DEVELOPMENTS OF THE CALIBATION TOOLS FOR BEAM POSITION MONITOR AT J-PARC LINAC

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Abstract

In the J-PARC LINAC, there are mainly two requirements for calibration of beam position monitors (BPMs). One is that BPMs need to be calibrated with the accuracy of less than about a hundred micrometers to minimize beam loss for the world highest class of proton intensity. The other is that about a hundred of BPMs need to be calibrated and maintained consistently. To achieve these requirements, the calibration tools are being developed. During development, experiences on real beam in a MEBT line set for the DTL commissioning are utilized. The status of the development of calibration tools is described in this paper.

BPM IN J-PARC LINAC

As a joint project of JAERI (Japan Atomic Energy Research Institute) and KEK (High Energy Accelerator Research Organization), a MW class of proton accelerator is under construction [1].

A prime role of the BPMs is to provide non-destructive way to monitor and to control center of the high intensity beam toward center of beam ducts with position accuracy of about one hundred micrometer, in order to minimize beam loss (typically, 0.1~1 [W/m]). Another possible role of BPM is to provide some information about beam size (RMS value), e.g. to see if momentum spread changes in L3BT section (non-zero dispersion section) for RCS injection.

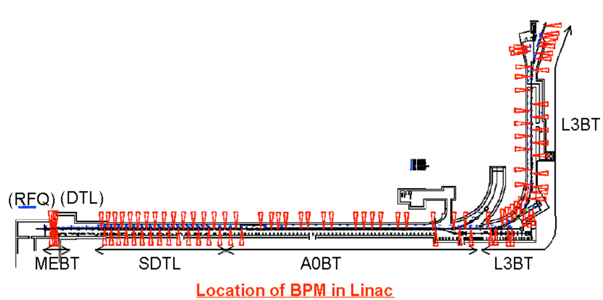

Figure 1: Location of BPM in the J-PARC LINAC. (LINAC consists of, from upstream, IS, LEBT (not shown), RFQ, MEBT, DTLs, SDTLs, A0BT, and L3BT (then connected to RCS synchrotron).) The tips of red arrows are the locations on the beam line.

Ninety-one BPMs are designed to be installed in LINAC, 8 in MEBT, 29 in SDTL section, 15 in A0BT (a section kept for ACS), 39 in L3BT. The overview locations of BPMs in the LINAC tunnel are shown in figure 1 (the apexes of red arrows are the place on the beam line). Diameters of BPMs are varying from 23.9, 29.4, 35 mm (MEBT), 37.7 mm (SDTL section), 37.7, 40 mm (A0BT), 70, 85, 120 mm (L3BT). These BPMs need to be calibrated consistently.

Four electrostatic stripline are implemented [2] on each beam position monitor located in LINAC section. Size of stripline in azimuth (to the beam axis) is larger for the larger BPM diameter. Table 1 shows relation between the size (and shape) in azimuth and the BPM diameter, as well as its location in LINAC. To get position accuracy with respect to the field center of quadrupole magnets, BPMs are position of yokes of the quadrupole magnet.

Table 1: Relation between the size (and shape) in azimuth of stripline and the BPM diameter. Location of BPM is also shown.

BPM location	**BPM diameter [mm]**	**Size (in azimuth) of stripline**	**Shape (in azimuth) of stripline**
MEBT	23.9, 29.4	7.2 mm	Flat
SDTL section	37.7	7.2 mm	Flat
A0BT (for ACS)	37.7, 40	7.2 mm	Flat
L3BT	70	32.6 deg	Round along duct
	85	36.4 deg	Round along duct
	120	39.6 deg	Round along duct

CALIBRATION OF BPM

Calibration of BPM is taken in two steps.

First step is, at test bench, to calibrate relation between a physical position and its reconstructed position via electrical readout. The induced current on the stripline is transmitted to 50-ohm line to logarithmic amplifier and then digitized (in 16 bits).

Second step is, with beam, to calibrate relation between the electromagnetic field center of quadrupole magnet which houses a BPM and the reconstructed position by the BPM electrical readout. This is called Beam Based Calibration (BBC).

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First step: Calibration at Test Bench

To relate physical position and its reconstructed position via electrical readout, the following scheme is used in the test bench. The accuracy of measurement is aiming for a half hundred micrometers.

- Scanning the wire hanging through the cross section of BPM, horizontally and vertically, and put 324 MHz RF on the wire during scan to simulate the beam. The 324 MHz is a frequency used for the RF cavity of LINAC.
- Amplifying logarithmically the induced voltage on 50 ohm, and take the ratio, between the left stripline and the right stripline for horizontal position, and between the top and the bottom for vertical position. The voltage is digitized by 16 bits ADC. This requires linearity calibration for ~400 channels (= 4 striplines * ~100 BPMs) of the amplifier.
- Interpolating (analytically fitting) position among scanned points. As seen in the figure 2, as outer the wire goes (especially for off-XY-axis position) the discrepancy get larger. The fitting functions need to be optimized especially around the center of the beam duct.

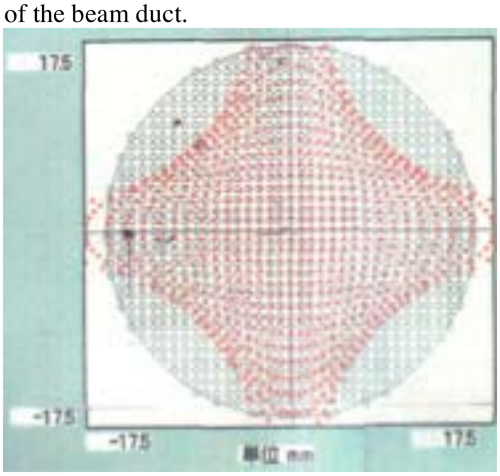

Figure 2: Simple reconstruction of position during online data taking. Red points for reconstructed position, and black points for wire position. This is for BPM with 37.7 mm diameter and scan is done by 1 mm step.

Currently we have tuned the configuration of termination of the wire so that stability during the scan is acquired [3]. The configuration is shown in figure 3. The transformer is placed on both edges of the wire to get better impedance matching from input line (50 ohm), and the reflected signal forced to terminate through circulator. Transmitted signal is terminated with a spectrum analyzer (50 ohm) so that we can monitor the stability of calibration continuously during the wire scanning.

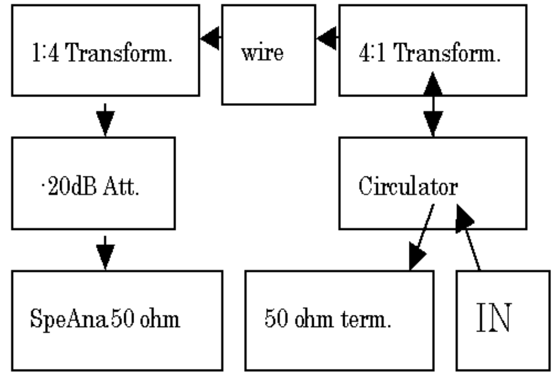

Figure 3: Configuration around scanning wire for calibration at test bench. Signal generator (324 MHz) is shown as "IN" in this diagram.

Second step: Calibration with Beam (BBC)

To relate the center of quadrupole magnet which houses the BPM and the reconstructed position by electrical readout, the following procedure is used with real beam. The accuracy of measurement is aiming for a half hundred microns.

- Scanning the beam by steering magnet (or additional coil on quadrupole magnet to steer a beam).
- Varying magnetic field of quadrupole which houses examined BPM for each of the steered position of beam.
- Measuring dependence of beam trajectory at downstream upon the varied quadrupole magnetic field.
- Extrapolate (or interpolate) electrically reconstructed position for the examined BPM when the steered beam is traversing at the field center of its housing quadrupole magnet.

In the section where BPMs are housed in each quadrupole magnet, e.g. MEBT, the upper scheme is simply applied.

In the section where BPMs are housed only every some quadrupole magnets and the power supplies for the magnets are common to them, e.g. SDTL section, the extrapolation (or interpolation) is analytically complicated [4], but possible.

During commissioning of DTL at KEK, the BPMs in MEBT are calibrated with the beam. We have seen the calibration is done with measurement accuracy less than 50 micrometers [5]. The measurement is semi-automated with a script code written with SAD [6], a language used in the accelerator design and control. Connection to the T3D model [7] used for LINAC beam transport is under development.

Parameters got by Calibration

Parameters need to be well stored, i.e. well structured, for usage and its maintenance. So far we are listed following parameters.

- Linearity of logarithmic amplifier. Conversion from voltage [V] to voltage [V], for each of ~400 channels.
- Linearity of digitizer. Conversion from voltage [V] to voltage [V], for each of ~400 channels.
- Relation between ratio of signal voltage and reconstructed position (taken step1). Conversion from voltage ratio [V/V] to position [mm], for each of ~100 BPMs
- Relation between reconstructed position and position relative to the center to the quadrupole magnet. Conversion from position [mm] to position [mm], for each BPM (Note that some BPM cannot perform BBC. For example, most downstream BPM has no way to see the quadrupole field dependence during BBC.).

SUMMARY

J-PARC LINAC has ~100 pieces of BPMs with 4 striplines for each. Those are, thus, read through ~400 channels of logarithmic amplifiers, and digitizers. To minimize beam loss, the center of beam needs to be monitored with measurement accuracy of about a hundred micrometers (with respect to the field center of its housing quadrupole magnet).

Linearity of readout electronics needs to be calibrated. Also, two steps of calibration for position reconstruction are needed. The first step is to relate physical position and position reconstructed by electrical readout. The second is to relate the reconstructed position with the center of field center of its housing quadrupole magnet. The optimized setup for the first step is configured. And demonstration of the second step is done during DTL commissioning with measurement accuracy of less than a half hundred micrometers. The acquired parameters need to be well stored for usability.

REFERENCES

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