Microwave Detection using Real Measurement Data

Douglas A. Woten[1], Obadiah Kegege[2], Reza Hajihashimi[3], Ahmed Hassan[3] and Magda El-Shenawee[3]

[1] Microelectronics-Photonics Program
University of Arkansas, Fayetteville, AR 72701, USA
dwoten@uark.edu

[2] Space and Planetary Science Program
University of Arkansas, Fayetteville, AR 72701, USA
okegege@uark.edu

[3] Department of Electrical Engineering
University of Arkansas, Fayetteville, AR 72701, USA
magda@uark.edu

Abstract: An experimental setup is under development for testing microwave detection and imaging algorithms. The setup uses broadband antennas to send and receive electromagnetic waves from around the target. The system employs only two antennas; one transmitter and one receiver. These antennas are rotated around the target controlled by the Labview program. The preliminary results show accurate determination of the targets location.

Keywords: Microwave detection and broadband antennas.

1. Introduction

An experimental setup is built at the University of Arkansas for validating numerical algorithms developed for target detection. These numerical algorithms were designed for multiple applications including statistical detection of breast tumors [1] and shape and location reconstruction [2]. These algorithms rely on forward solvers based on the Method of Moments and the Finite Element Method. The development of a hardware system allows these algorithms to be tested on real measurements and vice-versa.

2. Experimental Setup

A broadband antenna is connected to each port of the VNA to measure the S-parameters (S_{11},S_{12},S_{21} and S_{22}). Each of these antennas is connected to a rotating arm controlled independently by an HIS DCM 8028 motion control driver. Each driver controls a PowerMax II hybrid stepper motor. The stepper motors allows each antenna to rotate around a central location independently, with 1.8° angular steps. Rotating the antennas allows for the collection of a large amount of data from all around the target without using an array. The setup relies on a HP 8510C Vector Network Analyzer (VNA) to analyze the received signals. This 2-port VNA model allows for frequency sweeps from 45MHz to 26.5GHz with up to 801 points per sweep. The VNA communicates directly with a central computer through a GPIB cable. The computer provides a central control for all the various components and acts as a collection point for the measured data. A sketch of the experimental setup is shown in Fig. 1.

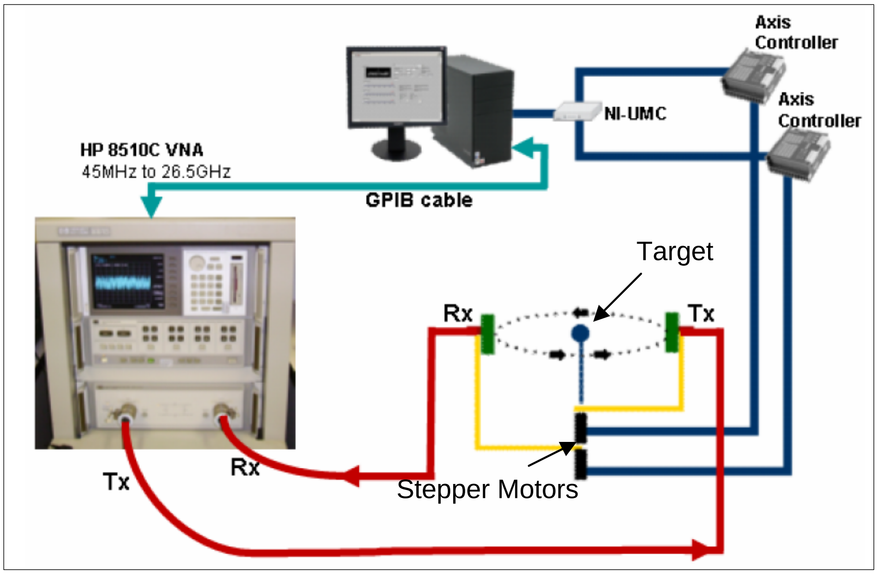

Fig. 1. Schematic of experimental setup.

The antennas considered here are the cavity backed spiral antenna, log periodic antenna and the Vivaldi antenna. The spiral and log periodic antennas were purchased from commercial vendors (BAE Systems), while the Vivaldi antennas were fabricated to specification by Obadiah Kegege at the University of Texas Pan-American [5]. For the preliminary results presented here the Vivaldi antennas were used.

As a first step, it is necessary to validate the performance of the Vivaldi Antennas in the frequency band of interest. Measuring the input impedance of each antenna in the frequency band (2-18GHz) allows for the measurement of the VSWR. The VSWR is given by:

$$VSWR = \frac{1+|\Gamma|}{1-|\Gamma|} \quad . \tag{1}$$

The measured VSWR for the two antennas is shown in Figs. 2 and 3. These results show that the VSWR is below 3 from 2GHz to 18GHz for antenna 1 in Fig. 2, while it is higher for the second antenna shown in Fig. 3.

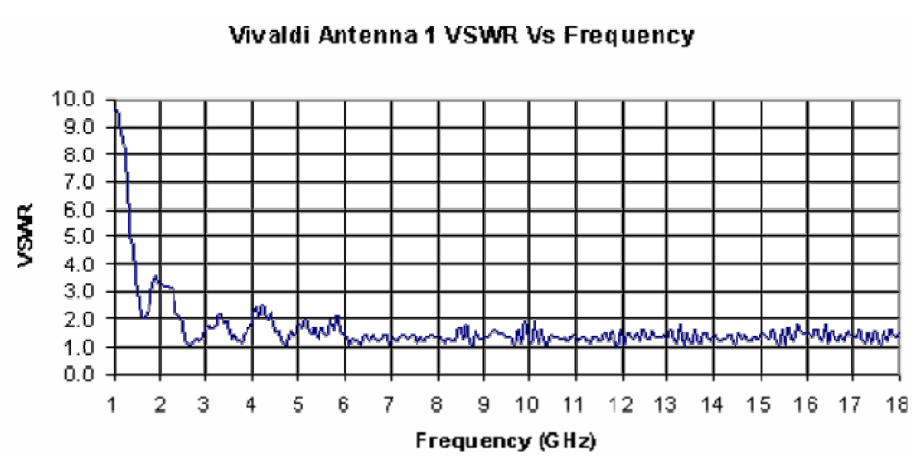

Fig. 2. Measured VSWR of Vivaldi antenna 1.

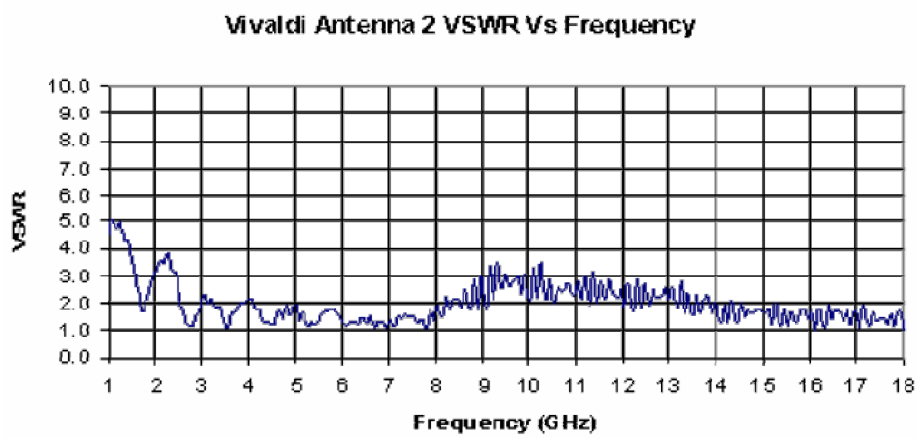

Fig. 3. Measured VSWR of Vivaldi Antenna 2.

The system is then calibrated using the kit supplied with the network analyzer. First the antennas are connected to the VNA and are placed a known distance from each other. A “Thru” calibration is conducted to remove any effects of the transmission lines. Then a calibrating target is positioned at a known distance from the antennas. This is implemented to offset any errors in the range/distance profile to ensure accurate measurements. Figure 4 shows the configuration for the later calibration procedure.

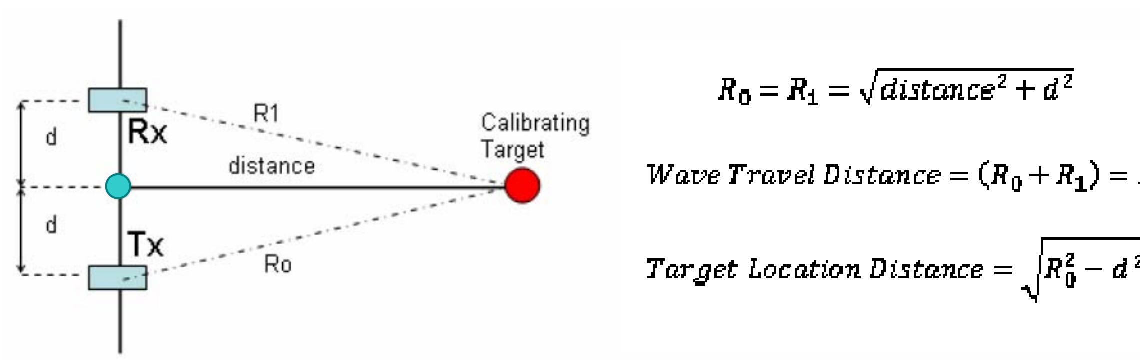

Fig. 4. Configuration for transmission measurement calibration.

Once all calibrations are completed, measurement data is collected using the VNA. The frequency domain data from the VNA is passed to a PC where MATLAB is used for signal processing. The data is transferred to the time domain using a Fourier Transform and analyzed to determine the position of the object. A schematic of this process is shown in Fig. 5.

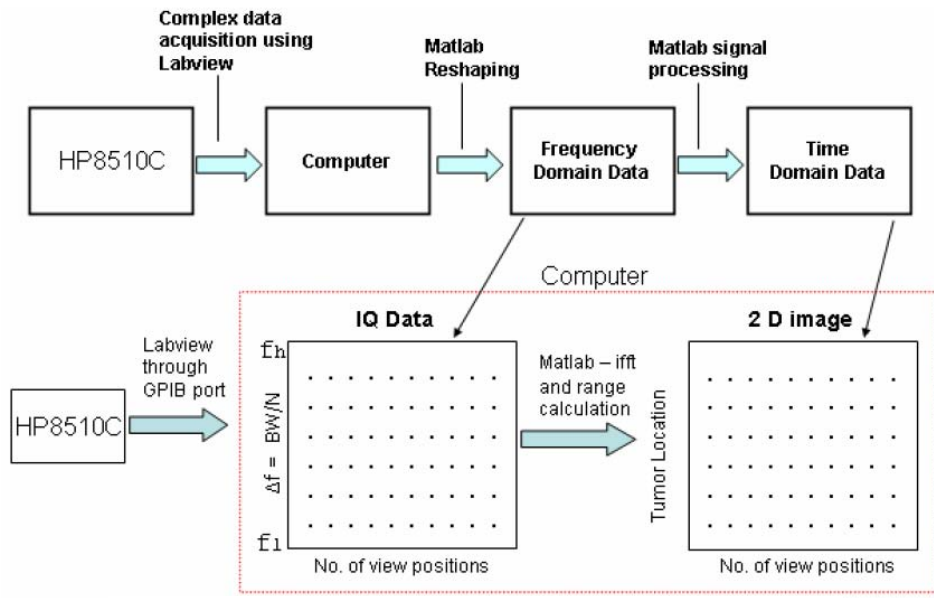

Fig. 5. Schematic of data acquisition and signal processing.

3. Preliminary Results

An initial test was conducted using a metallic plate and a single measurement angle of 0° (backscatter). The metallic plate is placed at 40cm away from the antenna faces. In this case, the two antennas are located above the plate. Figure 6 shows the analyzed signal showing the initial antenna to antenna reflection followed by the reflection from the metal plate. Repeating the measurement without the metallic plate and subtracting the result from the total allows for the calculation of the reflection from only the metallic plate. Subtracting antenna to antenna reflection allows for a clear determination of the location of the metallic plate as shown in Fig 7.

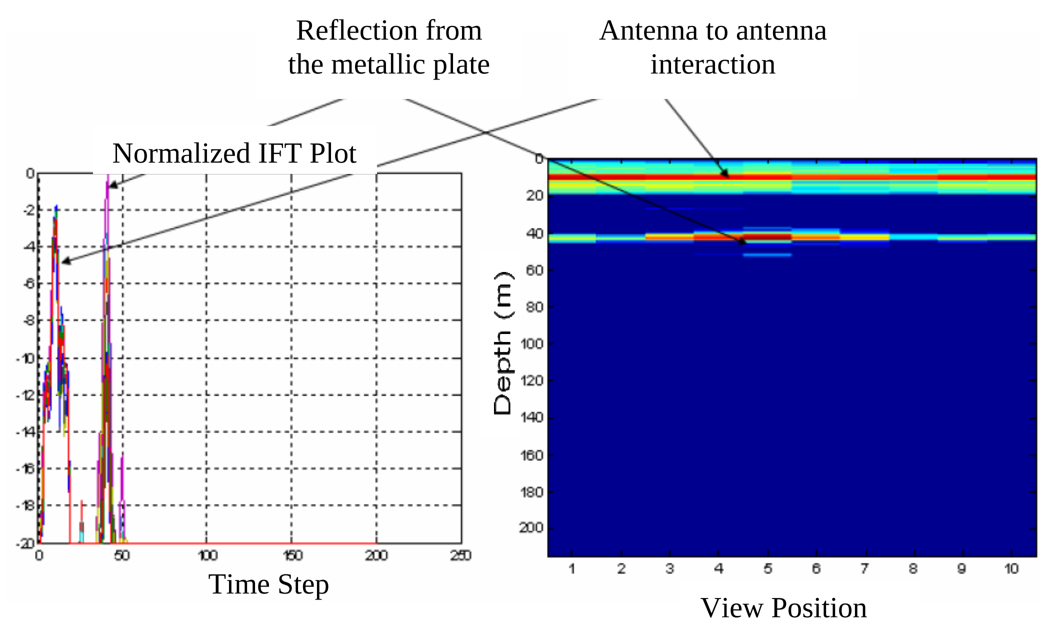

Fig. 6. Measured data when a metallic plate is placed approximately 40cm from the antennas.

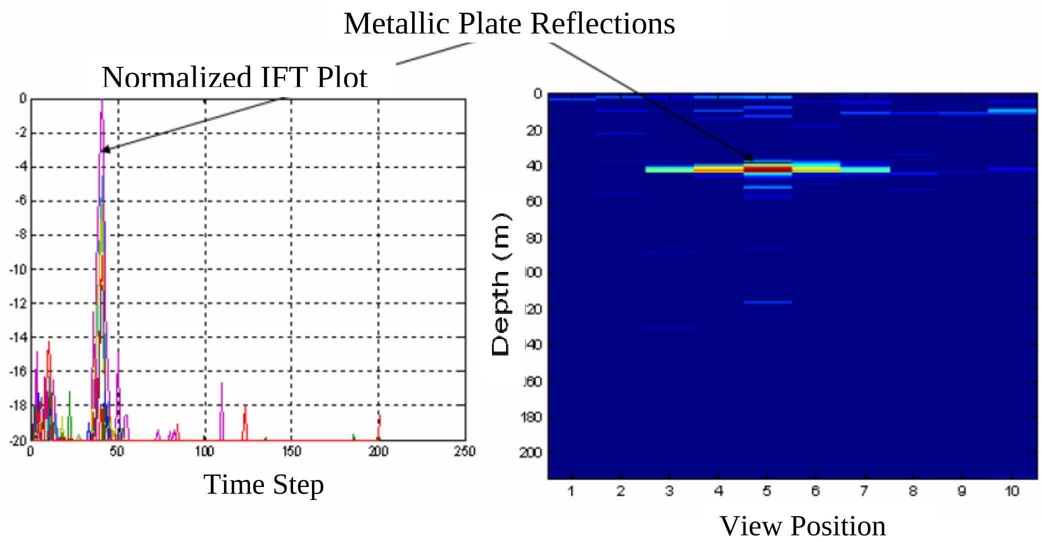

Fig. 7. Measured data when a metal plate is placed approximately 40cm from the antennas and antenna to antenna interaction is removed.

This process is repeated where a glass ball was suspended approximately at 10cm away from the transmitting antenna. Measurements were taken every 36° round the target for a total of ten measurements. Figure 8 shows the analyzed signal showing the ball placed approximately 10 cm away from the transmitting antenna at each measurement angle.

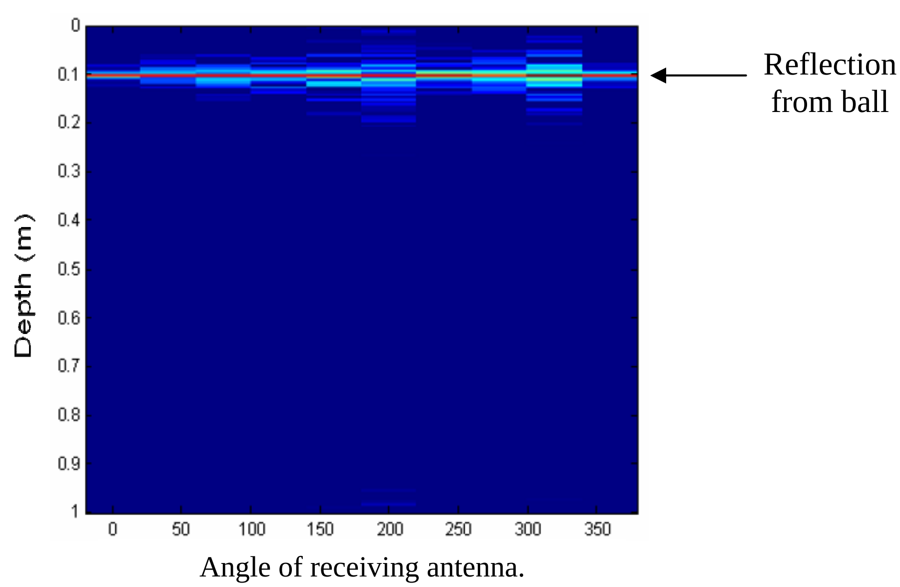

Fig. 8. Measured results from glass ball suspended 10cm away from antenna.

To reduce the significant noise present in the measurements, a chamber of 75cm×75cm was built using microwave absorbing material. The absorbing material used is a graded-dielectric absorber which is capable of reducing reflectivity levels by -20dB (RFProducts). This material is designed specifically to reduce the reflected signals and eliminate the interference. The antennas are fed through a small opening in the bottom corner of the chamber. Results show that the noise is considerably reduced when using the chamber and allows for increased accuracy in determining the target’s position.

4. Conclusions and Future Work

Preliminary results utilizing the experimental hardware setup is presented. These preliminary results show that the system is operating reasonably when tested on simple targets. The real measurements to be collected using this system will be employed to validate three imaging and detection algorithms under development. The first statistical detection technique was developed based on artificial neural network (ANN) [1]. The second imaging algorithm is based on the adjoint-fields scheme [4]. The third imaging algorithm is based on the Level Set method [5]. The validation results using real measurements will be presented in the conference.

5. Acknowledgements

This work funded in part by the National Science Foundation Graduate Research Fellowship, National Science Foundation GK-12 Program, National Science Foundation Graduate Research Supplement, the University of Arkansas Doctoral Academy Fellowship, and the National Science Foundation Award Number ECS – 0524042.

References

[1] D. A. Woten, J. Lusth and M. El-Shenawee, "Interpreting Artificial Neural Networks for Microwave Detection of Breast Cancer," *IEEE Microw. Wireless Comp.*, Vol. 17, no. 12, Dec. 2007.
[2] M. El-Shenawee and E. Miller, "Spherical Harmonics Microwave Algorithm for Shape and Location Reconstruction of Breast Cancer Tumor," *IEEE Transaction on Medical Imaging*, Vol 25, pp. 1258-1271, 10/2006.
[3] Obadiah Kegege, "Ultra-Wide Band Radar for Near-Surface and Buried Target Detection," M.S. Thesis, University of Texas Pan American, Edinburg, TX, 2006.
[4] Magda El-Shenawee, Oliver Dorn and Miguel Moscoso, "Reconstruction of Irregular Shape of Breast Cancer Tumor Using the *Adjoint*-Fields Scheme in the Microwave Imaging Algorithm," *Proc. of the Applied Computational Electromagnetics*, pp. 1288-1293, Verona, Italy 2007.
[5] Ralph Ferraye, Jean-Yves Dauvignac, and Christian Pichot, "An inverse scattering method based on contour deformation by means of a level set method using frequency hopping technique," *IEEE Trans. Antenn. Propagat*. Vol. 51, no. 5, pp. 1100-1113, May 2003.