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# A COMPARATIVE STUDY FOR THE CORRECTION OF RANDOM GAMMA RAY SUMMING EFFECT IN HPGe - DETECTOR BASED GAMMA RAY SPECTROMETRY

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## ABSTRACT

Random coincidence summing of gamma rays is a potential source of errors in gamma ray spectrometry. The effect has a little significance at low counting rates but becomes increasingly important at high counting rates. Careful corrections are required to avoid the introduction of errors in quantitative based measurements. Several correction methods have been proposed. The most common is the pulser method that requires a precision Pulse Generator in the electronic circuitry to provide reference peak. In this work, a comparative study has been carried out both by using pulser method and utilizing radioactive source based method. This study makes the use of $^{137}$Cs radionuclide as a fixed source and the $^{241}$Am as a varied source. The dead time of the system has been varied and the acquisition of the spectra at each position yielded the resulted peak areas with pulsed pile up losses. The linear regression of the data has been carried out. The study has resulted in establishing a consistent factor that can be used as the characteristic of the detector and thereby removes the need of the calibrated or precise Pulse Generator.

## 1. INTRODUCTION

The accuracy in the quantitative determinations of elemental concentrations making use of gamma emitting character of sample constituents or the high precision measurements of radionuclide activity, absolute gamma emission probabilities using gamma ray spectroscopy necessarily requires correction for counting losses due to gamma ray summing events. The corrections for losses due to summing of cascade gamma rays depend on the decay schemes and become important in close source-detector counting geometries. The correction formulae [1] and computer codes such as KORSUM etc [2-4] present the solution to this problem. Dias

et al (2002)[5] also described Monte Carlo based correction procedures. This effect, however, can be cancelled out if measurements are made relative to the similar reference nuclide.
In contrast, the losses due to random gamma summing i.e. pulse pile-up is however count rate dependent effect. With the exception of a weak source, it is important in nearly all situations and a potential source of errors if not accounted with proper methodology. Combining with dead time losses the phenomenon is referred as dead time and pulse pileup effect and usually dealt simultaneously. This work studies the correction methodology for pulse pile-up and dead time effect. Several methodologies [6-14] have been suggested for correcting dead time and pulse pileup losses. Among these, the pulser method [7, 8] has been widely employed. The popularity of the pulser method was evident in an IAEA inter comparison [15]. The necessary requirement of the method is incorporating a highly stable and well calibrated pulser into pulse processing system. Debertin et al. [12] however, pointed out problem related with the pulser method. Some publications in recent years have also carried out the task of testing the count loss correction procedures [16-17]

In this work, comparative study of the Wyttenbach Procedure [9] and the pulser method have been carried out by employing $^{137}$Cs radionuclide. An IAEA $^{137}$Cs source was placed in a fixed counting geometry that ensured the equivalence of the counting rates under both live and real time condition. The counting losses were inducted and varied by introducing $^{241}$Am nuclide source having its gamma ray energy in the lower energy region. A linear least square fit was made to the measured peak ratio data. This has resulted in the determination of experimental Wyttenbach factor ($2\tau/\theta$) [9, 18]. The present study has established that the same Wyttenbach factor once determined can be used under the same experimental measuring conditions for dead time and pulse pileup loss correction without any need to induce the pulser in the pulse processing chain.

## 2. EXPERIMENTAL METHOD

In reactor based neutron activation analysis and similar studies utilizing high resolution gamma ray spectrometers incorporated with HPGe- detectors, many of the elements of interest are usually covered with in 50-1500 keV the energy range. The main radioactive calibration standards also provide the detector efficiency information in this range. Keeping in view of this intermediate energy range aspect $^{137}$Cs radionuclide was selected that provides the mono-energetic gamma ray at 661.6 keV, which can be approximated as the mid-region of the range. The gamma ray spectroscopy was carried out using a high resolution gamma ray detection system incorporating HPGe-detector having energy resolution of 1.9 keV at 1332 keV peak of $^{60}$Co. A pulser peak from a well calibrated pulser with a known frequency of 60 HZ was injected at 1490 keV energy position of the multi channel analyzer. The $^{137}$Cs source was fixed in a position that yielded a negligible dead time (i.e; Real time ~ live time). The source along with the pulser was counted at this position for a time that gave less than 1% uncertainty in the peak area of 661 keV peak. Next, a $^{241}$Am source was counted sequentially with the above mentioned arrangement with changing positions in order to vary the dead time of the system and to increase the pulse pile-up effect. The spectral distortion and changes in the region of the $^{137}$Cs peak and pulser peak are shown in Fig. 1a) and 1b).

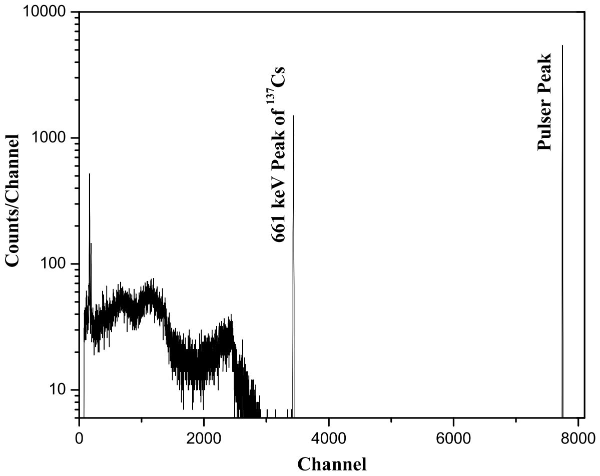

Figure 1a. Gamma ray spectrum of Cs-137+Pulser (negligible dead time)

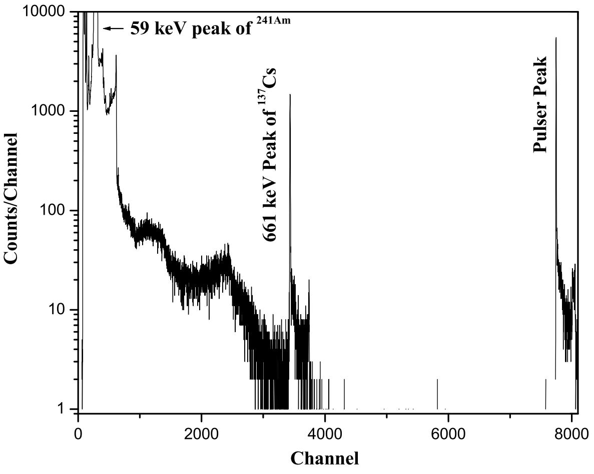

Figure 1b. Gamma ray spectrum of $^{137}$Cs + Pulser +$^{241}$Am (23% dead time)

## 3. RESULTS AND DISCUSSION

The gamma ray spectral data were acquired in six different dead time counting conditions. The spectral comparison of figure 1a and 1b is an indicative of the pile up effect but since the live counting times are same the difference in pulse amplitudes is visually indistinguishable. The variation of the real time count rates of the $^{137}$Cs peak and the pulser peak against the increasing dead times (in percent), where the dead time is defined as the difference between real and live time divided by the real time, is presented in Table-1. It can be seen that the count rates suffered a proportional loss of about 22%. The pulser peak areas (not given in the table) have also suffered with about similar fractions. The ratios of the real counting to live counting times and the count rate (Peak Area/Real time) variation ratios i.e., the ratios of the varied count rates to the count rate with negligible dead time, were computed. Linear regression to these ratio data was performed by fitting a straight line as shown in fig.2. The parameters determined as a result of fitting are given in table 2. A good merit of fit indicated by the regression co-efficient value of 0.991 is obtained. The absolute value of the slope is used to calculate the necessary correction factors for the dead time and pileup suffered count rates according to the Wyttenbach formula [9, 18]

$$CorrFact = 1 - \mathrm{W_f}\left(\frac{T_R}{T_L} - 1\right)$$

Where

$T_R$ : Real counting time

$T_L$ : Live counting time

$W_f = \frac{2\tau}{\theta}$ (Wyttenbach factor, determined from the slope of fig.2)

$\tau$ Represents the resolving time and $\theta$ is the sum of the fixed and mean channel dependent memory cycle conversion time.

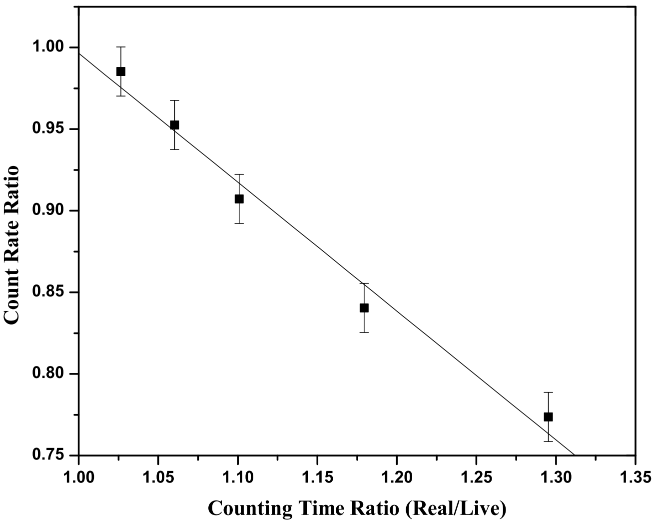

**Figure 2. Linear regression of 661 keV peak data of $^{137}$Cs**

Table 1: Corrected and uncorrected count rates against the detector dead time

| S.No. | HPGe-Detector Dead Time (%) | Count Rates | Wyttenbach method | | Pulser Method | |
|---|---|---|---|---|---|---|
| | | | Correction factors | Corrected Counts | Correction factors | Corrected Counts |
| 1 | 3 | 25.34 | 0.9791 | 25.88 | 0.9730 | 26.04 |
| 2 | 6 | 24.50 | 0.9524 | 25.72 | 0.9345 | 26.22 |
| 3 | 9 | 23.33 | 0.9204 | 25.35 | 0.9027 | 25.85 |
| 4 | 15 | 21.62 | 0.8583 | 25.18 | 0.8353 | 25.88 |
| 5 | 23 | 19.90 | 0.7669 | 25.94 | 0.7563 | 26.31 |
| Average Corrected Count Rates | | | | 25.62 ± 0.33 | | 26.06 ± 0.33 |
| Experimental Count rate at negligible dead time | | | | 25.72 ± 0.30 | | |
| Percentage difference | | | | 0.4% | | 1.32% |

Table 2: Fitted parameters and merit of fit to the experimental data

| Parameter . | Value |
|---|---|
| Intercept | 1.786 ±0.080 |
| Slope | -0.789 ±0.070 |
| Regression Coefficient | 0.991 |

The correction factors for the counting losses are determined and presented along with the corrected count rates in Table 1. The correction factors and the corrected counts obtained by using the pulser method are also provided in the same table. These results indicate that the use of Wyttenbach factor has corrected the count rates with a marginal difference of 0.4%, where as the correction margin (1.3%) obtained in the case of pulser is also good and fall with in the uncertainty limit, though somewhat larger in comparison with the formerly described one. The main observation in using the Wyttenbach factor is that it has yielded results with better precision than the pulser.

In another independent study carried out in different timings, but under same experimental conditions, we forced the cobalt peak at 1332 keV to suffer with a dead time and pulse pileup losses to about 24% and used the factor obtained from fig 2 (this work), the correction obtained was to 1.04% whereas the with pulser method the uncertainty was higher. The 1.04% as compared to the above value of 0.4% can be attributed to the relatively poor statistics obtained in the peak of $^{60}$Co. This was a weak $^{60}$Co source that was prepared by irradiating a cobalt wire under the cadmium shield at the IPEN Reactor to approximate the count rates with zero dead time conditions. It leads to conclude that a better dead time and pileup corrections can be achieved using $W_f$ -factor once it is determined under the similar experimental conditions and no longer requires a pulser in pulse processing chain which generates the pulses with non Poisson behavior contrary to the decay of radio nuclides that follow Poisson statistics.

## 4. CONCLUSION

The present study has determined the Wyttenbach factor for gamma random summing and dead time loss corrections. The study has demonstrated and concluded that the same factor can effectively be used for any loss affected gamma spectra acquired under the same experimental conditions. The corrections for a data with good statistics can be performed even with less than 1%. It has been concluded that with the use of this factor, we no longer need a highly calibrated pulser in the pulse processing chain.

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