White Paper

Enhanced Standoff Detection Capability for SNM Using High Purity Germanium Detector-Based Instrumentation

The difficulty of locating and identifying radiological sources over large areas is well known. The signal strength of a small-volume source diminishes according to the familiar "inverse square law" as the detector is moved away from the source. Ever-present fluctuating background levels exacerbate the problem when the source strength is weak compared to the background count rates from other sources and scattered radiation.

It is now recognized that detector energy resolution is very important in the context of specific nuclide detectability and speed to detect. Energy resolution is not just important when source mixtures are present, but also has a strong effect on instrument detection limits for single nuclides. This work also suggests even a relatively small, high-resolution detector-based instrument can provide surprising good standoff radionuclide identification and location.

Signal strength (SS) as one moves away from a small volume source is approximately:

> SS@pd = SS@id/ $(id/pd)^2$ where pd is the present measuring distance and id is the initial measuring distance.

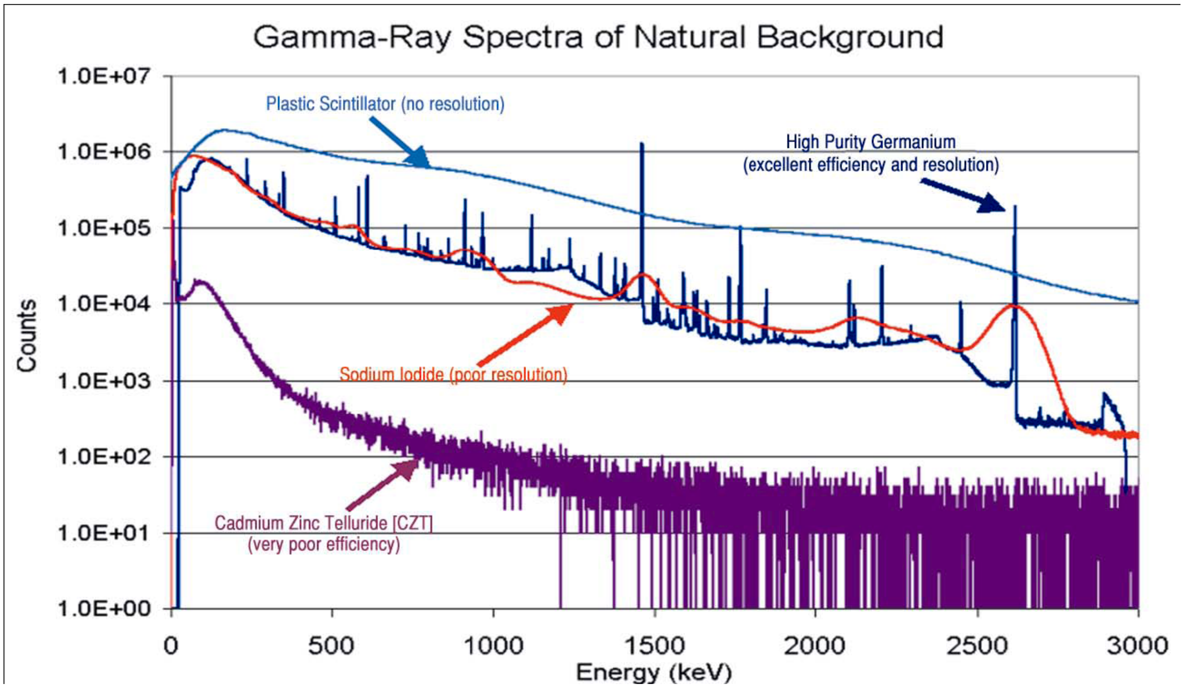
Thus, if a source measures 1000 CPS at 10 CM the same detector will measure only about 8 CPS at 110 cm. As distance from the source increases the source signal drops rapidly and eventually becomes lost in the background noise. Soon, due to the poor signal-to-noise ratio of the detection instrument, background fluctuations present a more likely observed phenomenon than the presence of an actual source.

Generally, the approach to this problem has been to use larger and larger detectors to increase the detection efficiency at a given distance. This can help somewhat but only to the extent that the source is stronger than background at the measurement distance. In other words while larger detectors increase signal amplitude they do nothing to improve the signal-to-noise (background) ratio. A larger detector will have a higher background, all other things being equal. The signal-to-noise ratio which is crucial in defining instrument performance is already "pre-defined" to an extent by the type of detector used and its energy resolution.

Clearly improving the signal-to-noise ratio of a search instrument would be better than increasing the detection efficiency alone. Improving signal-to-noise of any search system is the key to better performance. So how is this done?

First, let us explore what is meant by signal-to-noise in gamma spectroscopy. There are many sources of noise in a gamma energy detection instrument starting with the detector and including the preamplifier, power supplies, and histogramming circuitry. With modern, "high-end" instruments the noise contribution of electronic components have been minimized. By far the largest driver of noise is the detector.

Let's again look at Figure 1 shows a background energy spectrum from each of the major detector types superimposed for easy comparison.



The relative energy resolutions of various common detectors
Figure 1

Let us now consider the role of detector types in signal-to-noise. A plastic detector for example may be thought of as having very poor signal-to-noise as it can make little if any distinction between signal and noise as illustrated in Figure 1. In other words, a plastic detector can only detect radiation. It has minimal ability to discern the signal from the source of interest from that of background.

A NaI detector is somewhat better than plastic scintillators as it can reject signals (counts) from energy regions not included in the region where the energies of the sought radionuclide are known to exist. Thus if the energies identifying the nuclide of interest occupy only 10 percent of the detected spectrum, one might initially assume a ten-fold improvement in signal-to-noise could be achieved by using a NaI over a plastic detector. Unfortunately, there are other issues such as the effect of Compton scatter that diminish this apparent signal-to-noise improvement. The energy ranges that we wish to uniquely contain the nuclide of interest in fact contain very significant signal (counts) from background.

With HPGe detectors the signal-to-noise improves dramatically. The peaks from the nuclides of interest are approximately 40-50 times narrower (sharper) in terms of energy than those from a NaI detector. The benefits in situations of attempted masking of one nuclide by another are obvious, but what is not always so obvious is what happens to the instrument sensitivity for single nuclides. Consider the simplified case where two detectors, one HPGe and one NaI, are detecting a single-peaked source in the presence of the same background. For the sake of example and for the sake of simplicity, assume there are the same number of counts in the peak in each case, say 100 counts above background. Assume that the background is 100 counts per channel. In the case of the HPGe spectrum we might choose to sum the peak over, say, 4 channels giving us:

HPGe Net counts = Gross Counts - Background = 500 - 400 = 100 +/- sqrt(400) = 100 +/-19.

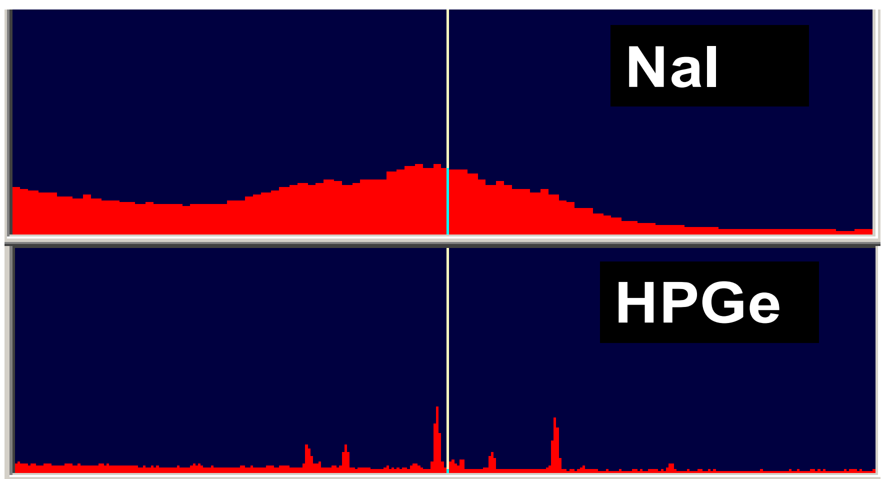
For the NaI detector, when integrated over the same range of energy, and assuming a 50-fold degradation in resolution, the calculation would be:

NaI Net Counts = 20100 -20000 = 100 +/- sqrt(20000) = 100 +/-141.

So in the case of the NaI detector, it is very difficult to set a threshold value for the peak net counts which will reliably result in the detection of the nuclide. Even zero is not enough because of statistical variation. For The HPGe detector a setting of say 50 counts will result in reliable detection AND false alarm resistance. As the number of signal counts falls away with distance, the difference between the HPGe and the NaI becomes even more marked.

This simple example assumed that the detectors were otherwise identical. In fact the signal-to-noise ratio in HPGe is better than that because the peak to background ratio in the HPGE spectrum is better than in the NaI spectrum, again because of the energy resolution effect.

Figure 2 illustrates the effect of improving energy resolution.



NaI and HPGe spectra of Pu-239 220-280 keV
Figure 2

The tremendous improvement in signal-to-noise is obvious.

The Detective-EX portable nuclide identifier from ORTEC has been shown, because of the fact they use a HPGe detector element to be on the order of one hundred times faster to identify than “similar” NaI based instruments. This speed advantage allows The Detective-EX to operate in a new mode “SNM Search Mode”. In this mode, a different CONOPS is possible. Rather than the traditional “search for radiation, find radioactive source, then identify”, SNM Search Mode allows the operator to “search for SNM”. In fact a simultaneous search for multiple nuclide classifications is possible, allowing the operator to ignore innocent sources and background fluctuations and be directed to the site of the SNM source in a single continuous operation.