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Domestic Development of Single-Photon Emission Computed Tomography (SPECT) Unit with Detector based on Silicon Photomultipliers

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Abstract. The idea of creating a single-photon emission computed tomography unit with solid-state photomultipliers is not new [1], as the problems of analog-to-digital conversion with a lot of noise and a wide range of values of intrinsic spatial resolution of the detector in a center and relevant fields of view could not be solved by means of gamma-camera detector architectures based on vacuum photomultipliers. This paper offers a new SPECT imaging solution that is free from these problems.

1. Introduction
Radionuclide diagnostics is a technique that allows evaluating structure-functional state of organs and tissues of human body by means of different diagnostic radiopharmaceuticals administered in the body to acquire imaging information about the state of cellular systems under examination.

Radiopharmaceuticals are specific chemical or biochemical compounds labeled with gamma-emitting radionuclides with a short half-life. Gamma radiation emitted from the body of a patient is recorded by a gamma camera detector and the received information is converted into a functional image of the examined organ after computer processing. Spatiotemporal pattern of the radiopharmaceutical distribution provides the information about shape, size and location of the organ, as well as about presence of lesions in it.

Radionuclide diagnostics is widely used in oncology (brain tumors, scintigraphy of malignant breast tumors, bone and liver scintigraphy), endocrinology, cardiology, urology and nephrology.

2. From prototype to industrial design
Nowadays, the most common gamma camera units are based on vacuum photomultipliers. Known user problems are defined by specifications of gamma camera detectors [2], this can be described by two values having determining competitive advantage at the market. These are the values of the spatial resolution of the detector in the center and in the relevant field of view at the level of 0.5 (FWHM) and the value of energy resolution of the unit for 99mTc. The problem of detector energy resolution values for 99mTc gets prominent coverage in literature as well as in this article. The authors focus on devices

electronic component which determines detector energy resolution values. For silicon photomultiplier detector, channels number defines this value. Channel is a complex of the silicon photomultiplier (detector pixels), buffers and comparators with external control, analog-digital, time-to-digital converters and high-speed data bus.

The creation of a gamma camera detector with the field of view of 400 x 540 mm^2, based on silicon photomultiplier, requires minimum 13824 pixels. This detector architecture allows obtaining the values of the spatial resolution of the detector in the center and in the relevant field of view at the level of 0.5 (FWHM) with minimal differences. Practically, the absolute values equality could not be obtained [3] because the measured modulation transfer function is unimodal and similar to a Gaussian function [4]. The values of 2.9 mm at the level of 0.5 FWHM and of 5.3 mm at the level of 0.1 FWHM were obtained. This fact is confirmed by the advance advertising of the new unit by General Electric [5]. The unit parameters of the spatial resolution are 2.5 mm and 3.8 mm respectively.

The value of the internal energy resolution for 99mTc [6] is determined by a manufacturer during the unit acceptance tests and depends on the specified detector architecture. In our design the detector is made of large single-crystal CsI(Tl) pixels, and silicon photomultipliers are joined by optical glue. Such architecture and recovery algorithm for gamma event allow reaching internal energy resolution of 9.2% for 57Co [7]. According to authors [8], the energy resolution of the detector is inversely proportional to the square root of the energy of gamma quanta of the radioactive isotope used in the measurement. Consequently, the recalculation of the internal energy resolution for 99mTc gives the value of 8.5%.

Obviously, the cost of single-photon emission computed tomography units with solid-state pixels is higher than the cost of units with detectors based on the vacuum photomultipliers. This situation will not change until the market is filled with modern analogues. For this purpose, the price of components of such units should fall for a manufacturer. For detectors on silicon photomultipliers, this is decisive for entering the competitive market.

Alternative way, when a manufacturer introduces new technology, can be applied in the modernization of the existing technical base. GE used this option for the introduction of CZT technology. Other manufacturers will do the same. The time will show if we should look for our own way to solve the problem or we should rely upon the experience of the colleagues.

3. Conclusions

Nowadays there is a tendency towards the use of modern materials in gamma-camera detectors and SPECT. The SPECT imaging unit was developed in Russia. Its parameters can compete with world latest developments. The standard [4] underlines that its application to the detectors with the architecture of many pixels is incorrect. So we need new applications to the standards for a new generation of gamma cameras, and a direct comparison of the specifications of gamma camera based on the vacuum photomultipliers and silicon photomultipliers is also incorrect. However, the market has its own rules, and a buyer will choose a cheaper unit capable to satisfy minimal necessary requirements of a user.

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