PS/AR/Note 88-19
SVDM/afm

9 December 1988

CHANGING Q AND α_p IN THE AA BY MEANS OF SHIMS ANS SHUNTS

S. van der Meer

Abstract

Simple rules are given for changing Q_H vs the revolution frequency f_0, and for changing the horizontal orbit position in the long straight sections vs f_0 by shimming the F quadrupoles.

Independent change of Q_H and α_p in the long straight sections by means of shunts on the F quadrupoles is also discussed.

Geneva, Switzerland
December 1988

1. INTRODUCTION

This note contains some recipes that have been used in the past for improving

a) the shape of the Q_H vs f_0 curve,

b) the horizontal orbit position Δx in the long straight sections vs f_0 (both by shimming; f_0 is the revolution frequency) and

c) for changing the overall value of Q_H and α_p independently by using shunts across certain quadrupoles*.

Changing only Q_V vs f_0 is more difficult than changing Q_H, because the dispersion in the D quadrupoles (which mostly influence Q_V) is small. In practice, it has (fortunately) never been necessary.

The shimming rules were derived from very early measurements by R. Brown on a wide quadrupole. These measurements of relatively small effects were difficult and probably not very precise. In any case, the shims (washers on stainless steel pins) tend to saturate; especially, if many washers are put on one pin, the saturation may be strong and the effect of different washers will probably not add up linearly. Moreover, orbit changes caused by the shims will have a second-order effect on Q. Also, the exact orbit position versus f_0 in the different quadrupoles may change with time, because of bumps made for various purposes. As a result of all this, these shimming rules may easily be wrong by a factor 2. All they pretend to be is a starting point for successive approximations.

2. NOMENCLATURE OF QUADRUPOLES AND SHIMS

F quadrupoles exist in 3 groups of 4 quadrupoles each, traditionnally called F_1, F_2 and F_3 (Fig. 1 and Table 1).

F_3 quadrupoles are not used for shimming because they are at zero dispersion.

D quadrupoles could also be shimmed but are not considered here.

---

* In this note, "α_p" is short for "α_p in the long straight sections" and Δx also refers to these straight sections.

Table 1

F_1	F_2	F_3
QFW04	QFW06	QFN02
QFW10	QFW08	QFN12
QFW16	QFW18	QFN14
QFW22	QFW20	QFN24

Shims are standard steel washers on pins numbered as shown in Fig. 2. The pins on the inside of the ring (stack region) have the same numbers as those on the outside (injection), but these two groups should, of course, be treated separately.

3. *CHANGING Q_H AND ΔX INDEPENDENTLY*

The properties of the AA lattice are such that changing Q_V only (leaving Q_H constant) by changing the currents in the F and D quadrupoles will not influence α_p in the long straight sections. However, if Q_H is changed, α_p will also change.

The same happens if Q_H is adjusted by shims on the F_2 quadrupoles. In fact, these quadrupoles are especially interesting for adjusting Δx (or its derivative, proportional to α_p). Their influence on Q_H may be compensated by shimming the F_1's, which do not influence Δx very much. The reason is that between two F_1's in the same bend (e.g. QFW04 and QFW10) the horizontal betatron phase difference is not too far from 180° (in fact, it is about 205°). If it would be exactly 180°, changing QFW04 and QFW10 by the same amount would just cause an orbit bump between them, and nothing elsewhere. Therefore:

> ***Rule 1**: Use F_1's for Q_H, F_2's for Δx*

4. *TABLES OF ΔQ_H FOR DIFFERENT SHIMS*

In Tables 2 and 3 (for F_1 and F_2), Q_H changes vs f_0 are given per added washer per pin. It is assumed that a washer is added simultaneously on the upper and lower poles, upstream and downstream of each F_1 or F_2

quadrupole, i.e. 4 washers/quadrupole, 16 washers in total for each figure quoted in the Table.

As stated before, these figures are not very precise.

TABLE 2

ΔQ_H in 10^{-5} per washer per pin (top, bottom, downstream and upstream), all F_1's

	f_0 KHz	Pin no. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
OUTSIDE Injection	1844	0	0	0	21	47	111	154	107	11	-66	-73	-60	-36	-26	-17
	1845	0	0	0	11	20	46	81	127	94	22	-35	-44	-35	-24	-15
	1846	0	0	0	5	11	22	44	80	107	80	22	-16	-24	-20	-13
	1847	0	0	0	3	7	11	27	47	72	83	54	18	-11	-10	- 9
	1848	0	0	0	0	3	5	15	23	36	57	59	34	11	2	2
	1849	0	0	0	0	0	0	6	10	14	34	39	41	27	14	7
	1850	0	0	0	0	0	0	0	5	8	16	18	27	30	18	14
	1851	0	0	0	0	0	0	0	3	5	11	9	18	25	25	14
	1852	0	0	0	0	0	0	0	0	3	7	5	11	18	18	16
	1853	0	0	0	0	0	0	0	0	0	3	3	9	12	14	16
	1854	0	0	0	0	0	0	0	0	0	2	1	7	8	9	13
	1855	0	0	0	0	0	0	0	0	0	0	0	4	4	4	11
	1856	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
INSIDE Stack	1844	0	0	0	0	0	0	0	0	0	0	0	0	0	1	7
	1845	0	0	0	0	0	0	0	0	0	0	0	2	2	4	11
	1846	0	0	0	0	0	0	0	0	0	0	0	6	5	7	13
	1847	0	0	0	0	0	0	0	0	0	1	3	9	9	11	16
	1848	0	0	0	0	0	0	0	0	0	3	5	12	16	17	16
	1849	0	0	0	0	0	0	0	0	2	7	8	16	21	23	16
	1850	0	0	0	0	0	0	0	0	5	9	11	23	27	25	14
	1851	0	0	0	0	0	0	0	2	9	23	23	32	32	21	14
	1852	0	0	0	0	0	0	5	9	23	41	46	41	23	9	5
	1853	0	0	0	0	5	7	14	27	26	72	60	32	7	- 2	0
	1854	0	0	0	2	11	16	36	67	42	89	40	4	-16	-16	-13
	1855	0	0	0	13	26	22	87	122	60	22	-35	-39	-35	-24	-14
	1856	0	0	4	34	63	85	156	72	0	-89	-76	-59	-34	-25	-19

TABLE 3

ΔQ_H in 10^{-5} per washer per pin (top, bottom, downstream and upstream), all F_2's

		f_0 KHz	Pin no. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
OUTSIDE	Injection	1844	6	14	63	176	259	94	-132	-176	-138	- 88	-77	-39	-30	-27	-22
		1845	6	7	13	57	119	221	178	0	- 65	-135	-97	-70	-46	-32	-24
		1846	3	2	5	20	40	80	141	170	74	- 37	-69	-69	-45	-32	-21
		1847	0	0	0	7	16	26	57	99	131	94	21	-21	-31	-26	-16
		1848	0	0	0	3	5	11	28	41	70	88	67	26	- 5	-10	- 5
		1849	0	0	0	0	3	4	13	16	31	51	54	46	23	10	5
		1850	0	0	0	0	0	0	3	8	10	20	20	36	33	23	15
		1851	0	0	0	0	0	0	0	5	7	13	13	20	30	28	18
		1852	0	0	0	0	0	0	0	3	5	8	7	13	20	20	18
		1853	0	0	0	0	0	0	0	0	3	5	5	10	12	13	18
		1854	0	0	0	0	0	0	0	0	0	3	3	6	5	8	15
		1855	0	0	0	0	0	0	0	0	0	0	0	3	3	3	7
		1856	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
INSIDE	Stack	1844	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		1845	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
		1846	0	0	0	0	0	0	0	0	0	0	0	4	3	5	13
		1847	0	0	0	0	0	0	0	0	0	1	1	8	8	10	16
		1848	0	0	0	0	0	0	0	0	2	3	3	11	13	16	18
		1849	0	0	0	0	0	0	0	0	5	5	5	16	20	23	18
		1850	0	0	0	0	0	0	0	3	7	10	11	23	31	30	16
		1851	0	0	0	0	0	0	4	5	15	35	28	41	33	20	14
		1852	0	0	0	0	4	4	11	10	41	61	63	46	15	5	5
		1853	0	0	0	5	8	15	20	20	96	97	51	15	-15	-18	-10
		1854	2	2	3	15	23	51	52	111	118	46	-26	-41	-37	-26	-18
		1855	4	4	10	41	83	166	92	148	- 52	-109	-93	-67	-41	-31	-23
		1856	5	8	37	127	180	185	0	- 55	-164	- 95	-63	-53	-34	-26	-24

<u>Rule 2</u>: Do not try to make complicated changes in the Q distribution, using many pins at the same time.

Changing these shims will also change Q_V in the same direction as Q_H but multiplied by β_V/β_H. This factor is 0.67 for the F_1's and 0.27 for the F_2's.

5. *TABLES OF Δx AT THE BLG PICK-UPS*

In the same way, Table 4 gives the recipe for Δx changes at the BLG pick-ups. Only the F_2 table is given because the F_1's hardly influence Δx at all. Δx is defined to be positive towards the outside of the ring.

6. *SOME PRACTICAL HINTS FOR SHIMMING*

The pins are threaded over their entire length. They are screwed into the end plates of the quadrupole. Pins and nuts are non-magnetic.

Sometimes, when the nut that keeps the washers in place is unscrewed, the pins will also turn relative to the end plate. In fact, some pins that are full of washers are not screwed in completely to make space for more washers on the pin. If the pin is loose, take care that it is screwed far enough into the end plate before fixing the nut. The end plate is made of soft steel and its thread may easily be damaged if the pin is not far enough into its hole. Do not tighten the nut more than necessary.

Take care that washers do not drop onto the floor; it may be surprisingly difficult to find them back. Do not temporarily put them onto coil covers, etc. They tend to be forgotten and will be sucked into the quadrupole when it is switched on.

Reducing the number of washers on a given pin is of course only possible if there are enough to start with. It may be useful to check this first. Note that for historical reasons (compensation of effects from ferrites, removal of orbit asymmetries in the straight sections) the number of washers per pin may not be the same for all quadrupoles in a group.

7. *SHUNTS ON F QUADRUPOLES*

With the currents in F and D quadrupoles, the overall values of Q_H and α_p cannot be adjusted separately. This may be done by shunting certain types of quadrupoles.

TABLE 4

Δx in mm per washer per pin (top, bottom, downstream and upstream), all F_2's

		f_0 KHz	Pin no. 3	4	5	6	7	8	9	10	11	12	13	14
OUTSIDE		1844	0.1	0.2	0.4	0.5	0.5	0.3	0.2	0.1	0	0	0	0
		1845	0	0.1	0.1	0.3	0.4	0.5	0.4	0.3	0.1	0.1	0.1	0.1
		1846	0	0	0	0.1	0.2	0.3	0.4	0.4	0.2	0.2	0.1	0.1
	Injection	1847	0	0	0	0	0.1	0.1	0.2	0.3	0.3	0.2	0.2	0.1
		1848	0	0	0	0	0	0	0.1	0.2	0.2	0.2	0.2	0.1
		1849	0	0	0	0	0	0	0	0.1	0.1	0.2	0.1	0.1
		1850	0	0	0	0	0	0	0	0	0	0.1	0.1	0.1
		1851	0	0	0	0	0	0	0	0	0	0.1	0.1	0.1
		1852	0	0	0	0	0	0	0	0	0	0	0	0
		1853	0	0	0	0	0	0	0	0	0	0	0	0
		1854	0	0	0	0	0	0	0	0	0	0	0	0
		1855	0	0	0	0	0	0	0	0	0	0	0	0
		1856	0	0	0	0	0	0	0	0	0	0	0	0
INSIDE		1844	0	0	0	0	0	0	0	0	0	0	0	0
		1845	0	0	0	0	0	0	0	0	0	0	0	0
		1846	0	0	0	0	0	0	0	0	0	0	0	0
		1847	0	0	0	0	0	0	0	0	0	0	0	0
		1848	0	0	0	0	0	0	0	0	0	0	0	0
	Stack	1849	0	0	0	0	0	0	0	0	0	-0.1	-0.1	-0.1
		1850	0	0	0	0	0	0	0	0	0	-0.1	-0.1	-0.1
		1851	0	0	0	0	0	0	0	-0.1	-0.1	-0.2	-0.1	-0.1
		1852	0	0	0	0	0	0	-0.1	-0.2	-0.2	-0.2	-0.2	-0.1
		1853	0	0	0	0	-0.1	-0.1	-0.2	-0.3	-0.3	-0.2	-0.2	-0.1
		1854	0	0	0	-0.1	-0.2	-0.3	-0.4	-0.4	-0.2	-0.2	-0.1	-0.1
		1855	0	-0.1	-0.1	-0.3	-0.4	-0.5	-0.4	-0.3	-0.1	-0.1	-0.1	-0.1
		1856	-0.1	-0.2	-0.4	-0.5	-0.5	-0.3	-0.2	-0.1	0	- 0	0	0

The simplest case is a change of Q_H without changing α_p. This can be done by shunting the F_3 quadrupoles, since they are at zero dispersion. At the time of writing, each of the F_3 quadrupoles is shunted by a resistor of 0.84 Ω whose value may be adjusted between 0.57 Ω and 1.14 Ω. The voltage across each of these quadrupoles is 19 V and for the influence on Q_H we have

$$\Delta Q_H \approx 0.66 \times 10^{-3} \Delta I_3$$

where ΔI_3 is the change in current (in A) in the F_3 quadrupoles (i.e. opposite in sign to the shunted current).

If α_p has to be changed, or a combination of α_p and Q_H, the simplest scheme is still to use these same quadrupoles in combination with an overall change in QF and QD currents, remembering that the slope of Δx (in mm) varies as follows with "normal" Q_H changes:

$$(\Delta x)_{1844.5\text{kHz}} - (\Delta x)_{1855.5\text{kHz}} \approx 500 \Delta Q_H$$

If a negative shunt current would be required (i.e. a positive ΔI_3), the same effect could be obtained by increasing the QF current and shunting the F_1 and F_2 quadrupoles. Some of these quadrupoles have been shunted already. These shunts are all different; they were used to symmetrise α_p around the ring, and especially to make it equal at the four BLG pick-ups.

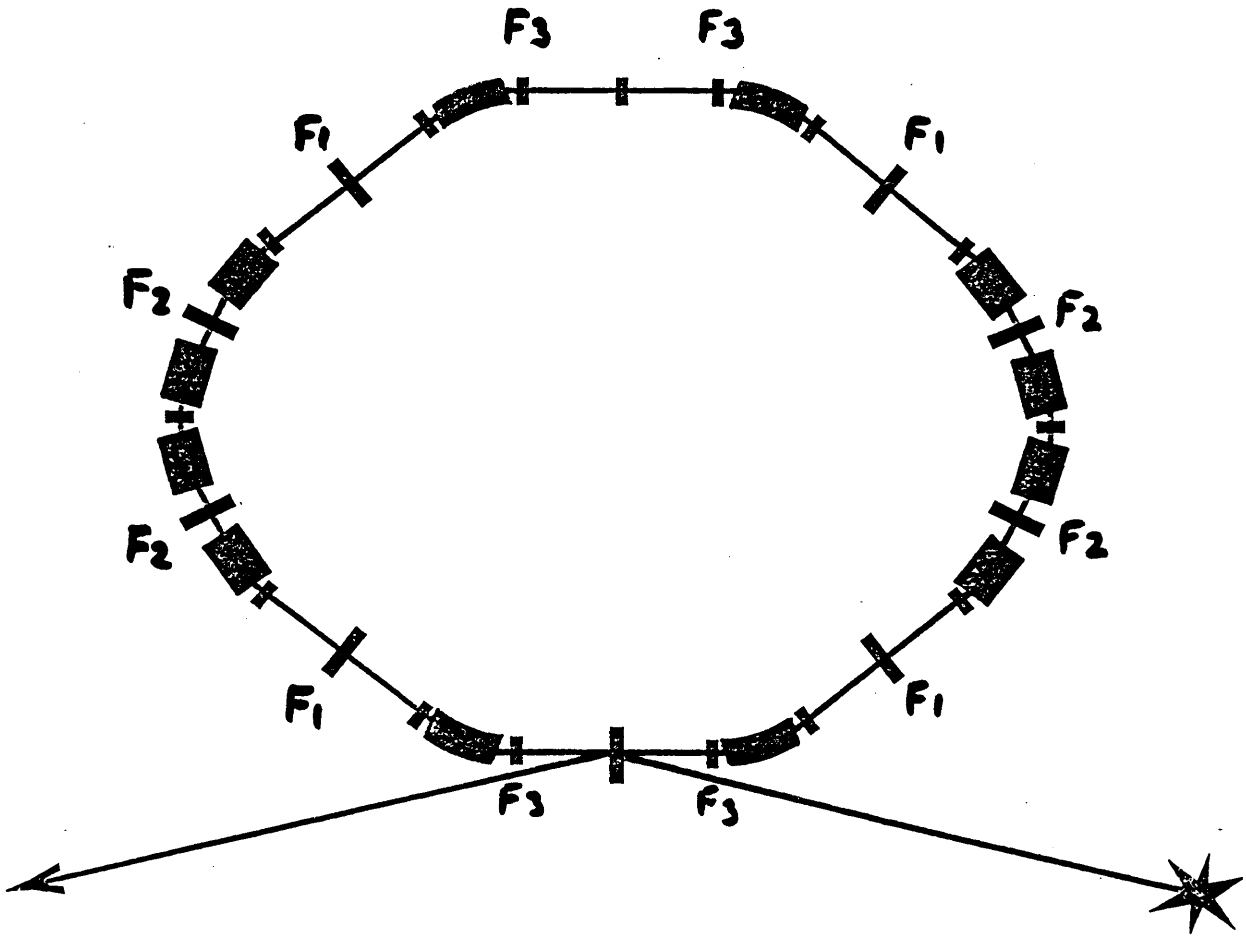

FIGURE 1

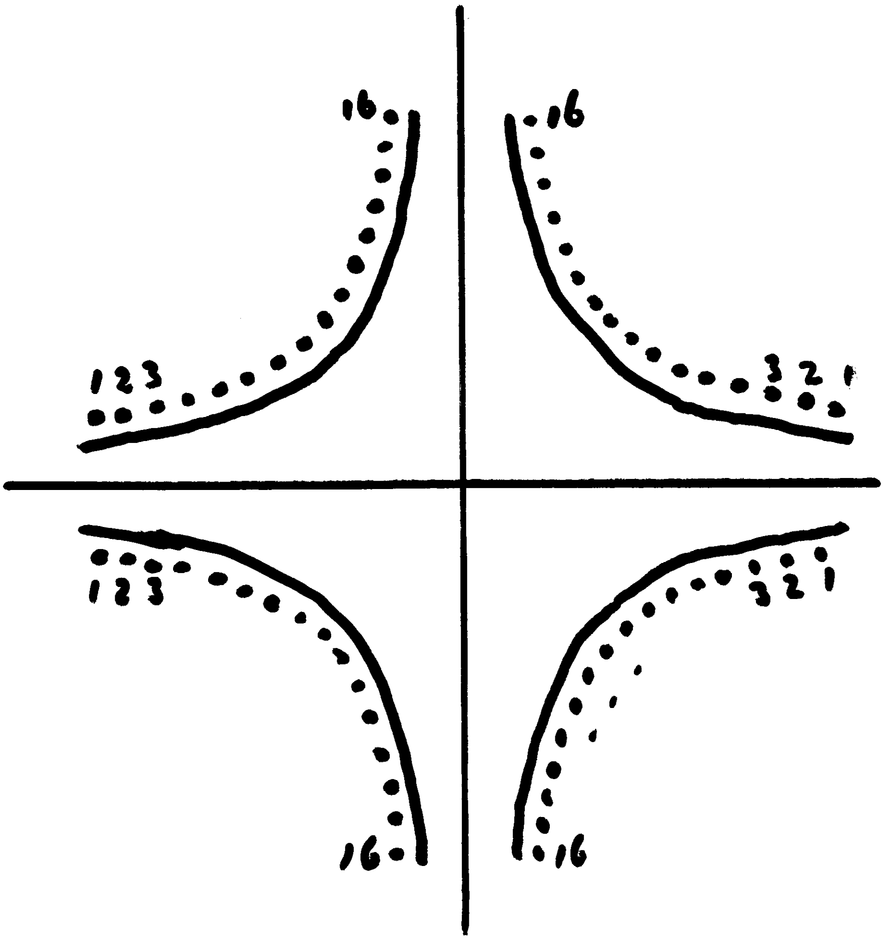

FIGURE 2