APPLICATION OF REAL TIME SPECTRUM MEASUREMENT TO RADIATION MONITORS

K. Matsuno,[1] M. Watanabe,[1] and T. Sakamaki[2]

[1]Fuji Electric Techno Engineering Co.,LTD., Tokyo, Japan
[2]Fuji Electric Co.,LTD., Tokyo, Japan

ABSTRACT

A multichannel analyzer (MCA) and two realtime spectrum monitoring methods have been developed for use in radiation monitors. The new MCA was designed to be installed at a local site as a component of a radiation monitor. The MCA repeats spectrum measurement at short intervals (Δt) and, after each measurement, transmits a spectrum datum to the operation console. The authors applied two methods to process Δt spectrum counts for each channel for longer time interval.

One method of processing counts is the "running average (RA) method". The other method is the "exponential smoothing (ES) method", which simulates RC rate meters by subtracting a fraction corresponding to the accumulated counts. Relative standard deviations for each channel can be made the same by selecting an appropriate value. The response with the "ES" method is initially faster than that with the "RA" method, but the "RA" method allows a full response to be reached at a predictable time.

INTRODUCTION

In order to measure various radionuclides contained in typical radioisotope facilities, gamma spectrometry is necessary. The detectors of radiation monitors are installed at a local site, separately from a control room.

Radiation monitors must be able to operate continuously and respond quickly to changes in radiation levels. The MCA conventionally used in labolatory analysis is not designed to measure varying radiation continuously or as quickly as radiation monitors need. The conventional MCA is also expensive.

For these reasons, spectrum measurement has not been applied to radiation monitors. Only the count rates of the total spectrum have been measured until now.

We have developed a relatively inexpensive MCA and data reduction methods with a real time response to be used in radiation monitors.

REAL TIME SPECTRUM MEASUREMENT

Table 1 shows the specifications of the MCA.

The MCA contains an amplifier, a high voltage power supply, a temperature sensor and an optical interface for data transmission to the console. Detector bias voltage, amplifier gain and Δt are adjustable at the personal computer in the console.

Table 1. Specifications of the MCA.

Bias voltage supply	600 - 1,200 V
Amplifier gain	1.1 V/pc ×1,2,3
ADC conversion gain	512 ch
Counts per channel	$2^{16}-1$
Integral non-linearity	± 0.5 %
Differential non-linearity	± 2 %
Operating condition	0-45 ℃, 95 %RH

A specturm measurement is repeated at short intervals (Δt) in the MCA and, after each measurement, spectrum data are transmitted to the operation console via an optical fiber cable. The personal computer in the operation console processes Δt spectrum counts for each channel for longer time interval.

We applied two computing methods. Both methods have been utilized in digital count rate meters. One method is the "running average (RA) method". Each Δt spectrum datum transmitted from the preamplifier is stored in a rotating 10 stage memory stack. The most recent datum replaces the oldest cyclically. The total of all the counts for the same channel in the memory stack is updated each time a datum is replaced. Thus the spectrum is refreshed every Δt measurement. The counting time of the spectrum is $10\times\Delta t$. Because the spectrum of the "RA" method is simply the mean value in $10\times\Delta t$ interval, its response is delayed with fast radiation changes.

The other method is the "exponential smoothing (ES) method", which responds exponentially to radiation changes. It simulates the response of analogue RC rate meters by subtracting a fraction corresponding to the accumulated counts.

$$N_i = R_i^{-1} [N_{in} + (R_i - 1) N_{i(n-1)}], \quad (1)$$

$$\tau_i = (R_i - 0.5) \Delta t, \quad (2)$$

$$P = [2 \tau_i N_{i(n-1)}]^{-1/2} \times 100, \quad (3)$$

where

N_i = Counts of i-channel after refreshment;
R_i = Exponential smoothing coefficient;
N_{in} = Counts of i-channel transmitted;
$N_{i(n-1)}$ = Counts of i-channel before refreshment;
τ_i = Time constant of i-channel; and
P = Relative standard deviation which is common to whole channel.

The exponential smoothing coefficient R_i is derived from equations, (1),(2) and (3).

$$R_i = [2 N_{i(n-1)} \Delta t]^{-1} (100/P)^2 + 0.5 . \quad (4)$$

This method has been used in digital count rate meters. Although digital count rate meters have only one channel, there are i number of channels with spectrum monitoring. By setting the values of Δt and P beforehand, R_i is calculated with $N_{i(n-1)}$. Then, the count numbers of each channel are exponentially smoothed. The time constant for each channel changes according to the count for each channel. As the results, relative standard deviations of whole channel have the same value in the range of τ_i from 1 to 10 min. The range is limited from the the point of actual application to radiation monitors.

THE RESULTS OF MEASUREMENT

In the background radiation field, we put two radiation sources, ^{137}Cs and ^{60}Co, whose radiation intensities are less than 3.7 MBq, near to a 2"ϕ NaI(Tl) scintillator. After the spectrum reached equilibrium, we picked up both sources.

Figure 1 shows changes in the spectrum measured with the "RA" method with Δt=1 min. Figure 2 shows changes in the gross counts of the ^{137}Cs peak area.

The counts increase, then decrease according to the same ratio step.

Figure 3 shows changes in the spectrum measured with "ES" method when the relative standard deviation is set to 5 %. Figure 4 shows changes in the gross counts of the ^{137}Cs peak area when the standard deviation is set to 5%, 10% and 20%. It is recognized that each time constant varies according to standard deviations.

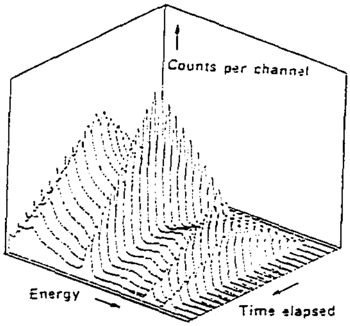

Figure 1. Changes in spectrum with running averaging.

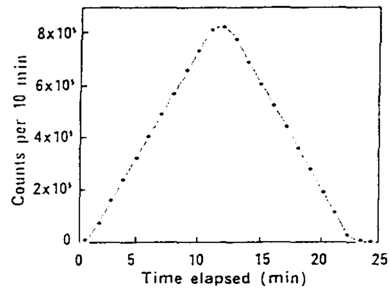

Figure 2. Changes in gross counts of ^{137}Cs with running averaging.

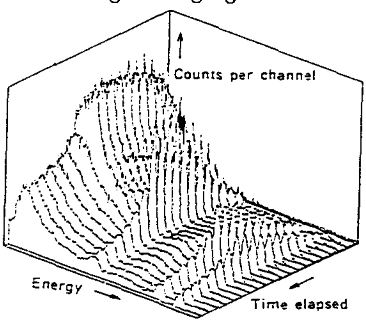

Figure 3. Changes in spectrum with exponential smoothing.

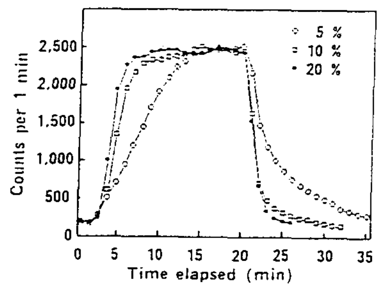

Figure 4. Changes in gross counts of ^{137}Cs with exponential smoothing.

APPLICATION TO RADIATION MONITORS

Real time spectrum measurement is applicable to area monitors, liquid effluent monitors and gaseous effluent monitors. NaI(Tl) scintillators are suitable for such radiation monitors. In liquid and gaseous effluent monitors, specific energy regions are set to determine the radioactive concentration of each radionuclide, which will be released from a radioisotope facility. The dose equivalent rate of an area monitor is calculated from the measured spectrum and energy weighting factors. Such an area monitor is more sensitive than one with an ionization chamber.

In routine radiation monitoring, only calculated radioactive concentrations and dose equivalent rates are stored in the personal computer. When those values exceed the preset levels, the spectrum at that time is also stored automatically.

SUMMARY

We have developed an MCA and two real time spectrum monitoring methods for use in radiation monitors. The "running average method" cannot keep up with radiation changes, but shows a precise spectrum. The "exponential smoothing method" has a fast response because of an automatically variable time constant.
The latter method is preferable for area monitors and gaseous effluent monitors.