TURN-BY-TURN SYSTEM DESIGN OF HLS*

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Abstract

During the PhaseII project of NSRL, a turn by turn system is proposed for storage ring diagnostics which engage log-ratio electronics circuit to characterize machine properties of the updated HLS storage ring. The log-ratio processors working at 204MHz are applied to detect the varying position at two points of the ring. In this paper we will present the design performance and basic expectation of the turn-by-turn BPM electronics system in details.

1 INTRODUCTION

In order to monitor the injecting effectiveness, damping rate and β oscillation after update of injection and RF system, a turn-by-turn system of HLS have been started. The turn-by-turn system based on the Log-ratio technique, which is a fairly new idea for BPM and tend to become maturity gradually. Benefited from the progress of semiconductor technology, low cost wide bandwidth logarithmic amplifiers working directly at 100-500MHz or more are available now. Compared with the familiar Δ/Σ and AM/PM method, highlighted the features of the log-ratio technique: low noise, high bandwidth and wide dynamic range, as well as response linearity are superior to both for circular aperture BPMs[1]. The difference of Log-amplifier of two signals from opposite electrodes is proportional to normalize beam position.

The circuit described in this paper is based on synchronous process with HLS RF(204MHz) and logarithmically demodulation. Electronics working at bunch pass frequency can reduce the complexity of signal processin chain and make it easy to implement.

2 THE TURN BY TURN SYSTEM AND EACH FUNCTION

HLS turn by turn system consists of the front pick-up electrodes, Log-ratio electronics, timing system, and data acquisition system which will be placed in Controller IPC, and Log-ratio electronics and timing system will be put in NIM Crate. The principle architrave as Fig 1 shows. The turn by turn system contribute two functions. Select one BPM for turn by turn measurement and two BPMs for phase space one.

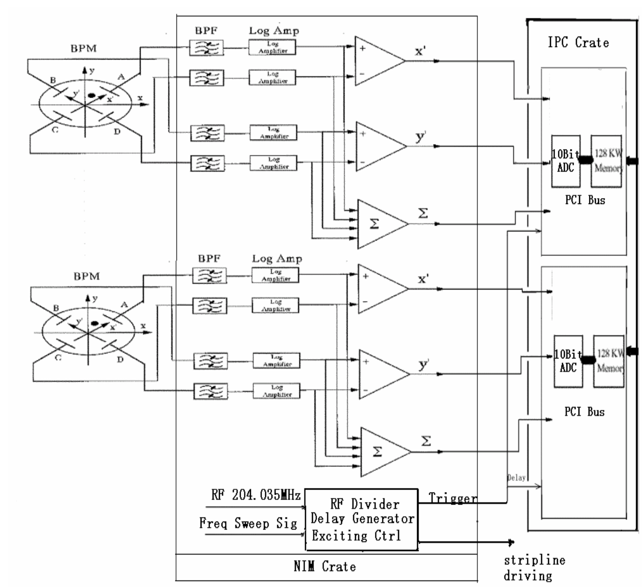

Fig.1 Block diagram of the turn-by-turn BPM system

Because Log-ratio processor have been featured two inputs, so it is suitable for a couple of electrodes placed at the horizontal or vertical direction. BPM electrodes of HLS are mounted at skew direction, as Fig.2 shows.

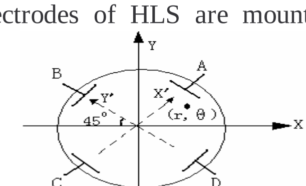

Fig.2 BPM section

We replace the commonly used hybrid junction with coordinate transform. The transform matrix between two coordinate as below($\alpha=45^0$):

$$\begin{pmatrix} X \\ Y \end{pmatrix} = \begin{pmatrix} \cos\alpha & -\sin\alpha \\ \sin\alpha & \cos\alpha \end{pmatrix} \begin{pmatrix} X' \\ Y' \end{pmatrix} \qquad (1)$$

2.1 Log-Ratio Processor

The log-ratio processor consists of the 204MHz band-pass filters with 10MHz bandwidth and two logarithmic amplifiers and one differential amplifier. One commercial available amplifier chip is AD8309, a demodulating logarithmic amplifier with limiter output. For two opposite electrodes the working function of log-ratio circuit is shown in Fig.3.

* Supported by National Important Project on Science- Phase II of National Synchrotron Radiation Laboratory

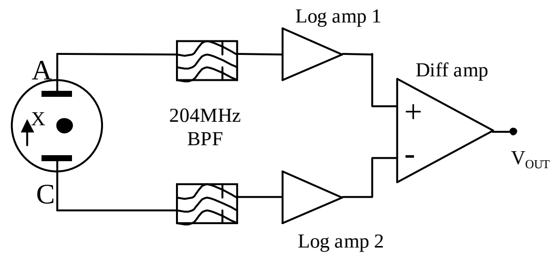

Fig.3 Log-ratio processor

The beam position calculated with the log-ratio technique is formulated by the following expression[2]:

$$X = \frac{20}{SG_{STM}} \times \log\left(\frac{A}{C}\right) = \frac{1}{SG_{STM}} \times [20\log A - 20\log C]$$
$$= \frac{1}{SG_{STM}} \times V_{out} \qquad (2)$$

where A and C are the electrode potentials; S [dB/mm] is the detector sensitivity, for circular aperture BPM $s = \frac{80}{\ln(10)} \cdot \frac{1}{a}$ (a-radius); V_{out}[V] is the output from the differential amplifier; G_{STM} (mV/dB) is system gain which include both of log-ratio and differential amplifier gain. Due to the output of the log-ratio amplifier have been normalized, the calculating value independence to beam amplitude.

2.2 Timing System and Data Acquisition

The timing and control system is also illustrated in Fig.1. It includes the circuits module like pulse-shaping, fre-dividing, timing delay and excite signal switching etc. It has two iuputs and three outputs signals. One of inputs is synchronization RF and another is frequency sweep signal for exciting the strpline.

Revolution frequency of HLS storage ring is 4.533MHz, we choose two 20SPS 10bit ADC for data acquisition of two BPMs. For different lattices, different BPMs are chosen. The timing of two BPMs should are adjusted step by step. The specifications are listed in Tab.1 in details. The control between all modules of the timing system can be set via com-ports of IPC.

For the 200Mev injection beam, coherent oscillation damping time is about 1.38s. While for the 800Mev stored beam, it is 22ms. In order to be competent for these two modes, the data acquisition module is designed to capture data and write into disk simultaneously to provide enough details(The max sampling-time is up to 2 seconds). And another favorable character of this system is that it is designed to be operated under single bunch and multi-bunch modes.

2.3 Excitation Signal Generation

In order to measure the damping rate of transverse oscillation and phase space of stored beam, a fast kicker is needed in most cases. In order to save the project budget, we replace it with the horizontal and vertical stripline stimulator. The excitation signal can be triggered via a control module packaged in the timing and control system. The excitation power and lasting time could be adjusted at will to provide enough stimulus on beam motion. When the stimulus ends, a delayed trigger is sent to start the turn by turn detect. In our case the delay time is set to be about 50ms, which is enough for the stripline stimulus.

3 TURN BY TURN MEASUREMENT

HLS ring can be operated in single bunch and multi-bunch mode, with 50mA and 350mA as the achievable maximum storage current respectively now. RF is 204.035MHz, and harmonics is 45. So we hope that the system meet the requirements as listed in Tab.1.

Tab.1 Parameters of HLS turn-by-turn BPM system

Dynamic range	10dbm-(-50dbm)
Output SNR	40db
Dynamic linearity	<1%
Pulse repetition rate	220ns
Trigger delay step	0.5ns
adjust precision	0.1ns
Total jitter time	〈 0.2ns
Sample rate	4.533MHz

3.1 Turn by Turn Measasurement Analysis

Take only the beta free oscillation into count, $y(s) = A\sqrt{\beta(s)}\cos(\int \frac{ds}{\beta} + \Phi_0)$. If we record BPM data turn by turn, suggest phase advance is ϕ_0 at time T_0, then the phase would be ($\Phi_0 + 2\pi n\nu$) for the coming n turns. For the convenience of plotting, set ϕ_0 to be zero, a series of oscillation plots corresponding to different ν are shown as Fig.4.

From the plots we can see that the closer ν is to N=0.5, the deeper the oscillation is modulated with a longer period. Moreover, if the data points is enough, we can extract the time dependent tune variation from a series of values of the particle trajectory. Among the feasible methods, numerical analysis of fundamental frequency(NAFF) is a favorable one which can provide higher resolution with as few as turns as possible[3].

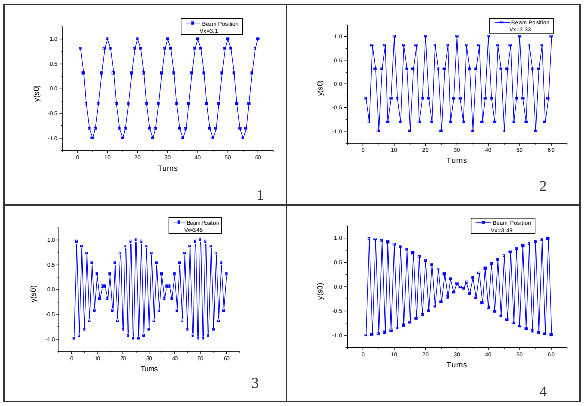

Fig.4 Turn by turn beam motion record
(N<ν1<ν2<ν3<ν4<N+0.5)

3.2 Phase Space Measurement

Two BPMs are chosen for phase space tracking and analysis. Different BPM pairs are chosen for different lattices. They are chosen according as such principles as: large β_x and β_y, phase advance between the BPM pair be close to $\pi/2$ or $3\pi/2$.

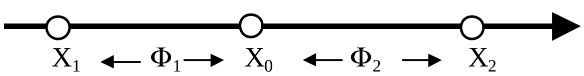

Fig 5 Phase space sketch

For Fig. 5, from the transport matrix we can calculate phase coordinates of any point between X_1 and X_2(including these two points),

$\left(X_0, \beta_0 X_0' + \alpha_0 X_0\right)$.

$$X_0 = \frac{\sqrt{\beta_1}\sin\Phi_1 X_2 + \sqrt{\beta_2}\sin\Phi_2 X_1}{\left[\sqrt{\frac{\beta_1\beta_2}{\beta_0}}\sin\Phi_1(\cos\Phi_2 + \alpha_0\sin\Phi_2) + \sqrt{\frac{\beta_1\beta_2}{\beta_0}}\sin\Phi_2(\cos\Phi_1 - \alpha_0\sin\Phi_1)\right]}$$
$$= \frac{\sqrt{\frac{\beta_0}{\beta_2}}\sin\Phi_1 X_2 + \sqrt{\frac{\beta_0}{\beta_1}}\sin\Phi_2 X_1}{\sin(\Phi_1+\Phi_2)} \quad (3)$$

$$\beta_0 X_0' + \alpha_0 X_0 = \sqrt{\frac{\beta_0}{\beta_2}}\frac{\cos\Phi_1}{\sin(\Phi_1+\Phi_2)}X_2 - \sqrt{\frac{\beta_0}{\beta_1}}\frac{\cos\Phi_2}{\sin(\Phi_1+\Phi_2)}X_1 \quad (4)$$

From the phase space ellipse equation:

$$\frac{1}{\beta}\left[X^2 + (\beta X' + \alpha X)^2\right] = W \quad (5)$$

To minimum the error of W due to position measurement error:

$$\Delta W = 2X_0\Delta X_0 + 2(\beta_0 X_0' + \alpha_0 X_0)\Delta(\beta_0 X_0' + \alpha_0 X_0)$$
$$= \frac{2\beta_0}{\beta_2\sin^2(\Phi_1+\Phi_2)}X_2\Delta X_2 + \frac{2\beta_0}{\beta_1\sin(\Phi_1+\Phi_2)}X_1\Delta X_1$$
$$-\frac{\beta_0\cos(\Phi_1+\Phi_2)}{\sqrt{\beta_1\beta_2}\sin(\Phi_1+\Phi_2)}\Delta(X_1X_2) \quad (6)$$

Then it requires that $|\sin(\Phi_1+\Phi_2)|=1$ and β to be as large as possible. Besides this, to assure the resolution and precision of system, all BPMs should be in sections with no nonlinear devices.

4 SUMMARY

The newly developed turn by turn system which is based on log-ratio processor working at 204 MHz has been implemented for HLS machine study. With the application of high speed data transmission and acquisition technics, the system can accomplish turn by turn measurement task and would be indispensable for our storage ring study. Due to the feature of our ring, there are something which need special attention. First, if used for injection monitoring, the ring must be tuned to single bunch injection mode. Second, because HLS storage ring is small ring(diameter 66 m) and operating at 45 bunch in ring, the bunch length is 3-8cm[4], so it have rigorous request for timing system. The system is expected to be commission at the end of the year.

5 ACKNOWLEDGEMENT

Authors would like to thank Dr. K.T. Hsu for the beneficial discussion and communication. We also would like to present our thanks to Dr. R.Hettel of SLAC, Prof. C.Y. Yao of APS as well as T.Kasuga and T.Ieiri of KEK for their kindly help. Discussions with Prof. Y. J. Pei and G.C. Wang are also appreciated.

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