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Pulse Shape Processing to correct Pile Up and Dead Time at High Count Rate by Using Digital Spectroscopy Analyzer (DSA).

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Abstract

Rise time parameter in digital spectroscopy analyzer (DSA) is used to obtain a new method for pulse shape processing which is used to correct dead time and pile up at high count rate. When the pile up rejecter has been used the dead time did not eliminate so much, but as the new method has been used (rise time parameter) the dead time decreased to its half value. The effect of rise time on the spectrum such as the relationship between the rise time and each of width pulse shape, dead time, gauss ratio, peak to valley ratio and peak to Compton ratio ,have been studied .

Keywords: - Gamma pulse shape processing, dead time and pile up optimization.

Introduction

In all counting system of nuclear radiation detection dead time will appear, especially in detector which has a large ratio of dead time. At high count rate the dead time ratio increases.

Dead time occur in detector when the frequency of nuclear radiation becomes larger than the velocity of transition of (Excited or ionized) electron or ion in detector medium. The detector dead time can be calculated as follows: [1]

$$N - n = nN\tau \quad ....(1)$$

where N : is a count strikes surface cross section of detector , n : is a count recorded by crystal medium of detector and τ: is dead time .

Spectroscopy research is needed as much as possible to correct dead time in order to approach its measurement to actual information of the sample.

Either nuclear electronic system or nuclear spectrometer parameter have been used as a certain method for this purpose, Batt and McDaniels [1] have used a method for the dead time correction by non-paralyzable electronic device (time to amplitude converter-TAC), Byrd and Goosy[2] have used automatic differential dead time correction in (MCA_4096 channel) at input rates up to 5*10^4 /sec, Meggitt [3] has used electronic modules to correct the counting of multi-channel analyzer by dead time , and Wargelin Yaron Danon(et al) [4] have used Spectroscopy of parametric X-rays (PXR) from pulsed electron sources is usually done with very low electron beam currents in order to avoid dead time losses and pileup problems and M. Capogni (et al) [5] have used random -summing and dead time effects processing to optimizing count rate of the sum-peak method by using Two NaI(Tl) detector of different volumes.

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In this study a new method is used to correct dead time and pile up by the new spectrometer (DSA).

The counting system usually consists of a counter, an amplifier and a discriminator or an analyzer.

Each part of this electronic unit can participate in a certain manner in the pulse losses and therefore could be characterized by a certain dead time. The dead time of the pulse shaper amplifier depends on the type of pulse spectrum and counting rate Zidek and Plch [6].

There are two types of dead time in a time digitizer:

Extending (pile up) dead time

The arrival of a pulse causes a dead time interval τ_e. If another pulse arrives during the dead time caused by preceding pulse, the second pulse is not counted, and the dead time will extended by an additional τ_e from the arrival time of the second pulse. At high counting rates,multiple (pile up) pulses that are separated by less than τ_e caused considerable extension of dead time, and commensurately large dead time loss [7].

Non - Extending dead time

The arrival of a pulse causes a dead time interval τ_{ne}. If another pulse arrives during the dead time caused by preceding pulse, the second pulse is not counted. The ignored second pulse has no effect on the dead time.

In both cases, higher counting rates lead to a higher probability of a pulse arriving during the dead time from a previous pulse. Consequently the dead time losses increase with counting rate [7].

Each electronic unit that used in a nuclear system measurement has a self dead time. In order to determine total dead time the delay method should be applied via time to amplitude converter (TAC) unit in a nuclear system measurement. The delay caused by electronic units equal to dead time of these apparatus.

The main factor for increasing the dead time is pile up pulses which arises from a high counting rate. The pulse pile up divide into two portions, the peak portion during the time interval $0 \le t \le \tau_R$, and the tail portion during the time $\tau_R \langle t \langle \infty$ as shown in Fig (1).

Peak pile up: It occurs when the peak of the pulse overlaps with the peak portion of another pulse as shown in Fig (2).

Tail pile up: it occurs when the tail of the pulse overlaps with the peak portion of another pulse as shown in Fig (3), Nicholson [8].

To separate two pulses or more, the pile up rejecter circuit is shown in Fig (4) should be used, thus each of separating pulses has pulse width shorter than pile up pulse. This due to reducing dead time for each of them because the ADC unit and the other digital units of MCA become not busy for long time as occurring for pile up pulses.

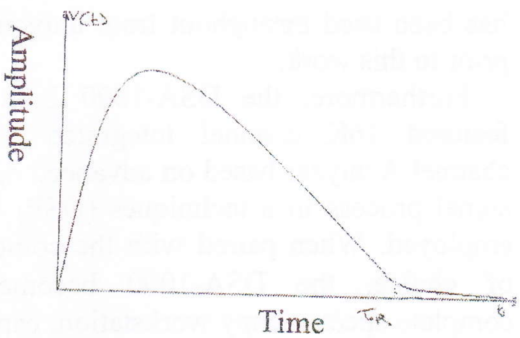


Fig (1) Pulse containing (peak and tail) pile up

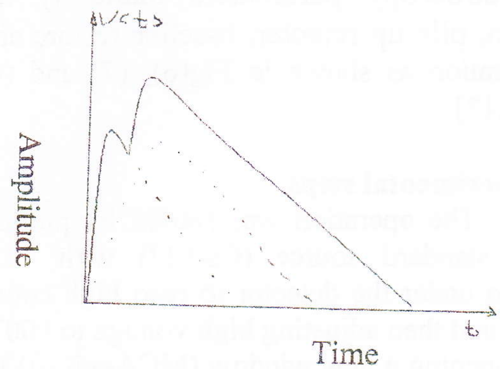


Fig (2) Peak pile up pulses

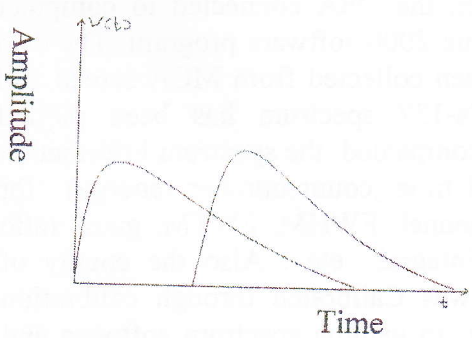


Fig (3) Tail pile up pulses

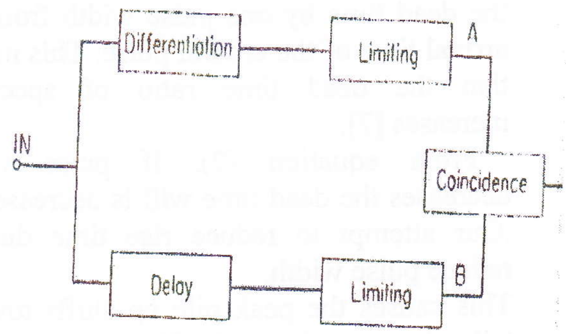


Fig (4) Pile up rejecter

Pulse shape process mechanism {The method}

There are some methods for minimizing dead time, Harm method, Westphal method, the pulser method and the virtual pulse generator method [9].

In the present method the dead time is reduced by reshaping the pulse out of the detector. The extending (pile up) dead time source is controlled by the pulse shape from the rise time and fall times of preamplifier, pulse amplitude, and the discriminator threshold voltage [10].

The first step of pulse shape processing is started by passing the pulses through the amplifier of (DSA). The pulse width is minimized by minimizing the rise time without varying the top of the pulse therefore the amplitude of the pulse remaining constant as shown in Fig (5) also as given by Wargelin [11]:

$$\tau_{dead} = \tau_{peak} + \tau_{width} \quad \ldots\ldots. (2)$$

In ordinary case (before pulse shape processing) The width of analog pulse at the threshold causes an extending (pile up)dead time .If a second pulse arrives while the first pulse is still above the threshold, the second pulse adds to first , and extends the dead time by one pulse width from the arrival time of the second pulse. This means that the dead time ratio of spectrum increases [7].

From equation (2), if pulse width decreases the dead time will is decrease too .Our attempt to reduce rise time due to reduce pulse width.

This causes the peak pile up shifts toward tail pileup as shown in Fig (5) hence tail pile up easily will be eliminated from pile up rejecter circuit. Thus counting rate will increase as a result of reducing analog width pulse this causes Analog to Digital Converter (ADC) unit does not become busy, this means that the pulse does not suffer any noise or any degradation because the collection charge remains at its constant value, if top pulse has been varied the ballistic deficit noise would be created. Therefore, in this study reducing of rise time was applied without any noise thus it causes to reduce width pulse and separating pileup pulses which means that the pulse shape processing also it acts as pile up rejecter.

In general this mechanism compensates some pile up rejecter circuits as appear in this work.

Experimental method

In this experiment, the radioactive source (Cs-137 with 18.6 MBq) was used and nuclear electronics unit (NaI(Tl) detector with crystal size (2*2) join with preamplifier, digital spectroscopy analyzer-DSA which has multi functions like spectroscopy amplifier, single channel analyzer-SCA, multi channel analyzer and personal computer with Genie2000 soft ware program. Indeed it is a first time DSA has been used throughout Iraqi universities prior to this work.

Furthermore, the DSA-1000 is a full featured 16K channel integrated Multi-channel Analyzer based on advanced digital signal process in a techniques (DSP) were employed. When paired with the computer of choice, the DSA-1000 becomes a complete spectroscopy workstation, capable of highest quality acquisition and analysis. The instrument interfaces to all existing detector technologies like HPGe, NaI, Si(Li), CdT or Cd(Zn)Te.

From DSA it is possible to reset all spectroscopy parameters manually as, gain, pile up rejecter, baseline restore and Filtration as shown in Fig(6), (7) and (8) [12,13].

Experimental steps

The operation was started by putting the standard source (Cs-137) with 18.6 MBq under the detector to read high count rate and then adjusting high voltage to 900V by opening a new window (MCA-adjust) in gamma spectrum software as shown in Fig (9).

The detector was connected to the DSA and then the DSA connected to computer via Genie 2000 software program. The data have been collected from MCA screen and then Cs-137 spectrum has been plotted which companied the spectrum information as dead time ,count number (energy) for each channel ,FWHM, FWTM, gauss ratio ,count integral etc . Also the energy of source was Calibrated through calibration window in gamma spectrum software and then the data were collected for interval (200 sec) to record the spectrum at each certain case this source has a high count rate, therefore a high count rate must be

controlled to cause the spectrum to be stable as more as possible by two ways ;
1- By minimizing amplifier amplification to (10).
2- By reducing space window to (32). According to this formula;

$$S = A / K \quad ...... (3)$$

S: is instability, A= ΔV =Vu (thr) – Vl (thr) is gain spacing, K: is gain window [14].

The spectrum has been more stable because S proportional directly with A. On the other hand another evidence was a peak spectrum remained in its location (without peak location shift) during the time of the operation as shown in Fig (10).

Although we used pile up rejecter parameter the dead time remained at grate ratio (28.45%) but from pulse shape processing via reducing rise time from (2 to 0.4) µsec the dead time is reduced to the half.

Discussion and Conclusions

When the pulse rise time reduced from (2 to 0.4) µsec due to reduce the width of pulse shape from (2.9 to 1.8) µsec as shown in Fig (5), thus it is concluded that the dead time is proportional directly with width pulse shape as shown in Fig (11).

On the other hand, decreasing the rise time from (2 to 0.4) µsec causes dead time to minimize from 28.45 % to16.48%. By this new method the dead time is reduced to its half value. This means that method is very effective at high count rate. Also, by pulse shape process the two pulse pile up are separated .It means that this method acts as additional pile up rejecter for reading more count rate and record minimum ratio of dead time as shown in Fig (5-D) . Before this method has been used the dead time remained at 28.45 % although a pile up rejecter has been used. It may be concluded that the dead time is proportional directly to rise time value as shown in Fig (12).

Another evidence to prove this method is that by reducing the rise time from 2 µsec to 0.4 µsec the count rate increases from 424831 counts to 480466 counts as shown in table (1). This means that nuclear electronic units can read count being optimized by ratio 12.15% due to increase efficiency of DSA by amount 12.15%.

It may also be conclude that the rise time is proportional inversely to count rate as shown in Fig(13) because the width pulse minimized upon putting through digitize DSA unit. This causes reducing its busy. This result read more count at the same time interval. The above relationship between rise time and count rate is not correct for coincidence case at low count rate [15]. This method is different from pile up rejecter because in pile up rejecter all of the piles up pulses are rejected totally which causes decreasing the count rate. In this method the pulses, pile up firstly separate and then minimize the rise time to increasing the count rate and at once minimizing the dead time.

In this method the best Gaussian ratio is obtained at 0.4 µsec this means that when the rise time decreased the Gaussian ratio will approach to ideal ratio as shown in Table(2).Pulse shape processing causes to reduce noise time jitter which was satisfied when the slope of pulse shape becomes grater as shown in Fig(5) [16].

A part of this work is about rise time (pulse shape processing) effect on gamma spectroscopy. When the rise time is decreased peak to Compton is varied. Peak to Compton ratio determines Compton noise ratio in the spectrum which affects on a resolution and then to determine value of life time. This attempt was done to reduce each of Compton ratios and background ratio in the spectrum by decreasing rise time, satisfying that at 0.4μsec rise time obtains minimum value for each of Compton ratio and background ratio in the spectrum as shown in Fig (14).

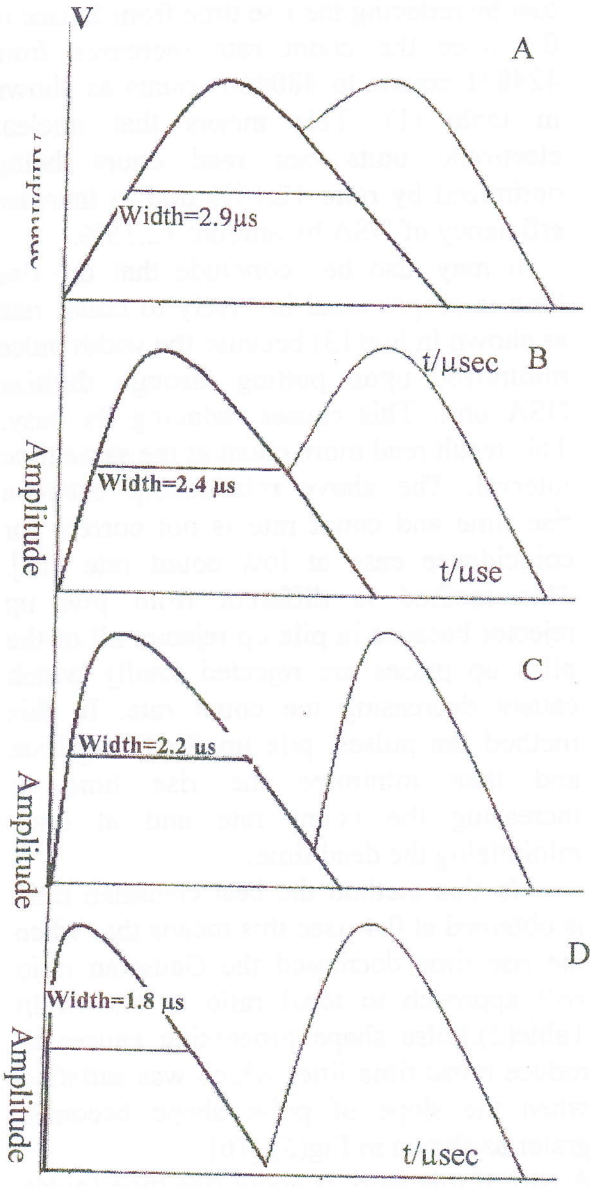


Fig (5) pulse shape process as a function of minimizing rise time timtime

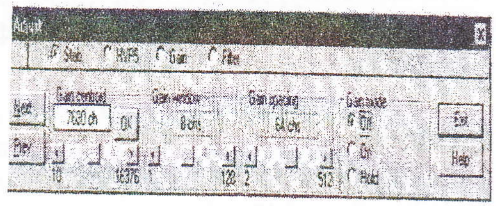
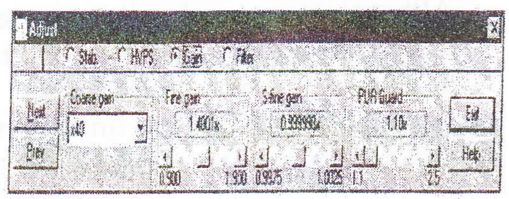


Fig (6) Adjust Screen's Stabilizer Settings



Fig(7) Adjust Screen's Gain Settings

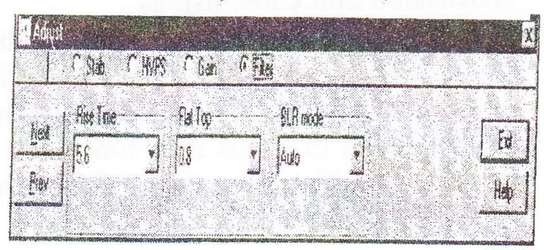


Fig (8) Figure 21 Adjust Screen's DSP Filter Settings

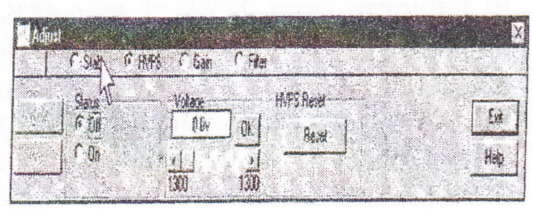
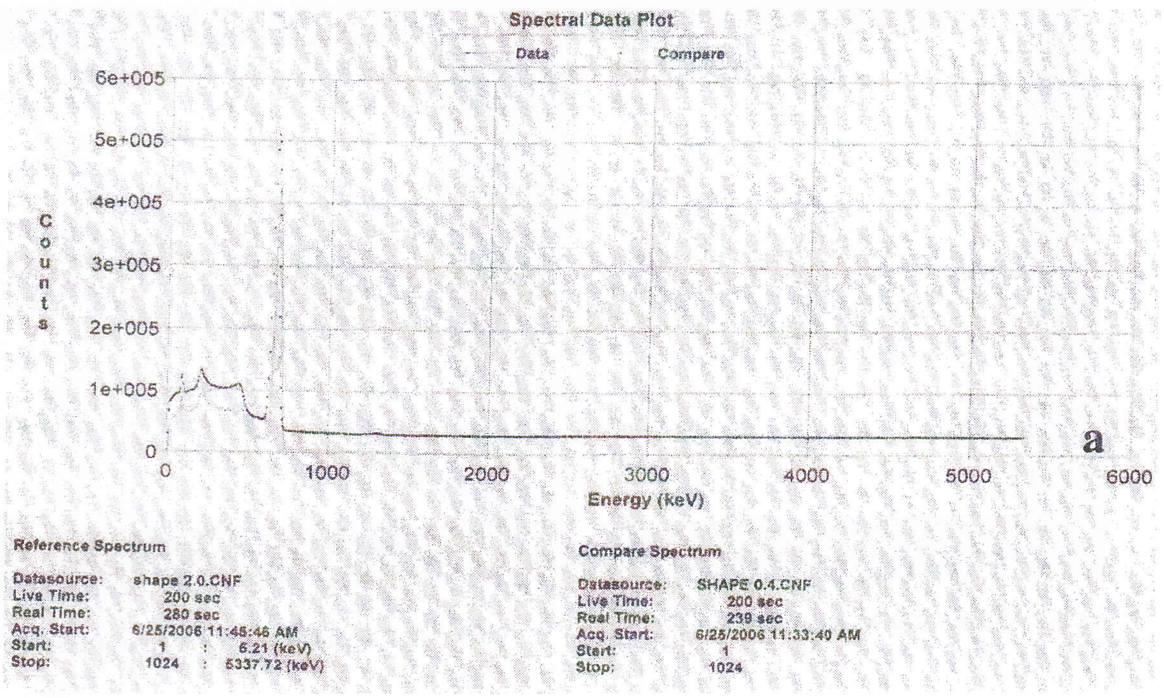


Fig (9) Adjust Screen's HVPS Settings



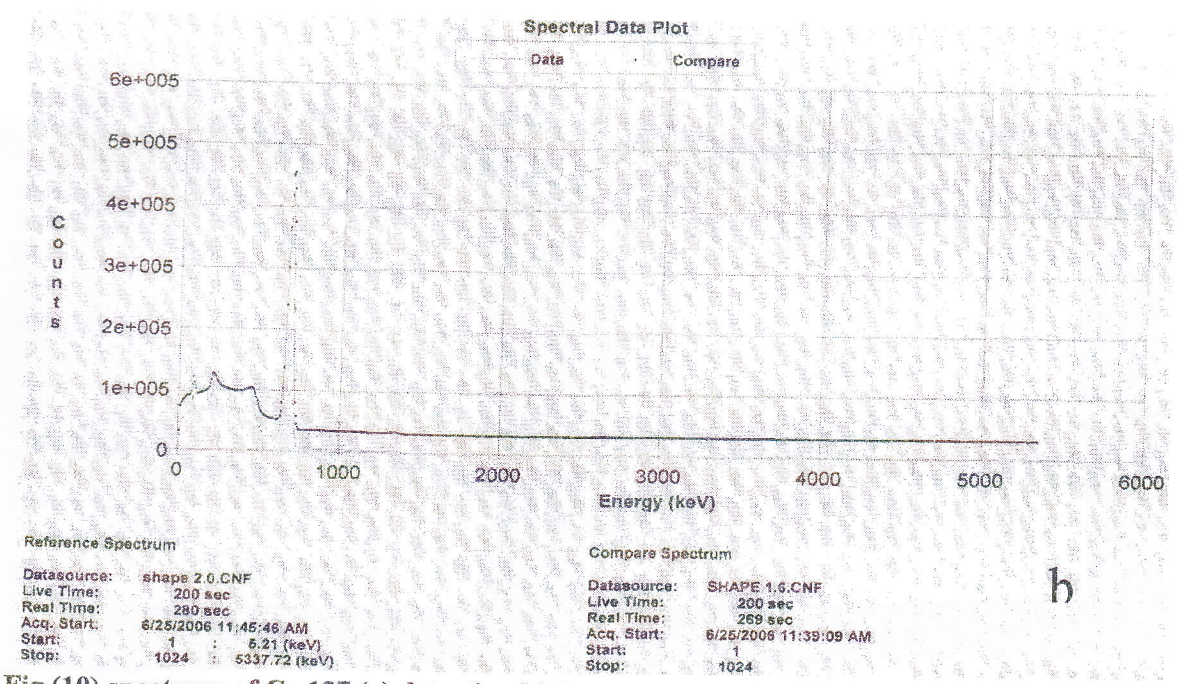


Fig (10) spectrum of Cs-137 (a) detecting high count more than 500000 count at rise time (0.4 μ sec) if compared with normal case at(2.0μ sec) (b) detecting high count More than 450000 count at rise time 1.6 μ sec if compared with normal case at(2.0 μ sec).

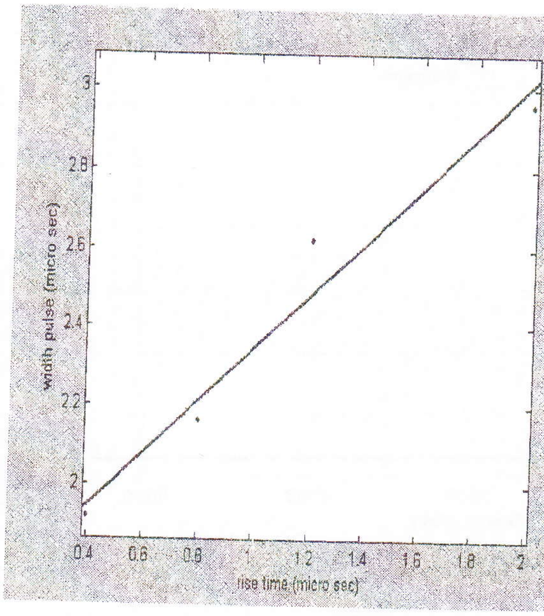


Fig (11) Pulse width as a function of dead time

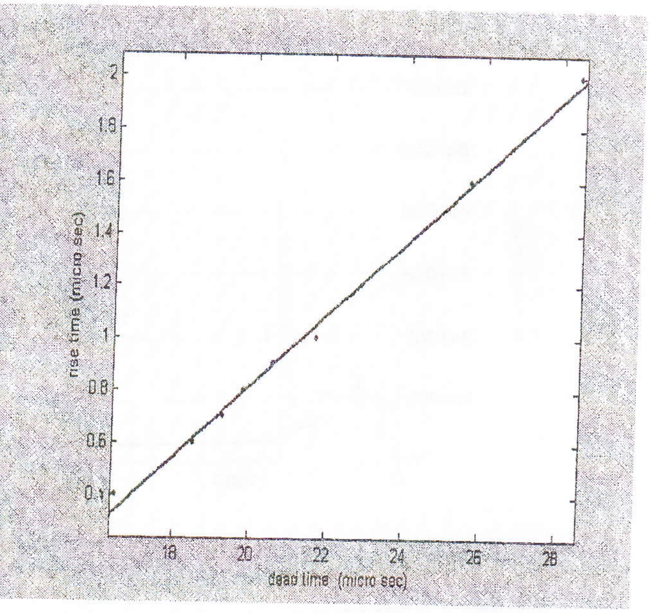


Fig (12) Rise time as a function of dead time

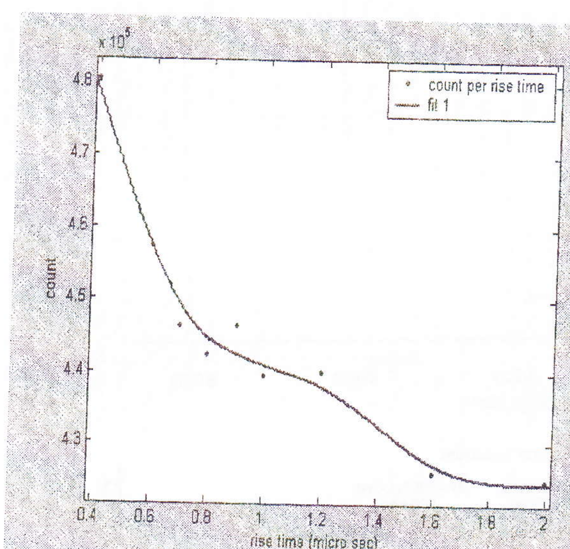


Fig (13) Count as a function of rise time

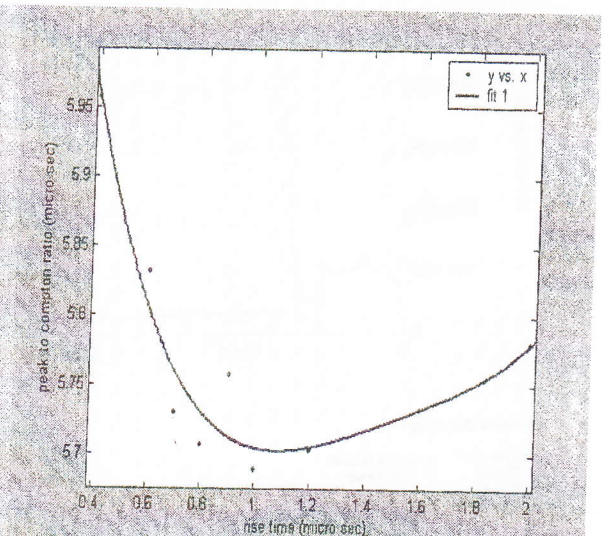


Fig (14) Peak to Compton ratio as a. function of rise time

Table (1) peak count, peak to valley, Compton count and peak to Compton ratio as a function of rise time.

Rise time (µsec)	Peak count	Peak to Valley ratio	Compton count	Peak to Compton ratio
2.0	424831	19.177	73485	5.781
1.6	425833	19.126	74275	5.733
1.2	439901	19.044	77137	5.703
1.0	439440	18.874	77249	5.689
0.9	446272	19.132	77132	5.758
0.8	442261	18.921	77498	5.707
0.7	446311	19.164	77888	5.730
0.6	457269	19.157	78401	5.832
0.4	480466	19.506	80654	5.957

Table (2) dead time, Gauss ratio and pulse width as a function of rise time.

Rise time (µsec)	Dead time%	Gauss ratio %	Pulse width (µsec)
2.0	28.45	0.995	2.9µs
1.6	25.62	0.989	
1.2	22.85	0.994	2.4 µs
1.0	21.69	0.994	
0.9	20.58	0.992	
0.8	19.81	0.992	2.2 µs
0.7	19.27	0.994	
0.6	18.52	0.996	
0.4	16.48	1.000	1.8 µs

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کرداری چاکسازی کردنی شێوەی پرتە شە پۆل بۆ کەم کردنەوەی دیاردەی سەریەکچوونی پرتە شە پۆلەکان هەروەها بۆ کەمکردنەوەی کاتی مردوو (ووچانە کات)، لە باری تیشکاوەری ڕادە بەرزدا بە بەکارهێنانی ئامێری شیتەلکەری شەبەنگی ناوەکی دیجیتالی -DSA.

عادل محمد حسین، بەشی فیزیک ، کۆلیجی زانست ، زانکۆی سلێمانی، هەریمی کوردستان/ عێراق

پوختە

پارامیتەری کتی بەرەوسەر (Rise time) بەکارهاتووە لە دەزگای شەبەنگ پێوی دیجیتالی DSA وەك ڕێگایەکی نوێ لە بواری چارەسەرکردن و سازدانی شێوەی پرتە نیشانە (pulse shape processing) کە ئەمەش بەکاردێت لە کەمکردنەوەی کاتی مردوو (dead time) بەهۆی بەکارهێنانی شێوازێکی تازە کە بریتی یە لە کرداری جیاکردنەوەی دوو پرتەی سەریەك چووی تیشکی ناوەکی, ئەم پرۆسەیە ئەنجام درا لەباری ڕادەی بەرزی دەرچوونی تیشکی ناوەکی لەسەرچاوە تیشکاوەرەکەوە. گرنگی بەکارهێنانی ئەم ڕێگە تازەیە لەوەدایە خوێندنەوەی تیشکی ناوکی زۆر زیادی کردووە و لەهەمان کاتدا کاتی مردوو کەمی کردووە بۆ نیوەی ئەو نرخەی کە تۆمار کرا لە ڕێی بەکارهێنانی سوڕی پرتە سەریەکچووی دەرکەرەوە(pile up rejecter circuit) کە دەبێتە هۆی کەم کردنەوەی خوێندنەوەی تیشکی ناووکی ئەمەش کاریگەری زیان بەخشی هەیە لەسەر دیاری کردنی چالاکی تیشکاوەری سەرچاوەکە. بەکارهێنانی ئەم ڕێگا تازەیە دەبێتە هۆی چاکسازکردنی شەبەنگی ناووکی هەروەك دەرکەووت تاوەك و کاتی بەرەوسەر کەم بکرێتەوە ڕێژەی فۆتۆپیك بۆ کۆمپتن زیاد دەکات, هەروەها دیاری کردنی پەیوەندی نێوان کاتی بەرەوسەر و لەفراوانی پرتە.

معالجة شكل النبضة لتقليل الظاهرة التراكم النبضة وزمن الميت لحالة العدّ العالى باستخدام محلل الطيف النووى دجتالى (DSA).

عادل محمد حسين ، قسم الفيزياء، كلية العلوم ، جامعة السليمانية ، اقليم كوردستان / العراق

الخلاصة

لقد استخدمت باراميتر زمن الصعود لجهاز محلل الطيف ديجيتالى DSA لمعالجة شكل نبضة الكامية. هذة المحاولة هى لتحليل زمن الميت الأجهزة الاكترونية المستخدمة فى منظومات القياسات النووية. و ذلك من خلال طريقة جديدة و هى عبارة عن عملية فصل نبظتين متراكمتين (Pulse pile up) لحالة نسبة العد العالى لأشعة الكاما المصدر المستخدم. وحصلت على نتجة فائقة لأزدياد قراءة الكاشف (ازدياد العد الكافى للمصدر المستخدم) بالرغم من تقليل بنسبة زمن الميت الى نصف قيمة الذى يقلل عادة بواسطة استخدام دائرة طرد النبضة التراكمية (Pile up rejecter circuit). من جانب الأخر تم ايجاد تاثير زمن الصعود على المطيافية النووية خاصة ايجاد علاقة بين زمن الصعود وكل من توسيع النبظة و نسبة الذزة الى الكومبتن.

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وەرگرتن لە ١٩/ ١٠/ ٢٠٠٦دا ە پەسەندکردن لە ٢٤/٤/٢٠٠٧دا.