Elliptical Shaped UWB Antenna with Broadband Circularly Polarized Antenna for GPR Applications

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Abstract. In this paper, a compact elliptical shaped antenna with a broadband Circular Polarization (CP) performance is proposed for Ground Penetrating Radar (GPR) applications. The designed antenna is constructed by an elliptical patch and an inclined strip attached to a reduced ground plane. The working bandwidth measurement was done by employing R&S®ZNB Vector Network Analyzer. The experimental results indicate that a measured impedance bandwidth extending from 3.73 GHz to 10.6 GHz (95.88%) is achieved. The CP performance of the antenna is acquired by the use of the inclined strip; a simulated broadband Axial Ratio (AR) extending from 5.89 GHz to 10.3 GHz (54.83%) is attained. Furthermore, the simulated results show that the proposed antenna yields broadside CP radiations with high values of the radiation efficiency of more than 80 % and acceptable values of the gain varying between 1 and 5 dBi. Hence, these performances make the proposed antenna a good candidate for GPR applications.

Keywords and phrases: Ultra-Wideband (UWB) Antenna, Circular Polarization (CP), Ground Penetrating Radar (GPR) Applications.
1 Introduction

Ground Penetrating Radar (GPR) is a non-subversive technology that employs electromagnetic waves for the inspection of the ground and for the detection of buried targets [1-4]. Hence, GPR applications require a Circular Polarization (CP) performance for the antennas to improve the efficiency of the GPR systems which depend on the reflected waves containing the measures [5-6]. Besides, for a penetration of the surfaces at different distances downward and for a better resolution an Ultra-Wideband (UWB) performance is required for the GPR antennas [7-8]. Currently, the specifications and the requirements of the GPR technologies have drawn an increased concern to design novel GPR antennas with improved performances [9]. Besides, some of the UWB GPR antennas presented in the recent literature, such as those proposed in [10-12], have complex geometries or/and have enormous dimensions. Hence, there is a strong necessity to design other GPR antennas which ensure these characteristics.

In this paper, small and simple circularly polarized UWB antenna is proposed for GPR applications. The designed antenna is composed of an elliptical radiating patch and a reduced ground plane joined with an inclined corrugated strip. The simulations were realized using the commercial software CST microwave studio™ [13]. A prototype of the proposed antenna is fabricated and measured by the use of a well calibrated R&S®ZNB Vector Network Analyzer. The paper is organized as follows: section 2 illustrates the configuration of the designed CP UWB elliptical shaped antenna. Afterwards, the achieved results of the designed structure are presented and analyzed in section 3. Finally, a conclusion with a suggestion for the future works is drawn in section 4.

2 Antenna design and configuration

All the designs and the analysis were performed using the commercial software CST studio™. Fig. 1 shows the evolution of the antenna during the design process. An inclined strip with corrugations is related to the left side of a modified ground plane to introduce the CP performance and to enhance the impedance bandwidth. The proposed antenna is printed on the cheaper substrate FR-4 epoxy that has a dielectric permittivity of 4.4 and an overall size of about 22×25×1.5 mm³. The geometry of the proposed elliptical shaped UWB antenna is presented in Fig. 2. All the physical parameters of the antenna are defined in Table 1.

Figure 1: Antenna configuration evolution during the design process, (a) antenna 1, (b) antenna 2, (c) antenna 3.
Figure 2: Structure of the designed elliptical shaped antenna, (a) front view, (b) back view.

Table 1: Detailed parameters of the proposed elliptical shaped antenna.

<table>
<thead>
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<th>Dimension (mm)</th>
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<td>a</td>
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<td>L</td>
<td>25</td>
<td>b</td>
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<tr>
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<td>c</td>
<td>7</td>
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<tr>
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3 Results and discussion

Figure 3 shows that the impedance matching and the impedance bandwidth of the designed elliptical shaped antenna are highly improved after the insertion of the inclined strip with corrugations and after introducing modifications in the reduced ground plane. The final structure exhibits an UWB operating bandwidth extending from 3.05 GHz to upper than 11 GHz (113.17%). The fabricated prototype is depicted in Fig. 4. Fig. 5 shows the simulated and the measured Voltage Standing Wave Ratio (VSWR) of the proposed elliptical patch antenna. A good concordance between the two curves is achieved. The measured VSWR is in a good agreement with the simulated one. The slight variances at lower frequencies may be due to the
measurement and the fabrication errors. The measured bandwidth is extending from 3.73 GHz to 10.6 GHz; a measured fractional bandwidth of about 95.88% is attained. The Axial Ratio (AR) bandwidth of the proposed elliptical shaped antenna is presented in Fig. 6 to prove the CP performance of the antenna. It is clear that the designed antenna presents a broadband AR extending from 5.89 GHz to 10.3 GHz and a fractional AR bandwidth of about 54.48%; hence the CP performance is confirmed. Fig. 7 and Fig. 8 depict the simulated right-handed circularly polarized (RHCP) and the left-handed circularly polarized (LHCP) far-field radiation patterns respectively of the designed antenna in two principal planes $H$ and $E$ at two frequencies 6 GHz and 9 GHz. It is clear that the designed antenna radiates RHCP in the $+z$-direction and LHCP in the opposite direction. Fig. 9 shows that high values of the radiation efficiency of more than 80% and reasonable values of the gain varying between 1 and 5 dBi are attained within the operating bandwidth.

![Graph](image_url)

**Figure 3:** Comparison of the proposed antenna’s VSWR with those of initial structures.

![Antenna Images](image_url)

**Figure 4:** Fabricated prototype of the proposed elliptical shaped antenna, (a) front view, (b) back view.
Figure 5: Simulated and measured VSWR of the proposed elliptical shaped antenna.

Figure 6: Axial ratio of the proposed elliptical shaped antenna.

Figure 7: RHCP patterns at two frequencies, (a) $H$-plane, (b) $E$-plane.
Figure 8: LHCP patterns at two frequencies, (a) $H$-plane, (b) $E$-plane.

Figure 9: Gain and radiation efficiency obtained by the proposed elliptical shaped antenna.

4 Conclusion

In this work, small and simple UWB elliptical shaped antenna with broadband CP performance has been proposed for GPR applications. A prototype of the designed structure has been fabricated and measured. The measured results indicate that the fabricated prototype operates between 3.73 GHz and 10.6 GHz (95.88%). The CP performance of the antenna has been achieved by attaching an inclined strip to the minimized ground plane; a broadband AR extending from 5.89 GHz to 10.3 GHz (54.78%) is achieved. Besides, the simulated results indicate that the designed antenna generates broadband CP radiations. High values of the radiation efficiency of more than 80% and acceptable values of the gain varying between 1 and 5 dBi are achieved within the working bandwidth. Hence, these satisfactory results support the candidature of the proposed antenna for GPR applications. As a recommendation, the high gain is another desirable performance that to be considered for the future GPR antennas.
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References


