Guidelines for injection dipole multipole

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This note proposes guidelines for the field multipoles introduced by the four dipole magnets in the injection chicane.

To establish guidelines for the injection chicane multipoles, the stopband widths of the resonances excited by the injection chicane multipoles are compared with the stopband widths due to the random error multpoles in the dipoles and quadrupoles in the SNS ring.

The field multipoles in the four magnets that make up the chicane are defined by

$$B_y = B_j[1 + b_{1,j}(x/R) + b_{2,j}(x/R)^2 + b_{3,j}(x/R)^3 + ...] \quad j = 1, 2, 3, 4 \tag{1}$$

R=8 cms. B_j is the field in the jth magnet. $b_{k,j}$ is the kth multipole in the jth magnet. These multipoles will drive the following resonances which are close to the assumed working point, $\nu_x = 6.23, \quad \nu_y = 6.20$.

$$b_{1,j} \rightarrow 2\nu_x = 12, 2\nu_y = 12$$

$$b_{2,j} \rightarrow 3\nu_x = 18, \nu_x + 2\nu_y = 18, 3\nu_y = 18$$

$$b_{3,j} \rightarrow 4\nu_x = 24, 2\nu_x + 2\nu_y = 24, 4\nu_y = 24$$

The b_k multipole in the four dipoles in the chicane will drive several resonances whose stopband widths will be indicated by $\Delta\nu_{n,m}, \quad n + m = k + 1$. In comparing the stopband widths of the resonances excited by the injection chicane multipoles with the stopband widths due to the random error multpoles in the dipoles and quadrupoles in the SNS ring, the stopband $\Delta\nu_{k+1,0}$ was used. This stopband is given by

$$\Delta\nu_{k+1,0} = \frac{1}{2^{k-1}}\frac{1}{4\pi}\int ds \;\; \frac{B}{B\rho}\frac{b_k}{R^k}\beta_x(\beta_x\epsilon_x)^{(k-1)/2}exp[(k+1)\psi_x] \tag{2}$$

The stopband due to the 4 injection dipoles in the chicane can be written as

$$\Delta\nu_{k+1,0} = \frac{1}{2^{k-1}}\frac{1}{4\pi}\sum_{j=1}^{4}\ \frac{B_j}{B\rho}\frac{b_{k,j}}{R^k}\beta_{x,j}(\beta_{x,j}\epsilon_x)^{(k-1)/2}exp[(k+1)\psi_{x,j}]L_j \qquad (3)$$

The guidelines probably should not be interperted rigidly. It is not clear that having the injection chicane stopbands larger than the ring dipole-quad stopbands is harmful. Also to make the guidelines useful, it may be desireable to make them as simple as possible. With this in mind, the following approximations will be made. β_x varies from 10.43m to 11.707m and will be replaced by its average value, $\beta_{x,av} = 11.07m$.In the same way, L_j, and B_j will be replaced by their average values, $L_{av} = .904m$ and $B_{av} = 2.785kg$. ϵ_x is assumed to be 120 mm.rad. Eq.3 then becomes

$$\Delta\nu_{k+1,0} = \frac{1}{2^{k-1}}\frac{1}{4\pi}\frac{B_{av}}{B\rho}\beta_{x,av}(\beta_{x,av}\epsilon_x)^{(k-1)/2}L_{av}\sum_{j=1}^{4}\ \frac{b_{k,j}}{R^k}exp[(k+1)\psi_{x,j}] \qquad (4)$$

The phase term $exp[(k+1)\psi_{x,j}]$ can vary quite a bit over the four injection dipoles. $\psi_{x,j}$ varies from 0 to .336. For the sake of simplicity in the final result, the inequalty

$$\sum_{j=1}^{4}\ \frac{b_{k,j}}{R^k}exp[(k+1)\psi_{x,j}] \le \sum_{j=1}^{4}\ \frac{|b_{k,j}|}{R^k}$$

will be used to obtain the result

$$\Delta\nu_{k+1,0} = \frac{1}{2^{k-1}}\frac{1}{4\pi R^k}\frac{B_{av}}{B\rho}\beta_{x,av}(\beta_{x,av}\epsilon_x)^{(k-1)/2}L_{av}\sum_{j=1}^{4}\ |b_{k,j}| \qquad (5)$$

One can see from Eq.5 that the guidelines will suggest limits on the size of $\sum_{j=1}^{4}\ |b_{k,j}|$. I do not think that one should try to rely on possible cancellations that might occur in the sum over the four magnets, according to Eq.4.

In order to compare stopbands due to the $b_{k,j}$ in the injection chicane with the stopbands due to the random field errors in the quads and dipoles of the ring , one needs an expression for the rms stopband , $\Delta\nu_{k+1,0,rms}$, due to the random errors in the ring magnets as given by $b_{k,rms}$ for each magnet. Using Eq. 2, one finds

$$\Delta\nu_{k+1,0,n} = \frac{1}{2^{k-1}}\frac{1}{4\pi}\frac{B_j}{B\rho}\frac{b_{k,n,rms}}{R^k}\beta_{x,n}(\beta_{x,n}\epsilon_x)^{(k-1)/2}exp[(k+1)\psi_{x,n}]L_n \qquad (6)$$

$$\Delta\nu_{k+1,0,rms} = [\sum_{n}^{ring} |\Delta\nu_{k+1,0,n}|^2]^{.5} \quad (7)$$

where $\Delta\nu_{k+1,0,n}$ is the contribution of the nth magnet in the ring which has random multipoles with the rms value of $b_{k,n,rms}$.

The guidelines for $\sum_{j=1}^{4} \ |b_{k,j}|$ will be found by requiring that

$$\Delta\nu_{k+1,0} = \Delta\nu_{k+1,0,rms}$$

It may seem desireable to make $\Delta\nu_{k+1,0}$ much smaller than $\Delta\nu_{k+1,0,rms}$. However, this does not appear likely to be achievable [1]. The guidelines for $\sum_{j=1}^{4} \ |b_{k,j}|$ are given in Table 1 for k=1,2,3. Also given in Table 1, are the computed stopbands due to the quads in the ring, the stopbands due to the dipoles in the ring, the rms multipoles, $b_{k,rms}$ for the ring magnets that were used in computing the stopbands. The results are given for the SNS lattice with $\nu_x = 6.23, \nu_y = 6.20$.

	k=1	k-2	k=3	
guidelines for $\sum_{j=1}^{4} \ |b_{k,j}|$	7.05	14.9	3.7	x 10^{-4} at R=8 cms
$\Delta\nu_{k+1,0,rms}$ dipoles	.98	.52	.033	x 10^{-4}
$\Delta\nu_{k+1,0,rms}$ quads	3.31	1.58	.090	x 10^{-4}
$b_{k,rms}$ dipoles	.149	.485	.19	x 10^{-4} at R=8.5 cm
$b_{k,rms}$ quads	1.0	2.67	.83	x 10^{-4} at quad iron radius

Table 1: Guidelines for the multipoles b_1, b_2, b_3 in the four dipoles in the injection chicane. The table also lists the rms stopbands due to the ring dipoles and the ring quads, and the rms b_k in the dipoles and quads that were used to compute the stopbands. The $b_{k,rms}$ in the dipoles came from J. Wei,ASAC review, 2/2/02, and in the quads from J.Wei,TN 76, 5/00

Comments on the results

The guidelines found above were described as the guidelines for the multipoles in the 4 dipoles in the injection chicane. There are eight additional injection dipoles, with time dependent excitations, whose multipoles should also be included in $\sum_{j=1} \ |b_{k,j}|$. Some of the nearbye resonances are also driven by the systematic error multipoles in the ring magnets. The contributions due to these systematic error multipoles, which do not appear to be known for the ring quads, should also be included in computing the stopbands due to the ring magnets.

Acknowlegements

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References

1. N.Tsoupas, private communication