

SINGLY-FED CIRCULARLY POLARISED PATCH ANTENNA WITH WIDE IMPEDANCE AND AXIAL-RATIO BANDWIDTH

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1. Introduction

Traditional single layer singly-fed circularly polarised (SL-SFCP) microstrip patch elements are classified as Type-A and Type-B in the literature [1] according to the polarity of perturbation, and the sense of circular polarisation is decided by the axis on which the feed is located. However, owing to the imperfect excitation of the two degenerate modes as well as the high unloaded Q-factor of the patch resonator, SFCP microstrip patch antenna exhibits narrow 3-dB axial-ratio bandwidth (A_x BW) and limited 10-dB impedance bandwidth (ZBW), typically less than 1% and 5% respectively [2]. On the other hand, traditional two-layer electromagnetically coupled patch (EMCP) antennas have additional degrees of freedom and have been shown to have high gain and broadband characteristics for both linear and circular polarisation cases [3]-[4]. However, the attractiveness of SFCP microstrip patch antenna comes from its simple feeding structure, and there is a need to improve the A_x BW of EMCP antennas [5]. Broad 3-dB A_x BW has recently been reported [6]-[7], in which the axial-ratio (AR) curves follow a W-shape that can be obtained by combining two V-shaped curves. Although a W-shaped AR curve results in a broad A_x BW, the cost paid for that is the low cross-polarisation discrimination (XPD) at the centre frequency, which may not be acceptable for a number of applications in satellite communications. Hence, it is necessary to design patch antennas that have wide A_x BW while at the same time have very high XPD at centre frequency.

In this paper, we present a novel SFCP patch antenna, which is an evolution of Type-A element, is based on two-layer EMCP designs by making use of airgap tuning [8]. The objective of the present design is mainly focused on the improvement of the minimum AR at the centre frequency, A_x BW, ZBW, antenna gain and gain bandwidth (GBW) for the antenna. We also examine the radiation characteristics such as XPD, the half-power beam-width as well. The proposed antenna element has a measured ZBW of 43% and a 1-dB A_x BW of 3.5% with a XPD of higher than 30 dB at boresight, which will have wide applications in satellite and wireless communications. In the following sections, the structure of the proposed antenna is described; the simulation and experimental results are also presented.

2. Antenna Structure

The proposed EMCP antenna is a right-hand circularly polarized (RHCP) design operating in C-band with a desired centre frequency of 5.7 GHz. The top layer is formed using a RT/Duriod 5880 dielectric material with a thickness of 1.575 mm and a permittivity of 2.2. It serves as a superstrate for an inverted square patch of size $18 \times 18 \text{ mm}^2$ with a perturbation (q_2) of -6.53% . An airgap of 3.2mm ($\sim 0.06\lambda_0$) is adopted as the separation between top and bottom layers in order to yield a low Q-factor for the element. The advantage of using an air dielectric is that it allows adjustment of the airgap for the fine tuning of the AR as well as the input impedance during measurements phase [8]. The bottom layer uses a RO3010 dielectric material as the substrate with a thickness of 1.270 mm and a permittivity of 10.2. A driven patch of size of $8.6 \times 8.6 \text{ mm}^2$ with a perturbation (q_1) of -11.37% is

printed on the top of the substrate with its bottom being a ground plane with size of $80 \times 80 \text{ mm}^2$ ($1.52 \times 1.52 \lambda_0^2$). A 50-ohm microstrip feed-line with a shunt stub of 1.55 mm (L) is used to feed the lower patch and the dielectric layers are supported by nylon spacers and bolts. The patch geometry and variables of the proposed antenna is shown in Figure 1(a) and 1(b) whereas the key parameters of the layers are summarized in Table 1.

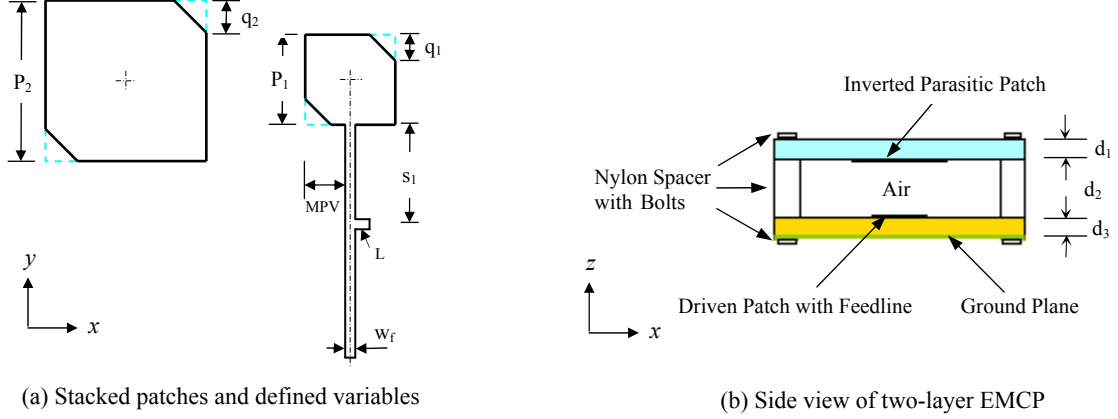


Figure 1 Geometry of the proposed antenna

Table 1

Layer	Dielectric	ϵ_r	$\tan \delta$	Thickness [mm]
Top	RT5880	2.20 ± 0.02	0.0009	$d_1 = 1.575$
Separation	AIR	1.0	0.0	$d_2 = 3.200$
Bottom	RO3010	10.2 ± 0.30	0.0035	$d_3 = 1.270$

3. Tuning Approach and Experimental Results

The proposed antenna was designed and tuned by using an em simulator – Ensemble[®]. The perturbation on the parasitic patch, q_2 , is adjusted from zero inward whilst the perturbation on the driven patch, q_1 , is tuned in the opposite way, i.e., from a maximum possible value (MPV) down to an optimum value. It is noted that the airgap also has a significant effect on minimum AR and 3-dB A_x BW as can be observed from Figure 2. Both the simulated and measured VSWR are depicted in Figure 3, which show that the simulated and measured ZBW ($VSWR \leq 2$) is 41% and 43.6%, respectively. The simulated and measured gain and AR are shown in Figure 4, and it can be seen that the measured 3-dB A_x BW is 8% with a centre frequency of 5.67 GHz and the corresponding 1-dB A_x BW is also in excess of 3.5% while the minimum AR of less than 0.3 dB occurred at 5.67 GHz. On the other hand, the measured 6-dBic GBW is 37% with a centre frequency of 5.87 GHz and a mean level of 7 dBic whilst a peak gain of 8.5 dBic is measured at 5.77 GHz. The radiation patterns for both RHCP and LHCP in two orthogonal planes at 5.70 GHz are shown in Figure 6 while the reduced scale RHCP patterns are plotted in Figure 5. As can be seen, the measured XPD is 30 dB and 38 dB at boresight and the measured half-power beam-width is 86° and 69° in x - z and y - z plane, respectively. It is interesting to note that the measured values of antenna gain and beam-widths agree closely with the well-known Kraus's formula [9]:

$$G \text{ [dBi]} \approx 10 \log_{10} \frac{4 \pi}{HP_0 HP_{90}}$$

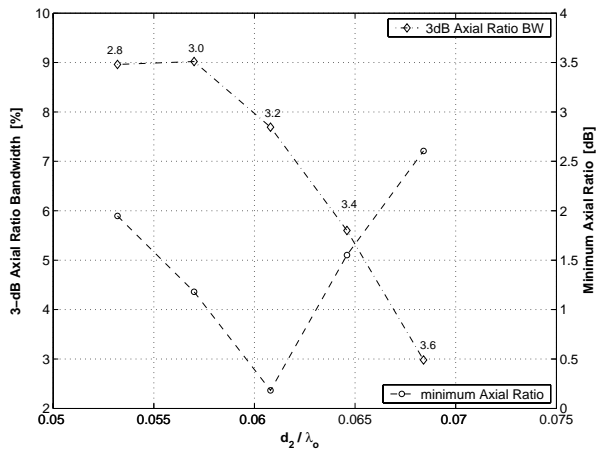


Figure 2 The 3-dB Axial Ratio Bandwidth and minimum Axial Ratio as a function of airgap.

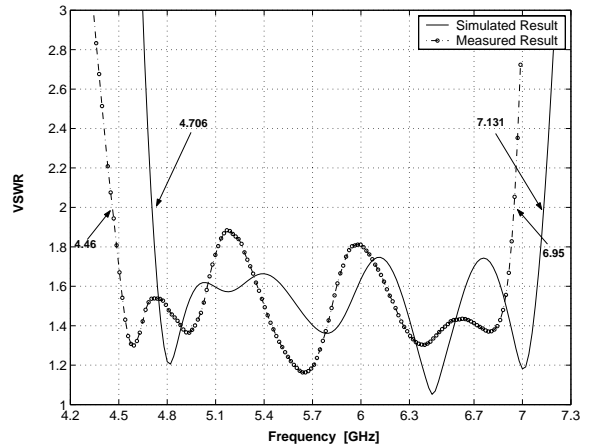


Figure 3 A comparison of simulated and measured VSWR and the corresponding impedance bandwidth.

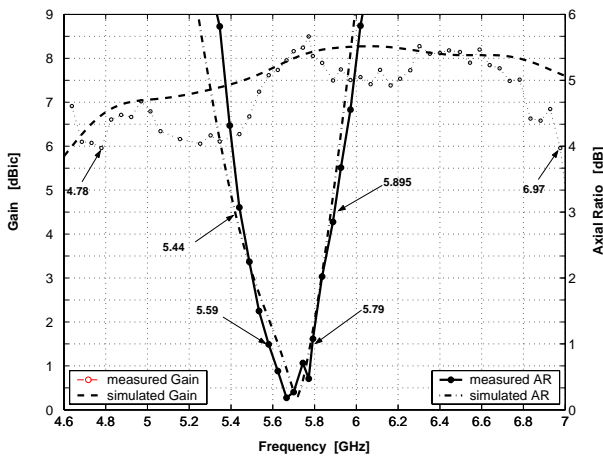


Figure 4 A comparison of simulated and measured Gain and Axial Ratio.

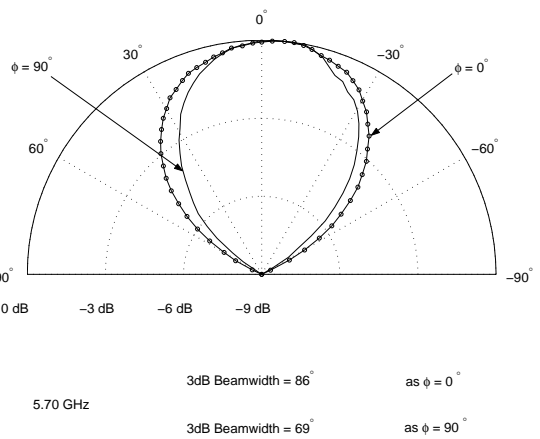


Figure 5 Measured half-power beam-width in two orthogonal planes.

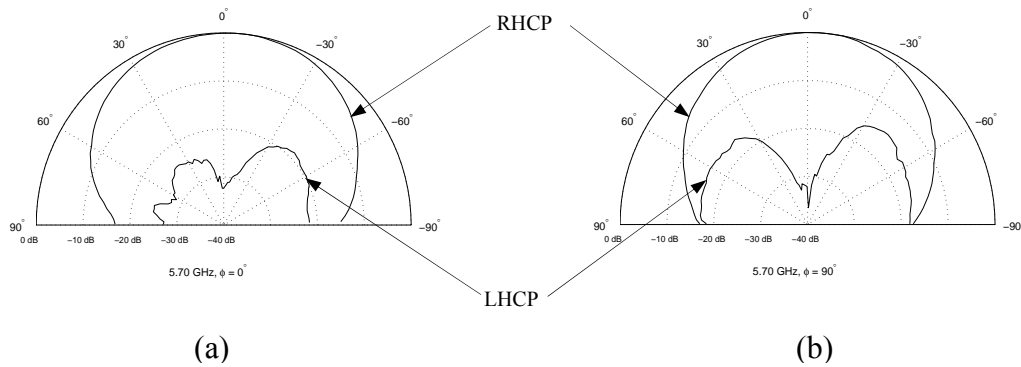


Figure 6 Measured radiation patterns of both senses in two orthogonal planes: (a) x-z plane and (b) y-z plane.

4. Conclusion

A broadband two-layer EMCP antenna with single-point feed has been designed, fabricated and tested. This antenna element is designed for RHCP operations in C-band with a centre frequency of 5.7 GHz. The measurement results show that impedance bandwidth ($VSWR \leq 2$) and 1-dB AR bandwidth is obtained in excess of 43% and 3.5%, respectively while a low boresight axial-ratio (< 0.3 dB) and the corresponding XPD (> 35 dB) at the centre frequency are also achieved which have not been reported so far in any previous studies. The radiation characteristics such as gain bandwidth, circular polarisation gain and beam-widths are examined and verified with the Kraus's formula. The simplicity of feeding structure helps to reduce the manufacturing cost, and further, the performance based on the measured results confirm that the proposed EMCP antenna is well suited for applications requiring broadband characteristics and circular polarisation.

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