SSC High Energy Booster Resonance Corrector and Dynamic Tune Scanning Simulation

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Abstract

A resonance correction system for the High Energy Booster(HEB) of the Superconducting Super Collider (SSCL) was investigated by means of dynamic multiparticle tracking. In the simulation the operating tune is scanned as a function of time so that the bunch goes through a resonance. The performance of the half integer and third integer resonance correction system is demonstrated.

I. INTRODUCTION

The 2 TeV superconducting High Energy Booster is the last synchrotron ring in SSC injection chain, which consists of 512 dipole and 318 quadrupole magnets. It appears as an oval ring with two long strait sections, two short strait sections and six arcs. Because of the multi-pole errors in these magnets, betatron resonances of several orders are exited. Local non 0th-order-effect correctors are designed to compensate the resonance for this large synchrotron [1]. Correcting these resonances can be done by calculation the bandwidth of a resonance. For a real machine, not all the error information, especially random errors, is obtainable, therefore one must adjust the corrector interactively by looking at beam behavior. The corrector schemes described in this article are tested with a dynamic simulation study that looks at the emittance growth and beam loss using macro particles in the lattice with and without the resonance correction system.

II. RESONANCE CORRECTION SCHEME

The working point of the HEB is (39.42, 38.41) in tune space, which is between half integer and third integer resonance lines (see Figure 1). Therefore a half integer and third integer resonance corrector are needed to compensate the strong half and third integer resonance lines.

The correctors are placed in the arcs of HEB. The arcs consist of 90° FODO cells. Figure 2 shows two cell layout and the betatron functions. The correctors are inside spool pieces that are close to each quadrupole magnet.

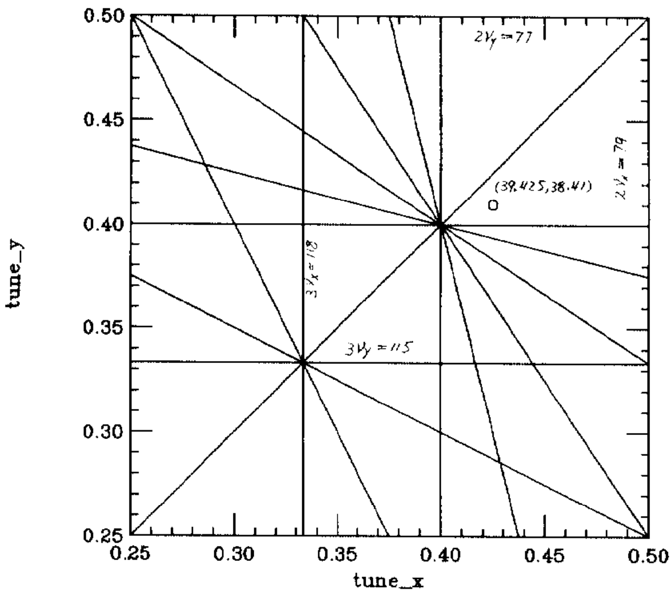

Figure 1. HEB working point in tune diagram.

A. *The half integer correction scheme*

The half integer corrector consists of eight quadrupole magnets, four of them for resonance line $2\nu_x = 79$ and the other four for resonance line $2\nu_y = 77$, respectively. Each of the four magnets is assigned into two groups, powered by two adjustable power supplies, and those groups of magnets form two orthogonal vectors in phase space to generate harmonics with the desired magnitude and phase. To avoid generating 0th harmonics or tune shifts, two magnet sets in each group are wired in series with opposite polarity and placed in the positions with 90° betatron phase advance or 180° for 2nd harmonic. The driving force is $\int B'\beta_x exp(2i\phi_x)ds$ for $2\nu_x = 79$. The quadrupole magnets are placed in high β_x regions and the scheme is shown in Figure 3. 45° betatron phase advance or 90° for 2nd harmonic between the two sets of magnets is needed to form a pair of orthogonal vectors, which is achieved by using straight section phase advance.

A similar scheme for $2\nu_y = 77$ is shown in Figure 3. The quadrupole magnets are placed in a high β_y region for this case.

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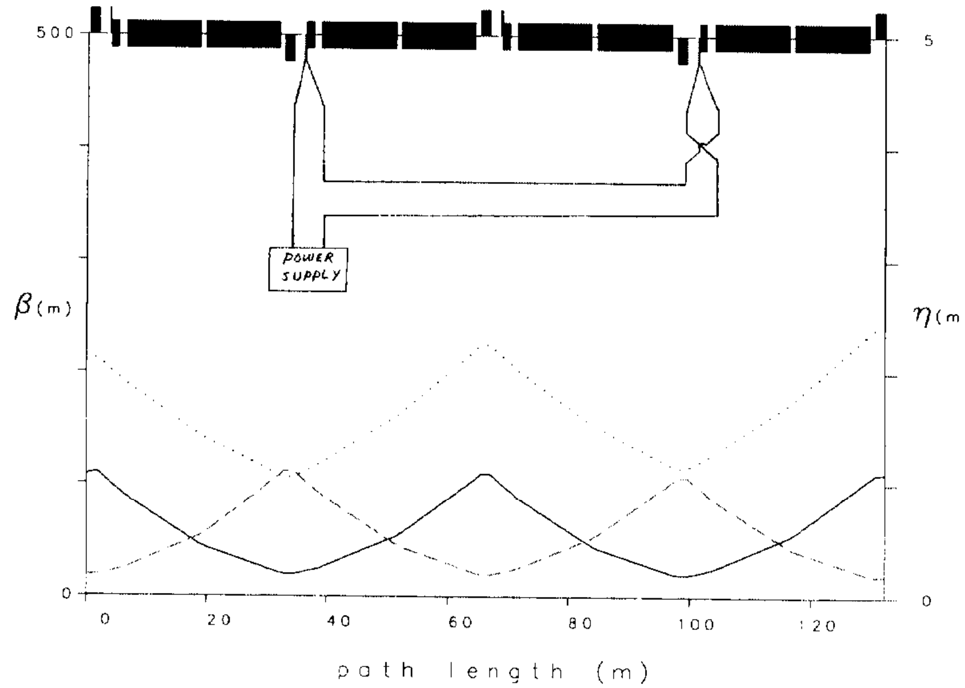

Figure 2. Two FODO cells and the betatron functions. Magnets in series with opposite polarity.

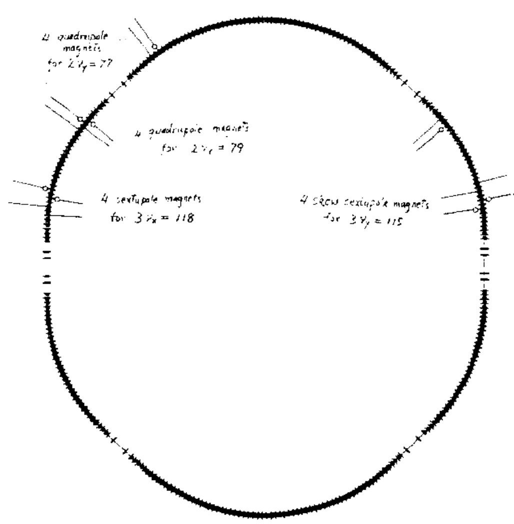

Figure 3. The correction scheme in half HEB ring. The little circles represent reversed polarity.

B. The 3rd integer correction scheme

The working point of HEB is close to $3\nu_x = 118$ and $3\nu_y = 115$ resonance lines. The driving force for $3\nu_x = 118$ resonance lines is $\int B'' \beta_x^{3/2} exp(3i\phi_x)ds$ and four sextupole magnets are used to compensate the line. Two sextupole magnets are placed where the betatron phase difference is 180° and they are wired in series with opposite polarity to avoid generating the 0th harmonic or chromaticity (see Figure 3).

Four skew sextupole magnets are used to compensate $3\nu_y = 115$.

III. DYNAMIC TUNE SCANNING SIMULATION

A modified version of Simpsons code is used to evaluate the performance of the resonance correction system. This code is a fully 6-D multiparticle tracking program with acceleration [2]. In the simulation, time is the independent variable instead of the longitudinal position that can dynamically change machine parameters, such as tune and chromaticity as a function of time just like real machines. This feature makes the simulation of resonance crossing much easier. The table of quadrupole magnet strength at several times, for instance, is read into the code and interpolated at the time when a tracking particle passed the element. We observed the rms emittance and beam loss, due to the resonance crossing, to check the performance of the proposed resonance correction system. The bandwidth of the individual resonance is estimated, and the needed strength of correctors is then calculated so that the bandwidth is reduced to near zero. The simulation of both lattices with and without correction is performed and a comparison is made to check the effect of the correction.

In the dynamic tune scanning simulation for half integer correction, the working point is linearly moving from (39.424, 38.414) to (39.543, 38.533) in 10 msec. At about 6 msec, the working point crossed the half integer. 1024 particles are used to calculate emittance. Emittance growth is occurring at a half integer crossing, while corrector circuits are turned off. A smooth half integer crossing is also shown in Figures 4 and 5 for a well corrected HEB.

The results for horizontal and vertical planes are shown in Figures 4 and 5 respectively.

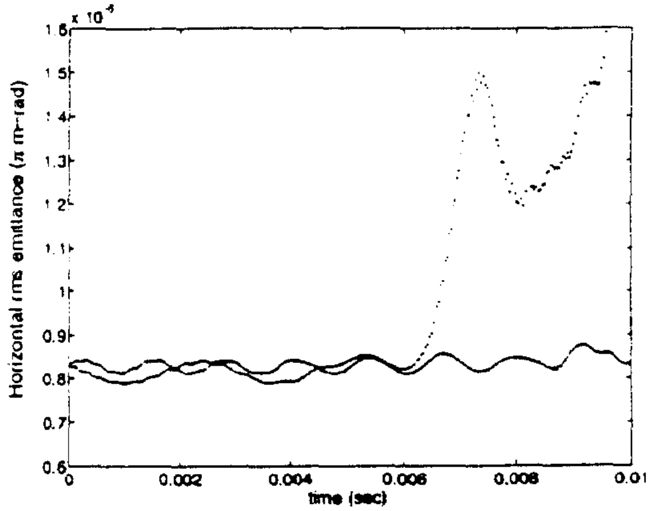

Figure 4. Horizontal emittance with and without half integer correction.

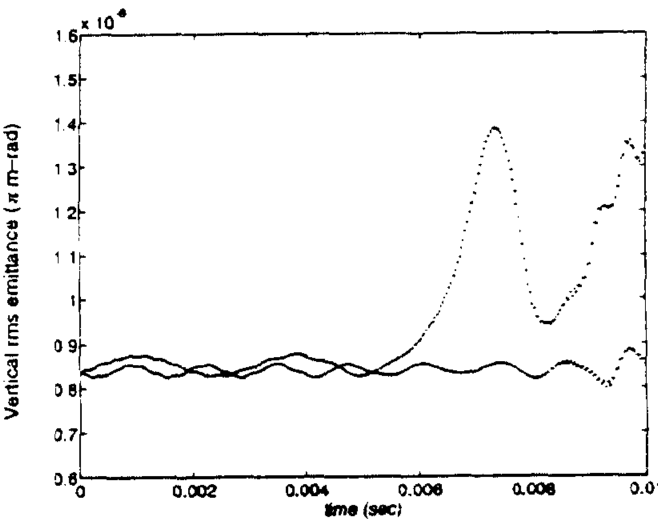

Figure 5. Vertical emittance with and without half integer correction.

In the dynamic tune scanning simulation for third integer correction, the working point is linearly moving from (39.398, 38.261) to (39.252, 38.095) in 40 msec. Figure 6 shows the correction effect with the comparison of emittance growth with and without corrector. Without correction, the emittance grows quickly since some particles under resonance move off the bunch center. These particles finally lose, and the calculated emittance temporary drops. Then some particles move outwards and emittance grows again. As a result, a saw tooth like emittance growth picture has been seen.

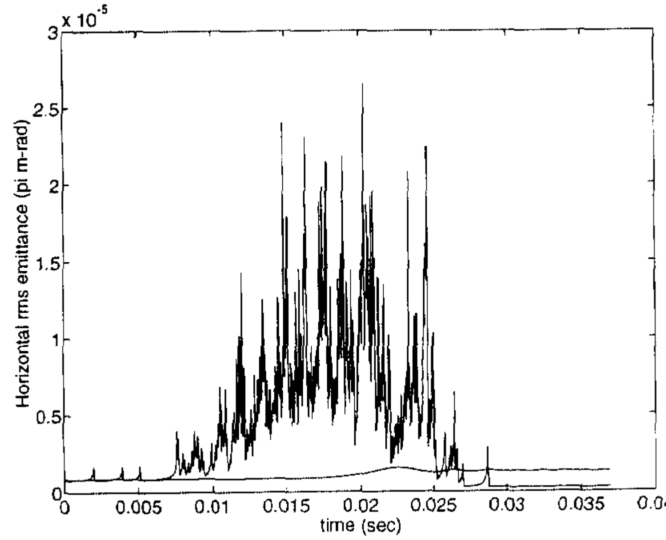

Figure 6. Horizontal emittance with and without 3rd integer correction.

IV. SUMMARY

Local non 0th-order-effect half integer and third integer correction schemes work well with large synchrotrons. A dynamic tune scanning simulation is close to real machine operation.

V. REFERENCES

[1] P. Zhang, 'A Study of Tunes near Integer Values in Hadron Colliders' *Fermi National Accelerator Laboratory, FN-577.*

[2] S. Machida, *Computational Accelerator Physics Conference 1993.*