Dual-Frequency Proximity Coupled Circularly Polarized Microstrip Antenna

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***Abstract* —In this paper, a new dual-frequency circularly-polarized microstrip antenna using a proximity-coupled feed method is described. Resonant elements of 1.55 GHz and 2.685 GHz bands are entire square patch and inner square patch divided by slots, respectively. Experimental results show that the proposed designs can provide dual-band operation with circularly-polarized radiation, and they have good agreements with the simulated data carried out by HFSS.**

Key words: microstrip antenna, dual-frequency, circularly-polarized.

I. INTRODUCTION

With the rapid development of multi-band wireless communication systems, an antenna with dual-band operation is required to cover different frequency, mobile devices that can operate with different standards or different applications, such as wireless local area network (WLAN), satellite communications such as GPS and DMB, are desirable. However, many satellite and wireless communication systems require low-profile, lightweight and low-cost circularly polarized (CP) antenna. In addition, some applications require dual-frequency operation. Examples include GPS or another wireless communications each other integration. The circularly polarized microstrip antenna are classified as single feed type or dual feed type depending on number of feed points necessary to excite circularly polarized. The single-feed type has the advantage of not requiring an external circular polarizer such as the 90-degree hybrid [1] or Wilkinson power combiners [2]. However, this dual-feeding mechanism has more complex geometry, larger size and higher loss at the feeding network [1]-[2].

Dual-band microstrip antennas could be categorized into multi-resonator or reactive-loading antenna [3]. The former needs more than one radiation element such as multi-layer, stacked-patch antennas [1]-[2]. These structures are large, complex and costly, thus they are not desirable for many application. The latter uses a single radiating element with reactive loading for resonance where shorting pins and slot loading are among the popular method [4]. Simplicity, low cost and small size makes reactive loading desirable for dual-band antennas. The technique of loading a square slot at the center of a rectangular microstrip antenna [4], a square slot is proposed to be cut in the center of the rectangular patch to lengthen the excited surface current paths of both the TM_{01} and TM_{10} modes, the frequency ratios of the two operating frequencies are in the ranges of about 1.276 to 1.281. By embedding a pair of properly-bent narrow slots closed to the non-radiating edges of a rectangular microstrip patch [5], it is found that, with the bent slots, the fundamental mode (TM_{10}) of the unslotted patch antenna is perturbed and a new resonance mode is excited, the mode between the TM_{10} andTM_{20} modes, the frequency ratios of the two operating frequencies are in the ranges of about 1.29 to1.6. However, [4]-[5] are mainly for achieving a dual-band linear polarization. Various dual-band circularly polarized patch antenna, which adopt the configuration of single-layer and single-feed, have been proposed in [6]-[7]. A square patch loaded T-shaped or Y-shaped slots, operation at the resonant frequencies of TM_{01} and TM_{03} [6]. A method similar to [6] is used in [7], which proposes a square patch with multiple slotted, a dual-frequency operation can be obtained. The frequency ratio of the two operating frequencies is in the ranges of about 1.76. The method of feed for dual-band circularly polarized patch antenna, single-feed designs have many advantageous features, mainly less installation space and less circuitry. However, this feed with probe directly feeding the patch, must be drilled and soldered of the patch.

The purpose of this paper is to propose a simple, new single-feed antenna configuration for dual-band circular polarization without a 90-degree hybrid coupler. In this paper, a proximity-coupled for dual-band circular polarization is proposed. The measured results of the proposed antenna are presented to demonstrate the proposed antenna configuration. Good impedance and axial ratio characteristics are realized. Details of the antennas design are described, and both the simulated and measured results are presented.

II. ANTENNA CONFIGURATION

The proximity feed dual-band circular polarization microstrip antenna is shown in Fig. 1. The rectangular strip is placed blow the patch. A 50-Ω SMA coaxial probe is used as the feeding structure mounted via a low profile FR4 substrate of relative permittivity 4.4 and thickness 0.4 mm and air (thickness of 3.5 mm).The antenna structure in Fig. 1 involves two radiating elements, they are divided by slots. One is the corner-truncated square-ring patch, having an outer side length of $\boldsymbol{L}_1$ (64 mm) and inner side length (54 mm). The other inner square patch, having a side length $\boldsymbol{L}_2$ (46 mm) is printed on an FR4 substrate of relative

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permittivity 4.4, but has a thickness of 1.6 mm. An air-layer substrate is present between the two microstrip patches and a thickness of 3.5 mm. The rectangular strip and the radiating patch are respectively fabricated on the opposite sides of the upper FR4 substrate, the rectangular strip position was at (0,-15), the probe directly feed position was at (0,-17) of the rectangular strip. To excite the two elements well, proximity coupled feed through the rectangular strip is adopted. Such a feed mechanism can be regarded as an L-type impedance matching network, in which the inductance is introduced by the thin probe and the capacitance is contributed by the rectangular strip. The rectangular strip has a side length 10 mm and position of the center at (0,-15). The dimensions of the square ground plane is 100× 100 mm^2, the square-ring patch has a pair of corner-truncated $\triangle \boldsymbol{l}$ is 6 mm. A narrow slot at the center of the inner square patch is inclined with respect to the ***x***-axis at an angle of 45 degree. The antenna is designed to operate at two frequencies of 1.55 and 2.685 GHz. The commercial electromagnetic software ANSOFT HFSS is used for the simulation.

The lower band and the upper band are controlled by the square-ring patch and square patch respectively. By introducing a pair of corner-truncated on the square-ring patch, an inclined slot on the square patch, circularly-polarized radiation at the frequencies can be obtained.

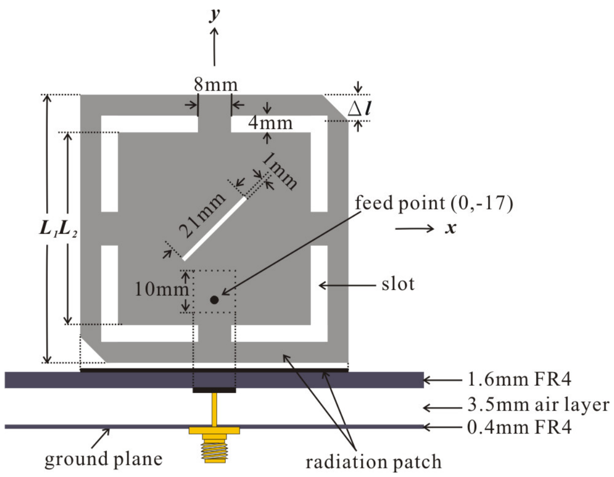

Figure 1 Geometry of the proposed dual-band circularly- polarized microstrip antenna.

III. EXPERIMENTALRESULTS

According to the dimensions revealed in Fig.1, a prototype of the proposed antenna was constructed and studied. The antenna is first studied, measured and simulated return loss results (by HFSS) are shown in Fig.2. The measured results are in good agreement with simulation. The measured results show the (10dB return loss) input impedance bandwidth for the lower frequency is about 80 MHz from 1.51 to 1.59 GHz, representing 5.16% with respect to 1.55 GHz, and the bandwidth of the higher frequency is about 50 MHz from 2.65 to 2.7 GHz, representing 1.87% with respect to 2.675 GHz. Fig. 3 illustrates a plot of the measured and simulated results for the axial ratio of the constructed prototype. Measured results have minimum axial ratios are 0.53dB at 1.55 GHz and 0.45dB at 2.685 GHz, respectively. The measured 3dB axial-ratio bandwidth for the low band is 15 MHz, from 1.55 to 1.565 GHz for RHCP, corresponding to about 0.97% with respect to 1.55 GHz, and the measured axial-ratio bandwidth for the high band is 20 MHz, from 2.675 to 2.695 GHz for RHCP, corresponding to about 0.74% with respect to 2.685 GHz.

In order to further study the dual-band operation property of the proposed antenna, surface current distributions of the whole antenna at the frequencies of 1.55 and 2.685 are given in Fig.4 and 5. It can be clearly seen from the figure that the current distributions are different in the two bands. When the antenna operates at 1.55 GHz, most of the surface currents are concentrated along the square-ring patch as show in Fig.4. This indicates that the square-ring patch acts as a resonator to generate the lower resonance. Fig.5 shows the simulated current distributions at 2.685 GHz, the strong resonant currents flow along the square patch to yield the upper resonance. It can be clearly seen from the figure current distributions rotate in the counterclockwise direction, the antenna can radiate the right-hand circular polarization (RHCP).The measured RHCP radiation patterns are illustrated in Fig.6 and 7 for frequencies of 1.55 and 2.685 GHz, respectively. The cross polarization is better than 15 dB for the low and high frequency. The peak measured gains of for the low and high frequencies are 7.3 and 7.57 dBic, respectively.

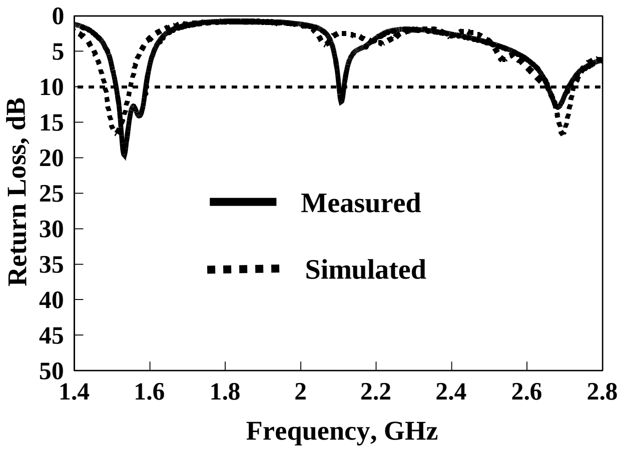

Figure 2 measured and simulated return loss for the proposed antenna

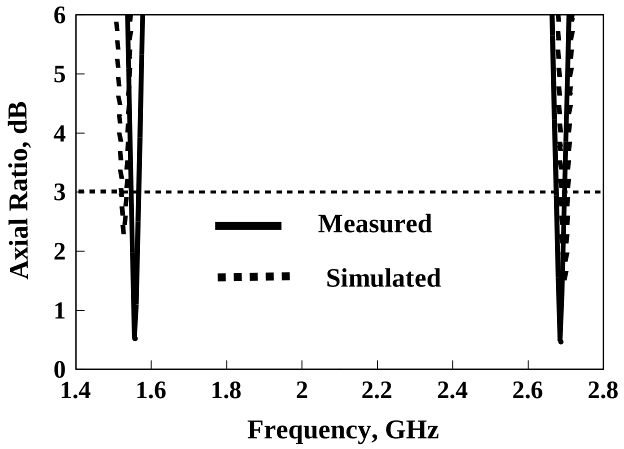

Figure 3 measured and simulated axial-ratio against frequencies for the proposed antenna.

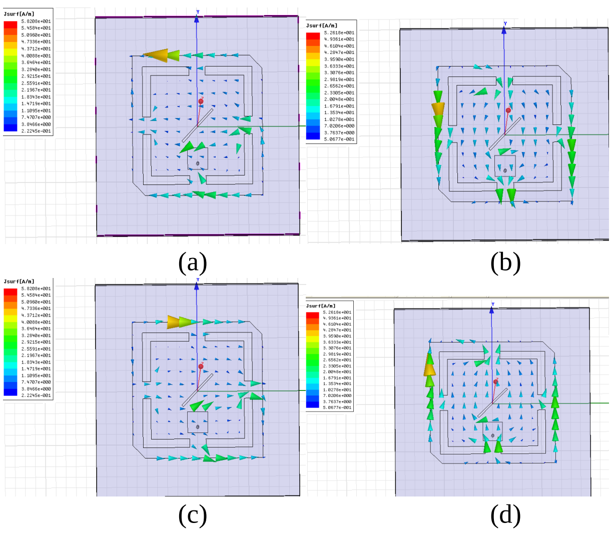

Figure 4 Surface current distributions of the proposed antenna at 1.55 GHz (a) 0° (b) 90° (c) 180° (d) 270°

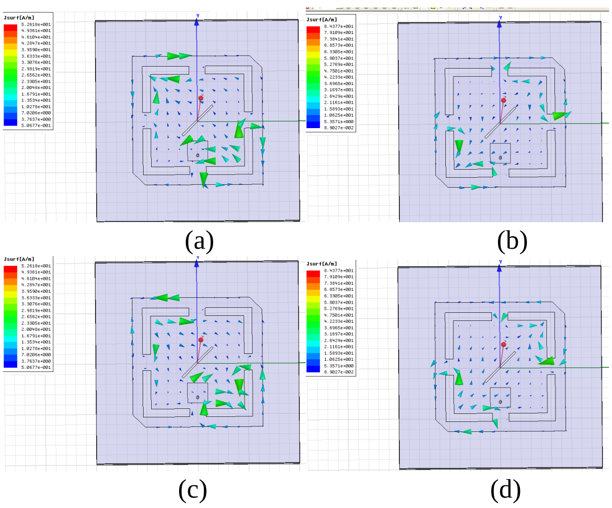

Figure 5 Surface current distributions of the proposed antenna at 2 GHz (a) 0° (b) 90° (c) 180° (d) 270°

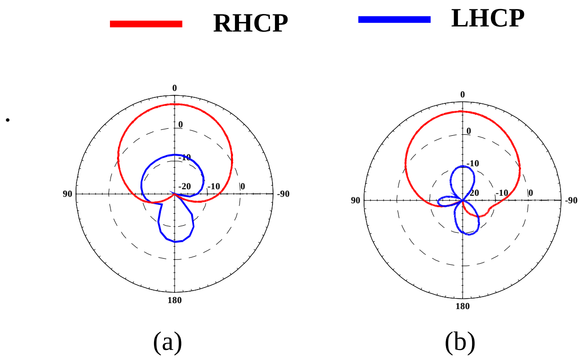

Figure 6 measured radiation patterns at 1.55 GHz.
(a) *x-z* plane (b) y-z plane

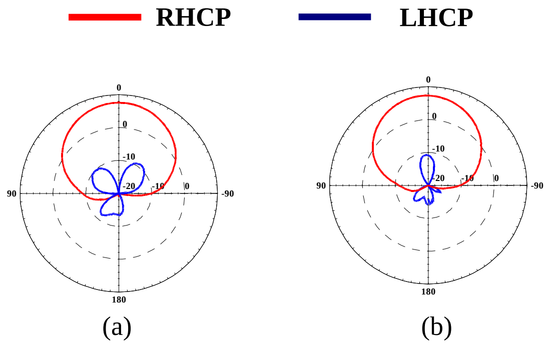

Figure 7 measured radiation patterns at 2.685GHz.
(a) *x-z* plane (b) y-z plane

IV. CONCLUSION

A new design single-layer, single-feed dual-frequency circularly-polarized microstrip antenna has been presented. The two operating frequencies obtained show similar broadside-pattern radiation characteristics, with RHCP and a high frequency ratio 1.73. The new proximity-coupled method without external circular polarizer, the probe directly connected the rectangular strip, simple structure and easy fabrication. Experimental results indicate that the proposed antenna can provide circularly-polarized radiation within the two operating frequencies. Moreover, the low-profile appearance makes the antenna suitable for some applications of present satellite mobile communications.

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