 to 2.41 GHz). As for UWB, the measured RL is below -10 dB between 2.1 to 10.1 GHz, and the measured AR is below 5 dB between 4.1 to 7.75 GHz.

1. INTRODUCTION

Generally, a conventional thin dipole (or monopole) antenna exhibits linear polarization (LP), and features an omni-directional radiation pattern in the H-plane with about 2 dBi antenna gain. It has found wide applications in the consumer products due to its good characteristics and low cost, which has been comprehensively reported in several studies [1–3]. On the other hand, the circular polarization (CP) antennas [4–14] have become more and more popular not only in the satellite communications but also in the territorial communications. For example, CP antennas can be used in radio frequency identification (RFID) systems and global positioning system (GPS) to reduce power loss due to polarization mismatch. To realize

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CP operation, two conditions should be satisfied. One is that the antenna must excite two degenerated orthogonal modes with different resonant frequencies. The other is that the phase difference between two orthogonal modes is 90° . A well known and often employed technique to generate a CP wave is to choose a suitable asymmetric feed-point on the asymmetric microstrip patch, thus resulting in two degenerated modes and good impedance matching [4, 5]. However, it is impossible for a thin dipole antenna to radiate a CP wave because only one directional current exists on the dipole surface. Recently, some papers [6–8] design a CP antenna by modifying the conventional dipole antenna. In [6, 7], a CP wave is created by feeding the two antennas with the currents that have a 90° phase difference between each other. In [8], the CP operation is achieved by combining a dipole antenna with an artificial ground plane. In addition, the C-type feeding technique [9, 10] is a useful technique for improving the axial ratio (AR) bandwidth and quality of CP stacked microstrip antennas. In [11], the authors modify the conventional dipole antenna by replacing a thin conductor by two non-coplanar wide strips. The wide strips excite two orthogonal modes with a phase difference of 90° , thus making it possible to radiate a CP wave. However, the -10 dB return loss (RL) and 3 dB AR bandwidths are not broad enough, because the impedance matching can only be adjusted by the overlapped area of and the gap between two non-coplanar strips. The object of this study is to improve the CP antenna presented in [11] by using two coplanar strips instead of two non-coplanar ones, based on the advantages of easy implement, good impedance matching, and wide AR bandwidth. Two examples will be given. The first example, designed for the lower band around 1.8 GHz, serves to demonstrate that the proposed antenna features wider RL and AR bandwidths than those in [11]. On the other hand, it is interesting to design an ultra-wideband (UWB) antenna for CP operation, since most of the reported UWB antennas radiate LP waves [1, 15–18]. Hence, the second example is to propose a UWB antenna for CP operation by resizing the same antenna structure as the first one. Moreover, the relevant researches on CP antenna have been reported in [19–33].

2. ANTENNA CONFIGURATION

The configuration of a coplanar-strip dipole antenna for CP operation is shown in Fig. 1. The antenna consists of two coplanar strips of size $L \times W$ with a gap g in the x -direction and an overlapped length $2h$ in the y -direction. The feeding point is at the center of the overlap region. A rigid mini-coaxial cable with a radius of 0.6 mm is adopted

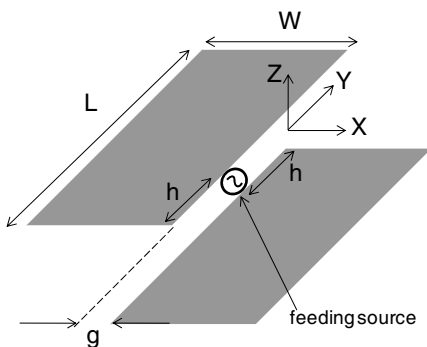


Figure 1. Configuration of a coplanar-strip dipole antenna for CP operation.



Figure 2. Photography of a coplanar-strip dipole antenna for CP operation.

to feed the RF power to the antenna. The inner conductor of the cable is soldered to one strip, while the outer conductor of the cable is connected to the other strip. It is the strip width W that makes the proposed antenna capable of radiating CP waves due to there being two orthogonal currents on the strip. The parameters g and h are responsible for the impedance matching. It should be pointed out that the proposed antenna has several key advantages over the previous work [11], such as easy implement, better impedance matching, and wider AR bandwidth. The first example is to design a CP antenna with the center frequency around 1.8 GHz. The Ansoft HFSS high frequency simulator based on the finite element method is used as the simulation tool. After the optimization process, the final dimensions used for fabrication are: $L = 102$ mm, $W = 40$ mm, $h = 23$ mm, and $g = 1.5$ mm. The photography of the fabricated antenna is shown in Fig. 2.

3. RESULTS

3.1. Return Loss

Figure 3 shows the variation of return loss with frequency. The measured data are in good agreement with the simulated ones. Taking -10 dB as reference, the frequency ranges and impedance bandwidth of the proposed antenna are summarized in Table 1 for comparison. The proposed antenna's measured RL bandwidth and frequency ratio are 2.19 GHz (119%) and 3.96, respectively, and the corresponding data for the non-coplanar structure [11] are 0.51 GHz (34%) and 1.4,

Table 1. Summary of the frequency ranges and bandwidths of the proposed antenna in the lower band around 1.8 GHz.

		f (GHz)	bandwidth (%)
Simulation	RL	0.70–3.10	2.40 GHz (126%)
	AR	1.45–2.45	1.00 GHz (51%)
Measurement	RL	0.74–2.93	2.19 GHz (119%)
	AR	1.45–2.41	0.96 GHz (50%)
Measurement	RL [11]	1.25–1.76	0.51 GHz (34%)
	AR [11]	1.69–2.22	0.53 GHz (27%)

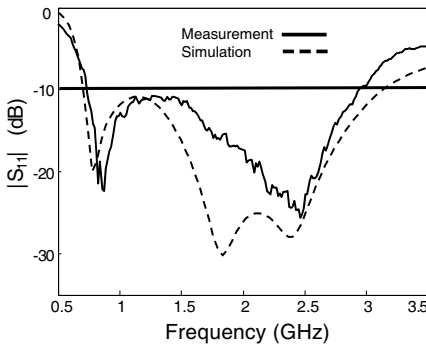


Figure 3. Measured and simulated return losses of the proposed coplanar-strip dipole antenna.

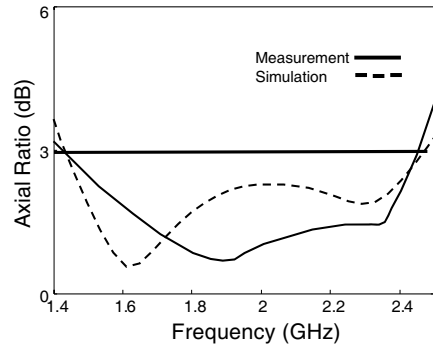


Figure 4. Measured and simulated axial ratios of the proposed coplanar-strip dipole antenna.

respectively. Obviously, the proposed antenna achieves a much wider RL bandwidth than the antenna in [11], implying that the coplanar structure provides better impedance matching than non-coplanar one.

3.2. Axial Ratio

To verify the CP operation of the proposed antenna, the measured and simulated axial ratios in the z -direction are illustrated in Fig. 4. Taking 3 dB as reference, the measured and simulated bandwidths are summarized in Table 1 for comparison. The proposed antenna's measured AR bandwidth and frequency ratio are 0.96 GHz (50%) and 1.66, respectively, and the corresponding data for the non-coplanar structure [11] are 0.53 GHz (27%) and 1.31, respectively. As shown in Table 1, the proposed antenna is a good candidate for broadband CP applications due mainly to its much wider RL and AR bandwidths

than previously reported [11].

3.3. Radiation Patterns

The radiation patterns at 1.0, 2.0, and 3.0 GHz are shown in Figs. 5, 6, and 7, respectively. Only $x-z$ and $y-z$ patterns are considered due to symmetry. To observe the CP radiation, the radiation patterns are divided into a right-hand circularly polarized wave (RHCP) and a left-hand circularly polarized wave (LHCP). The three figures indicate that the forward radiation is dominated by LHCP and the backward radiation RHCP. In the z -direction, the difference between the intensity of LHCP and that of RHCP is larger at 2.0 GHz (see Fig. 6) than at 1.0 and 3.0 GHz (see Figs. 5 and 7), which implies a larger AR at 2.0 GHz than at 1.0 and 3.0 GHz (see Fig. 4). In addition, the antenna gain at 1.0, 2.0, and 3.0 GHz are 1.99, 3.57, and 4.81 dBic, respectively.

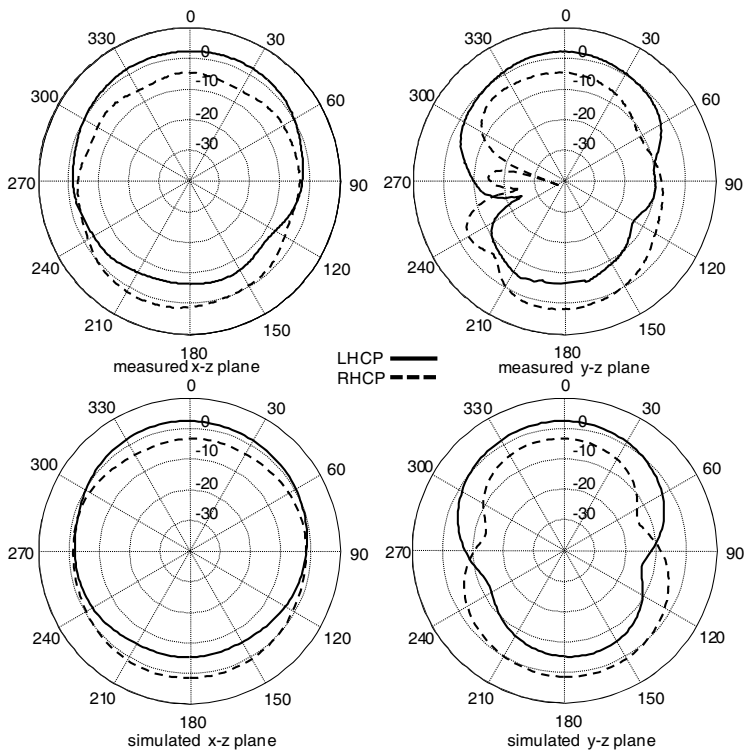


Figure 5. Measured and simulated radiation patterns at 1.0 GHz.

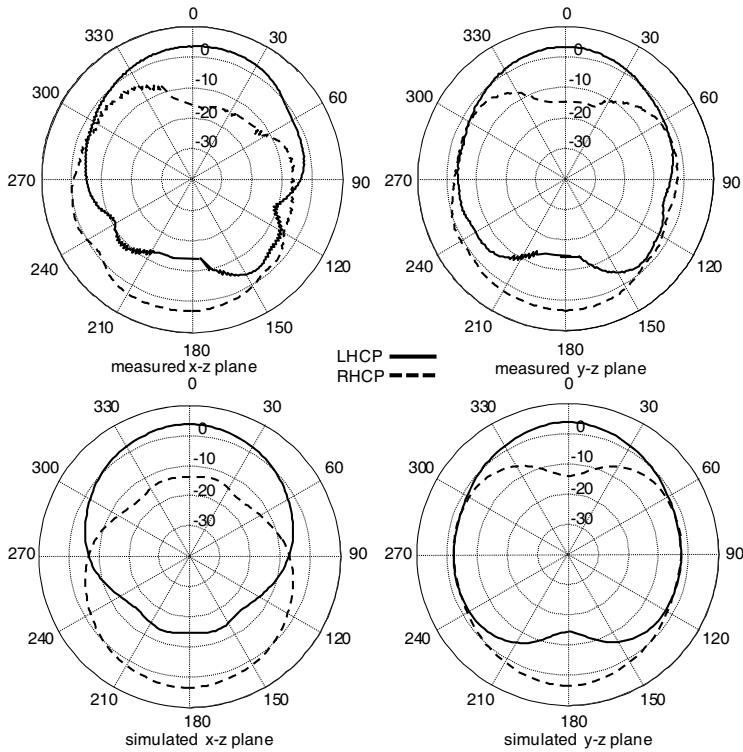


Figure 6. Measured and simulated radiation patterns at 2.0 GHz.

3.4. Current Distributions

From Figs. 3 and 4, the proposed antenna emits linearly polarized radiation at the lower frequency 0.8 GHz, which can be explained by the current distributions on the metal strip, as shown in Fig. 8. Only the half part is shown due to symmetry. Most of the current distributions are directed in the positive or negative y -direction for four different phase angles: $\omega t = 0^\circ, 45^\circ, 90^\circ,$ and 135° . Hence, the proposed antenna radiates linearly polarized waves at 0.8 GHz. Similarly, From Figs. 3 and 4, the proposed antenna performs CP operation at 2.0 GHz, which can also be understood by the current distributions, as shown in Fig. 9. The current vectors on the metal strip rotate clockwise with time, resulting in the fact that the forward radiation and backward radiation patterns are dominated by LHCP and RHCP, respectively. (see Fig. 6).

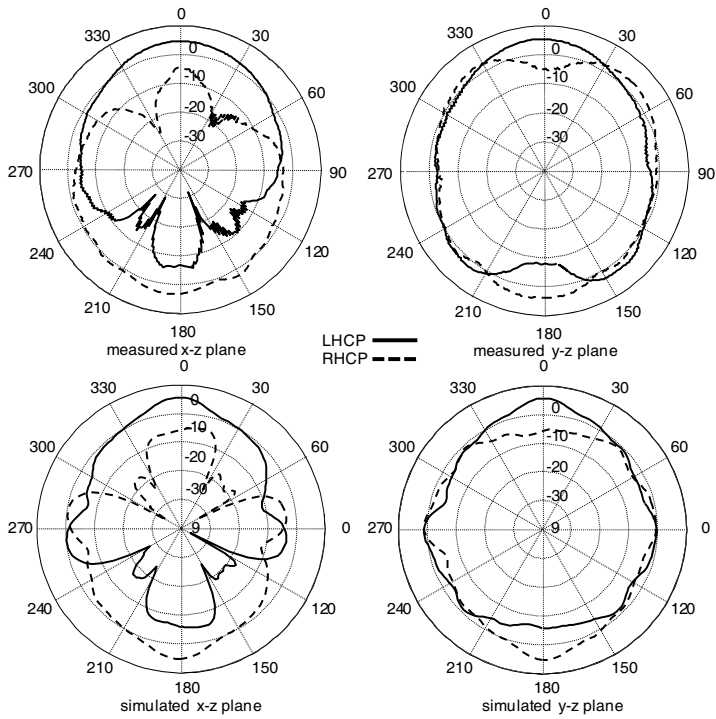


Figure 7. Measured and simulated radiation patterns at 3.0 GHz.

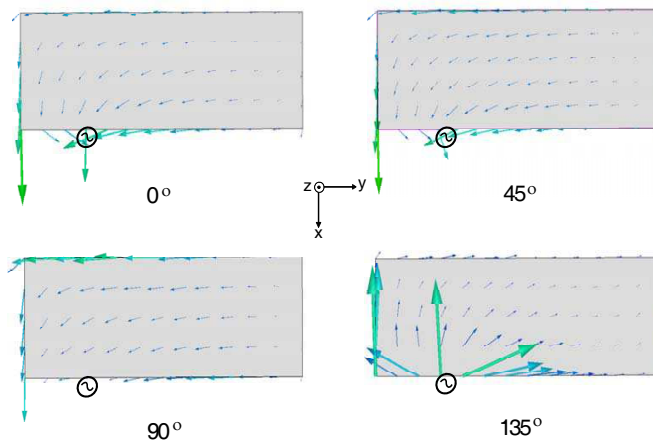


Figure 8. Current distributions at 0.8 GHz.

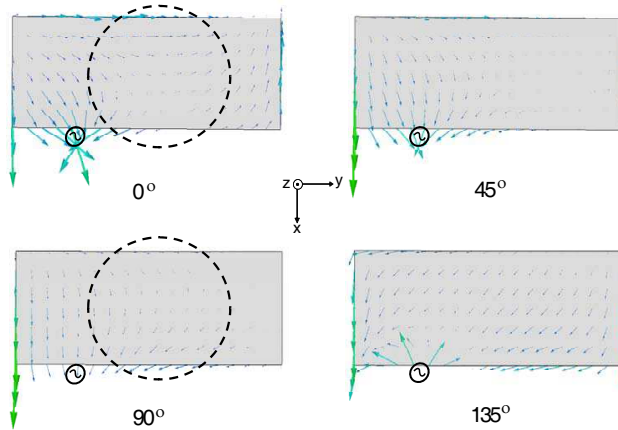


Figure 9. Current distributions at 2.0 GHz.

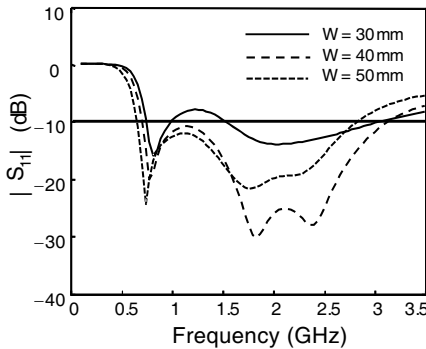


Figure 10. Simulated return losses for different slab width W .

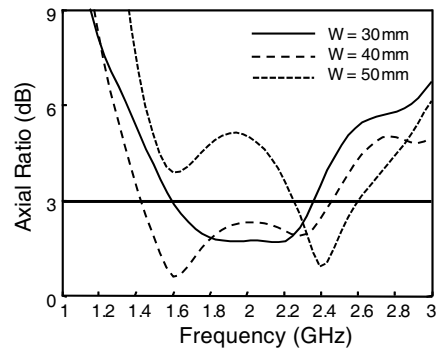


Figure 11. Simulated axial ratios for different slab width W .

4. PARAMETRIC STUDY

4.1. The Influence of the Slab Width W

Having shown the good performances of the proposed antenna on RL and AR bandwidths, it would be interesting to investigate the influence of the structure parameters W , g , and h (see Fig. 1) on the antenna characteristics such as RL and AR bandwidths. First, the structure parameters are taken the same as those in Section 3 except the parameter W . As shown in Fig. 10, the variation of the slab width W has a significant influence on RL, which implies that the impedance matching can be done by tuning W . In addition, Fig. 11 indicates that

the increase of the slab width W results in the CP radiation. It should be noted that the conventional thin dipole antenna can be regarded as a special case of the proposed antenna when the slab width W approaches zero. The thin dipole radiates a LP wave due to only one directional current; however, the existence of two orthogonal currents on the proposed antenna makes CP operation possible.

4.2. The Influence of the Overlap Length

With the structure parameters, except h , being the same as those in Section 3, Figs. 12 and 13 illustrate the RL and AR against frequency for different h , respectively. The parameter h has a considerable influence both on RL and AR. The reason for this result is that the

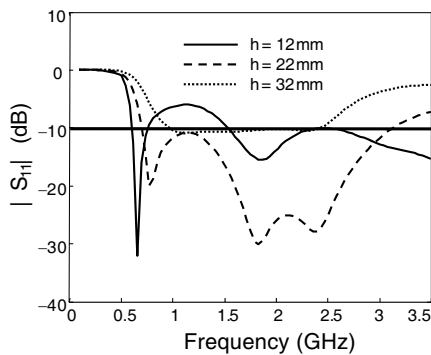


Figure 12. Simulated return losses for different h .

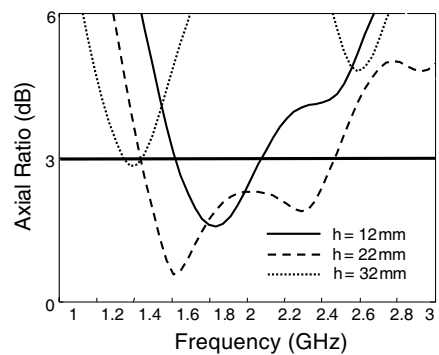


Figure 13. Simulated axial ratios for different h .

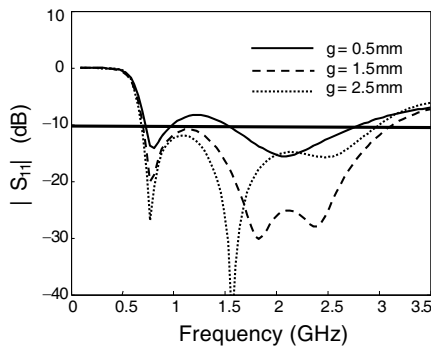


Figure 14. Simulated return loss for different gap g .

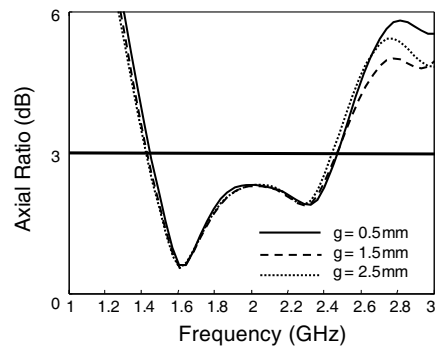


Figure 15. Simulated axial ratio for different gap g .

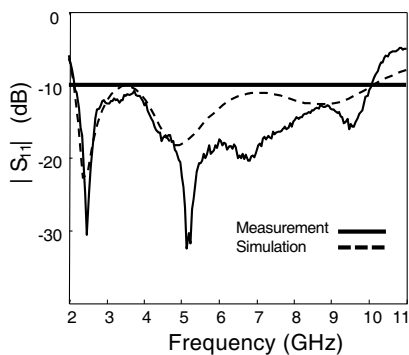


Figure 16. Measured and simulated return losses of the proposed coplanar-strip dipole antenna.

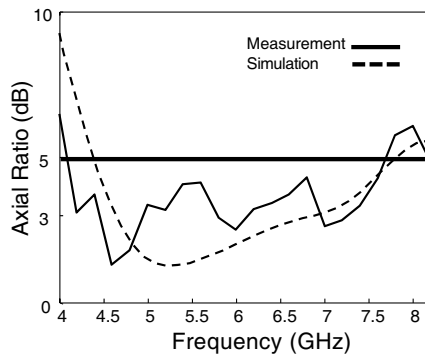


Figure 17. Measured and simulated axial ratios of the proposed coplanar-strip dipole antenna.

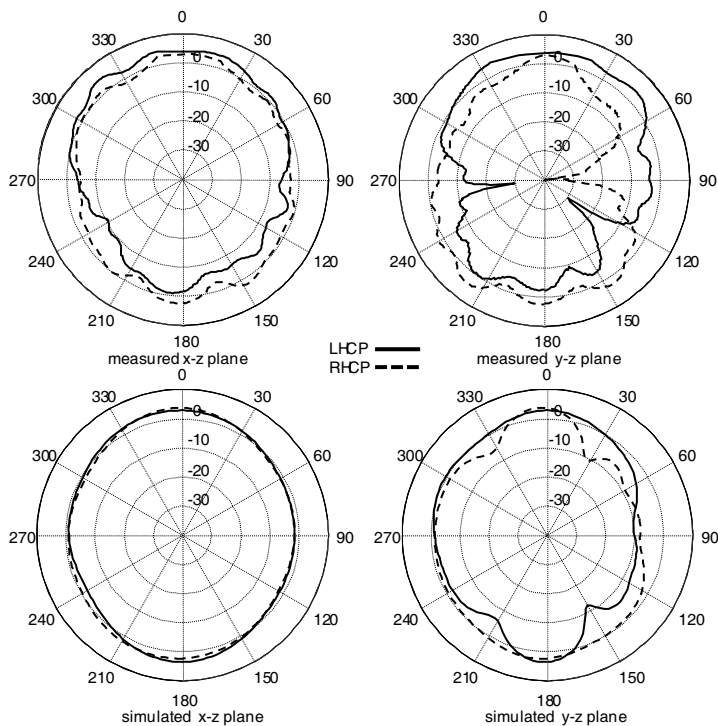


Figure 18. Measured and simulated radiation patterns at 3.0 GHz.

position of the feeding point will affect not only the input impedance of the proposed antenna but also the phase difference between two orthogonal currents on the strip.

4.3. The Influence of the Gap

Figures 14 and 15 show the RL and AR versus frequency, respectively, with all parameters in Section 3 kept unchanged except the gap g . The parameter g has a significant influence on RL but little effect on AR. From these parametric studies, the design procedure can be completed by three simple steps. The first step is to determine the parameter L by the required center frequency. The second step is to achieve good AR matching by tuning the parameters W and g . The final step is to do impedance matching using parameter g .

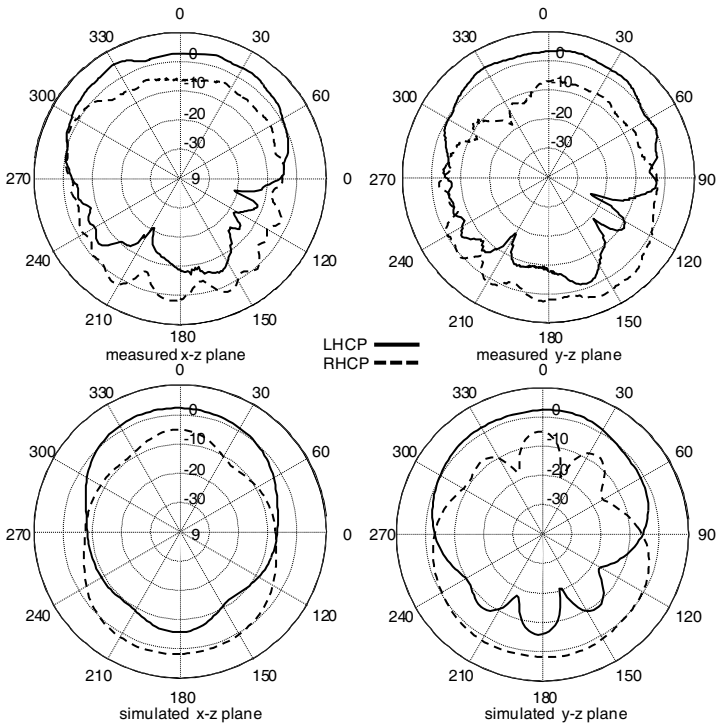


Figure 19. Measured and simulated radiation patterns at 4.0 GHz.

5. APPLIED TO UWB

5.1. Return Loss

In Sections 3 and 4, the proposed antenna (see Fig. 1) has been successfully applied in the lower frequency band around 1.8 GHz. In this Section, the same structure will be applied in the UWB with the parameters modified as $L = 32$ mm, $W = 12.5$ mm, $h = 7$ mm, and $g = 1.5$ mm. Fig. 16 shows the measured and simulated return losses. The measured -10 dB RL bandwidth is from 2.1 to 10.1 GHz, and the simulated one is also from 2.1 to 10.1 GHz. Both measured and simulated data match well and show that the proposed antenna can work well in UWB.

5.2. Axial Ratio

Figure 17 shows AR of the proposed antenna by receiving signal in the z -direction. With $AR < 5$ dB, the measured AR bandwidth is from 4.10

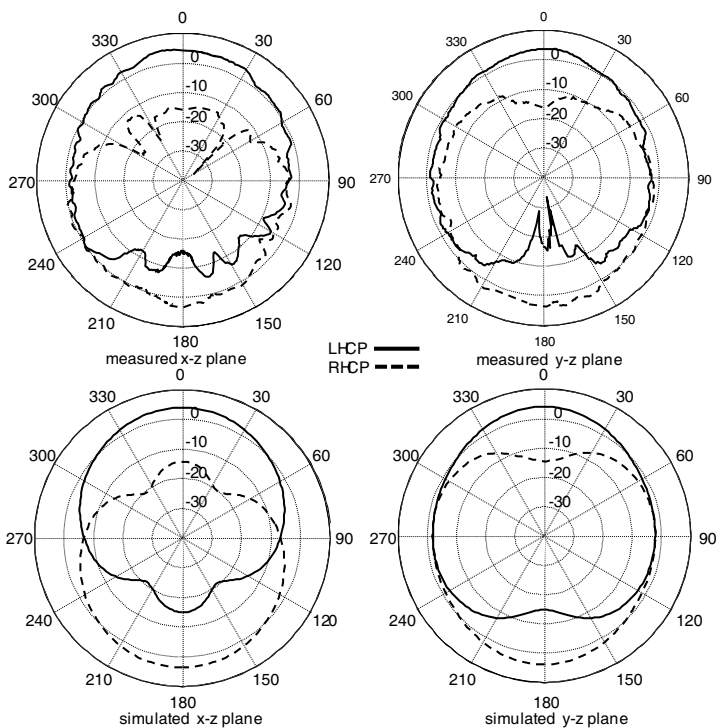


Figure 20. Measured and simulated radiation patterns at 6.0 GHz.

to 7.75 GHz, and the simulated one from 4.38 to 7.82 GHz. It should be noted that the conventional UWB antenna can only radiate LP waves. However, the proposed antenna can radiate CP waves in the band of 4.1 to 7.75 GHz. To the author’s best knowledge, little literature has been published on CP UWB antenna. The present work is an attempt to design a CP UWB antenna by using wide-strip dipole. The RL bandwidth covers UWB, but the AR bandwidth only occupies 4.1–7.75 GHz band with the lower and higher bands of UWB not covered. Therefore, based on the proposed antenna, other improved structures, whose AR bandwidth can cover UWB, will be of great interest in the near future.

5.3. Radiation Pattern

Figures 18, 19, 20, and 21 show the measured and simulated radiation patterns at 3.0, 4.0, 6.0, and 8.0 GHz, respectively. The proposed antenna exhibits dipole-like patterns, especially in the lower frequency

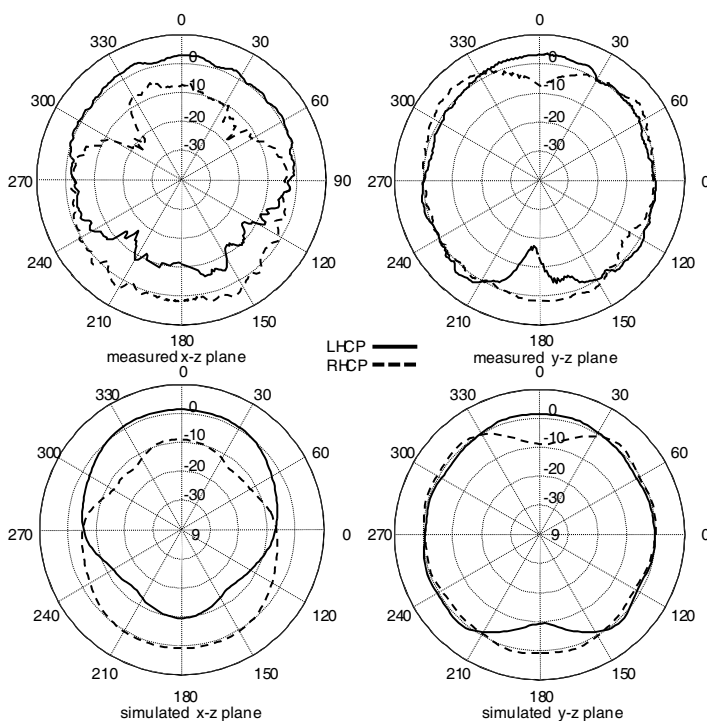


Figure 21. Measured and simulated radiation patterns at 8.0 GHz.

band. At 3.0 GHz (see Fig. 18), the proposed antenna radiates LP waves due to the little difference between LHCP and RHCP, which can also be observed in Fig. 17. However, at 4.0, 6.0, and 8.0 GHz, the proposed antenna shows obvious CP operations which the conventional UWB antenna does not possess. The forward radiation is dominated by LHCP, and the backward radiation RHCP, which is similar to the results in Section 3 (see Figs. 6 and 7). Moreover, the antenna gain at 3.0, 4.0, 6.0, and 8.0 GHz are 3.38, 2.1, 3.52, and 2.1 dBic, respectively.

6. CONCLUSION

It is well known that a conventional thin dipole antenna radiates a LP wave. In this work, a coplanar-strip dipole antenna for broadband CP Operation has been investigated and successfully implemented. The replacement of a thin dipole by a wide strip is the key design feature for the proposed antenna to radiate CP waves, which results in two degenerated orthogonal modes with different resonant frequencies. In addition, the use of coplanar strip instead of non-coplanar one has advantages of easy implement, good impedance matching, and wide AR bandwidth. The parametric studies suggest three easy steps to design the proposed antenna. Two examples are given, one for the lower band around 1.8 GHz and the other for UWB. For the lower band, the measured -10 dB RL is from 0.74 to 2.93 GHz, with a bandwidth of 2.19 GHz (119%) and a frequency ratio of 3.96; the measured 3 dB AR is from 1.45 to 2.41 GHz, with a bandwidth of 0.96 GHz (50%) and a frequency ratio of 1.66. As for UWB, the measured -10 dB RL bandwidth is from 2.1 to 10.1 GHz, and the measured 5 dB AR bandwidth is from 4.1 to 7.75 GHz. It can be concluded from these two examples that the proposed antenna is a good choice for broadband CP applications due mainly to its much wider RL and AR bandwidths than previously reported.

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