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DEVELOPMENT OF A HIGH-GAIN CIRCULARLY POLARIZED PATCH ANTENNA

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6.1 INTRODUCTION

There are many applications, where circularly polarized is required. In a communication system that uses circularly polarized radiation the rotational orientations of the transmitter and the receiver antennas are unimportant in relation to the received signal strength. With linearly polarized signals, on the other hand, there will be very weak reception if the transmitter and receiver antenna orientations are nearly orthogonal. Also in circularly polarized, after reflection from metallic objects, the sense of polarization reverses from left-hand circularly polarized (LHCP) to right-hand circularly polarized (RHCP) and vice versa to produce predominantly orthogonal polarization. The system then tends to discriminate the reception of such reflected signals from other signals arising from direct paths. Therefore, CP is useful for a number of applications, such as radar, communication, and navigational systems. Cutting off two diagonally opposite corners makes the resonance frequency of the mode along this diagonal to be higher than that for the mode along the uncut diagonal. The patch is fed along the central axis so that the orthogonal modes are generated. In case of comparison between the circularly polarized and linearly polarized antenna; we can say; since circular polarized antennas send and receive in all planes, the signal strength is not lost, but is transferred to a different plane and is still utilized and circular polarized antennas give higher probability of a successful link because it is transmitting on all planes. The circularly-polarized signals are much better at penetrating and bending around obstructions. Also circular polarization is more resistant to signal degradation due to inclement weather conditions. Finally circular polarization is much more effective than linear polarization for establishing and maintaining communication links. To provide a wide impedance bandwidth, a thick air-layer substrate can be used. To excite antennas that have thick air-layer substrates some modifications on the probe to compensate the large inductance introduced by the long probe pin in the thick air-layer substrate. For a better bandwidth of a single-feed single-element patch antenna, the antenna structure is usually designed to have a thick air-layer. For a circularly polarized bandwidth to be greater than 10%, an air-substrate thickness of about 20% of the operating wavelength is desired. The conventional dimension of CP patch antenna is much less than this dimension. The required bandwidth for WLAN systems operated at the 2.4 GHz band is about 3% of the centre operating frequency. The required antenna air-layer substrate thickness is less than 10% of the operating wavelength for achieving 3% bandwidth. This research proposes a novel broadband RHCP patch antenna designed using a simple feed structure. The air-substrate thickness of the proposed antenna is about 2.5% of the wavelength at a resonant operating frequency. Details of the antenna design and the obtained experimental results are presented in the following sections.

6.2 ANTENNA DESIGN

Figure 6.1 depicts the geometry of a single-feed circularly polarized microstrip antenna. The patch antenna with a square area of (51x51 mm2) was printed on a substrate with a thickness of 1.6 mm and a relative permittivity of 4.6. This radiating patch was located on the other h mm thickness of the air substrate layer and on 1.6 mm thickness of a ground plane. The feeder for this radiating patch was a short a short probe pin (h mm).

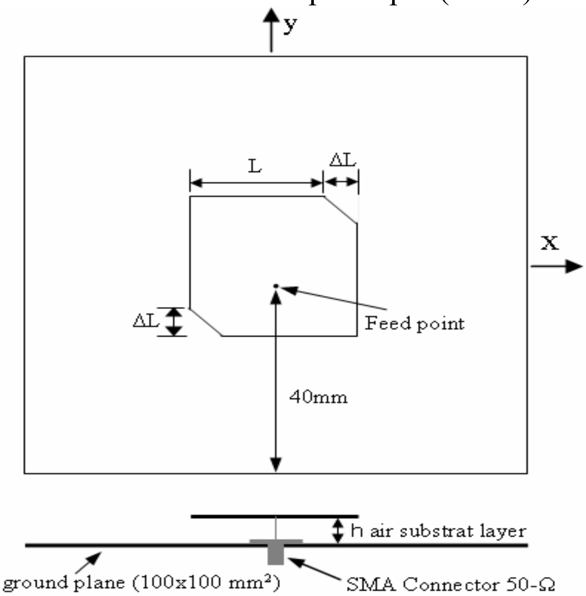

Figure 6.1 The geometry of the CP microstrip antenna with a thick air substrate layer.

A power splitter or a coupler can be used to feed square patch antenna to achieve a circular polarization. A single probe or a microstrip as the feed element can be also used to obtain more compact CP antenna structure. However, the using of single probe feed to create and achieve the circular polarization operation; some change mechanism should be introduced. The change for the circularly polarized patch antenna should be able to cause the fundamental mode to be split into two degenerate modes, namely, the TM0l and TMl0 modes. These two modes are equal in magnitude and ±90° out of phase to establish the necessary conditions for circular polarization. The level of change of the square patch antennas is determined by the ratio of truncated portion length (ΔL) to length of the square patch (L) and the position of the feeding probe, as shown in Figure 6.1. The antenna gain is enhanced by a thicker air-layer substrate and the ratio. The right-hand Circular Polarized operation is generated for the antenna geometry shown in Figure 6.1. The centre wavelength is about the double of the length of square patch and eight times of the length of the truncated portion.

6.3 RESULTS AND DISCUSSION

In this work, prototypes of the proposed antenna with a centre frequency at about 2.45 GHz and for WLAN operation in the 2.4 GHz band (2.4–2.484 GHz), with a different substrate thickness were fabricated and investigated. Figure 6.2 shows the measured and simulated (Using AWR Microwave Office Software) return loss of the proposed antenna. Good agreement between the simulated and measured results were observed, and the obtained 10 dB return-loss impedance bandwidth can be about 350 MHz (2.3~2.65 GHz) or 14.2% of the designed centre frequency at 2.46 GHz for the simulated result and 10 dB return-loss impedance bandwidth can be about 300 MHz (2.3~2.6 GHz) or 12.3% of the designed centre frequency at 2.45 GHz for the measured result. This is wide enough to cover the 2.4 GHz WLAN operating band. Also note that for the operating frequencies within the 2.4-GHz WLAN band, the measured return loss is even better than 6 dB.

Figure 6.3 presents the measured axial ratio in the broadside direction. It shows that the CP bandwidth determined by 3-dB axial ratio is about 220 MHz (2.37~2.59 GHz) or 8.9% of the designed center frequency at 2.475 GHz. The axial ratio comes to a minimum around the center frequency, with the minimum value of about 0.6 dB. This demonstrates that the proposed antenna has good purity of circular polarization at 2.4 GHz.

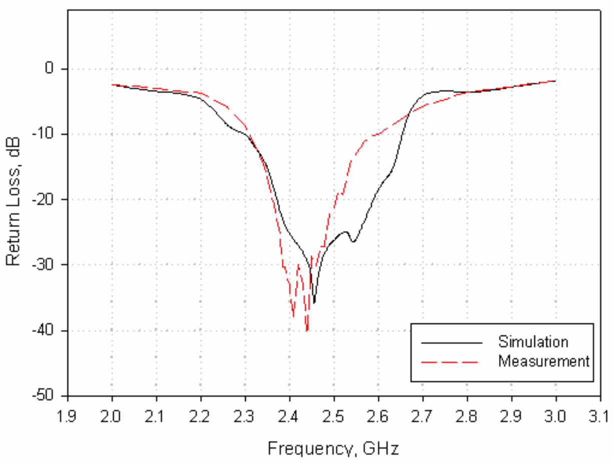

Figure 6.2 Measured and simulated return loss of the proposed antenna

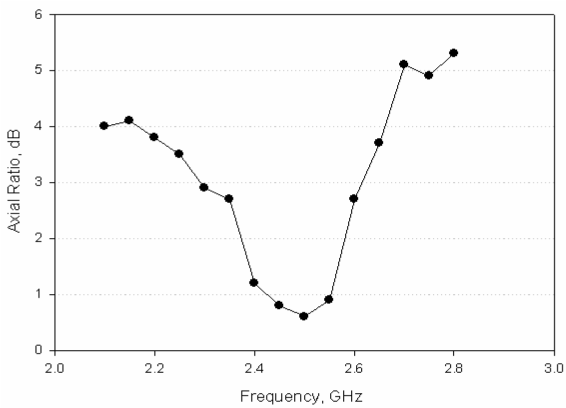

Figure 6.3 The measured axial ratio

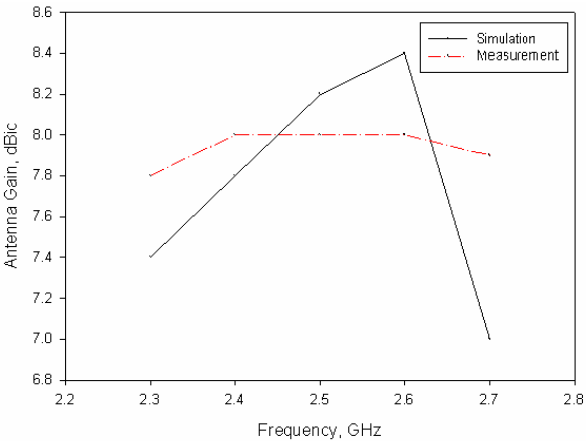

Figure 6.4 Antenna Gain

The right hand circular polarized antenna gain is shown in Figure 6.4 at boresight. The figure shows the results of both measured and simulated CP antenna gain, in the band 2.45-2.6 GHz the simulated gain results better than measured results in 0.4 dBic. The maximum gain of 8 dBic was measured at (2.4-2.6) band GHz and for the simulation result is 8.6dMic at 2.6 GHz. It is more than 7.5 dBi over the 3 dB AR bandwidth.

Figure 6.5 plots the measured radiation patterns in two principle planes at 2.4 GHz. In the broadside direction, good CP radiation (right-hand) is obtained. The conclusions obtained from the graph are; Main lobe magnitude is 8.64 dB, Main lobe direction is 0.87 deg, Angular width (HPBW) (3dB) is 88.6deg and Directivity is 10.241 dB.

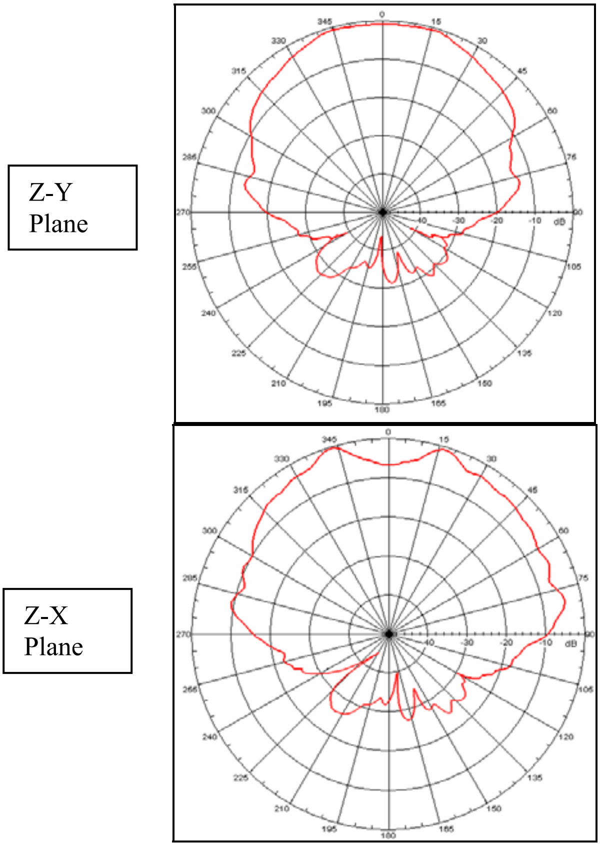

Figure 6.5 Measured radiation patterns of the proposed antenna

6.4 CONCLUSIONS

This chapter, a novel truncated square patch antenna for broadband CP operation has been proposed. A prototype suitable for WALN systems operating in the 2.4-GHz band has been implemented and experimentally investigated. By incorporating a folded ground plane, the proposed broadband CP patch antenna can be fed with a relatively short probe pin while retain the thick air-substrate to give wide CP bandwidth. The fabricated prototype showed a wide 1.5:1 VSWR impedance bandwidth of about 14.2% and a wide 3-dB axial-ratio CP bandwidth of about 8.9%. Antenna gain level of about 8.5 dBic across the operating bandwidth is obtained with a small variation less than 0.6 dB. This indicates that the proposed antenna has well stable gain across the 2.4 GHz operating band. The design process is simple because the return loss and AR requirements are achieved at different stages almost independently. The return loss, axial ratio, gains and radiation patterns of the antenna have been measured and presented. Further optimization of the substrate thickness and the aspect ratio of the driven patch may provide even wider AR bandwidth.

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