Trolley Mounted Neutron Backscattered System for Landmine Detection

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A landmine detection system based on measuring thermal neutrons back scattered from objects hidden in the ground has been developed and installed. The system consists of sixteen ^{3}He proportional counter tubes (100 cm length and 2.5 cm diameter) placed in an aluminum tray. The sixteen tubes are divided in two groups separated by a gap of 15 cm width where the neutron source(s) are fixed. Especially designed and constructed graphite reflectors and shadow steel bars are used to enhance the neutron flux incident towards the ground and to assure to some extent the same incidence of the same fast neutron flux along the detector tube axis. The detector tray is mounted on a platform fixed at the front of a trolley driven by electric motor and electric control unit. The trolley can move by velocities vary from 3 mm/s to 50 cm/s. The detector platform is provided by two electric motors, one to move the detectors along the side direction and the other to change the stand off distance.

The system workability was checked for the cases where one neutron source and two neutron sources are used. The results of the performed tests are presented in the form of attenuation relations and displayed images.

I. INTRODUCTION

Most of the techniques used for detection of landmines are based on conventional methods deploying prodders, metal detectors and sniffing dogs. This makes the demining of vast areas of contaminated land a difficult, dangerous, slow and very costly operation [1]. Some of these methods are very effective for locating metal anomalies, but they suffer from high false alarm rates because they cannot recognize a landmine from other scattered debris. Nuclear and sniffing sensors have proved that they are capable to distinguish explosive materials, like a landmine from other materials. However sensors based on sniffing lose their validity for detection of explosives after sometime and when the explosives are placed in perfectly sealed containers [2]. Hence, nuclear methods become the only way that can be used to identify a landmine from other scattered objects for demining operations.

A nuclear technique based on the measurement of thermal neutrons produced from the moderation of fast neutrons by elastic scattering with hydrogen nuclei is effective for distinguishing explosive material, i.e., a landmine from other non hydrogenous materials. Accordingly, a method which employs the measurement of thermal neutrons back scattered from the ground can be considered as an effective way to discriminate between a landmine and other objects (stones and metals). However, this method loses its capability for identifying a landmine buried in soil with relatively high moisture content [3, 4].

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II. EGYPTIAN SCANNING LANDMINE DETECTION, ESCALAD

The Egyptian Scanning Landmine Detector, ESCALAD was financially supported by the IAEA through the TC project **EGY/ 1 / 024** and is designed and constructed through a fruitful cooperation with the University of Delft, the Netherlands [5]. The ESCALAD is a trolley mounted system consisting of a thermal neutron detector array, neutron sources and electronic equipment for data acquisition and image analysis. A photograph of the system is shown in Fig. 1.

FIG. 1: Photograph of Egypt Scanning Landmine Detector, ESCALAD.

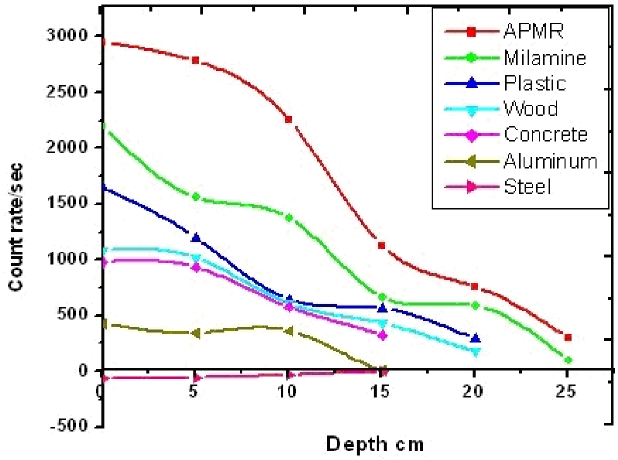

FIG. 2: Dependence of detector response object materials and buried depth.

A. Detector Array

The detector array consists of sixteen ^{3}He proportional tubes each of 100 cm length and 2.5 cm diameter fixed in aluminum tray of 140 cm length, 75 cm width and 6 cm depth. The ^{3}He tubes are divided into two equal groups separated by a gap of 15 cm width where the neutron source / sources are placed during the scanning operation. The ^{3}He tubes are wrapped with Cd sheet (except from the bottom side) to prevent the detection of thermal neutrons coming from top and side directions.

B. Neutron Sources

Two Pu-α-Be neutron sources of equally neutron emission ($\sim 10^6$ n/s) were fixed at separated distance of 50 cm on the axis of the gap between the two groups of ^{3}He tubes. Two cylindrical steel attenuators of 3 cm thick were placed under the sources to flatten to some extent the distribution of fast neutrons impinging into the ground. Also specially designed and constructed two graphite reflectors were used above the neutron sources to enhance the number of fast neutrons incident on the ground.

C. Trolley

The specially designed and constructed electric motor driven trolley is used to carry the aluminum tray on a platform fixed at front of the trolley. The trolley moves forward and backward with velocity varies from 3 mm/s to 50 cm/s. The trolley is also equipped with two electric motors, one to shift the platform along the side direction and the other to change the stand off distance between the detectors and the ground.

D. Data Acquisition and Image Analysis

The measured raw data consists of the response due to the buried landmine or landmine signal, the contribution of neutrons backscattered from the ground and the contribution of neutrons which come directly from the source and hit the detector. The contribution from the latter two sources gives the background signal. The buried landmine can only be detected if the landmine signal is larger than the spatial fluctuations in this background signal. The difference between the two depends on the size of the mine, the buried depth of the mine and the moisture content in soil.

The output of the 16 ^{3}He tubes is connected to two MPSD-8 units which in turn are connected to the event builder module. The event builder acts as communication unit between the central module and the power DAQ board. The data of the neutron events which contain all

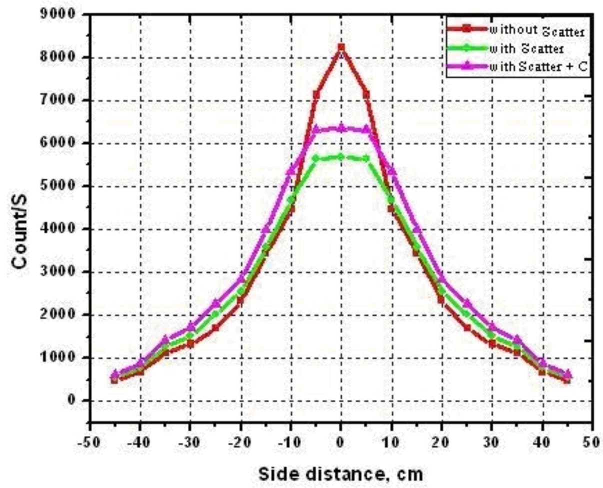

FIG. 3: Distribution of Fast neutrons along the tube axis from a single source.

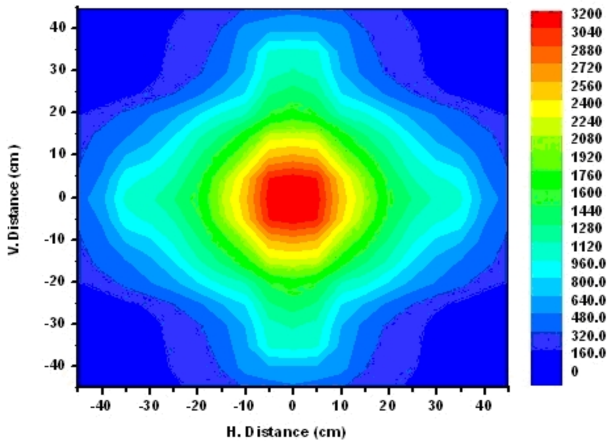

FIG. 4: Constructed image of fast neutrons along the tube axis from a single source.

the neutron information are synchronized and feed to the DAQ board. The output signals are digitized and added into a PC to give the pixel display. Detailed description of the electronics for measurement and data acquisition are given elsewhere [6].

III. MEASUREMENTS

The capability of the system for discrimination between objects of different materials was tested by measuring objects of explosive (a landmine), plastic, melamine, stone and wood buried at different depths. The measured results are presented in the form of attenuation relations shown in Fig. 2. These relations shows that the NBS technique is quite capable to distinguish between anomalies with and without hydrogen content and can therefore be considered as a powerful filtration sensor between landmines and other non hydrogen containing objects scattered in the landmine field.

The dependence of the scanning width on the change of the incident fast neutron flux distributions along the ^{3}He tube axis was checked for cases where the measurement is carried out by one and by two sources. The fast neutron flux was measured by a neutron/gamma spectrometer with a stilbene scintillator applying pulse shape discrimination to reject undesired pulses of gamma rays. Figures 3 and 4 show the fast neutron flux distribution and image constructed when one neutron source Pu-α-Be is placed at the center of the gap between the two groups of tubes. The plotted relations show that the flux intensity decreases sharply with increasing the distance from the center. However, the rate of depression in flux intensity becomes less when a fast neutron scatter is fixed under the source. The figure also shows that the use of a graphite reflector above the source tends to increase the incident fast neutron flux by about 10%.

The plotted relations and image constructed for the case of two neutron sources fixed at 60 cm apart on the axis of the gap between the two groups of ^{3}He tubes are shown in Figs. 5 and 6. The relation plotted and the image shown in this figure shows that the flux intensity slightly decreases with increasing the side distance and stays nearly the same at any point along the tube axis. This means that a mine buried at positions near the tube edges will give to some extent the same response as one buried at the central region. This tends to increase the width of the scanning area.

The flux distribution relations and images presented in Figs. 3 to 6 show that in case of one neutron source placed at the center of the tubes, the maximum scanning width will not be more than 30 cm since the mine response outside this width can not be used to indicate the presence of a mine. But the scanning width has increased and becomes more than twice by using two sources separated by 60 cm distance.

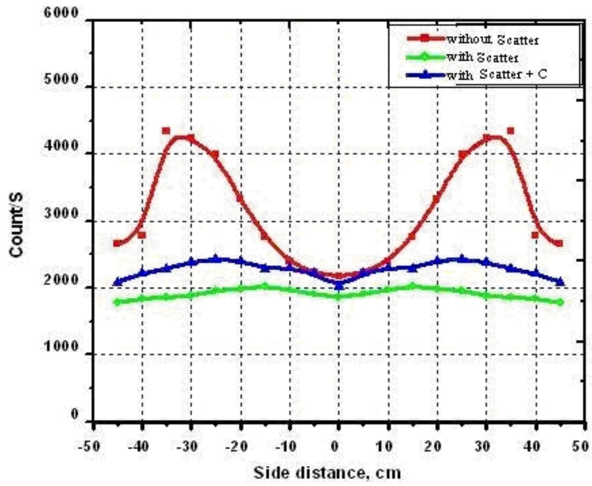

FIG. 5: Distribution of Fast neutrons along the tube axis from two sources.

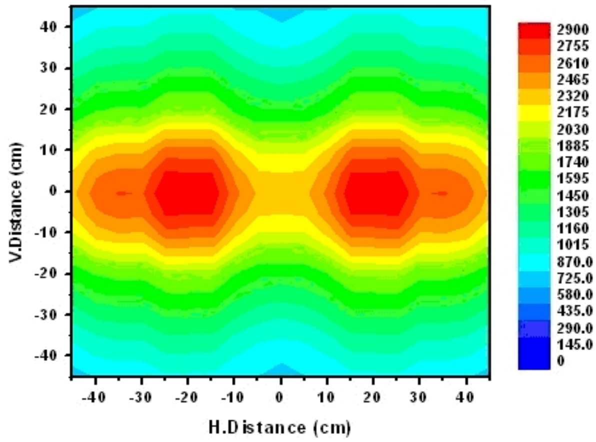

FIG. 6: Constructed image of fast neutrons along the tube axis from two sources.

IV. ESCALAD WORKABILITY

Measurements were performed to evaluate the capability of ESCALAD for detecting landmines buried at different depths and different side distances in a realistic landmine field. The system workability was also tested in combination with metal detectors like GPR.

Measurements were performed to evaluate the maximum depth at which anti-personnel mine of type, PMH with 150 g explosive and antitank mine of Israeli making with 9 kg explosive can be detected. For a real landmine field it is not possible to fix the stand off distance at a certain value because of the natural undulations of the soil surface and therefore tests were done for a stand off distance varying from 5 to 15 cm. The detection speed was fixed at 6 mm/s. The measured thermal neutrons backscattered from these mines were used to construct the two dimensional images shown in Figs. 7 and 8.

Measurements were also performed to test the scanning

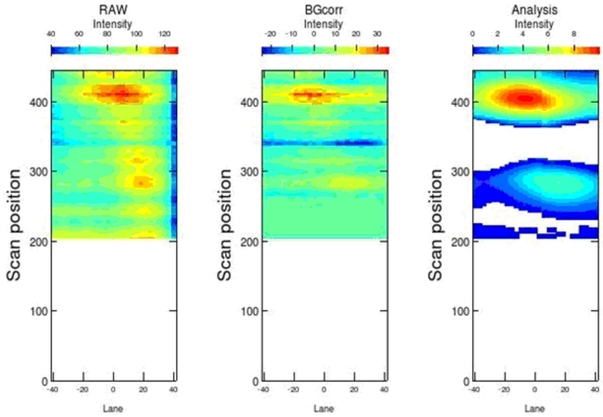

FIG. 7: APM buried at 20 cm depth.

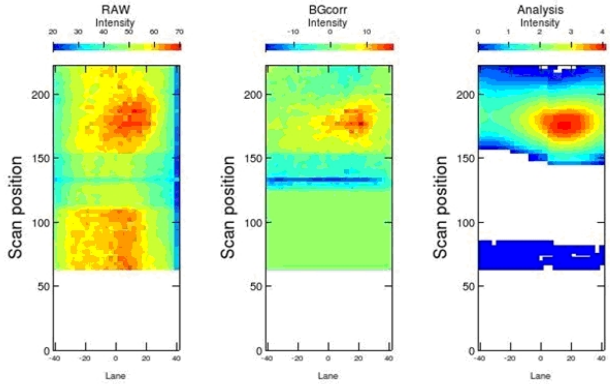

FIG. 9: APM buried at surface and shifted by 25 cm from the center.

width when two sources are placed at 50 cm separated distance on the axis of the gap between the two groups of ^{3}He tubes. Tests were done using the APM, scanning speed and stand off distance as mentioned before. The mine position is shifted from the center of the tubes to the side by 25 cm and measurements were performed for the mine buried at 0, 5 and 10 cm depths. The obtained images are displayed in Figs. 9, 10, and 11 respectively. These images show that ESCALAD is capable of scanning a strip with width more than 80 cm.

Further, initial measurement was performed to check the system workability when scanning is carried out with varying speed. This was done using two ATMs: one with a plastic casing and explosive material of weight 2.5 kg and the other of metal casing and explosive material of weight 6 kg. These mines were buried at 20 cm depth at the tube center and the scanning was carried at 17 mm/s speed. The constructed images displayed in Fig. 12 shows that the system is quite efficient to detect landmines with scanning speed even more the one meter/s.

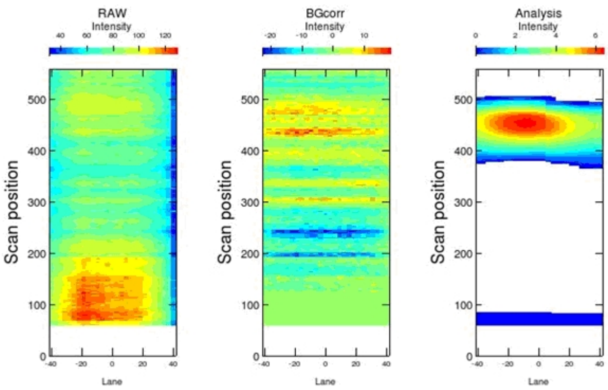

FIG. 8: ATM buried at 30 cm depth.

V. CONCLUSIONS

The nuclear sensor based thermal neutron back scattering technique is an effective and fast way to detect landmines buried in arid soil of countries like Egypt. The sensor is very efficient to distinguish hydrogen containing objects like explosive material from other non hydrogen containing ones. A combination of a neutron back scattered sensor and metal detector will enhance the demining operation and reduce the cost due to the reduction of the false alarm rate.

The ESCALAD has proved its capability to detect APM buried at depths 20 cm and ATM buried at depth 30 cm in dry soil at speed varies from 0.4 m/s to 10 m/s. In addition, the use of two sources instead of one tends to increase the width of the scanning strip from 30 cm to 90 cm.

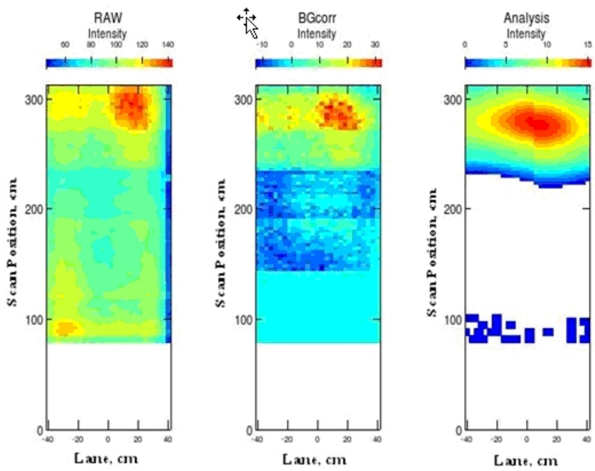

FIG. 10: APM buried at 5 cm and shifted by 25 cm from the center.

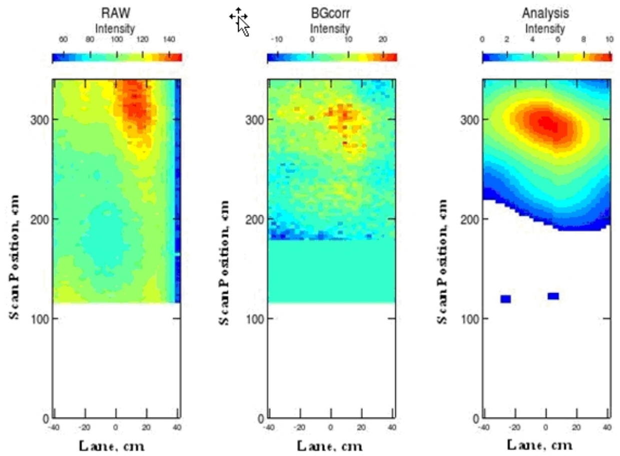

FIG. 11: APM buried at 10 cm and shifted by 25 cm from the center.

VI. ACKNOWLEDGMENTS

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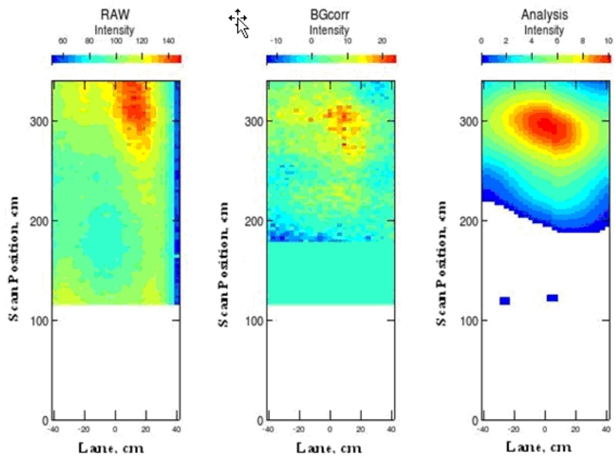

FIG. 12: Two ATMs buried at 20 cm.

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