

Compton Suppression System with Simplified Slow Anti-Coincidence Circuit

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ABSTRACT

Slow coincidence circuits for the anti-coincidence measurements have been considered for use in Compton suppression technique. The simplified version of the slow circuit has been found to be fast enough, satisfactory and allows an easy system setup, particularly with the advantage of the automatic threshold setting of the low level discrimination. A well-type NaI detector as the main detector surrounded by plastic guard detector have been arranged to investigate the performance of the Compton suppression spectrometer using the simplified slow circuit. The system has been tested to observe the improvement in the energy spectra for medium to high-energy gamma-ray photons from terrestrial and environmental samples.

INTRODUCTION

In gamma-ray spectrometry measurements, some of the photons from the sample under investigation (placed on the top of a flat-detector or inside a well-type detector) are scattered within the radiation detector itself depositing part of their energy within the detector and escape. This leads to the generation of Compton associated background representing incomplete energy deposition of the incident photons, which leads to the distortion of the obtained spectrum from the actual energy distribution. It is possible to detect such (escaping) scattered photons by the use of a larger detector made of a less expensive material such as Plastic or NaI surrounding the main detector. By correlating events in the main detector and the surrounding "shield" detector with timing electronics, events counted in the shield detector can be used to reject simultaneous events in the main detector (veto signal).

Although fast coincidence circuits are important for the ultimate in timing measurements and also commonly used in Compton suppression techniques (Hasinoff et al., 1974; Parus et al., 2003), the use of a slow timing circuit has been found to be satisfactory in similar measurements for low-level studies and was recommended due to its simpler electronic setup (Bikit et al., 1999). Furthermore, it has been reported that anti-coincidence measurements for the Compton suppression technique do not require fast coincidence circuits to provide good suppression. Equivalent results may be provided with "simple" instrumental arrangements without the need for special setup procedures or adjustments (¹).

MATERIALS AND METHOD

Some of the energy amplifiers (i.e. Canberra 2025 and 2026) are provided with an extra feature in which logic pulses are produced for each signal input from the detector "incoming event" (known as: Incoming Count Rate "ICR"), thus the need for additional electronic components (NIM units) such as T-SCA's as used in standard Slow Circuits that produce the logic pulses for the timing analysis is omitted in this case. This arrangement is a simplified version of the slow coincidence circuit and results in a further reduction in the required number of electronic components (NIM units) compared to other circuits (fast and

¹ Compton Suppression, Made Easy. Application Note AN-D-8901, Canberra, USA

standard slow) as well as an easier system setup, particularly, due to the automatic adjustment of the low level discriminators, Figure 1.

The main detector is a well-type NaI(Tl) of a size of 7.6 cm X 7.6 cm with a well size to accommodate vials of capacity of 20 ml. The surrounding active shield is a plastic detector of a well-type shape of size 18.4 cm diameter x 15.2 cm long with a well cavity that can accommodate the NaI(Tl) detector. The detector wall-thickness and bottom-thickness are of 5 cm thick, Figure 1. Both detectors (main well-NaI detector and surrounding guard detector) have been supplied with standard PM-tubes.

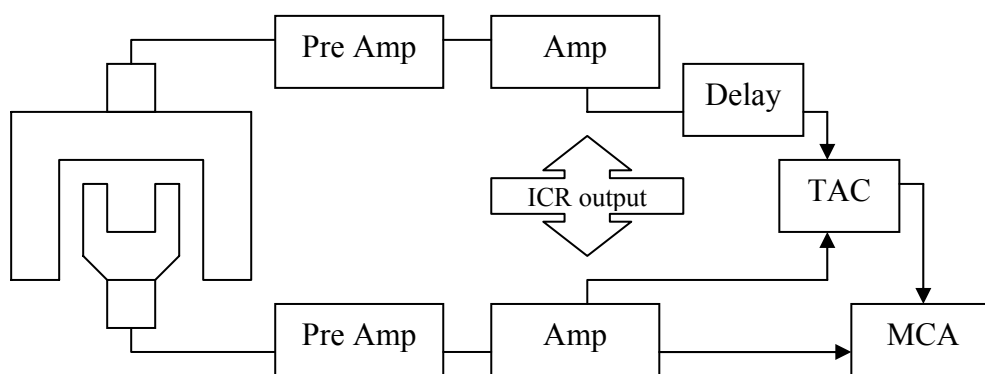


Figure 1 The "Simplified Slow Coincidence circuit" is based on the use of the ICR outputs "logic pulses" available with the energy amplifiers (Canberra 2025/2026) for timing analysis. The main detector is the well-type NaI(Tl) detector where the sample contained in a vial is placed inside its cavity. The larger well-type detector is the plastic active shield.

RESULTS AND DISCUSSION

Pulse Gating

The threshold of the discrimination level against the system noise can be examined by making the logic pulse from the discriminator to open the electronic gate for the same corresponding energy signal from the detector to pass through. Figure 2 shows the lower part of the energy spectra acquired with different amplifier gains using the Canberra amplifier (either model 2025 or 2026) that are provided with the additional feature of producing a logic pulse "ICR" (Incoming Count Rate) output for each preamplified input signal. As observed, the Auto-Discrimination Level is always at a fixed position regardless the amplifier gain setting when using the ICR logic outputs. However, increasing the amplifier gain will allow the discrimination level to be set at lower energy threshold values, if desired.

Time Spectra for the Standard Slow and Simplified Slow coincidence circuits

Evaluation/Comparison of the two different coincidence circuits (Standard Slow using Ortec T-SCA's and Simplified Slow using ICR outputs) requires the study of their time resolution. So, the two detectors were arranged opposite to each other for this measurement. Using ^{22}Na source, the time resolution FWHM is 53.7 ns and 56 ns for the Canberra ICR and Ortec T-SCA circuits respectively, whereas the FW1/10M values are 152 ns and 128.5 ns for the Canberra ICR and Ortec T-SCA circuits respectively. Generally, both systems of Simplified Slow and Standard Slow circuits show a similar timing performance.

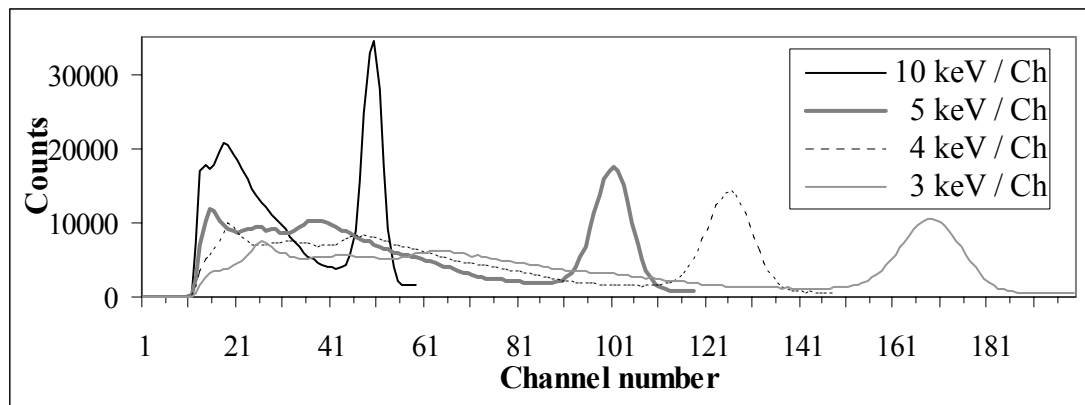


Figure 2 ***The well-NaI detector:** Four ^{22}Na energy spectra (each of them was examined with a different amplifier gain setting) are provided together to show the start of the low level discrimination when the energy spectrum is gated by the ICR logic pulse generated using the Canberra 2025 amplifier (automatic threshold adjustment). The 511 photopeak shifts to the right with increase in gain while the low level discrimination remains unaffected.*

Time Window of the Compton Suppression Spectrometer

Sources emitting single photons are used to evaluate the rejection of the Compton scattered photons in Compton suppression measurements. The maximum gamma-ray energy (observed in terrestrial/environmental samples) is 2.614 MeV from ^{208}Tl of the ^{232}Th series. Therefore, the RGTh-1 IAEA reference material (^{232}Th powder in radioactive equilibrium with its decay products) contained in a vial and placed inside the NaI detector cavity was used to record the time spectrum between the two detectors in their position for Compton suppression and accordingly, to determine the time window that allows the two detected events to be considered for the veto action. It was found that the coincidence peak was very broad due to the coincidences between photons with multiple energies and such a peak is completely confined within a time width of about 500 ns. However, it was observed that the position of the coincidence peak on the time spectrum changes with different gain setting for the main energy amplifier. Therefore, it was decided to use a wider time window of 1000 ns (instead of 500 ns) to allow for such minor changes with different gain settings for either energy amplifiers. This is useful to avoid further system adjustments when switching the spectrometer between high and low energy photon measurements by changing the amplifier gain of the main detector.

Assessment of the Compton Suppression Spectrometer

The Background energy spectrum collected for 100,000 s is shown in Figure 3. The count rate was reduced from 5.25 CPS for normal to 3.13 CPS for the Compton suppressed spectrum for the energy region of 140-3000 keV. An overall reduction of 40% has been achieved as an improvement in background reduction within this energy range. More reduction of scattered photons is seen for the high-energy region.

CONCLUSION

The timing measurement technique for Compton suppression systems has been traditionally (and still commonly) based on the use of fast coincidence circuits in order to have a fast response for the accurate veto action required for the desired improvement. A move has already been initiated to show that the adoption of the slow coincidence circuit in these systems is satisfactory (Bikit et al., 1999). Compared with the fast coincidence circuit,

the slow coincidence circuit avoids the use of the complicated instrumental arrangement and the time consumed for the system adjustment.

As seen in the literature, time windows of typical widths of one-microsecond have been used in Compton suppression systems utilizing fast coincidence circuits, whereas in the present work with the adoption of the simplified slow coincidence circuit, a similar time window width (or even shorter) has been found to be sufficient in spite of the use of standard PM tubes. This shows that the simplified slow circuit is fast enough for the Compton suppression measurements. The automatic threshold setting of the low level discrimination adds further simplicity towards an easier system set-up and adjustment.

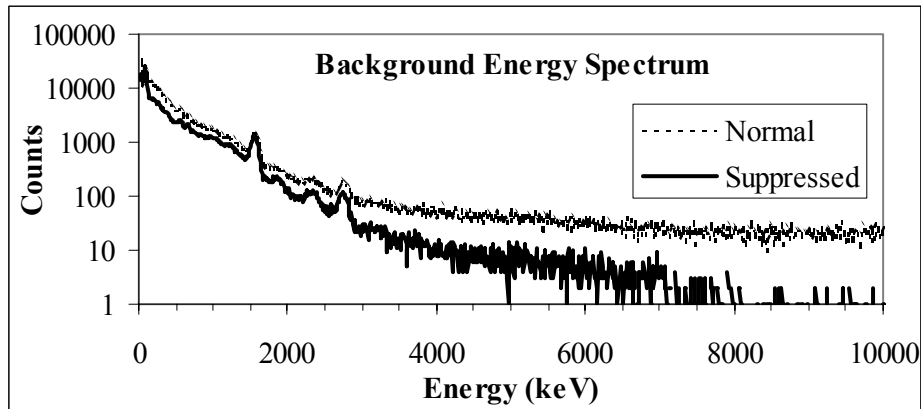


Figure 3 Background energy spectrum (normal and Compton suppressed) collected for 100,000 s. An overall reduction "improvement" of 40% has been achieved for the energy range of 140-3000 keV with the use of the Compton suppression method.

ACKNOWLEDGEMENT

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