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Effect of time walk in the use of single channel analyzer/discriminator for saturated pulses in the 4πβ–γ coincidence experiments

Yasushi Kawada [a,*], Akira Yunoki [a], Takahiro Yamada [b], Yoshio Hino [a]

[a] National Metrological Institute of Japan, National Institute of Advanced Industrial Science and Technology, Tsukuba Central 2, 1-1-1, Umezono, Tsukuba, Ibaraki 305-3068, Japan

[b] Japan Radioisotope Association, 2-28-45 Hon-Komagome, Bunkyo-ku, Tokyo 113-8941, Japan

HIGHLIGHTS

- Timing properties of several kinds of SCA/Discriminators were studied, including trailing edge CFT.
- Focus of study on saturated pulses, using a 4πβ–γ coincidence counting system and TAC.
- Validity of two novel techniques to overcome this problem was shown.

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ABSTRACT

Using the TAC technique, the timing properties of a 4πβ–γ coincidence counting system were experimentally studied with an emphasis on saturated pulses. Experiments were performed for several discriminators (integral mode of TSCA) each with different kinds of timing techniques. Timing spectra were measured at various applied voltage to the 4π proportional detector covering the entire region of the plateau.

Most of timing discriminators show good timing property when the pulses remain the linear region, but suddenly deteriorate after the pulses was saturated, and the timing spectra expands seriously up to a few μs in some types of timing discriminator. To overcome this problem, two techniques were proposed.

1. Introduction

The timing of single channel analyzer/discriminators is a well established technique. This is mainly achieved with the constant fraction timing technique (CFT), and good timing properties can typically be achieved provided that the amplifier is operated in a linear range and the pulses are not saturated. However, if the pulses exceed the linear range and the pulse-top is saturated, the timing properties of the SCA as used an integral discriminator are diminished.

Two different techniques have been used in most timing single analyzer (TSCAs); one is by means of the crossing-time of the attenuated signal and the leading portion of the slightly delayed and inverted signal (Gedcke and McDonald, 1967, 1968) and the other uses the trailing edge instead of the delayed signal (US. Patent 3714464, ORTEC Technical guide). The former technique provides excellent fast timing properties especially for pulses from fast scintillation or semiconductor detectors. In 4πβ–γ coincidence measurements, however, linear amplifiers involving pulse-shape circuitry are inevitably used in both β- and γ-channels, and a 4π proportional counter (4π-PC) is often used (Bobin, 2007; Keightley and Park, 2007; Fitzgerald et al., 2015). These fundamental requirements in 4πβ–γ coincidence measurements make the use of the fast timing module inconvenient, because these fast timing modules are designed for negative fast pulses, and not for positive slow pulses.

On the other hand, TSCAs using the trailing edge for the constant-fraction time recognition are becoming in popular use (e.g., ORTEC 551). This versatile technique is ideally suited for timing when the input pulses maintain linearity. However, if the pulse-height deviates from the linear range, the timing properties degrade, and the relative time distribution between β- and γ-channels expands gradually as the saturation become dominant, and

* Corresponding author.
E-mail address: kawada.t4@gmail.com (Y. Kawada).

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finally the relative time delay between channels may exceed the coincidence resolving time. In this study, we tested relative time spectra between β- and γ-channels of a 4πβ(PC)–γ coincidence counting system particularly with use of such a trailing-edge type TSCA in an integral discriminator mode. The experimental results were compared with those obtained by other techniques including the classic leading edge timing and the zero-crossover-timing technique used with a double-delay-line (DDL) amplifier.

In this study, two ideas are proposed and we experimentally examined the means to overcome the disadvantages of TSCAs with the trailing edge CFT recognition.

2. Measurements of relative time distribution and discussions

Prior to the relative time distribution measurements, we recorded the pulse-height distributions of the β-signals for a ^{60}Co source at different applied voltages to the 4π-PC, where the coarse gain of the amplifier (Canberra model 2024) changed from $\times$300 to $\times$30 so as to evaluate the saturating components. The results are shown in Fig. 1. We usually set the amplifier-gain at $\times$300 and the pulse-height saturation appears at 12 V, so that the all pulses exceeding 120 channels in this figure (see the vertical dotted line) should be subject to the saturation.

In order to test and to compare the timing properties of several kinds of discriminators under the conditions associating saturated pulses with considerable proportions, the relative time-distribution between β- and γ-pulses in a 4πβ–γ coincidence counting system were measured by means of the time-to-amplitude converter (TAC) method (Williams and Campion, 1965). A 4π-PC flowed with P-10 gas and a 76 mm $\phi \times$ 76 mm NaI(Tl) scintillation detector were employed and ^{54}Mn and ^{60}Co sources were chosen, as typical X(e)-γ and β–γ emitting nuclides, respectively. The source strength is about 5000 Bq. Gamma-pulses were always used as the starting signal of the TAC (ORTEC model 567), where the 835 keV- and 1333 keV-peaks were selected for ^{54}Mn and ^{60}Co sources, respectively. In the β-channel, the signals from the 4π proportional counter (PC) were fed to a Canberra model 2006 preamplifier and a Canberra model 2024 amplifier and the TSCA, timing signals were fed to the TAC as the stop pulses.

2.1. Trailing-edge CFT

An ORTEC model 551 timing single channel analyzer (trailing-edge CF recognition) was tested as integral discriminator mode. This type of TSCA is in popular use especially for the timing of slow systems. In our system, the plateau extended from 1300 V to

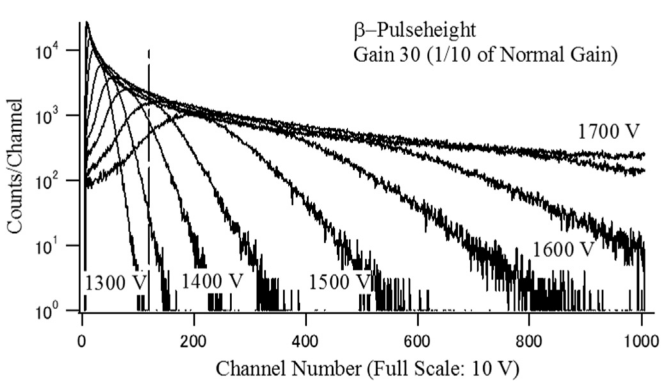

Fig. 1. Pulse-height distributions of β-pulses for various applied voltages to the 4π proportional detector as the amplifier-coarse-gain was reduced to $\times$30. Normally the gain was set at $\times$300. The saturation pulse-height is about 12 V, and hence pulses whose pulse-height exceed 120 channel (see vertical dotted line) in the figure are all subject to the saturation in normal use.

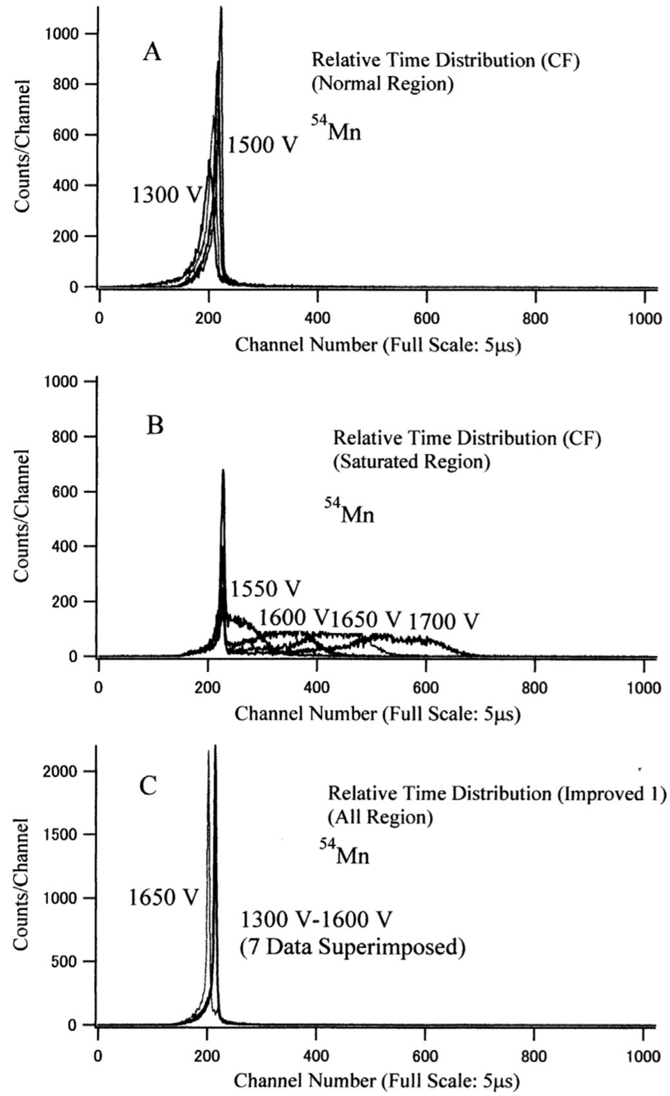

Fig. 2. Relative time distributions for various applied voltages to 4π-PC, where a ^{54}Mn source was used. Shaping time was set at 0.5 μs. Full scale corresponds to 5 μs. A: Normal pulse-height region, B: saturated region, C: results of the improved method (see Section 3).

1700 V for ^{54}Mn and ^{60}Co sources. So, the time spectra were measured from 1300 V to 1700 V with 50 V steps, and the results were superimposed in Fig. 2A for 1300–1550 V, and in Fig. 2B for 1550–1700 V. The shaping time of the β-amplifier was 0.5 μs. Using a ^{60}Co source, similar experiments were also performed with 0.25 μs time constant, and the result are shown in Figs. 3A and B. From the figures, it is found that the timing property was well behaved in the lower half (1300–1550 V) of the plateau region, in which the pulses mostly remained in a linear range, giving moderate time spectra within $\pm$300 ns in full width. In the higher region where the applied potential to the β-detector exceeded 1500 V, however, the timing property of TSCA suddenly diminished and the time distribution expanded to a few μs or more, which may exceed the coincidence resolving time (usually in the region of 1 μs).

As compared with the results for ^{54}Mn, the time resolution for ^{60}Co was deteriorated considerably, even when the pulses maintained linearity. This trend has been mentioned by Williams and Campion (1965). It must be further noted that the improper swelling at the upper foots appeared in the time spectra of Figs. 2A and 3A. When a sandwiched 4π plastic scintillation detector