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RESONANCE ANALYSIS FOR SCC WITH HARMON AND NONLIN

Zohreh Parsa

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ACCELERATOR DEVELOPMENT DEPARTMENT
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ABSTRACT

WE have examined the effects of the non-linear structure resonances in the SSC - CDR Clustered lattices. The comparison is made between the results obtained from the program HARMON and our algorithm "NONLIN".

I. Introduction

We have studied the nonlinear effects on the dynamical systems, (e.g. circular accelerators) and have implemented some of our developments into an algorithm that calculates and obtains information about nonlinear contributions in accelerators [1] including: the perturbation of tune; emittance growth; smear; linear aperture, Hamiltonian resonance strength; generating function resonance strength; fixed points; Chirikov criterion; Island width etc. Using our algorithm "NONLIN" we have investigated the structure resonances for the SSC - CDR clustered lattices for BETA* = 0.5 and BETA* = 6.

Comparison of our results obtained from NONLIN [2] with those obtained from HARMON [3,4] for the same lattices [5] are also discussed. In Section II, we describe the differences in the notations of these programs. In section III, the conclusion is given, and in Section IV the results obtained from these programs for the SSC - CDR Lattices are tabulated and labled as [NONLIN] and/or [HARMON] respectively.

Note that, for a given (Table number) lattice the Tables labled with "[NONLIN]" corresponds to the same Tables labled with "[HARMON]".

II. PROGRAMS' NOTATION:

The following differences between the notations and magnitudes in the results obtained from programs HARMON and NONLIN [are given for clarity] should be noted:

The stop bandwidths (given under the heading of "DQ") in the HARMON output is twice as large as the stop bandwidth obtained from NONLIN's output (given under the heading "Stp bnw"), because, the stop bandwith calculated from HARMON is over the full width of the interval whereas NONLIN calculates over half of the interval;

We calculate two different resonance strengths, the Hamiltonian and the generating function resonance strengths. The resonance strengths obtained from HARMON's output which is normalized (under the "MODULUS" heading) when multiplied by Ex**(|nx|/2)*Ey**(|ny|/2), [where Ex and Ey are the transverse beam emittances], corresponds to the Hamiltonian resonance strength obtained from NONLIN's output (under the heading of "Strength" given next to the stop bandwidth column).

Furthermore, the perturbation to tunes in NONLIN (i.e., the Q shift parameters in HARMON) are the same as those calculated by HARMON.

III.CONCLUSION

In this paper we have given some of the preliminary results obtained from the program "NONLIN" that was used to calculate (and obtain information about) the nonlinear effects in the SSC lattices. The comparison of our results using NONLIN and the program HARMON is given for the investigation of nonlinear effects in accelerators .

We find that the results between HARMON and NONLIN agrees qualitatively for the lattices tested (i.e. the strength of resonances may agree qualitatively but not quantitatively).

These programs agree quantitatively, in tune shift parameters and the stop bandwidth calculation for the third order resonances [see Tables in section IV]. The differences in the stop bandwidths of the other resonances may be due in part to the difference in the canonical transformations used on the Hamiltonian.

Additionally, with preliminary version of NONLIN we can calculate the beam emittance growth; variation in the particle action; smear; linear aperture; sixth order resonances; the Chirikov criterion (i.e., to determine when two or more resonances could lead to chaotic behavior) and generating function resonance strength (as was illustrated in the previous section, and can be seen from the following tables).

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11. Analytical Method for Resonance Analysis (to be published).

** We thank E. Courant and S. Tepikian for discussions and assistance.

RESULT OBTAINED FROM PROGRAM "NONLIN"

TABLE I-A [NONLIN]

```
CDR LATTICE FOR SSC BET*=.5
--------------------------------------------------------
Perturbation of tunes

vx = vx0 + -2659.335 * Ex + -9080.386 * Ez
vy = vz0 + -9080.386 * Ex + -1773.600 * Ez

where the unperturbed betatron tunes are
vx0 =    78.26497     and  vz0 =   78.27995
with circumference =   82944.00
and periodicity    =        1

Given a beam with emittances
Ex = 2.4939999E-07 and  Ez = 2.4939999E-07
              (*pi m-rad),
the perturbed tunes become
------------------------
vx =   78.26204     and  vz =   78.27724

The emittance can grow to
------------------------
Exmax = 3.5259643E-07 at the 331 th element and
Ezmax = 3.4869160E-07 at the 331 th element.

The smear is found to be
--------------------------
Smear= 6.1362222E-02 at the 331 th element and
Smear= 6.1362222E-02 at the 331 th element

The linear emittance when the smear = .1 is
-------------------------------------------
Elin = 4.0493774E-07 at the 331 th element and
Elin = 4.0493774E-07 at the 331 th element
```

TABLE I-B [NONLIN]

CDR LATTICE FOR SSC BET*=.5

The resonances are numbered as follows:

No.	Resonance	Strength	Stp bndw
	Fix pts.	Width	Chirikov cr
1A	0 vx +2 vz = 156	3.4703E-12	5.5658E-05
	6.1188E-05	2.2117E-08	4.7544E-08
1B	0 vx +2 vz = 157	1.4823E-14	2.3774E-07
	2.5768E-07	1.4455E-09	3.1073E-09
2A	0 vx +4 vz = 313	1.7570E-14	1.1272E-06
	5.9411E-07	3.9343E-10	6.7660E-09
2B	0 vx +4 vz = 314	1.3314E-12	8.5412E-05
	4.6071E-05	3.4248E-09	5.8897E-08
3A	1 vx -2 vz = -79	2.7258E-10	3.2788E-03
	1.0929E-03	0.0000E+00	0.0000E+00
3B	1 vx -2 vz = -78	5.4127E-15	6.5108E-08
	2.1703E-08	0.0000E+00	0.0000E+00
4A	1 vx +0 vz = 78	1.9272E-14	7.7273E-08
	1.2070E-07	0.0000E+00	0.0000E+00
4B	1 vx +0 vz = 79	7.1171E-10	2.8537E-03
	4.6124E-03	0.0000E+00	0.0000E+00
5A	1 vx +2 vz = 234	2.1122E-14	4.2345E-07
	2.5407E-07	0.0000E+00	0.0000E+00
5B	1 vx +2 vz = 235	1.6659E-11	3.3398E-04
	2.0039E-04	0.0000E+00	0.0000E+00
6A	2 vx -4 vz = -157	2.4985E-15	6.0108E-08
	0.0000E+00	1.5333E-10	4.9374E-09
6B	2 vx -4 vz = -156	4.7933E-13	1.1532E-05
	.0000E+00	2.1238E-09	6.8388E-08
7A	2 vx -2 vz = -1	1.9748E-13	3.1672E-06
	2.8676E-06	1.8964E-09	3.1553E-08
7B	2 vx -2 vz = 0	3.3390E-10	5.3553E-03
	4.8323E-03	7.7979E-08	1.2975E-06
8A	2 vx +0 vz = 156	2.7347E-12	4.3860E-05
	5.8832E-05	1.6034E-08	5.1680E-08
8B	2 vx +0 vz = 157	1.5569E-14	2.4971E-07
	2.7242E-07	1.2098E-09	3.8995E-09
9A	2 vx +2 vz = 313	2.6094E-14	8.3701E-07
	8.3701E-07	5.3733E-10	1.4715E-08
9B	2 vx +2 vz = 314	1.8681E-12	5.9922E-05
	5.9922E-05	4.5465E-09	1.2450E-07
10A	2 vx +4 vz = 469	3.1514E-12	2.5272E-04
	1.6174E-04	4.1351E-09	2.3093E-07

10B	2 vx +4 vz = 470		1.6226E-10	1.3012E-02
		8.3275E-03	2.9671E-08	1.6570E-06
11A	3 vx +0 vz = 234		1.2683E-14	4.5770E-07
		4.5770E-07	0.0000E+00	0.0000E+00
11B	3 vx +0 vz = 235		6.6735E-12	2.4082E-04
		2.4082E-04	0.0000E+00	0.0000E+00
12A	4 vx -2 vz = 156		2.8298E-13	6.8079E-06
		4.5386E-06	8.6005E-10	4.9849E-08
12B	4 vx -2 vz = 157		1.0417E-15	2.5061E-08
		1.6708E-08	5.2182E-11	3.0245E-09
13A	4 vx +0 vz = 313		1.1546E-14	7.4075E-07
		6.2142E-07	2.6046E-10	6.7162E-09
13B	4 vx +0 vz = 314		8.6702E-13	5.5623E-05
		4.8206E-05	2.2570E-09	5.8199E-08
14A	4 vx +2 vz = 469		2.4711E-14	1.9816E-06
		1.1890E-06	1.7802E-10	2.1030E-08
14B	4 vx +2 vz = 470		9.7230E-13	7.7971E-05
		4.6782E-05	1.1167E-09	1.3191E-07
15A	6 vx +0 vz = 469		7.2325E-13	1.0440E-04
		6.9599E-05	9.1619E-10	7.9733E-08
15A	6 vx +0 vz = 470		3.5795E-11	5.1668E-03
		3.4445E-03	6.4454E-09	5.6092E-07

TABLE I-C [NONLIN]

CDR LATTICE FOR SSC BET*=.5
The generating function resonance strength for the resonances:

Elements	Resonance numbers 1	2	3
331	2.59284E-11	4.83069E-12	1.94224E-09
	4	5	6
	5.27804E-09	4.99578E-10	1.43731E-11
	7	8	9
	4.16080E-09	5.07310E-11	3.12842E-12
	10	11	12
	8.33345E-10	1.90890E-10	2.51736E-12
	13	14	15
	1.36763E-12	5.30889E-12	1.69158E-10

TABLE II-A [NONLIN]

```
CDR LATTICE FOR SSC BET*=6.
---------------------------------------------------

Perturbation of tunes

vx = vx0 + -716.3168 * Ex + -2445.579 * Ez
vy = vz0 + -2445.579 * Ex + -477.6593 * Ez

where the unperturbed betatron tunes are
vx0 =   78.26496     and  vz0 =   78.27999
with circumference =   82944.00
and    periodicity =       1

Given a beam with emittances
Ex = 2.4939999E-07 and  Ez = 2.4939999E-07
              (*pi m-rad),
the perturbed tunes become
vx =   78.26417     and  vz =   78.27927

The emittance can grow to
Exmax = 2.7996103E-07 at the 43 th element and
Ezmax = 2.7773686E-07 at the  7 th element.

The smear is found to be
Smear= 1.5864842E-02 at the 43 th element and
Smear= 1.5863875E-02 at the  7 th element

The linear emittance when the smear = .1 is
Elin = 1.5132670E-06 at the 43 th element and
Elin = 1.5134377E-06 at the  7 th element
```

TABLE II-B [NONLIN]

CDR LATTICE FOR SSC BET*=6.
The resonances are numbered as follows:

No.	Resonance / Fix pts.	Strength / Width	Stp bndw / Chirikov cr
1A	0 vx +2 v z= 156	9.2759E-13	1.4877E-05
	1.6352E-05	2.2034E-08	1.2756E-08
1B	0 vx +2 vz = 157	1.0190E-15	1.6343E-08
	1.8145E-08	7.3028E-10	4.2279E-10
2A	0 vx +4 vz = 313	1.1625E-15	7.4577E-08
	3.9350E-08	1.9500E-10	9.0316E-10
2B	0 vx +4 vz = 314	3.6566E-13	2.3459E-05
	1.2648E-05	3.4585E-09	1.6018E-08
3A	1 vx -2 vz = -79	1.4156E-10	1.7028E-03
	5.6760E-04	0.0000E+00	0.0000E+00
3B	1 vx -2 vz = -78	6.7001E-15	8.0594E-08
	2.6865E-08	0.0000E+00	0.0000E+00
4A	1 vx +0 vz = 78	3.0714E-14	1.2315E-07
	1.9978E-07	0.0000E+00	0.0000E+00
4B	1 vx +0 vz = 79	3.6928E-10	1.4807E-03
	2.3932E-03	0.0000E+00	0.0000E+00
5A	1 vx +2 vz = 234	5.1178E-14	1.0260E-06
	6.1561E-07	0.0000E+00	0.0000E+00
5B	1 vx +2 vz = 235	8.6008E-12	1.7243E-04
	1.0346E-04	0.0000E+00	0.0000E+00
6A	2 vx -4 vz = -157	1.7968E-16	4.3227E-09
	0.0000E+00	7.9233E-11	6.8715E-10
6B	2 vx -4 vz = -156	1.2893E-13	3.1018E-06
	0.0000E+00	2.1224E-09	1.8407E-08
7A	2 vx -2 vz = -1	8.9075E-15	1.4286E-07
	1.2893E-07	7.7609E-10	3.4778E-09
7B	2 vx -2 vz = 0	8.9925E-11	1.4423E-03
	1.3015E-03	7.7978E-08	3.4943E-07
8A	2 vx +0 vz = 156	7.2071E-13	1.1559E-05
	1.5685E-05	1.5860E-08	1.3769E-08
8B	2 vx +0 vz = 157	1.0819E-15	1.7352E-08
	1.6868E-08	6.1448E-10	5.3349E-10
9A	2 vx +2 vz = 313	1.6702E-15	5.3576E-08
	5.3576E-08	2.6195E-10	1.9320E-09
9B	2 vx +2 vz = 314	5.1299E-13	1.6455E-05
	1.6455E-05	4.5908E-09	3.3859E-08
10A	2 vx +4 vz = 469	2.0670E-13	1.6576E-05

			1.0609E-05	2.0407E-09	3.0692E-08
10B	2 vx +4	vz =	470	4.3760E-11	3.5092E-03
			2.2459E-03	2.9692E-08	4.4657E-07
11A	3 vx +0	vz =	234	2.0203E-14	7.2906E-07
			7.2906E-07	0.0000E+00	0.0000E+00
11B	3 vx +0	vz =	235	3.4952E-12	1.2613E-04
			1.2613E-04	0.0000E+00	0.0000E+00
12A	4 vx -2	vz =	156	7.5609E-14	1.8190E-06
			1.2126E-06	8.5665E-10	1.3372E-08
12B	4 vx -2	vz =	157	2.7160E-17	6.5340E-10
			4.3560E-10	1.6236E-11	2.5344E-10
13A	4 vx +0	vz =	313	6.8462E-16	4.3921E-08
			3.6246E-08	1.2220E-10	8.4877E-10
13B	4 vx +0	vz =	314	2.3752E-13	1.5238E-05
			1.3200E-05	2.2762E-09	1.5809E-08
14A	4 vx +2	vz =	469	1.6166E-15	1.2964E-07
			7.7782E-08	8.7737E-11	2.7915E-09
14B	4 vx +2	vz =	470	2.6073E-13	2.0908E-05
			1.2545E-05	1.1142E-09	3.5451E-08
15A	6 vx +0	vz =	469	4.6614E-14	6.7285E-06
			4.4857E-06	4.4816E-10	1.0505E-08
15B	6 vx +0	vz =	470	9.6572E-12	1.3940E-03
			9.2932E-04	6.4506E-09	1.5121E-07

TABLE II-C [NONLIN]

CDR LATTICE FOR SSC BET*=6.
The generating function resonance strength
for the resonances:

Chromaticity sextupoles	Resonance numbers 1	2	3
43	6.84477E-12	1.27363E-12	1.00860E-09
	4	5	6
	2.74030E-09	2.59494E-10	3.84700E-1
	1.12059E-09	1.36535E-11	7.96476E-13
	10	11	12
	2.24002E-10	9.89518E-11	6.82071E-13
	13	14	15
	3.61567E-13	1.42736E-12	4.54290E-11
Elements	1	2	3
7	6.97217E-12	1.30371E-12	1.00845E-09
	4	5	6
	2.73891E-09	2.59353E-10	3.86933E-12
	7	8	9
	1.12059E-09	1.36619E-11	8.46263E-13
	10	11	12
	2.24590E-10	9.88886E-11	6.77308E-13
	13	14	15
	3.67257E-13	1.42967E-12	4.55659E-11

RESULT OBTAINED FROM PROGRAM "HARMON"

TABLE I-A [HARMON]

```
HARMON - CDR LATTICE FOR SSC WITH BETA*=.5
[INITIAL EMITTANCE:  Ex0= Ez0 = 2.4940E-07 ]
-------------------------------------------------------
 TOTAL LENGTH = 82944.         NSUP = 1
 QX     =  7.82650E+01   QZ        = 7.82800E+01
 BETAX  =  1.11371E+02   BETAZ     = 3.31656E+02
 ETAX   =  2.36230E+00
NORMALIZED STRENGTHS:    SF = 9.87283E-03
                         SD = -1.59109E-02
FOURTH ORDER EFFECTS OF SEXTUPOLES
Q SHIFT EFFECTS
                 G22000        DQXDEX         DQX
-1.32967E+03  1.77976E-11 -2.65934E+03 -6.63238E-04
                 G00220        DQYDEY         DQY
-8.86800E+02  3.88949E-11 -1.77360E+03 -4.42336E-0
-9.08039E+03  9.78699E-11 -9.08039E+03 -9.08039E+03
                                DQX           DQY
                           -2.26465E-03 -2.26465E-03
RESONANCE EFFECTS
[G's are the 2nd order coefs.]
                     COS         SIN          DE
 G4000,313      -2.8384E-04 -6.7087E-05  1.1638E-09
                                 DQ       DQ(20)
                             7.0245E-10  1.0163E-09
                     COS         SIN          DE
 G0040,313       1.5723E-04  2.0873E-04  1.0428E-09
                                 DQ       DQ(20)
                             6.2936E-10  9.1052E-10
                     COS         SIN          DE
 G2020,313       5.5679E-04  6.4937E-04  1.7067E-09
                                 DQ       DQ(20)
                             1.4567E-09  2.1075E-09
                     COS         SIN      MODULUS
 G2002,  0       2.2334E+03  4.1045E+02  2.2708E+03
                     COS         SIN          DE
 G4000,314       1.3490E+00 -1.5349E+00  8.1542E-06
                                 DQ       DQ(20)
                             4.9215E-06  7.1201E-06
                     COS         SIN          DE
 G0040,314       1.7868E+00 -1.0828E+00  8.3369E-06
                                 DQ       DQ(20)
                             5.0318E-06  7.2796E-06
                     COS         SIN          DE
 G2020,314       2.7285E+00  4.6935E-01  5.5238E-06
                                 DQ       DQ(20)
                             4.7149E-06  6.8212E-06
                     COS           SIN      MODULUS
 G2002,  1      -1.0100E-01 -5.8778E-02  1.1686E-01
```

TABLE I-B [HARMON]

HARMON - CDR LATTICE FOR SSC WITH BETA*=.5
[INITIAL EMITTANCE: Ex0= Ez0 = 2.4940E-07]

FOURIER ANALYSIS. ORDER OF RESONANCE = 1

Qx = 78.

COSINE	SINE	MODULUS	RANDOM
5.2259E-07	8.8016E-07	1.0236E-06	1.4088E+00
DE(S)	DE(R)	DQ(S)	DQ(R)
2.0497E-03	2.8209E+03	2.0497E-03	2.8209E+03
		DQ20(S)	DQ20(R)
		2.0497E-03	2.8209E+03

Qx = 79.

COSINE	SINE	MODULUS	RANDOM
-1.9044E-03	-3.8091E-02	3.8138E-02	1.4088E+
DE(S)	DE(R)	DQ(S)	DQ(R)
7.6368E+01	2.8209E+03	7.6368E+01	2.8209E+03
		DQ20(S)	DQ20(R)
		7.6368E+01	2.8209E+03

2Qx = 156.

COSINE	SINE	MODULUS	RANDOM
1.6494E-01	7.7258E-02	1.8213E-01	5.2518E+00
DE(S)	DE(R)	DQ(S)	DQ(R)
7.2854E-01	2.1007E+01	3.6427E-01	1.0504E+01
		DQ20(S)	DQ20(R)
		3.6427E-01	1.0504E+01

2Qz = 156.

COSINE	SINE	MODULUS	RANDOM
-4.0726E-02	3.1391E-01	3.1654E-01	7.5138E+00
DE(S)	DE(R)	DQ(S)	DQ(R)
1.2661E+00	3.0055E+01	6.3307E-01	1.5028E+01
		DQ20(S)	DQ20(R)
		6.3307E-01	1.5028E+01

2Qx = 157.

COSINE	SINE	MODULUS	RANDOM
5.8869E-06	-4.5762E-06	7.4564E-06	5.2518E+00
DE(S)	DE(R)	DQ(S)	DQ(R)
2.9826E-05	2.1007E+01	1.4913E-05	1.0504E+01
		DQ20(S)	DQ20(R)
		1.4913E-05	1.0504E+01

2Qz = 157.

COSINE	SINE	MODULUS	RANDOM
2.5700E-05	9.7124E-05	1.0047E-04	7.5138E+00
DE(S)	DE(R)	DQ(S)	DQ(R)
4.0187E-04	3.0055E+01	2.0093E-04	1.5028E+01
		DQ20(S)	DQ20(R)
		2.0093E-04	1.5028E+01

TABLE I-C [HARMON]

HARMON - CDR LATTICE FOR SSC WITH BETA*=.5
[INITIAL EMITTANCE: Ex0= Ez0 = 2.4940E-07]

FOURIER ANALYSIS. ORDER OF RESONANCE = 3

3Qx = 234.

COSINE	SINE	MODULUS	RANDOM
-9.9370E-05	8.7357E-07	9.9374E-05	1.4396E+01
DE(S)	DE(R)	DQ(S)	DQ(R)
8.9329E-07	1.2941E-01	2.9776E-07	4.3137E-02
		DQ20(S)	DQ20(R)
		6.1538E-07	8.9150E-02

Qx + 2Qz = 234.

COSINE	SINE	MODULUS	RANDOM
9863E-05	-1.3371E-04	1.6689E-04	4.1921E+01
DE(S)	DE(R)	DQ(S)	DQ(R)
8.3342E-07	2.0935E-01	3.7272E-07	9.3626E-02
		DQ20(S)	DQ20(R)
		7.7028E-07	1.9349E-01

-Qx + 2Qz = 78.

COSINE	SINE	MODULUS	RANDOM
1.3377E-05	-1.9811E-05	2.3904E-05	4.1921E+01

3Qx = 235.

COSINE	SINE	MODULUS	RANDOM
-4.8457E-02	-2.2859E-02	5.3578E-02	1.4396E+01
DE(S)	DE(R)	DQ(S)	DQ(R)
4.8163E-04	1.2941E-01	1.6054E-04	4.3137E-02
		DQ20(S)	DQ20(R)
		3.3179E-04	8.9150E-02

Qx + 2Qz = 235.

COSINE	SINE	MODULUS	RANDOM
-3.1601E-02	-1.2999E-01	1.3377E-01	4.1921E+01
DE(S)	DE(R)	DQ(S)	DQ(R)
6.6806E-04	2.0935E-01	2.9877E-04	9.3626E-02
		DQ20(S)	DQ20(R)
		6.1745E-04	1.9349E-01

-Qx + 2Qz = 79.

COSINE	SINE	MODULUS	RANDOM
1.8372E+00	-1.1891E+00	2.1885E+00	4.1921E+01

TABLE I-D [HARMON]

HARMON - CDR LATTICE FOR SSC WITH BETA*=.5
[INITIAL EMITTANCE: Ex0= Ez0 = 2.4940E-07]

FOURIER ANALYSIS. ORDER OF RESONANCE = 4

4Qx = 313.

COSINE	SINE	MODULUS	RANDOM
1.8933E-04	4.3472E-05	1.9426E-04	3.1176E+01
DE(S)	DE(R)	DQ(S)	DQ(R)
1.8714E-09	3.0034E-04	4.6785E-10	7.5084E-05
		DQ20(S)	DQ20(R)
		6.7686E-10	1.0863E-04

2Qx + 2Qz = 313.

COSINE	SINE	MODULUS	RANDOM
5.0792E-04	3.7613E-04	6.3203E-04	1.2394E+02
DE(S)	DE(R)	DQ(S)	DQ(R)
3.0444E-09	5.9698E-04	1.0763E-09	2.1106E-04
		DQ20(S)	DQ20(R)
		1.5572E-09	3.0535E-04

4Qz = 313.

COSINE	SINE	MODULUS	RANDOM
1.2588E-04	1.1795E-04	1.7250E-04	4.9352E+01
DE(S)	DE(R)	DQ(S)	DQ(R)
1.6618E-09	4.7544E-04	4.1546E-10	1.1886E-04
		DQ20(S)	DQ20(R)
		6.0106E-10	1.7196E-04

2Qx - 2Qz = 0.

COSINE	SINE	MODULUS	RANDOM
-3.5974E+02	0.0000E+00	3.5974E+02	1.2394E+02

4Qx = 314.

COSINE	SINE	MODULUS	RANDOM
-1.1823E+00	-7.2436E-01	1.3865E+00	3.1176E+01
DE(S)	DE(R)	DQ(S)	DQ(R)
1.3358E-05	3.0034E-04	3.3394E-06	7.5084E-05
		DQ20(S)	DQ20(R)
		4.8312E-06	1.0863E-04

2Qx + 2Qz = 314.

COSINE	SINE	MODULUS	RANDOM
-3.0054E+00	-5.4531E+00	6.2264E+00	1.2394E+02
DE(S)	DE(R)	DQ(S)	DQ(R)
2.9992E-05	5.9698E-04	1.0604E-05	2.1106E-04
		DQ20(S)	DQ20(R)
		1.5341E-05	3.0535E-04

4Qz = 314.

COSINE	SINE	MODULUS	RANDOM
-5.0083E-01	-2.1191E+00	2.1775E+00	4.9352E+01
DE(S)	DE(R)	DQ(S)	DQ(R)
2.0977E-05	4.7544E-04	5.2443E-06	1.1886E-04
		DQ20(S)	DQ20(R)
		7.5872E-06	1.7196E-04

2Qx -2Qz = 1.

COSINE	SINE	MODULUS	RANDOM
1.5463E-02	9.2375E-03	1.8012E-02	1.2394E+02

TABLE II-A [HARMON]

```
--------------------------------------------------------------------
| HARMON - CDR LATTICE FOR SSC WITH BETA*=6.
| [INITIAL EMITTANCE:  Ex0= Ez0 = 2.4940E-07 ]
|-------------------------------------------------------------------
|  TOTAL LENGTH = 82944.        NSUP = 1
|  QX      =  7.82650E+01   QZ        = 7.82800E+01
|  BETAX   =  1.11371E+02   AZ      = 3.31656E+02
|  ETAX    =  2.36230E+00
| NORMALIZED STRENGTHS:     SF = 5.12380E-03
|                           SD =-8.25720E-03
| FOURTH ORDER EFFECTS OF SEXTUPOLES
| Q SHIFT EFFECTS
|-------------------------
|                    G22000        DQXDEX            DQX
| -3.58180E+02  2.14884E-12 -7.16360E+02 -1.78660E-04
|                    G00220        DQYDEY            DQY
| -2.38812E+02  1.29191E-12 -4.77625E+02 -1.19120E-04
|                    G11110        DQXDEY         DQYDEX
| -2.44556E+03  1.02414E-11 -2.44556E+03 -2.44556E+03
|                                  DQX            DQY
|                           -6.09923E-04 -6.09923E-04
|RESONANCE EFFECTS
|-------------------------
|[G's are the 2nd order cpefs.]
|                  COS          SIN          DE
| G4000,313     2.5856E-04 -1.0971E-04  1.1208E-09
|                              DQ       DQ(20)
|                          6.7646E-10  9.7866E-10
|                  COS          SIN          DE
| G0040,313     1.7267E-05 -1.5545E-04  6.2414E-10
|                              DQ       DQ(20)
|                          3.7670E-10  5.4499E-10
|                  COS          SIN          DE
| G2020,313    -2.9871E-04 -5.5839E-04  1.2635E-09
|                              DQ          DQ(20)
|                          1.0785E-09  1.5602E-09
|                  COS          SIN        MODULUS
| G2002,  0     6.0136E+02  1.1105E+02  6.1153E+02
|                  COS          SIN          DE
| G4000,314     3.6264E-01 -4.1347E-01  2.1946E-06
|                              DQ       DQ(20)
|                          1.3246E-06  1.9163E-06
|                  COS          SIN          DE
| G0040,314     4.8055E-01 -2.9350E-01  2.2469E-06
|                              DQ       DQ(20)
|                          1.3562E-06  1.9620E-06
|                  COS          SIN          DE
| G2020,314     7.3629E-01  1.2623E-01  1.4905E-06
|                              DQ       DQ(20)
|                          1.2722E-06  1.8406E-06
|                  COS          SIN        MODULUS
| G2002,  1     2.7284E-02  1.5417E-02  3.1338E-02
--------------------------------------------------------------------
```

TABLE II-B [HARMON]

HARMON - CDR LATTICE FOR SSC WITH BETA*=6.
[Initial Emittance: Ex0 = Ez0 = 2.4940E-07]

FOURIER ANALYSIS. ORDER OF RESONANCE = 1

Qx = 78.

COSINE	SINE	MODULUS	RANDOM
-6.3516E-07	-1.4859E-06	1.6159E-06	7.3111E-01
DE(S)	DE(R)	DQ(S)	DQ(R)
3.2358E-03	1.4640E+03	3.2358E-03	1.4640E+03
		DQ20(S)	DQ20(R)
		3.2358E-03	1.4640E+03

Qx = 79.

COSINE	SINE	MODULUS	RANDOM
-9.8864E-04	-1.9764E-02	1.9788E-02	7.3111E-01
DE(S)	DE(R)	DQ(S)	DQ(R)
3.9624E+01	1.4640E+03	3.9624E+01	1.4640E+03
		DQ20(S)	DQ20(R)
		3.9624E+01	1.4640E+03

FOURIER ANALYSIS. ORDER OF RESONANCE = 2

2Qx = 156.

COSINE	SINE	MODULUS	RANDOM
8.5630E-02	4.0122E-02	9.4563E-02	2.7255E+00
DE(S)	DE(R)	DQ(S)	DQ(R)
3.7825E-01	1.0902E+01	1.8913E-01	5.4511E+00
		DQ20(S)	DQ20(R)
		1.8913E-01	5.4511E+00

2Qz = 156.

COSINE	SINE	MODULUS	RANDOM
-2.1020E-02	1.6284E-01	1.6419E-01	3.8994E+00
DE(S)	DE(R)	DQ(S)	DQ(R)
6.5677E-01	1.5598E+01	3288E-01.7988E+00	
		DQ20(S)	DQ20(R)
		3.2838E-01	7.7988E+00

2Qx = 157.

COSINE	SINE	MODULUS	RANDOM
-1.0742E-05	-5.6483E-06	1.2136E-05	2.7255E+00
DE(S)	DE(R)	DQ(S)	DQ(R)
4.8545E-05	1.0902E+01	2.4272E-05	5.4511E+00
		DQ20(S)	DQ20(R)
		2.4272E-05	5.4511E+00

2Qz = 157.

COSINE	SINE	MODULUS	RANDOM
1.2857E-05	-9.3333E-08	1.2858E-05	3.8994E+00
DE(S)	DE(R)	DQ(S)	DQ(R)
5.1431E-05	1.5598E+01	2.5716E-05	7.7988E+00
		DQ20(S)	DQ20(R)
		2.5716E-05	7.7988E+00

TABLE II-C [HARMON]

HARMON - CDR LATTICE FOR SSC WITH BETA*=6.
[INITIAL EMITTANCE: Ex0= Ez0 = 2.4940E-07]

FOURIER ANALYSIS. ORDER OF RESONANCE = 3

3Qx = 234.

COSINE	SINE	MODULUS	RANDOM
1.6132E-04	1.3147E-05	1.6185E-04	7.4714E+00
DE(S)	DE(R)	DQ(S)	DQ(R)
1.4549E-06	6.7162E-02	4.8497E-07	2.2387E-02
		DQ20(S)	DQ20(R)
		1.0023E-06	4.6267E-02

Qx + 2Qz = 234.

COSINE	SINE	MODULUS	RANDOM
2.2752E-04	3.4173E-04	4.1055E-04	2.1756E+01
DE(S)	DE(R)	DQ(S)	DQ(R)
2.0503E-06	1.0865E-01	9.1691E-07	4.8588E-02
		DQ20(S)	DQ20(R)
		1.8949E-06	1.0042E-01

-Qx + 2Qz = 78.

COSINE	SINE	MODULUS	RANDOM
3.0156E-05	-3.7527E-05	4.8142E-05	2.1756E+01

3Qx = 235.

COSINE	SINE	MODULUS	RANDOM
-2.5380E-02	-1.1974E-02	2.8062E-02	7.4714E+00
DE(S)	DE(R)	DQ(S)	DQ(R)
2.5226E-04	6.7162E-02	8.4086E-05	2.2387E-02
		DQ20(S)	DQ20(R)
		1.7378E-04	4.6267E-02

Qx + 2Qz= 235.

COSINE	SINE	MODULUS	RANDOM
-1.6364E-02	-6.7091E-02	6.9058E-02	2.1756E+01
DE(S)	DE(R)	DQ(S)	DQ(R)
3.4487E-04	1.0865E-01	1.5423E-04	4.8588E-02
		DQ20(S)	DQ20(R)
		3.1875E-04	1.0042E-01

-Qx + 2Qz = 79.

COSINE	SINE	MODULUS	RANDOM
9.5364E-01	-6.1833E-01	1.1366E+00	2.1756E+01

TABLE II-D [HARMON]

HARMON - CDR LATTICE FOR SSC WITH BETA*=6.
[INITIAL EMITTANCE: Ex0 = Ez0 = 2.4940E-07]

FOURIER ANALYSIS. ORDER OF RESONANCE = 4

4Qx = 313.			
COSINE	SINE	MODULUS	RANDOM
-2.8860E-04	-4.8607E-05	2.9266E-04	1.6180E+01
DE(S)	DE(R)	DQ(S)	DQ(R)
2.8194E-09	1.5587E-04	7.0485E-10	3.8967E-05
		DQ20(S)	DQ20(R)
		1.0197E-09	5.6375E-05
2Qx + 2Qz = 313.			
COSINE	SINE	MODULUS	RANDOM
-8.6381E-04	-7.1929E-04	1.1241E-03	6.4319E+01
DE(S)	DE(R)	DQ(S)	DQ(R)
5.4145E-09	3.0981E-04	1.9143E-09	1.0954E-04
		DQ20(S)	DQ20(R)
		2.7695E-09	1.5847E-04
4Qz = 313.			
COSINE	SINE	MODULUS	RANDOM
-1.8434E-04	-2.7677E-04	3.3254E-04	2.5612E+01
DE(S)	DE(R)	DQ(S)	DQ(R)
3.2036E-09	2.4674E-04	8.0089E-10	6.1684E-05
		DQ20(S)	DQ20R)
		1.1587E-09	8.9240E-05
2QX -2QZ = 0.			
COSINE	SINE	MODULUS	RANDOM
-1.8668E+02	0.0000E+00	1.8668E+02	6.4319E+01
4Qx = 314.			
COSINE	SINE	MODULUS	RANDOM
-6.1293E-01	-3.7561E-01	7.1887E-01	1.6180E+01
DE(S)	DE(R)	DQ(S)	DQ(R)
6.9253E-06	1.5587E-04	1.7313E-06	3.8967E-05
		DQ20(S)	DQ20(R)
		2.5048E-06	5.6375E-05
2Qx + 2Qz = 314.			
COSINE	SINE	MODULUS	RANDOM
-1.5619E+00	-2.8292E+00	3.2317E+00	6.4319E+01
DE(S)	DE(R)	DQ(S)	DQ(R)
1.5567E-05	3.0981E-04	5.5036E-06	1.0954E-04
		DQ20(S)	DQ20(R)
		7.9623E-06	1.5847E-04
4Qz = 314.			
COSINE	SINE	MODULUS	RANDOM
-2.6192E-01	-1.1006E+00	1.1314E+00	2.5612E+01
DE(S)	DE(R)	DQ(S)	DQ(R)
1.0899E-05	2.4674E-04	2.7248E-06	6.1684E-05
		DQ20(S)	DQ20(R)
		3.9421E-06	8.9240E-05
2Qx-2Qz=1.			
COSINE	SINE	MODULUS	RANDOM
-7.7929E-03	-4.6573E-03	9.0785E-03	6.4319E+01