Digital LLRF Test on Renascence
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Introduction

Renascence was the first opportunity for testing the newly designed Digital LLRF system using an SC cavity. Tests took place during October 2005, in the Cryomodule Test Facility (CMTF) and lasted for several days. Numerous measurements were completed, starting with basic phase and amplitude stabilization, and ending with resonance tests using the stepper and piezo tuner (PZT) control. Although originally it was planed to test field and resonance control at gradient >17.5 MV/m, the cavities were limited to ~ 7 MV/m. Still the testing was successful in that we demonstrated field control at or better than specification and resonance control using a stepper motor. Due to the time limitation additional resonance tests using the PZT did not take place.

System Components

Fig. 1 shows block diagram of the system. The LLRF system is a version of the normal conducting LLRF system that was modified to operate at 1497 MHz [1]. The DSP code was also changed to accept the different operating parameters from a superconducting cavity. To replicate the master oscillator an Agilent RF source was used as a 1427 MHz local oscillator and then synchronized to the 70 MHz LLRF system clock (not shown).

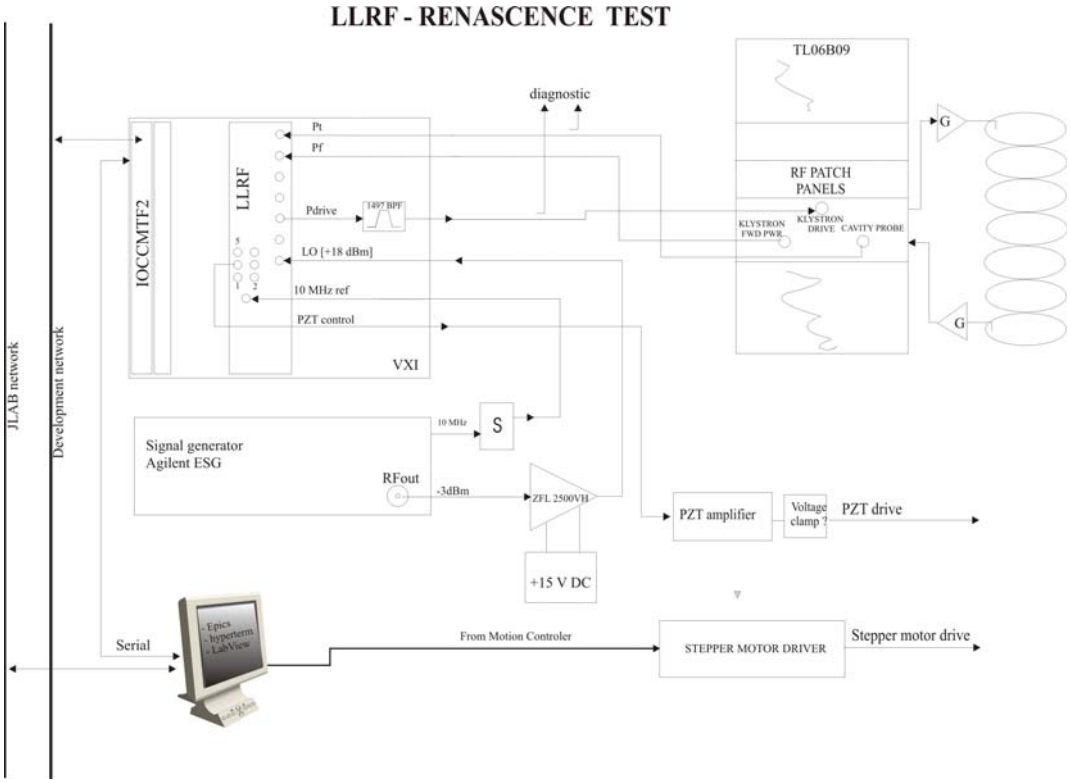

Fig. 1 LLRF Block Diagram

Cavity Test Result

Amplitude control was tested independently using an Analog Devices (AD8361) amplitude detector (linear in Volts) and an Agilent Vector Signal Analyzer. Using the ratio of spectral density (dc to 1 MHz) of the detected signal to its DC component gave us the rms. residual amplitude noise. Our goal was 0.01%. Measured rms. noise was **0.0097%**. Figure 2 below show power spectral density of DC and AC coupled signal from AD8361, open and closed loop respectively.

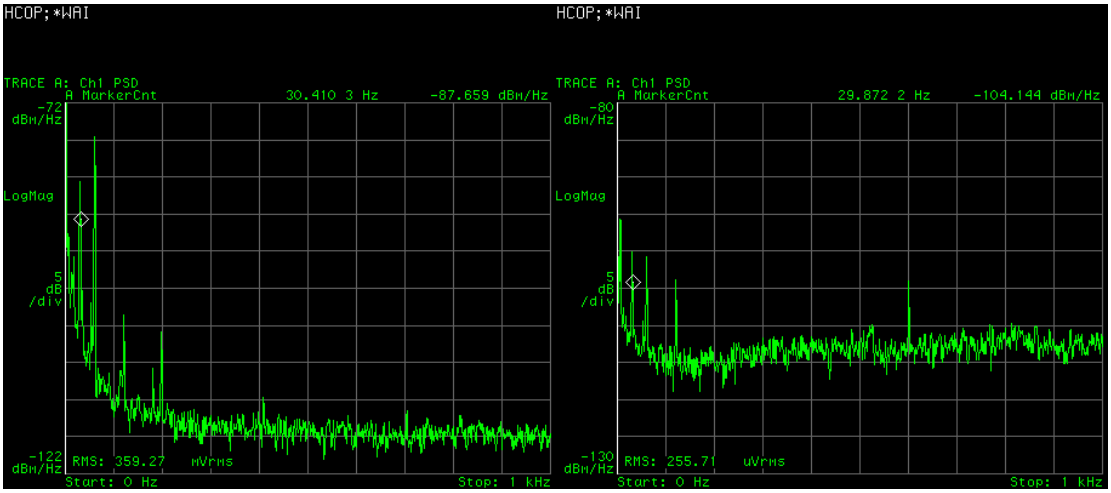

Figure 2 Cavity 2: Gradient = 7.08 MV/m QL=8.59e6 "Closed loop"

Phase Noise Measurements

For residual phase noise characterization we have used the Agilent E5052A Signal Source Analyzer. Measurements again were made for both open and closed loop cases. In the open loop case, Figure 3, it was easy to see the microphonic background of the cavity.

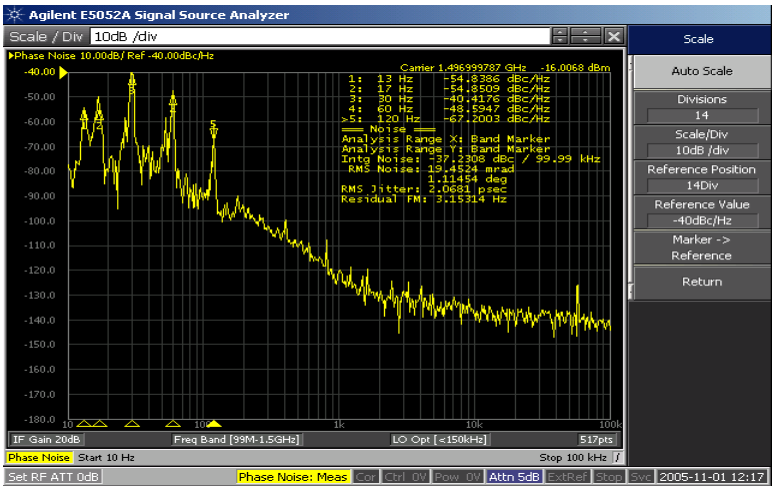

Figure 3 **Cavity 2:** Gradient: 7.08 MV/m , QL = 8.59e6 "Open Loop" Residual phase noise: 1.11mdeg rms.

Figure 4 shows the closed loop operation and in this case the feedback greatly suppresses the cavity microphonics.

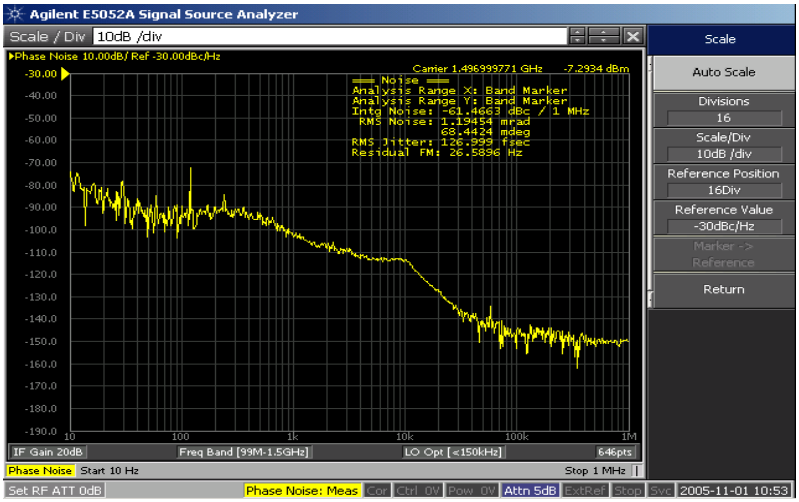

Figure 4 “Closed Loop” residual phase noise: 0.068 mdeg rms

Resonance tracking software:

The resonance tracking algorithm was successfully tested with the mechanical tuner. With all improvements, the system appears to be able to handle step changes of ~100-150 Hz in less than 10 seconds, and brings the detuning angle to within +/-0.02 radians of the set-point.

Summary

The LLRF test on Resonance was a fruitful venture for the designers. We were able to verify performance of our 1497 MHz prototype and demonstrate technical feasibility of the LLRF architecture. The concept control algorithm was tested and modified in situ. The receiver digital signal processing was modified and improved (made more efficient) by adding new digital filters, among them a CIC (Cascaded integrator-comb). We were also able to begin tests on the resonance control. In the future we plan to tests the LLRF system up to 17+ MV/m and complete turn on tests using the Piezo tuner (PZT).

References

1. C. Hovater et al, “A New RF System For The CEBAF Normal Conducting Cavities”, LINAC 2004 Proceedings, August 2004, Hamburg Germany