Ultrawideband Antipodal Vivaldi Antenna for Road Surface Scanner Based on Inverse Scattering

Tarik Namas [1] and Moamer Hasanovic[1]

[1] Faculty of Engineering and Natural Sciences
International University of Sarajevo, 71320 Sarajevo, Bosnia-Herzegovina
tnamas@ius.edu.ba, mhasanovic@ius.edu.ba

Abstract: High quality inverse scattering based scanner for pavement nondestructive testing needs a high performance antenna with certain characteristics. This paper considers an UWB antipodal Vivaldi antenna for this application. Simulation results for the targeted frequency range obtained through the use of Sonnet modeling software show that this antenna is characterized by a good match over the broad frequency range as well as a frequency dependent gain. The antenna performance has also been analyzed in the near field by considering tangential electric fields in the close proximity of the radiating structure.

Keywords: Ultra-Wideband (UWB), Vivaldi antenna, Inverse scattering, Sonnet

1. Introduction

The antenna described in this paper is a part of a larger research project with a goal to develop a scanning device based on inverse scattering methods and used for accurate, non-destructive, and inexpensive characterization of road pavements. The system will use a state-of-the-art, fast and accurate numerical solver for 3D inverse scattering problems in stratified media. The solver will utilize as input the measurement data provided by the antenna scanner to reconstruct several properties of the paved structure under test.

The pavement under test will be illuminated by a number of transmitting antennas, and the scattered field collected by receiving antennas in the measurement plane. The scanning system will measure the amplitude and phase of the scattered electric and magnetic field vectors at the receiving antennas, at a set of discrete frequencies in the microwave range. Both monostatic and bistatic measurement configurations will be considered [1].

Based on the collected data, the inverse scattering problem will be created and its solution used to reconstruct geometric, electromagnetic, mechanical, structural and chemical properties of the material layers of the pavement structure. The system will also be capable of full or partial capturing of the cracks and other in-homogeneities in the structure.

In order to meet the top-level requirements of the larger system, i.e. in order to supply the numerical solver with an accurate, comprehensive set of data, the antenna configuration used in the system interface must be characterized by the following properties: (1) Broadband coverage (UWB) – frequency range 4-10 GHz, (2) Linear polarization, (3) Good return loos (8-10 dB) and good radiation efficiency over the entire frequency band, (4) Major lobe in broadside direction (towards the scanning surface) and reduced back-lobe in backside direction, with a good front-to-back ratio of 10dB or better, (5) Large 3 dB beam-width of minimum 20^o to enable a wide scanning surface for near field measurements, and (6) Consistent radiation patterns throughout the entire frequency band.

The most suitable antenna geometry for the above requirements would be some sort of broadband (ultra wideband) antenna or antenna array. A couple of choices have been considered – horn antenna, broadband dipole or monopole, Vivaldi geometry or some sort of patch antenna with a good feeding (preferably slot in order to avoid undesirable reactance that comes with other types of feeds). Stacked patch antennas with slot feeds have also been considered as a suitable choice for this application.

2. Description of Antenna

In this paper we are considering an antipodal Vivaldi antenna. Vivaldi antennas are among the envisaged choices to meet the requirements of the design due to their high gain, small size, relatively wide band, simple structure, easy fabrication, and frequent use in UWB applications. These antennas based on the tapered-slot-antenna (TSA) architecture can also be integrated to work in transmitter/receiver modes.

An antipodal Vivaldi antenna has three main sections; microstrip line feed section, transition section and radiating section. The design under consideration was suggested by [2], and it is shown in Fig 1. The tapered semi elliptical arcs of the antenna aim to reduce reflection by ensuring a continuous transition. The transition sections with its gradient structure work as a wide bandwidth balun.

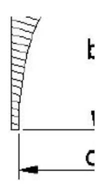

Fig 1. Geometry of antipodal Vivaldi antenna under consideration.

The design of the antenna is a tradeoff between its dimensions and the performance; the parameters of the considered antenna are similar to the optimum parameters found in the original design given by [2]. They are: *a =16.15mm,b =21.6mm, c =1.8mm, d =10mm, l =25mm, w =12.7mm.* The overall antenna size is *46mm *45mm * 0.8mm.*

The antenna is fed by a microstrip line, while the substrate board which has 2.55 of dielectric constant is PTFE, the loss tangent is 0.002 and the thickness of the board is 0.8 mm.

3. Antenna Simulation in Sonnet

For the purpose of evaluating its performance and suitability for the application described above, the antipodal Vivaldi antenna has been modeled, simulated, and analyzed in Sonnet, version 13.56. As curved lines and splines based on equations are not easily drawn in Sonnet, we have used AutoCAD to create antenna geometry. The corresponding dxf file has then been imported into the Sonnet to create the full antenna model ready to be analyzed by the Sonnet solver. An alternative approach to creating the antenna model is also under consideration in which Matlab program would be used to parametrically define the curved edges of the antenna and then to use the SonnetLab API to convert to a Sonnet model.

A careful attention has been paid to other important elements of the model. At this point it is important to remind any user of Sonnet software that Sonnet uses open waveguide simulator technique to simulate radiating structures. In order to properly use this technique, the antenna model must meet certain conditions. First condition is for the lateral substrate dimensions to be greater than one wavelength. In order to avoid any fringing fields, we have added more than λ/4 from the metallic edge of the antenna to the edge of the substrate that carries the antenna. Also, at least λ/2 has been added between the metallization and the top and bottom of the outer box in order to avoid any fringing fields associated with the near field zone. The top and bottom of the outer box are still metal, but they are changed to a really lossy metal, designed to lose radiation at the same rate free space would. The antenna model has been shown in Fig. 2.

Fig 2. Different views of the simulated antenna: 3D view (left), top view (right).

Antenna has been simulated in the frequency band 4-10GHz. Figure below shows the current distribution on the antenna at frequency 6GHz.

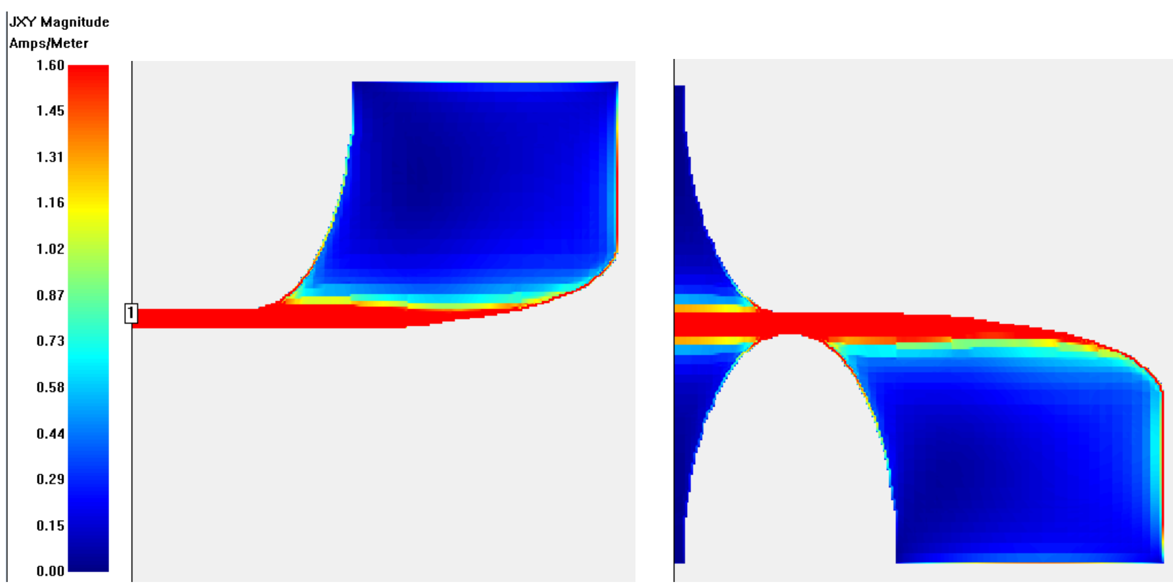

Fig 3. Current distribution on the antenna (frequency f=6GHz).

As Fig. 4 shows, the antenna is characterized by return loss of less than -10 dB over the entire frequency band (4-10 GHz). It can also be shown that this return loss mainly depends on three geometrical parameters d, l, and w (see Fig. 1). [2]

Fig 4. Return loss of the simulated antenna.

Radiation pattern for the simulated antenna can be obtained from the Far Field Viewer. This software feature utilizes the current density data produced by the electromagnetic simulator to create the antenna radiation pattern. Fig. 5 and Fig.6 present the radiation patterns of the antenna in H-plane and E-plane, respectively.

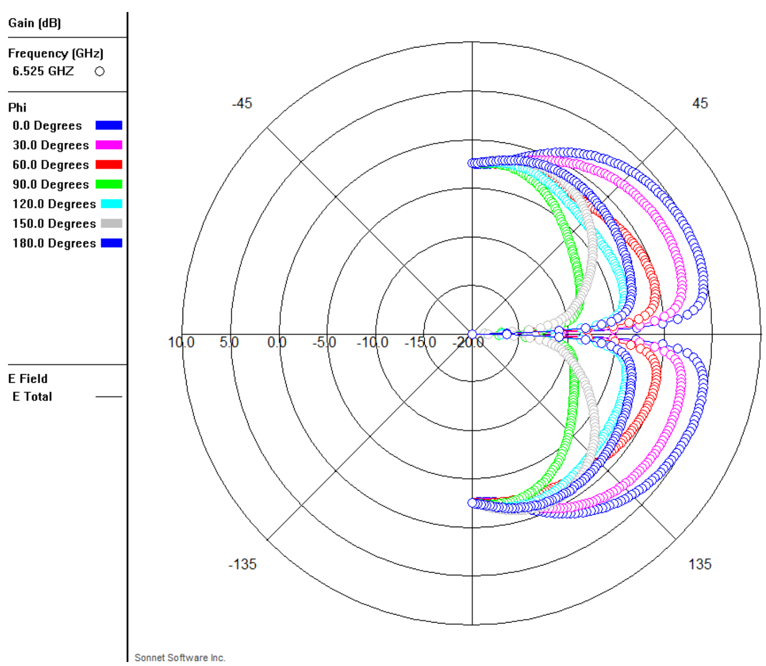

Fig 5. Far field radiation pattern of the simulated antenna at f=6.525GHz (H-plane).

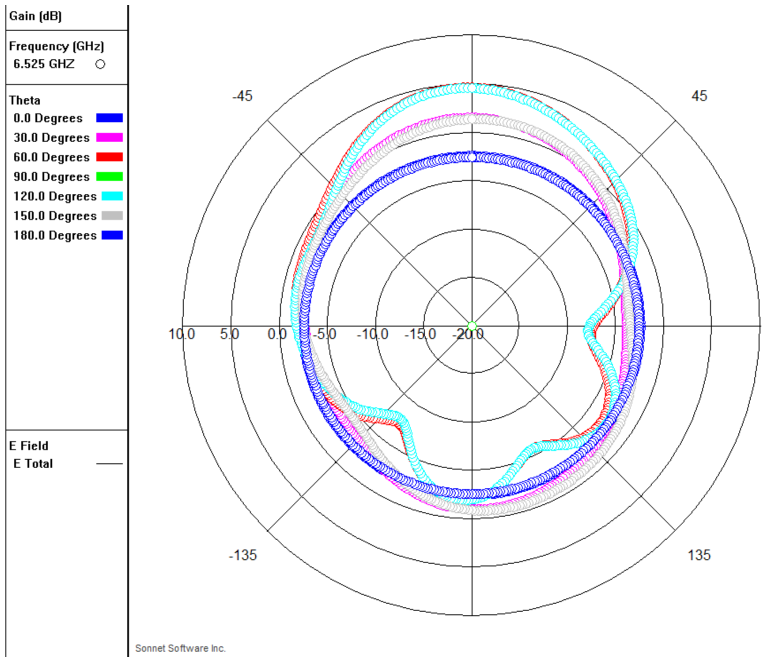

Fig 6. Far field radiation pattern of the simulated antenna at f=6.525GHz (E-plane).

Fig. 7 shows the frequency dependence of the maximum gain. As observed, the maximum gain reaches its peak at around 6 GHz. The gain is shown for various values of angle θ and for $\phi=0^o$.

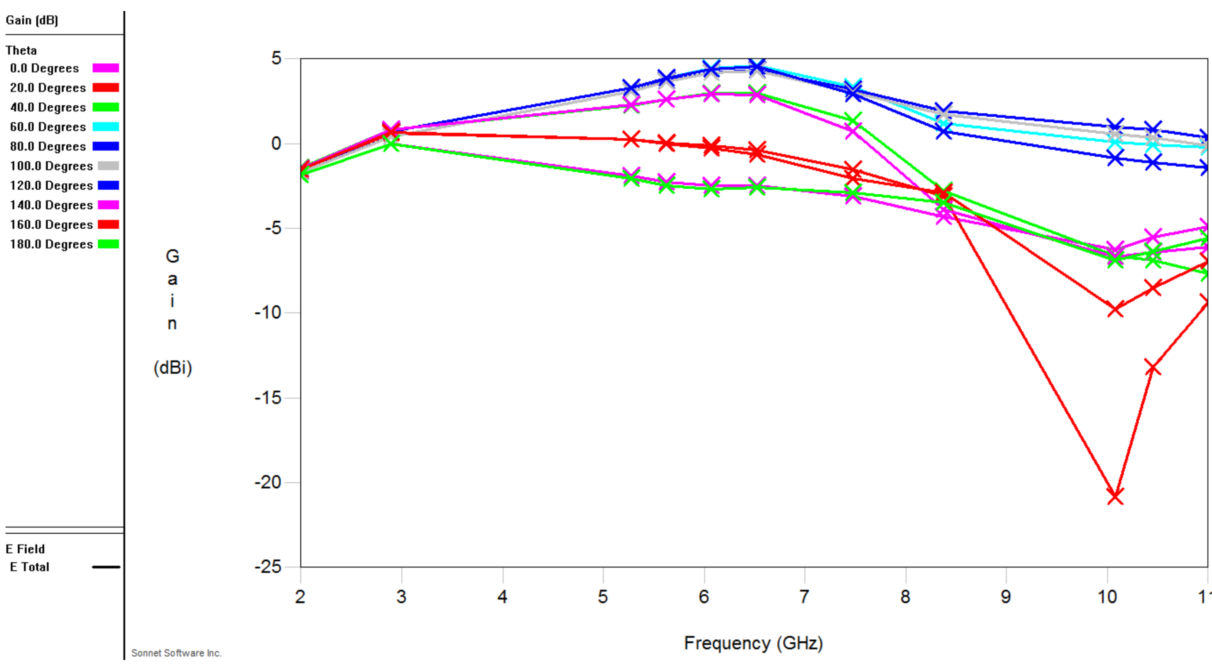

Fig 7. Far field radiation pattern of the simulated antenna at f=6.525GHz (E-plane).

As the application of interest requires antenna operation in the near field, we are currently investigating various ways on how to evaluate this antenna in the near field. One approach for example would be to use “sense metal” feature to view the tangential E-fields on any pre-defined plane. The results of this analysis will be included in the final draft of the paper.

4. Conclusion

This paper presents the simulation performance of antipodal Vivaldi antenna obtained through the use of Sonnet Software. Sonnet proved to be a very valuable, efficient, and affordable simulation tool for the purpose of obtaining preliminary results for this as well as other types of antennas considered for the use in the application of interest.

5. Acknowledgments

The authors express their warm thanks to Greg Alton from Sonnet Software for providing software licenses as well as for many useful suggestions during the process of antenna modeling and simulation.

References

[1] M. Hadziabdic et al, “Advanced Non-destructive Characterization of Roads (ANCHOR)”, Proposal for Seventh Framework Programme (FP7), by International University of Sarajevo, 2011.

[2] L. Yang, H. Guo, X. Liu, H. Du, and G. Ji, “An Antipodal Vivaldi Antenna for Ultra-Wideband System,” IEEE International Conference on Ultra-Wideband (ICUWB2010), 2010