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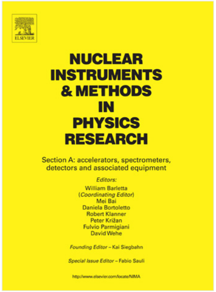

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PII: S0168-9002(17)31022-7
DOI: https://doi.org/10.1016/j.nima.2017.09.052
Reference: NIMA 60131

To appear in: *Nuclear Inst. and Methods in Physics Research, A*

Received date : 13 June 2017
Revised date : 5 September 2017
Accepted date : 20 September 2017

Please cite this article as: J. Brennan, E. Brubaker, M. Gerling, P. Marleau, M. Monterial, A. Nowack, P. Schuster, B. Sturm, M. Sweany, Source detection at 100 meter standoff with a time-encoded imaging system, *Nuclear Inst. and Methods in Physics Research, A* (2017), https://doi.org/10.1016/j.nima.2017.09.052

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Source detection at 100 meter standoff with a time-encoded imaging system

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Abstract

We present the design, characterization, and testing of a laboratory prototype radiological search and localization system. The system, based on time-encoded imaging, uses the attenuation signature of neutrons in time, induced by the geometrical layout and motion of the system. We have demonstrated the ability to detect a $\sim$ 1 mCi ^{252}Cf radiological source at 100 m standoff with 90% detection efficiency and 10% false positives against background in 12 min. This same detection efficiency is met at 15 s for a 40 m standoff, and 1.2 s for a 20 m standoff.

Keywords:
fast neutron imaging, time-encoded imaging, radiological search instrument

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1. Introduction

The detection and localization of radiological sources in various environments is an important nuclear security capability. Some scenarios require quick localization of sources in highly cluttered background environments, and others may demand detection of sources over large areas. Because of their relatively low and isotropic natural background, ability to penetrate shielding, and long attenuation length in air (approximately 100 m at fission energies), fast neutrons are a strong candidate signature of illicit nuclear material. However, despite the relatively low background flux, variability caused by environmental factors such as weather conditions (pressure and humidity), geographic location (geomagnetic rigidity), local scattering sources, and even solar cycle, lead to a systematic uncertainty in the absolute neutron background rate [1, 2]. For example, the dominant factor in the time variation for a fixed location is the solar cycle, causing a 30% variation [3]. This variability ultimately limits the detection sensitivity of gross counting detectors.

Neutron imaging can reduce susceptibility to background variability, but in the case of double scatter imagers [4] the efficiency is low, and coded-aperture imagers [5] have a limited field of view and poor imaging signal to background. Both systems typically involve large numbers of detector/electronics channels that could impede fieldability and introduce systematic variability due to, for example, differences in photodetector gain and overall detector light collection efficiency. While gain variation and and light collection efficiency in these systems can be calibrated to reduce systematic variability, the large number of channels adds a time and labor intensive calibration step in any measurement.

The time-encoded imaging (TEI) system described in this paper, however, has a 360-degree field of view, low channel count leading to reduced susceptibility to systematics, and does not require double scatters for localization, resulting in improved efficiency. Recently, we reported on a two-dimensional fast neutron imager using time-encoded imaging (2D-TEI) [6]. That system was designed as a proof of principle for an alternative to coded-aperture imaging, with the distinction that, rather than modulating the radiation field in space and recording the modulation with position sensitive detectors, the field was modulated in time and recorded with a time sensitive detector. The main systematic effects for such a system are those that induce a time modulation with the same rotational period as the detector rotation, of which there are few. Presented here is another system based on the TEI concept; targeting the application of radiological search at large standoff as opposed to high-resolution imaging yields a distinct detector sys-

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