Landmine detection using backscattered x-ray radiography

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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 fieldwork and to evaluate the systems performance with real landmines. To assess the system's response to a variety of objects, buried simulated plastic and metal antitank landmines, surface simulated plastic antipersonnel landmines, and surface metal fragments were used as targets for the field test. The location of the test site was an unprepared field at SNL. The tests conducted using real landmines were held at UF using various burial depths.

The field tests yielded the same levels of discrimination between soil and landmines that had been detected in laboratory experiments. The tests on the real landmines showed that the simulated landmines were a good approximation. The real landmines also contained internal features that would allow not only the detection of the landmines, but also the identification of them.

Keywords: Backscattered x-ray, imaging, mine detection

1. 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.)[2,3] 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.[4,5] This research focuses on the configuration of the system for imaging the landmines under field conditions and image performance with real landmines

2. FIELD TESTS

2.1 X-ray generator

The x-ray generator that was used for the field tests was a Philips industrial x-ray machine model MCN 225. For the field experiments it was operated at 150 kV and 5mA. 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 2cm diameter x-ray spot on the soil. A generator provided all the power for the equipment used in this experiment. The total power used by the fielded system was less than 5 kW.

2.2 Detector system

The detector system used for the field tests consisted of one collimated detector and one uncollimated detector. Both the detectors were made by BICRON and used a photo-multiplier tube as the light sensing element and BC400 as the 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.

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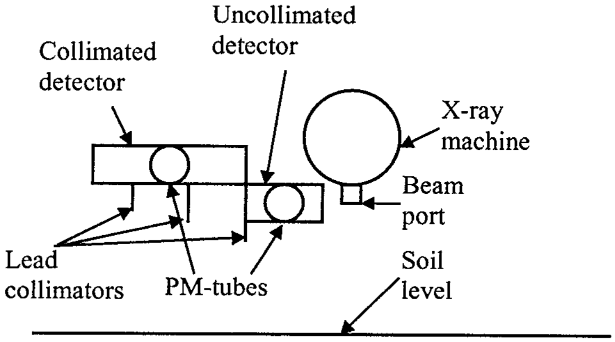

Figure 1. Drawing of detector layout

2.3 Motion control and data acquisition

To allow a 1m 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. Figure 2 shows an overview of

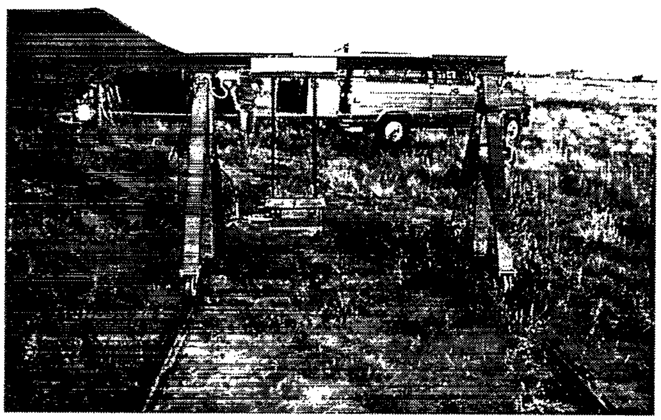

Figure 2. Picture of experimental configuration and inert landmine field.

the experimental configuration showing the gantry that supports the detectors and the x-ray head. The weight of the detector system and the x-ray head was ~ 100 lb.

The data acquisition system used a National Instruments 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 the van seen in Figure 2. A schematic of the data acquisition system and the motion control system is shown in Figure 3.

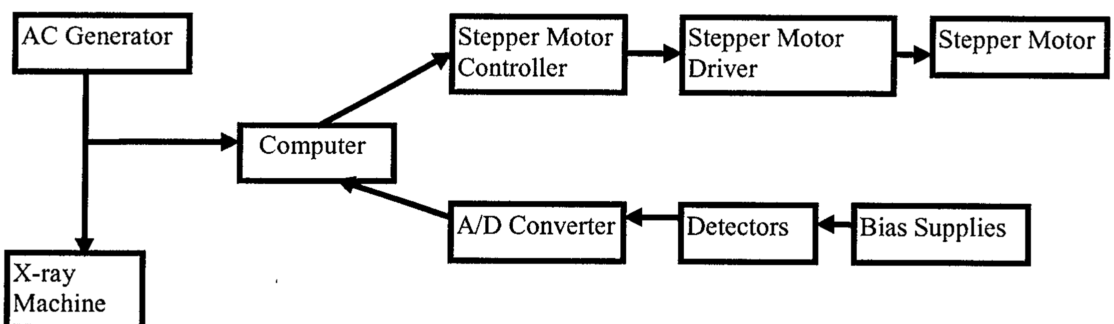

Figure 3. Block diagram of the experimental configuration

2.4 Landmine field

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

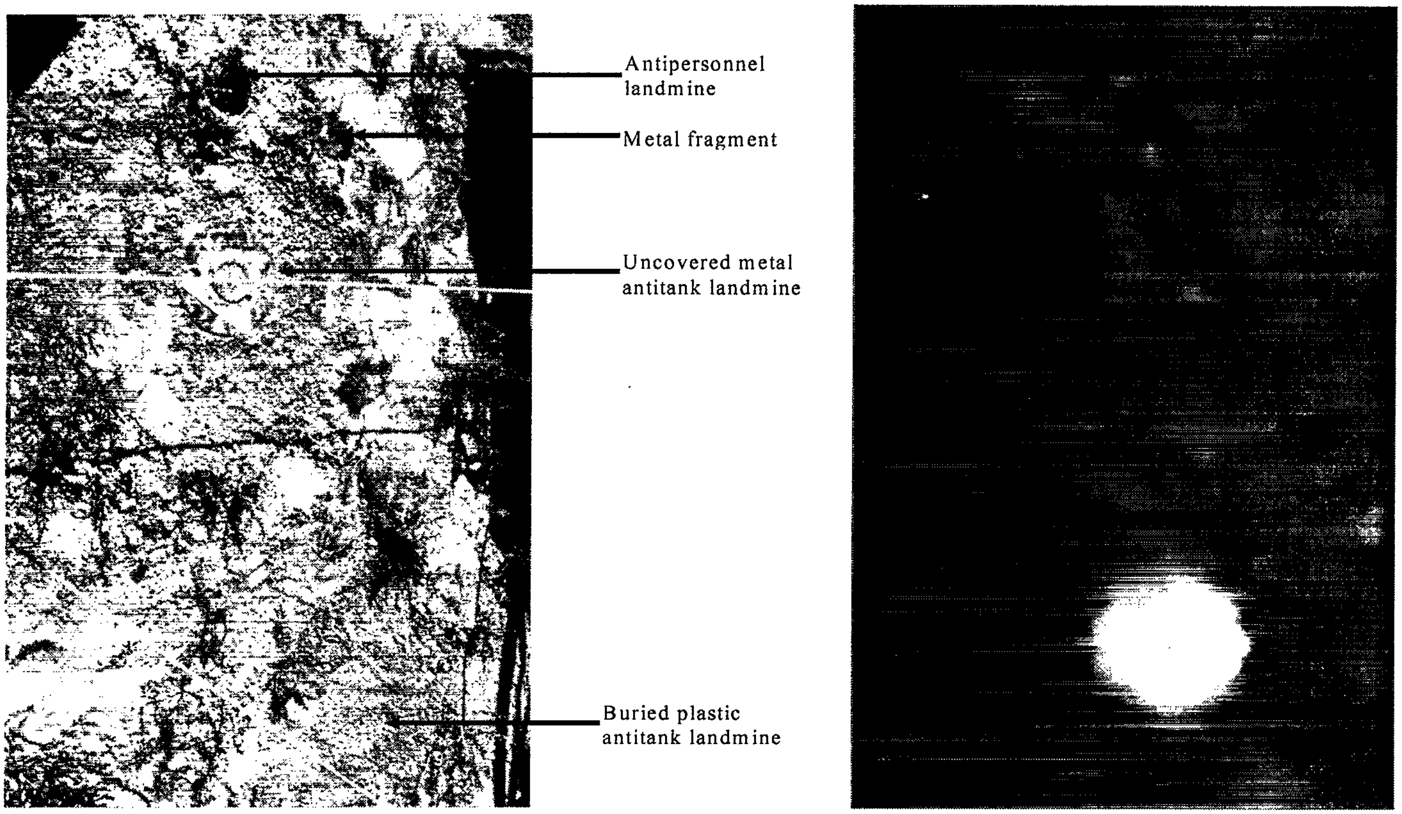

Figure 4. Picture of landmine field and backscattered image of landmines.

3. FIELD TEST 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. 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 also identification of the landmine. The irregularities of the surface and the native vegetation had no noticeable effect on the images of the landmines.

4. REAL LANDMINE IMAGES

4.1 X-ray machine

The x-ray generator that was used for the field tests was a GE Maxitron 300 industrial x-ray machine. For the real landmine experiments it was operated at 150 kV and 5 mA. The Maxitron produces a half-wave rectified output at 1200 Hz. The spot size used was 2.5 cm x 2.5 cm for the antitank landmines and 1.5 cm x 1.5 cm for the antipersonnel landmine. The landmine detection group at UF[6] performed the work for the real landmine tests.

4.2 Detector system

The detector system used for the real landmine tests consisted of two collimated detectors and two uncollimated detectors. Both of the collimated detectors were made by BICRON and used a photo-multiplier tube as the light sensing element and BC400 as the plastic scintillator. The uncollimated detectors were built and designed at UF and used a scintillating sheet created by DuPont. The collimated detectors were 30 cm wide by 30 cm deep by 5 cm thick, the uncollimated detectors were 30 cm wide by 7.6 cm. Figure 6 shows a drawing of the detector positions relative to the x-ray machine.

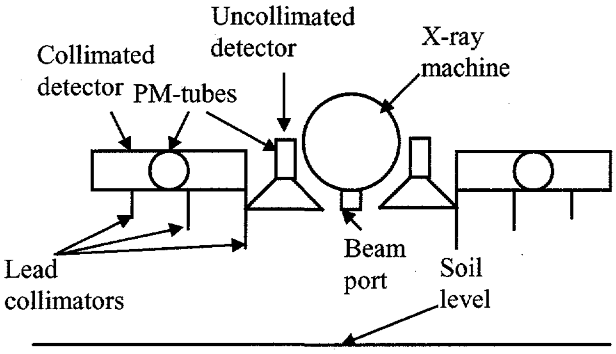

Figure 6. Drawing of detector layout

4.3 Motion control and data acquisition

The Maxitron x-ray machine could not be readily moved so a sandbox on an x-y table was used to simulate the motion of a vehicle and the rastering of the x-ray head. LabView was used to control the two DC servomotors and optical encoders were used to create a closed loop positioning system. The data acquisition system was also integrated with the motion control. All four detectors were simultaneously sampled and the integrated energy deposited in each detector was calculated.

5. REAL LANDMINE RESULTS

The four landmines that were imaged were the M-19, TMA-4, VS-1.6, and the TS/50. Figure 7 shows pictures of the real landmines. The M-19, TMA-4 and the VS-1.6 are all plastic cased antitank landmines. The TS/50 is plastic cased antipersonnel landmine. The antitank landmine images were all taken at a burial depth of 2.5 cm. The antipersonnel landmine image was taken with the TS/50 placed on the surface. Figure 8 shows the resulting images of the landmines.

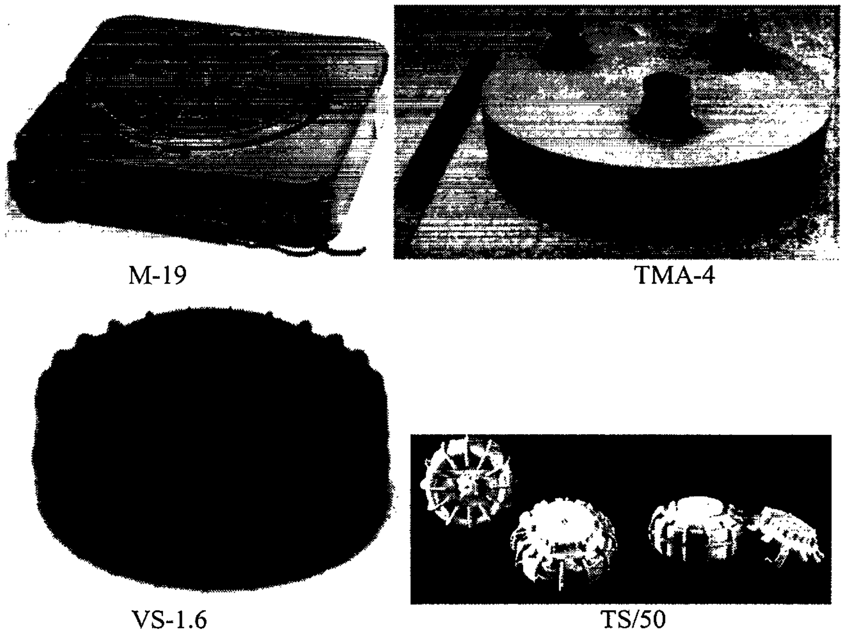

Figure 7. Pictures of the real landmines.

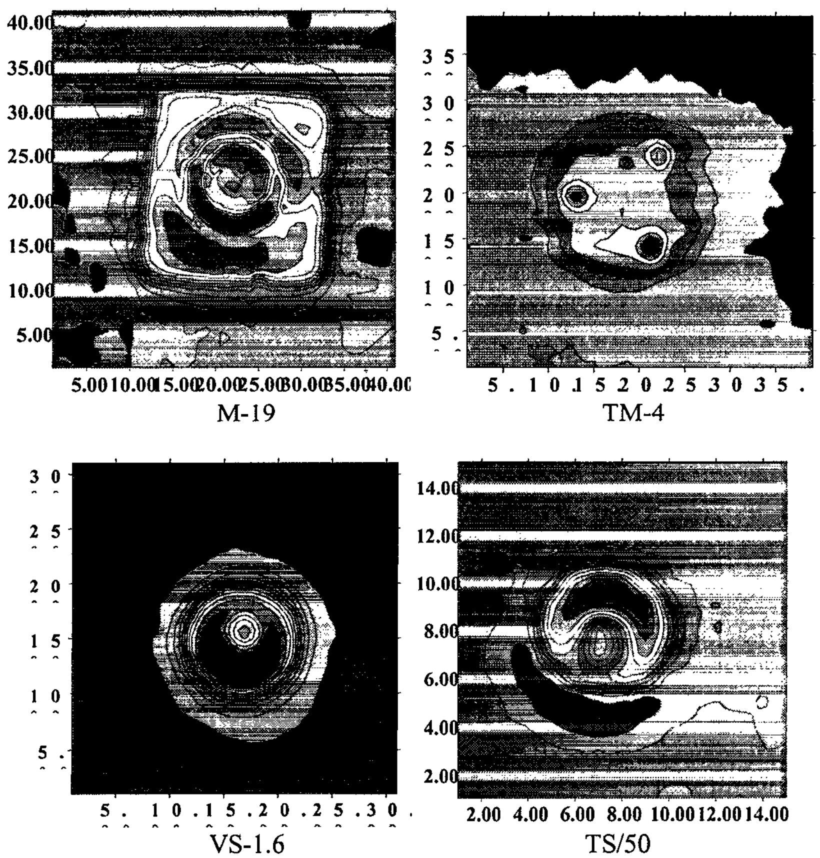

Figure 8. Image of the real landmines.

6. CONCLUSIONS

The images of the real landmines show that not only can landmines be located, the features of specific landmines can be identified. The field work and the real landmine tests 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, 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.

7. ACKNOWLEDGEMENTS

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