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A multiple-detector Radioactive Material Detection Spectroscopic (RMDS) portal

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ABSTRACT

This paper describes an optimization process for a Radioactive Material Detection Spectroscopic (RMDS) portal, designed to detect and identify radioactive materials concealed inside cargo containers. The system is based on a combination of conventional 3 in. NaI(Tl) gamma detectors and ^{3}He neutron detection tubes. The basic concept and the advantages of the new segmented spectroscopic detector approach are presented with several algorithms that were developed to enhance the detection capability of the portal and improve the signal to noise ratio. The results of field tests performed in several locations in Israel are also presented. The RMDS portal fully meets the demands of new ANSI Standard 42.38 for spectroscopic portals. In addition, the portal has some unique features, such as the ability to find the exact location of a point source inside the cargo and the ability to differentiate between a point source and Naturally Occurring Radioactive Materials (NORM) radiation. During the tests, the RMDS portal was compared to other detection systems, such as a PVT-based portal and a handheld spectroscopic HPGe detector. In these tests, the RMDS system was found to have a unique technique for background subtraction, which results in a higher detection sensitivity.

1. Introduction

The threats to homeland security from nuclear and radiological terrorism can be grouped into several categories: stolen state-owned nuclear weapons or weapon components modified for terrorist use, Improvised Nuclear Devices (INDs) constructed from stolen or diverted Special Nuclear Material (SNM), attacks on nuclear reactors or spent nuclear fuel and attacks involving Radiological Dispersive Devices (RDD) [1,2].

In the last decade, there has been an increase in the use of radioactive sources around the world, from devices to determine the strength of concrete at construction sites to devices for sophisticated medical examinations and therapies [3]. Thus, it is quite possible that terrorist organizations are already in possession of various types of radioactive sources or will have them in the near future [4,5]. A radioactive gamma, beta or alpha source, combined with conventional explosives, can form a RDD, which may be used in an attempt to contaminate a large area [6]. The question of radiological terrorism has to be addressed in this context, namely, by taking the appropriate measures needed in order to prevent the illegal movement of radioactive materials [7,8]. In a series of international conferences held over the last five years by the International Atomic Energy Agency (IAEA) [9], it was decided that the safe and secure management of radioactive sources is essential for ensuring the long-term security and control of these sources [10]. Therefore, most of the countries around the world are taking the necessary steps needed to close their borders against the movement of unauthorized radiation sources by installing radiation detection portals, X-ray and neutron scanning systems [11,12].

Most of the first generation Radiation Portal Monitors (RPMs) installed at border crossings and at the entrances to harbors around the world are non spectroscopic. The gamma detectors in these portals consist of large volume Polyvinyl-Toluene (PVT) plastic scintillators coupled to photomultipliers [13]. These types of detectors are characterized by high sensitivity and low resolution for gamma rays [14]. Therefore, the ability of these non-spectroscopic portals to distinguish between naturally occurring radioactive materials (NORM) and a harmful radioactive source is very limited. As a result, these portals are characterized by a high rate of nuisance alarms resulting from NORM [15–17].

For that reason, a second generation of radiation detection portals with superior gamma ray spectroscopic abilities were developed [18] according to the ANSI N42.38-2006 standard for spectroscopic portals [19].

Most of the spectroscopic gamma-ray detectors used in these new portals are based on scintillation crystals [20], solid-state semiconductor detectors or noble gas scintillation-based detectors [21].

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The scintillation detectors are usually thallium-doped sodium iodide, NaI(Tl), or cesium iodide, CsI(Tl) [22]. These detectors have a limited energy resolution of approximately 7.5% for the 662 keV gamma-ray emitted by the radioactive isotope ^{137}Cs, but they offer a significant advantage over the former PVT portals, mainly because their NORM rejection ability reduces the number of nuisance alarms [23–27].

Most of the SPM systems used today are based on existing large volume NaI(Tl) gamma-ray detectors. This technology meets ANSI N42.38-2006 standard requirements at a reasonable cost [28]. These new types of spectroscopic portals can balance between the two requirements of non-interference with commerce and accurate radiation measurement at the border [29].

In this paper, the concept for an identifier-type multiple detector Radioactive Material Detection Spectroscopic (RMDS) portal, developed for the detection and identification of radioactive materials concealed inside a moving cargo is described. The new system is based on conventional 3in. NaI(Tl) detectors, combined with ^{3}He tubes. The basic concept for and advantages of the new multiple spectroscopic detector approach are presented with several algorithms developed to enhance the detection capability of the portal and improve the signal to noise ratio. The results of field tests performed at several sites in Israel to verify the portal's performance are also presented.

2. System design

The RMDS portal consists of 32 NaI(Tl) gamma radiation detectors, 2–4 ^{3}He neutron detectors and 4 true break-beam occupancy sensors. The basic scheme of the portal configuration is shown in Fig. 1, and the configuration of the NaI(Tl) gamma-ray detectors inside one of the pillars is shown in Fig. 2. The pillar configurations are identical and have the following dimensions: height of 4.5 m, length of 0.82 m and width of 0.35 m. The distance between the pillars is approximately 5 m.

The block diagram of the portal is shown in Fig. 3. The distance between the control assembly and the electronics cabinet can be up to 15 m without the need for communication repeaters. The system can also be controlled over Ethernet or the internet, if such a connection exists. The wire distance between the pillar

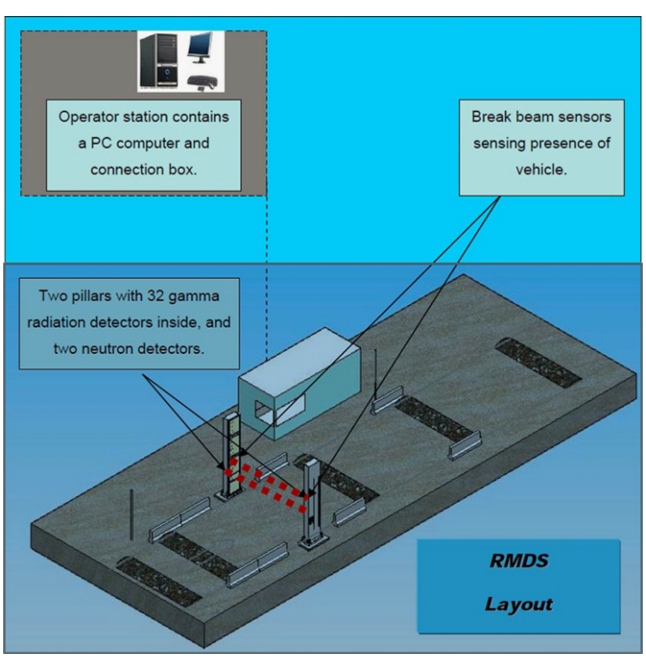

Fig. 1. Basic layout of the RMDS system.

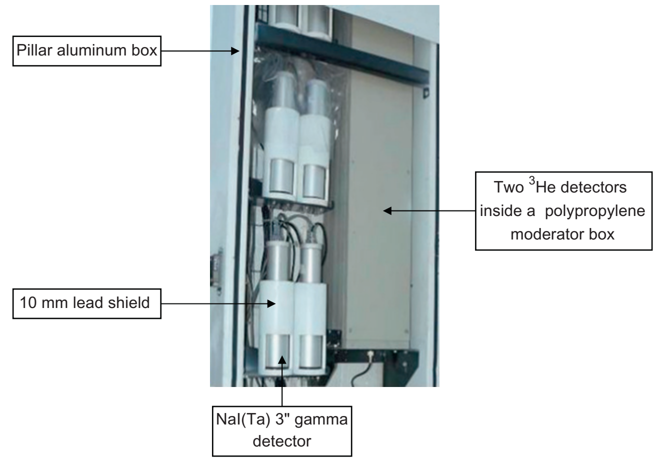

Fig. 2. RMDS NaI(Tl) gamma (left) and ^{3}He neutron (right) detectors setup inside the pillar.

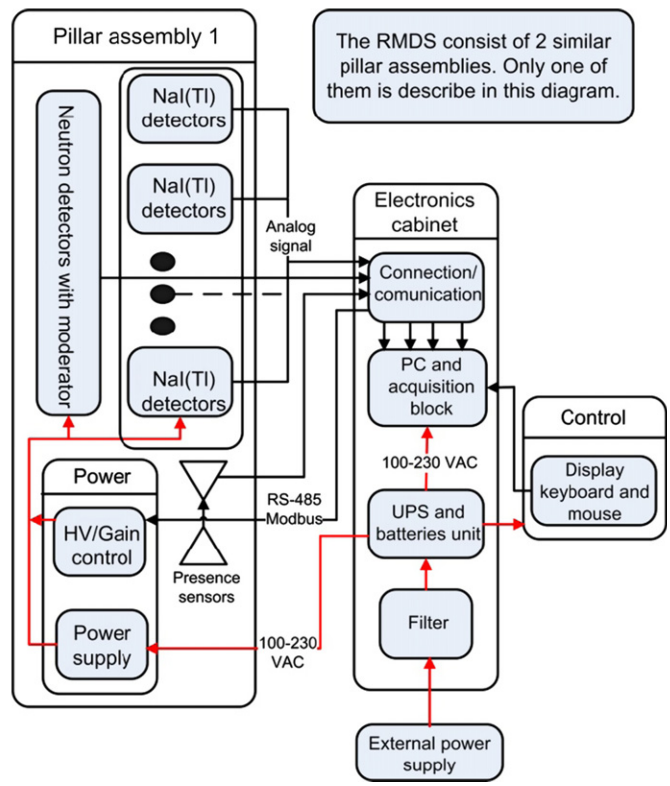

Fig. 3. Principal block diagram of the RMDS system.

assembly and the electronics cabinet can be up to 100 m using RG58 cable.

The PC and acquisition blocks are based on the Windows XP platform. The PC integrates all of the data collected by the acquisition boards via a multiple input Analog to Digital Converter (ADC) with a high acquisition rate of at least 1 mega sample per second. The energy range of the ADC was between 25 and 3000 keV, based on the gamma lines of the isotopes listed in the ANSI 42.38 standard. To maintain good resolution over such a wide energy range, the ADCs have a resolution range of 12 bits.

The pillar assembly is sealed and properly grounded, and some insulation is applied inside the pillar to prevent rapid temperature changes. Inside the pillar, an AC to DC low ripple linear converter provides voltage to the high voltage power supplies and preamplifiers through a power management box. The power management