DISCLAIMER

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A POSITIONING AND DATA LOGGING SYSTEM FOR SURFACE GEOPHYSICAL SURVEYS

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ABSTRACT

The Ultrasonic Ranging and Data System (USRADS) developed at ORNL is being adapted to work with two commercially available geophysical instruments: a magnetometer and an EM31 terrain conductivity meter. Geophysical surveys have proven an important preliminary step in investigating hazardous waste sites. Magnetometers and terrain conductivity meters are used to locate buried drums, trenches, conductive contaminant plumes and map regional changes in geology. About half the field time of a typical geophysical investigation is spent surveying the position of the grid points at which the measurements will be made. Additional time is lost and errors may be made recording instrument values in field notebooks and transcribing the data to a computer.

Developed for gamma radiation surveys, the USRAD system keeps track of the surveyor's position automatically by triangulating on an ultrasonic transmitter carried in a backpack. The backpack also contains a radio transmitter that sends the instrument's reading coincident with the ultrasonic pulse. The surveyor's position and the instrument's reading are recorded by a portable computer which can plot the data to check the survey's progress. Electronic files are stored in a form compatible with AutoCAD to speed report writing.

INTRODUCTION

A number of surface geophysical methods developed for oil and mining industry applications have been adapted for the investigation of hazardous waste sites, for example: magnetic field intensity, resistivity, time domain electromagnetics, and frequency domain electromagnetics (1,2). While formerly the geophysical prospector used a magnetometer to search for iron

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ore, now the same instrument may be used to locate buried drums of toxic waste (3,4). But the goal of geophysical surveying remains the same: to learn as much as practical about the subsurface before going to the expense of drilling. Often fewer wells are required to characterize the subsurface as the geophysical data can be used to choose the best well sites and to interpolate between wells. In some cases, such as searching for buried drums, a geophysical survey can save thousands of dollars in hit-or-miss excavation efforts.

While geophysical surveys are relatively fast and inexpensive, time and money are lost while surveyors set up the measurement grid. Additionally, although most modern geophysical instruments have a built-in data logger and can dump the survey data to a portable computer at the end of a survey, there is no way to view the collected data while the survey is in progress. Often the grid lines turn out to have been too widely spaced, or the grid did not cover a large enough area; as a result, the surveyors must be brought back to the field to refine or extend the grid.

The need to expand or refine a measurement grid and to analyze the data while the survey is in progress are common to all field surveys. The same problems arose, when as part of the Department of Energy's Uranium Mill Tailings Remedial Action Project (UMTRAP), ORNL was requested to survey, in three years, 8,000 properties where presence of uranium mill tailings were suspected. To save time and money ORNL developed a technology to automate much of the survey process and provide tabular and graphical data display in the field or in the office for report generation. This technological development is called the Ultra Sonic Ranging and Data System (USRADS) (5).

Our recent work has focused on interfacing two geophysical instruments, a proton procession magnetometer (Omni IV) and an electromagnetic terrain conductivity meter (Geonics EM31) with the USRADS. This work is still in progress. In this paper we will describe the application of the two geophysical instruments and the USRADS separately, and the work which being done to combine them.

CASE STUDY: EVAPORATION PIT AT DYESS AIR FORCE BASE

An evaporation pit at Dyess Air Force Base in Abilene, Texas received liquid waste from the late 1950's to the late 1970's, when it was backfilled and abandoned. The pit's approximate areal dimensions are 45 x 30 m (150 x 100 ft) from base records. After the pit was closed, base personnel continued to use a buried 38,000 liter (10,000 gal) railroad tanker car to the east of the evaporation pit as a liquid waste repository until 1982. The tanker has since been removed.

Although it was believed that only liquid waste was disposed of at the site, a preliminary inspection found crushed drum fragments, railroad spikes and other metal debris on the surface. We decided to use a magnetometer to check for buried metal as well. A rectangular grid consisting of 194 points on a 15 m (50 ft) spacing took two days to survey. The region in the southwest corner was not surveyed because small trees interfered with sighting the transit. A team of two completed the actual magnetometer survey in a single morning. The results show strong dipole anomalies (paired lows and highs, Figure 1). For each pair, the buried source, probably one or more 208 liter (55 gal) steel drums, is located about halfway between the adjacent positive and negative peaks. Notice that the peaks are always located on a grid point. This is because the anomalies are smaller than the grid spacing. The actual buried object producing the anomaly may lie as much as one half grid spacing away (7.6 m or 25 ft). The grid would have to be refined to locate the objects more precisely. Anomalies near the boundary of the grid suggest that the survey region needs to be expanded as well as refined, even though the grid is already much larger than the expected size of the evaporation pit. This did not become apparent until the data were plotted and the grid survey team had left the site.

The terrain conductivity data (Figure 2) adds to the picture formed from the magnetic gradient contours. This survey took two people an afternoon. While the magnetometer responds only to the total mass of ferrous metal, the terrain conductivity meter responds to anything conductive which depends on the conductivity and surface area. It is less affected by the small buried metal, but shows a strong anomaly centered on the former location of the buried railroad tanker car and a plume appears to have formed to the west. Sixteen grid points were surveyed around the tanker car, extending the grid to the east and verifying that the tanker car was the source.

If time had permitted, more measurements would have been made to the east of the tanker car to more completely characterize the plume. Such surprises in the field are common. We later learned that the our survey had caught only the very edge of the evaporation pit (northwest corner of Figures 1 and 2); most of the survey grid was over a hardfill area where metal scrap had been dumped. The grid should have been expanded to the west as well. This illustrates that surveying the grid point locations and reducing the geophysical data handicap an otherwise fast, effective and inexpensive reconnaissance. A way is needed to analyze the data in the field and adjust the survey lines, without mobilizing the field crew a second time.

ULTRASONIC RANGING AND DATA SYSTEM (USRADS)

System Operation and Setup

Real-time analysis of the data is a major advantage of the USRADS. As the surveyor walks the property, an ultrasonic crystal in the surveyor's backpack is pulsed each second and the data from the survey instrument are transmitted to the computer by radio. Each second, the computer reads the time-of-flight data from stationary receivers placed in the survey area, triangulates the surveyor's location, plots the surveyor's location on the computer screen, and stores all raw data. By plotting the surveyor's location each second, the computer operator can view the surveyor's coverage of the property at any time during the survey. In addition to plotting the surveyor location, the computer highlights any data point that exceeds a threshold entered by the operator, so that any areas of concern are identified on the display, to ensure that sufficient data have been obtained to characterize that area.

The system setup takes only about fifteen minutes. Stationary receivers are placed so that the surveyor is in view of at least three of them from any location on the property (Figure 3). Only the first few receivers need to be located by a surveyor; once the stationary receivers have been placed on the property, they are used to calculate the speed of sound and the locations of the remaining stationary receivers are computed automatically.

System Hardware

The USRAD system consists of one surveyor's backpack, fifteen stationary receivers, a master receiver, custom computer interface and counter timer module, Compaq Portable II personal computer, and a small trailer to transport this equipment. The backpack contains the interface circuitry to receive the signal from the field instrument (originally a portable gamma detector), an ultrasonic transmitter and radio frequency equipment to establish a bi-directional communication link with a computer mounted in the trailer. The ultrasonic transmitter is a lead-zirconate-titanate crystal that is in the form of a circular cylinder with a hollow core. The crystal dimensions are 5.6 cm (2.2 in) in diameter and 3.670 cm (1.445 in) in height. This crystalline material and its dimension result in a natural resonating frequency of 19.5 kHz. The crystal is pulsed for 10 msec each second as the data from the portable survey instrument are transmitted to the computer via the radio telemetry link. If the computer detects any problems, either with the data or in determining the surveyor's location, a message is transmitted to the surveyor and displayed on the handheld terminal to alert the surveyor of the malfunction. The backpack can be operated for a normal eight-hour day from a rechargeable gel-cell.

The stationary receivers contain an ultrasonic receiver and a radio transmitter. The dimensions of the metal box that houses the ultrasonic receiver card, transmitter card, and rechargeable gel-cell battery pack are 10 x 10 x 15 cm (3.9 x 3.9 x 5.9 in). Each stationary receiver has a unique radio frequency so that the master receiver can identify which stationary receivers heard an ultrasonic signal. The master receiver therefore contains 15 radio receivers, one for each stationary receiver, and a receiver and transmitter for communication with the backpack. Both the master receiver and the computer are powered by a gasoline-operated generator also carried in the trailer.

System Software

A digitized schematic drawing of the property is stored in the computer prior to the survey using AutoCAD, a commercial computer-assisted drawing software package already widely used at ORNL. The survey data are added to this information. The property schematic is displayed on the computer's monitor. As the surveyor traverses the property, his past and present position are displayed to denote the completeness of coverage by the surveyor. During the survey, the software checks incoming information and alerts the surveyor (via the backpack terminal) if errors are detected either in the survey data or position data. To ensure data integrity, all data are stored on the hard disk every 30 seconds.

The surveyor can view the data in a number of different graphical formats as well as obtain summary reports. The graphical formats supported by the USRADS are Replay, Block Statistics, Contour, and 3-D plots of the radiation data. The Replay program will generate the same display that the surveyor viewed when the survey of the property was completed. The data are replayed in the same order as they were collected. The Block Statistics routine enables the operator to select a grid block size and have the data analyzed for each block. If the mean of the data for a particular grid block is greater than the operator-entered threshold, then that block is highlighted on the CRT, and the statistical information for that grid block are stored in the summary report. Raw data are converted to appropriate units and displayed or printed out in tabular or graphical format. By indicating preset thresholds, areas of contamination can be identified and statistics can be calculated (area size, number of measurements, measurement range, average and standard deviation). Graphical representations are made in two and three-dimensional display. The contour routine generates a summary report and outlines the areas that exceeded the user input threshold. The 3-D plot generates two different views of the data and provides a means by which the surveyor can view the entire data obtained during the survey. Information displayed in the field is output directly into a report-ready format.

COMBINING USRADS AND GEOPHYSICAL INSTRUMENTS

Check for Interference

The first step was to insure that the USRAD system and the geophysical instruments would not interfere with each other. The USRADS backpack contains very little ferrous metal and we found no changes in magnetometer readings taken with and without the backpack. We also found no interference with terrain conductivity (EM31) readings.

Interfacing the Instruments

No change is required in the geophysical instruments or USRADS hardware. Our current efforts are devoted to rewriting the USRAD backpack software to digitize and transmit the terrain conductivity meter's readings. The EM31 is an analogue instrument which can operate in one of two modes: inphase or quadrature. The inphase mode has a non-linear response to conductivity changes but is especially sensitive to sudden changes in near-surface conductivity, as might be produced by a buried drum (6). The quadrature response is directly proportional to the conductivity of an equivalent uniform half-space. This is the mode generally used for geologic mapping and mapping conductive contaminant plumes (7). We are modifying the USRADS software to record both modes simultaneously, along the range switch setting, and to display either data set to the computer operator. We are taking this opportunity to replace the backpack's ROM chips with new chips coded in the C programming language instead of assembler. This will make the backpack software compatible with software written for the COMPAQ portable computer and make the interfacing of USRADS with other survey instruments easier by making reprogramming simpler. Work will begin on interfacing a magnetometer with USRADS at the same time as the terrain conductivity/USRAD system is being field tested.

Field Testing

We expect to begin field testing in August, 1988. There are several locations on the Oak Ridge reservation where terrain conductivity and magnetometer surveys have been conducted on a grid surveyed by transit. We plan to re-survey one or more of these areas and compare the time required to complete the geophysical surveys and the quality of the results with those of the earlier surveys.

SUMMARY AND CONCLUSIONS

Geophysical surveys are frequently a part of initial investigations at hazardous waste sites. Searching for buried drums with a magnetometer is a classic example. The slowest step in a geophysical survey consists of locating the measurement points, and often this step has to be repeated when the geophysical data suggest that the survey grid needs to be expanded or refined. By combining the USRAD system with geophysical instruments this step can be virtually eliminated as the surveyor's position and the instrument's reading are automatically recorded every second. Only a few ultrasonic receivers have to be located in advance. In addition, the computer operator can notify the surveyor when the data displayed on the portable computer suggests that an anomaly has been found, and additional measurements are needed. Thus the USRAD system will add automatic position location, real-time data processing, and automatic data transcription to geophysical surveys.

ACKNOWLEDGEMENTS

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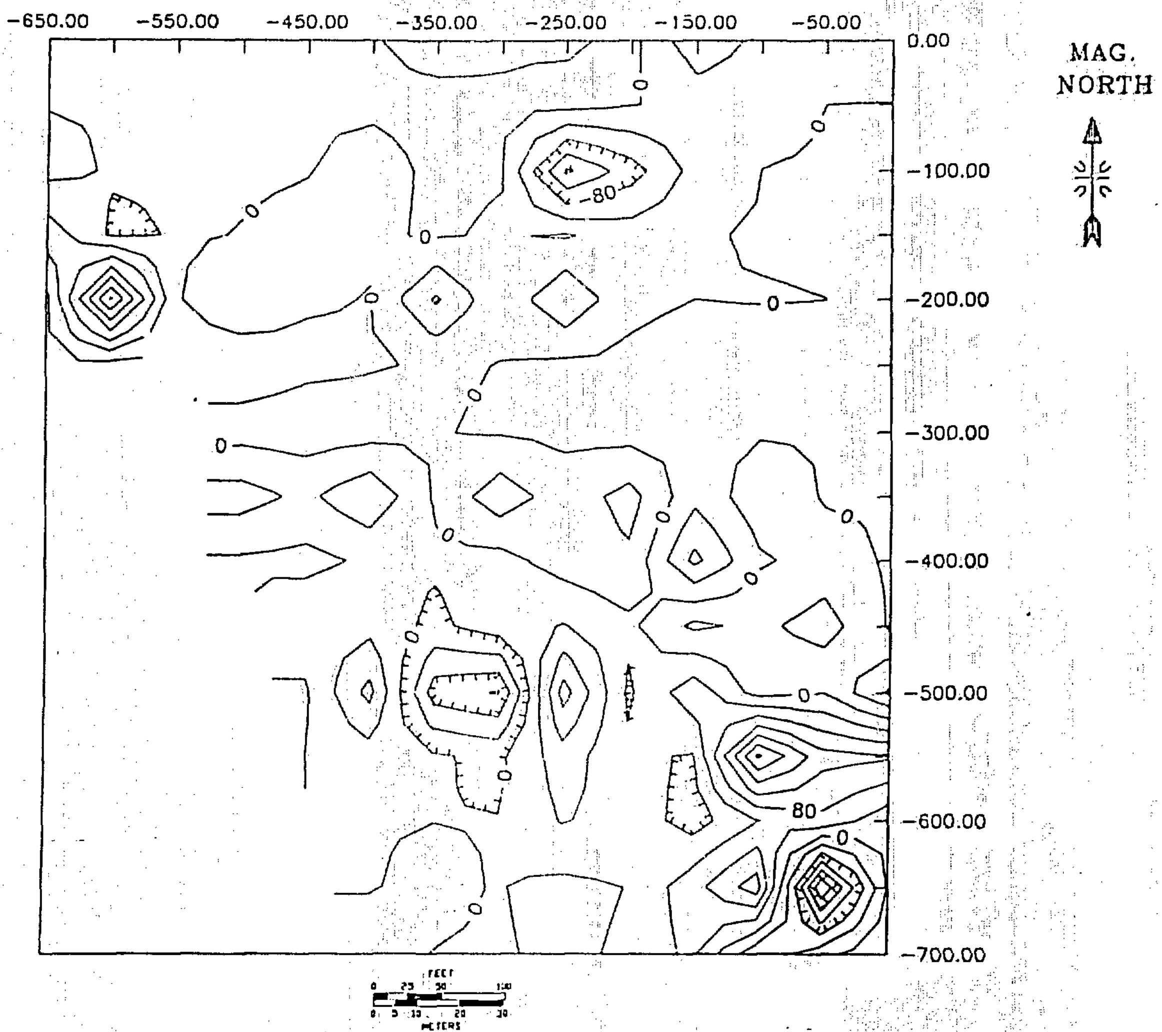
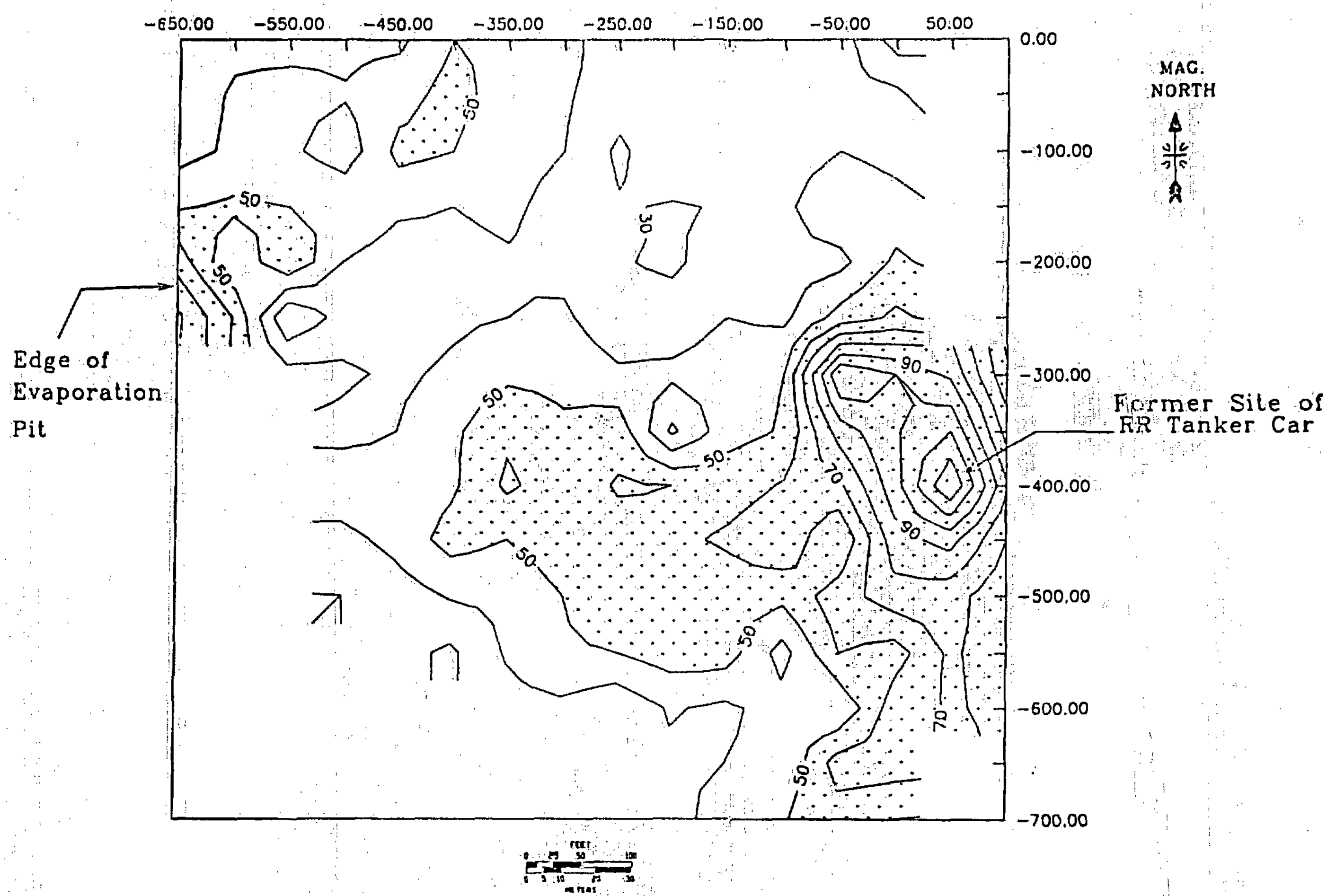


DYESS AFB HARDFILL #1 AND EVAPORATION PIT
MAGNETIC GRADIENT DATA. CI=40 GAMMAS/M

Figure 1.



DYESS AFB HARDFILL #1 AND EVAPORATION PIT

EM31 QUADRATURE DATA CI=10 MILLIMHOS/M

Figure 2.

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LOCATING THE USRADS SURVEYOR BY TRIANGULATION

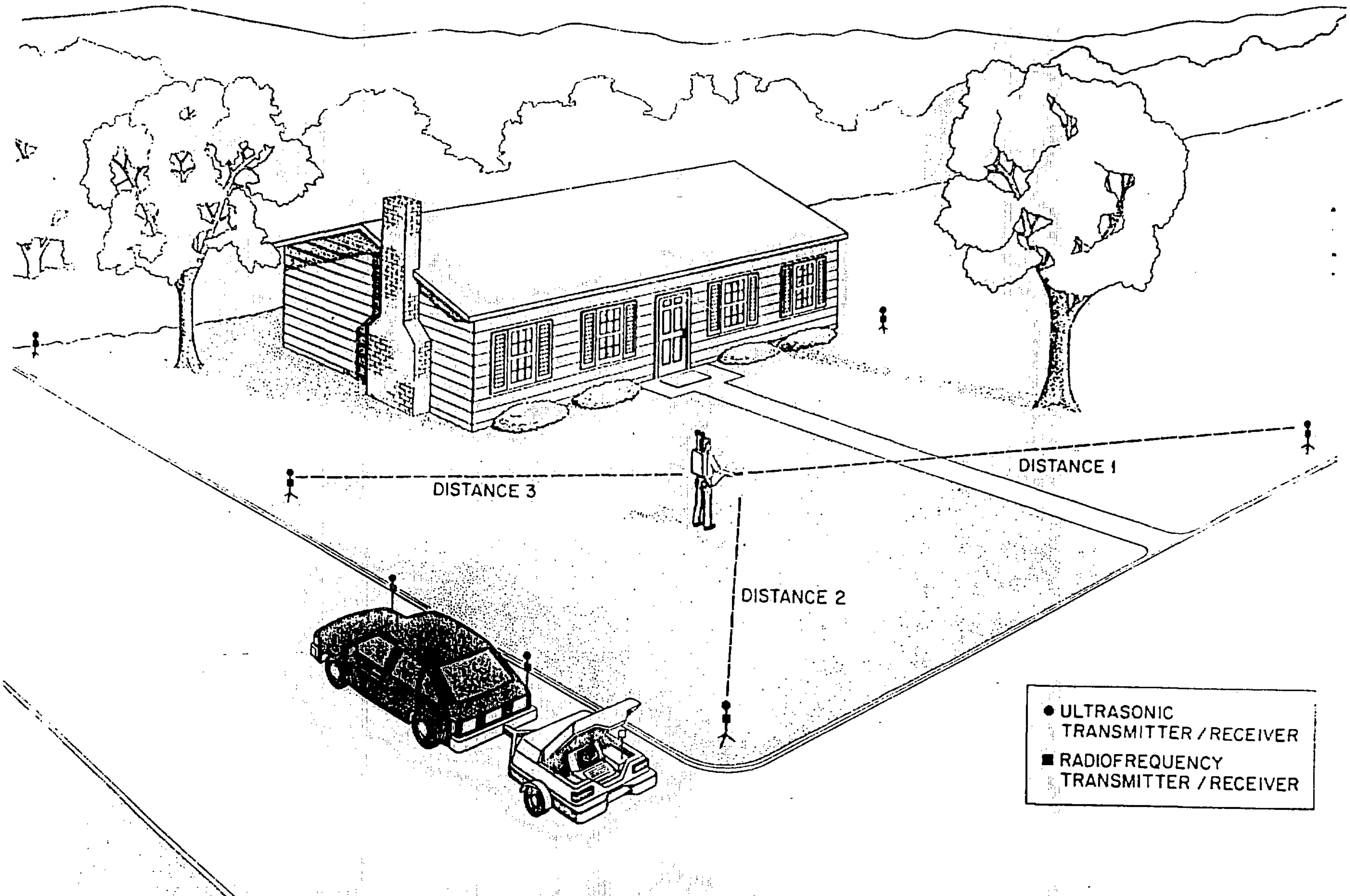

Figure 3.