UNDERWATER LOW-BACKGROUND NaI(Tl) GAMMA-RAY SPECTROMETER

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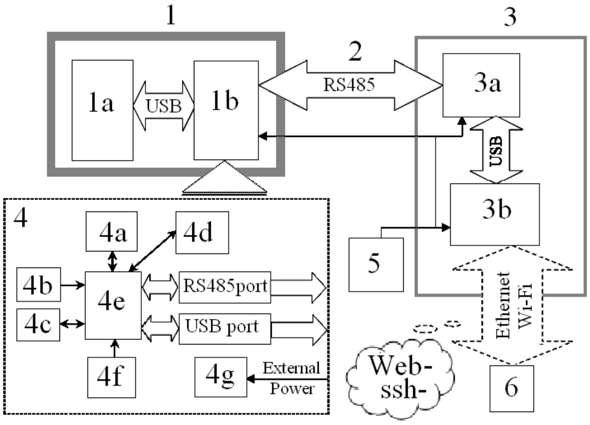
The traditional approach for measuring the activity of radionuclides includes representative sampling with transportation to the laboratory, preparation and laboratory analysis using stationary gamma-spectrometers that is time-consuming and costly. A key problem in constructing a high sensitivity gamma-spectrometer for on-line measurements that operates stably with a high resolution over a wide range of gamma-ray energies and of ambient temperatures is the development of an integrated approach to calibration procedures of the device [1]. A set of both experimental (software and hardware) procedures and theoretical ones based on Monte-Carlo simulation of the detection process is considered.

A NaI(Tl) gamma-ray spectrometer for in situ underwater measurements consisting of a submersible unit with the radiation detector and of a surface microcomputer unit is developed. Along with an ultra low-background NaI(Tl) radiation sensor, the submersible unit contains a specially designed FPGA-based electronics with low energy consumption and with abilities both for remote data acquisition by a 1200m conducting cable and for an autonomous operation mode. The unit is enclosed in a polyacetal housing withstanding pressure of 4.5 MPa at a depth of 450 meters. The surface microcomputer unit contains an all-in-box software for acquisition, storage, and processing of data from the detector unit, for real time monitoring activities of dissolved radio-nuclides, for their identification and quantification. The software functions are accessed remotely by a user-friendly web- interface using Wi-Fi or Ethernet. Several techniques for gain control (including an auto-adjustment of the gain by setting a selected photo-peak in a prescribed channel) together with the corresponding energy scale calibrations approaches are implemented and examined over a wide temperature range -10 ÷ +50°C in a thermo-chamber calibration experiment with ^{152}Eu point gamma-ray sources. Calibration of the energy resolution of the detector is performed from line-width measurements of reference gamma-ray sources. Calibration of detection-efficiency is carried out using Monte Carlo simulations based on the GEANT4 code taking into account the materials and geometry of the detector as well as the water environment. In addition, the efficiency of the detector immersed in a 8m^3 water tank with dissolved gamma-ray sources of ^{139}Ce, ^{137}Cs and ^{40}K of known activities is determined experimentally and compared with the theoretical findings.

The developed underwater gamma-ray spectrometer is made of two blocks. One of them is a submersible unit and another one is a surface control unit as shown in the Figure 1.



1 – Submersible Unit:
1a – NaI(Tl) radiation sensor; 1b – Controller;
2 – Submarine Communication Cable;
3 – Surface Unit:
3a – Data Transmitter; 3b – Microcomputer;
4 – Remote Software Unit:
4a – Flash Memory; 4b – Osc; 4c – Usb Host FTDI; 4d – Clock with Battery; 4e –FPGA Cyclone V; 4f – Sensors; 4g – Power Supply;
5 – External Power Supply, 9–18 V;
6 – External PC Tablet Phone

Fig. 1. Function diagram of the underwater gamma-ray spectrometer

The background spectrum of the submersible gamma- spectrometer in the water tank is shown in the Figure 2.

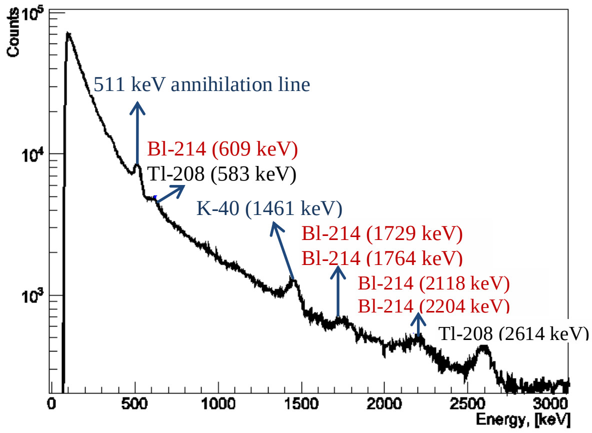


Fig. 2. Background spectrum in the water tank

As the comparison shows, the experimental efficiency and the efficiency simulated by the Monte-Carlo method are consistent with each other within a 7% uncertainty interval.

The activity concentrations of the natural radionuclides (such as ^{40}K, ^{214}Bi, ^{208}Tl, ^{212}Pb and ^{214}Pb) were found in the water tank experiment together with the Minimum Detectable Activity concentration for artificial ^{137}Cs. The later is 35 Bq/m^3.

1. *Jones D.* // Journal of Environmental Radioactivity 2001. V. 53, № 3, P. 313–333.