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SINAP

THE DEVELOPMENT OF BUNCH-BY-BUNCH TRANSVERSE FEEDBACK SYSTEM AT SSRF BASED ON RF DIRECT SAMPLING

WEP39

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•Abstract

The commonly used bunch-by-bunch transverse feedback system (TFB) is based on the scheme of analog down-conversion, which down converts the 3×f_{RF} beam signal to the baseband with a phase adjusted local oscillator. The system contains a large number of analog devices, which make the system complex. Today, sampling the high frequency signal directly with high performance ADC is available. A new bunch-by-bunch TFB based on RF direct sampling is under development at SSRF. The new system structure is much simpler compared to the traditional one and much powerful. The direct sampling processor has 4 input channels, which can simultaneously process horizontal, vertical, large bunch vertical feedback, and bunch charge measurement. The RF processor has 4 ADC channels (maximum sampling rate is 2.6GHz, bandwidth is 9GHz), 4 DAC channels (maximum frequency 500MHz). The processor uses Xilinx system-on-chip UltraScale+ MPSoC FPGA. Paper will introduce the system structure, the processor design and performance.

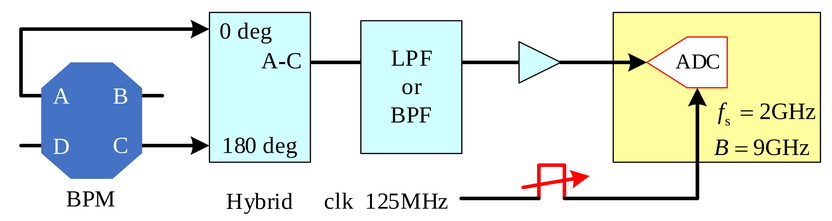
•RF Direct Sampling Prototype

The processor is composed of an FPGA mainboard and an ADC sampling daughterboard, which are connected via an FMC interface and use the JESD204B communication protocol. The ADC sampling daughterboard includes four ADC channels, with the external clock being frequency-multiplied by the LMX2582 and LMK04832 to serve as the ADC sampling clock.

Parameter	Value
Channels	4
Bandwidth	9 GHz
ADC bits	14
Max ADC rate	2.6 GHz
FPGA	Xilinx ZCU15EG
Clock	External
Trigger	Ext./Self/Period
SFP	2 UDP, 2Aurora
Interlock	Lemo
PL DDR4	2 GB
GPIO	12
Software	Arm-Linux/EPICS

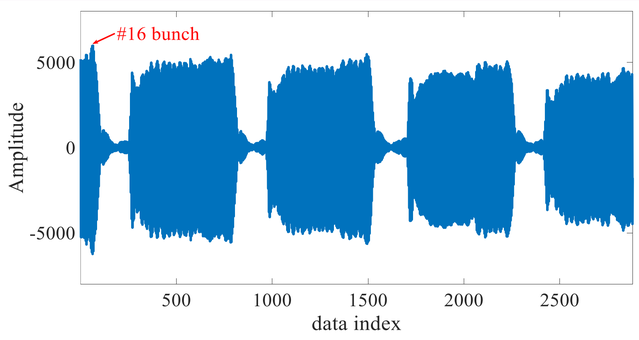
•RF Direct Sampling Experiment Platform

The processor is configured in a threshold-triggered sampling mode, with an ADC sampling frequency of 2 GHz, where each bunch corresponds to four sampling points. During the transient process after injection, sampling is performed, The peak method and the four-point method were used to calculate the position data of the bunch. The experimental platform was configured with different filters to extract signals from various frequency bands. We tested four types of filters: 580 MHz LPF, 700 MHz LPF, 780 MHz LPF, and 1.5 GHz BPF (B=500 MHz).

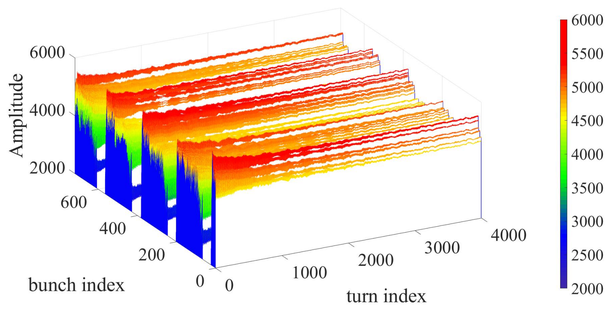


The verification test schematic of the RF direct sampling scheme

•RF Direct Sampling Beam Experiment Result

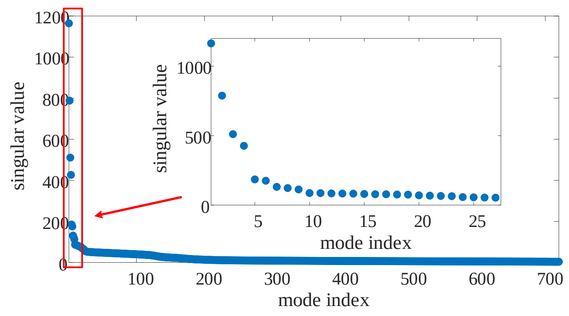


Raw ADC Data (First Turn)

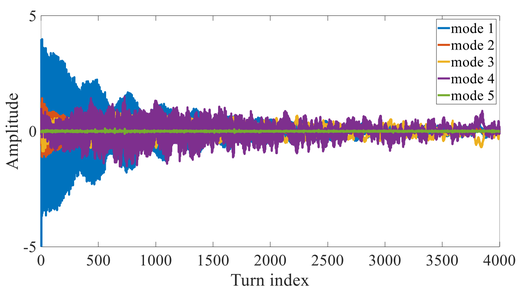


Turn-by-Turn Position of All Bunches

The noise of the entire system is evaluated using the Mode Independent Analysis (MIA) method. The method is based on the principle of Singular Value Decomposition (SVD).

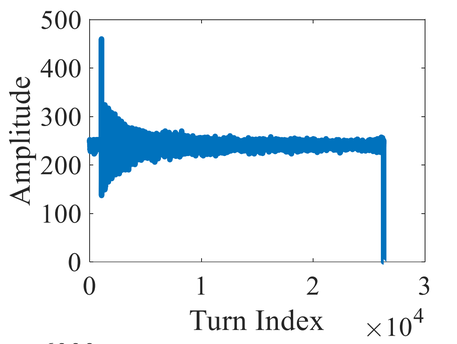


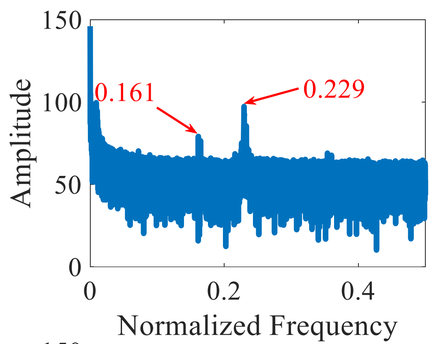
Distribution of Singular Values with Mode ID

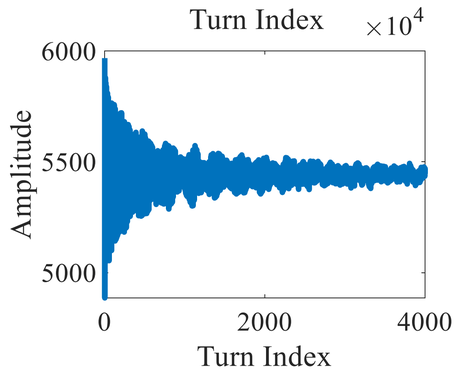


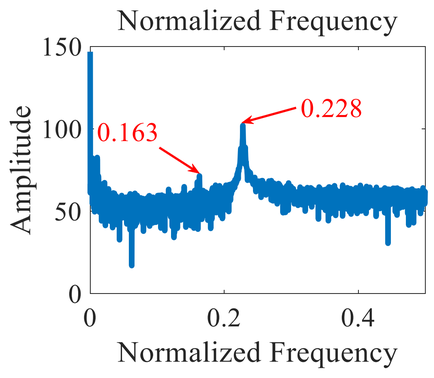
Transverse Oscillations of the First Five Modes

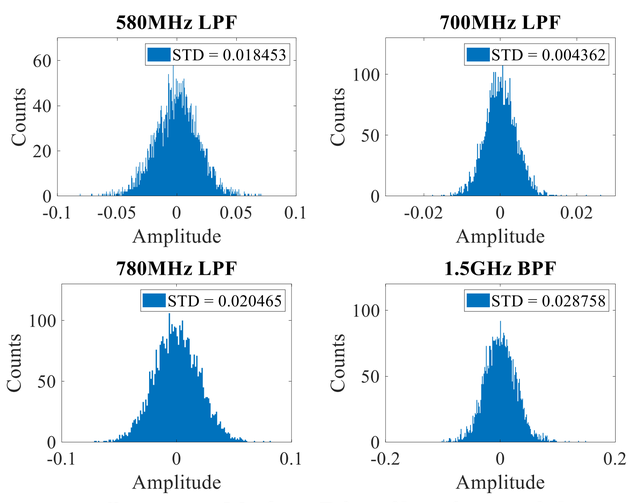
iGp12 Transverse Feedback Processor VS RF Direct Sampling Prototype



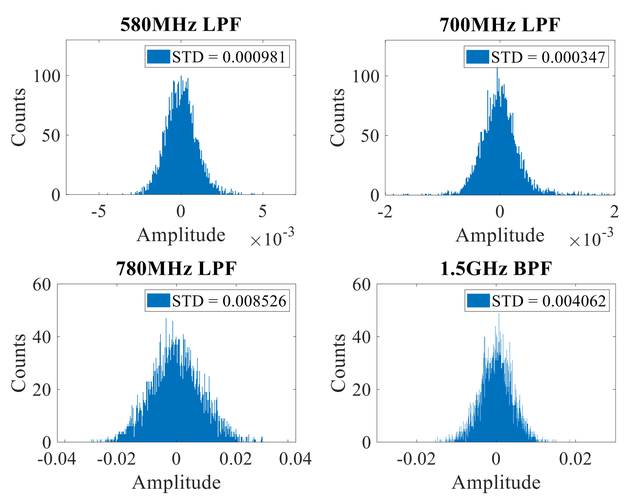








System Noise Distribution with Different Filters (Peak Value Method)



System Noise Distribution with Different Filters (Four-Point Method)

•Conclusion

The paper explores the use of RF direct sampling technology for transverse feedback signal processing, conducting experimental verification through an RF direct sampling prototype. The results show that the RF direct sampling scheme can measure the transverse oscillation and tune of the bunches, making it suitable for transverse feedback. A comparison of noise between peak sampling and four-point sampling methods demonstrates that the four-point method effectively reduces the impact of longitudinal jitter. Future work will focus on developing a complete transverse feedback processor and upper-level software based on these findings.