A DAMPER SYSTEM FOR THE ELECTRON COOLING BEAM IN THE RECYCLER

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Abstract

The antiproton stacking rate in the Fermilab Recycler has been dramatically improved with the commissioning of the Electron Cooling system last year. Various disturbance sources such as mechanical vibrations in the Pelletron , power line fluctuations and coupling from beam ramps in the nearby Main Injector have added noise components in the electron beam position in the 0.5 to 200 Hz range. An AC coupled damping feedback loop with corrector coils for horizontal and vertical position correction at two upstream points from the BPMs was added to the existing BPM system . The system provides 10 – 20 dB damping in the frequency range above without interfering with other DC beam positioning control loops.

INTRODUCTION

Electron cooling involves the use of an electron beam to reduce the longitudinal and transverse emittances of anti-protons stored in the Recycler. A DC electron beam of upto 0.5A propagates co-linearly with the anti-proton beam in a 20 m straight section of the Recycler.[1] Scattering between the particles and the consequent friction results in thermal equilibration between the particles and thus cooling. The beam lines for the system are shown in Fig. 1

Noise components in the low frequency range from the 0.5 to 200 Hz range are present in the beam position . The sources vary from the 2 second ramps in the nearby Main Injector to vibrations in the Electron Accelerator(Pelletron) hardware (~30 Hz) as well as power line frequency components. A feedback system consisting of vertical and horizontal corrector coils at two locations along with detector BPMs was installed to damp the oscillations. The damping system has to be AC coupled so that it does not interfere with the DC beam positioning system. A digital feedback controller with a sample rate of 50 kHz and a closed loop bandwith of 800 Hz provides 10 - 20 dB damping of the noise components.

DAMPING SYSTEM HARDWARE

The main components of the feedback system are shown in Fig. 2. The Digital Signal Receiver(DSR) is a VXI module with 8 channels that is used in the main BPM system of the Electron Cooling beamline [2]. A pair of channels is used for each of the 4 BPMs (horizontal and vertical) at the two locations shown in Fig. 1.

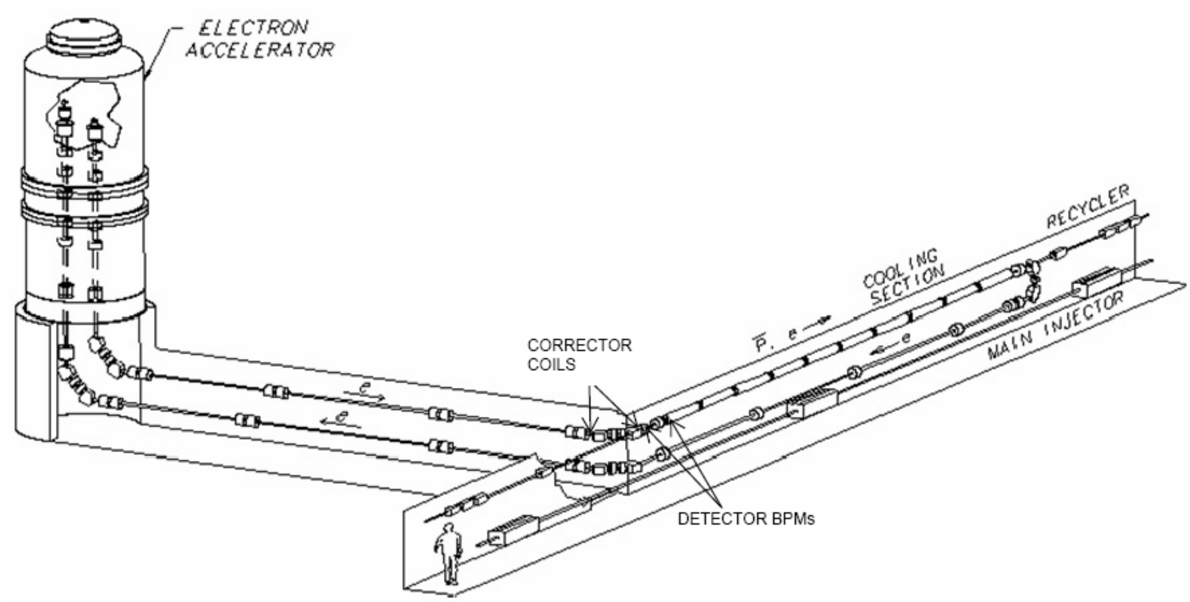

Figure 1: Location of damping system components.

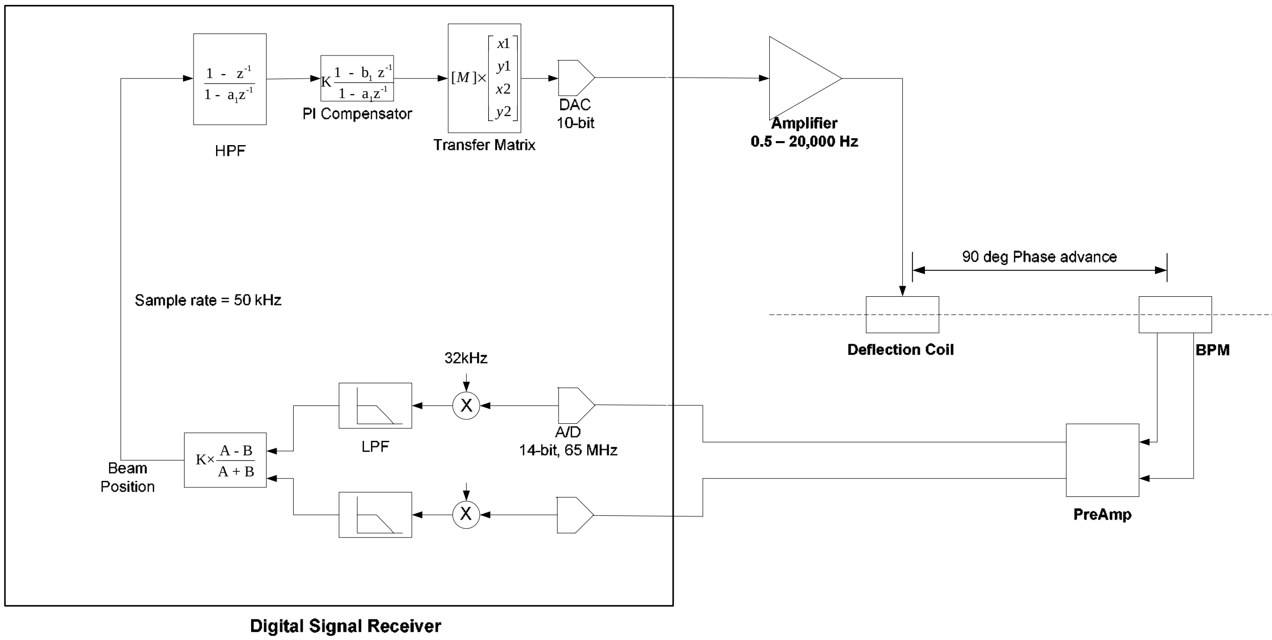

Figure 2: Damper system hardware.

The A/D is a 14-bit, 65 Mhz followed by a downconverter that brings the 32kHz modulated beam position to baseband while decimating the I and Q outputs to a 50kHz rate. Beam position calculation and the digital controller are implemented in a SHARC DSP. The controller output is provided through 4 channels of 10-bit DACs The corrector coils are copper foils embedded in a flexible capton enclosure that is wrapped around the beam tube. The amplifier is a modified off the shelf 4 channel audio amplifier (QSC model CX-404) with 250W per channel providing a maximum of 36dB gain. The input circuits were modified to lower the poles from around 5 Hz to about 0.5 Hz to provide adequate damping at the lower end of the required frequency range. A frequency response measurement of the corrector coil showed a pole around 1 kHz.

CONTROLLER DESIGN

The Hipass filter pole was chosen to be 2 Hz and the pole and zero of the PI controller were adjusted to provide about 20 dB of loop gain. The upper and lower limits for the bandwidth were determined by the corrector coil and the amplifier respectively. The amplifier gain was set to 15 dB. With a zero at 800 Hz and the pole at 10 Hz for the PI controller the open loop frequency response shown in Fig. 3 was obtained by simulation with Matlab. The magnitude response shows about a 10 db loop gain at the low end frequency of 0.5 Hz and a maximum of about 20dB.

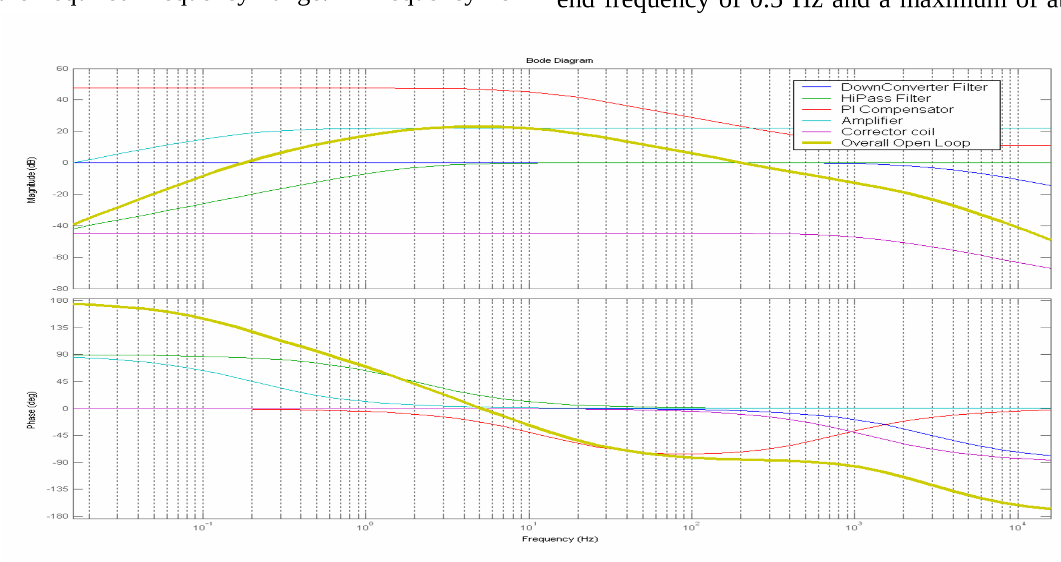

Figure 3: Open loop frequency response.

DAMPER PERFORMANCE

Position measurements from the 4 detector BPMs are shown in Fig. 4 with the damper off and in Fig. 5 with the damper on.

The large amplitude oscillation in the second waveform corresponds to the 0.5 Hz component from the Main Injector ramp. An FFT of the data shown in Fig. 6 and Fig. 7 shows that all the major noise components were damped by 10 – 20 dB.

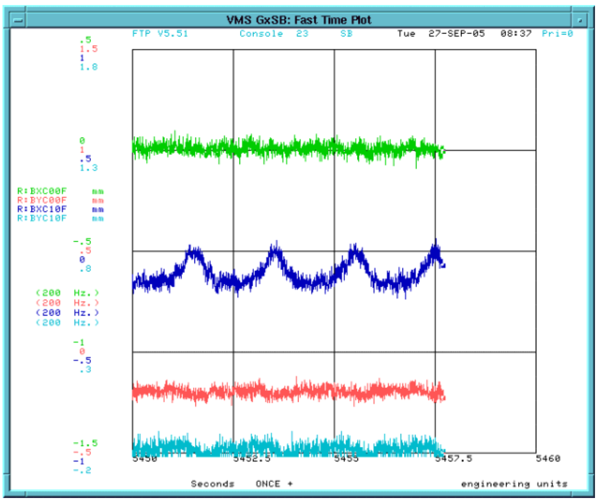

Figure 4: Beam positions with damper off.

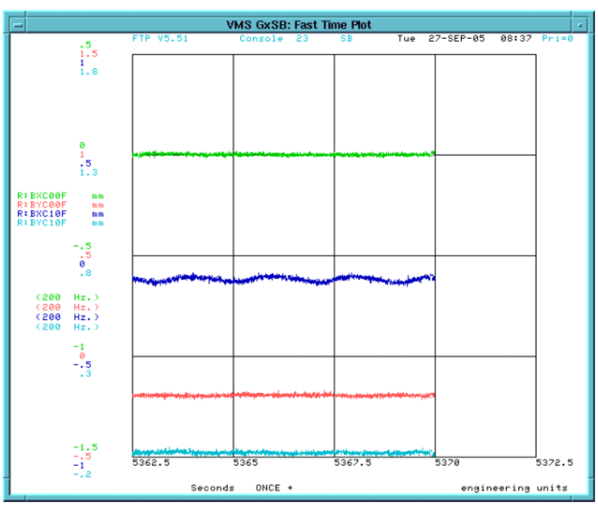

Figure 5: Beam positions with damper on.

The transfer matrix M shown in Fig. 2 is a 4x4 matrix that transforms the beam positions to coil currents. This matrix is computed by inverting the matrix M^* obtained by a calibration measurement, whose columns represent the position change in each BPM for a unit current in one coil with the other three coils de-energized. The noise suppression at the lower end is essentially limited by the amplifier pole location. Subsequent to the commissioning of the damper system additional modifications were made to the amplifier poles to reduce them to about 140 mHz. This should improve the suppression of the 0.5 Hz component by an additional 6 to 10 dB.

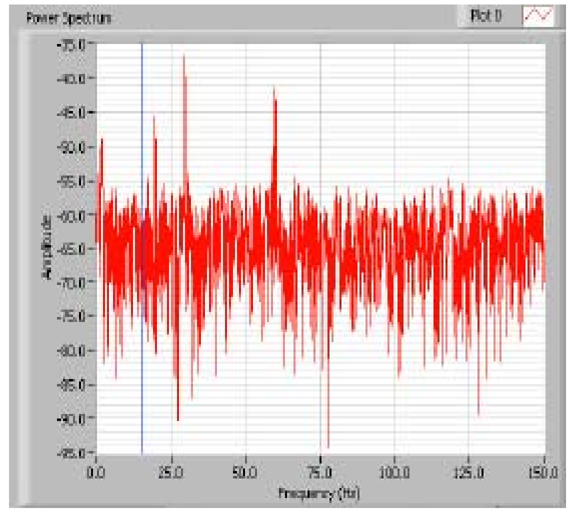

Figure 6: Noise spectrum with damper off.

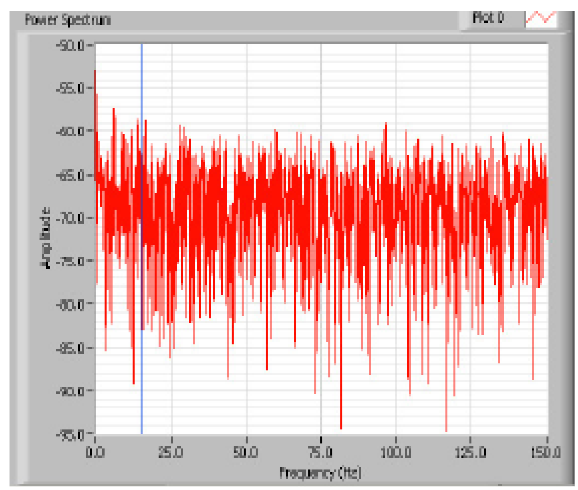

Figure 7: Noise spectrum with damper on.

REFERENCES

[1] S. Nagaitsev, "Antiproton Cooling in the Fermilab Recycler", COOL'05, Galena, Sept 2005.

[2] P.W. Joireman, J. Cai, B. Chase and G.W. Saewert, "BPM System for Electron cooling in the Fermilab Recycler Ring", BIW'04, Knoxville, June 2004.