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# UWB ANTENNA APPLICATIONS IN GROUND PENETRATING RADAR SYSTEMS - A TECHNICAL STUDY

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## ABSTRACT

The frequency band ranging from 3.1 to 10.6 GHz which finds applications in the field of Wireless Body Area Networks, Wireless Interoperability for Microwave Access (WiMAX), Wireless Local Area Networks (WLAN), Wireless Personal Area Networks and Ground Penetrating Radar (GPR) systems is referred to a ultra-wide band (UWB) frequency range. Research and development in a number of sectors have been made easier by Ground Penetrating Radar (GPR) technology. It is a non-invasive invasive technique for exploring beneath the surface. GPR systems functions on the same principle as RADAR systems. They are widely used in the fields of archaeology, geophysics, civil engineering, environmental studies and military.

This review provides a comprehensive study about the ultra-wide band antennas suitable for GPR systems.

**Keywords**:
GPR systems. Ultra-Wide band (UWB), Frequency range, Depth of penetration.

## I. Introduction

GPR systems are specialized extension of radar systems. The foundation of the radar system was initially laid by the formulation of the Maxwell's equations and later by the development of practical RADAR systems in 1904 by German engineer Christia Hulsmeyer [1]. A significant advancement in radar technology occurred in 1930. Later Radar systems found applications in civilian sectors in addition to strict military usage resulting advancements in research field such as meteorology, air traffic control and navigation.

When digital processing technology was introduced, radar systems advanced quicky.Radar systems become much more efficient because of advanced antenna technologies likephased array antennas.Technologies like multiple target detection greatly improved the effectiveness of advanced radar systems.As a specialized radar technique, ground penetrating radar was developed to find targets that are buried under ground. [2]. Figure-1 shows such a system.

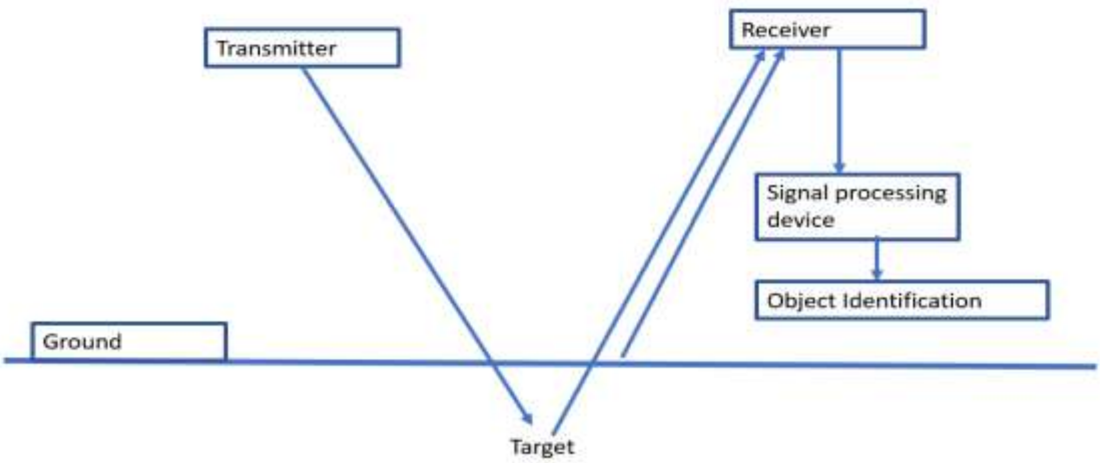


Figure-1 Block diagram of a GPR System

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Imaging of buried objects in a non-invasive is used in GPR systems. Applications like archaeology, environmental studies, detection of buried object etc. uses GPR systems. Variation of dielectric constants between different surfaces is used in GPR systems. High-frequency electromagnetic waves are emitted into ground and they propagate through materials with different values of dielectric constants and get reflected back. When the electromagnetic waves passes through surfaces with different dielectric constants a part of the total transmitted energy is reflected back to the surface and the remaining propagate through the material. The GPR system notes the time taken by reflected waves to return to the surface This helps to identify depth and size of buried objects can be estimated. Unit for signal generation, transmitting and receiving antennas, signal processing unit are present in a GPR system. Transmitted wave frequency decides the depth of penetration and the image resolution. GPR systems can have multiple sub-systems like RF transmitter and receiver system, Antenna system, and Data Processing System.

GPRs can utilize UWB technology. It finds application in military like detection of land-mines [3]. Remote sensing techniques, detection of trapped people in landslides also uses GPR systems [4]. By analyzing the transmitted and back reflected wave the properties of the targeted object can be studied. Similar to conventional radar, the role of the antennas is crucial in GPR. GPR works close to the ground.. Lower the frequency greater the penetration depth but at the expense of resolution. The greater part of GPR's are short-range radar frameworks. As the intended objectives are generally situated in the close or middle zone, the close field attributes of the reception apparatus are significant. The antenna selection is easier in frequency domain GPRs as the antennas can be calibrated using signal processing [5,6]. The radar antenna should detect the size and distance of the targeted object from the returned signal. And the GPR antenna should be able to distinguish buried object from noise. Imaging capability of GPR antenna increases with antenna foot print. But too small footprints makes image detection impossible. While selecting a GPR Antenna the parameters listed above should be taken into account.

## 1. Antenna selection in GPRs

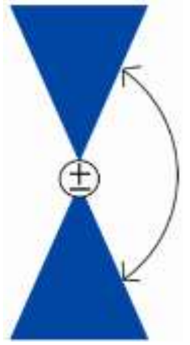
Ultra-wideband antennas finds a lot of applications in GPR systems. This is due to better resolution imaging for GPR systems. Lower frequency band antennas are mainly used to improve the penetration depth. Antennas in UWB frequency range enhance the bandwidth and gain enhancement. Antennas such as bow-tie antennas, horn antennas, Vivaldi antennas etc. have been studied and implemented for GPR applications.

The antenna is the main component of a GPR system. A very short duration time signal with small distortion and ringing so as to prevent generation of the target echo is transmitted by the antenna. So the requirement is a wide bandwidth and very short impulse response antenna. Most of the GPR antennas are bow-tie in nature due to larger band width and planar structure.

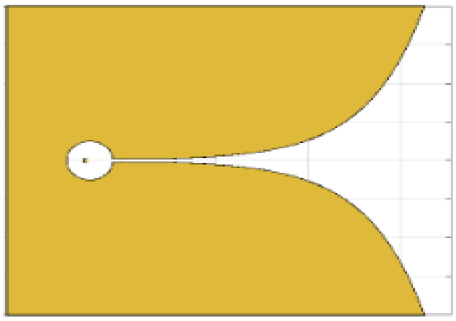
### 2. a. Bow-tie Antenna

A bowtie antenna is a broadband planar antenna with two conductive elements in triangular or trapezoidal form in the shape of a bowtie as shown in figure 2. Both elements are arranged symmetrically on a dielectric substrate, directly above a ground plane, so they exhibit a bidirectional radiation pattern. They are frequently used in GPR systems due to a wide operational frequency range, simple design, and the ability to produce high-resolution subsurface images.

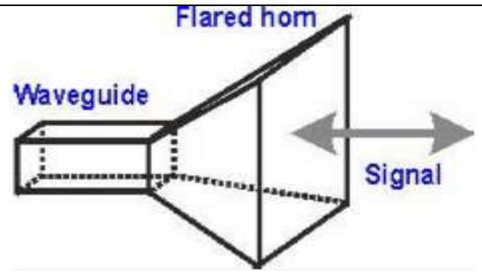
Ultra-Wideband Performance, Compact Design, High Resolution, Cost-Effective production are other advantages offered by bowtie antennas. They have the ability to reduce ground susceptibility, so it is widely used in the design for GPR applications. [7]. A 1.1 GHz, bandwidth bowtie-slot antenna for GPR applications is presented in [8].



Fiure 2. (a). Bow-tie antenna [11]



(b). Vivaldi Antenna [12]




( c ). Horn Antenna [13]

Figure-2 Models og antennas suitable for GPR applications.

**2.b. Vivaidi Antenna**

Most popular directive antenna for commercial UWB applications are Vivaldi antennas. They have simple structure and small size., Both the time domain and frequency domain performance need to be analysed in ultra short pulse communications. So Vivaldi antennas are abetter choice for GPR applications.

Army persons need to face unknown and hidden threats and so strict precaution measures for risks mitigation are needed. So unobstructed detection and monitoring human presence from a far distance is essential. UWB antennas and radar systems provide significant advantages in this context. UWB radars have intense penetrating high-range resolution and better target discrimination capability [14]. Vivaldi antenna are highly suitable for applications requiring a broad bandwidth and directional characteristics. Vivaldi antennas are capable of achieving a fractional bandwidth and gain.[15]. So they are suitable for GPR applications.

**2.c. Horn Antennas**

Scanning of shallow targets needs elevated antennas since the energy must be radiated into the ground. So a horn antenna which is less susceptible to the effects of ground is agood choice for GPR applications[16 ]. A typical horn antenna can be seen in Figure 2.c. UWB quad ridged horn (QRH) antenna with deep penetration , suitable for GPR applications is presented in [17]. Table- 1 presents a Comparison of parameters of antennas suitable for GPR applications.

Table-1

| Reference | Antenna Model | Band width | Penetration Depth | Radiation Pattern | Signal to Noise Ratio |
|---|---|---|---|---|---|
| [7] | Bow-tie | Wide | Moderate | Broad | Moderate |
| [14] | Vivaldi | Ultra Wide | Moderate | Directional | High |
| [16] | Horn | Moderate | High | Bi - directional | High |

Table- 1 Comparison of parameters of antennas suitable for GPR applications

## 3. CONCLUSION

A review based analytical study on design parameters and techniques for antenna selection in GPR systems is presented. Different design methodologies of bow tie antenna, Vivaldi and Horn antenna are studied. The study mainly concentrated on antenna model, bandwidth radiation pattern and depth of penetration of the antennas suitable for GPR applications. Further exploration in terms of time domain analysis is required.

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