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Comparison of Energy Resolution of NaI (Tl) Scintillation Detectors Obtained by Analog and Digital Ways

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Abstract: Gamma-ray energy spectra were acquired using a Multichannel Analyzer (MCA) and a digitizer. A spectrometer which was consisted of a NaI(Tl) inorganic scintillation detector and a digitizer were used to obtain energy spectra of ^{137}Cs radioisotope. The energy resolution values from analog and digital ways were calculated and compared with each other. The average analog and digital energy resolution values were determined as 7.69 % and 6.80 %, respectively. Obtained results showed that the digital systems are more preferable than the analog ones from the energy resolution point of view.

Keywords: Energy Spectrum, Energy Resolution, Digitizer

1. Introduction

Most of the inorganic scintillators are crystals of the alkali metals, in particular alkali iodides, that contain a small concentration of an impurity [1]. In addition to its efficient light yield, sodium iodide doped with thallium NaI(Tl) is almost linear in its energy response [2]. A NaI(Tl) scintillation detector is commonly used for gamma ray detection. Its relatively high density and high atomic number combined with the large volume make it a γ-ray detector with very high efficiency. NaI(Tl)'s relatively high density (3.67×10^3 kg/m^3) and high atomic number combined with the large volume make it a γ-ray detector with very high efficiency [1].

For detectors which are designed to measure the energy of the incident radiation, the most important factor is the energy resolution. In general, the resolution can be measured by sending a monoenergetic beam of radiation into the detector and observing the resulting spectrum [1]. Energy resolution is the extent to which a detector can distinguish two close lying energies. The resolution (R) is usually given in terms of the full width at half maximum (FWHM) of a peak. It is calculated by dividing the value corresponding to the peak centroid E of the full width (ΔE) at FWHM of a peak in a spectrum [3]. Its formula is given in equation 1.

$$R = \Delta E/E \quad (1)$$

Multichannel analyzer (MCA) is a device that exhibits the energy spectrum of a radioisotope. The MCA takes counts of the number at each pulse height in multichannel memory and the increments in a memory channel whose address is proportional to the digitized value. Incoming pulses are sorted out according to pulses height. The number at each pulse height stored in memory locations corresponds to the amplitudes of incoming pulses. The contents of each channel can be displayed on a screen to give a pulse height spectrum [3]. The horizontal axis of MCA screen is called as channel number, or particle energy. The vertical axis is the number of particles recorded per channel [1].

The new way in the design of computer-based measurement systems can be seen in the use of up - to-date measurement, control and testing systems based on reliable devices. Digital signal processing (DSP) methods are widespread in recent instrumentation for several disciplines (including some nuclear physics experiments) to replace conventional analogue systems and to build measurement and test systems with an easy configuration, user-friendly interface, and possibility to run sophisticated experiments [4]. Many commercially available digitizers either in the form of modular plug-in boards or stand-alone instruments is used in these systems where detector data can be acquired by DSP software code [5]. It is used to build measurement and test systems with an easy configuration and user-friendly interface. Nowadays, nuclear DSP systems are commonly realized by the virtual instrumentation (VI) technique performed in LabVIEW (Laboratory Virtual Instrumentation Engineering Workbench) graphical programming environment. The advantages of this approach lie in the use of ready-to-start measurement functions, instrument drivers delivered with measurement devices, and in the possibility to improve a particular system when new algorithms, drivers or devices are available [4].

The energy resolution calculation of the gamma-ray spectrometer was investigated by Moszynski [6]. Wang et al. constructed a gamma-ray spectrometer in order to calculate energy resolution for 662 keV ^{137}Cs gamma-ray photons [7]. The energy resolution value of the spectrometer which was consisted of Bismuth germinate single crystal was calculated by Nestor and Huang [8], also energy resolution values of different scintillators were investigated by Kapusta et al. [9]. Shah et al. investigated energy resolution of 662 keV gamma-rays (^{137}Cs) by means of scintillation crystal [10], similarly, gamma-ray energy spectrum of a ^{137}Cs radioactive source was obtained by Celiktas et al. [11], and recently Pechousek et al. carried out energy and time measurements using VI technique [5].

In this work, gamma energy spectra of ^{137}Cs radioisotope were obtained using an MCA and a digitizer. The energy resolution values of the detector from both spectra were calculated and compared with each other.

2. Materials and Methods

A Bicron NaI(Tl) detector whose dimension is 3” x 3” and a point standard ^{137}Cs gamma source which has the activity of 5 µCi and the half-life of 11,000±90 days were used in this study [12].

A block diagram of the used spectrometer is shown in Fig. 1.

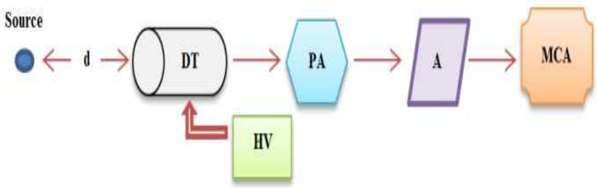


***Figure 1**. Block diagram of the used spectrometer.*

In the experimental circuit, the detector output was sent to a preamplifer (PA, Ortec 113). Its output was forwarded to a main amplifier (A, Ortec 485). Then the amplifier output was connected to an MCA (Ortec Trump 8K) to obtain energy spectrum. In this block diagram, HV, d and DT stand for high voltage supplier, source to detector distance and detector with photomultiplier tube, respectively.

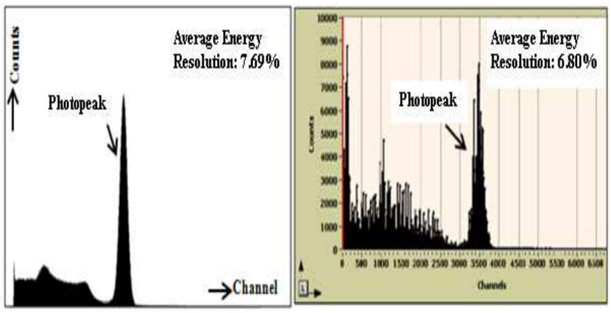
In the experiment, preamplifier capacitance, amplifier coarse gain, power supply voltage and source to detector distances were adjusted to 100 pF; 16; 1,000 V and 4 cm, respectively since these values were the optimum ones for our spectrometer.

DSP systems use a device that digitizes an analog signal. A digitizer records the output signal from the radiation detector as an unprocessed signal or can acquire pulses coming through the signal amplifier or another preprocessing module. In the acquired signal, the pulse represents the nuclear event registration, and the amplitude of the peaks generally depends on the detected energy [4]. The gamma energy spectrum of ^{137}Cs was also obtained by a digitizer. For this process, the MCA was substituted with the digitizer (NI USB-5133) in the spectrometer. In order to operate the digitizer and to acquire the spectrum, a code was generated using LabVIEW software.

3. Results and Discussion

Gamma energy spectra of ^{137}Cs source from MCA (analog) and digitizer (digital) are shown in Fig. 2.

The analog (from the MCA) and the digital (from the digitizer) experiments were repeated five times and the average of the calculated energy resolution values were determined. These values are presented in Table 1.



(a) (b)

***Figure 2.** Energy spectra of ^{137}Cs from (a) MCA (analog) and (b) digitizer (digital).*

***Table 1.** The analog and digital energy resolution values.*

Experiment No.	Energy resolution (analog) (%)	Energy resolution (digital) (%)
1	8.90	7.70
2	7.41	7.07
3	7.41	6.68
4	7.38	5.52
5	7.35	7.06
Average	7.69	6.80
Standard deviation	0.60	0.72

4. Conclusion

Gamma energy spectra of a ^{137}Cs radioisotope were achieved by analog and digital ways by setting optimum adjustments of the preamplifier capacitance, the coarse gain, the source to detector distance and the power supply voltage. As can be seen from Table 1, the average analog and digital energy resolution values were determined as 7.69 (±0.60) % and 6.80 (±0.72) %, respectively. It was found that the average energy resolution from the digital method was smaller than that of the analog one. This showed us that the digital system has advantages for distinguishing the very close energy peaks. This success of the digital way is arisen from the high sampling rate of the digital system. Furthermore, distortion or noise, which are always present in analog circuits, might easily alter the information in analog signals [3]. Obtained results showed that the digital systems are more preferable rather than the analog ones from the energy resolution point of view.

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References

[1] Tsoulfanidis, N., "Measurements and Detection Radiation, Taylor&Francis", USA, 1995.

[2] Turner, J. E., ''Atoms, Radiation and Radiation Protection'', Wiley-VCH VerlagGmbH&Co. KGaA: Germany, 2007.

[3] Leo, R.W., "Techniques for Nuclear and Particle Physics Experiments", Springer Verlag, Germany, 1994.

[4] Folea, S., ''In Application of Virtual Instrumentation in Nuclear Physics Experiments; J. Pechousek'', Eds. InTech.: Croatia, 2011 (Accessed 06, 26, 2015).

[5] Pechousek, J., Prochazka, R., Prochazka V. and Frydrych, J., "Virtual instrumentation technique used in the nuclear digital signal processing system design: Energy and time measurement tests," Nuclear Instruments and Methods A, vol. 637, pp. 200-205, 2011.

[6] Moszynski, M., ''Inorganic scintillation detectors in γ-ray spectrometry'', Nuclear Instruments and Methods A**,** vol. 2003, pp. 101-110, 2003.

[7] Wang, Y. J., Patt, B. E., Iwanczyk, J. S., ''High efficiency CsI(Tl)/I_2 gamma ray spectrometers'', IEEE Transaction on Nuclear Science, vol. 42, pp. 601-605, 1995.

[8] Nestor, O. H., Huang, C.Y., ''Bismuth germanate: A high-Z gamma-ray and charged particle detector'', IEEE Transaction on Nuclear Science, vol. 22, pp. 68-71, 1975.

[9] Kapusta, M., Balcerzyk, M., Moszynski, M., Pawelke, J., ''A high-energy resolution observed from a YAP: Ce scintillator'', Nuclear Instruments and Methods A, vol. 421, pp. 610-613, 1999.

[10] Shah, K. S., Glodo, J., Klugerman, M., Higgins, W. M., Gupta, T., Wong, P., ''High energy resolution Scintillation spectrometers'', IEEE Transaction on Nuclear Science, vol. 51, pp. 2395-2399, 2004.

[11] Celiktaş, C., Ermis, E. E., Bayburt, M., ''Energy resolution improvement of NaI(Tl) scintillation detectors by means of a timing discrimination method'', Journal of Radioanalytical and Nuclear Chemistry, vol 293, pp. 377-382, 2012.

[12] Eckert, Ziegler Reference, Calibration Sources,

[13] http://www.ezag.com/fileadmin/ezag/user-uploads/isotopes/isotopes/Isotrak/isotrak-pdf/Decay_Schema_Data/Cs-137.pdf (Accessed 06, 26, 2015).