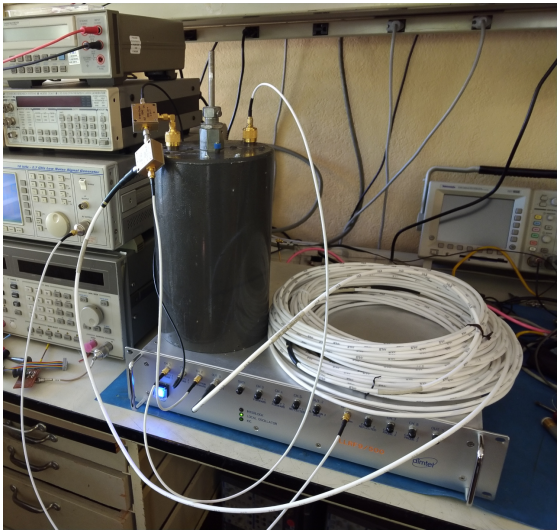
LLRF9 with SPEAR3 Signals

D. Teytelman

Dimtel, Inc., San Jose, CA, USA

September 25, 2020

LLRF9 Bench Test Stand



- Cavity filter with 90 kHz bandwidth;
- Long cable for loop delay;
- Two directional couplers for monitoring
  - Forward power;
  - Reflected power.

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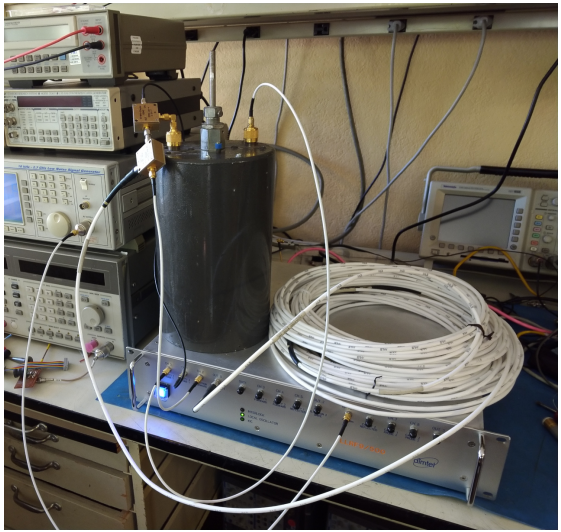

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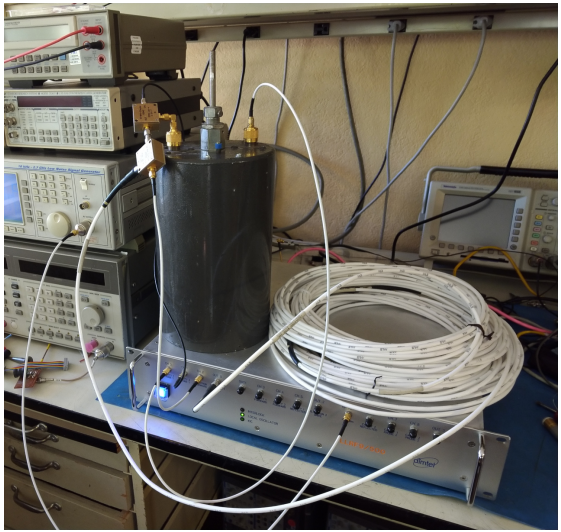

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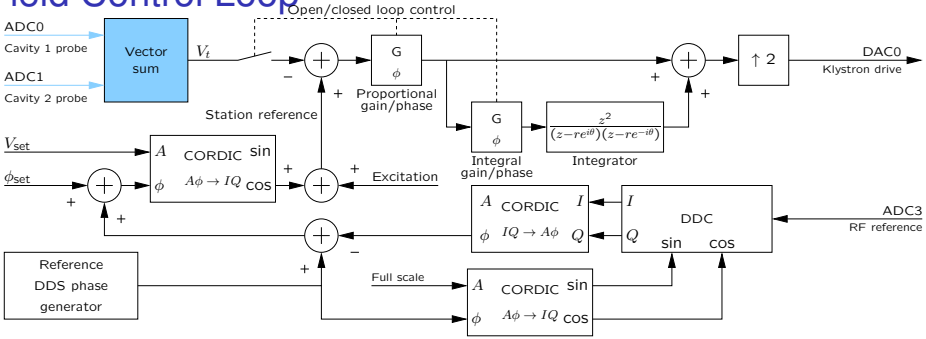
Field Control Loop



- Single cavity or vector sum of two;
- Reference phase is compensated in real-time;
- Proportional (direct) and integral loops;
- Double rate DAC drive;
- 512-point amplitude and phase profiles;
- Excitation input for built-in network analyzer.

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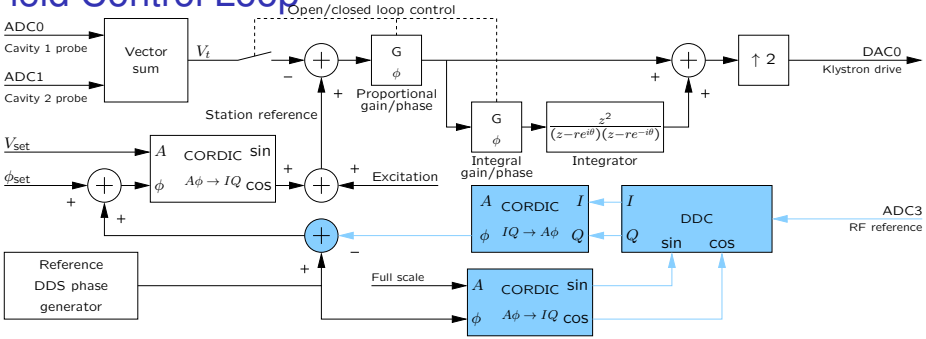

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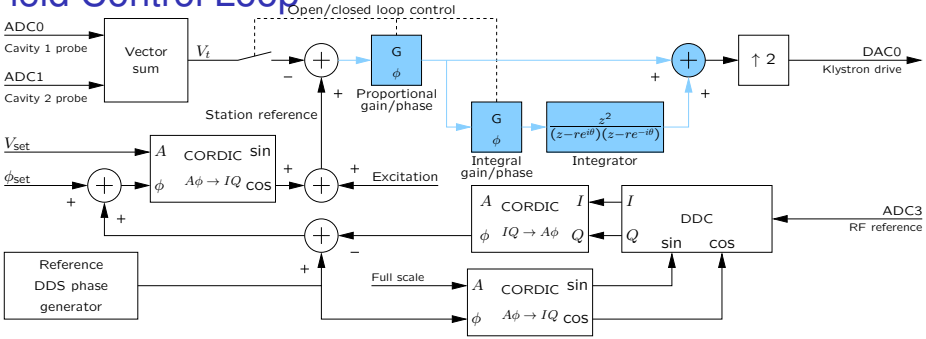

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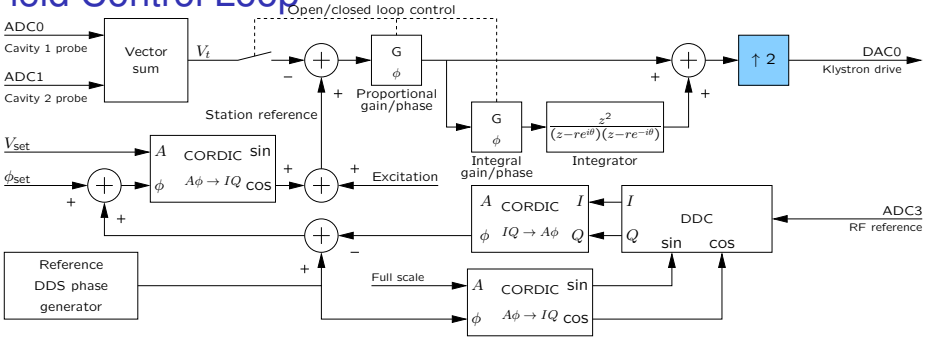

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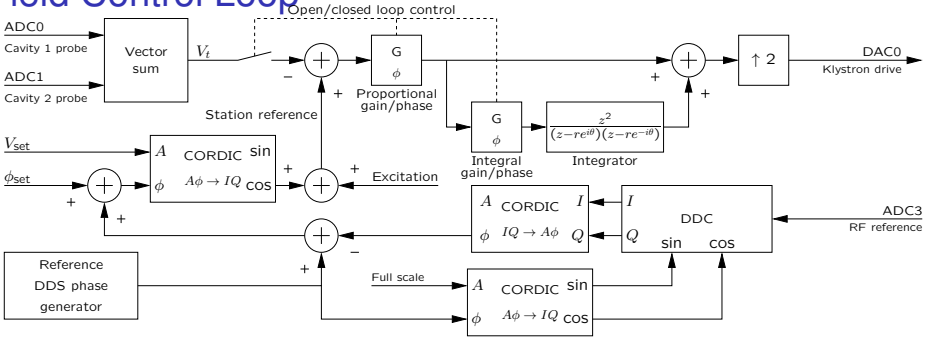

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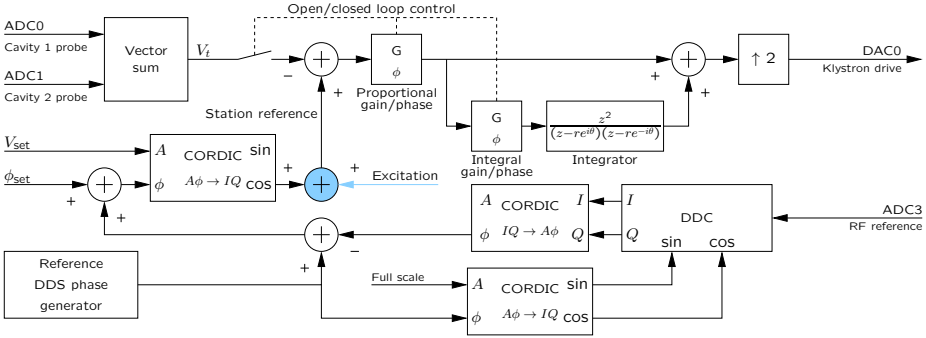

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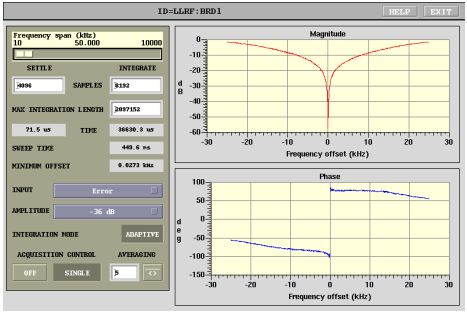
Network Analyzer



- High resolution (1024 point) swept analyzer;
- Adjustable excitation level;
- Fast sweep times with proprietary carrier suppression algorithm;
- Multiple probe points within the system:
  - Cavity probe;
  - Cavity sum;
  - Error signal;
  - Drive output.
- Spectrum analyzer mode with excitation disabled.

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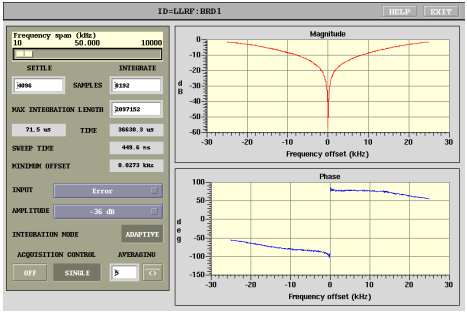

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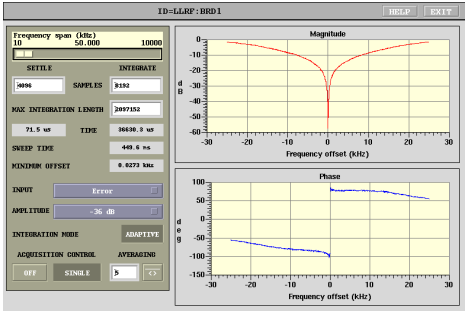

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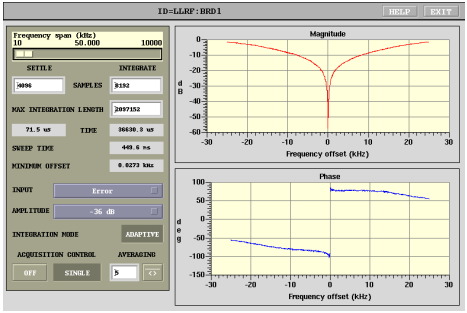

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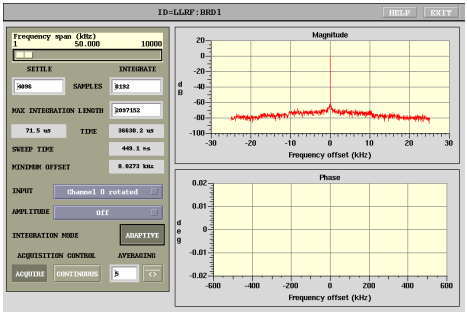

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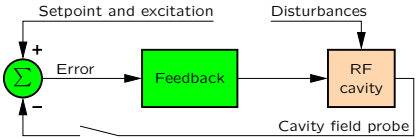
Open Loop Transfer Function



- Measured from setpoint to the cavity probe;
- Feedback block in open loop has no dynamics, just gain and phase shift;
- Open loop cavity response and the fit.

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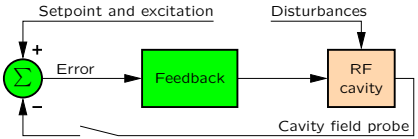

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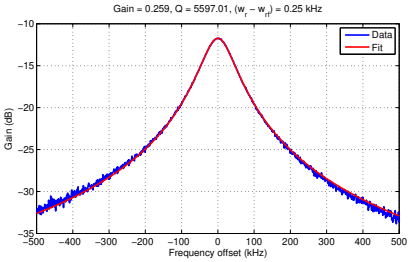

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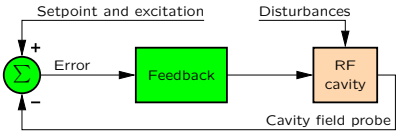
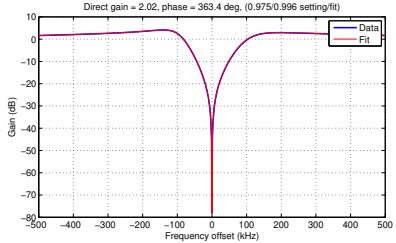
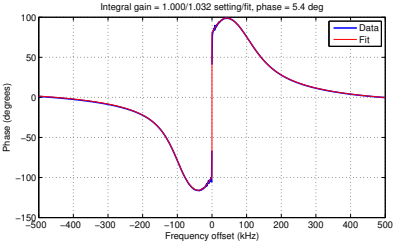
Closed Loop Transfer Functions



- Measured from setpoint to the error signal, $S(\omega) = 1/(1 + H(\omega))$;
- Shows attenuation at frequencies where feedback has gain;
- Fit closed-loop response (using open loop model);
- Perturbations at the input of the cavity should be rejected with the same transfer function;
- Proportional only;
- Wide span;
- Proportional and integral, much higher rejection at low frequencies;
- At small offsets.

Closed Loop Transfer Functions





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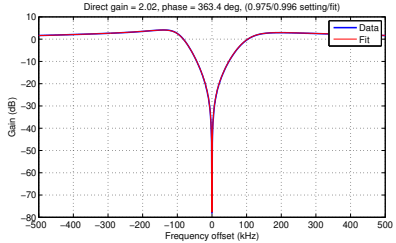

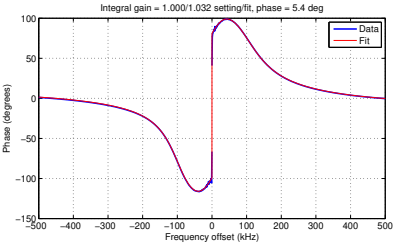

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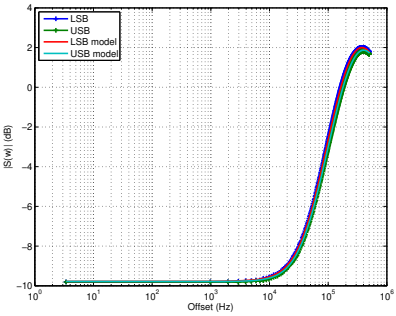

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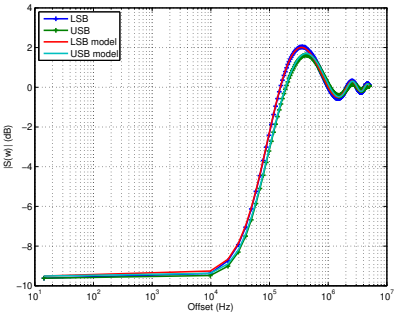

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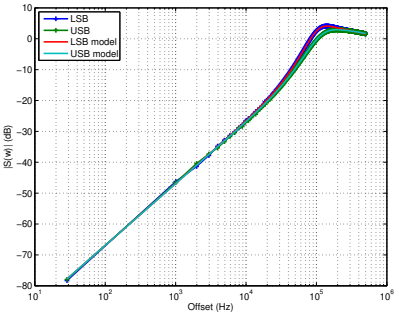

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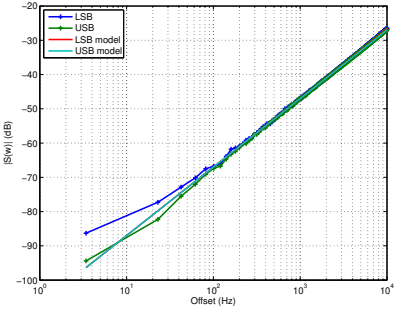

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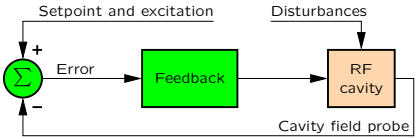
Closing the Loop with SPEAR3 Data



- Extracted model can be used to estimate disturbance suppression under LLRF9 control;
- Start with SPEAR3 cavity probe signal (open-loop); shift;
- Filter the signal through $S(\omega)$ to compute residual modulation;
- Add mean value to estimate closed-loop cavity probe signal.

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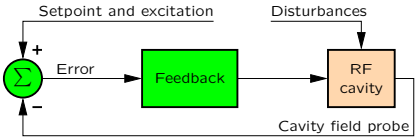

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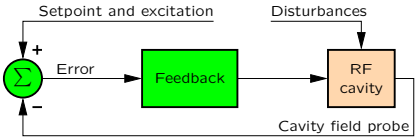

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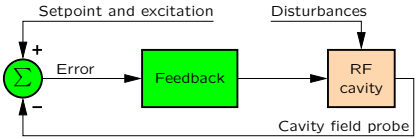

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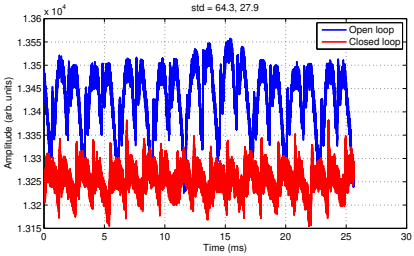

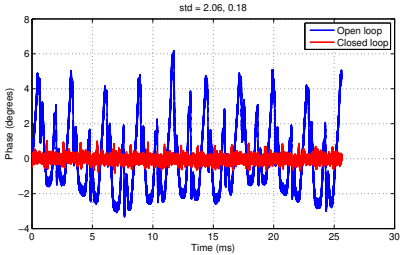

- SPEAR3 data: open loop and closed loop;
- Proportional gain 2, integral 219 at 1 kHz; shift;
- Step response;
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- Closed loop comparison: existing system and LLRF9.

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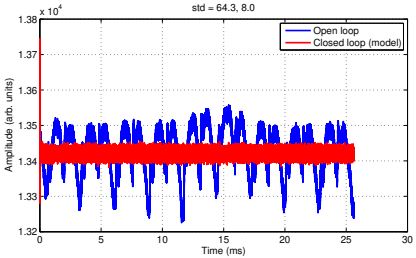

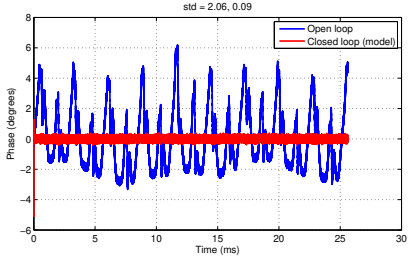

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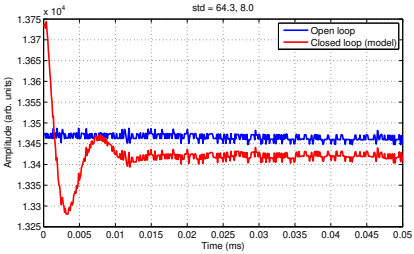

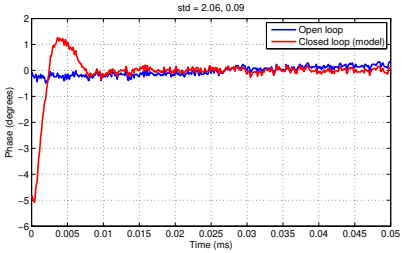

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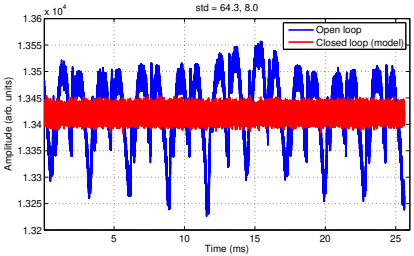

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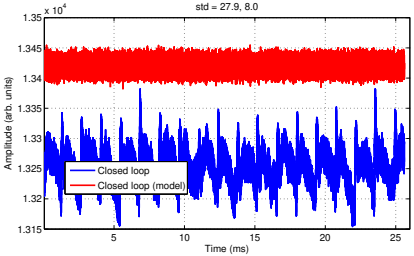

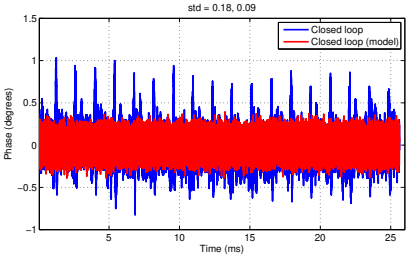

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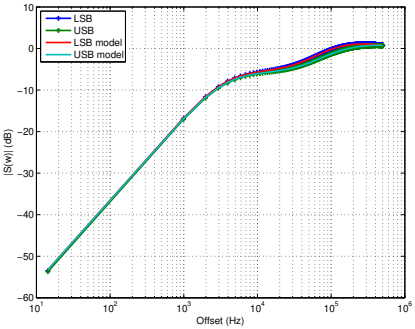

- High gain setup runs into trouble under heavy beam loading;
- Gains need to be reduced to maintain stability margins;
- Proportional gain 1, integral 6.6 at 1 kHz; shift;
- Measured open-loop and computed LLRF9 closed-loop signals;
- Closed loop comparison: existing system and LLRF9.

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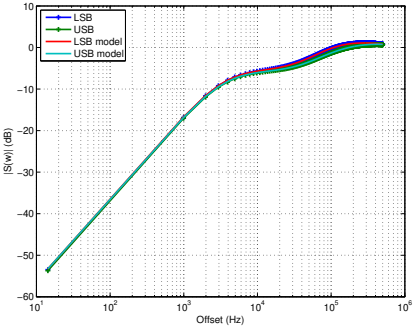

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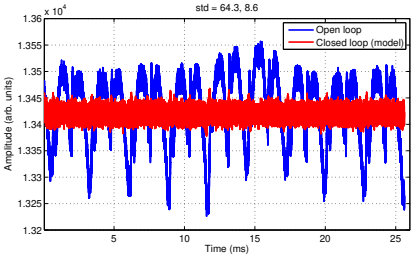
Low Gain Case



- High gain setup runs into trouble under heavy beam loading;
- Gains need to be reduced to maintain stability margins;
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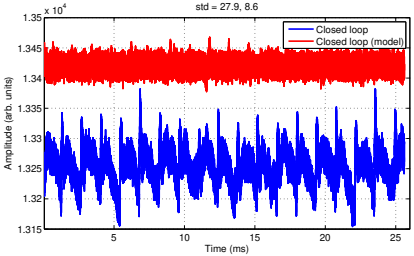

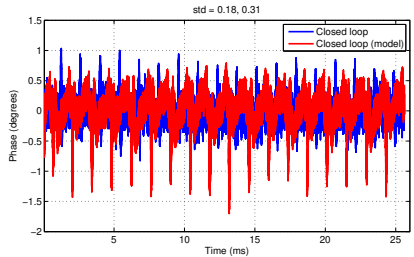

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