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Ground Penetrating Radar (GPR) Antenna Design: A Comparative Study

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***Abstract:** A detailed study on Ultra-wideband (UWB) antennae equipped Ground Penetrating Radar (GPR) applications is done. High gain and wide bandwidth are the two antenna parameters to be considered for deep penetration in GPR applications. Among the many antennae, a comparative study on six different geometry is presented. The six different geometries include Planar, Slot, Horn, Vivaldi, Reflector and Bowtie are compared with respect to physical dimensions, operating frequency, S11, Gain and Bandwidth. Among these six structures, Vivaldi and slot antennae outperform the others with respect to gain as well as bandwidth. Planar monopole antennae are also highly preferred to achieve high gain and wide bandwidth. Use of planar monopole antenna for GPR applications is also suggested.*

***Key Words:** UWB antenna , GPR, S11, Gain, Planar Monopole.*

I. INTRODUCTION

Antenna is a metallic device that functions as transducer for the conversion of guided waves. Antenna connected with transmitter and receiver majorly helps to match the impedance b/w source and load. The antenna should behave as consistent and likely to be in entire band. Nowadays, a need of spectrum for many applications within our limited RF range(3KHz-300GHz) makes us to rethink some space where the things to be carried out freely(i.e) unlicensed manner. RF (Radio) spectrum is a scarce resource and lifeblood of human mankind to make footprints in communication technology.So the interest on UWB system makes to think that the resource given by FCC in 2002 to use the limitless spectrum (3.1GHz to 10.6GHz) for wide applications in unlicensed fashion[1]. The plentiful availability of wideband spectrum makes deployment of UWB system invarious applications leads to the need of UWB antennas in very high saturation. Thus the role of UWB antenna plays an acute role in UWB system design. Nevertheless, a UWB system requires a responsible resonator (antenna) of receiving on all frequencies at the same time. The abnormal revolution of UWB antenna are enumerated more with the help of tradeoffs considered in olden history of antennas. At the same time, UWB design should fulfill some mathematical play at its backhaul in a reasonable manner.

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It has a much attraction to cover all indoor short range high speed wireless communication. It also supports a real time indoor and outdoor precision tracking for many purposes. This UWB principle falls with a character of pulse signals to transmit high data-rate at extremely low power within a short range. These covered higher frequencies have several bands available to provide huge bandwidth capacity and throughput.

Antennas are classified based on many characteristic considerations[2]. Further be divided based on physical nature. For UWB systems, the most suitable antennas are Spiral antenna, Log periodic antenna, Bowtie antenna, Monopole antenna, Biconical antenna, Slot-typed antenna, Fractal antenna etc. This paper gives in depth sense to study the suitable design for ground penetrating radars with the occupancy under UWB band. At the last, good candidate for GPR being inherited in the systems with respect to gain, directivity and neutralized complexity with respect to time domain analysis. The organization of this paper is as follows: Section II gives a brief about Penetrating radars, Section III discusses various antenna designs suited for GPR and followed by Section IV which has its comparative discussions. Finally the paper concluded in Section V.

II. PENETRATING RADARS

This eye opening of UWB spectrum enhances new application like penetrating radars, microwave imaging to participate more because of its wide bandwidth requirement. Most of the past studies of this application based on frequency in the range of 300MHz to 3GHz because of its characteristic nature. Lower the frequency makes the EM waves to penetrate or pass through long distance for communication. Furthermore, many researchers designed antenna in terms of lower frequency to go deeper but they are not able to compensate operating bandwidth occupancy. Now, [3] the discussions are grown in this range of UWB to achieve wider bandwidth with some tradeoff in penetration.

Ground Penetrating Radar(GPR) is a non- destructive method that employ EM wave to map the buried features in the ground, man-made trap holes, detection of Improvised explosive devices (IED's) or Unexploded ordnance(UXO's) in terms of humanitarian demining. It consists of major three components namely antenna, control unit, display unit[4]. Its operating frequency is very much related to the position and properties of the targets that enclosed in the ground surface. This way of finding outs are used in many applications such as civil engineering, search & rescue, military and security, geophysical, archaeologies, concrete inspection, utility locating, road inspection, Railway evaluation etc.,

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Construction and mineral exploration industries get profited over this systems[5]. In variant, it can be also used to detect the sub-surface objects. The results obtained through penetration process will have higher reflection over wet seashore soil and also gets attenuated if it propagate over wet soil dielectric[6]. There are some factors to be noted which affects dielectric property of soil (i.e) soil type/texture, water content and salinity. The cluster removal technique of microwave imaging are carried out in along with antenna design to remove the unwanted signals[7]. Based on setup configuration, GPR is classified as ground-coupled radar, and air- launched radar. Ground-coupled radar's antenna being mounted at close proximity to the detection surface and results with higher sensitivity and small signal loss[8]. In the case of air-launched radar, the antenna be mounted and operated at heights greater than one-fourth of the operating wavelength.

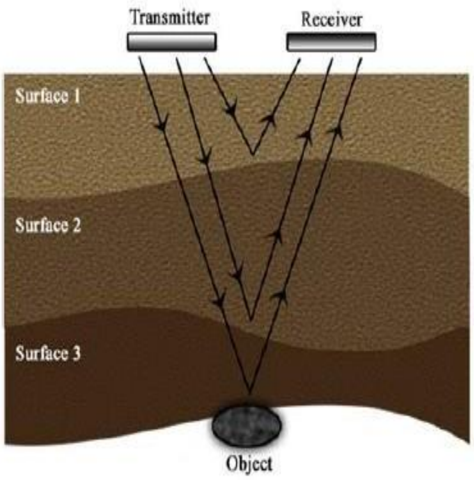

Fig (1) General GPR transmission and Reception

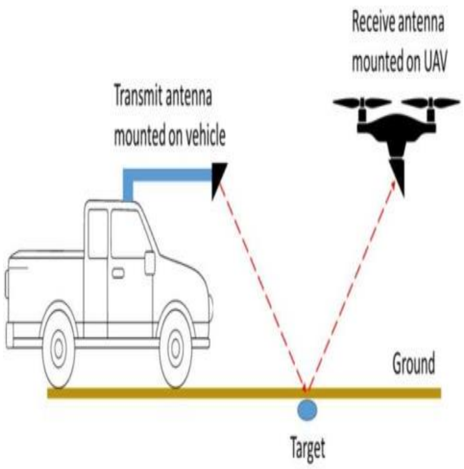

Fig (2) Forward looking GPR system

The fundamental concepts of various GPR architectures such as mono-static, bi-static and multi-static architectures. In a forward looking GPR,[9] the antennas are mounted on infront of vehicle to cover widespread coverage. The receive antenna is mounted on Unmanned aerial vehicle (UAV). Furt her, the system started to work and collect data over large sequence with respect to time

Fig (3) Trapped victim under collapsed building

Fig (4) - Horn antenna

III. ANTENNA DESIGN FOR GPR

Antenna choice is one of the most decisive factor in Penetrating radars. Many paper gives a detailed review on antenna design especially for the Ground penetrating radars and Wall penetrating radars. This discussions are going to offer an additional loop holes needed in antenna design for Ground penetrating radar systems. The most promising candidate of antenna suitable for GPR system are horn antenna, Vivaldi antenna, Bowtie antenna, Spiral antenna, TEM horn antenna, Tapered slot antenna, Loaded dipole antenna, Monopole antenna etc. Microstrip antennas are not preferred over this ultra–wideband because of its low efficiency, high Q and spurious feed radiation. Metal reflectors and horn type antennas are not particularly suitable with demining missions[10]. Antenna frequency is one major factor in depth penetration. Higher the frequency of an antenna, shallower more into the ground it will penetrate. This going deeper helps also to outsource information about smaller targets. Most of the UWB antennas are fed with a two type of feed structures, namely microstrip line and coplanar waveguide (CPW) lines. CPW feed line is preferred over other feeds because of its small size, low profile, low radiation loss and easy to integrate with MMIC's.

A. Horn Antenna Profile

In a GPR system, better penetration and deeper into shallower objects can be performed by angular antennas. Such progress be achieved by horn types with good

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radiation into ground surfaces. The optimized horn antenna is then modeled with the typical GPR environment to detect hidden object inside the earth and for the characterization of non-homogenous layered structure. A typical horn is viewed in figure (4).

Fig (5) Quad ridge Horn type

In the work of Jamali et al[11], the TEM horn antenna are designed for the frequency range of 2-19 GHz followed by its optimized transient behavior. Impedance characteristics of VSWR is computed and compared, which results with less than 2 in the frequency band of operation. Double-ridged waveguide is used for the smooth transition of waves from coaxial cable to the horn section.An elliptical shaped cavity is added to the structure to couple the energy in direction of the horn opening. Here, the author have simulated the time domain characteristics with an amplitude modulated raised cosine pulse of two cycles (RC2) and resulted with some reflections and ringing coming from different parts of the antenna structure itself. By Panzner et al[12], a compact double ridged horn antenna with an additional variation in the curvature of the dielectric waveguide between the two ridges is presented. To improve return loss, a complex shaped metallic back plate have been introduced. Furthermore, the effect of different tapering of antenna walls as well as of the ridges will be analyzed. The inner dimensions of the rectangular

Fig (6) TEM double-ridged horn antenna

feeding waveguide have been set to 72×29mm^2 for the operation near S-Band. The condition of equal beamwidth in E and H plane helps us to calculate aperture dimensions. The length (l) of the horn affects the gain at mid-frequency. A neutralization gain of 10 dB has been chosen in order to keep the antenna dimensions small.

The transition between the rectangular feeding waveguide and the diverging antenna walls will reflect a considerable amount of input power. Effort has been made on decreasing the reflection coefficient of the antenna by minimizing the influence of the discontinuity. The power received at the target can be calculated as follows,

$$Pr = \frac{Pt\,Gt\,Ar\,\sigma s}{(4\pi)^2 R^4} \text{with} Ar = \frac{Gr\,(c/f)^2}{4\pi} \qquad (1)$$

A continuous decreasing width of the dielectric waveguide towards the antenna aperture will improve the transition of the impedance from feeding point 50 Ω to free space 377 Ω slightly.The scattering parameter is taken into account to generate and interpret an image.

B. Vivaldi Antenna Profile

Vivaldi antennas are significantly used in applications such as GPR, where the place of greater bandwidth is needed. In 1979, Gibson proposed a tapered slot antenna which is renowned to be vivaldi antenna[13]. In this, feeding

Fig (7) Vivaldi antenna

structures are improved to get broad impedance bandwidth. This Vivaldi structure of antenna provides high gain, low profile with purest polarization and shown in figure (6). Regarding side lobe suppressions, EBG structures with Vivaldi helps to increase E-field distributions[10]. The new term of ringing behavior is improved, which attenuates evanescent fields in the antenna surrounding. This ringing to be observed sharply as it needs in the time domain analysis.

By Zubhair et al[14], a new variant of hemisphere lens-loaded Vivaldi antenna for the microwave imaging applications is designed and tested. It works in the wide frequency band of 1–14 GHz, and is fabricated on the FR-4 substrate.The directivity of this Vivaldi antenna is improved using a hemispherical shape dielectric lens, which is fixed on the end-fire direction of the antenna.The two-dimensional (2D) microwave images of these objects are successfully obtained in terms of the measured wide band scattering data using a novel time domain inverse scattering approach, which shows the applicability of the antenna.

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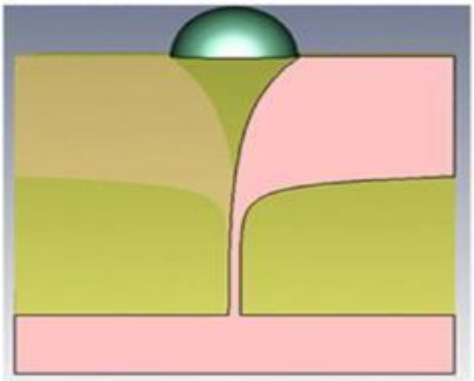

Fig (8) Dielectric lens loaded Vivaldi

From Yang et al [15]point of view, adding an elliptical strip on substrate can decrease the lower frequency band and variation on reflection coefficient becomes smaller than -10dB in the rest of the band. The design formed through this attain a peak gain of 5dBi with the help of ground plate as transition curve. Two exponentially symmetrical tapered patches are placed on opposite of substrate. Working with higher frequency (fH), the width (w1) of vivaldi antenna should satisfy the below equation to avoid any grating lobes for the vivaldi antenna.

$$w1 = \frac{c}{fH - \sqrt{\varepsilon_e}} \qquad (2)$$

Where, c is the speed of light in vacuum, is the effective dielectric constant. The gain reflects the ability of an antenna to radiate its power of some waveform and overall the physical characteristics effectively adds the current path. Beside other details, there is an important parameter namely group delay which represents the degree of distortion of pulse signal. The group delay of an antenna is the frequency dependence of time delay. It is depicted as,

$$\tau(\omega) = -\frac{dj(\omega)}{d\omega} = -\frac{dj(f)}{2\pi df} \qquad (3)$$

Where, j(f) is the frequency dependent phase of the radiated signal. The nonlinearity of a group delay indicates the resonant character of the device, which implicates the ability of the structure to store the energy. It produces ringing and oscillation of the antenna impulse response.

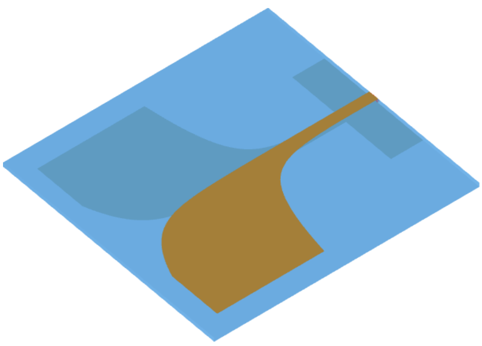

Fig (9) Antipodal Vivaldi antenna

In another idea Yang et al[16], proposed a variant antipodal antenna with major critical as transition section of antenna design and high frequency component is very sensitive to structure discontinuity. Furthermore, transition section acts as a balun, and because its gradient curve exhibits very wide bandwidth. Improvement in slot width w increases, the surface current distribution become smaller and leads to antenna resonance point shifting to higher frequency band. By Kun ma et al[17], a vivaldi antenna with two pair of eye shaped slots is designed to improve radiation pattern in the nature of microstrip to slotline transition structure. The performance of the antenna can be improved by decreasing the current on outer edges. The gain over 3 to 4 GHz exhibits a value by 3dBi.By increasing the size of the eye- shaped slots, the impedance matching will be getting worse. As a result, the side lobe levels are reduced in E-plane with slight changes in H-plane and indicates the antenna is more effective on lower frequencies than at higher frequencies.

C. Bowtie Antenna Profile

Through the design of Karamzadeh et al [18],the self-complementary bowtie antenna with reliable information about the objects and following gain to be achieved exponentially high. Circularly polarized profiles are designed with bowtie structures to reach deeper distance. Further studies are going on to impose frequency independent characteristics in the complementary antennas as well to improve broad impedance bandwidth. Most self-complementary antenna exhibits homogenous current distribution only. If all elements are summed as a single unit, then the outcome will helps to penetrate easier into the ground or sub-surfaces.

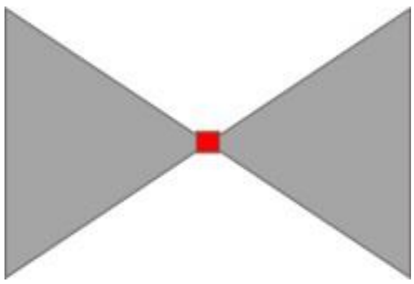

Fig (11) Bowtie antenna

Fig (10) Self complementary structure

In Sagnard et al[19], bowtie slot antenna gives peak resonance transition of response for an ground coupling radar to investigate the subsurface objects(i.e) cracks, delamination in civil structures. Here, the polarization diversity in E plane and H plane are mainly concentrated under measurements in a dry and wet sand of different system configurations.

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The radar system can also be primarily used to detect objects in a wet sand. Also the direct full wave modeling based on FDTD attribute remains significant in the study of UWB radiation properties in both planes of air and common soil. The characteristic impedance of bowtie antenna is expressed as[20],

$$Zc = 120\ln(\cot(\theta o/4)) \quad (4)$$

Where, is the opening angle of each side (also known as flare angle).The length (l) and width (w) of the flares in bowtie antenna can be expressed as,

$$l = \frac{1.6\,\lambda o}{\sqrt{\varepsilon_r}} \quad (5)$$

$$w = \frac{0.5\,\lambda o}{\sqrt{\varepsilon_r}} \quad (6)$$

Where, is the wavelength of low frequency range in free space and flare angle is totally dependent on impedance. For the investigation we need definitions of the impedance relative bandwidth and its expressed as[2],

Bandwidth % = Δf/f0*100 (7)

Where, fo is the Centre frequency and f is the range of frequencies. Another discussion by Sagnard[19], gives a bowtie antenna well suited with GPR in the place of evaluating structural changes in civil engineering works and to detect buried pipelines, small objects in depths. The ratio between length and width of antenna to be 1.57. Furthermore, to reach an amplitude less than -40dB with an offset of greater than 40mm was added. The coherent analysis of various estimate made the author to find relative real permittivity = 3.5 for both polarizations. The measurement observed in the test of canonical buried objects show the satisfying ability of the radar system to detect quite smaller than the antenna dimensions. These bowtie antennas are mostly fed with CPW to reduce the end-fire reflection of the UWB antenna for GPR application.

D. Slot Antenna Profile

Slot antennas for radars used in UWB range has a primordial role in the place of navigation usually as an array fed by a waveguide. The shift of feed point over the slots from center to the edge steadily decrease the impedance. Slot antenna is a best suitable replacement for dipole type of resonators. Ming et al's [21], slot antenna with low profile, small dispersion and good penetrating capability to be inherited into this GPR with typical high gain of 5-6dBi.Various type of slot antennas are introduced with some additional credentials to improve their radiation pattern for impulse GPR system. In [22], a slot antenna fed with coplanar waveguide are designed and fabricated in low profile manner of wide fractional bandwidth of 1.4 - 3.5GHz with a resultant of radiation gain over 6dBi. This purpose of work especially helps to design a well flexible to air coupled types. The schematic size of 10.6cm * 6.8cm are taken with an eye-shaped slots. The antenna dispersion is serious when the comparative results of transmitted signal and distorted received signal.

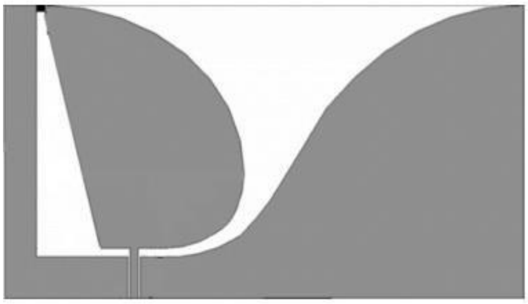

Fig (12) Tapered slot antenna

Babinet's principle portrays the relation b/w input impedance of dipole Zd and complementary slot Zs as given by,

$$Z_d Z_s = n^2/4 \quad (8)$$

At the time of results, both gain and radiation efficiency to be watched sensibly. With this slot type, an additional feature like time domain evaluation also possible. The main effect exploited to attain a pivoting of antenna beam as a function of change of broadcast frequency

The designed antenna fig (13) by Zhang et al[23], forms a double exponentially tapered slot resonator with an influence of return loss less than -10dB in the band of 220MHz – 6GHz. To extend the bandwidth, we can use lengthened arms of feed and lumped resistors near the end of arms. Those arms are roll backed to extend prolonged current path. Another important switching of network from coplanar waveguide (CPW) to coupled strip line (CPS) transition takes place to avoid the use of an air bridge. Furthermore, the reflected wave from the end of rolled arms is shortened by lumped resistors.

E. Planar Antenna Profile

For the past few years, planar monopole candidate has not given importance into this GPR systems. But we can use it in radar equipment's as well to acquire wider bandwidth occupancy with larger efficiency. The planar monopole antennas of different shapes likely to have square, elliptical, triangular, rectangular, annual ring, pentagonal, hexagonal radiator geometries that were discussed in many literatures on the road to exhibit different response plots.

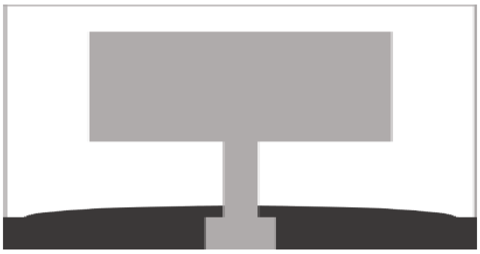

Fig (14) Planar monopole antenna

A discussion initiated with Sharif et al's[24] paper of tree shaped radiator which is responsible for GPR application help us to concentrate more on environment related planar antenna designs.

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Especially, these structure offers a wide operating frequency covering a bandwidth from 250MHz to more than 6GHz. Two ellipse are added on radiators in turn to lower down operating frequency and thereby increase bandwidth.

Fig (13) Double exponentially tapered slot antenna

In [25]Cao et al's paper, a UWB monopole for GPR has been designed and fed by coplanar waveguide with a broad response of bandwidth from 0.4 to 3GHz. This have an advantageous of integrating easily into PCB board. With the basic circular structure, two circle of ears are added at radiator to improve the bandwidth especially at lower frequencies. The above idea were carried out by author's design to increase current path length without increasing the total size of monopole antennas. Larger conducting radiator leads to wider impedance bandwidth. From the results, we can modify a shift from lower responsive frequency to higher by making an adjustment on ground plane.

In another enhancement profile depicted in fig (15), a new palmate leaf shaped radiator element and is fed by a modified CPW feed line. In addition, a current element distributions on the ground plane has a significant effect over antenna impedance bandwidth. So the truncation takes place in ground plane improves a much responsive drift in UWB's behavior. From an observation, it is noted that bandwidth of more than 10GHz starts from 3.08GHz to 14GHz with optimal result of VSWR ≤ 2.

Fig (15) Palmate leaf shape monopole

In point of Bajracharya et al's view[26], an excitation is with 50Ω waveguide port where the length of the ground plane is equal to the length of the transmission line goes to our radiator. With respect to the slots introduced in the ground plane (i.e) DGS, EBG structures, we can obtain wide operational bandwidth and a gain of 2.1dB and 4.6dB respectively. A planar antenna consists of radiator, a partial or full ground plane with a defected ground structure (DGS) which can be varied based on following length and width calculation as mention belowed

$$w = \frac{c}{f}[\sqrt{\frac{c}{\varepsilon r+1}} \quad (9)$$

$$L = \frac{c}{2f} - \Delta L \quad (10)$$

Where,

$$\frac{\Delta L}{h} = \frac{0.412(\varepsilon reff+0.3)\left(\frac{w}{h}+0.264\right)}{\varepsilon reff-0.258\left(\frac{w}{h}+0.8\right)} \quad (11)$$

$$\varepsilon reff = \frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{2}\{1+12\frac{h}{w}\}^{\wedge} - 0.5 \quad (12)$$

A planar monopole designed for UWB communication by anvesh et al[27], gives an advantageous point of high speed data transmission over smaller distances. It covers 10dB return loss ranging from 2.72GHz to 12.68GHz and obtained a gain of 5.24dBi at 9.25GHz. The most familiar numerical techniques like FEM, FDTD are analysed with this design. Variation in group delays may distort UWB signals and degrade the overall performance. In this workout two different scenario of making a ground to be full and partial in planes followingly its results been compared.

F. Reflector Antenna Profile

The design of reflector antenna focuses us to concentrate much on pulse radiation characteristics of GPR systems. Microwave imaging and conformal imaging are well accurate with the help of information gathered from reflector model. In GPR system[26], obtained result of microwave imaging is the one to detect the abnormalities in a dielectric medium or to retrieve the dielectric properties of an object through inverse scattering techniques.

If we use single antenna for both transmission and reception, then the operation requires an Ultrafast transmit-receive switch to provide adequate isolation between transmit and receive ports. After obtaining the received signal into the device, traces being done for with and without target experiments. Due to ripples in the signal, makes us not to predict correct response. So, we can employ an offset feed arm to replace the centered feed arm in our described reflector antenna.

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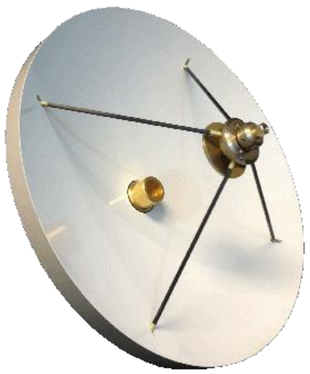

Fig (16) Reflector antenna

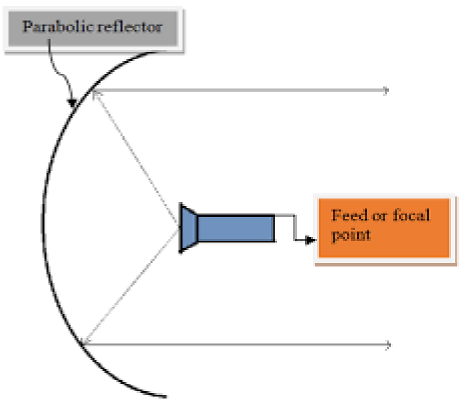

Fig (17) Principle of reflection from source

The amount of energy received at the receiving antenna is more significant for the analysis and it can be through reflection coefficient (i.e) how much reflection takes place which is expressed as(13)

$$\Gamma_{\parallel} = \frac{-\cos\theta i + \sqrt{\frac{\varepsilon 1}{\varepsilon 2}}\sqrt{1-\frac{\varepsilon 1}{\varepsilon 2}\sin^2\theta i}}{-\cos\theta i + \sqrt{\frac{\varepsilon 1}{\varepsilon 2}}\sqrt{1-\frac{\varepsilon 1}{\varepsilon 2}\sin^2\theta i}}$$

Where, is the permittivity of air, is the permittivity of the medium that going to pass through and is the angle of incidence. In order to maximize transmitted power, the EM wave at the Brewster angle is given by(14)

$$\theta_B = \sin^{-1}\left(\sqrt{\frac{\varepsilon 1}{\varepsilon 1+\varepsilon 2}}\right)$$

IV. COMPARATIVE RESULTS & DISCUSSIONS

Ultra wideband antenna for this systems requires greater frequency bandwidth along with high gain. Based on some parameters, various antenna design been discussed in above Section III and presented with its basic design calculations. The operating frequency of each antenna, its bandwidth and gain achieved over the UWB region are summarized and given in table [1]. Another attractive feature of polarization is attained in parabolic resonator where reflectors are adjusted to form either vertical or horizontal direction by rotating the antenna.

Ref no #	Frequency (GHz)	Dimensions (mm)/(cm)	Bandwidth (%)	Maximum Gain (dB)	Reflection coefficient (S11)
[11]	2 - 19	Not reported	161	10	< -10 dB
[12]	1.2 – 6.5	Feeding waveguide 72*29 mm^2	150	10	< -15 dB
[28]	2.9 – 3.21	120*180*120 mm	10	15	< -10 dB
[29]	0.75 - 12	42.9*26.8*20 cm	176	13	< -25 dB
[14]	1.05 - 14	Not reported	-	10	< -10dB
[30]	0.5 - 3	405 × 12 × 318 mm	142	5.8	< -10dB
[20]	0.4 – 4.8	225 * 505 mm	169	7	< -8dB
[31]	2.5 - 15	80 * 150 mm^2	142	10.8	< -15dB
[16]	3.1 – 10.6	46 * 45 * 0.8 mm	109	5.03	< -10dB
[17]	3 – 12.8	36mm * 36mm	124	8.3	< -10dB
[32]	0.6 - 6	6 * 12 * 3 mm	163	9.9	< -20dB

Table [1] Performance of Horn, Vivaldi and Bowtie antennas

Ref no #	Frequency (GHz)	Dimensions (mm)/(cm)	Bandwidth (%)	Maximum Gain (dB)	Reflection coefficient (S11)
[30]	0.5 - 3	405 × 12 × 318 mm	142	6.6	< -10dB
[15]	2.64 – 6.96	34 * 50 mm^2	90	5.2	< -10dB
[33]	3 - 12	Not reported	120	7.5	< -10dB
[27]	2.72 – 12.68	a=5.25mm microstrip line 11.05mm×3mm	129	5.24	< -10dB
[34]	2.23 – 11.4	29.44 * 38 mm	135	3.54	< -17dB
[35]	3 – 11.6	x=y=15, b=12, g=0.9, t=1.6	117	9.5	< -9dB
[23]	0.2 - 6	30 * 15.7 mm^2	187	12	< -10dB
[36]	2.5 - 14	27.21 * 32.264 mm	139	8	< -20dB
[37]	3.6 – 12.6	36 * 45 mm^2	111	12.5	< -10dB

Table [2] Performance of Slot, Planar and Reflector antenna

The results obtained from planar antenna design as shown in Table 2. In the place of slot antennas, an overall performance was improved in terms of coplanar properties of radiator, ground and tapering characteristics. These tapered slot antenna also have the ability to improvise deeper penetration and imaging from the received signal for GPR system. From the given table, planar types of partial ground or ground length less than /4 gives a bandwidth enhancement in < -10dB reflection coefficient around our all operating frequencies. The significant increase in bandwidth characteristic an excessive electromagnetic coupling between ground and the radiator.

The overall results and discussion of different type of antennas, with multiple design for GPR application to detect buried objects and some useful identifications made us to observe vivaldi and slot designs have significantly better performance. Till now, there is no such importance been given to planar antennas. It have an advantageous of obtaining wider bandwidth as well as high gain. So we can choose this candidate more for GPR under UWB region.

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V. CONCLUSION & SCOPE

A review of various prospective UWB antenna for GPR applications has been investigated and compared in this paper. The detailed summary of horn, vivaldi, slot, bowtie, planar and reflector antennas are discussed based on radiation and impedance characteristics individually. Eventually, the main focus of design should be on wide impedance bandwidth and to achieve deeper penetration under the subsurface of ground. Although, further exploration is needed in the time domain characteristics and group delay at higher frequencies

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