IONIZING RADIATION MEASUREMENTS

EXPERIMENTAL DETERMINATION OF THE LIMITS AND CONDITIONS OF APPLICABILITY OF PAIRWISE AGGREGATION OF RADIOMETRIC INSTRUMENTS FOR THE DETECTION OF SOURCES OF IONIZING RADIATION

V. T. Minligareev, A. V. Yashin, and D. P. Bachurin

The method of pairwise aggregation of radiometric devices for the detection of radioactive substances is studied. The limits of applicability of the method for gamma-neutron fields are determined.

Key words: ionizing radiation, detection of sources, pairwise aggregation, limitations of method.

Measurement problems that involve the detection, localization, and identification of artificial sources of ionizing radiation have become critical problems today. Experience has demonstrated that gamma-neutron sources of artificial origin are the most widespread of such sources. These types of artificial sources of ionizing radiation are characterized by complex, including gamma-neutron radiation. The fields of such sources carry far more information than do alpha- and beta-sources, since they may be detected at distances of several meters and sometimes several dozen meters, even where masking measures are applied.

When it is necessary to detect sources that comprise components of several different types of radiation (in the present case, neutron and associated gamma radiation), there arises the need to measure the parameters of different types of fields [1, 2]. In many research situations, one of the most commonly employed methods for the measurement of fields of artificial ionizing radiation is the radiometric method. The method is based on an integral count of neutron pulses \(N_n\) or gamma quanta \(N_y\) over a fixed observation period [3, 4]. However, with the use of the method it is possible to disclose the parameters of the sources of only one type of radiation at a time, either gamma radiation or neutron radiation. Combined processing of the results of measurements of these types of radiation is not possible in gamma-neutron radiometers. To increase the reliability and certainty of the detection of complex artificial ionizing radiation, the detection process should be performed with respect to several identifying features. Combined processing of two classifying features that characterize a flow of gamma quanta and neutrons makes it possible to significantly increase the reliability of the measurements.

A theoretical evaluation of this interpretation is reviewed in [1]. To increase the reliability with which gamma neutron sources are detected, it may be suggested that the number of pulses be measured along two channels possessing different spectral ranges with subsequent joint processing of the information. A number of assumptions of importance for practical applications are made. However, questions related to verification of the validity of these assumptions [1] are not considered. The limits and conditions of applicability of the method of pairwise aggregation of radiometric instruments for the detection of artificial ionizing radiation were experimentally determined by the method described in [5] in order to solve this problem. The following problems were successively solved:


1) determining whether it is possible to apply the model of the normal law of distribution of the probability density function of a system of two random variables – the number of pulses of a neutron channel and of a gamma channel \((N_x, N_y)\) – for approximation of the Poisson distribution by a normal distribution law; and

2) investigation of signals belonging to the class of background as regards the favorability and stability for attaining a required precision and reliability of measurements in the process of detecting artificial ionizing radiation.

Measurements of the values of the characteristics of gamma neutron fields belonging to the class of background or to the class of signal were performed on a secondary standard of the flux density of neutrons at distances of 1.5–5 m and in an enclosed space where the standard had been placed at distances of 10–13 m from the artificial ionizing radiation. The natural gamma neutron background was measured in enclosed spaces and in open air. INK-4 type \(^{232}\text{Cf}\) artificial ionizing radiation served as the subject of the detection, and an SRPS22 gamma neutron radiometer was used as the measuring instrument (the measurement characteristics of the device are presented in Table 1). The conditions of the experiment ensured the independence of the results of observations.

In most cases of practical importance, the Poisson distribution proves to be an acceptable model for the description of the random number of occurrences of neutrons and gamma quanta in a fixed time interval [1, 3]:

\[
P(x = b) = \frac{\lambda^b e^{-\lambda}}{b!},
\]

where \(\lambda > 0\) is the parameter of the Poisson distribution and \(b = 0, 1, 2, \ldots\)

For high values of \(\lambda\), there exists an approximation, for example, for \(x [3]\):

\[
P(x \leq b) = \Phi \left( \frac{b + 0.5 - \lambda}{\sqrt{\lambda}} \right),
\]

where \(\Phi(x)\) is a normal (0, 1) distribution function.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range of measurements of gamma radiation</td>
<td>10 keV – 1.3 MeV</td>
</tr>
<tr>
<td>Range of measurements of neutron radiation</td>
<td>0.025 eV – 14 MeV</td>
</tr>
<tr>
<td>Sensitivity to the (^{232}\text{Cf}) neutron isotope</td>
<td>(10^{-3}) pulses-m(^2)/neutron</td>
</tr>
<tr>
<td>Sensitivity to gamma quanta of the (^{137}\text{Cs}) isotope</td>
<td>(10^3) pulses-sec per (\mu)Sv/h</td>
</tr>
</tbody>
</table>

Fig. 1. Theoretical (1) normally distributed and empirical (2) probability density functions of the records of pulses of background gamma radiation.