Background correction for SESAM

by Jörg W. Müller

Bureau International des Poids et Mesures, F-92310 Sèvres

One of the few corrections which have to be applied to the data directly obtained in the selective sampling (SESAM) method concerns background. Although for the preferred domain of applicability, namely high count rates, background will in general be of little influence, it is clearly desirable to perform the correction properly.

For the sake of clarity, the combination of background and dead-time effects will be ignored in what follows. It is possible to account for both influences in a rigorous way.

Background radiation may be considered as originating from some secondary source. As the fraction of time-correlated beta and gamma pulses will in general be different from the one observed in the primary or main source, the activity of which we want to measure, one is led to consider two separate detector systems. A possible model suitable for investigating the effect of background in the SESAM method is sketched in Fig. 1. The two sources with activities N_1 and N_2 are assumed to be completely separated from each other.

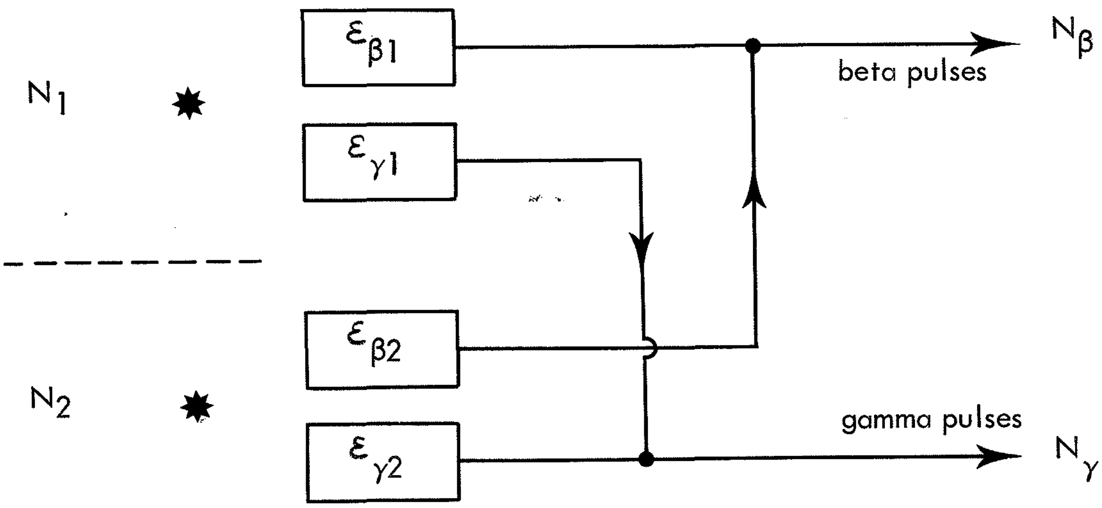

Figure 1 - Schematic block diagram of the discussed two-source arrangement. The detectors are indicated by their counting efficiencies.

The experimentally available (superimposed) beta pulses, with count rate N_β, are then led in the usual way to the circuit which imposes an extended dead time. Any of the output pulses marks the end of a time zone of length T which is free of beta events, and it is around this region that the delayed gamma pulses are observed and accumulated by repeated sampling on a multichannel analyzer. In this way one obtains the time spectrum with its two main regions which we have previously characterized by their average channel contents g and G, respectively [1].

What is the effect of a "background" source N_2? In the beta channel little is changed. The time zones T are now free of beta pulses from both sources, and their frequency of occurrence is somewhat changed. As long as $(N_1 \varepsilon_{\beta 1} + N_2 \varepsilon_{\beta 2})\, T < 1$, their number, for a given time of observation, is higher; otherwise it will be lower. In any case, this has only a marginal influence on the counting statistics. For the gamma channel, on the other hand, we now have (for the notation see [1])

$$\begin{aligned} G &= \kappa[N_1\, \varepsilon_{\gamma 1} + N_2\, \varepsilon_{\gamma 2}] \quad \text{and} \\ g &= \kappa[N_1\, \varepsilon_{\gamma 1}(1 - \varepsilon_{\beta 1}) + N_2\, \varepsilon_{\gamma 2}(1 - \varepsilon_{\beta 2})] \;. \end{aligned} \tag{1}$$

For checking purposes let us first assume that the detector systems are identical for both sources, i.e.

$$\varepsilon_{\beta 1} = \varepsilon_{\beta 2} = \varepsilon_\beta \qquad \text{and} \qquad \varepsilon_{\gamma 1} = \varepsilon_{\gamma 2} = \varepsilon_\gamma .$$

In this case we have

$$\begin{aligned} G &= \kappa(N_1 + N_2)\, \varepsilon_\gamma \quad \text{and} \\ g &= \kappa(N_1 + N_2)\, \varepsilon_\gamma(1 - \varepsilon_\beta) \;, \end{aligned}$$

hence

$$g/G = 1 - \varepsilon_\beta \;. \tag{2}$$

As was to be expected, the arbitrary subdivision of the total activity N_o into N_1 and N_2 is without any effect on the determination of the detection efficiency ε_β of the beta particles.

Of more relevance for our problem is the situation where N_2 is taken as the (fictitious) background source. We then can write

$$N_2\, \varepsilon_{\gamma 2} = B_\gamma \;, \qquad N_2\, \varepsilon_{\beta 2}\, \varepsilon_{\gamma 2} = B_c$$

and identify N_1 with N_o. This leads with (1) to

$$\frac{g}{G} = \frac{N_o\ \varepsilon_\gamma(1 - \varepsilon_\beta) + B_\gamma - B_c}{N_o\ \varepsilon_\gamma + B_\gamma} = \frac{N_\gamma^{(o)} - N_c^{(o)} + B_\gamma - B_c}{N_\gamma^{(o)} + B_\gamma}\ , \tag{3}$$

where the efficiencies now refer to N_o and the superscript (o) signifies "without background". The constant κ which relates channel contents to count rates is given by the ratio

$$\frac{1}{\kappa} = \frac{N_\gamma^{(o)} + B_\gamma}{G} = \frac{N_\gamma}{G}\ , \tag{4}$$

where both N_γ and G are directly measured. If we denote by g_o and G_o the channel contents one would have in the absence of background, equation (3) becomes

$$\frac{g}{G} = \frac{g_o/\kappa + B_\gamma - B_c}{G_o/\kappa + B_\gamma}\ , \qquad \text{or}$$

$$\frac{g - \kappa\ (B_\gamma - B_c)}{G - \kappa\ B_\gamma} = \frac{g_o}{G_o} = 1 - \varepsilon_\beta\ . \tag{5}$$

This shows how the measured quantities g and G have to be corrected for background. Obviously, this correction could also have been found directly. It is interesting to note that the beta background enters here only in a somewhat indirect way.

The determination of the three background count rates is simple. In the absence of the source N_1 we measure directly

$$N_\beta = N_2\ \varepsilon_{\beta 2} = B_\beta \qquad \text{and}$$

$$N_\gamma = N_2\ \varepsilon_{\gamma 2} = B_\gamma\ .$$

As regards the background "coincidence" rate B_c, we stress that no coincidence circuit is needed for its determination. Indeed, we can use the normal experimental arrangement, count the number W of writing cycles (which are now all initiated by beta pulses from the background) and measure the total number S of gamma events appearing in the channel(s) corresponding to the end of the gap g. The numerical value of B_c is then obtained as

$$B_c = B_\beta \frac{S}{W}\ . \tag{6}$$

This method of determining B_c has the advantage of being also applicable to an isomeric gamma transition: in this case the total area of the exponential distribution has to be taken for S (see Fig. 2). It is easy to see that the contribution of the unpaired events is negligible in the small time region of interest; the measurement of S is therefore not disturbed by a "background" problem.

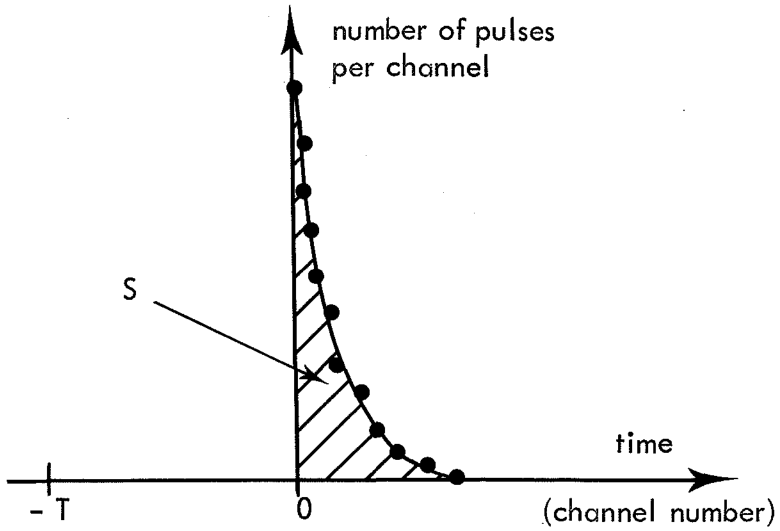

Figure 2 - Experimental determination of the quantity S needed in (6) for a delayed decay.

Measurements performed with artificially increased background have well confirmed the correction formula (5).

It may be worth mentioning that the above simple model with two sources can also be used for finding the background correction to be applied in the traditional coincidence counting [2], but it turns out to be somewhat less trivial. The details will be left to the reader as an interesting exercise.

References

[1] J.W. Müller: "Selective sampling - an alternative to coincidence counting", Nucl. Instr. and Meth. 189, 449-452 (1981)

[2] D. Smith: "Improved correction formulae for coincidence counting", Nucl. Instr. and Meth. 152, 505-519 (1978)

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