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# Compact broadband circularly polarized monopole antenna

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***Abstract* –This paper presents the design of a broadband circularly polarized (CP) monopole antenna. The proposed CP antenna is developed from a primitive structure consisting of only a half-circular patch and an inverted-L feeding strip connected to a coplanar waveguide. By loading a rectangular tuning stub to and etching a sector-ring slot from the half-circular patch and by adding an extended section to the inverted-L feeding strip, one can obtain a measured 3-dB axial-ratio bandwidth of 39.7% for the proposed CP antenna. The designed antenna is relatively compact as compared with another CP monopole antenna of similar structure.**

***Index Terms* —circularly polarized antenna, broadband, monopole antennas, compact.**

## I. INTRODUCTION

In order to stabilize the received signals, polarization mismatch between the transmitting and receiving antennas should be minimized and multipath interference should be suppressed [1-3]. For that purpose, circularly polarized (CP) antennas are a better candidate. In recent years, printed planar antennas with an enhanced 3-dB axial-ratio bandwidth (ARBW) have received much attention [4-9]. However, most of these antennas have relatively large radiator sizes or antenna sizes. On the basis of the simple CP antenna structure in [9], we will propose in this paper a miniaturized one without sacrificing the ARBW.

## II. ANTENNA DESIGN AND ANTENNA DEVELOPMENT

The top and bottom views of the proposed CP antenna are shown in Fig. 1. As in [9], the antenna is designed on a 1.6-mm-thick FR4 substrate with dielectric constant 4.4 and loss tangent 0.02. The length $G$ and width $L$ of the substrate are purposely chosen to be 60 and 40 mm, respectively, resulting in an area of only two thirds the substrate area in [9]. The radiator is a half-circular patch with a radius of $r_o$ = 12 mm and is printed on one side of the substrate. A sector-ring slot with width $g_r$ = 5 mm is etched from the half-circular patch, the lower region of which is connected with a rectangular tuning stub with length $\ell_t$ and width $w_t$. Printed on the opposite side of the substrate is the feeding structure consisting of an asymmetric coplanar waveguide (CPW) and the feeding strip protruded out of the CPW. The ground plane of the asymmetric CPW comprises two patches having the same height of $G_h$ = 10 mm but different lengths of $G_1$ = 36.5 mm and $G_2$ = 17.5 mm. The signal conductor (or called center conductor) of the CPW with width $w_f$ = 5 mm is separated from the two ground patches with the same gap of $g$ = 0.5 mm. For convenience, we will regard the signal conductor of the CPW as part of the feeding strip. The feeding strip is then composed of three sections: the straight section parallel to the $x$ axis with length $G_h + s$ and width $w_f$, a transverse section parallel to the $y$ axis with length $\ell_s$ and width $w_s$, and an extended section parallel to the $x$ axis with length $\ell_m$ and width $w_m$. Note that along the $y$ direction the extended section is symmetric with respect to the half-circular patch. Without the extended section, the feeding strip has an inverted-L shape. It is assumed that the outer edge of the straight section, if extended and projected onto the other plane, is tangent to the half-circular patch at the leftmost point of the patch (see the left plot in Fig. 1), and the upper edge of the transverse section when projected onto the other plane is tangent to the patch at its lowermost point if the rectangular tuning stub is absent. With $s$ = 0.5 mm and $w_s$ = 7.5 mm set, the relative position of the half-circular patch with respect to the feeding structure is fixed throughout the design.

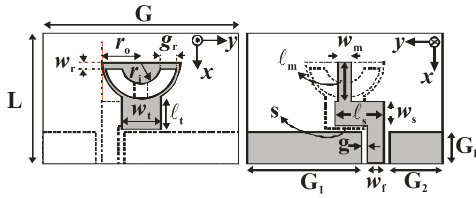


Fig. 1 Geometry of proposed broadband circularly polarized monopole antenna: top view on the left and bottom view on the right.

The procedures for developing the proposed broadband CP antenna are clearly depicted in Fig. 2. The development starts from adjusting the parameter $\ell_s$ of the Type 1 antenna, which is a half-circular patch fed by an inverted-L strip. In the second step, the half-circular patch is loaded by a rectangular tuning stub with its length $\ell_t$ determined to become the Type 2 antenna. Proceeding in a similar manner, we must determine $\ell_m$ and $w_m$ of the Type 3 antenna in the third step of the development procedures and $g_r$ and $r_i$ (the inner radius of the sector-ring slot) of the Type 4 antenna in the fourth step. In the last step, the preset parameter $w_t$ must be re-adjusted to reach the optimal design, called Ant. 1. In the course of the development going from one step to the next, relevant structural parameters are determined according to the results obtained from parametric studies, in which the return loss, axial ratio, and magnitude ratio of and phase difference between two orthogonal far fields are carefully examined. Those relevant structural parameters must be adjusted so that the magnitude ratios (phase differences) are brought close to 1 ($\pm 90^{\circ}$) in the desired frequency region.

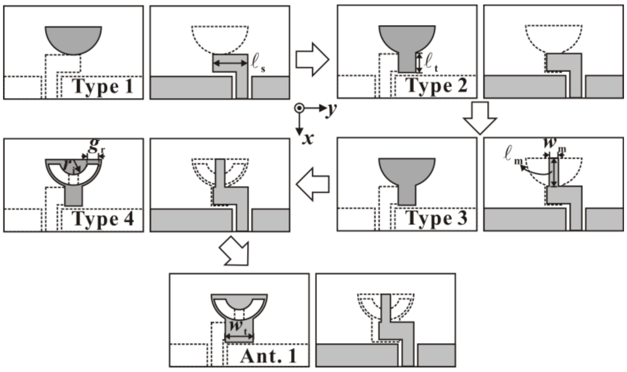


Fig. 2. Procedures for developing the proposed wideband CP antenna.

## III. Results And Discussion

Fig. 3 shows the return losses, axial ratios, magnitude ratios, and phase differences of the Types 1-4 antennas. Here, the magnitude ratio is defined by $|E_x/E_y|$ and the phase difference by $|\angle E_x - \angle E_y|$. For the Type 1 antenna, the axial ratio in 1.5–3.5 GHz is greater than 9 dB because $|E_x|$ is weaker than $|E_y|$ throughout and the phase difference is larger than 105° for frequencies over 2 GHz. With the *x*-directed tuning stub connected to the half-circular patch in the Type 2 antenna, it is expected that more *x*-directed current will be induced in the patch, thus enhancing $|E_x|$ in the far-field region. As can be seen from Fig. 3, not only is the magnitude ratio increased for frequencies below 2.8 GHz, but the phase difference is also closer to 90°. The resulting axial ratio of the Type 2 antenna is within 3 dB around 2.7 GHz. In the Type 3 antenna, the added *x*-directed extended section of the feeding strip can further bring the magnitude ratio closer to 1, leading to a widened CP band. In the Type 4 antenna, the sector-ring slot etched from the half-circular patch can even lower the axial ratio to within 1 dB around 2 GHz, for at that frequency the magnitude ratio is nearly 1 and the phase difference is nearly 90°.

From Fig. 4 we can observe that the axial ratio of the Type 4 antenna is still larger than 3 dB around 2.45 GHz. This is because the magnitude ratio is approximately 1–3 dB in 2.4–2.8 GHz and the phase difference is approximately 105–115 degrees in 2.2–2.55 GHz. To lower the axial ratio around 2.45 GHz, $|E_y|$ should be increased (or the magnitude ratio should be decreased). Observe that when $w_t$, the width of the tuning stub, is increased from 7.5 mm (which is previously set for the Types 2-4 antennas) to 12 mm, the axial ratio is largely optimized in 2.3–2.7 GHz. If $w_t$ is increased to 14 mm, the magnitude ratio is further lowered and deviates more from 0 dB in 2.6–3 GHz, thus narrowing the CP band. Hence, we choose $w_t$ = 12 mm for our final design, i.e., Ant. 1. The simulated (measured) 3-dB ARBW for Ant. 1 is 1955–2855 (1930–2887) MHz, which is 37.4% (39.7%) with respect to the center frequency 2405 (2409) MHz and which can be covered by the VSWR ≤ 2 impedance band of 1852-4110 (1874–4115) MHz. Note that the measurement agrees quite well with the simulation. If the antenna size is defined by the area of the smallest rectangle that can enclose the metal of the antenna, a size reduction of 46% has been achieved by the proposed antenna as compared with the antenna in [9]. Although having been miniaturized, the designed antenna possesses an even larger measured 3-dB ARBW as compared with the achieved 36.1% in [9]. The field radiated by Ant. 1 is right-hand CP along the +*z* direction and left-hand CP along the –*z* direction. The peak gain is between 0 and 3 dBic. Because of the page-number limitation, detailed data pertaining to radiation patterns will be presented in the conference.

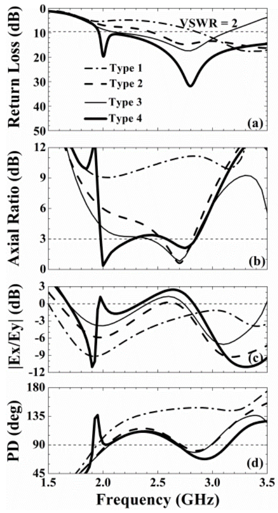


Fig. 3. Simulated (a) return loss, (b) axial ratio, (c) magnitude ratio, and (d) phase difference for the Types 1-4 antennas.

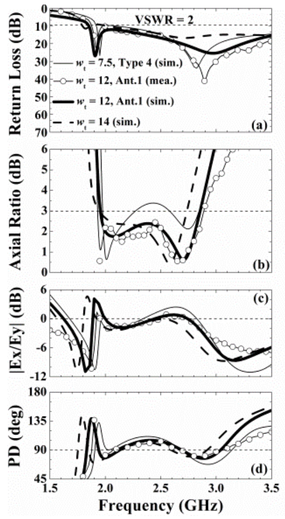


Fig. 4. Measured and simulated (a) return loss, (b) axial ratio, (c) magnitude ratio, and (d) phase difference for the antennas with different widths of the rectangular stub.

## IV. Conclusion

A wideband CP monopole has been designed with a measured CP band of 1930–2887 MHz (39.7%), which can be completely covered by the VSWR ≤ 2 impedance band of 1874–4115 MHz. The antenna is compact, and its size is only 46% that of a structurally similar CP monopole antenna in the literature.

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