CURRENT STATUS OF THE ELETTRA/SLS TRANSVERSE MULTI BUNCH FEEDBACK

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Abstract

We report on the current status of the ELETTRA/SLS transverse multi bunch feedback system, consisting of pickup, analog RF front end, a 500 MS/s multi tap filter implemented via a parallel DSP farm, broadband amplifiers and microwave kickers. With the RF front end prototype, a set of measurements with beam has been done and various transverse instabilities identified. To minimize the effect of the analog-to-digital converter granularity, we developed a stand alone, analog common mode rejection module. The module, using analog multipliers and dividers to process the signals from the RF front end, outputs horizontal and vertical position signals with reduced common mode components. Design and construction of the microwave kickers has been completed and first tests have been performed.

1 INTRODUCTION

A Transverse Multi Bunch Feedback is being developed in collaboration between ELETTRA and the Swiss Light Source. It consists of a wide-band bunch-by- bunch system where the positions of the bunches, separated by 2 ns, are individually sampled and corrected. Figure 1 shows the block diagram of the system which is being installed at ELETTRA. The wide band signals from the four button pickups of a Beam Position Monitor (BPM) are combined in a hybrid network producing X, Y and I signals. These are demodulated into baseband by an RF front-end working at a center frequency of 1.5 GHz. In order to detect any possible mode of oscillation, a 250 MHz bandwidth is needed for the baseband X, Y signals, which represent the position of the bunches as they pass through the BPM at a frequency of 500 MHz. Considering now only one of the two transverse planes, the horizontal X signal enters into a 'Common Mode Rejection' module rejecting its DC closed orbit and revolution harmonic components, which can limit the dynamic range of the feedback and eventually lead to a waste of expensive RF power.

The baseband bunch-by-bunch position signal is sampled by an eight bit 500 Msample/s analog-to-digital converter (ADC) and digitally processed by an array of Digital Signal Processors (DSP) calculating the correction kick amplitude for each of the bunches independently. A more detailed description of the digital processing and timing electronics is given in [1]. After being re- converted by an eight bit 500 Msample/s digital-to-analog converter (DAC), the correction kicks are amplified by a RF power amplifier and applied to the kicker.

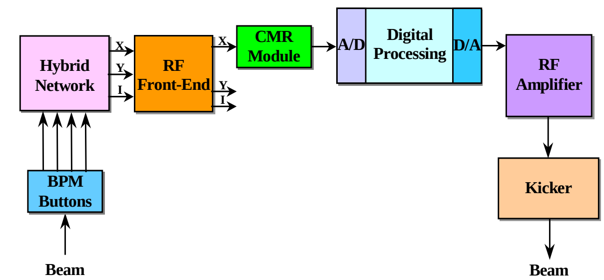

Figure 1: Block diagram of the multi bunch feedback.

2 RF FRONT END

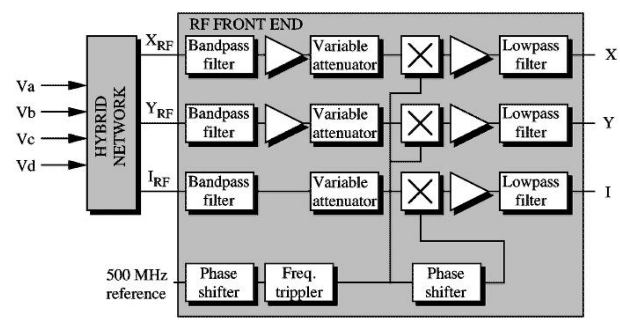

Figure 2: Layout of the RF front end.

The RF front end, whose layout is shown in figure 2, takes the raw sum and difference signal coming from the hybrid and mixes the 1.5 GHz input signal to base band. A list of technical parameters is given in table 1. For the common mode rejection described in the next paragraph, also the sum signal is processed.

Table 1: Parameters of RF front end

Center frequency	1.5 GHz
X,Y input signal range	-49 dBm to -29 dBm
I input signal range	-23 dBm to -3 dBm
X,Y channel noise figure	5 dB at -49 dBm input
Output spectrum window	40 kHz to 250 MHz
Max output level	1 Vpp/+4 dBm at 50 ohm
Overall bandwidth	
1 dB	250 MHz
3 dB	300 MHz
Phase shift control range	$>$ 430 degrees at 1.5 GHz
Gain control range	20 dB

A prototype of the RF front end has been manufactured and tested together with beam. The measurement setup consisted of a button BPM and a set of passive hybrids to generate the sum and difference signals leading into the RF front end. In order to be able to see ongoing multi bunch instabilities, the follow approach was chosen. With a real time scope, several turns of position and intensity data were recorded from the RF front end output. Each turn of data was transformed into the Fourier domain separately. The absence of instabilities means, that all turns and so also their Fourier transforms are equal. An ongoing instability leads to a change in phase and amplitude of consecutive Fourier transforms, of which the phase is quite easy to detect, as shown in figure 3. The signature of a longitudinal shows up in all, position and sum signals, whereas transverse movements only show in their respective position signal.

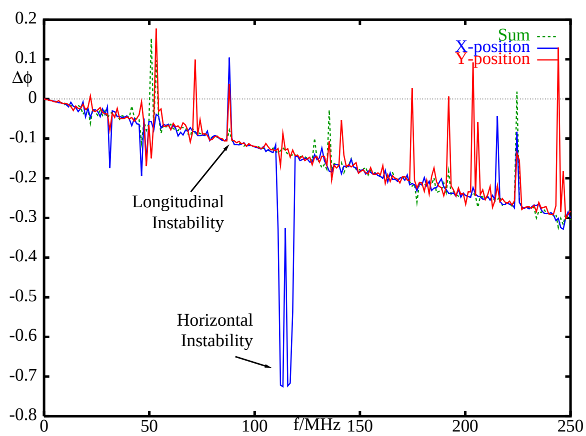

Figure 3: Measurement of multi bunch instabilities with the RF front end.

3 COMMON MODE REJECTION

An important factor for the noise behavior and sensitivity of the feedback system is the required position range, which has to be digitized by the ADC. This range consists of instability movements of the beam and static position offsets, which should be removed by a common mode rejection.

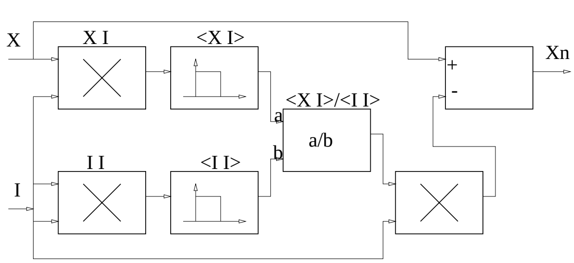

Figure 4: Block schematic of common mode rejection.

With X as position and I as intensity, we use an approximation of the least squares method in order to remove this static offset:

$$X_n = X - I\frac{< XI >}{< II >}$$

For ease and affordability, we implemented this using commercial analog circuits for multiplication and division with the averaging being done via low pass filters as shown in figure 4.

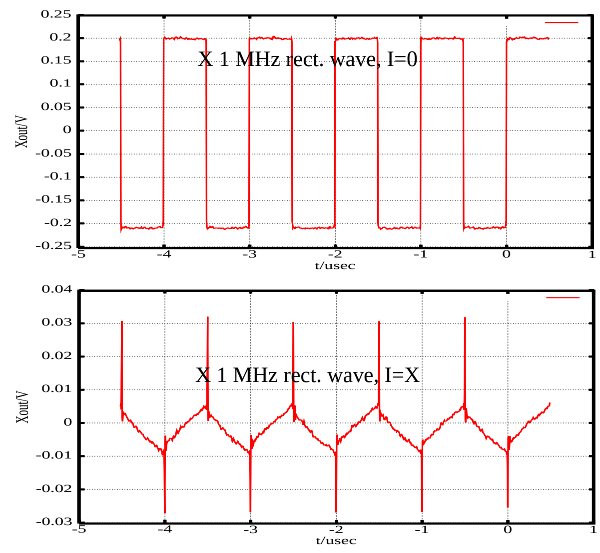

Figure 5: Measured performance of CMR.

Measurements showing the performance of the system are displayed in figure 5. As an excitation for the position input X, a 1 MHz rectangular wave was used. In the first measurement, the sum input I was grounded, so that simply the original input shows up. In a second measurement, the sum input received the same signal as the position input, so that ideally the output should go to zero. In reality, one sees two effects, one being a triangular wave, which is due to the low pass filters, and the other being sharp spikes, which are probably due to slight mismatches in the group delays for the different signals. Overall, on sees a reduction of the output signal by a factor seven, which is appropriate for our purposes.

4 FEEDBACK KICKER

The last part in the feedback chain are the horizontal and vertical microwave kickers, which have been optimized for a high shunt impedance and low broad band interaction with the beam. A drawing of the whole ensemble is shown in figure 6.

The electrode configuration was chosen to match closely the chamber cross section in the injection straight of the SLS storage ring in order to minimize the broad band impedance. Since the chamber is rather wide horizontally (90 mm), a split electrode design was chosen for the horizontal kicker in order to improve the shunt impedance to a value of 15 kohm. Further details can be found in [2].

Since ELETTRA has a different chamber cross section, a set of 300 mm long taper was fabricated in order to have a

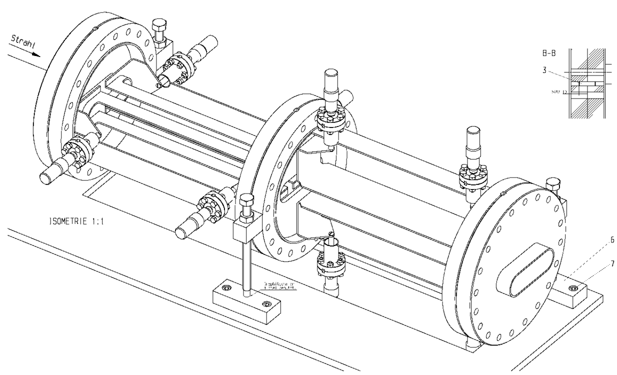

Figure 6: Cut away view of the feedback kicker ensemble

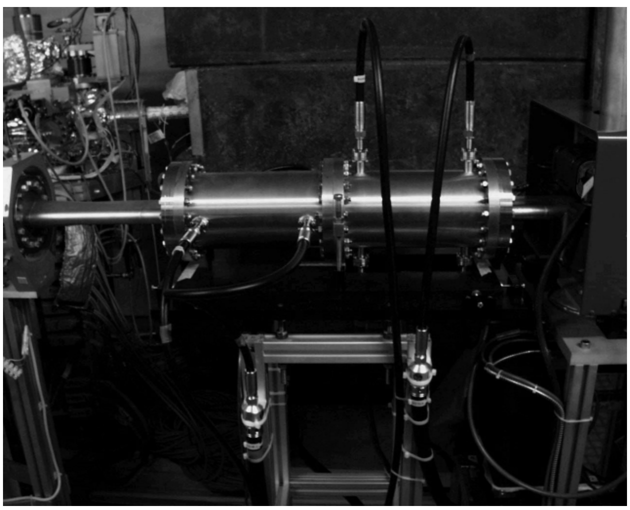

Figure 7: Photo of the feedback kickers in the ELETTRA storage ring.

smooth transition. A first set of kickers has been fabricated and brought into the ELETTRA storage ring (Figure 7).

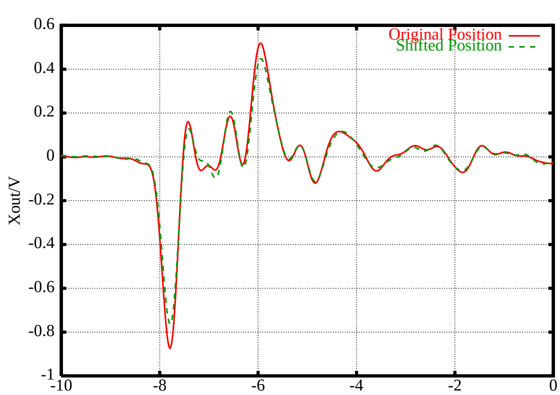

Figure 8: Response of the upstream port of horizontal kicker to single bunch beam at different positions

Among the beam tests done was one trying to evaluate the time domain response of the kickers. Since the beam response to a pulse at the kicker input is hard to measure, we used the inverse method, by evaluating the response of the upstream kicker ports to a single bunch beam. The response is dominated by the even mode TEM wave on the electrode pairs of the kicker, whereas one is interested in the deflecting odd mode wave. A way to get it is to measure the kicker response at different beam positions, as seen in figure 8. The difference of both gives the odd mode impulse response. To come from there to the time domain response of the deflection, we have to integrate the corresponding signal. As we can see in figure 9, the behavior of the signal corresponds relatively good to theory, with big peaks, when the beam is passing the strip line gaps, and the long term pulse response dominated by high frequencies in the GHz region. The kick response shows a nice rectangular shape, with an overlap at neighboring bunch positions of 20%.

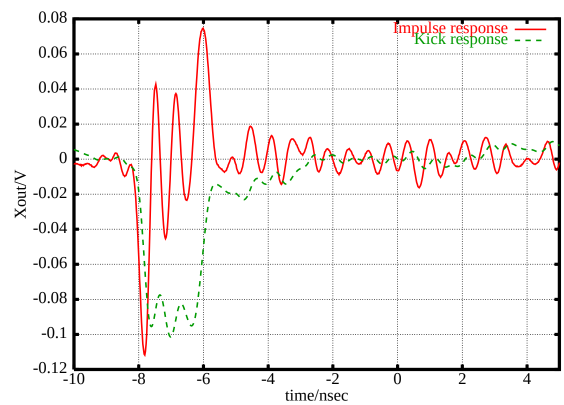

Figure 9: Difference signal giving the odd mode response of the kicker and resulting kick response.

5 OUTLOOK

The Transverse Multi Bunch Feedback system is being installed at ELETTRA. The hybrid network and RF front-end electronics have been installed together with the horizontal, vertical kickers and RF amplifiers. A Common Mode Rejection module prototype is under test. The processing electronics for the first of the two transverse planes will be available from mid of July. Timing electronics is completed. Installation at the Swiss Light Source is foreseen by 2001. Taking advantage of the modular architecture of the processing electronics, the same ADC, DAC and DSP board types will be used in a future Longitudinal Multi Bunch Feedback system for the two facilities, whose development should start by next autumn.

REFERENCES

[1] D. Bulfone, C. Gamba, M. Lonza, “Digital Processing Electronics for the ELETTRA transverse Multi-Bunch Feedback System”, proceedings of the icalepcs 99, 4-8 October 1999, pp. 255-257.

[2] M. Dehler, “Microwave kicker design for the transverse multi bunch feedback ”, SLS note, to be published.