A Novel Broadband Omni-Directional Circularly Polarized Antenna for Mobile Communications

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Abstract—**This paper presents a new broadband omni-directional circularly polarized (CP) antenna for mobile communications operating nearby 2 GHz. The new omni-directional CP antenna consists of four broadband CP rectangular loops which are bent to form a hollow cylinder. A conducting cylinder is introduced inside the hollow cylinder to improve the CP performance. A broadband balun is developed to feed the CP antenna. This antenna has a compact cylindrical configuration with a diameter of 0.4λ. The simulation shows that this antenna has a bandwidth of 30.8% (1.7 GHz-2.32 GHz) for return loss (RL) ≥10 dB and 36.1% (1.75 GHz-2.52 GHz) for average axial ratio (AR) ≤3 dB. Good agreement between simulated and measured results is achieved.**

Keywords-broadband antenna; circularly polarized antenna; omni-directional antenna; mobile communications

I. INTRODUCTION

The use of circularly polarized (CP) antennas can enhance the signal reception in modern mobile communication systems. Omni-directional radiation patterns are desirable for some applications by reducing the number of cell sectors. A considerable number of designs have been studied recently for omni-directional CP antennas. For example, simple dipole arrays have been proposed in [1], [2]. The dipole array includes several tilted dipoles and can be considered as a combination of an electrical dipole and a magnetic dipole. When all dipoles are arranged and excited properly, an omni-directional CP antenna could be obtained. However, the design of this type of antenna always leads to a large size and narrow bandwidth. Several low-profile designs have been reported in [3], [4]. A patch antenna can produce vertically polarized wave while the arms around the patch produce horizontally polarized wave. When patch and arms are excited orthogonally, a CP wave can be excited. However, patch antennas usually have a narrow bandwidth. The design in [5] has a simple structure (an array of half-wavelength dipole), but leads to a large size (~4.7λ in diameter). The design described in [6] has the advantages of low-profile and simple structure. But the CP performance in the plane is parallel to the patches is poor. For all the antennas mentioned above, there is a narrow bandwidth which limits their practical applications.

This paper presents a novel 3D broadband omni-directional CP antenna configuration for mobile communications，that consists of four broadband CP rectangular loop elements. The design for each individual broadband CP element can be found in [7]. A bandwidth of ~50% for the CP element has been achieved. The rectangular loop has a big aspect ratio, which can lead to a compact cylindrical size of the omni-directional CP antenna. A conducting cylinder and a broadband balun are introduced respectively to achieve simultaneously a good CP performance and impedance matching. The antenna structure will be described in section II and simulated and measured results will be presented in Section III.

This work was supported by the National Nature Science Foundation of China (60871061), the GDSF (8151064101000085), the SRFDP (20080561), and the Oversea Distinguished Professor Program from the Ministry of Education of China.

II. ANTENNA STRUCTURE

Fig. 1 shows the configuration of the proposed omni-directional CP antenna. The design includes four broadband CP rectangular loops printed on thin flexible dielectric substrate, which is rolled into a hollow cylinder for an omni-directional radiation pattern. The diameter of the hollow cylinder is 60 mm (0.4λ at 2 GHz), much thinner than the omni-direcational CP antenna (~4.7λ) presented in [5]. The configuration of each loop is displayed in Fig.1 (b). There are two small gaps on each primary loop to excite a travelling wave which leads to a CP wave [8]. A pair of parasitic loops (with a gap) is introduced inside the primary loop to enhance the bandwidth of the CP element.

An inner conducting cylinder is introduced to improve the CP performance of the omni-directional CP antenna. Without inner conducting cylinder, each rectangular loop radiates a bidirectional pattern in the directions perpendicular to the loop plane with opposite CP senses. This feature results in a poor CP performance for the omni-directional CP antenna. To improve the CP performance, a conducting cylinder is added to the inside of the hollow cylinder. Foam is filled into the space between the hollow cylinder and the conducting cylinder to support the CP antenna. A gap is introduced at the middle of the conducting cylinder to leave a space (g_1) for the feed structure.

A broadband balun is designed to feed the omni-directional CP antenna. The configuration of the broadband balun is shown is Fig. 1(c). A line-slot transition is used to provide good impedance matching over a wide bandwidth. The proposed broadband balun makes use of the electromagnetic coupling between the microstrip line printed on one side of the substrate and the slot etched on the other side for a wide impedance bandwidth [7]. A good impedance matching can be achieved by adjusting the length ls of the slot and the length l5 of the microstrip line. The broadband balun is soldered to each element at the "Driving point" (see Fig.1 (b)) of each loop, and is fed through a coaxial line at the "Feed point" (see Fig.1 (c)).

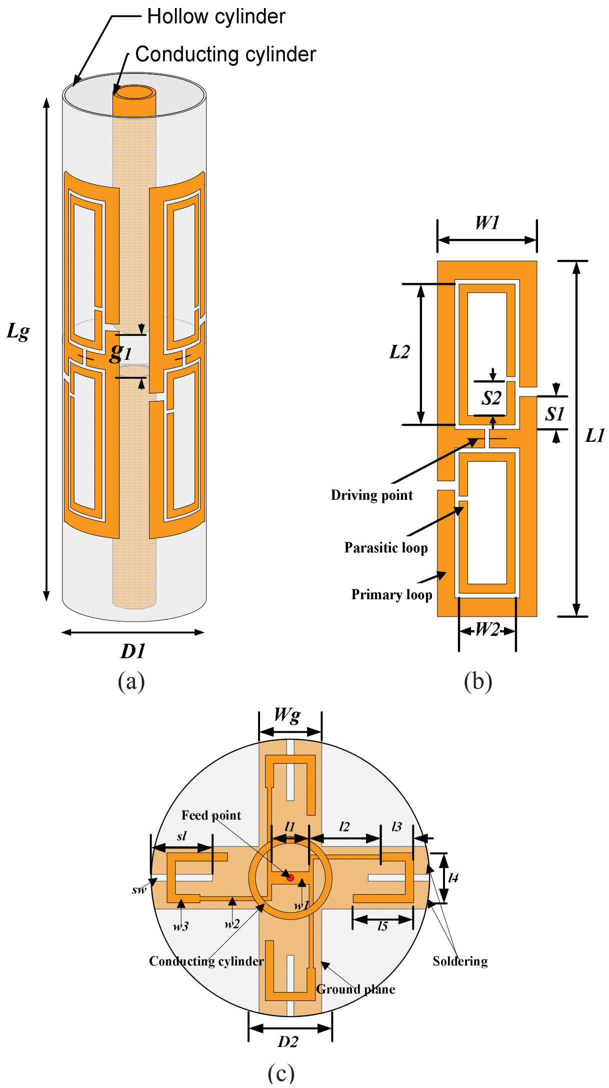


Figure 1. A new broadband omni-directional circularly polarized antenna. (a) perspective view, (b) One element, (c) Top view. (The strip widths of the primary loop and the parasitic loop are 6.0mm and 3.0 mm respectively; the gap widths on the primary loop and on the parasitic loop are 3.0 mm and 1.5 mm respectively; the gap length (g_1) on the metal reflecting cylinder is 19mm; other geometrical paramters: ***Lg***=220 mm, ***D1***=60 mm, ***D2***=18 mm, ***L1***=114.6 mm, ***L2***=45.3 mm, ***W1***=34.6 mm, ***W2***=20 mm, ***S1***=10.6 mm, ***S2***=11 mm, ***l1***=4 mm, ***l2***=15.4 mm, ***l3***=6.9 mm, ***l4***=10.8 mm, ***l5***=13.8 mm, ***w1***=2.7 mm, ***w2***=0.9 mm, ***w3***=1.8 mm, ***Wg***=13.5 mm, ***sl***=13.3 mm, ***sw***=1.6 mm.)

III. Results and Discussion

The proposed antenna was fabricated and measured. Fig. 2(a) shows the photos of the antenna prototype. Four rectangular loops were first printed on a thin flexible dielectric substrate (Panasonic R-F775, ε_r=3.2, thickness=0.05mm), and then were rolled into a hollow cylinder. The broadband balun was printed on a substrate with a low dielectric constant (Taconic TLY-5, ε_r =2.2) and a thickness of 0.8mm.

Fig. 3 shows the simulated and measured results for return loss (RL) and axial ratio (AR) performances. The simulated results for the omni-directional CP antenna without the conducting cylinder are plotted in Fig. 3. After adding the conducting cylinder, we can see that the simulated 10-dB RL bandwidth is 30.8% (1.7 GHz-2.32 GHz), and the 3-dB average AR bandwidth is 36.1% (1.75 GHz-2.52 GHz). The measured 10-dB RL bandwidth is 39.2％(1.68 GHz-2.5 GHz) and the 4-dB AR bandwidth is 35.3 ％ (1.75 GHz-2.5 GHz). The difference between the simulated and measured AR results is due to the fabrication measurement errors. It can be also seen from Fig.3 (b) that without the inner conducting cylinder the AR performance deteriorates dramatically

The measured radiation patterns in the horizontal plane at the low frequency (1.75 GHz) and the high frequency (2.45 GHz) are plotted in Fig. 4. Good omni-directional CP radiation patterns are observed.

A four-element omni-directional CP antenna array (see Fig. 2(b)) is under investigation. The results will be presented in the conference.

IV. Conclusion

A new broadband CP antenna with an omni-directional radiation pattern has been developed in this paper. By introducing a conducting reflecting cylinder inside the flexible dielectric cylinder that the antenna elements are mounted on, the AR performance is significantly improved. A good RL performance has been realized by introducing a broadband balun. The simulated and experimental results demonstrate that the proposed antenna can achieve a bandwidth of ~35%. As a conclusion, a very good broadband omni-directional CP performance is achieved for an ultracompact (0.4λ in diameter) cylindrical configuration.

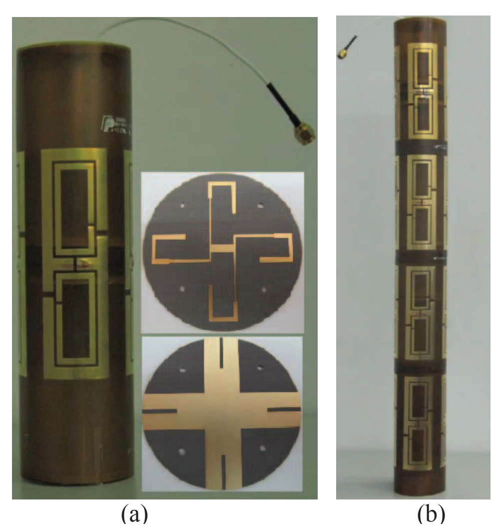


Figure 2. Photos of the prototyes of (a) an omni-directional CP antenna (with broadband balun) and (b) a 4-element antenna array.

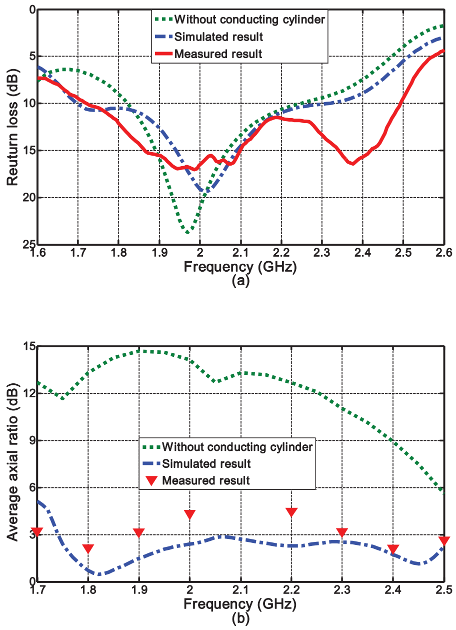
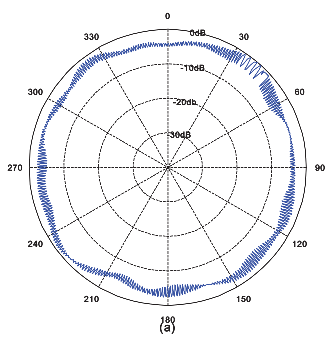


Figure 3. Simulated and experimental results for (a) RL and (b) AR performances of the proposed omni-directional CP antenna.



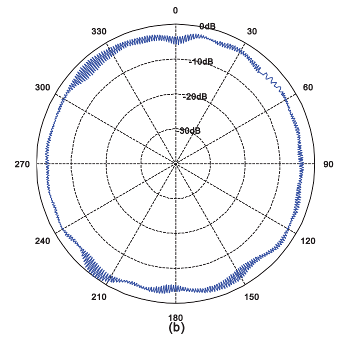


Figure 4. Experimental radiation patterns in the horizontal plane at (a) 1.75 GHz and (b) 2.45 GHz.

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