Wide Band Printed Bowtie Antenna Element Development for Post Reception Synthetic Focusing Surface Penetrating Radar.

R.Nilavalan, G.S.Hilton and R.Benjamin
Centre for Communications Research, Merchant Venturers Building, Woodlands Road, Bristol BS8 1BU, UK

Abstract A printed bowtie antenna for a Post Reception Synthetic Focussing Surface Penetrating Radar (PRSF-SPR) has been developed with the aid of FDTD analysis. Antenna free space characteristics were compared against practical measurements and its performance was analysed when soil is present.

Introduction: The Post Reception Synthetic Focussing Surface Penetrating Radar (PRSF-SPR) [1, 2] system requires the use of a planar array of antenna elements with each element having wide band matching and wide beam radiation patterns over this frequency band. For an operating frequency of 1 GHz, the system requires approximately 400MHz bandwidth for transmission of a three cycle pulse.

The first comprehensive investigation of the input impedance and radiation from bowtie antennas was performed by Brown and Woodword [3]. Where they investigated flat top Unipolar Bowties fed through an image plane.

In this paper the Bowtie antenna analysis is performed using the Finite Difference Time Domain [FDTD] method. The FDTD analysis includes modelling of antenna element in free space for comparison with practical measurements and investigation of the antenna properties when ground is present. Accurate practical measurements of the radiation pattern in subsurface is difficult due to the complexities involved in such measurement.

FDTD Modelling in free space and measurements: The printed bowtie dipole antenna was represented by the FDTD model shown in Fig 1. The antenna element 210mm in length, and the feed were produced on a substrate of dielectric constant 2.2.

The antenna element was fed by a balanced co-planar strip line, which passed through a rectangular hole in the ground plane. The co-planar strip line was fed from a coaxial cable via a $\lambda/4$ balun with the strip line being tapered to obtain suitable impedance matching. The model space was limited using absorbing boundary conditions [4]. For wideband excitation, a single Gaussian pulse of 250 ps width was employed in the simulation process. Better antenna-feed matching was obtained by varying the model parameters. Fig 2 shows the comparison of the final FDTD model and measured responses of the practical antenna.

It can be seen that the antenna has a -10dB antenna-feed match from 0.8 to 1.8 GHz. The far-field radiation pattern of the dipole antenna was found by post processing the FDTD frequency domain data at specific frequencies and these are compared with measurements performed in an anachoic chamber. The calculated (shown only for 1.2 GHz) and the measured co-polar radiation patterns for the principal planes are shown in Fig 3. The measured cross-polar levels (not shown) were 20dB lower than the co-polar levels. The far field patterns were obtained for 0.8 and 1.2 GHz, which corresponds to the lower and upper operating frequencies of the antenna.

Although better than –10dB antenna feed match was obtained from 0.8 to 1.8 GHz, due to the formation of a null at 0^0 in the H plane pattern, the antenna could only usefully be operated from 0.8 to 1.2 GHz. The null formation is due to bowtie-ground plane spacing, which corresponds to $\lambda/4$ at 1 GHz.

It should be noted that in the FDTD model, the tapered strip line and the bowtie are staircase approximated to fit the actual dimensions. The connector, the dielectric substrate losses and the finite size of the antenna ground plane were also not incorporated in the FDTD model. These effects were the prime cause of the small difference seen in FDTD model and practical measurements.

Analysis with soil: Since the antenna element is to be employed in a SPR system, the input and radiation characteristics have been analysed incorporating soil in the FDTD model. Homogenous soil was modelled with a dielectric constant of 4 (equivalent to sandy loam), which was placed 2 wavelengths (at 1 GHz) from the antenna element (for the non-contact mode PRSF-SPR being developed here). The computed radiation patterns in soil were similar in shape to those in figure 3 with reduced half power beamwidths due to refraction in soil. The measured and calculated input responses were almost identical to fig 2 as the 2λ antenna-soil separation produces marginal effects and would have no effects in the operating bandwidth.

Conclusions: It has been shown that this design of the printed bowtie antenna produces a bandwidth of approximately 40% and a beamwidth of approximately ± 45^o in air. Antenna analysis with soil further demonstrated that the antenna characteristics are only marginally affected by the presence of soil as the spacing between element and soil of this non-contact SPR is 2λ.

REFERENCES

1. Benjamin R, Synthetic Post Reception Focusing in Near Field Radar, EUREL/IEE Conference on the detection of abandoned Land Mine, Edinburgh, pp. 133-137, Oct 1996.
2. R.Nilavalan, G.S.Hilton and R.Benjamin, A FDTD Model for the Post-Reception Synthetic Focusing Surface Penetrating Radar, Proceedings of the IEE Conference on Antennas and Propagation, York, pp. 69-72, 1999
3. G.H.Brown and O.M.Woodword Jr, Experimentally determined radiation characteristics of conical and triangular Antennas, RCA Review, Vol. 13, pp. 425-452, 1952.
4. G.Mur, Absorbing Boundary Conditions for the Finite Difference Approximation of the Time Domain Electromagnetic Field Equations, IEEE Transactions on Electromagnetic Compatibility, Vol. EMC-23, No. 4, 1981, pp. 377-382.

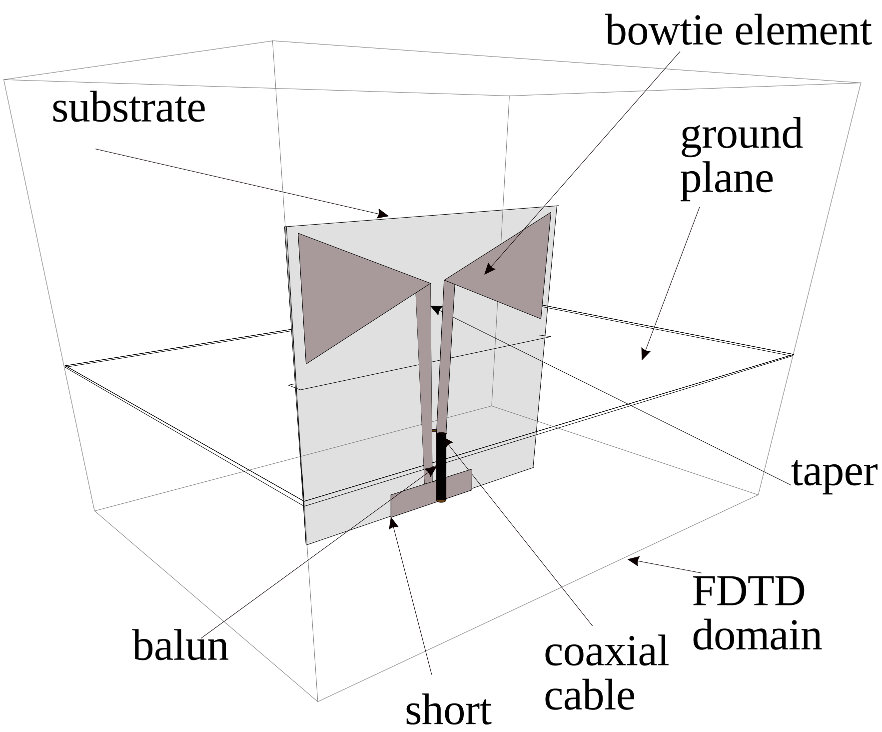

Figure 1: The FDTD antenna model

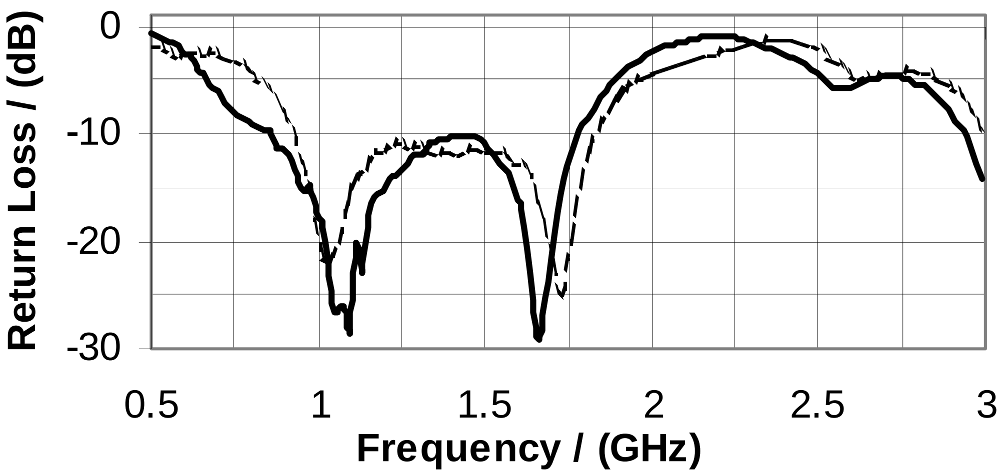

Figure 2: Input response of the antenna
______ measured
--------- FDTD

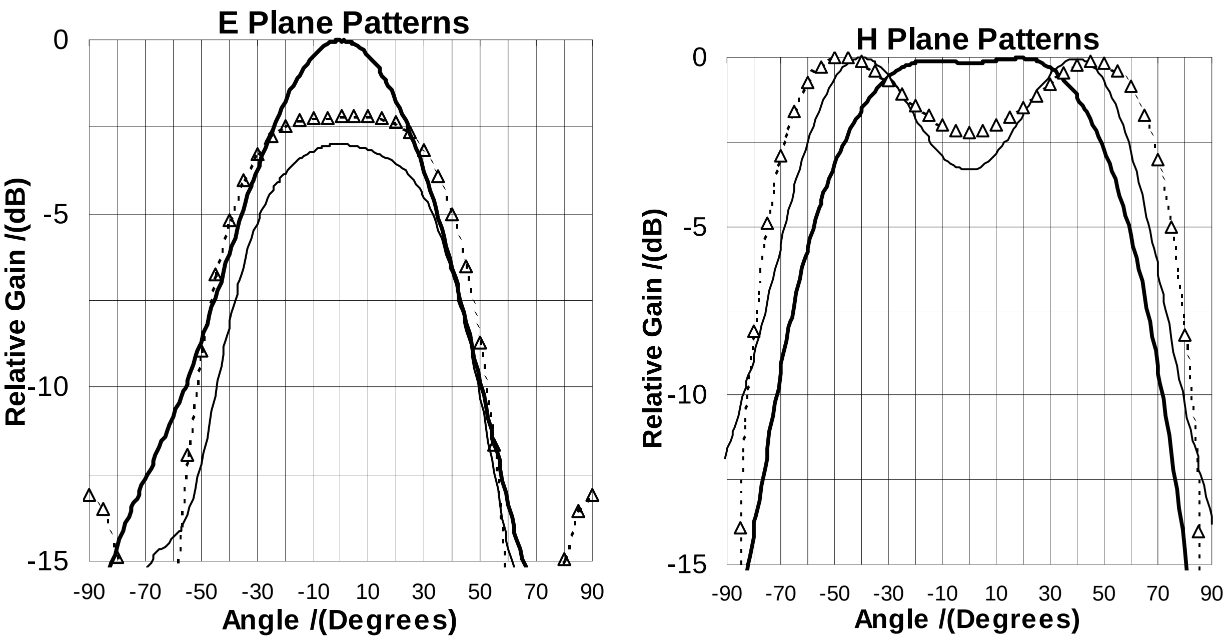

Figure 3: Far field radiation patterns
________ measured-copolar at 0.8 GHz
________ measured-copolar at 1.2 GHz
----Δ------ FDTD-copolar at 1.2 GHz