FUNCTIONALITY ENHANCEMENT OF THE MULTIPLEXING BPM SYSTEM IN THE STORAGE OF SRRC

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Abstract

An extension of existing multiplex BPM electronics to provide capability for turn-by-turn beam position and phase advance measurement is implemented. The system can be configured as turn-by-turn beam position measurement or phase advance and coupling measurement. For turn-by-turn mode, the system performed four consecutive measurements of four BPM buttons. Data acquisition is synchronize with beam excitation. Turn-by-turn beam position is reconstructed by these four independent measurements. This system was named as pseudo-turn-by-turn beam position monitor system (PTTBPM). Resonance excitation of the stored beam and adopting lock-in techniques can measure betatron phase and local coupling. Design considerations of the system and preliminary beam test results are presented in this report.

1 INTRODUCTION

Measured betatron function and phase advance information is essential for precision beam-based machine modelling and is helpful to achieve ultimate machine performance. The BPM system of SRRC is a multiplexing system for precision closed-orbit measurement [1]. Using all BPMs for machine optics measurement is highly desirable. However, at present stage, only a couple of BPMs are equipped with log-ratio processor for turn-by-turn beam position measurement. Based upon the ideas of ESRF's "Mille-Tour" BPM system [2], we made a simple functional extension of the SRRC BPM system. A log-amplifier video detector mezzanine is implementing and installing at all BPMs electronic. Accompany with beam excitation and data acquisition system, turn-by-turn beam position at all BPMs site can be acquired. The data from four measurement of individual button can be reconstructed as pseudo-turn-by-turn beam position. Averaging out time dependent information is its drawback. Using lock-in amplifier to detect coherent oscillation with resonance excitation can support fast betatron phase measurement. PTTBPM system can acquire a lot of information for various beam physics study. However, the data analysis is tedious. On the other hand, the lock-in detection techniques accompany with resonance excitation can also be used for betatron phase measurement, betatron functions measurement, local coupling parameter measurement, and determines the errors of the lattice.

2 MEZZANINE MODULE

The multiplexing BPM electronics is a commercial units (Bergoz's MX-BPM). It is designed for averaged beam position measurement with micron resolution. The electronics composed of low pass filter, GaAs RF switch, band pass filter, high performance mixer and IF amplifier, quasi-synchronous detector, analog de-multiplexer and position computation circuitry. To observe betatron oscillation, wide bandwidth detector is needed. The IF bandwidth of MX-BPM before quasi-synchronous detector is larger than 5 MHz which is sufficient for betatron oscillation observation. This simple log amplifier detector was implemented due to its simplicity, no need of gain control, and small component counts. This mezzanine supports more than 50 dB dynamic range. When mezzanine module is engaged, AGC function of MX-BPM is disabled and single button is enable. The mezzanine is installed near the IF amplifier and detector circuitry. Small signal sensitivity is limited to about – 60 dBm that is due to deteriorate of the operation of PLL in synchronous detector. The functional block diagram of the mezzanine is shown in Figure 1. The mezzanine demodulates bunches signal at IF frequency (21.4 MHz). Position error of reconstructed position due to log conformance is acceptable for small oscillation amplitude.

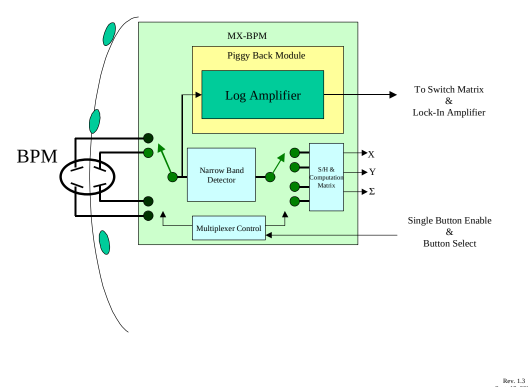

Figure 1. Functional block diagram of BPM processing electronics.

3 PTTBPM SYSTEM

The idea of PTTBPM is shown in Figure 2. Four measurements of individual BPM button signal can be reconstructed to obtain the turn-by-turn beam position.

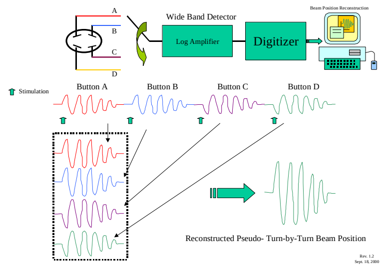

Figure 2. Concepts of PTTBPM

Reconstruction is based upon log-ratio normalization technique and is done by computer. Data acquisition is synchronized with beam excitation and controlled by VME crate. Figure 3 shows the system implementation. Matlab scripts running at control console arranges the sequence of data acquisition, data construction and analysis. Data reconstruction is done by the relationship

$$x = K_x\left[\log(\frac{A}{C}) - \log(\frac{B}{D})\right]\cos\alpha$$

$$y = K_y\left[\log(\frac{A}{C}) + \log(\frac{B}{D})\right]\sin\alpha \text{-------------------..(1)}$$

where, α is the effective button skew angle of BPM, K_x and K_y are the sensitivity of BPM and A,B,C,D are the button signal strengths.

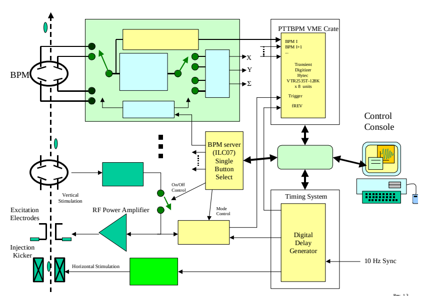

Figure 3. Functional block diagram of PTTBPM system.

4 BETATRON PHASE AND COUPLING MEASUREMENT

Resonance excitations of the stored beam and measure the betatron phase are adopted by several experiments [3]. We use the MX-BPM mezzanine to detector betatron oscillation. An RF lock-in amplifier is used to measure the amplitude and phase of the coherent oscillation. Basic concept of the operation is shown in Fig. 4. Resonance excitation is done by phase locked loop. The loop has functions of search and tracking. Coherent signal is detected by a commercial log-ratio BPM electronics (Bergoz's LR-BPM) [4]. On each MX-BPM, a log video detector is installed. RF multiplexer and single button select circuitry are used to select single button signal. Measured revolution harmonic phase shift are used to compensate the cable and detector circuitry delay. Since the betatron oscillation of the storage ring is between 300 kHz and 800 kHz and is out of the working frequency range of a low frequency lock-in amplifier. Consequently, an RF lock-in amplifier is selected.

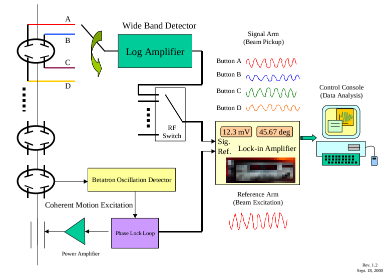

Figure 4. Concepts of betatron phase and local coupling measurement.

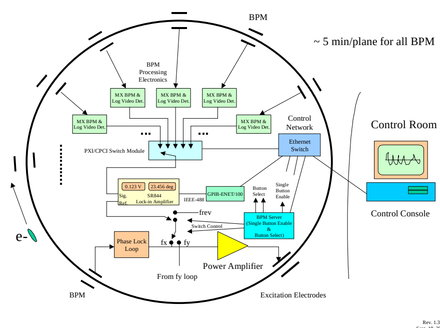

Figure 5. Block diagram of the experimental set-up.

The measured betatron phase can be used to extract betatron function by the relationship of $1/\beta_{x,y} = d\phi_{x,y}/ds$. Concept of the implementation is shown in Figure 4.

The coupling can be parameterised by using $\bar{C}$ matrix [3]. Based on the weak coupling assumption, the motion of the horizontal normal mode at the detector is given by equation (2). For the vertical normal mode, the $\bar{C}_{11}$,giving the in-phase component of the horizontal normal mode at the detector, is described by equation (3).

$$x = A_x\sqrt{\beta_x}\cos(n\omega_x)$$
$$y = -A_x\sqrt{\beta_y}\left[\bar{C}_{22}\cos(n\omega_x) + \bar{C}_{12}\sin(n\omega_x)\right] \text{-----------(2)}$$

$$x = A_y\sqrt{\beta_x}\left[\bar{C}_{11}\cos(n\omega_y) - \bar{C}_{12}\sin(n\omega_y)\right]$$
$$y = A_y\sqrt{\beta_y}\cos(n\omega_y) \text{----------------------(3)}$$

where A_x is the overall amplitude, β_x and β_y are the beta functions, ω_x is the mode tune, and n is the turn number, $\bar{C}_{22}$ is the normalized amplitude of the vertical component of the motion that is in phase with the horizontal motion, and $\bar{C}_{12}$ is the normalized amplitude of the out-of-phase component of the vertical component of the motion.

The $\bar{C}_{ij}$ is a measure of the coupling with $\bar{C}_{ij}$ ~1 corresponding to full coupling. $\bar{C}_{11}$, $\bar{C}_{12}$, and $\bar{C}_{22}$ are calculated from measurement using above equations. $\bar{C}_{21}$ is not a direct measurable parameter. It can be measured if the transverse momentum, x' and y', are measurable. The $\bar{C}_{12}$ data have a better signal-to-noise ratio than the $\bar{C}_{11}$

or $\bar{C}_{22}$ data from experimental viewpoint. This is due to the fact that any cross talk from the reference signal into the beam signal will tend to pollute the in-phase component but not the out-of-phase component. Also, any twisting of the beam pipe will result in changes in the in-phase $\bar{C}_{11}$ and $\bar{C}_{22}$ components but not in $\bar{C}_{21}$.

Figure 5 shows the functional block diagram of the betatron phase and local coupling measurement system. Experimental procedures for betatron phase advance and local coupling measurement is to excite coherent betatron oscillation firstly. Selecting signal source, acquire phase and amplitude data by lock-in amplifier is the second step. Repeating the procedure until all button data are acquired. Performed analysis is the last step.

5. PRILIMINARY BEAM TEST AND DISCUSSION

Two out of six super-periods of MX-BPM are installed with log video mezzanines at this stage. The storage ring does not have vertical kicker. Only limited vertical betatron oscillation can be excited by applying vertical betatron frequency burst to excite the system. Preliminary beam test was done recently. The horizontal betatron oscillation is excited by one of the injection kicker with ~ 1 mrad kick strength. Figure 6 shows the data of a BPM with horizontal kick. Betatron oscillation is clearly observed by the output of the log video demodulator.

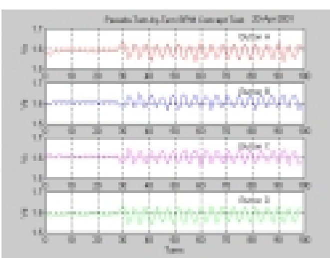

Figure 6. Concept of beam test of the PTTBPM. These four subplots are the raw data acquired from four consecutive measurements of BPM's four buttons.

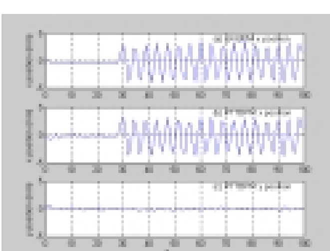

Figure 7. Comparison of single turn beam position and reconstructed beam position. Top figure is the x position reading of single turn log-ratio processor. Middle and bottom subplot shown the reconstructed x and y position.

The reconstructed beam position is shown in Figure 7(b) and (c). Figure 7(a) is the signal of a log-ratio BPM [5] that is paralleled connected to the same BPM with high isolated four divides by two power splitters. It shows that both results are consistent.

Measuring the phase advance in comparison with model calculation is shown in Figure 8. It shows that the discrepancy is small. A systematic study will be started after all BPM are equipped with log amplifier mezzanine.

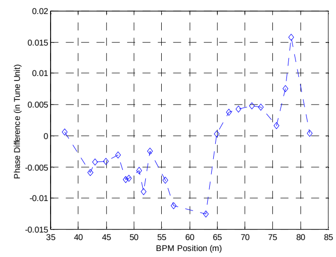

Figure 8. Phase advance difference between measured phase data and model phase advance of two super-period.

System integration and preliminary beam test is on going. The beam test results show that the basic operation principle is working properly. Remaining work includes integrating the system and develops Matlab scripts to support data acquisition and analysis.

6. ACKNOWLEDGEMENT

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