RESULTS OF BACKGROUND SUBTRACTION TECHNIQUES ON THE SPALLATION NEUTRON SOURCE BEAM LOSS MONITORS*

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Abstract

Recent improvements to the Spallation Neutron Source (SNS) beam loss monitor (BLM) designs have been made with the goal of significantly reducing background noise. This paper outlines this effort and analyzes the results. The significance of this noise reduction is the ability to use the BLM sensors [1], [2] distributed throughout the SNS accelerator as a method to monitor activation of components as well as monitor beam losses.

OVERVIEW

Any study of the effects and causes of system noise must contain some identification of the nature of the system noise and its sources. We will identify the sources of noise in the BLM circuits and show the results of reduction techniques used to mitigate these noise sources.

Identifying Noise Sources

The SNS BLM sensors are primarily high-gain transimpedence amplifiers that collect the change in charge when particles or energy are incident on the sensor. The effects of noise associated directly with components used in high-gain transimpedence amplifiers are actually surprisingly low. The largest source of noise is induced currents and Electro Motive Interference (EMI) [3] on the long cables from the sensors located in the LINAC tunnel and the data acquisition system located in the instrument galleries. The distance between the sensors and the front end amplifier is large typically on the order of 100 meters. External influences such as electrical and electromagnetic sources make up the majority of the background noise seen at the front end amplifier (Fig. 1).

Design Approach

Having sufficiently determined the noise associated with the measurements, the BLM amplifier was designed to mitigate the bulk of the system noise in the design:

- Ultra low noise input bias current Op Amps were used in the transimpedence amplifier stage. A classic large-series resistor is used to ensure the voltage gain was low while the current gain was sufficiently large for the signal range.
- A second amplifier stage identical to the signal stage is attached to a second cable terminated in the LINAC tunnel and routed in juxtaposition to the signal cable.
- The signal and background input transimpedence amplifiers and the subsequent background subtraction stage have a bandwidth at least 4x the desired system bandwidth to decrease any phase error or effects in the signal subtraction.
- Post background subtraction low-pass filter is available, selected through software, to further smooth any noise effects present on the subtracted signal.

The resulting signal can be adjusted to not only remove a significant amount of EMI noise present on the signal wire, but also allows removal of the induced radio frequency (RF) pulse present on the signal and the subtraction cable. The resulting signal is a closer representation to actual loss of beam present during LINAC operations. This data is fed directly to the integrators used for the SNS Machine Protection System (MPS) [4] with no error caused by excess induction of non-loss noise sources. Additionally, the loss signal is available for digitization and analysis. Loss spectrum has been an interesting study to determine if the source of the losses can be identified, as has a study of methods to determine actual activation levels by monitoring the growth of non noise-related signals during periods of no beam or RF.

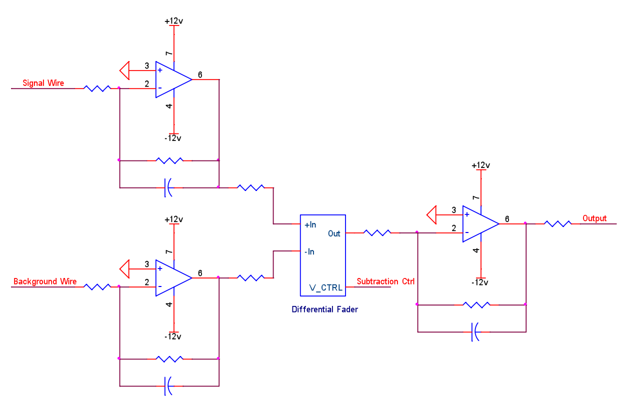

Figure 1: Front End Block diagram.

The new BLM amplifier module is a consolidation of four separate systems used on the current BLM design. This new circuit is a single-channel solution, including MPS, digital control and high-Voltage (HV) bias power supply. This new design helps to further reduce the noise associated with the Photo Multiplier Tube (PMT) and Ion Chamber BLM sensors by eliminating multiple sensors and allowing the digital, HV supply and amplifier to work

* ORNL/SNS is managed by UT-Battelle, LLC, for the U.S. Department of Energy under contract DE-AC05-00OR22725

in unison with small identifiable power sources and signal paths (Fig. 2).

INSITU RESULTS

A test was conducted using two BLM modules connected to a new Dual BLM sensor. This sensor has two separate PMT chambers, one sensitive to gamma/x-ray and neutrons, and the second sensitive to only gamma/x-ray losses. The purpose of this experiment is to use the new circuitry to subtract the neutron signals leaving only the neutron loss representing actual activation and loss. The RF pulses and resulting x-rays are removed from the analyzed signals. The results are checked using a much more expensive multi-channel analyzer (MCA) spectrum analyser, which would be cost prohibitive as a system solution. Data was taken with background subtraction enabled and disabled. Both sensors were placed downstream from the superconducting LINAC module 15, designated SCL:15c., in the SNS accelerator.

Figure 2: BLM module layout.

No Background Subtraction

Initially, data was taken with background subtraction disabled showing a signal similar to the original BLM amplifier. The pulse shown includes the RF signal represented by both x-rays incident on the PMT and a slight offset due to the induced RF currents on the BLM cable itself.

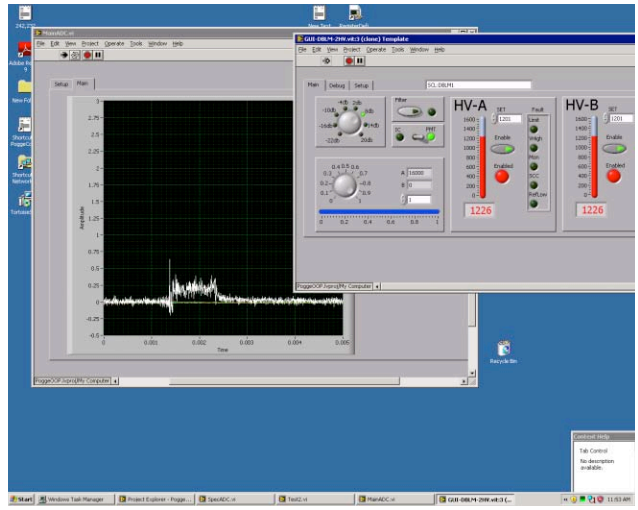

Figure 3: Background Subtraction disabled.

With Background Subtraction

Once background subtraction is enabled and adjusted the results are immediately visible. The resulting signal passed to both the data acquisition system and the MPS integrator sub-circuit. Figure 4 is a screen capture of background signals removed from the same BLM signal of interest.

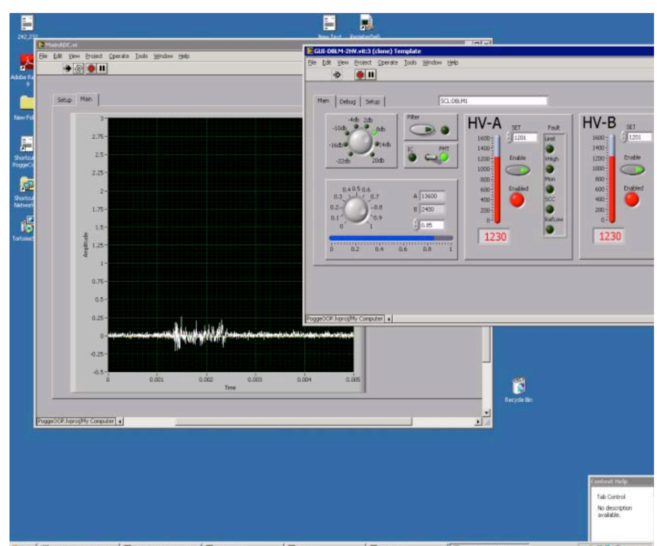

Figure 4: With background subtraction.

SPECTRUM ANALYSIS

The subtracted signal was then sent to an MCA spectrum analyzer in an attempt to identify the energy spectrum of the loss and, thus, the probable sources of the losses at the sensor location. Initially, the spectrum is as expected and the signals seen are promising for further processing and identification.

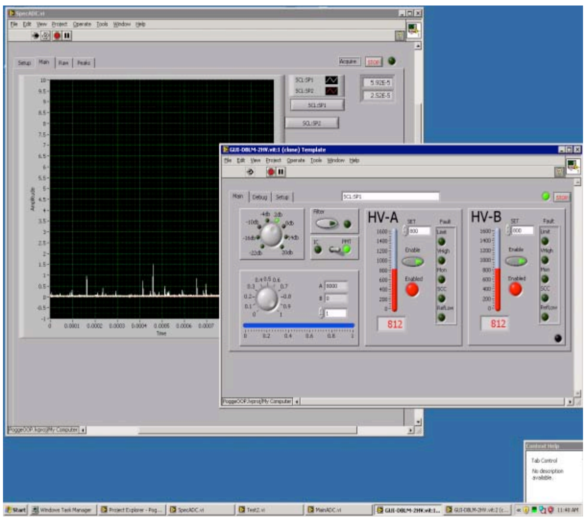

Figure 5: Background spectra.

It is clear that any residual noise in the system is negligible and the result of random signals on individual cables. The remaining noise is largely Gaussian white noise and is easily reduced by incorporating the internal low pass filters. Figure 5 was taken with the internal filters disabled.

As further proof that background subtraction is removing x-ray and noise signals that have little to do with actual losses, the HV power supplies servicing both PMT sensors present in the dual BLM are switched off. This leaves only signals not present on the PMTs themselves (Fig. 6). The resulting waveform is any induced RF or other EMI sources present on the four cables each > 100m from the LINAC tunnel to the system test rack located in the High-Energy Beta Transfer service building. Clearly the MCA has lost nearly all spurious peaks associated with random noise.

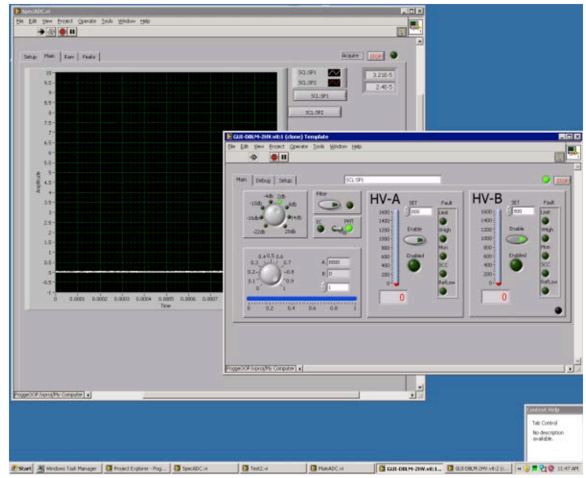

Figure 6: Background without HV.

CONCLUSIONS

The results of this test were dramatic; it has become clear that these systems will have the ability to monitor activation during accelerator downtime. Improved control and sensitivity allow the end user to easily adjust the MPS threshold levels to represent true loss levels. Additional new BLM systems will be deployed in areas where activation is probable and further studies are required. The new systems are also being deployed in areas that historically had been noisy and BLM data was used for only MPS.

REFERENCES

[1] Witkover, R. L. and Gassner, D., Design of an Improved Ion Chamber for the SNS, BIW2002, AIP Conf Proc 648 (2002) p. 337.

[2] Witkover, R. L. and Gassner, D., Preliminary Design of the SNS Beam Loss Monitoring System, BIW2002, AIP Conf Proc 648 (2002) .

[3] C. Sibley and D. Anderson, “SNS Noise Studies,” internal SNS document.

[4] C. Sibley, “Machine Protection Strategies for High Power Accelerators,” PAC03.