GROUND PENETRATING RADAR TECHNOLOGY - THE USAGE IN AGRICULTURE

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Abstract: *This paper presents one of active remote sensing technology, based on the use of electromagnetic waves from the microwave frequency range - Ground Penetrating Radar scanning technology (GPR). GPR technology is classified as near surface sensor radar scanning technology. From the point of the usage of GPR technology, where the antenna is close to, or in contact with the surface layer, the application is based on the analysis of both geometric and general characteristics of underground soil layers to a depth of 10m. Using a comparative analysis through the most important examples, a common area of GPR application in the form of complex, composite technologies is defined*.

Key words: *GPR technology, soil classification, volumetric moisture content.*

INTRODUCTION

The term "radar" is shortened from "**RA**dio **D**etection **A**nd **R**anging" and accepted in nowadays terminology. Radar belongs to the group of active sensors for remote sensing. Emitting part of radar antenna sends electromagnetic (EM) waves, which reflect from detected object to a receiving part of the antenna (WOODHOUSE, *2006*). Radar works in microwave range of EM spectrum, mostly in frequency range of 0.05-40GHz. Various applications of radar technology are common nowadays, and have an expanding trend. Primary functions of radar are remote sensing and monitoring of the flying objects (RICHARDS, *2005*), followed by the appropriate visualization of the results. Monitoring of the flying objects is a real time process. The central discussion of this paper is directed to objects detection and visualization, which involves acquisition and processing of the signals reflected from the detected object.

Historical development of the GPR scanning technology (DANIELS, *2004*), has its beginnings in the demonstration of reflection of electromagnetic waves, that was held by Hertz in 1886. In 1900, Tesla explained concepts of EM detection and speed measuring, in detail. In 1926, Hülsenback defined first usage of impulse radar technique for detection of underground objects. In period from 1930 to 1970, impulse radar techniques were used to analyze geologically specific areas, such as ice deposits, rivers, saline dry deposits, desert formations, collieries etc. During past thirty years, new ways of GPR applications were developing evenly, but the most important - fundamental event was emerging of non-military applications (last years of previous century) and development of new, special GPR types adapted for long distance scanning of the underground layers. Thereafter, the development of GPR was performed in two directions:

- The first one (REIGBER, *2001*), which includes simultaneous scanning of large areas, embracing a dozens of square kilometers, with radar antennas placed on a long distance from surface area (SAR). Widely used spatial resolutions are in between 0.5-10m. The research was commenced in late 1970s, and was intensified in 1996, after first successful mission to the Mars. In period from 1996 to 2010, development and usage of SAR were expanding, with better results becoming available every day (RICHARDS, *2005*).

▪ The second one (ALLRED ET AL., *2008*), which includes scanning of relatively small areas (up to 1 km^2) and detection of long, liny objects (several dozens of km), with radar antennas placed close to or in touch with ground surface (GPR). Widely used spatial resolutions are in between 1-10cm. It is important to mention that there have been a certain number of applications in millimeter precision (RISTIĆ ET AL., *2009a)*. The depth is defined according to type of application and desired resolution:

- millimeter precision – the propagation depth in range of 0.1-1 m
- centimeter precision – the propagation depth in range of 1-10 m
- decimeter precision – the propagation depth in range of 10-200 m

In the beginning of 21st century GPR was gradually introduced as standard measuring equipment for geophysics, geodesy, civil engineering, hydrology, agriculture and other engineering disciplines (DANIELS, *2004*), (RISTIĆ AND PETROVAČKI, *2005*), (PETROVAČKI AND RISTIĆ, *2007*), (GOVEDARICA ET AL., *2008*), (RISTIĆ ET AL., *2009a*), (RISTIĆ ET AL., *2009b*), (RISTIĆ ET AL., *2009c*)).

MATERIAL AND METHOD

Remote sensing with the usage of antenna close to or/and coupled to the soil surface (GPR tehnology) can be divided in two groups: shallow surface surveying and deep borehole surveying ((DANIELS, 2004), (PETROVAČKI AND RISTIĆ, 2005)). The research presented in this paper analyzes the procedure for data interpretation, where the data were collected from radargram which is formed using shallow surface surveying technique. Data interpretation, where the data were collected using GPR scanning, refers to the soil type's characterization. GPR consists of: emitting/receiving antenna, control unit (with appropriate operating system), battery and survey cart. The vehicle is equipped with rotating incremental encoder, which provides precise positioning of the antenna center above the detected structural change (GOVEDARICA ET AL., *2008*). There is also a marker embraced in hardware, which is used for marking the position of interest in radargram during the data acquisition. Additional part of equipment is Global Positioning System (GPS) rover, which is used for georeferencing of collected data. Processes of scanning and measuring of the data can be held synchronized or separated from each other. First step in separated acquisition processes is to define spatial location of change in soil structure, using GPR. Maximal precision of positioning antenna above reflection is 0.65cm (1/4"), defined for all work circumstances. Final step, in acquisition process, is measuring of the antenna center coordinates, with GPS rover. During the synchronized acquisition, points on GPR antenna's trajectory are recorded either continually, or just start and end point of trajectory are recorded. Synchronized process includes direct communication of GPR and GPS rover (GOVEDARICA ET AL., *2008*). Functional parts of the equipment (Fig. 1b) and its connections (Fig 1a) are shown in Figure 1. GPR is suitable for analyses in different depths, in range of 0-10m. There is shielded antenna with frequency in range of 100-1600MHz, defined for each range of scanning depths and resolutions. In extreme cases, unshielded antenna (with frequency from 16-80MHz for depths from 0-50m) and (horn antennas with frequency 2.2GHz for depths up 0.75m) are used. All the other components of the system are mutual. As a result of geospatial data acquisition with GPR scanning, there is two-dimensional view of subsurface layer, called radargram. The radargram abscissa (x-coordinate) represents the antenna's trajectory during scanning, with defined scanning resolution (the number of emitted impulses per length unit, that is the number of emitted signal reflections recorded-"scans"). The radargram ordinate represents the depth of wave propagation, which is limited by acquisition demands and terms that are limited by the medium (RADAN, *2006*).

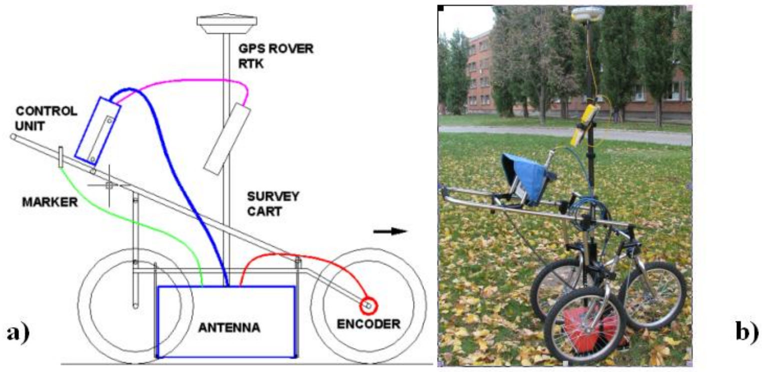

Fig. 1. One implementation of GPR technology

RESULTS AND DISCUSSIONS

One of the most interesting aspects of the application of GPR technology in agriculture is the estimation of lithological soil layers ((FREELAND ET AL., 1998) (ALLRED ET AL., 2008), (RISTIC ET AL., 2009)). Layers can be defined with centimetre accuracy, which provides significant automation of both processes: analysis of soil structure and procedures for land consolidation. The result of acquisition using GPR technology is radargram, presented in Figure 2, where all the results of the estimation of lythologic soil layers are marked. Classification process of lithological layers was performed using classical procedures of soil analysis in the control points.

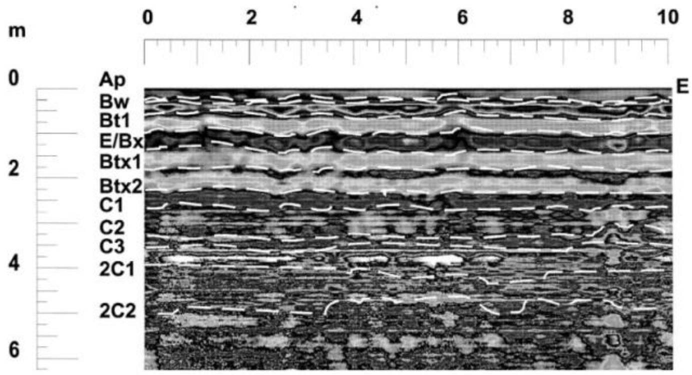

Fig. 2. GPR radargram with soil classification overlay

The results can be used for GPR device calibration and for the usage of GPR technology in the process of land consolidation, where the application of GPR technology significantly reduces the need for the pedology profile preparation. Figure 3 shows the comparative analysis of the results obtained from pedology profile and radargram of the same location, in the area of the village Selenca, Serbia ((RISTIC ET AL., 2007), (RISTIC ET AL., 2008)).

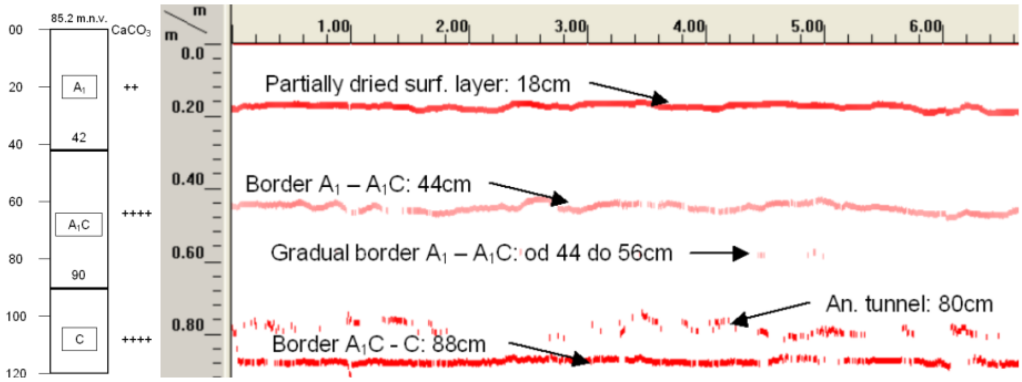

Fig. 3. GPR technology use for land consolidation

Since the value of the volumetric moisture content in the soil is directly related to the speed of EM waves ((HUISMAN ET AL., 2003), (RISTIC ET AL., 2009)), it is possible to perform radargram analysis and estimation of volume content of moisture in the soil, and also to perform monitoring of the spatial distribution of water/pollutants/agrochemicals, in other words perform the analysis of soil salinity ((YODER ET AL., 2001) (DOOLITTLE ET AL., 2006)). Figure 4 represents the appearance of new layers in radargram, which are a consequence of agrochemicals movements. Radargram results, shown in Figure 4, are given in the form of comparative analysis before (Figure 4a) and after (Figure 4b) treatment of soil with agrochemicals. Radargrams are formed on the soil thickness from 1m to 3m, below which there are underlying paleosol forms.

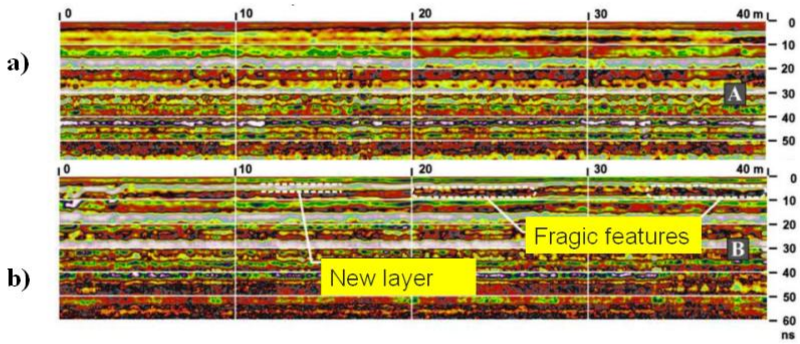

Fig. 4. GPR technology use for agrochemicals movement detection

GPR technology can provide rapid, quantitative-qualitative and non-destructive monitoring of changes in the development of root biomass of woody plants under the influence of irrigation ((BUTNOR ET AL., 2003), (SERBIN AND OR, 2005)). Monitoring is defined as the analysis of changes in the volume of the root biomass and lateral root biomass distribution, in case of systems with and without irrigation. Comparative radargrams of root biomass of loblolly pine (*Pinus taeada L.*) in loamy, kaolinitic soil, without (Figure 5a) and with (Figure

5b) the presence of irrigation systems are shown in Figure 5. Radargrams were processed using Hilbert's transformation of the signal. Correlation between the root coring procedure and the results obtained by GPR exceeds 85%. Using GPR radargram analysis, it is possible to define the impact of changes of the fertilizer types and amounts, and other silvicultural treatments. This approach to the case of compatible land can significantly reduce the number of required soil cores samples in analysis.

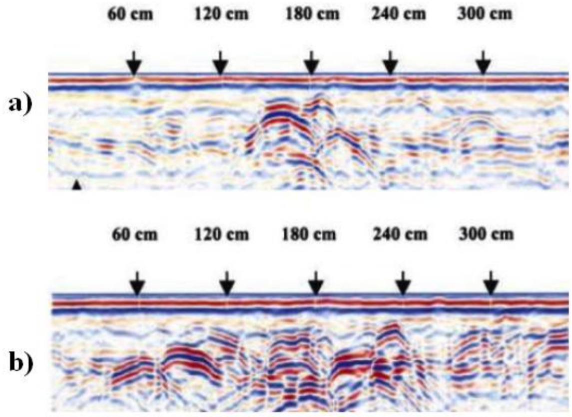

Fig. 5. GPR technology use for detection of agrochemicals movement

CONCLUSIONS

This paper showed the possibilities of applying modern technology of remote detection of active sensors in terms of application of radar technology. The basic principles of technology and the possibilities of application in agriculture are briefly explained. The main advantage of GPR technology reflects in multiple time savings during the implementation of standard research in the domain of agriculture, both from the point of the acquisition process and from the point of results processing. For this technology, several typical examples of application in agriculture have been chosen and analyzed. It should be noted that the list of possible applications in agriculture is significantly higher, and is not final due to the possibility to expand through new projects and experiments.

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