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Testing Experiments of a Digital Signal Processing System for a High Count Rates Gamma-ray Detection

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1. Introduction

In order to determine an activity accurately from a radioactive source, the dead time and uncertainty in the number of counts should be identified. Live time clock has been used as the most common method to compensate for a dead time in MCA. However, the live time extension mode is only accurate if the activity of the source is constant during a measurement period. In the measurement of short-lived nuclides, it induces a significant systematic uncertainty. Therefore, ORTEC introduced the DSPEC^{PLUSTM} with a loss-free counting method called a "zero dead time counting"[1,2].

In this study, comparison experiments between conventional and digital signal processing systems (DSPEC^{PLUSTM}) were firstly performed in terms of count rates with a variation of the dead time. And performance tests by using a live time extension mode and a zero dead time mode in the DSPEC^{PLUSTM} were executed to reveal whether the difference in count rates is significant during the measurement of short-lived nuclides. Finally, to demonstrate its applicability in NAA, some elements in actual samples were determined by using two modes in the DSPEC^{PLUSTM} system.

2. Experimental

2.1 Comparison between Conventional and Digital Signal Processing System (DSPEC^{PLUSTM})

To compare the DSPEC^{PLUSTM} with a conventional signal processing system, an MCA which consisted of a 672 amplifier and 919A MCB was used. To process an input signal under the same condition, the shaping time of the 672 amplifier and the rise time of the DSPEC^{PLUSTM} were set to 6 μs and 12 μs following the instructions of the ORTEC. Eu-152 source(half-life : 13.33 y) was measured according to a variation of the dead time. Al and Ti wire were irradiated using the NAA #1 irradiation hole for a few seconds. Al-28(half-life : 2.24 min.) and Ti-51(half-life : 5.76 min.) nuclides were measured with changes of the dead time.

2.2. Testing Experiments of DSPEC^{PLUSTM}

Al-28 nuclide could be produced by an irradiation of an Al wire and successively measured for 60s. Dead time varied from 82 % to 2.3 % and the count rates were determined using the live time extension mode and the zero dead time mode. NIST SRM 1575a-Pine Needle and 2586-Soil were chosen as actual samples to demonstrate its applicability in NAA. 100 mg of samples were irradiated for 10 s using the NAA#1 irradiation hole. Al monitors were co-irradiated for a correction of the neutron flux. Gamma-ray measurement was carried out by using a high purity Ge detector of a 20% relative efficiency and 1.85keV resolution(FWHM) at 1332 keV of ^{60}Co, coupled to DSPEC^{PLUSTM} and a personal computer. Each spectrum collected was interpreted and the elemental concentration in the samples was calculated by an absolute method using nuclear data[3,4].

3. Results and Discussion

3.1 Comparison of the Count Rates with Two Systems

Count rates were compared with the changes of the dead time using the Eu-152 source. This result is shown in Table 1. The ratio of the count rates were calculated with gamma-ray energies. The biggest difference between the conventional and DSPEC^{PLUSTM} was found at 1408 keV of a 48% dead time.

Table 1. Ratio of count rate according to dead time

Dead time (%)	Live time(s)	Ratio of count rate (DSEPC/conventional system)				
		122 keV	344 keV	778 keV	964 keV	1408 keV
12	500	1.010	1.014	1.016	1.032	1.033
20	180	1.005	1.021	1.041	1.028	1.047
48	180	1.019	1.037	1.046	1.045	1.053

The measurement results of the Al-28 and Ti-51 nuclides according to the dead time are summarized in Figure 1 and 2. The slope of fitted line means a decay constant of the measured nuclide. The dead time of Al-28 varied from 70 % to 5%. The biggest difference was found at the highest dead time. The estimated half life values by the conventional and DSPEC systems were 2.42 min and 2.28 min., respectively and the relative errors compared to the literature value were 9.3% and 1.8%, respectively. For the Ti-51 nuclide, the same trend was observed as Al-28. In the measurement of Ti-51, the dead time varied from 80 % to 9% in accordance with the decay of Ti-51. The estimated half life values by the conventional and DSPEC systems were 5.89 min and 5.80 min., respectively and the relative errors compared to the literature value were 2.3% and 0.7%, respectively. From these results, the DSPEC system is able to perform a more accurate measurement, especially for short-lived nuclides, than the conventional system.

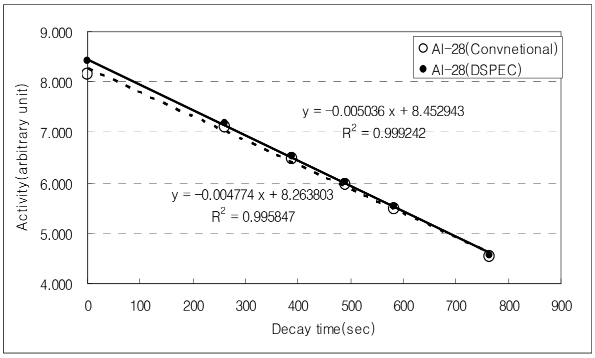

Figure 1. Measurement results of Al-28 according to the changes of dead time using conventional and DSPEC system.

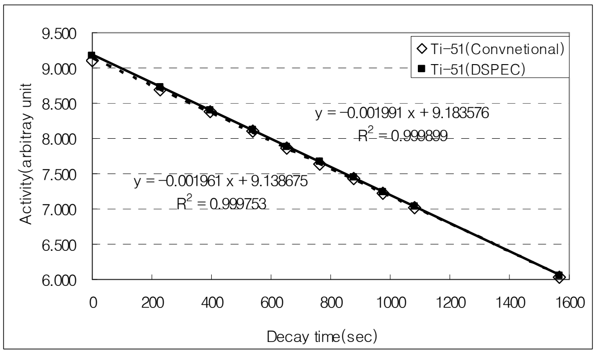

Figure 2. Measurement results of Ti-51 according to the changes of dead time using conventional and DSPEC system.

3.2 Test Results of DSPEC ^{PLUSTM}

The count rates of the Al-28 nuclide were determined using the live time extension mode and the zero dead time mode in DSPEC ^{PLUSTM}. The result is shown in Figure 3. The estimated half life values by the two modes were 2.22 min and 2.20 min., respectively and the relative errors compared to the literature value were 0.8% and 1.8%, respectively.

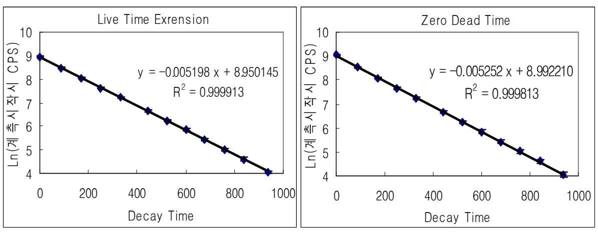

Figure 3. Measurement results of Al-28 according to the changes of dead time using live time extension mode and zero dead time mode in DSPEC system.

NIST SRM 1575a-Pine Needle and 2586-Soil were analyzed to demonstrate the applicability of DSPEC ^{PLUSTM} in NAA and compared to the results by the calculation and interpretation of the spectra collected from the live time extension mode and the zero dead time mode. The dead times for the measurement of the irradiated samples were above 30%. Five elements such as Al, Ca, Cl, Mg and Mn in the Pine Needle samples and nine elements such as Al, Ba, Ca, Dy, Mg, Mn, Na, Ti and V in the Soil samples were determined. The analytical results are shown in Tables 2 and 3. In Table 2, the values by the zero dead time mode are closer to the certified values than those by the live time extension mode. Al concentration has the biggest difference between the two modes. The analytical results of NIST SRM 2586-Soil have a good agreement with the certified values and the relative errors are within 5% except for Ca.

Table 2. Analytical results of NIST SRM 1575a-Pine Needle

Element	Certified value			Live Time Extension			Zero Dead Time		
				Mean	±	SD	Mean	±	SD
Al	580	±	30	446	±	13	536	±	19
Ca	2500	±	100	2004	±	87	2125	±	88
Cl	421	±	7	367	±	11	380	±	13
Mg	1060	±	170	800	±	101	840	±	113
Mn	488	±	12	407	±	13	412	±	14

Table 3. Analytical results of NIST SRM 2586-Soil

Element	Certified Value			Live Time Extension			Zero Dead Time		
				Mean	±	SD	Mean	±	SD
Al	66520	±	760	63690	±	1942	66433	±	1759
Ba	413	±	18	407	±	26	409	±	11
Ca	22180	±	540	19705	±	838	19988	±	810
Dy	(5.4)			5.96	±	0.24	6.02	±	0.23
Mg	17070	±	840	15720	±	746	15680	±	1080
Mn	1000	±	18	936	±	33	939	±	29
Na	4680	±	730	4741	±	201	4764	±	188
Ti	6050	±	660	6436	±	153	6498	±	167
V	(160)			158	±	6	159	±	7

4. Conclusion

To demonstrate the applicability of DSPEC ^{PLUSTM} in NAA, test experiments were carried out. In comparison with the conventional mode, a significant count rate difference was found for the short-lived nuclide, Al-28. Comparison experiments between the live time extension mode and the zero dead time mode in DSPEC ^{PLUSTM} were performed. The difference of the count rates at a high dead time (80%) is about 5%. Zero dead time mode revealed a better results than the live time extension mode for the analysis of the short-lived nuclides as well.

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