Comparative Testing of the MCA-527 and MCA-166 Mini Multi Channel Analysers

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Abstract:

This paper presents a comparative study of the two multichannel analysers MCA-166 and its successor the MCA-527 from GBS electronic with the focus of the operation at high counting rates. The MCA-166 is widely used by the IAEA and Euratom for safeguards inspections in the field. The performed tests included the influence of peak shaping parameters, count rate and temperature on the operation of the two multichannel analysers.

Keywords: Gamma measurement, Multichannel analyzer, comparative study

1. Introduction

In recent years the pulse height analysis of signals from all kinds of gamma detectors has largely shifted from analogue to digital electronics. Digital multichannel analysers promise better stability due to less analogue components with varying tolerances, lower dead time, and increased throughput because of digital signal processing and thus improved performance. The MCA-527 from GBS Elektronik is such a digital multichannel analyser and the successor of the widely deployed and successful MCA-166. In addition to a completely new and modern architecture, it features many minor improvements.

Under the German support program to the IAEA, Fraunhofer INT has conducted comparative performance tests with these two multichannel analysers in order to access the differences and similarities. These include the stability of gamma peak parameters as function of input count rate, time, and ambient temperature. Special attention was put to the performance under high count rate conditions. At Forschungszentrum Jülich, supplementary comparative testing was performed on LN-cooled HPGe detectors, these results will be presented elsewhere. Further tests included the performance of the multichannel scaling and multispectrum scaling modes and the non-linearity of the two MCAs. In a last test series, the influence of electromagnetic radiation on the operation of the MCA-527 and the effect on the recorded spectrum was examined. Performance test of these MCAs have been performed before [1,2], but these measurements were aimed especially for a comparative testing of both MCAs and especially under high count rate conditions.

2. Description of performed measurements

For the measurement at the Fraunhofer INT, the equipment was provided by the IAEA. This included one MCA-166 and one MCA-527, NaI and LaBr scintillation detectors, two different CZT semiconductor detectors, two laptops with the WinSpec software, as well as necessary accessories like a serial to USB converter. For the tests, radioactive sources of ^{60}Co (up to 380 MBq), ^{137}Cs (up to 1 GBq), ^{133}Ba (1 MBq) and ^{152}Eu (1 MBq) were available at Fraunhofer INT. With the two strong sources of ^{60}Co and ^{137}Cs count rates in the range of 10,000 to 200,000 cps were achievable. This allowed investigating the effect of different count rates on the performance of both MCAs and comparing the observations.

The performed tests included the influence of the count rates and peak shape parameters on the peak resolution, the influence of count rate, temperature, and time on the peak channel stability, measurements of the integral and differential nonlinearity, and the performance of the multichannel and multispectral scaling depending on the input count rate. Additionally, the battery performance at different environmental temperatures, the stability of the high voltage supply and the timing accuracy were compared. For the MCA-527 the possible effects of electromagnetic interferences on MCA operations were evaluated.

For the measurement of temperature effects, a small environmental chamber with forced air circulation was used. It allows changing the temperature according to a predetermined profile with fixed ramps and holding times. Both MCAs were placed inside the chamber at the same time to optimally utilize the measurement time. The temperature within the climate environmental chamber and at the surfaces of the MCAs was recorded by PT 100 sensors every 5 seconds. During these tests, only the MCAs were subjected to the varying temperatures, the source and detectors were placed outside the chamber and signals were routed to the MCAs by feedthroughs.

The electromagnetic influence tests were carried out in a TEM waveguide with fields of 10 V/m in the frequency range from 80 MHz to 1 GHz, with 3 V/m from 1.4 GHz to 2 GHz and with 1 V/m from 2 GHz to 2.7 GHz. Several distinct frequencies used for wireless communication were tested with 30 V/m. The MCA-527 was placed in the waveguide, along with the LaBr detector and all cabling. In order to avoid data transmission disturbances caused by malfunction due to RF, the connection to the laptop was via USB-to-fiber-optics-converters. During these tests, a small ^{60}Co source was used, in order to have the MCA to record a real spectrum with sufficient count rate in the order of 1000 cps. The WinSpec software was used in automatic measurement mode to record one spectrum every 10 seconds. While the frequency was ramped in the waveguide, this spectrum was observed by the operator and a possible deviation from the intended operation would have been recorded by him. These tests were performed in two orientations, with the E-Field in parallel and perpendicular to the cable harness, respectively.

During the course of these tests, more than 45,000 spectrum files have been recorded. In order to handle this large amount of data, a set of python scripts have been written and used to semi-automatically extract the relevant information. Both MCAs performed very well without any outage during the complete measurement campaign.

Comparative tests of the MCA-166 and the MCA-527 were performed with a High Purity Ge-Detector (Canberra Detector GL 0515R) at Forschungszentrum Jülich using a Ra-226 and a Am-241 source. For the MCA-527 digital pulse processing settings (Shaping Time, Flat Top, Trigger Filter, Base Line Restorer, Coarse/Fine Gain) were evaluated to find the optimal combination with respect to resolution and peak stability in the 0-300 keV energy window. These optimal settings were used to compare the performance with the MCA-166 for different count rates ranging from below 5,000 to a maximum count rate of approximately 125,000 cps. For each count rate 20 spectra with 300s live time were acquired. The peaks selected for evaluation where the gamma peak at 59 keV for Am-241 and 186 keV for Ra-226.

2.1 The two multichannel analysers MCA-166 and MCA-527

Figure 1: The two multichannel analysers under test, to the left, the analogue MCA-166, to the right the digital successor MCA-527. Both devices have roughly the same size.

The two multichannel analysers are both compact, battery powered devices, which integrate in addition to the multichannel analyser, a preamplifier power supply, a high voltage modules and the main amplifier. Together with a detector and a laptop, they form a complete detection system. The MCA-166 is now obsolete, because some of its electronic components are no longer available. Thus GBS Elektronik developed the MCA-527 as its successor, with similar features and some improvements.

	MCA-166	**MCA-527**
Technology	Analog	Digital, 14 bit ADC, 10 MSps
Channels	Max. 4k	Max. 16k
Main Amplifier	Gaussian shaping amplifier	Corse Amp. With 5 gains
Pulse Shaping	Shaping Time 1 and 2 µs Pile up rejection	Shaping Time 0.1 .. 25 µs Flat Top Time 0 .. 5 µs
Battery	Li-Ion, 32 Wh	Li-Ion, 10-25 h
Size	155 mm x 95 mm x 45 mm	164 mm x 111 mm x 45 mm
Weight	700 g	820 g
Environment	0°C … +50°C	-20°C … + 60°C
Temp. class	TK 100 (ADC), TK500 (Amp)	TK50
Interface	RS-232 (USB)	Ethernet, USB, RS-232

Table 1: Comparison of technical features the MCA-166 and the MCA-527. Information taken from the manual [3,4].

3. Results of the tests

In the following, we will present some exemplary results from the whole measurement campaign. These are data from the influence of the count rate and the peak shaping parameters on the recorded peak width and peak position for one combination of MCA and detector, the outcome of peak parameter dependence on the temperature and the results of the electromagnetic influence tests.

3.1. Influence of count rate and peak shaping parameters on peak parameters

One major difference between the MCA-166 and the MCA-527 is the implementation of the peak shape parameters. The MCA-166 only has two settings for the shaping time, 1 µs and 2 µs, respectively and in addition one can enable or disable the pile up rejection. This leaves exactly four different combinations for the peak shaping parameters, which were all used in these tests. The MCA527 on the other hand offers to set the shaping time and the flat-top time of its digital input filter. The shaping time is adjustable from 0.1 µs to 25 µs in 0.1 µs steps, the flat top time from 0 µs to 5 µs in 0.1 µs steps. Here, we used the parameters as supplied by the IAEA as a starting point and from these adjusted either the shaping time or the flat top time, but not both at the same time.

For each parameter set, the distance from the source to the detector was adjusted, so that a specific count rate was recorded. Five to seven different count rates were measured and the spectra recorded for 120 s. For each spectrum, the peaks of the used isotope were fit (662 keV for ^{137}Cs, 1173 keV and 1332 keV for ^{60}Co) with a gaussian and the peak position, area and FWHM were extracted. Figure 2 shows these data for one particular data set, the measurement of ^{60}Co with the LaBr detector and the MCA-527.

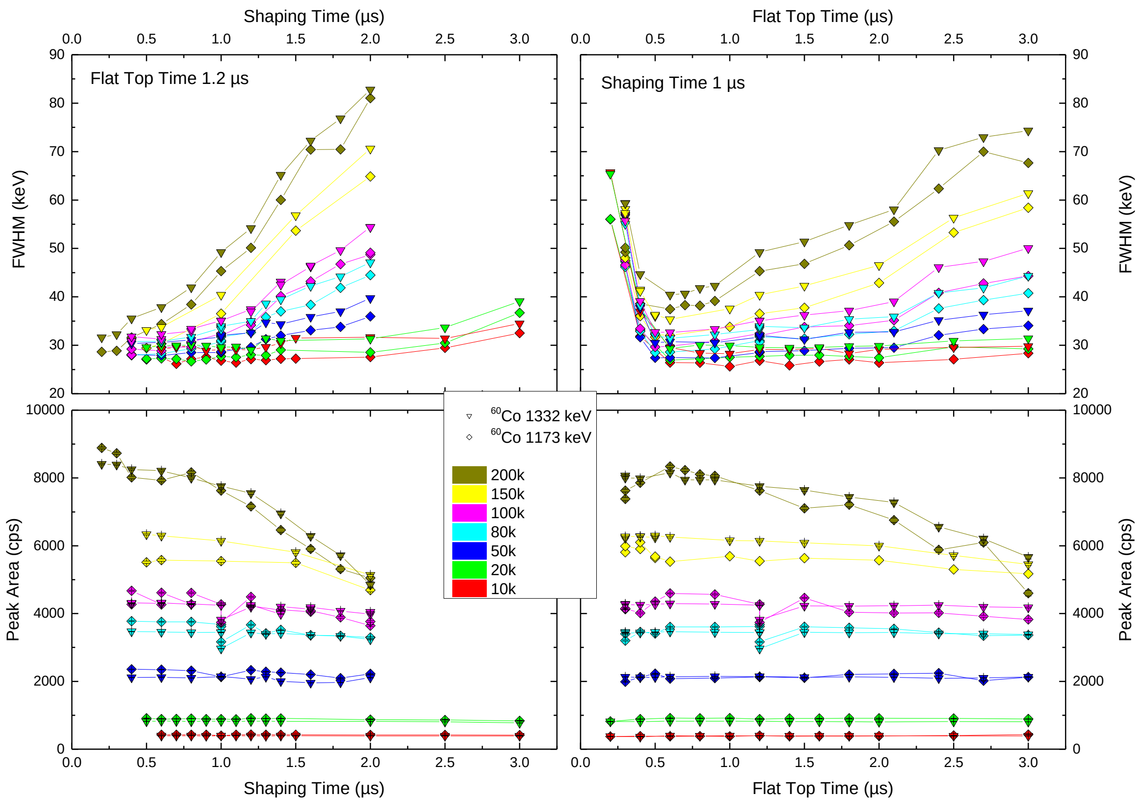

Figure 2: Influence of peak shape parameters on the peak area and width for different count rates for the MCA-527 and a LaBr detector. The supplied values for shaping and flat top time were 1.0 µs and 1.2 µs, respectively. A 380 MBq ^{60}Co source was used for these tests.

An increase in the shaping time leads to an increase in the peak width and a decrease in the peak area. The peak broadening is severe for count rate above 100 kcps. For lower than the nominal shaping time, the peak shape is still well defined. For the flat top time, the picture is different. While the peak area shows a similar behaviour as function of the flat top time compared to the shaping time dependence, the peak width shows a clear minimum as function of the flat top time. The best flat top time for this system is about 0.7 µs, while the value supplied by the IAEA was 1.2 µs. The effect in the peak broadening is only pronounced for count rates above 100 kcps.

3.2. Influence of ambient temperature on peak width and peak position

To determine the influence of the ambient temperature on the performance of the MCAs, tests with an environmental chamber were carried out. Both MCAs were subjected to the temperature program at the same time, but with different detectors, in order to save measurement time. One such temperature ramp could be finished per day. As explained in the experimental section, only the MCAs were subjected to temperature changes, the source and the detectors were placed outside the environmental chamber in the air-conditioned laboratory. The resulting spectra were automatically fitted and the peak position, peak with and peak area were extracted.

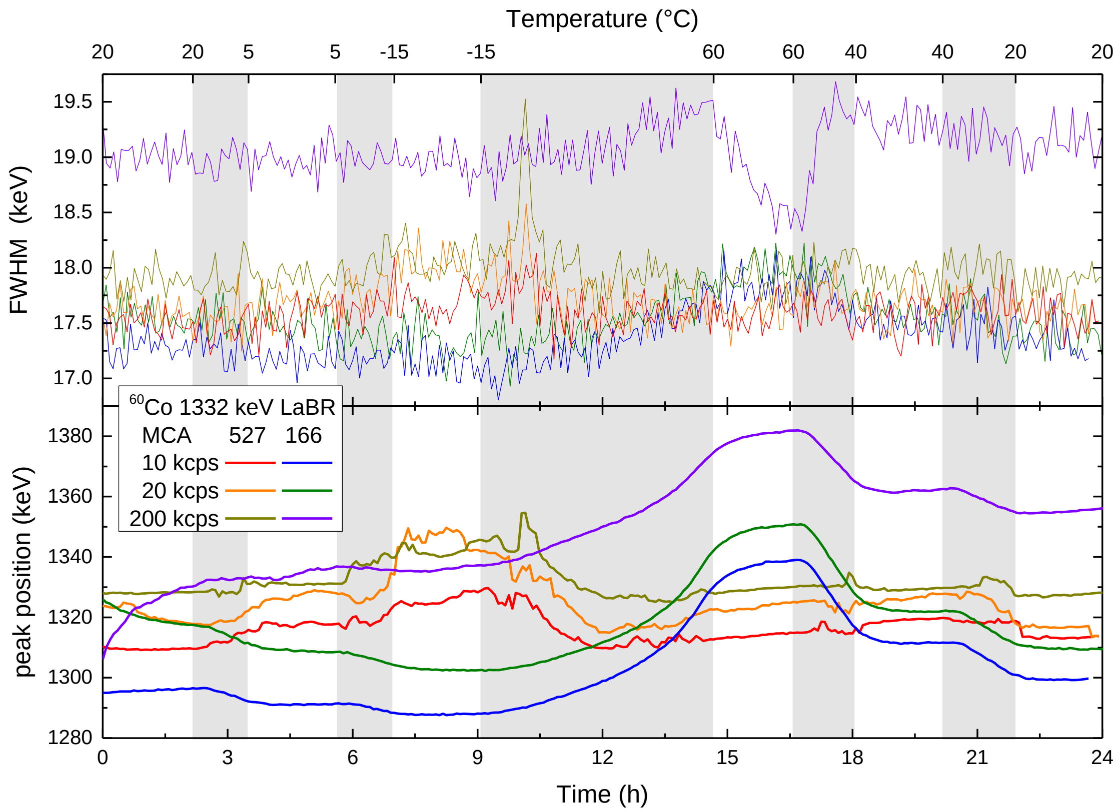

Figure 3: Peak position (lower panel) and peak width (upper panel) for three different count rates and both MCAs as the function of time and temperature. During the experiment time of 24 h, the temperature is first decreased from 20°C to -15°C, then heated to 60°C and finally decreased back to 20°C. The white vertical bands indicate times, for which the temperature was held constant, the grey band indicate temperature changes with a ramp of 15 K/h. The temperatures at the band boundaries are given at the upper scale.

Figure 3 shows the results of these tests for the LaBr detector. The data for the MCA-166 show a strong peak shift and peak broadening for the high count rate, the curves for 200 kcps is shifted up. The same is evident for the MCA-527, but to a much lesser extent and these effects are in line with the observations from e.g. the test described in section 3.1.

Additionally both MCA show a temperature dependency of the peak parameters. Most prominent feature is the increase in peak position for the MCA-166 at a temperature of 60°C. When increasing the temperature from -15°C to 60°C, also a slight increase of the peak width is visible. The high count rate data shows a large decrease of the peak width, while the MCA-166 is held at 60°C. The MCA-527 shows less pronounced features. But also here, a slight increase in peak position is identifiable the lowest temperature, and upon heating from -15°C a spike in the peak width is observable. One clear difference is the fact that the variations for the MCA-166 are a smooth function of temperature and time, while the smaller variations for the MCA-527 are somewhat noisier. This might indicate a varying component value (e.g. temperature dependencies of resistors or of capacitors), while the MCA-527 might use its internal temperature sensor to mitigate these effects by the firmware. In this case, BGS electronic might improve the behaviour at -15°C with a firmware upgrade.

On the other hand, these effects show no increase or decrease in strength with different count rates, with the exception of the peak with decrease at elevated temperature. So, while both MCAs show some effect on the peak parameters with ambient temperature, this is not strongly correlated to the count rate.

3.3. Results of the electromagnetic influence tests

The MCA-527 together with the LaBr detector was tested as an entire system for RF immunity according CE EMC standards. Is has been assumed that the single devices passed these tests individually as CE conform products. No visible changes in the spectrum have been observed by the test site operator during the RF exposure. As this was the defined failure criterion within these tests, no failure or anomaly was observed.

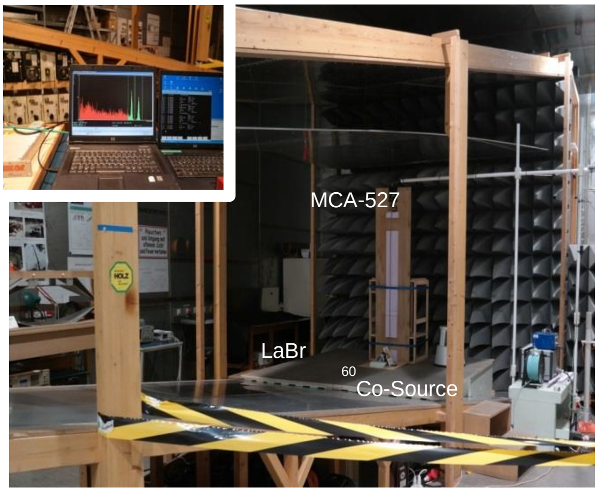

Figure 4: Setup for the electromagnetic influence tests. The MCA-527 and the LaBr detector are located inside the TEM waveguide. A ^{60}Co source is placed next to the detector. Upper insert: The recorded spectrum is shown to the site operator.

In retrospect, it was possible to examine the recorded spectra in more detail. Fits of the peak width and peak position showed virtually no effect. But combining all spectra for one frequency ramp in a waterfall diagram revealed finally three minor changes in the recorded spectra, as seen in figure 5. The set of spectra could not be linked afterwards to the recordings of the RF system, so an assignment of a frequency to these changes is not credibly possible. The changes were observed during the measurements in the 80 MHz to 1 GHz frequency band and for the distinct communication frequencies. No changes in the spectra were observed for the measurements in the 1.4 GHz to 2 GHz and the 2 GHz to 2.7 GHz bands. The exact frequency, where these changes happened and deeper investigation of the impact on a longer measurement or the possible cause could not be determined during this project.

3.4. Results of the comparative testing with HPGe detector

For each count rate and the average of 5 spectra was calculated and the FWHM in the ROI centered on the 59 keV (Am-241) and the 186 keV (Ra-226) peak was determined. Additionally, the peak stability is assessed by the variability of the centroid peak channel over the five measurements, which is calculated from the standard deviation of the centroid peak channel in each respective ROI. In Figure 5 the FWHM values (in [keV]) for both MCAs are plotted for both ROIs. The x-axis presents the five different count rate regimes. The values from the Ra-226 186.1keV peak resulted in higher FWHM values with larger error bars, which is a result of the low counting statistics for the gamma-line from the 300 s live time with a branching ratio of this gamma peak of only 3.28 %.

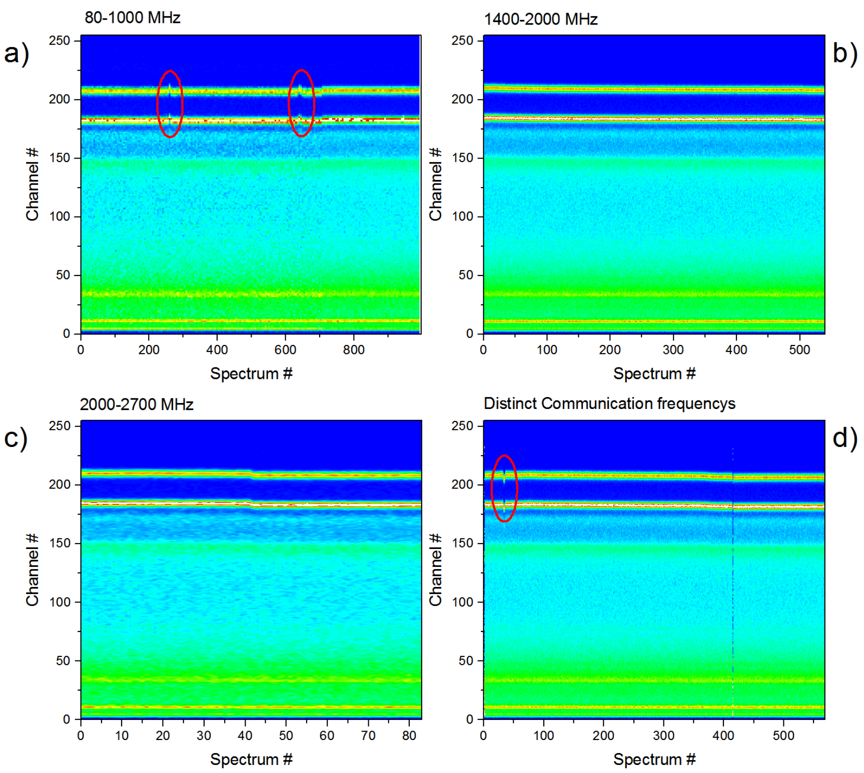

Figure 5: Waterfall diagrams of the recorded spectra during the electromagnetic influence tests. The x-axis shows the spectrum number since the start of the frequency sweep. The y-axis shows the channel number. The two ^{60}Co lines of 1173 keV and 1332 keV are located in the proximity of channel 200. The four graphs show the frequency sweeps from a) 80 MHz to 1 GHz, b) 1.4 GHz to 2 GHz, c) 2 GHz to 2.7 GHz and d) the distinct communication frequencies. Marked are the observed minor changes in the runs a) and d).

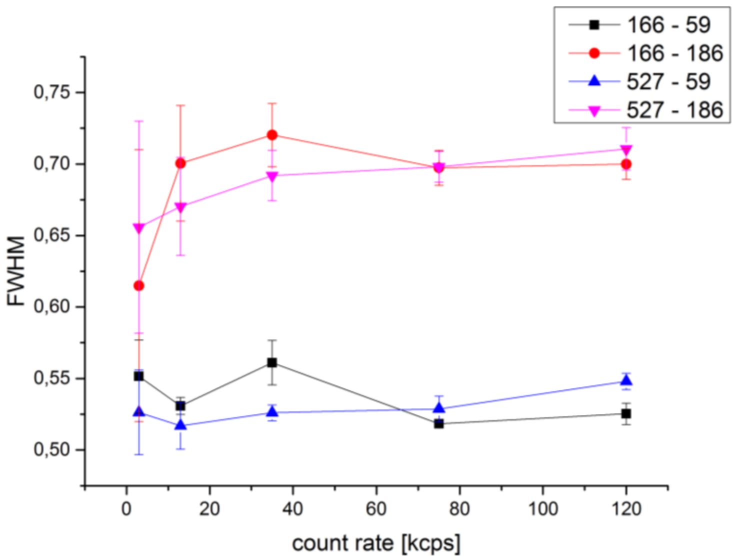

Figure 6: Comparison of resolution (FWHM in [keV] between MCA-166 and MCA-527 for two different gamma peaks at 59 keV and 186 keV.

As a conclusion of this comparison, the MCA-527 is at least as good as the MCA-166 in terms of resolution because the FWHM values for each line only differ by max. 0.04. What indicates an improvement of the MCA-527 is the lower variability of values and the slow, continuous slope of the lines. In the User Manual of the MCA-527 [3]**Fehler! Verweisquelle konnte nicht gefunden werden.** a resolution for typical 500 mm^2 planar HPGe detector (count rate ≤10.000cps) of ≤510eV at 1 µs shaping time (Am-241 source at 59keV) and ≤460eV at 2 µs shaping time (Am-241 source at 59keV) is listed. Figure 6 shows values between 520eV and 550eV. A possible reason may be the different detector used and the influence of the laboratory environment during the measurement. It is noteworthy, that the MCA-527 has a lower dead time which allows for a higher effective throughput (see Table 2), and therefore, in this respect outperforms the MCA-166.

	< 5 kcps	5-20 kcps	20-50 kcps	50-100 kcps	> 100 kcps
MCA-166	0.6 %	2.4 %	7.28 %	9.99 %	15.93 %
MCA-527	0.5 %	1.6 %	3.7 %	5.04 %	7.3 %

Table 2: Comparison of the dead time for acquisition of gamma spectra with the HPGe detector.

4. Conclusions

The presented results of this paper show a small part of the obtained results for the comparative study of the two multichannel analysers. Both MCAs showed a good performance during these tests and there was no indication that the MCA-527 would perform worse than its predecessor.

5. Acknowledgements

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6. References

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