TEM HORN ANTENNA FOR GROUND PENETRATING APPLICATIONS

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Abstract – A TEM HORN Antenna is presented in this paper. This antenna is designed for GPR applications. This antenna is suitable for this application due to its compact transition section and possesses a wide bandwidth, good radiation characteristic, and easy integration with microwave circuits. Two specially tapered metal flares have been designed to make a wideband characteristic and reduce the reflection. To overcome aperture reflections at low frequencies and unbalanced aperture field at higher frequencies, an arc surface is added at the end of the flare plates, and an absorbing material is loaded on the outer surface of the flare section. Measured results show that the presented antenna has a wide bandwidth from 0.83 to more than 12.8 GHz under a return loss 10 dB, small input reflection, a moderate gain from 0 dBi at 0.83 GHz to $\leq$ 10 dBi at 12 GHz, and a good radiation characteristics in the time domain, which can be suitable for ground penetrating radar (GPR) applications.

I INTRODUCTION

1.1 GPR SYSTEM

GPR stands for Ground Penetrating Radar, which allows scanning the soil in a nonevasive way. In GPR electromagnetic signals are transmitted into the ground and by analyzing and post-processing the received signals an insight can be obtained in objects present in the soil. Just like with normal radar for detection of ships and aircrafts analysis of the received signal gives the distanceto objects. These objects can be a range of things depending on the applications. Possible applications are landmine detection, archaeological surveys, road or rail inspections and of course the before mentioned utility detection. For transmitting these electromagnetic signals into the ground probes can be placed in the ground or an antenna can be placed on top of the surface. Placing the antennas above ground makes operation of the radar system easier as it can be easily moved, but an extra challenge arises for this problem as the soil will introduce an extra reflection. When the antenna is placed above ground the propagation time from the first reflection is usually short than the signal duration hence a dual antenna system is chosen where one antenna functions as a transmitter and another antenna as a receiver.

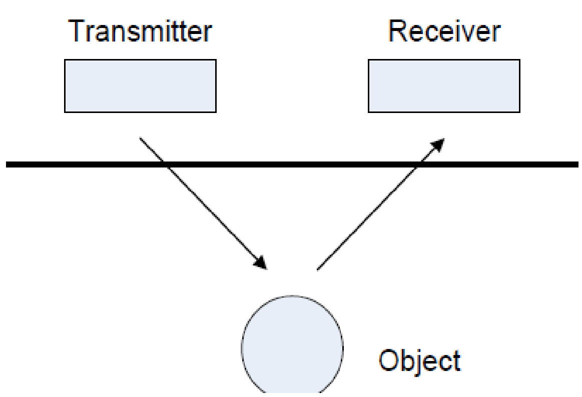

FIG 1 determining the objects in GPR application

1.2 TEM HORN ANTENNA

The TEM horn is the most common type of horn antenna and is a so-called waveguide antenna. Its main principle of operation is two parallel plate lines that towards the end of the antenna increase in separation. For the lowest mode of operation the maximum wavelength that can be transmitted from the antenna is determined by the separation at the end of the antenna. Hence the same problem arises as with the Vivaldi antenna. For a minimum frequency of 100 MHz the size should be 1.5 m, unless the separation between the plates is filled with a dielectric.To reduce ringing effects in the antenna the transition of the feed to freespace or the electrical permittivity close to that of the soil must be smooth in order to suppress reflections. Since the energy is transmitted via the horn the dimensions of the horn can steer the energy and a focussed beam can be formed to emit the waves. The footprint therefore is dependent on the shape of the horn. This antenna type is also characterized by linear polarization and the footprint is determined by the antenna shape at the end of the flares.

II ANTENNA DESIGN

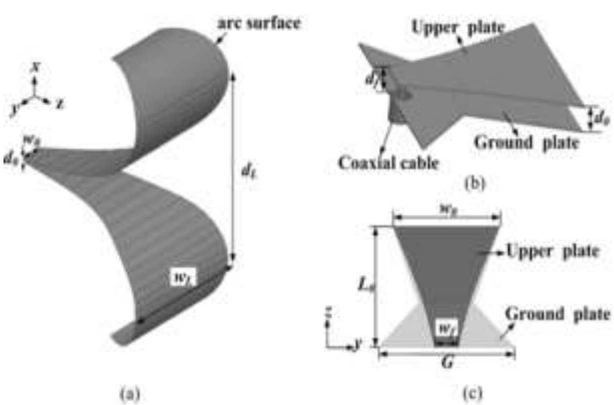

FIG 2 Configuration of the proposed antenna. (a) Symmetrical flare section.
(b) 3-D view of feed section. (c) Top view of feed section.

The geometry of the proposed TEM horn antenna with full dimensions of mm is illustrated in Fig. 2, which consists of two thin metal sheets with thickness of 0.5 mm and two pieces of absorbing material. It is divided into two parts: a microstrip-to-parallel-plate transition and a symmetrical flare section. The microstrip-to-parallel-plate transition is designed to provide a good impedance matching between unbalanced coaxial line and symmetrical flare section. The input impedance of the transition is calculated as a microstrip line with the air substrate based on the standard microstrip-line approach [2]. Fig. 1(c) gives out its top view; the dark gray plate is the upper side, and the light gray plate is its ground plane, where *wf* is the initial width of the strip line,*df* is the height of the air substrate, and G is the edge width of the ground plane. The width of the ground plane gradually narrowed along *z* and finally became the same as the upper plate. The initial impedance of symmetrical flare section is also designed close to 50Ω for a compact transition size, where *wo* and *do* are the initial parameters of the symmetrical flare section.

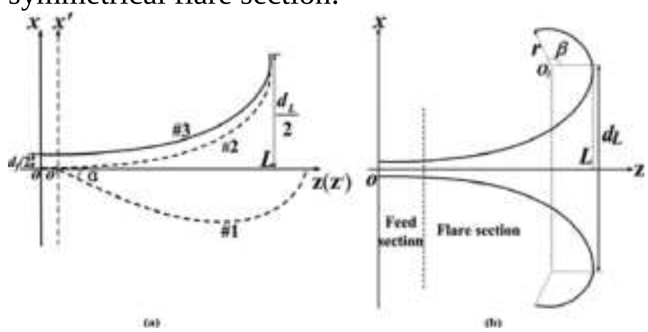

FIG 3 Geometry of proposed antenna. (a) Exponential flare function. (b) Side view of proposed antenna.

In this letter, a novel exponentially tapered structure is designed to match the input impedance at feed port with the characteristic impedance of free space at the antenna aperture. The specific shape is shown in Fig. 3. An arc surface is added at the end of the antenna aperture for a smoother low-frequency characteristic in contrast to [3].

First, a novel exponential expression

$$\begin{cases} x' = -36\sin(2\pi k) \\ z' = 200\cos(\pi k)\cdot e^{-0.32k} \end{cases} \qquad 0 < k < 0.5 \qquad (1)$$

is designed as curve #1 in Fig.3 (a). Then, curve #1 is rotated an angle around the axis and shifted horizontally along –Z to the location #2 as

$$\begin{cases} x = x' \cdot \cos(\frac{2\pi}{15}) + z' \cdot \sin(\frac{2\pi}{15}) \\ x = x' \cdot \sin(\frac{2\pi}{15}) + z' \cdot \sin(\frac{2\pi}{15}) - 11. \end{cases} \quad (2)$$

After the operation, curve #2 is elevated a height of *df/*2 along *x* to the location #3. Finally, one arc surface with angle and radius is added to the end of curve #3 as the final flare function of the actual upper side. The complete side view of the proposed antenna is shown as Fig. 3(b), which includes a feed section of the microstrip-to-parallel-plate transition and symmetrical flare section. The bottom curve is symmetrical to the upper one.

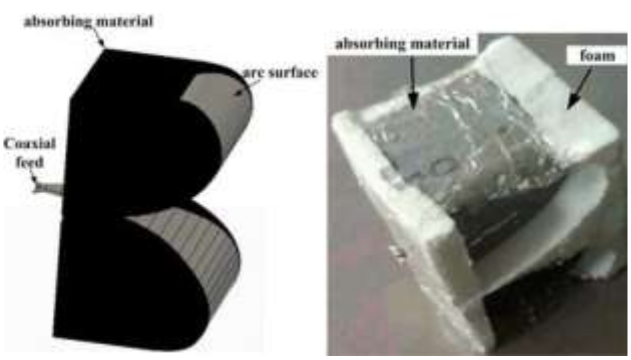

FIG 4 Prototype antenna.

The specific configuration of the flare section is shown as Figs. 2(a) and 3. It is divided into 15 sections, and each edge of the section is approximately considered as a parallel-plate waveguide. To determine the characteristic impedance of each parallel-plate waveguide, *Z (zi)* [4] is used

$$Z(z_i) = \frac{d(z_i)}{w(z_i)}\eta.$$

d(zi) is the vertical distance between two parallel plates, and *w(zi)* is the edge width of each section. The specific parameters of the flare section are calculated and optimized using (3). The total length of the horn is determined as$L=0.49\lambda$,λ where is the wavelength at the lowest operating frequency of 0.83 GHz.

The basic design parameters are

L =	178 mm
dl=	158.6 mm
wl=	140 mm
wf=	5.1mm
df=	2.5
G=	30
Lo=	24.5
Wo=	23.6
do=	3.2
α	24°
β	98°
γ	38.8

In Fig. 4, the left side is a complete antenna model that is made up of two pieces of thin metal sheets and absorbers. The absorbing material is sliced according to the flare profile and directly placed on the outer surface of the flare section by some adhesive tapes. In order to avoid structural deformation, one piece of lightweight foam is filled in the flare section. The right side is the prototype antenna.

III CONCLUSION

A special tapered TEM horn antenna loaded with an arc surface and absorber has been proposed in this letter. It is fed directly by a coax and possesses an easy integration with microwave circuits. The antenna has been simulated and tested. It can yield a wide operating bandwidth, covering the whole frequency range from 0.83 to 12.8 GHz and a good endfire over the entire bandwidth with moderate gain and small distortion loss. Finally, the proposed antenna is applied for the asphalts pavement investigation, which proves that this presented antenna can be used in GPR systems.

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