Calibration of Beam Position Monitors using a Stored Beam

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1. Introduction

In the early stage of commissioning of the SPring-8 storage ring, closed orbit distortion (COD) was reduced down to about 250μm in rms distortion in both horizontal and vertical directions. However, we could not reduce COD any further. To find a way out of this difficulty, we thought that it will be effective to estimate "offset" values that beam position monitors (BPMs) will have and subtract these values from BPM readouts. In the following we describe how we carried out this by using a stored beam and improved the COD.

2. Method

Since BPM "offset" values that we want to know have nothing to do with real orbit distortions, parts of these can be estimated by summing Fourier components of COD whose frequency is much higher than betatron tunes. This will work well for the SPring-8 storage ring, since 6 BPMs (BPM1, BPM2, ..., BPM6) are located in one unit cell in such a way that the phase difference of betatron oscillations between BPM1 and BPM2, BPM3 and BPM4, and BPM5 and BPM6 becomes small. In other words, BPM readouts should not include Fourier components whose frequency is much higher than betatron tunes.

To apply the above method to the ring and obtain real orbit positions, we need to set a suitable cutoff frequency for subtracting higher Fourier components. This cutoff must be determined so that a contribution from higher Fourier components of real orbit distortion is much smaller than that of BPM "offset". We determined this cutoff frequency with the help of computer simulations in the following way: We first computed COD by using measured values of alignment and field errors of main magnets. We then made a Fourier decomposition of the resulting COD and reconstructed the orbit by summing low-frequency components up to some frequency. In this way we examined a cutoff dependence of a contribution from higher Fourier components of real orbit distortion. We determined the cutoff value so that this contribution becomes about 50μm in rms distortion, which is one third of a roughly estimated value of the rms BPM "offset" 150μm.

Another point that we should take care is an operation point of the ring. To separate components coming from real orbit distortion and from BPM "offset" as clearly as possible, we lowered betatron tunes of the ring from a nominal point (ν_H, ν_V) = (51.23, 16.32) and measured COD. Other operation points (or other optics) that we used for checking the optics dependence of the "offset" were (42.20, 15.32), (42.24, 12.21), (21.35, 9.17) and (18.25; 13.69). A rough correction of COD was done by using a small number of steering magnets with weak strengths, when necessary for beam injection and for reduction of COD at BPMs. The effect of this rough COD correction can be neglected if the cutoff value is chosen to be sufficiently high compared with the betatron tune, because the COD generated by steering magnets has dominant Fourier components around the betatron tune as can be seen from the following well-known formula:

$$X(s)= \sum_{k=-\infty}^{\infty} \frac{\sqrt{\beta(s)}\,\nu^2}{\nu^2-k^2} f_k e^{ik\phi(s)} \quad ,$$

where

$$f_k=\frac{1}{2\pi\nu}\sum_i \sqrt{\beta(s_i)}\,\theta_i\, e^{-ik\phi(s_i)} \quad ,$$

and $\beta(s)$ and $\phi(s)$ are the betatron function and phase at the position s, respectively, and θ_i is the kick angle by the i-th steering magnet.

3. Results

In Fig. 1 we show BPM "offset" values obtained from measured COD data for three different optics. Fig. 1(a) is for the horizontal and Fig. 1(b) is for the vertical directions. From these figures we can see that the optics dependence of the "offset" is not so significant, especially for the vertical direction. The rms values of the "offset" for these optics differ by about 40μm in the horizontal and 10μm in the vertical directions, respectively. These differences are smaller than the estimated contribution of remaining high Fourier components of real orbit distortions. We can then conclude that a dominant contribution to the "offset" was obtained by the present method.

In the COD corrections, we used the "offset" for the optics with low betatron tunes (21.35, 9.17) which are indicated by the solid curve in Fig.1. The rms values of this "offset" were 160μm in the horizontal and 210μm in the vertical directions, respectively. After subtracting this "offset" and performing corrections for the nominal optics, the leakage of the dispersion function into straight sections reduced from about 23mm to 12mm in rms values. This fact shows that the subtraction of the "offset" worked well in our COD correction scheme and the resulting orbit is expected to pass through closer positions to magnet centers on the average.

4. Remarks

We remark here that since the BPM "offset" was obtained by using high Fourier components of COD, the resulting "offset" is, strictly speaking, not a conventional offset as obtained by using a calibration antenna[1]. The "offset" obtained here is for making a smooth orbit from which high Fourier components are

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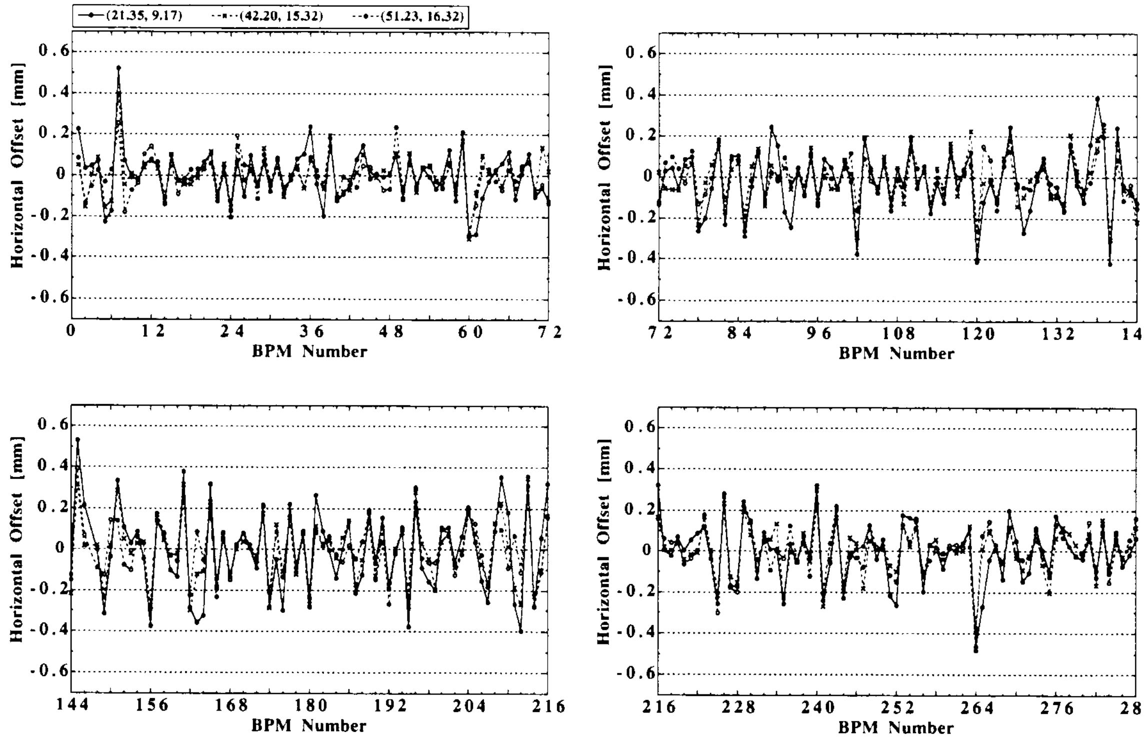

Fig. 1(a). Horizontal BPM "offset" obtained for three different optics with betatron tunes (ν_H, ν_V) = (21.35, 9.17), (42.20, 15.32) and (51.23, 16.32). These "offset" values were obtained from a measured horizontal COD by summing its Fourier components higher than 70th, 150th and 150th order for the three optics, respectively.

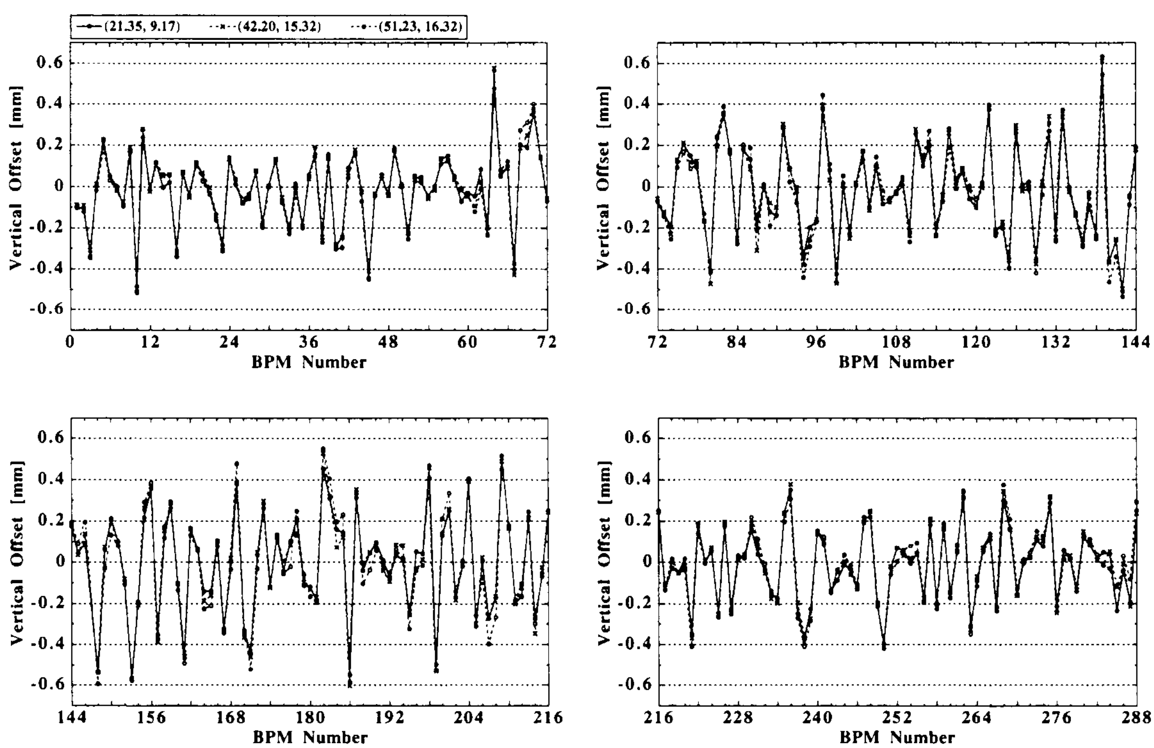

Fig. 1(b). Same as Fig. 1(a) but for the vertical direction. Fourier components of a vertical COD higher than 40th order were summed for all optics.

excluded as much as possible. Since in the SPring-8 storage ring main magnets were aligned on girders quite accurately[2] to reduce sensitivity against misalignment[3], a smooth orbit without high Fourier components are expected to be rather good and close to the ideal one.

Another thing that we should point out is that low frequency components of BPM offset cannot be separated by the present method. To check the significance of these components, it is necessary to measure the BPM offset by using another method and compare the results.

For thorough understanding of the BPM offset these will be studied in the future.

References

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