Recent Progress with Digital Coincidence Counting

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SUMMARY Digital Coincidence Counting (DCC) is a new technique, based on the older method of analogue coincidence counting. It has been developed by ANSTO as a faster more reliable means of determining the activity of ionising radiation samples. The technique employs a dual channel analogue to digital converter acquisition system for collecting pulse information from a 4Π beta detector and a NaI(T*l*) gamma detector. The digitised pulse information is stored on a high speed hard disk and timing information for both channels is also stored. The data may subsequently be recalled and analysed using software based algorithms. The system is operational and results are now being routinely collected and analysed. Some of the early work is presented for Co-60, Na-22 and Sm-153.

1. INTRODUCTION

The ANSTO Radiation Standards Group, more recently in collaboration with the National Physical Laboratory in the United Kingdom, has been pioneering the development of a digital acquisition and analysis system for coincidence counting applications (1,2). Development of this new technique of ionising radiation activity determination began at ANSTO in the early part of the decade and has now progressed to the stage where Digital Coincidence Counting (DCC) has been realised as a working technique.

Analogue based coincidence counting has been used for many years in radiation metrology to accurately determine the activity of radioactive samples. Campion pioneered the present technique, which is called 4Πβ-γ coincidence counting, though his work was itself reliant on the still earlier work of Dunworth (4). Since the time of Campion there has been little change in the apparatus used in coincidence counting for metrology purposes. For typical experiments two radiation species are detected from the radioactive decay of a sample, usually a beta particle and a gamma photon (though gamma-gamma and alpha-gamma counting are also quite common). The efficiency of pulse detection for both these species is usually not well known due to variations in the sample preparation, and in the detector efficiencies. This means that there could be associated inaccuracies in determining the activity of the sample by simple counting methods. For the emission of particles which occur through the same decay branch there are relationships in time which allow coincidence counting to accurately determine source activity – for instance a beta decay is often very promptly followed by a gamma decay. By counting both species; the number of times that detected pulses from both species are coincident in time, and by applying appropriate corrections, the activity of the sample can be found with a high level of accuracy. This can be shown with a set of idealised equations:

$$N_\gamma = \varepsilon_\gamma N_o \qquad (1)$$

$$N_\beta = \varepsilon_\beta N_o \qquad (2)$$

$$N_C = \frac{N_\beta N_\gamma}{N_o} \qquad (3)$$

where N_γ, N_β, and N_C are the count rates for gamma photons, beta particles and their coincidences; N_o is the absolute activity which is required, and ε_γ and ε_β are the efficiencies of the two detectors used (usually a NaI(T*l*) scintillation counter for gammas, and a 4Πβ proportional gas counter). It can be seen from the equations that, for a simplistic analysis, counting beta particles, gamma photons and their coincidences will allow you to find an absolute activity via equation 3, while the detector efficiencies can subsequently be found using equations 1 and 2.

DCC represents a significant departure from the traditional methods of coincidence counting, although the same analysis equations are used, and the same detector systems, the analogue electronics which has been used for over forty years is now largely redundant.

Traditionally coincidence counting is carried out by banks of dedicated analogue modules, typically NIM based nucleonic modules. These would include separate modules for amplifiers, single channel analysers, multichannel analysers, time to amplitude converters, coincidence mixers, nucleonic pulse delay units, etc. And with these units there would be a considerable effort in set up time, a high cost for rack type analogue electronics and a large expenditure in system maintenance. With Digital Coincidence Counting (DCC) all these analogue units are eliminated. A data acquisition card digitises the pulse data for the two counting species in two separate channels and the pulse data for both channels are time stamped. The data - including timing and pulse shape information - is stored on a high-speed hard disk where it can be recalled at a later stage for analysis. A suite of offline user friendly analysis routines have been developed to carry out the functions of the NIM based modules. At present these enable conventional coincidence counting and the so called "computer discrimination method" (5,6) to be carried out, however they also provide a baseline for the development of counting techniques which are generally regarded as being too expensive to implement in analogue electronic form – see Buckman (7) for a listing and explanation of alternative techniques.

The advantages of the DCC system are many. It is a more cost affective means of implementing coincidence counting than standard nucleonics. The measurement set up time is considerably less than for traditional analogue systems. Less system maintenance is required. Electronic drift is removed from much of the system by using software algorithms instead of electronic modules. There can be a reduction in dead time corrections. Methods of activity determination not widely used because they are thought to be too expensive to implement for routine analysis, such as selective sampling or correlation counting (see Buckman (7)) can be applied using software routines. Other forms of analysis can also be introduced including pulse shape analysis that can be implemented in conjunction with coincidence counting for greater accuracy in activity determination. Finally the data can be stored for future referral. This last point is important from a quality assurance point of view since the analysis can be re-checked at any later stage.

2. DCC ACQUISITION SYSTEM

The ANSTO Radiation Standards Group has already started to use a second generation prototype DCC system using technology developed by the ANSTO Nucleonics Systems Group. CPLD (translated to FPGA format) and front end data acquisition technology developed by the Nucleonics Group has been incorporated onto a PCI high-speed data transfer card independently developed by a British company sourced by our NPL partners. The first prototype system was delivered to ANSTO in the April of this year, with an identical system being delivered to NPL at a later date. The testing of the card was carried out at ANSTO by Radiation Standards Group and Nucleonics Systems Group staff. Minor electronic bugs have been identified and solutions have been found for all of these. Data collection now proceeds with reliable integrity. The system is in regular operation with results being checked against the old analogue system, as described in the section 4, below.

Some of the properties of the data acquisition system include: two independent nuclear pulse input channels with 12 bit resolution; a 20 MHz data acquisition rate (per channel) with data capture above a user set threshold. Continuous data hard-disk transfer for 1 microsecond wide pulses at repetition rates of up to at least 30 kHz (dependent on computer and platform). This can equate to samples with activity of greater than 30 kBq. Files up to 2 GigaByte can be and have been collected. Data collection periods depend on sample activity, but continuous data collection has been achieved for periods of greater than an hour for ~ 5 kBq samples.

3. ANALYSIS SOFTWARE

The DCC software is being written with a Labview version 5.1 user interface, while processor intensive operations are carried out by faster turbo C++ routines, which operate transparently to the user. The software is presently in operation and can be used for radiation calibration purposes, however work still proceeds in improving the user interface. The hardware is now ready for commercialisation and with improvements to the DCC software it is hoped that system commercialisation will occur early in the year 2000.

4. MEASUREMENTS

DCC calibrations at ANSTO have been carried out to confirm that the new hardware and software is operating so that it provides the same isotope activity as the traditional analogue system. So far measurements have been carried out on Co-60, Na-22 and Sm-153.

Samples were prepared on gold/palladium alloy coated VYNS foils for counting in the ANSTO $4\pi\beta$-γ counting apparatus. The stock solution from which the samples were prepared had been calibrated previously with the Australian secondary activity standard, at ANSTO, in a TPA ionisation chamber using standard geometry. An accurately measured mass of solution was used in preparing the source so that the activity was known at a specified date and time.

Measurements for Co-60 and Na-22 were carried out using the standard coincidence counting techniques available with the DCC system, corrections were made for background counts, accidental coincidences and resolving time. The calculated activities were corrected to a standard reference time for comparison. Results are given below and all errors are for confidence levels of 99.7%.

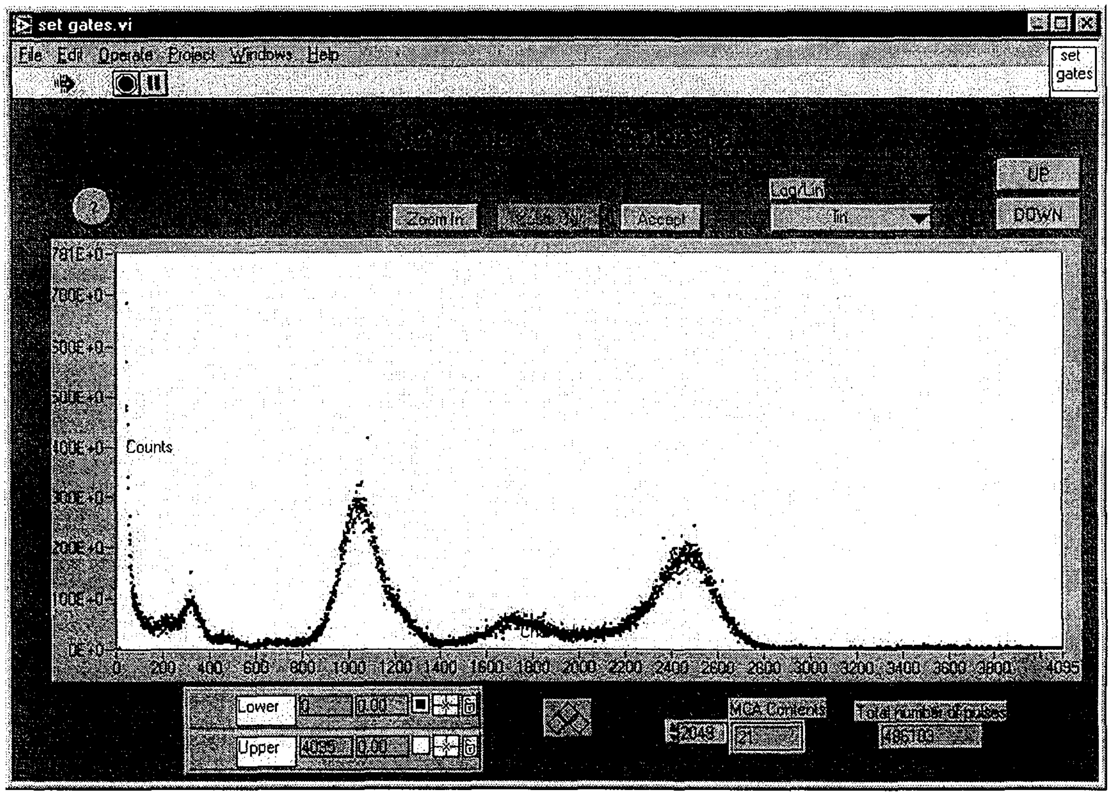
Using the analogue system VYNS foil 7249 had a Co-60 activity of 4893.4 Bq +/- 0.3%. For the same sample the DCC system measured 4881.9 Bq +/- 0.8% so that the analogue and DCC results were within 0.3% of each other.

For Co-60 VYNS foil sample 7250 the analogue system gave an activity of 4600.1 Bq +/- 0.4%. DCC measurements for the same sample gave an activity of 4589.4 Bq +/- 0.9%, so for this foil the analogue and DCC results were within 0.2% of each other.

For Na-22 foil 7269 the DCC gave 5770.5 +/- 0.3% Bq; the analogue measurements gave 5781.7 +/- 0.4% Bq. This gives a 0.19% difference between the two. All of these results for Na-22 and Co-60 are well within statistical error. There was also statistical agreement with the secondary standard measurements.

The gamma spectra displayed by the DCC software for a Sm-153 sample (to allow the setting of a single channel analyser window) is shown in figure 1 over page. For Sm-153 the DCC computer discrimination method was used and preliminary results were again in agreement with the secondary standard measurements. There is also some pleasing agreement with the analogue coincidence counting unit, for which efficiency extrapolation was used. However, further work is still necessary for comparisons with Sm-153.

Figure 1: Gamma Spectra for Sm-153



Lower 0 0.00

Upper 4095 0.00

2048

MCA Contents 21

Total number of pulses 486103

5. CONCLUSIONS

To date excellent agreement has been obtained between the old analogue system and the DCC system for the standardisation of Co-60 and Na-22 - to within statistical error. More recent work has been carried out on Sm-153 – though this is still preliminary. Further standardisation's will continue throughout the year. The hardware and software for DCC now constitute a working system and it is envisaged that commercial units will begin to be sold by the end of the year. Inquiries by interested parties are welcome before hand.

ACKNOWLEDGEMENTS

The development of the DCC system has been an ongoing project at ANSTO for a number of years with a large number of staff participating in its evolution. In particular we would like to acknowledge the early work of Dr Stephen Buckman who put into train the development of the system based on Stewart Sherlock's original vision. Our beloved Division Leader Dr Claudio Tuniz is much thanked for his ongoing support of the project, the general divisional support received is also much appreciated. We would like to thank Mr Dino Ius for his electronic and audiovisual contributions. Thanks also to members of the ANSTO Radiation Standards Group for their support including Dr Haitse van der Gaast, Mr Justin Davies, Ms Li Mo and Dr Hugh Wyllie. The contribution of Marie-Pierre Pertus-Hopman in her efforts to help with commercialisation is also much appreciated.

Finally we would like to thank our NPL collaborators who have contributed substantially to the DCC software development. Members of that team include Mr John Keightley, Dr David Smith and Mr. Mike Woods.

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