

STABILIZING LOW FREQUENCY BEAM MOTION IN THE TEVATRON *

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Abstract

A feed back orbit stabilization system is being developed using a set of BPMS and existing Tevatron corrector magnets to stabilize beam motion up to 50 microns below 25 Hz. The construction of this system is described and the stability limits and magnitude of beam motion reduction is explored.

INTRODUCTION

A persistent low frequency beam motion in the horizontal plan has been observed in the Tevatron. This beam motion may lead to higher losses at the experiments, reduced BPM resolution and may hamper efforts at beam-beam compensation by the TEL. Past studies of this phenomena has shown that these oscillations are due to vibrations of the low beta quads at D0 and B0 [1],[2] ,[3]. The frequency of these vibrations correspond to the frequencies driven by helium liquefier pumps and stand resonances driven by the HVAC system and ground vibrations due to passing nearby vehicles. Much effort has been devoted to minimize these vibrations by reinforcing the stands holding the quadrupoles yet still the orbit motion remains. We propose developing a system to actively damp this beam motion using a small number of existing BPM signals and corrector magnets. The system would link two BPMs near B0 and D0 to two nearby corrector magnets. A rough schematic of this system is shown in Fig. (1).

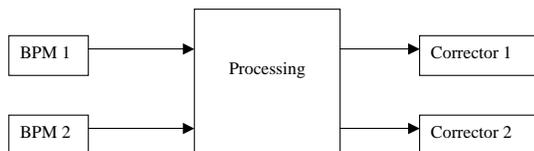


Figure 1: Scheme of low frequency damping system

TEST OF CORRECTOR MAGNETS

The results from some of our tests of the existing corrector magnets show that we can cycle them with enough speed and strength to counter the existing beam motion. Fourier spectrum of the beam motion in Fig. 2 shows horizontal beam motion grouped around 12 Hz and peaking at about 32 microns, by 25 Hz this motion has completely fallen off. In Fig 3-4. an applied corrector signal at 15 Hz was able to produce 174 micron amplitude beam motion. Since at 15 Hz we can generate a 174 micron kick we should be able to generate at least a 131 micron amplitude kick at 20 Hz

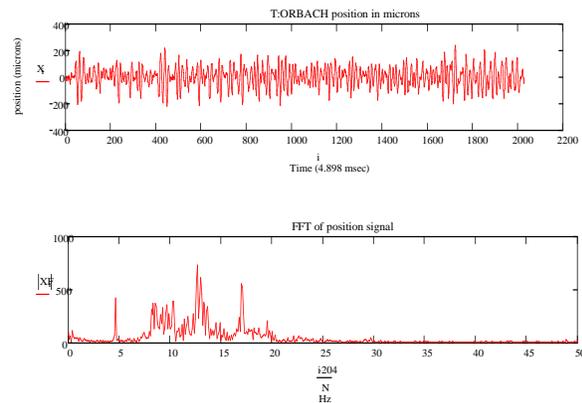


Figure 2: Beam signal sampled at 204 Hz at 980 GeV on device T:ORBACH BPM at A0

which is much stronger than the strongest signal of 32 microns observed at 12 Hz. So the correctors are able to damp all oscillations below 20 Hz if driven correctly. Despite the success there are still some issues of phase delay as function of amplitude the few points we have show a direct relationship between the phase of the applied signal and the measured beam motion. This relationship is shown in table 1.

Table 1: Phase difference between reference signal and measured beam signal versus reference current

Current (Amps)	Phase Difference (degrees)
0.616	38
0.738	40
1.2	54

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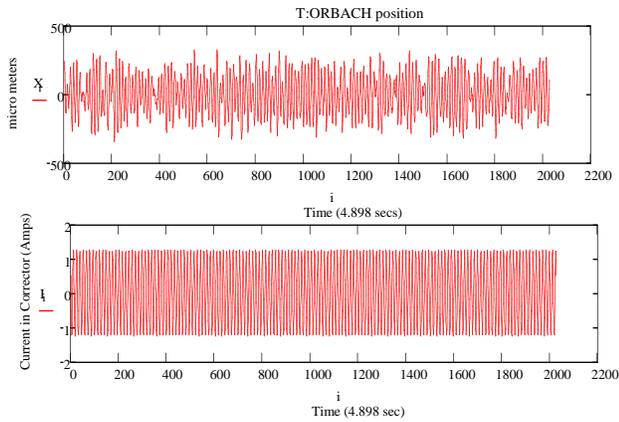


Figure 3: Beam signal sampled at 204 Hz at 980 GeV (top) with reference current in HA49 correctors (bottom) cycling at 15 Hz.

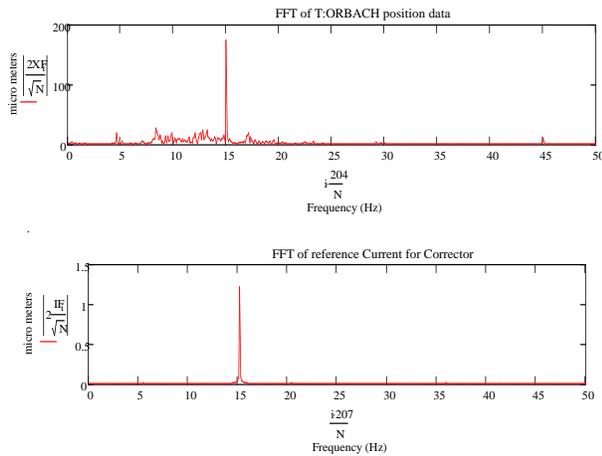


Figure 4: Frequency spectrum of beam (top) and reference current in HA49

ALGORITHM FOR ORBIT CORRECTION

Given a proper knowledge of the linear optics between the two boms and correctors it should be possible to correct both beam position and angle. In Fig. 5-6 are the results of a simulation of a kick of .5 micro-rad originating at the low beta quad at D0. If two dipole correctors at HD13 and HD19 are driven by boms at D11 and D13 the linear orbit can be corrected. We have selected these boms and correctors since they are a group of boms and correctors in close physical proximity to each other so that pulling extra cable will be not be necessary and they are closest to the D0 low beta quad one of the sources of beam motion

REFERENCES

[1] Vibrational Analysis of Tevatron Quadrupoles, Craig D. Moore Fermilab-TM-1959 (1996)

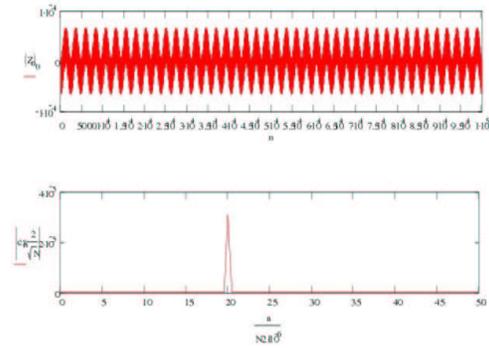


Figure 5: Simulated beam response to applied kick 0.5 micro-rad kick of 20 Hz at D0 low beta quad as measured at A0 yield 30 micro-meter oscillations. Turn-by-turn (top) and frequency (bottom).

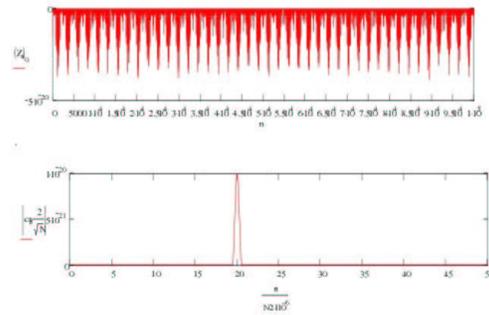


Figure 6: Simulated beam response with damping feedback turned on. Now beam motion down to 2×10^{-20} meters at A0. Turn-by-turn (top) and frequency (bottom).

[2] Ground vibration measurements for Fermilab future collider projects, B. Baklakov, T. Bolshakov, A. Chuprya et. al., Phys. Rev. ST-AB Vol. 1 Issue 3 (1998)
 [3] Tevatron magnets and orbit vibrations, V. Shiltsev, T. Johnson, X.L. Zhang, Fermilab-conf-02/250 October 2002.

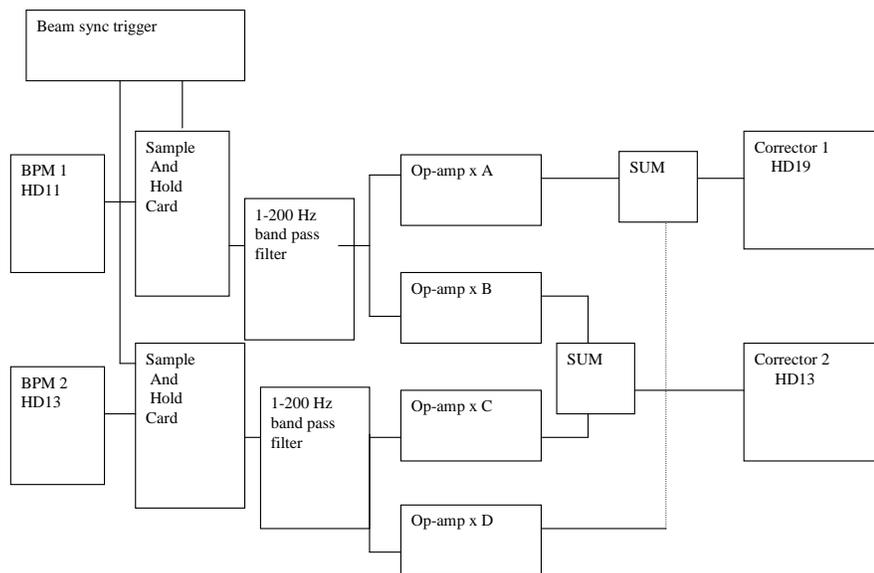


Figure 7: A more detailed schematic of the damping system. Here Gains A,B and C are determined by the optics, voltage to position ratio of BPMs and voltage to Amp ratio for the correctors reference voltage. We have BPM transfer function of 12V/m, corrector transfer ratio of 2.54m-rad/Amp and controlled by reference voltage transfer function 5 Amps/volt. This gives a total BPM voltage to reference voltage multiplicative factor as $(1/12) \times (1/2.54 \times 10^{-6}) \times (1/5) = 6561.67$. The optics factor are $F_a = 1.694 \times 10^{-3}$, $F_b = 0.024$, $F_c = 0.01$, and $F_d = -0.021$. So a first estimate has $A = 11.1154$, $B = 157.48$, $C = 65.6167$ and $D = -137.795$. The stability thresholds for this feed back system are per optics parameter, $F_{ad} = \pm 0.015$, $F_{bd} = \pm 0.008$, $F_{cd} = \pm 0.01$ and $F_{dd} = \pm 0.05$. This translate into an instability threshold of ± 52.49 gain for F_b the most sensitive optics parameter