EXPERIMENTAL TESTING OF THE DIGITAL MULTICHANNEL ANALYZER FOR GAMMA SPECTROMETRY MEASUREMENTS

by

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The results of experimental testing of the digital multichannel analyzer which digitalizes the signal after a preamplifier are presented. The recordings of some of the characteristics of the spectrometer containing a digital MCA, such as full-peak efficiency, net-area ratio of the two peaks and the stability of the peak position, were carried out under different input counting rates, with different radioactive sources. The tested MCA has shown some excellent features, like the stability of the peak position over a long-term period and flexibility in the adjusting of optimum measurement conditions. However, the performed tests have also shown some serious and unexpected disadvantages of the digital MCA when it operates under certain circumstances, one of them having to do with the automatic tuning of live-time correction at low-input counting rates.

Key words: digital multichannel analyzer, digital spectrometer, live-time corrector, pile-up rejector

INTRODUCTION

We have carried out detailed experimental tests of a digital spectrum analyzer in order to measure some subtle effects of radioactive decays [1]. The gamma spectrometer used in this experiment consists of a Schlumberger HPGe (efficiency 15%, resolution 2.1 keV) and a Canberra digital MCA, model DSA-1000. This digital multichannel analyzer (MCA) has a complete chain of devices: a high voltage power supply, amplifier, analog-to-digital converter (ADC), digital oscilloscope, and a spectrum stabilizer. The DSA-1000 is supplied with excellent software packages for spectra analyzing, "Genie 2000 Basic Spectroscopy Software". It also has an option for manual adjustment of the optimum measurement parameters of pulse shaping [2].

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RESULTS AND DISCUSSION

The DSA-1000 has an integrated circuit for spectrum stabilization. An amplification correction which recovers spectrum stability is automatically created at the spectrum shift. The proper functioning of spectrum stabilization assumes having a pronounced peak with respect to which the spectrum may be stabilized [2].

On the left and right of the peak's Gaussian (fig. 1), there are defined windows whose loading rate differences generate a pulse which corrects the applied amplification during the course of measurements.
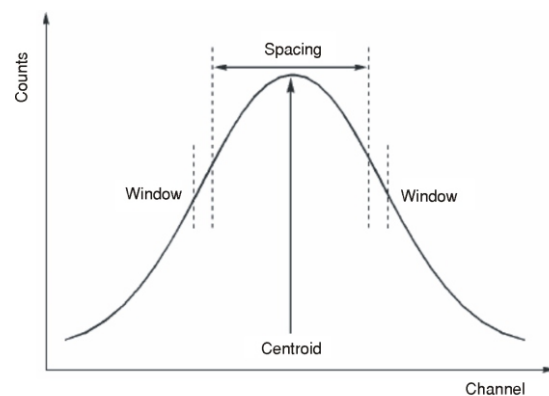

Figure 1. Tuning the spectrum stabilization functions

The windows should be centred in the area of the inflection points of the Gaussian, because the highest change in the loading rate difference of the windows occurs during the peak shift. The width of the windows should be chosen with respect to the width of the peak. Spectral stabilization tuning is maintained by software. The appearance of a typical tuning window is shown in fig. 2.
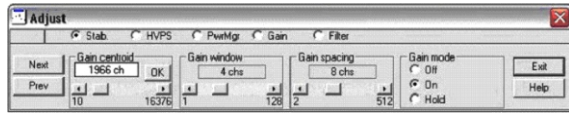

Figure 2. Window of a spectrum stabilization tuner

We have set the centroid of the stabilizer at the peak of gold, ^{198}Au, at 411.8 keV with ~800 cps (counts per second) in the net peak area and this has provided fascinating spectrum stabilization. All spectra have been recorded in 10 000 seconds of real pre-set time and a typical set of stabilized centroids is presented in tab. 1.

Table 1. Typical set of centroids (given in channels) of gold, ^{198}Au, 411.8 keV peak after spectrum stabilization, over a week of measurements

Number of recorded peaks	Centroids of the peaks [channel]
1	1965.433
2	1965.436
3	1965.436
4	1965.432
5	1965.431
6	1965.439
7	1965.428
8	1965.435
9	1965.427
10	1965.436
11	1965.431
12	1965.430
13	1965.424

During the course of measurements, the spectrum shifts amounted to several thousandths of a channel. This provides excellent long-term spectrum stabilization. The primary aim of our investigations was the optimization of the sum peak method. We used cobalt, ^{60}Co, sources of different activities and measured the detection efficiencies of their two peaks. A serious fault in the functioning of DSA-1000 was observed. Namely, a decrease of detection efficiencies for low-activity sources (fig. 3). An increase of the efficiency ratio of the two cobalt peaks (1173/1332) for low-activity sources has also been observed. We have used an ORTEC MCA 916 to check the said malfunctioning of the DSA-1000. These investigations are presented in fig. 3.
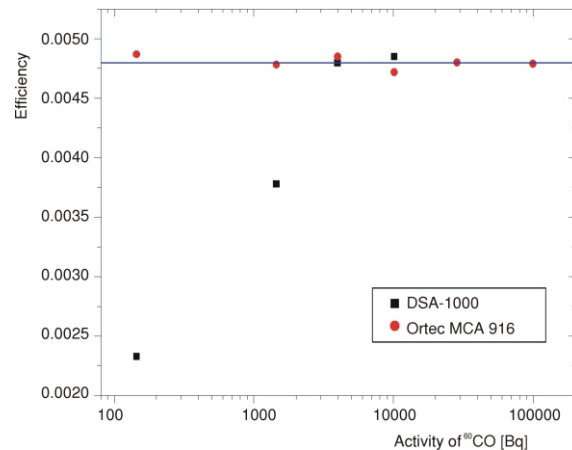

Figure 3. Dependence of detection efficiency of the 1173 keV peak on the activity of cobalt, ^{60}Co

For further examination of the said fault of the DSA-1000, we chose a single cobalt source and measured the ratio of its two peaks and in a very wide range varied the incoming counting rate (ICR) by a ^{137}Cs source. The result of this measurement was the most surprising one. Namely, there was no dependence of the ratio of the two peaks on the ICR. It seems that the ratio of the two peaks does not depend on the total ICR, but only on the ICR which comes from cobalt. Even the recommendation of the manufacturer for using the live-time trim (LT trim) has not given better results [2].

The most critical point in our measurements was the process of pile-up rejection (PUR) and the involved mechanism of live-time correction (LTC). We have found that the PUR-LTC mechanism is responsible for the fault of the DSA-1000. Namely, if we turn of the PUR-LTC mechanism, measurement results become much better. The possibility of recording only the pulses which have not experienced the pile-up is fascinating. In that case, the PUR mechanism could be used as a tool to attain spectra cleaning and an increase in spectral resolution. However, in practice, this would be very hard to achieve.

The main function of the LTC is to eliminate the dependence of the counting rate on the total ICR in the net peak area. There are several ways of accounting for this correction occurring during the course of our measurements. The digital spectrum analyzer which we have been dealing with has an integrated circuit for parallel pulse processing (fast branch) with an extremely short-shaping constant. The role of this branch is to determine which pulses in the slow branch have been experiencing the pile-up and to calculate the time correction lost during the processing of piled-up pulses.

We made the decision to vary the fast discriminator threshold manually. It seems that we have touched the root of the pile-up problem by doing so. The role of the fast discriminator threshold is to al-

low for pile-up analyses only for pulses with amplitudes exceeding this threshold level. Figs. 4 and 5 represent the detection efficiencies of the two cobalt peaks at different values of the fast discriminator's threshold levels. It is perfectly clear that decrease of the fast discriminator threshold level causes an increase in the pile-up rejection criterion which affects the decrease of recorded pulses (at the moment of live-time measurements). Figures 4 and 5 show that, as the efficiency decreases, there is a decrease of the fast discriminator's threshold level, as well. However, if the PUR works properly, all the points on the graphic (fig. 5) should be arranged along the line which assures a constant ratio of the two cobalt peaks. On the other hand, if the LTC works entirely properly, then the acquisition time should be corrected on the piled-up pulses and all these points should cumulate in one point (the cumulating point on the graphic).

We have concluded that the automatic regulation of the fast discriminator's threshold level varies in a mysterious fashion over a range of 10% to 15%, depending on the counting rate in cobalt peaks resulting
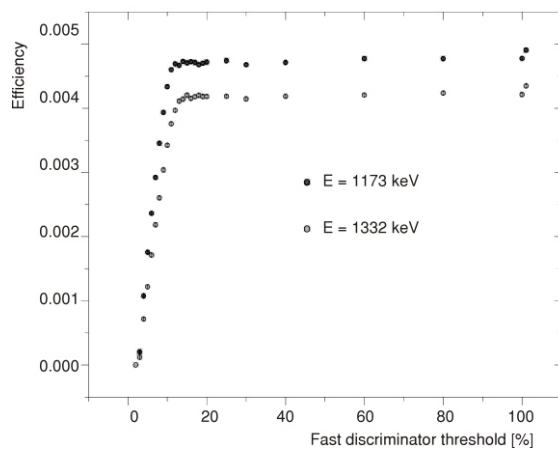
from the changes of detection efficiency and detection efficiency ratio of the two cobalt peaks. Namely, the fast discriminator's threshold level should be set above the noise level. Actually, this is what the fast discriminator mechanism is probably trying to do. It is quite clear that the automatic of the DSA-1000 recognizes the noise level on the basis of the distribution of the pulses, meaning that these pulses depend on the counting rate. It seems that the fast discriminator's threshold tuning mechanism of the DSA-1000 has set the amplitude interval of the processed pulses inside which it determines the counting rate on the basis which it tunes the discrimination threshold.

This malfunction of the automatic tuning of the parameters of the PUR-LTC could cause some serious errors in the evaluation of low-activity sources. In order to escape said problems with the automatic tuning of the fast discriminator threshold level, we have decided to set this level manually to 13% after which we have obtained satisfactory results in a very wide range of the counting rate.

CONCLUSIONS

We have found extraordinary spectrum stabilization features of the DSA-1000 in long-term measurements. Along with this feature, we have found a disappointing feature of the automatic tuning of PUR-LTC parameters which could cause fatal errors in the evaluation of low activities. Manual tuning of the PUR-LTC parameters gives satisfactory results in a very wide range of applications.

REFERENCES

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[2]   ***, DSA-1000 Digital Spectrum Analyzer, Hardware Manual, Canberra Industries, Inc., Meriden, Conn., USA, 2001

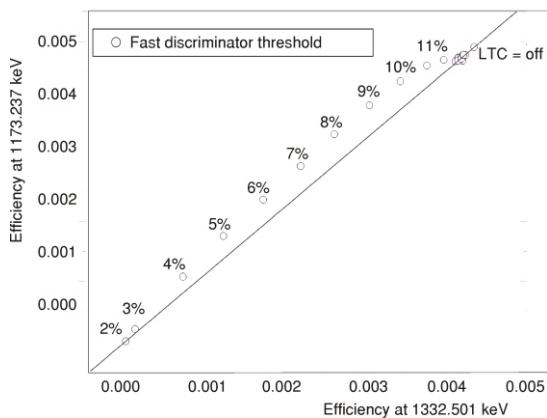**Figure 4. Dependence of detection efficiency on the manually tuned, fast-discrimination threshold**

Figure 5. Dependence of the efficiencies of the two cobalt, ^{60}Co, peaks on the manually tuned, fast discrimination threshold

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ЕКСПЕРИМЕНТАЛНА ПРОВЕРА ДИГИТАЛНОГ ВИШЕКАНАЛНОГ АНАЛИЗАТОРА ЗА ГАМАСПЕКТРОМЕТРИЈСКА МЕРЕЊА

Приказани су резултати експерименталне провере рада дигиталног вишеканалног анализатора који дигитализује сигнал на излазу из претпојачавача. За различите брзине бројања и различите радиоактивне изворе, снимане су карактеристике спектрометра који садржи дигитални вишеканални анализатор: ефикасност у пику, однос нето површина одговарајућих пикова и стабилност положаја пика. Показано је да тестирани анализатор има неке изванредне карактеристике, као што су дуговременска стабилност положаја пика и флексибилност у подешавању оптималних услова мерења. Међутим, резултати су указали и на постојање озбиљних и неочекиваних непоузданости у раду анализатора, на пример, код аутоматског подешавања "live-time" корекције при ниским улазним брзинама бројања.

*Кључне речи: дигитални вишеканални анализатор, дигитални спектрометар, "live-time"
корекција, "pile-up rejector"*