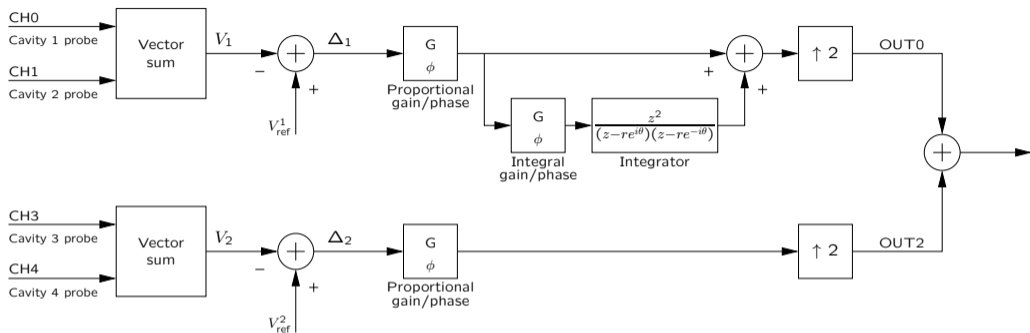# LLRF9 Dual Output Test

D. Teytelman

Dimtel, Inc., San Jose, CA, USA

January 21, 2021

Topology Under Test

- ▶ Symmetric combining of outputs;
- ▶ Only one loop has the integrator;
- ▶ Setpoints V_{ref}^1 and V_{ref}^2 should be set to half the total station voltage;

- ▶ The integrator keeps Δ_1 at zero;
- ▶ $\Delta_2 \approx 0$ since $V_2 \approx V_{\mathrm{ref}}^2$;
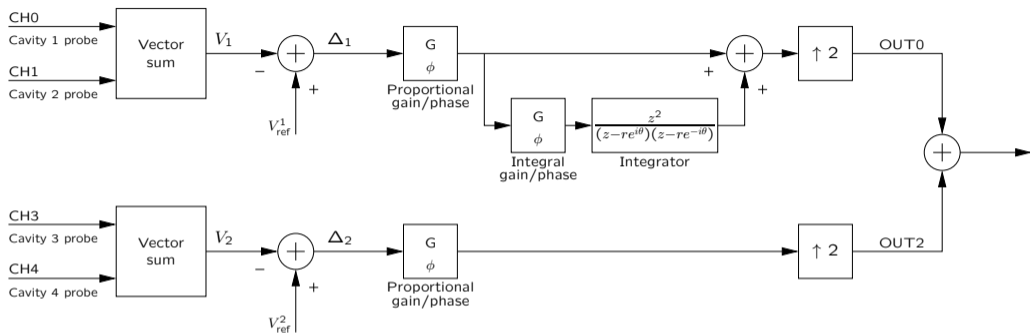- ▶ Precision control of the overall vector sum — an EPICS loop that acts on V_{ref}^1 and V_{ref}^2.

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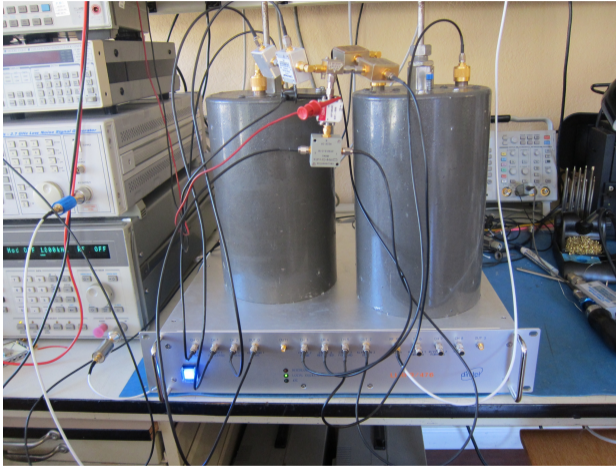- Precision control of the overall vector sum — an EPICS loop that acts on V_{ref}^1 and V_{ref}^2.
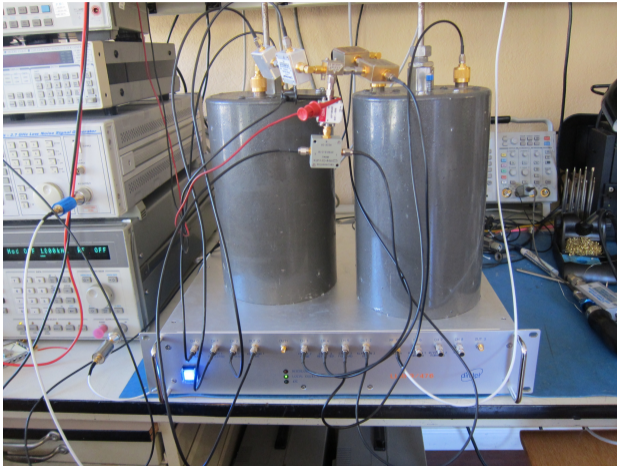
LLRF9 Bench Test Stand

- ▶ Two cavities:
    - ▶ Probe
    - ▶ Forward power (directional coupler);
    - ▶ Reflected power (directional coupler).
- ▶ Amplifier and a splitter simulate one klystron driving both cavities;
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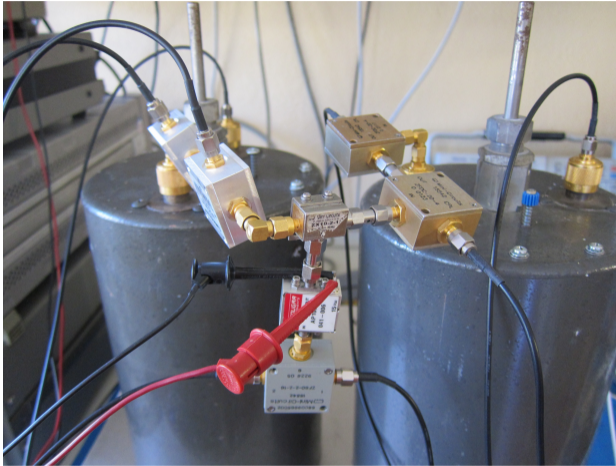# LLRF9 Bench Test Stand

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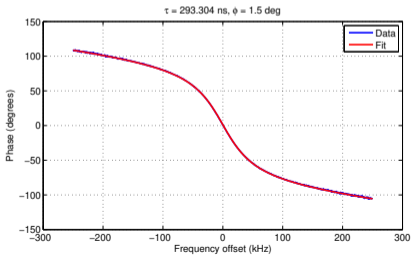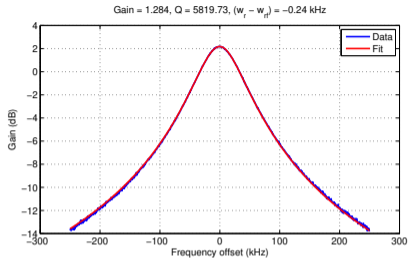- ▶ LLRF9 outputs are combined with Mini-Circuits ZFSC-2-2-10.

Cavity Tuning

Gain = 1.284, Q = 5819.73, $(w_r - w_n)$ = −0.24 kHz

τ = 293.304 ns, ϕ = 1.5 deg

▶ Open loop transfer function measurements;

▶ Good cavity model fit;

▶ Somewhat different coupler adjustments on two cavities;
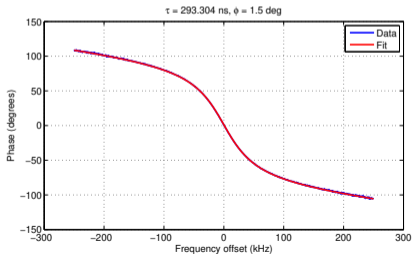
▶ Matched voltages and loop gains in LLRF settings.

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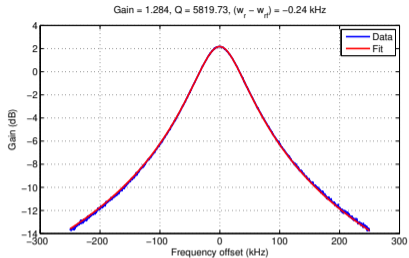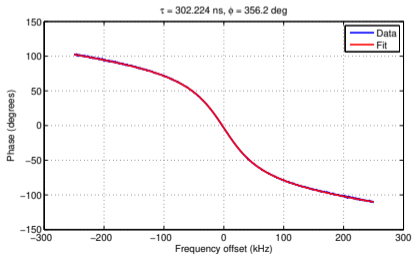# Cavity Tuning

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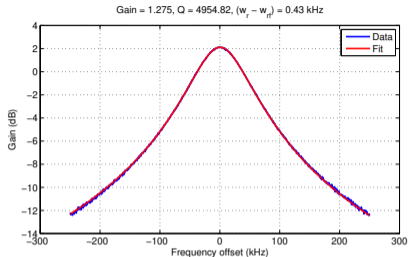- ▶ Matched voltages and loop gains in LLRF settings.

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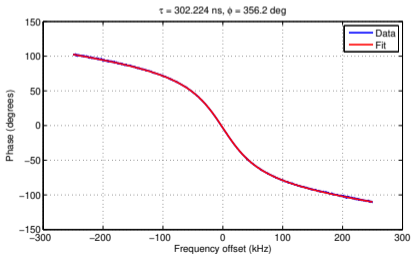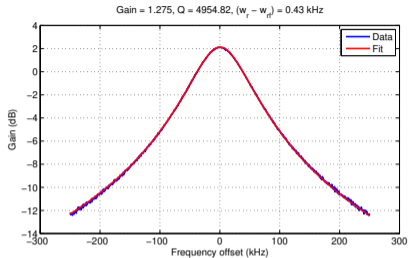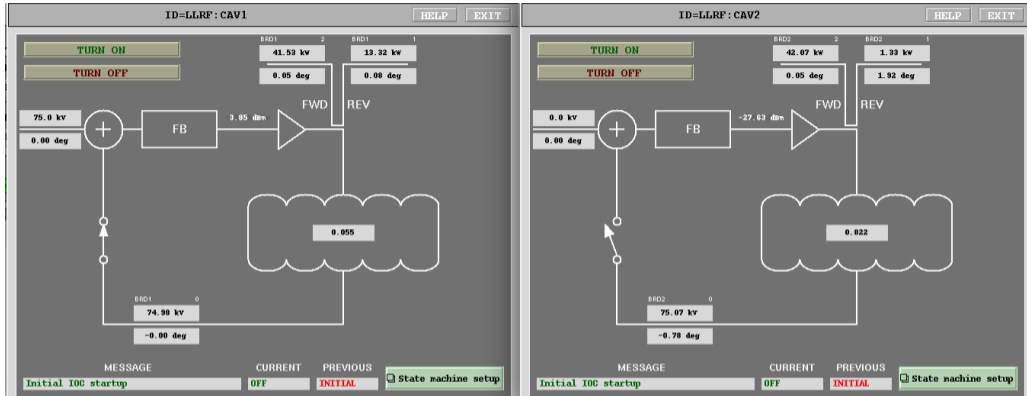- ▶ Matched voltages and loop gains in LLRF settings.

Closed Loop Operation

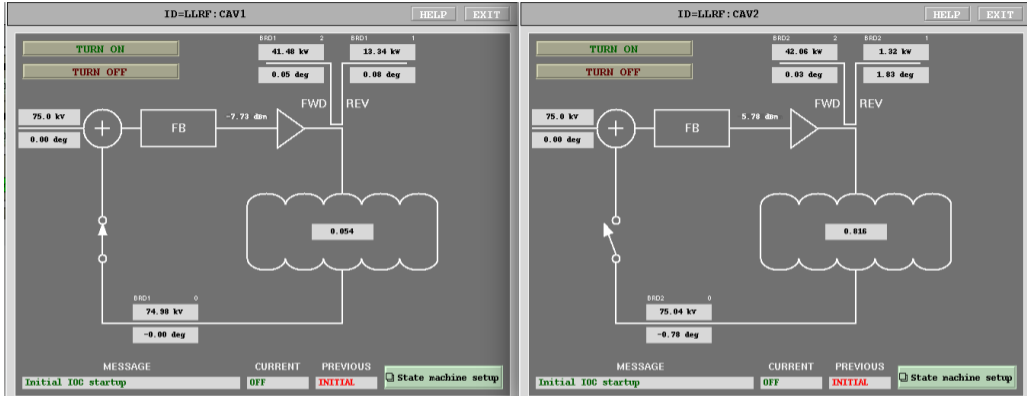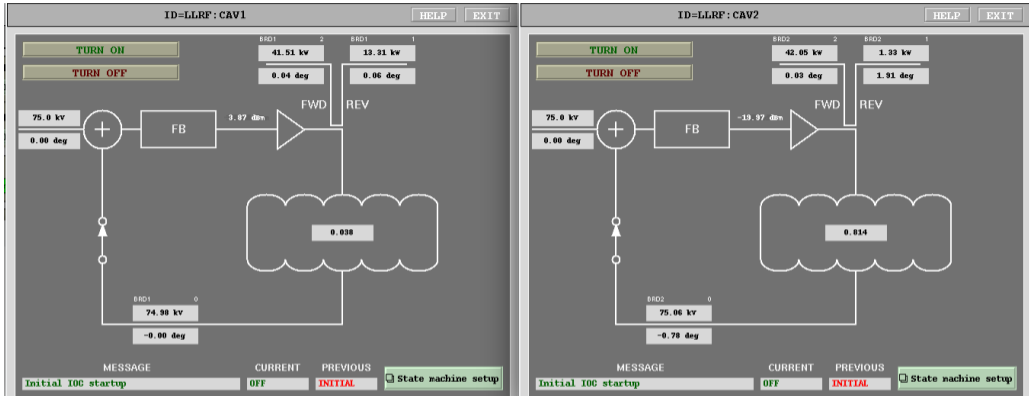- ▶ Cavity 1: closed loop with integrator, 75 kV setpoint;
- ▶ Cavity 2: open loop, zero setpoint.
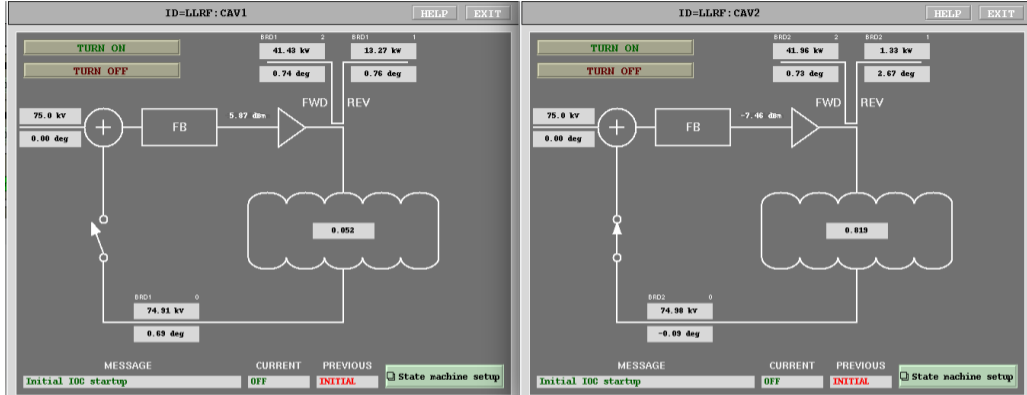- ▶ OUT0: 3.9 dBm, OUT2: -28 dBm.

Closed Loop Operation

- ▶ Cavity 1: closed loop with integrator, 75 kV setpoint;
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- ▶ OUT0: -7.7 dBm, OUT2: 5.8 dBm.

Closed Loop Operation

- ▶ Cavity 1: closed loop with integrator, 75 kV setpoint;
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- ▶ OUT0: 3.9 dBm, OUT2: -20 dBm.
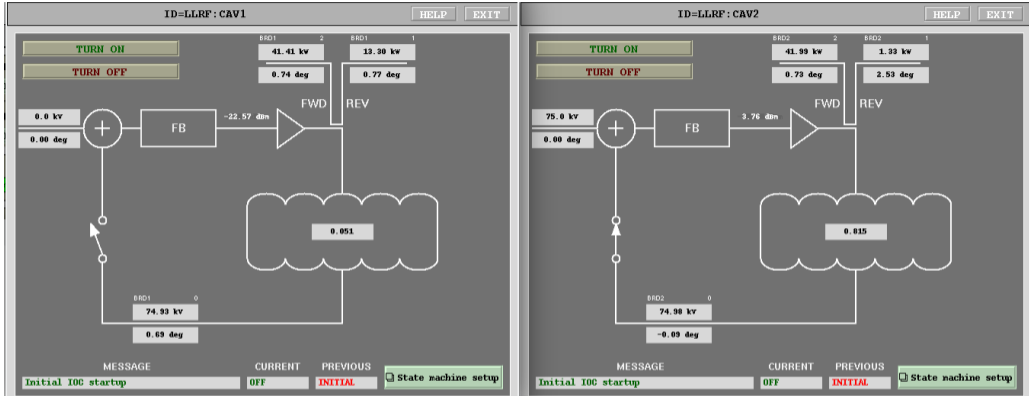
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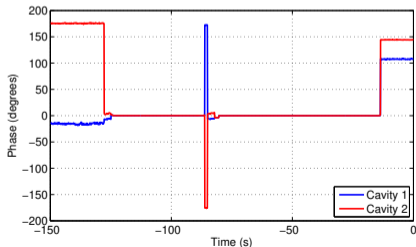- OUT0: 5.9 dBm, OUT2: -7.5 dBm.

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- ► Cavity 1: open loop, zero setpoint;
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Running One Station at a Time

▶ Normal feedback (proportional and integral) configured in both stations;

▶ Stripchart capturing signals at 10 SPS;

▶ The first station is turned on and off, then the second;

▶ Zooming in at the steady state;

▶ Power readings:
  ▶ Forward;
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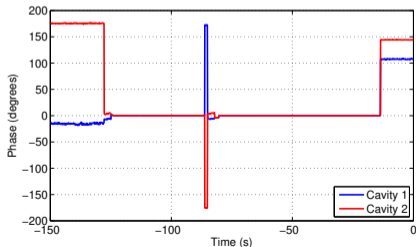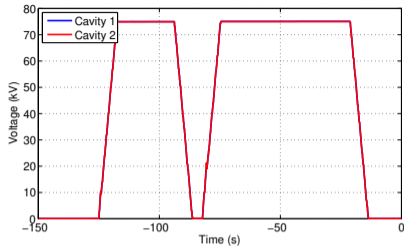 - ▶ Reflected;
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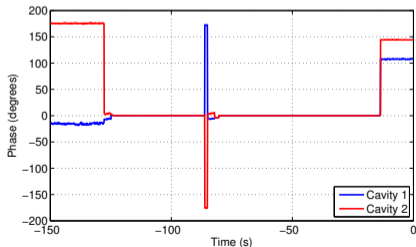 - ▶ Reflected;
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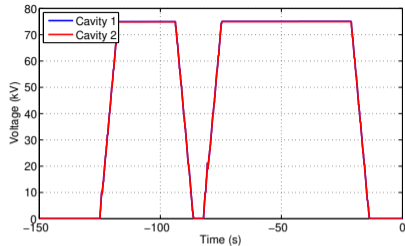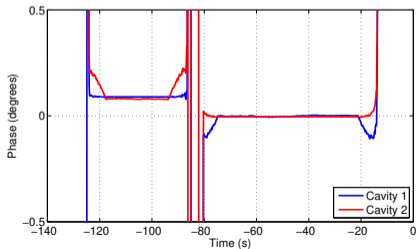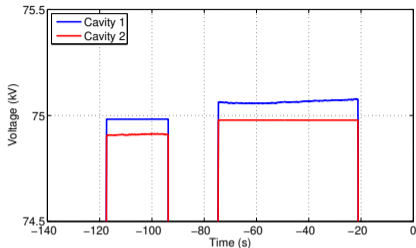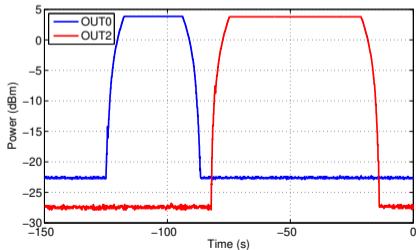   - ▶ Reflected;
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Summary

- ▶ Running two loops together is feasible;
- ▶ Combining both outputs at full scale is risky — can potentially overdrive the preamplifier;
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- ▶ Make up the gain digitally;
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- ▶ Second option: run only one loop with 2 cavity vector sum.

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