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 mm², 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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