YÜZEYE YAKIN YAPILARIN BELİRLENMESİNDE
JEOFİZİK VE UZAKTAN ALGILAMA SEMPOZYUMU
30 Nisan – 2 Mayıs 2008 İzmir

HIGH RESOLUTION 2-D AND 3-D IMAGE GENERATION AT MICROWAVE FREQUENCIES: APPLICATION TO REAL SOIL MEASUREMENTS

Ozdemir, Demirci and Yigit.

***Mailing Address*:** Dept. of Electrical-Electronics Engineering, Mersin University, Ciftlikkoy, Mersin, 33343 TURKEY.
***E-mail*:** cozdemir@mersinedu.tr, sdemirci@mersin.edu.tr, enesyigit81@mersin.edu.tr

Keywords: Ground Penetrating Radar, B-scan, C-scan, 3-D Imaging.

ABSTRACT

In this paper, detailed ground penetrating radar (GPR) survey on detecting and imaging of shallowly buried objects in real soil medium is presented. The dataset is collected by B-scan and C-scan measurements with the help of a GPR system operating with a stepped-frequency continuous wave (SFCW) radar. The classical and newly developed imaging procedures are then applied to obtain high resolution 2-D and 3-D GPR images. Within these images, the key scattering mechanisms from the subsurface environment are clearly displayed and the GPR signatures of electrically different objects varying from metals to dielectrics are compared.

INTRODUCTION

A common way of generating high resolution subsurface images is to use ground penetrating radar (GPR) technique (Daniels 2004). Generally, successful GPR imaging techniques require increased transmission bandwidth to achieve the desired range (depth) resolution. Other critical issues are having an efficient EM coupling into the ground and having an adequate penetration depth up to the target (Lanbo 2004). In addition, the reconstruction algorithms need to be employed to be able to constitute a successful GPR imaging. For different field conditions; therefore, radar equipments (antenna, SFCW, impulse radar), measurement techniques (A-, B-, C-scans) and signal processing (migration, focusing) schemes have been employed at different applications by different researchers (Maida 2006, Morrow 2002, Ozdemir 2006, Yigit 2007). In this paper, we investigate the general uses and limitations of GPR imaging at microwave frequencies. For this purpose, we have conducted a series of GPR experiments to detect and image electrically different objects with a laboratory set-up and outdoor soil measurements. In these experiments, a stepped-frequency continuous wave (SFCW) radar was utilized. The data was collected within a broadband of frequencies (3 to 5 GHz and 4.8 to 8.5 GHz) in aiming to possess sufficient depth resolution. First, a B-scan measurement set-up was prepared for the outdoor soil medium. After collection of measured data out of the experimental set-up, classical GPR images were constructed. Then, a recently developed focusing technique for GPR imaging was applied (Yigit 2007). Distinguished electromagnetic (EM) signatures of the objects were clearly displayed and the detection performances were compared. Then, the measurements were extended to C-scan experiments to observe three-dimensional (3-D) visualization of the buried objects.

MEASUREMENT SET-UP

The experimental setup for measuring the backscattered fields from various buried targets is shown in Figure 1. For the measurements, we have utilized a stepped-frequency continuous wave (SFCW) system by the help of an Agilent E5071B ENA vector network analyzer (VNA) and various 3-5 GHz and 4-8 GHz horn antennas. For the B-scan configuration, the data was gathered along a straight synthetic aperture line. In a similar way, C-scan data was collected on a two dimensional spatial grid as illustrated in Figure 1. When the antenna platform moves along the synthetic aperture, the magnitude and the phase of the EM scatterings were measured at each discrete spatial point. The data gathered by VNA was then recorded to a computer via VNA's GPIB port.

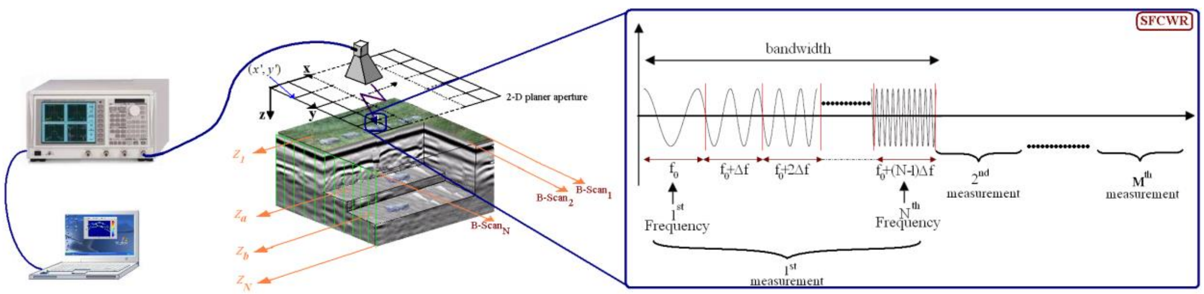

Figure 1. GPR measurement set-up and SFCW radar operation.

EXPERIMENTS AND IMAGING RESULTS

Initially, a B-scan experiment in an outdoor soil medium was conducted. Three objects, namely; a water-filled plastic bottle, a metal pipe and a metal plate were buried at a depth of approximately 15 cm. Two identical horn antennas were kept at a height of 25 cm above the ground surface in the bistatic mode. To provide satisfactory horizontal resolution, the frequency-diverse S_{21} data were collected in every 2 cm steps along the synthetic aperture of 130 cm. At each spatial point, the spectrum of the VNA was varied from 3 to 5 GHz for a total of 201 distinct frequency points.

Then, the classical B-scan image was formed by taking the IFT of the raw data along the frequency axis. The resulted B-scan GPR image is shown in Figure 2(a). It is observed from the figure that the water-filled bottle and the metal pipe targets have not been easily detected within the display's dynamic range of 20 dB. Of course, this is due to the strong bounce from the ground surface. This dominant scattering fairly masks weaker scattering mechanisms. It is also notable to observe that the signature of the metal plate is shown to be defocused. To enhance the image quality, our recently developed GPR imaging method (Yigit 2007) that focuses the EM signatures and increases the resolution was applied to the raw data. The resulted focused GPR image is presented in Figure 2(b). It is clear from the figure that reflections from all objects are greatly enhanced.

Moreover, the signatures of the objects are satisfactorily resolved by exposing an effective and reliable detection.

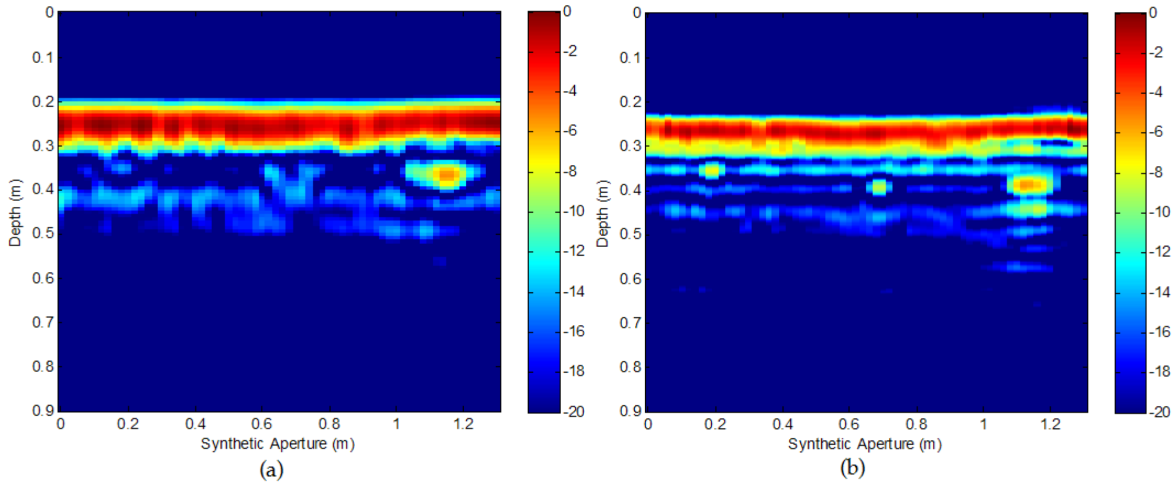

Figure 2. B-scan images of outdoor soil experiment. (a) Classical image (b) Focused image.

Next, a C-scan experiment in a sand medium was practiced. Four objects were buried at different depths and locations. According to the geometry in Figure 1, (x, y, z) coordinates of the buried objects in centimeter were; a piece of foam at (41, 30, 15), a plastic bottle filled with water at (4, 50, 21), a metal pipe at (18, 19, 25) and a metal plate at (38, 35, 38). A total of 16 B-scan measurements were performed in the y-direction to constitute the full C-scan process. For each B-scan along the x-axis, the synthetic aperture was of 60 cm in length for 21 discrete spatial points. The frequency was altered within the spectrum of 4.8-8.5 GHz for a total of 201 discrete points. 3-D visualization of the 3-D GPR image together with the objects is demonstrated in Figure 3. The 2-D images at various depths are also given in Figure 4. These figures indicate that the objects are accurately detected at their true locations. Also, 3-D GPR image representation provides better visual appearance thanks to C-scan processing.

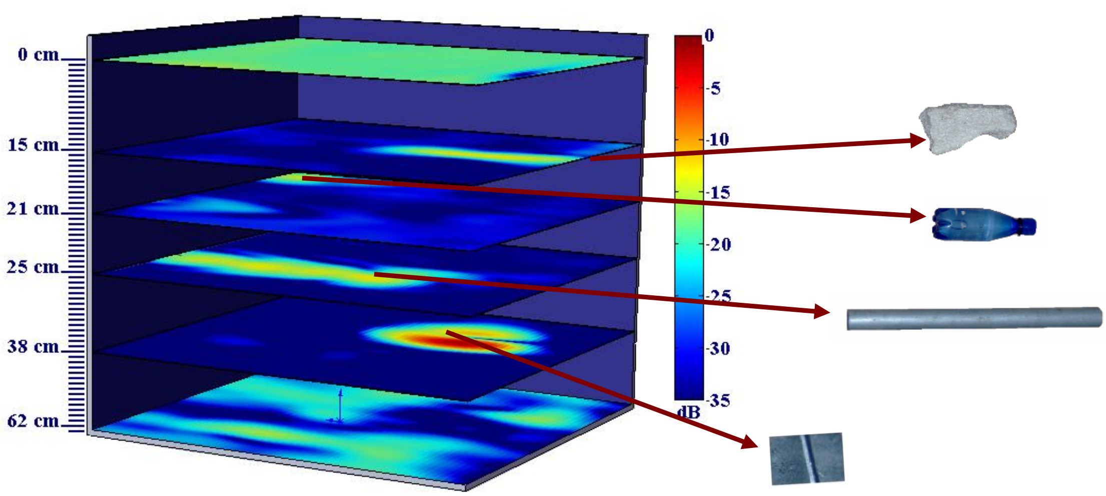

Figure 3. 3-D visualization of the buried objects.

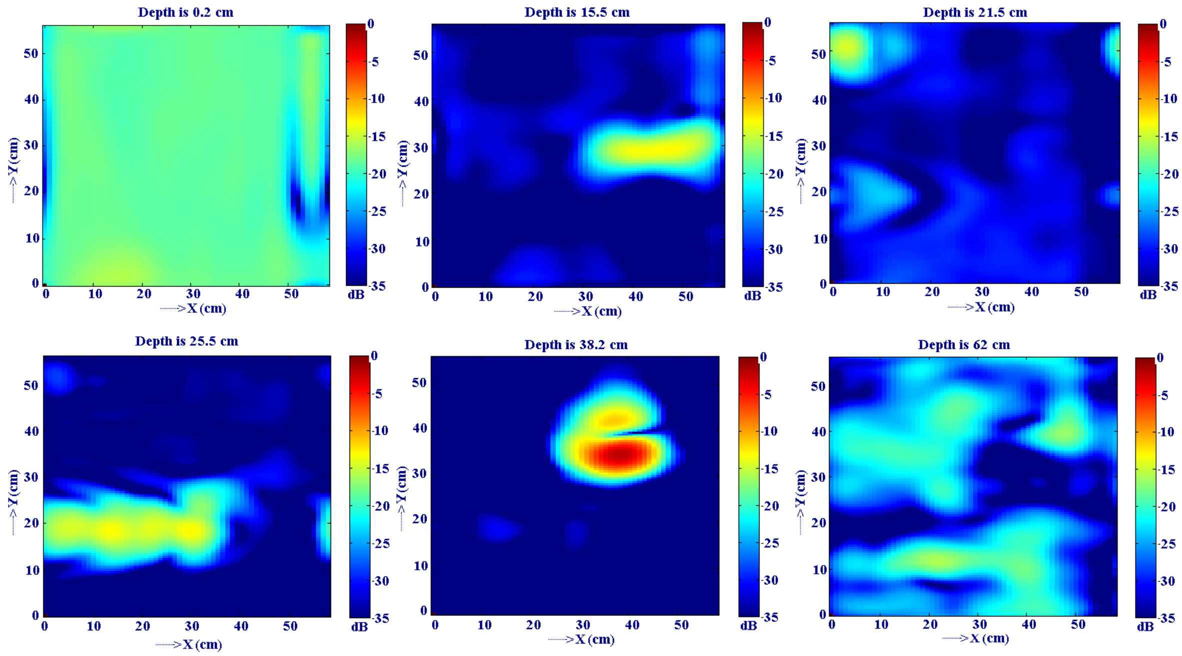

Figure 4. B-scan images of the C-scan experiment at various depths.

DISCUSSION AND CONCLUSION

High resolution GPR imaging of shallowly buried objects at microwave frequencies was investigated. Accurate and efficient 2-D and 3-D GPR images of various buried objects were acquired and presented. Applying microwave band of frequencies to the B-scan GPR imagery has yielded better resolved images. Application of recently developed focusing algorithm to the classical GPR images enhanced the quality of the images. The 3-D interpretation of GPR data has been demonstrated to be visually more effective.

ACKNOWLEDGMENT

This work is supported by the Scientific and Research Council of Turkey (TUBITAK) under grant no: EEEAG-104E085.

REFERENCES

Daniels D. J. 2004. ***Ground Penetrating Radar***, 2nd Ed., IEE, London.

Lanbo L. and Lieyuan Z. 2004. GPR signal analysis: can we get deep-penetration and high-resolution simultaneously. ***Tenth International Conference on Ground Penetrating Radar (GPR 2004)***, Delft University of Technology, Netherlands.

Maida A., Pennock S. R. and Shepherd P. R. 2006. Detection and resolution enhancement of closely spaced targets in ground penetrating radar. ***11th International Conference on Ground Penetrating Radar Columbus***, Ohio, USA.

Morrow I. L. and Genderen P. V. 2002. Effective imaging of buried dielectric objects. ***IEEE Transactions on Geoscience and Remote Sensing*** 40(4), 943-949.

Ozdemir C. and Ling H. 2006. An experimental investigation of buried object imaging in a homogeneous medium using synthetic aperture radar concepts. ***Microwave Opt. Tech. Letters*** 48(6), 1209–1214.

Yigit E., Demirci S, Ozdemir C. and Kavak A. 2007. A synthetic aperture radar-based focusing algorithm for B-scan ground penetrating radar imagery. ***Microw. Opt. Tech. Letters*** 49, 2534-2540.