A noise suppression method based on system identification for the HEPS-TF 166.6 MHz LLRF system

The most common cavity field feedback control loop is to have one PI(D)-controller for each of the I&Q channels. This however does not have a satisfactory suppression of the low-frequency noise within the bandwidth of the superconducting RF system. These noises are often originated from ripples of the transmitter power, cavity microphonics, system noise from helium pressure fluctuations and vacuum pumping group caused vibrations. Thus a noise suppression method based on system identification has been proposed and is the focus of this paper. PRBS was used as the input signal, while the corresponding cavity field signal was used as the output signal. Both signals were processed by the system identification method in MATLAB and a system transfer function was then obtained. Based on these, two low-pass IIR digital filters, and subsequently a noise suppression loop was finally set up. A noise suppression loop for the 166.6 MHz HEPS-TF LLRF system has been designed and tested on a cavity mock-up in the lab. An effective noise suppression was observed. The design and the tests will be presented in this paper.

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Why design this method?

Many low-frequency noises influence the cavity field stability， such as cavity microphonics, system noise from helium pressure fluctuations and vacuum pumping group caused vibrations, or ripples of the transmitter power and so on.
it can't be suppressed well by normal PI-controller, so a noise suppression loop was proposed .

System identification

White-black-gray box, 3 methods for system identification. it's useful for understanding RF system, simulation and analysis，adaptive feed forward and so on.

Tools

Quartus II, PRBS as input signal，pick up as output signal, two IIR-filters designed for loop.
Matalb, ARX or RLS(real-time) tools ,identify the system model with input and output data.

design steps

First, system identification of the whole RF system including LLRF controller, SSA, Cavity, wave guide or coaxial feed tube and so on.
Second, based on the system identification model, two IIR-filters were designed.
Third, the noise suppression loop was implemented with the IIR-filters designed in FPGA.

Denoise control loop

The noise suppression loop and PI control loop were designed and the block flow diagram as figure 1.

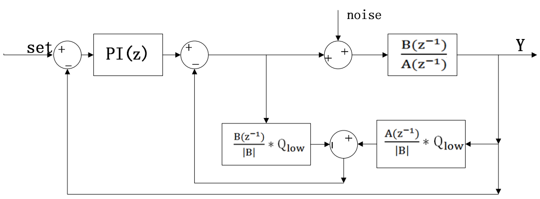
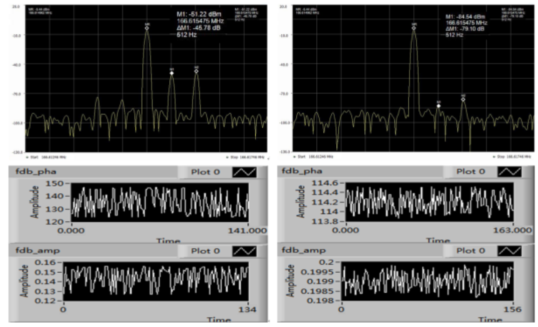


Fig 1. LLRF system PI and denoise control loop

Result

A noise suppression loop for the 166.6 MHz HEPS-TF LLRF system has been designed and tested on a cavity mock-up in the lab. An effective noise suppression was observed.



Without noise suppression loop **With the noise suppression loop**

Fig 2. Amplitude and phase stability difference between with the noise suppression loop on and off

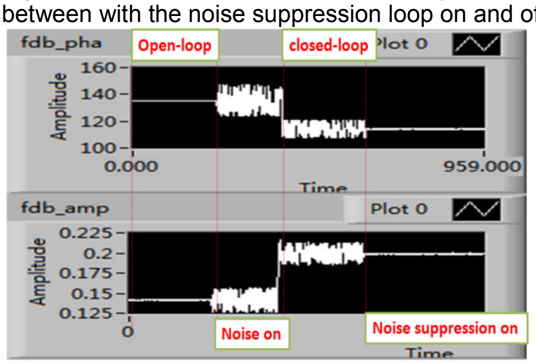


Fig 3. the field stability with different status

Table 1 Amplitudes of two sidebands in different status.

status / sideband	Open-loop Denoise off	Closed-loop Denoise off	Closed-loop Denoise on	Open-loop Denoise on	No noise
512Hz	-45.8 dbm	-42.8 dbm	-79.1 dbm	-75.7 dbm	-87.5 dbm
1012Hz	-21.5 dbm	-21.5 dbm	-21.8 dbm	-52.3 dbm	-95.1 dbm

NEXT STEPS

The system was identified with cavity tuned but not detuned. In that case， the I-Q and Q-I transfer function should be considered and the noise suppression loop will be complicated.
The design is to be verified in the HEPS-TF system.