Bump Compensation and System Error Detection using a Microsoft® EXCEL Spread Sheet.

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Abstract

On the synchrotron storage ring at Daresbury the local steering at each experimental beam line is carried out using a three magnet bump. The experimentally measured response of all the steering magnets at the beam position monitors has been used to find the best magnet ratios for good orbit compensation. For simplicity the solutions were found using a spreadsheet solver. Further analysis of this data using the solver has been able to detect the mis-calibration of BPMs and has also proved a useful method of estimating the beta functions at both the steering magnets and monitors in the storage ring.

1. INTRODUCTION

Compensated three magnet bumps are used for steering the electron beam to achieve optimum synchrotron radiation output into the beamlines. Initially theoretical magnet current ratios were applied and bumps compensated by manual iteration. This process was carried out for each bump (16 bumps for each of eight different types) in each of two different operating modes of the machine (Tune = 6.2, 3.2 for multibunch and 4.2, 3.2 for single bunch). The SRS lattice contains two superconducting wiggler magnets, which have the effect of modulating the orbit by a small amount in the vertical plane. While a compensation for this is applied, the orbit conditions are sufficiently different that bump ratios must also be calculated for all combinations of wiggler magnets on, and off. Clearly this was a very time consuming exercise.

A technique has been developed to calculate ratios of magnet currents which give minimum ripple outside the defined local bump using the measured machine response matrix and the spreadsheet solver in the commercial software package Microsoft Excel.

A similar technique has been employed to calculate the vertical beta function in the SRS, and this also brings to light any incorrect responses of the BPM system.

2. THREE MAGNET BUMP

Theory

The response of the machine to a current I on magnet i at BPM j is IY_{ij}. For a three magnet bump applied in location k having elements i=k-1, k and k+1, the response of the machine to this bump at the same BPM is given by

$$A_k Y_{(k-1)j} + B_k Y_{kj} + C_k Y_{(k+1)j} \qquad (1)$$

Where A_k, B_k and C_k denote the magnet currents of the three elements. The ratio of A:B:C is set such that the residual ripple outside the local bump is minimised.

Bumps used on the SRS

The local bumps used on the SRS have been documented elsewhere [1]. In summary, in the vertical plane two 'long bumps' (affecting two dipoles) and three 'short bumps' (affecting only one dipole) are used. In the horizontal plane two long bumps and one short bump are available. In the first instance, the correcting algorithms have been concentrated on the vertical bumps.

3. COMPENSATION OF THREE MAGNET BUMPS

An Excel spreadsheet has been set up which uses the measured machine response matrix to calculate the expected response of each of the 16 BPMs to each of 16 bumps. The magnet currents A_k, B_k and C_k were initially set to theoretical values. The spreadsheet solver can then be used to vary two of the three magnet currents in order to minimise the BPM responses outside the bump. The solver uses an iterative technique, and therefore it is important to define the starting point sensibly. The parameters of the iteration (ie step size, number of iterations etc.) can be set by the user. A minimisation of the RMS of the residuals has been found to be an effective technique. All 16 bumps of a given type can be optimised simultaneously, however better results have been gained by optimising individual bumps.

The expected residual outside the bump can be predicted, and a comparison made with the result when applied to the storage ring. In preliminary tests with vertical orbit bumps, 1 - 3mm bumps were applied and the expected residuals compared with those seen with beam. In three cases out of four the results were very encouraging. However one set of short bumps showed poorer compensation, the reasons for which were not fully understood. Table 1 shows the levels of residual orbit ripple as compared with that predicted by the program.

Bump	Predicted Residual (%)	Real Residual (%)
V A Long Bump	2.4	1.6 - 3.3
V B Long Bump	1.9	0.7 - 1.3
V C Short Bump	5.0	1.5 - 4.0
V E Short Bump	6.3	3.2 - 20

Table 1. Predicted and real residual orbit ripple on vertical bumps.

It must be borne in mind that the residual orbit errors seen here in fact only constitute fractions of a millimetre. However the difference in prediction and measured residual in the case of the E bump was cause for concern, and further experiments are being undertaken to find an explanation. BPM errors or non-linearity have been ruled out. Furthermore, the same data was used to calculate all four sets of results. BPM errors can lead to poor compensation, and large errors are usually quite obvious. Smaller errors, of the order fractions of a millimetre, are more difficult and a careful scrutiny of the response matrix is required to spot any small discrepancies. During a period of commissioning of a new BPM system [2], this problem necessitated great care when calculating bump ratios. Of late, greater confidence in the BPM system will allow this method to be used to routinely predict magnet ratios for many different operating conditions of the machine.

4. CALCULATING BETA FUNCTION

The inclusion of two superconducting Wiggler magnets in the SRS lattice has introduced vertical focusing fields which result in tune shift and a modulation of the vertical beta function. Shunts across the D-Quadrupoles adjacent to the magnets are employed to restore the vertical tune [3,4], however a small amount of beta modulation remains.

Previously beta function has been estimated using the displacement at a given BPM i caused by the vertical steering magnet (VSTM) j, under which the BPM lies, using the expression

$$y = \frac{\sqrt{\beta_i}\sqrt{\beta_j}}{2\mathrm{Sin}\pi Q}\frac{\partial BL}{B\rho}\mathrm{Cos}\big(Q(\pi - |\phi_i - \phi_j|)\big) \qquad (2)$$

The average beta through the VSTM is assumed to be equal to that at the BPM which is a reasonable approximation for the short magnet.

A theoretical response matrix has been generated using equation (2) with the measured vertical tune value of 3.36, and a calibration of 1A = 23.2 Gauss m on the VSTM. This is then compared with the measured response matrix, and the difference in the two minimised using the spreadsheet solver to make iterations of β_i, β_j, ϕ_i and ϕ_j. ϕ_i and ϕ_j can be assumed to be identical due to the proximity of the corrector and BPM.

This method is less prone to the effects of BPI errors than that used previously as more data is used for each calculation. Furthermore, the beta function is calculated in two ways at each point - 1) at the magnet, from the response of each of 16 BPMs to that magnet, and 2) at the BPM from the response of that BPM to each of the 16 magnets. Given that the beta value at the BPM and at the magnet are expected to be almost identical, a comparison of the two sets of results should bring to light any BPM responses that are incorrect.

Figure 1 compares the vertical beta function around the machine as calculated using the old method, described earlier, with the two solutions calculated using the spreadsheet solver. The average value and standard deviation are also included.

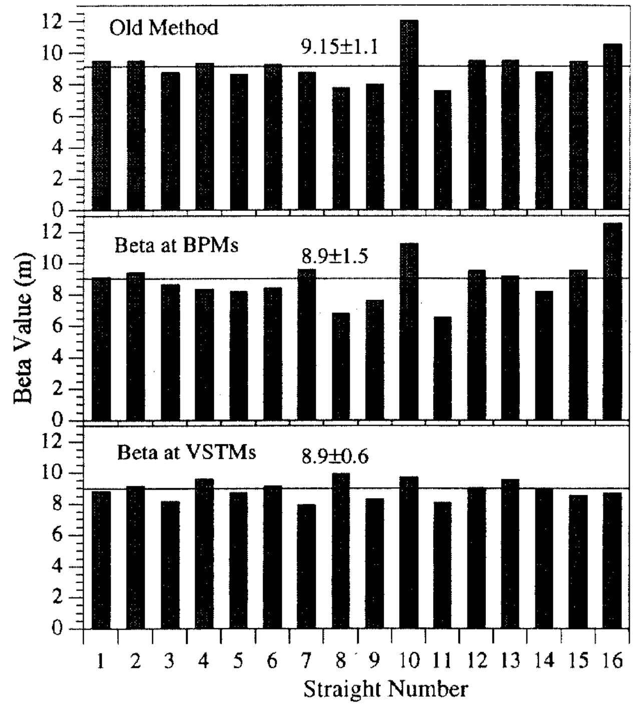

Fig 1. Calculated Vertical Beta Values in the SRS

The indication is that the best estimate to the real beta value comes from that fitted at the magnet, as the standard deviation is significantly smaller. Variation in the other methods can be introduced by BPM errors, which in the case of the beta value at the magnet, are averaged. This view is reinforced by a second experiment which was carried out with the 6T wiggler in straight 16 energised. Figure 2 shows the beta values as calculated at the vertical steering magnet and at the BPM.

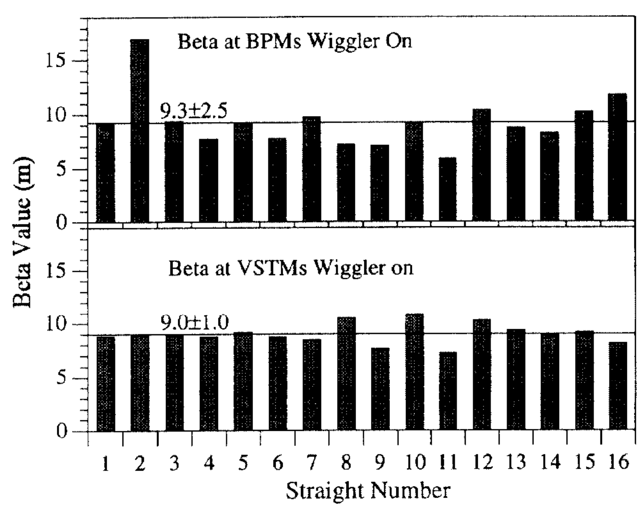

Fig 2 Beta values at BPM and steering magnet illustrating result of BPM response error.

The result for straight 2 in the latter case gave cause for concern, and careful checks of the measured response matrix revealed an abnormally large response on this BPM, possibly due to an attenuator switching error. With recent new developments in the SRS BPM system the occurrence of such errors will be infrequent [2,5].

5. CONCLUSIONS

The commercially available software package Microsoft Excel has been implemented to set up a spreadsheet which uses the measured response matrix of the SRS to calculate magnet current ratios for compensation of closed orbit bumps. The results are encouraging and this method can be used to save time in preparing operational files. The ease and simplicity of this method of calculation has allowed quick calculations to be carried out where previously complex multi-parameter optimisations were required. Furthermore the spreadsheet method can be used to do rapid calculations and analysis of results virtually on line, while accelerator physics experiments are in progress, allowing efficient use of data collection during valuable accelerator physics time.

A similar method has been used to calculate beta function at the BPM and at the steering magnets in each straight of the SRS. This process brings to light any errors which may be present in the BPM responses. A comparison of the differing values at the BPM and the magnet, which are at the same point in the lattice, gives an estimate of the accuracy of each set of values. Difficulties caused by poor BPM readout will be much reduced following the completion of commissioning of a new BPM system.

6. REFERENCES

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