SIMULATION OF ORBIT ERRORS USING THE SSC CLUSTERED-IR TEST LATTICE

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ABSTRACT

Quadrupole roll and misalignments, dipole strength errors, dipole roll and misalignments, and monitor misalignments were added to the regular cells of the SSC clustered-IR test lattice. All multipole errors were added to the cell dipoles. The orbit was corrected using the beam bump technique described in (1). The resulting lattice was tracked using TEAPOT (2) to determine the linear and dynamic apertures. Some studies were also done of corrector failure.

LATTICE AND INITIAL ANALYSIS

The initial analysis of the SSC clustered-IR test lattice $(2,4)_b$ (with $\beta^* = 1m$ at all six interaction points) was the same as that in Reference 3. Briefly, all multipoles were added to the dipoles (only one random distribution was used), and the dipoles were sorted on a_1 and b_2. The cell quadrupoles were then adjusted to obtain the desired tunes (89.265 in the horizontal (x), 89.285 in the vertical (y)), and the chromaticity was set to zero with the arc sextupoles. Next the machine was decoupled using four families of skew quadrupoles in the interaction regions. All tracked particles were launched at the first interaction point in the cluster of four (the one farthest from the utility straights), which we will call the reference interaction point.

ORBIT ERRORS AND ANALYSIS

The $(2,4)_b$ test lattice was augmented with correctors and monitors for orbit correction. Beam position monitors which read both x and y coordinates were placed at the end of each quadrupole. A horizontal corrector was placed at each horizontally focussing quadrupole (at the end opposite the monitor), and a vertical corrector at each vertically focussing quadrupole. The only exceptions to this were the six quadrupoles in the triplet on either side of each interaction point. These quadrupoles had no monitors or correctors associated with them.

The cell quadrupoles and dipoles (and also those in the dispersion suppressors) were misaligned in both x and y with sigma of $0.5mm$. The cell quads and dipoles were also given a roll angle about the beam with sigma of $0.5mr$. Dipole strength errors were added, $(a_0 = 5.9, b_0 = 3.0)$, and the monitors were misaligned with respect to the associated quadrupole with sigma of $0.1mm$. All these error distributions were cut at 10σ. The orbit was then corrected using the beam bump technique described in Reference 1.

In practice, the orbit before correction will be outside the vacuum chamber and a global correction scheme will not be useful until a first turn has been es-

tablished. Since the orbit before correction is so large, the program had difficulty when all the closed orbit errors were added to the machine at once, so the errors were added in parts. First the errors associated with the bends were added, then the quadrupole errors were added in five equal parts ($0.1mm$ misalignment and $0.1mr$ each time). When the dipole errors were added, the orbit at the monitors before correction was

$$< x^2 >^{1/2} \sim 2mm$$
$$< y^2 >^{1/2} \sim 4mm.$$

All orbits at the monitors quoted here are the real orbits there, not the orbits as read by the misaligned monitors. When one-fifth of the quadupole errors was added, the orbit at the monitors before correction was

$$< x^2 >^{1/2} \sim 3mm$$
$$< y^2 >^{1/2} \sim 5mm.$$

After orbit correction, the next set of errors was added, and finally the monitors were misaligned.

When all errors were added and the global orbit correction done, the resulting orbit at the monitors was

$$< x^2 >^{1/2} = 0.35mm$$
$$< y^2 >^{1/2} = 0.36mm.$$

Figures 1 and 2 show the orbit. The rms orbit deviation as read by the (misaligned) monitors was $0.26mm$ in x and y, and the maximum orbit displacements were in the arcs, $1.2mm$ in x and $1.6mm$ in y. The corrector strengths were

$$< \theta_h^2 >^{1/2} = 7 \times 10^{-6} radians$$
$$< \theta_v^2 >^{1/2} = 8 \times 10^{-6} radians.$$

and the maximum corrector strengths were

$$\theta_{hmax} = 20 \times 10^{-6} radians$$
$$\theta_{vmax} = 30 \times 10^{-6} radians.$$

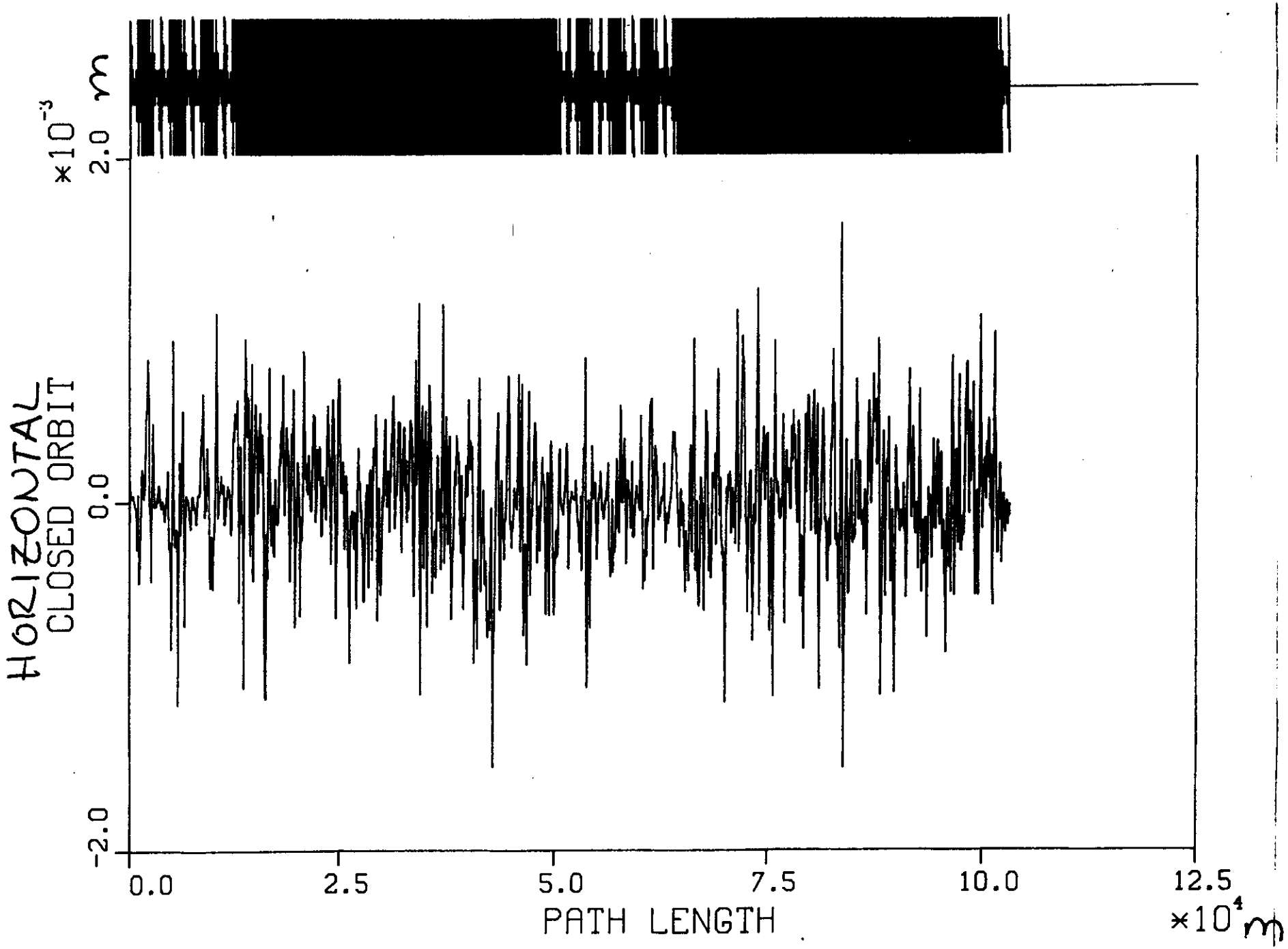
HORIZONTAL
CLOSED ORBIT
$\times 10^{-3}$ m
2.0
0.0
-2.0
0.0
2.5
5.0
7.5
10.0
12.5
PATH LENGTH
$\times 10^{4}$ m

FIGURE 1

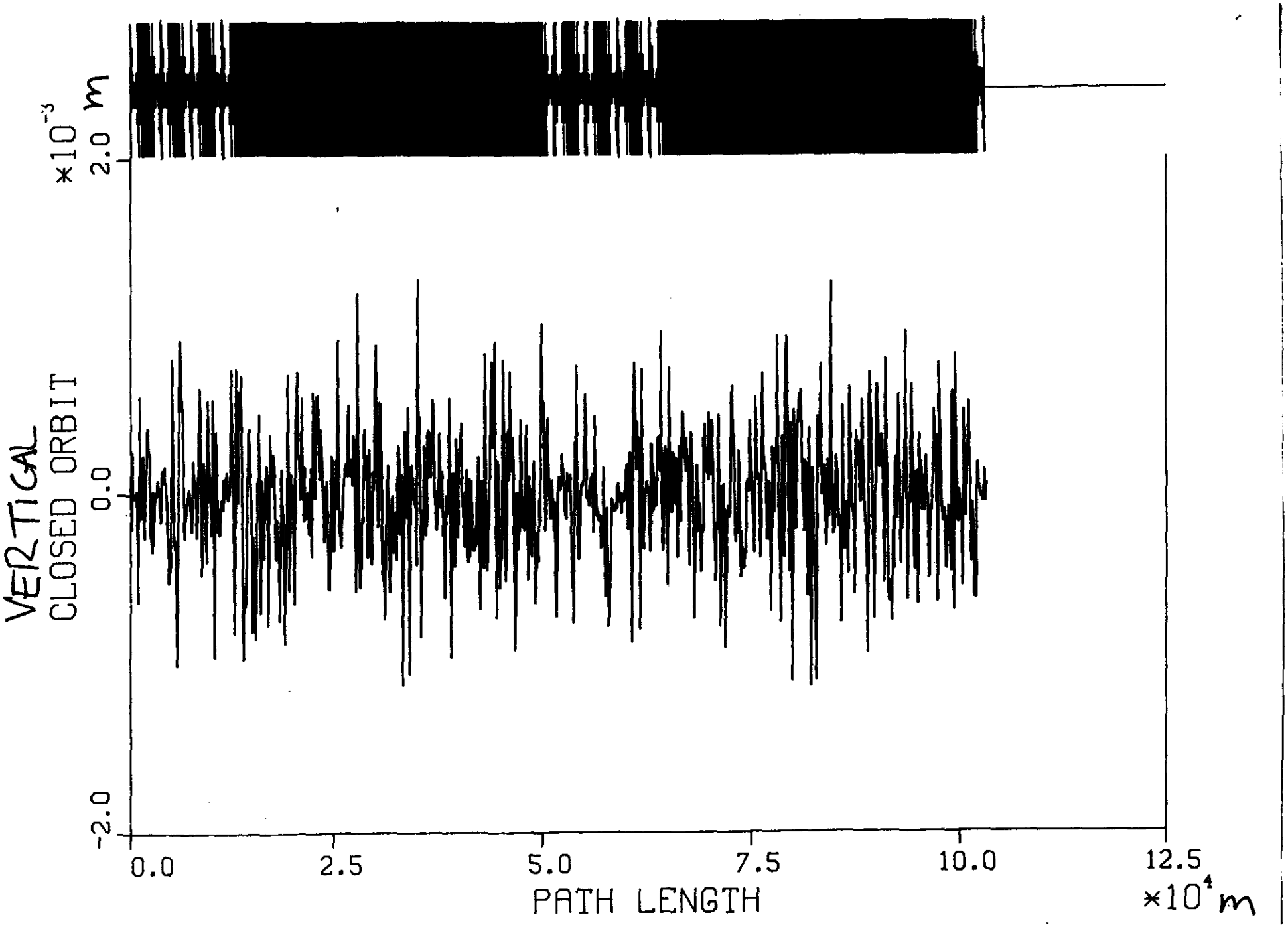
VERTICAL
CLOSED ORBIT
×10⁻³ m
2.0
0.0
-2.0
0.0
2.5
5.0
7.5
10.0
12.5
PATH LENGTH
×10⁴ m

FIGURE 2.

These results are all in good agreement with the analysis in Reference 1.

As a check, the orbit errors were doubled, and the above analysis was performed again. All the numbers given above approximately doubled.

APERTURES

Tracking was performed to determine the linear (4) and dynamic apertures for the machines with no orbit errors, full errors and double errors. Only one random seed was used. The apertures were measured with respect to the closed orbit at the reference interaction point, which for the full errors case was $x = 0.04mm$, $x' = 0.45 \times 10^{-3}mr$, $y = 0.03mm$, and $y' = 0.19 \times 10^{-2}mr$.

	rms orbit (x,y)	dynamic aperture	linear aperture
no errors	$0.0mm, 0.0mm$	$12.8mm$	$9.6mm$
full errors	$0.35mm, 0.36mm$	$12.8mm$	$9.6mm$
double errors	$0.70mm, 0.72mm$	$11.5mm$	$9.6mm$
1/100 corr. off	$2.2mm, 2.6mm$	$12.8mm$	$7.0mm$
1/10 corr. off	$4.6mm, 5.2mm$	$3.84mm$	$1.8mm$

Table 1. Apertures at $\widehat{\beta}$ in the cells

All the apertures measured are shown in Table 1. At the reference interaction point the linear aperture was $0.375mm$ for all three machines or $9.6mm$ at $\widehat{\beta}$ in the cells. Thus, the linear aperture of the machine is not degraded when orbit errors are added.

Both for the machine with no orbit errors and for the machine with full errors the dynamic aperture at the reference interaction point was $0.50mm$ ($12.8mm$ at

$\widehat{\beta}$ in the cells). When the errors were doubled, the dynamic aperture decreased to $0.45mm$ at the reference interaction point ($11.5mm$ at $\widehat{\beta}$ in the cells).

CORRECTOR FAILURE

A study was done of the machine tracked above with some correctors turned off, to simulate corrector failure. We were interested to know whether the beam would be stable when the correctors were not all working. Two cases were studied, every tenth corrector off (horizontal and vertical separately) and every hundredth corrector off. No attempt was made to correct the orbit again without these correctors.

When every tenth corrector was turned off, the closed orbit at the reference interaction point became $x = -0.14mm$, $x' = -0.1mr$, $y = 0.20mm$, and $y' = -0.38mr$. The orbit at the monitors was

$$< x^2 >^{1/2} = 4.6mm$$
$$< y^2 >^{1/2} = 5.2mm.$$

The dynamic aperture for this machine was $0.15mm$ at the reference interaction point ($3.84mm$ in the cells). This is to be compared with $0.50mm$ ($12.8mm$ in the cells) dynamic aperture with all correctors working. Under these conditions one could presumably then proceed to correct the orbit using the working correctors. However, the orbit is $4cm$ in at least one of the IR triplets, which is outside the beam pipe (radius $1.5mm$). Remember that there are no multipole errors in the IR quads here, but with those errors such large orbits in the IR quads could cause beam instability.

Turning off every hundredth corrector gives a closed orbit at the reference interaction point of $x = -0.04mm$, $x' = -0.39 \times 10^{-2}mr$, $y = 0.09mm$, and $y' = -0.18mr$. The orbit at the monitors was

$$< x^2 >^{1/2} = 2.2mm$$
$$< y^2 >^{1/2} = 2.6mm.$$

and the dynamic aperture at the reference interaction point was $0.50mm$ ($12.8mm$ in the cells) with respect to the closed orbit at the reference interaction point. In this case, greatest orbit excursion is $2cm$ at one of the IR triplets.

REFERENCES

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