Blind selective sampling*

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Abstract

The method of selective sampling has been handicapped since its invention by the need to employ a speed converter, which is an elaborate electronic system. We present here a simplified version of the method, called blind sampling, involving only time delays and gates. When the counting zones are properly chosen, activity measurements performed with this new system are fully equivalent to those obtained with an apparatus based on the original concept.

1. Introduction

The novel method of measuring the activity of radionuclides which decay in at least two steps, published four years ago [1], has aroused much interest in the standards laboratories and initiated a number of checks, in real time or by simulation. If, for the time being, there still seems to exist no apparatus outside BIPM capable of using the selective sampling method on a routine basis, there must be an obstacle to its implementation. This is indeed the case, as many discussions have confirmed: it is the apparent need to have available a "speed converter" for applying the method. While a simple, but rather slow, version of such an apparatus is fairly easy to build [2], really practical usefulness can only be achieved by a more sophisticated version which will have to be constructed by a skilled electronician.

However, even if this possibility does not exist, there still remain two other solutions. The first is entirely passive and consists in simply waiting till the manufacturers of multichannel analyzers offer products with dwell times per channel as short as 1 μs, and this technological progress seems to be practically at hand (with, e.g., Le Croy Model 3521, MCS module). The second (more active) way is to have recourse to a simple variant, called "blind sampling", which will be described briefly in this report.

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* This topic was presented to the members of CIPM on October 23, 1985, by Prof. A. Allisy, in the framework of an overview on recent work performed at BIPM in the field of ionizing radiations.

The present report is dedicated to the memory of Johannes Steyn (1927-1983), NAC, South Africa.

2. The sampling principle

Although we may assume that the ideas which are at the basis of the selective sampling method are by now widely known, it will be useful for what follows to recall some simple facts.

A dead time is said to be of the extended type when it acts in such a way that any incoming pulse - independently of whether it will subsequently be counted or not - starts a new time span T of paralysis (or extends one initiated beforehand). Detected pulses arriving within such a dead time are not registered. As a consequence of this behaviour, any pulse observed at the output of an electronic circuit designed to impose an extended dead time is necessarily preceded by a period of length T in which there was no pulse in the original sequence of detected events. This must be so, indeed, since any such pulse would have imposed a dead time and thus suppressed our output pulse. The fact that an output has been observed proves that there was no other event in the preceding interval T.

Let us now consider a nuclear decay which occurs in two steps, producing a beta and a gamma. If the extended dead time is inserted into the beta channel, we are assured that all gamma pulses arriving in the interval T before the registered beta (at time t_o) cannot have a "partner", i.e. a detected beta pulse originating from the same decay. By a repeated accumulation of the arriving gamma pulses in their respective time channels (e.g. of a multichannel analyzer used in time mode), we obtain a time spectrum as shown schematically in Fig. 1. If the average channel contents in the two time regions are denoted by g and G, respectively, then their ratio is equal to the inefficiency of the beta detector, thus

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

As a consequence, the source activity N_o is simply given by

$$N_o = \frac{N_\beta}{\varepsilon_\beta} = \frac{N_\beta}{1 - g/G} , \tag{2}$$

where N_β is the count rate of the detected beta pulses (corrected for dead time).

However, the practical realization of this idea is rendered difficult by the fact that the commercially available multichannel analyzers are not fast enough when used in time mode. For a dead time T of, say, 20 µs, a dwell time of 10 or 15 µs, as normally offered, is clearly insufficient for a detailed observation of the distribution of the arrival time. This is why P. Brêonce, of BIPM, has constructed a "speed converter" which allows us to store the arrival times of the gammas in narrow time channels. The transfer of their contents to the multichannel analyzer (MCA), where the distribution becomes visible on a screen, is still slow, but actually so rarely performed that this has a negligible effect on the counting efficiency. This electronic system works perfectly well, but it is quite complex; it would be useful, therefore, to find a way of applying the sampling technique in which no speed converter is needed.

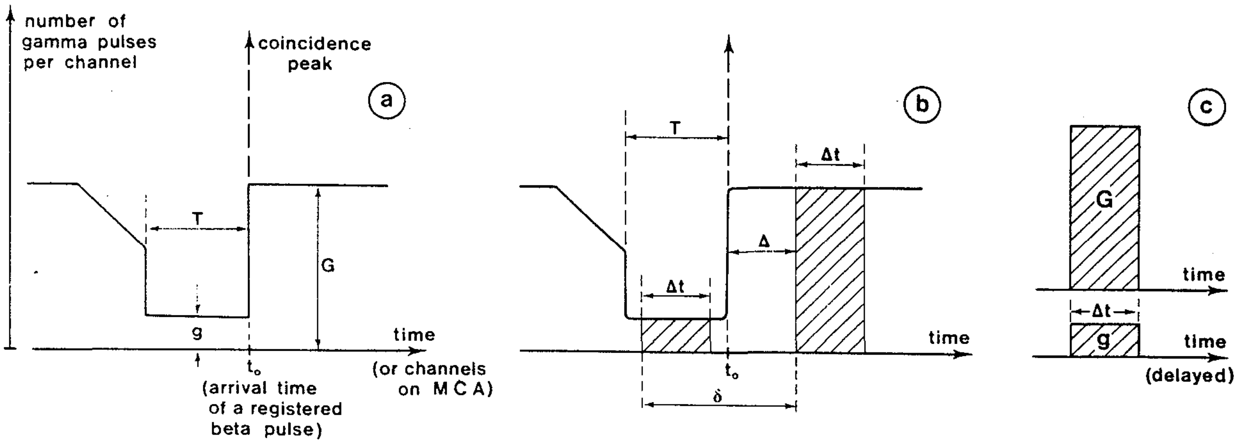

Fig. 1 - Time distribution of gamma pulses.

a) Complete time spectrum, as visible on the screen of a rapid MCA used in time mode. t_0 denotes the arrival time of a registered beta pulse.
b) The two counting windows (of length Δt) needed for the evaluation of the ratio g/G, in their position with respect to t_0. Δ and δ are suitably chosen fixed time delays.
c) Arrangement in real time, when the time zone g has been delayed ("to the right") by δ, allowing thereby a simultaneous counting of both G and g pulses during the measuring period Δt of a cycle.

3. Blind sampling

The basis of "blind" sampling lies in the simple observation that for the practical determination of the quantities g and G, which are needed in (1) or (2), we sum over the contents of a suitably chosen number of channels, and this corresponds to counting the total number of gamma pulses which have arrived during a given time interval. Although previously g and G have been used for denoting the average channel contents in the corresponding time zones, we may well keep the same symbols for the number of registered pulses: since only their ratio is needed, there is no danger implied by applying this somewhat loose, but practical, notation. The position of the two counting periods with respect to t_0 is essential, of course (cf. Fig. 1b), but it is possible to choose them in advance (thus blindly) if we can have full confidence in the proper functioning of the electronic circuit producing the extended dead time T as well as in the absence of any disturbing dead time effect (compare [3]). All we then need for applying the method are time delays, gates and scalers, i.e. electronic components which are easily available.

A possible realization is sketched in Fig. 2. A beta pulse at the output of the dead time T is delayed by Δ and then triggers a monostable multivibrator delivering a rectangular pulse of length Δt. This pulse is used for opening the gates through which pass the delayed ("g") and undelayed ("G") gamma pulses. Note that the counting time Δt does not have to be known precisely and that it might even jitter from one cycle to another: since both g and G would be affected in the same way, this would have no influence on their ratio. The arrangement could be readily used for several gamma branches (γ_1 and γ_2 in Fig. 2). The practical choice of the delays (δ, Δ) and of the gate time Δt is illustrated in Fig. 1b. The positioning of the counting periods is important, and special care should be taken to exclude the time regions which are known to be distorted by dead-time effects (the beginning of the gap and in particular the zone immediately after t_0). A rough check is possible by choosing Δt small compared to T and comparing the results of g/G when the position of Δt is changed within the useful domain of the gap; a systematic trend would point to a deviation from the assumed uniformity that is required for a correct functioning of the method.

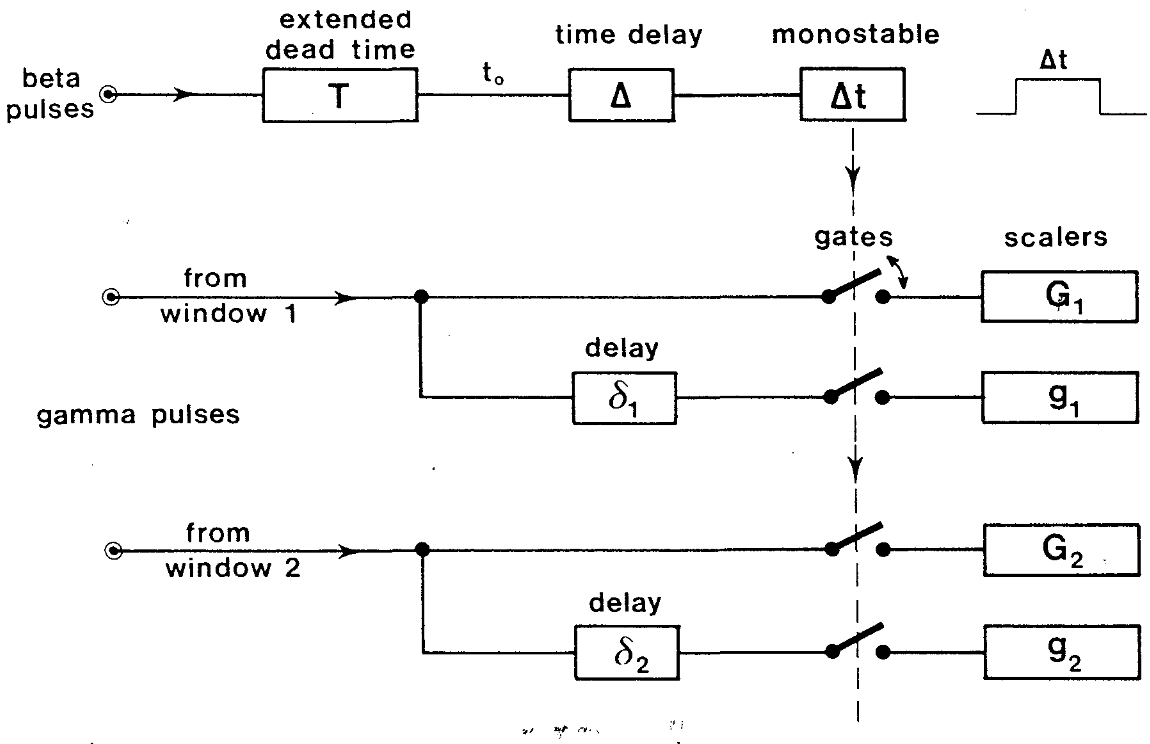

Fig. 2 - Schematic electronic arrangement for a measurement by the blind selective sampling method, assuming two energy windows for the gammas. All the gates are simultaneously activated by the signal from the monostable Δt.

The corrections due to background and a possible gamma dead time are simple and have been described previously (see, e.g. [4]). An advantage of the "blind" version of sampling is that it has a higher counting efficiency than the "lucid" one, because now all pulses at the output of T will actually start a registration cycle and no time is lost for transferring data to the MCA. The difference can be important at high count rates. A simple evaluation of the optimum counting conditions is possible according to [5].

For the introduction of the necessary time delays any of the usual methods is suitable, provided no dead time is added. A particularly convenient solution is provided by the new principle of numerical electronic delays [6].

4. One-eyed sampling

For a laboratory possessing a rapid MCA or some kind of speed converter, an experimental arrangement may be of interest which is somehow half-way between the normal (or "lucid") and the blind sampling, and therefore called "one-eyed" sampling. It is particularly useful for an optimal choice of Δt within the gap region (length and position), because this can now be fully controlled by means of a direct optical display of the selected part of the counting distribution.

The scheme for such a measurement is shown in Fig. 3, and a possible electronic realization, due to P. Brêonce, is given in Fig. 4.

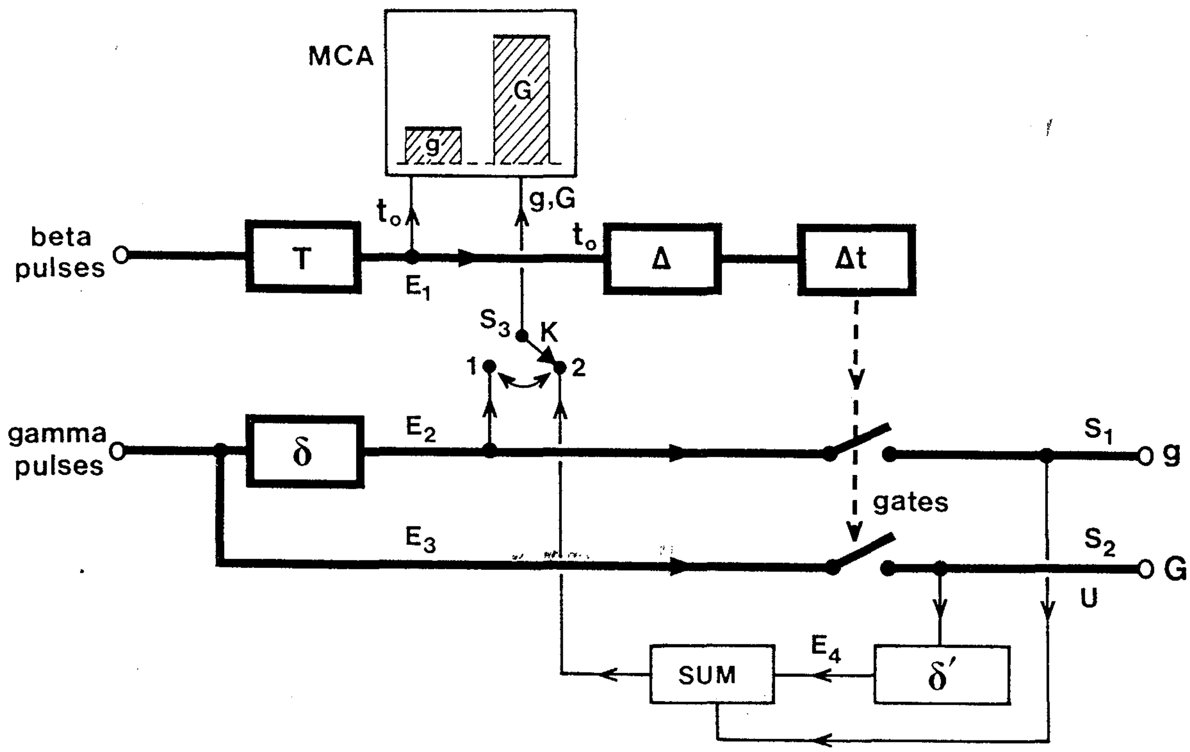

Fig. 3 - Scheme for the one-eyed sampling (with a single gamma channel). The picture on the screen of the MCA is conditioned by the switch K: in position 1 we see the complete time spectrum, whereas in position 2 only the gated spectrum (i.e. the parts G and g) is visible.

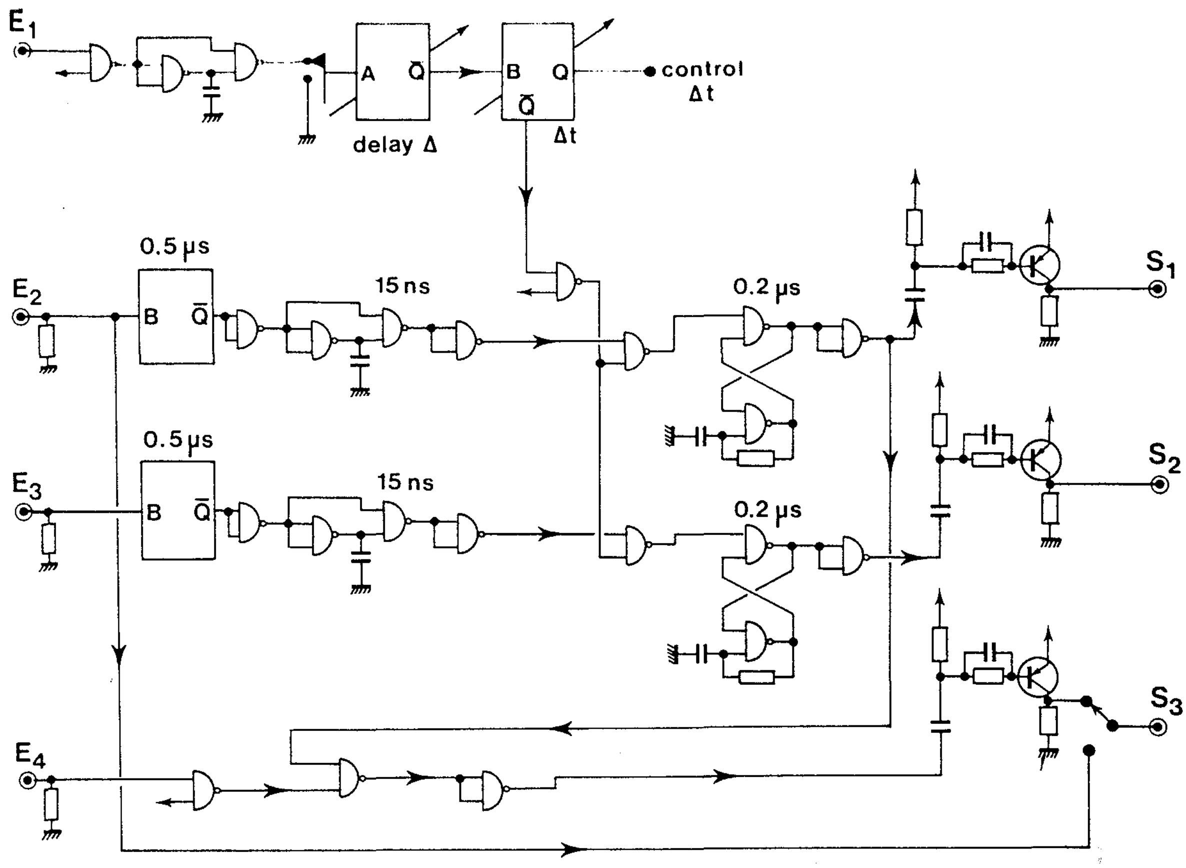

Fig. 4 – Possible electronic realization of the one-eyed version. Note that E_1 contains only beta pulses from the MCA which start a registering cycle. Electronic delays, dead times, as well as the MCA, are outside this scheme which details the central part of Fig. 3.

As in the previous blind version (Fig. 2), of which Fig. 3 is a generalization, the scalers labelled g and G always record the gamma pulses which arrive in the corresponding time intervals, independently of the position of the switch K which has only an influence on what can be seen on the MCA. In position 1, all the gammas, after a delay δ, are directed to the MCA on which we therefore see the usual pattern, as shown in Fig. 1a. In position 2, we deal only with the pulses which have passed the gates (of duration Δt). In order to restore the original relative position in time of all the registered gammas (g and G), those of the zone G have to be delayed by δ' = δ, since the pulses of zone g have already undergone the same delay previously. This had been necessary to synchronize them with G and use a common time gate Δt, but for the display on the screen of the MCA we want to have the two time zones in their original time relation. The addition of the two contributions, performed in SUM, concerns time regions which do not overlap.

The exact position of the selected counting zones Δt with respect to the complete time spectrum can now be easily seen by using alternatively the positions 1 or 2 of switch K. By adjusting the gate length Δt and the position of the zones (with respect to the shape of the gap) by an appropriate choice of Δ and $\delta = \delta'$, safe counting conditions can be chosen. This procedure may be applied to several gamma channels, if necessary. Afterwards, the MCA is no longer needed and the actual measurement can be performed in the "blind" version.

5. Conclusion

One might suspect that an activity measurement performed by blind selective sampling is a rather dangerous procedure since the direct optical control, known from the traditional (lucid) version, is not possible. In fact, this anxiety is difficult to justify; it may be appropriate to remember that all the traditional measuring methods, including the coincidence method, are equally "blind".

We expect that the variant of blind selective sampling, as a result of its simple implementation, will rapidly become a routine method in the field of activity measurements. Because of its basically different conception, the selective sampling method can serve as a welcome alternative to the well-known coincidence method and provide a useful independent control. For very high count rates, the new method may often be the only reliable way to arrive at accurate results.

During the recent stay at BIPM of B. Meyer, of the National Accelerator Centre at Faure, South Africa, we have learned that Dr. J. Steyn, during the last weeks of his illness, was still actively engaged in experimenting with a system which, in essence, must have corresponded to our version of blind sampling. Unfortunately, this work remained unfinished and nothing has been published.

Dr. Steyn was closely associated with BIPM from 1975 to his untimely death in 1983. As a member of Section II of CCEMRI, he has made possible several international comparisons of radionuclides by graciously supplying the required active solutions. All those who have had the good fortune of knowing him personally will gladly remember him both for his scientific achievements and his human qualities.

References

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

[2] P. Bréonce: "Convertisseur de vitesse d'enregistrement", Rapport BIPM-76/4 (1976), 9 p.

[3] J.W. Müller: "Statistiques de comptage", Rapport BIPM-81/9 (1981), 7 p.

[4] id.: "Background correction for SESAM", BIPM Working Party Note 223 (1982), 4 p.

[5] id.: "On the best measuring conditions for SESAM", Rapport BIPM-83/3 (1983), 8 p.

[6] P. Bréonce: to be published. A scheme of the circuits involved is available upon request.

Note - As the BIPM contemplates applying for a patent for the method of blind sampling, the distribution of the present description has to be withheld for the time being.

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