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An extremely wideband radome-enclosed cylindrical dipole antenna for wireless communication

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Abstract: A radome-enclosed extremely wideband cylindrical dipole antenna for wireless communications applications was proposed with a simple structure. The antenna is fed at the center with the help of a coaxial cable through the lower hollow metallic pole. The feed area is composed of cones at both sides in order to obtain wideband impedance matching. The proposed antenna can cover 1.8 GHz to 28 GHz with S11 of less than –10 dB and excellent stable omnidirectional radiation characteristics. However, at high frequencies, some ripples are introduced in the radiation pattern. The frequency band of the cylindrical dipole antenna can be controllable and the size can be changed with the required band. The design details, the simulated and experimental results of the proposed omnidirectional dipole antenna, and the effect of the radome on the performance of the antenna are presented and discussed. The measured results confirm the validity of this design, which meets the requirements of wireless applications.

Key words: Dipole antenna, CST Microwave Studio, wideband, omnidirectional, wireless

1. Introduction

With the advancement in communication systems, ultrawideband (UWB) technology is attracting great attention. Researchers have proposed a variety of UWB antennas, such as monopole antennas [1], dipole antennas [2], slot antennas [3], circular disc monopole antennas [4], and tapered ring slot antennas [5]. The available literature has proposed many schemes for the design of UWB antennas, whose design methodologies are radiators in gradually changing structures to achieve ultrawide impedance bandwidth. The purpose of this method is mainly to reduce the reflection. With this technique there are some more common antennas with modified structure designs, such as the circular and the elliptic structured monopoles and dipoles. The second method is to introduce some loadings, both at the radiator and feed, to achieve wide impedance bandwidth. In this manuscript a radome-enclosed coaxial dipole antenna with an omnidirectional radiation pattern in the azimuth plane that can cover a large service area and has wide applications in mobile systems, world interoperability for microwave access (WiMAX), UWB communication systems, wireless local area network (WLAN) systems, and jammer systems in outdoor applications is proposed. The designed antenna uses the balanced coaxial cable to excite the dipole antenna. This UWB dipole antenna can also be used for IEEE 802.15.3a and IEEE 802.16 standard UWB communication systems at 3.1–10.6 GHz and 2–11 GHz bands. It is a challenge for antenna engineers to design a simple, compact, robust, and low-cost multiband or wideband antenna for wireless applications, which can be easily accommodated with movable and immovable platforms. To meet these radiation pattern requirements, a planar dipole array antenna for WLAN operations was designed in [6]. A cylindrical omnidirectional patch array

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antenna was designed in [7,8]. The omnidirectional array antenna achieved a higher gain, but the bandwidth is usually very narrow. A printed dipole array omnidirectional antenna employed double-sided dipoles and added some stubs for impedance matching [9]. The antenna in [10] performs UWB design, but the structure is complex and requires very sophisticated technology to be fabricated. On the other hand, coaxial feed dipole antennas are easy to fabricate because of the central feeding system, which cancels the return current on the coaxial cable. Thus, the need for a balun (a balanced to unbalanced system) is avoided [11,12]. In side-feed dipole antennas a T-shaped configuration is formed, which requires more area and thus the overall size of the antenna is reduced due to the central coaxial feeding. Coaxial dipole antennas can be designed in any diameter due to the inline configuration. Moreover, these types of antennas can be used in very sophisticated applications like in cancer therapy; the cancerous tissues can be heated by electromagnetic waves using an external or internal antenna, especially in sensitive regions like the brain or prostate tumors [13]. A radome-enclosed coaxial antenna is proposed, which has numerous practical applications in wireless communications, vehicular jammers, and UAV communication [14–22]. In Section 2, the geometry and design of the proposed antenna are given. In Section 3, the theoretical and practical results are discussed. The effect of the radome on the performance of the antenna and concluding remarks are given in Sections 4 and 5, respectively.

2. Design of the proposed cylindrical dipole antenna

This article proposes an omnidirectional extremely wideband dipole antenna as shown in Figure 1. The antenna exhibits a very low S_{11} parameter and can easily be constructed. The proposed antenna has a dipole configuration, which is composed of two hollow cylinders. These cylinders act as the radiating poles. The thickness of the cylinder is 1 mm and it is made of copper. The feed point is made of cones on both sides of the poles in order to get broadband impedance matching. A coaxial cable is inserted in the lower hollow metal cylinder and into the hollow cones. The outer metal part of the EZ-141 standard semirigid coaxial cable is connected to the lower cone and the inner conductor is extended through the gap at the center between two cones. The feed area may then be filled with low-loss composite material, which keeps the feed intact. The proposed antenna was modeled using CST microwave technology. The currents on the coaxial cable are automatically canceled by their counterpart on the lower metallic cylinder. Thus, the antenna requires no balun network. The sizes of different parts of the antenna are given in Figure 1. The cylindrical dipole antenna with the feed antenna is enclosed in the radome, which is made of glass epoxy.

The antenna at the center point is symmetrically excited and requires no balun, which decreases the size and cost of the antenna. The geometry of this antenna, which is a cylindrical tube structure with cones at the feed at each side, is fully described by parameters such as length of tube and cone, radius of tube and cone, feeding gap, and distance between the connector and lower pole. By properly adjusting these parameters we get an extremely wideband dipole antenna.

3. Results and analysis

In this section, the model is simulated using commercial CST Microwave Studio software. Simulation is done over the frequency band of 1.5 GHz to 30 GHz. Full wave analysis is done to calculate accurate S parameters and return loss at the desired frequency band. Radiation characteristics of the antenna at any frequency can be obtained using broadband far field analysis. The optimum design dimensions are given in Figure 1.

The distance between the antenna poles and radome is S. The antenna exhibits very wideband performance, suitable for UWB and jammer applications. In Figure 2 the simulated and measured scattering

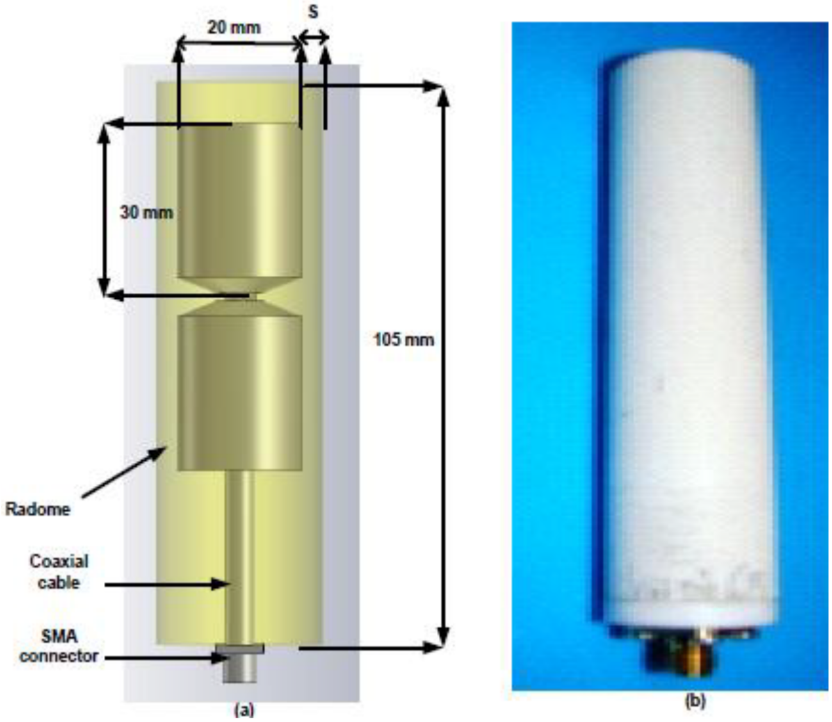

Figure 1. (a) Simulated model and dimensions of the proposed antenna, (b) final radome-enclosed fabricated antenna.

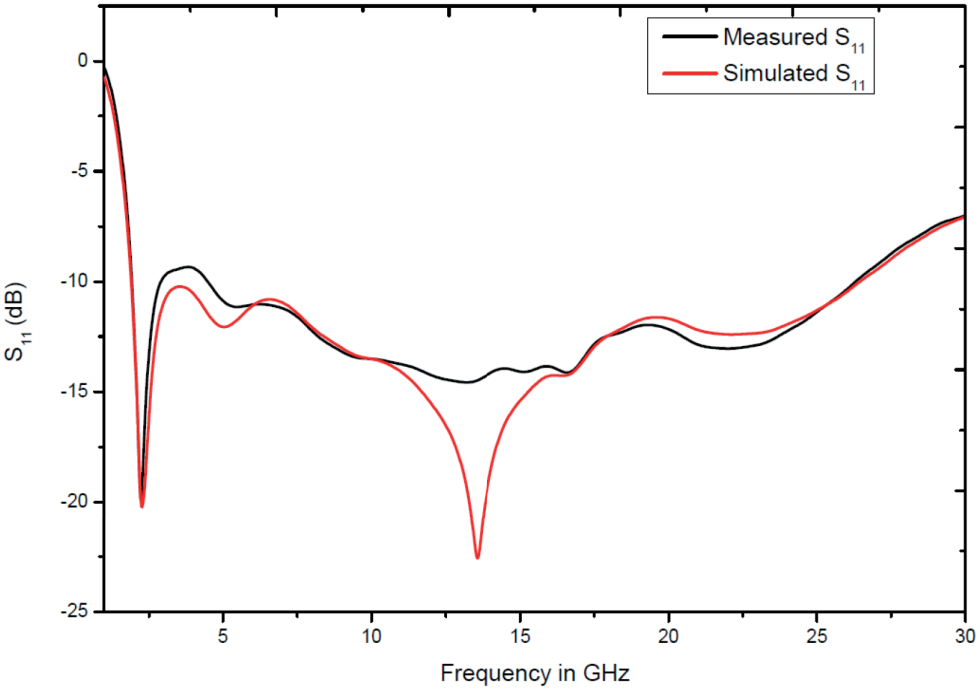

Figure 2. Plot of the measured and simulated scattering parameter S_{11} of the cylindrical dipole antenna.

parameter (S_{11}) is given, which illustrates that over the whole frequency band the return loss is more than 10 dB.

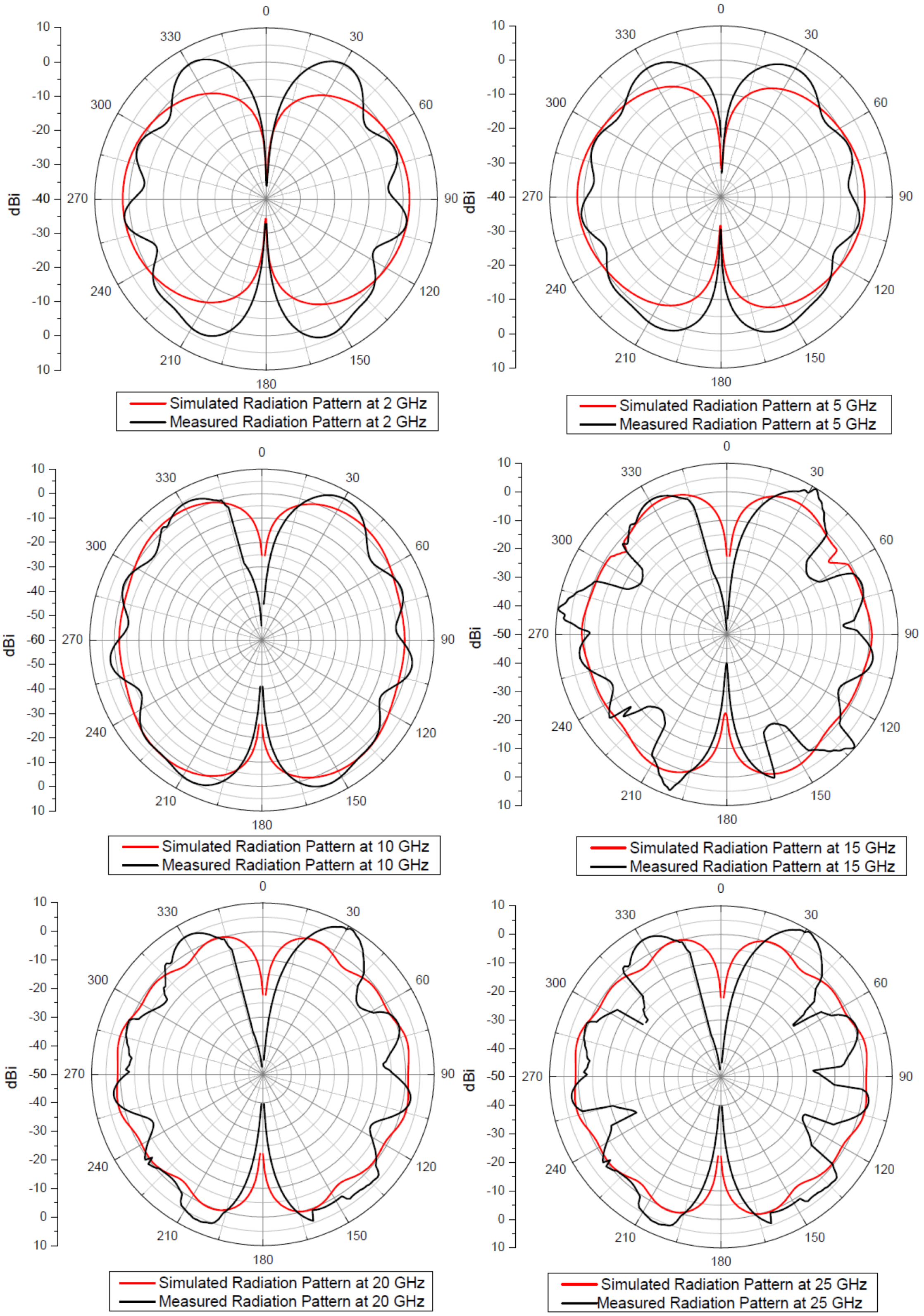

Figure 3. Comparison of the simulation and measured radiation pattern at 2 GHz, 5 GHz, 10 GHz, 15 GHz, 20 GHz, and 25 GHz in the E plane.

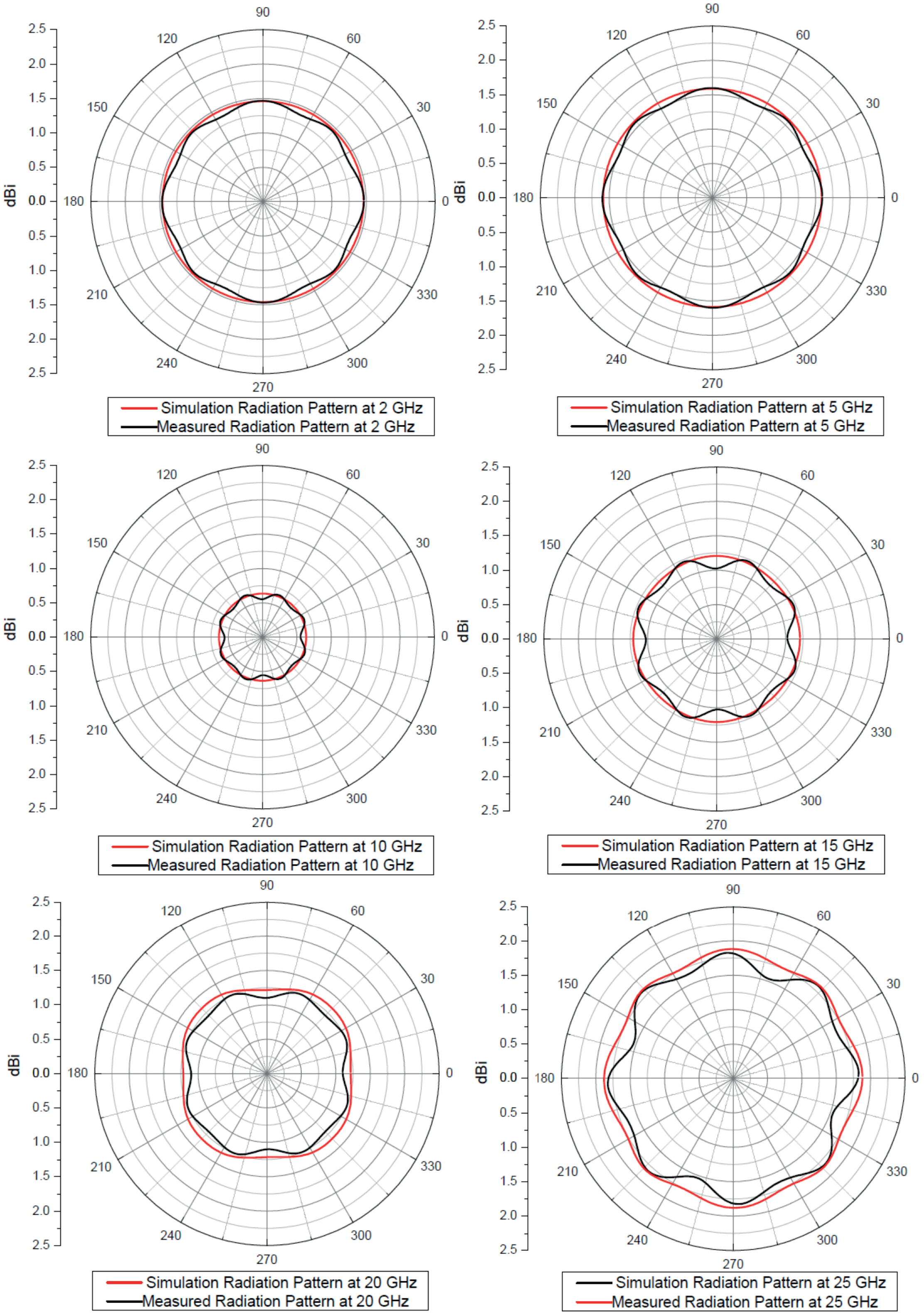

Figure 4. Comparison of the simulation and measured radiation pattern at 2 GHz, 5 GHz, 10 GHz, 15 GHz, 20 GHz, and 25 GHz in the H plane.

The impedance bandwidth of the antenna is very high over the band of 1.5 GHz to 30 GHz, which shows potential applications in UWB communication systems, jammers, and EMC applications. Figures 3 and 4 show simulated and measured radiation patterns at 2 GHz, 5 GHz, 10 GHz, 15 GHz, 20 GHz, and 25 GHz in the E and H planes, respectively. The values of all the radiation patterns are given in dB. The simulated and measured radiation patterns show close resemblance. The gain versus frequency plot is depicted in Figure 5, which indicates a uniform gain over the whole frequency band. However, the antenna's omnidirectional radiation patterns at high frequencies are not stable and have some fluctuations. Moreover, some differences between simulation and measurement results have been observed; the authors describe this difference as the limit of simulation and fabrication errors that are inherent.

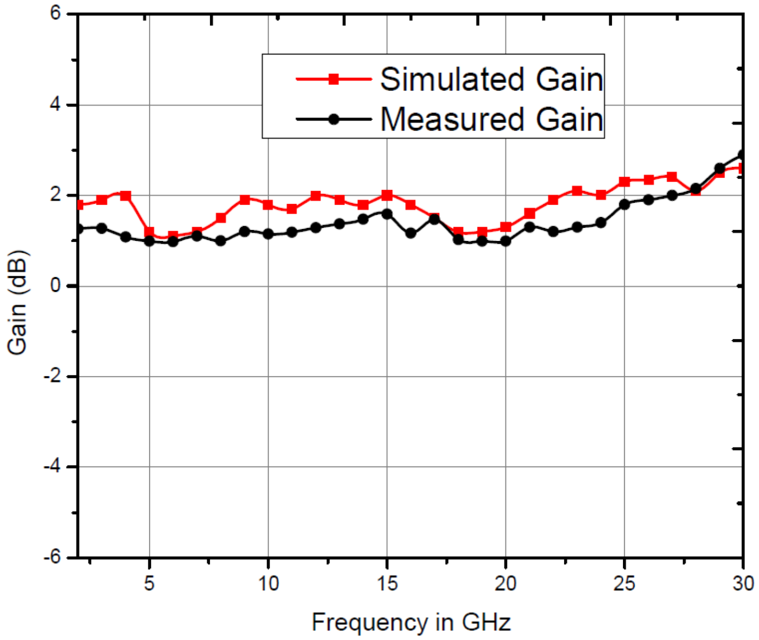

Figure 5. The comparison of the simulated and measured gain plot over the frequency band.

4. The effect of the radome on the performance of the antenna

Radomes play a very important role in the design of antennas for radar and communication systems. As our designed antenna's radiation pattern is omnidirectional, the effect of the radome on the radiation pattern in this case is minimal. However, the effect of the radome on the scattering parameter is shown in Figure 6, which illustrates that when the distance between the radiating part and the radome increases, the frequency band shifts downward and the reflection characteristics also deteriorate. Moreover, materials used for airborne radomes must have low dielectric constants and high mechanical strength as compared to other applications. Therefore, a compromise solution according to the required application must always be considered because of the mutual exclusiveness of these properties. The radome in this case is fabricated using epoxy materials. A hand-lapping technique is used for the fabrication of the radome.

The final shape of the optimized fabricated radome-enclosed antenna is shown in Figure 1. The low-cost manufacturing of the radome suggests that the antenna has wide commercial applications. Moreover, the antenna can also be used for airborne applications like drones and low-speed aircrafts. Furthermore, the antenna has potential applications in improvised explosive device jammers installed on vehicles to guard military conveys and VIP movements.

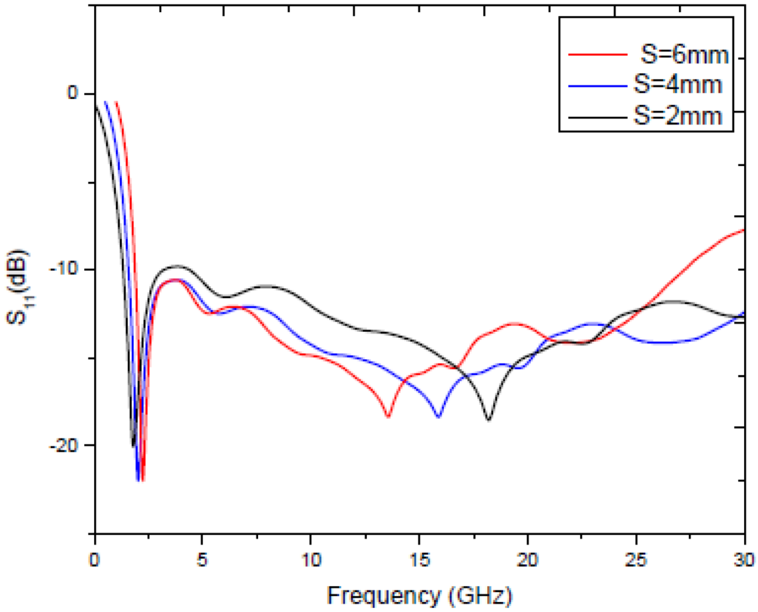

Figure 6. The effect of distance between radome and radiation part of the antenna on scattering parameter S_{11}.

5. Conclusions

The cylindrical dipole antenna is fed by a coaxial cable enclosed in a radome with an omnidirectional pattern and vertical polarization. The bandwidth of the antenna represents a very practical wideband means of realizing vertical polarization with an omnidirectional pattern over an extremely wide band. The radome-enclosed dipole antenna can be installed on both the ground and vehicles with excellent electrical and mechanical properties and also can withstand diverse environmental conditions. The antenna has potential applications in unmanned aerial vehicles, jammers, and other wireless communication systems.

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