

RESEARCH ON THE METROLOGICAL CHARACTERISTICS AND STABILITY OF GAMMA-DOSIMETERS USING SWFM

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In this work we discuss the problem of precise energy calibration of gamma-dosimeters, using the Spectral Weight Function Method (SWTM). We provide some comparative measurement results for the dose rate, gathered using the aforementioned method and through spectrometric measurements.

Keywords: γ -dosimeter, SWFM, energy calibration, comparative measurements

1. INTRODUCTION

The dosimetric measurements are important branch of the ionized emission/radiation metrology, closely related to the safety of people working in radioactive hazard conditions, as well as to the quality of the environment. Due to this, special attention is paid to the accuracy, stability and dynamics of the dosimetric devices.

Special dosimeter, using the SWTM, has been designed for the needs of defining the dose rate in real-time. It has been developed according to Contract No. 970НН-3/2007, part of the scientific research programme of The Technical University in Sofia (TU-Sofia).

Our present work aims at determining the impact of the gamma-quanta energy spread on the accuracy of the dose rate measurement when following the SWTM, and also compare the method's stability and precision, to those of the spectrometric measurement methods.

The carried out research is based on the comparative analysis of the results, derived from the experimental data, gathered through different methods for defining the dose rate. We apply statistical methods for evaluation of the measurement uncertainty. All experiments are conveyed in laboratory conditions with the equipment of the Nuclear Electronics Laboratory.

2. DOSIMETRIC EQUIPMENT TESTING STANDARDS - IEC1017-1 AND IEC1017-2

This standards are applicable to portable, mobile and stationary environment monitoring devices for measurement of dose rates in the range of 30 nGyh^{-1} - 10 mGyh^{-1} ($3 \text{ } \mu\text{radh}^{-1}$ - 1 mradh^{-1}), emitted by X-ray and γ -ray sources with energies in the range of 50 keV – $1,5 \text{ MeV}$.

These standards define the terminology, the units and the correlations used for evaluation of the metrological characteristics of dosimetric equipment. The test procedures are described, defining:

- The common regulations for test execution;
- The characteristics of the used radiation sources;
- Electrical characteristics that have to be observed;
- Mechanical characteristics subjected to examination;
- Requirements to the environment regarding test execution.

The document templates for the results of the carried out research are also standardized.

All these regulations have been observed during the conducted comparative measurements with different equipment and methods used to determine the dose rates of γ -radiation sources.

3. ENERGY CALIBRATION IN SWFM MODE

The energy calibration for work with SWTM comprises two procedures. The first one of them refers to the tuning of the analogue sub-circuit (the gain of the impulse amplifier). The second one is for estimation of the actual energy levels when a change of the discrimination threshold occurs within the accepted range.

3.1. Analogue sub-circuit tuning

The aim of the circuit tuning is to reach certain correlation between the amplitude of the integral discriminator input impulses and the energy of the registered γ -quanta. This can be achieved through change in the regime of the PMT (Photo-Multiplier Tube), or by impulse amplifier gain regulation. The tuning is conveyed relative to a well distinguishable γ -line of a known radioactive isotope. Most suitable for this task is the ^{137}Cs , which has one single characteristic γ -line, which γ -quanta have energy of 662 keV. The gain is selected to achieve a ratio of impulse amplitude to γ -quanta energy equal to 2 mV/keV. Within the range limits, imposed by the discrimination threshold change possibilities, the maximum energy limit is 2.5 MeV, and the scanning resolution of the range is 2.5 keV.

The circuit tuning cannot be carried out with sufficient accuracy because the amplitude of the impulses, output by the amplifier, is controlled by a cathode-ray oscilloscope (CRO). Simultaneously with the impulses generated by the interaction of the calibration source γ -quanta, we get incoming impulses resulting of the natural γ -background. Some uncertainty is added also due to the finite energy resolution of the scintillation detector.

3.2. Range energy calibration

The energy calibration is an external procedure for the system, controlled by a PC. This implies the introduction of several supplementary commands into the base software:

1. Command enabling diagnostic-radiometric mode – the system functions as a counter unit. At the end of each measurement is automatically started another one while the current data is transmitted over the serial communication interface.
2. Command for change of the discrimination threshold – the threshold is externally controlled with the desired speed-rate and following a chosen algorithm.

3. Command to input the calibration results to the system EEPROM.

The existence of the first two commands allows for downloading of the integral spectrum of the emission during the spectrometric sub-circuit's actual work regime. The energy calibration is realized using radioactive isotopes with easily distinguishable γ -lines, located at both ends of the desired energy range. A convenient combination is the use of ^{241}Am (59,6 keV) and ^{60}Co (1173 and 1332 keV).

No specialized Pc software needs to be coded for the realization of the measurements. One of the embedded terminal programs, such as *Hyper_Terminal*, can be used. At chosen measurement time interval is sent a command for change of the discrimination threshold (the sequence is beforehand outlined in a text file) and in the meantime the incoming data from the intensimetric system is written. If the discrimination threshold is raised with a regular step, between the consecutive measurements, the total accumulated data for the number of registered impulses represents the integral spectrum of the emission.

From the integral spectrum we derive the differential one through channel-by-channel subtraction of the results. The procedure is equivalent to the digital differentiation and is characterised by high noise resistance. In this case this shortcoming is irrelevant as our interest is focused on the location of the energy peaks of the used isotopes. By using isotopes with similar activity and with careful choice of the experiment geometry, can be seen distinctive peaks. Their position can be precisely defined, as well as their channel energy correspondence.

4. COMPARATIVE MEASUREMENTS

During those measurements have also been applied some alternative readings, which are not previewed in the standard regulations, in order to get extensive results, characterizing the equipment.

4.1. Comparative measurements with SWFM and energy spectrum readings in single-channel spectral analyzer mode

Those measurements have been carried out with the evaluated dose rate measurement device. The structure of the test setting is shown on Fig. 1. The data gathered from the measurements with ^{241}Am , ^{137}Cs и ^{60}Co isotopes, in single-channel spectrometer mode, have been used for the refinement of the energy calibration in SWFM mode.

The dose rate has been defined through the data readings from the measurements, employing the built-in calibration mode and the floating threshold mode (implementing the SWFM).

A series of measurements have been carried out on isotopes with characteristic gamma-lines, located within the range, recommended by the standard. Something specific about the measurements is the fact that they are carried out consecutively (in different moments in time). Besides that, the time needed for the measurement with both methods is substantially different, which reflects on the statistical truthfulness of the accumulated data.

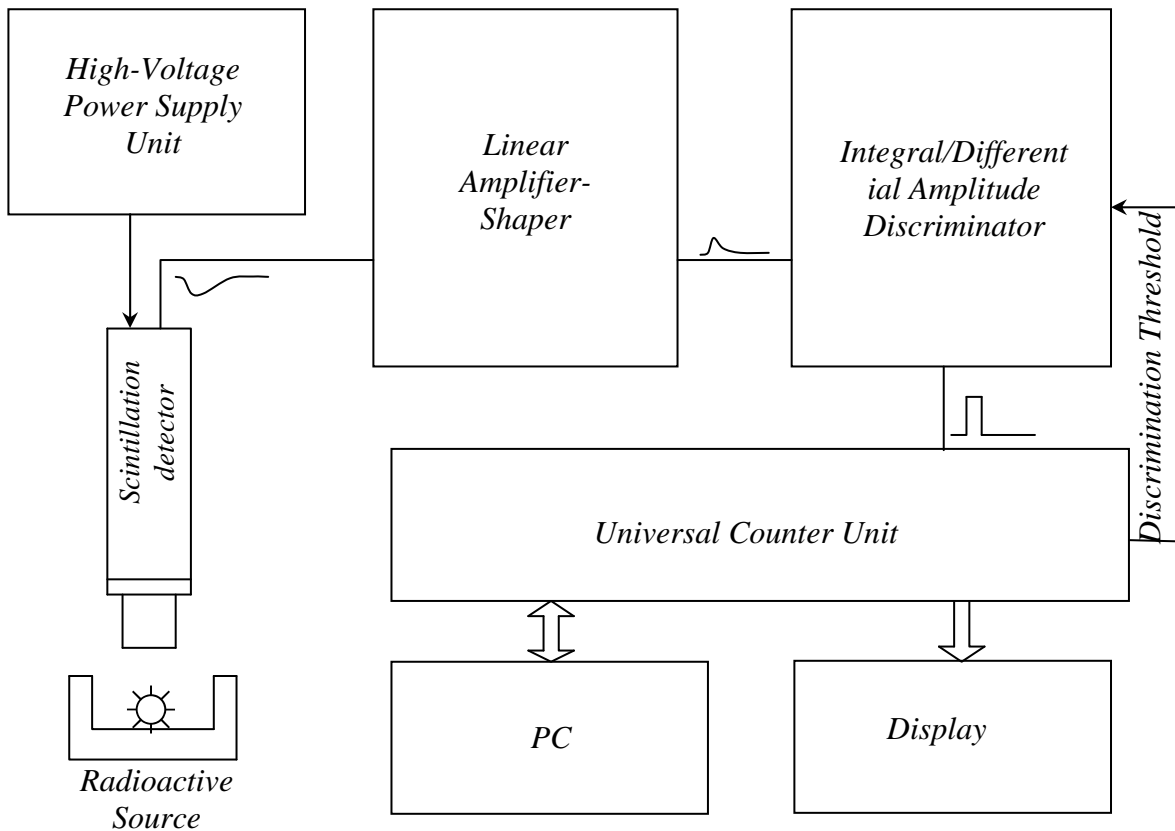
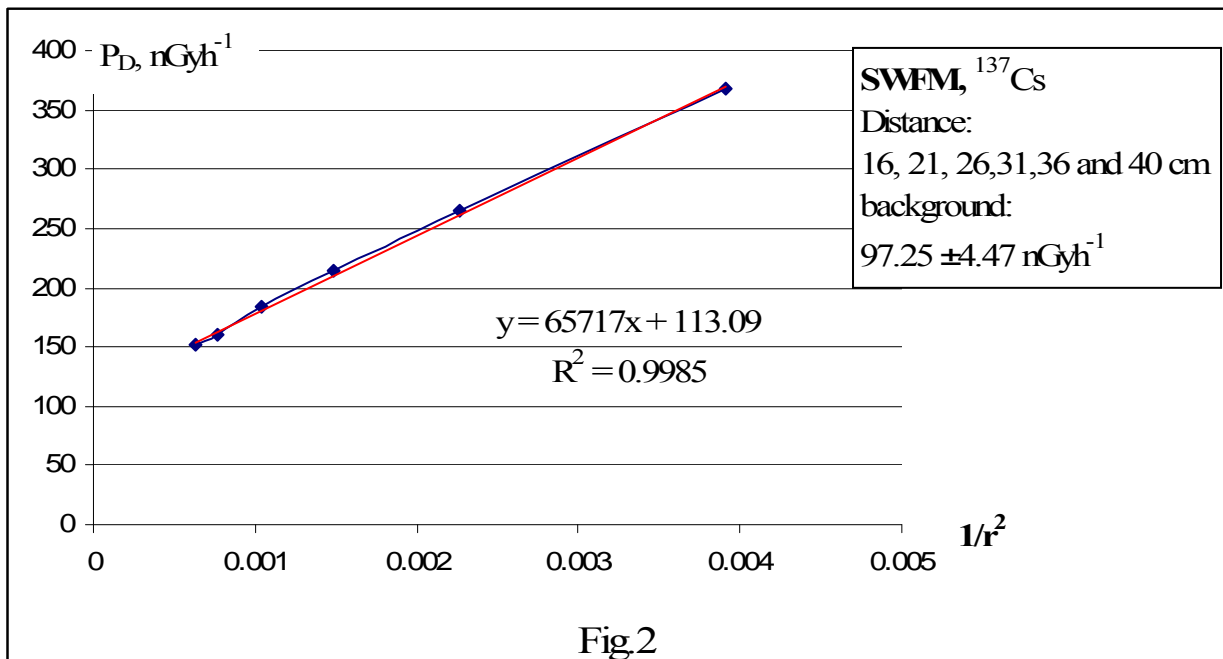


Fig. 1

The correlation of the dose rate, emitted by the radioactive source, as function of reciprocal value of the square of the distance from the detector system, is shown on Fig. 2. It is visible that the interpolation polynomial at $r^{-2}=0$ tends to a certain background value accuracy, limited by the mean deviation.



The value of the dose rate of the natural gamma-background, derived from the measurements in single-channel spectral analyzer is 108.26 nGyh^{-1} . The mean value of the dose rate, taken under the same conditions using the SWFM is 99.59 nGyh^{-1} with statistical mean deviation of 6.09 nGyh^{-1} . The experimental results from both methods show very good convergence, but one should keep in mind, that in this case the analogue measurement sub-circuit is the same.

4.2. Comparative measurements with SWFM and energy spectrum readings with multichannel spectral analyzer

The comparative measurements of the evaluated SWFM dosimeter have been conducted against linear energy spectra, taken with a multichannel spectral analyzer MCA8000A, manufactured by the American company Amptek. Fig. 3 shows the test setting. It gives the unique ability to measure the signal of a single detector (in this

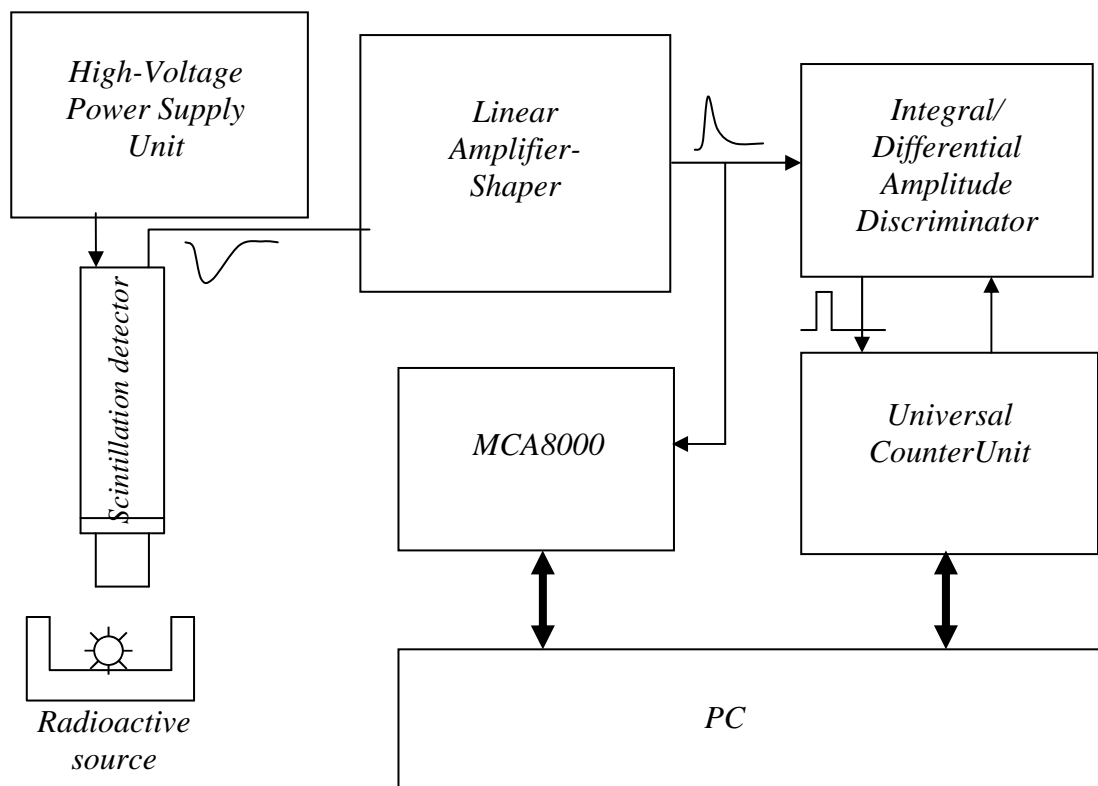
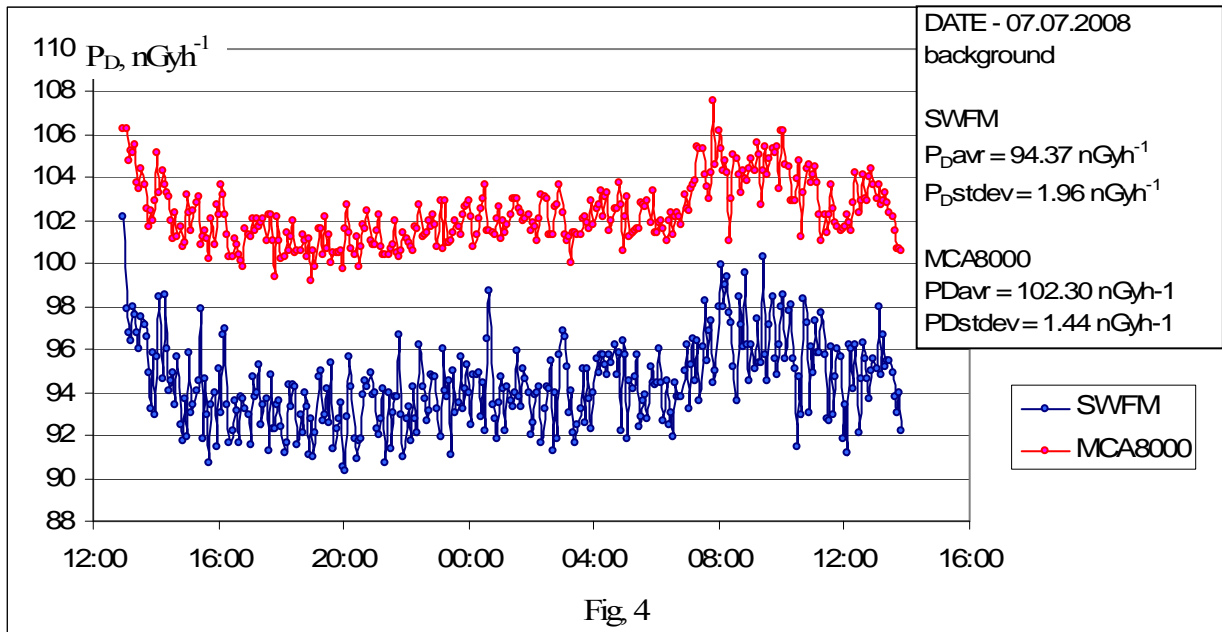


Fig. 3

case a scintillation detector with NaI (Tl) crystal, 4x4,5 cm in size), using two different devices and analyzed using two different methods. Additionally the data reading modes have been carefully selected in order to achieve equal measurement times.

Energy calibration of both dosimeters has been carried out using ^{241}Am , ^{137}Cs and ^{60}Co radiation sources. Next a continuous measurement of the natural radioactive background was conducted. The results are presented on Fig. 4. It can be seen that the course of changes, registered by both apparatuses is identical. The differences are in the range of the statistical truthfulness.



5. CONCLUSIONS

The application of the proposed energy calibration procedure, comprising initial tuning of the analogue sub-circuit and subsequent accurate definition of the actual energy calibration through energy spectrum accumulation, leads to improvement of the measurement accuracy with gamma-dosimeters, functioning with the SWFM.

6. ACKNOWLEDGEMENTS

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