A wideband Circular polarization cross printed dipole antenna with four quadrants parasitic

Mustafa Hasan¹, Nasr AlKafaji² and Hussam Al-anssary³
¹, ² & ³ Najaf technical college, Al-furat Al-awsat technical university, An Najaf Al-Ashraf, Iraq.

mus1901@atu.edu.iq

Abstract. The cross printed dipoles antenna is the best solution to generate wide band circular polarization, in this design prepared cross rectangular printed dipoles (antenna1) then added four inner quadrants parasitic (antenna2) with perfect arrangement and excellent dimensions. The quadrants, (inner parasitic) rotate sequentially round the crossed dipole, are used to persuade new resonance and increase the activity bandwidth, additional improving the AR bandwidth. The results show that the antenna achieves an impedance bandwidth (IBW) of 88.38% (4.66-12.04 GHz) for |S11| < −10 dB and a wide axial ratio bandwidth (ARBW) of 55.80% (5.75-10.2 GHz). The proposed antenna would be utilized in C-band applications and for wireless local area network (WLAN) applications. The structures modelled and analysed by the Ansoft’s HFSS simulation software.

1. Introduction

Because of their superior transceiver efficiency, low multipath interference, and high polarization matching, circularly polarized antennas have attracted a lot of attention as wireless communication systems have advanced. As a consequence, broadband CP antennas in wireless communication systems are in high demand. Because the simplicity of this structures and large operating bandwidths, the crossed dipoles have been commonly used in the proposal of CP antennas.

The crossed strip line dipoles presented in [1] which it used VCR achieved IBW of 30.7% and a narrow ARBW of 15.6%. To improve the ARBW [2], then a type of cavity structure (cavity-backed ) have been been used in its place of the original metal ground, also by using the dual cavity, the -10 dB IBW and the 3 dB ARBW in CP crossed dipole antenna displays a good enactment 79.4% and 66.7%, respectively. Furthermore, the parasitic configurations also give a great role in promoting the IBW and ARBW. The antenna surrounded by an irregular crossed loop in [3] reports two additional CP modes due to its creative parasitic structure. While that the four square open parasitic is presents in [4], there is a minimum AR point generated. To boost the antenna's efficiency, the antennas in [5] use parasitic magneto-electric dipoles. The antenna has a broad AR beam width (>165°) and a high radiation efficiency (>94%) due to four metal rectangular patches grounded by four metal posts but a narrow ARBW. pair of a driven crosses striped dipole give wideband CP in [6], the same author enhances his design by adding additional four square-slot patches to get on broadband CP in [7]. Despite its larger size, the antenna in [8] It achieves a wider IBW of 106.5% and an ARBW of 96.6% using a novel composite cavity and elliptical dipoles. This reduces the size of cross-dipole antenna by using stepped rectangular patch arms and AMC reflectors in [9]. A large number of CP cross dipole bowtie has been extensively investigated, four trapezoidal patch arms make up the crossed dipoles [10]. One bowtie-
shaped feature aids in the generation of additional resonance by the crossed bowtie dipoles in [11]. A crossed bowtie dipole loading with parasitic cross-slots and eight parasitic patches yields a broad IBW of 93.1% and a strong ARBW of 90.9% in [12]. Moreover, a wide bandwidth with different feeding techniques has been studied like L-shaped electric dipole [13] and center-slot [14] feeding.

In this paper, we propose cross dipole printed antenna with traditional arm shape (strip line) have excellent impedances bandwidth and a good 3db-AR. with the additional main components are pair of vacant quarter rings and four of quadrant rotated dipoles. The quadrants, which rotate sequentially around the crossed dipole, is used to induce new resonance and increase the activity bandwidth by obtaining an excellent IBW and a good ARBW.

The paper consist antenna design with antenna configuration and how it is operate and then the antenna mechanism with the results, that was in section two. In section one and three we discussed the introduction and the conclusion of this work.

2. Antenna design

2.1 Antenna configuration and antenna operation

The advantages are described in the above section that the cross dipole structure is used. Many structure studies are included in the classic form in [1]. Wideband has recently become available as a result of various modifications to this form, including the addition of parasitic elements [2-7]. Here, the four quarters is gives a unique results as IBW compare with the used parasitic elements and geometrical comparing at its most basic than bowtie shaped or the different shapes of CDA in [8-12].

The both dipoles have equal real part admittance but different input angles by 90° [15] this researcher who is first one used the cross dipole with different arm’s length it was in 19961. Pair of vacant quarter rings [1-12] are designed to link the two dipole arms with \( \lambda_g/4 \) length (\( \lambda_g \) is the guided wave length) are printed on both sides of 0.5mm high substrate and the martial form is FR4 (\( \varepsilon_r \) is 4.4 with loss tangent 0.02) they are symmetrically mounted on the semi-rigid coaxial cable of 50 Ω, making 180° phase difference between the two dipoles. The top arm was connected to the inner PEC, while the bottom arm was connected to the outer PEC. The ground plane is positioned at a distance of \( H \) 0.25 \( \lambda_0 \) (\( \lambda_0 \): 6 GHz free space wavelength) from the radiator, and its size \( L_r \) 0.785 \( \lambda_0 \) (39.25×39.25mm) as cleared in table 1 is chosen large enough to minimize its effect on the antenna's characteristics. The ANSYS EM suite 2020 R1 software is used.

![Figure 1](image)

**Figure 1.** The geometrical antenna1 (a) top view (b) zoom out arm top view (c) side view

The sequence phase is calculated by two equivalent input admittances for both arms of the two cross dipole antennas with a 90° phase shift difference for getting on CP associated by coaxial cable, it will be (0°, 90°, 180° and 270°). Figure 2 illustrates an evolution that can be used to analyse the antenna's functioning mechanism. Three antennas have been proposed: 1- Ant. 1 across strip line dipole 2- Ant. 2 across strip line dipole with four quarter parasitics added on top side of substrate.
### TABLE 1. Dimensions of the antenna (unit: mm)

| Lr  | Ls  | W  | S  | L1 | L2 |
|-----|-----|----|----|----|----|
| 39.25 | 22  | 1.2 | 0.1 | 9.3 | 7.3 |
| r1  | r2  | R1 | R2 | h  | H  |
| 1.1 | 1.6 | 1.58 | 5.6 | 0.5 | 12.5 |

**Figure 2.** The proposed antenna’s evolution (a) Antenna 1 (b) Antenna 2.

#### 2.2 ANTENNA MECHANISM (analysis)

Figure 3 represents the corresponding simulated effects. Since there is only one CP resonance mode, the Ant.1 has an IBW of 38.26% from 5.20 to 7.66 GHz and a narrow ARBW of 11.54% from 5.55 to 6.23 GHz. The IBW is increased from 38.26% to 88.38% and the ARBW is increased from 11.54% to 55.80% simultaneously, when four quarter parasitics are added, as shown in Ant. 2.
Figure 3. Comparison of output between two antennas: (a)$|S_{11}|$ and (b) AR

The main parameter is changed in R2 with fixed R1 to investigate the effects of the dimension and position of the four quadrants (inner parasitic) dipoles on the output of the proposed antenna to provide good sequentially between the cross dipole arms then getting on wideband -10 dB and 3dB ARBW according to Fig. 4.
It is clear the value R2 equal to 5mm is gave best return loss but is not in AR because we need to generate circular polarization so we by optimizing the value of R2 to 5.6mm, and so on, the -10dB IBW 88.38% (4.66-12.04GHz) and the 3dB AR is 55.80% (5.75-10.2 GHz), as well as the four quadrants parasitic resonators and the sequentially rotated configuration as reported in [4, 5], which generate the two minimum points in the IBW and AR curves In most other words, the crossed dipole and four quadrants parasitic with R2-R1 radius, respectively, produce the two deep points of the simulated IBW and AR curve in region 1 and 2 seen in Fig. 3. A broadband CP efficiency is achieved in the proposed CP antenna by integrating the two minimum points properly.

Even though they have evaluations to increase antenna characteristics, the four quadrant parasitic factor gives good return loss bandwidth when compared to the conventional strip line in [1-6]. In addition, it is a good competitor to other shapes such as the bowtie, which is known for having a broad impedance bandwidth, as well as other CDA shapes [8-12], as shown in table 2, which are summarized in the literature comparison between the proposed antennas and previous works.

### TABLE 2. Compared between the prepared antenna and former antennas that have the same design

| The Ant. In reference | Size (\(\lambda_0\)) | Antenna’s Structure | -10 dB IBW % | 3-dB ARBW % | Average Gain (dBi) |
|-----------------------|---------------------|---------------------|--------------|--------------|-------------------|
| [2] 0.57 \(\times\)0.57 \(\times\)0.24 | Crossed dipole + Dual squared cavity reflector | 79.4 | 66.7 | 8.5 |
| [3] 1.1 \(\times\)1.1 \(\times\)0.28 | Crossed dipole + Cross loop + Squared cavity reflector | 67.5 | 53.4 | 8 |
| [4] 1.05 \(\times\)1.05 \(\times\)0.24 | Crossed dipole + Parasitic Loop Resonators | 38.2 | 28.6 | 8 |
| [5] 1.05 \(\times\)1.05 \(\times\)0.24 | Crossed dipole + Magneto-Electric Dipole | 54.65 | 27.67 | 7.8 |
| [6] 1.04\(\times\)1.04\(\times\)0.26 | Crossed dipole + Parasitic elements + Conventional reflector | 77.6 | 66 | 7.2 |
| [7] 1.04 \(\times\)1.04 \(\times\)0.26 | Crossed dipole + Parasitic elements+ Conventional reflector | 95.5 | 94.4 | 7.2 |
| [8] Circular ground plane | Crossed dipole + elliptical dipole +composite cavity | 106.5 | 96.6 | 9 |
| [9] 0.88 \(\times\)0.88 \(\times\)0.13 | Crossed dipole + stepped rectangular + AMC | 47.3 | 25.3 | 7.8 |
| [11] 0.79 \(\times\)0.79 \(\times\)0.27 | Crossed dipole + Simple single parasitic element | 68 | 58.6 | 8.2 |
| Proposed Ant.1 | 0.18 \(\times\)0.18 \(\times\)0.27 | Crossed dipole + rectangular arms | 38.26 | 11.54 | 7.4 |
| Proposed Ant.2 | 0.18 \(\times\)0.18 \(\times\)0.27 | Crossed dipole + rectangular arms + four quadrants parasitic | 88.38 | 55.8 | 7.4 |

It is very clear in the antenna 2 how we increase the impedance bandwidth 88.38% comparing with the previous work, in ref. [8] maybe has 106.5% IBW but in lowest frequency than this work (sub. 5G and whole the x band frequencies). So it is big challenges to get this design with this unique results also the simplicity of the structure is present.

Figure 5 depicts simulated radiation patterns in the xoz- and yoz-planes at 6 GHz. In xoz-plane, the patterns are symmetrical to those in yoz-plane. In the boresight direction, the antenna produces unidirectional CP patterns. The RHCP (right-hand circular polarization) is greater than the LHCP (left-hand circular polarization), resulting in exceptional RHCP radiation.
3. Conclusion

A method for greatly increasing the CP bandwidth of the crossed dipole antenna was presented in this report. A wideband antenna with two rectangular orthogonal patches and a four quadrant parasitic portion put in the gap between arms was designed using the methodology. To test the proposed design, the antenna was simulated. The antenna was capable of achieving a small 3-dB AR bandwidth of 55.8% (5.75–10.2 GHz) and a wide impedance bandwidth matching $|S11|$ $\leq$ 10 dB of 88.38% (4.66–12.04 GHz) according to simulation performance. Furthermore, the radiation patterns are stable, and the average large side gain is about 7.4 dB. It is extremely beneficial to keep up with the rapid development of modern wireless communication, in which both of these aspects are crucial due to the benefits of very broad AR bandwidth and high gain radiation.

Acknowledgments

The thankfulness to my supervisors Dr. Naser Nomas and Dr. Husam AlAnsary at Al-Furat Al-Awsat Technical University /Engineering Technical College Najaf. My thanks to my ministry (ministry of electricity Iraq) which it gave me the opportunity to do this?

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