Wide-Span Systems of Mine Detection

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ABSTRACT

In this paper we describe a new method of minefield reconnaissance with use of the broad size detector. The method allows getting the terrain's radio images to be obtained 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 were proposed. A mine detector of this kind can be used in peacekeeping and humanitarian operations.

INTRODUCTION

The existing detection systems 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 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 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 object can be made based on the outline shape by extending the results of sounding to a surveying plan, [1, 2]. In this case reflections from subsurface objects present correlated sequences which are identifiable even at high levels of local reflections; and in the case of detection of subsurface mines, they can be distinguished from 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 ground. The mine detector mockup is shown in Figure 1, on next page.

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 computer processing. 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.,

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Manuscript received July 21, 1998.

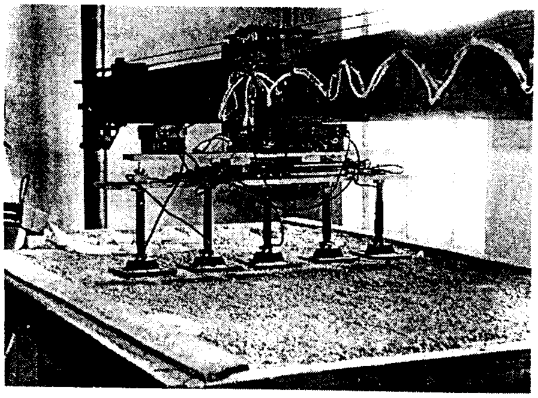

Fig. 1. General View of the Experimental Installation

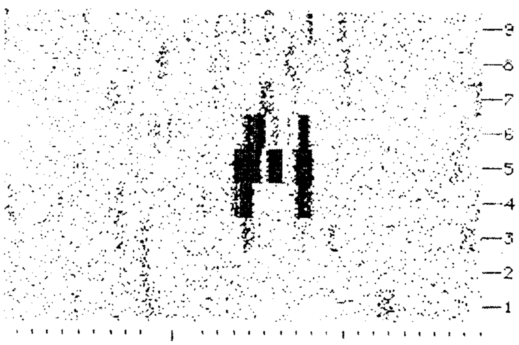

Fig. 2. Radio Image of a Plastic-Body Antitank Mine in the Soil

the i-th transducer was related to i-th picture line. Transducer signals are analogous 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 τ_k to $t_k + \Delta_\tau$ the following equation:

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

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;
Δ_τ = quantization.

In this case:

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

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

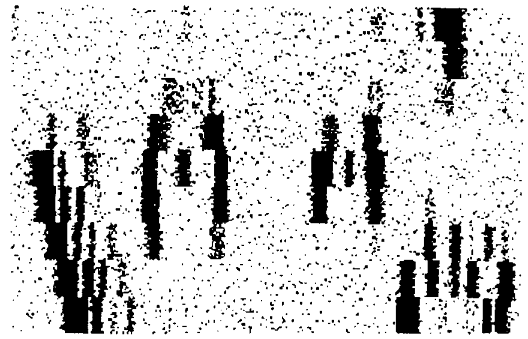

Fig. 3. Radio Image of Antitank Mines and Different Things in the Soil

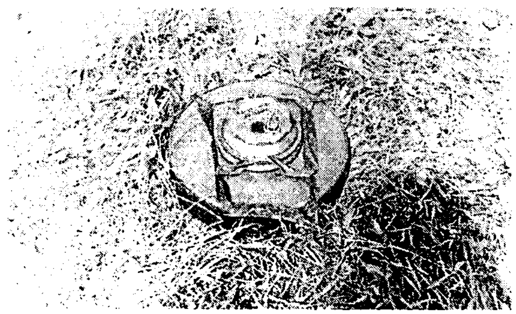

Fig. 4. TM-62M Type Metallic-Body Antitank Mine

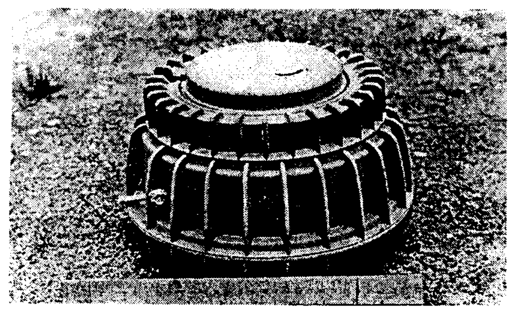

Fig. 5. TS-6 Type Plastic-Body Antitank Mine

including I lines and K columns, and its elements will be set by the matrix $M = ||m_{ik}||$, $i = 1,2,3 \ldots I$; $k = 1,2,3 \ldots K$.

EXPERIMENTAL RESULTS

Figure 2 shows the radio image of a plastic-body antitank mine placed in the soil. 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 is a metal pipe cut in the lower left comer of the picture, a $30 \times 30\ cm^2$ metal plate in the lower right corner and a brick in the upper right comer. All these things are buried in the soil at a depth from 5 cm to 10 cm.

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 in Figures 4 and 5.

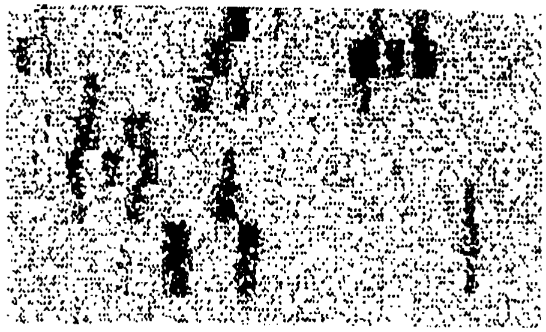

Fig. 6. Initial Radio Image of the Proving Ground With Mines and Other Things

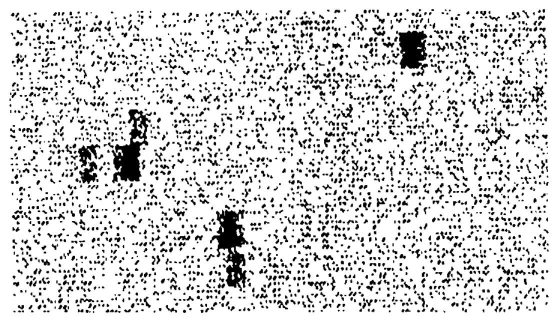

Fig. 7. Result of Filtering the Radio Image in Figure 6

The analysis of radio images in Figures 2 and 3 show 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 images obtained 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 the mine and design of the transducers of a wide-span mine detector. Further experiments have shown that this image is sufficiently immune to 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 proven 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.

$$F_{j,n} = \|f_{j,n}\| = \begin{Vmatrix} 0 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 0 \\ 1 & 1 & 1 & 0 & 0 & 1 & 1 & 0 & 0 & 1 & 1 & 1 \\ 0 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 0 \end{Vmatrix}; \quad \begin{matrix} j=1,2,3 \\ n=1,2..12 \end{matrix} \tag{3}$$

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 $\|m_{ik}\|$ and the element of the matrix $\|I_{ik}\|$ is calculated as follows:

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

where: p = the value of the detection threshold.

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

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

Also, it should be noted that the calculated values of the matrix $M = \|m_{ik}\|$ 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 Equation (4). Let us consider the example of filtering of radio image obtained using the above-mentioned experimental stand shown in Figure 1.

A target background environment meeting actual conditions was created to determine the efficiency of mine identification against the background of soil heterogeneities. For this purpose holes and mounds were made in the surface of the soil in 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 surface survey of the experimental stand resulted in the image shown in Figure 6.

The result of filtering the radio image in Figure 6 by using the above algorithm is given in 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.

CONCLUSION

It may be said that the technique proposed can be very efficient when 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 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.

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