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Research Article

The Crossed-Dipole Antenna with Torang-shaped Parasitic Elements and Circular Polarization for GPS Application

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Abstract

This paper presents a circularly polarized (CP) printed crossed-dipole antenna for Global Positioning System (GPS) receptions in the L1 (1575 MHz) band. Its structure consists of two orthogonally printed dipoles, two integrated baluns to feed the dipoles, and a feed network connected to the baluns. The feeding network comprises a Branch-Line Coupler with two quadrature outputs. Accordingly, providing two orthogonal dipoles with a 90-degree phase difference leads to right-handed circular polarization (RHCP), a must for GPS applications. Four Torang-shaped parasitic elements have been used in the upper part of the dipole arms to improve the circular polarization of the antenna. Based on the practical results obtained with the technique, the antenna's Axial Ratio (AR) bandwidth is increased by about 21%. At the same time, the purity of the circular polarization can also be seen. The experimental results show that the proposed GPS antenna has an impedance bandwidth of 46.28% (from 1.327 to 2.126 GHz), an axial ratio bandwidth of 41.36% (from 1.329 to 2.022 GHz), and a maximum gain of 6.40 dB. The dimensions of the proposed antenna are compact, and this antenna has a stable radiation pattern. In the last step, the proposed GPS antenna is fabricated and tested in the antenna laboratory.

Keywords: Crossed Dipole Antenna, Parasitic Element, Circular Polarization, GPS.

Highlights

- In this research, a new design of orthogonal printed dipole antennas with circular polarization is presented.
- This antenna is useful for use in global positioning system receivers in the 1575 MHz band.
- In this design, four Torang-shaped parasitic elements are used to improve the circular polarization of the antenna.
- According to the practical results obtained with the used technique, the bandwidth of the axial ratio of the antenna has increased by about 21%.
- The purity of the circular polarization of the antenna has been significantly improved by using the Torang-shaped parasitic elements.

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1. Introduction

Today, circularly polarized antennas have a wide range of satellite applications in the L-band frequency range [1-3]. Since the antenna signal passes through the Unisphere layer in satellite applications and at the same time, due to the effect of the Faraday rotation phenomenon on radio waves in linear polarization, the circular polarization feature of the antenna is a popular option in wireless communication systems, especially for Radio links between ground stations and satellites [4]. In addition, circularly polarized antennas have many advantages compared to linearly polarized antennas, such as the ability to overcome the problem of multipath fading, which leads to increased radio link quality. Using circular polarization, it will also be possible to tolerate adverse atmospheric conditions in satellite applications [5,6].

Currently, circular polarization dipole antennas are highly interested in wireless navigation systems such as global positioning systems [7-10]. The Global Positioning System is a navigation system that consists of several satellites located in the Earth average orbit. These satellites provide microwave signals that indicate a user's geographical position [11]. The three popular operating frequency bands for the Global Positioning System are L1 (1.575 GHz), L2 (1.227 GHz), and L5 (1.176 GHz). In reference [12], a circular polarization antenna of dipole type, which includes two crossed dipoles, two integrated balloons, and a 90-degree hybrid coupler, is presented for L1 band global positioning system receivers. The coupler stimulates the dipoles using the square outputs and implements the circular polarization operation in this design. Similarly, a small microstrip GPS antenna for the L1 frequency band is proposed in [13], except that this antenna has a single feed, and its circular polarization performance is achieved by adjusting the size of the fractal imperfect ground structure.

In addition, the cooperation of different frequency bands in the global positioning system improves the navigation service stability, increasing the positioning quality and its high accuracy. In reference [14], a circular polarization antenna of stacked patch type for global positioning system receivers, including L1, L2, and L5 frequency bands, has been investigated. This paper presents a new design of a crossed dipole antenna with circular polarization for L-band applications (913.7-1513.1 MHz). Also, in recent years, many studies have been conducted on global positioning systems and their performance and investigating methods based on their optimization [15-18].

2. Innovation and contributions

This article presents a new design of crossed printed dipole antennas with circular polarization for use in Global Positioning System (GPS) receivers in the L1 band (1575 MHz). The antenna structure consists of two printed dipoles placed orthogonally to each other. It also includes two integrated balloons for feeding the dipoles and a feeding network connected to the balloons. In this design, four Torang-shaped parasitic elements are used in the upper part of the dipole arms to improve the antenna circular polarization. According to the practical results obtained with the applied technique, the antenna bandwidth of the axial ratio (AR) has increased by about 21%. At the same time, the purity of the circular polarization of the antenna has also improved significantly.

Among the innovations of this article, we can mention the role of two separate factors in creating and strengthening the circular polarization of the antenna. The first and foremost factor is the use of crossed dipoles with square feeding, which is the basis of circular polarization in this design. The second factor is the rotation of surface currents on the parasitic elements above the antennas. The structure of the Torang-shaped elements consists of a vast part and a narrow part. This issue causes the optimal orientation of the surface currents on these elements and creates the desired rotation for the surface currents. In this way, the second factor is mostly responsible for strengthening and increasing the purity of the antenna's circular polarization, which increases the antenna bandwidth.

3. Materials and Methods

All antenna simulation results using HFSS Ver. 15 are performed based on the finite element method. To prove the antenna performance, the crossed-dipole antenna with the proposed parasitic elements was built after the optimization process and extraction of the final physical parameters, and it was tested and measured in the antenna and microwave laboratory of Urmia University. The bandwidth of the antenna impedance was tested using the network analyzer device (E8363C), and the antenna radiation parameters were measured in the anti-reflection room of the antenna laboratory.

4. Results and Discussion

The antenna proposed in this article is developed using crossed dipoles and a square coupler to achieve circular polarization performance. Dipoles are fed by two balloons connected to a coupler to stabilize the radiation pattern. Also, using parasitic elements significantly improves the antenna's circular polarization performance at about 379 MHz. The circular polarization antenna proposed in this research has a maximum gain of 6.40 dB and dimensions of $42.25 \times 113 \times 110$ mm^3. The proposed antenna can be used in L1 band (1575 GHz) global positioning systems and meteorological radar in the 1.327-2.126 GHz frequency band.

5. Conclusion

This article presents the simulation and construction of a crossed printed dipole antenna with branch coupler feeding for global positioning system receivers in the frequency band L1 (1575 MHz). By placing the dipoles orthogonally, using the square feeding technique, and using a ground plane as a reflector, the proposed antenna has achieved directional right-handed circular polarization radiation in the working frequency band. According to the results, the proposed orthogonal printed dipole antenna has an impedance bandwidth of 2.135-1.304 GHz with a return loss criterion smaller than -10 dB and an axial ratio bandwidth of 314 MHz (1.384-1.698 GHz) with an axial ratio criterion smaller than 3 dB. Four Torang-shaped parasitic elements have been added to the upper part of the dipoles to increase the purity of circular polarization as much as possible. According to the laboratory results, using parasitic elements above the crossed dipoles results in a circular polarization bandwidth of 693 MHz from 1.329 GHz to 2.022 GHz with an axial ratio criterion smaller than 3 dB for the antenna. That is, by adding parasitic elements, an increase of about 21% in the circular polarization bandwidth of the antenna is observed. The proposed antenna pattern is stable, and this antenna, with a maximum gain equal to 6.40 dB, is suitable for global positioning applications in the frequency band of 1.575 GHz. A crossed dipole antenna with proposed parasitic elements was built, tested, and measured in the antenna laboratory. The test and simulation results showed good agreement.

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Appendix

Table (1): Comparison of the proposed antenna with similar antennas

Antenna Type	Impedance Bandwidth [MHz]	Circular Polarization Bandwidth [MHz]	Maximum Gain [dB]	Dimensions [mm^3]	Reference
Crossed Dipole Antenna with Unequal Feeding Network	1010-2010	1210-1970	6	140*140*50	**[7]**
Crossed Dipole Antenna with Branch Coupler	1260-2210	1307-1938	5.72	113*113*40	**[12]**
Microstrip Antenna with Fractal Structure in the Ground	1558-1588	1572-1578	2.2	45*45*3.18	**[13]**
Crossed Dipole Antenna with Box-shaped Ground Plane	907-1495	1078-1439	3.1	140*140*38.8	**[18]**
Crossed-Dipole Antenna with Torang-shaped Parasitic Elements	1304-2135	1304-1698	6.4	110*113*42.25	**This Article**

Declaration of Competing Interest: Authors do not have conflict of interest. The content of the paper is approved by the authors.

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