Ground Penetrating Impulse Radar for Detection of Small and Shallow-Buried Objects

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Abstract: The video impulse system ground penetrating radar system for detection of small and shallow buried objects has been developed. The hardware combines commercially available components with components (e.g. antennas) specially developed or modified for being used in the system. Antenna system has been designed so that it provides sufficient spatial resolution and power budget together with small coupling and ringing. The GPR has been tested in different environmental conditions and has proved its ability to detect small and shallow buried targets.

INTRODUCTION

Recently considerable efforts are put in development of Ground Penetrating Radar (GPR) systems for detection of surface-laid and shallow buried targets such as antipersonal landmines. The International Research Centre for Telecommunications-transmission and Radar (IRCTR) in the Delft University of Technology performs intensive research and development work in this area. Two GPR systems are under construction: video impulse system and step-frequency continuous wave system. Both systems should cover a bandwidth more than 2GHz each in order to achieve sufficient down-range resolution. Due to some technological restrictions of pulse generators the video impulse system will operate at lower frequencies (from 100MHz till 3GHz) and the step-frequency system will cover the frequency band from 4GHz till 6GHz. With respect to these frequency bands the primary aim of the video pulse system is to detect targets buried up to 50cm deep in the ground, while the step-frequency system is primarily aimed to detect surface laid mines. In this paper the main guidelines of the video impulse system design are presented. The step-frequency system is described elsewhere.

HARDWARE DESCRIPTION

The present video pulse system at the moment comprises a pulse generator, antenna system, front-end conditioner and sampling converter. The construction is quite flexible needed for system optimization under different operational configurations. A set of 0.35ns impulse and 0.8ns, 1.1ns and 2.5ns monocycle pulse generators were delivered by SATIS Co. (Russia). The magnitude of the impulse is 40V, and the peak-to-peak values for the 0.8ns, 1.1ns and 2.5ns monocycles are 45V, 100V, 154V correspondingly. The unique feature of these generators is their small trailing oscillations. For example, trailing oscillations of the 0.8ns generator are below 2.4% during the first 2ns and below 0.5% afterwards. The advantage of monocycle pulse is that its spectrum decreases to zero at low frequencies, which cannot be efficiently transmitted via antenna system and cause substantial antenna ringing. The advantage of impulse is a simplicity of transmitted signal and target response.

Spectra of these generators cover a wide frequency band from dc till 3GHz. At the frequencies below 1GHz attenuation losses in the ground are small [1] and considerable penetration depth can be achieved. It was found experimentally that 0.8ns monocycle optimally combines penetration and resolution abilities. The spectrum of this pulse (Fig.1) has a maximum at frequencies where the attenuation losses in the ground start to increase; the spectral content of the monocycle below this maximum penetrates deep into the ground and the spectral content above this maximum provides sufficient down-range resolution.

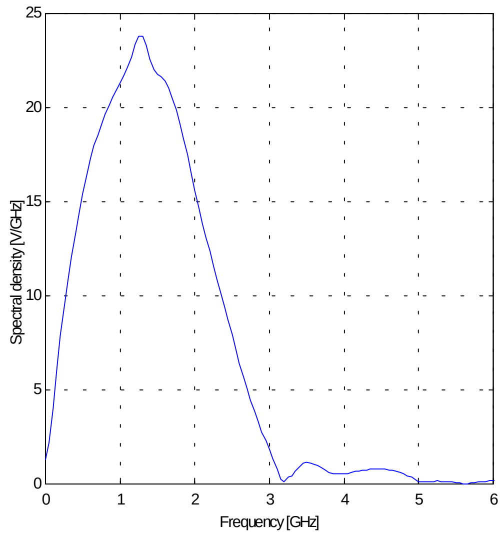

Fig.1. Spectrum of the output signal from the 0.8ns generator.

The four channel sampling converter from GeoZondas Ltd. (Lithuania) has a sampling 100kHz (by one channel operation), bandwidth up to 6GHz and a RMS noise level below 0.5mV. The 12-bit A/D converter provides 66dB dynamic range from -1V till 1V. The disadvantage of the device is a substantial internal EMI level, which goes up to 0.46mV peak-to-peak and limits sensitivity of the system.

An important part of the receiver chain is a front-end conditioner. It was found that different approaches should be used for surface laid and deep buried targets and each of these approaches should be realized as different front-end conditioner in different channels of the sampling converter. For a surface laid target its response comes together with surface reflection, which has the largest amplitude among all received signals and reaches up to 800mV peak-to-peak value. This signal should be processed linearly otherwise the target response cannot be distinguished from the surface reflection. Thus in this channel only 1V limiter is needed just for protection of the sampling head. For a deep buried target its response is quite weak due to the attenuation in the ground and is separated in time from the surface reflection, which can be clipped without any damage for signal detection. Thus in this channel a front-end conditioner consists of a low level limiter and a ultra-wide band LNA. The limiter protects LNA from deep saturation, which is caused by the surface reflection. If the LNA would be saturated, the recovery time should be shorter than 1.0ns. The combination of such limiter with LNA is under investigation now.

ANTENNA SYSTEM

Significant efforts have been put in the design of the antenna system. For video pulse systems both transmitting and receiving antenna should be ultrawideband, have linear phase characteristics, constant phase center, constant polarization and short ringing. Two types of GPR antennas have been developed in close collaboration with SATIS Co.: a dielectric filled TEM horn (DTEM) and a dielectric embedded shielded dipole (DED) [2]. It was shown experimentally that these antennas satisfy all above mentioned demands to a high extent. The EM field transmitted into the ground by these antennas has been measured in order to determine the footprint of the antenna and the EM field waveform. In DTEM antenna fed by 0.8ns generator ringing as small as 11% during first 2ns after main signal and below 4.6% afterwards has been achieved (Fig. 2). This is less than 3 times larger than the trailing oscillation of the generator.

A number of experiments have been done in order to find an optimal antenna's configuration with respect to detection of small and shallow-buried targets. Antenna's elevation above the ground, distances between antennas and their mutual orientations have been varied. Magnitude and duration of antenna's coupling, reflection from the ground and from targets have been investigated (Fig.3).

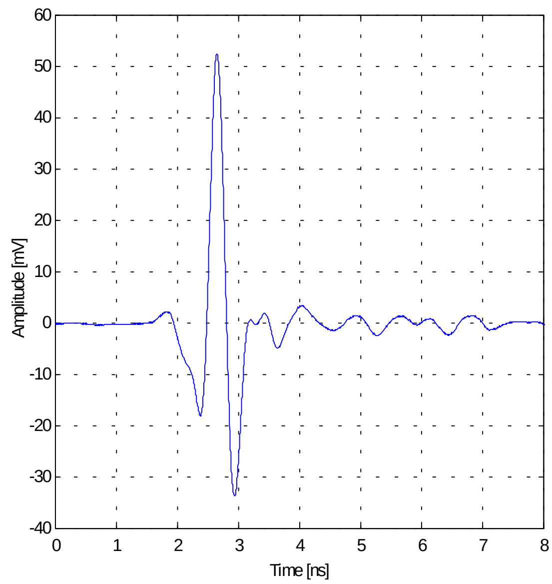

Fig.2. Sensor response to the field transmitted by DTEM antenna

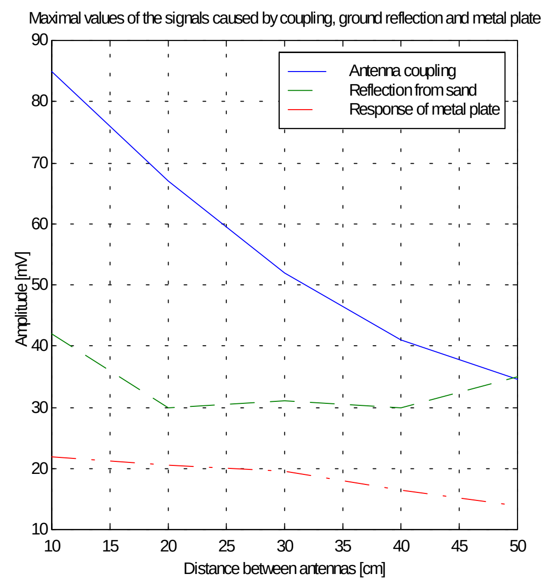

Fig.3. Maximal value of Tx-Rx antennas mutual coupling, ground reflection and a target return as functions from antenna separation

Minimal antenna elevation above the ground has been determined from the maximal acceptable value of the antenna coupling at the moment, when the reflection from the ground arrives. Tx-Rx antennas separation has been determined by maximizing the ratio between magnitude of surface target response and magnitude of the antenna coupling.

Different antenna types have been used as Tx and Rx antennas. It was found that for detection of deep buried targets, which produce weak response in the late time (with respect to the ground reflection), usage of the dielectric filled TEM horn as a Tx antenna and the dielectric filled shielded dipole as a Rx antenna is more preferable. For detection of shallow buried targets a special approach has been used. To achieve sufficient signal level in the ground it was decided that antennas will be elevated not more than 1m above the ground, so the far zone conditions are not met for the surface laid targets. A geometry of the antenna system is presented on Fig.4.

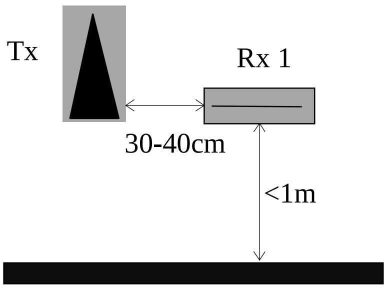

Fig.4. Antenna system geometry

EXPERIMENTAL RESULTS

The GPR system has been tested in different environments, e.g. sand, clay, forest ground, etc. An example of the A-scan over shallow buried in sand target is presented on Fig.5.

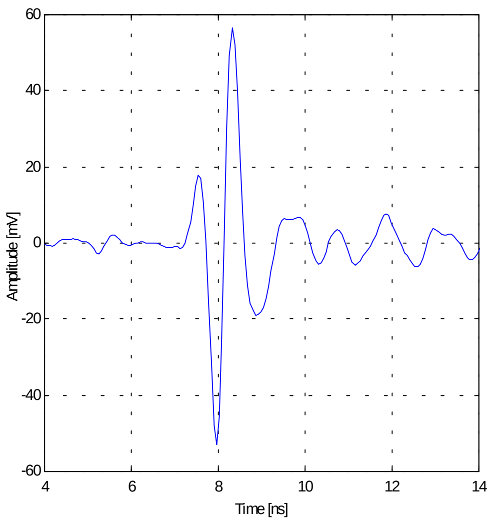

Fig.5. Target response after background subtraction

Magnitude of a target response usually is sufficient to be detected by the system. However due to antenna coupling and subsurface clutter this response can be masked. In order to remove these background a pre-processing has been used. Afterwards targets can be identified on a B-scan picture. A typical example of a B-scan over shallow buried in a sand objects is presented on Fig. 6. These objects are a dielectric parallelepiped with permittivity 15 and dimensions 97*97*12mm (left image), an empty coke can (center image) and a dielectric parallelepiped with permittivity 5 and dimensions 97*97*18mm(right image).

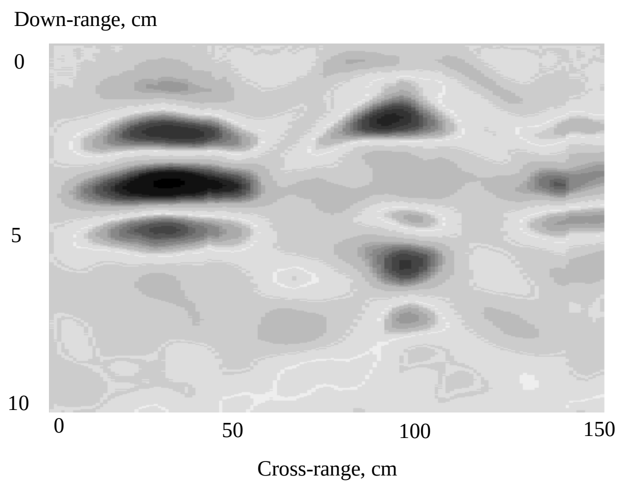

Fig.6. B-scan over shallow buried objects

CONCLUSION

The video impulse system ground penetrating radar system for detection of small and shallow buried objects has been developed in IRCTR. First experimental results show that the system can detect small dielectric and metal targets at depth up to 50cm. In the next step of the program software for image processing, localization and identification of targets will be developed and implemented into the system.

ACKNOWLEDGMENTS

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