© 2017 IJEDR | Volume 5, Issue 2 | ISSN: 2321-9939

Development of TEM Horn Antenna for UWB Applications

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***Abstract*—The design and development of a TEM Horn Antenna for high directivity applications is presented in this paper. The designing and simulation has been carried out using CST Microwave Studio. The antenna designed operates in the range of 2.25GHz-18GHz. The simulations results and the design procedure are being presented here.**

***IndexTerms*—TEM Horn, Wide bandwidth, High Directivity, UWB, Ground Penetrating Radar (GPR)**

I. INTRODUCTION

Ultra-wideband (UWB) technology is now becoming widely used in a variety of applications such as radar, short-range communications and positioning systems. This is because this technology offers advantages of large channel capacity, multipath propagation performance and potential for ultralow-power implementation of transmitting-only devices. As is the case in conventional wireless communication systems, an antenna plays a crucial role in UWB systems. However, there are more challenges in designing a UWB antenna than a narrow band one. In particular, a suitable UWB antenna should be capable of operating over an ultra-wide bandwidth as allocated by the FCC, that is, 3.1–10.6 GHz. Recent UWB antenna research tends to focus on ultra compact planar antennas as they are more practical in terms of manufacturing, integration with the system electronic board and form factor. Typical configurations exhibit radiation similar to traditional monopole antennas with quasi-omni-directional patterns [1] [2] [3]. This feature is desirable for UWB communication systems, whereas it is a strong limitation in the case of radar applications [4]. In the past few years, several planar broadband monopole-like configurations have been reported for UWB applications [5]-[6]. None the less, very few efforts have been made to increase directionality of printed UWB antennas to be employed, for example, in radar applications [7],[8]

Ultra wide-band (UWB) antennas are demanding for many ultra-wideband applications like UWB pulse radar and broad band communication systems. Different kinds of UWB antennas like bow-tie, log periodic dipole array antenna, spiral, and ridge horn antenna have been working in many applications. TEM horn antenna is one of most well-known UWB antenna that has been used in many ground penetrating radar system due to its UWB characteristics.

The TEM Horn is a very attractive structure for impulse radar. It is non dispersive, directive and can have ultra-wideband (UWB) properties. It is usually fed by a parallel plate line. The structure requires the use of a Balun. One of the most important design goals for the TEM Horn Antenna is to attain the wide-band characteristics. Here, the antenna design and development for the frequency range of 2.25-18GHz is being introduced.

II. UWB, TEM HORN & GROUND PENETRATING RADAR (GPR)

Ultra-wideband (also known as UWB, ultra-wide band and ultraband) is a radio technology that can use a very low energy level for short-range, high-bandwidth communications over a large portion of the radio spectrum. UWB has traditional applications in non-cooperative radar imaging. Most recent applications target sensor data collection, precision locating and tracking applications.

TEM horn antenna is made by two tapered metal plates. This structure guide current flows on antenna flares to generate TEM wave propagation. Magnetic and electric fields are generated by flowing currents and voltage difference between and over the plates accordingly. A TEM horn antenna is a kind of impedance transformer from transmission line to the medium of propagation. Different plate widths along with different gap between antenna plates produce variations of impedance that has to be calculated carefully to minimize reflection coefficient for ultra-wideband of frequencies.[9]

GPR uses the principle of scattering of electromagnetic waves to locate buried objects. The basic principles and theory of operation for GPR have evolved through the disciplines of electrical engineering and seismic exploration, and practitioners of GPR tend to have backgrounds either in geophysical exploration or electrical engineering. The fundamental principle of operation is the same as that used to detect aircraft overhead, but with GPR that antennas are moved over the surface rather than rotating about a fixed point. This has led to the application of field operational principles that are analogous to the seismic reflection method.

GPR is a method that is commonly used for environmental, engineering, archeological, and other shallow investigations. Ground Penetrating Radar has been applied to problems in many areas, including agriculture, archeology, landmine and unexploded ordnance detection, environmental site characterization and monitoring, forensics, geological mapping, ground water quality, lunar and planetary exploration, minerals exploration and development, earthquake, landslides and subsistence hazards assessment, void detection and pavement evaluation. There are many more applications of Ground Penetrating Radar (GPR) than can be discussed here.[10]-[11]

III. ANTENNA DESIGNING

A. Balun Design

Coaxial cables are used to feed the TEM horn antennas in most of the cases. Balun is needed to connect antenna to the coaxial line to provide a symmetrical excitation which in turn ensures a symmetrical radiation pattern.
Here, a U-shaped balun is used as shown in the figure.

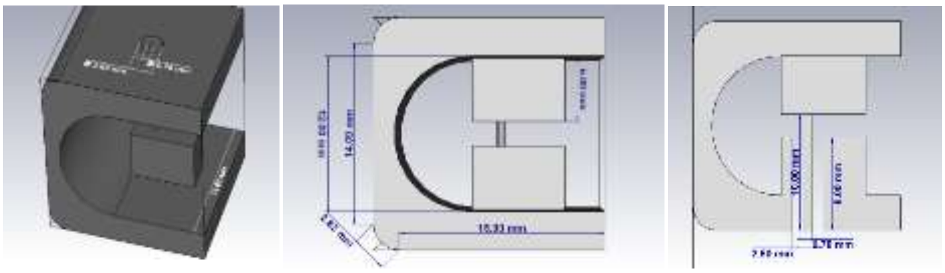


Figure 1: Balun for TEM Horn

The ridges play an important role for impedance matching between the antenna and the cavity.
The balun should be designed to facilitate low reflection coefficients from the excitation port. The ridges play an important role for impedance matching between the antenna and the cavity.

B. Design of Flares

The dimensions used for designing the modified TEM Horn antenna from a conventional TEM Horn antenna [12], is considered in this designing. The designing and simulation has been carried out in CST Microwave Studio. The dimensions of the flares; their length, width and gap between the flares are as given in the Fig. 2.
The flares of the antenna are divided into three segments; First Segment, Second Segment and Third Segment. Each of these segments consists of ten parts for the purpose of designing in CST Microwave Studio. A fourth segment is added to reach penetration depth at lower frequencies.
The designed TEM Horn Antenna is as shown in Figure 2.

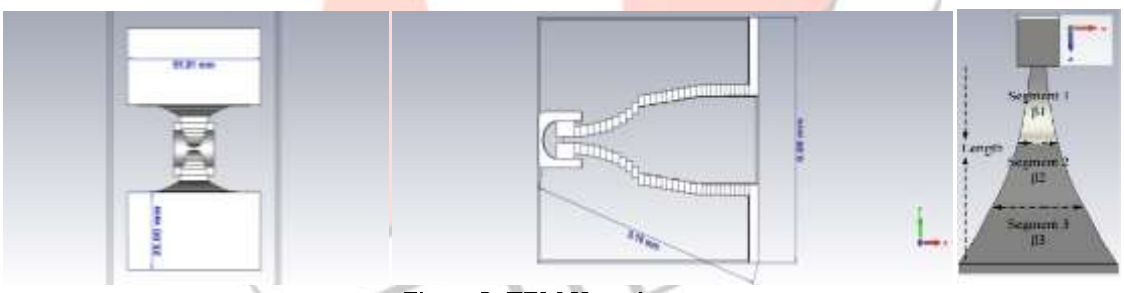


Figure 2: TEM Horn Antenna

IV. SIMULATION RESULTS

In this section, simulation results of the designed TEM Horn Antenna are discussed. The designing and simulation has been carried out in CST Microwave Studio.

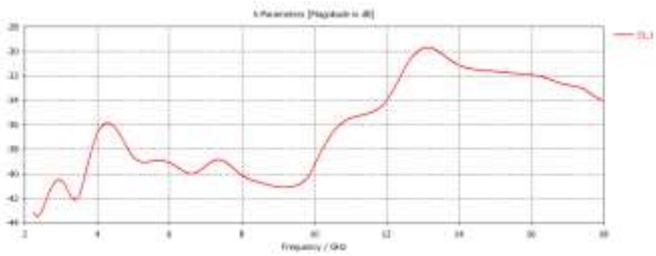


Figure 3: Reflection Coefficient

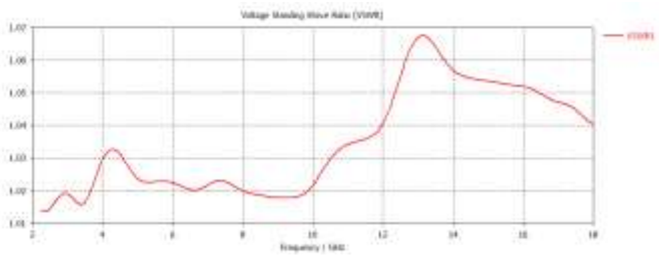
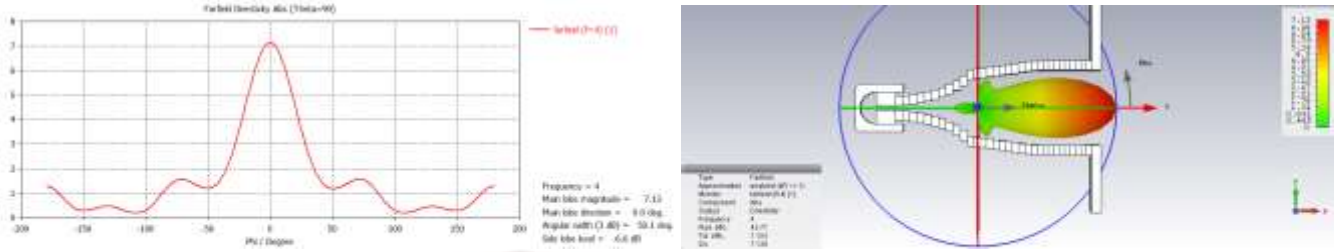


Figure 4: VSWR

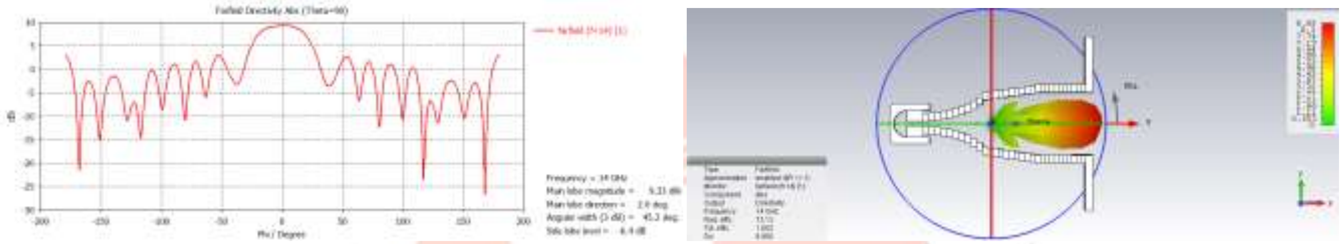
The reflection coefficient of the antenna designed is less than -10dB which implies that the reflections are very less and hence antenna has high directivity. This satisfies the purpose of the design of the antenna i.e., high directivity. The directivity obtained for the simulation of the antenna is shown in Fig.5. From the fig.5 it is indicative that the designed antenna is highly directional.

Considering the results, the antenna has high directivity and hence is suitable for the applications which require wide bandwidth and high directivity.

(a)



(b)



(c)

(d)

Figure 5: Directivity of TEM Horn Antenna at a)2.5GHz b)4GHz c)14GHz d)18GHz

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V. APPLICATIONS

From [13], we know about a novel TEM horn antenna placed in a solid dielectric medium proposed for microwave imaging of the breast. The major design requirement is that the antenna couples the microwave energy into the tissue without being immersed itself in a coupling medium. The antenna achieves this requirement by: 1) directing all radiated power through its front aperture, and 2) blocking external electromagnetic interference by a carefully designed enclosure consisting of copper sheets and power absorbing sheets. In the whole ultra-wide band the antenna features: 1) good impedance match, 2) uniform field distribution at the antenna aperture, and 3) good coupling efficiency. The range of operation of this antenna is 2GHz-10GHz. Hence the TEM Horn Antenna designed can be used in medical applications like given [13] and also in all the applications of medical imaging that operate in the UWB range and the range of the antenna designed.

A short-pulse UWB technique has several radar applications such as higher range measurement accuracy and range resolution, enhanced target recognition, increased immunity to co-located radar transmissions, increased detection probability for certain classes of targets and ability to detect very slowly moving or stationary targets [14]. UWB is a leading technology candidate for micro air vehicles (MAV) applications [15][16]. The nature of creating millions of ultra-wideband pulses per second has the capability of high penetration in a wide range of materials such as building materials, concrete block, plastic and wood.

In military sector, the GPR is used for finding and mapping metallic and nonmetallic mines and unexploded bombs, finding secret rooms, cellars, internal boxes and 'stashes', finding underground warehouses, bomb-shelters, wall investigations – finding secret transmitters, receivers, microphones and internal boxes, forensic investigation[17]. As these applications require an antenna with high directivity, the TEM Horn Antenna designed can be used.

Position location and tracking have wide range of benefits such as locating patient in case of critical condition, hikers injured in remote area, tracking cars, and managing a variety of goods in a big shopping mall. For active RF tracking and positioning applications, the short-pulse UWB techniques offer distinct advantages in precision time-of-flight measurement, multipath immunity for leading edge detection, and low prime power requirements for extended-operation RF identification (RFID) tags [19][20]

VI. CONCLUSION

The antenna designed has a wideband range of operation (2.25-18GHz). It also operates in the UWB range (3.1-10.6GHz). It has high directivity and gain. Hence it finds best application in Ground Penetrating Radar (GPR). Further modifications can enable the antenna to find applications in higher and lower frequencies as well.

VII. ACKNOWLEDGMENT

The author would like to thank her family and friends for their unconditional support and reviewers for their fruitful comments.

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