# Circularly Polarized Crossed Dipole on an HIS for 2.4/5.2/5.8-GHz WLAN Applications

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***Abstract*—A triband circularly polarized (CP) crossed-dipole antenna is introduced for 2.4/5.2/5.8-GHz wireless local area network (WLAN) applications. It employs a single feed and only two crossed trident-shaped dipoles as the primary radiating elements. To achieve a compact radiator size, two techniques are utilized, namely, insertion of a meander-line segment in the middle branch of the tridents and termination of all trident arms with arrowhead-shaped tips. The crossed trident-shaped dipoles are backed by a high impedance surface (HIS) to achieve a broadband characteristic and unidirectional radiation pattern at three bands. The measured impedance bandwidths, based on the $-10$-dB reflection coefficient values, are 2.21–2.62 GHz (410 MHz), 5.02–5.44 GHz (420 MHz), and 5.62–5.96 GHz (340 MHz), and the measured 3-dB axial-ratio bandwidths are 2.34–2.58 GHz (240 MHz), 5.14–5.38 GHz (240 MHz), and 5.72–5.88 GHz (160 MHz). The proposed antenna exhibits right-hand circular-polarized radiation with high gain.**

***Index Terms*—Circular polarization, crossed-dipole, high impedance surface reflector, wireless local area network.**

## I. Introduction

OWING to the proliferation of wireless communication systems nowadays, people rely more and more on their information search applications using mobile, handheld, and portable terminals. Thus, wireless local area networks (WLANs) have become the popular choice for Internet access. WLAN uses a lower frequency band of 2.4–2.485 GHz for the IEEE 802.11b/g standard and two upper frequency bands of 5.15–5.35 and 5.725–5.875 GHz for the IEEE 802.11a standard. The antennas for some applications in the WLAN bands, such as Wi-Fi access points [1], gap fillers [2], and RFID readers [3], require a unidirectional pattern to provide high security and efficiency of the propagation channels. Additionally, to mitigate the multipath problem due to the reflections from building walls and ground surfaces, circularly polarized (CP) antennas have been widely used in these WLAN applications [4]. A single antenna for all of these WLAN applications would require stable triband CP operation covering entirely the 2.4/5.2/5.8-GHz bands with broad impedance and 3-dB axial-ratio (AR) bandwidths, as well as similar radiation pattern characteristics. Several CP antenna types for WLAN applications have been reported, including a dielectric resonator antenna [4], a microstrip patch antenna [5], and a slot antenna [6]. However, these antennas were presented simply for single- or dual-band operations.

On the other hand, in the past few years, various antennas have been intensively engineered using electromagnetic metamaterials to improve their performance characteristics. Linearly polarized antennas have been incorporated with metamaterial substrates to achieve impedance bandwidth enhancements and unidirectional radiation patterns along with profile miniaturization [7]. Furthermore, metamaterial structures have been widely applied in CP antennas [8], [9]. However, the above-mentioned CP antennas are not suitable for multiband communications with large frequency ratios because of the nature of their radiators and the bandwidths of the metamaterial structures.

This letter introduces a triband antenna for 2.4/5.2/5.8-GHz WLAN applications. Two compact-sized trident-shaped dipole elements are employed as the primary radiating elements for the indicated three bands. They are fed by a vacant-quarter printed ring that acts as a 90° phase delay to generate the desired CP radiation [10]. The crossed dipoles are characterized first in free space (without a reflector) and then in the presence of a high impedance surface (HIS) reflector. The HIS reflector-backed trident-shaped elements achieve broad impedance bandwidth, good AR performance, and unidirectional radiation patterns over all of the operating bands. Compared to the crossed dipoles on the metallic cavity-backed reflector [10], [11], the presented antenna yields a lower profile ($\lambda_0/8$) and an improvement in the 3-dB AR bandwidth at the lower band. The resulting antenna system is characterized first with the ANSYS-Ansoft High Frequency Structure Simulator (HFSS); its simulated performance is then verified by measurements.

## II. Antenna Geometry and Design

Fig. 1 shows the geometry of the proposed antenna. It is composed of two printed dipole elements, a coaxial line, and an HIS reflector. The HIS reflector is constructed as a compact two-dimensional array of square patches printed periodically on a conductor-backed substrate [7]. The RT/Duroid 6010 board material was selected for the HIS substrate. It has a relative permittivity of 10.2, a loss tangent of 0.0023, and a thickness of $h_{\rm HIS}$. The size of the square patch in a unit cell is $W_{\rm p} \times W_{\rm p}$ and the overall size of the unit cell is $P \times P$. The printed dipole elements are suspended at a height of $H$ above the HIS reflector. The radiating elements are printed on both sides of a $W_1 \times W_1$-sized sheet of RT/Duroid 5880 substrate, which has a relative permittivity of 2.2, a loss tangent of 0.0009, and a thickness of $h_{\rm s}$. Each trident-shaped arm of each dipole element is divided into

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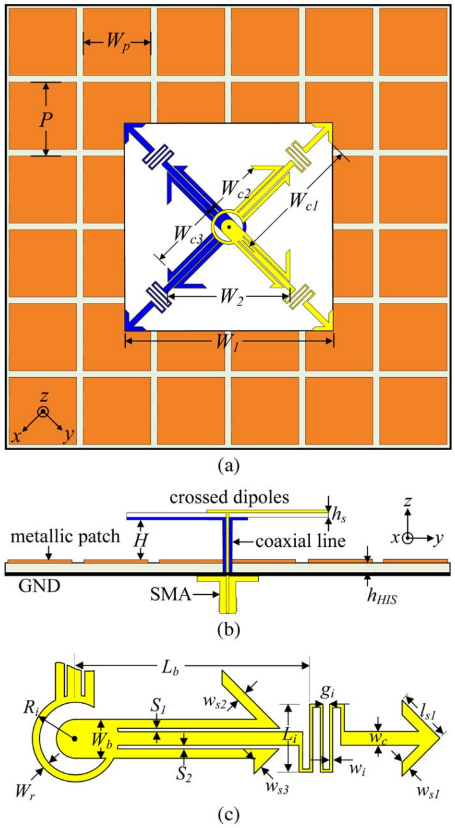


Fig. 1. Geometry of the crossed trident-shaped dipole elements: (a) top view, (b) side view with coaxial feed, and (c) a trident arm with its vacant-quarter printed ring.

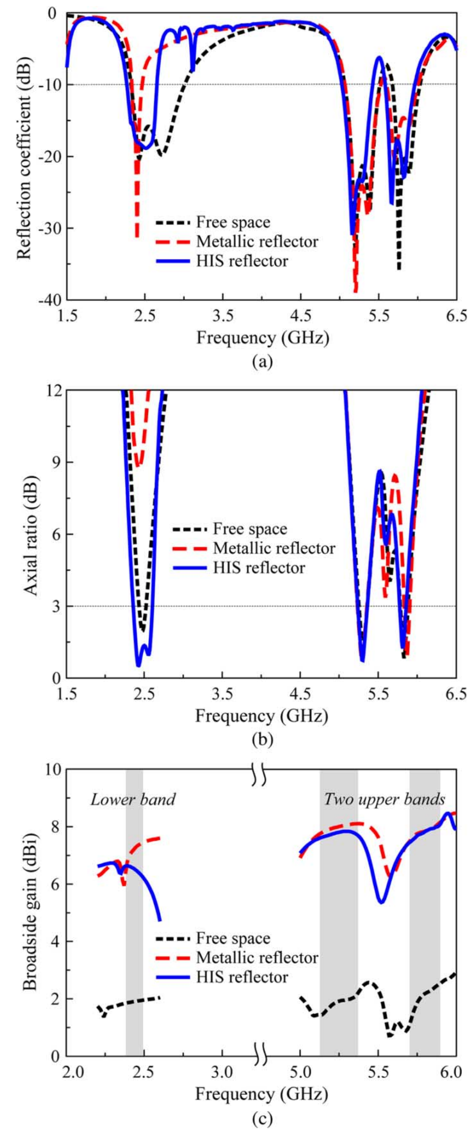


Fig. 2. Simulated (a) reflection coefficient, (b) AR, and (c) broadside gain of the crossed trident-shaped dipole elements radiating in different configurations. For the metallic and HIS reflector cases, the spacing from the bottom of the radiating elements to the top of the reflectors was $H = 15$ mm.

three branches with different lengths, which were specifically designed to operate in the 2.4/5.2/5.8-GHz WLAN bands. The center branch of each trident arm is designed to operate over the 2.4-GHz band. It contains a compact meander line and has an end that is shaped like an arrowhead to reduce its size [10]. The meander line was placed at a distance $L_{\rm b}$ from the center with trace width $w_i$, gap size $g_i$, and length $L_i$. The two other branches also are barbed at their ends; their sizes are adjusted to operate separately in the 5.2- and 5.8-GHz bands. To generate the desired CP radiation, two of these trident-shaped elements are crossed via a 90° phase delay line that consists of a vacant-quarter printed ring, whose radius and width are $R_i$ and $W_{\rm r}$, respectively. One pair is located on the top side of the RT/Duroid 5880 sheet, the other on its bottom side. The combined pairs are arranged to form two dipole radiators. The vacant-quarter printed ring has a length of approximately $\lambda_{\rm g}/4$ at the lower band and $3/4\lambda_{\rm g}$ at the relatively close upper bands ($\lambda_{\rm g}$ being the guided wavelength at the center frequency). In this manner, the requisite 90° phase difference is obtained for each of the three different frequency bands.

A simple model based on simulating the scattering parameters of a single-port air-filled waveguide with two PEC amd two PMC walls was used for the HIS simulation [12]. The HIS thickness was $h_{\rm HIS} = 2.54$ mm ($\sim 0.02\lambda_0$ at 2.45 GHz). The size of a unit cell was $12 \times 12$ mm$^2$ ($\sim 0.1\lambda_0 \times 0.1\lambda_0$ at 2.45 GHz), and each metal patch in the unit cell had $W_{\rm p} = 11.6$ mm. This design yielded a frequency of 2.475 GHz for the 0° reflection phase and frequencies in the range of 2.30–2.60 GHz for the 90° to $-90°$ reflection phase values, which completely covered the 2.4-GHz WLAN band.

The crossed trident-shaped dipole elements were first optimized in free space for triband operation covering the 2.4/5.2/5.8-GHz WLAN bands with good CP radiation characteristics. Referring to Fig. 1, the parameters were as follows: $W_1 = 30$ mm, $W_2 = 17.6$ mm, $W_{\rm c1} = 19$ mm, $W_{\rm c2} = 8.5$ mm, $W_{\rm c3} = 10.4$ mm, $R_i = 2.5$ mm, $W_{\rm r} = 0.4$ mm, $W_{\rm b} = 2.2$ mm, $S_1 = S_2 = 0.2$ mm, $L_{\rm b} = 13$ mm, $L_i = 4$ mm, $w_i = 0.2$ mm, $g_i = 0.4$ mm, $w_{\rm c} = 0.8$ mm, $w_{\rm s1} = w_{\rm s2} = w_{\rm s3} = 0.6$ mm, $l_{\rm s1} = 3.5$ mm, $l_{\rm s2} = 4.5$ mm, $l_{\rm s3} = 2$ mm, and $h_{\rm s} = 0.508$ mm. As shown in Fig. 2(a) and (b), the antenna in free space yielded impedance matching bandwidths of 2.33–3.00, 5.07–5.51, and 5.68–6.00 GHz for the $-10$-dB reflection coefficient and 3-dB AR bandwidths of 2.44–2.52, 5.20–5.31, and 5.75–5.85 GHz with CP center frequencies of 2.47, 5.3, and 5.83 GHz, respectively. The CP center frequency is defined here as the frequency at which the AR has its minimum value.