Correction of the First Turn with Injection Error

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Introduction

This is an addendum to SSC-N-189 [1]. In that note, the correction of the first turn in the SSC was investigated by repeatedly injecting beam and correcting the orbit. In this note, the same process is carried out, but with random error in the injected beam energy and transverse displacement.

The errors are random from one injected beam bunch to the next, so that the errors work against the process of orbit correction. In order to approximate the actual closed orbit in the presence of these injection errors, a running average is made of the tracks of successive injected bunches: At any point in the machine, let x_i be the displacement of injected bunch i and $\langle x\rangle_i$ be the running average computed after this bunch is injected. The average is given as

$$\langle x\rangle_i = (1-\alpha)\langle x\rangle_{i-1} \;+\; \alpha x_i \;,$$

where $0 < \alpha \leq 1$, and $\alpha = 1$ corresponds to no averaging. Then $\langle x\rangle_i$ is the track used to correct the lattice at that iteration.

The errors are given maximum values of $\pm 1.5\times 10^{-4}$ in energy and ± 1.5 mm in each transverse plane, which are taken from the conceptual design [2]. The errors are distributed as a truncated Gaussian, and two different σ have been tried: σ was set equal to the maximum error to give a fairly uniform distribution, and σ was also set to half the maximum error.

The lattice used is an SSC test lattice as described in SSC-N-189, and the IR correction scheme is the third case described in that note: There is assumed to be a corrector and a beam position monitor at each end of the IR triplet.

Results

The simulation was done with values of α^{-1} of 1, 2, and 3, and with distributions of errors cut off at σ and 2σ, where σ is always scaled to make the cutoff value equal to the maximum specified error. Ten different random seeds were used for each set of conditions, and after each lattice was corrected a single bunch was tracked with no averaging but with similar errors in order to inspect the injection into the corrected lattice. N is the number of iterations necessary to complete the correction, and α^{-1} is the number of shots over which the track is averaged. The results given for each parameter is the range over the ten seeds.

For the distribution with cutoff of σ:

α^{-1}	N	x_{rms}	x_{max}
1	13–35	0.68–3.10	2.07–8.98
2	29–47	0.46–2.59	1.77–7.88
3	49–75	0.55–1.90	1.91–6.32

For the distribution with cutoff of 2σ:

α^{-1}	N	x_{rms}	x_{max}
1	16–29	0.37–2.40	1.50–8.26
2	21–42	0.51–1.48	1.92–4.93
3	38–72	0.48–1.65	1.86–4.93

Note that the number of required iterations N increases roughly in proportion to the averaging number α^{-1}. There was not any significant difference between the horizontal and vertical orbit displacements. The energy error does not seem to make a significant difference in the results until the maximum energy error is greater than $\pm 5.0 \times 10^{-4}$.

Conclusions

The SSC lattice may be corrected for the first turn, even in the presence of the maximum random injection errors specified in the CDR. However, the importance of averaging to reduce the random errors depends on the actual distribution of the errors. As the distribution of errors becomes more uniform between the maxima, averaging becomes more important. In the case of cutoff at 2σ, an averaging parameter of $\alpha^{-1} = 2$ gives the optimum result, whereas in the case of cutoff at σ, the correction is still improving with $\alpha^{-1} = 3$. The longer averaging time is also very costly in the time required to correct.

References

1. R. E. Meller, Correction of the First Turn in the SSC, SSC-N-189

2. CDR, section 4.3.2