FIRST COMMISSIONING RESULTS OF THE ELETTRA TRANSVERSE MULTI-BUNCH FEEDBACK

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Abstract

A wide-band bunch-by-bunch Transverse Multi-Bunch Feedback, developed in collaboration with the Swiss Light Source (SLS), has been installed at ELETTRA. After a description of the main hardware/software components, the first commissioning results and the present status of the system are given.

1 INTRODUCTION

The ELETTRA Transverse Multi-Bunch Feedback (TMBF) [1] consists of a wide-band bunch-by-bunch system where the positions of the 432 bunches, separated by 2 ns, are individually corrected. After combining and demodulating the wide-band signals from a standard ELETTRA electron Beam Position Monitor (BPM), the X (Y) baseband signal (0-250 MHz) is sampled by an eight-bit 500 Msample/s Analog-to-Digital Converter (ADC). The resulting 500 Mbyte/s data flux is first de-multiplexed into six 32 bit FDPD (Front Panel Data Port) channels. The data from each of them is then distributed by means of a programmable switch to the four TI-TMS320C6201 programmable Digital Signal Processors (DSP) housed in one VME board. In the present configuration all of the data coming from one FPDP channel, which correspond to 72 bunches, are passed to one DSP for on-line diagnostics and concurrently split over the remaining three DSPs for the execution of the feedback algorithm. A detailed description of the digital processing electronics is given in [2]. The calculated corrective kick values are recombined following a symmetric multiplexing scheme and transmitted to an eight-bit 500 Msample/s Digital-to-Analog Converter (DAC), amplified by an RF power amplifier and applied to the beam by a stripline kicker. A flexible timing system provides the necessary synchronization signals.

2 CLOSED-LOOP RESULTS

Commissioning has focussed on the vertical plane since the instabilities are stronger and users are more sensitive to vertical emittance. The TMBF loop has been characterized and successfully closed on beams of increasing current and energy, up to 320mA@2GeV and 130mA@2.4GeV, which are the typical target values during users' shifts. Figure 1 shows the effect of the TMBF as seen on the synchrotron radiation profile monitor image of a 200 mA stored beam affected by vertical transverse coupled-bunch instabilities.

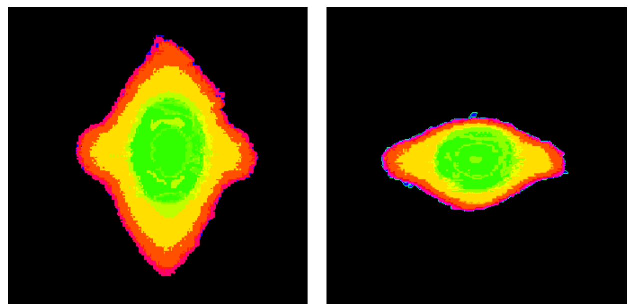

Figure 1: Synchrotron radiation profile monitor images of a 200 mA beam affected by vertical transverse coupled-bunch instabilities with TMBF off (left) and on (right).

The developed DSP software allows the adoption of Finite Impulse Response (FIR) filters with up to 5 taps for the feedback algorithm. However, the presently used filter is a 3-tap FIR that provides rejection of the closed orbit signal while ensuring the right phase and gain at the betatron frequency. The total closed-loop delay is four revolution periods plus the BPM-to-kicker delay. One RF amplifier per plane powers the downstream port of a single kicker stripline.

3 DIAGNOSTIC TOOLS

In parallel to the closed loop functionality, the digital implementation of the TMBF system opens the way for additional diagnostic features that can be built by appropriate programming of the system. A number of them have been developed starting from the commissioning phase.

3.1 Bunch-by-Bunch Data Acquisition

As already mentioned, one of the four DSPs on each VME board is dedicated to data acquisition for on-line diagnostics and 16 Mbytes of Synchronous Dynamic RAM are available for this purpose. The whole system made up of six boards allows 96 Mbytes of bunch-by-bunch continuous data at 500 Msample/s, corresponding to 192 ms, to be recorded in parallel during normal feedback operation.

A VME OS/9 based host computer acts as the TMBF system supervisor and communicates with the DSP boards via the VME bus. It triggers the recording and collects the stored data from the DSPs. Two Mbytes of Global Static RAM, which is accessible both from the VME bus and from the DSPs, are used as a communication buffer.

3.2 Change of the Digital Filter Coefficients

The values of the coefficients used by the 5-tap FIR filters can be changed on the fly while the feedback is running. This feature is implemented using the TMS320C6201 Host Port Interface (HPI), which is an additional 16-bit wide parallel port through which the VME bus host computer can read/write the DSP internal memory locations where the coefficients are stored without interfering with the currently executed code. The complete operation of changing the 90 filter coefficients on all of the 18 DSPs involved in the feedback loop is carried out in 150 µs.

3.3 Integration with the Matlab Environment

Beside managing the DSPs' operation as described above, the VME host computer is used to interface all of the TMBF system components (timing, ADC, DAC and RF amplifier) to the ELETTRA control system through the Remote Procedure Call (RPC) protocol running over the Ethernet network.

A set of newly developed Matlab commands, implemented as M/Mex-files on top of RPC, also allows to access the TMBF equipment from any Matlab session running on the control room workstations (Figure 2). This provides a powerful unified platform for both commissioning operations and machine physics studies as it merges TMBF system control, on-line analysis of the acquired data and graphical visualisation of the results.

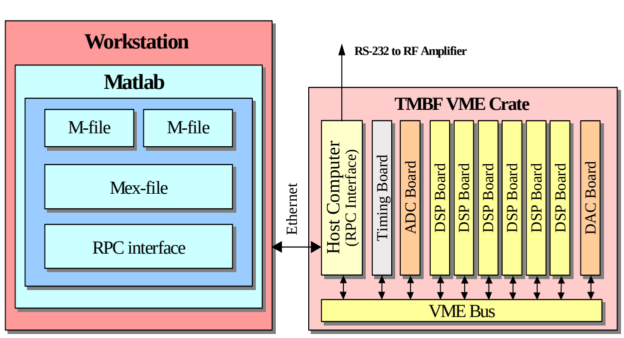

Figure 2: Block diagram of the hardware/software TMBF system architecture.

The following are some of the developed Matlab commands:

get_all(): acquires an array of bunch-by-bunch position samples of all the bunches. An option allows to reject the DC closed orbit component from each bunch as well as the spurious low frequency components due to longitudinal coupled-bunch modes.

get_bunch(): acquires an array of turn-by-turn position samples of a chosen bunch.

set_filter(): sets the digital filter coefficients.

set_filter_sync(): changes the digital filter coefficients in time according to a specified sequence of intervals and contemporarily records the position data containing the transients generated by the filter changes.

4 DIAGNOSTICS MEASUREMENTS

During the commissioning period several measurements have been carried out to test the TMBF system and evaluate its performance and effect on the beam. The most significant of them are reported here.

4.1 Frequency Domain Analysis

The data acquisition features make the feedback system a powerful tool for spectrum analysis. 250MHz-wide spectra for complete multi-bunch mode analysis with 1 kHz resolution can be obtained in the control room at a repetition rate of about 0.5 Hz. Figure 3 is an example of such a measurement and shows the base-band (0-250MHz) open/closed loop amplitude spectra of a beam with vertical coupled-bunch instabilities.

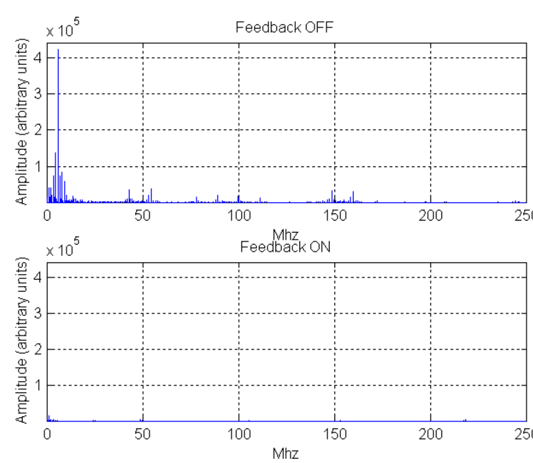

Figure 3: Feedback off/on base-band (0-250MHz) multi-bunch amplitude spectra (with rejected DC closed orbit component) of a 210 mA vertically unstable beam.

4.2 Growth/Damp Transients

Figure 4 shows the spontaneous growth of the oscillation amplitudes of the bunch train of a vertically unstable beam when the feedback is switched off and the subsequent damping effect when the feedback is switched back on. This time domain transient has been obtained using the Matlab routine *set_filter_sync()*, which sets the filter coefficients to zero and restores them back to their original value after a specified 2.3 ms interval.

The same transient can be analysed also on a 3D plot where the evolution of the entire beam spectrum is plotted vs. time. Figure 5 illustrates how the amplitude of the vertical modes sidebands grows and the effect of the feedback when it is switched on.

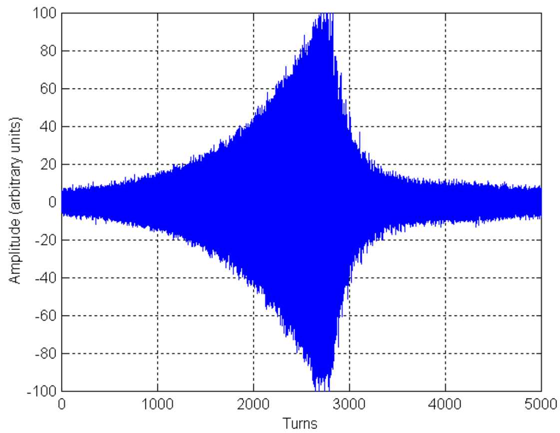

Figure 4: Vertical growth/damp transient generated by switching off/on the feedback.

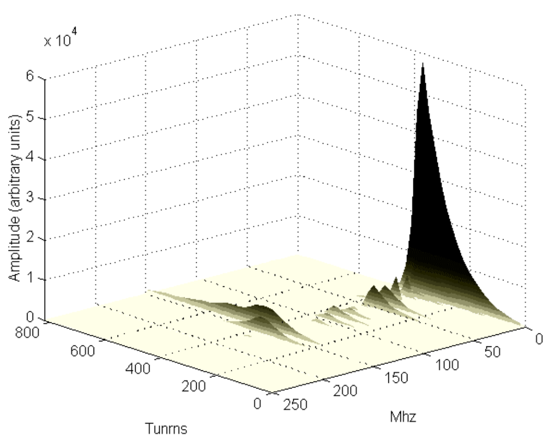

Figure 5: Base-band spectra vs. time showing the growth of unstable vertical modes when the feedback is turned off and the damping effect when the feedback is turned back on.

4.3 Betatron Tune Measurements

Accurate betatron tune measurements can be performed using the TMBF system. The spectrum of the motion of a single bunch clearly reveals the betatron tune line at the fractional tune frequency when an unstable mode is excited. If no multi-bunch instabilities are present, changing the FIR filter taps in order to produce an anti-damping effect with a positive feedback can artificially excite transverse oscillations. The Matlab routine *set_filter_sync()* is used to create anti-damping/damping transients during which betatron oscillations can be detected and measured.

In particular, the filter coefficients can be changed only for those 24 bunches managed by one selected DSP. The feedback can therefore be switched off/on on some bunches while it continues to run on the rest of them. This technique allows performing tune measurements in parallel to TMBF operation with no effect on the stored beam.

5 CONCLUSIONS

A bunch-by-bunch TMBF system based on programmable DSPs for the processing of the position data coming from all of the 432 2ns-spaced bunches has been installed at ELETTRA and is finishing its commissioning phase. As of today, commissioning has been done on the vertical plane. Vertical coupled-bunch instabilities have been completely damped on beams of different energies/currents that correspond to the ELETTRA standard operational values during users' shifts.

In addition to the verification of the main hardware components, a number of software based diagnostic tools that can run in parallel to feedback operation have been tested and used since the first phases of commissioning. Such tools allow an effective characterization of both the TMBF system hardware and beam behaviour.

The availability and integration of beam diagnostics routines in the Matlab environment make the TMBF system a valuable tool also for general machine physics studies.

In order to improve the usable dynamic range at the input of the ADC and simplify machine operations by relaxing the present constraints on the closed orbit whose offsets has to be minimized at the TMBF BPM location, a dedicated DC signal rejection electronic circuit is under development.

The TMBF system has been developed as a collaboration project with the Swiss Light Source, where it will be installed during the next summer. The necessary DSP software changes to deal with 480 2-ns spaced bunches are in progress.

A Longitudinal Multi-Bunch Feedback is also being designed for both the accelerators and will use the already developed digital processing hardware, running the appropriate software.

REFERENCES

[1] D. Bulfone et al., “Design Considerations for the ELETTRA Transverse Multi-Bunch Feedback”, PAC’99, New York, March 1999.

[2] M. Lonza et al., “Digital Processing Electronics for the ELETTRA Transverse Multi-Bunch Feedback System”, ICALEPCS’99, Trieste, October 1999.