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New Monitoring System to Detect a Radioactive Material in Motion

Karim Boudergui, Vladimir Kondrasovs, Romain Coulon, Gwenolé Corre, Stéphane Normand

Abstract—Illegal radioactive material transportation detection, by terrorist for example, is problematic in urban public transportation. Academics and industrial systems include Radiation Portal Monitor (RPM) to detect radioactive matters transported in vehicles or carried by pedestrians. However, today’s RPMs are not able to efficiently detect a radioactive material in movement. Due to count statistic and gamma background, false alarms may be triggered or at the contrary a radioactive material not detected. The statistical false alarm rate has to be as low as possible in order to limit useless intervention especially in urban mass transportation.

The real-time approach depicted in this paper consists in using a time correlated detection technique in association with a sensor network. It is based on several low-cost and large area plastic scintillators and a digital signal processing designed for signal reconstruction from the sensor network. The number of sensors used in the network can be adapted to fit with applications requirements or cost. The reconstructed signal is improved by comparing other approaches. This allows us to increase the device speed that has to be scanned while decreasing the risk of false alarm.

In the framework of a project called SECUR-ED Secured Urban Transportation - European Demonstration, this prototype system will be used during an experiment in the Milan urban mass transportation.

Index Terms— Correlation time, Nuclear, Portal Monitor, Radiation Plastic scintillator, RPM, Monitor, SECUR-ED, Sensor network, Signal processing,

I. INTRODUCTION

RADIATION Portal Monitors are currently more and more required to detect radioactive source in motion, especially in urban mass transportation (train, bus, car ...).

As count statistic may be low depending on the nature of the radioactive material and its packaging, long integration time is required to differentiate gamma background from the actual signal emitted by the threat. The use of a sensor

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network along the source track contribute to increase the detection sensitivity and to decrease the false alarm level. This last scenario is due a lack of count statistics, mainly because of the vehicle speed being too fast regarding the integration time.

The systems usually developed consist in triggering an alarm when an individual signal rises over a threshold initially estimated in regards to the natural background signal. The detection efficiency is then proportional to the number of detectors in use, due to the fact that each sensor is taken as a standalone sensor. This kind of detection systems are based only on counting statistics [1].

Our new system uses a network of 3 large plastic detectors to improve efficiency. We also implement a new method taking into account the temporal periodicity of the signals provided by all distributed detectors as a whole. As already demonstrated in [2] and [3] the temporal correlation between each detection module contribute to increase the detection level and to decrease the false alarm level.

II. MATERIALS AND METHODS

The concept consist to use 3 sensor units aligned and separated by the same distance (eg. 2 m in our case), the radioactive source is supposed to move in the same direction from sensor unit 1 to the sensor unit 3. Count rate from each sensor are recorded in a memory and analyzed together in order to find a time correlation and to establish the correlation function.

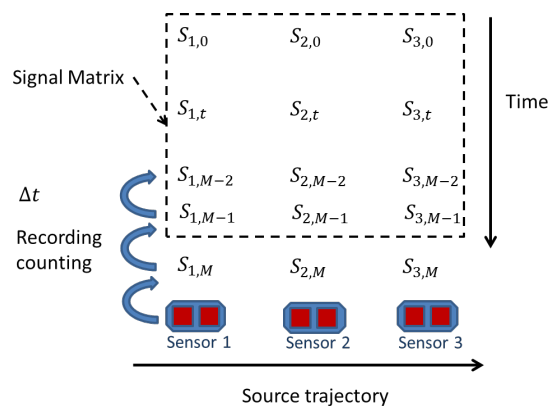


Fig 1. Principle of signal collection

A. Methods

The collected counting rate values are noted $S_{i,t}$ where i represents the sensor unit number (or channel number) and t the index time in the memory.

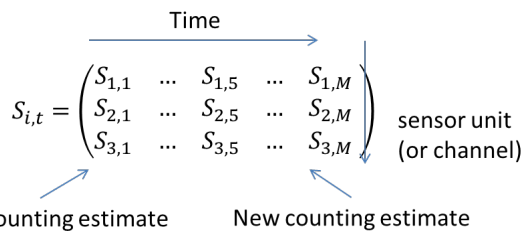


Fig 2. Matrix of counting rate values from each sensor units

The delay time m is directly link to the distance between the sensor unit and the speed of the radioactive source. This delay could be defined manually or automatically. Assuming that the source speed is known in this stage of the study the delay time “ m ” between the 3 sensor units is manually determined. A static product $R(n)$ (depending of timestamp “ n ”) is defined in (1). A depth time M is also set in order to improve the signal smothering.

$$R(n) = \sqrt{\frac{V_1(n)+V_2(n)+V_3(n)}{3}} \quad (1)$$

With

$$V_1(n) = \frac{1}{M} \times \sum_{n-\frac{M}{2}}^{n+\frac{M}{2}} S_1(n) \times S_2(n-m) \quad (2)$$

$$V_2(n) = \frac{1}{M} \times \sum_{n-\frac{M}{2}}^{n+\frac{M}{2}} S_2(n) \times S_3(n-m) \quad (3)$$

$$V_3(n) = \frac{1}{M} \times \sum_{n-\frac{M}{2}}^{n+\frac{M}{2}} S_1(n) \times S_3(n-2m) \quad (4)$$

B. Hardware Description

The hardware of this system is composed by 2 principal functions: detection function based on 3 sensor units and command control function Fig 3.

1) Sensor Unit

The sensor unit is composed by a detection part using 2 plastic scintillation detectors (coupled to fast linear focused 12 stages PMT) 100 x 100 x 1000 mm (EJ-200 produced by Eljen Technology [4]), a data acquisition electronics (DAQ) developed by CEA [5] and an embedded video camera to record movies of the suspect object.

This DAQ is made of a compact set of a DC module providing power supply to the other module (5 W), a Field Programmable Gate Array (FPGA) board and High Voltage board for 2 PMT.

The FPGA card aims to digitalize the signal directly from

detector (800 MHz).

2) Control Command Unit

This control command unit includes an embedded computer, power supply and communication part (network connection).

This unit provides power supply (24 Volts) to all 3 detection units and collects all data from them (time and counting rate information), it represents command control of the system.



Fig 3. Prototype system with 3 sensor units and a control command unit

C. Software Description

The software using in this system is based on a client/server model. The server software aims to manage and to collect data from sensor units, save them to a file and send them to the connected client.

The client can be a portable computer (PC) based near the control unit or deported to a control room. A standard network is used to establish the connection and to communicate.

The server can collect all datas every 100 ms from each sensor units, analyze the correlation results and send automatically an alarm in case of the radioactive source detection.

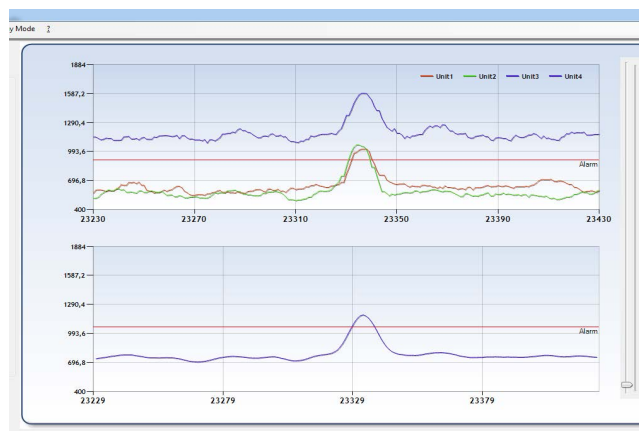


Fig 4. Software display from the client side (after delay adjustment)

The client has the possibility to display in real time different data series and correlation result.

The top part of the Fig 4 is the raw counting rate from the 3

sensor units, with the corresponding delay time in (.2), (3) and (4). The bottom part represents the correlation product calculated see (1).

III. PRELIMINARY RESULTS

In this paper two tests are presented, the first one the use of a periodic signal to adjust the different parameters and processes, and the second one the simulation of the passage of a vehicle along the 3 sensors units.

A. Test with a Rotating Source

The source is fixed on rotating system with an adjustable speed (Fig 5.).



Fig 5. Test bench for periodical detection

TABLE I

Setup	SOURCE IN MOTION	background
1	^{241}Am	Natural
3	^{137}Cs	^{60}Co

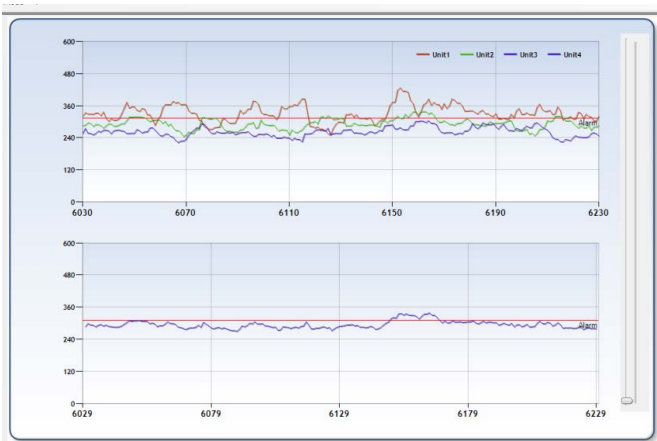


Fig 6. ^{241}Am source in static position (after delay adjustment)

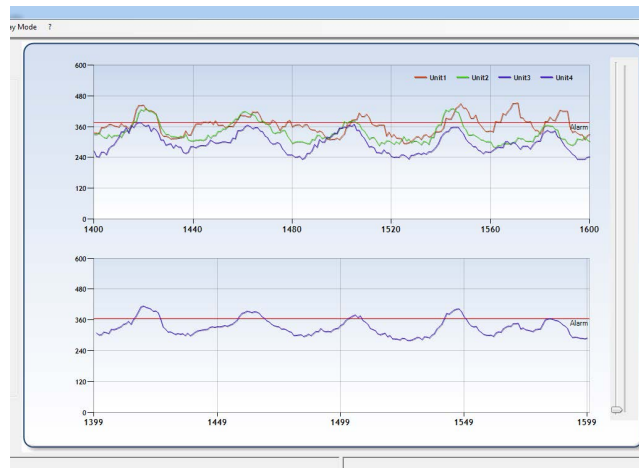


Fig 7. ^{241}Am source in rotation (after delay adjustment)

Considering the independent signal channels the background is comprised between 240 and 460 c/s as well with the source in rotation and without it. On contrary the correlation signal is comprised between 260 and 340 c/s without source and between 260 and 400 c/s with the source in rotation. The correlation approach shows then a significant increase of the signal to noise ratio allowing an improvement of the detection sensitivity.

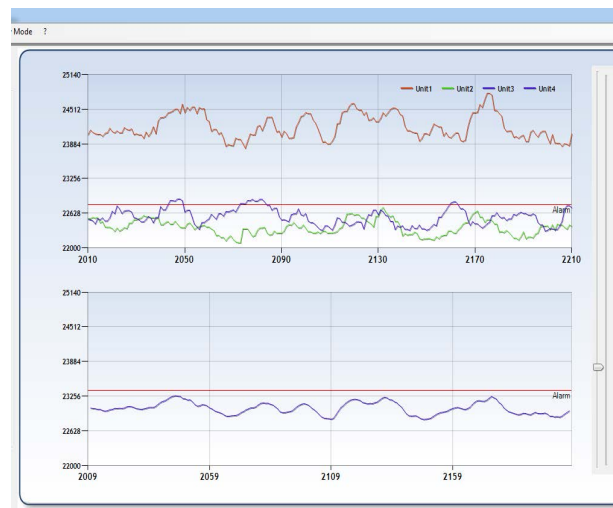


Fig 8. ^{137}Cs source static close to channel 1 with ^{60}Co as background source (after delay adjustment)

Even if the background is increased the improvement given by the time correlation algorithm still contributes to increase the detection performance (signal to noise ratio). As seen in the Fig 8. the background source is near the channel 1. The time correlation techniques maintain a good stability when the background changes in space distribution

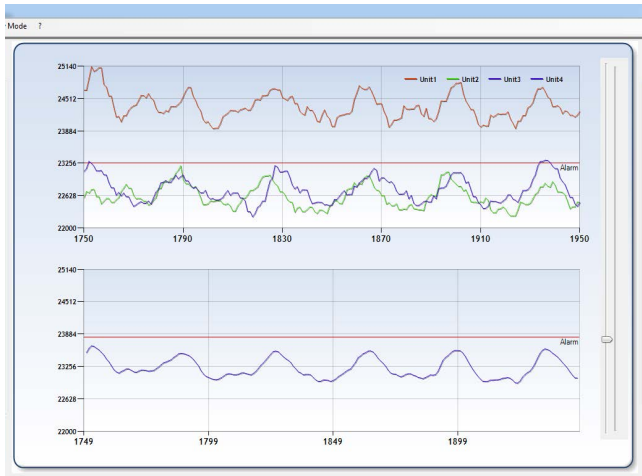


Fig 9. ^{137}Cs source in motion with ^{60}Co as background source (after delay adjustment)

B. Test with a Linear Moving Source in One Direction

This test consists to align the 3 sensors units separated by the same distance and put a source on a robot in order to simulate a vehicle passage. In the Fig 10 all system is deployed in a corridor and a robot with a source runs along the sensor units.

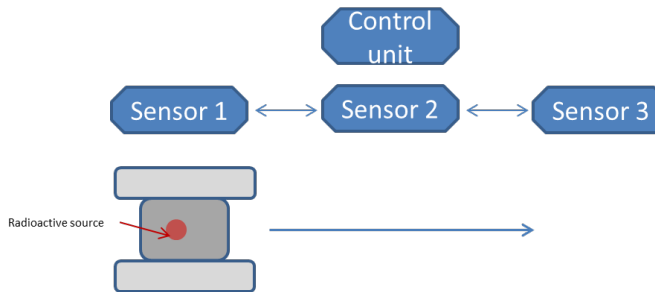


Fig 10. linear moving source in one direction test bench

TABLE II
SETUP DESCRIPTION

Setup	SOURCE IN MOTION	comments
1	^{137}Cs	Near sensor units
2	^{137}Cs	Far sensor units

In this test the robot runs with a constant speed and the decay time value has been defined after several runs with a source. By adjusting the distance between the robot (with the source) and the sensor units, the level of the detected source increase (Fig 11) or decrease (Fig 12).



Fig 11. ^{137}Cs source in a robot in motion near sensor units (after delay adjustment)

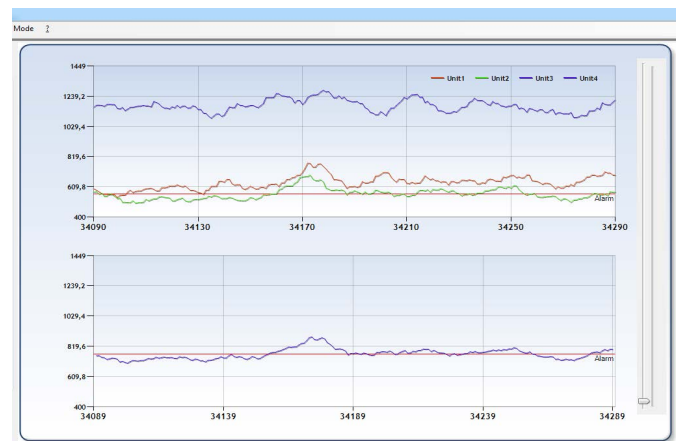


Fig 12. ^{137}Cs source in a robot in motion far sensor units (after delay adjustment)

The next step of this experimentation consists to perform and define a procedure to obtain detection limit and efficiency of the system compare to aver existing products. This system will be adapted to the context of rails vehicle ANSI42-35 [6].

IV. CONCLUSION

The proposed approach shows a significant improvement of the signal to noise ratio. This system offers a flexible solution to different homeland security applications.

The test to be compliant with the standards ANSI 42.35 will be held during the SECUR-ED demonstration. In this framework of the project this system will be along a rail in order to scan a train and detect a radioactive source. The train has a 15 km/h maximum speed. Detection must be almost in real time in order to send the alarm earlier to route the train to an inspection area.

For this demonstration the decay time must be define and adjust automatically. This could be possible by taking into account a maximum of time correlation function with several decay time (like a memory). Research of the minimal of correlation to estimate a background level and then an adaptive detection threshold is also under study.

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