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MOBILE, SCANNING X-RAY SOURCE FOR MINE DETECTION USING BACKSCATTERED X-RAYS

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Abstract

A continuously operating, scanning x-ray machine is being developed for landmine detection using backscattered x-rays. The source operates at 130 kV and 650 mA. The x-rays are formed by electrons striking a high Z target. Target shape is an approximate 5 cm wide by 210 cm long racetrack. The electron beam is scanned across this target with electromagnets. There are 105, 1-cm by 1-cm collimators in each leg of the racetrack for a total of 210 collimators. The source is moved in the forward direction (the direction perpendicular to the 210-cm dimension) at 3 mi/h. The forward velocity and collimator spacing are such that a grid of collimated x-rays are projected at normal incidence to the soil. The spacing between the collimators and the ground results in a 2-cm by 2-cm x-ray pixel on the ground.

A unique detector arrangement of collimated and uncollimated detectors allows surface features to be recognized and removed, leaving an image of a buried landmine. Another detector monitors the uncollimated x-ray output and is used to normalize the source output. The mine detector is being prepared for an Advanced Technology Demonstration (ATD). The ATD is scheduled for midyear of 1998. The results of the source performance in pre ATD tests will be presented.

Keywords: Landmine detection, X-rays, X-ray backscatter, Imaging

1. Introduction

The Compton backscatter imaging technique has been shown in the laboratory that it can be used to detect buried or hidden nonmetallic mines as well as metallic mines.[1,2] This technique relies on the absorption and scattering of energetic photons. The probability that a photon will be absorbed or scattered is a function of the energy of the photon and the properties of the materials in which it interacts. The differences between mine and soil that allow this technique to provide images are the higher absorptive and lower scattering properties of soil compared to the nonmetallic mine and the lower absorptive higher scattering properties of soil compared to metallic mines. A narrow beam of photons is directed into the soil in which a mine may or may not be present. A detector system located above the soil intercepts backscattered photons. A higher detector response is recorded when the beam strikes the mine than when

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it strikes only soil. Other materials in the soil, such as organic matter, may have photon interaction properties similar to the nonmetallic mine. To avoid false alarms from such materials, the beam is scanned over the area of interest and the detector response is recorded as a function of the position that the beam strikes the ground. A microprocessor produces a visual real-time image for immediate observation and analysis. The result is an image of the buried object whose shape and intensity can be used to reduce false alarms. A low false alarm rate is important for military applications since it affects the speed at which a "safe path" is obtained. We are preparing a source for this application.

2. Mobile Mine Detection System

The system consists of an x-ray source, detectors, cooling system, auxiliary generators, and computers. The x-ray source power supply is run by a 100kw, 440 volt, 400 Hz, diesel generator. There is an additional 45 kW, 60 Hz, diesel generator to supply power to the rest of the electrical equipment, such as vacuum pumps, cooling pumps, computers, etc. The source, high voltage power supply and 100 kW generator will be mounted on a custom built, air-ride, axleless trailer. The rest of the equipment will be mounted on a 5-ton, 6 X 6 Army truck. The truck and trailer are shown in Figure 1. Figure 2 shows a model with a potential layout of equipment on a trailer. An umbilical cord will connect the truck and trailer.

The x-ray source is designed on a pivotal mount. When in use for mine detection the source will be tilted up so that the collimated x-ray beams strikes the ground at normal incidence and is 30 cm above the ground. There will be two sets of detectors mounted on each side of the source. Each set will consist of a 5.8 cm x 7.6 cm x 245 cm Bicron scintillating detector with a photomultiplier on each end and a 5.8 cm x 30.5 cm x 245 cm collimated detector with light pipes coupling two photomultipliers, one at each end. The collimators were designed in collaboration with the University of Florida (UF) to only detect multiply backscattered x-rays. The smaller detector will detect both first backscattered and multiply backscattered x-rays. The first backscattered x-rays mainly come from the surface and surface clutter. This unique detector arrangement and algorithms developed at UF allow surface features to be removed leaving only the image of a buried mine. Images of buried mines detected and imaged using these algorithms are given in references 1 and 2.

The source and associated equipment will be mounted on the truck and trailer in the near future and field tested at Sandia National Laboratories before going to the ATD. There are still some improvements that need to be made to the source and it's operation before mounting on the vehicle.

3. Scanning X-ray Source

A scanning x-ray source was built for the Army by Imatron, Inc. It is a modified computed tomography cat scanner.[3,4] The x-ray source is shown in Figure 3. An 130 kV, 650 ma, electron beam is generated by a Dispenser cathode and transported 2.7 meters to the high Z targets. A total of 10^6 photons/pixel is projected onto the ground in a 2 cm x 2 cm pixel. The electron beam is shaped, focussed and guided in a racetrack configuration by six electromagnets located near the cathode. The electron beam is scanned in a racetrack that is approximately 5 cm x 210 cm. The position and timing of the electron beam is measured by 30 "W"- wires, see Figure 4. As the beam sweeps across the wires there are three current peaks which gives shape and timing information as well as beam position. The beam position and shape on the "W"-wire is controlled by adjusting the appropriate guiding magnet. The entire source is shielded with Mu metal to reduce the effects of stray magnetic fields. Typical magnetic guiding fields are on the order of a few tens of gauss so that the earth's magnetic field or other stray fields can have a significant effect on the beam if not properly shielded.

When the electrons strike the high Z target x-rays are produced. At these low energies the x-rays are isotropic. The targets are angled at 35 degrees with respect to the incident electron beam. Two sets of collimators, each consisting of 105, 1 cm x 1 cm tubes, produce a well-collimated x-ray beam to strike the ground at normal incidence. The collimator spacing is 2 cm center to center. Each racetrack leg is angled such that a forward speed of 3 mi/h will provide 2 cm x 2 cm pixels on the ground, see Figure 5. To match a forward velocity of 3 mi/h the scan time must be 15 ms for one complete circuit around the racetrack. This time is 6.5 ms to traverse each set of 105 collimators plus the time for the beam to move from one set of collimators to the other. Each individual collimator is made up of 12-0.32 mm tubes soldered to a 0.64 mm tube. The collimators are sandwiched in an aluminum frame. The total length of each collimator is 20 cm. Figure 6 is a picture of the collimator array. During the testing of the source Polaroid film with an intensifier screen was placed on the collimators to look at the x-ray output. There was significant x-ray leakage around the collimators. A final x-ray mask made from tantalum defines the discrete x-ray beams. Figure 7 shows the x-ray output before and after this modification was made.

To achieve reliable mine detection with a low false alarm rate the x-ray output must be constant and reproducible to ± 1%. There are several variables that can affect the x-ray output. The high voltage power supply must be constant with little or no ripple. Measurements have shown that there is a ± 2.5 % ripple on the power supply. This is will cause the electron beam to move 1 cm on the convertor. We are building a feed back circuit that will apply a portion of the ripple signal to the correction magnets to compensate for this change. We have also installed a 1 cm x 1 cm x 200 cm fiber optic scintillating detector and photomultiplier tube behind the convertors to measure the total x-ray output on each scan so that the x-ray output can be normalized. Figure 8 shows the output of this detector compared to the collimated signal out measured with one of the 5.8 cm x 30.5 cm x 245 cm detectors. We then placed a 30 cm diameter piece of plastic on the detector and compared it to the normalizing detector. These results are shown in Figure 9. The backscatter signal from the plastic is clearly shown when compared to the normalizing detector.

4. Summary

All necessary equipment has been designed and fabricated for mobile field tests. This test will be conducted in the summer of FY 97 at Sandia National Laboratories. The ATD will be conducted in FY 98. Several problems in the source operation have been identified and most have been corrected. For those that have not been corrected solutions have been found and are being implemented.

5. Acknowledgments

The authors would like to thank Charlotte Burchanowski of the Night Vision and Electromagnetic Sensor Division (NVESD) of the U.S. Army at Ft. Belvoir, VA. and Robert Moler of Systems Support, Inc. for their valuable technical advice and support. This program was funded by NVESD (MIPR 7DDOE2717A) and a DoD/DOE Memorandum of Understanding.

6. References

1. Grant Lockwood, et. al., "Mine Detection Using Backscattered X-ray Imaging of AntiTank and AntiPersonnel Mines", *Proc. of SPIE's 11th Annual Symposium on Aerospace/Defense Sensing, Simulation, and Control, 20-25 April 1997, to be published.*
2. Joseph Wehlburg, et. al., "Geometric Considerations Relating to Lateral Migration Backscatter Radiography (LMBR) as Applied to the Detection of Landmines",. *Proc. of SPIE's 11th Annual Symposium on Aerospace/Defense Sensing, Simulation, and Control, 20-25 April 1997, to be published*
3. R. Rand, "Continuous Anode Scanned Beam X-ray Source Feasibility Study," Final Scientific and Technical Report, Contract DAAK70-88-C-0011, Imatron, Inc., 1989.
4. R. Smith, "Design, Fabrication,and Testing of a Testbed Linear-Anode Scanned-Beam X-ray Source for a Mine Detection System", Final Report, Contract DAAK70-90-C-0009, Imatron, Inc., October, 1994.
5. J. Campbell, "Landmine Detection by Compton Backscatter Imaging: Data Analysis", Dept. of Radiological Health Sciences, Colorado State Univ. June 30, 1996.

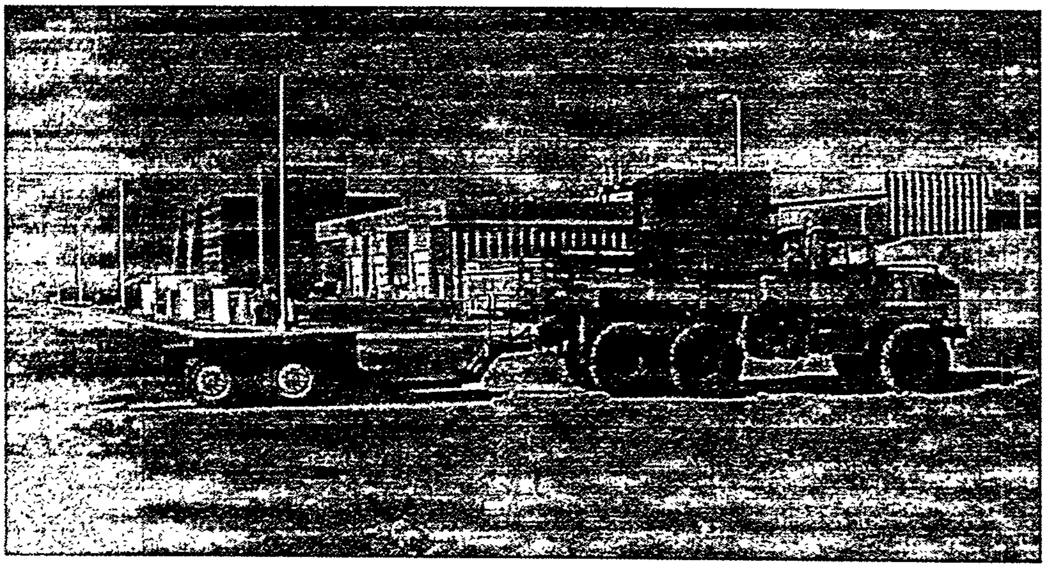


Figure 1. The truck and trailer for the mobile tests. The truck has the housing for the computer mounted.

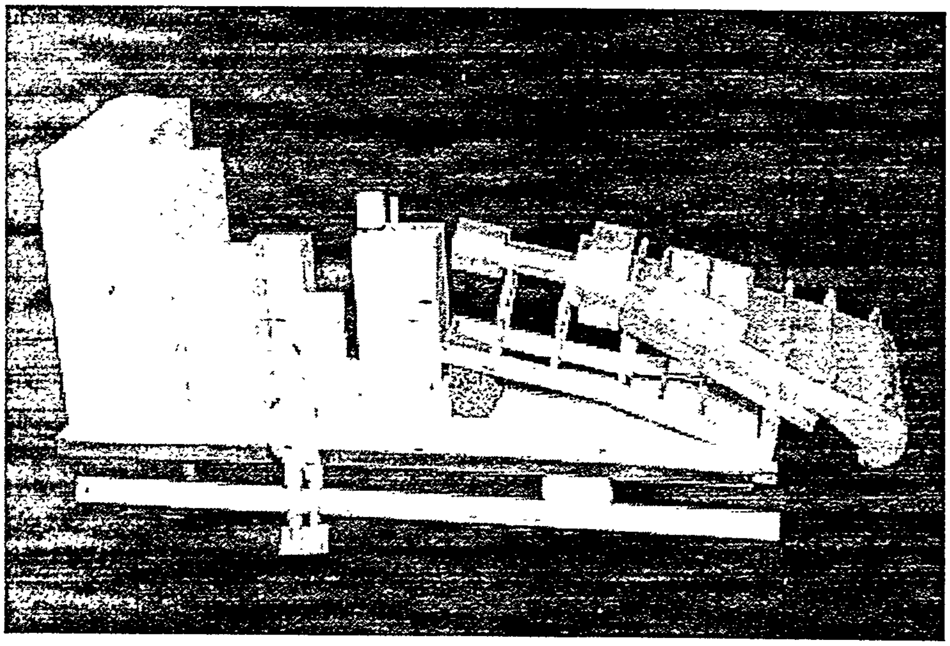


Figure 2. Model of the source and equipment mounted on trailer.

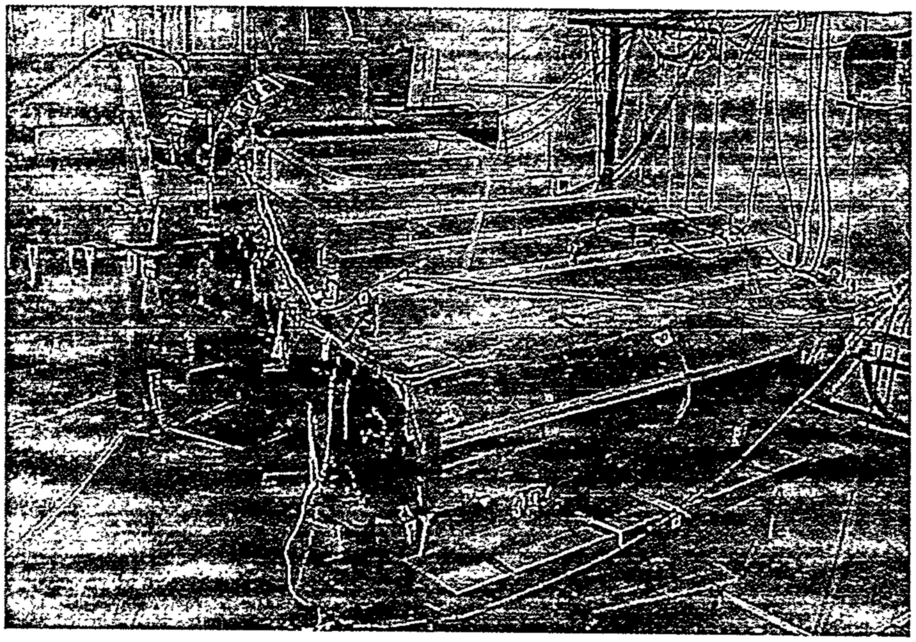
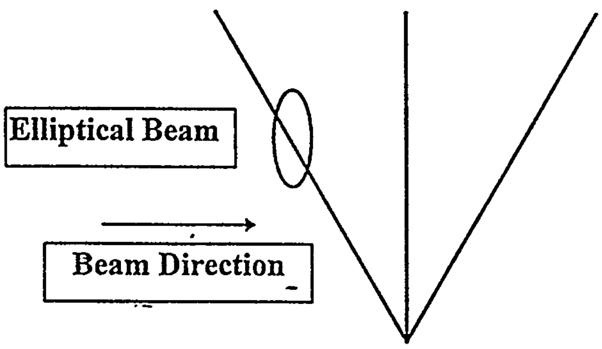
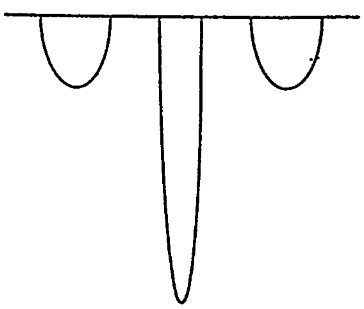


Figure 3. Photograph of the x-ray source.



a.



b.

Figure 4. a. The "W"-wires with an elliptical beam crossing them. b. Output waveform from properly tuned beam. (from reference 4). The width of the peaks, peak height, and spacing are related to the beam shape, position and timing.

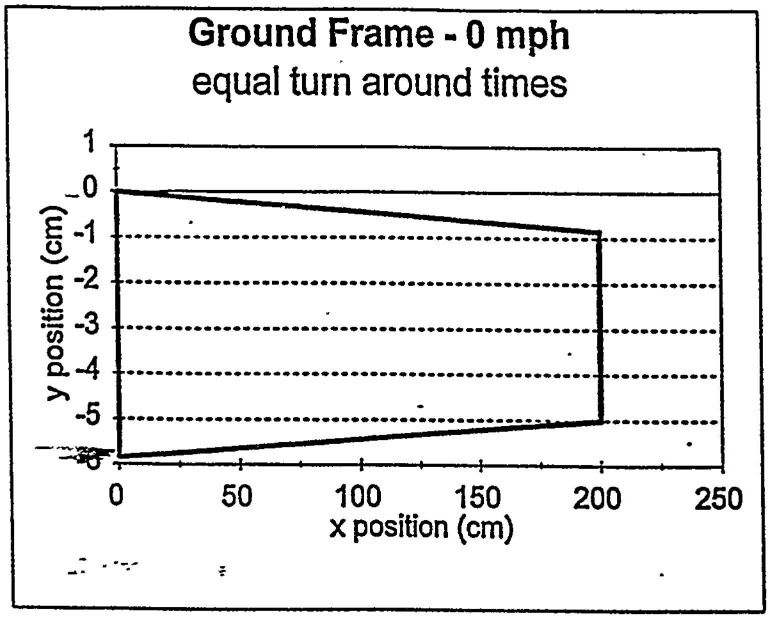


Figure 5a. The x-ray scan pattern when the vehicle carrying the source is at rest. This scan pattern is the vehicle frame pattern.

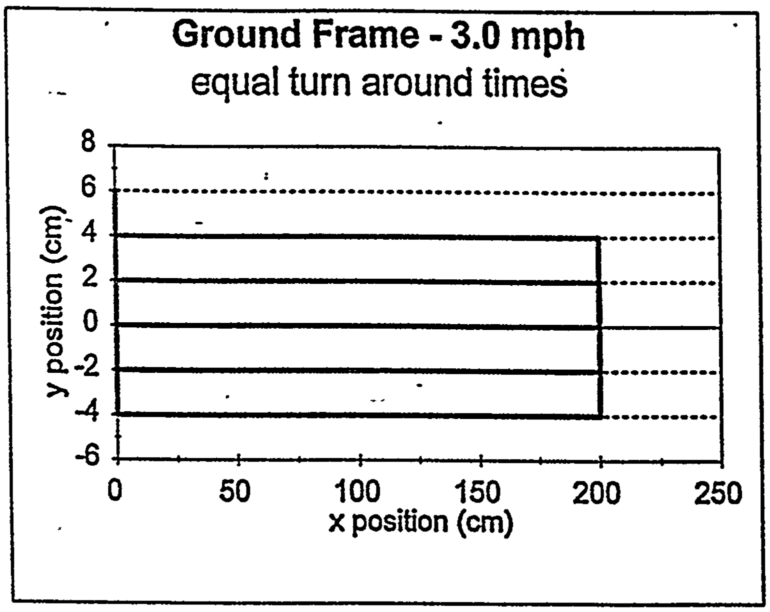


Figure 5b. The x-ray scan pattern when the vehicle carrying the source is moving forward at 3 MPH. The collimators in the source have been angled to produce this pattern.

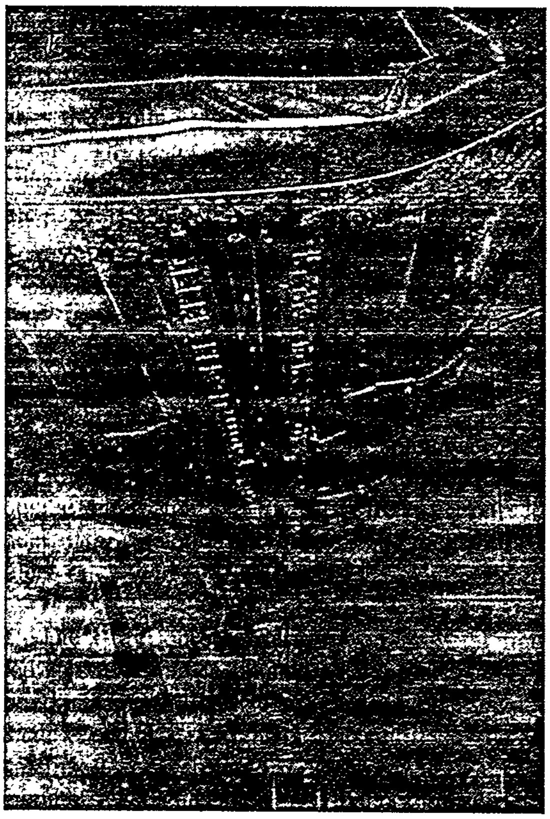


Figure 6. Photograph of the angled collimators.

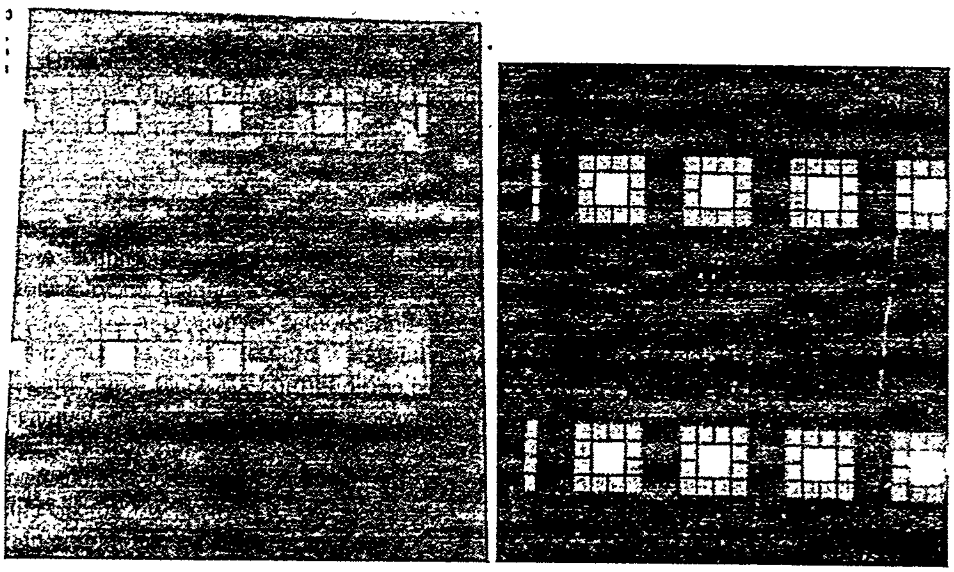


Figure 7. X-ray output of source. The radiograph on the left shows the x-ray leakage. The radiograph on the right is after the Ta mask was added.

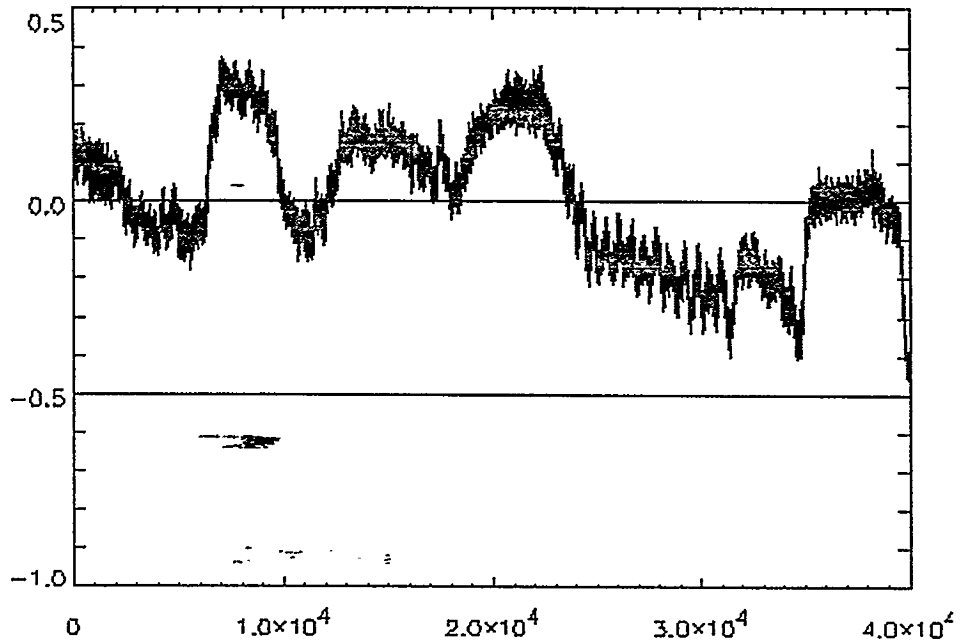


Figure 8. Comparison of the regular detector (light trace) and the normalization detector (dark trace). The two traces are nearly equal and difficult to tell apart..

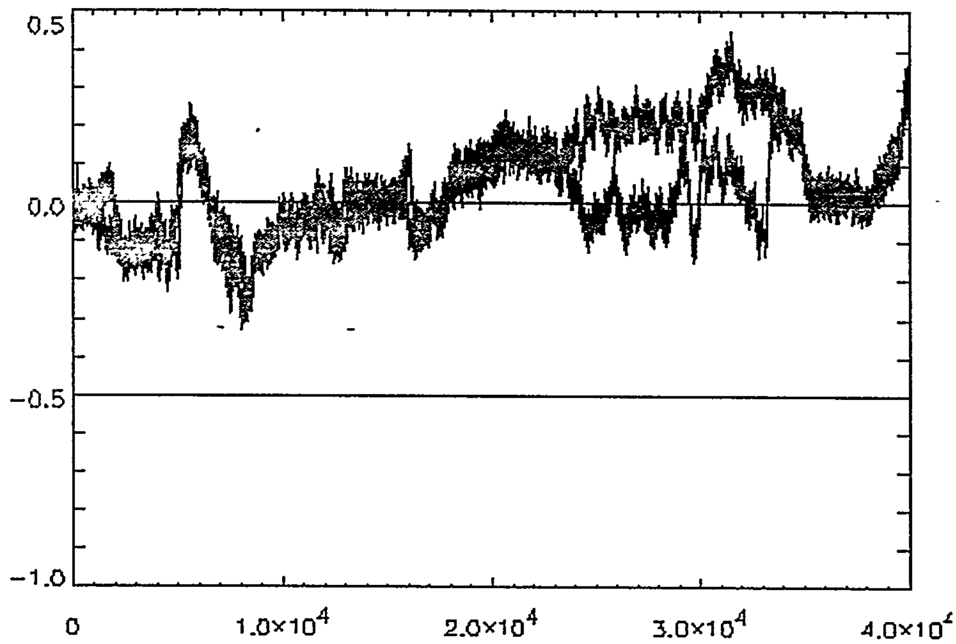


Figure 9. Same detector arrangement as Figure 8 with a simulated mine in place. The difference in the two traces at x equal to 2.3×10^4 and 3.6×10^4 is caused by the plastic.