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ONE NEW CONTROL MODEL FOR BEAM INSTABILITIES

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Abstract It is very difficult for us to make up beam instabilities. In this paper we will make different control model for transversal and longitudinal beam instabilities on account of different reasons. One new system control model will be developed.

INTRODUCTION

Beam instability is one important problem of one's interests. Many scientists make a lot of research work for overcoming it by different kind of methods. Now we discuss it in another way for breaking fresh ground. First, we consider the bunched beam delta function instead of Gaussian distribution. Second, the one dimension process method is employed in analysing the stable region of beam motion. Finally, according to the stability aperture suppressed by statistical filter, one new feedback control system is made up. It is a convenient model for developing developed control model in future.

THE CLASSIFICATION OF BEAM INSTABILITY AND FEEDBACK CONTROL

There are different reasons that cause beam instability. They are longitudinal effects, transverse stability, synchro-betatron resonances, beam-beam effects and so on.[1] If the motion of the particles inside a bunch is completely defined by $N(x,y,\phi,t)$, the mode decomposition chosen is[2]

$$N(x,y,\phi,t)=\sum_{\text{modes } i} a_i P_i(t) M_{ix}(x) M_{iy}(y) M_{i\phi}(\phi)+\langle N\rangle(t) \qquad (1)$$

We consider f(t;P0,t0) a possible trace from point P0 at initial time t0, Pe is an equiblium point. Then for any small real number e>0 and d>0, there always exists a point P* in the region ||P0-Pe||<d, and from this point the trace f will not satisfy an inequality as follow

||f(t;P*,t0)-Pe||<=e

So we say that the particle motion in system is unstable.

In order to cure the problem of beam instability, we must be careful to avoid unstable region during machine design, check every main component before machine commissioning, and choose best operation range when machine commissioning begans to run. Normally, the convenient feedback system is possible in all three phase planes by appropriate interconnection of the pick-ups and kickers. For example, feedback system for longitudinal dipole instability,[3] reactive feedback on the transverse mode conpling instability,[4] a loop feedback for injection damping. [5] We will discuss and summary them in next few section by basic concept of dynamic system stability.

BEAM INSTABILITY IN TIME-FREQUENCY DOMAIN

The bunched beam distribution is normally discribed as Gaussian shape. Now we use delta function instead of Gaussian distribution in time domain. It is easy for us to discuss, but also the Gaussian distribution is more relaxed than delta function in popular regime.

General feedback control system is one additional loop, i.e., one practical beam path with feedback branch. The function of time response is

$$h(t)=d(t)+d(t-T) \tag{2}$$

Its frequency response that we calculate or measure in spectum is shown in Figure 1.

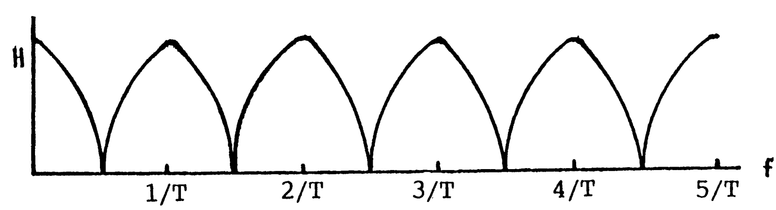


FIGURE 1 Frequency response of convenient feedback

We may see from Figure 1 that the both sides of central frequency n/T have stop-points. The dipole mode of centre frequency will vanish if they are near stop-points. The convenient feedback loop will lose its capacity of suppressing frequency spread, if they are not far from the centre frequency. For keeping the frequency of the coherent oscillation constant, we would like to extend equation(1). So the popularization of feedback systemis writen as

$$h(t)=\sum_{m=1}^{k} d(t-mT) \tag{3}$$

Then the frequency response for this system is

$$H(w)=|\sin(mwT/2)|/|\sin(wT/2)| \tag{4}$$

We show the system frequency response curve as m=32 by micro-computer as Figure 2. Compared Figure 2 with Figure 1, It is very clear that the coherent frequency shift can be limited as the region of very narrow band that makes the oscillation around baseband stable.

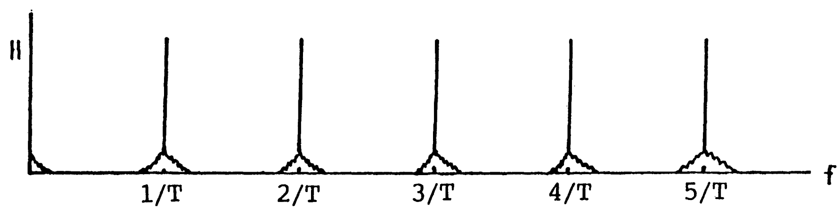


FIGURE 2 Frequency response of equation(3) at m=32

It is not possible for us to increase number m for keeping frequency constant infinitely. There are two reasons, it is very difficult to realize and other instabilities will be come all of a sudden when number m is enough large.

BEAM INSTABILITIES IN SPACE DOMAIN

The worst situation for beam stabilities is that beam distribution is uniform along the tree phase space (x,y,ϕ), but in practice it is much better. If we examine them in space-frequency-space domain, the response of moving beam is a delta function at oscillation number V. Now we construct a periodical delta function h(V), V is oscillation number.

$$h(V)=\sum_{m=1}^{K} d(V-ml) \qquad (l \text{ is wave length}) \qquad (5)$$

Compaired with equation (3), the space response function for equation (5) will be similar to equation (4). That is

$$H(V)=|\sin(mVl/2)|/|\sin(Vl/2)| \qquad (6)$$

Where $V=(x,y,\phi)$.

In order to examine equation (5) and equation (6), we define moving particles $N(V,t)$ stability as follows

DIFINE: There always exists a real number $e>0, d>0$ in the region $||V0-Ve||<=d(e,t0)$, then the particles motion must obey inequality

$$||f(t;V*,t0)-Ve||<=e, \text{ for all } t>=t0 .$$

Where t0 is an initial time, V* is an initial point of particle motion, Ve is a point in equiblium state. We say the particles motion is stable.

According to this definition and equation (6), the one dimension stability of beam is explained as Figure 3. Curve(a) represents the border of original aperture in absence of feedback, curve (b) is one desired, curve (c) is one with feedback. If machine works in good operation condition, curve (a) will converge on curve (b). If machine works in bad operation

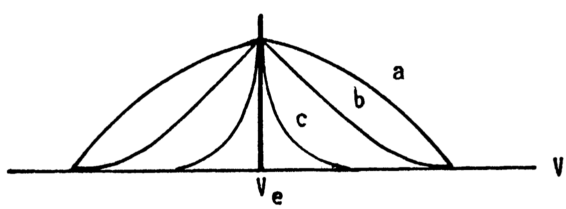


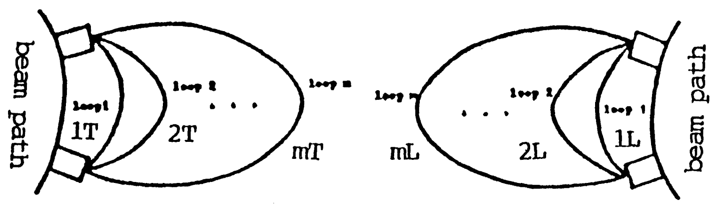
FIGURE 3 One dimesion dynamic aperture

condition, curve (a) will extend from curve (b). Curve (c) will be inside of curve (b) by increasing m large enough when correct feedback loops connect to machine. In other words, the more stop bandwidth enlarge, the larger stable region. In statistical way, the bunched beam noise bandwidth is suppressed by factor m.

It is not easy for us to get beam stable as one's insatiable desirability. Example, made it very stable in one dimension, it may be unstable in other dimension, i.e, one is convergence, the other is deconvergence. We have to compromise on the tree directions which we discussed it else.

MULTI-LOOP FEEDBACK SYSTEM

We discussed beam instability with feedback system in two sections above. There is one loop connected between pick-up monitor to knockout in convenient feedback system. Equation (3) and equation (5) give us more information. We may develop the traditional one feedback loop mode into multi-loops for beam stabilities. We mean that other additional loops with different time delay or different wavelength multiplied as Figure 4.



(a) (b)

FIGURE 4 Multi-loop feedback

The pick-up signals may be electronic signal, photon signal, [7] and so on. It depends on monitors that will be position sensor,[8] phase sensor,[9] frequency sensor, thermal sensor and photon sensor. The knockout may be injection kicker, RF klystron, RF quatrupole, et al. Each loop comprises time delay or wave lengthening, amplifier, time-space converter, driver, etc. High credible precise signal from pick-up monitor and high quality of the feedback loops are the keys which make feedback success. In the case of absence of many loops, it may use computer to simulate instead of part of loops.

Come into notice that one direction signal from pick-up is always coherent with other direction, and one direction knockout is also conpling with other direction. The combination of three phase space feedback so compact as to make cost less. However it depends current situation as you can manage.

CONCLUTIONS

The concepts of time-frequency and space frequency-space clear idea of us in question of beam instability with feedback system. The multi-loop feedback method is discussed here based on basic theory of dynamic system stability. We can also find best method for making dynamic aperture smaller in absense of multi-loops. A compromise in four variates will be useful .

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