NEW POSSIBILITIES OF ROOM TEMPERATURE SEMICONDUCTOR DETECTORS WITH USING OF A MODERN PULSE PROCESSING METHOD

V. Ivanov, A. Loutchanski, V. Garbusin, P. Dorogov
RITEC Ltd., P. O. Box. 25, LV-1015 Riga, Latvia,
R. Arlt
IAEA, Wagramerstrasse 5, P. O. Box 100, A-1400 Vienna, Austria

SUMMARY

For safeguards and other applications a reliable, portable apparatus having high spectrometric characteristics is needed. Examples are:

1) measurement of gamma spectra to determine initial enrichment in fresh fuel assemblies;

2) measurement of gamma spectra and gamma profiles from spent fuel assemblies to verify the presence of irradiated nuclear material, radiating monitoring;

3) recording of gamma spectra to verify presence of un-irradiated plutonium and un-irradiated enriched uranium;

4) measurement of gamma spectra to determine enrichment of fuel mixtures at different stages of the fuel cycle;

5) underwater verification of MOX fuel assemblies.

Large area planar detectors (CdTe, HgI_2, CdZnTe) can be used but they have the disadvantage of poor spectral performance. The development of the electronic processing methods allows, however, to solve these problems.

A new pulse shape correction method combined with a pulse shape selection method provides a significant spectrometric characteristic improvement of planar room temperature semiconductor detectors [1]. An energy resolution and peak-to-Compton ratio may be improve without decreasing or with increasing of registration efficiency in a total absorption peak. The capability of the new technique for the spectrometric characteristic improvement is based on the use of specific features of the detector output pulses.

We developed, fabricated and tested two types of devices using correction and correction-selection modes. Application of these devices with different wide-band semiconductors detectors, such as CdTe, HgI_2 and CdZnTe show a significant improvement of spectrometric characteristics within a wide range of an energy registrated.

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PULSE PROCESSING TECHNIQUE.

We developed, fabricated and tested several versions of the correction and selection schemes based on the methods suggested [1].

A simplified block schematic of the simplest version of the correction scheme is shown in Fig.1. It represents an electronic key controlled by a logical scheme. In normal state the key is closed. The logical scheme preassigns a key unlocking time counted relative to the arrival of time control signal. The pulses from the count rate meter (CRM) output of the shaping amplifier are usually used as control signals. The key unlocking time is adjusted by the resistor R_t and chosen individually for each detector and each shaping time.

For convenient application, we developed and fabricated the correction unit made as a single chip - Pulse Correction Scheme (PCS). This scheme is easily introduced into each standard shaping amplifier. We had introduced PCS into CANBERRA 2024 spectroscopy amplifier. A small size pulse correction unit which may be connected with each spectroscopy amplifier was done too.

To obtain a combined effect of the correction and selection, we developed a special correction-selection pulse processing unit. Corrected pulses may further be subjected to the selection in this unit. For selection are using signals from gate integrator output.

The correction-selection pulse processing unit may be used in combination with any shaping amplifier with CRM output. There is the possibility to use this unit only in correction or selection regime or in correction mode with additional selection.

We made a pulse correction-selection processing unit in a two wide NIM module design.

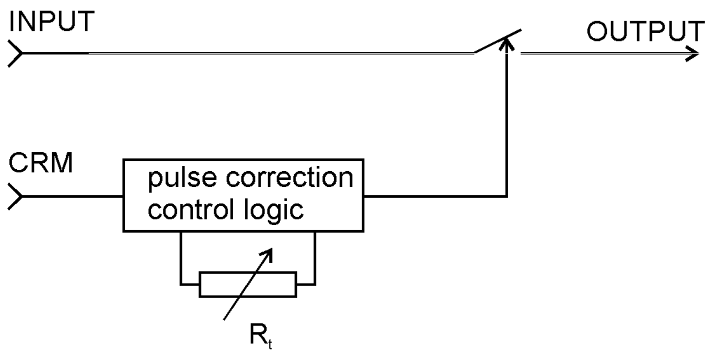

Fig. 1 - Simplified block schematic of a correction scheme.

EXPERIMENTAL RESULTS

Different room temperature detectors were tested with application of a pulse correction-selection processing unit.

CdTe Detector

Spectrum of Cs-137 obtained by means of detection unit (produced by EURORAD, France) with CdTe detector with size 5x5x2 mm^3 using a pulse correction-selection processing unit is presented in Fig.2. Spectrum was registered by using a shaping amplifier ORTEC 572. Initial energy resolution (FWHM) of a CdTe detection unit was 25 keV at 662 keV. It is seen that the application of a single gated integrator gives only a small improvement of detector spectrometric characteristics. The correction significantly improves both the energy resolution up to 10.2 keV, peak-to-Compton ratio up to 2.4 and increases the registration efficiency in the total absorption peak approximately in three times. The selection application improves still further the energy resolution up to 9 keV, peak-to-Compton ratio up to 5.1 with reduction of the registration efficiency in the total absorption peak by two times. The best energy resolution with CdTe detection unit and application of pulse processing unit was about 6.5 keV at 662 keV.

A possibility of smooth adjustment of a selection level allows the user to choose an operation mode with the maximal registration effectiveness in the total absorption peak or an operation mode with the greatest energy resolution when the registration effectiveness is reduced.

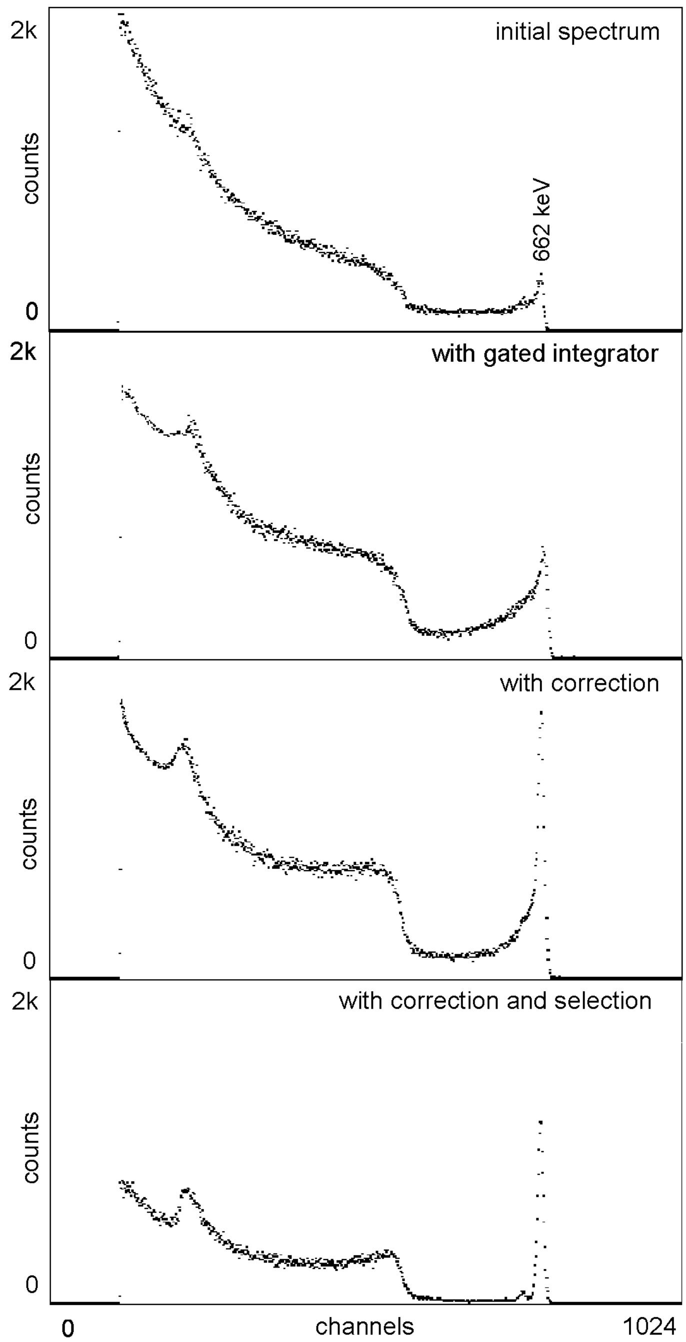

Fig. 2 - Spectrum of Cs-137. Planar CdTe detector, size 5x5x2 mm^3. Time of measurement is the same for all cases.

HgI_2 Detector

We performed tests of the pulse processing unit with high area HgI_2 detector with size 20x20x2 mm^3. We found a considerable improvement of the spectrometric characteristics for 662 keV line too. The initial energy resolution (FWHM) was about 33 keV with peak-to-Compton ratio less than 1. The energy resolution 8.5 keV at 662 was obtained with using of pulse processing unit. The correction-selection unit improves considerably the spectrometric characteristics within a wide range of an energy registered. Spectra of Co-57, Ba-133 and Co-60 are shown in Fig.3.

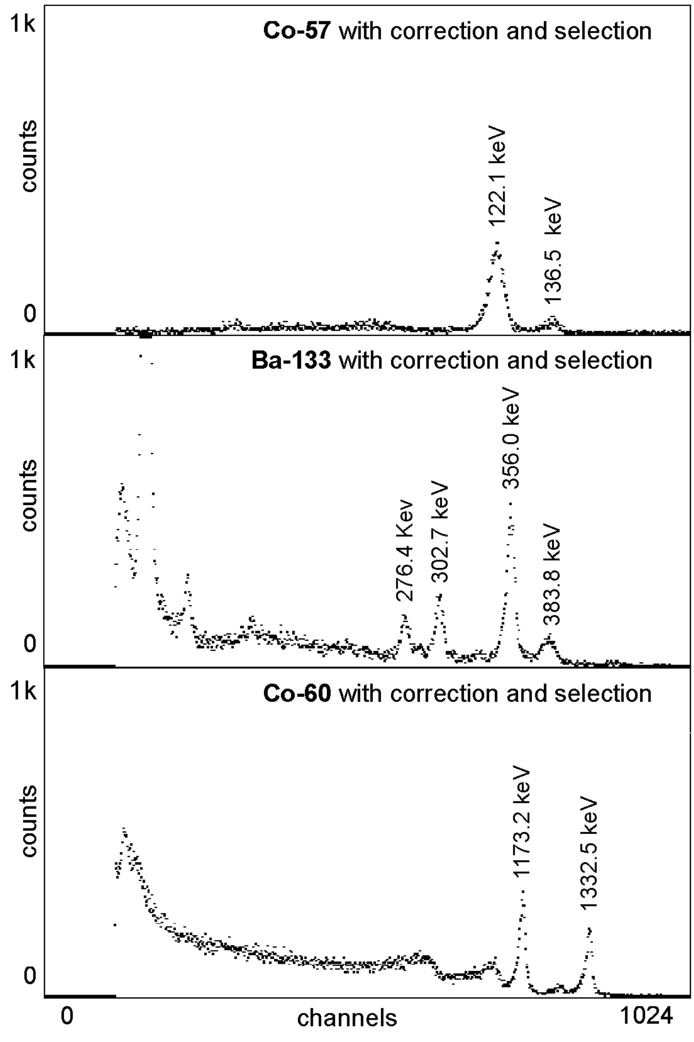

Fig. 3 - Spectra of Co-57, Ba-133 and Co-60. Planar HgI2 detector, size 20x20x2 mm^3.

CdZnTe Detectors

We performed tests of the pulse processing unit with CdZnTe detectors with different sizes. This detectors are produced by eV PRODUCTS, USA. A considerable improvement of the spectrometric characteristics within a wide range of an energy registrated was obtained too. Complicated spectrum of Ba-133, Cs-137 and Co-60 registrated by CdZnTe detector with size 10x10x4 mm^3 are shown in Fig.4. Is possible to see an improving of a peak-to-Compton ratio for lower energies lines with presence of higher energies. In Fig.5. is shown spectrum of Cs-137 registrated by large volume CdZnTe detector with size 15x15x5 mm^3.

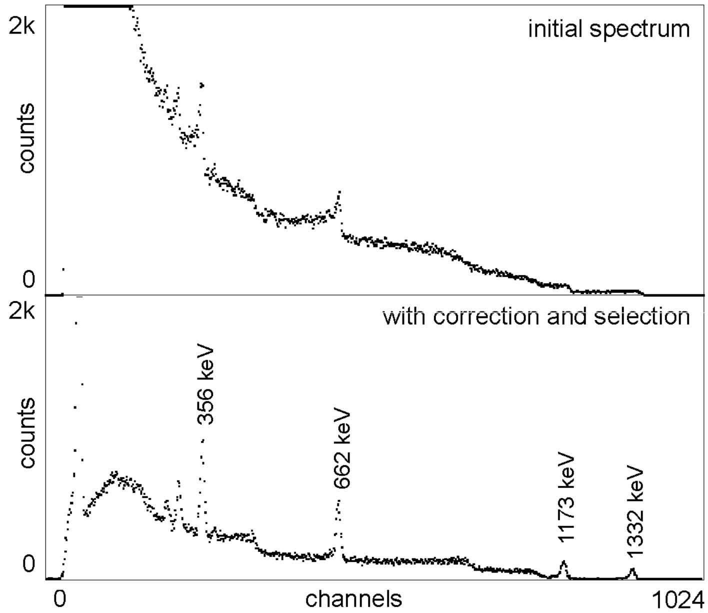

Fig. 4 - Complicated spectrum of Ba-133, Cs-137 and Co-60. Planar CdZnTe detector, size 10x10x2 mm^3.

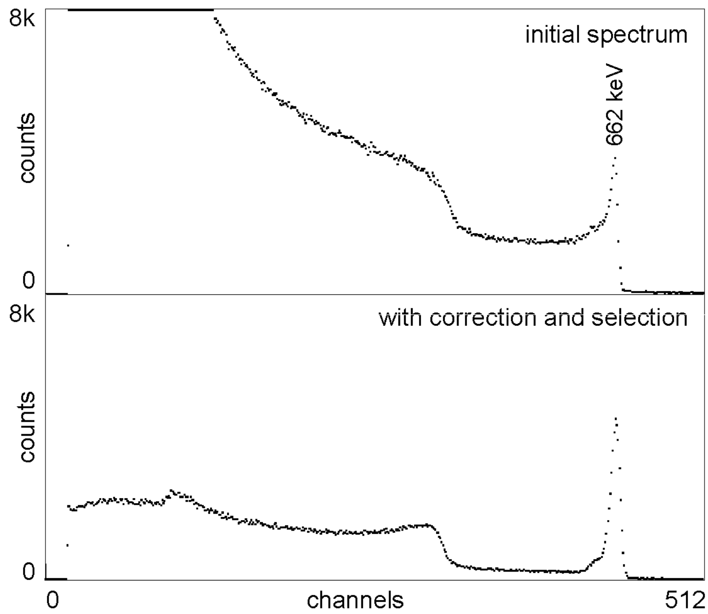

Fig. 5 - Spectrum of Cs-137. Planar CdZnTe detector, size 15x15x5 mm^3.

CdTe P-i-N Detector

Notwithstanding the fact that cooled CdTe detectors with P-I-N structure possess the highest energy resolution. But there are some CdTe P-i-N detectors with rather bad registrated spectrum shape, as a result of unhomogenious charge collection. The application of the pulse correction-selection processing unit allows to improve spectrometric performance of such detectors. The energy resolution of 2.9 keV at 662 keV with peak-to-Compton ratio 7.2 was obtained with CdTe P-i-N detector (size 4x4x0.5 mm^3) and with application of pulse processing unit in correction mode, Fig.6. Application pulse processing unit in correction and selection mode allows slightly improve energy resolution up to 2.8 keV.

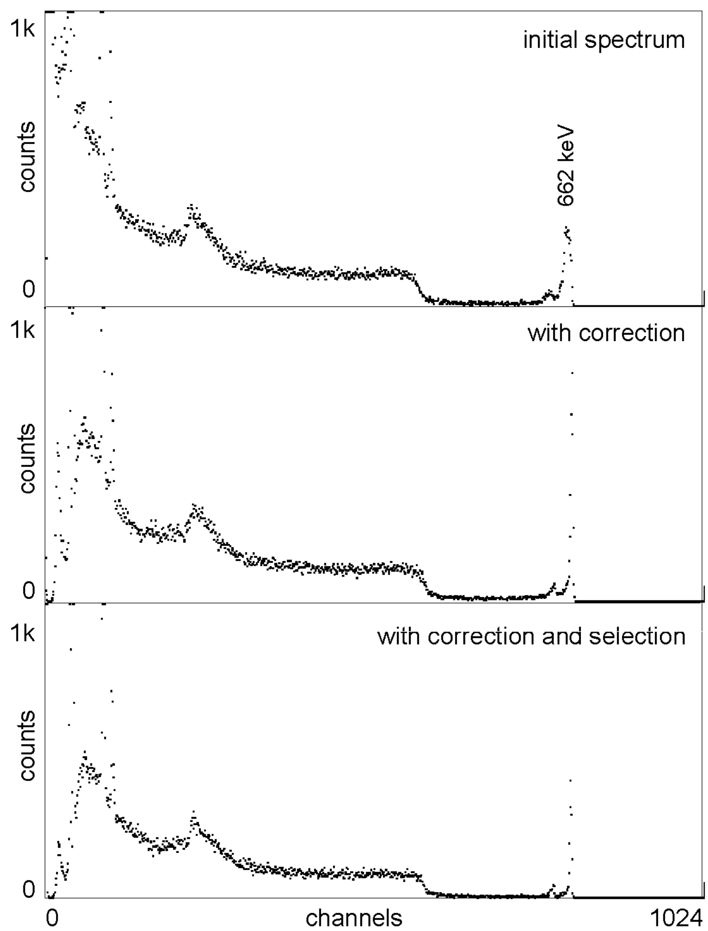

Fig. 6. Spectrum of Cs-137. CdTe P-I-N detector, size 4x4x0.5 mm^3.

SPENT FUEL SPECTRA REGISTRATION

The spent fuel spectra with using of pulse correction-selection unit were registrated by CdTe detector. Measurements were done at the Latvian Nuclear Research Center. The spent fuel is a nuclear research reactor spent fuel assemblies with burnup - about 50%. The spent fuel are stored under water in a spent fuel storage pond. Detection unit was placed for measurements within a dry tube.

Spectra of the spent fuel assemblies with cooling time 1400 days and 120 days are shown on Fig.7, 8. For comparison the same spectra but registrated with the ordinary techniques - detection unit with a hemispherical CdTe detector and with a gaussian shaping amplifier are shown. The preference of a detection unit with a planar CdTe detector working with pulse correction-selection processing unit can see.

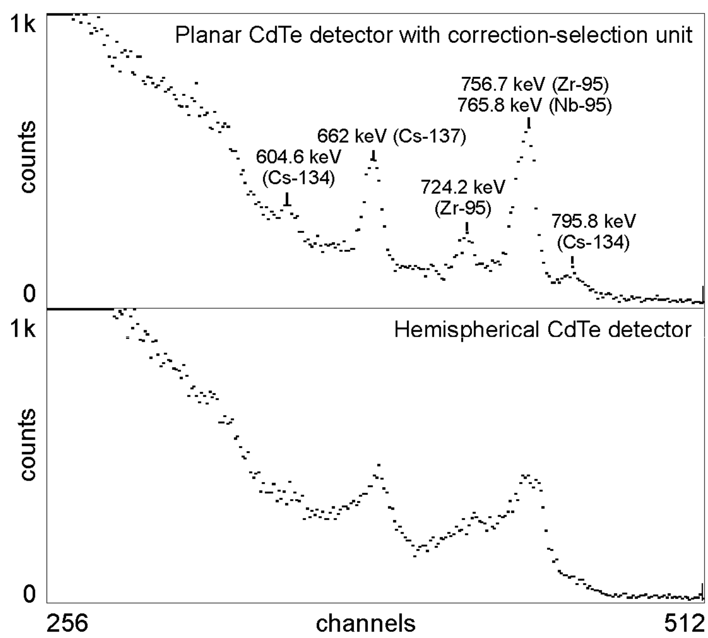

Fig. 7 - Spent fuel spectrum. Cooling time 120 days.

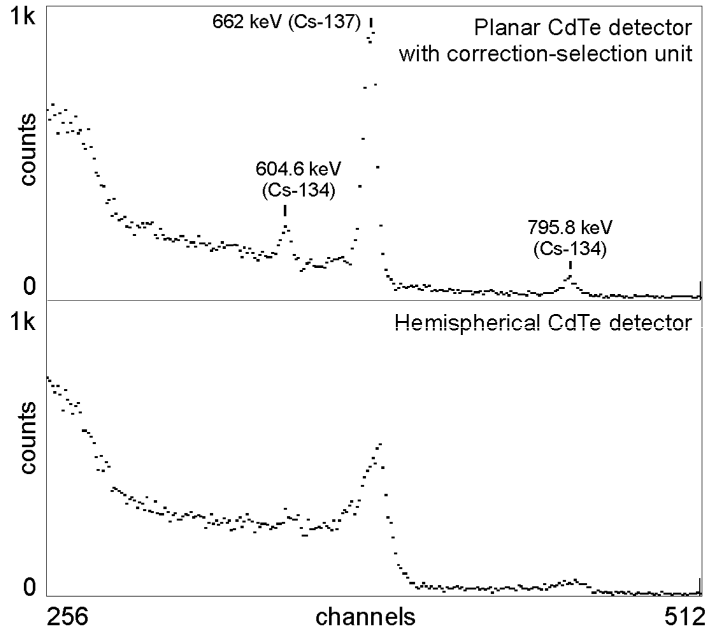

Fig. 8 - Spent fuel spectrum. Cooling time 1400 days.

CONCLUSIONS

Application of pulse processing unit suggested allows to improve spectrometric performance of all room temperature semiconductor detectors which were tested.

Spectrometric performance of different type wide-band semiconductor detectors with using of pulse shape correction-selection processing unit allows to use this detector type for safeguards applications.

The further result of development a small and portable detection probe can also be used in differ fields like health physics, radiation protection, medicine and the detection of illegal nuclear trafficking.

[1] V.I.Ivanov, V.A.Garbusin, P.G.Dorogov et al., "Spectrometric Characteristic Improvement of CdTe Detectors", will be published in *IEEE Transaction on Nuclear Science*, vol. 42.,no.4., August 1995.