WIDE-SPAN SYSTEMS OF MINE DETECTION

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Abstract. In this paper is considering a new method of minefield reconnaissance with use of the broad size detector. The method allows getting the terrain's radio images in the band of the mine detector sensors. The experimental installation was created with set of radio ground probing sensors. To treat the radio images and to reduce the number of false alarms the spatial algorithms was proposed. The mine detector of this kind can be used in peacekeeping and humanitarian operations.

INTRODUCTION

The existing systems of detection of «inconspicuous» plastic-body mines planted in the soil use, as a rule, radio transducers. The detection principle of these systems is associated with measuring the variations in the dielectric properties of the soil in the place of minelaying. In view of the low contrast of a mine, the level of false alarms in a mine detector appears to be unacceptably high at a sufficient level of detection. This relates primarily to the reflections of radio signals from natural heterogeneities present in the soil and its surface.

One of the methods to overcome arising difficulties is the use of wide-span mine detection systems. The advantages of wide-span systems include their higher efficiency and, as will be shown below, the possibility of reducing the probability of false alarms in the course of mine clearance due to space selection.

Similar problems arise in the subsurface location when detecting lengthy objects in the soil: cables, pipes, fragments of old foundations, etc. Rather credible inferences as to the type of an object can be made on the basis of the shape of the outline of this object by extending the results of sounding to a surveying plan, Vasilev (1), Bruschini (2). In this case reflections from subsurface objects present correlated sequences which are well identifiable even at a high level of local reflections. And in the case of detection of subsurface mines, mines can be distinguished from the local heterogeneities of the soil by their shape and size because the characteristic size of an antitank mine (20...30 cm) is known.

Experimental System

To test these possibilities, a mockup of a wide-span mine detector involving radio wave transducers was developed presenting a series of mine detectors arranged in a line, together with a mechanical gear providing for the movement of this mine detector above the ground. The mine detector mockup is shown on Figure 1.

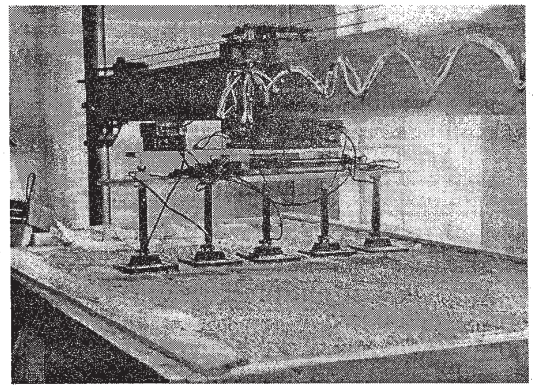

Figure 1: General view of the experimental installation

The movement of the wide-span mine detector mockup was performed above the surface of the proving ground of the size of 2×6 m^2 in its surveying plan and 1.5 m deep. The signals of the mine detector transducers were transmitted through an interface for further processing to a computer. Each signal level from the receiver of the mine detector transducer corresponds to a certain level of the density of pixels on the picture.

The picture of the soil surface under investigation was formed as follows. Each transducer formed one picture line. By adding up picture lines obtained sequentially following the movement of the mine detector transducers, a two-dimensional picture was formed, i.e. the i-th transducer was related to i-th picture line. Transducer signals are analogous in themselves and require quantization to be processed by a computer. Let us establish a relation between the average level of the i-th transducer signal within a time interval from t_k to $t_k + \Delta t$ the following expression:

$$m_{i,k} = \frac{1}{\Delta t} \cdot \int_{t_k}^{t_k+\Delta t} g_i(\tau) \cdot d\tau \quad , \qquad (1)$$

where: $m_{i,k}$ - the brightness density of the k-th pixel of the picture line obtained by the i-th transducer;
g_i - the signal from i-th transducer of the wide-span mine detector;
τ - integration parameter;
Δt - quantization.

In this case:

$$t_k = (k-1) \cdot \Delta t, \qquad k = 1,2,3,...K; \qquad (2)$$

where: K - the total number of pixels in a picture line.

Let the total number of transducers be I. Then the above transformation results in a discrete half-tone picture including I lines and K columns, and its elements will be set by the matrix $M = \|m_{i,k}\|$, i = 1,2,3,...I; k = 1,2,3,...K.

Experimental Results

We can present some experimental results. Figure 2 shows the radio image of a plastic-body antitank mine placed in the soil. The other picture (Figure 3) shows the image of two mines in its center, one of which is in a metallic body (left side) and the other one is in a plastic body. There are a metal pipe cut in the lower left corner of the picture, a 30×30 cm^2 metal plate in the lower right corner and a brick in the upper right corner. All these things are buried in the soil at a depth from 5 cm to 10 cm.

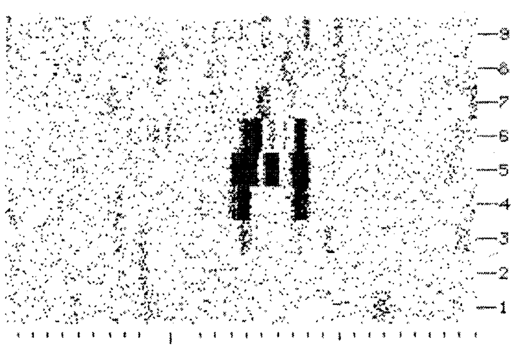

Figure 2: Radio image of a plastic-body antitank mine in the soil

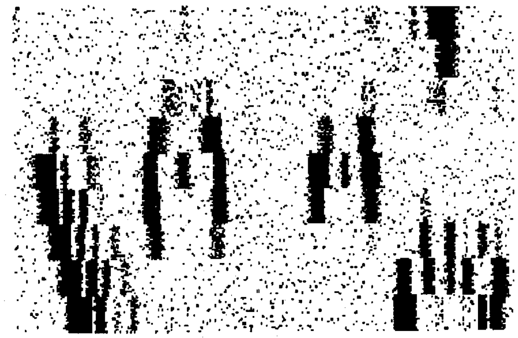

Figure 3: Radio image of antitank mines and different things in the soil.

The domestic TM-62M type antitank mine was used as a metallic-body mine, and the Italian TS-6 type antitank mine was used to simulate plastic-body mines. The pictures of these mines are shown on Figure 4 and 5.

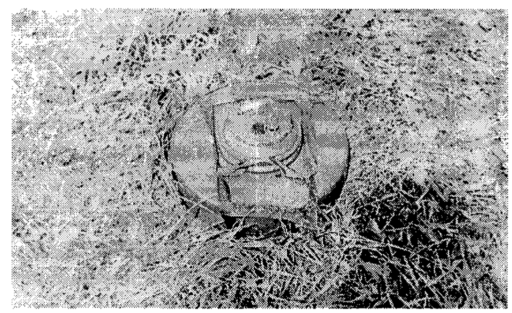

Figure 4: TM-62M type metallic-body antitank mine

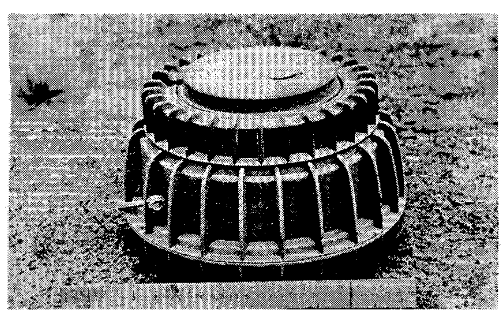

Figure 5: TS-6 type plastic-body antitank mine

The analysis of radio images on Figure 2 and 3 shows that the image of a mine presents two arcs perpendicular to the direction of the movement of transducers and a dark mark between them. The characteristic size of the obtained images of mines is close to the size of a mine in plan, i.e. 20...30 cm. Also, it should be noted that the shape, which is taken by a mine on the picture, is determined both by the size of a mine itself and the design of the transducers of a wide-span mine detector. The further experiments have shown that this image of a mine is sufficiently immune to the local heterogeneities of the soil.

In view of this circumstance, the space filtering algorithm «identifying» mines in the soil by the characteristic shape of their images has proved its sufficient efficiency. In order to perform identification, let us use a correlation filter with a recognition matrix which depends on the shape and size of objects to be searched.

$$F_{j,n} = \left\| f_{j,n} \right\| = \left\| \begin{matrix} 0 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 0 \\ 1 & 1 & 1 & 0 & 0 & 1 & 1 & 0 & 0 & 1 & 1 & 1 \\ 0 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 0 \end{matrix} \right\| ; \quad \begin{matrix} j=1,2,3 \\ n=1,2,..12 \end{matrix} \qquad (3)$$

The following algorithm will be chosen as a procedure of recognition.

Let us establish a relation between each element of the radio image brightness matrix $\left\| m_{i,k} \right\|$ and the element of the matrix $\left\| l_{i,k} \right\|$, which is calculated as follows:

$$l_{i,k} = \Theta\left(\sum_{j=1}^{3} \sum_{n=1}^{12} f_{j,n} \cdot m_{i+j-2,k+n-5} - p \right), \qquad (4)$$

where: p - the value of the detection threshold.

The function $\Theta(x)$ in the expression (4) is determined as follows:

$$\Theta(x) = \begin{cases} 1; & npu \;\; x > 0. \\ 0; & npu \;\; x \le 0. \end{cases} , \qquad (5)$$

Also, it should be noted that the calculated values of the matrix $M = \left\| m_{i,k} \right\|$ may go beyond the scope of the region of its determination. In this case the corresponding values of the matrix are taken to be zero. A binary image is derived from the initial half-tone radio image as a result of the transformation (4). Let us consider the example of filtering of the radio image obtained using the above-mentioned experimental stand shown on Figure 1.

A target background environment meeting actual conditions was created to determine the efficiency of mine identification against the background of the soil heterogeneities. For this purpose holes and mounds were made in the surface of the soil of the experimental stand, and a brick, a metal pipe cut and a metal plate were buried in the soil. Also, three antitank mines were buried in the soil, one of them being in a metal body (Figure 4) and another two being in a plastic body (Figure 5). The surveying of the surface of the experimental stand resulted in an image shown on Figure 6.

The result of filtering the radio image shown on Figure 6 by using the above algorithm is given on Figure 7. This Figure shows that all three mines have been detected. At the same time linear-shaped objects and the occasional heterogeneities of the background are completely filtered and removed from the image.

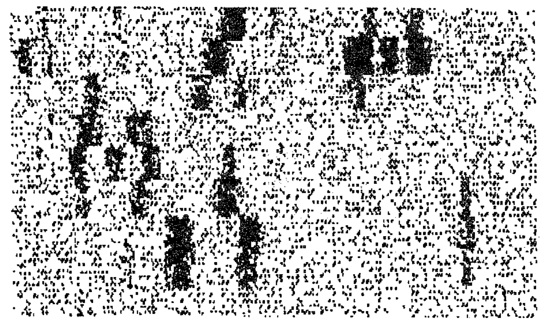

Figure 6: Initial radio image of the proving ground with mines and other things

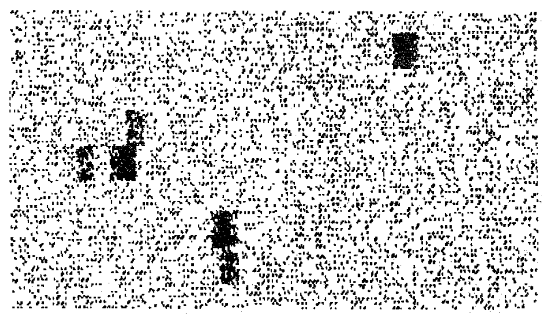

Figure 7: Result of filtering the radio image shown on Figure 6

Conclusion

It may be said that the technique proposed can prove to be very efficient when it is used in performing mine clearance and eliminating the consequences of local conflicts. In this case the wide-span mine detector proposed could be mounted on a remotely controlled gear, and signals received by transducers will be transmitted by a radio channel and processed at a control station situated outside a minefield. To improve detection characteristics, the above-discussed wide-span mine detector based on radio wave transducers could be complemented by ferrosondes and other means of mine detection. In this case a coincidence circuit could be used in several channels of a mine detector.

1. Vasilyev I.A., Ivashov S.I. and Sablin V.N., 1998, Radio Frequency Countermine System with Broad Size Detector, Radio&Comm.Techn., 4, 55-58.

2. Bruschini C., Gros B., Guerne F., Piece P.Y. and Carmona O. 1996, Ground Penetrating Radar and Induction Coil Sensor Imaging for Antipersonnel Mines Detection. 6th Int. Conf. on GPR, Japan, 211-216.