

# FIRST TESTS OF THE TRANSVERSE MULTIBUNCH FEEDBACK AT DIAMOND.

A. F. D. Morgan, G. Rehm, I. Uzun, Diamond Light Source, Oxfordshire, UK

## Abstract

This paper describes the design and initial tests of the transverse multibunch feedback system under development at Diamond. The system is designed to damp instabilities up to 200 MHz in both the vertical and horizontal planes. This will lead to an increase of effective instability thresholds which will permit a reduction of chromaticity and thus should improve dynamic aperture and lifetime.

## OVERVIEW

The Transverse multibunch feedback system (TMBF) is used to damp down instabilities below 200 MHz. It operates on a per bunch basis and is intended to be used in parallel with the global orbit feedback system. Figure 1

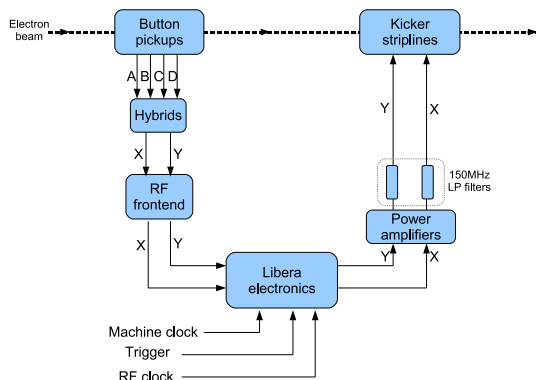


Figure 1: Current TMBF schematic

shows the system level structure of the TMBF system. The position of each bunch is picked up by a set of four button pickups. The resulting signals are then passed through a set of hybrid combiners to generate the X and Y position signals. These signals are passed into the RF frontend where the signal is filtered and amplified to the correct level for the electronics. The electronics calculate the motion of each bunch and the resulting correction required to damp any instabilities. This information is passed to a power amplifier which, through some low pass filters, drive two sets of kicker striplines (one in X and one in Y) to apply the corrections to the beam.

## DETAILS

The button pickups are capacitive pickups of the same type as are used in the EBPM system. The basic geometry is shown in figure 2.

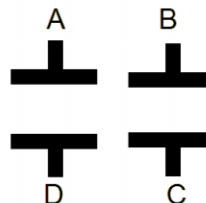


Figure 2: Button pickup geometry

The hybrid system comprises four hybrid combiners in the configuration shown in figure 3. The hybrids are located close to the beam pipe and are connected to the buttons with well defined lengths of semi-ridged cable, in order to maintain the relative phases of the signals. This arrangement means that the phase dependent conversions are done as soon as possible and eliminates the need to maintain the exact phase relationships over the 30 m of cable from tunnel to instrumentation area.

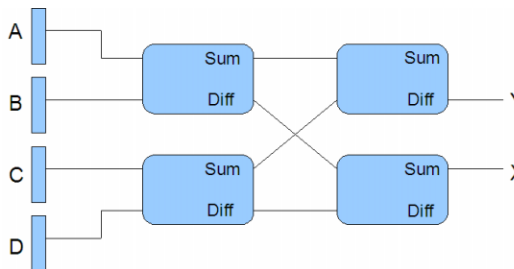


Figure 3: Pickup hybrid configuration

The RF frontend is an in house development inspired by an existing ESRF design [1]. Its job is to clean up the incoming signals to a quality suitable to go into the electronics. It first passes the X (Y) signal through a band pass filter to select the 4<sup>th</sup> harmonic (The 4<sup>th</sup> harmonic is used as it has the most power in it). This is then amplified and mixed with the frequency quadrupled machine RF signal to bring the signal back to baseband. It is then passed through a 200 MHz low pass filter to remove any residual high frequency signal generated by the mixing process. Finally it is passed through a last amplification stage to output the correct signal level for the electronics.

For the electronics we selected the Libera Bunch-by-Bunch processor platform developed by Instrumentation Technologies for the digital signal processing and correction signal generation. A block diagram of Libera electronics is shown in figure 4.

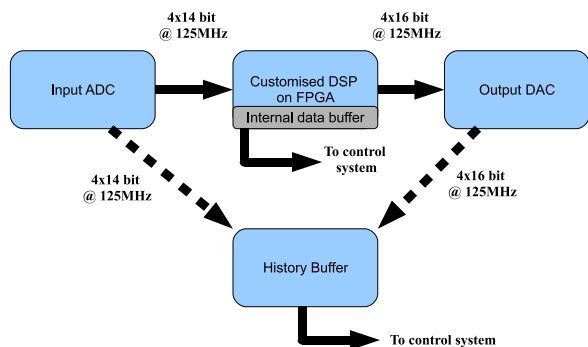


Figure 4: Libera electronics schematic

The X (Y) position data provided by the RF frontend is sampled by the Libera analog module which consists of four ADC channels. Each ADC is clocked at 125 MHz ( $\frac{f_{RF}}{4}$ ) and the channels have phase shifts of  $0^\circ$ ,  $90^\circ$ ,  $180^\circ$  and  $270^\circ$ . This interleaving effect allows the 4 ADCs to act as 1 ADC clocked at RF frequency, thus allowing every bunch to be measured individually.

Data from the four ADCs is processed in the customised DSP block implemented on a VirtexII Pro FPGA. The FPGA design is based on an ESRF design [2]. It consists of four identical FIR filtering channels for parallel processing of the four ADC channels. Each channel (n) processes bunch numbers n, n+4, n+8, . where n=1,2,3,4 is the channel number. The FIR filters are sinusoidal in shape with no windowing and have 8-taps for the vertical plane and 9-taps for the horizontal plane. The design also has a 16K-sample internal data buffer for mode scan response analysis to allow us to find the loop delay of the system, and grow damp scan analysis to allow us to calculate the damping time of the system.

The correction signal (Z) for each bunch, every turn, is calculated from the input error signal of an FIR band pass filter centered around the tune frequency, then a  $-(G \times Z)$  correction kick is applied to each bunch every turn (G being gain of the FIR feedback term).

Finally, the output data goes to a fast DAC for analog output and then to the power amplifier.

Additionally, there is a history buffer which is used to store data for off-line analysis. Either data from the input ADC or the output DAC can be stored. Both the history buffer and the internal data buffer can be accessed from the control system, allowing us to troubleshoot problems much

Beam Instrumentation and Feedback

more efficiently [3].

The power amplifiers take the analog output signal from the electronics and drive the striplines to apply the correction. The striplines are of the SLS 500 MHz resonant type [4]. Currently only one of each pair of striplines is excited. The 150 MHz low pass filters are to protect the amplifier from beam induced signal coming back from the striplines. These are a temporary measure until the final 300 MHz filters are available.

The loop delay of the system has to be such that the correction is applied an integer number of turns after the pickup (to ensure the correct bunch is addressed) and the signal must be  $180^\circ$  out of phase with the motion to achieve damping. In our setup the nominal delay between pickup and correction is 9 turns in the horizontal plane and 8 turns in the vertical plane. The phase of the analog output can be adjusted by tuning the FIR filter coefficients. The phase can be tuned from  $-\pi$  to  $\pi$ . The correct loop delay was achieved in two stages. The delay in the FPGA can be adjusted in 8 ns steps from 0 to revolution period. So the initial delay was corrected to within 8 ns in this fashion. The fine tuning was done by adjusting the cable lengths between the components. In the horizontal plane the actual delay has been adjusted to within 0.1 ns. of the nominal.

## INITIAL RESULTS

The system for the horizontal plane has been tested by setting the horizontal chromaticity to zero and applying the feedback. As can be seen in figure 5 the TMBF system is generally effective at damping down the horizontal instabilities.

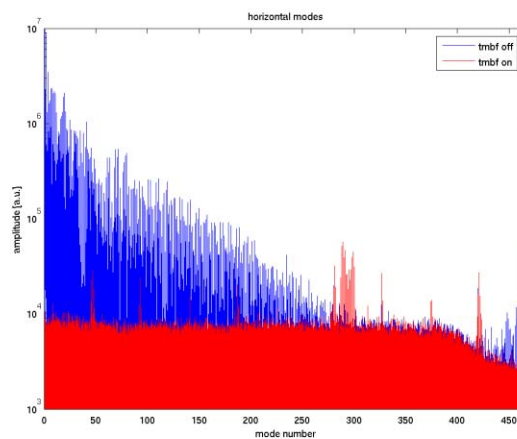


Figure 5: Amplitudes of the modes of horizontal beam motion with and without feedback

The enhancement around mode number 300 is thought to be due to the roll off (and related phase shift) of the 150 MHz low pass filter between the amplifier and the kicker striplines. The further reduction after mode 400 is due to the 200 MHz low pass filter in the RF front end.

Feedbacks

A first damping time measurement was done by exciting a mode 10 for 350 turns, then turning on the feedback and waiting for the amplitude of oscillation to drop to  $\frac{1}{e}$ . Figure 6 show the effect of increasing the strength of the feedback correction. The damping time for the system is about 700 turns and we are currently limited by the accuracy of our loop delay. However, we hope to improve this as the commissioning of the system continues.

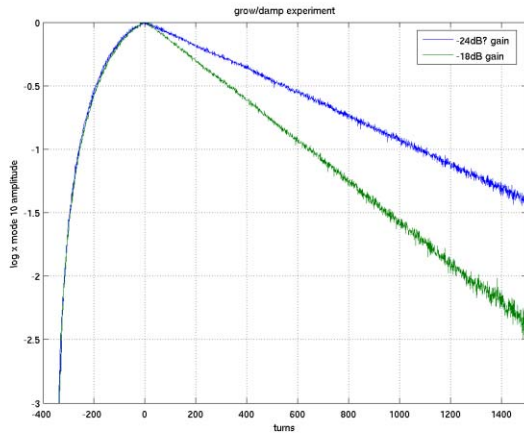


Figure 6: Damping time of mode 10 for two correction strengths

Figure 7 shows the effect of the feedback on the oscillations within the bunch train. Our initial results show an overall reduction in the amplitude of the instabilities at zero horizontal chromaticity, however, the feedback system also seems to drive an oscillation at 62 MHz, corresponding to an oscillating period of 8 bunches which needs further investigation.

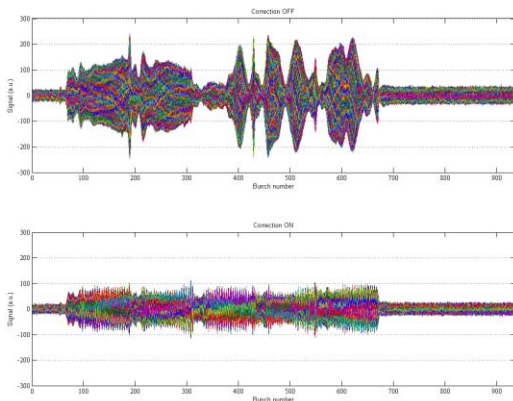


Figure 7: Amplitudes of motion of individual bunches with and without feedback

## FUTURE DEVELOPMENTS

We are planning to pass the correction signal through some hybrids to allow the kickers to be driven in a differential mode, which results in a more uniform field and lower power demands on the amplifier. The hybrids will also offer the amplifier some additional protection as only out of phase signals will be routed back to the amplifier (the rest being passed to a termination on the 4<sup>th</sup> port).

It is also intended to replace the 150 MHz low pass filter with a 300 MHz low pass filter to allow correction of the higher frequency modes and to remove the enhancement around mode 300. Figure 8 shows the final system design.

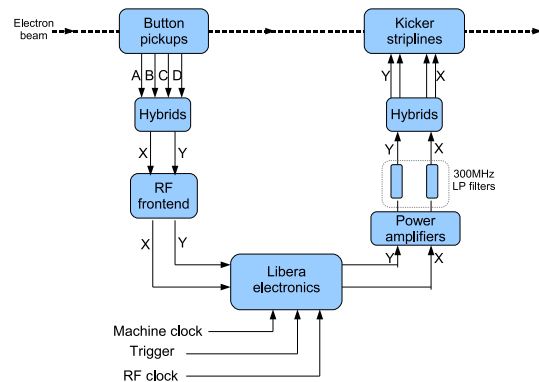


Figure 8: Final TMBF schematic

## CONCLUSION

The TMBF system has been tested in the horizontal plane and proven its ability to correct horizontal instabilities with chromaticity set to zero. The initial results are encouraging, however, further commissioning is required to optimise the correction and to bring the vertical system up to the same standard.

By combining existing designs into a full system we have been able to very rapidly develop and implement a very competent TMBF system.

## REFERENCES

- [1] Private communications with E. Plouviez
- [2] E. Plouviez, P. Arnoux, F. Epaud, J. Jacob, J-M. Koch, N. Michel, G. A. Naylor, J-L. Revol, V. Serriere, D. Vial Broadband Bunch by Bunch Feedback for the ESRF using a Single High Resolution and Fast Sampling FPGA DSP. Proceedings of EPAC 2006
- [3] G. A. Naylor, Beam Diagnostic Features of the ESRF Multibunch Feedback Systems (This conference)
- [4] M. Dehler, V. Schlott, D. Bulfone, M. Lonza, R. Ursic, Current status of the ELETTRA/SLS transverse multibunch feedback. Proceedings of EPAC 2000