SHOT-BY-SHOT BEAM POSITION MONITOR SYSTEM FOR BEAM TRANSPORT LINE FROM RCS TO MR IN J-PARC

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Abstract

To adjust the beam orbit of beam transport line from RCS to MR in J-PARC (3-50 BT), 14 beam position monitors (BPMs) were installed. Their signals gathered in the local control building (D01) have been measured by using 14 digitizing oscilloscopes. The data acquisition system have a performance of shot-by-shot measurement.

INTRODUCTION

The Japan Proton Accelerator Research Complex (J-PARC) consists of 3 accelerators, a 181MeV linac, a 3 GeV rapid cycle synchrotron (RCS), and a 50GeV (Max) synchrotron (MR) [1]. Figure 1 shows a schematic view of a beam transport line from the RCS to the MR. Some kind of beam diagnostics, 14 Beam Position Monitors, 50 Beam Loss Monitors (BLMs), 5 Fast Current Transformers (FCTs) and 5 Multi Wire Profile Monitors (MWPMs) were installed in the 3-50 BT [2]. The beam commissioning of the MR started in May 2008. 3-GeV proton beams injected into the MR from the RCS were circulated with rf capture, and extracted to a beam dump [3].

Their beam diagnostics have been useful to maintain a good transfer efficiency of the 3-50 BT. Pulsed beam (bunch) from the RCS is switched to the 3-50 BT by a pulse-bending magnet. The two buckets among the nine buckets in the MR accept the two bunches from the RCS at a time. This is repeated four times. Shot-by-shot Beam Position Monitor System was developed to make measure the orbit of the beam of every shots. This report describes a summary and the performance of the BPM system of the 3-50 BT.

BPM HEAD

The vacuum chamber of the 3-50 BT has large diameter to accept the large emittance beam from the RCS. Each emittance of before and after of the collimator section are different. To keep the physical aperture, two sizes of the BPM heads were fabricated as ϕ200mm and ϕ230mm. We adopted electrostatic electrode with 230 mm long, 60 degrees azimuthal width as shown in figure 2. All BPMs were installed near Q-magnets as shown in figure 1. The BPM head is made of a stainless-steel material to avoid magnetization. The coaxial cable was connected to the feedthrough through the matching transformer to protect from sag [4].

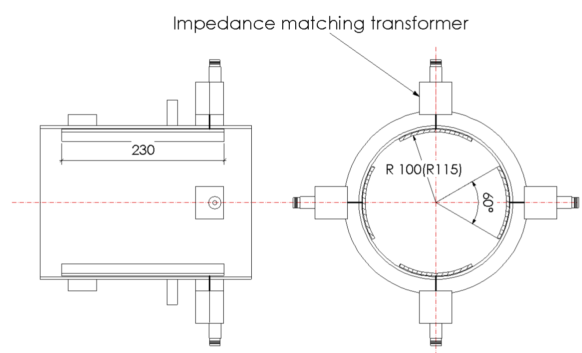

Figure 2: BPM head for the 3-50 BT.

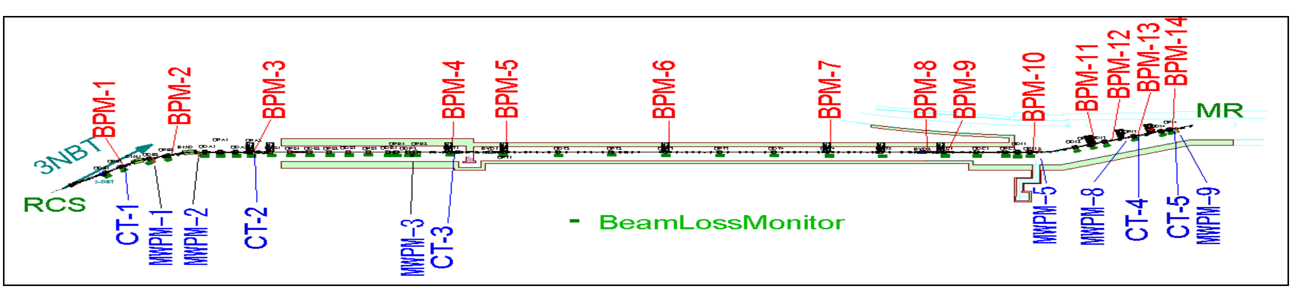

Figure 1: Beam monitors in the 3-50 BT.

SIGNAL PROCESSING

Hardware

We adopted a simple signal processing method which is 14 digitizing storage oscilloscopes (DSOs) for each BPM. Each DSO is linked to a Input / Output Controller (IOC) through a local area network. A schematic view of the Beam Position Monitor system is shown in Figure 3. Four signals detected in each BPM are transmitted through independent coaxial cables (the average length is about 400m long).

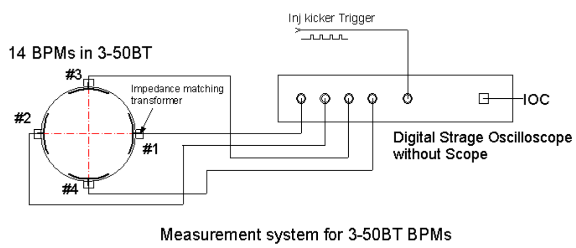

Figure 3: Schematic of the BPM system for the 3-50 BT.

The waveform of a beam signal from pickup electrode is observed with a digitizing storage oscilloscope. The digitizing rate is 1 Giga samples/second with 100MHz bandwidth.

Segmented memory acquisition

The beam is extracted with 25Hz from the RCS to the MR so that the BPM of the 3-50 BT detects the signals by a 40ms period. Therefore the signals have relatively long idle times, that is, low-duty-cycle pulses. However, it is necessary to keep sampling speed of 1GHz/sec because a signal of the BPM is a short pulse signal less than 100nsec.

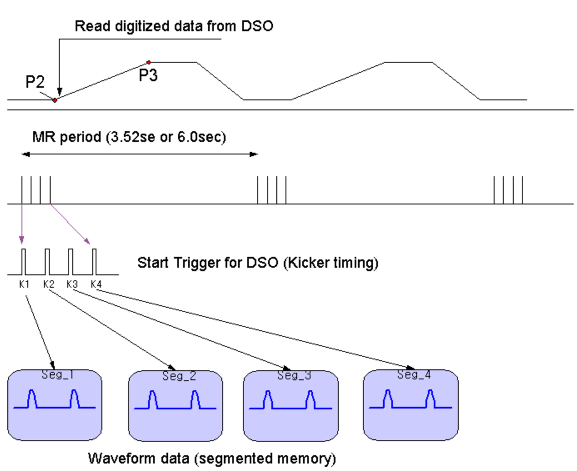

Figure 4: Time chart for segmented memory acquisition.

The segmented memory option for DSO is useful to digitize the low duty cycle pulses. The option optimize the acquisition memory to capture more selective signal with less memory.

With segmented memory, the scope's acquisition memory is divided into multiple smaller memory segments.

For four shots of extraction from the RCS in the 3-50 BT, the number of segments of DSO is set to 4, and a memory size of segment is 1,000 points.

The segmented memory acquisition is performed by a timing of K1, K2, K3 and K4 which is trigger timings for the MR injection Kicker magnet. After segmented memory acquisition was performed, every waveform data are transferred from each DSO to a IOC at timing P2 of the MR cycle, P2 is start timing of the acceleration.

DATA PROCESS

Figure 5 shows waveforms (BPM1~BPM7) of two bunches in each given segmented memory. To reject noise components of waveform, the data were processed by digital filter which is Band Pass Filter. After filtering process, voltage amplitudes were estimated by analysis of the waveform data.

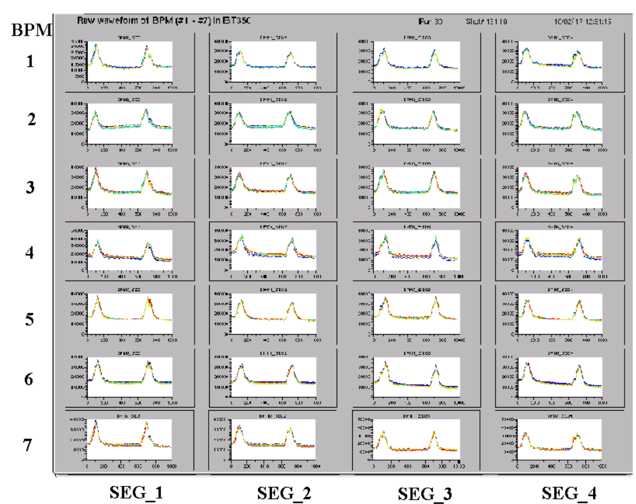

Figure 5: Waveforms after segmented memory acquisition. Each waveform of four electrodes are overlapped on a respective screen.

Now, in order to obtain the beam position, the following two calculating steps are necessary. The first is the normalizing procedure as

$$H = \frac{V_1 - V_2}{V_1 + V_2}, \quad V = \frac{V_3 - V_4}{V_3 + V_4}$$

V_1, V_2, V_3, V_4 are voltage amplitudes of four electrodes.

The second is converting procedure from normalized values (H,V) to beam position (X,Y), following a first order approximation as

$$X = K \cdot H, \quad Y = K \cdot V$$

Where K is coefficients of sensitivity which are determined by calibration result of test bench, that is , K=62 (BPM#1,#2) and K=54 (BPM#3~#14) .

PERFORMANCE

Shot-by-shot measurement

We can measured shot-by-shot of beam positions in the 3-50 BT. Figure 6 shows all orbits of eight bunches in the 3-50 BT. In this example, although each vertical orbit of each bunch is almost consistent, each horizontal one is inconsistent. We adjusted the pulse bending magnet and Horizontal steering magnets in the 3-50 BT.

Figure 6: Orbits of 8 bunches in the 3-50 BT.

Position resolution

In the 3-50 BT, the beam orbits are frequently drifting or changing due to ground motion, condition of the RCS, magnetic fields from another accelerator, power lines, etc. It is necessary to reject these changes to estimate the resolution from beam position data. The three-BPM method is convenient for this. We can calculate position correlation coefficients among three BPMs based on the transfer function. The correlation variances are calculated at all BPMs from 50 sets of orbit data. The position resolutions were confirmed to be within about 0.3 mm at almost all BPMs as shown in Figure 7. The vertical resolution is almost the same as horizontal one.

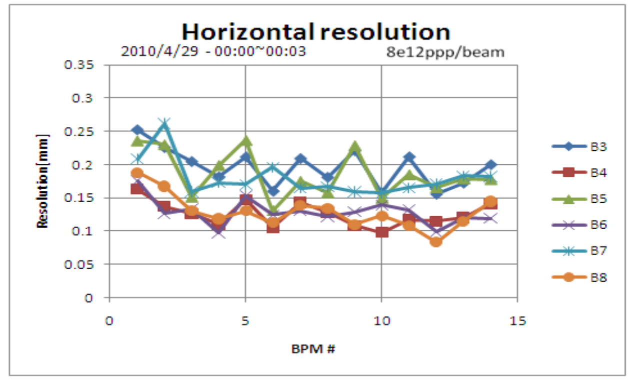

Figure 7: Distribution of all horizontal resolutions of the BPMs in the 3-50 BT.

SUMMARY

We applied a segmented memory acquisition to the 3-50 BT BPM system to measure the shot-by-shot of beam positions. The present resolution of the beam position measurement satisfied the requirement of the 3-50 BT, less than 0.3mm. This system is helpful for maintaining a good beam transfer efficiency.

ACKNOWLEDGMENT

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