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REMOTE CONTROL MINE DETECTION SYSTEM WITH GPR AND METAL DETECTOR

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ABSTRACT

In this paper we describe a method of minefield reconnaissance with the use of the multi-frequency ground-penetrating radar (GPR) combined with a metal detector. This method allows the mine images in the soil to be obtained in the band of the mine detector sensors. An experimental installation with remote control and scanning sensors has been designed and built. A mine detector of this kind can be used in peacekeeping and humanitarian operations.

Key words: Mine detection, Ground-penetrating radar, Metal detector, Remote control

INTRODUCTION

A potential area of application for ground-penetrating radar is humanitarian demining operations. As a result of local conflicts in various parts of the world, there have been vast mine fields left in place, and timeliness is an important factor to consider when securing the safety of the population. The geographical location of the conflict areas dictates climatic conditions and soil types. In addition, types of mines laid are continuously updated. Mine detectors currently in use do not meet the needs for detection of the new high-tech mines. Using old style mine detectors increases the risk of not detecting mines, especially those utilizing plastic casing and it also increases the likelihood of false alarms. These circumstances demand development of a more sophisticated means of mine detection, which would increase the rate of mine clearing works, simultaneously lowering the cost of these operations while decrease losses among sappers and civilians.

For the solution of these problems, research has been conducted on the use of a ground penetrating radar for detection of antipersonnel and antitank mines. Despite significant efforts and the expenditure of large sums of money their use in the course of practical works of mine clearing remains in question. In the first place, it associates with the difficulties of identification of signals (Daniels, 1998; Ivashov, Sablin and Vasilyev, 1998) reflected both from UXO (unexploded ordnance) and from natural heterogeneities of soil and also from different objects in the soil (bricks, tin cans, etc.), which are many in urbanized areas.

MIRASCAN SYSTEM DESCRIPTION

To overcome these difficulties, it had taken an initiative in the development of MiRascan ground penetrating radar to enable the operator to detect and identify objects buried under the ground at shallow depth (up to 20 cm) based on their shape analysis. The operating principle of the radar design is based on the method of multi-frequency sounding of a condensed media like building structures, grounds, etc. (Vasiliev et al., 1998).

In the initial segment of this work, the mock-up of a wide-span mine detector MiRascan, which included, in the capacity of a detecting element, a five frequencies ground penetrating radar receiving signals in two crossed polarities. The detector's sensor was installed on the cart, which was set in motion by an operator manually (Ivashov et al., 1999).

In the course of further research, the mock-up of the mine detector MiRascan underwent modernization. Basic features of it were as follows:

1. On the lower flange of the GPR cylindrical antenna, the head of the metal detector was installed
2. On the upper flange of the radar antenna, a generator metal detector block was installed
3. On the axes of chassis front wheels of the mine detector the electrical motors working in the impulse mode were installed
4. Remote control system of the mine detector movement was assembled. The operator via the remote control box, connected to the cart by the cable of 15 m length, exercises control over the movement of the mine detector

The radar has five operational frequencies in the range from 1.5 to 2.0 GHz and transmits unmodulated signals at each frequency. Its signals are received in two polarizations. Power emitted by the generator on each frequency is switched in sequence. It amounts up to 10 mW, which provides for the complete safety of staff. As previously mentioned, the induction loop of the metal detector was located on the butt end of the antenna of the ground penetrating radar, which provides spatial coincidence of received images from two channels of the mine detector. Operating frequency of the metal detector is 2 MHz, and the diameter of the induction loop is equal to 120 mm. The successive reception of signals on each frequency and in both polarizations of GPR and from the metal detector is conducted in the process of scanning the ground surface. The frequency switching rate is such that it provides for the spatial matching for all radio images of the GPR separate frequencies and metal detector image. A general view of the newest model MiRascan mine detector being used during experiments is presented in Figure 1.

Figure 1: Two-channel MiRascan mine detection system.

Scanning in the lateral direction is carried out at the expense of electromechanical movement of the radar with a metal detector, and in the longitudinal direction due to the movement of the entire device at speed of 1 m per 6 min. The mock-up of the mine detector makes it feasible to survey the lane of movement 112 cm wide. Figure 2 presents the block diagram of the MiRascan radar with metal detector.

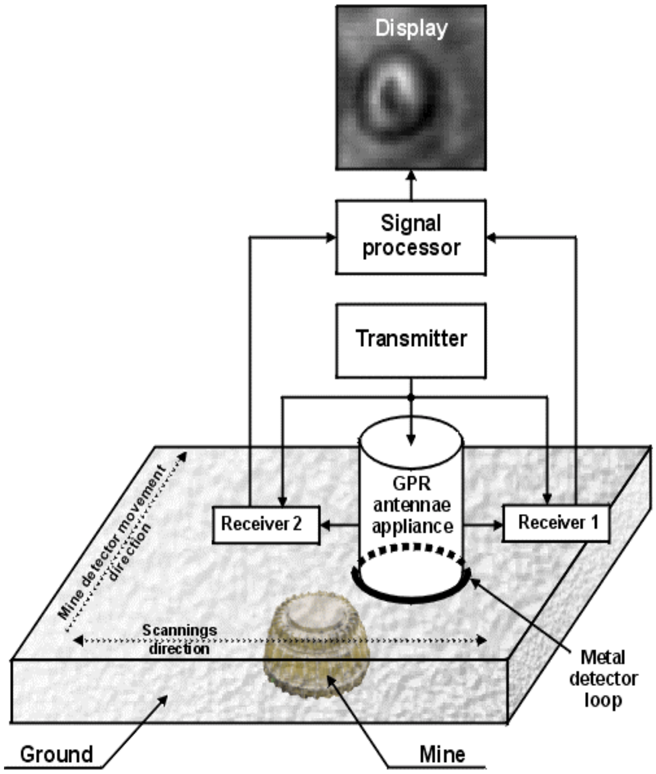

Figure 2: Block diagram of MiRascan radar with metal detector.

The scanning results are displayed in the form of gray scale images on the monitor screen for both channels. Since it is difficult for an operator to perform a simultaneous analysis of all images on different frequencies of GPR, one animated image is formed in which sequential frames correspond to different frequencies. We have only one picture for the metal detector channel. The size of images in the lateral direction corresponds to 112 cm, and in the longitudinal direction the length of the covered distance in the sweep defines the image. Correlation of dimensions is always equal to 1:1 for all visual data presented in the work images.

EXPERIMENTAL RESULTS

Some experimental results were obtained that display on two channels, the images of antitank and antipersonnel mines of different types placed in the soil. The Russian-made TM-62M and PTM-3 type antitank mines were used as metallic-body mines and the Italian-made TC-6.1; TC-2.5 and Russian TM-62PZ type antitank mines were used to simulate plastic-body mines. To simulate antipersonnel mines, Russian plastic-body PMN-2 type mines were used. We also used a plastic-body MS-3 booby trap. All these mines are shown in the Figure 3.

Figure 3: Different mines under consideration:
TC-6.1, TC-2.5
TM-62M, TM-62PZ
PTM-3,
MS-3, PMN-2 (two mines).

As it was pointed out earlier, objects of anthropogenic origin present significant difficulties in accurately detecting mines. For the study of their impact upon the detection of mine parameters, glass and plastic bottles (empty ones as well as filled with water) were buried in the ground, see Figure 4. The antitank mines and the bottles were laid in the ground at the depth of 5-10 cm, and for the antipersonnel mines the depth was 1-5 cm.

Figure 4: Two bottles and MS-3 mine.

The experiments to detect and identify mock-ups of the plastic-case and metallic-case mines were conducted under the full-scale conditions. The experiments were performed on the special proving ground near Moscow. The proving ground has sites with soil key types: sand, chernozem, loamy soil, etc., which ensures wide variation in their dielectric properties. In order to research the impact of humidity upon the quality of images received by different channels, tests were conducted under different weather conditions: both during dry and hot weather standing for a lengthy period of time and after a rain shower.

Experimental tests were conducted on June 29, 1999 while the air temperature was $+30^{o}$ C in bright and sunny weather. Their results are seen in Figures 5-8 for different mines and objects. Radio images are shown in two polarizations of GPR (the left images are for the cross polarization of received and transmitted signals and the center images are for the parallel polarization) and right images were received by the metal detector. To be short, just one out of five radio images received for each polarization is chosen – the most distinctive one. It is possible to judge the character of radio images based on the frequency of the results shown in the previous work (Vasilyev et al., 1998).

The experimental images for MS-3 booby trap are shown in Figures 5. High contrast in the channel of the metal detector is explained by the presence of a metal ring around the casing of MS-3. In the next experiment (see Figure 6) two PMN-2 type antipersonnel mines were examined, one of which was fully armed (at the top of the image), and in the second mine (on the bottom) the metal finger of the detonator was missing, e.g., it did not have any metal parts. In GPR channels both mines are seen (the lower one is seen only partially), and the metal detector discovers only the first mine.

The results of scanning a Russian TM-62M antitank mine are shown in Figure 7. For this type of mine the round form is clearly seen in all channels. Figure 8 presents the images of glass (on the top) and plastic (on the bottom) bottles filled with water in sand. Since the bottles haven't any metal, there is no signal in channel of metal detector.

CONCLUSION

Experiments have shown that use of a two-channel system with GPR and metal detector is one of the ways, which should a lower level of false alarms while increasing the probability of the mine detection on a background of local reflections and heterogeneities of soil. The MiRascan design is a technology demonstrator at this time. It has low velocity of moving and bad passability. The next stage of work involves the full-scale development for the purpose of building a device for the task of live mine detection. We are going to use TV and IR cameras for the detection of surface and shallow deep mines also.

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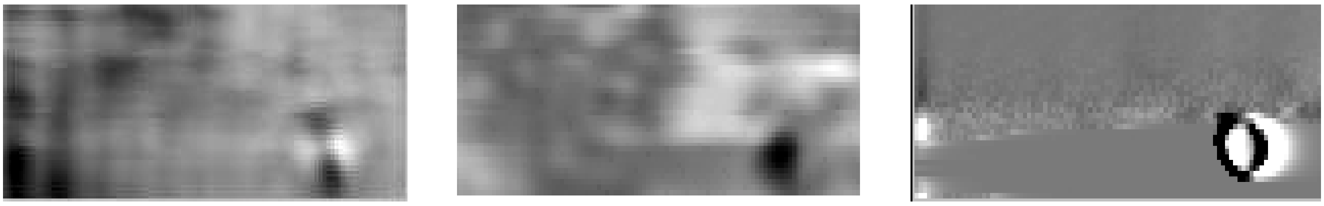

Figure 5: The images of MS-3 booby trap in chernozem.

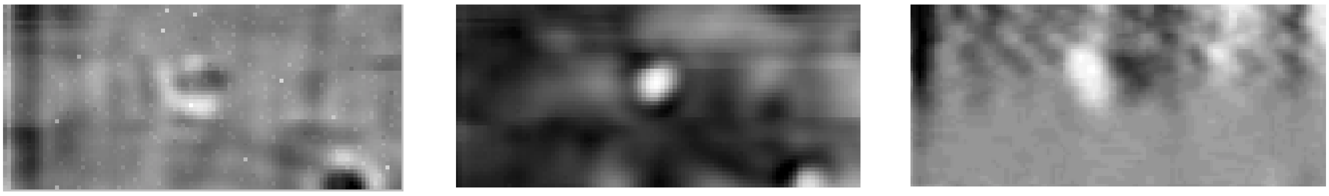

Figure 6: The images of two PMN-2 antipersonnel mines in chernozem.

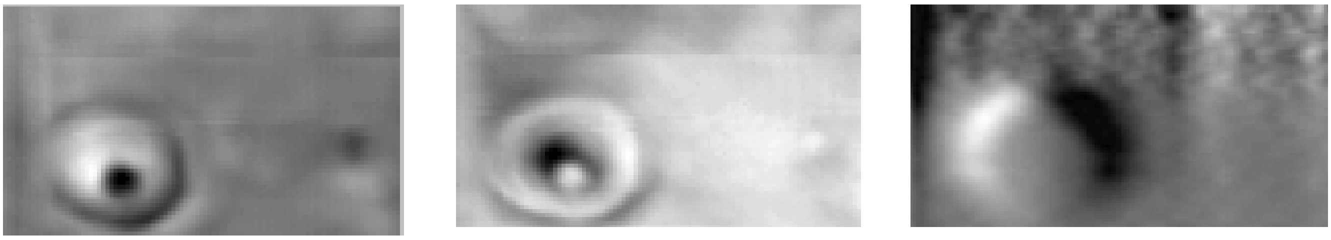

Figure 7: The images of Russian antitank mine type TM-62M.

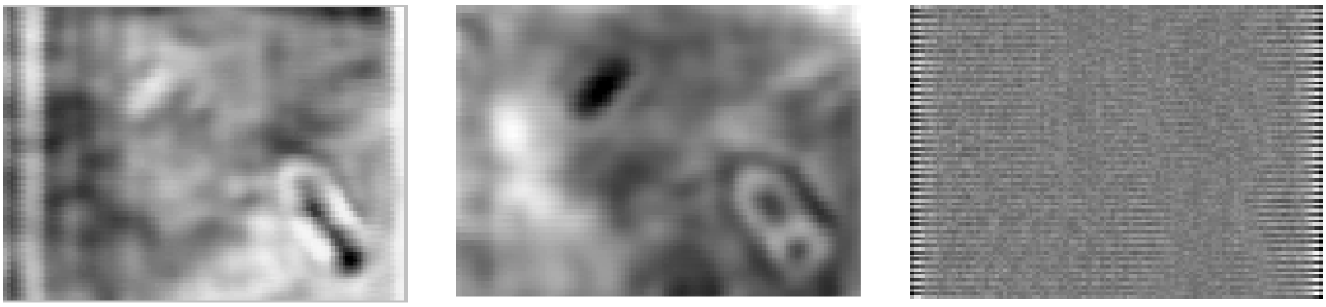

Figure 8: The images of glass and plastic bottles filled with water in sand.

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