Contributed Paper

Detection of Unauthorized Movement of Radioactive Sources in the Public Domain for Regaining Control on Orphan Sources - Systems and Feasibility

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Abstract. Radioactive sources are used extensively throughout the country for various medical, industrial, agricultural and research applications. Specia Nuclear Materials (SNMs) like Plutonium and Uranium are handled at reprocessing plants, fuel fabrication units and in reactors for power generation applications. These SNMs are fissile material and have to be stored very carefully in criticality safe proper geomentries and quantities. All radioactive materials i.e. sources and SNMs need to be properly safeguarded and accounted to prevent their unauthorized movement and also illegal trafficking. This necessitates monitoring of these materials even in very small quantities not only at the entry/exit gates of the nuclear facilities but also at entry and exit ports of the country. Most widely used radioactive materials are gamma ray emitters. The fissile materials (SNMs) may also emit neutrons due to presence of spontaneously fissioning isotopes of the SNMs. Therefore, detectors, which can detect gamma rays and / or neutrons, can be used to detect the presence and movement of these materials in the public domain. Different types of systems with plastic scintillator coupled with a Photomultiplier Tube (PMT) as a sensor offers a very simple and efficient detection method. Because of its easy availability in large sizes, ease of handling and reasonable efficiency for gamma-rays a plastic scintillator is an ideal radiation detector for such applications. Plastic scintillator enclosed in a non-metallic enclosure, can detect low energy gamma rays. Portal monitor and Limb monitor are two such systems that have been developed and installed at various locations. A combination of transit detection system and assertive detection systems have to be used for an effective methodolgy to stop pilferage of radioactive materials. This paper describes the systems developed using plastic scintillators and their applications in monitoring in the public domain in India. The systems make use of microcontroller based single board computer that provides data acquisition, data transfer and display alongwith activation of alarm. The systems have sensitivity of the order of few hundred milligrams for Pu and can detect a low levels (order of kBq) of Cs-137 or Co-60. False alarm rate was found to be less than 2% of total number of alarms generated by the system. The applications of such stealth detection systems find much importance in the present day scenario of nuclear terrorism.

1. Introduction:

Scintillation detectors have been in use since the beginning of this century for the detection of ionizing radiation. These detectors make use of the property of certain chemical compounds which emit short light pulses (scintillation) after excitation by the passage of charged particles or by photons[1]. Scintillation is characterized by the absorption spectrum, emission spectrum, and decay times; the latter range from less than 1 nsec light yield (modern fast plastic scintillators) to few tens of nsec. Because of its easy availability in large sizes, ease of handling and reasonable efficiency for gamma-rays, plastic scintillator is an ideal radiation detectors for use in monitoring systems for detecting the presence of the radioactive materials and Special Nuclear Materials (SNM)[2]. This paper describes two such systems developed indigenously using plastic scintillator detectors for detection of radioactive materials in nuclear facilities as well as in the public domain. The gamma rays emitted by SNMs and other radioactive materials forms the basis for detection. In India the monitoring requirements in the public domain makes it mandatory to have simple and compact system to meet the large requirement. Basically two types of systems i.e. a portal montor for pedestrians and a camouflaged Limb/Pole monitor have been developed, calibrated and installed at a few facilities. The paper describes the design, analysis and sensitivity of these systems. Metal detectors and neutron detection systems can be used to augument these systems to detect shielded sources and/or neutron emitting radioactive materials. Once a subject or package is isolated by these monitors, the extensive search and identification can be performed by using hand held monitors by authorized persons. When there is no movement of fissile / radioactive material, the system monitors the ambient radiation background and transmits data to PC to study the variation in background in the area.

2. System Description:

2.1. Portal Monitor

The system basically comprises of four plastic scintillators (0.05 m diameter and 0.5/1 m long, Fig-1&2) coupled to PMTs which are used for the detection of gamma rays. The detectors are fitted on all four sides of the portal. Simpler systems can also be made with two or three detectors depending on the requirement. The plastic scintillators are enclosed with good light reflectors and placed in a PVC / Delrin enclosure with an integrated preamplifier assembly. The PVC or Delrin covering ensures that there is negligible attenuation for even low energy gamma rays emitted from the fissile materials. The signal from the PMT is amplified by the integrated pre-amplifier and is processed by amplifier-discriminator module to give digital pulses (Fig-1). These pulses are counted by custom made Phillips 235 chip based 8-channel counter-timer that is interfaced to the microcontroller based Single Board Computer (SBC)[3]. The detector counts and alarm values are displayed on a LCD display and the alarm levels is enterd using a 16 key Hex keypad. The keypad and LCD display are password protected to avoid unauthorized modifications of the system settings . Standard serial RS 232 protocol is used to transmit the data to a printer or to a PC for permanent storage and further analysis. The alarm monitor is a self-contained unit designed to provide remote audio-visual alarm for counts exceeding the pre-fixed levels, low background radiation levels indicating system problem and in the event of unauthorized tampering with the system. The system also incorporates a watchdog timer for uninterrupted system operation.

2.2. Limb Monitor

The Limb monitor comprises of one 1 m long 2”diameter plastic scintillator detector coupled with a Photomultiplier Tube (PMT) (Fig.1). The detector is covered with a good light reflector and placed in PVC/ Derlin covering ensuring negligible attenuation for the low energy gamma radiations. The electrical pulses produced by the detector and PMT due to incident gamma ray are amplified by a pre-amplifier and shaped to TTL pulses. The pulses are then counted by a compact Atmel series microcontroller AT 89C52-based Single Board Computer (SBC)[3]. The SBC acquires data, analyses and activates alarm at a remote place when counts exceed the preset level. Dip-switches are provided on the SBC to set alarm levels. The acquired counts are displayed on a 16X1 characters LCD to facilitate calibration and alarm level setting. To minimize the size of the monitor the pre-amplifier, amplifier, electronic processing units,and the high voltage unit are encapsulated in the pole of the Limb monitor which makes the system fully integrated into a single pole. A provision for remote alarm is also provided to alert the security personnel in case of un-manned system operation. The SBC can communicate with computer using RS 232 protocols for settings the system parameters and for alarm activation. The Limb monitor has been specially designed to prevent tempering. The monitor can be deployed at strategic places in such a way that it can go unnoticed in the area of application. It can be operated on a maintenance free 6 V/4Ah battery for 24 hrs. This makes it possible to use this system for portable and transit applications. Factors, like isotopic contents, ambient background and electronic noise affect the sensitivity of the monitor The system design has been optimized by improving the associated signal processing modules to provide a good gain to the low amplitude pulses and keep signal to noise ratio high to ensure maximum sensitivity.

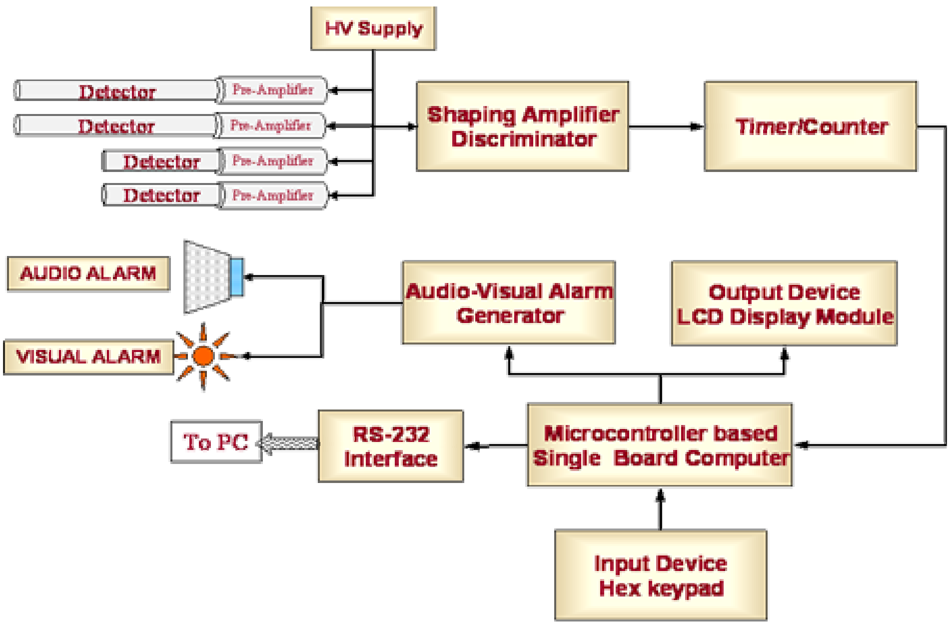

FIG. 1. Block Diagram of Portal Monitor and Limb Monitor

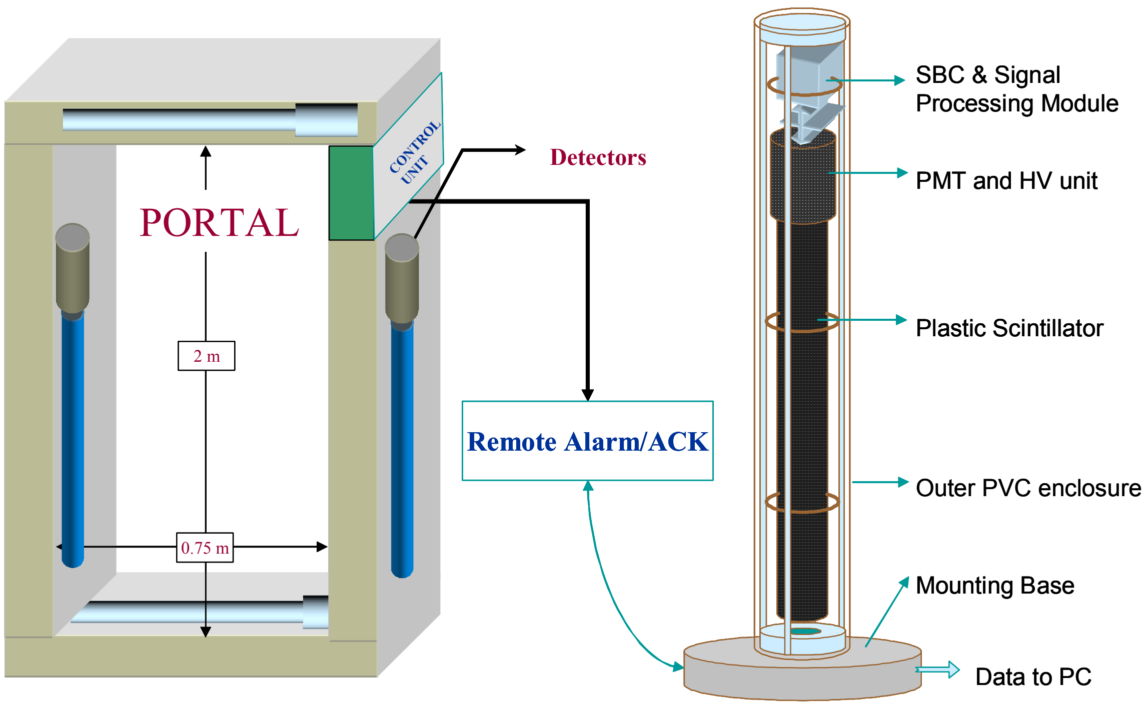

FIG. 2. Schematic Sketch of the Portal Monitor and Limb Monitor

3. Sensitivity of the systems:

The performance of both systems has been evaluated by collecting data from the systems over one-second time interval to assess their usage as walk through monitors. Data was collected with the sources placed in the centre of portal and 0.5m away from the Limb Monitor. The background CPS recorded was around 214.13 ± 17 cps at an ambient background radiation level of of 0.10 μSv/h (~10 μR/h) resulting in a minimum detectable level corresponding to 265 counts with 3σ counts above background.

The sensitivity of the systems under actual conditions of operation was analysed taking into account the least sensitive zones in the portal and at 0.5 m away from the limb monitor. The false alarm rates and failure rates was studied and accounted while arriving at the sensitivity levels shown in Table-1.

Table 1. Sensitivity of the systems

Source	**Source strength / Weight**	
	Portal Monitor (at the centre of the portal)	Limb Monitor (at 0.5 m)
Pu (RG)	0.2×10^{-3} kg	0.5×10^{-3} kg
U(Nat.)	0.2 kg	0.8 kg
Cs-137	37 kBq	92 kBq
Co-60	20 kBq	37 kBq

The variation in the counts of the detector along the length was within 10% and the radial response was found to be nearly uniform. The false alarm rate was found to be less than of 2% of total alarm generated by the system, which is comparable to the ASTM standards[4]. The failure rate (number of times the system could not detect the presence of radioactive material) of the system was 1.5% at the minimum detectable levels. The detection technique or methodology adapted in these systems can be extended to develop radiological access control systems and baggage checking systems at air/sea ports and monitoring vehicles or containers to detect inadvertant movement of radioacitve material with a very low level of detection limits. Thus the systems developed or techniques used can be utilized effectively to detect orphan sources and unauthorised movement or illicit trafficking of radiation sources or radioactive materials.

ACKNOWLEDGEMENTS

Authors wish to express their sincere thanks to Shri. H.S. Kushwaha, Director, Health, Safety and Environment group for his keen interest in the work. The authors also acknowledge with thanks Dr. K.S. Pradeep Kumar, Shri. D.A.R Babu and Shri. S.J. Chothramani for their valuble suggestions and advice in the development of the systems.

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