TUP31

Elettra Sincrotrone Trieste

IBIC2024 Sept. 9-13, 2024 · Beijing, China

First Experiences with the new Pilot-Tone based eBPM System in Elettra Storage Ring

G. Brajnik, S. Bassanese,
R. De Monte, G. Gaio

(Elettra - Sincrotrone Trieste, Trieste, Italy)

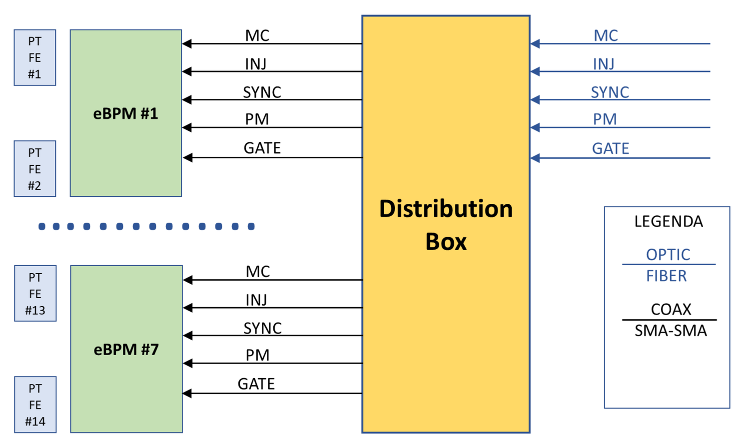
We present the first experiences acquired with the new eBPM system based on pilot tone compensation, developed for Elettra 2.0. After the successful delivery of seven complete systems, belonging to a pre-series production within the signed partnership with Instrumentation Technologies, we started their integration in the current machine.

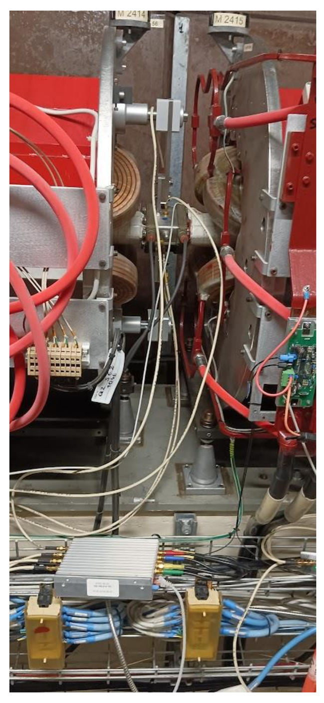
To do so, an entire section of Elettra storage ring has been equipped with the new systems: eight Pilot Tone Front End (PTFE) and four digital platforms (DAQ10SX). Tests were carried out during dedicated machine shifts, focusing on integration with the new global orbit feedback at different data rates (10/100 kHz and turn-by-turn), with and without pilot tone compensation.

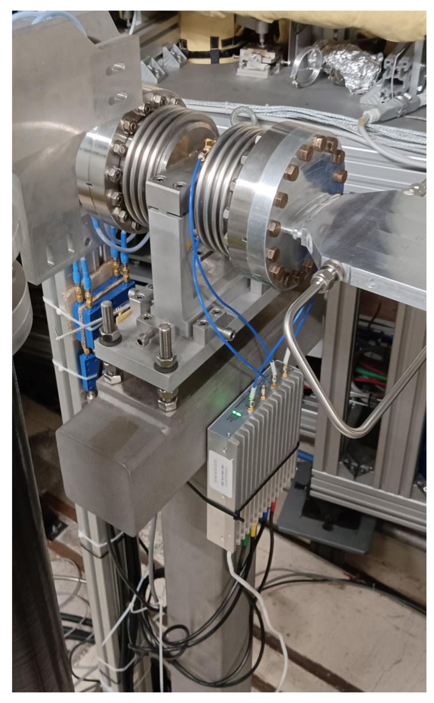
Nevertheless, triggered acquisitions were made in order to test first turn capability of the system. Another unit has been attached to a pair of spare pick-ups (low-gap BPMs), to continue the development of new features and to provide different types of data (raw ADC data, turn-by-turn calculated positions, etc.) for machine physics studies, even during user-dedicated shifts.

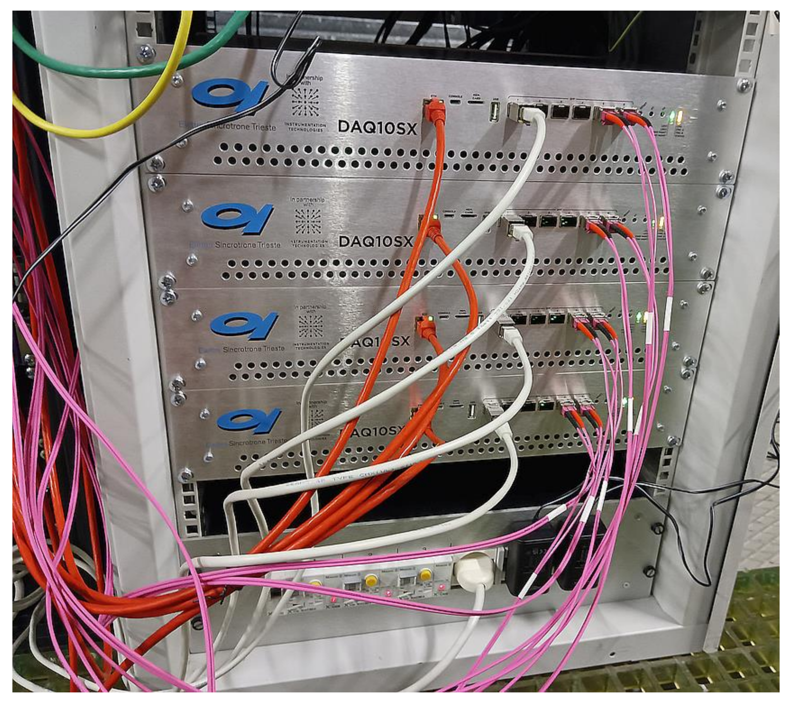
System Installation

Thanks to the a modular design, the analog front end with pilot tone injection (PTFE) is separated from the digital unit (DAQ). The front end have been installed in Elettra tunnel and connected to eight existing BPM pick-ups of section 6. Every DAQ unit is capable to acquire signals from two BPMs. Moreover, for machine physics studies, another pair of front ends have been connected to two low-gap spare BPMs in section 7, not involved in orbit calculation and thus available anytime. The digital units have been installed in Elettra service area side by side with older Libera Electron electronics and connected to two separate networks: the former for housekeeping and configuration, the latter, with 10 Gbit optical Ethernet connections, for feedbacks only. Useful timing and trigger signals are distributed to the electronics, like machine revolution clock (MC) for global synchronization and injection event (INJ).

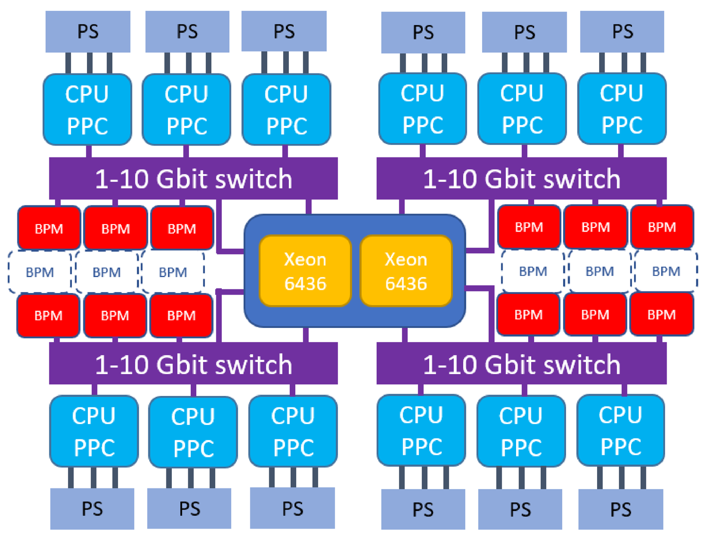








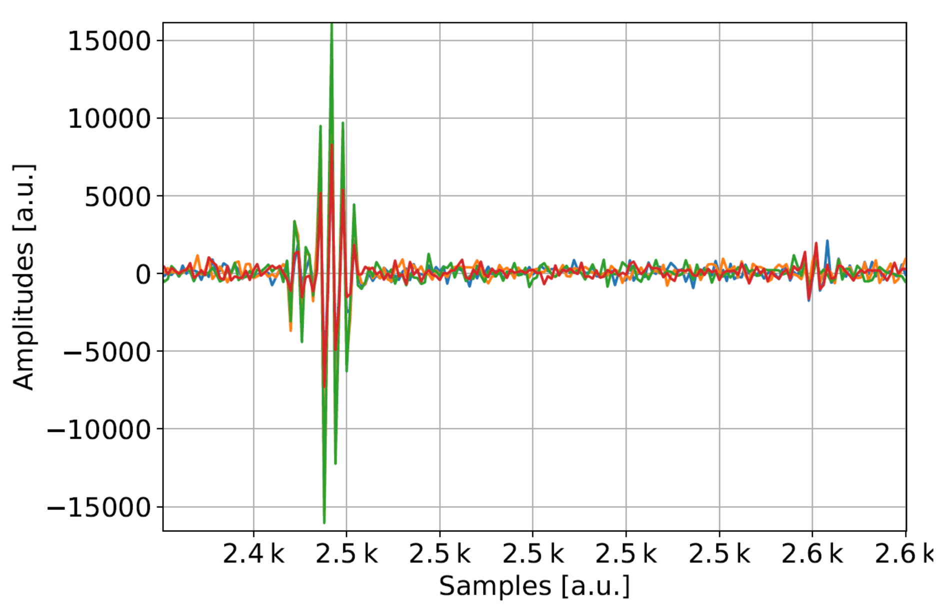
DPDK and Fast Global Orbit Feedback (GOF)



The Data Plane Development Kit (DPDK) is a critical framework enabling high-performance packet processing by allowing direct interaction with network hardware. DPDK is an industrial-grade solution widely used across various fields, including telecommunications, cloud computing, and research. In particular it is vital for real-time applications at Elettra, where both low latency and high throughput are essential. One of the main objectives of the latest fast orbit feedback upgrade is the integration of eight new BPMs into a test bench designed to closely simulate the operating conditions of Elettra 2.0. Additional goals include evaluating the hardware/software processing and network platforms, and addressing the limitations of the legacy fast orbit feedback system's processing power. These limitations had previously prevented the system from effectively eliminating noise from the aging power supplies, which are over 30 years old and produce harmonics up to 1 kHz due to the gradual deterioration of out of maintenance components. The new system, while is not the Elettra 2.0 configuration (which will be based on Xeon 6-P processors), already offers significant advancements. It is equipped with four 100 Gbit ports for receiving data from the BPMs and four 10 Gbit ports dedicated to setting the power supplies. The legacy correction system's CPUs now serve only as bridges, receiving settings and applying them to the DAC boards of the power supplies, instead of processing data from the Libera units. In this upgraded system, each network interface is supported by two dedicated cores. Additionally, there is one core dedicated to calculation, one for processing triggered data, and another core specifically for dynamic feedback gain control to prevent instability.

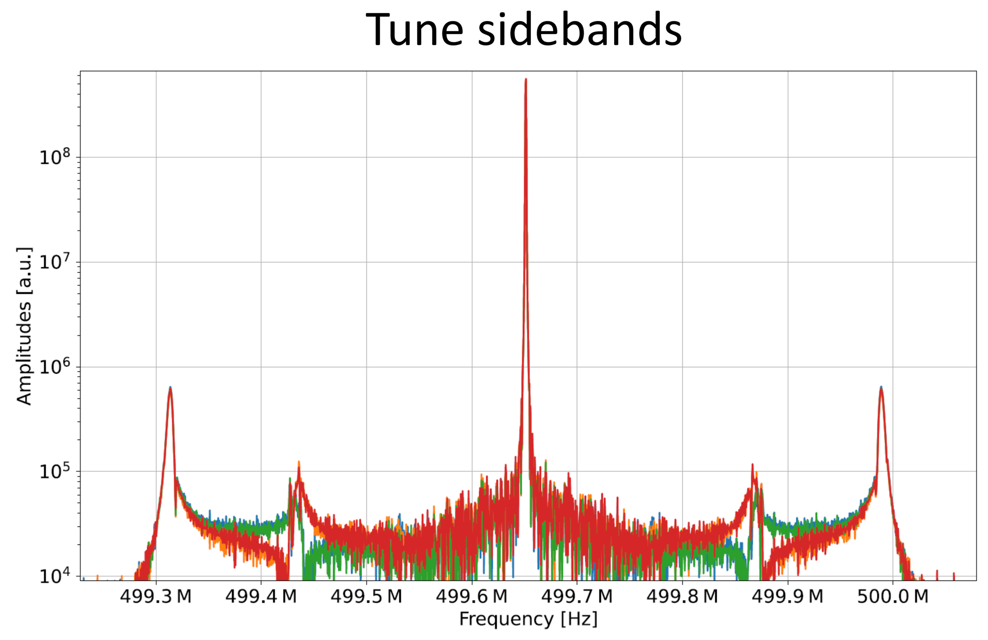
Tests with Beam

ADC buffer with first turn



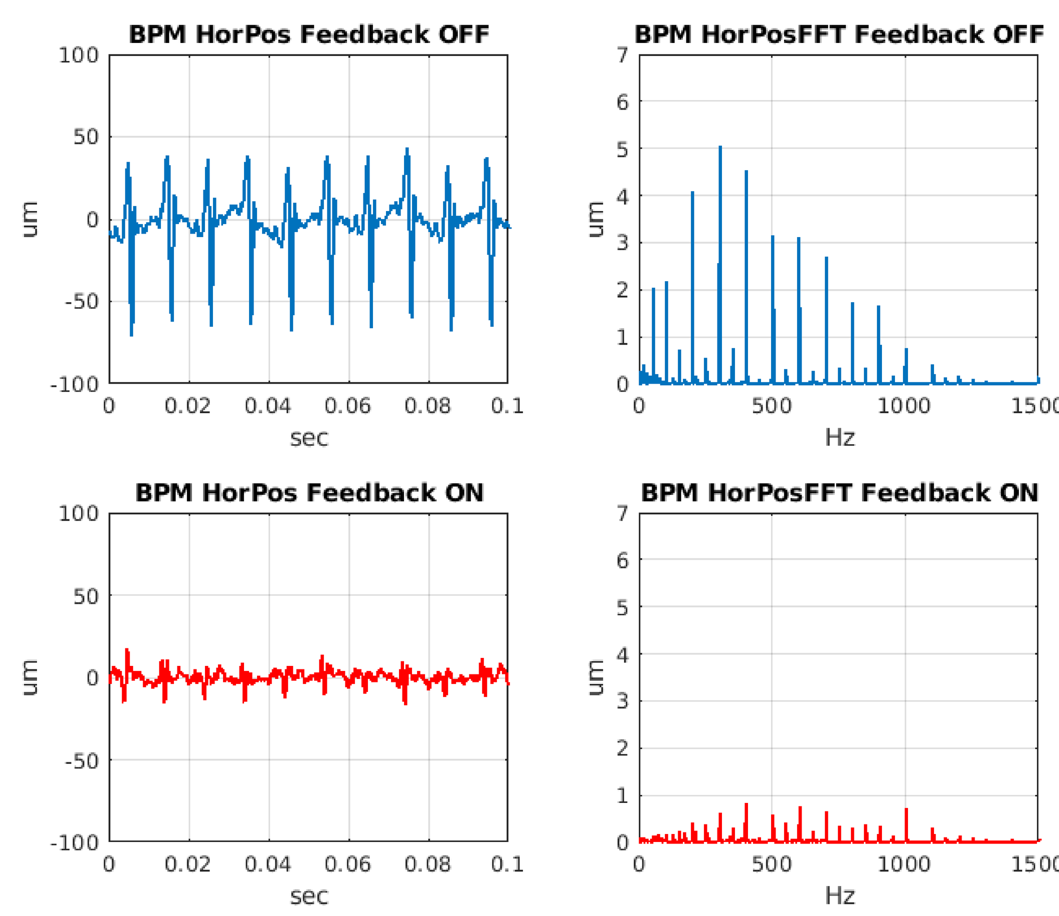
After extracting a single bunch of 0.75 mA coming from the booster, we inserted a fluorescent screen in the storage ring to stop it after one turn. The residual charge that is not completely stopped by the screen can be seen exactly 130 samples after the main signal, corresponding to one turn.

Tune sidebands



Tune sidebands are clearly visible during injection with stored beam at nominal current: horizontal tune is at 0.347 kHz from the carrier, while vertical tune is at 0.231 kHz (respectively 0.4 and 0.2 of the revolution frequency).

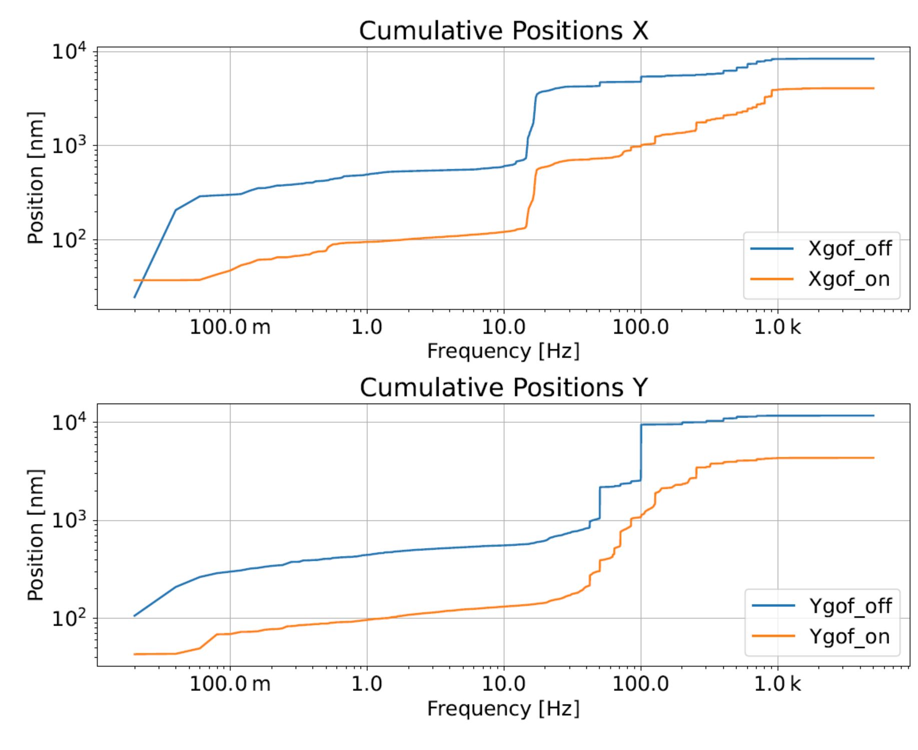
This enhanced setup has been operational under user conditions for over a month without any issues, seamlessly replacing the previous system without requiring modifications to high-level programs or graphical interfaces. Apart for the enhancement in the orbit stability, the system provides additional diagnostics that were not previously available in old Elettra storage ring, such as the capability of acquiring both data streams at 1.15 MHz and long ADC buffers from the new BPM electronics in parallel to feedback processing. The control algorithms in the new system include a PID controller for feedback, along with 13 notch filters at frequencies of 50, 100, 150, 200, 250, 300, 350, 400, 500, 600, 700, 800, and 900 Hz, effectively suppressing periodic disturbances. The total calculation time for these processes is just 10 microseconds.

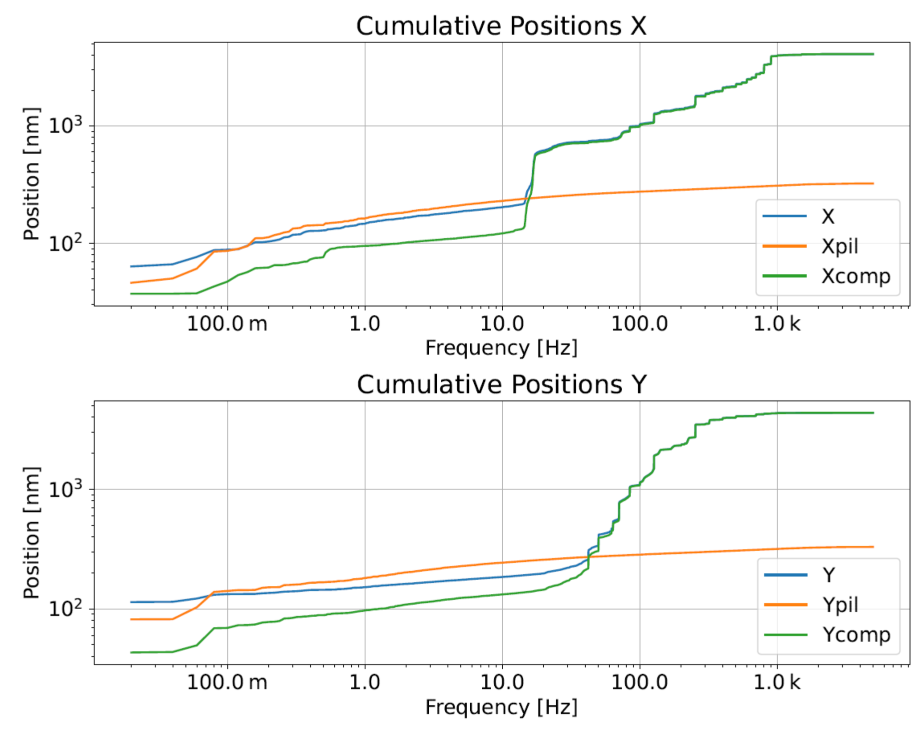


We successfully replaced a complete section of Elettra storage ring with new eBPM electronics based on pilot tone compensation, and integrated them in the control infrastructure of the current machine, enabling orbit correction and simultaneous operation with the remaining Libera Electron BPMs in the upgraded global orbit feedback. This transition has allowed us to test the new system's ability to handle the increased demands of Elettra 2.0, demonstrating its readiness for the upcoming full-scale implementation.

Noise Analysis

Figures below show various comparisons in terms of beam positions' cumulative power spectral density (CPS). While the former confirms the noise reduction due to the feedback, in the latter it can be seen the usefulness of pilot tone compensation in reducing 1/f correlated noise at low frequencies, with respect to uncompensated positions.





REFERENCES

G. Brajnik et al., "Integration of a Pilot-Tone Based BPM System Within the Global Orbit Feedback Environment of Elettra", IBIC'18
G. Brajnik et al., "Test and Measurements Results of the Pilot Tone Front End Industrialization for Elettra 2.0", IBIC'22
G. Gaio, et al., "A New Real-Time Processing Platform for the Elettra 2.0 Storage Ring", ICALEPCS'23
G. Brajnik, et al., "Elettra 2.0 eBPM: Complete System Overview", IPAC'23

FUTURE WORK

- Replace a second complete cell in Elettra storage ring with the new electronics
- Fine-tuning (firmware and software development) of the new system
- Increase reliability and usability in anticipation of Elettra 2.0 commissioning