Subject EQUILIBRIUM ORBIT CORRECTIONS FOR THE MAIN RING

A scheme for MR orbit correction has been analyzed and will be described here. The procedure is very simple, and I believe it is the minimum system which will give satisfactory performance. The system consists of horizontal dipoles located at each of the odd-numbered stations, and vertical dipoles at each of the even-numbered stations. Station 0(35) has no dipoles. This corresponds to 102 horizontal dipoles, and 102 vertical dipoles. The system is completely symetric between horizontal and vertical, and in what follows the results are equally applicable in both planes.

The method of correcting the orbit requires position monitoring devices at the same location as the dipoles. This means 102 horizontal and 102 vertical position monitors. There is a simple algorithm for correcting the orbit. We will consider the case for a normal cell. In the special cells (within the insertion of the long straight) the situation is essentially the same, but the analysis is more complicated.

Consider an orbit bump x_j at position j, where j denotes the dipole number. It can be corrected by powering 3 dipoles at location j-1, j, and j + 1 according to the following rule:

$$\theta_{j-1} = \theta_{j+1} = \frac{-x_j}{\beta \sin \mu_0} \qquad \theta_j = -2 \cos \mu_0 \theta_{j+1}$$

β corresponds to the value at the dipole location (~ 93 meters, say), and μ_0 is the phase shift/cell (~ 70.9° typically).

In general, the best method of correcting the orbit is not to start sequentially around the machine, one point at a time, but rather to measure all 102 points and calculate the θ_j's which result. For instance, suppose we had a perfect orbit except for a dipole disturbance at one point. In general this would result in non-vanishing x_j at all positions. However, the end result would be that the only dipoles being powered would be those in the immediate vicinity of the disturbance.

In principal, powering a triplet of dipoles according to the above algorithm will not disturb the orbit elsewhere. In practice, because of uncertainties in β and μ_0, there will be small effects. Exact precision is not needed, however, since even rather large deviations will lead to a rapidly convergent result upon iteration. Another nice feature of the method is that the algorithm can easily be applied for the case where one or more position monitors are non-operable, or otherwise suspect. These locations can then have the orbit corrected a la Collins, i.e., by diddling the position at that location to see where losses occur, and then moving to the "center." In fact, there is no better procedure for the ultimate determination of the "best" orbit, which is not necessarily coincident with the one which is centered on all the detection devices. In principal, one could do a better job of orbit correction with more dipoles and more beam detection devices. Therefore it is interesting to see how well this procedure does. If we assume that the orbit deviations are due to randomly distributed dipole error such that the peak orbit distortion which resulted was ±50 mm (with 98% probability), then the residual error at a $\overline{\beta}$ will be ~1/2 mm. This is sufficiently close to the survey errors, position detection uncertainty, etc., that it is doubtful that more dipoles would really make an improvement. For an orbit deformation of this size, the maximum dipole strength at injection is 180 gauss-ft. This corresponds to RMS dipole error of ±60 gauss-ft per half cell (4 MR dipoles).