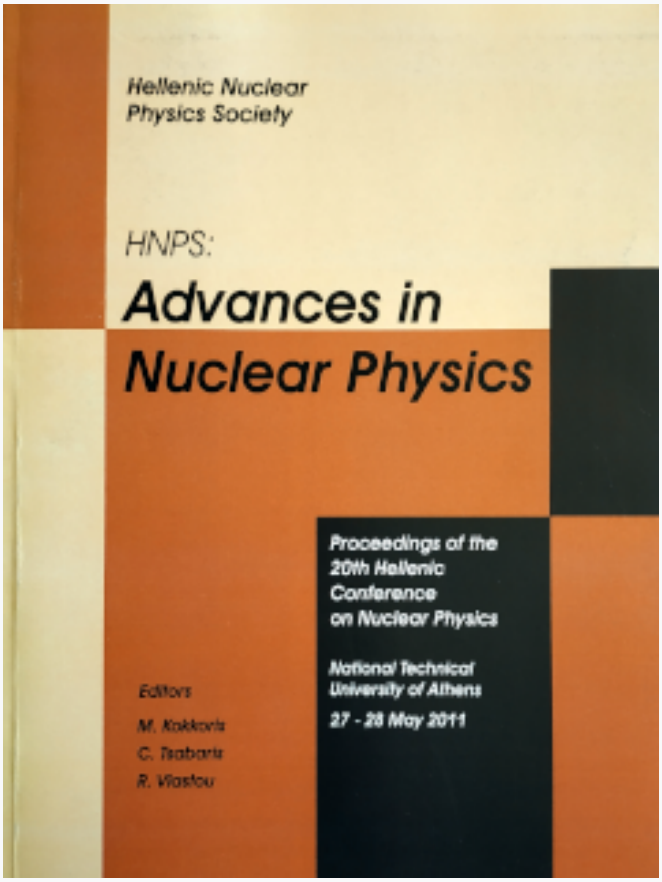
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Sensitivity and Resolution Study of a Small-Field γ-Camera System on a Tomographic Level

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Abstract

The sensitivity and the spatial resolution of a small-field γ-Camera system based on a Position Sensitive Photomultiplier Tube (PSPMT) on a tomographic level are examined in this study. A cylindrical Gel-Phantom ($d = 40\,mm,\ h = 50\,mm$) with cylindro-conoidal tubes and capillaries (from 64 to 640 mm^3 in volume) containing water solution of ^{99m}Tc is used as a test phantom in the present work. A total of 24 projections covering the full angle region ($0^0 - 360^0$) are obtained with the γ-Camera system under examination. The planar information is further analyzed to reconstruct the tomographic images taking into account all off-line corrections needed to remove barreloid deformations appearing at the edges of the Field-of-View. The reconstruction procedure is performed with iterative algorithms and for comparison reasons two different techniques (MLEM and accelerated ART) are used. The variety of the ^{99m}Tc-volumes in the phantom with the given specific radioactivity and the phantom axial asymmetry, due to the different radial distances of the tubes in the gel environment, allow a realistic characterization of the system's performance on a tomographic level. Obtained experimental results for the system sensitivity and spatial resolution are presented and discussed in this work.

Key words: γ-Camera, SPECT, Tomographic Image Reconstruction, ART, MLEM

1 Introduction

A small-field γ-Camera system, based on the HAMAMATSU R2486 Position Sensitive Photomultiplier Tube (PSPMT) and utilizing the resistive chain

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readout technique, is being, in the last years, developed in our laboratory. Attention has been paid to the removal of the spatial distortion appearing at the edges of the system's Field-of-View [1]. On a planar level the spatial resolution has been found to be $\sigma_X = (0.95 \pm 0.05)mm$ and $\sigma_Y = (1.07 \pm 0.07)mm$ with respect to the X- and Y-direction of the PSPMT's multi-anode grid [2]. Having in mind a future use of this γ-Camera in a clinical environment, the next logical step was to characterize the system on a tomographic level. In order to achieve that, a careful investigation of the system's sensitivity and resolution was needed, especially the ability to detect minimal volumes of a radioactive tracer within a complex phantom-geometry.

2 Experimental Procedure

The 3in-diameter circular envelope R2486 PSPMT, which is the heart of the γ-Camera system, enables the projection of a 2-dimensional information with a crossed-wire construction (Figure 1). Output signals from these multiple anode wires can be divided through external resistive chains and derived from X and Y electrodes as the position signals.

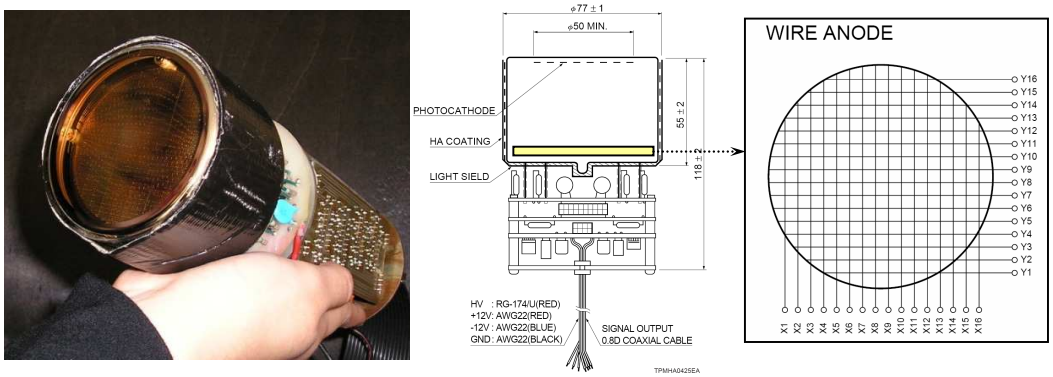


Fig. 1. The small field γ-Camera System with the Position Sensitive Photo-Multiplier Tube (PSMPT) and a schematic diagram of its multi-wire anode grid.

In order to characterize the performance of the system on a tomographic level prior to a clinical evaluation, a sensitivity and spatial resolution examination has to be performed. A proper phantom prototype with a variety of different tracer volumes and activities, possibly without axial symmetry, is in our case desirable. For this reason, a five element phantom prototype consisting of three cylindro-conoidal tubes and two capillaries, each one of different volume and shape, was assembled. These elements were immersed in a cylindrical glass container filled with agarose gel. Agarose gel could be easily cast and handled allowing the positioning of the tubes in any specific arrangement.

The phantom construction has a diameter $d = 40\ mm$ and a height $h =$

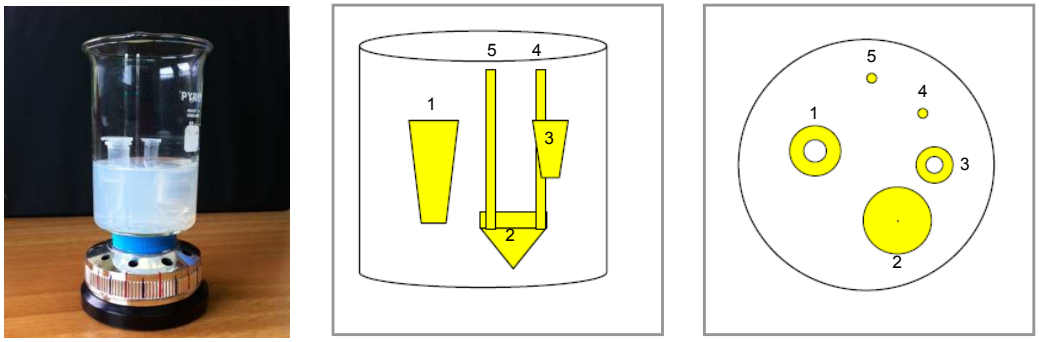


Fig. 2. Picture of the gel-phantom used in the SPECT imaging procedure on its rotating support. The shape and the relative position of the tubes and capillaries is shown in the schematics; they are filled with ^{99m}Tc water solution (exact volumes and activity are summarized in Table 1) and placed inside the gel.

50 mm; the five elements, ranging in volume from 64 to 632 mm^3, could be filled with ^{99m}Tc water solution of a given specific activity. This Gel-Phantom with the three cylindro-conoidal tubes and the two capillaries, which is used as a test phantom in the present study, is shown in Figure 2. The exact element volumes, as well as the tracer activity for a ^{99m}Tc solution of special concentration 0.25mCi/ml, are summarized in Table 1.

N	Volume $[mm^3]$	Specific Activity $[\mu Ci/mm^3]$	Activity $[\mu Ci]$
1	580	0.25	145
2	632	0.25	158
3	184	0.25	46
4	64	0.25	16
5	64	0.25	16
TOTAL	1525	0.25	381

Table 1
Calculated volumes and ^{99m}Tc activity for the five elements used in the phantom.

The main intention of using a gel phantom in the present study, is to be able to appropriately simulate all absorbing effects occurring in the soft tissue of the human body, hence to recreate the proper scattering conditions taking place during *in-vivo* experiments. The variety of the ^{99m}Tc activity in the phantom (from 0.016 mCi to 0.158 mCi) with the given specific radioactivity and the phantom axial asymmetry, mainly caused by the different shapes and radial distances of the tubes in the gel environment, allows a realistic characterization of the system's performance on a tomographic level.

3 Data Acquisition and Reconstruction

The Gel-Phantom is placed on a small rotating support and a total of 24 projections with 15^0-step covering the full angle region ($0^0 - 360^0$) are obtained with the γ-Camera system under examination. The planar information is further analyzed to reconstruct the tomographic images, taking into account all off-line corrections needed to remove barreloid deformations appearing at the edges of the Field-of-View, as they have been described in [1].

Afterwards, every projection was sliced 21 times along the Z-axis, from -21 mm to +21 mm, where the minimum corresponds to the bottom and the maximum to the top of the phantom. Recorded events are offline analysed by taking into account the appropriate energy cut to reduce the background noise mainly created by Compton scattering. 64×64-pixel reconstruction images are created by using back-projection techniques from all information recorded in the planar images and for the whole angular range. The reconstruction procedure is performed with iterative algorithms and with software developed in our laboratory. For comparison reasons two different techniques are used: The Maximum Likelihood Expectation-Maximization (MLEM) technique and an accelerated variation [3] of the Algebraic Reconstruction Technique (ART). Finally, all 21 tomograms produced by the reconstruction procedure along the Z-axis are synthesized to a 3D tomographic image using MATLAB software (Figure 3).

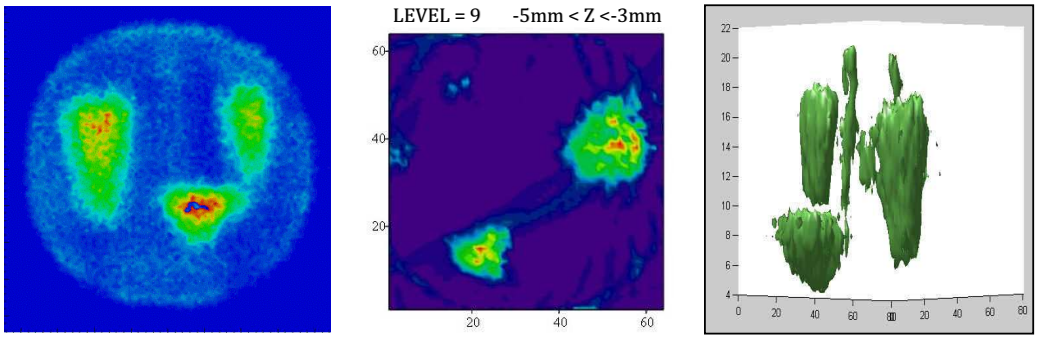


Fig. 3. *Left:* Planar image taken with the γ-Camera at 15^0 angle. *Center:* Reconstructed 64×64 matrix of the 9^{th} slice (out of 21) at $Z = -4.00 \pm 2.0\, mm$ using all planar images. *Right:* The obtained 3D tomographic image of the gel-phantom by contour plotting all the 21 reconstructed tomograms.

After completing the previous steps, it is clear that the smallest elements of the Gel-Phantom (capillaries with volume $0.073\, cm^3$) pose a low limit in the system's sensitivity on a tomographic level. After careful examination of the obtained images and following the standard methodology, the tomographic resolution was estimated in the order of 2 mm for both X- and Y-Axis.

4 Concluding Remarks

As normally expected, the spatial resolution of γ-imaging systems at a tomographic level is at least by a factor of two worse compared to the planar one. Our γ-Camera system, examined in the present work, shows a tomographic resolution in the order of 2 mm for both X- and Y-Axis. The minimum volume, which easily can be detected under realistic conditions, is in the order of $V = 0.080\,cm^3$. With the used special activity of $0.25\,mCi/cm^3$, this result is translated to a minimum detectable absolute tracer activity of $20\,\mu Ci$.

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