FIELD TESTING AND APPLICATIONS OF THE ULTRASONIC RANGING AND DATA (USRAD) SYSTEM[1]

K. S. Dickerson, D. A. Pickering, M. S. Blair,* M. L. Espegren, and J. E. Nyquist

Health and Safety Research Division
**Instrumentation and Controls Division*
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831

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ABSTRACT

The Ultrasonic Ranging and Data (USRAD) System is a patented, computerized data-acquisition system developed to relate the radiological surveyor's precise physical location to instantaneous radiation data taken during walk-on surveys. The USRAD System incorporates three technologies: radio frequency communications, ultrasonics, and microcomputers. Initial field testing of the USRAD System has resulted in several improvements to walk-on radiological surveys including real-time position data, reproducible survey results, on-site verification of survey coverage, on-site data reduction and graphics, and permanent data storage on magnetic media. Although the USRAD System was developed specifically for use with a gamma-ray detector, it is adaptable to other instruments. Applications of the USRAD System may include verification of remediated and uncontaminated areas, emergency response in mapping pollutant locations after accidents, and characterization of hazardous waste areas.

INTRODUCTION

The Pollutant Assessment Group (PAG) of the Health and Safety Research Division at Oak Ridge National Laboratory (ORNL) is the inclusion survey contractor (ISC) for the Uranium Mill Tailings Remedial Action (UMTRA) Project. The role of the ISC is to conduct radiological surveys on over 11,000 properties potentially contaminated with uranium mill tailings. The PAG has developed advanced field survey techniques for characterizing these UMTRA vicinity properties. The USRAD System was developed in an effort to better manage and compile the survey data, and to conduct the radiological surveys in a more cost-effective manner. The USRAD System technology also automates much of the radiological survey process and provides tabular and graphical survey data output in the field or in the office for report generation.

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The purpose of this paper is to identify the benefits and limitations of the USRAD System as determined by field testing. Further applications of the USRAD System can be identified through an understanding of the USRAD System and its benefits.

BACKGROUND

From the early 1940s through 1970, uranium ore was processed at mills owned by private companies under contracts with the Manhattan Engineer District and the U.S. Atomic Energy Commission (AEC) to be used in weapons, reactors, and research. As the demand for uranium oxide decreased, many of the mills were deactivated. Large quantities of processed ore residue (tailings) were deposited in stockpiles and were left uncontrolled. The public was allowed to access some of the tailings piles for use as an aggregate or as backfill in construction activities. Properties that used the tailings are termed vicinity properties (VP) and include residences, commercial buildings, schools, and open lands.

In 1972, Congress passed Public Law 92-314 to provide funds for cleanup of VPs under the Grand Junction Remedial Action Project (GJRAP) in Grand Junction, Colorado. Also in 1972, the AEC, in cooperation with the U.S. Environmental Protection Agency (EPA), initiated a program to determine the radiological inventory and public health effects associated with the mill tailings. In 1978, Congress passed Public Law 95-604, the Uranium Mill Tailings Radiation Control Act (UMTRCA), requiring the federal government to perform remedial actions at the sites and associated VPs that had been used by the federal government.

The Department of Energy (DOE) was tasked with conducting remedial actions at the 24 inactive sites under the auspices of the UMTRA Project. Thus, the DOE is responsible for overseeing all aspects of the UMTRA Project, from identifying candidate VPs to certifying that properties and sites have been remediated in compliance with the EPA standards set forth in 40 CFR Part 192. All activities are coordinated with the appropriate federal, state, local and tribal governments, and with the Nuclear Regulatory Commission (NRC).

Once a property has been identified, ISC conducts a radiological walk-on survey. The objective of the survey is to locate regions of contamination and determine if the contamination exceeds the EPA Standards (EPA 1982) (Fig. 1). The amount of contamination is investigated by a direct measurement of the gamma exposure rate at the surface. When the exposure rate is above a threshold value, a soil sample is taken and laboratory analysis performed for ^{226}Ra concentration.

The initial step has been to generate a map of the property by hand or by computer-aided drafting. The gamma measurements have then been manually recorded on the map. All subsequent data reduction and report writing have been performed by field technicians. Based on this data, a final inclusion recommendation is delivered to the DOE.

HARDWARE

The USRAD System incorporates three technologies: radio frequency (RF) communications, ultrasonics, and personal computers (PC). RF is used for system timing, communications, and data transfer. The propagation time of an ultrasonic signal serves as a device to measure the distance travelled while scanning. The PC is used to calculate the surveyor position; reduce, store, and display data; prepare reports; and transfer data into electronic data bases. Hardware included in the USRAD System consists of a surveyor's backpack

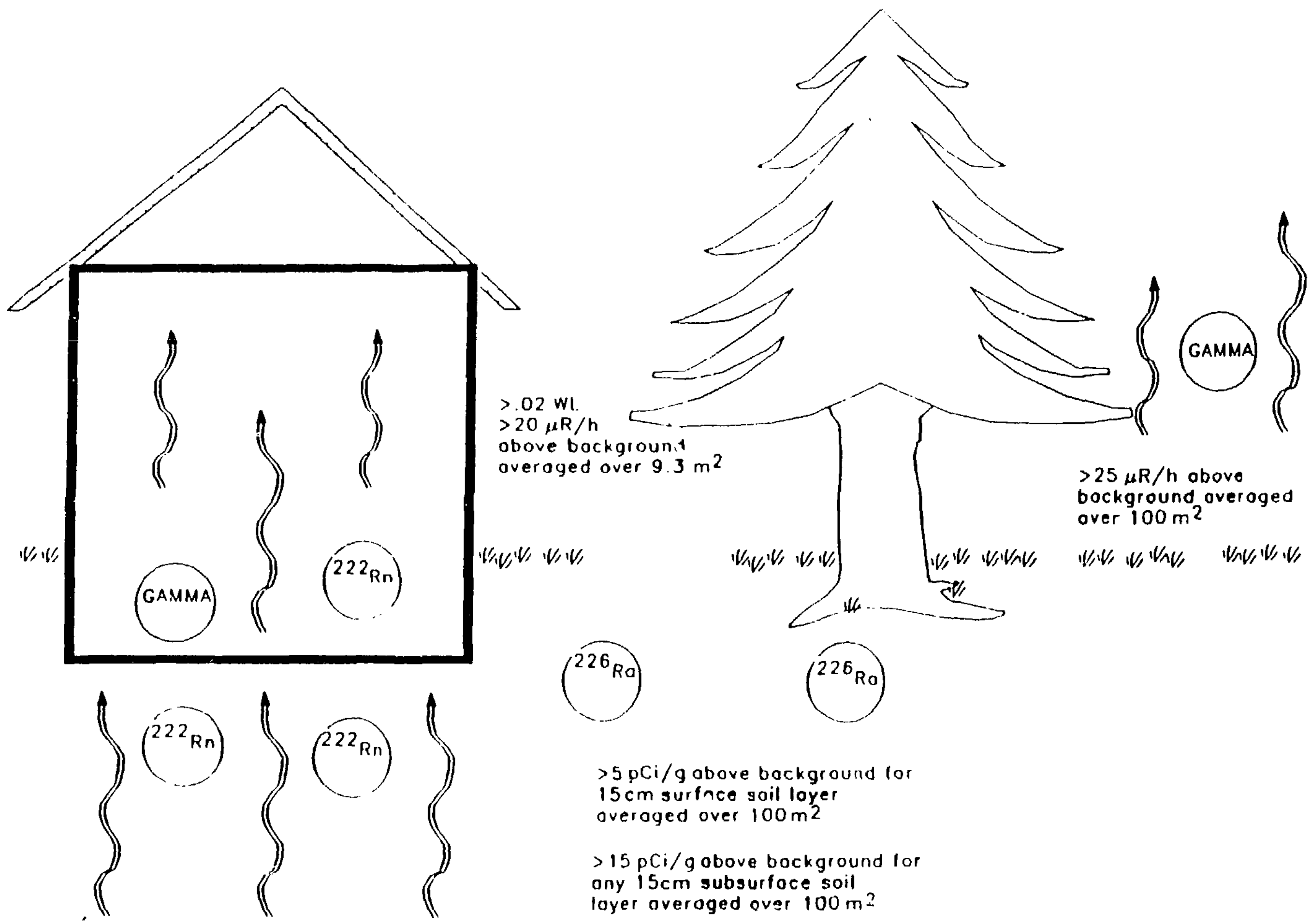

Fig. 1. EPA standards as set forth in 40 CFR 192 UMTRCA.

(SB), 15 stationary receivers (SR), a master receiver, custom computer interface or counter time module (CTM), and a PC (Fig. 2).

The SB contains an ultrasonic transmitter, an RF transmitter and receiver, a survey instrument interface, and a hand-held terminal and microcomputer chip. The ultrasonic transmitter emits a characteristic ultrasonic signal once each second to locate the surveyor's position. The RF transmitter and receiver provide two-way communication between the SB and the PC and provide a signal for system timing. The survey instrument converts input from the survey instrument to a digital signal for transmission to the PC. The microcomputer chip is the master timing device for the entire system; it is operated through the hand-held terminal. The microcomputer chip and terminal in the SB also encode and decode messages from the personal computer and allow the surveyor to remotely control several survey functions.

Each of the 15 SRS contains an ultrasonic receiver, ultrasonic signal identification electronics, and an RF transmitter. The ultrasonic receiver detects the signal from the surveyor backpack. The ultrasonic signal electronics identifies specific ultrasonic signals from the surveyor backpack and trigger the RF transmitter. The RF transmitter sends a signal to the master receiver on a frequency assigned to each stationary receiver.

The master receiver contains 16 RF receivers and 1 RF transmitter. Each receiver is on a characteristic frequency corresponding to 1 of 15 SRs plus 1 for the SB. The transmitter, also on an assigned frequency, enables communication from the PC to the SB.

The CTM is a customized interface board which plugs into the PC. The module times the ultrasonic signal from the SB to each SR, processes that data, and transmits that information to the PC. The CTM also connects the PC and the system, enabling other communications.

The PC is presently a Compaq portable, which is an IBM compatible.

OPERATION

The distance between two points can be measured by the length of time it takes sound to travel from one to the other. To measure this distance, the speed of sound in air [normally 1100 ft/s (335 m/s)] must be known. This method is used in the USRAD System. The time it takes a signal transmitted from the backpack to reach each of the 15 SRs is established, and this relationship is then used to calculate the surveyor's location on the property. The surveyor's location and survey instrument response are determined once each second during a scan, providing detailed information about the property which is then stored and interpreted.

Setup of the USRAD System begins with placing the SRs in appropriate locations over the property (Fig. 3). The surveyor backpack is then used to input (or code) the location of each of the SRs into the system and to determine the speed-of-sound-in-air at the time of the survey.

As the surveyor begins to scan the property, the surveyor's backpack emits an ultrasonic pulse once each second. At the same time, the SB transmits an RF signal to the PC. Receipt of this RF transmission at the PC initiates the timer in the CTM card. When each stationary receiver detects a valid ultrasonic signal, the SR immediately transmits an RF signal to the PC. The RF signal from the SR stops the timer for that particular SR. The characteristic frequency transmitted by the SR is coded in the CTM card for that specific

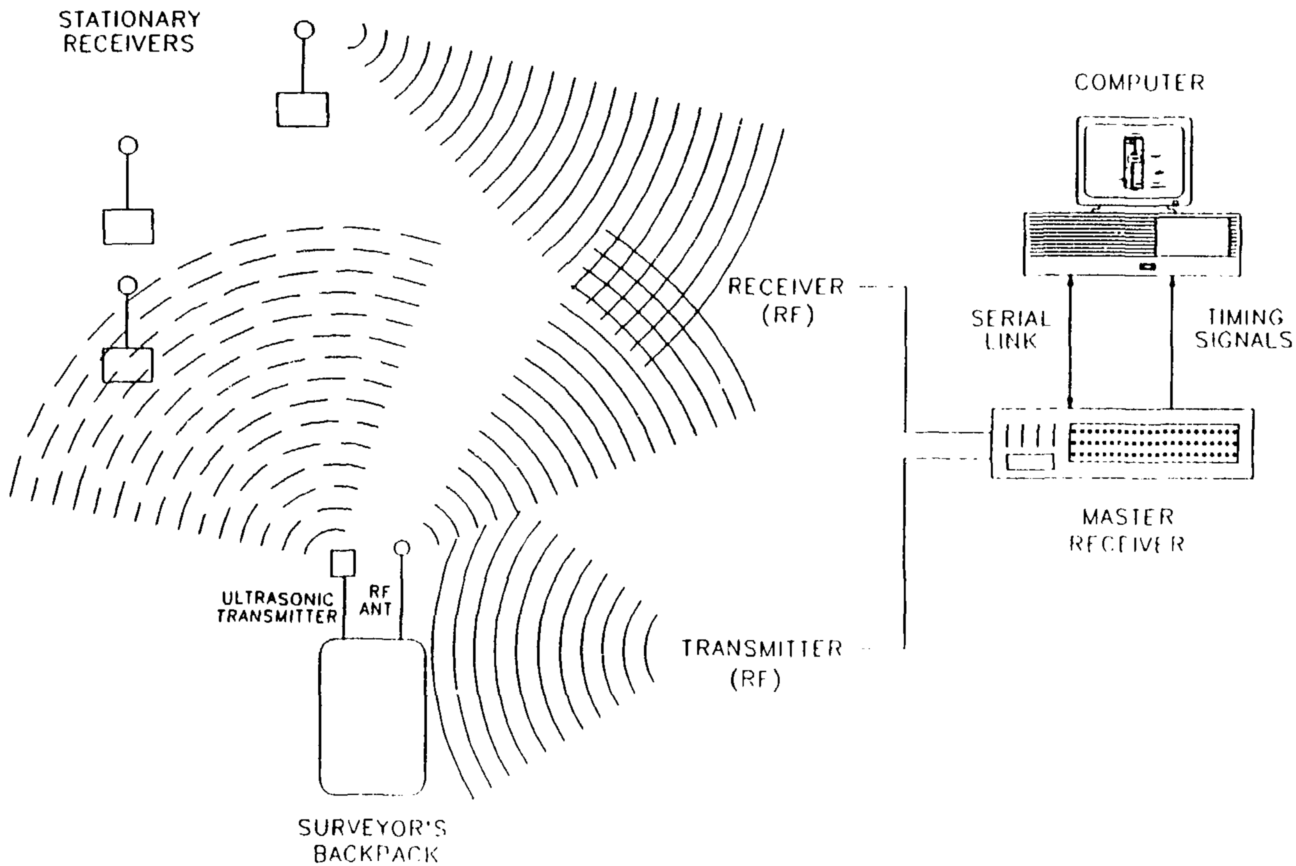

Fig. 2. Diagram of the USRAD System hardware.

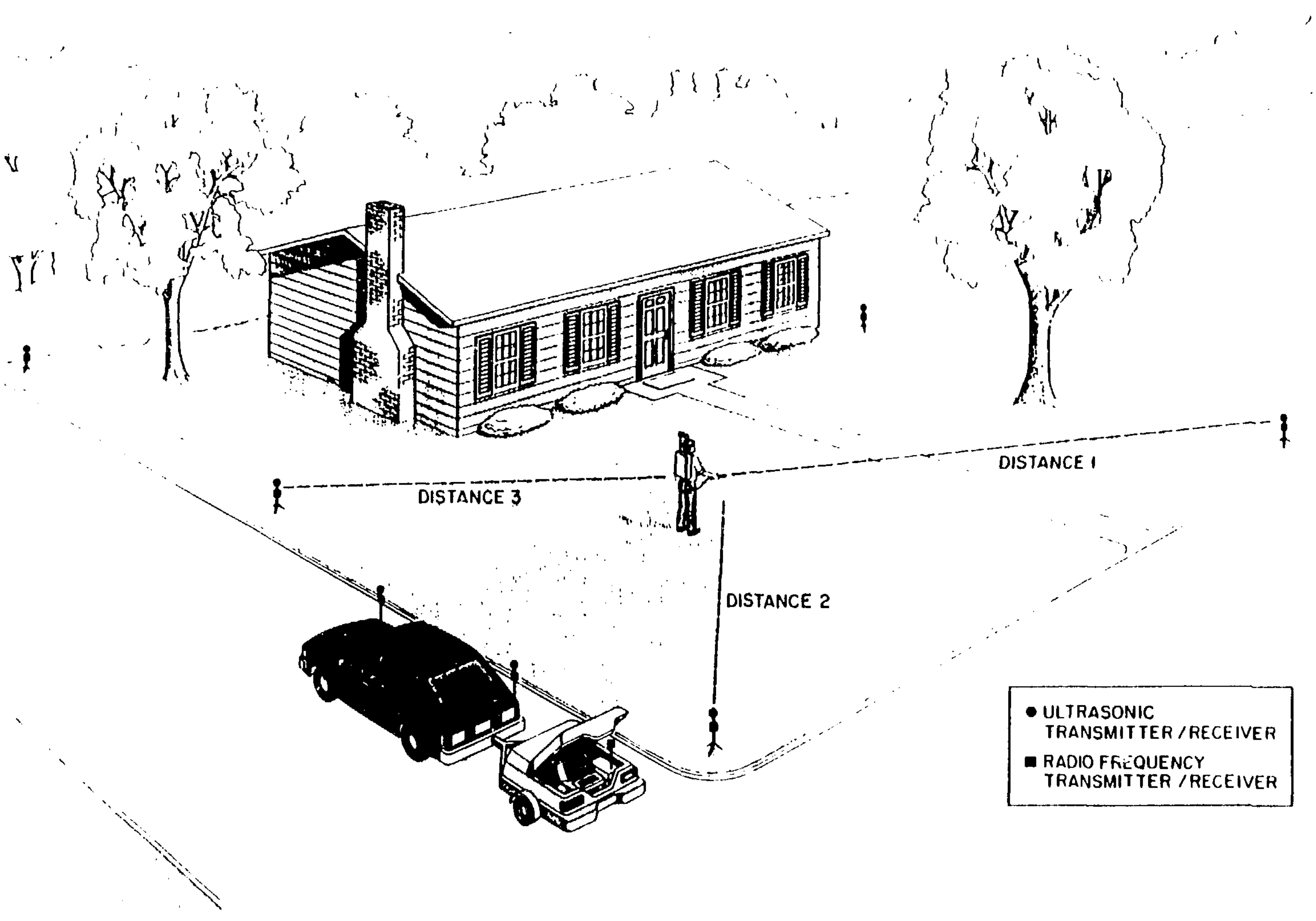

Fig. 3. Diagram of the USRAD System set-up.

instrument. The stop signal establishes the length of time the sound traveled and enables the PC to calculate the distance from the surveyor to the SR. As each SR detects the ultrasonic signal, corresponding stop signals are sent and distances are calculated. From this information, the PC can determine the location of the surveyor within the array of SRs.

To associate the surveyor's location with the survey instrument data, the RF start signal is encoded with the value from the survey instrument collected the previous second. This automatically connects the instrument measurement with the proper location. As each 1-s position is calculated by the PC, a dot is plotted on the PC screen in correct relation to the SRs that have been placed on the property. The plotted position remains on the screen creating a track-map showing the surveyor's coverage of the property. At any time during the survey, the surveyor may look at the track-map to determine if any areas have been missed; if so, the surveyor may return to those areas and obtain the needed coverage.

The surveyor, through the hand-held terminal and microcomputer chip in the SB, can transmit certain commands to the PC by way of the RF link. This allows the surveyor to remotely control data collection and allows communication with the PC. The surveyor may suspend data collection to observe the track-map and then resume data collection after identifying areas in need of further coverage.

FIELD TESTING

The USRAD System underwent extensive field testing during 1986 and 1987. The testing was performed under varying conditions such as weather, terrain, temperature, number of buildings, and size of property to determine the benefits and limitations of the system and to determine what factors influence the system.

Over 50 vicinity properties were radiologically surveyed. Multiple setups were tested at each vicinity property to determine which configurations provided the best results and to determine the optimum number of SRs for property coverage. The majority of properties tested were residential properties ranging in size from 581 m^2 (6250 ft^2) to 6975 m^2 (75,000 ft^2) with one to five structures. The USRAD System was also tested on flat open land and on properties with steep slopes. Testing was performed throughout the year with temperatures ranging from 25°F (-4°C) to 100°F (38°C). These tests provided information on reproducibility of the measurement data and surveyor location.

RESULTS

Results of the USRAD System testing indicate both benefits and limitations compared to current manual methods.

Benefits:

- Real-time position data - Real-time position data enable the technician to view the scan while it is conducted (Fig. 4). The track-map shows regions which may have been missed or inadequately covered. If the survey has been terminated, the surveyor can resume the survey and cover those regions which need additional data.

- Verification of survey coverage - Because the USRAD System allows the survey to be viewed while it is being conducted, regions that need further investigation are identified before leaving the site. This eliminates returning to the site for additional data. During

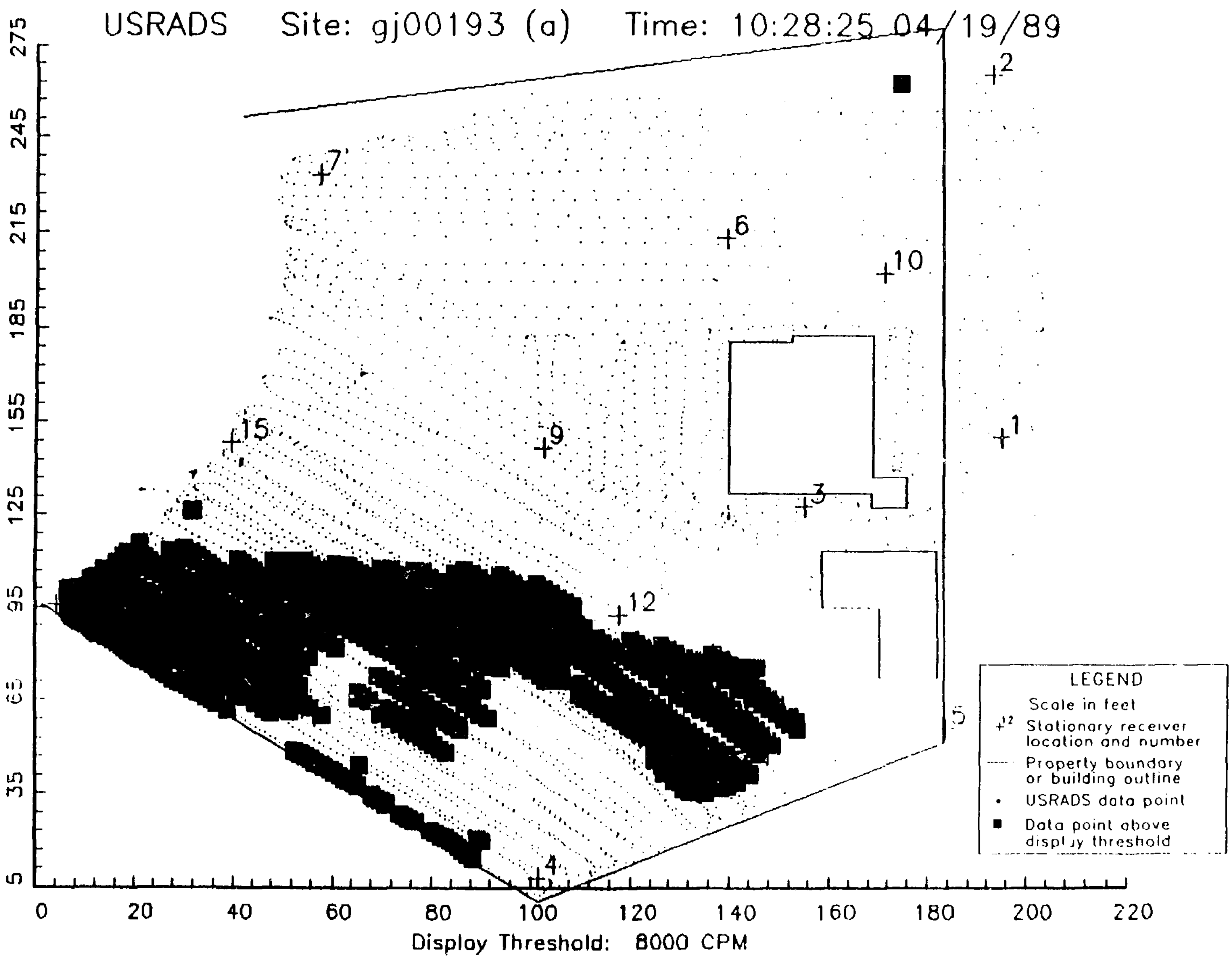

Fig. 4. Survey track-map generated by the USRAD System.

nonautomated scans, portions of a property may be missed because of the lack of documentation of scanned regions. The USRAD System highlights all data points above a chosen threshold (Fig. 4), showing areas of possible contamination that may need further data to better characterize the area. The electronically stored track-map is available for future verification of property coverage.

- Reproducibility - Because the data acquisition and surveyor location are automated, the USRAD System gives highly reproducible survey results. This is extremely important for quality assurance programs and for ensuring that correct decisions are made about the property.

- Reduction of error - Previous walk-on surveys relied on visual interpretation of an analog meter. This allowed for variations in recorded instrument data based on the personal interpretation of the instrument reader. Because the USRAD System collects data automatically and in digital form, errors in reading the instrument are eliminated.

- Data reduction on-site - Because the USRAD System collects and compiles the data on-site, data may also be reduced to generate various maps in the field. Figure 5 is a contour map with three regions of contamination defined above the chosen threshold. Generating the maps in the field allows a better understanding of the property and extent of the contamination before leaving the site. In addition, problems with data or survey coverage are usually easier to spot in graphic form.

- Relative interpretation through 3-D plots - The USRAD System can generate 3-D plots at the site. These plots provide excellent immediate interpretation of the site and of the contamination. Figure 6 is a 3-D plot of a property showing the relative relationship between contaminated and background regions. Although absolute data values are difficult to determine, varying views of the same plot allow evaluation of complexly contaminated sites.

- Electronic data storage - Data are collected and stored electronically by the USRAD System. This eliminates the time required to generate archive copies since all data are saved through daily backup procedures. The data can also be viewed later or reprocessed using different contamination thresholds without returning to the property for further measurements.

- Manipulation of data - Since the system collects and stores a measurement each second, statistical analysis of the minimum, maximum, and mean values, as well as the standard deviation, can be performed on a large data set. Figure 7 shows the statistical evaluation of the property as displayed on the monitor screen by the USRAD System.

Limitations:

- Property size - The USRAD System was designed to be used on residential properties in a populated area. Thus, the system had to be intrinsically safe with no high-power transmitters or potentially hazardous technologies (e.g., microwave emission). These factors limit the size of the property that can be surveyed with one setup to about 7 or 8 acres of open ground. Buildings and topography will reduce the size of the property that can be surveyed. However, the setup time is minimal, and moving the system to an adjacent section of property is not difficult.

- Field time - Actual time at a property using the USRAD System is usually increased over former methods since one surveyor must cover the entire property. Previous nonautomated gamma radiation surveys could be performed by as many as three field

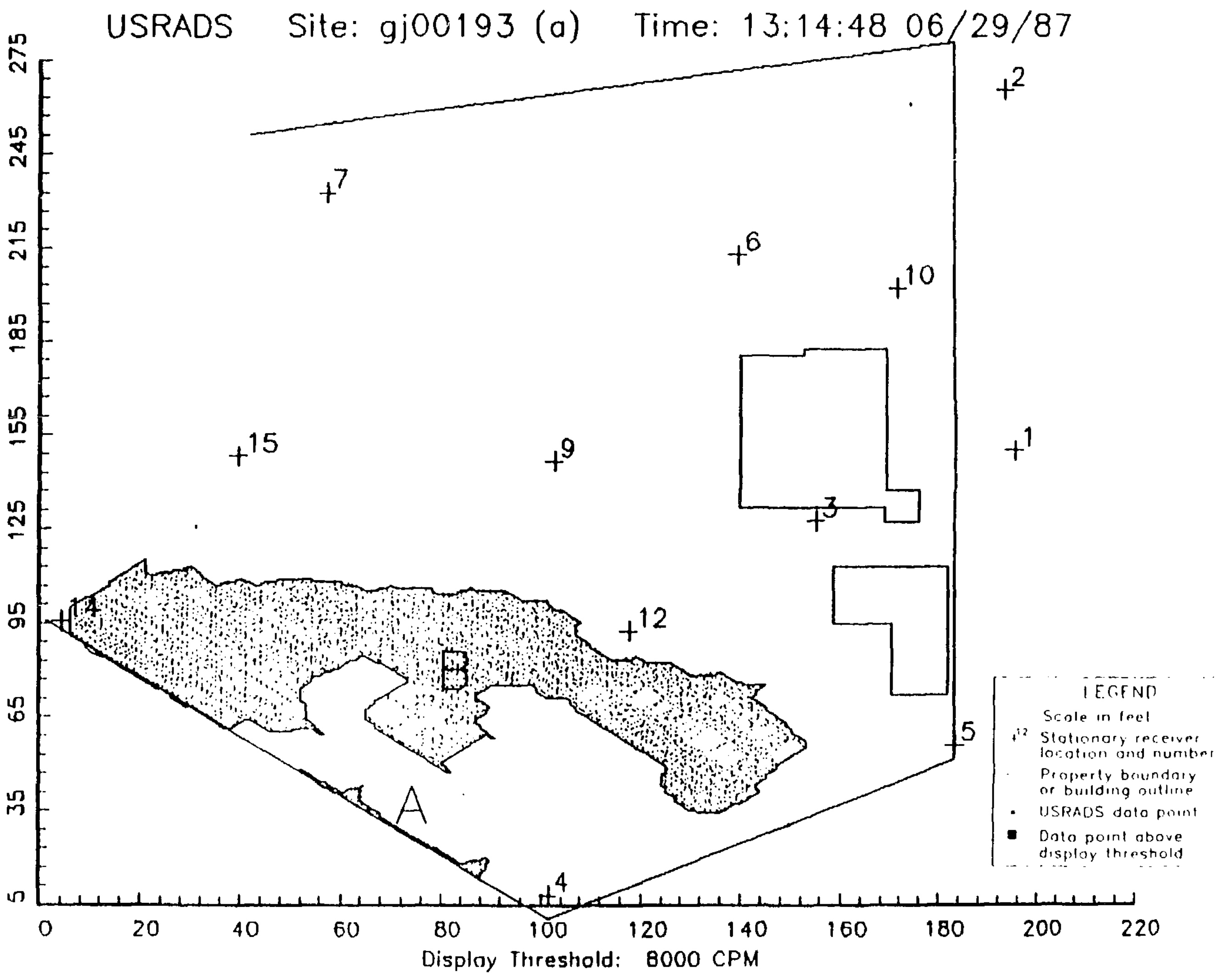

Fig. 5. Contour map generated by the USRAD System.

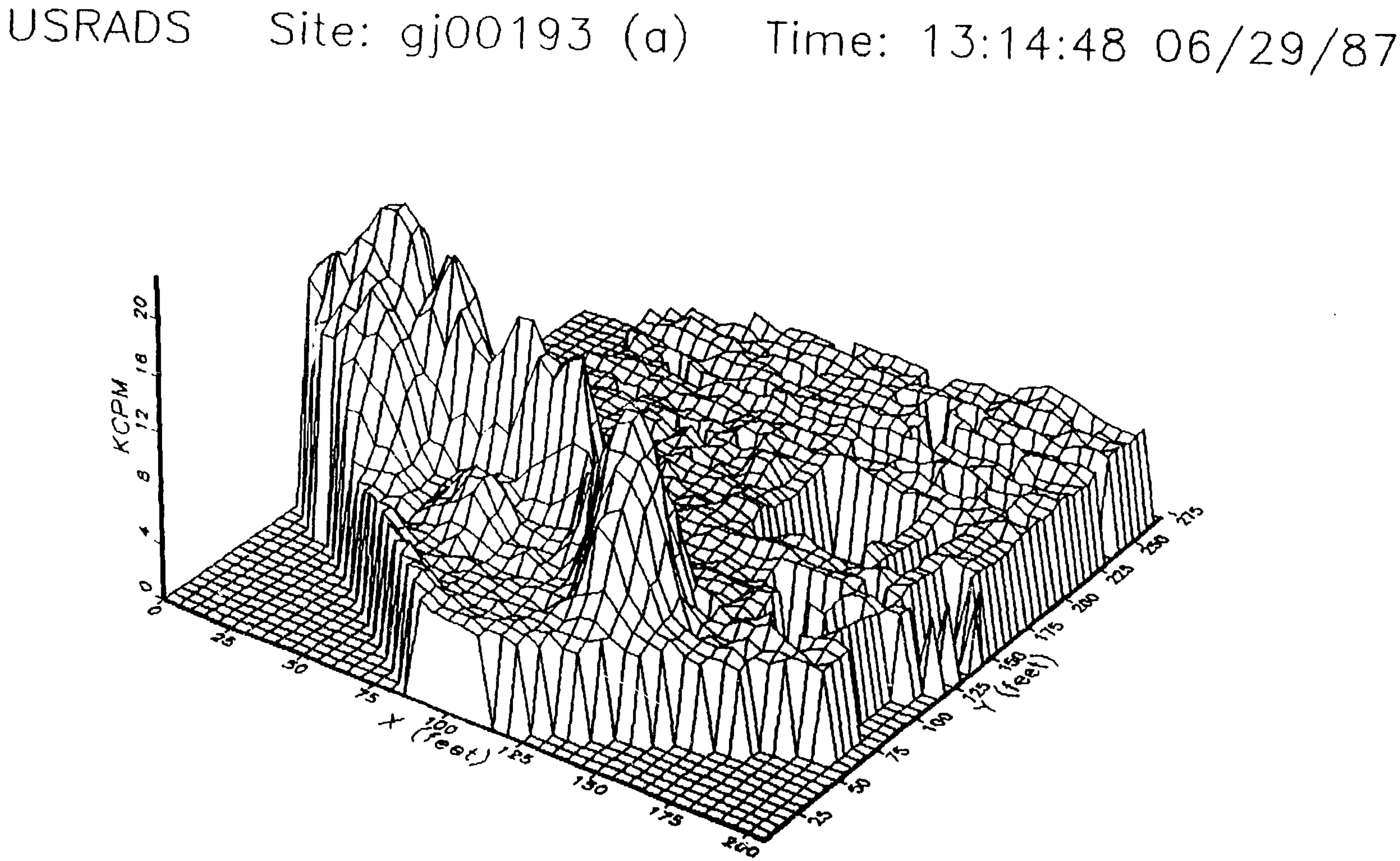

Fig. 6. 3-D plot generated by the USRAD System.

--- USRADS v3.0: Contour Area Statistics Summary ---

File: c:\usrads\gj00193a.SRV

Date: 06/29/87 Time: 13:14:48

Comment:

Display Threshold (CPM): 8000

Area Location					Radiation Statistics (in CPM)			
ID	(X)	(Y)	Npts	Sq Ft	Min	Max	Mean	Stdev
A	71	31	39	90	7500	9240	8312	373
B	79	74	973	5134	7140	24180	13723	4237

Fig. 7. USRAD System statistical evaluation as generated on the monitor screen.

personnel at one time. This would not be a limitation with other types of survey instruments, which can only be utilized by one surveyor at a time even during a manual survey. The increased field time is mitigated by reduced data reduction time in the office.

FURTHER APPLICATIONS

Although the USRAD System was developed specifically for use with a gamma detector, it is adaptable for use with other instruments. Examples might be portable instrumentation measuring physical, chemical, geological, or biological conditions. Applications may include verification of remediated and uncontaminated areas, emergency response in mapping pollutant locations after accidents, and characterization of hazardous waste areas.

The adaptation of additional types of instruments allows for multiple surveys and analysis of different parameters at a single site. Multiple surveys of a property, using different instruments for each survey but using the same system setup, would provide a wealth of information. Correlation of survey data would be simplified because all the surveys could be performed using one coordinate system. Property "gridding" would not be required to correlate different instrument measurements. Since all the data are stored electronically using the same coordinate system, the data are ready for computer mapping and interpretation.

Work is currently in progress to adapt the system for the EPA to assess heavy metal contamination with an x-ray fluorescence detector. This adaptation of the USRAD System will also provide transferable technologies for characterization and assessment of many radiological and chemical soil instruments. The USRAD System has also been adapted for use with geophysical equipment, the Geonics EM31. Initial field testing of the system has yielded excellent results in detection of underground conductivity contrasts (e.g., buried metals). Figure 8 shows the relationship between a 3-D plot and corresponding contour maps generated by the USRAD System using the EM31. The quadrature data is the conductivity of the studied area. The two linear anomalies are caused by dirt roads that are less conductive than the surrounding soil. Along the right side of the right-hand road was a buried utility such as an electric cable or conductive pipe that created the peak.

The capability of the USRAD System to document background areas will be beneficial in verification of noncontaminated sites or sites that have undergone remediation. The "negative" documentation obtained verifies that no contamination is present above the chosen threshold. The data obtained can be reanalyzed using any threshold. The electronic track-map documents that the site was adequately surveyed.

With the combination of the USRAD System and robotics, it is also possible that highly contaminated areas could safely be surveyed. These areas may include nuclear reactor cores or other areas too hazardous for human access.

CONCLUSIONS

The USRAD System has proven to be useful for automating walk-on radiological surveys. The system compiles and manipulates large data sets electronically in the field. The system also provides real-time survey coverage and graphics generation in the field, assisting in evaluation of the property while the surveyor is on-site. This method of data acquisition can provide important information to many types of surveys, including characterization of

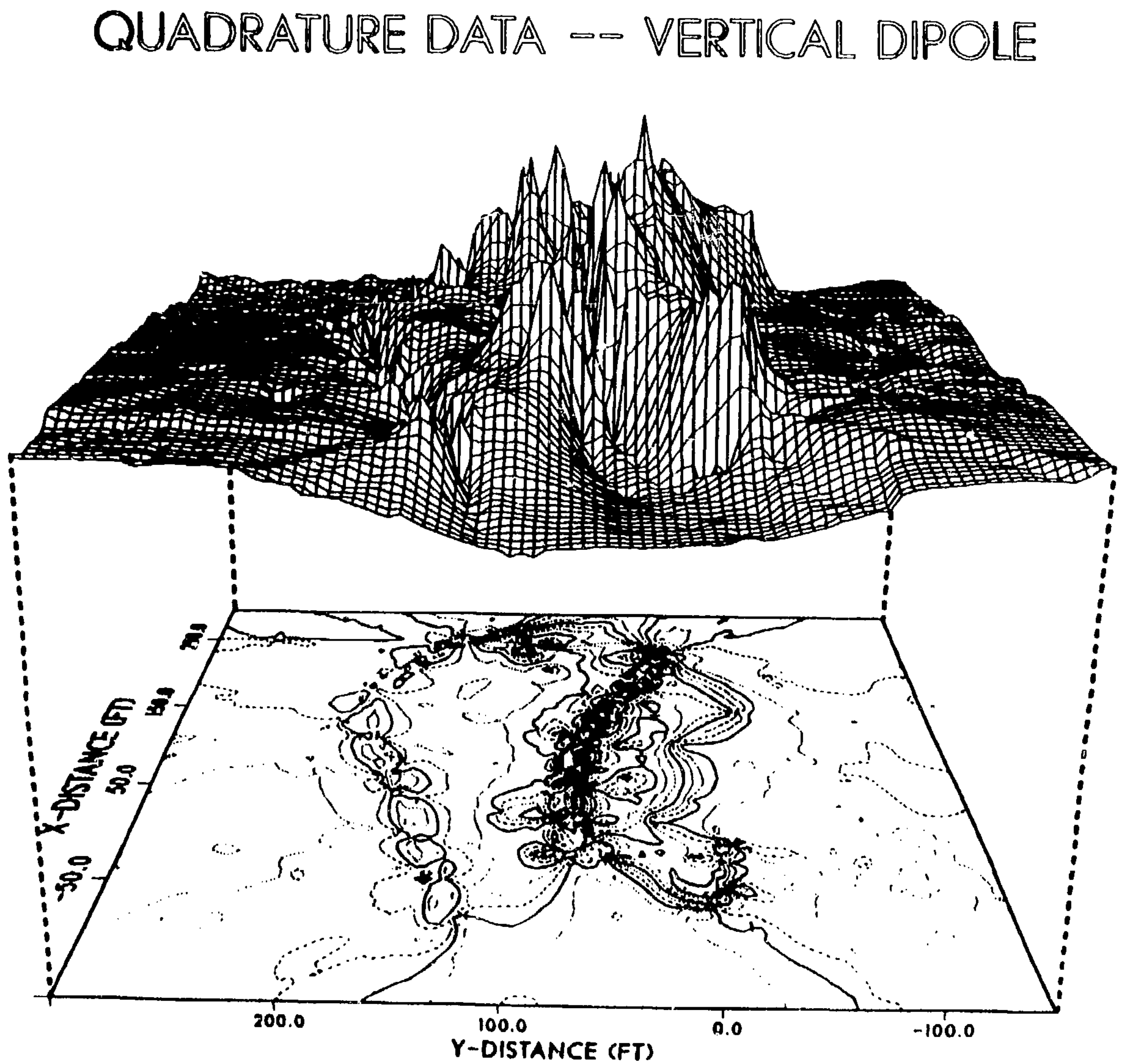

Fig. 8. Contour map and 3-D plot generated by the USRAD System using the EM31 (quadrature data — vertical dipole).

radiological and chemical sites, verification of remediated or uncontaminated sites, and emergency response contaminant leaks or spills. Further use of the USRAD System will lead to more adapations of the system to different types of surveys.

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