EVALUATION OF COUNTRATE CHARACTERISTICS OF A MULTI-CRYSTAL POSITRON CAMERA

Norimasa Nohara*, Eiichi Tanaka*, Takehiro Tomitani*, Hideo Murayama*, Takeshi Iinuma** and Yoshio Suda**
*Division of Physics, **Division of Clinical Research, National Institute of Radiological Sciences, Chiba.

Purpose of the present paper is a theoretical derivation of formula to evaluate overall countrate characteristics of a multi-crystal positron camera. The NIRS positron camera consists of two identical opposing banks of NaI detectors. Each of the banks consists of an square array of 196 crystals viewed by an array of 112 photomultiplier tubes. Timing signals from the detectors are grouped into each row and each column of the photomultiplier array. Fast coincidences between the detectors are performed by the grouped timing signals in a row-row and column-column mode.

From a standpoint of countrate characteristics, the system is divided into five parts as follows: (1) discriminators and grouping circuits causing data loss due to a dead time of discriminators, (2) fast coincidence circuits in which accidental coincidences occur due to a finite coincidence resolving time, (3) latch gates causing an increase of multiple events due to a finite gate opening time, (4) single event recognition circuit causing data loss due to non-paralyzable dead time for recognizing single events and for rejecting multiple events and (5) storing device with one-stage buffer.

A combination of derived formulae for these parts allows to estimate the overall countrate of the system for given activities of positron emitters. The estimation indicates that an increase in the accidental coincidence rate due to a row-row and column-column mode in comparison with one-to-one coincidence mode is very small, of a few per cent, for practical dose. For more intense activities, multiple coincidence event rate increases steeply, so that the greater part of measuring time is spent to reject these events.

POSITRON CT USING TIME OF FLIGHT TECHNIQUES

Takehiro Tomitani
Physics Division, National Institute of Radiological Sciences, Chiba.

Coincidence pairs in positron camera determine projection lines and position is indetermined along these lines. It is well known that 3-dimensional position can be obtained with time of flight (TOF) techniques. Lack of accuracy in current TOF techniques can be supplemented by correction method similar to conventional CT. Since TOF techniques localize depth position, in contrast to conventional CT, enhancement of statistical noise due to image reconstruction is less.

Since coincidence efficiency is proportional to square of the detection efficiency e, e^2/d can be regarded as a figure of merit of scintillators, where d is depth position indeterminancy. Figures of merit of NE-111 (plastic scintillator), ZnO(Ga), NaI(Tl) and liquid Xe relative to conventional P-CT with NaI(Tl) (d=15cm) are 0.5, 5.9, 2.0 and 6.0, respectively, while that of conventional P-CT with $Bi_4Ge_3O_{12}$ is 2.3. In this comparison, total cross sections are adopted as indices of efficiency. Although ZnO (Ga) seems good, its effective atomic number is too low. While atomic number of Xe is comparable to NaI (Tl), so that liq. Xe is the best among these scintillators. However main obstacles in practice are the fact that it is a U.V. scintillator and should be cooled down to -108°C.

Image can be reconstructed either by one-dimensional deconvolution or by two dimensional deconvolution. Assume that time spread function expressed in space domain is gaussian with variance σ^2, then 1-D correction function h(x), with which point spread function (PSF) of reconstructed image is also gaussian of variance ρ^2, is

$$h(x) \propto \exp(-x^2/2\sigma^2)[1-2x/\xi\, F(x/\xi)]$$

where $1/\xi^2 = 1/\rho^2 - 1/2\sigma^2$ and $F(x) = \exp(-x^2)\int_0^x \exp(s^2)ds$. Note that the term in [ ] is identical to a correction function of conventional CT.

2-D correction function G(R) in frequency domain, with which PSF would be gaussian of variance ρ^2, is,

$$G(R) \propto \exp(-\sigma^2R^2/4)/[\exp(-\sigma^2R^2/2)I_0(\sigma^2R^2/2)]$$

where I_0 denotes 0-th order modified bessel function of the first kind. Note that as $\sigma \to \infty$, $G(R) \to \exp(-\sigma^2R^2/4)\sigma R$ which is identical to 2-D correction function of conventional CT.