AN IMPROVED BEAM POSITION MONITOR SYSTEM FOR THE ELETTRA LINAC AND TRANSFER LINE

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Abstract

The Transfer Line Beam Position Monitor (BPM) system is briefly described and the measurement results are presented. To improve global performances of the system a major revision both of the software code and of the hardware structure has been implemented and tested. A low-level data processing has been added in order to improve the measurement quality by reducing rms noise. At the same time, a single pulse measurement has been realized by a simultaneous acquisition of the four electrode signals.

Finally, a new dedicated VME board for non-circular machine BPM systems is presented: this will be the final solution for the ELETTRA Linac and Transfer Line BPM system development of which is foreseen for the next year.

1 INTRODUCTION

The Beam Position Monitor system used for the Elettra Linac and Transfer Line has been presented in previous papers [1,2]. These are two similar systems measuring the beam position at 9 stripline monitors along the Linac and at 7 monitors in the Transfer Line.

In its first configuration, the BPM system made use of two levels of multiplexing in order to read the stripline signals by means of a single digitizing oscilloscope.

During the tests, some critical aspects have been found out which limit system performances.

A system review has therefore been carried out both on measurement software and on system hardware architecture. The new solution has improved the performance, yet the measuring rate is not as high as desired.

In order to have a real-time, pulse-by-pulse, trajectory of the Linac and Transfer Line, a dedicated BPM detector board has to be developed: nevertheless it is worth noting that the development time devoted to the system has greatly contributed to a deep understanding of the major problems related to a similar measurement.

2 MEASUREMENT RESULTS

2.1 First test conditions

Late in 1994, some tests have been performed on the Transfer Line BPM system, as described in [1], in order to evaluate its performance.

It appeared that, due to the very noisy environment, the trigger set-up would have been of great importance in order to have a reliable measurement. So during these first tests, the scope (Tektronix 2440) optimum trigger configuration has been investigated.

By fully exploting the scope trigger and acquisiton features [3], the set-up of Table 1 has been defined.

Timebase A	external delay 200 μsec	10 μsec/div
Timebase B	ch1, trig_after	2 nsec/div
Acquisition window		14 nsec

Table 1: Scope timebase settings.

The external trigger to the Timebase A is provided by the machine timing system and it is the same pulse which is driving the injection elements (Pulsed Magnet Trigger, PMT).

In figure 1 the acquired pulses of the Σ and Δ hybrid outputs are shown.

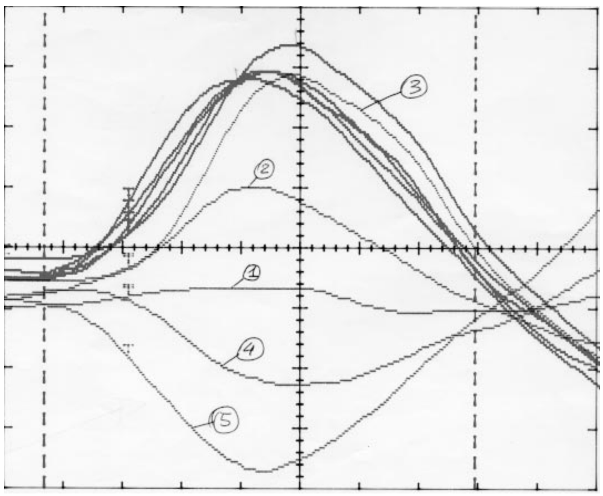

Figure 1: Σ and Δ signals from the hybrid: the Σ signals overlay, the Δ signals have different apmplitude according to upstream steering magnet corrector settings.
Vertical scale: 2mV/div
Horizontal scale: 2 ns/div

2.2 Test results

The tests on the machine were done with two Transfer Line BPMs (T1.1 and T1.2) and a steering magnet (CH_T1.2), on a 5 mA (@1 GeV) 20 ns long

Linac pulse. While changing the magnet current (in 1 A steps) the position was recorded. The main results are:

- good linearity
- good plane separation
- accuracy (rms) 150 µm within ± 2.5 mm

2.3 Critical aspects

Some critical aspects appeared to limit the global system performance.

1. Since the position was computed on two quasi-consecutive Linac pulses, the global measurement noise was affected by pulse-to-pulse Linac beam transverse movements.
2. Due to the use of an hybrid, to compute the Δ and Σ signals, with the beam in center the difference signal was almost equal to zero and therefore the scope was working at its resolution limit (8 bit A/D).
3. The position readings have large fluctuations and therefore they are not suitable even for a slow feedback operation, usefull for correcting long term drifts in the Linac orbit.

3 SOFTWARE IMPROVEMENTS

To overcome the above mentioned problems a major review of the system architecture has been carried out: both measurement software and hardware set-up have been improved.

3.1 Measurement code review

The system is based on a VME crate equipped with 68030 Central Process Unit (CPU), running under OS/9 operating system. The scope is driven via a GPIB interface. The measurement process has to be as fast as possible in order to keep a rate of 2 BPM readings/sec..

The bottleneck is represented by the CPU-scope communication via-GPIB, together with the scope response times. Therefore it was decided to minimize the scope-CPU communication, avoiding for instance the automatic level adjustment which was very time consuming. The scope is only acquiring the waveform and computing the peak value of the pulses, reporting if the acquisition has been correctly carried out.

3.2 Data average buffer

In order to reduce the rms noise on the measurement, an average on the row position data is necessary.

The scope can in principle perform the acquisition of up to 16 waveforms, but this solution has many dis-advantages:

- the read-out time is increased by a factor of 4
- as the initial system needed two Linac pulses (one for each X, Y plane) to compute one position value, doing the average on the scope would have meant to combine average values relative to time-separated pulses, even by more than one second.

To overcome these problems, a FIFO buffer (with a length of 10) has been implemented on the measurement software: this solution gives a new position value at each new instant position acquisition.

The introduction of these new data structure has led to an improvement of the rms noise by a factor of four, without any over head for the scope (refer to fig.2).

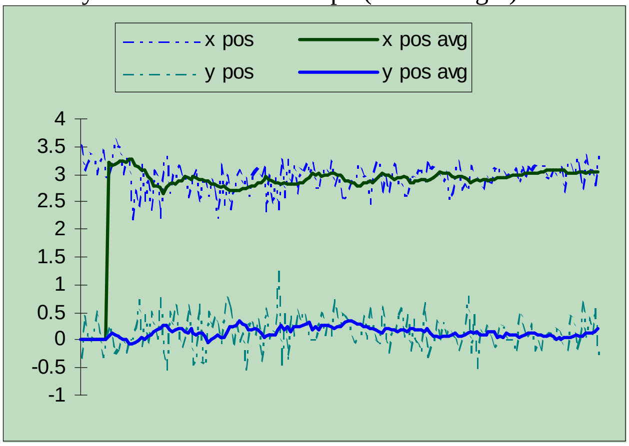

Figure 2: Noise reduction with low-level average (plot from real beam: data rms=300µm, avg rms=70µm).

Other improvements concern the strategy of the measurement process when the beam is absent (a search routine, with slower scope Timebase, is started while a flag is raised), the checking of not-consistent data (for example when a single plane has been acquired), the management of time-outs in case of an incorrect scope acquisition.

4 HARDWARE IMPROVEMENTS

4.1 Single pulse position reading

As stated before, by using a single two-channel digitizing scope two Linac pulses are necessary to compute the position at one BPM.

Beside slowing down the measurement (1 Linac shot/100 ms) this also adds some noise due to Linac pulse-to-pulse motion.

It was decided therefore to go to a two scope solution (see Figure 3) with a single-pulse position reading. In implementing this solution the hybrid has been removed so that the scopes always acquire signals that are not close to zero amplitude.

4.2 Acquistion synchronization

To synchronize the measurement on the two scopes we have to be sure that both of them are armed before acquiring a Linac pulse. This has been implemented by multiplexing the trigger signal as the CPU-to-scope write cycle is in the range of the repetition rate. Normally, PMT trigger signal is not connected to the scopes: only when the measurement process has armed both scopes, then it switches the multiplexer and the next PMT pulse get to both scopes simultaneously.

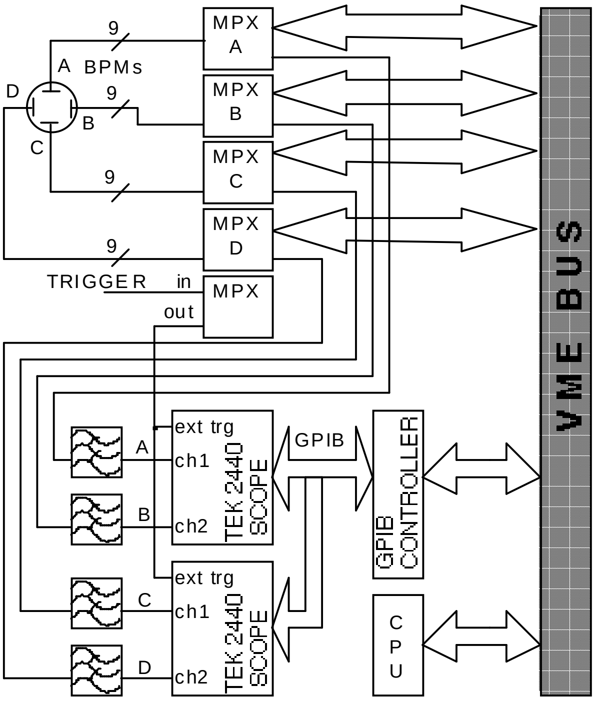

Figure 3: block diagram of the single pulse measurement

4.3 Tests with a simulated beam

The new solution has been tested on a simulated beam, by means of a pulse generator and two step attenuators. By varying the attenuation of one pair of simulated electrode signals with respect to the other pair, a beam motion in both planes has been simulated and the results plotted.

With an average peak of 17 mV on each scope input channel (rms noise=0.4 mV), the x,y position have been computed over ± 6 mm by attenuating the signals in steps of 2 dB. The rms on the instant position was ≈180 µm, whereas the averaged data rms was ≈40 µm (see Figure 4).

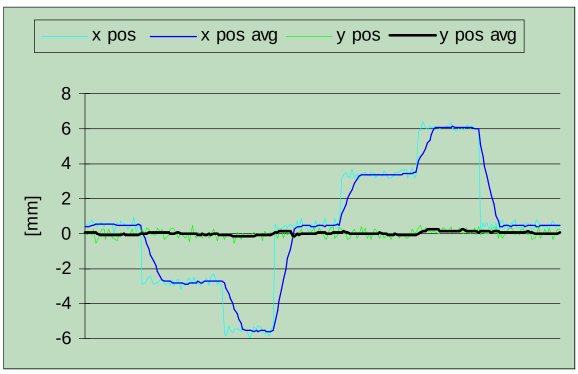

Figure 4: Position readings on a simulated beam.

4.4 Tests with beam

Some preliminary tests have been carried out on the Linac beam. The measurement results are in agreement with the expectations.

The rms of averaged data has been meaured to be as low as 20 µm (off-center beam) and 50 µm with in-center beam. The same improvement factor due to data averaging (4) has been measured.

At present the position is measured on a single Linac pulse. To reduce the variation in position readings multiple scope acquisition can be performed before calculating the position: an optimum value of four acquisitions has been found out. In this way the size of the FIFO buffer can be reduced (from 10 to 4) and the CPU time per cycle reduced. The global averaging factor results to be 16. Further tests will be performed.

5 THE PULSE BPM DETECTOR BOARD

The single pulse scheme improves the single measurement speed and accuracy, yet to have a whole Linac or Transfer Line trajectory, one has to wait for about 10 seconds. To reduce this time by an order of magnitude the only solution is to remove the multliplexing between the BPMs, together with the scopes, and to design a dedicated BPM detector VME board.

The main features of this board are:

- four inputs, to acquire one BPM
- smart trigger with external trigger input
- programmable delays for fine triggering
- low-pass filter and variable gain for each input
- on-board CPU (µ-P or DSP)
- dual-port RAM for master CPU communication

The use of an on-board CPU greatly improves both measurement rate and reliability. The master VME CPU is only dedicated to the data collection from the field and to the communication to the High Level of the Control System.

6 CONCLUSION

The BPM system for the Linac and the Transfer Line of ELETTRA is presented. The rms of the position data is now well below 100 µm, typically between 20 to 50 µm, depending on beam position. The only way to definitely improve the read-out speed is the implementation of the new dedicated board.

REFERENCES

[1] J. C. Denard et al., “Beam Diagnostics of the Elettra Injector” in EPAC ‘92 Berlin March 1992

[2] R. Ursic et al., “Measuring the Beam Position in the Elettra Linac” in EPAC ‘92 Berlin March 1992

[3] TEK 2440 User guide and Programmer’s Manual