Applications of Circularly Polarized Crossed Dipole Antennas

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***Abstract*—Circularly polarized crossed dipole antennas are presented in this paper. A compact crossed dipole is realized with the use of a meander line and a barbed end in each dipole arm. A vacant-quarter printed ring is used as a 90° phase delay line to achieve circularly polarized radiation. For multi-band applications, each dipole arm is divided into multi-branches with different lengths to obtain multiple resonances. These radiators can be equipped with different reflectors, such as a finite planar metallic conductor, a cavity-backed metallic conductor, and a finite artificial magnetic conductor to obtain the desired antenna radiation characteristics. These antennas are quite practical for many wireless communication systems, such as satellite communications, global positioning systems, wireless local area networks, and radio-frequency identification devices.**

Keywords*—*circular polarization, crossed dipole, printed-ring, multiple resonances

I. INTRODUCTION

It is well known that circularly polarized (CP) radiation is traditionally generated from two orthogonal currents that have a 90° phase difference. Based on this generation technique, broadband CP antennas that are constructed with two crossed dipoles of equal amplitude and a 90° phase difference have been reported [1]–[5]. However, these antennas are bulky because they use straight/bowtie dipoles as radiators. Additionally, they are not suitable for multi-band applications with large frequency ratios because of the nature of their radiator and feeding structure.

This paper describes CP crossed dipole antennas with different reflectors, which can be favorably used in many wireless platforms. CP crossed dipole antennas can be easily designed as single- or multi-band antennas depending on the application. To achieve a compact antenna, a printed inductor with a barbed end was inserted in each dipole. The crossed dipole antenna employs a 90° phase delay line realized with a vacant-quarter printed ring to produce CP radiation and broadband impedance matching.

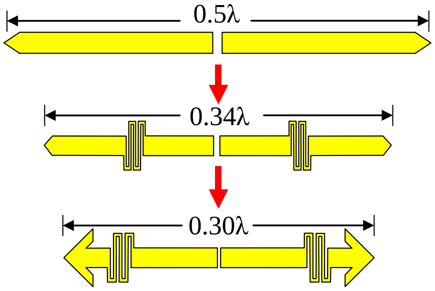
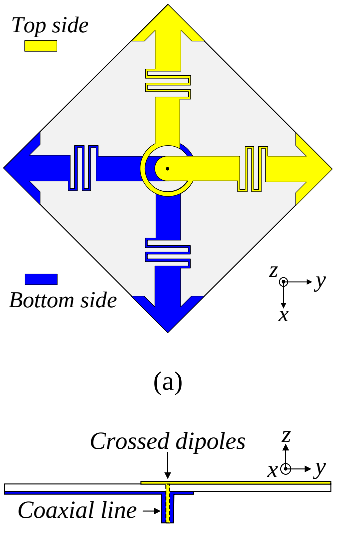


Fig. 1. Process to reduce dipole length.

II. ANTENNA DESIGN AND CHARACTERISTICS

Two techniques were employed to achieve primary radiating elements that are compact in size; the insertion of printed inductors in each dipole arm and a barb-shaped trace at its end [6], [7]. The process of length reduction is illustrated in Fig. 1. The initial design was a half-wavelength dipole (0.5λ), which is printed on a thin dielectric substrate. To reduce its length but keep the same resonance, two printed inductors were symmetrically inserted into the arms of the initial design. To further reduce its length, the ends of the dipole were formed into a barbed shape. The final design has a much shorter length (0.3λ) and the same resonance in comparison with the initial dipole. However, the size reduction was accompanied by degradation of the antenna characteristics such as an impedance matching bandwidth. Therefore, the design parameters of the dipole chosen were a compromise between compactness and broadband characteristics.

To generate CP radiation, two barbed dipoles were crossed through a vacant-quarter printed ring, as shown in Fig. 2. The antenna was fed with a 50-Ω coaxial cable; the outer conductor of the coaxial line was connected to the arms on the



(a)

(b)

Fig. 2. Crossed dipole antenna in free space: (a) top view and (b) side view.

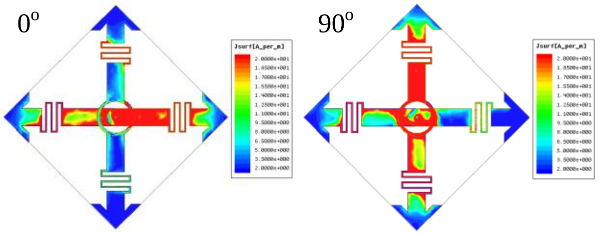


Fig. 3. Current distribution of the crossed dipole antenna at the CP center frequency.

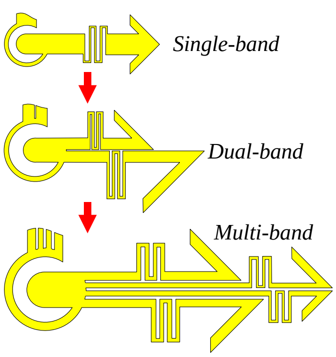
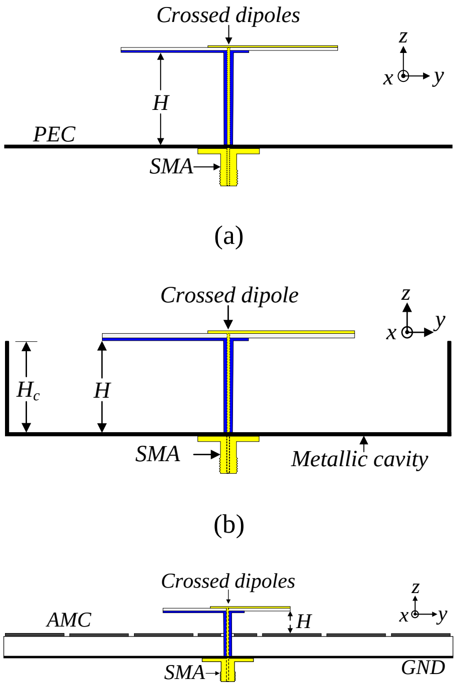


Fig. 4. Dipole arm of single-, dual-, and multi-band antennas.



(a)

(b)

(c)

Fig. 5. Side-view of the crossed dipole antennas with different reflectors: (a) a finite metallic surface, (b) a cavity-backed metallic surface, and (c) an AMC surface.

bottom side of the substrate. The inner conductor of the coaxial line extends through the substrate and connects to the arms on the top side. The presence of the printed ring provides a significant improvement of the impedance matching and 3-dB axial ratio bandwidths. Figure 3 shows the current distribution of the crossed dipole antenna at the CP center frequency for the two phase angles of 0 and 90°. Here, the CP center frequency is defined as the frequency at which the AR is at a minimum. The horizontally oriented dipole arms worked at the 0° phase angle, while the vertically oriented dipole arms worked at the 90° phase angle. This arrangement facilitated the antenna's CP radiation behavior.

To achieve dual- and multi-band operations, each dipole arm is divided into two and multi-branches with different lengths, respectively, as shown in Fig. 4. The arrangement of each branch must achieve multiple distinct resonances and avoided coupling between the adjacent branches. For multi-band applications with a small frequency ratio (~1.3 or less), such as global positioning system applications [8], [9], the vacant-quarter printed ring has a length of approximately $\lambda_g/4$ at all frequencies (λ_g being the guided wavelength at the center frequency). For applications with a large frequency ratio (~2 or greater), such as wireless local area network applications [10], the length of the vacant-quarter printed ring should be approximately $\lambda_g/4$ at the lower band and $3/4\lambda_g$ at the upper bands. Therefore, the 90° phase difference can be maintained for each dipole arm, and consequently, CP radiation can achieved at multiple frequency bands.

Without a reflector, crossed dipole antennas radiate a bidirectional electromagnetic wave; one side radiates right-hand circular polarization, while the other side radiates left-hand circular polarization. To generate a unidirectional radiation pattern in crossed dipole antennas, several reflectors can be added, namely a finite planar metallic surface, a cavity-backed metallic surface, and an artificial magnetic conductor (AMC) surface, as shown in Fig. 5. In the case of a planar metallic surface [Fig. 5(a)], the optimal distance for the crossed dipole is approximately a quarter-wavelength from the reflector and a high radiation resistance is the figure of merit. The antenna performances in terms of broadband and CP radiation characteristics can be considerably improved using a cavity-backed metallic reflector [7] – [9]. A side view of the cavity-backed crossed dipole antenna is shown in Fig. 5(b). Similar to a planar metallic reflector, the optimization of a cavity-based reflector requires a distance of approximately a quarter-wavelength between the radiator and the reflector. Therefore, metallic reflectors are suitable for single-band crossed dipoles or multi-band antennas with a small frequency ratio. For a large frequency ratio, multi-band crossed dipoles backed by an AMC reflector, as shown in Fig. 5(c), can be utilized to achieve multi-band characteristics with unidirectional radiation patterns [10]. An AMC structure, which generally consists of a lattice of metal plates printed on a grounded dielectric substrate reflects a normally incident wave with zero phase shift and exhibits high impedance characteristics within a given frequency range. The main benefit of an AMC compared to a conventional reflector (a planar metallic surface) is that it allows the radiator in close proximity with good impedance matching and efficient radiation [10, 11].

III. CONCLUSION

We have presented the design and characteristics of CP crossed dipole antennas with several different reflectors. The antennas employ a meander line with a barbed end to reduce the primary radiating elements' size, and a vacant-quarter printed ring is incorporated to produce CP radiation. For multi-band operation, each dipole arm of the radiator is divided into multi-branches with different lengths. Thanks to the compact size and easy resonance control, crossed dipoles can easily be combined with different reflectors, namely planar metallic, cavity-backed, and AMC surfaces, to achieve a broadband and unidirectional radiation pattern; consequently, these antennas can be widely applied in many current existing and future wireless communications.

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