Development of Low Profile Hybrid Printed UWB Monopole Antenna for Handheld GPR Applications

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Abstract

Handheld ground penetrating Radar needs to have a directional low profile light weight UWB antennas preferably in the frequency range of 500 MHz-3 GHz. A hybrid printed monopole antenna back by a reflector is designed and developed for requisite frequency band. The impedance matching and directional property is mentioned throughout the frequency band.

Keywords*-UWB; GPR;Bow-tie*

I. Introduction

Ground-penetrating radar (GPR) offers a good solution for detection and imaging of buried plastic mines, IEDs and UXOs. Ground penetrating radars (GPRs) are realized in either in time domain or in frequency domain [1]. In time domain approach either baseband radiation or modulated time domain waveforms are used. Stepped frequency is one of the commonly used frequency domain approach. The resistively loaded dipoles, bow-tie, vee and monopoles commonly used antennas [1-3] for both time domains and frequency domain approaches. The requirement of low frequency for better penetration and large bandwidth for finer resolution and size constraints for hand held GPR makes it very difficult to choose the most appropriate antenna type. The required frequency band of 500MHz-3GHz and size constraints for hand held requirement leads to design of printed bow-tie antenna category .The antenna profile is obtained using combination of bow-tie and elliptical profile [4]. The issues with this design are that its differential feed requirement and non-directional radiation pattern. The differential feed can be converted to single ended feed using UWB balanced to unbalanced (BALUN) line, which may add up to the size of the antenna. The single ended version of this antenna was designed using printed monopole and microstrip line impedance adaptor to match to 50Ω waveform generators. The directional property was improved by backing the printed hybrid monopole with a curved reflector In Section II of this paper design details of antenna element is presented. The analysis and measured results are discussed in Section III. Conclusion is presented in Section IV.

II. Antenna Element Design

The antenna is a hybrid antenna, which is derivative of a Bowtie antenna, and elliptical antenna. The major axis of the ellipse in the case of this antenna is 7.162 cm and the minor axis is of order of 4.162 cm. The Bowtie element of the Hybrid antenna has a design specification of length of one side of the triangle and value of one of its interior angles which is 85.34 degrees and the length of the side opposite to it is 6.7 cm [4]. The antenna element was designed with a 1.6 mm substrate RT Duroid 5880 ($\varepsilon_r = 2.2$) and the reflector was placed 5cm behind the printed element as shown in Fig.3.

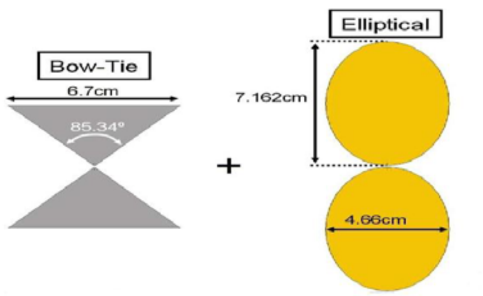


Figure 1: Combination of Bow tie and elliptical profile

The antenna geometry shown in Fig.2 is a balanced structure; hence either an Ultra wide band Balanced to Unbalanced (BALUN) line or a differential excitation signal is required to feed the antenna. This limitation was overcome by designing a microstripline impedance adaptor, which makes the antenna as single ended unbalanced geometry as shown in Fig.3. The non-availability of UWB duplexers with good isolation has prompted to use bistatic arrangement for GPR, wherein separate antenna should be used for transmit and receive. The transmit and receive antenna was separated by 5cm in a plastic enclosure.

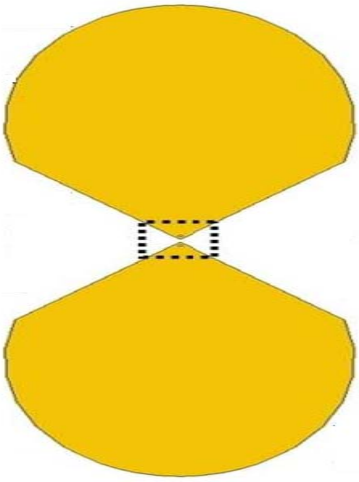


Figure 2: Antenna element geometry

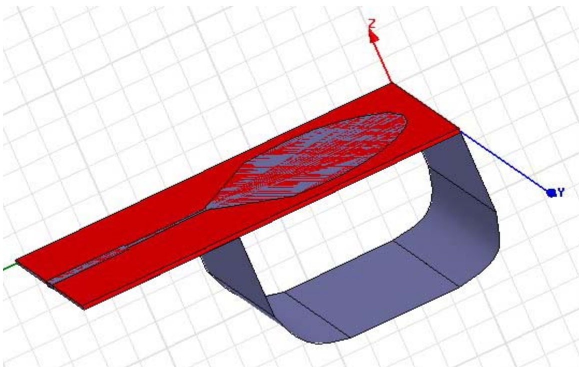


Figure 3:Solid model of Hybrid Bow tie Antenna

III. ANALYSIS & MEASUREMENT RESULTS

The antenna under consideration is UWB in nature analyses was done using FEM solver (HFSS v12.1). The calculated return-loss of the antenna is shown in Fig.4.The plot shows that the antenna offers excellent impedance matching in the frequency band of 500 MHz to 3.1 GHz. The impedance matching alone does not qualify an antenna as an UWB antenna. It is observed that the direction of main be shifts with the frequency, making it impossible to use for radar applications. The calculated three dimensional radiation pattern is at 1GHz, 2GHz, and 3GHz is shown in Fig.5.The figure shows that the direction of main beam is mostly in the boresight direction.

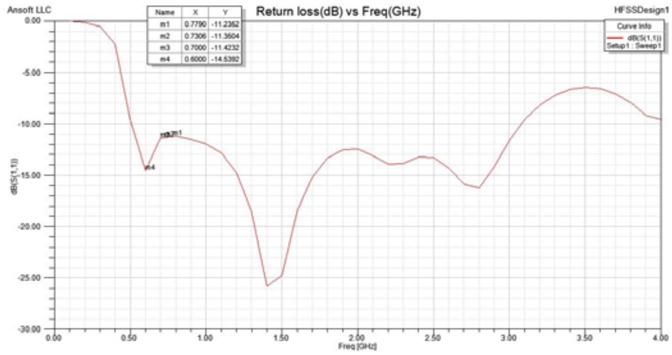
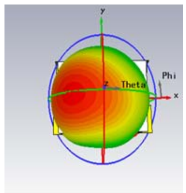
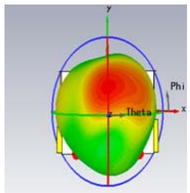


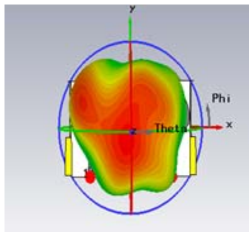
Figure 4 : Return loss (dB) Vs Frequency (GHz)



a) 1 GHz



b) 2 GHz



c) 3 GHz

Figure 5: 3-D Radiation Pattern at 1, 2, and 3 GHz.

The antenna was realized using RTduriod substrate of thickness 1.6mm and relative permittivity of 2.2.The curved reflector was realized using 1.2mm thick aluminum supported by nylon spacers. The scattering parameters of the antenna were measured using agilent network analyzer is shown in Fig.6. The Measured result of the realized antenna shows a bandwidth of 500MHz-3.5GHz as $|S11| \leq -10$ dB. The measured and the calculated return loss are closely matching in the requisite frequency band.

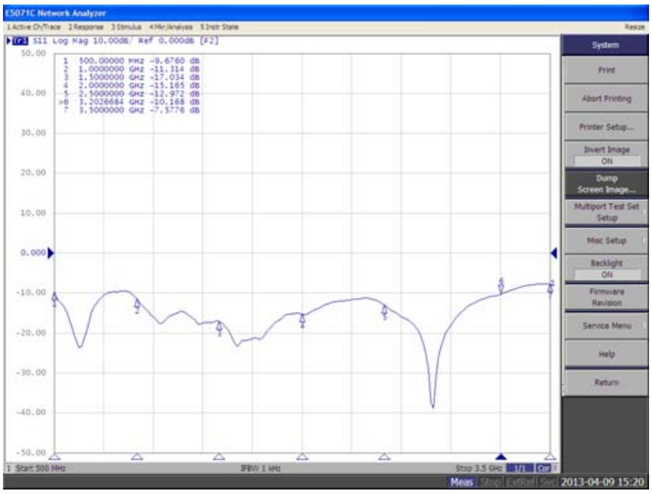


Figure 6: Measured return loss (dB) Vs Frequency (GHz)

IV. CONCLUSION

The contradicting requirement of low center frequency and light weight low profile antenna requirement for handheld GPR puts challenge on antenna design. The hybrid printed monopole designed and developed meets the required bandwidth, weight and dimension constrains to meet the requirements of a light weight handheld GPR.

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