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FIELD TESTS OF X-RAY BACKSCATTER MINE DETECTION

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ABSTRACT

The implementation of a backscattered x-ray landmine detection system has been demonstrated in laboratories at both Sandia National Laboratories (SNL) and the University of Florida (UF). The next step was to evaluate the modality by assembling a system for field work. To assess the system's response to a variety of objects, buried plastic and metal antitank landmines, surface plastic antipersonnel landmines, and surface metal fragments were used as targets. The location of the test site was an unprepared field at SNL.

The x-ray machine used for the field test system was an industrial x-ray machine which was operated at 150 kV and 5 mA and collimated to create a 2 cm diameter x-ray spot on the soil. The detectors used were two plastic scintillation detectors: one collimated (30 cm x 30 cm active area) to respond primarily to photons that have undergone multiple collision and the other uncollimated (30 cm x 7.6 cm active area) to respond primarily to photons that have had only one collision. To provide motion, the system was mounted on a gantry and rastered side-to-side using a computer-controlled stepper motor with a come-along providing the forward movement. Data generated from the detector responses were then analyzed to provide the images and locations of landmines. A new analysis method that increases resolution was used.

Changing from the lab environment to the field did not decrease the system's ability to detect buried or obscured landmines. The addition of rain, blowing dust, rocky soil and native plant-life did not lower the system's resolution or contrast for the plastic or the metal landmines.

Concepts for a civilian mine detection system based on this work using commercial off the shelf (COTS) equipment were developed.

INTRODUCTION

The use of backscattered x-rays for the detection of landmines has been demonstrated in the laboratory by both Sandia National Laboratories (SNL) (1) and the University of Florida (UF) (2). Using a collimated x-ray beam and a system of collimated and uncollimated detectors, images of buried and surface objects can be created when the x-ray beam is rastered across the surface. The uncollimated detectors receive most of their energy deposition from photons that have had only one scattering event and therefore respond primarily to surface features while the collimated detectors respond to buried features as well as surface features. Because the images generated have one set that predominately contains surface features (uncollimated) and another set that responds to both surface and buried objects (collimated), it is possible to first analyze and then remove any surface features before examining the buried objects.

Previous work has demonstrated the backscattered x-ray imaging system's ability to function with surface clutter i.e., rocks, branches, vegetation, with varying surface-to-detector heights, and with surface irregularities i.e., potholes and soil mounds. This research focuses on the configuration of the system for imaging the landmines under field conditions.

APPARATUS AND PROCEDURES

The x-ray generator that was used for the field tests was an industrial x-ray machine. For the field experiments it was operated at 150 kV and 5 mA. The control unit was placed in a tent, but could have been located in the instrumentation van. The output beam was collimated to produce a 2 cm diameter x-ray spot on the soil. The power for all the equipment used in this experiment was provided by a generator. The total power used by the fielded system was less than 5 kW.

The detector system used for the field tests consisted of one collimated detector and one uncollimated detector.

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Both the detectors used a photomultiplier tube as the light sensing element and plastic scintillator. The collimated detector was 30 cm wide by 30 cm deep by 5 cm thick, the uncollimated detector was 30 cm wide by 7.6 cm deep by 5 cm thick. Figure 1 shows a drawing of the detector positions relative to the x-ray machine.

A gantry supported the detectors and the x-ray head. The weight of the detector system and the x-ray head was ~ 100 lb. To allow a 1 m side-to-side travel distance for the x-ray head, a stepper motor and acme screw were used. The motion of the stepper motor was controlled using a LabView based program which was integrated with the data acquisition system. The forward motion was provided by a come-along that could be stepped in increments of 2 cm.

The data acquisition system used an analog-to-digital converter and a custom LabView program. The system sampled at 50 kHz for the entire side-to-side scan, then displayed the information from each scan on the operators screen. The system was controlled from an instrument van. A schematic of the data acquisition system and the motion control system is shown in Figure 2. A combination of filters were used to increase the resolution of the images.

Both surface and buried landmines were used to evaluate the systems capabilities. Figure 3 shows the landmine field. Prior to starting the imaging, the antitank landmines were buried to a depth of ~ 4 cm. A metal fragment was also placed on the surface to evaluate discrimination of surface, non-mine features.

RESULTS

In this demonstration the main limit to the scan speed was the swing caused by the length of the lever arm from the gantry to the detectors/x-ray head. This allowed only one scan a minute. After a scan was completed the come-along was used to pull the system forward 2 cm so the next scan could be started.

Figure 4 shows the image generated by the system when scanning over the simulated landmine field shown in Figure 3. In this image, white denotes a high detector response and black denotes a low detector response. Since plastic landmines have a high scattering-to-absorption ratio they cause the signal seen by the detectors to increase. Metal encased landmines have a low (compared to plastic or soil) scattering-to-absorption ratio and so they cause the signal seen by the detectors to decrease.

The 30 cm plastic antitank landmine, the 30 cm metal antitank landmine, and the metal fragment are clearly imaged. The 7.5 cm plastic antipersonnel landmine is also located, but because of the 2 cm x 2 cm resolution, it is not seen as clearly as previous experiments using finer resolution. The fuse well and the characteristic ridges on the plastic antitank landmine can be seen allowing not only the detection, but identification of the landmine. The irregularities of the surface and the native vegetation had no noticeable effect on the images of the landmines.

DISCUSSION

Based on the results of the laboratory studies and these field test results we believe that a civilian mine detection system can be economically assembled using commercial off the shelf (COTS) components. The system would consist of an industrial x-ray machine as the source and some form of scintillator with a photomultiplier output as the detector. The detector could surround the source for greater collection efficiency and move with the source. The source/detector assembly would move in an arc back and forth in front of a remote controlled vehicle, on which it is mounted. Power to the vehicle and signals from the detectors would be via an umbilical cord connecting the vehicle to the operator and control systems. Using this arrangement the operator and the most expensive components of the system would be safe from accidental mine explosion. Additional sensors such as a TV camera, metal detector or other appropriate devices could be mounted on the vehicle. An artists concept of what such a system might look like is shown in Figure 5. We estimate that such a system could clear a meter wide path at a rate of 10 m/hr.

CONCLUSIONS

This work combined with the previous experiments conducted at SNL and UF show that the backscatter x-ray imaging system has overcome many of the difficulties that are associated with landmine detection. It can work in areas with ground cover, surface irregularities, snow, surface and buried objects, and can image both plastic and metal landmines. The backscatter x-ray imaging system can also function under a variety of weather conditions. During the field test the weather varied from high heat to wind and blowing dust and rain. The images generated by this system can also be used to lower the false positives by comparing the current image with previously imaged landmines. It was also shown that all the equipment needed for this system was commercially available.

ACKNOWLEDGEMENTS

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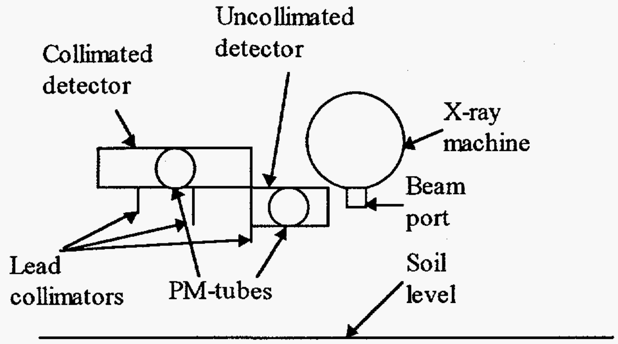

Figure 1. Drawing of detector layout

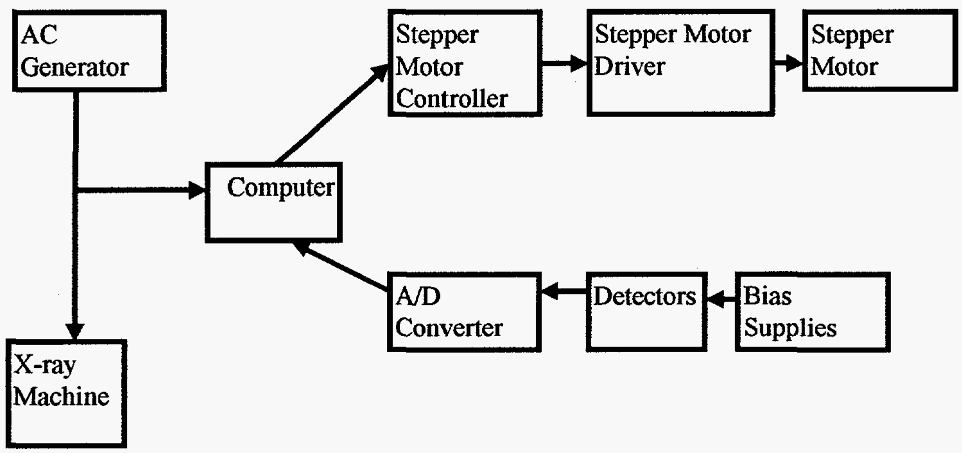

Figure 2. Block diagram of the experimental configuration.

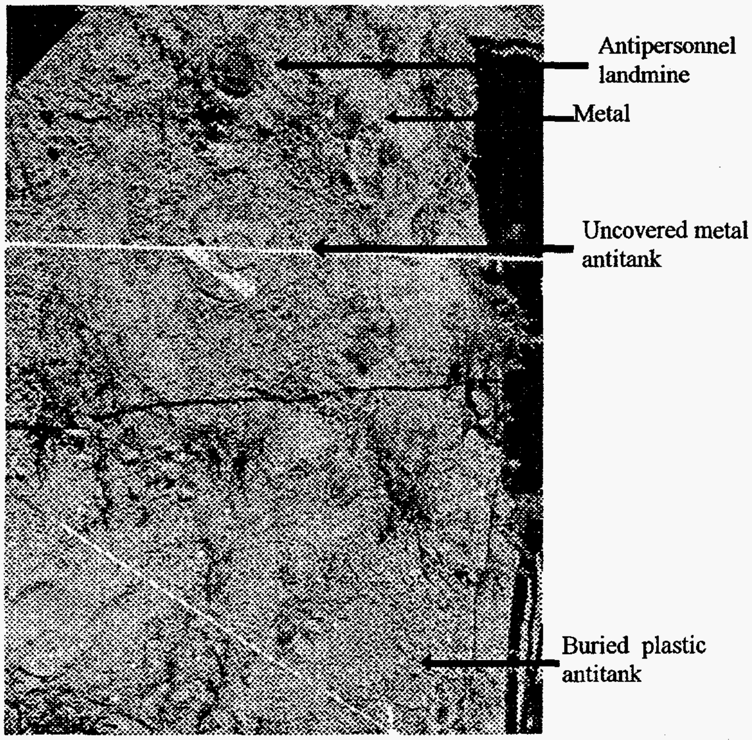

Figure 3. Picture of the landmine

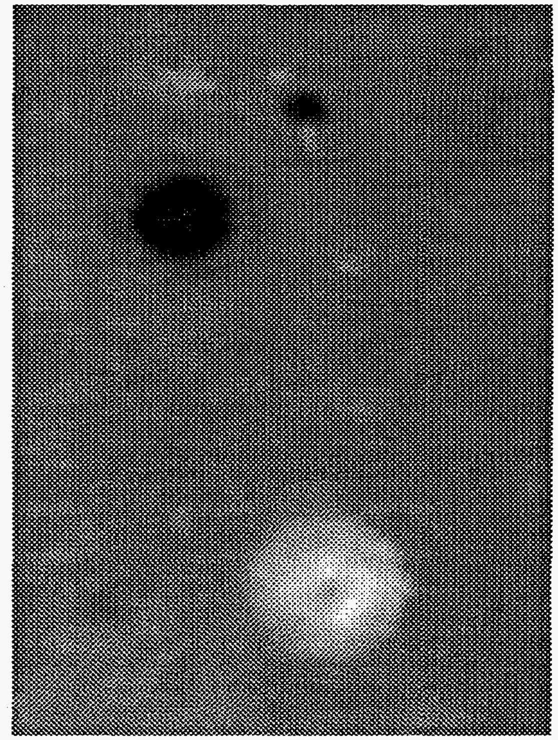

Figure 4. Image of the landmine

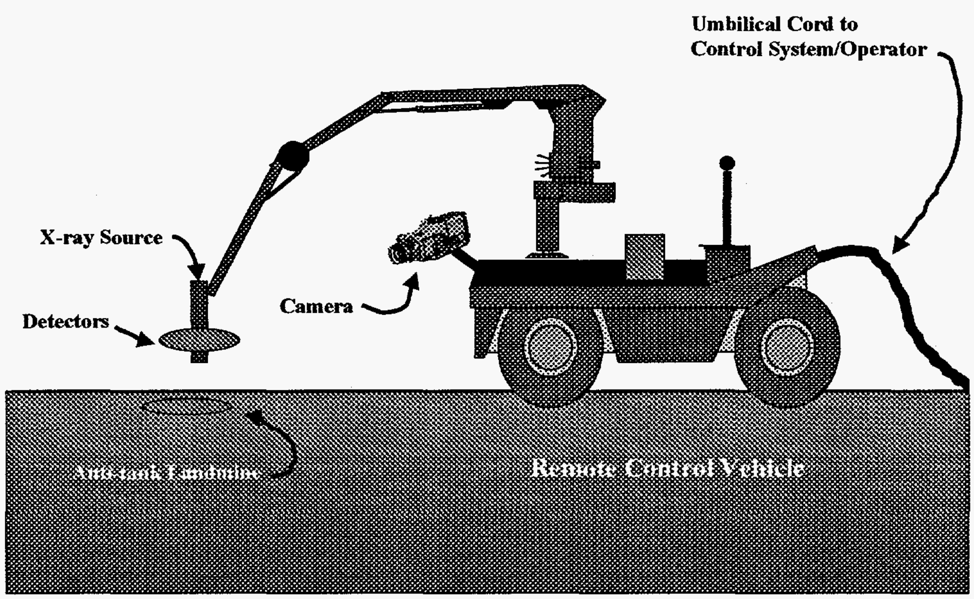

Figure 5. Artist's concept of landmine detection system.