Capacitive Probe Fed Broadband Circularly Polarized Omnidirectional Antenna

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***Abstract*—A broadband circularly polarized (CP) omnidirectional antenna fed by a capacitive probe is presented in this paper. To attain wideband vertical polarization, a circular monopole patch connecting to the ground by a set of shorting pins is applied. Two groups of curved branches are introduced to create wideband horizontal polarization. The CP radiation can be generated with a proper phase difference between the vertical polarization and the horizontal polarization. The antenna is fabricated and measured. It exhibits an impedance bandwidth (VSWR≤2) of 34.6% (ranges from 4.50 to 6.38 GHz) and an axial ratio bandwidth (AR≤3dB) of 33.5% (ranges from 4.60 to 6.45 GHz). The profile of the antenna is merely 0.06λ_L (λ_L is the wavelength corresponding to the lowest operating frequency).**

Keywords—omnidirectional antenna; circularly polarized; broadband; low profile; coupling feed structure.

I. INTRODUCTION

In recent years, circularly polarized (CP) omnidirectional antennas have attracted more and more attention. The CP omnidirectional antennas have extensive advantages, e.g., larger signal coverage, less multipath distortion, and lower polarization mismatch, etc. In response for the demands of wireless application technology, CP omnidirectional antennas are developing toward broadband and low profile [1] - [13].

The previous researches show that there are three kinds of methods to generate CP omnidirectional radiation. The first method is using wave polarizers to convert omnidirectional linear polarization into omnidirectional circular polarization. This approach is usually applied in dielectric resonant antennas (DRA) [1]-[3]. However, such CP omnidirectional antennas always had disadvantages of large size and narrow bandwidth. The second approach is employing a circular or square antenna array which consists of multiple end-fire CP antennas [4]-[6]. In [4] and [5], end-fire CP loop antenna [4] and crossed dipole antenna [5] were utilized respectively to compose antenna arrays to obtain omnidirectional circular polarization, but they both had high profiles. In [6], five planar sector-shaped end-fire elements were used to form an array and a low profile of 0.028λ_L was realized whereas a narrow bandwidth of 3.97% was obtained. The third method is combining two omnidirectional vertically and horizontally polarized waves with identical magnitudes and a phase difference of 90°. By this means, plenty of low profile antennas were put forward [7]-[13]. In [7], a small Alford loop and a short dipole were employed to excite an CP omnidirectional wave, and thus a narrow impedance bandwidth of 13.8%, a 3-dB axial ratio (AR) bandwidth of 17.5% as well as a profile of 0.07λ_L were obtained. In [8], a new CP omnidirectional patch antenna with seven curved branches was investigated, which had a profile of 0.024λ_L, an impedance bandwidth of 19.8% and an AR bandwidth of 19.3%. In order to satisfy the need of broadband applications, a wideband CP omnidirectional antenna with multi-resonant was presented in [10], which has an impedance bandwidth of 22.7%, an AR bandwidth of 33.6% and a profile of 0.09 λ_L. Therefore, it is the requirement of omnidirectional CP antennas to broaden the bandwidth while maintaining a lower profile.

In this paper, a low-profile wideband CP omnidirectional antenna is proposed. A capacitive probe fed circular monopole, loaded with eight shorting pins, is employed to enhance the impedance matching and reduce the profile. Two sets of branches are applied to improve the AR bandwidth. This antenna, with a profile of 0.06λ_L, realizes an impedance bandwidth (VSWR≤2) of 34.6% and an AR bandwidth (AR≤3dB) of 33.5%. The design of the antenna configuration and the results are shown below.

II. ANTENNA CONFIGURATION

The detailed geometry of the proposed CP omnidirectional antenna is illustrated in Fig. 1. The proposed antenna is primarily composed of one ground plane, one coupling patch, one top-loaded monopole patch and two groups of arcs. All of them are etched on two FR4 plates (ε_r =4.4, tangent loss tan δ=0.02, thickness=1mm). The two groups of arcs are separately printed on the top surface of upper substrate and the bottom surface of the lower substrate, and are connected by eight outer shorting pins. The coupling patch is printed on the bottom surface of the upper substrate. There is a round slot on the monopole patch, and its radius is smaller than the coupling patch. The monopole patch are loaded with eight inner shorting pins. The diameters of inner and outer pins are 1mm and

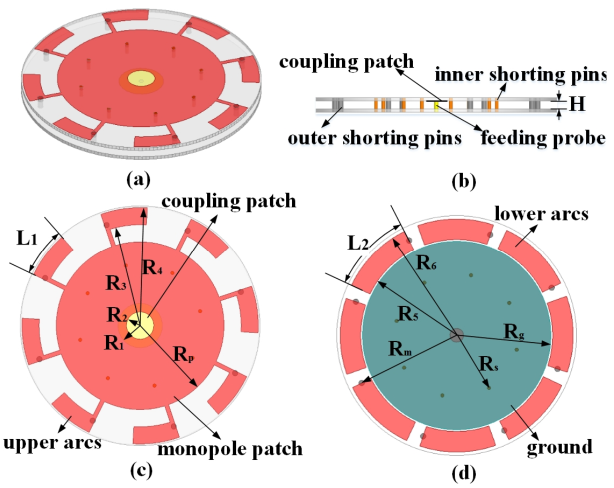

Fig. 1 Configuration of the proposed antenna. (a) 3-D view. (b) Side view (c) Top view. (d) Bottom view

TABLE I ANTENNA DIMENSIONS

Parameter	Value	Parameter	Value
H	2.2mm	R_5	28mm
L_1	22deg	R_6	34mm
L_2	38deg	R_p	24.5mm
R_1	6.5mm	R_g	27.5mm
R_2	4mm	R_m	31mm
R_3	29.5mm	R_s	18mm
R_4	34.5mm		

1.6mm, respectively. The optimized antenna dimensions are listed in Table I.

When the monopole patch is correctly loaded with shorting pins, TM_{01} was excited to realize CP omnidirectional radiation [13]. With the same principle, in this design, the monopole patch operates at TM_{01} mode to provide vertically polarized radiation and the shorting pins are applied to enhance impedance matching. With the coupling patch, the impedance bandwidth is further broadened and the profile is effectively reduced. The upper and lower arcs are introduced to generate horizontally polarized radiation at the high and low frequency, respectively. The 90° phase difference between the horizontally and vertically polarized waves at the low frequency is obtained by the distance between the inner shorting pins and the upper arcs, which can result in CP omnidirectional radiation with the identical amplitude. More specifically, as the details expressed in Fig. 1(a), the arcs are clockwise arranged, resulting in a right-hand CP (RHCP) wave. When the direction of these branches are opposite, a left-hand CP (LHCP) field will be generated.

III. Simulated and Measured Results

For verification, a prototype is simulated, manufactured and measured. Fig. 2 depicts the photograph of the prototype, which has the overall size of $\Phi 1.07\lambda_L \times 0.06\lambda_L$. The detailed parameters are displayed in Table I.

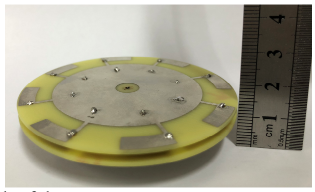

Fig. 2 Photograph of the prototype.

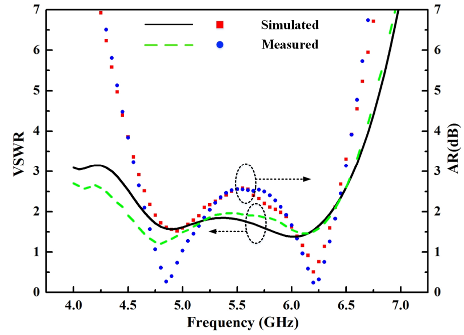

Fig. 3 Simulated and measured VSWRs and ARs of the proposed antenna

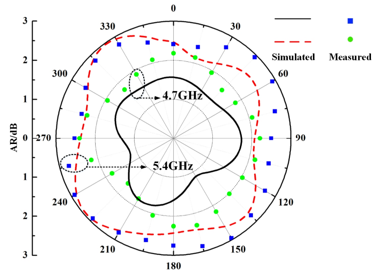

Fig. 4 Simulated and measured ARs of the proposed antenna.

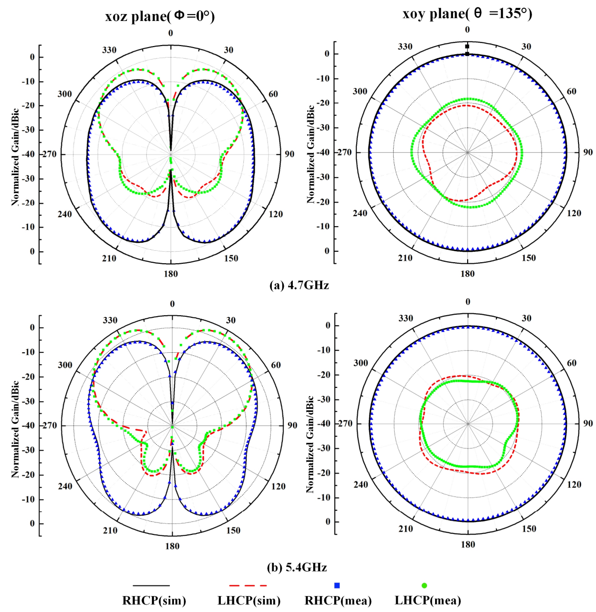

Fig. 5 Simulated and measured radiation patterns at 4.7 and 5.4 GHz

TABLE II
COMPARISON OF THIS WORK AND
OTHER LOW PROFILE CP OMNIDIRECTIONAL ANTENNAS

Ref.	VSWR Bandwidth (%)	AR Bandwidth (%)	Profile (λ_L)
[8]	19.8	19.3	0.024
[10]	22.7	33.6	0.09
[11]	8.2	9.2	0.077
[12]	0.9	27	0.03
This work	**34.6**	**33.5**	**0.06**

λ_L: wavelength at the lowest frequency of the passband

Simulated and measured VSWRs and ARs of the presented antenna at θ=135°，Φ=0° are plotted in Fig. 3. It can be observed that the measured impedance bandwidth for VSWR below 2 is 34.6% from 4.50 GHz to 6.38 GHz, which has a good consistency with the simulated result of 31.1% from 4.65 GHz to 6.36 GHz. The measured and the simulated AR bandwidth for AR below 3 dB are 33.5% from 4.60 GHz to 6.45 GHz and 34.4% from 4.57 GHz to 6.49 GHz, respectively. The tendency of the measured and the simulated results has a good agreement.

The simulated and measured ARs in the azimuthal plane (θ=135°) at 4.9GHz and 5.4GHz are depicted in Fig. 4. To reduce the measurement workload, the AR are measured at 15° intervals. It can be observed that the simulated and measured ARs at each frequency are less than 3 dB on the entire azimuth plane, which shows that the designed antenna has a good omnidirectional CP property.

Fig. 5 demonstrates the simulated and measured radiation patterns in the elevation (Φ=0°) and azimuth (θ=135°) planes at 4.9GHz and 5.4GHz. The gain at 4.9GHz and 5.4GHz are 1.79 dBic and 0.47 dBic, respectively. As shown in the radiation patterns, the proposed antenna radiates a RHCP wave in the required direction. In addition, there are two nulls in the bore sight directions (θ=0° and θ=180°) while the azimuth (θ=135°) patterns are omnidirectional. With the increase of operating frequency, the antenna maintains a good CP omnidirectional characteristic in the required direction of θ=135°, though the cross-polarization in the direction of θ=30° increases.

Finally, Table II tabulates the comparison of VSWR bandwidth and AR bandwidth among this work and several aforementioned CP omnidirectional antennas. It can be found that the proposed antenna can reach the wider bandwidth with the lower profile.

IV. CONCLUSION

In this paper, a capacitive probe-fed wideband CP omnidirectional antenna with low profile is proposed. A wide operating bandwidth is achieved by loading two sets of branches and shorting pins. To verify the analysis, a prototype is manufactured and measured. With a low profile of $0.06\lambda_L$, the antenna realizes the measured bandwidths of 34.6% from 4.50 to 6.38 GHz and 33.5% from 4.60 to 6.45 GHz for VSWR≤2 and AR≤3 dB, respectively. With the merits of easy manufacture, low profile and wide operating bandwidth, the proposed CP omnidirectional antenna is applicable for modern wireless applications.

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