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Technical Note

Some practical realizations of preset time count rate meters using optimized adaptive digital signal-processing solutions

Aleksandar Zigic*

Electronics Department, Institute of Nuclear Sciences VINCA, P.O. Box 522, Mike Alasa 12-14, 11001 Belgrade, Serbia and Montenegro

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Abstract

Two optimized adaptive digital signal processors were developed to implement the preset time count rate meters. The first processor improves stationary characteristics of the count rate meter by implementing the control of the error of the mean count rate when the changes of the mean count rate are only due to its stochastic nature. The second processor is focused on dynamic characteristics. Its time response is made adaptive to the changes of the mean count rate which are due to increased or decreased radiation levels. The change of the mean count rate is sensed by a specially devised detection algorithm.

Three mean count rate meters, based on the developed adaptive digital signal processors, were realized and were used for experimental validation of proposed adaptive digital signal processors. The experimental results, conducted without and with radioisotope for the specified errors of 10% and 5%, showed to agree well with theoretical predictions.

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1. Introduction

Signal fluctuations at the outputs of radiation detectors are caused by random variations of time intervals between successive input pulses, even in the stationary state [1]. This holds true for both preset count and preset time-mean count rate meters. The original preset count algorithm for suppression of the fluctuations is given in Ref. [2], and its practical applications in Refs. [3,4]. Although some algorithms for digital mean count rate meters are already known [5], adaptive digital signal processing was used mainly in the fields of optimum filtering of signals from radiation detectors in the measurement of event energy [6]. The analysis and design of digital mean count rate meters based on the preset time principle using some specific methods of adaptive digital signal processing were reported in Refs. [7,8].

The purpose of this paper is to present three practical realizations of the adaptive digital signal processors described in Refs. [7,8], using optimized digital filters [9] and specially devised adaptive digital signal-processing circuits [10]. The theoretical background of the presented realizations has already been given in Refs. [7,8], but is repeated here, with additional explanations, for reader's convenience.

2. Description of the methods

A possible way to quantitatively determine the radiation level is to measure the mean of the pulse rate from counting radiation detectors. Two methods were proposed to improve the performance of existing preset time algorithms. The reason for introducing the proposed two new methods were: to shorten preset time for higher stationary pulse rates, enable specified and controllable error when the mean count rate stays within certain predefined limits from its true value, and provide fast response to rapid changes of the mean count rate beyond the defined limits,

*Tel.: + + 381 11 2447189; fax: + + 381 11 2437929.
E-mail address: alex@vin.bg.ac.yu.

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by using two adaptive digital signal processors realizable in hardware or in software as modern, powerful and flexible solutions.

The first method starts with a longer preset time of 10 s assuming stationary pulse rates corresponding to background radiation levels and then uses an adaptation algorithm to adjust the duration of the preset time interval if the mean count rate is changed. The second method starts with a shorter preset time of 1 s, being immediately ready to react to sudden changes of the mean count rate, but switches to a longer preset time interval of 10 s if stationary pulse rates corresponding to background radiation levels are maintained.

Both methods use an optimized detection algorithm to sense the change of mean count rate, variable-length low-pass filter to implement mean count rate error control by controllable suppression of fluctuations of the mean count rate, and an optimized algorithm of adaptation of preset time interval based on the current value of the mean count rate. Relative standard deviation defined as the ratio of the standard deviation of the mean count rate and the mean count rate is used as the performance criterion for the selection of the optimum parameter values. Optimum values are those that minimize the relative standard deviation. The methods differ in the strategy of execution of the algorithm for adaptation of the preset time interval. In the first method, the preset time interval adaptation algorithm is executed after the low-pass filters. This allows obtaining shorter time constant intervals for higher stationary pulse rates. The second method executes the adaptation algorithm before the low-pass filters, which enables sensing of the rapid changes of the mean count rate before the fluctuations suppression is carried out.

Both methods were investigated using self-designed software package. The practical applications of the methods were: the second method was implemented in two versions of newly developed pocket digital gamma rate meter, and the first and second methods were implemented in a newly developed modified version of the digital portable beta and gamma rate meter. The second method was also implemented in the stationary gamma monitoring system installed at gates of Institute of Nuclear Sciences "VINCA".

3. Practical realizations of the proposed methods

The presentation of three practical realizations as experimental validation of the proposed methods are given in the following order:

- Section 3.1.: Monitoring System at gates of VINČA institute,
- Section 3.2.: Modified version of the digital portable beta and gamma count rate meter, and
- Section 3.3.: Pocket gamma radiation digital mean count rate meter.

3.1. Monitoring system at gates of VINČA institute

The first realization was the monitoring system installed at the gates of institute "VINČA". Its main purpose is to notify security personnel at gates of the institute of authorized and especially unauthorized transfer of radioactive material from or into the institute. Its duty is to give visual and audible alarm if it detects levels of gamma radiation in excess of some predetermined alarm level when people or vehicles pass by the monitoring system. Since it is an alarm-monitoring system, it has to react fast to sudden changes in the gamma radiation level. Therefore, it was realized using the second method.

3.1.1. Description of the detector

The gamma alarm monitoring system at gates uses a pan-cake GM counter SI-8B, with mica window thickness of 4 mg/cm^2 and surface of 33 cm^2. Its measuring range is 4000 c/s, or expressed in dose rate from 87 nSv/h to approximately 350 μSv/h. The GM counter SI-8B is used as soft beta and gamma radiation detector.

The monitoring system uses a suitable arrangement of four GM counters SI-8B in order to increase detection sensitivity compared with a single detector system, while preserving fast response to sudden changes in gamma radiation level that is an inherent feature of counting radiation detectors. Since it is primarily an alarm monitoring system, there is no need for the system to measure event energy, and, therefore, more sophisticated counting detections systems (proportional GM counters, scintillation detectors) are not needed. The information on the type of radioisotope detected by the alarm monitoring is provided, if required, by portable gamma spectrometry devices.

3.1.2. Measurement results

The experiments were conducted in order to validate the implementation of the second method for the alarm monitoring system at gates of the institute VINČA. The experimental setup is shown in Fig. 1. The four GM counters, forming a square, are placed in a PTFE holder which is fastened to a iron pillar with four screws. The pillar is welded to an iron footer. The center of the square formed by detectors is 1.2 m above ground according to standards.

The measurement results are given in Table 1. A set of 20 measurements was carried out. The duration of data acquisition for each measurement was 20 min. The specified mean count rate error was held fixed at 10% since tighter error limits were not necessary for alarm monitoring. The number of low-pass FIR1 filter used in stationary state was held fixed at 10 coefficients according to theoretical results for the second method given in Ref. [8].

Three quantities were derived from measurement results: the mean count rate, averaged over time interval of 20 min and over a set of 20 measurement runs, the mean relative standard deviation averaged over time interval of 20 min and over a set of 20 measurement runs, and the standard