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FILLING PATTERN MEASUREMENT USING A 500 MHz DIGITIZER AT SOLEIL AND APS STORAGE RINGS

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Abstract

Filling pattern was measured at SOLEIL and APS storage ring using a 500 MHz digitizer. Various filling patterns were measured: from a single bunch to a multi-bunch hybrid fill. The digitizer has 14-bit granularity and locks the sampling clock to exact RF frequency (352 MHz). Signals were sampled from the standard BPM pickup and APD diode. Data were retrieved using Matlab and Labview interfaces and compared to existing systems.

INTRODUCTION

An essential part of the synchrotron diagnostics system involves the investigation of the bucket distribution during the operation.

Modern light sources allow to operate with different filling pattern modes (e.g. single bunch, multi-bunch, hybrid patterns), and knowledge of the real-time bunch charge longitudinal distribution can help to tune the beam stability and performance [1].

Digitizers with high ADC resolution and wide dynamic range are an alternative to the existing high sampling rate oscilloscopes that are commonly used in combination with BPM pick-up or APD diode detectors.

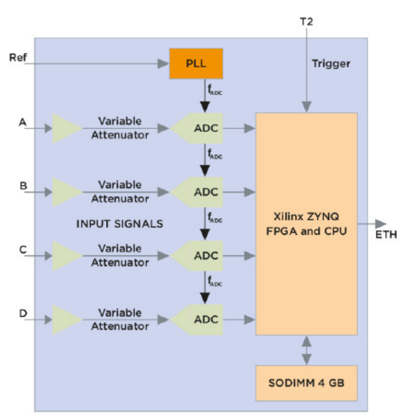

Figure 1: Libera Digit 500 block schematics.

The Libera Digit 500 is a 500 MHz/14-bit ADC digitizer based on the CavityBPM hardware [2] with the possibility to customize the frontend (e.g. input bandwidth, additional filters…). The sampling clock is locked to an external reference input to lock the internal PLL (maximum jitter 10 ps) on the machine RF clock. Data from the ADC are di-rectly sent to a Xilinx Zynq 7035 based SOC which runs both the signal processing and the OS.

The total dynamic range is 90 dB which is achieved with the use of the 0-31 dB frontend attenuators. The instrument is triggerable with a maximum trigger frequency of 1kHz (see Fig. 1).

The Libera Digit 500 DC version has an analog bandwidth of 0-250 MHz, the Libera Digit 500 AC version used during the testing at Soleil, and APS has a 250 MHz-2 GHz analog bandwidth.

The purpose of these measurements was to confirm that the Libera Digit 500 could be used as a filling pattern monitoring device in case of BPM pickups and to evaluate its behavior also using diode detectors [3].

Access to the interface can be performed using a TANGO client, Labview, or the SSH interface.

MEASUREMENTS – SOLEIL

The fill pattern monitoring testing consisted of testing two setups, the first using a BPM pickup as a bunch detector and the second using an APD diode setup.

Fill Pattern Monitor Using BPM

The original filling pattern monitoring instrumentation at Soleil consists of an Agilent Digitizer with 8 GS/s-8 bit resolution.

The setup with the Libera Digit 500 AC is illustrated in Fig.2 and it was implemented to retrieve the signal directly from a pickup using attenuators and phase shifters to tune the signal delays and the bunch flat top.

The pickup outputs (A, B, C, and D) were connected to fixed attenuators. Each attenuator output entered a mechanical phase shifter (API Technologies – Weinschel, bandwidth DC-3GHz). Since the signal power was still too high some additional attenuators were placed before the signal splitter-combiner (Mini-Circuits ZFRSC-4-842-S+, DC-8400 MHz). The combined signal then entered an additional mechanical phase shifter (4428C from ARRA, bandwidth DC-4 GHz).

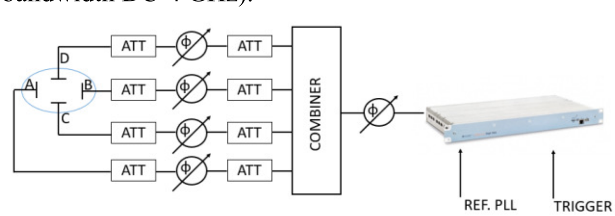

Figure 2: Setup schematics.

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Before the measurement, every single channel delay was set equal with the first mechanical phase shifter (maximizing each signal amplitude having the three other channels disconnected). This trick allows us to set the same time delay on all the 4 channels, resulting in a sync sum signal from the pickup to the Libera Digit 500.

Once all the 4 channels had the same time delay set the second mechanical phase shifter was used to reach the maximum signal amplitude which assured the sampling point to be on the flat top of the measured pulse.

The signal from the BPM was tested with different filling patterns and at different currents: single bunch, 8 bunches, and 1 quarter filling (reported in Fig. 3).

The signal level was adjusted with the frontend attenuators.

The length of the acquisition buffer was 650000 data points which correspond to 1562 turns. The acquisition noise is pretty constant over the input scale.

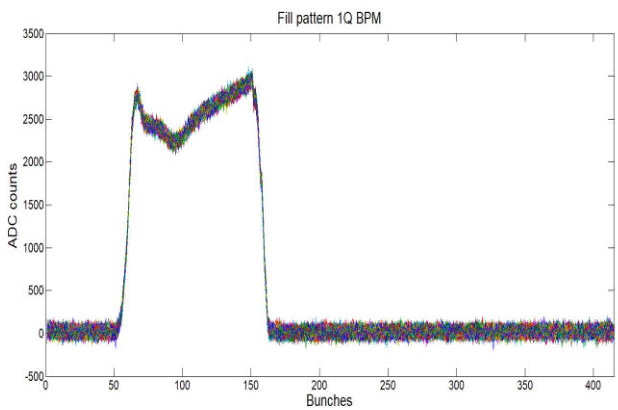

Figure 3: BPM fill pattern for a 1Q filling. The x-axis reports the bunches number while the y-axis the relative ADC counts.

During the 8 bunches machine operation mode, the flat top acquisition point was shifted in the slope direction reaching the 75% and 50% of the original maximum amplitude, RMS noise did not increase.

The AC Libera Digit 500 gives identical results in term of resolution compared to the initial SOLEIL setup on a BPM signal and is an appropriate system for filling pattern monitoring on such signal.

Fill Pattern Monitor Using an APD

The Libera Digit 500 was connected to an existing setup using an APD diode. The original setup was monitoring the signal with an oscilloscope (an Agilent Digitizer with 8 GS/s-8 bit resolution, 1 GHz bandpass frequency).

The Libera Digit 500 was connected to the diode output. The measurement with the diode is more delicate because its linearity range is too small to cover the current full scale. We kept the diode output amplitude constant at ~0.3 V adjusting for each current optical densities at the input. With 21 dB attenuation in the Libera Digit 500, it corresponds to ~7000 counts on the ADCs.

The effect of the AC coupling on the Libera Digit 500 can be seen and consists in a recovery effect due to the DC component (which was not present on the BPM setup), this is reported for a one quarter filling in Fig. 4:

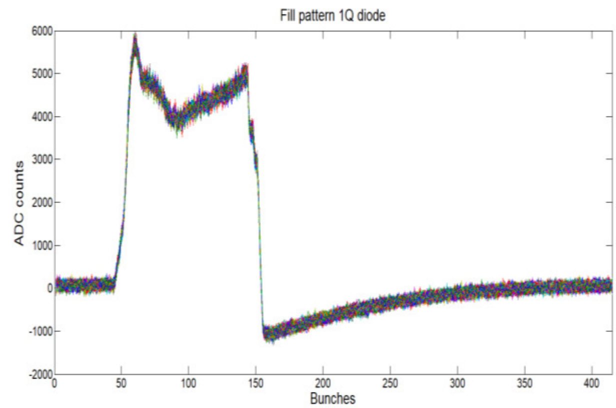

Figure 4: Diode DC recovery effect with 1Q filling.

The same recovery effect is reported in Fig. 5 with a 2Q fill pattern, leaving to an offset between Q1 and Q2:

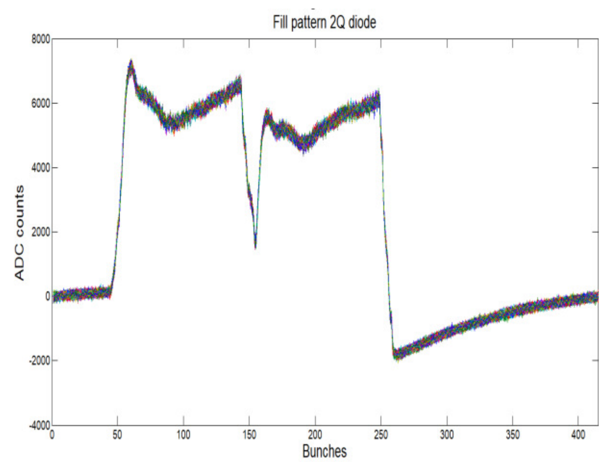

Figure 5: Diode DC recovery effect with 2Q filling.

The AC version of the Libera Digit 500 is not adapted to an APD diode signal. The DC version (with extended bandwidth) has not been tested.

MEASUREMENTS – SOLEIL

The BCM used for the reference measurement is a Xilinx FPGA-based device developed by the Advanced Light Source (ALS). It uses a Virtex-6 FPGA, with an FMC104 14-bit 250MSPS ADC. Interleaved sampling is used to obtain 46 sample points per bucket, and 1024 turns are averaged to determine the charge for each bunch. An EPICS IOC converts ADC counts into bunch current using the SR DCCT value.

The Libera Digit 500 was connected to a spare set of bpm buttons. These bpm cables were connected directly to

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the buttons and phase-matched with mechanical phase shifters, and then combined with a ZN4PD1-50-S+ combiner (500-5000 MHz). An attenuator was used on the combined signal to bring the output signal to a safe range for the Digit 500 input. The input RF clock phase was adjusted with phase shifters to maximize the ADC counts of the signal of the Digit 500. For the 'scaled' plot, the BCM units were in mA (positive peaks), while the Libera Digit 500 units were ADC counts (negative peaks). The mean of each was calculated to find the scaling factor to plot them both together.

Figure 6 reports a comparison between the Libera Digit 500 and the existing BCM device. The storage ring was filled with 324 bunches.

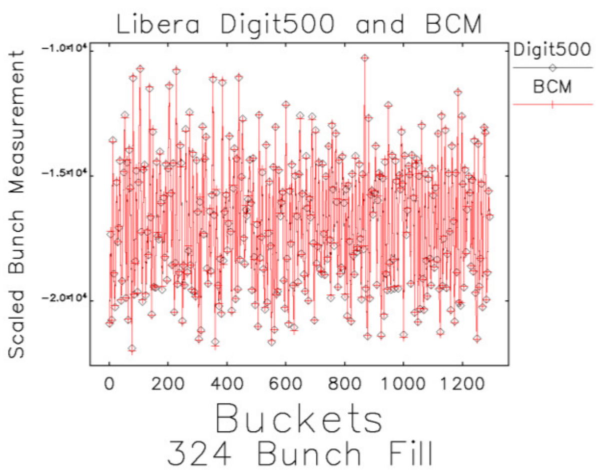

Figure 6: BCM and Libera Digit 500 comparison.

It is possible to see that the peaks corresponding to the BCM readout (in red) are well aligned with the peaks detected by the Libera Digit 500 (grey dots).

CONCLUSIONS

The performed measurements proved the capability of the Libera Digit 500 to perform as an efficient fill pattern monitoring system for light source storage rings.

The module works perfectly for acquiring the BPM signal. This behavior is supported by the results from both testings at SOLEIL and APS storage ring.

When connected to the photodiode detector the AC coupling distorts the signal due to the DC component coming from the diode.

ACKNOWLEDGEMENTS

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