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Dynamic Fast Tracing and Smoothing Technique for Geiger-Muller Dosimeter

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***Abstract*—**Environmental radiation dosimeter is a kind of detector that measures the dose of the radiation area. Dosimeter registers the radiation and converts it to the dose according to the calibration parameters. The limit of a dose is different at each radiation area and this limit should be notified and reported to the user and health physics department. The stochastic nature of radiation is the reason for the fluctuation of any gamma detector dosimetry. In this research we investigated Geiger-Muller type of dosimeter and tried to improve the dose measurement. Geiger-Muller dosimeter is a counter that converts registered radiation to the dose. Therefore, for better data analysis, it is necessary to apply an algorithm to smooth statistical variations of registered radiation. We proposed a method to smooth these fluctuations much more and also proposed a dynamic way to trace rapid changes of radiations. Results show that our method is fast and reliable method in comparison the traditional method.

***Keywords*—**Geiger-Muller, radiation detection, smoothing algorithms, dosimeter, dose calculation.

I. Introduction

VARIOUS dosimeters are used to detect ionizing radiation in radiation environments. Radiation dosimeter is a kind of sensor that is used for many purposes. These useful devices are produced in different types, shapes with various sensitive materials to detect ionizing radiations like neutron, gamma, alpha, beta, and muon. Environmental dosimeters are a type of radiation detector and have different types, the two most common types of environmental dosimeters are gas and scintillation types [1]-[4]. Because of natural and artificial sources of radiation, using dosimeter is an obligation for radiation workers and is mandatory in any nuclear areas. Most dosimeters have simple dose measurement algorithms, but some also have more sophisticated algorithms, including artificial intelligence and neural network [5], [6]. One of the most common and cheapest dosimeters is Geiger-Muller (GM) dosimeter, which is a gas-sealed type detector, with or without an entrance window. Because of some specific parameters like dimension and high voltage of the GM, this gaseous dosimeter works by the principle that each incident radiation could produce an avalanche of ion-pairs, then the dosimeter output signal is strong enough to detect that incident photon without a significant amplification when compared to the proportional counters [7]-[9].

Calibration of GM environmental dosimeter converts registered count per second (CPS) to the environmental dose. The stochastic nature of radiation is the reason for the CPS fluctuation of any gamma detection device. So many techniques are applied to smooth this fluctuation, and averaging is one of the simplest ones [10], [11]. The averaging method is necessary because some alarm levels and dose limitations should be determined according to each radiation area. The worst defect of averaging algorithms is that it is not sensitive to a rapid altering of doses. It means, if a radiation source crosses fast around the detector, averaging algorithm prevents fast radiation detection. For solving this problem, we proposed a method of fast-tracing and smoothing solutions by applying statistical science.

II. Materials and Method

Due to the random and statistical nature of the number of pulses counted (means CPS), different methods are usually used to average and smooth these changes. One of these methods is to create a buffer of the latest measured CPS values. For example, in a 10-item buffer by measuring the new CPS value, this value is stored in the last buffer cell and replaced on the first buffer cell value (the oldest value). All values also find a shift cell to be refreshed during each sampling cycle.

The smaller the buffer size, the higher the average dependence on the last instantaneous value, and the larger the buffer size, the lower the average dependence on the last instantaneous value (fluctuations also decrease).

Disadvantages of this method are occupying space from the microcontroller memory (depends on the size of a buffer) and performing buffer shifts per second (in addition to averaging all buffer cells), so this method is slow.

Another way is to use the EWMA (Exponentially Weighted Moving Average) formula. In this method, there is no need to use buffers and apply more calculations. The average value is calculated every 1 second using the same formula. Larger R_f values mean less dependence on the last instantaneous value (equivalent to a buffer with more cells), and smaller R_f values mean more dependence on the last instantaneous value and therefore more statistical fluctuation (equivalent to a small size buffer).

In routine GM dosimeters, pulse per second registers the CPS value, but in our research, 200 ms sampling was replaced instead of 1-second sampling. For averaging, EWMA operates as in:

$$Avg_{new} = \alpha Avg_{old} + (1 - R_f)c \qquad 0 < \alpha < 1 \qquad (1)$$

where Avg_{new} is the average of current CPS, R_f is the

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smoothing factor, Avg_{old} is the average of passed CPS, and c is the raw instantaneous value of CPS.

The parameter that must be set correctly in this relation is the R_f value. For better understanding the effect of R_f on the detector output response, (1) was used for the various values of R_f and results were plotted in Fig. 1. In this figure, the horizontal axis is the sampling number, and the vertical axis is the read amount. As can be seen, in the 500th reading, the read amount has increased from 5 CPS to 10 CPS. This figure shows the relationship between smoothing factor and time needed for final detection results.

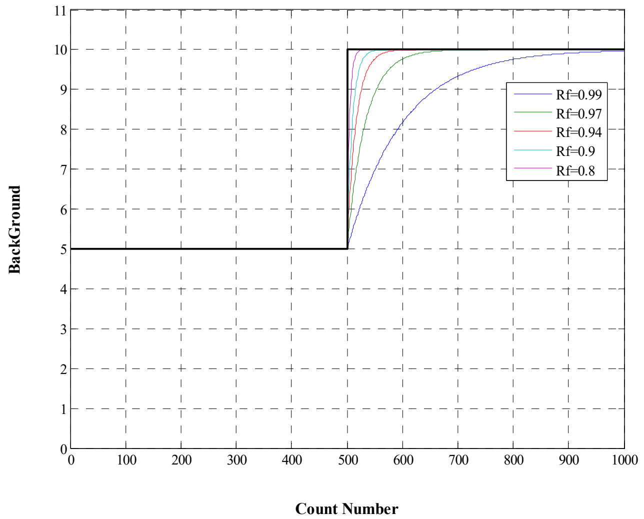


Fig. 1 Response variation related to the R_f parameter

From Fig. 1, for values close to 1 of R_f, more time must pass before U_i approaches its final value. In other words, this relationship reduces the fluctuations due to the statistical nature of the count. Equation (1) is a type of 1st-degree filter whose response to the step input is exponential. Therefore, the value of R_f should be adjusted according to the number of changes in the CPS and the required statistical dispersion of U_i. The closer value of the R_f parameter to one, the slower U_i's response to the CPS changes, and the smaller its statistical disperse. For each area and each detector system, measuring the background (BG) amount and subtracting it from the main amount is done as a pre-measurement process. In this research, selected GM is suitable for low dose areas and GM type is one model from LND company.

Fig. 2 shows the effect of pre-measurement from the BG of the environment. As shown in Fig. 1, some time must pass after the measurement starts to bring the measured counts closer to its final value due to the R_f parameter. In Fig. 2, pre-measurement is performed first by using (1), so the initial delay of BG measurement is no longer observed. This measurement is performed in the presence of the background, so in measurements where the amount of radiation is low, due to the statistical nature of the counts, dose detection may be erroneous.

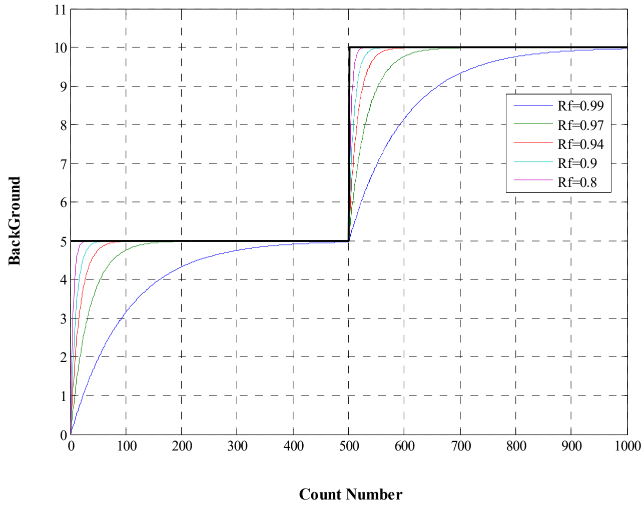
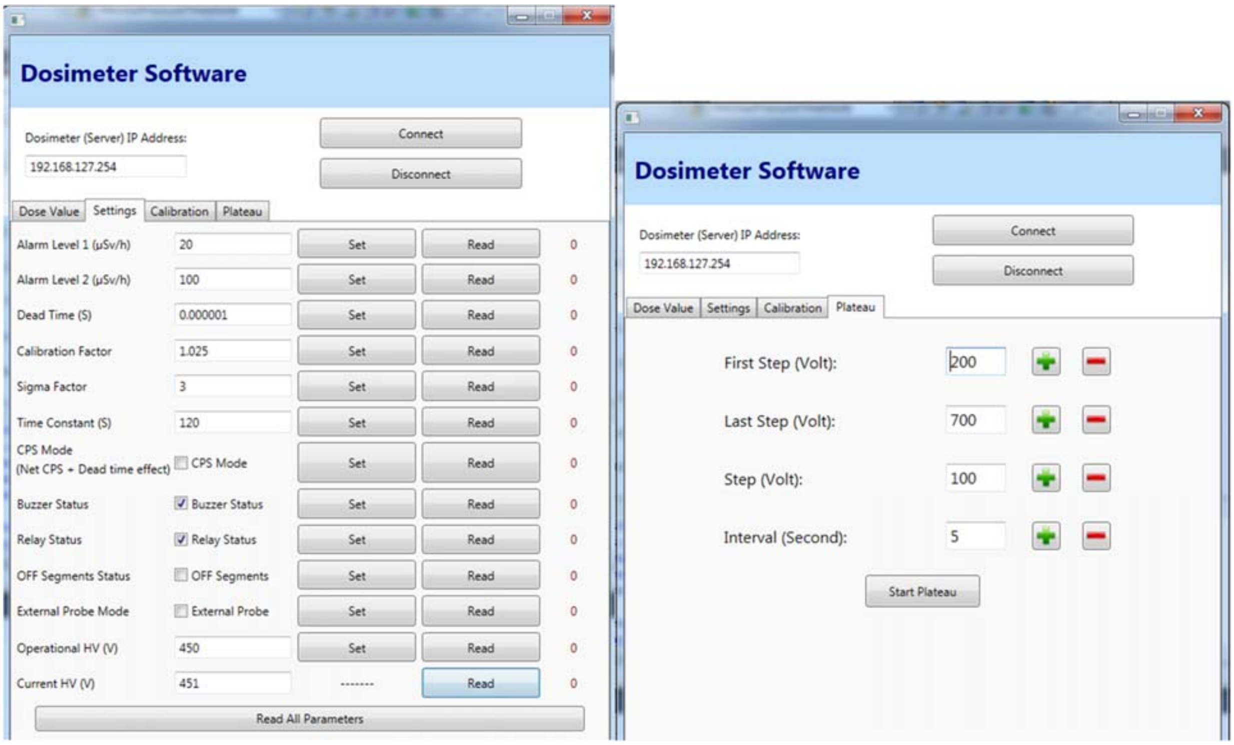


Fig. 2 The effect of pre-measurement

Despite a common method for averaging for calculation of smoothed CPS, the sample rate is about 200 ms and only considers the last-5 values. Then the algorithms find a median of the last-5 values and multiple it in 5. This value is now inserted in the EWMA formula for averaging, for c parameter.

Fig. 3 Software of GM dosimeter

Fig. 3 shows the designed dosimeter program. The dosimeter information is sent and displayed online via a LAN connection to the computer. The TCP-Modbus protocol is used to communicate between the dosimeter and the computer. Also, according to Fig. 4, through the same program, dosimeter parameters such as Alarm Levels, Dead Time, Calibration Factor, HV value of the working point, and etc. can be set. Furthermore, the plateau curve of the dosimeter can be obtained and the exact working point of the dosimeter can be determined from it.



(a) (b)

Fig. 4 Different parameters for adjustment of GM dosimeter

III. Results and Discussion

Due to the use of the median instead of direct averaging, outlier values are decreased in the dose calculations and therefore, the statistical fluctuations in the displayed dose amount are much less, consequently. So, CPS averaging will be much smoother than the common method at the end.

We continued our job to improve averaging much more by tracing technique. The R_f parameter in (1) is the value of smoothing in the EWMA formula. It means that, if this value is 1, the averaging does not relate to the instantaneous value, then the dosimeter will be smoothed and slow in measurement during rapid changes of radiation. Therefore, the dosimeter is stable but could not detect rapid changes of ionizing radiation. We implemented another method for our job, by tracing rapid changes. It means that our algorithms observe the last value of CPS continuously and calculate the average of CPS, then compare it to the instantaneous value at each 200 ms interval. If the instantaneous value is altered in ascending or descending manner 10 times consequently (means in 2 s), then by altering the factor to 0 value, the averaging will be related to the instantaneous value for fast tracing of dose changes. Then, the above procedure is repeated for smoothing dose calculation. In this way, we have used the advantage of averaging without entering the outlier values into the averaging formula, and therefore the displayed doses in the dosimeter have less fluctuation than before. In addition to the above improvement, by considering current dosimeters that use statistical formulas, we have made it possible to trace rapid changes for environmental dose measurement without using traditional statistical formulas.

TABLE I
Errors of Dose Measurement in Comparison to the Calibration Unit Results

Measured CPS	Calculated Dose	Calibration Dose	Error
140.88	11	11.1	1%
243.9	20.3	19.8	3%
488.96	44.7	44.36	1%
750.16	70.3	69.2	2%
1166.3	133.8	129.3	3%
1706.2	237.4	231.1	3%
2748	528.2	516.1	2%
3672	931.2	918.5	1%
4302	1317	1316	0%
5131	2010	2036	1%

In our research, for better curve fitting, we divided outputs data into two sections with two curves of grade 2 and grade 4 (areas below 750 CPS and above it). Finally, according to the values provided by the calibration unit, we obtained the amount of environmental dose (with a maximum error of 3%) according to Table I. Also, good agreement between calibration doses as a reference and our measurement doses is depicted in Fig. 4.

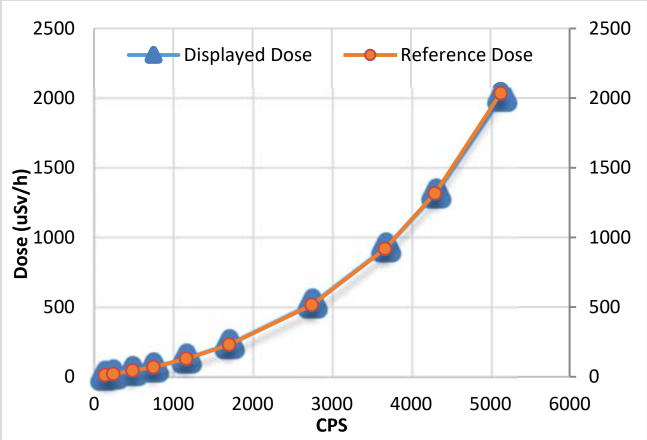


Fig. 4 Acceptable results between dynamic method and calibration results

IV. Conclusion

The dynamic method is compatible with calibration data. Also, this method succeeded to solve the problem of usual dosimeters, especially GM dosimeters. Even this method helps to measure environmental dose much smoother than the common averaging algorithms.

Acknowledgement

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