THE CEBAF BEAM SCRAPING MONITOR*

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Abstract

The Beam Scraping Monitor (BSM) is used to detect small amounts of beam loss in Jefferson Lab's Continuous Electron Beam Accelerator Facility (CEBAF). The BSM acts as an early warning system that alerts CEBAF operators when the beam loss exceeds 10 to 20 nA. This allows the CEBAF operators to adjust the beam orbit before beam loss reaches the Beam Loss Accounting (BLA) system threshold (presently 5000 μA-μ sec) which shuts down the accelerator. The reference oscillators of four digital signal processing (DSP) lock-in amplifiers are connected to two vertical and two horizontal corrector magnets in the CEBAF injector. These magnets excite transverse oscillations on the electron beam that are significantly smaller than the beam size, producing a negligible effect on beam delivery. To cover the entire accelerator enclosure, the two correctors of each plane are separated by π/2 betatron phase advance. When the electron beam approaches the beam enclosure some electrons get scraped off, causing an amplitude modulation of the beam current at the reference oscillator frequencies. This is picked up by the BCM cavities and relayed to the lock-in amplifiers for synchronous integrated detection. The lock-in amplifiers then transmit the scraping information serially to a LINUX computer running EPICS Portable Channel Access Server software.

1 INTRODUCTION

The CEBAF BLA system can detect beam loss as low as 2 μA however it was discovered that beam losses smaller than 2 μA could still damage the accelerator over time. A new detection scheme was needed to help protect the machine from these smaller amounts of beam loss. This would also allow operators to correct beam scraping before beam loss shuts down the accelerator. The BSM system was developed to be used in unison with the existing BLA system to detect small amounts of beam loss on the order of 1 nA. This is accomplished by inducing a minute oscillation on the electron beam in the CEBAF injector. The resulting motion on the beam causes electrons to be scraped away at the oscillation frequency when the electron beam approaches the beam enclosure. This creates an amplitude modulation of the beam current that is detected by lock-in amplifiers. The lock-in amplifiers then relay the data through a LINUX computer that is interfaced to EPICS.

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2 BLA SYSTEM

The BLA system [1] uses five Beam Current Monitor (BCM) 1497 MHz cavities to measure beam current. The first is located in the CEBAF injector before the electrons are injected into the accelerator. The other four cavities are located at the end of the electron beam's path at the Beam Switch Yard dump and the three entrances to Experimental Halls A, B, and C. Theses four cavity signals are down converted, detected, summed together and then subtracted from the detected injector cavity signal. This difference signal is representative of the beam loss. The accelerator uses this signal to trigger the Fast Shut Down (FSD) system if beam loss reaches 5000 μA μ sec.

3 BSM SYSTEM

3.1 Corrector Magnets

The BSM system excites four 25-turn air core corrector magnets in the CEBAF Injector. The magnets are located before the electron beam passes through the injector BCM cavity and before it is introduced into the five-pass accelerator. A block diagram of the BSM system is shown in Figure 1. The corrector magnets alternate between horizontal and vertical positions and the two magnets of each plane are separated by π/2 betatron phase advance. This allows the system to cover the entire accelerator more effectively. The excitation from the corrector magnets causes a beam oscillation that is much smaller than the beam's spot size and does not affect the Experimental Halls. However, the oscillation is large enough to cause electrons to be scraped off at the oscillating frequencies when the beam is steered too close to the beam enclosure. This scraping causes an amplitude modulation of the beam current that is ultimately detected in the BLA/BCM receivers.

3.2 Lock-In Amplifiers

The Injector corrector magnets are driven by the reference oscillators of four EG&G DSP lock-in amplifiers (Model 7220BFP) at 805.3 Hz, 867.7 Hz, 924.7 Hz, and 994.8 Hz. The electron beam contains low levels of noise and interference at these frequencies, making them an ideal choice for the BSM system. Having four corrector magnets operating at different frequencies and in different planes helps cause scraping in all directions around the beam. The amplitude of the reference oscillators where adjusted to produce the same level of excitation from all four corrector magnets so that the amount of scraping produced by each would be approximately equal. The lock-in amplifiers use a one second time constant which produces a large signal to noise ratio and aids in detecting weak scraping signals. The lock-in amplifiers use synchronous integrated detection to observe small beam current amplitude modulations at their reference frequencies and have a respective resolution of approximately 1 nA.

3.3 LINUX to EPICS Interface

Once the lock-in amplifiers detect scraping, the data is transmitted serially to a rack mount computer running LINUX. The scraping data is then added together and adjusted to reflect nA of beam loss. The LINUX computer runs EPICS Portable Channel Access Server [2] software that allows the LINUX operating system to communicate with EPICS databases. The BSM results are then displayed to the operators though an EPICS graphical user interface. The LINUX computer was chosen for its robustness and has been proven to be very stable. This method of running EPICS Portable Channel Access Server has shown itself to be useful when incorporating different operating systems into an EPICS environment. It also provides convenient features such as simple database creation and being able to update a software application without having to reboot the operating system or disturb any other software running on the computer.

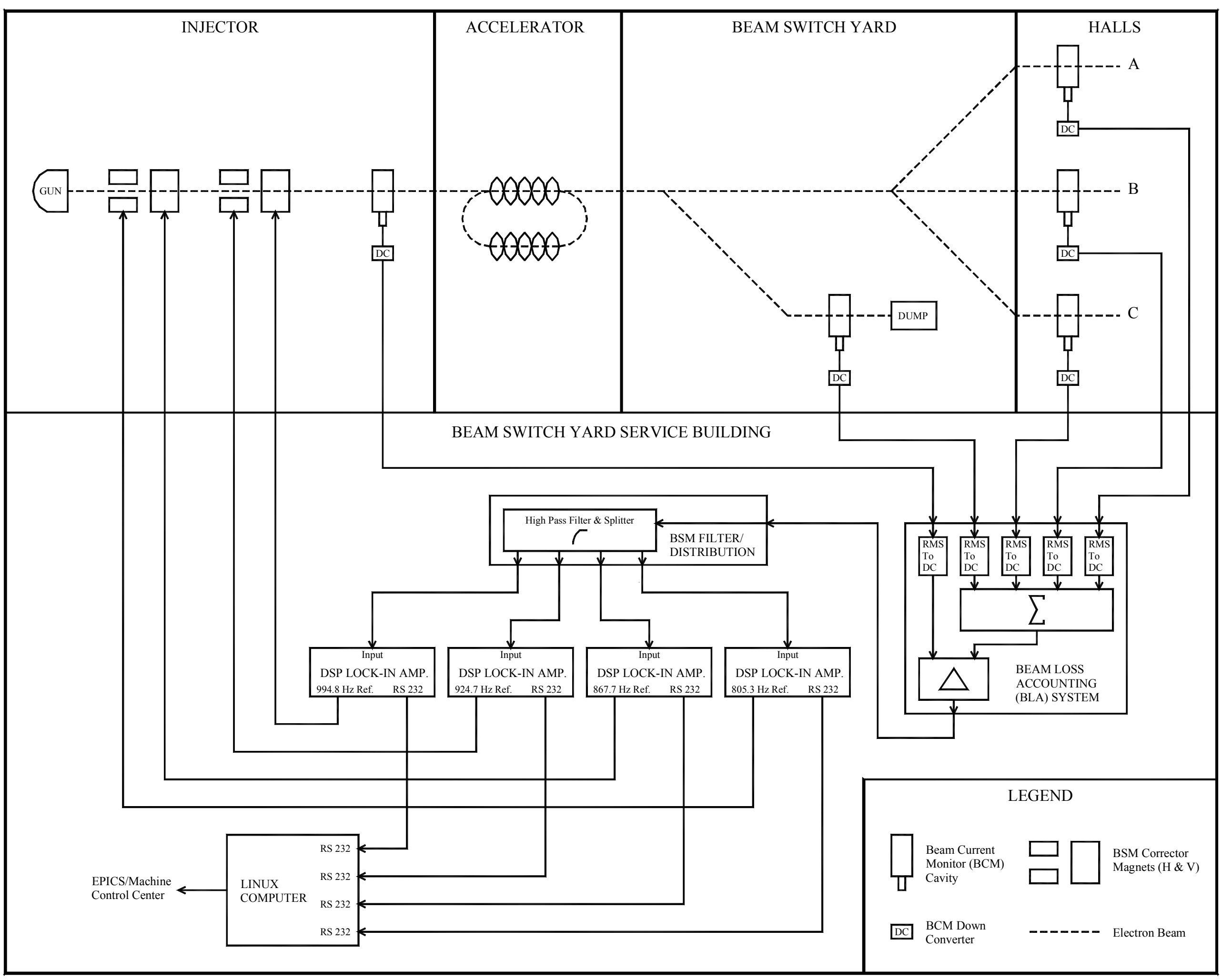

Figure 1: Block diagram of BSM system.

3.4 Calibration

Three methods were used to calibrate the BSM system in order to verify its operation. Each of these tests deliberately caused beam scraping. The first test used a wire scanner that passes a thin wire through the electron beam (this system is normally used to measure beam profile). The second test adjusted the accelerating cavity gang phase control to create large tails on the electron bunches. The third test consisted of inserting the Diffraction Radiation Monitor (DRM) paddle in millimeter increments into the beam path to cause scraping. In each case the four lock-in amplifier signals increased to reflect beam scraping. The BSM system detects periodic or AC beam loss. Data points were collected from the tests and used to approximate the continuous beam loss within a factor of ten. All three methods yielded similar results. This verifies the BSM system's ability to accurately determine beam loss at the nA level. Below is a graph of the results of one of the BSM tests using the DRM paddle with 500 nA of beam current at 5.6 GeV. The first graph shows the signals from the four Lock-In Amplifiers. The second shows the sum of the four signals and is representative of the beam loss.

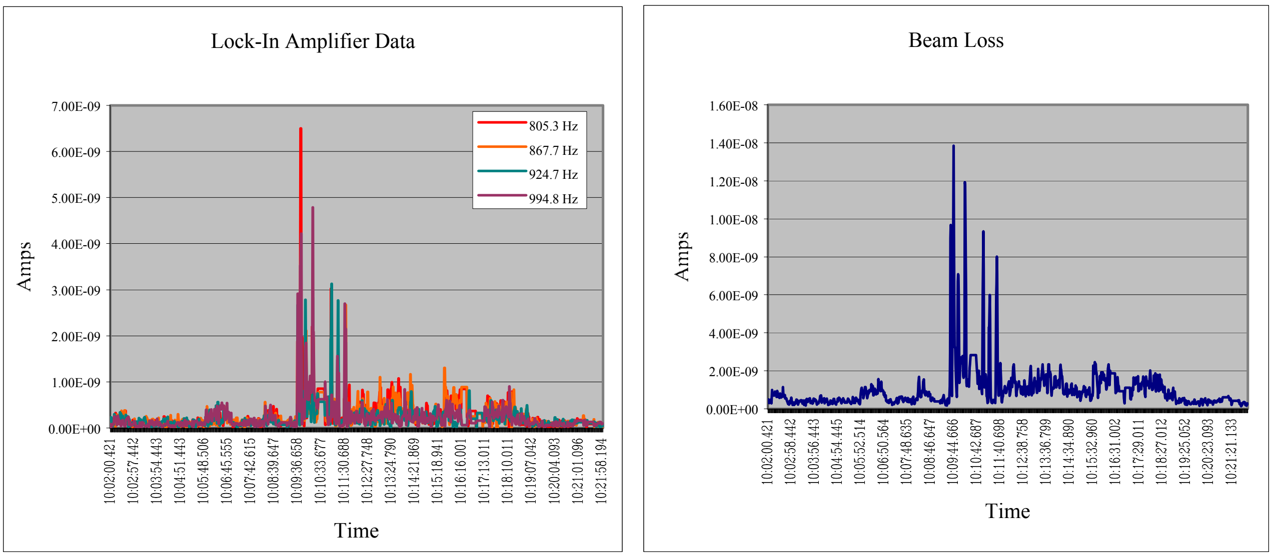

Figure 2: Data from the four lock-in amplifiers and corresponding beam loss.

5 CONCLUSION

The BSM system has been proven to detect nanoamps of beam loss. The system is still in development. Further tests will be preformed to determine the most effective frequency setting for the four lock-in amplifiers. Another possible feature would be to add BCM cavities in the main accelerator. This would allow operators to narrow down the source of the scraping to different sections of the machine. Once it has proved reliable it would be beneficial to incorporate the BSM into the CEBAF FSD system to protect the accelerator from prolonged periods of scraping.

6 REFERENCES

[1] CEBAF BEAM LOSS ACCOUNTING, R. Ursic, K.Mahoney, C. Hovater, A. Hutton, and C. Sinclair, Continuous Electron Beam Accelerator Facility News, VA 23606, USA, Particle Accelerator Conference and International Conference on High-Energy Accelerators (PAC), 1995.

[2] A Server Level API for EPICS, Jeffrey O. Hill, Los Alamos National Laboratory, International Conference on Accelerator and Large Experimental Physics Control Systems (ICALEPCS) 1995.

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