URSI GASS 2021, Rome, Italy, 28 August - 4 September 2021

Double Cavity-Backed Dual-Band Crossed Dipole

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Abstract

This paper presents a dual-band, circularly-polarized antenna for GNSS and telemetry applications. The radiating element is an asymmetric printed crossed dipole radiating in circular polarization (CP). The crossed dipole is backed by a square cavity to achieve a unidirectional radiation pattern. A second smaller cavity is introduced to widen the beam width and at the same time improve the CP quality of the radiation pattern. The proposed antenna covers the whole GNSS band from 1 to 1.9 GHz (62% relative bandwidth) with a 3-dB axial ratio (AR) bandwidth from 1.15 to 1.705 GHz (41%). In addition it is matched in an upper band from 2.1 to 2.5 GHz (17% relative bandwidth) and presents a 3-dB axial ratio bandwidth from 2.1 to 2.305 GHz (11%). This second band may be used for telemetry.

1 Introduction

Applications such as GNSS, telemetry, RFID or WLAN require robust wireless links between the transmitter and a moving receiver whose position and orientation may change with time. CP polarization is thus preferred to ensure a resilient link between the transmitting and receiving antennas.
A typical radiator used for such kind of applications is the "turnstile" antenna comprising two orthogonal dipoles embedded in a circular cavity [1]. Such an antenna provides a unidirectional, wide beam and circularly-polarized radiation pattern. The cavity operates as a backing reflector to provide the unidirectional radiation. The turnstile or crossed dipole antenna has received much attention in literature with different aims such as reducing its size; increasing its operation bandwidth or providing multi-band capability [2-8]. However, the wideband or multi-band capability of such solutions are generally associated to more directive radiation patterns. This is not suited to applications requiring an omnidirectional radiation to ensure wireless communications over a large field of view.
Crossed dipoles with volumetric arms (not flat) have been proposed to significantly improve the obtained gain and AR at low elevation angles over a given frequency band. However, such solutions are bulky and present limited bandwidths [5],[6].
Low-profile solutions have been also proposed by adding vertical parasitic elements replacing the side wall of the circular waveguide associated to the crossed dipole [7]. These parasitic elements exhibit a radiation pattern similar to a monopole antenna enhancing the gain and AR at low elevation angles. However, they also suffer from integration issues when mounting the antenna on moving platforms.
In [8], a crossed dipole coupled with a parasitic element is placed in a circular waveguide which lateral walls made by metal strips and slots. Such a solution offers very good dual-band performance in terms of gain and AR at low elevation angles at the cost of a bulky solution.
In this paper, an asymmetric printed crossed dipole backed by a novel full-metal double square cavity is presented. The double cavity is introduced to improve the radiation performance of the antenna at low elevation angles and at the same time enlarge its operating band without increasing the total size.

2 Radiating element

The proposed structure is represented in Fig. 1. An asymmetric-crossed dipole printed on both sides of a 1.8 mm thick Rogers 3210 substrate (ε_r=10.2) has been designed. The two arms of the crossed dipole have been splitted to cover the whole GNSS band and upper frequency range from 2.1 to 2.305 GHz.

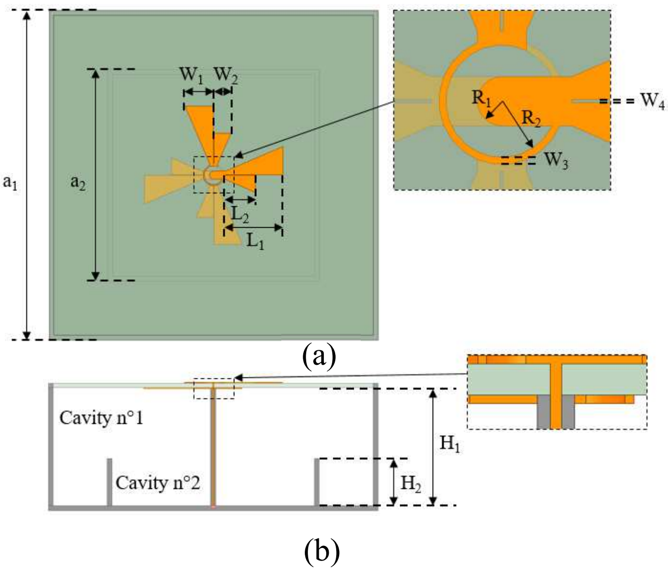


Figure 1. Proposed asymmetric-crossed dipole backed by a double cavity: (a) Top view; (b) Side view. a_1=140 mm; a_2=90 mm; W_1=12.2 mm; W_2=7.4 mm; W_3=0.5 mm; W_4=0.2 mm; L_1=24.5 mm; L_2=12.9 mm; R_1=1.75 mm; R_2=4 mm; H_1=50 mm; H_2=20 mm.

In particular, one dipole is fed directly by a coaxial probe as shown in Fig.1(b), one arm is connected to the coaxial pin and the second arm to the coaxial shield. The second dipole is fed by a pair of vacant rings as shown in Fig.1(a), providing the required 90° phase shift to produce circular polarization. The dimensions of the vacant ring have been optimized to ensure the best CP radiation in both frequency bands.

3 Double cavity

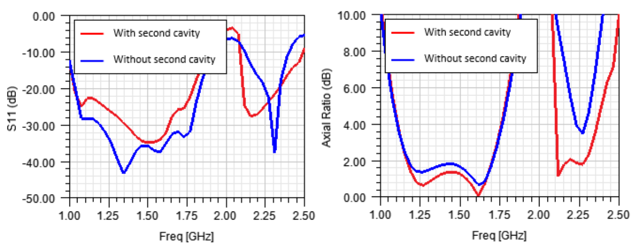
The crossed-dipole is backed by a double square cavity. Such a cavity has been designed using a modal analysis. In particular, the square cavity is assumed short circuited and thus Equ. (1) can be used to derive the propagating modes within the cavity.

$$\beta_{mn} = \sqrt{\left(\frac{2\pi f}{c}\right)^2 - \left(\frac{m\pi}{a}\right)^2 - \left(\frac{n\pi}{a}\right)^2}. \qquad (1)$$

Where a and c are the cavity size and the speed of the light. For CP and wide beam-width radiation, higher order propagating modes should be avoided. In this case, the cavity should allow a mono-modal propagation in both the lower and upper band of operation. Two square cavities with side a1 and a2 and heights H1 and H2 have been determined to meet this need. The final solutions is shown in Fig.1.(b). The smaller cavity is inserted within the bigger one.

4 Antenna performance

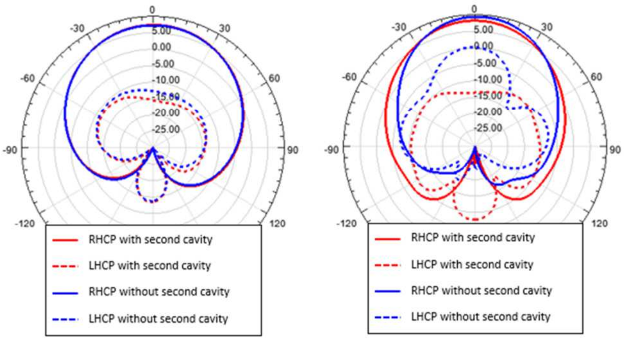
The antenna performance of the proposed antenna are here proved and compared to the case where a simple cavity is used as backing element. Fig. 2 represents the input reflection coefficient and AR in the two bands of operation with single and a double cavity.



(a) (b)

Figure 2. Simulated input reflection coefficient and AR with single cavity and double cavity: (a) Input reflection coefficient; (b) AR.

It is clear that the double cavity provides better performance in terms of matching and AR. In particular, the antenna is matched over a 62% and 17% relative bandwidth in the GNSS and in the upper band, respectively, with a 3dB AR bandwidth of 41% and 11%.



(a) (b)

Figure 3. Simulated realized gain with single cavity and double cavity: (a) At 1.4 GHz; (b) At 2.25 GHz.

The radiation patterns are plotted in Fig. 3 for both frequency bands. The impact of the double cavity is clearly visible in the upper band at 2.25 GHz resulting in a more omnidirectional pattern with lower cross-polarizing levels.

5 Conclusion

A dual band circularly-polarized antenna with hemispherical coverage has been proposed. A double backing cavity is used in combination with a crossed dipole to achieve better radiation performance in terms of polarization purity and coverage. Such an improvement make the proposed concept suited to GNSS and telemetric applications.

7 References

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