A Wavelet Based method for digital discrimination of neutron and γ −radiation

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 international safeguard, nuclear material control 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 rise time technique and charge comparison[2] techniques which are very popular and implemented using analogue electronics. In the recent years digital methods for discrimination of mixed field radiations have been investigated with scintillators [2]. Some of the digital techniques developed are pulse gradient analysis (PGA) [3], neural network technique [4], wavelet method [5] and frequency gradient analysis (FGA) [6]. In this paper, a wavelet based discrimination technique is proposed. To study the discrimination of mixed radiation field that contained neutron and gamma pulses are synthesized by using an empirical model [1]. Further, the quality of discrimination is found to improve as compared to PGA [3]. FoM of 6.48 is achieved through the proposed method.

Theoretical Formulation

The Continuous wavelet transform (CWT) is used to measure the similarity between a signal and wavelet function ψ by comparing the signal to shifted and scaled versions of wavelet. The CWT of a signal $f(t) \in L^2(\mathbb{R})$ at scale a and shift b is given as:

$$W_f(a,b) = \int_{-\infty}^{\infty} f(t) \frac{1}{\sqrt{a}} \psi^* \left(\frac{t-a}{b}\right) dt \qquad (1)$$

Here $\psi \in L^2(\mathbb{R})$ is called wavelet function with unit L^2 norm. The energy of wavelet transform is calculated by defining a function $P(a)$ called scaling function which is given as [5]:

$$P(a) = \frac{1}{1+n_b} \sum_{0}^{n_b} \left|W_\psi^s(a,b_j)\right|^2 \qquad (2)$$

Wavelet Gradient Analysis

The empirical formulism for characterization of a liquid scintillation detector that gives mathematical description of pulses have been used to simulate the response of detector [1].In this analysis 1000 n-γ pulses are generated out of which 700 were γ pulses and 300 were neutron pulses. The sample pulses are shown in fig.1 (a). The pulses are normalized to unity to remove the dependency of the wavelet transform on amplitude of the pulse.CWT of these pulses is carried out by using Haar wavelet. The scale function of n-γ waveforms are shown in fig1(b).

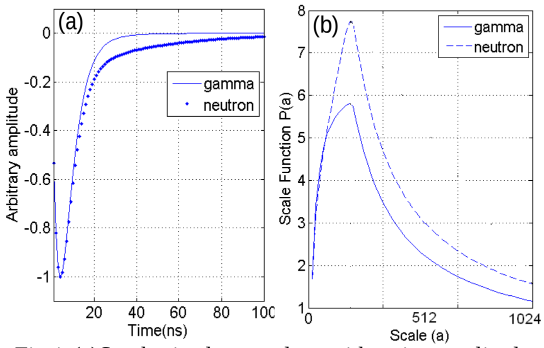

Fig.1 (a)Synthesized n-γ pulses with unity amplitude (b)and corresponding scale functions.

The gradient of falling part of scale function for neutron and gamma pulses was observed to be entirely different hence it was extracted to discriminate neutron and gamma. The gradient of scale function was obtained as:

$$Gradient = \frac{P(a)|_{a=176} - P(a)|_{a=960}}{176 - 960}$$

Here a=176 correspond to peak of $P(a)$. The discrimination value as function of probability of particular event is plotted in fig 2. A good amount of separation is observed between the gamma and neutron events as compared to PGA [3]. Amplitude of probability peaks shows that the total pulses were consisting of 70% of gamma and 30% of neutron

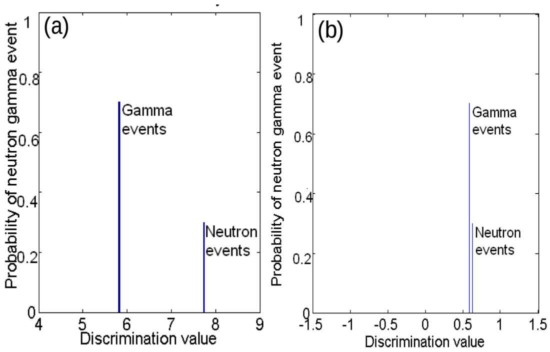

Fig.2 Histogram for 1000 pulses (70% gamma and 30% neutron) analyzed by the (a) proposed method and (b) PGA

The effect of presence of noise was also investigated to access the efficacy of the proposed method. In this regard a random component of noise was added to the amplitude of each sample of each of the synthesized pulses. Data was generated with 70% of gamma and 30% of neutron events. The proposed method was applied to data set and the histograms were plotted for pulses with noise are shown is fig.3.

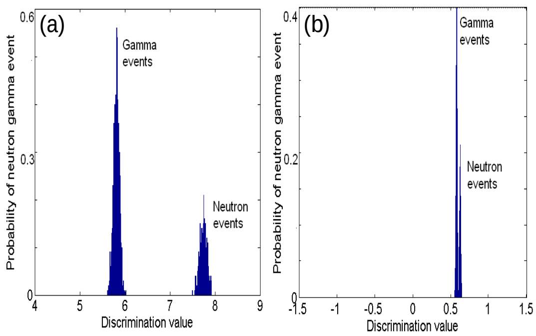

Fig.3 Histogram for pulses with noise analyzed by the (a) proposed method and (b) PGA

The figure of merit (FoM) was calculated using [3].

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

where S is the separation between the peaks of the two events. $FWHM_\gamma$ and $FWHM_n$ is full width half maximum of γ-radiation and neutron event spreads respectively. For 30 dB noise FoM of proposed method is 6.48 which is large as compared to PGA method (FoM=1.2). Moreover, PGA method gives no practical discrimination for 20 dB noise [3]. However, for 20 dB noised pulses the FoM is found to be 2.56 when calculated by proposed method.

Conclusion

During the analysis of mixed radiation field with simulated data it was found good improvement in discrimination of neutron gamma events by proposed method. FoM of 6.48 for 30 dB SNR pulses is achieved through the proposed method. Moreover, the proposed method needs to be verified for experimental data using liquid scintillators. The successful discrimination using wavelet gradient analysis is simple and opened new possibilities for pulse shape discrimination in scintillation detectors.

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