EXPERIMENTAL VERIFICATION OF PRESET TIME COUNT RATE METERS BASED ON ADAPTIVE DIGITAL SIGNAL PROCESSING ALGORITHMS

by

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Experimental verifications of two optimized adaptive digital signal processing algorithms implemented in two preset time count rate meters were performed according to appropriate standards. The random pulse generator, realized using a personal computer, was used as an artificial radiation source for preliminary system tests and performance evaluations of the proposed algorithms. Then measurement results for background radiation levels were obtained. Finally, measurements with a natural radiation source, radioisotope ^{90}Sr-^{90}Y, were carried out.
Measurement results, conducted without and with radioisotopes for the specified errors of 10% and 5%, showed to agree well with theoretical predictions.

Key words: experimental verification, rate meter, adaptive signal processing, FIR filter, mean count rate

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 software method for the suppression of fluctuations of the mean count rate in preset count digital rate meter algorithms is given in [2] and its practical applications in [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 [7, 8].

The purpose of this paper is to present measurement results as an experimental verification of the two proposed adaptive digital signal processing algorithms described in [8].

Two adaptive digital signal processing algorithms were proposed to improve the performance of existing preset time algorithms. Both algorithms enable specified and controllable errors when the mean count rate stays within certain, predefined limits from its true value. In addition, one adaptive digital signal processing algorithm makes it possible to shorten preset time intervals for higher stationary pulse rates, while the other one provides a fast response to rapid changes of the mean count rate beyond the defined limits [8].

The adaptive digital signal processing algorithm that improves stationary characteristics of the mean count rate meter was implemented in a stationary gamma monitoring system. The adaptive digital signal processing algorithm that improves the dynamic characteristics of the mean count rate meter was implemented both in a stationary gamma monitoring system and in a digital portable beta and gamma rate meter.

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EXPERIMENTAL VERIFICATIONS OF THE PROPOSED ADAPTIVE DIGITAL SIGNAL PROCESSING ALGORITHMS

The presentation of measurement results as an experimental verification of the two proposed adaptive digital signal processing algorithms is given in this section.

Measurement results for a stationary gamma monitoring system

The stationary gamma monitoring system is an alarm monitoring system which has to react fast to sudden changes in the gamma radiation level. Therefore, it was realized using the adaptive digital signal processing algorithm that improves the dynamic characteristics of the mean count rate meter.

The gamma alarm monitoring system uses a pan-cake GM counter used as a soft beta and gamma radiation detector. Its measuring range is 0-4000 c/s.

The monitoring system uses a suitable arrangement of 4 GM counters in order to increase detection sensitivity in comparison to a single detector system. Since it is primarily an alarm monitoring system, there is no need for the system to measure event energy, and, therefore, more sophisticated radiation detections systems are not needed.

Measurements for the stationary gamma monitoring system were conducted according to standards [9, 10].

Measurement results are given in tab. 1. A set of 20 measurements was carried out. The duration of data acquisition for each measurement was 20 minutes. 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 filters used in stationary state was held fixed at 10 coefficients, according to the theoretical results for the second method given in fig. 8 of [8].

Three quantities were derived from these measurement results. The first was the mean count rate, averaged over a time interval of 20 minutes and over a set of 20 measurement runs. The second was the mean relative standard deviation, averaged over a time interval of 20 minutes and over a set of 20 measurement runs. The third was the standard deviation of the set of relative standard deviation values, obtained from each of the 20 conducted measurements. Relative standard deviation is defined as the ratio of the standard deviation of the mean count rate and the mean count rate itself. The random pulse generator, realized using a personal computer, was used as an artificial radiation source for preliminary system tests and performance evaluations of the proposed algorithms. Then measurement results for background radiation levels were obtained. Finally, measurements with a natural radiation source, radioisotope ^{90}Sr-^{90}Y, were carried out.

After studying measurement results, one may notice that:

(1) The mean relative standard deviation for the measurements with the radiation source is larger than for background radiation. This is because, in the second method, the preset time for the mean count rates less than the threshold of 6 c/s is 10 s and, respectively, 1 s for the mean count rates above the threshold. Since the mean count rate is 5.4 c/s for background radiation and 10.2 c/s with the radiation source, at that distance from the radiation source, the number of pulses for background radiation is, on the average, larger than with the radiation source.

(2) The mean relative standard deviation for measurements with the radiation source is 11.11%, which is somewhat larger than the specified error of 10%, due to a certain level of measurement uncertainty. Also, theoretical predictions shown in fig. 3 in [8] for the first method, suggest that the expected mean relative standard deviation for similar conditions

Table 1. Measurements results for the adaptive digital signal processing algorithm that improves dynamic characteristics implemented in a Stationary gamma monitoring system

<table>
<tr><td rowspan="4">Stationary characteristics</td><td colspan="2">Background radiation</td><td colspan="2">Measurements with radioisotope</td></tr>
<tr><td>Mean count rate (20 measurements)</td><td>5.42 c/s</td><td>Mean count rate (20 measurements)</td><td>10.2 c/s</td></tr>
<tr><td>Mean value of relative standard deviation (20 measurements)</td><td>2.9%</td><td>Mean value of relative standard deviation (20 measurements)</td><td>11.11%</td></tr>
<tr><td>Standard deviation of relative standard deviation (20 measurements)</td><td>0.6%</td><td>Standard deviation of relative standard deviation (20 measurements)</td><td>3.26%</td></tr>
<tr><td rowspan="4">Dynamic characteristics</td><td colspan="4">Measurements with radioisotope</td></tr>
<tr><td colspan="2">Sudden bringing IN of the radioisotope</td><td colspan="2">Sudden bringing OUT of the radioisotope</td></tr>
<tr><td>Mean response time (20 measurements)</td><td>2.3 s</td><td>Mean response time (20 measurements)</td><td>3.6%</td></tr>
<tr><td>Standard deviation of response time (20 measurements)</td><td>31%</td><td>Standard deviation of response time (20 measurements)</td><td>47%</td></tr>
</table>

should be between 5% and 6%. However, these results [8] were obtained for the preset time interval of 4 s, which is the used preset time interval for the mean count rate of 10 c/s, as shown in fig. 6 in [8], while in the second method used here, it is only 1 s. Theoretically, the quadruple decrease in the preset time interval doubles the error, which explains the relatively larger value of the mean relative standard deviation obtained here.

(3) The dynamic characteristics given in tab. 1, in the case when the radiation source was suddenly brought into the specified location of the detectors, closely go with the theoretical expectations of response time matching 2 s given in [8]. However, in the case when the radiation source was brought out of the specified location, on the average, the response time increased to 3.6 s, which was somewhat larger than 2 s predicted in [8], but still acceptable for the given purpose. The response time could be somewhat reduced, if the lower decision threshold of the algorithm for the detection of the change of the mean count rate is increased from 90% to 95%, at the expense of the slight increase in the mean count rate error, as shown in fig. A1 curve C in [8].

Experimental results for a digital portable beta and gamma rate meter

The digital portable count rate meter is used for measurements of surface beta contamination and gamma radiation (the absorbed dose in the air). It uses the same GM counter as the stationary gamma monitoring system, already described in section 2.1. The adaptive digital signal processing algorithm that improves the stationary characteristics of the mean count rate meter is used for the measurements of surface beta contamination, since it is more convenient for essentially stationary environments. The adaptive digital signal processing algorithm that improves the dynamic characteristics of the mean count rate meter is used for measurements of gamma radiation (the absorbed dose in the air). For both adaptive digital signal processing algoritms, the mean count rate error can be selected from a set of two discrete values, *i. e.* those of 5% and of 10%.

The measurements for the digital portable count rate meter were conducted according to standards [11, 12].

The measurements for the digital portable count rate meter were carried out using a procedure similar to that used for the stationary gamma monitoring system. Namely, the number and duration of individual measurements, radiation sources and quantities derived from measurement results, were the same.

The specified mean count rate error was first set to 10% and then to 5%, for both adaptive digital signal processing algorithms. The number of low-pass FIR1 filter coefficients used for the error of 10% was 10, while the one for the error of 5% was 20, in accordance with fig. 8 in [8].

Measurement results are given in tab. 2.

After studying measurement results, one may notice that:

(1) Results for the first method, for specified errors both with and without radioisotopes, are in accordance with predictions given in [8].

(2) Error values for the second method, for both stationary and dynamic characteristics, are in accordance with results given in [8]. Error values for the second method concerning stationary characteristics proved to be slightly higher than those of the first method, which was to be expected for reasons already explained. The preset time interval for the mean count rate of around 30 c/s in the first method (with the presence of radioistopes) is 2 s and, respectively, only 1 s in the case of the second method. In the case of background radiation, the difference lies in the length of the FIR1 low-pass filter used to suppress fluctuations in the stationary state, which equals 10 coefficients for the specified error of 10% and 20 coefficients for the specified error of 5%, as given by fig. 8. in [8].

CONCLUSION

Experimental verifications of preset time count rate meters based on two proposed adaptive digital signal processing algorithms were performed. One of the adaptive digital signal processing algorithms proved to improve stationary characteristics of a classical preset time count rate meter. The other adaptive digital signal processing algorithm proved to improve the dynamic characteristics of a classical preset time count rate meter. The proposed algorithms were implemented in a stationary gamma monitoring system and in a digital portable beta and gamma rate meter.

A stationary gamma monitoring system was realized using the adaptive digital signal processing algorithm that improves dynamic characteristics. A digital portable beta and gamma rate meter uses both algorithms; an adaptive digital signal processing algorithm that improves stationary characteristics was used for measurements of surface beta contamination, and an adaptive digital signal processing algorithm that improves dynamic characteristics for measurements of gamma radiation.

Table 2. Measurements results for adaptive digital signal processing algorithm that improves stationary characteristics and adaptive digital signal processing algorithm that improves dynamic characteristics implemented in a Digital portable beta and gamma count rate meter

The algorithm that improves stationary characteristics				
Stationary characteristics	The specified error = 10%			
	Background radiation		Measurements with radioisotope	
	Mean count rate (20 measurements)	1.35 c/s	Mean count rate (20 measurements)	32.2 c/s
	Mean value of relative standard deviation (20 measurements)	6.73%	Mean value of relative standard deviation (20 measurements)	7.23%
	Standard deviation of relative standard deviation (20 measurements)	0.4%	Standard deviation of relative standard deviation (20 measurements)	0.98%
	The specified error = 5%			
	Background radiation		Measurements with radioisotope	
	Mean count rate (20 measurements)	1.35 c/s	Mean count rate (20 measurements)	32.3 c/s
	Mean value of relative standard deviation (20 measurements)	3.67%	Mean value of relative standard deviation (20 measurements)	4.84%
	Standard deviation of relative standard deviation (20 measurements)	0.29%	Standard deviation of relative standard deviation (20 measurements)	0.66%
The algorithm that improves dynamic characteristics				
Stationary characteristics	The specified error = 10%			
	Background radiation		Measurements with radioisotope	
	Mean count rate (20 measurements)	1.36 c/s	Mean count rate (20 measurements)	32.6 c/s
	Mean value of relative standard deviation (20 measurements)	9.54	Mean value of relative standard deviation (20 measurements)	10.57%
	Standard deviation of relative standard deviation (20 measurements)	0.59%	Standard deviation of relative standard deviation (20 measurements)	1.8%
	The specified error = 5%			
	Background radiation		Measurements with radioisotope	
	Mean count rate (20 measurements)	1.35 c/s	Mean count rate (20 measurements)	32.3 c/s
	Mean value of relative standard deviation (20 measurements)	4.9%	Mean value of relative standard deviation (20 measurements)	5.4%
	Standard deviation of relative standard deviation (20 measurements)	0.9%	Standard deviation of relative standard deviation (20 measurements)	1.1%
Dynamic characteristics	Measurements with radioisotope			
	Sudden bringing IN of the radioisotope		Sudden bringing OUT of the radioisotope	
	Mean response time (20 measurements)	1.7 s	Mean response time (20 measurements)	2.6 s
	Standard deviation of response time (20 measurements)	21%	Standard deviation of response time (20 measurements)	29%

Measurement results, conducted without and with radioisotopes for the specified errors of 10% and 5%, showed to agree well with theoretical predictions.

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ЕКСПЕРИМЕНТАЛНА ВЕРИФИКАЦИЈА АЛГОРИТАМА АДАПТИВНЕ ДИГИТАЛНЕ ОБРАДЕ СИГНАЛА ИМПЛЕМЕНТИРАНИХ У МЕРАЧИМА СРЕДЊЕГ ОДБРОЈА НА БАЗИ ПРЕДОДРЕЂЕНОГ ВРЕМЕНА

Експерименталне верификације два оптимизована алгоритма адаптивне дигиталне обраде сигнала који су имплементирани у два мерача средњег одброја на бази предодређеног времена, урађене су према одговарајућим стандардима. Генератор случајних импулса, реализован уз помоћ персоналног рачунара, коришћен је као вештачки извор радијације за прелиминарна тестирања система и евалуације перформанси предложених алгоритама. Затим су добијени резултати мерења за зрачење у нивоу позадинског јонизујућег зрачења. На крају, обављена су мерења са радиоизотопом ^{90}Sr-^{90}Y, као природним извором јонизујућег зрачења.

Резултати мерења, добијени без и са радиоизотопом за специфициране вредности грешки од 10% и 5% показали су блиско слагање са теоријским предикцијама резултата.

Кључне речи: експериментална потврда, мерач средњег одброја, адаптивна обрада сигнала, ФИР филтер, брзина средњег одброја