

Performance of a car-mounted neutron and gamma-ray monitoring system for illicit material detection.

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Abstract

A car-mounted, mobile system has been built for the detection and location of neutron and gamma-ray sources. The system is designed to be simple to install and operate yet highly sensitive. The system uses a large volume NaI detector for the gamma rays and moderated ^3He tubes for the neutron detectors. The gamma-ray spectrum from the NaI detector is collected using an ORTEC digiBASE. The neutron detector signal is conditioned in analog electronics and the output pulses are also counted using the digiBASE. The gamma-ray spectrum and neutron count rate data are collected and stored in 1-second intervals. There is no deadtime between spectra due to the list-mode capability in the digiBASE. Alarm conditions are continually monitored and plotted to the screen in a variety of user-friendly maps and spectral displays including time-stamped data events. A Global Positioning System (GPS) is used to determine the position of the system when each spectrum and count are collected. The digiBASE and the GPS are interfaced to a laptop computer using USB communications. The detectors and GPS are mounted in a conventional, inconspicuous waterproof car top carrier with the laptop computer mounted in the car. Power for the components is drawn from the car's battery using a standard DC connector plug. The system neutron performance was measured by driving past a fixed, known ^{252}Cf sources at various distances and speeds. The gamma-ray tests were conducted using ^{60}Co and ^{137}Cs source. The GPS was used to measure the car position. Results will be presented that show the system sensitivity for neutrons and gamma rays as a function of distance and time of measurement near the source.

Introduction

Recent events have increased the need for locating radiation sources in a wide variety of locations and situations, particularly those that might be used for terrorizing the public. The equipment for this needs to detect gamma-ray and neutron emitting nuclides. The alpha and beta emissions from these radiation sources would not be expected to penetrate the shielding or air between the detectors and the source. High sensitivity for both neutron and gamma-ray emissions is needed because of the large distances expected between the detector and the source. In many applications, the system must be portable or mountable in or on a vehicle and be powered by batteries. The location of the system needs to be recorded with the count rate data, so that the location or extent of the activity can be mapped if stationary or tracked if moving. To help with identification of the radionuclides and to discriminate against naturally occurring radioactive materials (NORM), the total gamma-ray spectrum is recorded rather than just the total count rate as done in previous systems. An ANSI standard is being drafted to help in the specification of such systems.

Equipment

The NaI-SS system used in these measurements consists of a 4" x 4" x 16" sodium iodide (NaI) detector, 4 each 1" x 18" ^3He tubes at 20 atm in a high density polyethylene moderator, both connected to a digiBASE, a GPS, and a laptop with special software, built into a standard roof-mounted car carrier. The entire system is powered from the 12 VDC car outlet. Figure 1 shows the system mounted on a car.



Figure 1 System on Car

The detectors are mounted in foam for both shock and temperature stabilization. The gamma-ray detector is mounted in the front of the carrier, with the long axis of the detector parallel to the long axis of the carrier (car). The neutron detector is mounted behind the gamma-ray detector, along the same axis, with the 4 tubes mounted one above the other. This orientation of both detectors gives maximum sensitivity to sources on the sides of the vehicle. Most sources are expected to be located on the sides as the system is driven on the street or through a parking lot in a search mode. The GPS is mounted above the gamma ray detector. Figure 2 shows the detectors inside the carrier with the top foam removed.

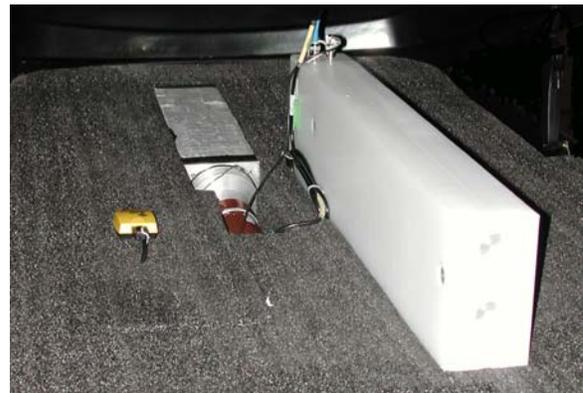


Figure 2 Detectors inside Carrier

The Windows-based software uses the list mode of the digiBASE to capture the gamma-ray spectrum and the neutron counts in 1-second time intervals. The short time is needed to help determine the location of the source with good accuracy. A car moving at 20 MPH (32 KPH) moves about 29 feet (9 meters) in one second. There is no dead time between spectrum "slices" due to the list mode operation. Each 1-second spectrum is recorded to disk in the MAESTRO channel file format.

The GPS location is also recorded at each second interval. Ten

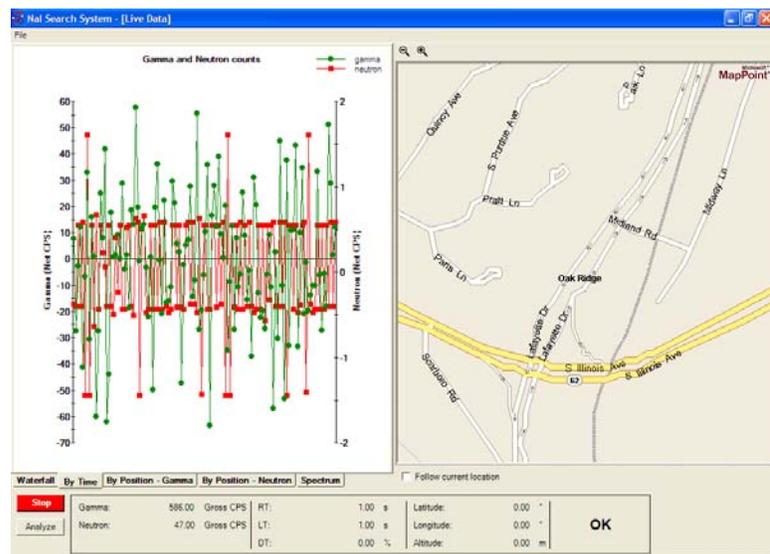


Figure 3 Counts by Time Plot with Street Map

separate energy regions, corresponding to the emissions of nuclides of interest, of the spectrum are summed and recorded. The individual region count rates, total gamma ray count, and neutron count are compared with user-set alarm levels. The spectrum name and all the other data are stored in an Access-compatible database. If any reading exceeds the user-selected alarm level, the position is marked on the street map display on the laptop at the GPS determined location. Additionally, several different display modes of the current count rate are available. The counts-by-time display is shown in Fig. 3. A “waterfall mode”, which shows the 30 most recent time slices for each of the regions in different colors depending on the count rate fraction of the alarm level, is also available. As times goes on, the waterfall flows down the screen.

The background is determined for each region as the average of the region count rate for a user-set number of time intervals, usually 30 seconds. The background is updated each second. This methodology is beneficial as it allows for dynamic compensation for naturally occurring changes in background count rate as the system is moved from location to location. The background at each point is stored in the database.

Experimental Method

The system was tested using ^{137}Cs and ^{60}Co gamma ray sources and ^{252}Cf neutron source. The sources were tested individually. The sources were positioned on a tripod about 1 meter above ground level. The NaI-SS was located on the car and driven past the sources at various distances from 3 to 32 meters and speeds of 10, 20 and 30 mph. The system was operated in the normal mode to collect the data in 1-second increments.

The count rate and position data were automatically stored in the database for each of the passes of the system past the source. Initially, the GPS data was used to determine the location of the system relative to the position of the source, but the GPS device did not change readings on each 1 second time slice, and was thus not usable as an indicator of position. The position of the system was calculated using the speed of the car and the time slide. The position of the system is given as the position along the direction of travel from the position where a line from the source intersects the path direction at right angles. This is shown in Fig. 4. The distance from the system to the source was measured from the source to the edge of the carrier (not the detectors). The uncertainty of this distance, especially at 30 mph, is about 50 cm.

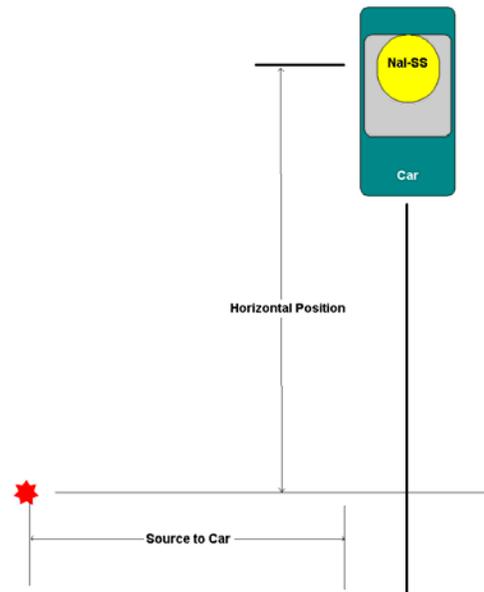


Figure 4 Measurement Distances.

Results

A typical spectrum for the ^{60}Co source is shown in Fig. 5. This is a 1-second spectrum of the 30 μCi source at 3 meter distance and 10 mph. Note the relatively few counts in the spectrum, but the identifiable peaks.

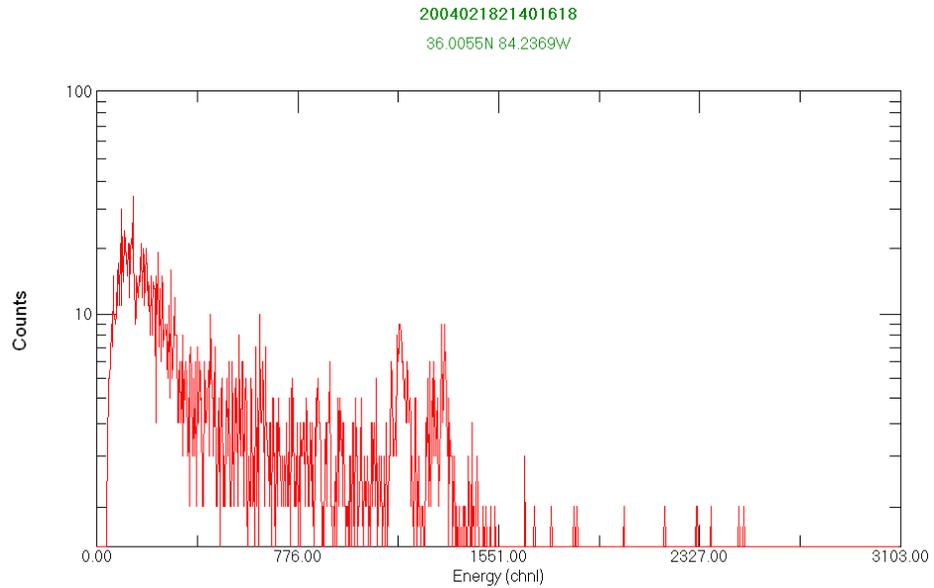


Figure 5 Spectrum of ^{60}Co at 3 meters and 10 mph.

Figure 6 shows the count rate for total counts, ^{60}Co , the energy regions centered at 1590 and 1980 keV for the source position at 3 meters and speed of 10 mph. The total number of counts in the spectrum is about 2100. Note the significant change in the count rate as the system approaches the source, going from background to maximum in less than 2 seconds.

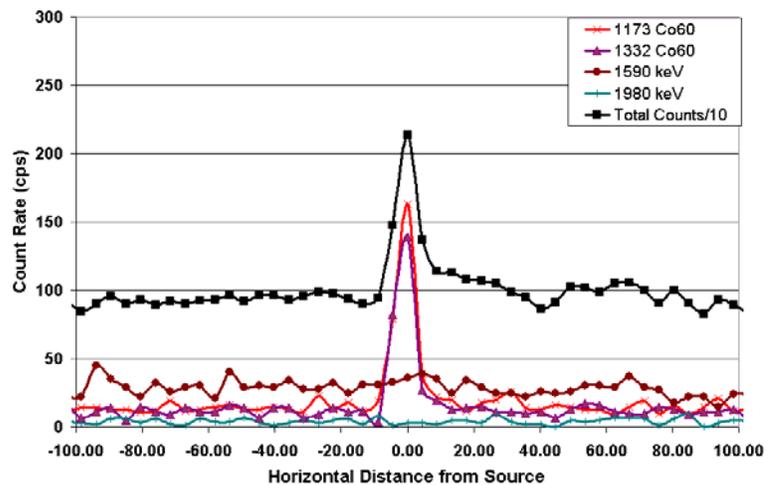


Figure 6 Count Rate of ^{60}Co at 3 meters and 10 mph.

Figure 7 shows the same signals, but at a speed of 30 mph. The count rate is lowered by about 20% and the counts are still mainly in one time slice. This shows that systems in which there is a deadtime or paralysis due to the data-store-restart cycle would be very vulnerable to missing this source completely at this speed. If the storage time was comparable to 1 second, and happened to be during the dead time.

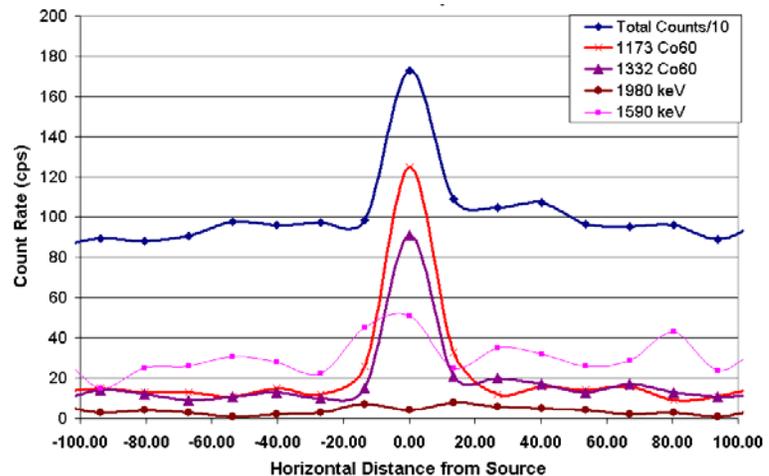


Figure 7 Count Rate of ^{60}Co at 3 meters and 30 mph.

Figure 8 shows the same signals at 12 meters and 10 mph. The signals are lower, but still visible.

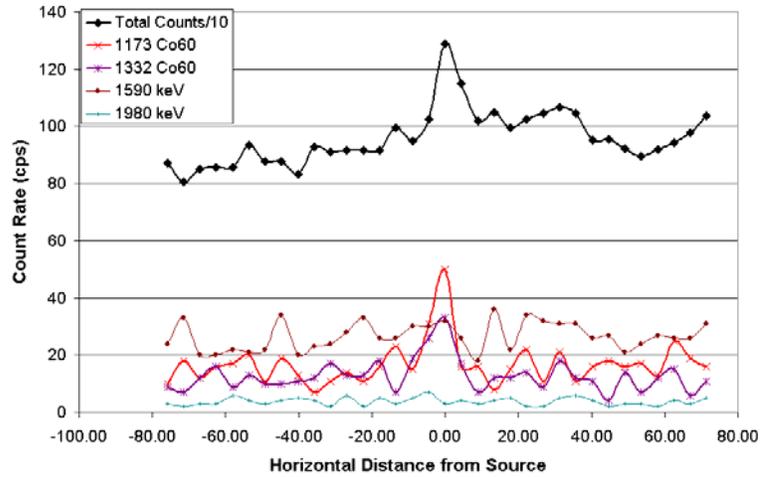


Figure 8 Spectrum of ^{60}Co at 12 meters and 10 mph.

Figure 9 shows the same signals at 12 meters and 30 mph. The signals are lower, but still visible.

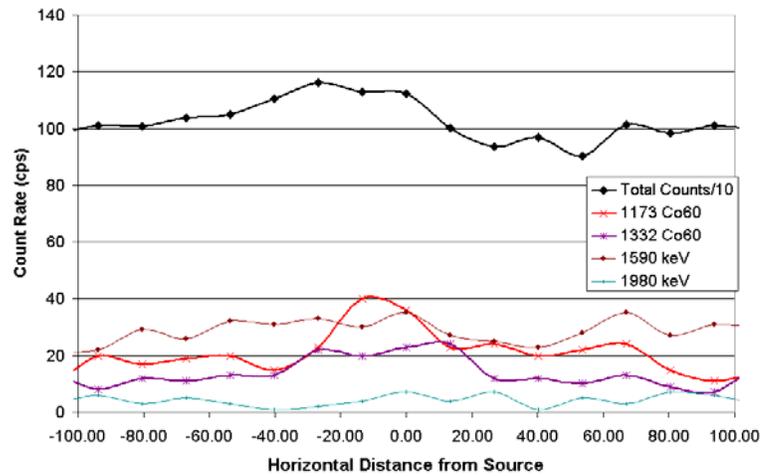


Figure 9 Spectrum of ^{60}Co at 12 meters and 30 mph.

At distances higher than 12 meters and 30 mph, the signal is not visible above the natural variation in the background. Figure 10 shows the variation with speed for each distance. The apparent crossing of the count rate with speed for different distances, such as the 3 and 6 meter distances, is due to the position of the time slice to the actual position of the source.

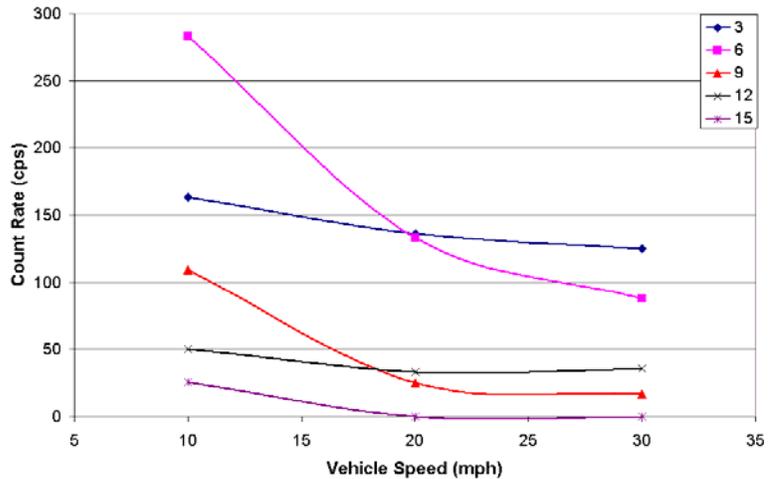


Figure 10 Variation of ^{60}Co with Speed.

The 10 μCi ^{137}Cs results are similar. Figure 11 shows the variation with distance for 10 mph.

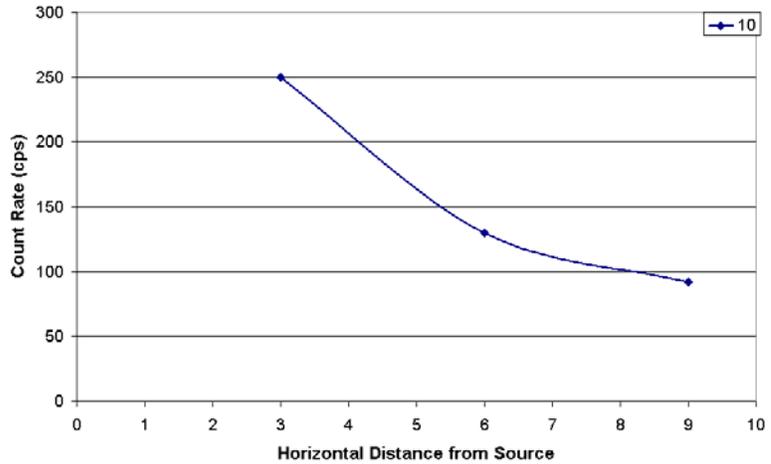


Figure 11 Variation ^{137}Cs with Distance.

Figure 12 shows the neutron count rate by position for 3 meters and 10 mph. The neutron source activity is 900 μCi . The neutron signal is only total counts summed from all 4 tubes. Note that the signal is visible over a wider distance than the gamma ray signal.

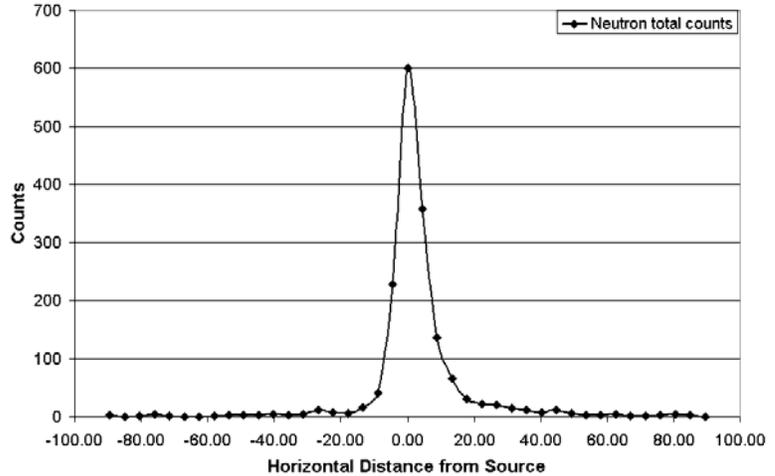


Figure 12 Neutron Signal for 3 meters and 10 mph.

Figure 13 compares the neutron count rate for 10 and 20 mph at 6 meters distance.

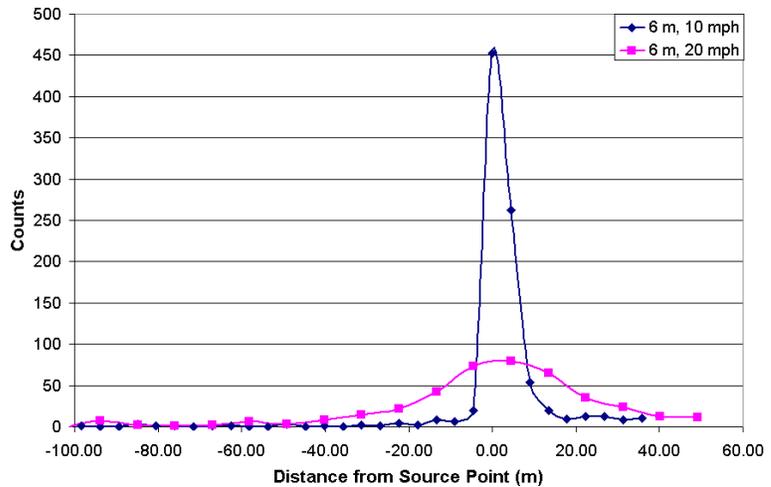


Figure 13 Neutron Signal for 6 meters for 10 and 20 mph.

Figure 14 shows the variation of neutron signal by distance. The deviation from the $1/r^2$ decrease is thought to be due to neutron scatter (room return) from the ground at close distances.

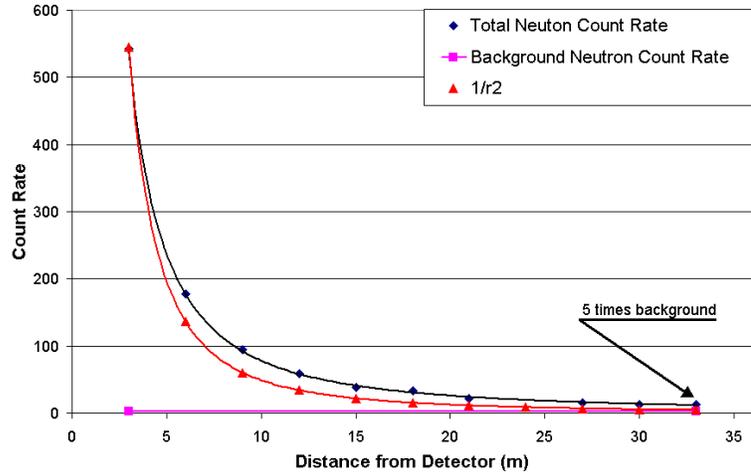


Figure 14 Neutron Signal by Distance.

Conclusions

The NaI-SS system has shown to have sensitivities for gamma ray and neutron signals acceptable for use as a search tool. The indications for the gamma ray signal show that the system should be used at 10 to 20 mph for the best results and the useful distances for sources in the 10s of μCi is 12 meters or less. The neutron signal has similar sensitivities. The distance is about the width of 4 typical traffic lanes. Further improvements in this system are ongoing as a result of these tests.