Effect of noise on the performance of Digital Charge Comparison method for $n-\gamma$ discrimination

Harleen Singh[1] and Rohit Mehra[2]
1. Kanya Maha Vidyalaya, Jalandhar, Punjab, India
2. Dr. B.R. Ambedkar National Institute of Technology, Jalandhar, Punjab, India

Introduction

The neutron-gamma discrimination from a mixed radiation field is of prime importance in the field of nuclear safeguards, nuclear fission, radiation therapy etc. The liquid scintillators are widely used for $n-\gamma$ discrimination as the relative decay rate of neutron pulse is less as compared to $\gamma - ray$ in these detectors [1].The most popular and simple technique for pulse shape discrimination (PSD) is the charge comparison (CC) [2]. Due to the availability of fast ADCs and FPGAs, the traditional analogue techniques can be implemented in digital domain by sampling the PMT pulses. The performance of a PSD method depends on various parameters like sampling rate, noise distortion in the pulses the duration of processing gate etc. In this paper, the effect of noise levels on the performance of CC method is investigated at optimized processing gate.

The Experimental Data collection

The mixed n-γ pulses are obtained with the help of 5”×5”, BC501 liquid scintillator coupled to Hamamatsu R4144 PMT. The pulses have been sampled at 2.5 GSamples/s with the help of a digital oscilloscope. The raw pulses have been corrected with operations viz. pileup rejection, pulse phase alignment and clipped pulse rejection [3]. The energy range of the pulses is calculated by doing Compton edge calibration of the detection system with the help of standard γ-sources. The energy range used in this research is 500keVee to 5 MeVee.

Processing gate optimization for CC method

The CC method exploits the ratio of the short integral to the long integral as a discrimination parameter over an optimized processing gate [4]. The optimized values of integration limits were obtained by varying the integration widths. The starting point of the long integration is kept fixed at peak amplitude and end point t_e was varied for optimization. The end point of short integration was taken same as that of long integration and starting point of short integration t_s was obtained by calculating figure of merits (FoM) from probability distribution graphs at varying values of t_e and t_s with respect to peak amplitude. The figure of merit of a probability distribution graph is given as

$$FoM = \frac{|\mu_n - \mu_\gamma|}{2.35(\sigma_\gamma + \sigma_n)} \quad (1)$$

Here μ_n and μ_γ are the arithmetic means and σ_γ and σ_n are standard deviations of neutron and γ-ray Gaussian distributions respectively. The values of t_e and t_s corresponding to maximum FoM are 80 ns and 12 ns respectively.

Addition of Noise

The white noise of different signal to noise ratio (SNR) levels is added to each pulse of the dataset in energy range 500keVee to 5 MeVee. The table I shows the variation in SNR, the percentage level of noise with respect to amplitude of the pulse and the corresponding energy thresholds. The 20 dB SNR means the noise level is 10% of pulse amplitude. The minimum amplitude of the pulse in the recorded data corresponds to 500keVee energy hence 20dB SNR is equivalent to the 50keVee uncertainty in the amplitude of the pulse. Different data sets are generated with SNR levels shown in the table. The CC algorithm at optimized processing gate is applied to each dataset and FOM is calculated from the probability distribution graphs. The variation of FOM with SNR is shown in figure 1.

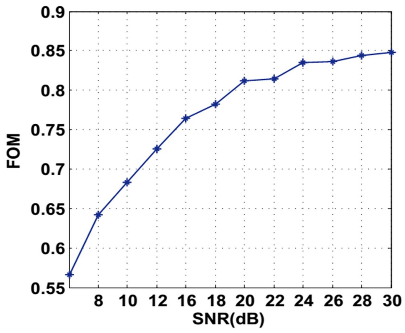

Fig.1 Figure of merit for 500keVee energy threshold AmBe data at different noise levels.

The SNR levels, the percentage noise with respect to pulse amplitude and the corresponding FOM values in are shown in table I. The noise level in the data set considerably affects the performance of CC method. The FOM values decrease with decrease in SNR values.

Table I: Noise percentage in amplitude of each pulse and corresponding SNR and FOM values.

SNR(dB)	Noise percentage in amplitude	FOM
8	39.8%	0.5663
10	31.6%	0.6419
12	25.1%	0.6837
14	19.9%	0.7262
16	15.8%	0.7646
18	12.5%	0.7818
20	10%	0.8119
22	7.9%	0.8142
24	6.3%	0.8352
26	5.0%	0.8367
28	3.9%	0.8437
30	3.1%	0.8476

Comparison with original data set

The figure 2 shows the probability distribution graph obtained for original data set. The FOM of 0.8550 is obtained for original data set by making use of (1). This is the maximum FOM that can be obtained for the raw dataset. A noise removal algorithm is used to further optimize the CC method. A 40 point moving average filter is used to further smoothing of the pulse shapes. The FOM obtained with filtered data is 0.8722.

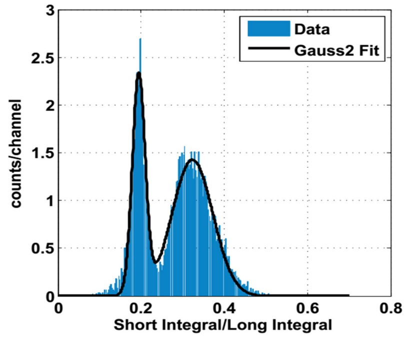

Fig.2 Probability distribution graph obtained with original dataset with CC method

Conclusion

The CC method exploits the time domain features to calculate the discrimination parameter for PSD. Hence the performance of digital charge comparison method is highly affected by the presence of noise in the raw pulses obtained from a liquid scintillator detector. The use of noise removal algorithm enhances the performance of CC method. However, the use of filtering algorithm needs more resources for the analysis.

Acknowledgement

The authors are thankful to Mr. A. Jhingan and Mr. Kundan Singh, Data Support Laboratory, IUAC New Delhi, India, for providing experimental facilities and help.

References

[1] S. Marrone et al.,*Nucl. Instruments Methods Phys. Res. Sect. A Accel. Spectrometers, Detect. Assoc. Equip.*, vol. 490, no. 1–2, pp. 299–307, Sep. 2002.

[2] M. L. Roush, M. A. Wilson, and W. F. Hornyak, *Nucl. Instrum. Meth.*, vol. 31, no. 1, pp. 112–124, 1964.

[3] H. Singh and R. Mehra, *IEEE Trans. Nucl. Sci.*, vol. 64, no. 7, pp. 1927–1933, 2017.

[4] M. Nakhostin and P. M. Walker, *Nucl. Instruments Methods Phys. Res. Sect. A Accel. Spectrometers, Detect. Assoc. Equip.*, vol. 621, no. 1–3, pp. 498–501, Sep. 2010.