Estimation of optimum time interval for neutron- γ discrimination by simplified digital charge collection method

Harleen Singh and Sarabjeet Singh

Dr. B.R. Ambedkar National Institute of Technology, Jalandhar, Punjab, India

Introduction

The discrimination of mixed radiation field is of prime importance due to its application in neutron detection which leads to radiation safety, nuclear material detection etc. The liquid scintillators are one of the most important radiation detectors because the relative decay rate of neutron pulse is slower as compared to gamma radiation in these detectors[1].There are techniques like zero crossing and charge comparison [2] which are very popular and implemented using analogue electronics. In the recent years due to availability of fast ADC and FPGA, digital methods for discrimination of mixed field radiations have been investigated [2]. Some of the digital time domain techniques developed are pulse gradient analysis (PGA) [3], simplified digital charge collection method (SDCC) [4], digital zero crossing method [5]. The performance of these methods depends on the appropriate selection of gate time for which the pulse is processed. In this paper, the SDCC method is investigated for a neutron-gamma mixed field. The main focus of the study is to get the knowledge of optimum gate time which is very important in neutron gamma discrimination analysis in a mixed radiation field. The comparison with charge collection (CC) method is also investigated [5].

Methodology

The empirical formulism for characterization of a liquid scintillation detector that gives mathematical description of pulses has been used to simulate the response of detector [1]. A mix radiation field of 5000 neutron and gamma pulses of unity amplitude is synthesized out of which 3500 were γ pulses and 1500 were neutron pulses. The sampling of pulses is done at 2.5GHz sampling rate with total pulse width of 300ns.The sample pulses are shown in fig.1 (a). As distortions or noise are always present in any detector system, a random component of noise at 15 dB SNR was added to the amplitude of each sample of synthesized pulses as shown in fig1(b).

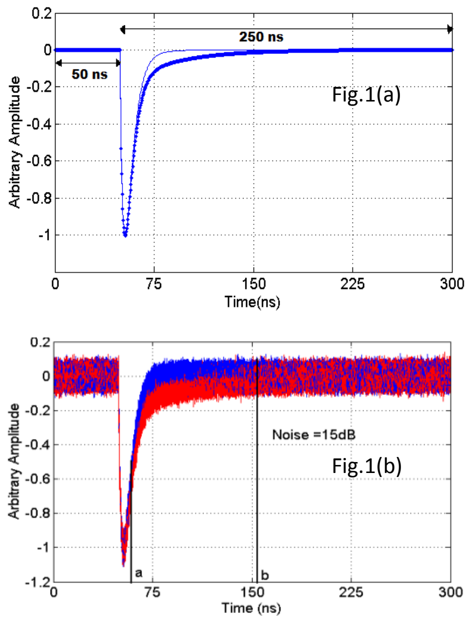

Fig.1 (a) Synthesized n-γ pulses with unity amplitude (b) 5000 mixed pulses with 15 dB SNR

The processing of pulses is done with the SDCC [6]. The discrimination parameter (D-Parameter) is calculated by squaring the each sample and then summing it over a time interval $b-a$ and is given by

$$D = \log \sum_{a}^{b} X^2$$

Here X is sample amplitude at time t, a and b are start time and end time respectively for processing the pulse.

Analysis

The effect of start time and end time is analyzed by calculation D-Parameter and Figure of merit (FOM). The D parameter is calculated by varying the values of end time b at fix values of start time a. A histogram is plotted and fitted with Gauss-2 distribution at each set of a and b. The quality of discrimination is defined by calculating figure of merit (FOM) [3] using the relation

$$FoM = \frac{S}{FWHM_{\gamma}+FWHM_{n}}$$

where S is the separation between the peaks of the two events i.e., neutron and gamma peaks. $FWHM_{\gamma}$ and $FWHM_{n}$ is full width half maximum of γ-radiation and neutron event spreads respectively. The fig. 2(a) gives variation of FOM with end time b at different values of a. To show the variation of FOM with start time a at a fixed value of $b = 290ns$ is plotted in fig.2 (b)

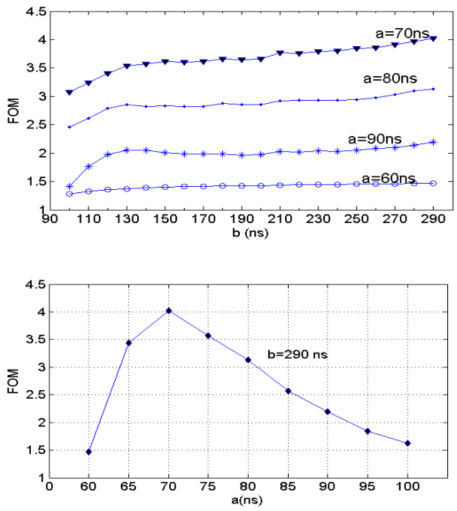

Fig.2 (a) Variation of FOM with end time b at different start times, (b) Variation of FOM with start time a at fixed end time 290ns.

Results

The final neutron-gamma spectra is plotted in the form of histogram in fig 3.It has been observed that the maximum value range of FOM is achieved at $a = 70ns$and $b = 290ns$ for a 300ns pulse with relative position of peak at $50ns$.The FOM achieved is 4.024 at 15 dB SNR. The FOM achieved by traditional charge collection method is 2.477 for the same data set at same gate time [5].

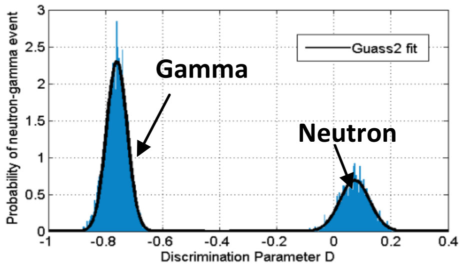

Fig.3 Histogram for neutron gamma pulses at $a = 70ns$ and $b = 290$ ns by SDCC method.

Conclusion

During the analysis of mixed radiation field with simulated data using SDCC method it is observed that the quality discrimination depends very strongly on selection of gate time. A quantitative separation between neutron and gamma events is seen with FOM 4.024 at a =70ns and b = 290 ns. There is improvement in FOM by 38.44% using SDCC than CC method.

References

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