Present status of calibration of rf-BPM for the SPring-8 Storage Ring

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1. Introduction

Beam Position Monitors (BPM) are installed for obtaining the electron beam position from electric signals. For the precise position measurement, calibration of each BPM is necessary for the BPM system of the SPring-8 Storage Ring.

The calibration was done for the purpose of obtaining the offset of electrical center and the mapping functions for each BPM.

The data for the calibration have taken for all the BPM, the analysis of the data has just begun, however.

The overview of the BPM system is summarized first. The calibration method is described next, followed by the preliminary result.

2. Overview of the BPM

A BPM consists of 4 electrodes welded on the vacuum chambers which are called Straight Section Chambers (SSC). Each SSC has two sets of BPM. The SSC were made of extruded aluminum and have the length of 4.2 to 5.7 m depending on the type. The locations of the BPM are about 1 m away from both end flanges of the SSC.

The cross sectional shape of the vacuum chamber at the BPM location is shown in Fig 1.

A reference block was attached to each BPM. The block has two reference planes to define the reference point and the coordinate system. The reference point is defined as the cross point of two lines with certain distances from the reference planes: 95 mm from the side plane and 107 mm from the top plane. The axes of coordinates are the lines which pass the reference point and parallel to the two reference planes.

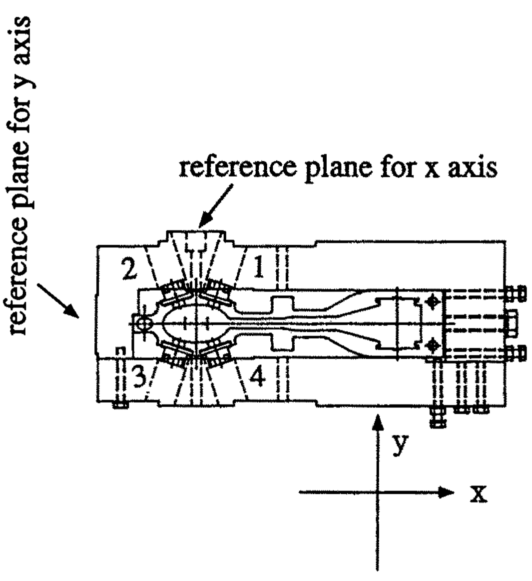

Fig 1. cross section of the vacuum chamber at BPM location

For obtaining the position information, the offset from the reference point to "the electrical center" should be known. In addition to the offset, the mapping functions, which relates the quantities u and v to the position x and y, $x = fx(u,v)$ and $y = fy(u,v)$, must be known.

Here u and v are defined by the signal amplitude of the four electrodes as $u = ((A1-A2)/(A1+A2) + (A4-A3)/(A4+A3)) / 2$, and $v = ((A1-A4)/(A1+A4) + (A2-A3)/(A2+A3)) / 2$, where A1, A2, A3, and A4 are signal amplitudes on the electrodes 1, 2, 3, and 4.

The offset is defined as the position difference between the reference point and the "electrical center", where the definition of the electrical center is $u = v = 0$.

Since the SSC are made of extruded aluminum, the inner cross sectional shape and the electrodes welding position may not be precise. Also, since the reference blocks are attached afterwards, the offset may differ from one BPM to another.

To calibrate these factors we have done the calibration as the following system and method.

3. Method of Calibration

The calibration system are made of following components: (1) a girder with two reference planes of x and y axes, (2) a two dimensional positioning stage, (3) magnetic scales with 1-μm resolution to measure the stage position, (4) an antenna made of semi-rigid coaxial cable supported by a rod. The total length of the semi-rigid cable and the supporting rod is 1.5 m, so that the antenna can be inserted to the BPM location of the SSC. (5) signal generator to feed power to the antenna, (6) measurement electronics, and (7) a precisely machined chamber with circular cross section.

The circular cross section chamber is used for positioning the antenna at the reference point. Four reference planes are attached to the chamber so that the chamber has the two-fold symmetry including the reference planes. Owing to the symmetry of the chamber, the offset between the electrical center and the mechanical center is obtained for the circular chamber. The method is as followings; the antenna was placed at the electrical center for one configuration by searching the point where u=v=0, then the chamber was rotated by 180 degree and the antenna was placed at the electrical center again. Then the middle point of the electrical centers of the two configurations gives the reference point.

The frequency used for the measurement is 508.58 MHz, which is the same frequency of accelerating RF frequency of the Storage Ring.

Process of the calibration are the followings. (1) Place the circular chamber on the reference plane of the girder so that both the planes of the girder and the circular chamber touch. (2) Position the antenna to the electrical center of the circular chamber. Since the offset of the circular chamber was measured beforehand, this process was equivalent to the positioning the antenna at the reference point. (3) Reset the magnetic scales to define the measurement origin. (4) Remove the circular chamber. (5) Place the SSC on the reference plane of the girder so that both the planes of the girder and the SSC touch. (6) Position the antenna to the electrical center of the SSC. (7) Start the mapping over a square area from the point of (x,y) = (-5 mm, -5 mm) to the point of (x,y) = (+5 mm, +5 mm) with 1-mm mesh.

The positions of the antenna measured by the magnetic scales were recorded with the signal strength of each electrode at each mapping point in order to obtain the relations fx(u,v) and fy(u,v).

The offset is obtained by measuring relative movement from the reference point to the electrical center of the SSC.

4. Preliminary Results of Measurement

An example of the mapping data is shown in Fig 2. If the relations fx(u,v) and fy(u,v) are linear, relation can be expressed as x = u / Sx, and y = v / Sy, where the proportional coefficients Sx and Sy are called sensitivity. For the first step of the analysis of the data, the data on the x and y axes are fitted with 3rd order polynomials. The first order coefficients are taken as approximation of the sensitivity.

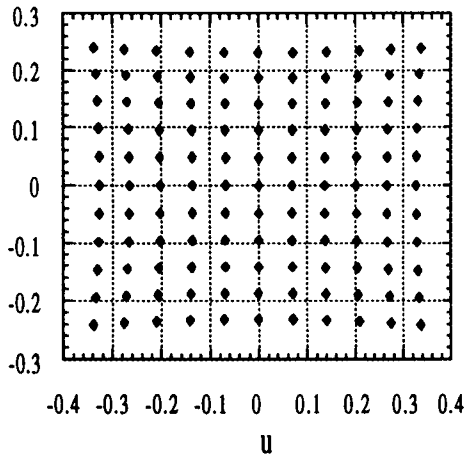

Fig 2. An example of a mapping data

The sensitivity values thus obtained are plotted for a partial sample of the BPM on different types of the SSC as shown in Fig 3. In the sensitivity distribution, clustering of the data in y direction are observed. Taking various factors which differ for the different types of SSC into account, the sensitivity values seem to depend on the length between the BPM location and the end flange of the SSC, and on the difference of the structure around end flange.

This clustering can be attributed to the existence of the mode other than Transverse Electric and Magnetic mode (TEM mode). Because the TEM mode has almost the same electric field distribution in the chamber as that is made by the beam, desirable situation is that this mode is the only mode that exist in the antenna-chamber system for the calibration.

If the frequency is lower than the cutoffs of wave guide modes, the only mode that propagate in the antenna-chamber system is TEM mode. However, there is a wave guide mode (TE10-like mode) whose cutoff is lower than the accelerating RF frequency: about 350 MHz. Although the boundary condition of the antenna-chamber system is different from the condition for the wave guide mode in the chamber alone, the clustering may be attributed to the existence of this mode.

The coupling to "wave guide modes" may depend on the structure around the end flange, where the uniformity of the cross sectional shape along the beam axis breaks. The "wave guide modes" may reflected back to the BPM location and give some distortion to the field distribution.

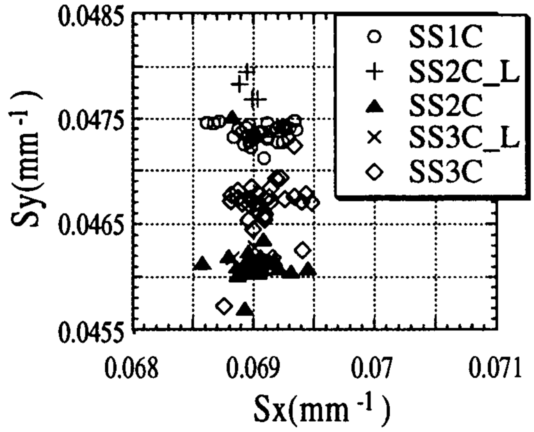

Fig.3. Sensitivity in vertical direction Sy vs sensitivity in horizontal direction Sx. Data sample taken with 508 MHz.

Measurement with 300-MHz frequency was done for partial sample of the BPM, to study the effect of the multiple modes, since the 300 MHz is the frequency lower than the cutoff of TE10-like mode.

The distribution of the Sy vs. Sx is shown in Fig 4. for the 300 MHz data samples. The clusters shrink to a region regardless of the differences of chamber types and lengths. This result supports the assumption mentioned above.

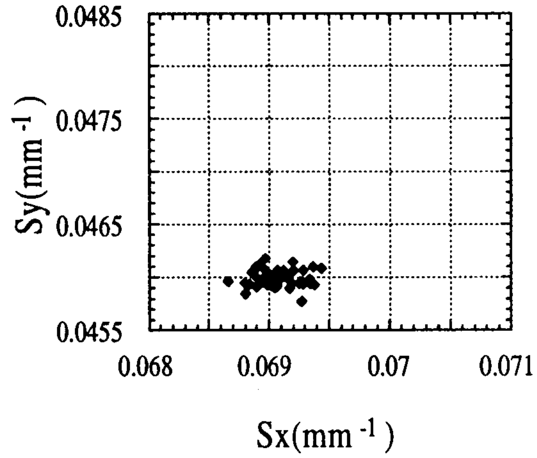

Fig.4. Sensitivity in vierical direction Sy vs sensitivity in horizontal direction Sx shown in the same axes range as figure 3. Data sample taken with 300 MHz.

Taking these facts into account, the corrections for the 508-MHz data are necessary. The study for the corrections of the data is one of the issues with great importance. Further analysis of the data is in progress.