Calibration of Beam Position Monitor for the SPring-8 Synchrotron

Tsuyoshi AOKI , Hiroto YONEHARA, Hiromitsu SUZUKI, Norio TANI, Hiroshi ABE
Kenji FUKAMI, Soichiro HAYASHI, Yasuo UEYAMA, Takayoshi KANETA, Kenji OKANISHI
Shigeki OHZUCHI, Takeji MIYAOKA*, Kiyokazu SATO*, Eiji TOYODA*, Hiromasa ITO*
and Hideaki YOKOMIZO

SPring-8, Kamigori, Ako-gun, Hyogo, 678-12, Japan
*)Toshiba Co, 1-6, Uchisaiwai-cho, 1-chome, Chiyoda-ku, Tokyo, 100, Japan

1. Introduction

The beam position monitors(BPMs), which are placed around the SPring-8 booster synchrotron, are designed to measure a closed orbit distortion (COD). The BPMs are located at the upstream positions of 80 quadrupole magnets. Each BPM pickup consists of four button-type pickup electrodes. They are attached to the SMA-type coaxial feedthroughs that are welded on a racetrack-type vacuum chamber. The sizes of vacuum chambers are 80 mm x 30 mm and 100 mm x 30 mm. The diameter of the electrode is 18 mm and the capacitance of the electrode including a feedthrough is about 6.8 pF.

Output signals from the BPM pickups are transmitted through the 3 dB attenuators and the coaxial cables to the electrode-selector which has fast PIN-diode switches. Heterodyne circuit is used at the signal detection system. One detection system obtains output signals from 20 BPM pickups, and four detection systems are used at the same time for 80-BPMs. It is expected that the measurement time of 80-BPMs is less than 30 ms.

To measure a beam position of single-pass in single-bunch operation, the output signals from a BPM pickup are observed simultaneously by digital sampling oscilloscope. Five BPM pickups and electrode-selectors which are located at the upstream position of the beam extraction systems are used.

The relationship between the beam position and the output signals from the electrodes were measured by the calibration system which have an antenna to simulate an electron beam. The antenna was mounted on the X-Y table which was driven to x, y, and s directions by the pulse motors. The 508.58 MHz signal, that was the acceleration RF of the synchrotron, was supplied from the tracking generator to the antenna. The output signals from the electrodes were measured by the spectrum analyzer. The normalized values of output signals about horizontal and vertical positions were related to the beam position as polynomials.

2. Calibration System

We develop a BPM calibration system for easy and accurate calibration. The schematic diagram of the system is shown in Fig. 1. We calibrated the installation error of electrodes, the capacitance variation of electrodes, and the characteristic error of feedthroughs, -3dB attenuetors, and coaxial cables before electrode-selectors. To simulate an electron beam, semi-rigid coaxial cable (UT-85) is used for an antenna and is mounted on the X-Y table which is driven to x, y, and s directions by the pulse motors. The coaxial cable is inserted in the stainless steal sleeve which has 3 mm inside diameter and 5 mm outside diameter. The length of the inner conductor outside of the sheathe is 50 mm. The optical sensors are used to set the antenna at the initial position before every measurement.

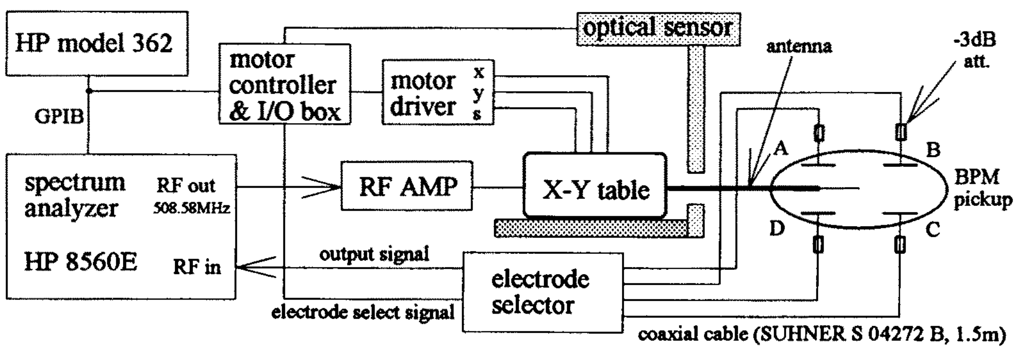

Fig. 1. The schematic diagram of BPM calibration system

The 508.58 MHz signal is amplified and is supplied to the antenna from the tracking generator of the spectrum analyzer (HP 8560E). The output signals from the electrodes: V_A, V_B, V_C, and V_D are switched by electrode-selector and are measured by the same spectrum analyzer. The spectrum analyzer, the motor controllers and I/O box are controlled by HP model 362 that is connected with GP-IB cables. The offset distances between the initial position of the antenna and the center of the BPM pickups have been measured previously, and they are compensated on the software.

To simulate a distribution of electromagnetic field in the BPM pickup and beam duct, two dummy ducts are attached both ends of the BPM pickup. To suppress a noise signal that is caused by the leakage of the electromagnetic wave from the end of the dummy ducts, electromagnetic shield rubbers are stuck on the inside of dummy ducts and on the base of antenna. At the longitudinal position, more than 60 mm from the end of sleeve, the electric field distribution is nearly uniform. Therefore, the X-Y table is driven in s-direction where that position comes at the center of the electrodes.

3. Result of Calibration

The normalized values, which are calculated with the output signals from electrodes:
$H=(V_A-V_B-V_C+V_D)/(V_A+V_B+V_C+V_D)$ and
$V=(V_A+V_B-V_C-V_D)/(V_A+V_B+V_C+V_D)$,
are obtained at a position (x,y) of the antenna. Figure 2 shows an example of a result of measurement between (H,V) and (x,y). The calibrated area is x=±15 mm and y=±8 mm. The relationship between (x,y) and (H,V) are expressed as sextic polynomials that are obtained by least square method. Figure 3 shows an example of a calibrated relationship between (x,y) and (H,V).

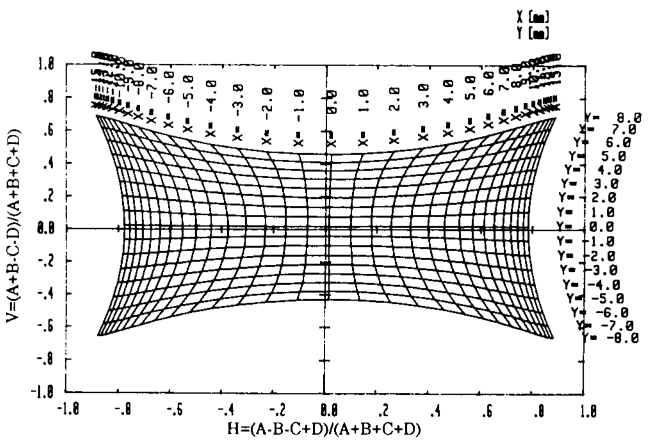

Fig. 2. An example of a relationship between (H,V) and (x,y) measured by the calibration system. The calibration area is (x,y)=(±15 mm,±8 mm), and the step of measurement is 1 mm.

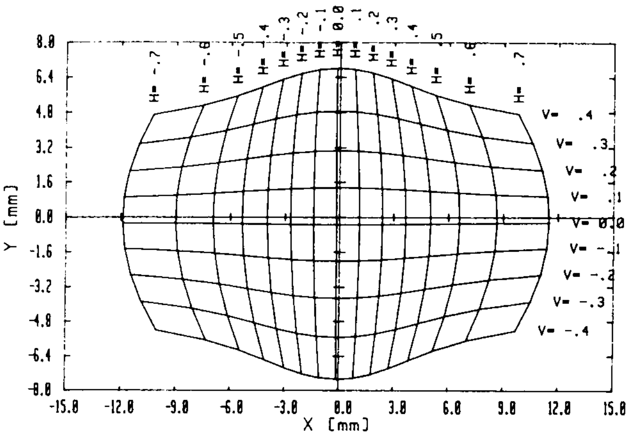

Fig. 3. An example of a calibrated relationship between (x,y) and (H,V). The relationship is expressed as sextic polynomials.

The accuracy of installation of BPM pickup on the calibration system was within 0.05 mm, and the accuracy of the driving system for X-Y table was about 0.005 mm. The accuracy of the optical sensors to set the antenna at an initial position was within 0.05 mm. Thus the accuracy of the calibration system is about 0.1 mm. To estimate the accuracy of this calibration system, we measured a reappearance of the electric center about a BPM pickup. The deviation of the electric center was within 0.04 mm.

4. Conclusion

Eighty BPM pickups were manufactured and the calibration system was developed. We calibrated the BPMs successfully. The accuracy of the calibration was about 0.1 mm.

The BPM pickups are already welded to the beam ducts, and the BPM control system is under construction.