LLRF9 Status Update

Second AP Results and More

D. Teytelman

Dimtel, Inc., San Jose, CA, USA

March 2, 2021

Outline

Current Status

- Verified the operation with the interlock chassis;
- Operated in the drive power-limited configuration first:
  - Removed load angle offset settings from the tuner loops and readjusted forward phases to tune all cavities on resonance;
  - Tested drive power loop operation with the HVPS limited to 50–52 kV range.
- Removed 10 dB of attenuation at the output of LLRF9 to raise the saturated drive power from ~6 to 60 W;
- Adjusted station setpoint ramping rates and drive power loop gain for a reasonable balance;
- Demonstrated controlled station turn-on and turn-off;
- Adjusted station phase to roughly match the old setup and injected ~20 mA.

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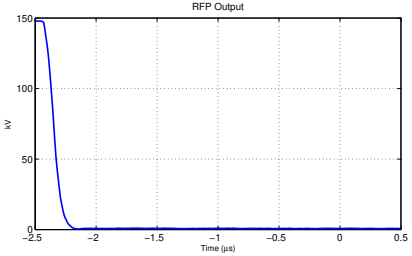
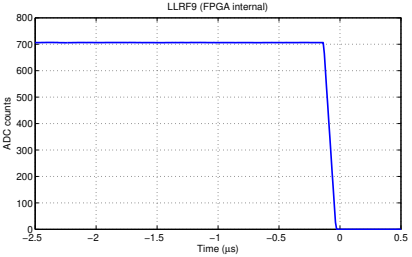
Outline

Verifying RFP Output to Interlock Delay





- RFP output is split between the LLRF9 channel 0 and the interlock chassis;
- Station in tune mode, output adjusted to −14 dBm;
- Set klystron reflected power interlock threshold to 0;
- 2.4 µs delay between the RFP drive going away and the LLRF reacting to the interlock;
- RFP connected directly to the interlock chassis and set to −17 dBm;
- Can use field damping transients to measure cavity Q and detuning.

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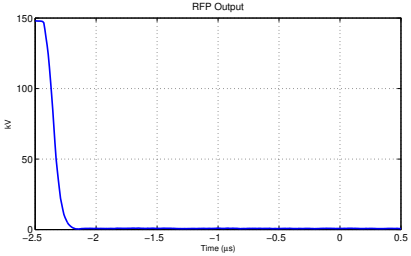

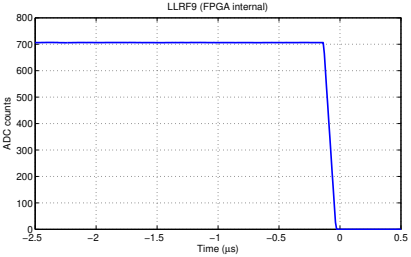

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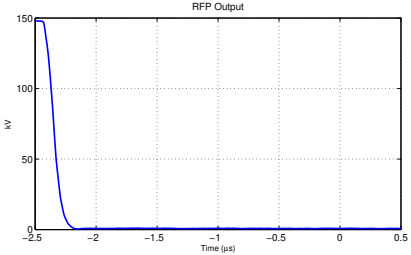

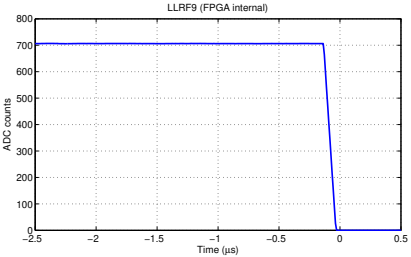

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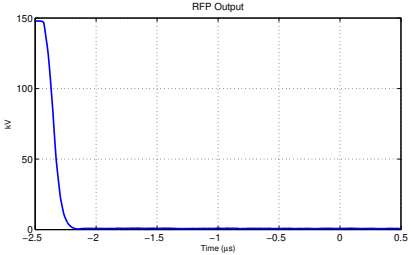

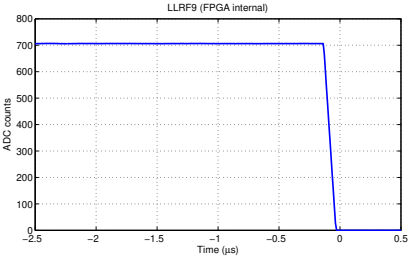

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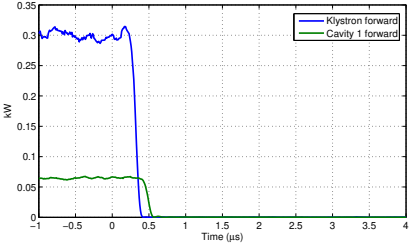

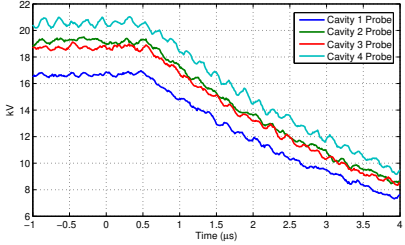

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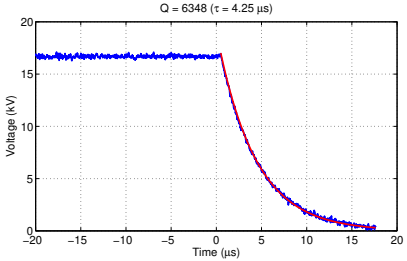

- Cavity 1;
- Cavity 2;
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- Some pulsed machines use such transients to automatically extract cavity parameters;
- Not immediately applicable in CW operation, but may be useful for diagnostics, if automated.

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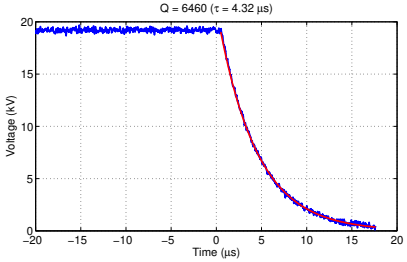

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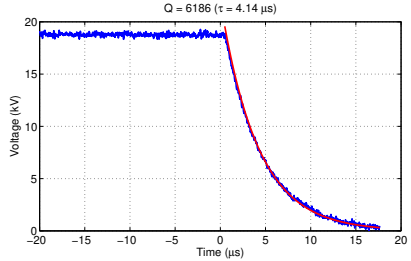

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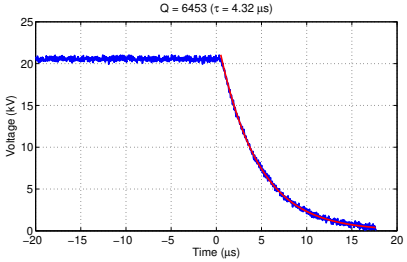

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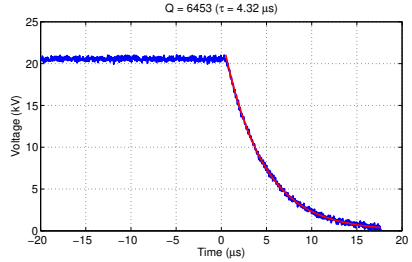

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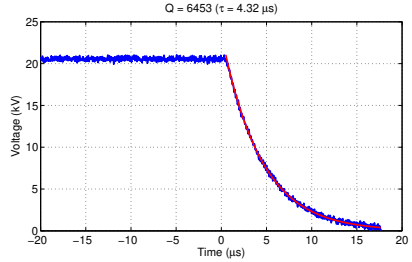

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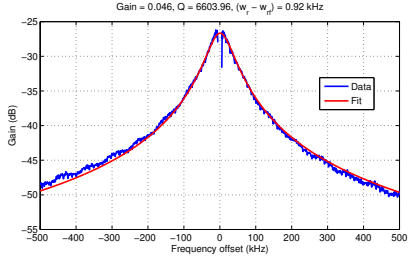
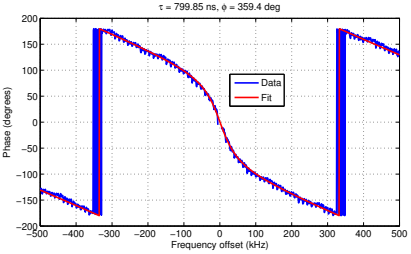
Cavity Transfer Functions





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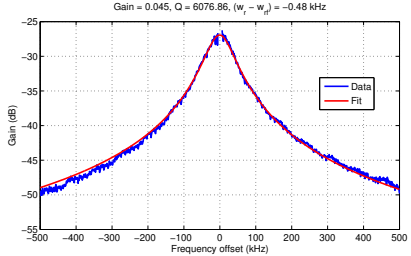

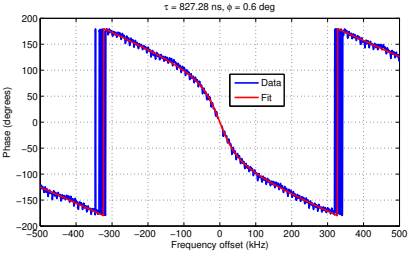

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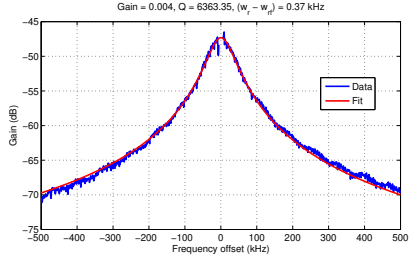

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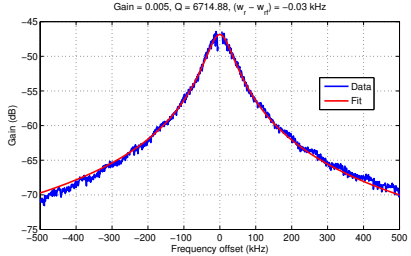

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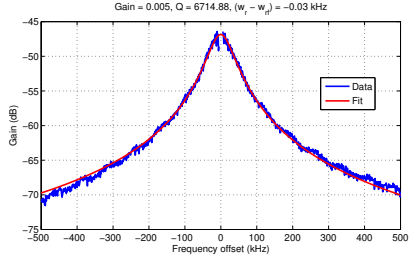

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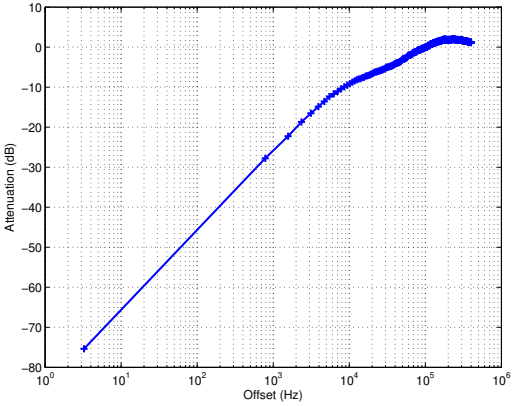

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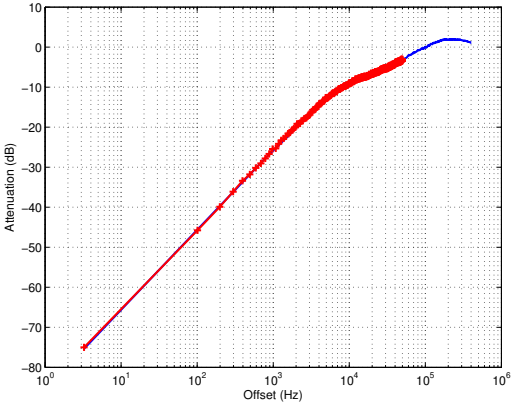

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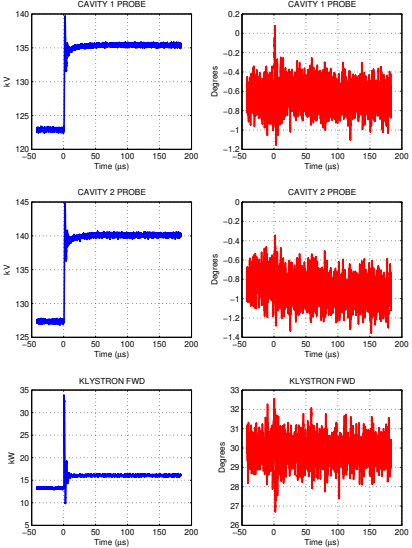

- Step response measurement in closed loop;
- 10% step from 500 to 550 kV;
- Proportional gain was too high (10 dB);
- Cleaner settling, little crosstalk to phase.

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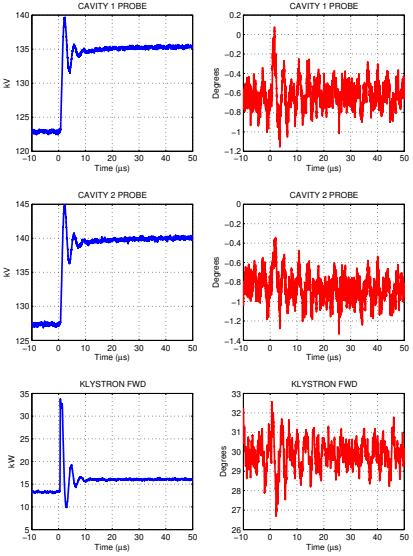

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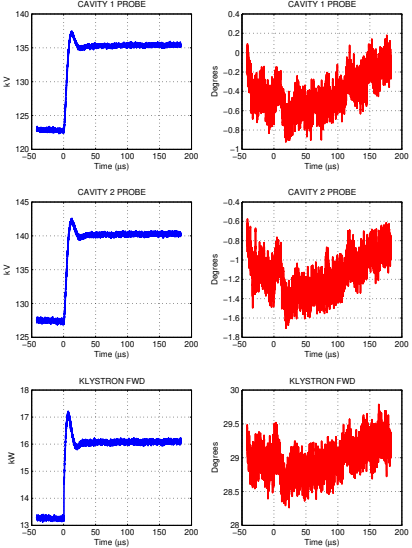

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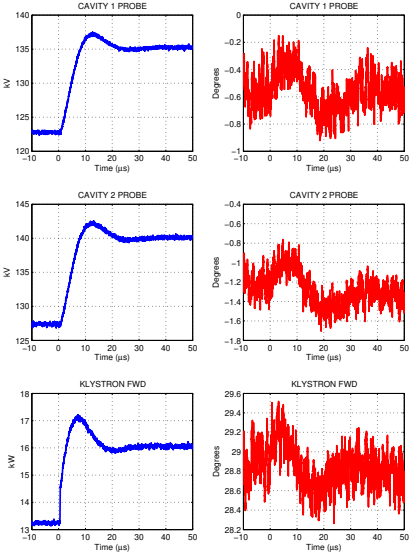

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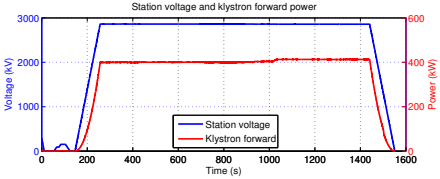
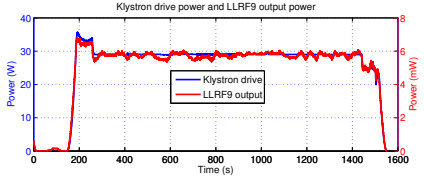
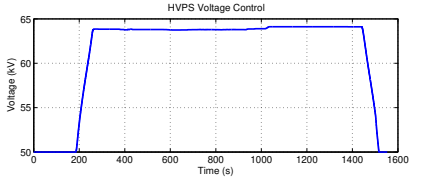
Full Station Cycle







- Full operational cycle from zero field to beam and back to zero;
- Demonstrates drive power loop operation — constant error during field ramping (± 5 W);
- Two beam injection events, at 940 and 1020 s;
- HVPS adjusted by the drive power loop each time;
- Transfer function sweeps are visible.

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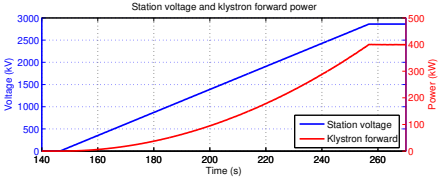

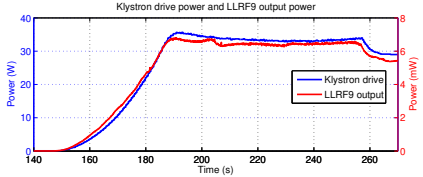

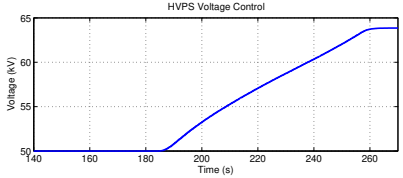

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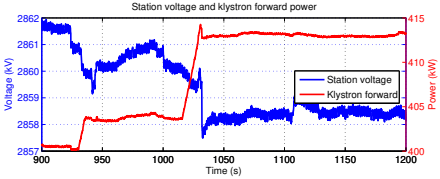

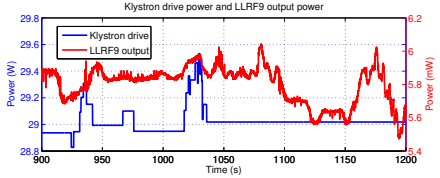

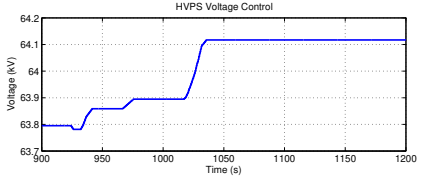

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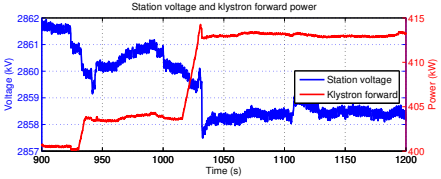

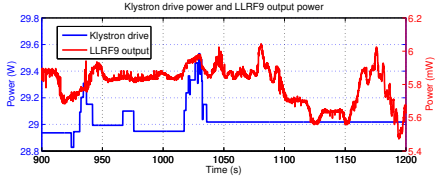

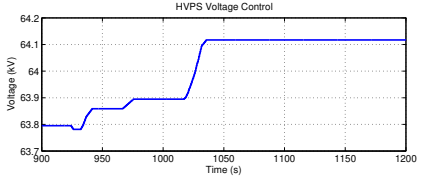

- Full operational cycle from zero field to beam and back to zero;
- Demonstrates drive power loop operation — constant error during field ramping (± 5 W);
- Two beam injection events, at 940 and 1020 s;
- HVPS adjusted by the drive power loop each time;
- Transfer function sweeps are visible.

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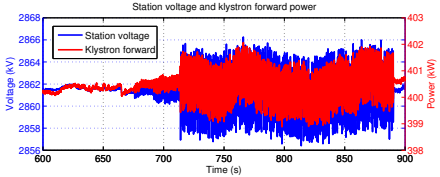

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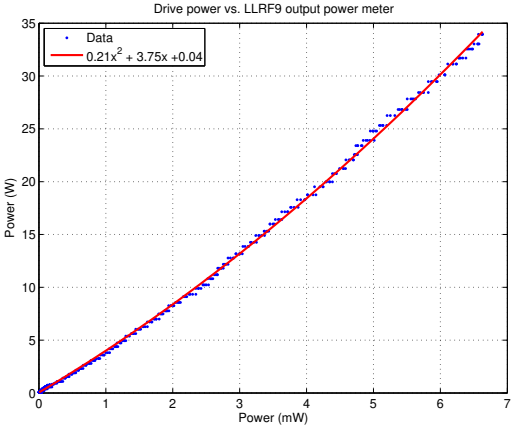
Drive Power and LLRF9 Output



- No saturation over this range;
- Slightly lower gain at low power settings;
- Voltage gain change around 30% from 0 to 35 W.

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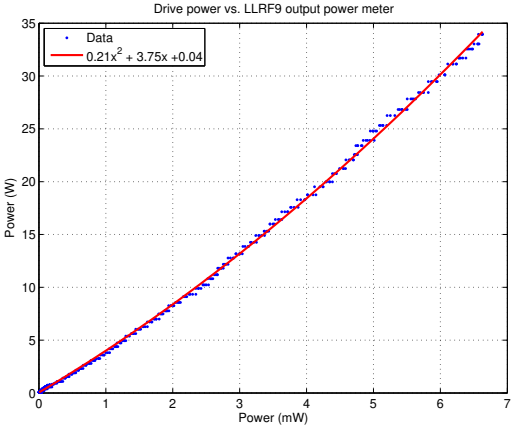

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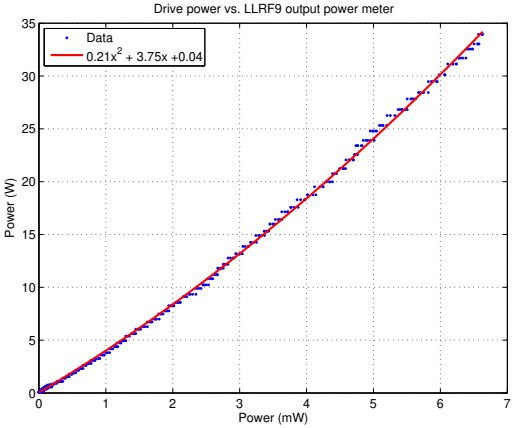

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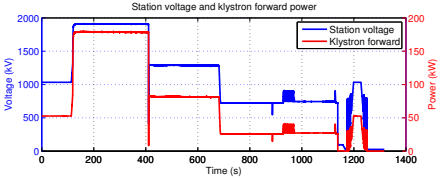
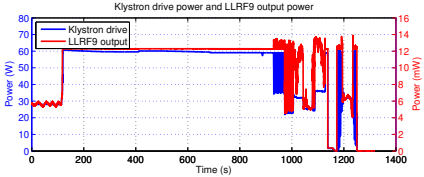
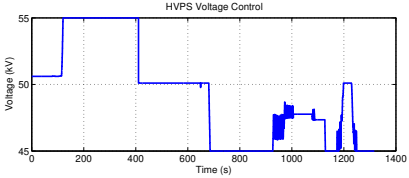
Outline

Loop Latchup







- In the process of slowly raising the field and the HVPS limit we ran into drive power latchup;
- Saturated at 60 W;
- The problem turned out to be the disabled klystron phase loop;
- Pure operator error.

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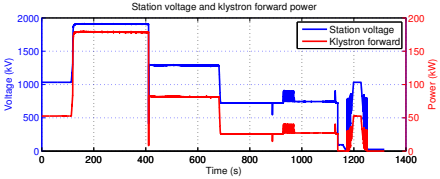

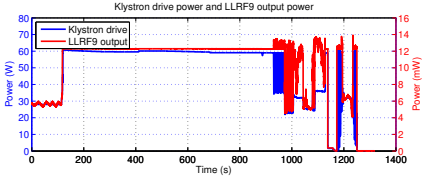

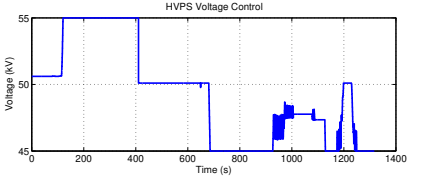

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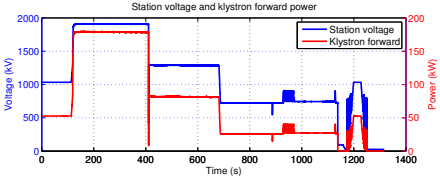

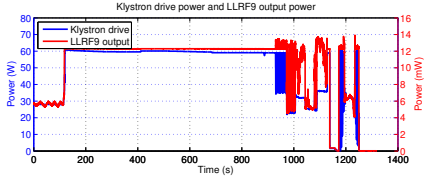

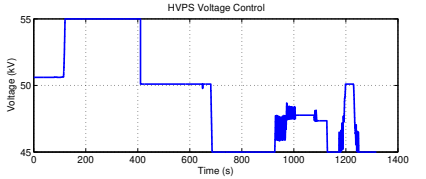

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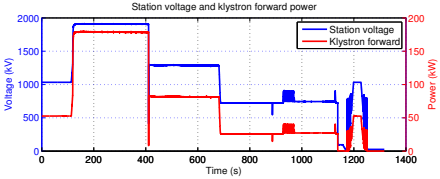

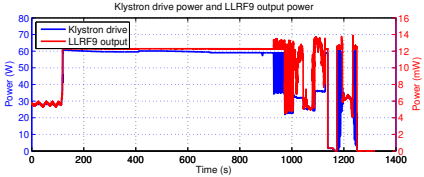

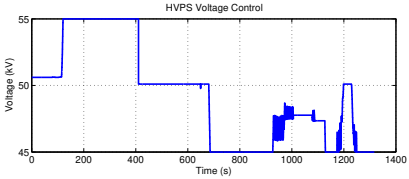

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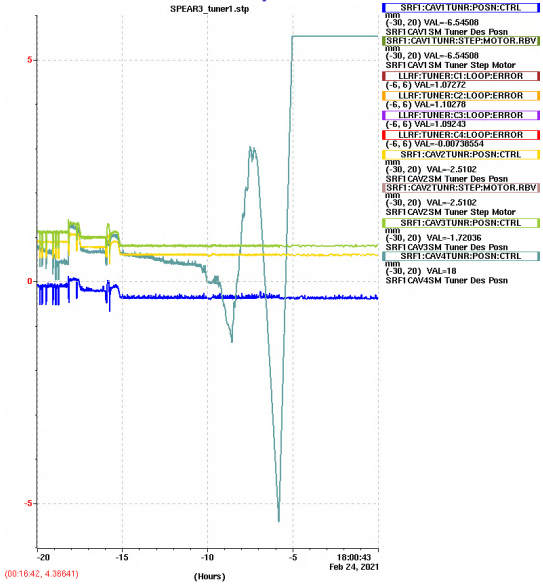
Dual Tuner Loops



- When we finished the shift, LLRF9 was left with the interlock tripped;
- Normally that is sufficient to guarantee that the unit is not actively controlling things;
- Closed tuner loops got enabled when the forward power threshold was exceeded;
- Mostly seen in tuner D control;
- Modified LLRF9 IOC to disable tuner loops when the interlock is tripped.

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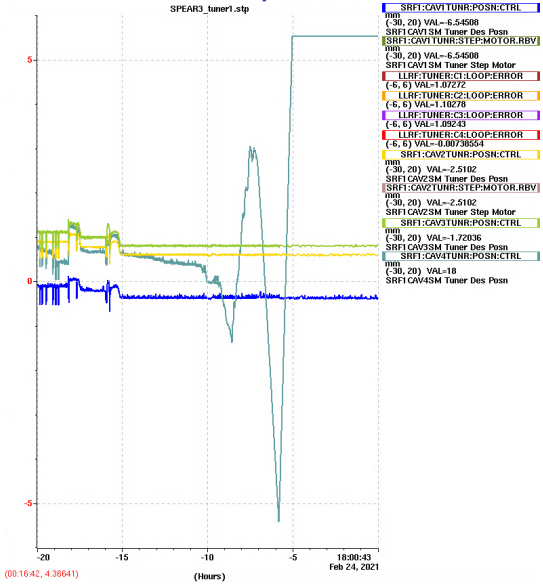

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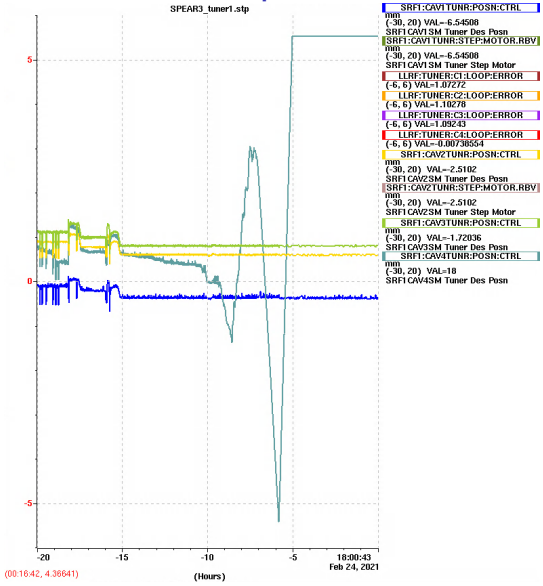

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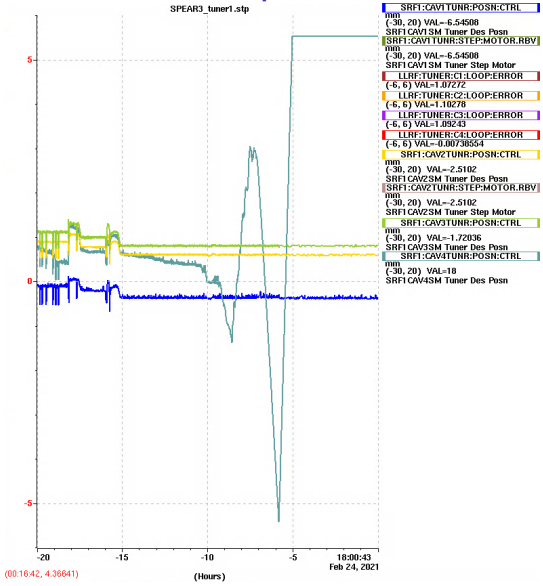

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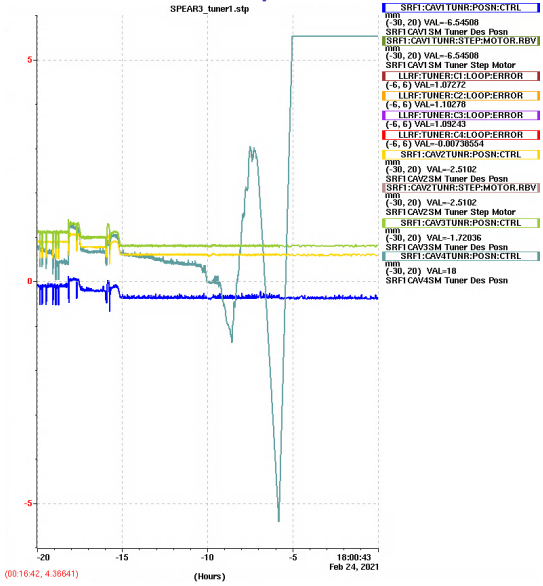

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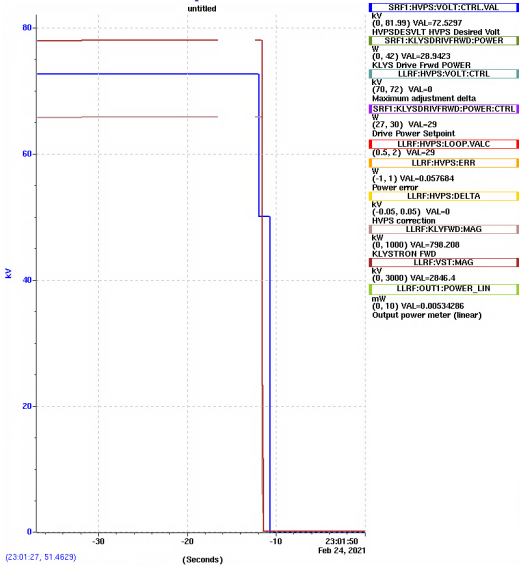

- After adding the tuner loop modification, I restarted the LLRF9 IOC at 22:50 on 2021-02-24;
- As it turns out, at startup the IOC resets the HVPS to the minimum value (50 kV);
- Caused the station to trip...
- Restarted the IOC during the access on 2021-02-26 to disconnect it from SRF1 EPICS control channels;
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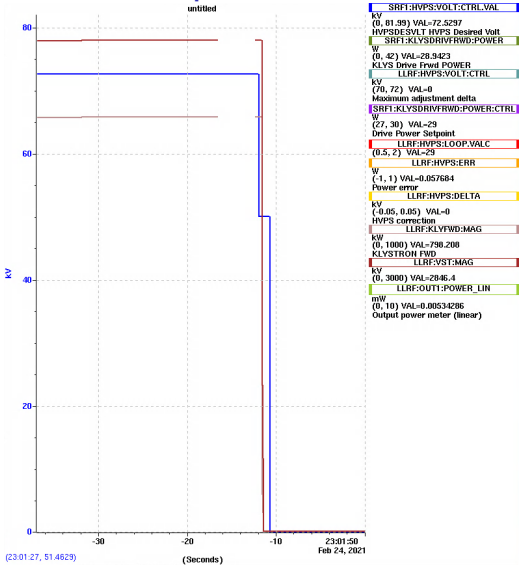

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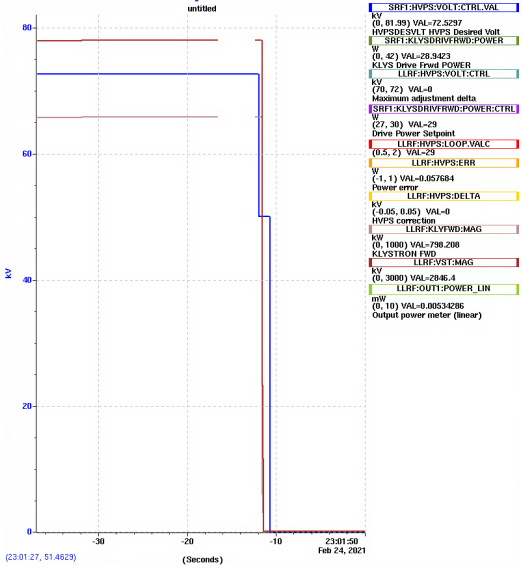

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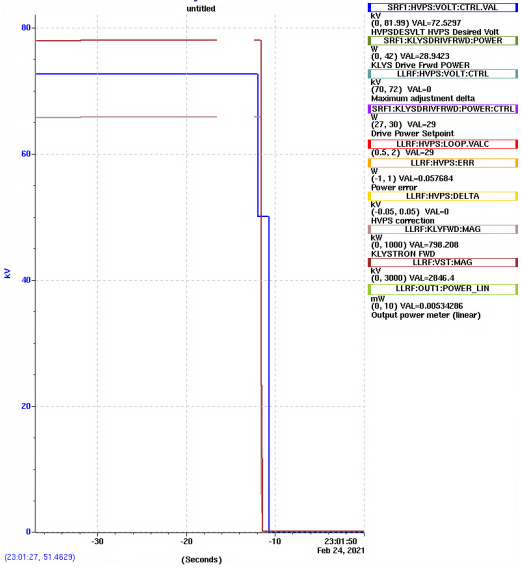

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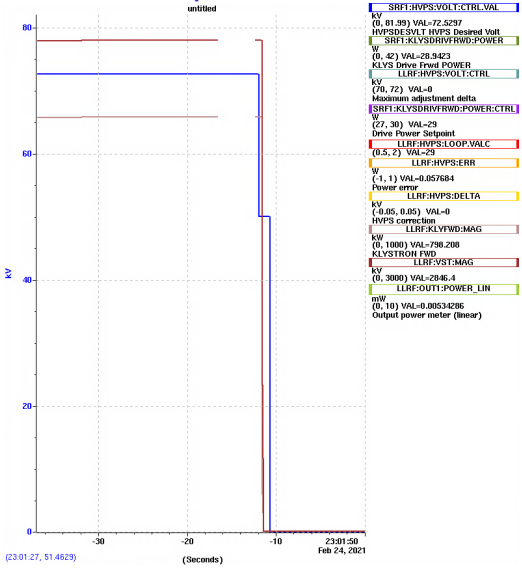

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- Ready for the high beam currents;
- TODO:
  - Implement the precision station voltage control loop;
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