

A Digital Method for the Discrimination of Neutrons and γ Rays With Organic Scintillation Detectors Using Frequency Gradient Analysis

Charles C. Lee, Michael D. Jones, Xiaoting Ma, and Richard D. Applegate

Abstract—A digital method for the discrimination of neutron and γ ray events from an organic scintillation detector is described by using frequency gradient analysis (FGA) based on the Fourier transform. Since the discrimination process used the photomultiplier tube (PMT) signals along one axis only, noise, event pattern shape, discrimination method, and scintillation detector system (e.g., the charge comparison (CC) method or pulse gradient analysis (PGA) using two channels) features of the signal depend greatly on the position of the scintillation detector in the detector. The performance of the new FGA method and the PGA method have been studied and compared with theoretical results and then verified by Monte Carlo (MC) and computer simulation. The results of the FGA method related to event discrimination in the scintillation detector system of the photomultiplier tube (PMT) and can be used for the scintillation detector and γ ray events. The FGA method has the potential to be implemented in current scintillation detector systems to provide real-time discrimination for scintillation detectors.

Index Terms—Digital discrimination, frequency gradient analysis, neutron, organic scintillation, pulse gradient analysis, time of flight.

I. INTRODUCTION

ORGANIC scintillation detectors have often been used for the detection and spectroscopy of γ -rays, measurement of neutrons, and the most majority of liquid organic scintillators, the composite fluid, are composed of two components: alcohols and alkyl aromatic compounds. The more the alcohols in the mixture, the more the discrimination effect depends on the nature of the scintillation process. One can use this dependence to discriminate different kinds of radiation. Current organic scintillators including alcohols and aromatic compounds and liquid scintillators, are particularly good examples of this phenomenon that is explained via pulse shape analysis method (PSA). This is because of the large difference in the decay component followed by different scintillators in these fluids. When organic scintillators are used in neutron detectors, PSA is an essential requirement because all neutron fields contain both

an immediate γ -ray component arising as a result of scattering reactions of the neutrons with materials in the environment, and an almost homogeneous of the primary reaction producing the neutron field [1].

A number of techniques for PSA have been investigated with varying degrees of success. The most popular of these are the charge comparison method [2] and the time-varying method [3]. Both of these methods were originally implemented in analog electronics, which is difficult to implement in modern computer instruments available (NIM) [4]. More recently, both of these methods have been been implemented in the digital domain as digital electronic systems have become available with their fast data speed and ability to make this possible. These methods have become the industrial standards for neutron systems with other new proposed discrimination methods, such as the correlation method [5] and the cosine fitting method [6].

In recent years, artificial neural networks (ANN) and fuzzy systems [7] have emerged as system technologies, with several applications across many fields. They are particularly effective in pattern recognition tasks, and in this sense, ANN and FFS can be used to classify neutron and γ -ray events from the measurements performed by organic liquid scintillation detectors. In particular, Li [8] used ANN with a linear back-propagation (BP) neural network to process the shape of light pulses in an organic liquid scintillation, while D'Astous [9] proposed an approach based on fuzzy logic for pulse shape discrimination in a liquid organic scintillation detector.

In order to take advantage of capabilities offered by fast digital electronics, Bortolotto et al. [10] presented a discrimination algorithm that is computationally simple, referred to as pulse gradient analysis (PGA). This technique provides real-time digital characterization of measurements where necessary and is easy to use. The performance of the PGA method has been compared against a digital implementation of the conventional charge comparison method which demonstrated the PGA method provides an improvement in discrimination ability. Very recently, a dedicated portable neutron detector has been developed that provides real-time discrimination of mixed fields that is based on the PGA algorithm deployed on Kilobit Space 177 field-programmable gate array [11].

One of the many pulse shape discrimination methods are time-domain features of the signal, e.g., the implementation of charge comparison method generally relies upon the integration of the pulse over two different intervals and that of PSA method is based on the comparison of the relative heights of samples at the trailing edge of the pulse. Since the scintillation process

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The authors are with the Department of Engineering, University of Illinois at Urbana-Champaign, U.S.A. (C. C. Lee, Xiaoting Ma, and Richard D. Applegate) and the Department of Physics, University of Illinois at Urbana-Champaign, U.S.A. (Michael D. Jones).

Digital logic devices in circuit are not shown.

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