Study of an UWB Spherical Monopole Antenna on the Dielectric Substrate

Seyed Ehsan Hosseini and Mostafa Attaran Kakhki

Abstract—A spherical monopole antenna on the dielectric substrate is proposed for UWB applications. The antenna uses a combination of the conductor spherical antenna, the dielectric substrate and the ground plane under substrate. The simulated results demonstrate that the design structure covers the frequency range 4.6 GHz-10.6 GHz and more. The radius of sphere and the height of the antenna is $R=5$ mm, $h=3.2$ mm, respectively. In this paper, the effects of varying the dielectric constant, the radius of spherical, and the height are investigated. Good radiations are obtained over the wide bandwidth with an acceptable gain. Also, the input impedance of the proposed antenna is simulated by HFSS and demonstrated. Details of design structure are presented and studied.

Index Terms—Spherical antennas, monopole antennas, UWB.

I. INTRODUCTION

In recent years, UWB antenna designing has been interested to be applied in short-range and high speed transmission signals. The technology of ultra-wideband (UWB) was allocated a bandwidth of 7.5 GHz (3.1-10.6 GHz) by the Federal Communication Commission (FCC) [1]. Several antenna structures were introduced for UWB technology. The history of broadband antenna was investigated in [2]. Dipole and monopole spherical and ellipsoidal antennas were proposed for broadband applications by Stohr [3]. Since the spherical antennas are substantially different from well-known designs, explaining their broadband behaviour is hard. One type of UWB antennas is spherical monopole antenna. The spherical antenna patent is presented in [4] that consist of a sphere, disk and coaxial cable. Various interesting spherical antenna designs are reported in the literatures [5]-[7]. In this letter, we propose a new spherical monopole antenna on the dielectric substrate that the ground plane is located under substrate. The feed of line in this antenna is 50- Ω coaxial cable. This antenna exhibit good impedance matching over the very large frequency range. In this antenna, the omni-directional and sufficient gain characteristics that are essential for UWB applications, are obtained. The article is organized as fellows. In the next section, we described geometry and design of the proposed antenna. The simulation results for different dimensions of the proposed antenna are given in section III. Finally, the paper is concluded in section IV.

II. ANTENNA DESIGN STRUCTURE

The antenna geometry is shown in Fig. 1. The radius of sphere is $R=5$ mm. The spherical antenna must be mounted at the centre of 3.2-mm-thick FR4 substrate of length 30 mm and width 30 mm. The FR4 substrate has a relative permittivity 4.4 and a loss tangent 0.0245. In this study, the spherical antenna is connected to central conductor of 50- Ω coaxial line and its outer grounding sheath is connected to the ground plane.

Fig. 1. Geometry of the spherical antenna with design parameters
(a) Cross section (b) 3-D view

III. RESULTS AND DISCUSSION

The proposed antenna structure was simulated and optimized using Ansoft High Frequency Structure Simulator (HFSS) using the finite element analysis method [8].

Fig. 2 shows the simulated return losses of the proposed spherical antenna on the different dielectric substrates. The effects of the various substrates with different dielectric constants are studied. It is seen that the broadband property of the antenna is lost with increasing the dielectric constant. The proposed antenna is resonated at several resonance frequencies, when a substrate is applied with high dielectric constant. For example, when the dielectric with $\epsilon_r=10$ is used as substrate, five resonant frequencies are excited in range

2-12 GHz.

Fig. 2. Return losses for substrates with various dielectric constants

In order to increasing the bandwidth of the proposed antenna, the radius of sphere has been increased. The increasing of radius lengthens the current path on the spherical antenna. The simulated return losses are shown in Fig. 3. It is observed, increasing the radius of sphere from $R=3$ mm to $R=5$ mm and $R=7$ mm, the bandwidths are increased about 1.85 GHz and 2.7 GHz, respectively.

Fig. 3. Return losses for various spherical radii

Fig. 4 shows the simulated return losses of the proposed spherical monopole antenna with the varying of the height from $h=0.8$ mm to $h=4.8$ mm with 0.8 mm steps. The simulated results clearly indicate that increasing h parameter causes impedance matching improvement until $h=3.2$ mm, but for further amount of h , the mentioned impedance matching is decreased. Having the widest bandwidth, $h=3.2$ mm is the best result for this parameter's sweep.

As it has been mentioned, increasing the dielectric constant to $\epsilon_r=10$, the spherical antenna will be excited at five resonance frequencies. The simulated return loss for $\epsilon_r=10$ is shown in Fig. 5. The simulated resonance frequencies are 4.72, 7.8, 9.04, 9.68 and 11.09 GHz with simulated return losses -19, -20, -9, -10, -25 dB and their impedance bandwidths are 29%, 8%, 0, 3.2%, 1.8% for return loss S_{11} less than or equal to -10 dB, respectively. The radiation patterns at three frequency of the proposed spherical monopole antenna are shown in Fig. 6. The radiation patterns for the spherical antenna with $\epsilon_r=10$ at resonance frequencies are simulated and shown in Fig 7. As it is observed, the radiation patterns in x-z plane and y-z plane are the same, because the structure of the spherical antenna is symmetrical.

Fig. 4. Return losses for substrates with various heights

Fig. 5. Return loss for the spherical antenna with $\epsilon_r=10$, $h=3.2$ mm, $R=5$ mm

Fig. 8 shows the simulated input impedance of the spherical monopole antenna versus frequency. As shown in Fig. 8, the input impedance of the antenna is about 40 Ω that its impedance performance is invariable if the antenna dimensions remain unchanged. In other words, frequency-independent behavior for input impedance property at frequencies above 7.7 GHz in this antenna is obtained.

IV. CONCLUSION

A new spherical monopole antenna that is suitable for UWB applications has been proposed. The spherical antenna that is mounted on the dielectric substrate has simple configuration and it is fed by coaxial cable. The return losses have been simulated for different parameters sweep. The effects of changing parameters for the proposed antenna have been investigated. Good radiation patterns for frequencies at the operating bands have been achieved. Since the antenna structure is completely symmetrical, the XZ plane and the YZ plane results are completely overlapped. Also, we observed frequency independent behavior for the proposed spherical monopole antenna on the dielectric.

(a)

Fig. 6. Simulated radiation patterns for the proposed spherical monopole antenna with $\epsilon_r=4.4$, $h=3.2$ mm, $R=5$ mm [XZ plane ($\phi=0$) and YZ plane ($\phi=90$) are the same and overlap]
(a) 5.25 GHz (b) 7.25 GHz (c) 9.25 GHz

Fig. 7. Simulated radiation patterns for the proposed spherical monopole antenna with $\epsilon_r=10$, $h=3.2$ mm, $R=5$ mm, [XZ plane ($\phi=0$) and YZ plane ($\phi=90$) are the same and overlap]
(a) 4.72 GHz (b) 7.8 GHz (c) 9.04 GHz (d) 9.68 GHz (e) 11.09 GHz

Fig. 8. Simulated input impedance of the spherical monopole antenna versus frequency

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