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Two-turns kicker scheme for high energy colliders

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A transverse beam damper system for providing beam stability agaist ground motion, resistive wall instability, and wake field multibunch instability in big colliders is outline. The system uses two beam position monitors single kicker, and a novel correction squeme which permits almost exact orbit compensation within two turns.

Keywords: Kicker; transverse damping system

Se esboza un sistema transversal amortiguador de un haz de partículas cargadas que provee estabilidad en el haz respecto a movimiento de la tierra, inestabilidad debida a la resistencia en las paredes, e inestabilidad debida al campo electromagnético residual en grandes aceleradores colicionales. El sistema hace uso de monitores posicionales del haz, un solo corrector (*kicker*) y un esquema novedoso de corrección que permite una compensación casi exacta en la órbita del haz en dos vueltas.

Descriptores: Kicker; sistema transversal amortiguador

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1. Introduction

The main goals of a transverse damping feedback system for a collider is to control the multibunch beam instabilities which appear due to wake fields [1] and resistive wall, and to control possibly the beam emittance grows due to ground motion [2] and other sources of noises, like power supply ripple in superconducting magnets. The control of these instabilities and the emittance grow are of fundamental importance for the new big colliders to reach their desired luminosity and operation time. Examples of these machines are the Large Hadron Collider (LHC), under construction in Europe, which will work at superfluid helium temperatures, and a possible bigger machines (200 TeV)under discussion [3] which may work at liquid Nitrogen temperatures (resistive wall instability is critical here). The minimal transverse damping system [4] (one or two beam position monitors (BPM) plus one kicker (K)) has several well known disadvantages [5]. A novel scheme of two BPM-two K was first propose by Chen and López [6] who show its enormous advantages. This scheme was optimized later on (reference [5]). Despite the advantages of this scheme to control multibunch instabilities and emittance grow, it has the complication of signal prossecing (two BPM) and hardware (two K) for each plane of motion (horizontal and vertical). In this paper a novel scheme using two BPM-one K and full correction in two turns is outline. This scheme has the same advantages of the scheme outlined on Ref. 5, but having simpler hardware [7].

It is important to point out that there is a very important reason why it is necessary to have very fast damping (one or two turns) of the beam instabilities. This one is that fast damping can reduce the emittance grow of the beam instabilities which may jeopardize the expected performance of the high intensity-high energy colliders [2].

2. Analytical analysis

A simplified diagram of two BPM's and one K feedback system is shown in Fig. 1 where a fully decoupled motion is assumed, and the motion is restricted to a single plane, say horizontal. B's and K represent the location of the two BPM's and kicker, ϕ and ψ represent the relative phases advances between these elements, (α's, β's) are the Courant-Snyder [8] parameters associated with the location of each element, μ is the tune of the machine, and X's and X''s represent the amplitude of the oscillation and the angle made by the bunch. Using the Courant-Snyder map, the coordinates of the bunch at the point B2 are given in terms of those at the point B1 as

$$\begin{pmatrix} X_2 \\ X_2' \end{pmatrix} = \begin{pmatrix} \sqrt{\frac{\beta_2}{\beta_1}}(\cos\phi + \alpha_1 \sin\phi) & \sqrt{\beta_2\beta_1}\sin\phi \\ -\frac{1+\alpha_1\alpha_2}{\sqrt{\beta_1\beta_2}}\sin\phi + \frac{\alpha_1-\alpha_2}{\sqrt{\beta_2\beta_1}}(\cos\phi & \sqrt{\frac{\beta_1}{\beta_2}}(\cos\phi - \alpha_2\sin\phi) \end{pmatrix} \begin{pmatrix} X_1 \\ X_1' \end{pmatrix} \tag{1}$$

Since the variables X_1 and X_2 are measured, using Eq. (1), X_1' and X_2' are given by

$$X_1' = -\frac{X_1}{\beta_1}\left(\frac{\cos\phi}{\sin\phi} + \alpha_1\right) + \frac{X_2}{\sqrt{\beta_1\beta_2}\sin\phi} \tag{2}$$

and

$$X_2' = -\frac{X_1}{\sqrt{\beta_1\beta_2}\sin\phi} + \frac{X_2}{\beta_2}\left(\frac{\cos\phi}{\sin\phi} - \alpha_2\right). \tag{3}$$

The coordinates at the kicker location are connected with those at the B2 as

$$\begin{pmatrix} X_3 \\ X_3' \end{pmatrix} = \begin{pmatrix} \sqrt{\frac{\beta_3}{\beta_2}}(\cos\psi + \alpha_2\sin\psi) & \sqrt{\beta_2\beta_3}\sin\psi \\ -\frac{1+\alpha_2\alpha_3}{\sqrt{\beta_2\beta_3}}\sin\psi + \frac{\alpha_2 - \alpha_3}{\sqrt{\beta_2\beta_3}}\cos\psi & \sqrt{\frac{\beta_2}{\beta_3}}(\cos\psi - \alpha_3\sin\psi) \end{pmatrix} \begin{pmatrix} X_2 \\ X_2' \end{pmatrix} + \begin{pmatrix} 0 \\ U_1 \end{pmatrix} \tag{4}$$

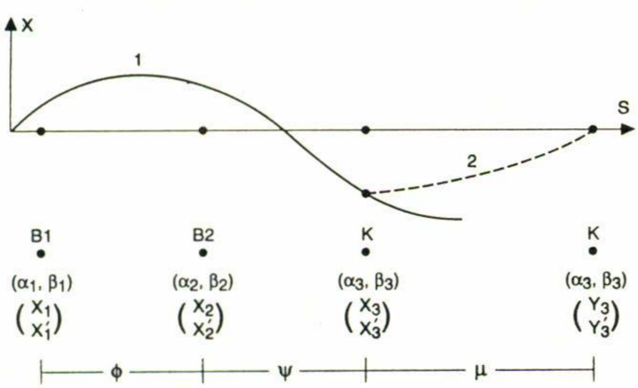

FIGURE 1. Model for two turns cancelation of coherent motion.

where the kick, U_1, is the correction made by the kicker which at this moment is unknown. Using Eqs. (2), (3) and (4), and making somere arrangements, it follows

$$X_3 = -X_1\sqrt{\frac{\beta_3}{\beta 1}}\frac{\sin\psi}{\sin\phi} + X_2\sqrt{\frac{\beta_3}{\beta 2}}\frac{\sin(\phi+\psi)}{\sin\phi} \tag{5a}$$

and

$$X_3' = -\frac{X_1}{\sqrt{\beta_3\beta_1}}\frac{\cos\psi - \alpha_3\sin\psi}{\sin\phi} + \frac{X_2}{\sqrt{\beta_3\beta_2}}\frac{\cos(\phi+\psi) - \alpha_3\sin(\phi+\psi)}{\sin\phi} + U_1. \tag{5b}$$

Then, a one-turn map is made in order to effectuate the second turn of the bunch. Its coordinates at the kicker location, (Y_3, Y_3'), are derived from the transformation

$$\begin{pmatrix} Y_3 \\ Y_3' \end{pmatrix} = \begin{pmatrix} \cos\mu + \alpha_3\sin\mu & \beta_3\sin\mu \\ -\frac{1+\alpha_3^2}{\beta_3}\sin\mu & \cos\mu - \alpha_3\sin\mu \end{pmatrix} \begin{pmatrix} X_3 \\ X_3' \end{pmatrix} + \begin{pmatrix} 0 \\ U_2 \end{pmatrix}, \tag{6}$$

where U_2 represents the new kick given to the bunch. Using Eqs. (5a) and (5b) in Eq. (6), the new coordinates of the bunch at the kicker location can be written as

$$Y_3 = -X_1\sqrt{\frac{\beta_3}{\beta_1}}\frac{\sin(\mu+\psi)}{\sin\phi} + X_2\sqrt{\frac{\beta_3}{\beta_2}}\frac{\sin(\mu+\phi+\psi)}{\sin\phi} + \beta_3 U_1\sin\mu \tag{7a}$$

and

$$Y_3' = -\frac{X_1}{\sqrt{\beta_3\beta_1}}\frac{\cos(\mu+\psi) - \alpha_3\sin(\mu+\psi)}{\sin\phi} + X_2\sqrt{\frac{\beta_3}{\beta_2}}\frac{\cos(\mu+\phi+\psi) - \alpha_3\sin(\mu+\phi+\psi)}{\sin\phi} + (\cos\mu - \alpha_3\sin\mu)U_1 + U_2. \tag{7b}$$

The complete cancelation of the coherent oscillation at this second turn is satisfied if the kicks U_1 and U_2 are chosen such that $Y_3 = 0$ and $Y_3' = 0$. Doing this in Eqs. (7a) and (7b), the following expressions for the kicks are brought about

$$U_1 = \frac{X_1}{\sqrt{\beta_3\beta_1}}\frac{\sin(\mu+\psi)}{\sin\phi} - \frac{X_2}{\sqrt{\beta_3\beta_2}}\frac{\sin(\mu+\phi+\psi)}{\sin\phi} \tag{8}$$

and

$$U_2 = (-\cos\mu + \alpha_3\sin\mu)U_1 + \frac{X_1}{\sqrt{\beta_3\beta_2}}\frac{\cos(\mu+\psi) - \alpha_3\sin(\mu+\psi)}{\sin\phi} - \frac{X_2}{\sqrt{\beta_3\beta_2}}\frac{\cos(\mu+\phi+\psi) - \alpha_3\sin(\mu+\phi+\psi)}{\sin\phi}. \tag{9}$$

These last two expressions represent the new scheme for damping the transverse beam instabilities. They depend on the first turn measurements, and the relative phases phi and psi are arbitraries. If the relative phase advance between B1 and B2 is $\phi = \pi/2$, and between B2 and K is $\psi = \pi/2$, the correction scheme is given by

$$U_1 = \frac{gX_1}{\sqrt{\beta_3\beta_1}}\frac{\cos\mu}{\sin\mu} + \frac{gX_2}{\sqrt{\beta_3\beta_2}} \tag{10}$$

and

$$U_2 = (-\cos\mu + \alpha_3\sin\mu)U_1 - \frac{gX_1(\sin\mu + \alpha_3\cos\mu)}{\sqrt{\beta_3\beta_2}} + \frac{gX_2(\cos\mu - \alpha_3\sin\mu)}{\sqrt{\beta_3\beta_2}}, \tag{11}$$

where the parameter g has been introduced to take into account the gain of the feedback system.

3. Comments and conclusions

Numerical simulation were made in the past with the scheme presented in this paper (see Ref. 7) confirming the excelent characteristics for damping the dipole mode multibunch instability arised from resistive wall impedance in big superconducting collider rings. The novel feature is the scheme which permits exact orbit compensation within two turns, using two beam position monitors and a single kicker, This damping system could be used for all stages of collider ring operation like injection, acceleration and collision if the dynamic range of the apparatus is made wide enough, from micrometers to millimiters. The power amplifier to make the correction within two turns may be a problem for comercially available kickers,but this power may be required if emittance grow must be controlled.

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1. A. Chao, *Physics of Collective Beam Instabilities in High Energy Accelerators*, (John Wiley and Sons, 1993).
2. V. Lebedev *et al.*, "Emittance Growth Due to Noise, ...", *SSCL*-Preprint-188, (1993).
3. V.D. Shilsev, "Pipetron Beam Dynamics with Noise", *FNAL, TM-1987*, October 1996.
4. J. Bengtsson *et al.*, *CBP Tech Note-026*, PEP-II AP Note 28-93.
5. E. Tsygonov *et al.*, *IEEE Trans. Nucl. Scie.* **41** (1994) 287.
6. S. Chen and G. López,"Simulation Studies of the Transverse Dipole Mode Multibunch Instability for the SSC Collider", *SSCL-614*, January 1993.
7. G. López,"New 2BPM-1K Scheme and Resistive Wall Instability", *SSCL-647*, October 1993.
8. E.D. Courant and H.S. Snyder, *Ann. of Phys.* **3** (1953) 1.