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Design of a Quasi-Hemispherical UWB Antenna

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***Abstract*—This paper proposes a design of three-dimensional antenna for ultrawideband applications. The antenna has dimensions of 58 mm x 58 mm x 76.5 mm and is composed of two identical arms. Each arm consists of a hollow quasi-hemisphere and an inner for it tube. In the simulation, a 50 Ω coaxial cable is employed to feed the antenna in order to assess the change of the antenna performance due to the cable effect. The simulated results show that the antenna is capable of operating in the frequency band from 7 to 32.5 GHz with S_{11} below -10 dB, while maintaining an omnidirectional radiation pattern. The simulated total efficiency is above 88 % over the entire impedance bandwidth which indicates a good antenna performance. The realized gain varies from 0.8 to 3.1 dBi with frequency.**

I. INTRODUCTION

In recent years, a large number of ultrawideband (UWB) applications, such as high data rate communications, UWB channel sounding, radar imaging, sensor data collection and precision locating, have been developed. One of the main issues related to the successful implementation of UWB systems is the design of an appropriate antenna. In other words, the performance of UWB antennas is of a paramount importance for the quality of operation of the systems. Generally, wideband antennas refer to a class of antennas, the performance of which is relatively stable over a broad frequency band [1]. The provision of an antenna, all electrical parameters of which remain relatively constant over a large bandwidth is a serious challenge. However, in most cases it is desirable the maintenance of certain antenna parameters stable depending on the concrete application for which the antenna is designed.

Typical three dimensional UWB antennas are horn, biconical, discone, and spherical. The horn antenna has a wide operating bandwidth and a directional radiation pattern [2]. The biconical antenna provides coverage of a large frequency band while maintaining an omnidirectional radiation pattern. Different variants of the biconical antenna have been studied in [3]-[5]. The discone antenna also has a wide impedance bandwidth and an omnidirectional radiation pattern. Designs of discone antennas have been shown in [6], [7]. Another class of UWB antennas with an omnidirectional radiation pattern are the spherical antennas. The spherical antennas are divided into spherical monopoles (composed of a solid sphere and a ground plane) and spherical dipoles (composed of two solid spheres) [8]-[11]. Also, designs with hemispherical and hollow radiators have been presented in [9], [12]. One of the designs in [9] is similar to the design presented in this paper. However, in [9] are used solid hemispheres (hemispherical dipole) with radius of 15 mm, while the presented antenna is composed of hollow quasi-hemispheres with radius of 30 mm. In addition, in [9] the cable effect on the antenna radiation pattern is not studied, although the antenna is fed with a coaxial cable.

In this paper, a design of three-dimensional UWB antenna is presented. A feeding coaxial cable is attached to the antenna in order to investigate the cable effect on the antenna performance. The antenna features with a compact size and has both wide impedance bandwidth and omnidirectional radiation pattern. Also, the antenna exhibits a high total efficiency. All studies were carried out with CST Microwave Studio version 2015 [13].

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II. PROPOSED ANTENNA DESIGN

Figure 1 shows the cross section of the antenna. The total size of the antenna is of 58 mm x 58 mm x 76.5 mm. The antenna is composed of two identical arms and each of them consists of a hollow quasi-hemisphere and an inner for it tube. Actually, it is used the term quasi-hemisphere since the radius of the sphere (r=30 mm) out of which the arm is made (also has a radius r=30 mm) is not equal to the height of the arm h_s, in contrast to the case of hemispherical antennas. The top/bottom part of the lower/upper arm is also tapered as indicated by d_o in Figure 1. In addition, brass (with electrical conductivity of 27.4x10^6 S/m) is used for building the structure.

It can be seen in Figure 1 that a coaxial cable is attached to the antenna, the inner conductor of which is connected to the upper arm, while the outer conductor to the lower arm. The feeding of an antenna directly by a signal source (without using a cable) in the simulation can lead to results differing substantially from the measured ones, where a feeding cable is used. The reason for such discrepancies is the cable effect. The latter changes the antenna performance by: 1) reflecting or scattering the radiated fields incident on the cable, and 2) radiation from the cable caused by the surface current flowing on the outer surface of the cable, i.e. the cable acts as an unintentional radiator [12]. All this leads to a distortion of the antenna radiation pattern and in order to assess the extent of this distortion for the presented antenna, a coaxial cable is attached to it. For speeding up the simulation, the cable length is truncated to l_c=100 mm. The geometric dimensions of the antenna and the cable are shown in Table 1.

There are two popular methods for reducing the influence of the cable radiation. The first method is by using a quarter-wavelength balun placed on the surface of the cable. However, the narrowband operation of the baluns make them appropriate only for narrowband applications. The second method is by placing ferrite beads around the cable. This technique have a wideband usage but the ferrite chokes are efficient up to a few GHz [14], [15].

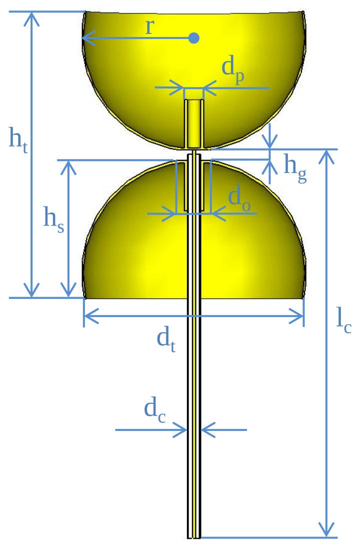


Fig. 1: Cross section of the antenna coupled with a coaxial cable.

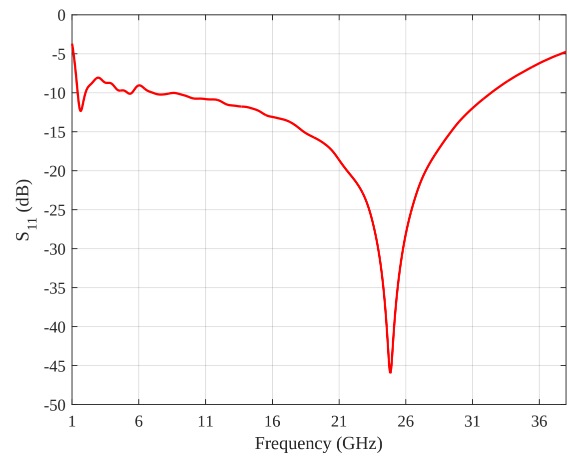


Fig. 2: Simulated S_{11} of the antenna.

Parameter	Value (mm)
r	30
h_t	76.5
h_s	36.9
h_g	2.7
d_t	58
d_o	8
d_p	5.2
l_c	100
d_c	3.58

TABLE I: Geometrical dimensions of the antenna and the cable.

III. RESULTS AND DISCUSSION

Figure 2 shows the simulated S_{11} of the antenna. Based on the results, one can see that the antenna covers the frequency range from 7 to 32.5 GHz with S_{11} below -10 dB. However, following the specification $S_{11} <$ -6 dB, the antenna can cover the frequency band from 1.2 to 36 GHz. For comparison, the antenna in [9] has 3.7:1 bandwidth while the presented antenna has 4.6:1 bandwidth (for $S_{11} <$ -10 dB).

The lowest operating frequency is mainly controlled by the length of the arm. The highest operation frequency mainly depends on the distance between the arms. In addition, the radius of the sphere out of which the arm is made (i.e. the radius of the quasi-hemisphere for the presented design) also influences the input impedance of the antenna [9].

The antenna has an omnidirectional radiation pattern in the H-plane because of the rotational symmetry of the structure. A comparison between the simulated E-plane radiation patterns (the realized gain is used) of the antenna with and without cable is shown in Figure 3. It should be noted that the term used in this paragraph “antenna with cable” is the structure presented in Figure 1, which in the rest of the paper is called simply “antenna”. The discrepancies in the radiation patterns at 7 GHz are due to the cable effect. It can be seen the presence of ripples in the lower half of the radiation pattern of the antenna with the cable. The difference between the beamwidth of the antenna with cable and that of the antenna without cable at 7 GHz is 10°. When the cable is used, in the lower half of the radiation pattern at 12 GHz ripples can be seen. However, the discrepancy between the radiation patterns (with and without cable) at 12 GHz is smaller than this at 7 GHz. As one can see with increasing frequency, the beamwidth decreases and the antenna becomes more directional in the E-plane. The ripples in the radiation patterns of the antenna with cable at 22 GHz and 30 GHz are insignificant and these patterns are quite similar to the corresponding ones of the antenna without cable. In other words, with increasing frequency the cable effect decreases and therefore the attached to the antenna cable leads to negligible changes in the radiation pattern.

The simulated results for the total efficiency (includes radiation efficiency and mismatch loss) of the antenna are shown in Figure 4. As one can see the total efficiency of the antenna is above 88 % over the covered frequency band 7-32.5 GHz. In addition, the radiation efficiency of the antenna is above 98 %. Figure 4 also presents the variation of the realized gain of the antenna with frequency. The data reveals that the gain varies from 0.8 to 3.1 dBi.

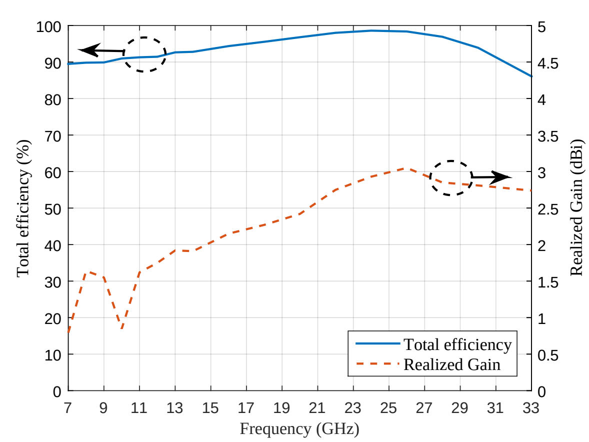
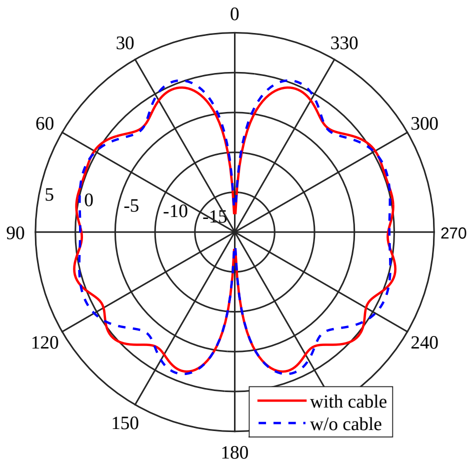
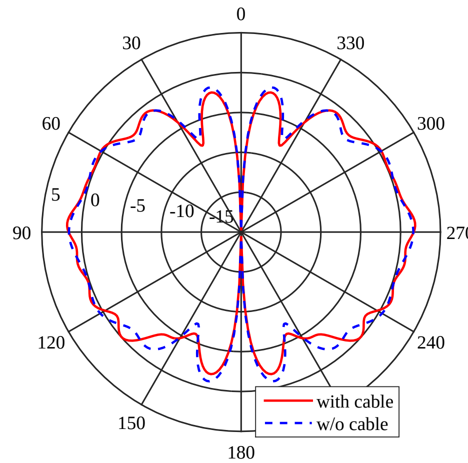


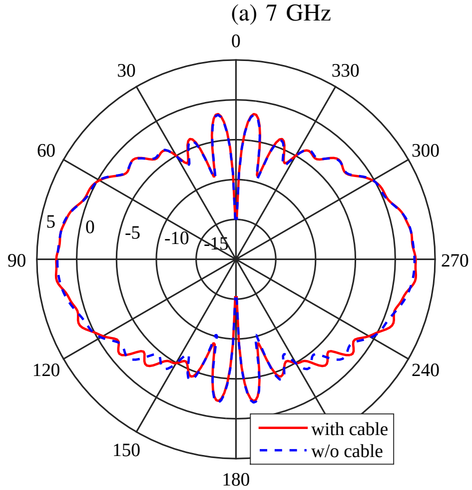
Fig. 4: Simulated total efficiency and realized gain of the antenna.



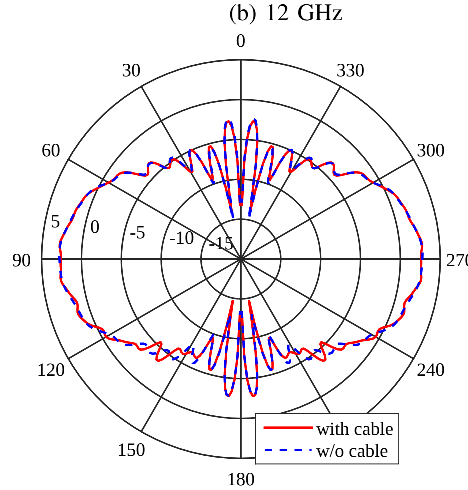
(a) 7 GHz



(b) 12 GHz



(c) 22 GHz



(d) 30 GHz

Fig. 3: Simulated E-plane radiation patterns of the antenna with and without a cable.

IV. CONCLUSION

A design of three-dimensional antenna for UWB applications has been presented in this paper. The antenna has dimensions of 58 mm x 58 mm x 76.5 mm and is composed of two identical arms as each of them consists of a hollow quasi-hemisphere and an inner for it tube. In order to assess the impact of the cable effect on the antenna radiation pattern, a coaxial cable is coupled to the antenna. The simulated structure covers the frequency range from 7 to 32.5 GHz with S_{11} below -10 dB or from 1.2 to 36 GHz following the specification S_{11} below -6 dB. Also, the antenna exhibits omnidirectional radiation pattern, which at low frequencies. The total efficiency of the antenna is above 88 % and the realized gain varies from 0.8 to 3.1 dBi over the frequency band 7-32.5 GHz. These features indicate that the proposed antenna is suitable for a variety of UWB applications.

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