Submitted to EPAC96, Barcelona, Spain
June 10-14, 1996

BNL--62947

BNL-62947

CONF-960621--1

Operations with the Digital Orbit Feedback System in the NSLS X-ray Ring*

E. BOZOKI, S. RAMMAMORTHY, O. SINGH, Y. TANG
Brookhaven National Laboratory
A. FRIEDMAN
Digital Secured Networks Technology Inc., Ronkonkoma, NY.

Abstract

The digital filtering and the eigenvector decomposition-based orbit correction is performed by two dedicated HP 742/743 rt micros which communicate with Motorola CPU based orbit-measuring and orbit-correction systems. The correction algorithm in the DFbk was orthogonalized with respect of the analog global harmonic feedback. Operational results concerning improvements in the noise suppression at low frequencies and especially in the dc drift as well as in the orbit stability are shown. Efforts are underway to improve the resolution of the orbit measuring system and the sampling rate using 16 bit 400 kHz ADC's which will allow orbit sampling with high resolution at 4 kHz frequency.

1 THE FEEDBACK SYSTEM

The hardware, software and filter design have been described earlier in [1]. The principles of digital filtering and feedback control as applied to our system as well as details of the NSLS digital feedback system is discussed in [2].

Hardware. The feedback system consists of three micros; the HP-742rt CPU based feedback micro, the Motorola-167 CPU based orbit micro and the Motorola-133 CPU based trim micro. The communication between the micros is done by the Bit-3 bus adapter boards through shared memory in the trim and in the orbit micro.

The orbit micro samples the PUE data at 555 Hz rate and the data is stored in memory. This memory is mapped by the adapter board to the address space of the feedback micro which calculates the orbit correction and optimizes it. The data communication between the feedback and trim micros is again through memory mapping. The trim micro then controls the power supplies of the orbit corrector magnets. The most computational intensive task is that of the feedback micro. Hence, we chose an HP 742rt, which runs more than to run six times faster than a Motorola 167/162 for this kind of application.

Software The orbit and trim micros are using the NSLS Control Monitor [3], which have been modified to place the read and set points into shared memory, and to synchronize data collection with the feedback micro.

The digital feedback program is an object oriented code written in C++ and running on the HP 742rt. At every cycle (555 Hz) the program "measures", "filters" and "corrects" the orbit. Thus the reading of the PUE values from the shared memory, the filter and correction calculations, the writing of the new trim values into the shared memory and the actual changing of the trim values have to be done within 1.8 msec.

For orbit correction we are using the Eigenvector Decomposition based orbit correction method described in Ref. [4]. This method will yield the 'minimum' kick vector required for a desired accuracy of orbit correction. It is also a very fast algorithm. The correction algorithm in the DFbk was orthogonalized with respect of the analog global harmonic feedback.

Elements of the feedback The feedback system and its elements are illustrated in Fig. 1.

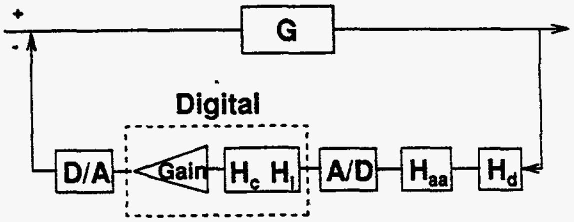

Figure 1:

Block diagram of the ring and feedback loop showing the elements of the feedback system.

The G(s) Laplace transform, which represents the effect of the vacuum chamber, behaves like a single pole low pass filter, with the pole measured at ≈25 Hz. H_{AA} is an "anti aliasing" filter which limits the bandwidth of the signal in order to prevent aliasing (folding) of the signal spectrum after the D/A conversion. It is a low pass filter with a single pole at ≈80 Hz. $H_d(z) = z^{-3}$ represents the phase delay due to sampling time, computation time and conversion time. (See Fig. 5) The H_c filter is designed to compensate for elements in the system G that may be limiting the bandwidth and adding phase retardation to the system. The $H_c(z)$ z-transform behaves as a high pass filter:

$$H_c(z) = \frac{1}{G(z)} = 8.026\frac{1 - 0.751z^{-1}}{1 + z^{-1}} \qquad (1)$$

---

* Work performed under the auspices of the U.S. Dept. of Energy under contract no. DE-AC02-76CH00016.

Similar studies in the vertical plane showed a typical rms orbit change of ≈20 μ with Standard Ops, and ≈5 μ when both, digital feedback and Standard Ops have been used.

The measured horizontal and vertical frequency response of the system is shown in Fig. 4. Curves (a), (b) and (c) correspond to no feedback, digital feedback only and both, harmonic and digital feedback turned on. The digital feedback has a bandwidth of ≈15 Hz with a horizontal and vertical noise reduction of 20 - 25 db at f = 1 Hz. The dc-noise reduction, which we measured at f = 0.1 Hz, was found to be ≈40 db. The bandwidth of the system can be greatly extended and the noise further reduced in the 2 - 100 hz region, when both, the digital and the harmonic feedback (with its >100 Hz bandwidth) was used.

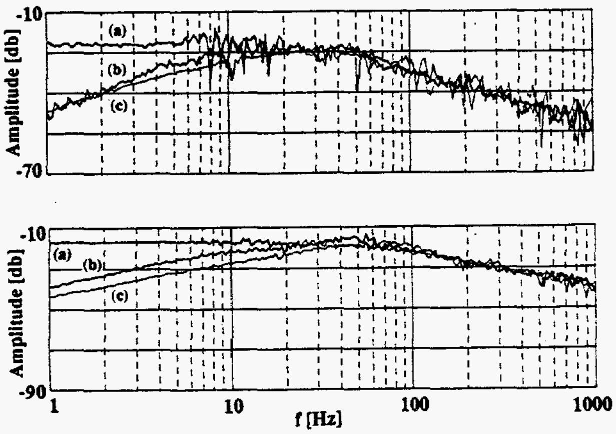

Figure 4:

Measured horizontal and vertical frequency response of the system, (a) no feedback, (b) DFbk only and (c) both, harmonic and digital feedback

The phase delay due to sampling time, computational time and conversion time was measured by driving a trim magnet with a square-signal of a pulse generator and monitoring the correction signal coming from the digital feedback system. Fig. 5 shows that the delay is ≈2.5 cycles.

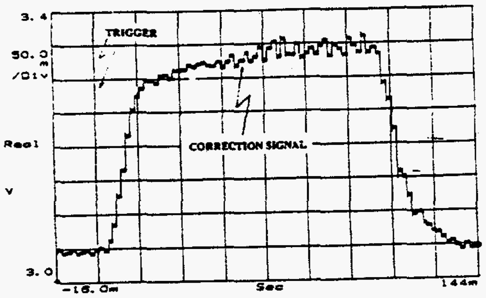

Figure 5: Measured delay in the system

3 SUMMARY

Our findings show that the digital feedback is very effective, taking out the dc-drift from the orbit and keeping it stable to ≈ 10μ. Presently, the digital feedback has a bandwidth of ≈15 Hz with a dc-noise reduction of ≈40db. Until the bandwidth of the digital feedback is increased using a faster sampling rate and higher resolution data, the three feedbacks are working together.

Efforts are underway to improve the resolution of the orbit measuring system and the sampling rate. We will use an Analogic DVX-2503 16-bit 400 kHz multichannel Data Acquisition System having 8 differential input ports and three Analogic DVX-2701 high-speed, high-accuracy 32 channel multiplexers. This setup will allow sampling of the 2x48 PUEs (in the horizontal and vertical plane) with high resolution at 4 kHz frequency. The upgraded feedback system will have a bandwidth of over 100 Hz and will make the use of additional analog global and local feedback unnecessary. The higher resolution also will allow us to use a notch filter.

4 REFERENCES

[1] A. Friedman and E. Bozoki, "A Digital Feedback System for Transverse Orbit Stabilization in the NSLS Rings", NIM A352, p. 393, 1995.
A. Friedman and E. Bozoki, "A Digital Feedback System for Transverse Orbit Stabilization", Proc. 4th EPA Conf., London, Vol. 2, p. 1586, 1994.
E. Bozoki, A. Friedman and S. Ramamoorthy, "First Results with a Nonlinear Digital Orbit Feedback System at the NSLS", Proc. IEEE Particle Accelerator Conf., Dallas, Vol. ?, p. ????, 1995.

[2] E. Bozoki and A. Friedman, "Digital Feedback System for Transverse Orbit Stability at the NSLS", submitted to NIM.

[3] S.Ramamoothy and J.Smith, "NSLS Control Monitor and its Upgrade", Proc. IEEE PAC, p. 1849, 1993.

[4] A. Friedman and E. Bozoki, "Use of Eigenvectors in Understanding and Correcting Storage Ring Orbits", NIM A344, p. 269, 1994.

[5] L.H. Yu et all., "Real Time Global Orbit Feedback System for NSLS X-ray Ring", Proc. IEEE Particle Accelerator Conf., San Francisco, Vol. 4, p. 2542, 1991.
O. Singh, "Electron Beam Stability and Beam Peak To Peak Motion Data for NSLS X-ray Storage Ring", Proc. IEEE Particle Accelerator Conf., Washington, Vol. 3, p. 2254, 1993.
J. Safranek, O. Singh and L. Solomon, "Orbit Stability Improvement at the NSLS X-ray Ring", Proc. IEEE Particle Accelerator Conf., Dallas, Vol. ?, p. ????, 1995.

[6] O.V. Singh, R. Nawrocky and J. Flannigan, "Automatic Local Beam Steering Systems for X-ray Storage Ring - Design and Implementation", Proc. IEEE Particle Accelerator Conf., San Francisco, Vol. 3, p. 1528, 1991.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

This report has been reproduced directly from the best available copy.

Available to DOE and DOE contractors from the Office of Scientific and Technical Information, 175 Oak Ridge Turnpike, Oak Ridge, TN 37831; prices available at (615) 576-8401.

Available to the public from the National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161; phone orders accepted at (703) 487-4650.