BEAM MEASUREMENTS RESULTS OF A BPM SYSTEM IMPLEMENTING THE PILOT-TONE STABILIZATION CONCEPT

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Abstract

The next generation light sources will require Beam Position Monitoring systems capable of performing high resolution measurements as well as assuring long-term measurement stability. One possible solution to stabilize the position measurements long-term drifts is using a pilot-tone signal which is transferred together with the BPM signal and measured by the BPM electronics. To investigate this solution, Elettra Sincrotrone Trieste developed a pilot-tone injector which was used together with the commercial BPM readout electronics Libera Spark to validate the concept with several measurements related to the typical figures of merit of the BPM systems: position resolution, long-term drift and dependence from beam current and fill pattern. In addition, the behaviour of the system was studied under different environmental conditions (changes in temperature and humidity). After the first measurements with beam at Elettra Sincrotrone Trieste, the test-setup was provided also to other laboratories and the measurement results are presented in this paper.

INTRODUCTION

The pilot-tone (PT) signal injector was placed between BPM pickup and readout electronics. The compensation concept derives from telecommunications field where a known signal (PT in this case) is used as reference signal in order to apply correction to the second signal transferred over the same cable. Compensation is continuous and is intended to compensate drifts caused by temperature variation, change of cable properties and system tolerances [1].

The readout electronics was a modified Libera Spark with a modified front-end analogue filtering. The new band-pass region allows both signals (the beam's RF and the PT) to go through the RF chain down to the A/D converters. The digital filtering in Libera Spark separates both signals in frequency domain and processes them in parallel. The PT digital filter is run-time reconfigurable which allows for online PT frequency changes [2].

In this document we present stability results obtained over a several long-term tests under different conditions, including stable temperature, variable humidity and also comparison to the standard Libera Spark ERXR with no active compensation.

LABORATORY TESTS

The RF signal was generated by R&S SMB100A signal generator and connected to the PT injector through a 4 way splitter. Signal generator, splitter and PT injector were placed in a climatic chamber while cables and Libera Spark were placed outside in a room environment. The setup is shown in Figure 1.

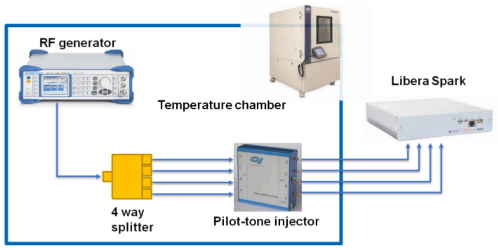

Figure 1: System setup.

The RF signal's frequency was set to 499.654 MHz and PT signal was generated at 502.17896 MHz. Both signals had same amplitude (within 0.2 dB). Since the PT injector's front-end consists of two consecutive attenuator stages, the first stage was set to lowest value in order to get higher SNR.

TEMPERATURE AND HUMIDITY LONGRUN IN CLIMATIC CHAMBER

The system was tested long-term in a climatic chamber, under different conditions and configurations:

- RF generator and PT injector kept in a climatic chamber at constant temperature
- RF generator and PT injector kept in a climatic chamber which varied the humidity

Libera Spark was placed outside the climatic chamber where environmental temperatures were recorded. Results are shown in Figure 2.

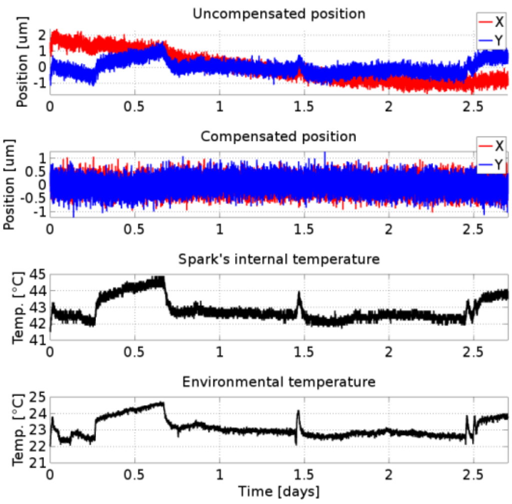

Figure 2: Results from long-term test at stable temperature.

The peak-to-peak position variation of non-compensated data is in range from 3-4 µm. After compensation is applied the peak-to-peak variation is approximately ±1 µm. The actual drift in the non-compensated position is between 1-3 µm while the compensated position drifts less than 0.5 µm (see Figure 2). Temperature inside the climatic chamber was set to 25°C. Spark and cables were exposed to room temperature which showed variation from 22.5°C to 24.5°C.

Table 1: Mean position variation when generators were placed to stable temperature.

	Horizontal position [µm]	Vertical position [µm]
Non-compensated	2.8	1.4
Compensated	~0.3	~0.3

The next test in the climatic chamber was to characterize the effect of the humidity variation (to the signal generator and pilot-tone injector) to position data. The Spark was still placed outside the climatic chamber and only RF and PT generators were exposed to variable humidity conditions. The temperature was kept at 20°C. Relative humidity was cycled between 30% and 80% (1 hour ramp, 8 hours stable, 1 hour descending ramp, 1 hour stable). The test ran for 1 complete cycle (1 day). Results are shown in Figure 3.

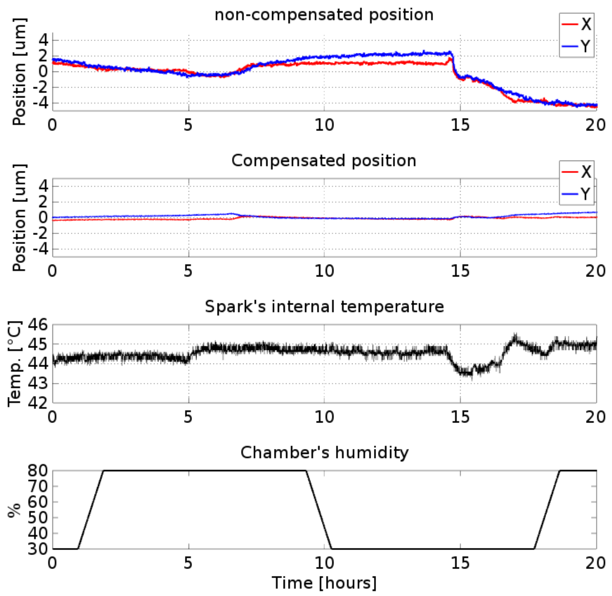

Figure 3: Results from long-term test at variable relative humidity.

Position drifts from non-compensated and compensated positions do not show any relation to humidity variation under which the RF and PT generators were exposed to. The absolute position drift, however, was large compared to results measured at stable climatic chamber temperature. Position drifted for about 6 µm in the non-compensated data and about 0.6 – 0.9 µm in the compensated data (see Figure 3). External temperature around the Spark varied in range from 23°C to 27°C.

Table 2: Mean position variation when generators were exposed to varying humidity.

	Horizontal position [µm]	Vertical position [µm]
Non-compensated	6.2	6.5
Compensated	0.4	0.8

LONG-TERM STABILITY TESTS AT ELETTRA

After the tests in the climatic chamber, we decided to compare a "standard" Spark with the pair composed by the pilot-tone injector and the modified Spark (without the SAW band-pass filters on the input channels) in a typical environment of an accelerator. The setup is shown in Figure 4 and schematically in Figure 5.

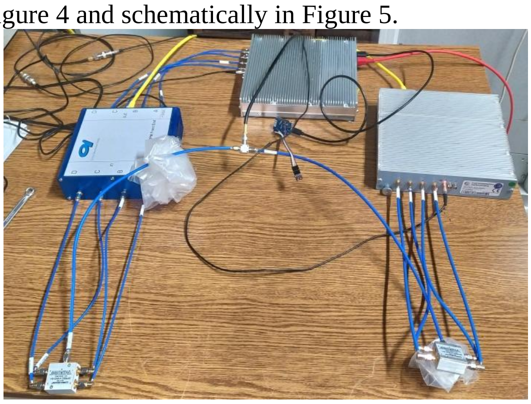

Figure 4: Test setup at Elettra.

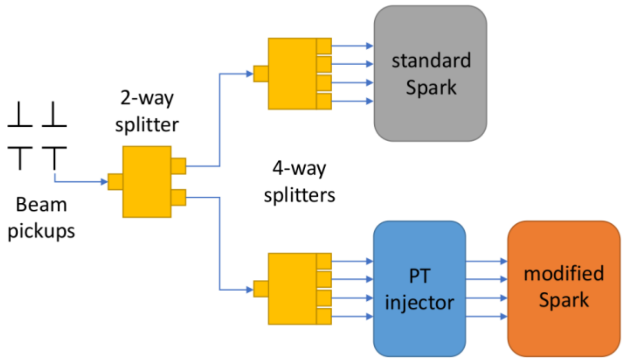

Figure 5: Setup overview.

Both the units were locked to Elettra machine revolution frequency (1.156 MHz), the RF frequency was 499.654 MHz, while the pilot tone was located between two revolution harmonics, at 502.6 MHz. The amplitudes of the carrier and the pilot were kept at roughly the same level (Figure 6).

Data was taken in a time window of about 20 hours, during a normal operation of the machine (beamtime for users), running at 2.0 GeV and 310 mA of current, in top-up mode with a standard fill pattern (90% of the buckets, without single bunch in the dark gap).

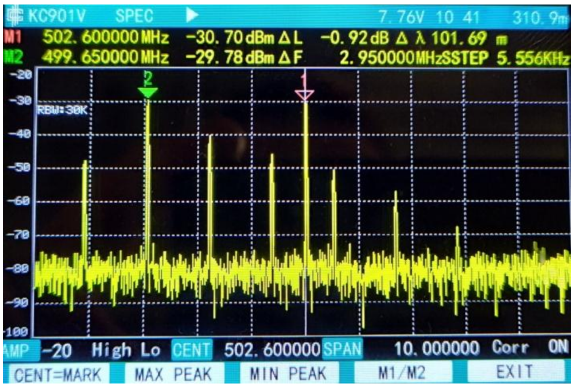

Figure 6: Spectrum at around 500 MHz showing beam and PT components.

The overall signal level at the ADCs inputs was about 2000 raw ADC counts for both units (full scale of 8191).

The Spark was equipped with temperature and humidity sensors that measured environmental conditions. During the test, environmental conditions were relatively stable (see Figure 7, lowest plot).

The wideband noise of the positions is about twice for the pair "modified Spark plus PT injector" with respect to the standard Spark (about 200 nm vs 400 nm). This was expected, due to higher noise figure of the injector and lower input signal from the beam in the modified Spark due to the presence of the tone (we choose to work at a constant ADC amplitude value).

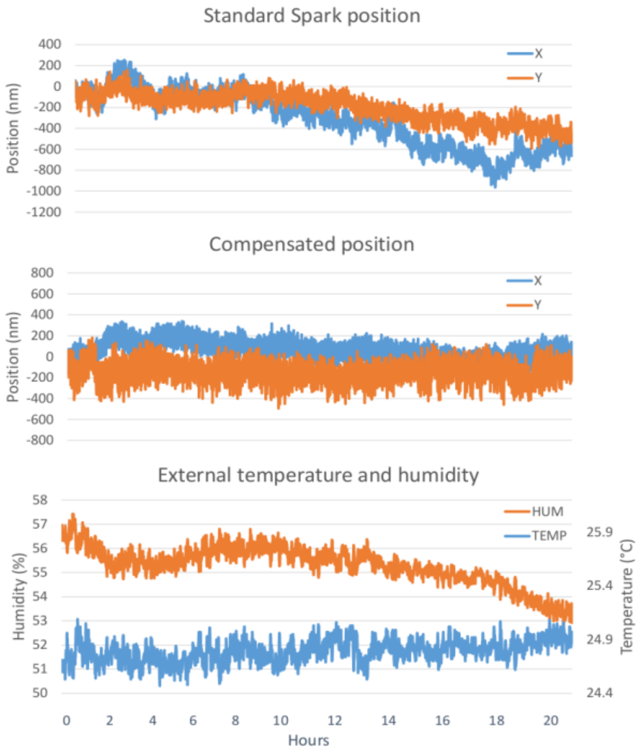

Figure 7: Comparison test results from beam measurements taken at Elettra.

Drift results are shown in Table 3 and Figure 7. For both setups the Kx and Ky button scale coefficients were set to 10 mm.

Table 3: Long-term test results.

Drift of mean position	**PT injector + modified Spark**	**Standard Libera Spark**
Horizontal	0.2 µm	0.9 µm
Vertical	0.2 µm	0.4 µm

There is no visible correlation between the standard Spark drifts and the temperature variations (internal and external). On the other hand, it seems that the little variation of the humidity has a certain impact both on standard Spark (heavier) and on the compensated X position (lighter).

CONCLUSION

The stability of the beam position monitoring system depends on many factors. Some of these are unavoidable and need a proper compensation mechanism that will correct for the drift caused by e.g. temperature or humidity variation, and minor change of gain in the cables. The system presented in the paper demonstrates the position stability is superior to the standard BPM readout system by at least a factor of 2. The effect of humidity changes needs further investigation. The pilot-tone stabilization concept has been integrated with Libera Spark electronics which provides the non-compensated and compensated narrow and wide-band data streams that can be used with orbit feedback systems.

ACKNOWLEDGEMENTS

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REFERENCES

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