COPLANAR STRIP LINE FED BOWTIE ANTENNA FOR GROUND PENETRATING RADAR

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ABSTRACT

The increasing demand for impulse ground penetrating radar (GPR) as a tool for detection and identification of subsurface objects has led to the need of a class of transient antennas especially designed to optimally operate in the vicinity of a lossy ground. Impulse GPR antennas should be wide band for proper transmission of wide band pulses, produce very low level of edge reflections to avoid masking of the targets and be efficient for allowing a low power budget. In recent years coplanar stripline fed antennas have gained popularity mainly due to inherent advantages, including their uniplanar nature and the ease of shunt connection of circuit components. Hence a coplanar stripline fed bowtie antenna is designed and developed for use as an element of a phased array antenna in GPR. The antenna is designed as a patch on a single layered substrate having ε_r = 4.28 and thickness 1.6 mm. The coplanar strip line is designed to have an input impedance of 50 Ω, to couple the antenna effectively with the measurement system. The parameters such as the distance to the image plane, flare angle of the bow and dimensions of the antenna are found to affect the bandwidth, resonant frequency and radiation characteristics. These parameters are optimized to enhance the performance of the antenna. An optimum distance for the image plane of 2 cm is selected, to obtain good bandwidth and maximum forward radiation in the operating band. The length of the antenna is selected as 4 cm to obtain a resonant frequency of around 3 GHz. E and H plane radiation characteristics show that the antenna exhibits low cross polarization and reduced back radiations. Theoretical investigation of the antenna is done by FDTD method. Here time-dependent Maxwell's equations are analyzed using the Yee's mesh. Fourier transform is then applied to these equations to obtain the return loss of the antenna. The slanted edges of the antenna are approximated using stair casing with sub millimeter spatial-grid resolution. The computation domain is discretized as 55 x 64 x 40 Yee cells in the *x, y, z* directions respectively. Space step of 1 mm is chosen to accommodate the antenna structure conveniently. The time step selected is 0.25 ps to ensure Courant Stability condition. The Gaussian half width T and the time delay t_o are set to be 15 ps and 45 ps respectively. The quasi-static approximated field distributions are exploited as the initial spatial distribution. The computation is performed for 2500 time steps so that the field stabilizes. Mur's second order absorbing boundary conditions are applied to terminate the FDTD grid. Experimentally obtained 2:1 VSWR bandwidth of 46 % in the operational band of 1.85 – 3.425 GHz complements the FDTD computed bandwidth of 52% in the operational band of 1.725 – 3.575 GHz.

INTRODUCTION

Impulse ground penetrating radar (GPR) has been used as a tool for detection and identification of subsurface objects such as gas pipes, land mines etc. [1]. This noninvasive time domain method for subsurface exploration, characterization and monitoring, have led to the need for a class of wide band antennas specially designed to transmit short transient pulses [2, 3]. The antenna should efficiently focus the microwave signal towards the target and collect the back-scattered energy. A wide band antenna with unidirectional radiation pattern is required for these applications. Moreover the antenna should be compact enough for easy mounting, integration with other electronic circuits, and the ease in fabrication of arrays.

Microstrip antennas are compact, but they exhibit narrow bandwidth. This makes them unsuitable for time domain applications.

The present paper reports an efficient wide band coplanar strip line fed bowtie antenna having improved bandwidth, low cross polarization and reduced back radiations. The new antenna is constructed by structurally modifying the conventional microstrip bowtie antenna design, by attaching an image plane.

GEOMETRY OF THE ANTENNA

Figure 1 shows the geometry of the antenna. The antenna is designed as a patch on a single layered substrate having $\varepsilon_r = 4.28$ and thickness 1.6 mm. The coplanar strip line is designed to have an input impedance of 50Ω [4], to couple the antenna effectively with the measurement system. The parameters such as the distance to the image plane, flare angle of the bow and dimensions of the antenna are found to affect the bandwidth, resonant frequency and radiation characteristics. These parameters are optimized to enhance the performance of the antenna. An optimum distance for the image plane of 2 cm is selected, to obtain good bandwidth and maximum forward radiation in the operating band. The length of the antenna is selected as 4 cm to obtain a resonant frequency of around 3 GHz. In the absence of the image plane, the antenna shows a higher bandwidth of 56.43 % and a figure of eight radiation pattern. As the flare angle of the bow is increased, the bandwidth increases, with the resonant frequency remaining almost constant. An optimum flare angle of 90^o is selected in the present design.

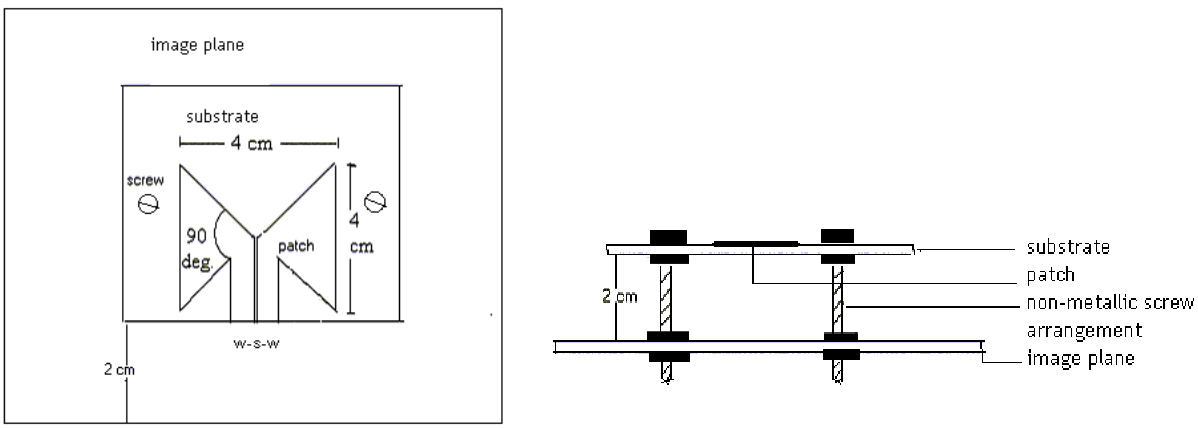

Figure 1. Geometry of the antenna- a) top view b) side view

FDTD METHOD

Theoretical investigation of the antenna is done by FDTD method. Here time-dependent Maxwell's equations are analyzed using the Yee's mesh. Fourier transform is then applied to these equations to obtain the return loss of the antenna [5]. The slanted edges of the antenna are approximated using stair casing with millimeter spatial-grid resolution. The computation domain consists of 55 x 64 x 40 Yee cells in the *x, y, z* directions respectively. Space step of 1 mm is chosen to accommodate the antenna structure conveniently. The time step selected is 0.25 ps to ensure Courant Stability condition. The Gaussian half width T and the time delay t_o are set to be 15 ps and 45 ps respectively. The quasi-static approximated field distributions are exploited as the initial spatial distribution. The computation is performed for 2500 time steps so that the field stabilizes. Mur's second order absorbing boundary conditions [6], are applied to terminate the FDTD grid.

RESULTS AND DISCUSSIONS

Figure 2 shows the reflection and transmission characteristics of the optimized antenna. Experimentally obtained 2:1 VSWR bandwidth of 46 % in the operational band of 1.85 – 3.425 GHz complements the FDTD computed bandwidth of 52% in the operational band of 1.725 – 3.575 GHz. Figures 3 (a, b, c) show the E and H- plane radiation patterns of the antenna. It is observed that the pattern remains similar throughout the operational band. The back radiations are less due to the presence of the image plane. A reduction of around 20dB in cross polarization is observed on the on-axis in both E and H planes. Figure 4 shows the FDTD computed end-reflections observed at the feed point of the bowtie antenna relative to the exciting pulse. End reflection of –24 dB.is an acceptable value for GPR application.

CONCLUSIONS

The design and characteristics of an efficient wide band bowtie antenna are presented. The experimental studies show that the distance to the image plane and the flare angle affect the bandwidth of the antenna. The antenna exhibits unidirectional radiation pattern with enhanced bandwidth, less back radiations and low cross polarization in the operational band. The antenna is suitable for time domain GPR applications.

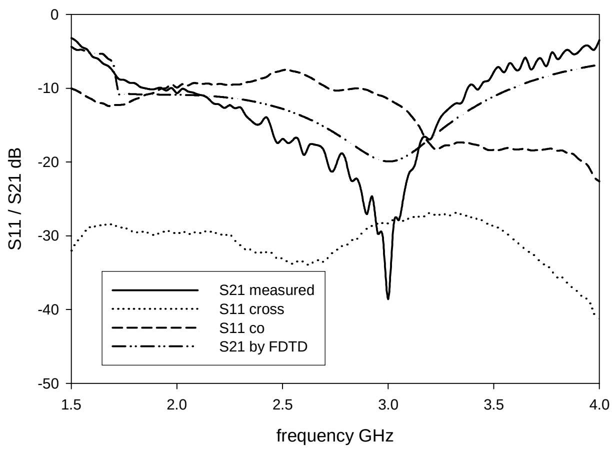

Figure 2. Reflection (S11) and Transmission (S21) characteristics versus frequency

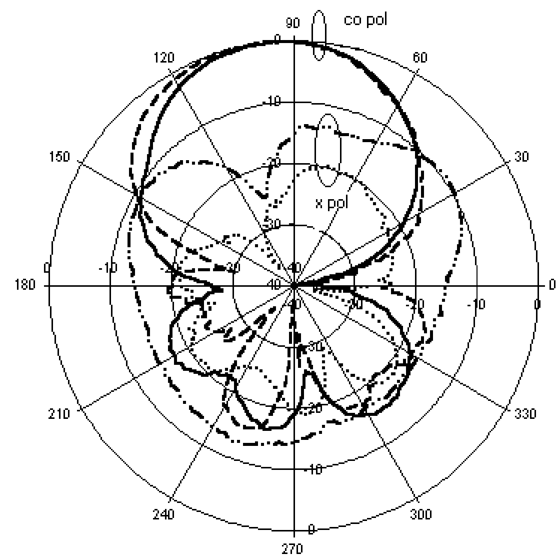

Figure 3 (a). Radiation pattern of the antenna measured at 2 GHz

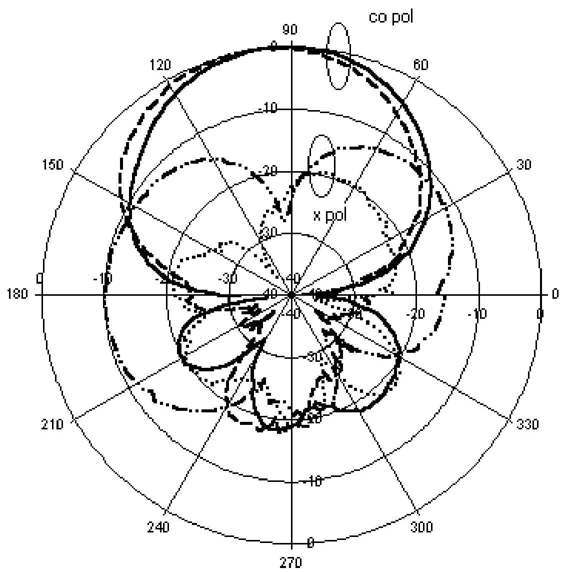

Figure 3 (b). Radiation pattern of the antenna measured at 2.6 GHz.

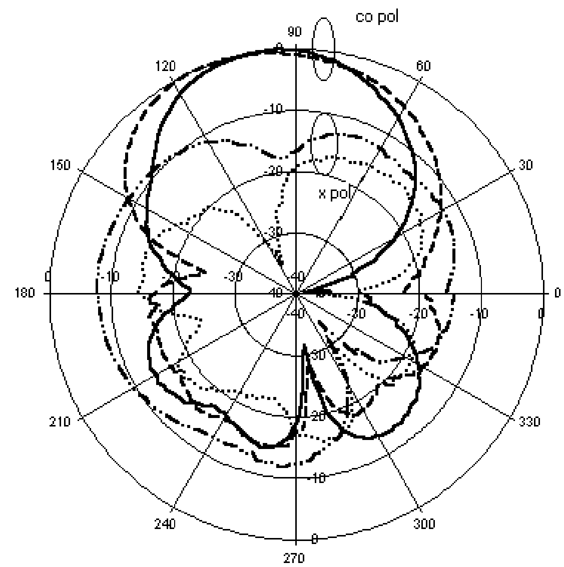

Figure 3 (c). Radiation pattern of the antenna measured at 3.2 GHz.

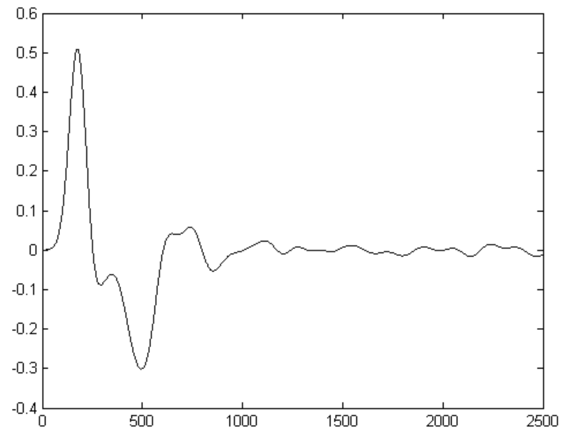

Figure 4. FDTD computed end reflections at the feed point of the antenna with respect to the exciting pulse.

ACKNOWLEDGEMENT

Authors G. Bindu and Anil Lonappan thankfully acknowledge the Council of Scientific and Industrial Research, Govt. of India for providing Senior Research Fellowships.

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