USING TRANSIENT WAVEFORM RECORDERS TO MEASURE AND STORE BEAM PARAMETERS*

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Abstract

Transient waveform digitizers are used to measure the tunes in the Stanford Linear Collider (SLC) damping rings. Since the beam injection and extraction from these rings occurs at a high rate (120 Hz) and because of the stringent extracted beam stability requirements, simpler asynchronous resonant excitation spectrum analyzer measurements are not possible. The beam position monitor signals are processed, digitized, and a Fast Fourier Transform (FFT) is applied to find the tunes. The coherent beam motion at injection, even though it damps quickly, is large enough to provide a strong tune signal. Recently, this technique has also been applied to several longitudinal signals [1]. The results from these monitors are recorded at six-minute intervals in the SLC control system history buffers [2]. This paper will describe the hardware setup and the software used to process the data, and will present some of the results.

I. INTRODUCTION

In the Stanford Linear Collider (SLC) two damping rings are used to achieve smaller beam emittances through radiation damping. The rings are both 35 m in circumference and operate at an energy of 1.21 GeV. During normal running, beams are injected and extracted at 120 Hz.

The Damping Rings turn-by-turn monitor (Fig. 1) is a modular digital signal processor system, using off the shelf CAMAC modules, and driven by the MATLAB [3] software package. It was originally installed to measure the ring tunes, but has recently been expanded to analyze other signals as well.

II. HARDWARE

The signals originate from four Beam Position Monitor (BPM) stripline detectors that are oriented at 45° with respect to the horizontal and vertical planes, and are brought out of the vault by four equally timed 1/2-inch heliax cables. These signals are combined in hybrid junctions to produce horizontal and vertical difference signals, ΔX and ΔY, as well as a sum signal (TMIT). Amplification or attenuation is provided by a LeCroy 6103 programmable CAMAC amplifier. The resulting beam position signals are digitized and recorded at each turn by DSP Technology 2008 transient waveform digitizers. The digitizers receive a clock pulse at each ring turn from a SLAC built Programmable Synchronization Unit (PSU), and they record data with eight bit resolution for up to 8192 turns. The clock is timed so that only one of the stored bunches per turn is recorded. The stored data is then read by the VAX computer and processed using the MATLAB software package to produce the FFT plots.

* Work supported by Department of Energy contracts DE-AC03-76SF00515 (SLAC).

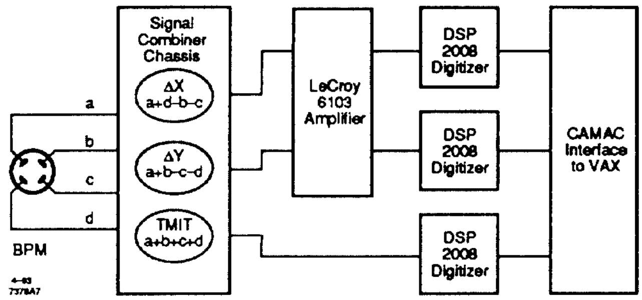

Figure 1. Block diagram of the Damping Rings turn-by-turn monitor.

III. SOFTWARE

The software used to process the data presented in this document is a prototype system that uses several existing software packages. To run the program, the user signs on to the VAX computer that is used to control the SLC and calls up a MATLAB program named "turns." This program is menu-driven and allows the user to select from several options, such as: set amplifier gains, select north or south ring, take data, calculate FFT, or print plots. An on-line help facility is also available. The MATLAB program then calls FORTRAN and other routines that control and read the hardware.

Recently, some of this software has been rewritten and integrated into the SLC control system. The new software makes better use of computer time and has a much-improved user interface. It is easily accessed by the SLC operators on the SLC console touch panels and displays.

IV. RESULTS

Figures 2 and 3 show the time domain and frequency domain (FFT) plots of typical data in the horizontal plane.

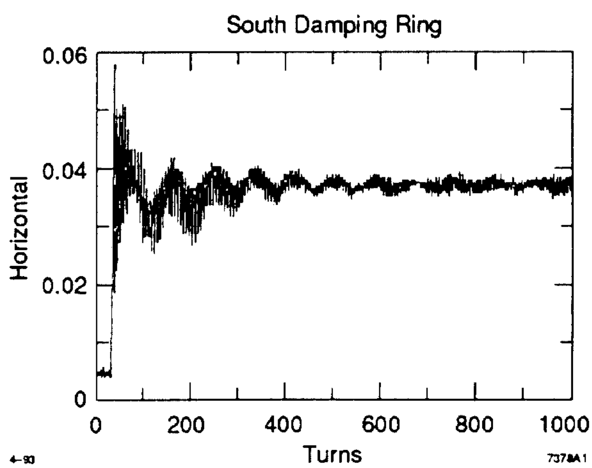

Figure 2. Raw data in the horizontal plane showing both the betatron tune and the lower frequency synchrotron tune.

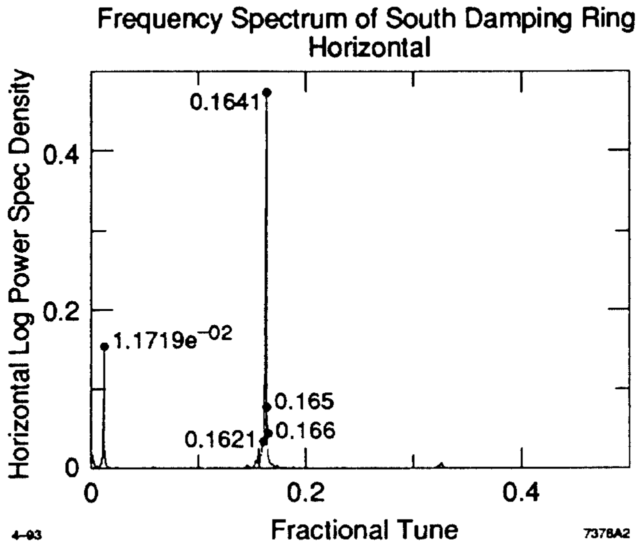

Figure 3. Fast Fourier Transform (FFT) of the horizontal data showing peaks at both the betatron tune and the synchrotron tune.

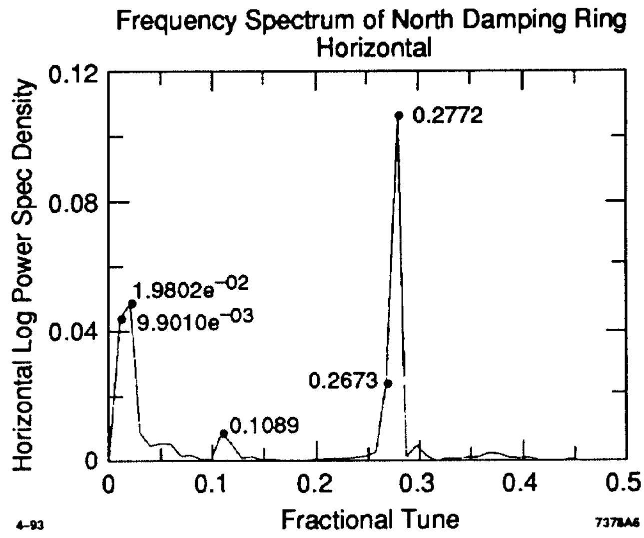

Figure 5. FFT of the data illustrating the systems ability to measure tunes when less than 100 turns is available.

The strong synchrotron oscillations immediately after . injection are readily apparent. The FFT of the data was taken from turn 200 through 1223 to somewhat suppress the strong sychrotron line on the frequency domain plot, see Figure 3.

The vertical axis in Figure 2 is in volt, where 20 mV represents approximately 760 μm. In Figure 3 the five highest points are labeled. The MATLAB routine allows choice of the number of points to be labeled.

Figures 4 and 5 illustrate the effectiveness of the system during startup, before stable beams have been established. This is a useful diagnostic tool in the event of a difficult startup.

During routine running, one of the quantities that it is important to monitor is Damping Ring transmission, or how much of the injected beam makes it through the ring. Figure 6 shows a plot of the response of a fast toroid installed in the south Damping Ring indicating losses in early turns.

Figure 7 is an example of one of the longitudinal signals that have been digitized. This data is derived from a BPM sum signal that is proportional to the inverse of the bunch length. Precompression of the bunch length is accomplished using a so-called "bunch muncher" that shock excites a bunch length oscillation by modulating the rf amplitude [4]. The timing is set so that a minimum bunch length occurs just before extraction. The data in Figure 7 clearly shows extraction occurring after the minimum bunch length has occurred.

Figure 8 shows a history buffer plot of the tunes and TMIT for a 24 hour period. The value of the tune recorded in the history buffer is computed by a MATLAB routine that searches

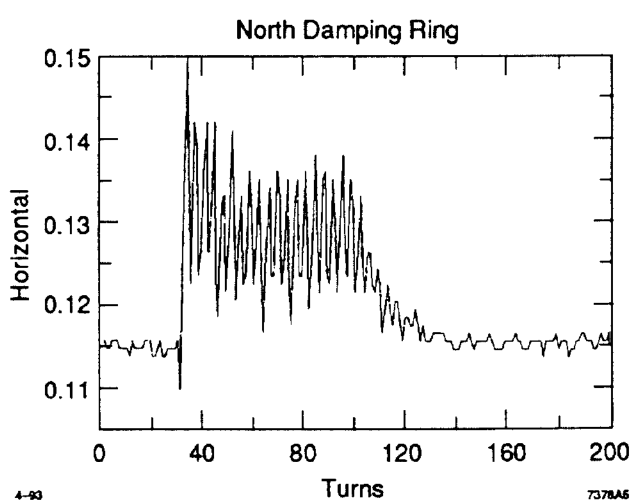

Figure 4. Raw data at the start of the cycle when less than 100 turns had been achieved.

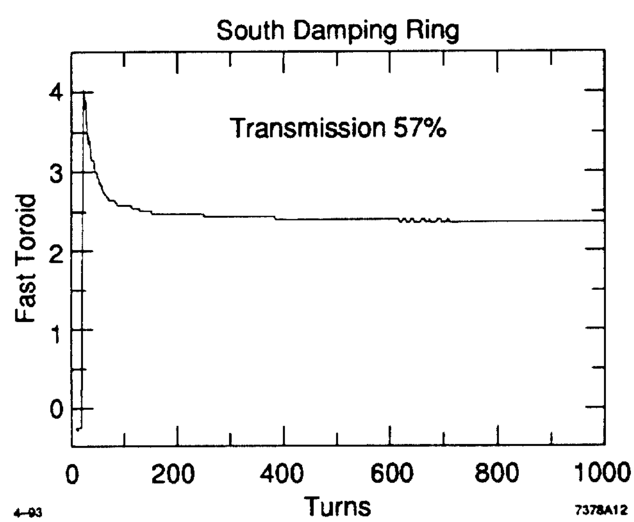

Figure 6. Measurement of beam loss in early turns using a fast toroid.

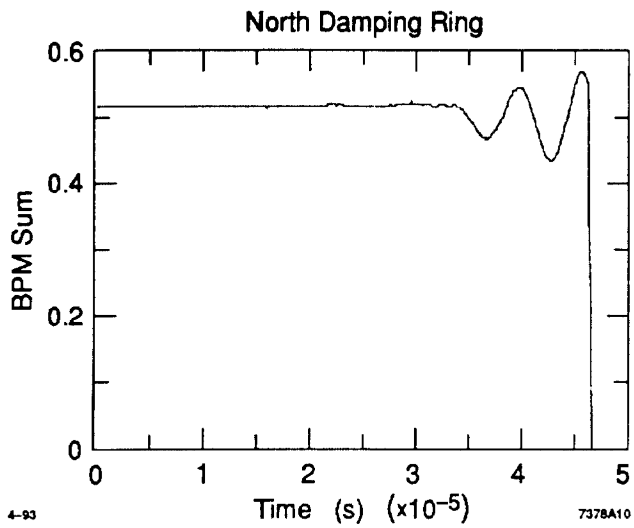

Figure 7. Data representing inverse bunch length just before extraction derived from a BPM sum signal.

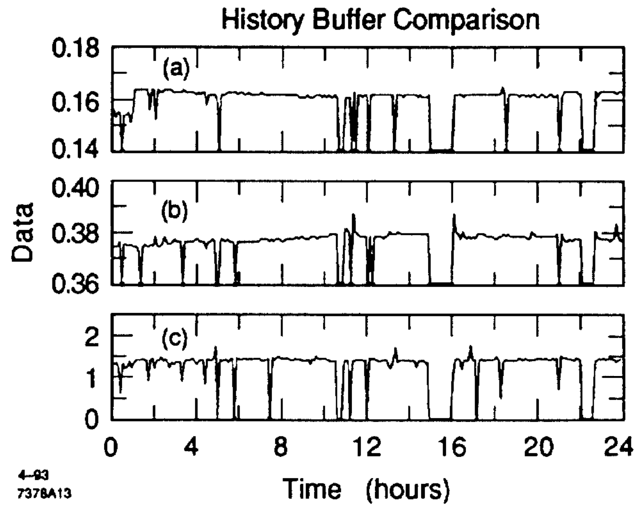

Figure 8. History buffer plot of the south damping ring: (a) horizontal tune, (b) vertical tune, and (c) TMIT for a 24 hour period.

for the highest peak within a specified range in the FFT data. The many routines available in MATLAB make it easy to choose and record in the history buffer the desired values from the digitized data.

Future plans for the system include adding the capability of synchronous data aquisition with other signals so that correlations can be made to diagnose sources of machine jitter.

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[3] MATLAB is a trademark of The MathWorks, Inc., Cochituate Place, 24 Prime Park Way, Natick, MA 01760-9889 (508) 653–1415.

[4] F.-J. Decker, T. Limberg, J. Turner, "Precompression of Bunch Length in the SLC Damping Rings," Proc. Int. Conf on High-Energy Accelerators (HEPAC '92), Hamburg, Germany, July 20–28, 1992; SLAC--PUB--5871 (1992).