Hardware Design of Data Acquisition Mechanisms in Small Organ Imaging Gamma Camera

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I. Introduction

Small Organ Imaging Gamma Camera is an innovative step towards providing a low cost solution for imaging organs of small size. The process of photoelectric effect starts due to absorption of gamma photon energy (140 KeV for Technetium 99m radio pharmaceutical) which produces a scintillation. The amount of energy required to produce a pulse differs from one crystal to other. Widely used scintillation detectors for Single Photon Emission Computerized Tomography (SPECT) are Sodium iodide (NaI) and Cesium iodide (CsI) and the two most important factors which are required in a SPECT study are Energy and Spatial resolution. [1]

High energy discrimination is required in a closed spaced energy study such as discrete emissions from two different isotopes (Tc^{99m} and Co^{60}) with very close photon energy (140 and 122 KeV respectively). Here, the energy resolution is a major limiting factor. NaI has around 7% inherent energy resolution at 140keV and CsI has an inherent energy resolution of 14%. The Photo-multiplier Tube (PMT) absorbs light, produces electrons which are collected by the data acquisition electronics and produce an image. The crystal, collimator, Multi-channel plate PMT and DAQ electronics all contribute to the degradation of the signal and resultant energy resolution is roughly over 15% for NaI and 22% for CsI. [2]

In this work, using the widely used GEANT 4 software, the crystal-PMT set up is emulated to study various spatial and energy resolution impeding factors.

II. Emulation of Pulse generation

Geometry And Tracking (GEANT) is a software platform for simulation of passage of particles through matter, using Monte Carlo methods. It is the successor of the GEANT series of software toolkits developed by CERN. GEANT4 was used to simulate various types of detector materials like NaI, CsI, LaBr crystals, semiconductor detectors and PMTs. [3]

The gamma photon may undergo one or many physical processes in the crystal like the Photo-electric, Compton and the back scatter. GEANT 4 provides a detailed description of the particle in a file, as it traverses through the detector system. This file also gives the location, time of occurrence and the energy deposition along the various anode pads.

The file thus generated through simulation with GEANT 4 is used as source file for pulse generation.

In our work, a monolithic 52mm x 52mm NaI crystal is coupled to Hamamatsu's H8500 position sensitive photo multiplier tube (PSPMT) which is same size as that of crystal with 64 anodes, each anode covering an area of 6.2 x 6.2 mm^2. The geometry of the detector is as shown in figure 1.

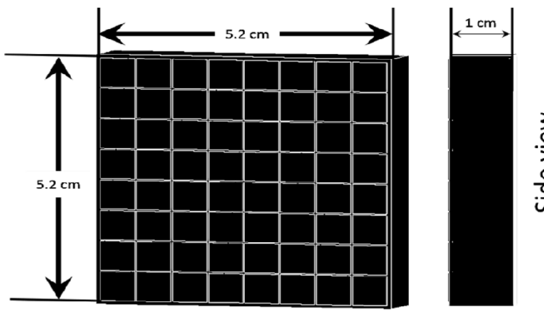

Figure 1: Geometry of the detector

The detector set up is radiated by a point source as shown in figure 2. It scintillates and produces light which is picked by the PSPMT and produces current pulses. The current output from each anode depends on the amount of energy deposited in each anode as shown in figure 3.

The data file containing all the details of these interactions are fed into Field Programmable Gate Array (FPGA) hardware board. Each pin of the

FPGA board acts as an anode and generates a current pulse which is proportional to the energy deposited. This current pulse is similar to the one produced by the PMT and follows the emission statistics.

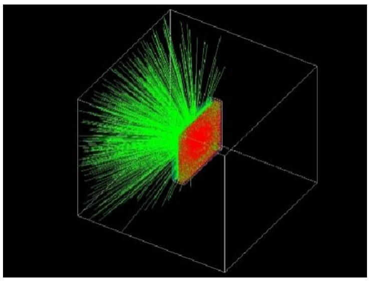

Figure 2: Scintillation (green) at the crystal (red)

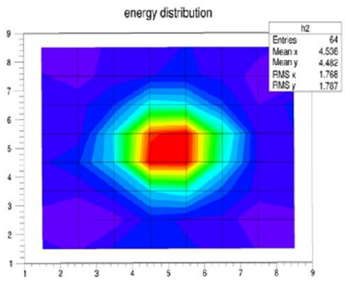

Figure 3: Energy distribution on the 8 x 8 anodes

The advantage of pulse production using GEANT 4 in this manner, allows us to design the data acquisition system and infer the limiting factors. The benefits of a fully digital data acquisition system is reported in our previous work. [4]

III. Digital Data Acquisition

Digital pulse processing (DPP) is a technique which digitizes the real time data with sufficient accuracy and time resolution to preserve the information which is carried by the pulses. The transformed digital pulses are immune to distortions caused by electronic noise and temperature instabilities. Pulse shapes are captured and stored. This allows to capture many pulses in buffer and process them later. DPPs have an enhanced ability to delay signals while accurately preserving time information. [5]

Work is underway in designing a system, which can acquire signals produced by the FPGA. Various techniques are being studied to reduce the dead time of the system while preserving the information contained in the pulses.

FPGAs also offer complete hardware customization while implementing various DSP applications. This allows us to design more accurate pulse shaping algorithms.

IV. Code synthesis using MATLAB

Xilinx offers a highly optimized library of blocks that can be simulated within Simulink (MATLAB) and then compiled for FPGA implementation. This tool is called Xilinx System Generator for DSP. The design of the system can be done in the Simulink environment and the system generator blocks produce the Verilog/VHDL codes which can be adopted into the FPGA.

The Virtex 7 FPGA is used for the data acquisition system. An Analog Devices FMC daughter card will be used as an ADC to interface with the FPGA.

V. Conclusions

In this work, an emulation of the SPECT pulse generation is attempted. This reduces the cost of the scientific study as various crystals and detector geometries can be evaluated by performing a simulation in GEANT 4 without needing to purchase them. A fully digital data acquisition system to acquire the pulses is in progress.

References:

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