High Level Applications for SwissFEL LLRF System

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SwissFEL Layout

The LLRF system provides the following functions:
- Provides precise and accurate phase and amplitude measurements of RF signals.
- Suppresses RF field fluctuations in cavities and accelerating structures.
- Facilitates the operators to easily setup and operate the RF stations.

Typical LLRF HLA

- HLA Algorithm and Procedure
- DAC offset correction.
- Calibration: Group delay calibration.
- Optimization: RF pulse shaping.
- Diagnostics: Cavity detuning measurement.

Pulse Shape Optimization

SwissFEL RF Gun is a 2.6-cell standing wave cavity working at 2998.8 MHz (n mode). The nearest pass-band mode (n/2 mode) is about 16 MHz away in spectrum. A square pulse is generated by DAC results in a wide band in the klystron output which stimulates the n/2 mode significantly. In order to reduce the bandwidth of the Gun drive power, the rising and falling edges of the RF pulse was smoothed with a half sine of 2.6 ns.

Group Delay Calibration

Why do we need to calibrate the group delays of RF signals with respect to the DAC pulse?
- To compare the relative RF errors in different locations of the RF system.
- To find out which DAC point needs to be adjusted to suppress the intra-pulse ripple at a certain point within the RF pulse.

DAC Offset Correction

Solution: A single point in the DAC pulse can be varied (e.g. with smaller magnitude) as a bump in the pulse to generate a transient in all RF signals.

Loop Gain and Loop Phase Calibration

Goals of loop gain and loop phase calibration:
- Determine amplitude feedback gain.
- Avoid klystron working over saturation.
- Allow amplitude or phase tuning in open loop, avoid jumping when closing the loop.

Structure Detuning Measurement

The detuning of the travelling wave structures can be measured by comparing the phases between the output and input RF signals.
- In order to reduce the uncertainties caused by the cable drifts, it is better to measure the structure input and output signals with the same cable and the same RF detector.

Conclusion / Outlook

The algorithms developed for the LLRF HLA provide practical automation to operate the RF systems of SwissFEL. A software package has been well architected and implemented based on EPICS and has been used in daily operation of SwissFEL. The HLA software tools have helped a lot in the commissioning of the RF system. The software architecture is flexible to add more functions to the HLA. Similar structure can also be easily applied to other aspects of the accelerator control like the beam based feedback system. The experiences of the design and usage of the LLRF HLA will also be helpful for other accelerator facilities.

References: