APPLICATIONS OF THE LOG-RATIO BPM IN NSRRC

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Abstract

Log-ratio BPM (LR-BPM) was applied to support booster, transport and storage ring applications at the NSRRC. These applications include monitoring the tune of the booster and monitoring the phase space, measuring the transport line beam trajectory and monitoring the phase space of the storage ring. This paper details the implementation and presents some applications.

INTRODUCTION

A logarithmic-ratio signal processing technique is commonly used to monitor the position of beam. It provides the advantages of a normalized real-time response, and a wide dynamic range of intensity and position measurement. It is based on the inexpensive integrated circuit family of demodulating logarithm amplifiers, manufactured by Analog Devices, Inc. The booster-to-storage ring transport line (BTS) of the NSRRC comprises seven stripline-type BPM used to measure the trajectory of the beam. LR-BPM was installed in the booster synchrotron to help to investigate variations in tune during energy ramping. The LR-BPMs installed in the storage ring is applied to study nonlinear beam dynamics, to measure injection tune and to study coupling effects.

LR-BPM

Log-ratio beam position monitors (LR-BPM) are used to measure the position of the beam in the booster synchrotron, booster-to-storage ring transport line and the storage ring. The log ratio processor is a two-channel device. Two pairs of LR-BPM are required to equip a BPM with four signal channels. The signal chain of an LR-BPM processor consists of a low-pass filter, a band-pass filter, a log-ratio amplifier, a sample and hold circuit, a timing control circuit and a position computation circuit. A commercially available LR-BPM was chosen [1]. The principles and implementation are detailed in reference [2].

LR-BPM IN TRANSPORT LINE APPLICATIONS

A 1.5 GeV electron beam is extracted from the booster synchrotron and transported via a 70m long transport line before being injected into the storage ring. Seven stripline-type BPMs are installed in the transport line, as shown in Figure 1. The striplines are mounted on a circular vacuum chamber with an inner diameter of 63mm. The striplines are 10 mm wide and 150 mm long. The beam intercept angle is about 10 Degrees. The sensitivity of the BPM is approximately 1 dB/mm near the center of the chamber. Figure 2 shows a functional block diagram of the LR-BPM for transport BPM.

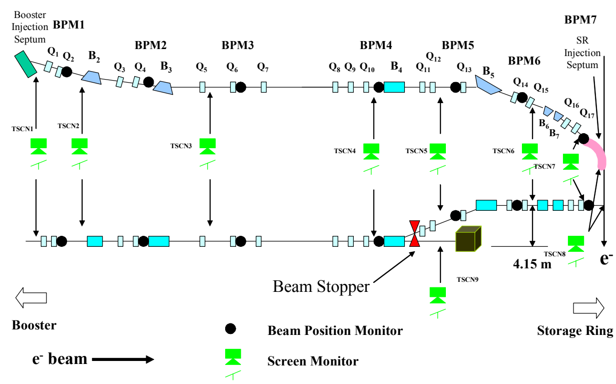

Figure 1: Transport line layout and the BPM installation.

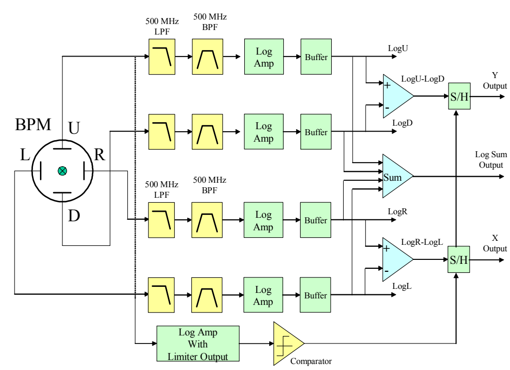

Figure 2: Functional block diagram of the LR-BPM.

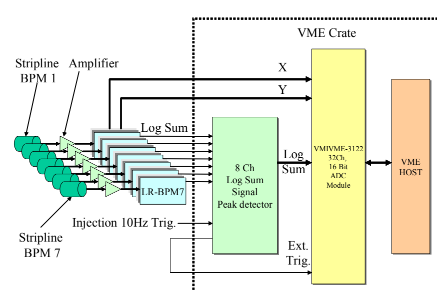

Figure 3: Data Acquisition System for the BTS LR-BPM.

Figure 3 shows the BTS BPM data acquisition system. It includes a stripline-type BPM, an amplifier, a LR-BPM module, a 16-bit VME ADC module, a log sum peak detector and a VME-based control system. The LR-BPM is configured in S/H mode with a self-beam trigger. The

S/H of the LR-BPM module held the position data X and Y. A peak detector module, made in-house holds the output of the log sum, which signal is used to validate the BTS position data. The application software in the control system can easily perform this check. A PPC CPU module, running LynxOS, controls the operation of the VME crates. Collected data are sent to a control database every 100 msec to be displayed and fed to various applications.

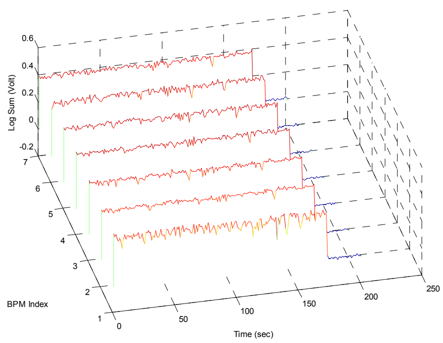

Figure 4: The BTS beam intensity (log sum) distribution as function of time in a routine injection scenario.

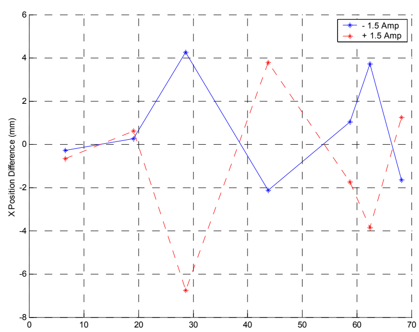

Figure 5: Horizontal trajectory difference when the first horizontal corrector (HC1) change ± 1.5 A.

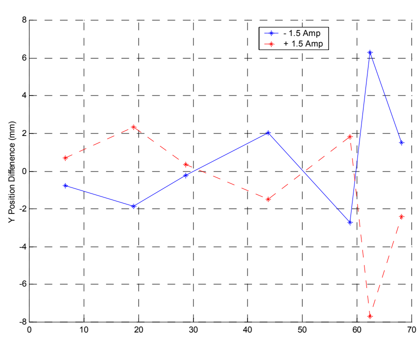

Figure 6: Vertical trajectory difference when the first vertical corrector (VC1) change ± 1.5 A.

Figure 4 shows the log sum of LR-BPMs along the beam transport line in a routine injection scenario. The triggering of the electron gun stops immediately when the beam accumulated in the storage ring beam has reached 200 mA, corresponding to a machine cycle of near 120. The intensity variation of the transport line indicates the performance of the booster synchrotron. The estimated variation in the intensity of the booster beam is under 25%. The log sum information can complement the screening to optimize the operating conditions of the transport line and the extraction conditions of the booster synchrotron, even if insufficiently accurate. The information also indicates the loss of the beam in the transport line.

The input current of the correct magnet power supply controls the position of the beam. HC1 is the first correct horizontal power supply; VC1 is first correct vertical power supply. Figure 5 plots HC1 versus variation in X position. Figure 6 plots VC1 versus variation in Y position.

LR-BPM FOR TURN-BY-TURN APPLICATION

Figure 7 shows the LR-BPM configuration. The button signal is processed and demodulated by a log amplifier. The analog axial rotational circuitry reconstructs the horizontal and the vertical positions. The output sampling and hold circuitry operate in track-and-hold mode with external triggering. The VME-based 12-bit transient digitizer digitizes the output of the log processor. The CPU module includes PPC CPU that runs LynxOS; it controls the data acquisition process. A graphic user interface has been designed to support the operation of turn-by-turn LR-BPMs. A Matlab script interface also supports the operation of the LR-BPM, based on a turn-by-turn beam position monitor.

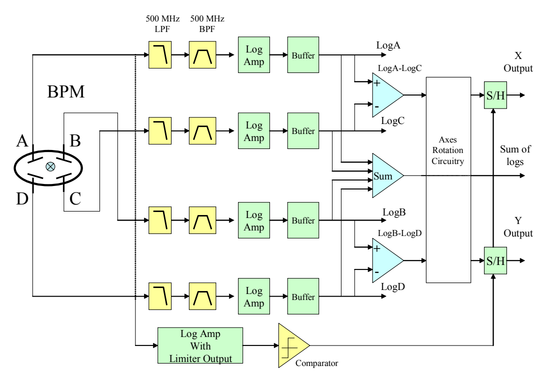

Figure 7: Block diagram of the turn-by-turn LR-BPM for the booster synchrotron and the storage ring.

Three sets of LR-BPM processors are installed in the booster synchrotron, to support the observation of variation in tune during energy ramping. Figures 8 and 9 shows the user interface and typical measurements. The dedicated diagnostics kicker excites the stored beam. The strength of the kicker and the delay of the injection trigger can be adjusted. The ramping tune variation can be measured by scanning the setting of the delay of the diagnostics kicker. The strength of the kicker is also scan as a value of energy.

Three sets of LR-BPMs are installed in the storage ring. An injection kicker is used to excite the stored beam. It is an elegant tool for observing tune during injection, nonlinear dynamics, coupling, and other information. Figure 9 and 10 plot typical measurements. Figure 9 shows the horizontal phase space when tune set near fourth-order resonance ($4\upsilon_x = 29$). Figure 11 pots the horizontal phase space plot show when tune set near fifth-order resonance ($5\upsilon_x = 36$).

Figure 8: User interface for the log-ratio BPM of booster synchrotron and typical measurement results for two horizontal BPM.

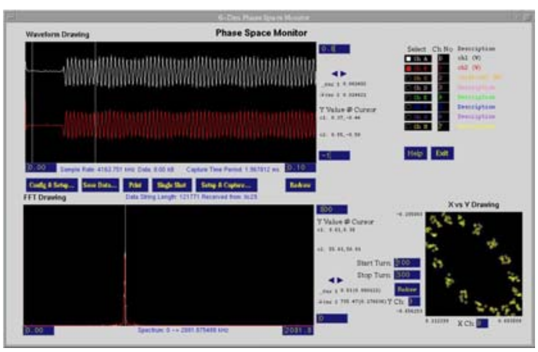

Figure 9: Turn-by-turn observation for the booster synchrotron at 1.5 GeV.

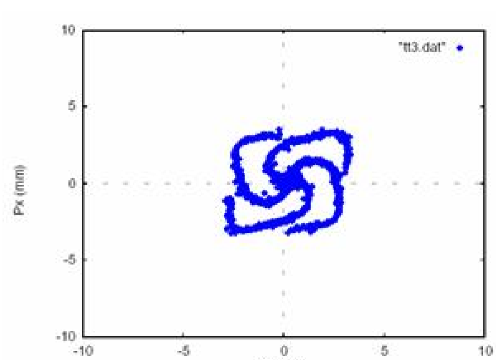

Figure 10: Horizontal phase space portrait near $4\upsilon_x = 29$ resonance of the storage ring.

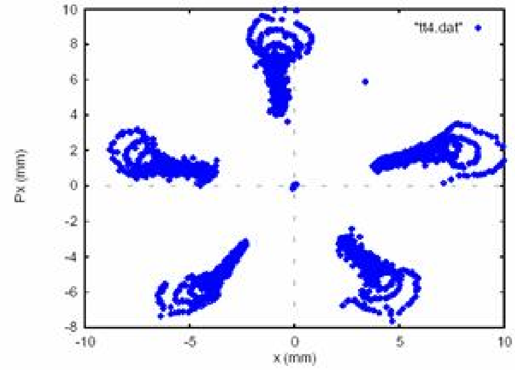

Figure 11: Horizontal phase space portrait near $5\upsilon_x = 36$ resonance of the storage ring.

SUMMARY

The LR-BPM system for the BTS non-destructively measures the trajectory of beams. It can simultaneously measure the position and the intensity during the injection period. This information complements the optimization of the BTS operating conditions, and the booster extraction conditions, improving the efficiency of injection. Further improvements are ongoing. This measurement system is expected to support the optimization of the transport line for routine operation, and top-up mode operations in the near future. Three sets of LR-BPM processor are installed in the booster synchrotron. The dedicated diagnostics kickers excite the stored beam, and variation in the tune is observed during energy ramping. Three LR-BPMs sets are installed in the storage ring. Injection kicker is used to excite the stored beam. This set-up elegantly supports not only the observation of tune during injection, but also studies of nonlinear dynamics and coupling.

REFERENCES

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[2] A. Kalinin, "The Log-Ratio Beam Position Monitor", AIP Conference Proceedings 648, Upton, New York, 2002, pp.384-392.

[3] Jeny Chen et al., "Preliminary Transverse and Longitudinal Phase Space Study At TLS", Proceedings of the 1999 Particle Accelerator Conference, New York, 1999, pp. 2412-2414.

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