An Intelligent Radiation Detector System For Remote Monitoring*

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Abstract. A unique real-time gamma radiation detector and spectroscopic analyzer, specifically designed for a "Homeland Security Radiological Network", has been developed by the Environmental Measurements Laboratory (EML). The Intelligent Radiation Detector's (IRD)** sensitivity and rapid sampling cycle assure up-to-the minute radiological data, which will indicate fast changes in atmospheric radioactivity. In addition, an immediate alert will occur within seconds to signal rapid changes in activity or levels elevated beyond a preset. This feature is particularly valuable to detect radioactivity from moving vehicles. The IRD also supplies spectral data, which allows the associated network computer to identify the specific radionuclides detected and to distinguish between natural and manmade radioactivity. To minimize cost and maximize rapid availability, the IRD uses readily available "off the shelf" components combined with an inexpensive, unique detector housing made of PVC plastic pipe. Reliability with no required maintenance is inherent in the IRD, which operates automatically and unattended on a "24/7" basis. A prototype unit installed on EML's roof has been in continuous operation since November 27, 2001.

INTRODUCTION

While the need for a radiation detection system for Homeland Security is obvious, the method of detection is far less obvious. However, by defining the ideal system, we can eliminate many competing techniques and close in on the best choice.

The ideal system should be sensitive, robust and reliable, and yet relatively inexpensive and easy to fabricate. It should operate automatically and unattended, require no maintenance, and should supply complete weather data. The ideal system should respond to a rapidly rising radiation level within seconds and give complete results in 15 minutes or less. These results should include a spectrum to allow identification of the detected nuclides. Upon sensing elevated radiation, it should alert nearby personnel with audible and visual alarms, as well as communicating with a network. All data should be transmitted to the network and also be backed up on the system's hard drive.

The Intelligent Radiation Detector (IRD) is the result of our efforts to incorporate all these features into a realizable instrument (see Figure 1).

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**Name has been changed to the Comprehensive Radiation Sensor

FIGURE 1. The IRD installed on EML's roof in downtown Manhattan, NY.

Description

The IRD, a unique gamma radiation detector and spectroscopic analyzer, specifically geared to the needs of a Homeland Security network, has been developed by the Environmental Measurements Laboratory (EML).

The IRD takes real-time measurements by using a continuously repeating 15-minute measurement sequence. The resulting gamma-ray spectrum, along with a single "activity number" that indicates the intensity of the radiation measured, is then transmitted to a network. If the "activity number" appears elevated, the network is alerted and performs a computer analysis of the spectra, which can then distinguish between natural and manmade radioactivity, as well as identify specific isotopes. The network can also signal the IRD to take shorter, more frequent measurements. Such a response would enable the rapid detection and tracking of a radioactive plume or cloud.

In addition, at any time during the normal measurement sequence, an immediate alert will occur within seconds to signal rapid changes in activity, or levels elevated beyond a 2 second preset limit. Thus, warnings of elevated radioactivity do not have to wait until a 15-minute sequence has been completed. When warnings do occur, both audible and visual alarms will alert nearby personnel. These same alerts are issued to the network. This mode is particularly useful for units installed at entrances to bridges and tunnels, at border checkpoints or near tollbooths to detect the passing of a vehicle carrying radioactive material.

In contrast with most conventional systems that simply show total gamma radiation activity, the IRD also supplies spectral data [1], which allows the specific radio-nuclides detected to be identified (see Figure 2). This important information can be extremely useful in minimizing radiological health effects and planning remediation efforts. For example, by identifying a radioactive release as isotopic iodine, protection against damaging thyroid uptake is possible by ingesting potassium iodide pills.

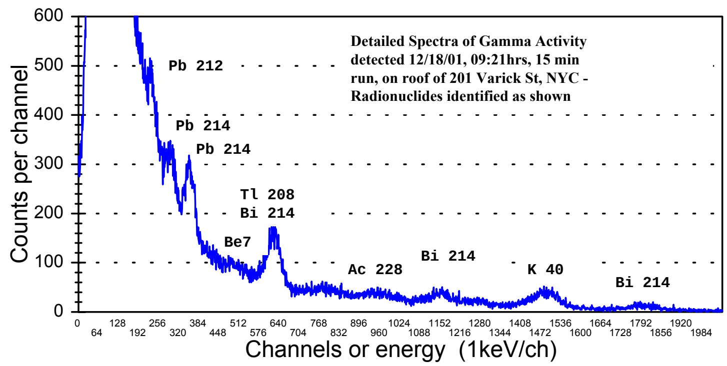

FIGURE 2. Gamma spectral data detected 12/18/01, 15 minute run (25 keV to 2035 keV).

Automatic and unattended operation is an important feature of the IRD. Once set up, this highly reliable unit needs no further attention, and in addition to transmitting all results to the network, the computer used with the IRD stores backup readings on its hard drive, which can hold some 30 years' worth of data.

Full meteorological capabilities are incorporated into the system as an aid in plotting the speed and direction of any radioactive clouds detected, as well as correlating normal activity peaks with precipitation (see Figure 3). Measured parameters include wind speed and direction, barometric pressure, rainfall, temperature, and relative humidity.

In the event of a domestic nuclear event, vast quantities of real time radiation data will be required for emergency response and crisis management. Radiation levels before the event (T-1), at the time of the event (T0), and immediately after the event (T++) will be required. A dense national network of IRDs can supply continuous real-time reporting of dose exposure related to a nuclear event, and will provide the required data. The network offers wide geographic coverage and because of multiple alarms, verifies any "above normal" radiation conditions. The network also acts as the communication link that will transmit data to a Central Station, which serves as a data collection facility. The Central Station would coordinate the data, and perform spectral unfolding and isotopic identification. The spectral unfolding program can also account for detector temperature effects by shifting and stretching the spectra to find the best fit using naturally occurring peaks. In addition, by using both the meteorological and nuclear data from the sites, the Central Station could accurately map the movement of any radioactive release in real time.

FIGURE 3. Weather station for meteorological data.

To minimize unit cost and maximize rapid availability, the IRD uses "off the shelf" components and a rugged, weather resistant, yet inexpensive detector housing made of readily available PVC plastic pipe. The system uses any low-end computer, a Davis "Vantage Pro" weather station, and a relatively inexpensive multichannel analyzer, the Radiation Safety Associates – Universal Radiation Spectrum Analyzer, URSA (Figure 4) [2]. While the URSA has had a number of new and useful features added to optimize the IRD concept, they are now included as standard features in all units.

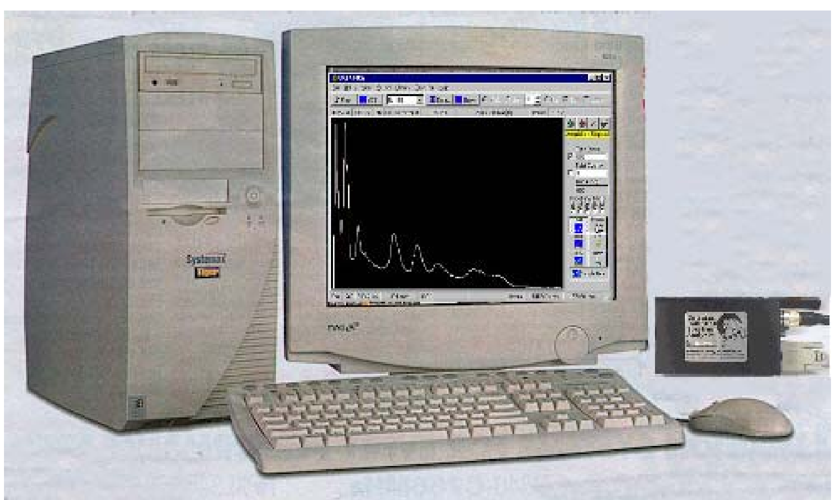

FIGURE 4. IRD computer system with URSA multichannel analyzer.

MATERIALS AND METHODS

Detector and Housing

The detector used in the IRD is a commercially available 3 by 3 inch inline, sodium iodide/ photomultiplier combination. This detector size was determined to be the best choice to maximize sensitivity, cost and physical configuration [3]. It is used in conjunction with a base/preamplifier that allows a long cable run between the detector and the URSA. At present, 50 feet of cable is being used.

The choice of sodium iodide (NaI) as the detector, rather than a competing technology, was in keeping with the goals of rapid response, reliability, efficiency, spectral information, economy, and zero maintenance [4]. Integrating systems, such as aerosol collection followed by counting, thermoluminescent dosimeters or film badges, were quickly eliminated for being far too slow to supply the results needed. Ionization chambers, Geiger counters and most other gas filled detectors cannot match the density, and thus the efficiency of NaI detectors, nor do they supply spectra. Germanium detectors, while capable of high resolution, are 35 to 50 times more costly than NaI detectors and add great complexity and maintenance effort to keep these detectors cooled. More exotic detectors, such as cadmium zinc telluride are expensive and only available in small sizes, and thus low efficiencies.

The detector and preamp are contained within a 24-inch high by 4-inch diameter weatherproof housing, constructed of readily available PVC Schedule 40 plastic pipe and associated fittings (Figure 5). The bottom of the housing consists of a cast iron flange, which lends great stability to the unit. Internally, two 3 to 2 inch adapters are cemented together and glued inside the 4-inch pipe to form a solid support for the detector/preamp. The cables going to the URSA are led out of a small slot near the base. The housing has proven itself to be thoroughly weather resistant, and should be able to sit in 6 inches of water without affecting operation.

Multichannel Analyzer

The multichannel analyzer used is the URSA, a compact, relatively inexpensive, stand-alone unit that operates with most computer operating systems. It communicates with the computer via the serial port and offers very user friendly and intuitive software. The URSA supplies detector bias and preamplifier power. The normal operating mode consists of a continuously repeating 15-minute spectrum acquisition, followed by a network transmission of the results, as well as a local "save" on the computer hard drive. The transmitted and saved data include both the detailed spectra and a single activity number that is the sum of all the counts in the spectrum from 25 keV to 2035 keV. This sum, the integrated gamma activity, is plotted against time and

FIGURE 5. Sodium iodide inline detector and preamplifier shown outside of housing.

offers a quick and easy way to assess rising levels of activity (Figure 6). The spectrum associated with any activity number can be easily retrieved so that specific isotopes may be identified. The URSA also offers up to 12 rapid alarm settings to cover all or part of the spectrum. Each alarm can be set to trigger above a preset value or a rate-of-rise occurring in a selectable time period of 1 second or more.

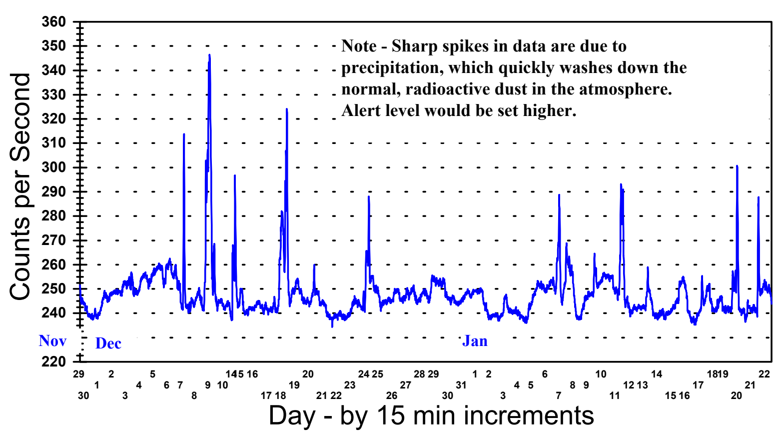

FIGURE 6. Integrated gamma activity (25 to 2035 keV) – roof data from November 2001 – January 2002.

RESULTS AND CONCLUSIONS

More than 16,000, 15-minute gamma-ray spectra have been recorded by the IRD since it was installed on EML's roof at 201 Varick Street, in lower Manhattan, NY, on November 27, 2001. The unit has been subjected to temperature variations from 20^{o}F to 80^{o}F with only minor gain shifts. The spectral unfolding program easily compensates for these small shifts.

Typical results during dry periods showed no isotopic activity above background. During periods of precipitation, either snow or rain, data analysis showed measurable amounts of naturally occurring bismuth-214 and lead-214 (from radon-222), as would be expected.

The IRD ideally meets the needs of a Homeland Security Radiological Network. It is inexpensive and completely maintenance free. Its only moving part is the computer hard drive, which stores the detector data. Since each IRD has its own computer, network operation, and communication with a central data center can be very flexible. Assembled with off-the-shelf components, deployments in large numbers will not be delayed because of production problems.

Data availability is extremely rapid due to the systems 15-minute measurement cycle and 2-second alert analysis protocol. Because the system measures and transmits a gamma-ray spectrum, it is possible to determine the composition of both natural and manmade radiation.

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