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Application of digital signal processing to neutron energy spectrometer for deuterium experiments in LHD/KSTAR

LHD/KSTAR重水素実験のための核融合中性子スペクトロメータにおけるデジタル信号処理の適用

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Digital signal processing (DSP) was applied to the associated particle coincident-counting neutron energy spectrometer (APCC-NES) for deuterium experiments in LHD and KSTAR. The on-line DSP in a digitizer was used for data acquisition in the APCC-NES and demonstrated an acceptable counting rate of 4×10^5 cps in the detector output. The on-line DSP was applied to the prototype of the APCC-NES system installed at J-port in the KSTAR during the 2014 experimental campaigns.

1. Introduction

Deuterium plasma experiments are prepared in the Large Helical Device (LHD) at National Institute for Fusion Science, in Japan. In the Korea Super Conducting Tokamak Advanced Research (KSTAR) at the National Fusion Research Institute, Republic of Korea, deuterium plasma operation is being carried out from 2010 campaign. In deuterium fusion plasma heated by neutral beam injection (NBI), 2.5MeV neutrons are emitted as accompanying products of DD reactions, which are mainly occurred as beam-plasma interactions. Thus, the neutron energy spectrum emitted from the deuterium plasma reflects the velocity distribution of fast ions in high temperature plasma. Toward LHD deuterium phase, we have developed associated particle coincident-counting neutron energy spectrometer (APCC-NES) [1] to understand beam ions behavior in the plasma. The prototype APCC-NES system was installed at J-port in the KSTAR in 2012 [2]. However, coincidence detection, which is included in the measurement principle in the APCC-NES and already demonstrated at the accelerator-based DD neutron source [1], failed in this experiment because the radiator and the scattered neutron detector did not work properly due to problems in high counting rate conditions and in noise caused by the power supply. In this study, we applied digital signal processing (DSP) to the APCC-NES to improve acceptable counting rate of detectors which are components of the APCC-NES.

2. Overview of APCC-NES and Digital Signal Processing

Figure 1 shows an overview of the APCC-NES system. The system is based on coincident detections of a scattered neutron and a recoil proton associated to an event of neutron elastic scattering. The incident neutron energy is simply derived from the sum of the recoil proton energy and the scattered neutron energy. Therefore the system consists of three detectors: a thin plastic scintillator worked as an incident neutron target and ΔE detector for recoiled protons (called as a radiator), a Si surface barrier detector for recoiled proton detection (RPD), and a plastic scintillator for scattered neutron detection (SND). The scattered neutron energy is measured by time-of-flight (TOF) method between the radiator and the SND.

A fast preamplifier was used for photomultiplier tube (PMT) output for the radiator. For output of the RPD, a preamplifier and a spectroscopy amplifier were used. We applied a waveform digitizer (DT5720, CAEN) for on-line DSP of outputs of these detectors. The digitizer allows analog to digital conversion and following on-line DSP for the charge integration. Figure 2 shows a schematic diagram of on-line DSP in the digitizer

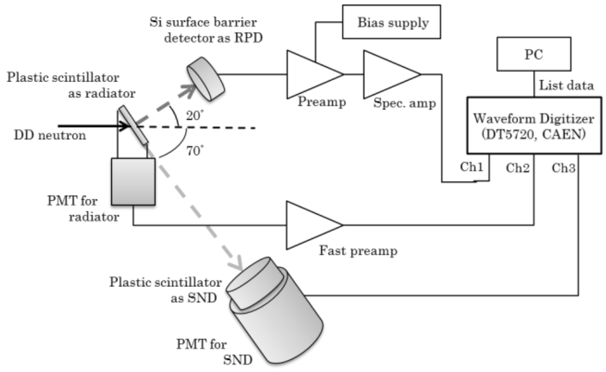


Fig.1. Overview of the APCC-NES

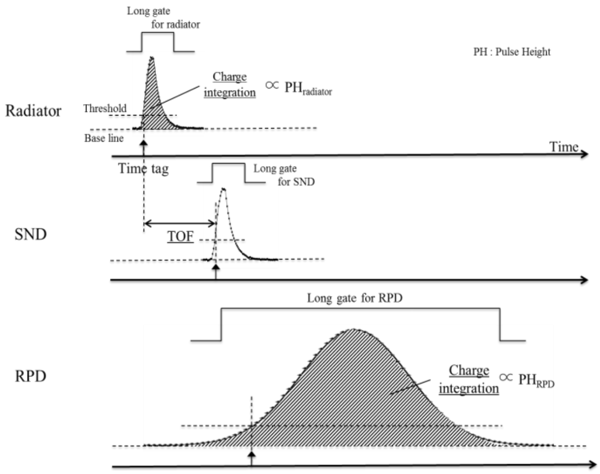


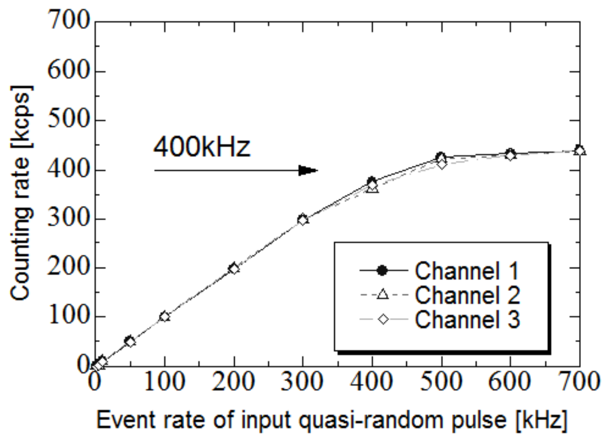
Fig. 2. Schematic diagram of on-line DSP
in the digitizer for the APCC-NES

for the APCC-NES.

Long gates for inputs for the detectors were optimized for the better energy resolution and time resolution. For the RPD output, the integration time of the spectroscopy amplifier was also optimized. List mode data, i.e. series of the timing and pulse height of each pulse was recorded in PC. After the measurement, the pulse height spectrum with/without coincidence events and the time-of-flight spectrum were obtained by off-line data analysis. The energy resolution of the RPD and the radiator, and the time resolution by the radiator and the SND were comparable with those by data acquisition based on a conventional multi-channel analyzer.

We also investigated the acceptable event rate of the digitizer in the parameter set for the APCC-NES. Figure 3 shows the dependence of counting rate for quasi-random pulses on the event rate of input pulses. The counting loss was not appearing up to about 4×10^5 cps, i.e. the DSP improved the acceptable counting rate by one order of magnitude compared with the conventional data acquisition.

The DSP was applied to the prototype of the APCC-NES system installed at J-port in the KSTAR during the 2014 experimental campaigns. To reduce the electrical noise in each detector output, a constant voltage constant frequency power supply was installed for the system. The digitizer worked properly up to about 4×10^5 cps.



3. Summary

We applied digital signal processing to the associated particle coincident-counting neutron energy spectrometer system to improve acceptable counting rate of each detector. The digitizer provided the pulse height and timing data of each pulse from the detectors up to about 4×10^5 cps. The on-line DSP was applied to the prototype of the APCC-NES system installed at J-port in the KSTAR during the 2014 experimental campaigns and off-line analysis of the obtained data is now ongoing.

Acknowledgments

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References

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