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Conceptual Design of Simulated Radiation Detector for Nuclear Forensics Exercise Purposes

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1. Introduction

According to the IAEA Incident and Trafficking Database, there has been a gradual increase in the illicit trafficking of nuclear material since the collapse of the Soviet Union. Since 2007, these incidents involving missing or stolen nuclear and other radioactive material have been drastically increased. These cases indicate a continuing nuclear security concern [1]. In this regard, nuclear forensics is recognized as an effective investigatory tool in providing evidence for the prosecution of these malicious acts related to the illicit materials [1]. Nuclear forensics can be defined as a scientific analysis of the interdicted and/or radioactively contaminated materials to trace the origin of the materials [2].

A site associated with an illicit trafficking or security event may contain trace evidence of criminal or malicious acts involving radioactive material. Such a site is called a radiological crime scene [3]. Management of a radiological crime scene requires a process of ensuring an orderly accurate and effective collection and preservation of evidence [3]. In order to effectively address such a security event, first responders and/or on-scene investigators need to exercise detecting, locating and recovering materials at the scene of the incident. During such the exercise, a sealed source can be used. This source is allowed to be a very small amount for exercises as there is the limit on the amount of radioactive material that causes no harm. So it is typically difficult to be found by some radiation detectors that the exercises have little effect on improving the ability of trainees [4, 5].

Therefore, we developed a conceptual design of a simulation radiation detector coupled with simulation sources which are designed to imitate a significant amount radioactive material for the purpose of a nuclear forensics exercise.

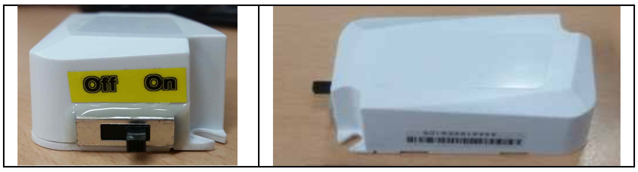
2. Modeling a simulated detector coupled with sources

Modeling used to simulate a virtual radiation detector is described in this section. A simulated detector is designed to respond to a safe electro-magnetic source that simulate ionizing radiation using Bluetooth Low Energy (BLE) communication technology. Electromagnetic wave from the safe source annihilates according to the distance away from it just as ionizing radiation. The distance between the detector and the source can be measured by BLE communication then the conceptual design of simulated radiation detector is developed.

A commercial beacon module can be used as an electromagnetic signal emitter and assumed as a safe simulated source. A receiver of the signal as a simulated detector is coupled with the beacon module based on BLE. BLE is a standardized protocol for sending and receiving data via a 2.4 GHz wireless link. This is a type of secure protocol for short-range, low-power, wireless transmission devices within 100m [6].

2.1 Beacon Module (simulated source)

A beacon module is an electromagnetic signal emitter that is used to simulate as it continues to generate spherically signal akin to real radioactive sources. The module is housed in a 70mm Ｘ 35mm Ｘ25mm container with 2 AAA batteries. It weighs around 100g (refer to Figure 1).



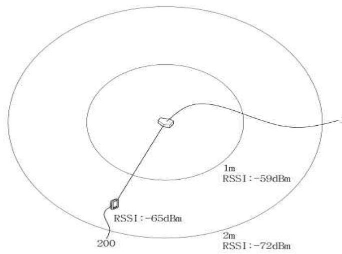
(Figure 1. Simulated Source)

A specific ID number is provided to each beacon module, which used to represents specific radioactive sources such as Co-60, Am-241 or U-235. A receiving device is designed to detect the ID number and identify it as specific source material within 20 m when the beacon module sends the data which consist of the value of the Received Signal Strength Indication (RSSI) and ID number.

2.2 Simulated radiation detector

The receiving device can be a simulated radiation detector applicable to nuclear forensics exercises. The device measures the distance away from the beacon module as the RSSI value reduces linearly with the distance [7]. Figure 2 shows how one meter and two meters distances can be set to match the intensity of -59dBm and -72dBm respectively. The distance could be technically extended to a 100m range, but the distance is limited within 20m which is effective in detecting the signal. The measured distance by the device can be used to simulate radiation exposure with function of radiation intensity which changes inversely proportional to the square of the distance from the source.

In addition, the device is designed to display the characteristic energy graphs of diverse radioactive sources. The change of graphs represents the change of the radiation intensity along with distance. In order to characterize radiation in a graph, some characteristic energy data related to diverse radioactive sources are generated by MCNPX, a Monte Carlo radiation transport code designed to track many particle types over a broad range of energies.

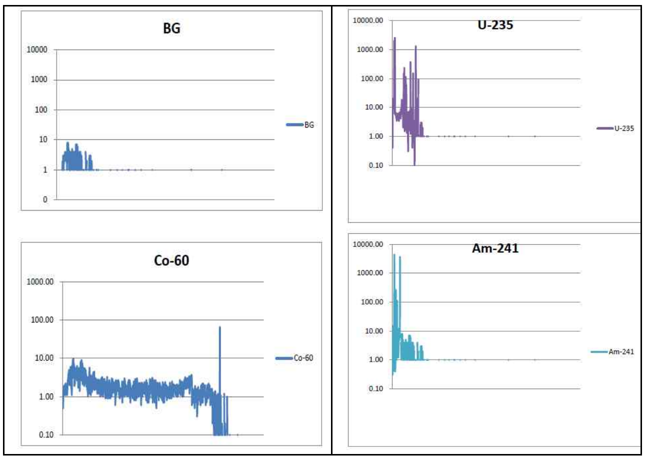


(Figure 2. Schematic diagram of RSSI strength changes with distance)

2.2 MCNPX 5.0 code calculation for characteristic energy graphs

MCNPX is used to obtain an energy distribution of pulses created in a detector by radiation from various sources. This distribution is used to create graphs for display in the simulated detector. The simulated detector can be an instrument utilizing a solid state CZT detector. For the calculation of the code, the source term is set to be 10^8Bq of Co-60, Am-241 and U-235 equivalent to 20-30mCi. The distance between the detector and the source is 30cm.

Figure 3 shows graphs of measured background and the calculated graphs of the sources such as U-235, Co-60 and Am-241. These graphs are obtained to display the energy distribution of radiations in the simulated detector by MCNPX calculation.



(Figure 3. MCNP Calculation of samples of U-235, Co-60 and Am-241 and Measurement of Background)

3. Conclusions

With the potential of a terrorist attack using radioactive materials, the first responders should regularly perform the nuclear forensics exercise in order to prepare for a recovery operation. In this regard, some devices such as simulated detector, coupled with a virtual source, can replace a real detector and a surrogate source of material in field exercises.

BLE technology could be applied to create similar environments to that of an actual radiological attack. The detector coupled with the simulated sources could be very helpful for first responders in testing and improving their ability in the case of a nuclear security event.

In addition, this conceptual design could be extended to develop a simulated dosimeter coupled with a beacon signal emitters. The dosimeter is a personal device used for indicating the cumulated exposure of radiation in real time in the field.

The development of these simulated devices could hopefully contribute to the education of first responders and investigators in nuclear forensics.

ACKOWLEDGEMENT

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