Bunch-by-bunch feedback and diagnostics in SSRF

Demonstration of iGp12 and FBE-500LT

D. Teytelman

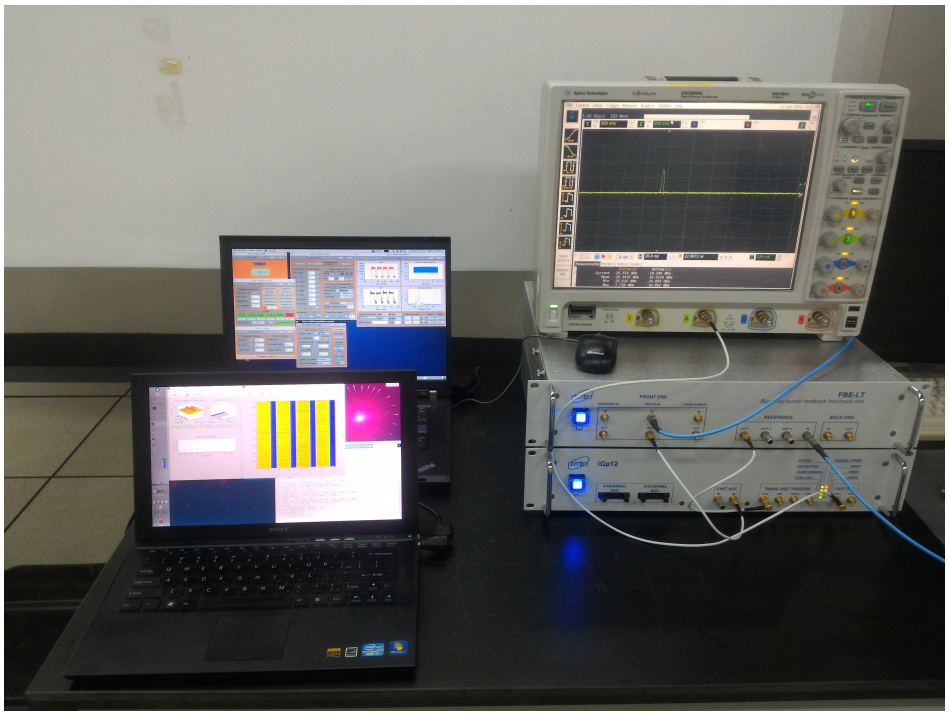
Dimtel, Inc., San Jose, CA, USA

December 14, 2016

Outline

1. Setup
2. Spectra and Modal Analyses
   - Parasitic Measurements
   - Active Studies
3. Beam Transfer Functions
4. Tune Tracking
5. Injection Transients

Setup



- Baseband processor (iGp12) and front end (FBE-500LT) set up on a table;
- Used two buttons (BPM8), unused by the existing feedback processor;
- Minimal perturbation of the existing system.
- Took advantage of the maintenance day to check amplifier responses, establish drive levels.

Day by Day Summary

- Monday (2016-12-12):
  - Unpacked the hardware;
  - Found unused BPM signals and RF clock source;
  - First parasitic measurement at 13:58.
- Tuesday (2016-12-13):
  - Late start to rest before the night shift;
  - Temporarily connected two power amplifiers, adjusted drive levels and measured pulse responses.
- Wednesday (2016-12-14):
  - Started at 5:45, done by 9:00;
  - Multibunch beam at 50 mA by 7:47;
  - Full current by 8:08;
  - Too little time to optimize the setup.

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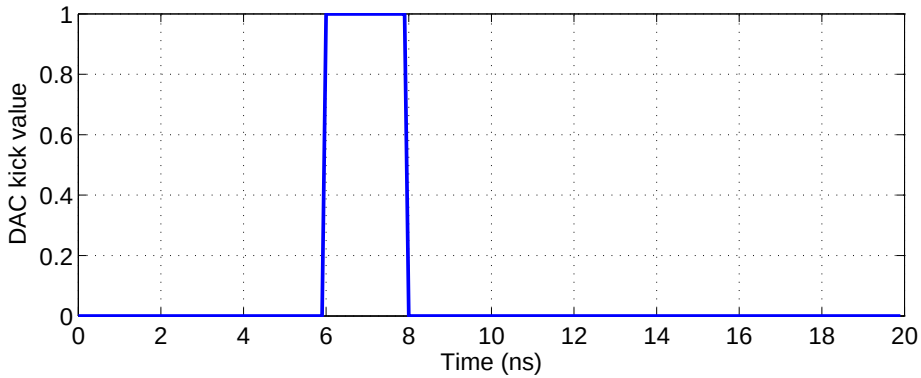
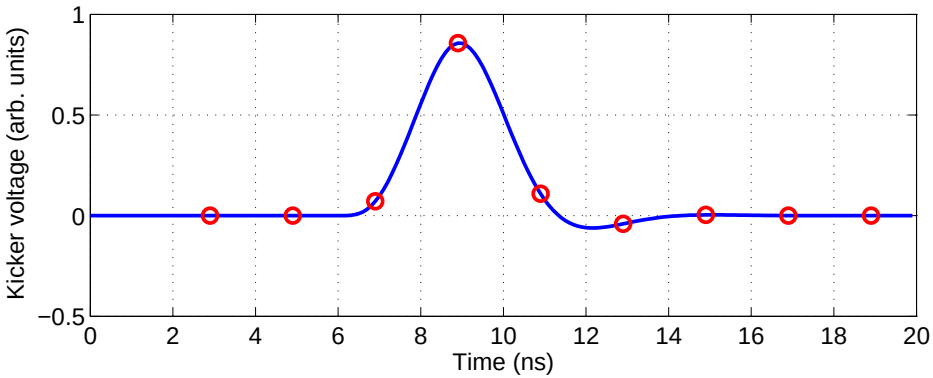
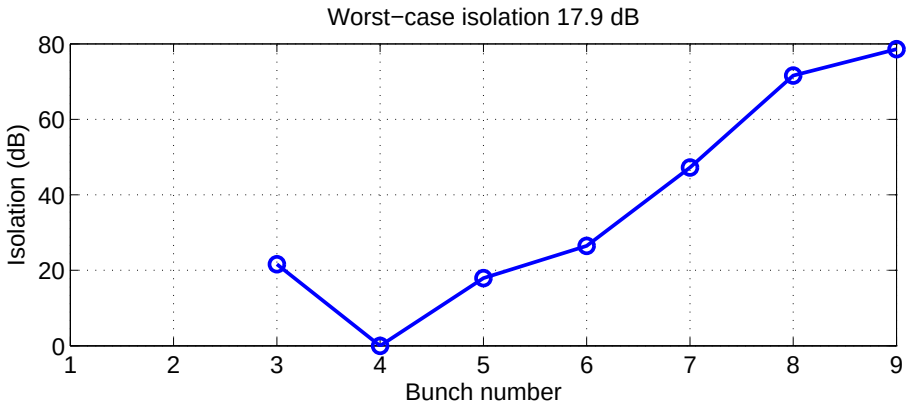
Amplifier Responses







- Conceptual sketch of the measurement;
- Measured response to a 2 ns pulse from iGp12 DAC;
- Used two amplifiers, 1 and 3;
- Significant differences between the two;
- Easier to see if waveforms are normalized;
- Both amplifiers are 1 dB into saturation, 16 and 31 W at peak.

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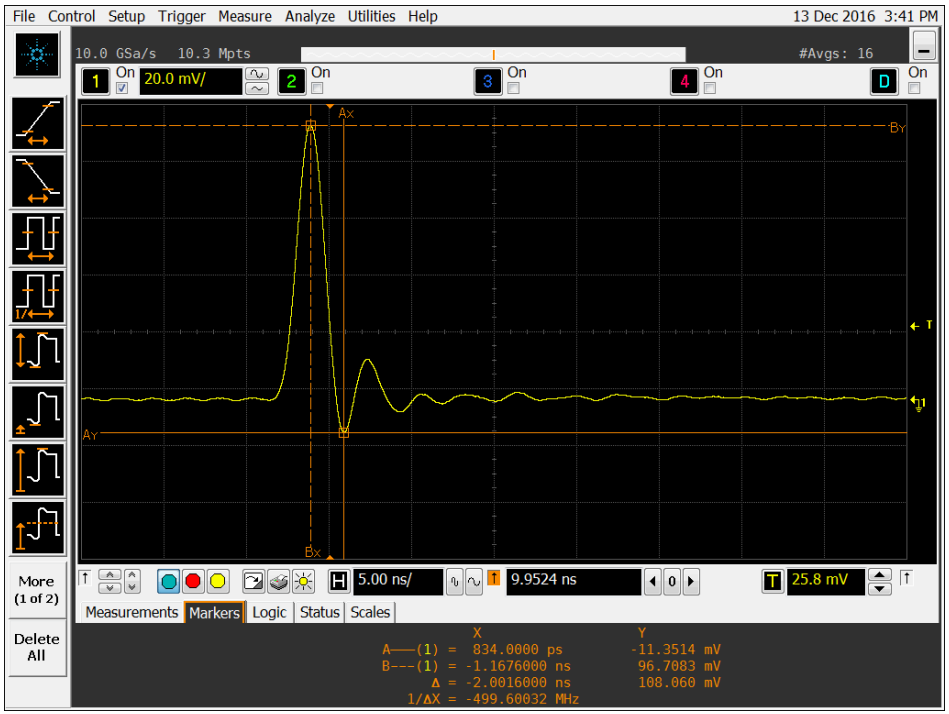

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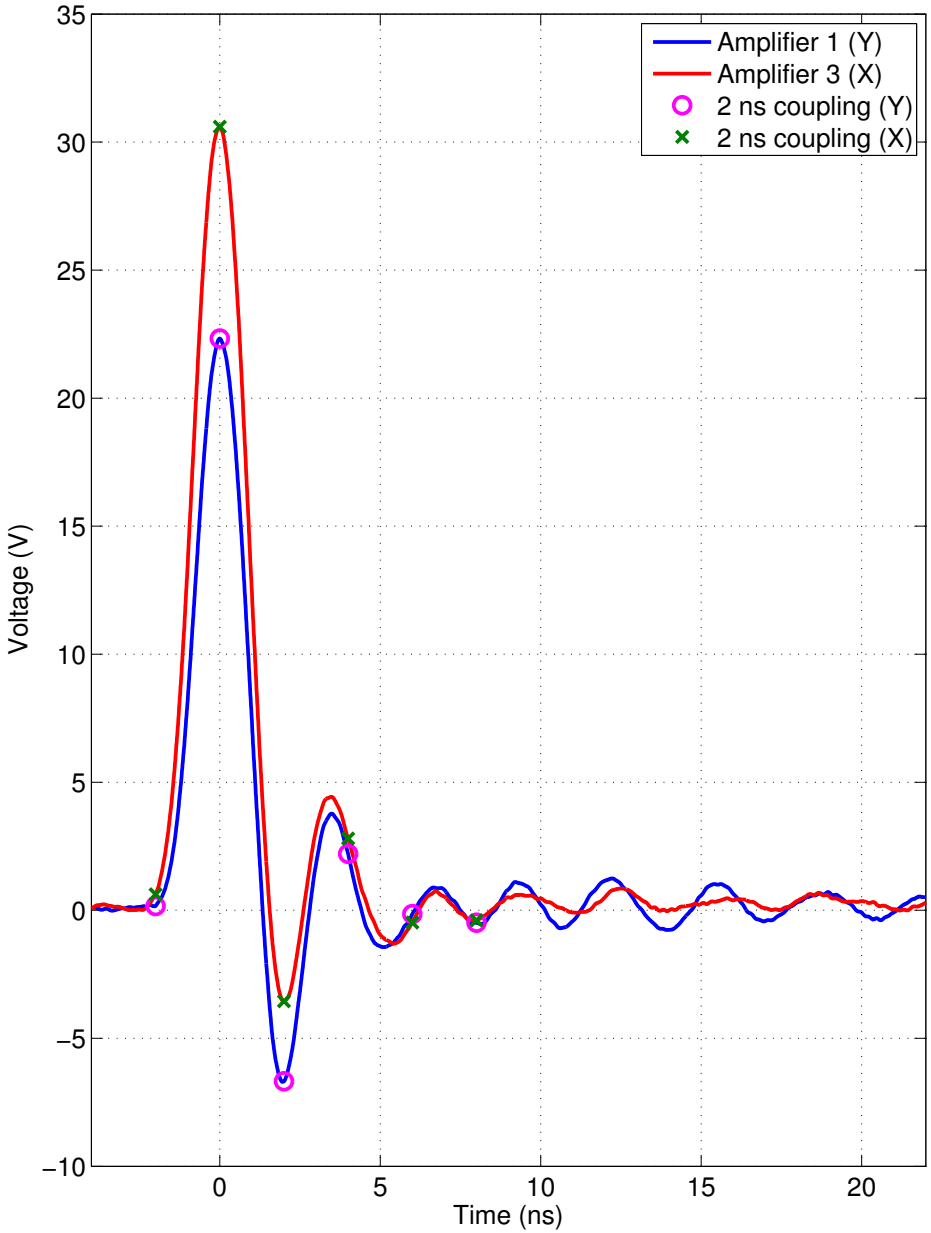

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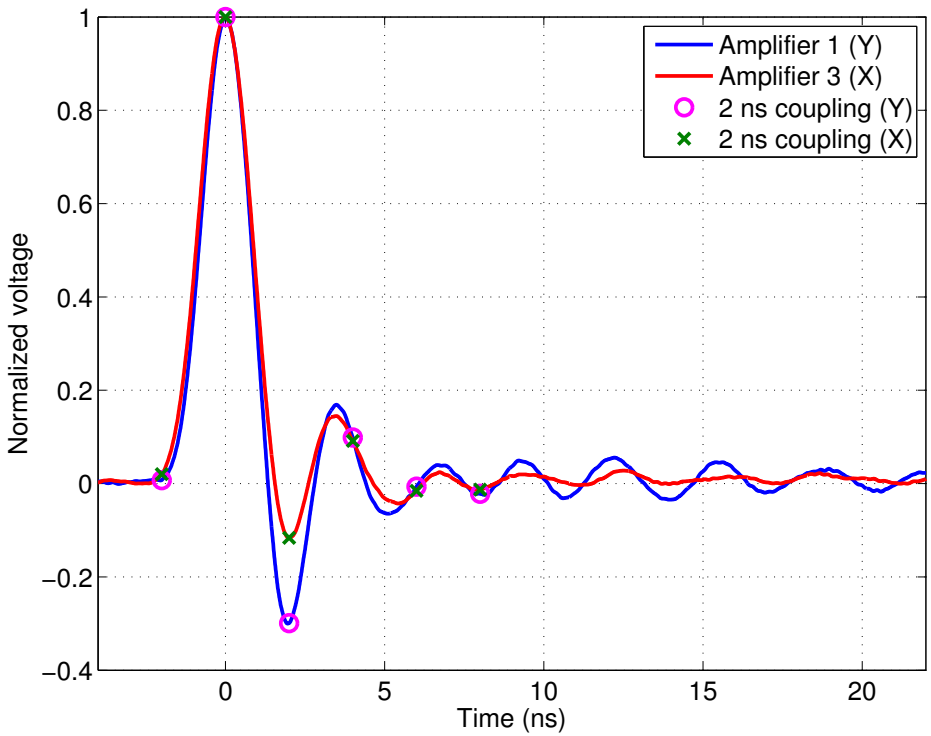

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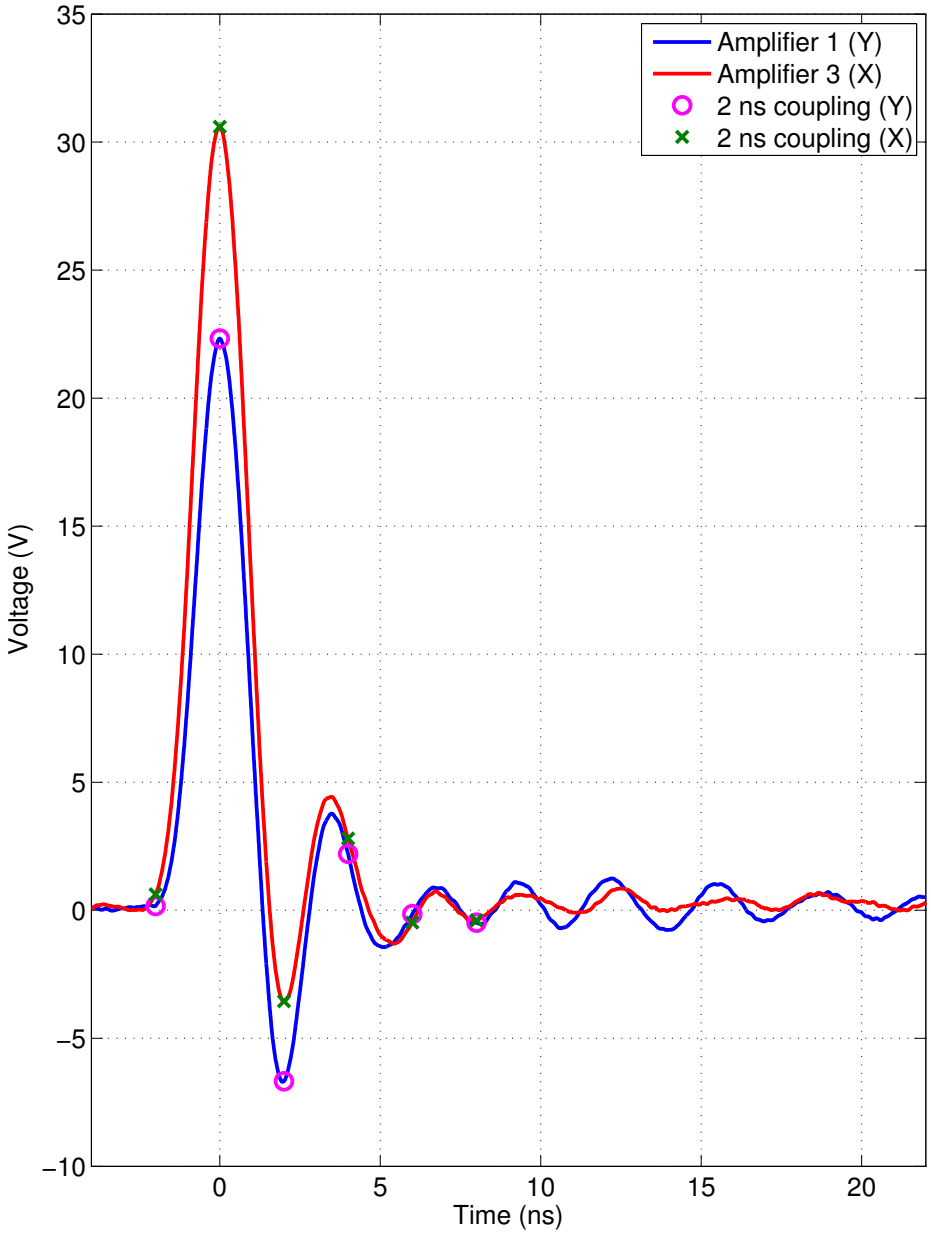

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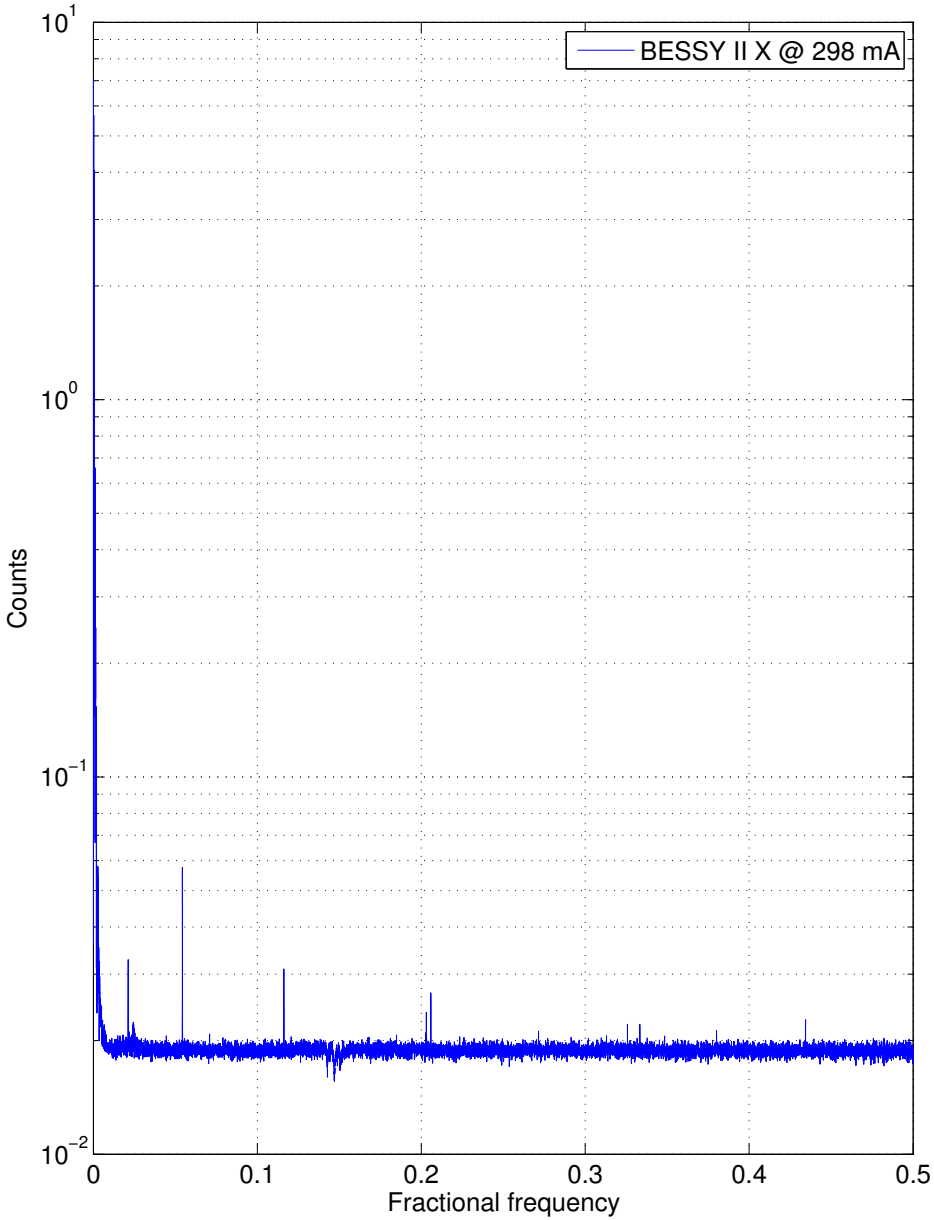

- Comparison with a few other machines:
  - BESSY II horizontal;
  - BESSY II vertical;
  - ALS vertical;
  - SSRF.
- Wideband spectra show a wide range of spurs (ALS lines are revolution harmonics);
- All 22 machines with commissioned Dimtel systems use direct signal from the master oscillator as RF reference.

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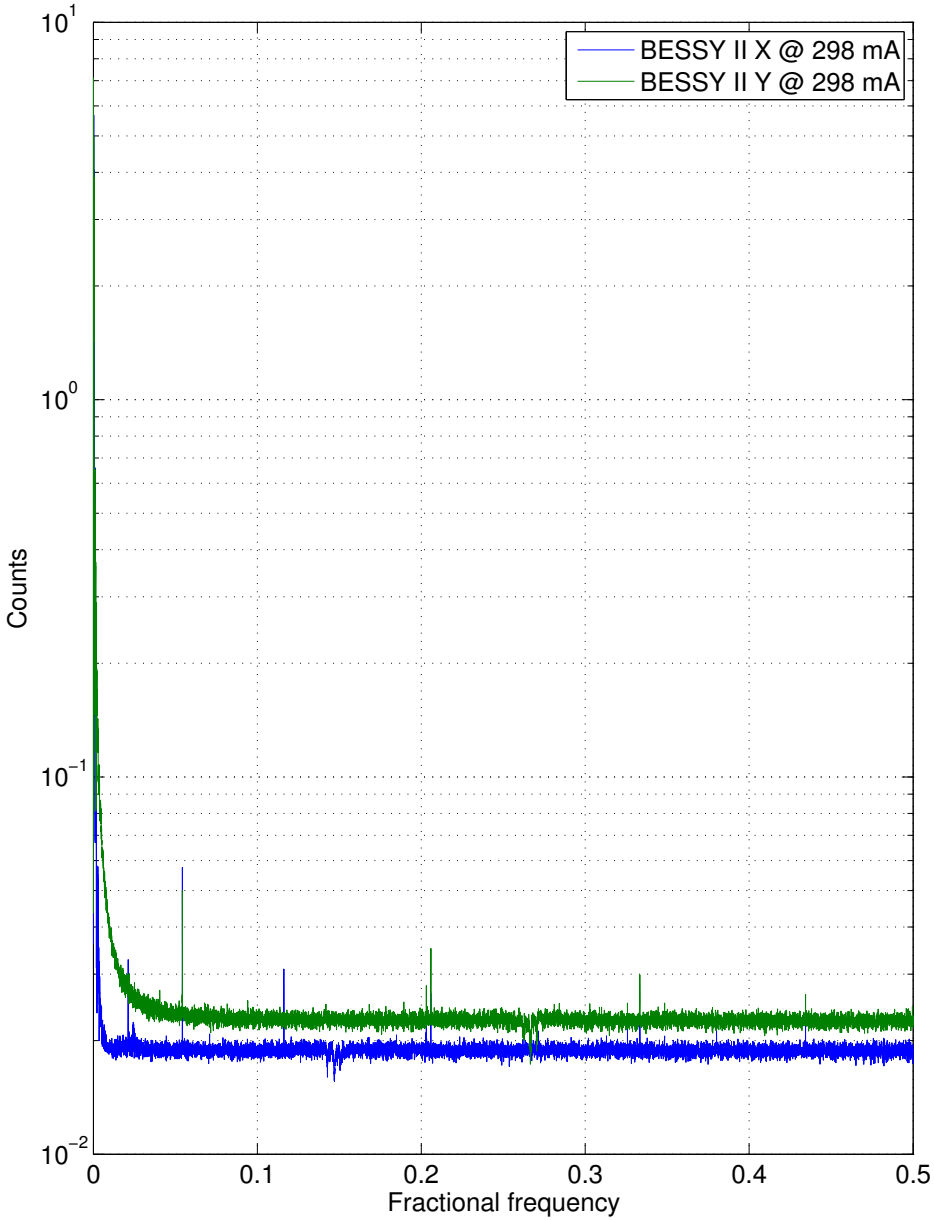

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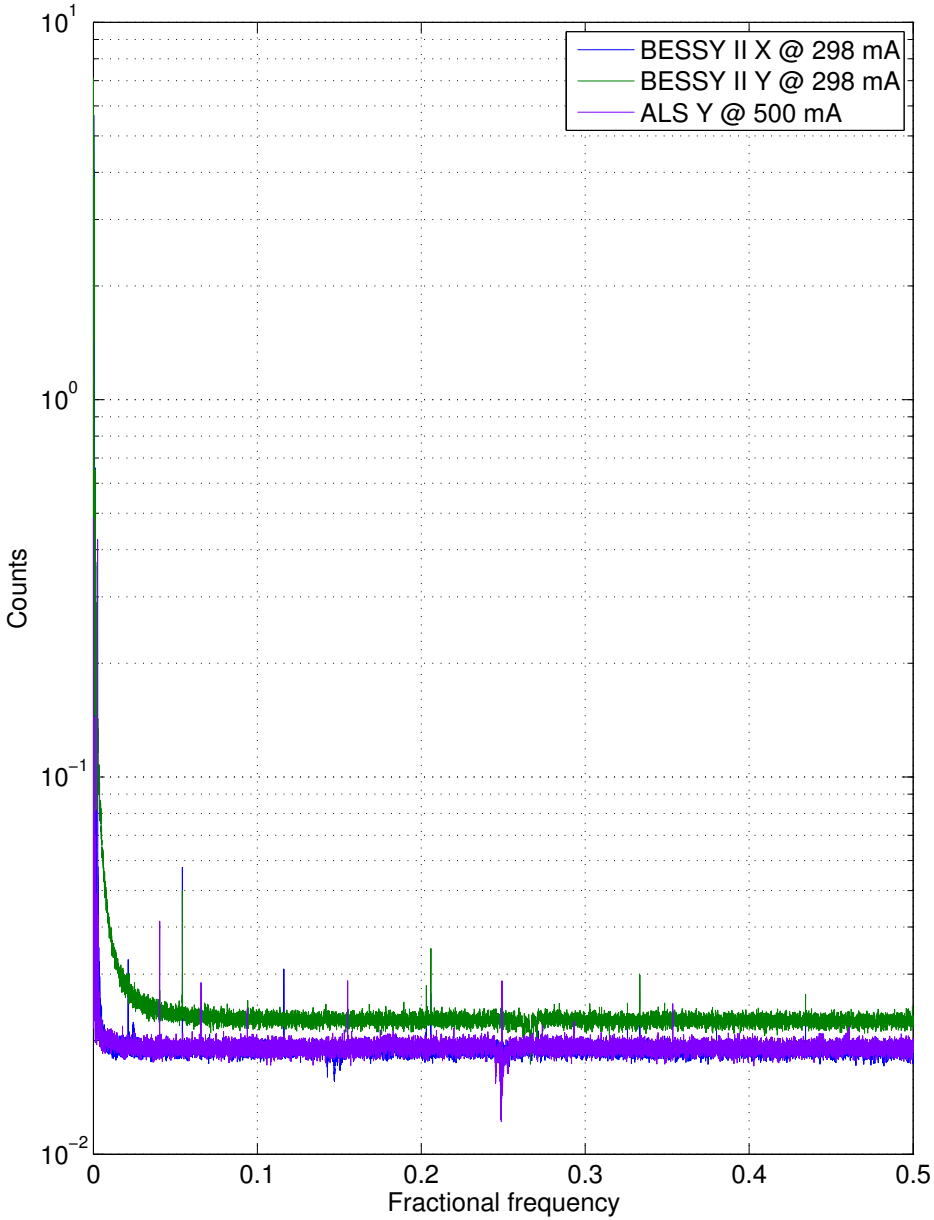

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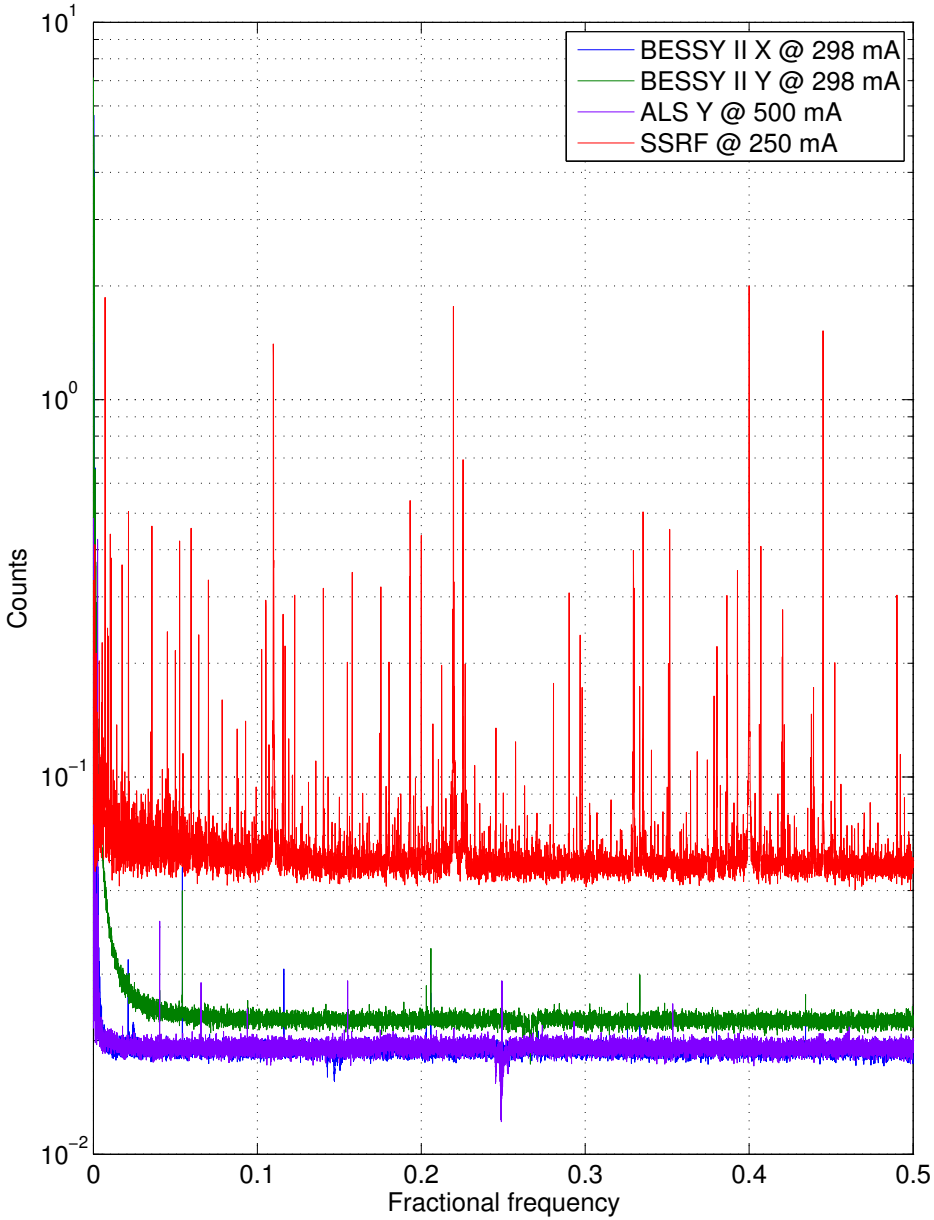

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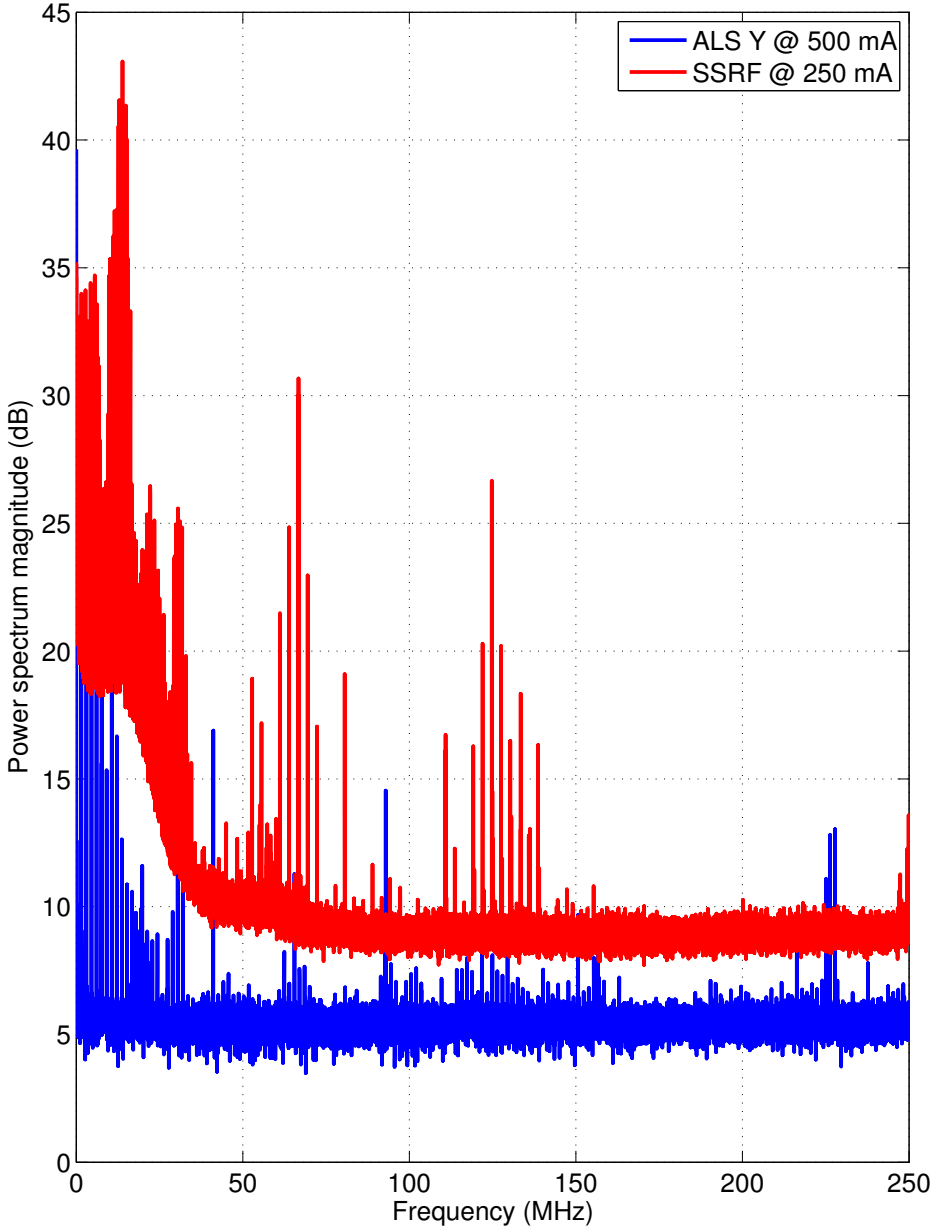

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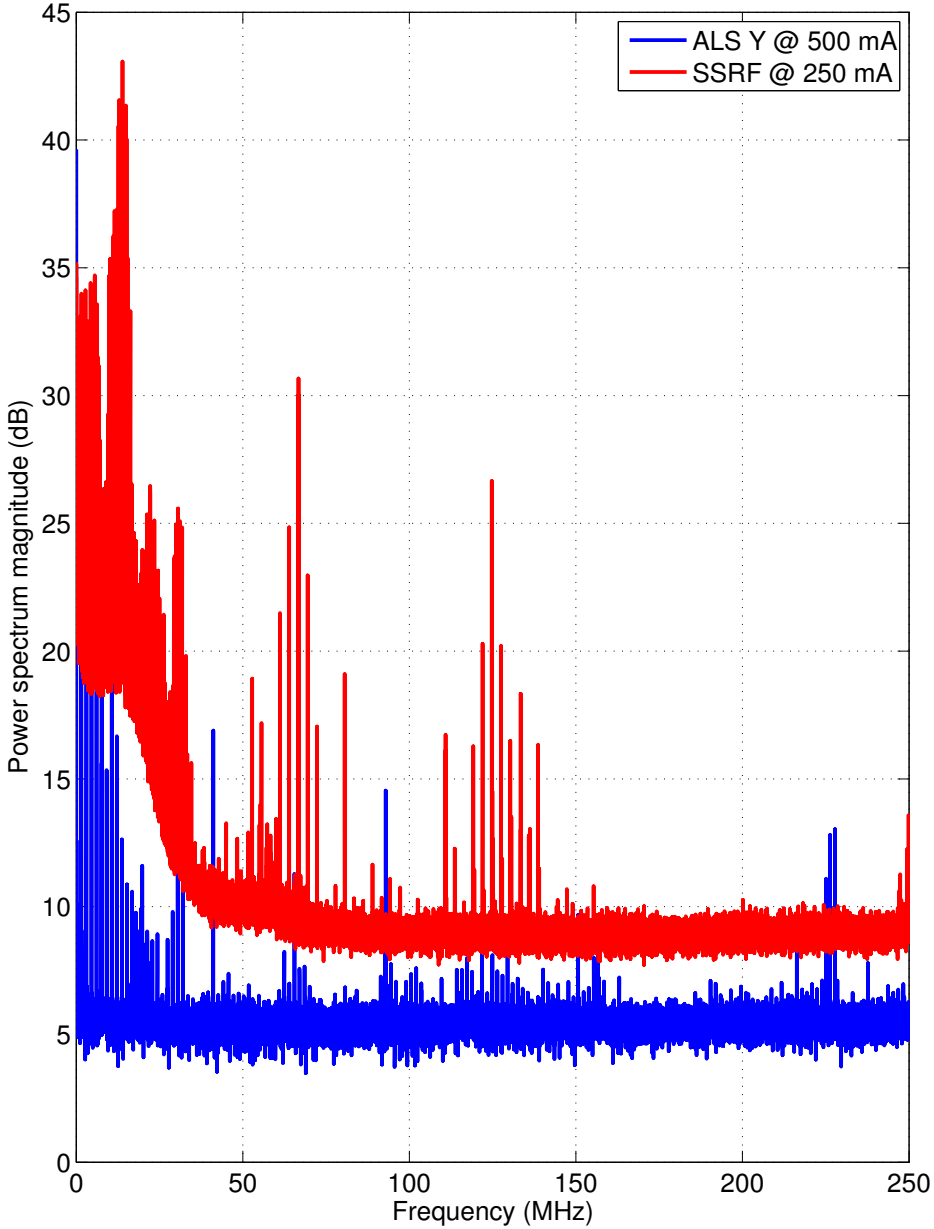

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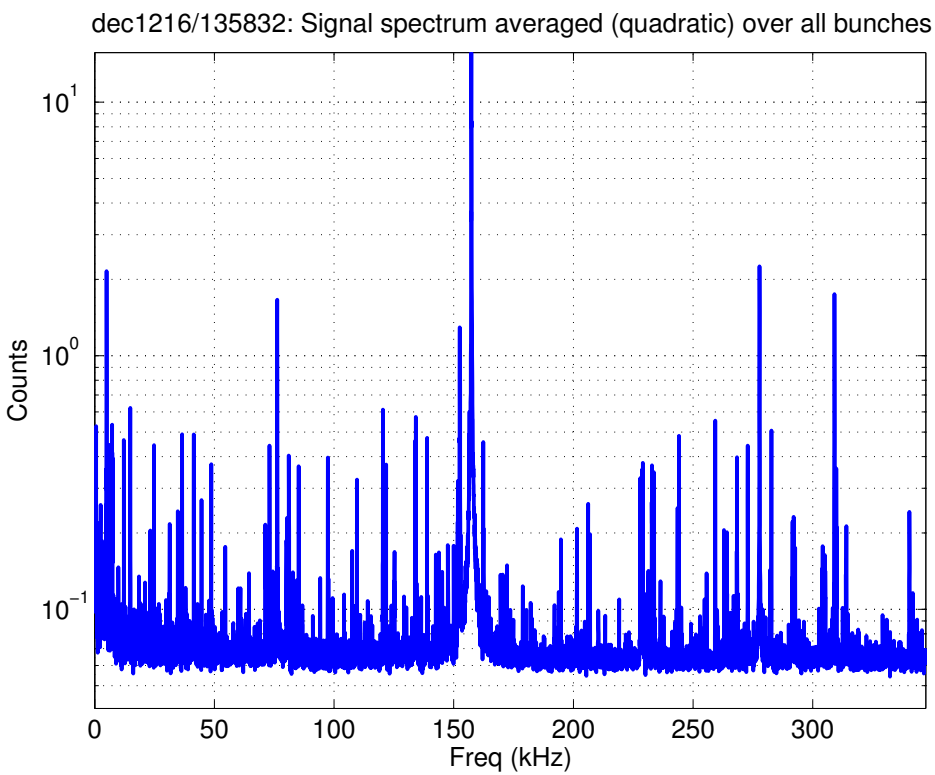

- Surprisingly, found a large line at the horizontal frequency;
  - Later on discovered that some connectors on Spring-8 system were not fully tightened;
  - Possibly a cable was disturbed during our setup, causing loss of horizontal control;
  - Fixed at 16:00.
- Steady oscillation amplitudes;
- Single mode 719 (-1) — resistive wall.

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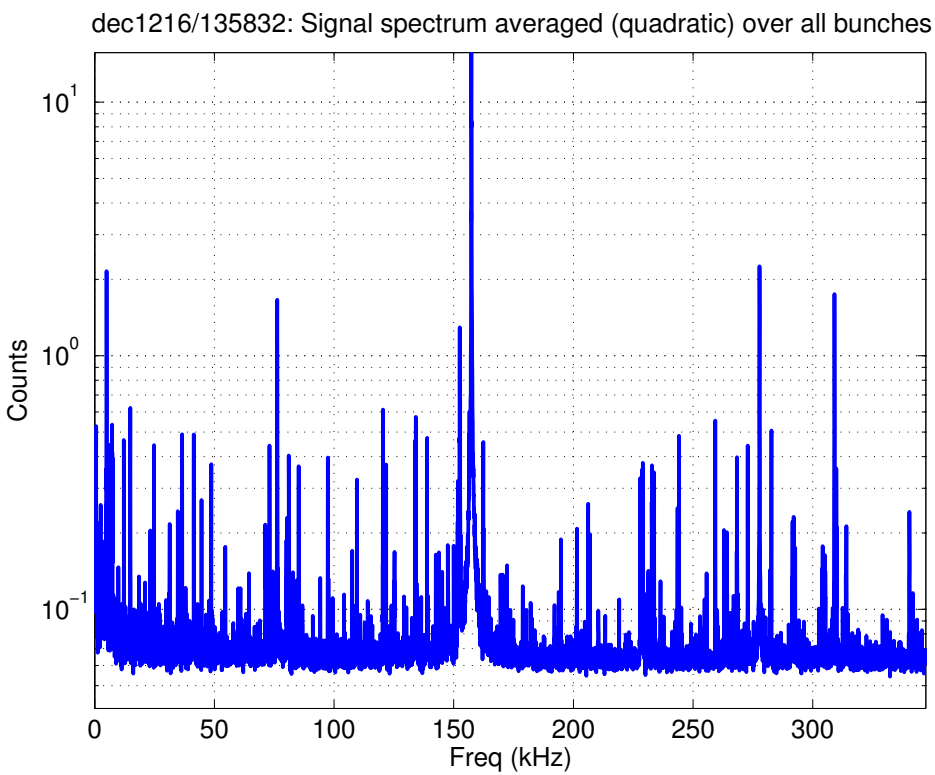

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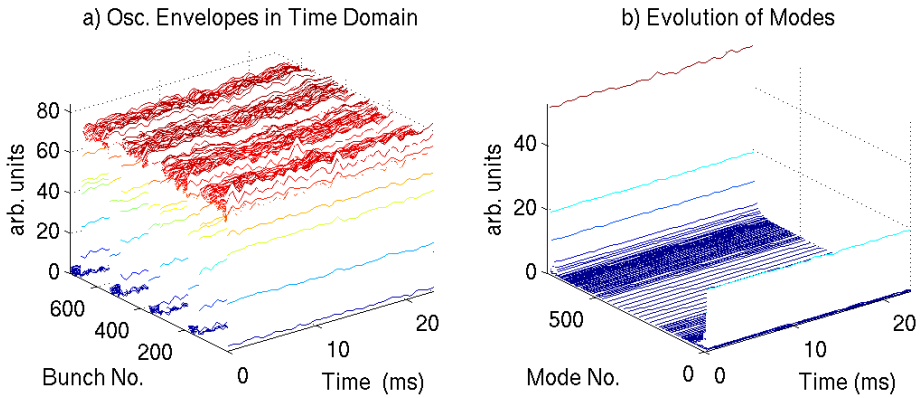

SSRF:dec1216/135832: Io= 250mA, Dsamp= 1, ShifGain= 0, Nbun= 720,
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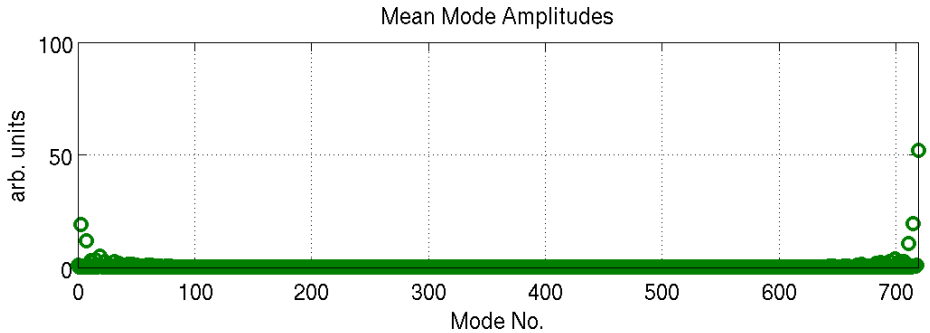

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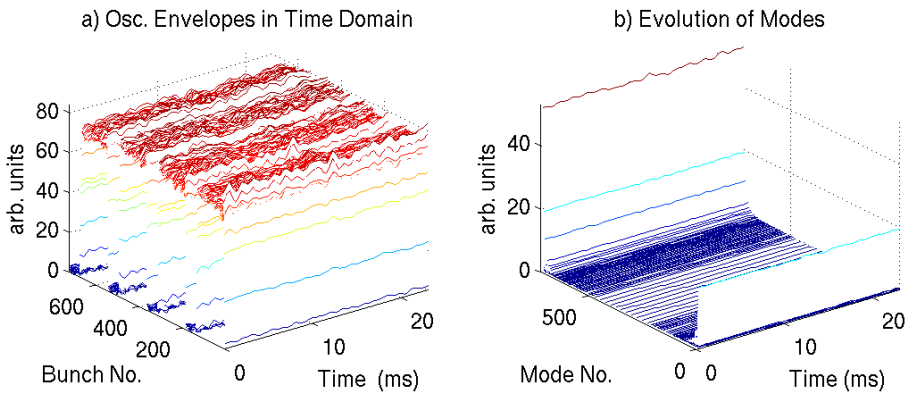

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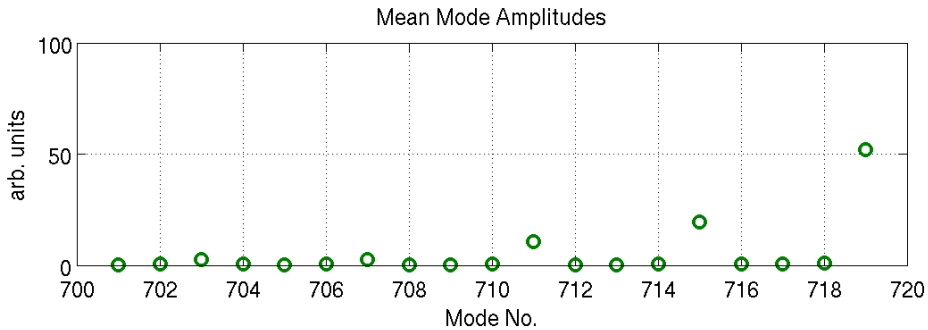

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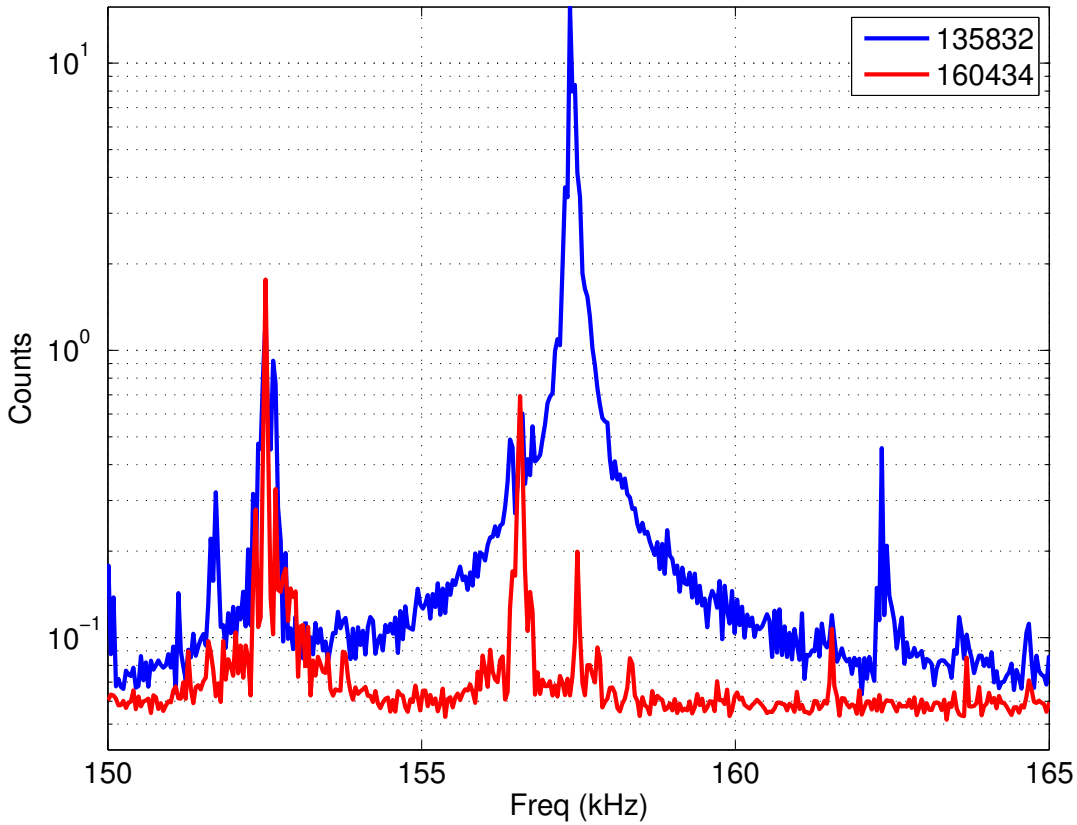
Horizontal Spectra



- Stable and unstable spectra;
- Second one taken after poor cable connections were re-torqued.

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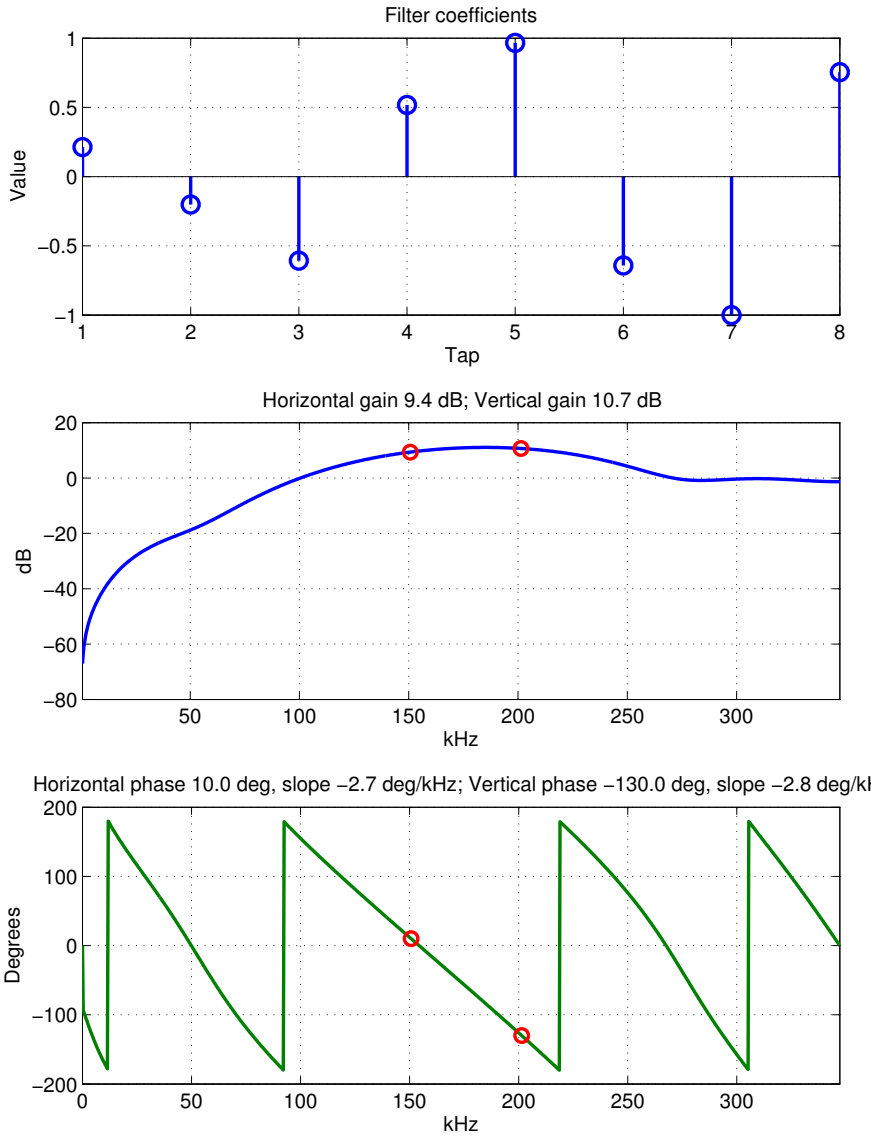
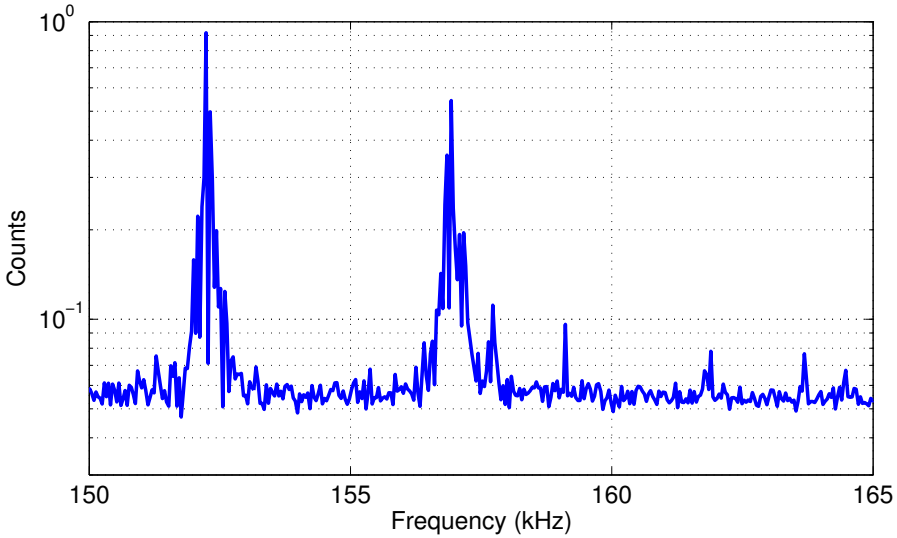
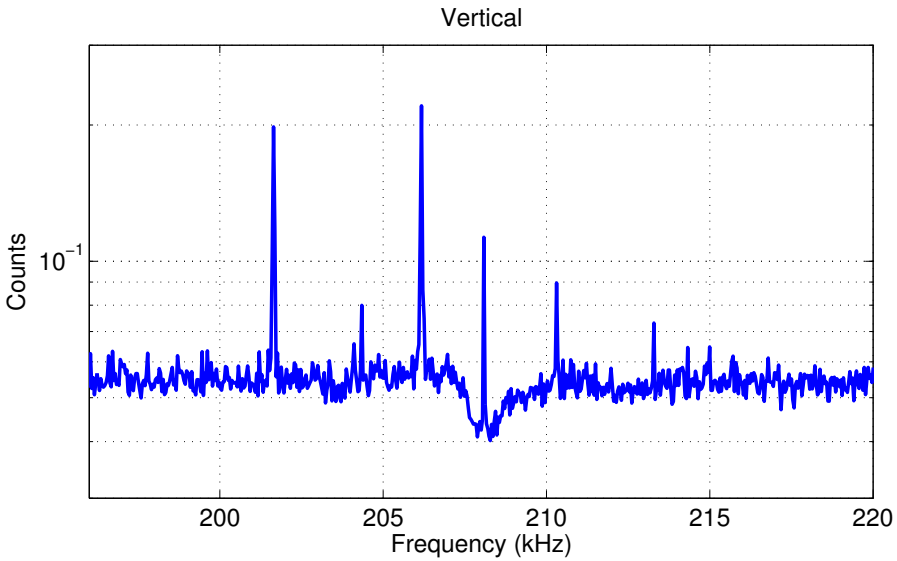
Feedback Filter



- 8-tap FIR filter;
- Designed by a Matlab optimizer from a specification of tunes, gains, and phases for X and Y;
- Phases optimized for resistive feedback;
- Guaranteed DC rejection (orbit offsets).

Closed-loop Steady-state Spectra





- Same spectrum, zoomed around f_x and f_y;
- iGp12+FBE-500LT at 250 mA;
- Existing system at 237 mA;
- Very similar performance.
  - In case of iGp12 performance is dominated by RF reference noise.

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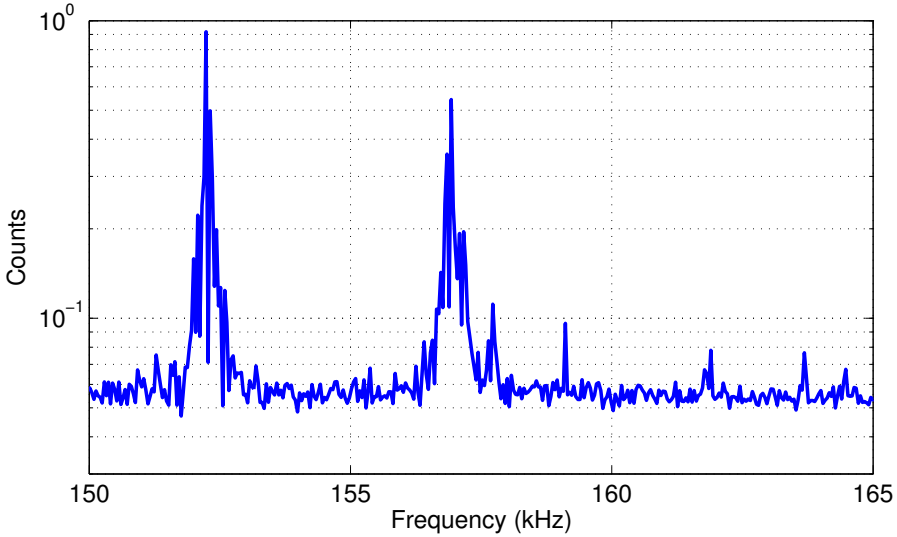

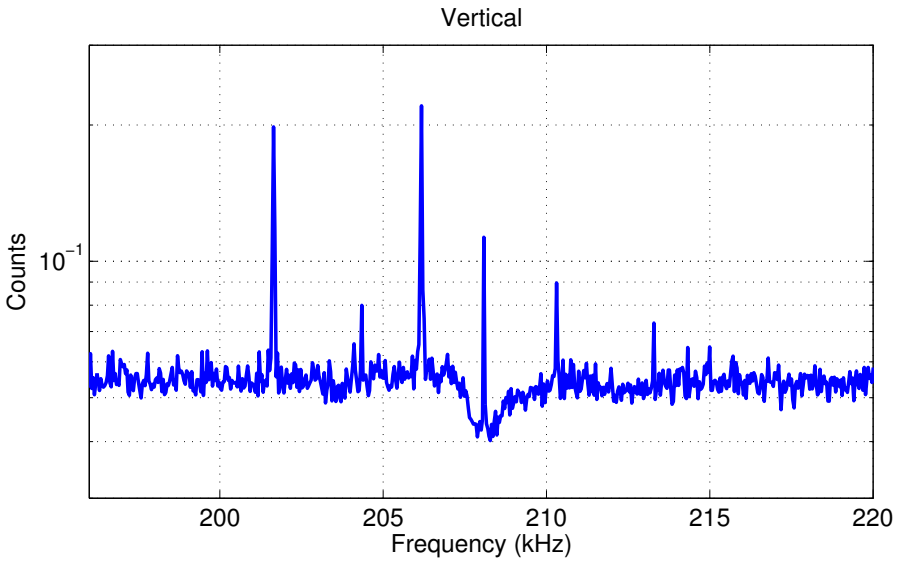

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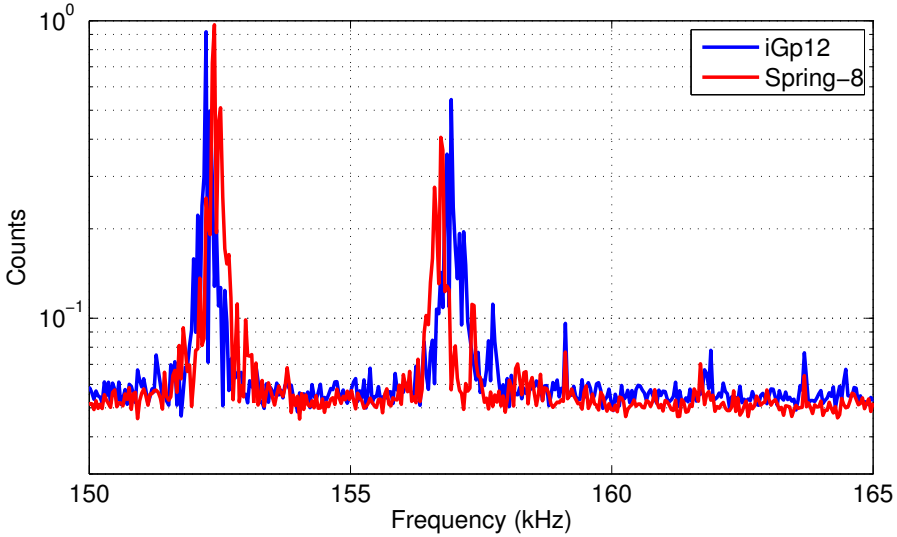

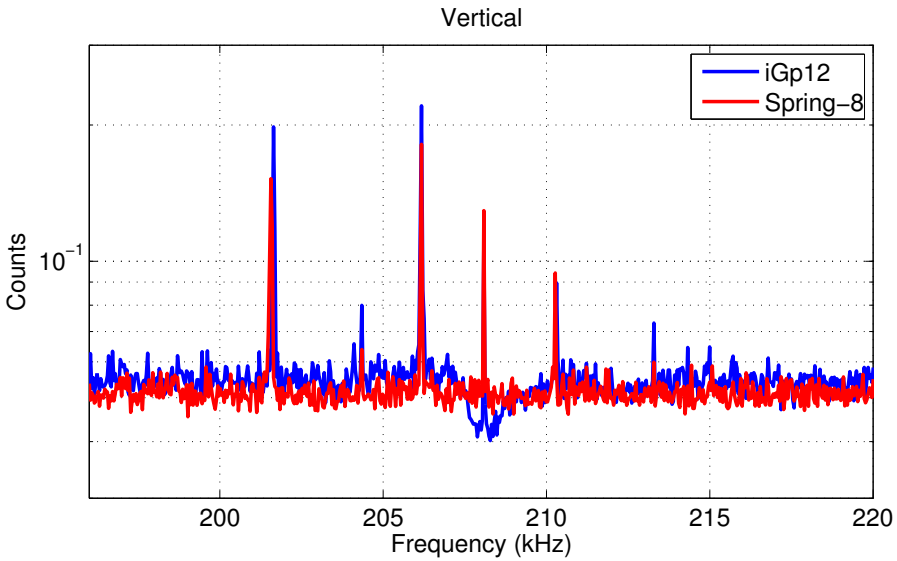

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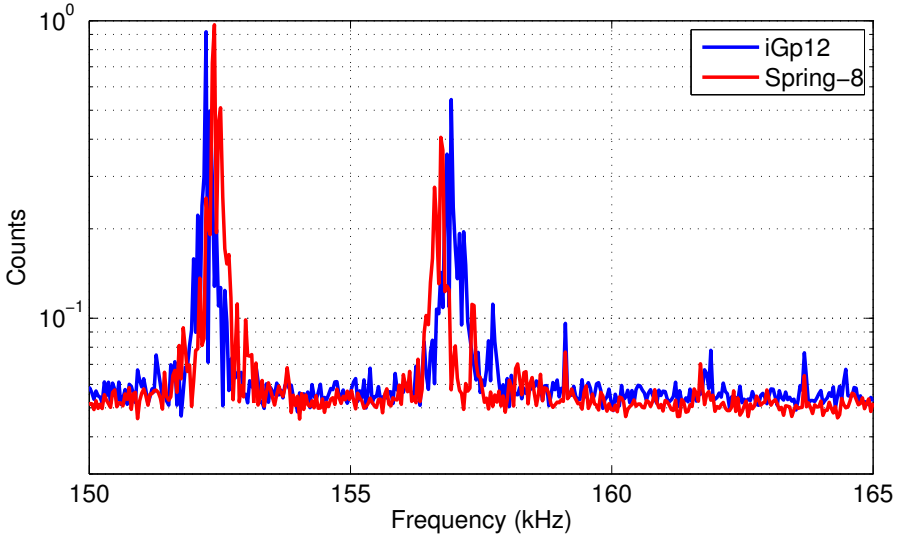

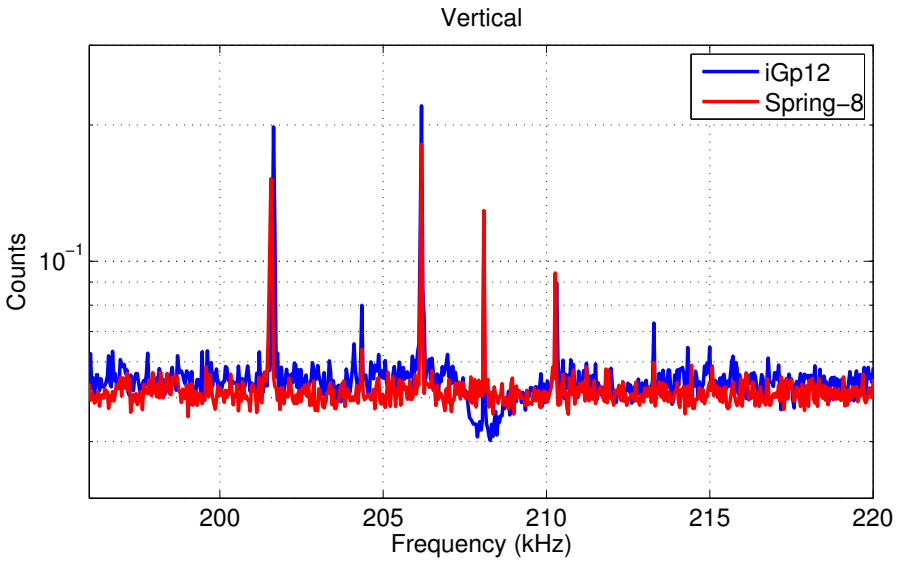

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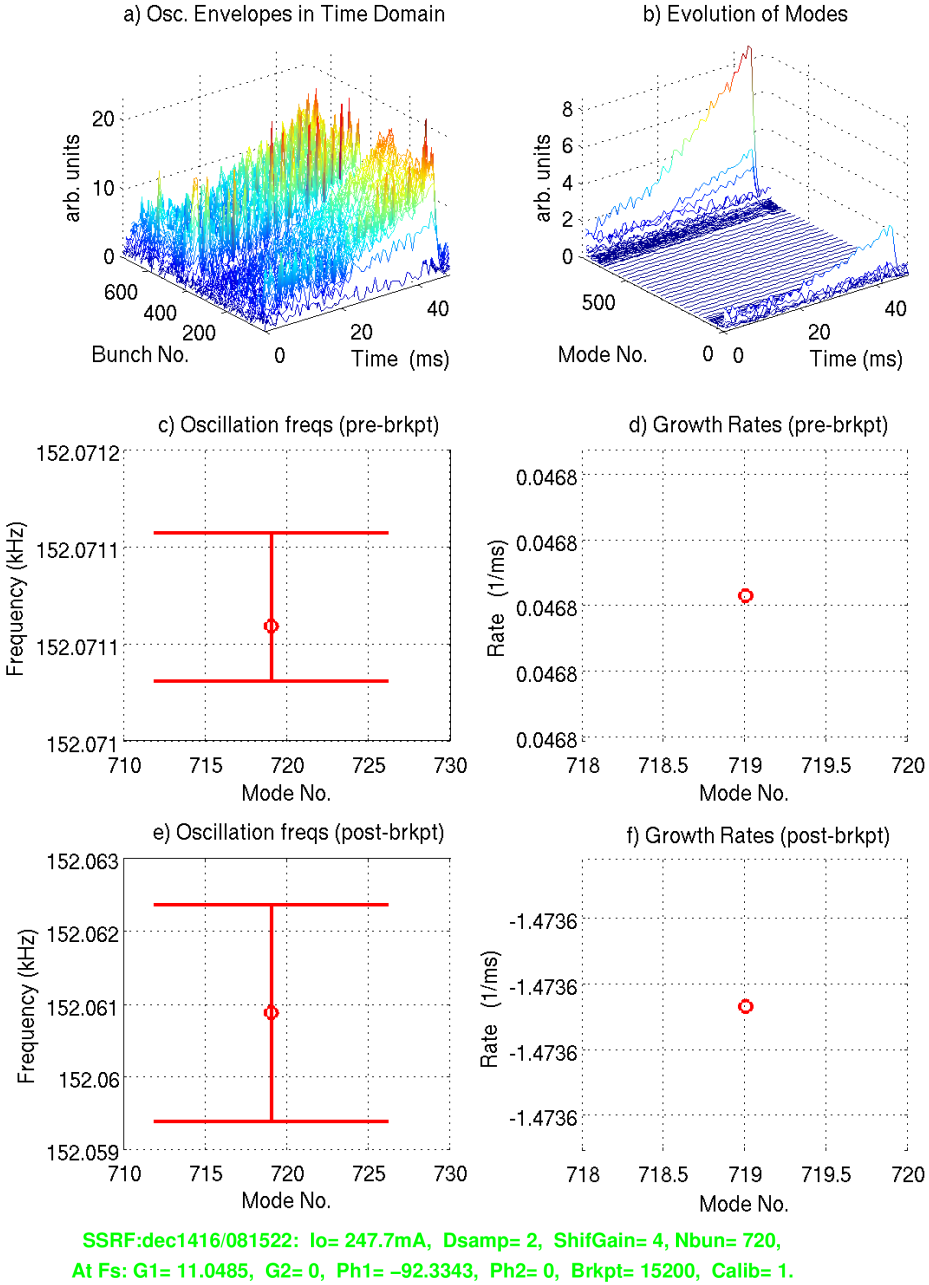
Horizontal Grow/Damp



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At Fs: G1= 11.0485, G2= 0, Ph1= –92.3343, Ph2= 0, Brkpt= 15200, Calib= 1.

- Feedback loop is open for 45 ms;
- Captured data shows mode −1 growing and damping;
- Growth time 21.4 ms, damping time 0.7 ms;
- Very little frequency shift, feedback tuned for resistive damping;
- Modulation of the modal amplitude is due to a nearby spur.

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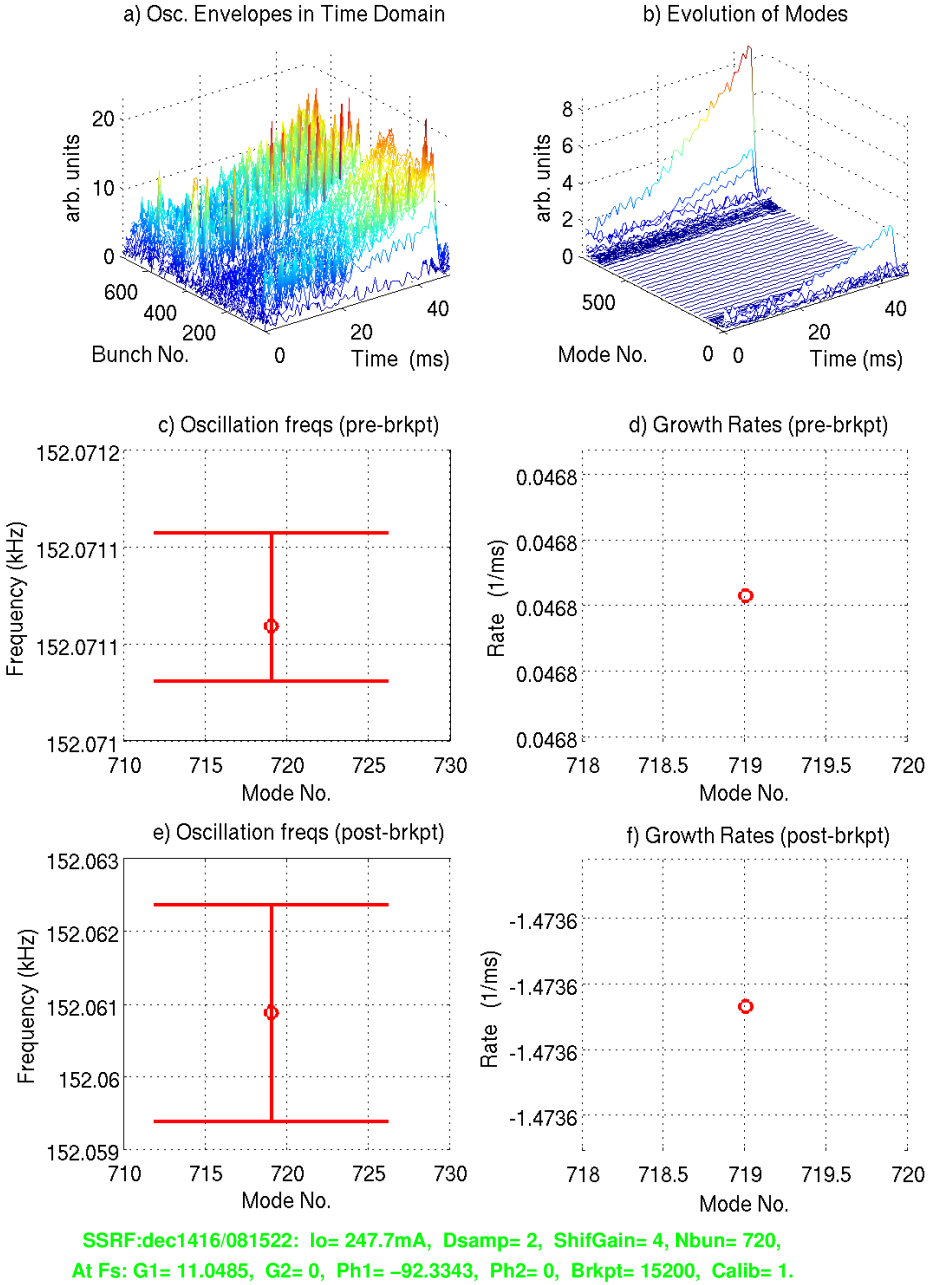

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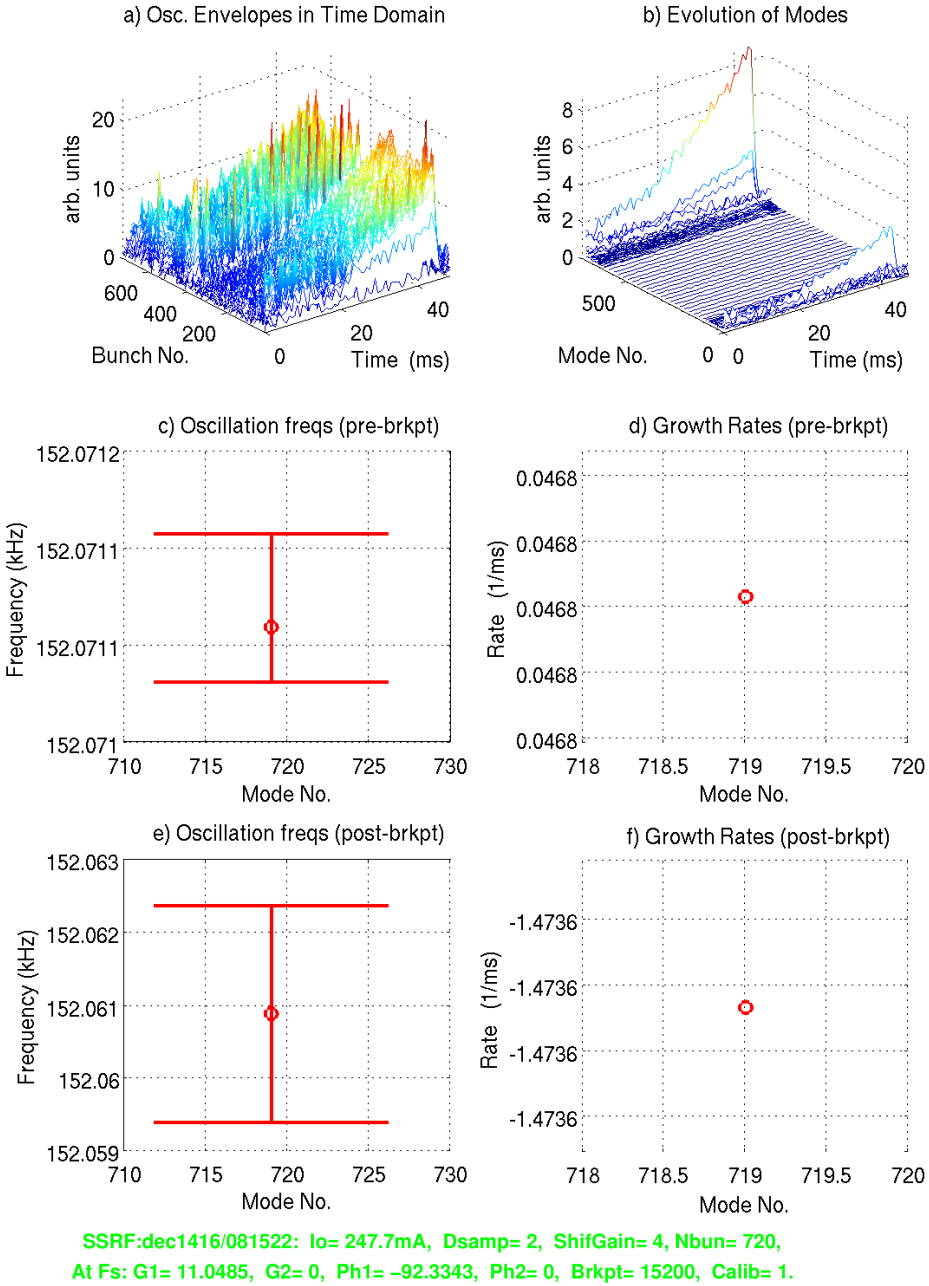

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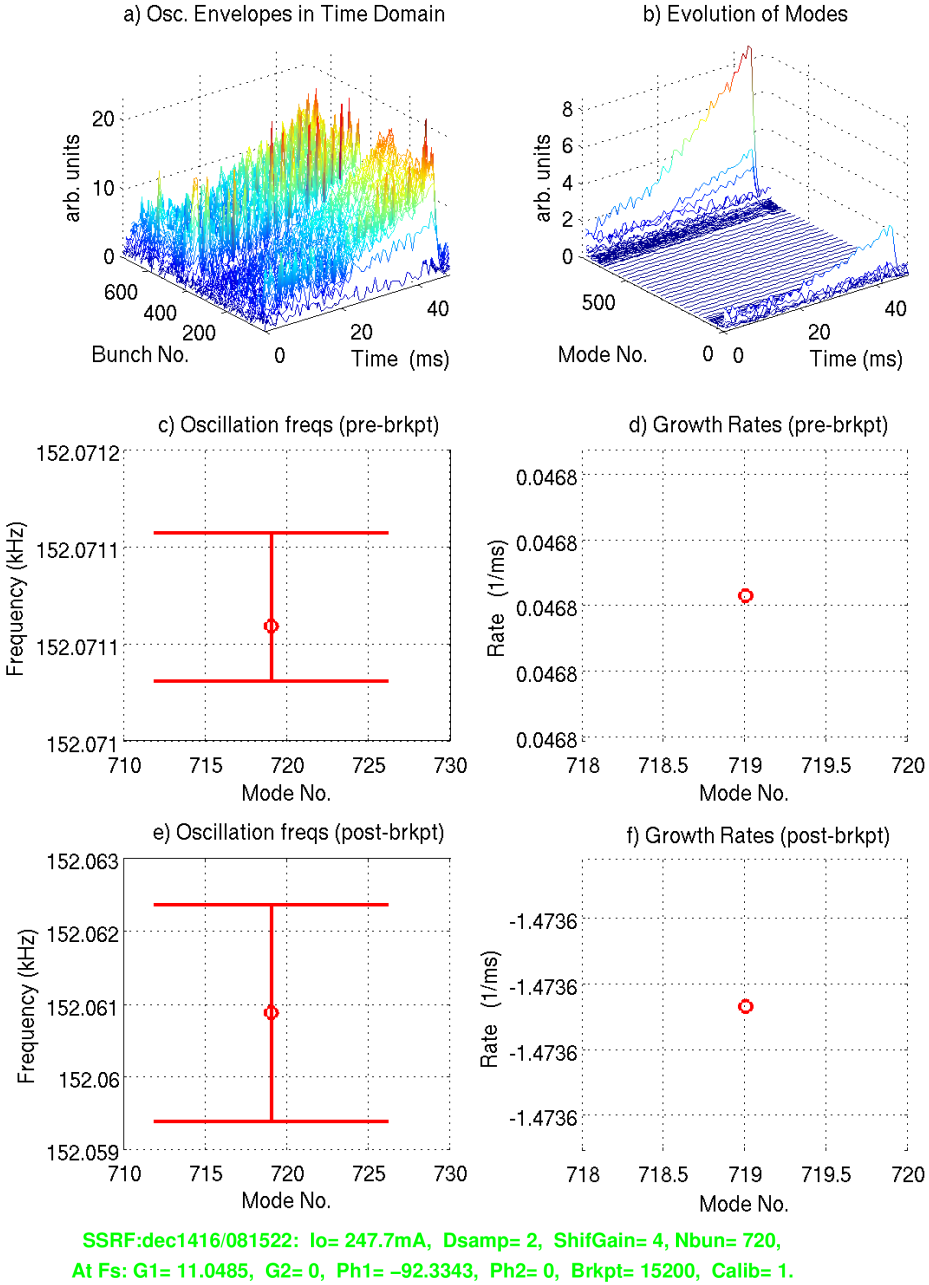

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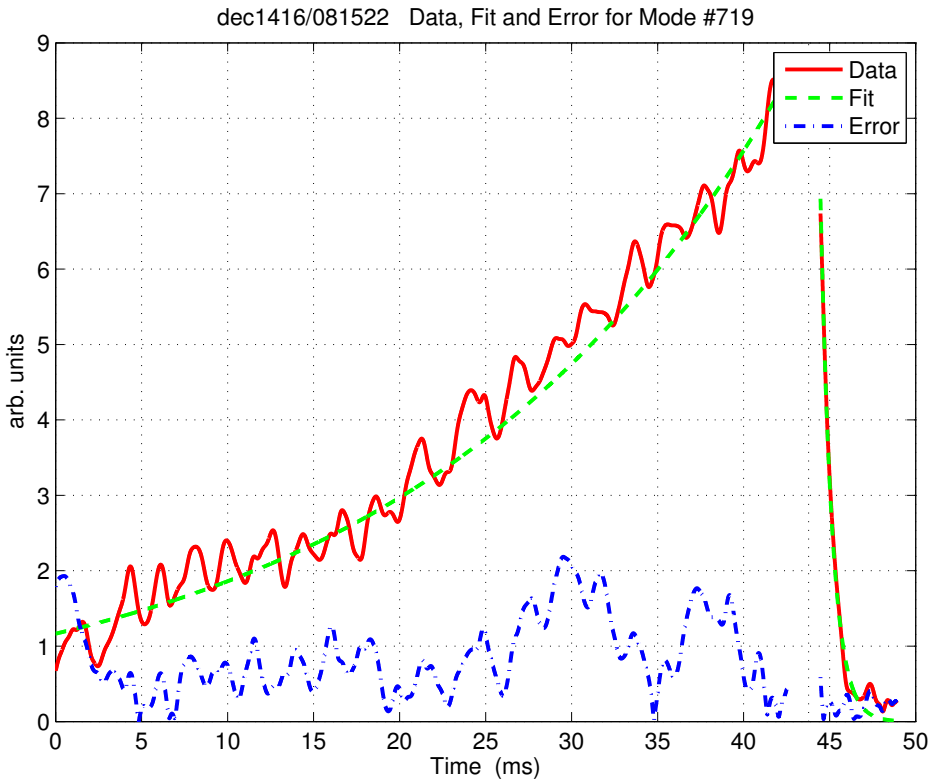
At Fs: G1= 11.0485, G2= 0, Ph1= –92.3343, Ph2= 0, Brkpt= 15200, Calib= 1.

- Feedback loop is open for 45 ms;
- Captured data shows mode −1 growing and damping;
- Growth time 21.4 ms, damping time 0.7 ms;
- Very little frequency shift, feedback tuned for resistive damping;
- Modulation of the modal amplitude is due to a nearby spur.

Horizontal Grow/Damp



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   - Parasitic Measurements
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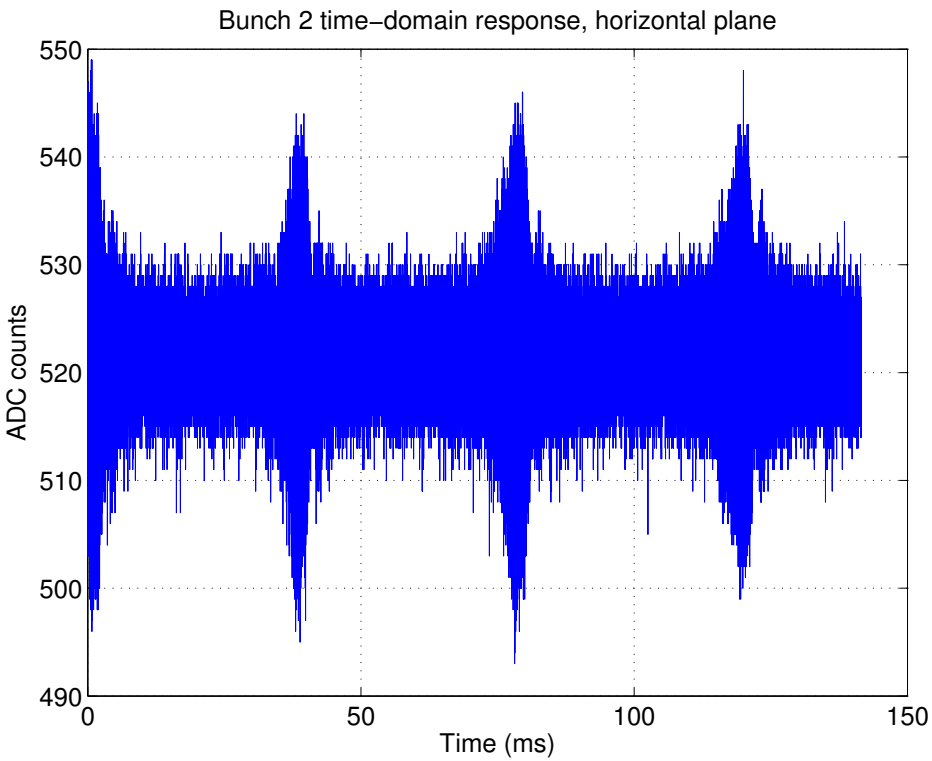
Single Bunch Acquisition



- Single bunch acquisition engine captures 98304 samples of a single selected bunch (141 ms);
- Swept sinusoidal excitation with 40 ms sweep period;
- Multi-bunch fill, feedback disabled for this bunch;
- State of the drive generator is captured simultaneously, allowing beam transfer function estimation;
- Analytical fit.

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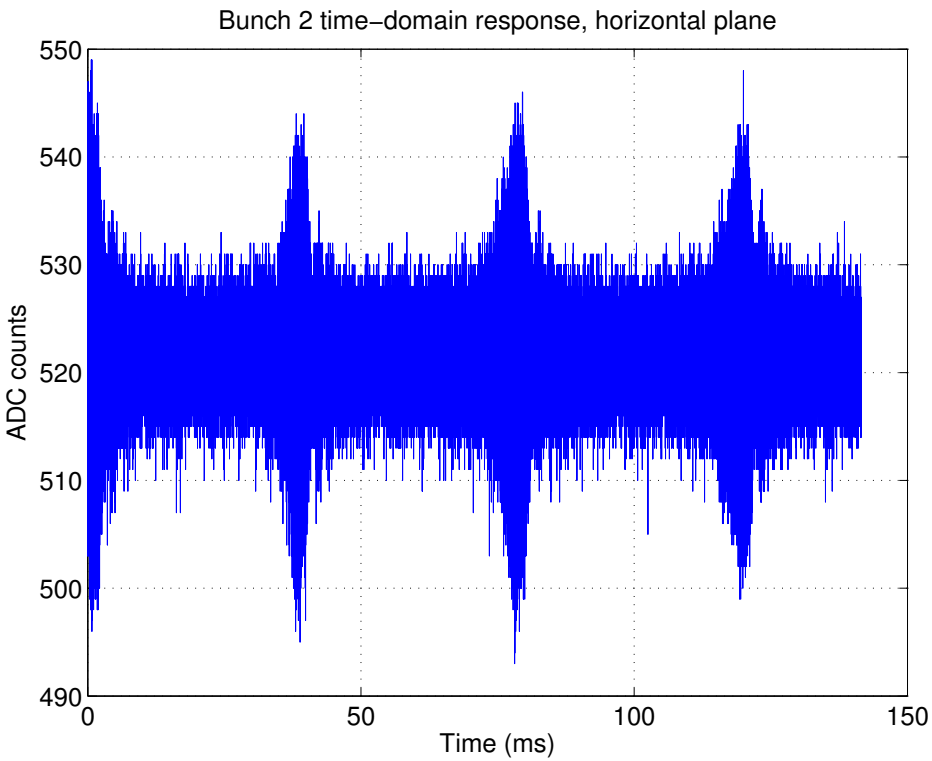

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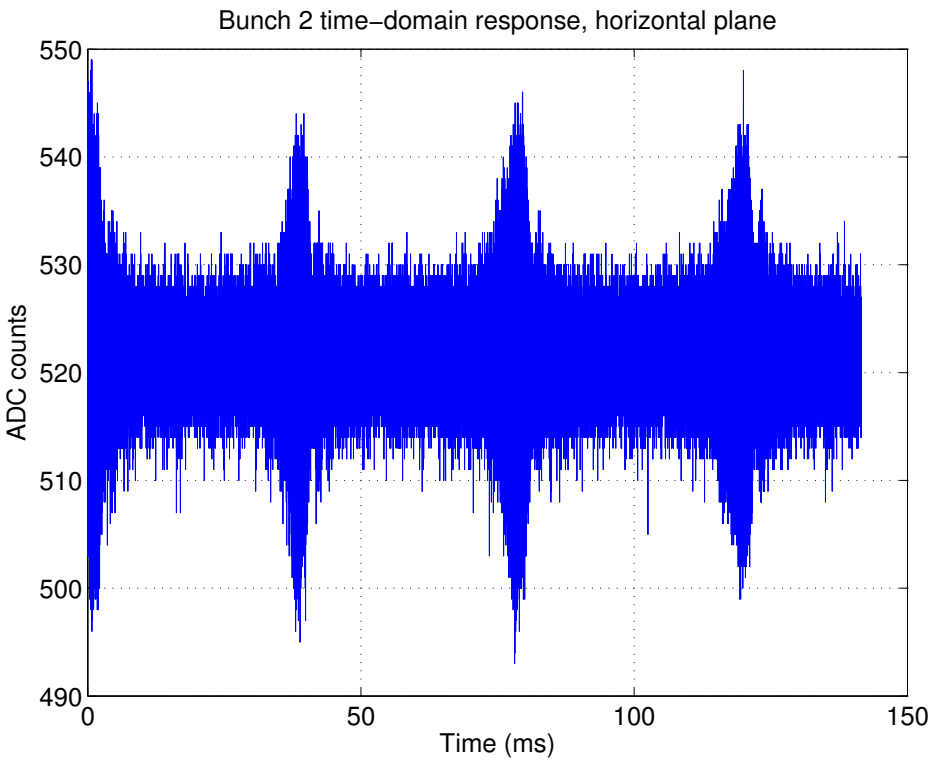

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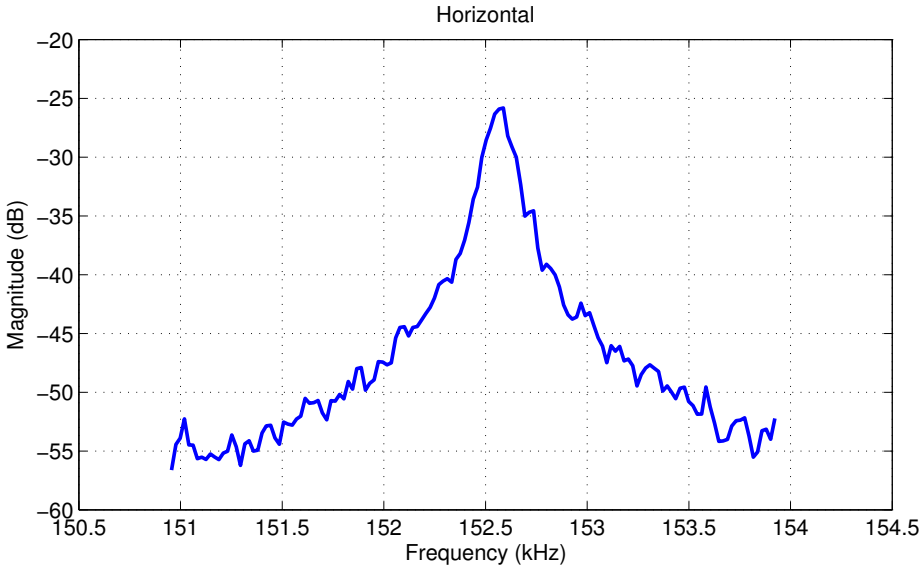

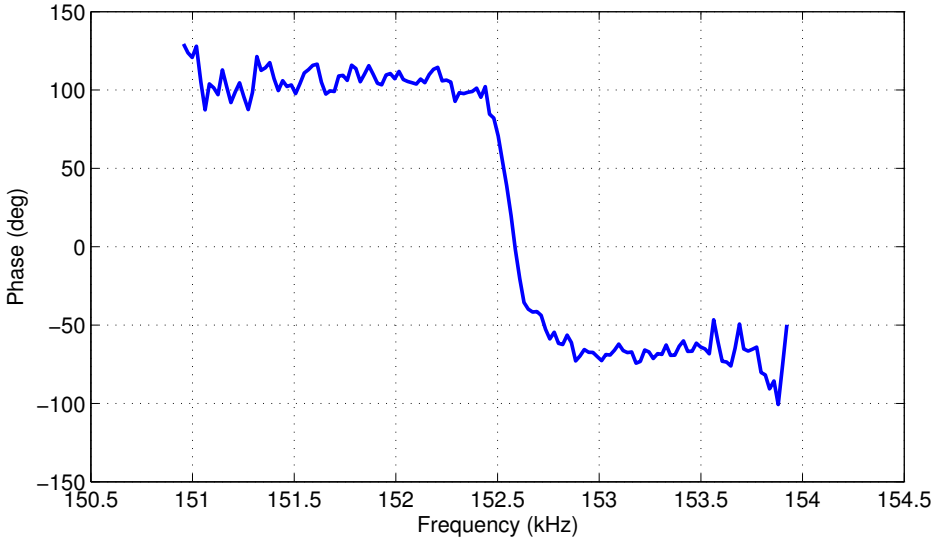

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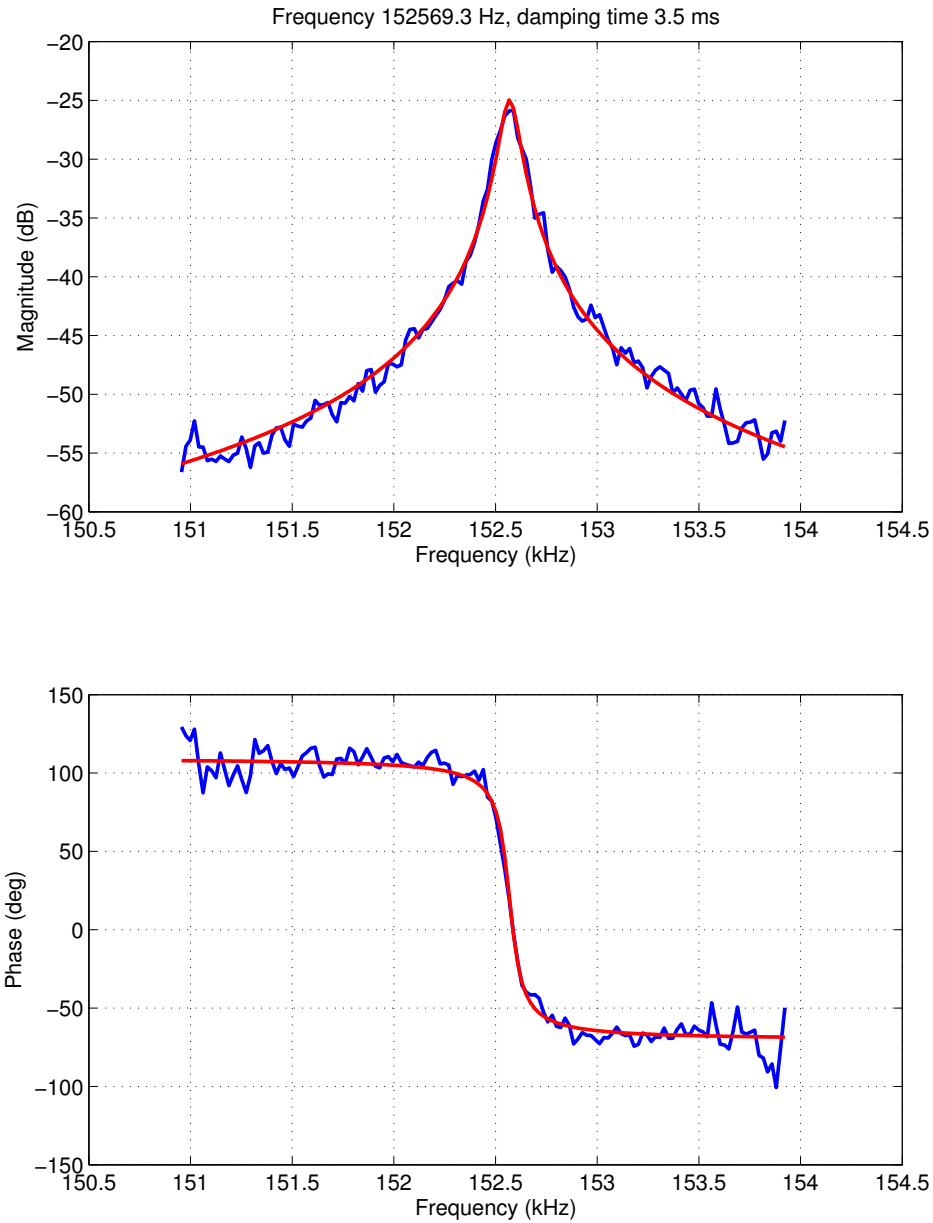

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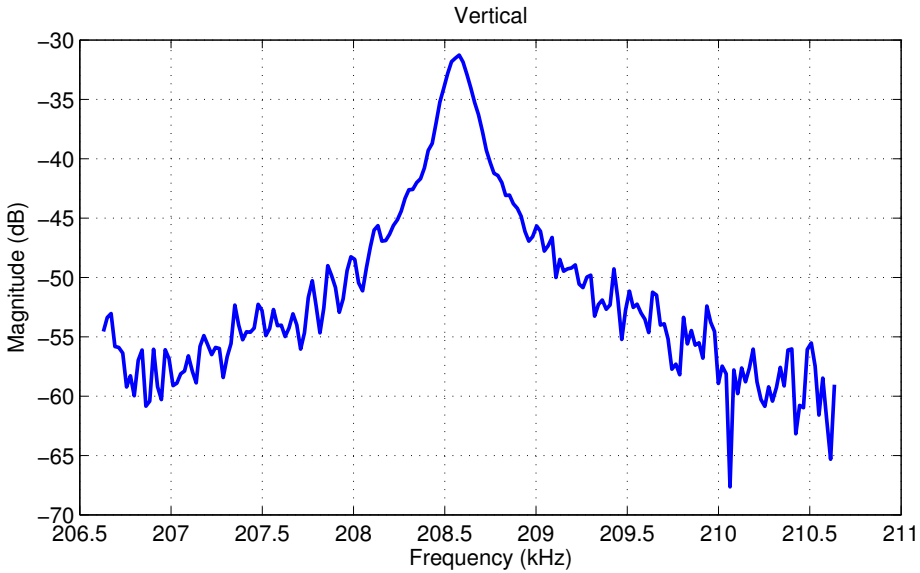
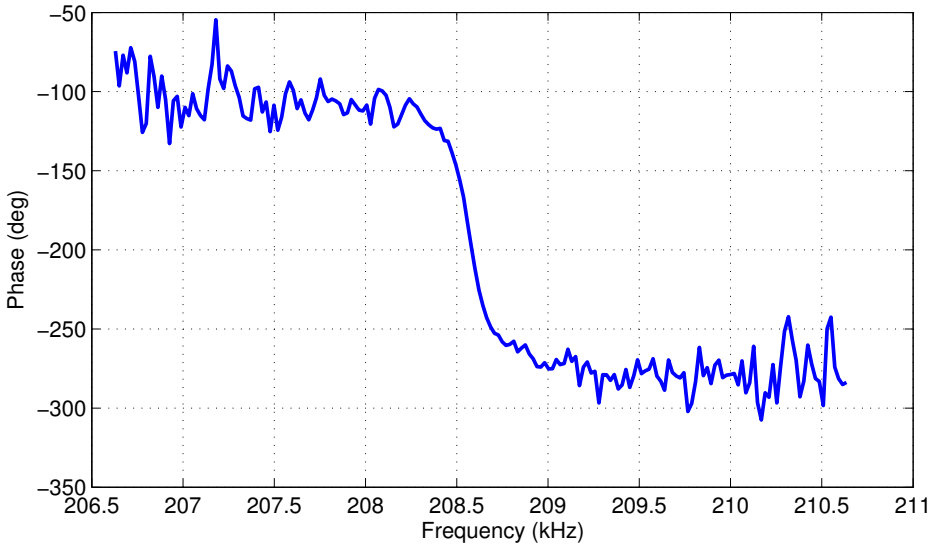
Vertical Beam Transfer Function





- Same approach, excitation centered around nu_y;
- Analytical fit;
- Caveat — if the tune changes during the measurement, resulting BTF is widened.

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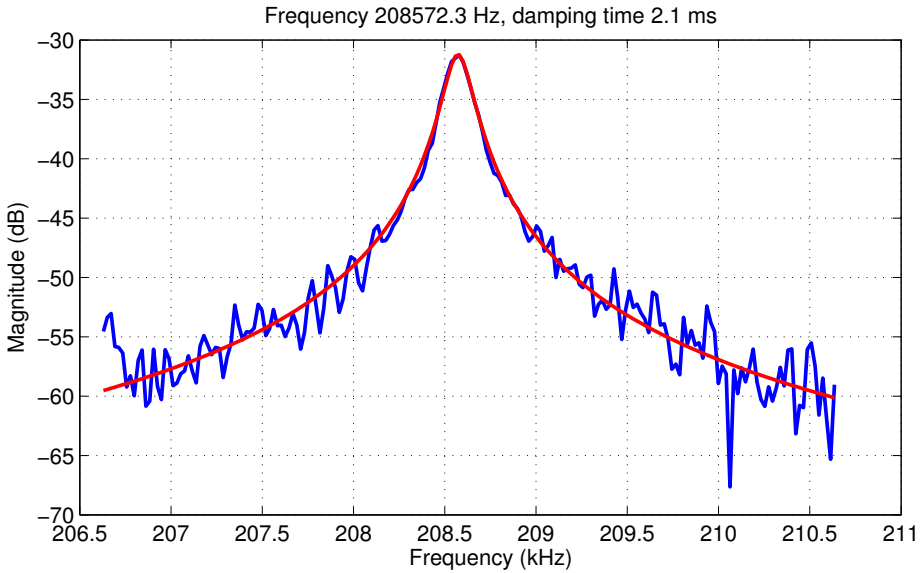

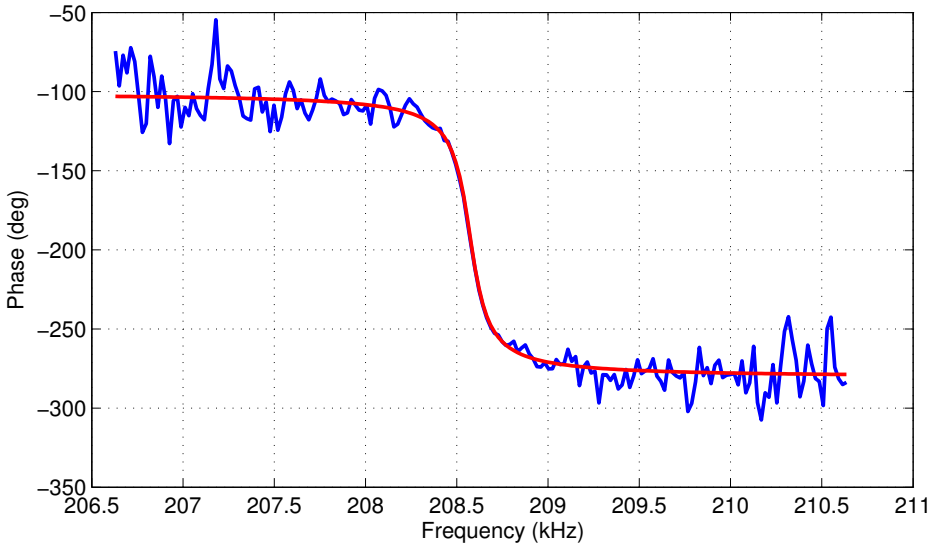

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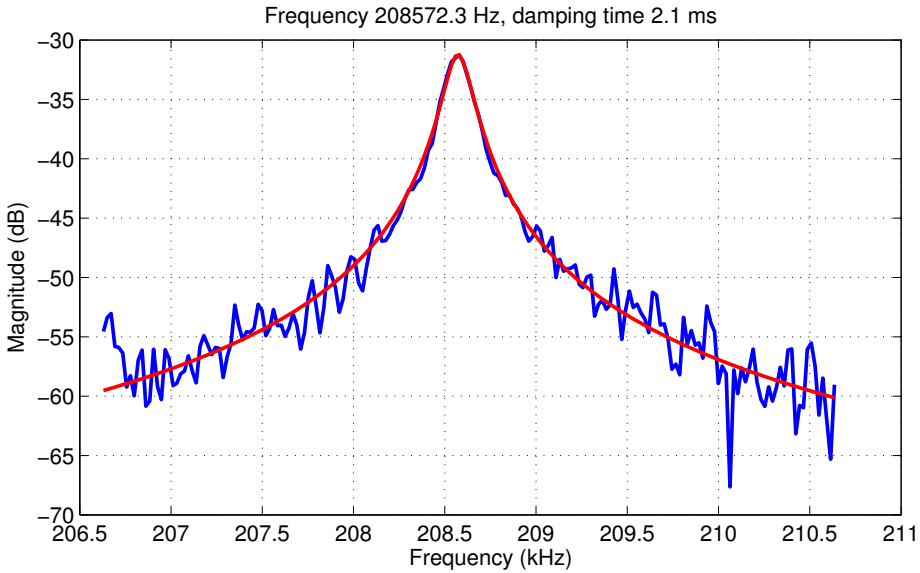

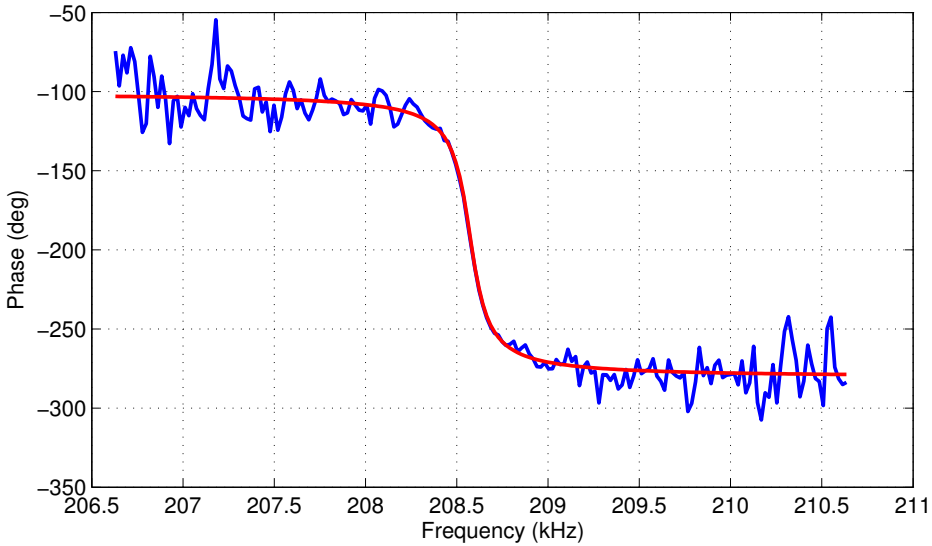

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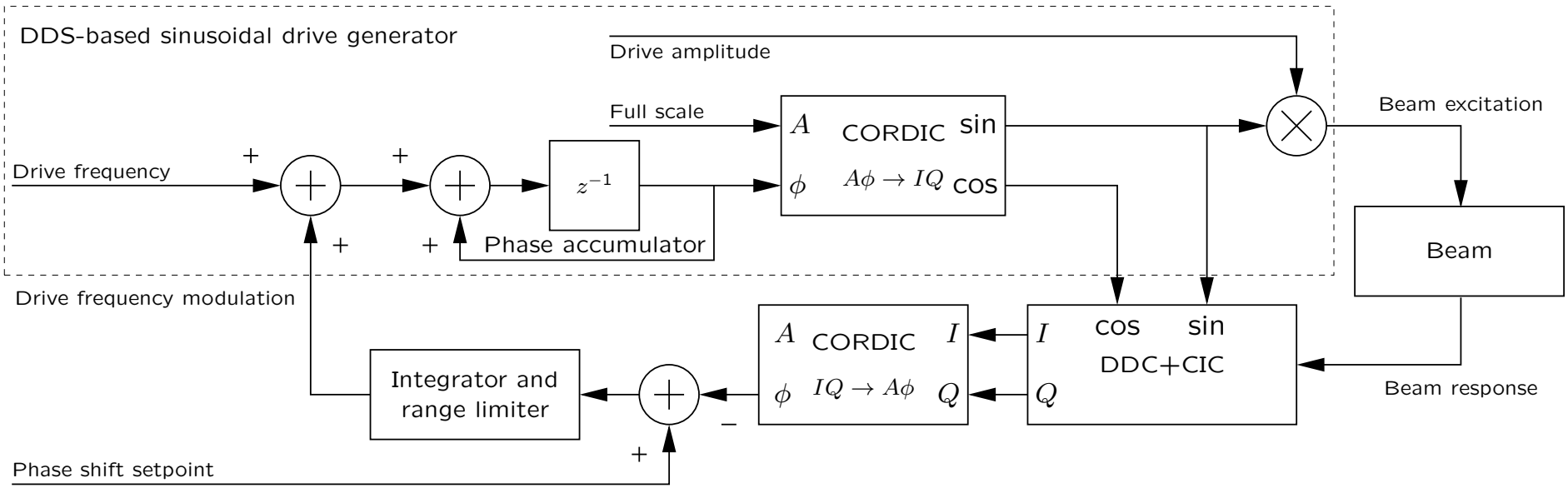
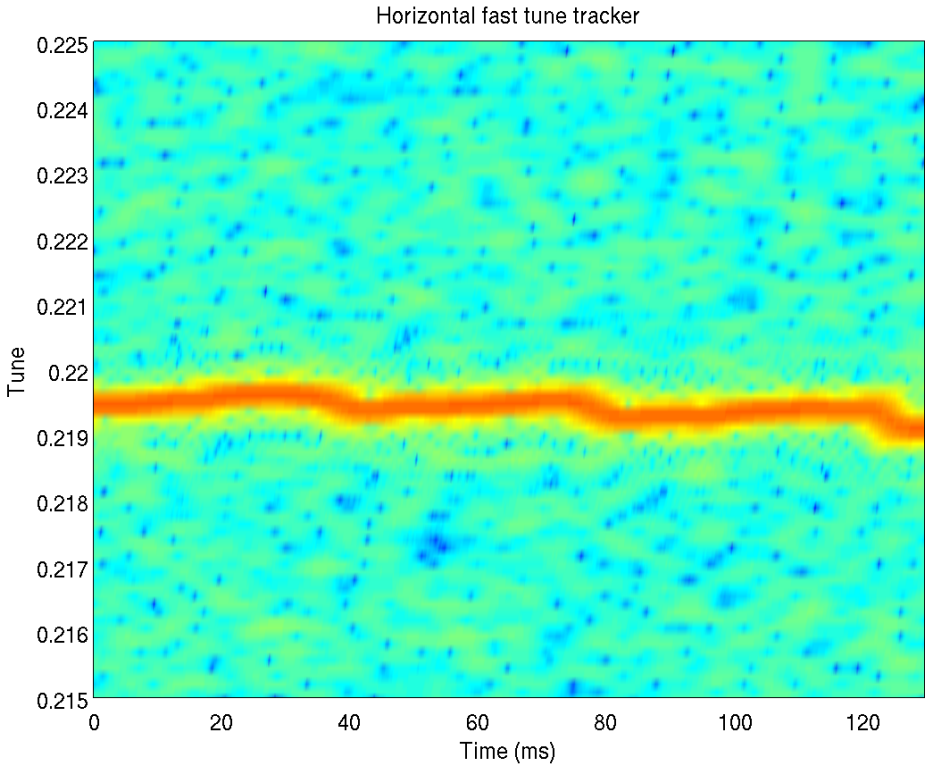
Tune Tracker Block Diagram



Tune Tracker: Horizontal



- Fast tracking, 500 turns integration;
- Several shots in quick succession;
- Drifts on the scale of seconds, smaller fast transients.

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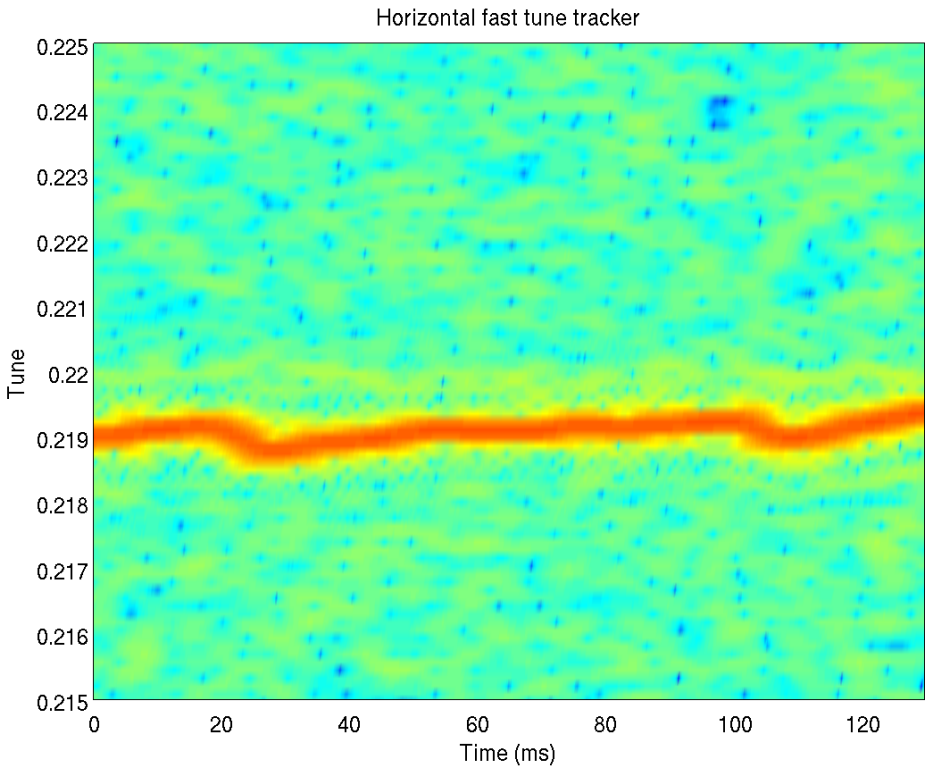

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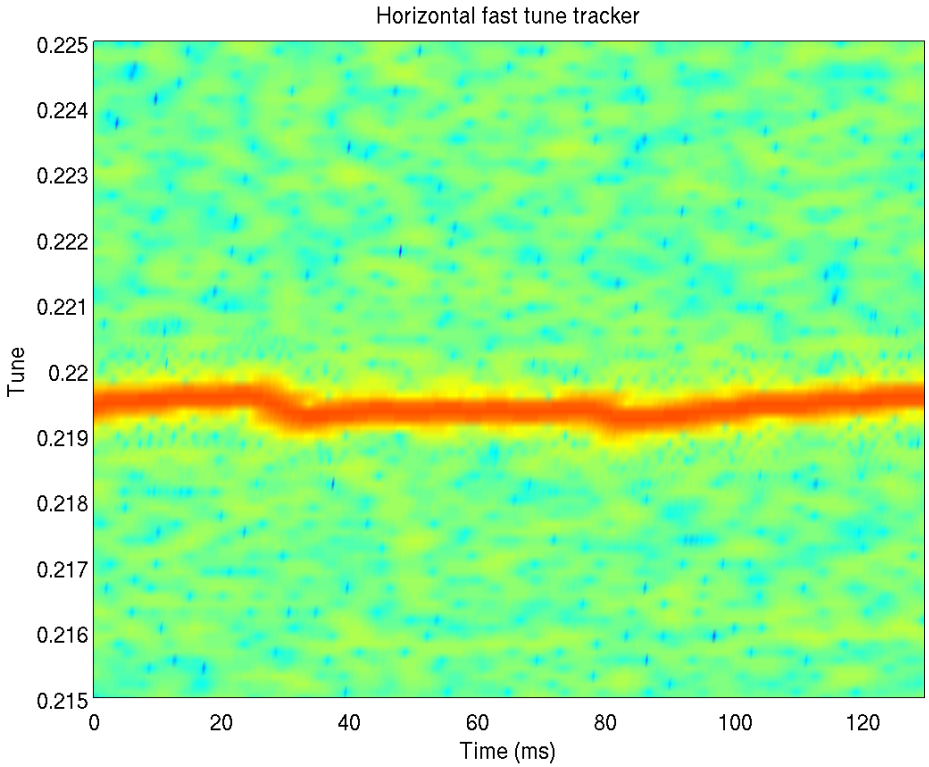

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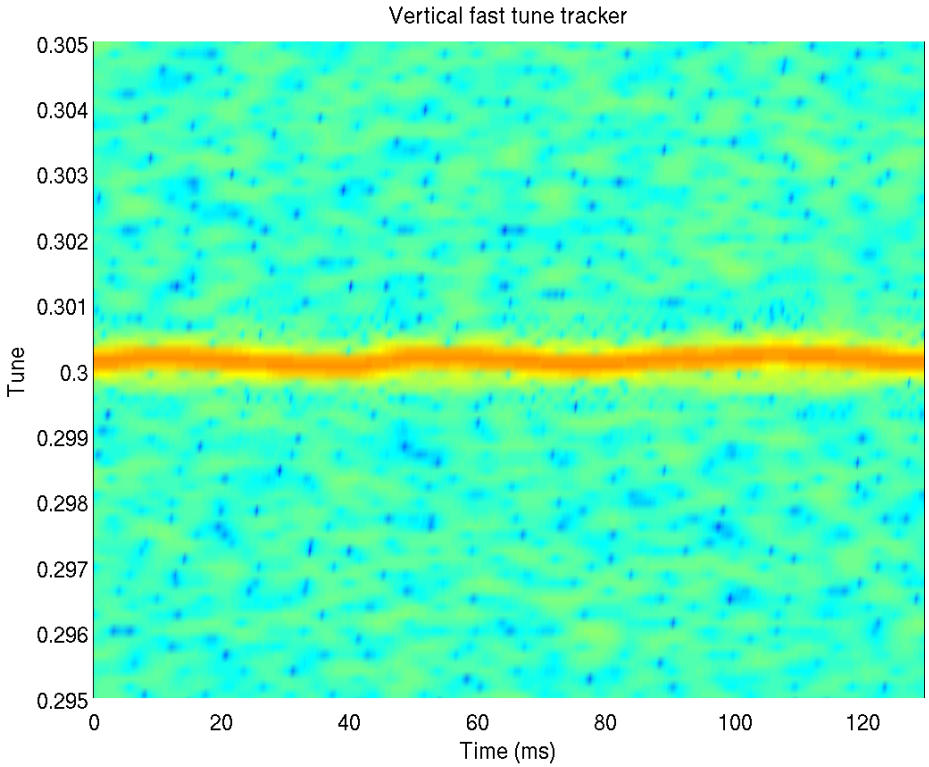

- Similar behavior to that observed in the horizontal plane;
- Drifts on the scale of seconds also present.

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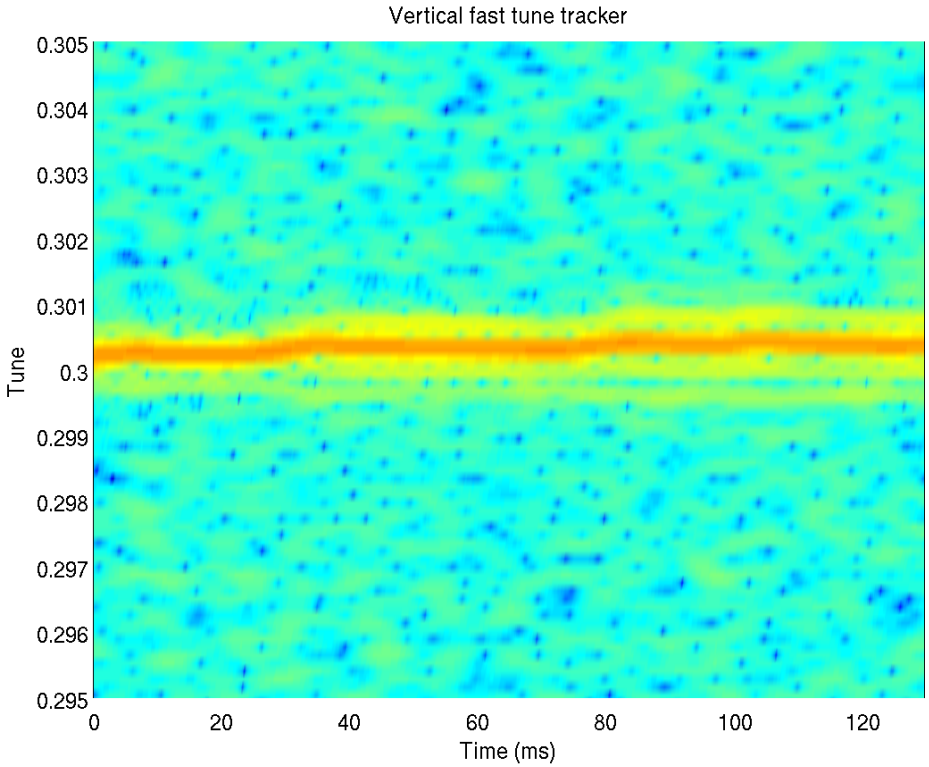

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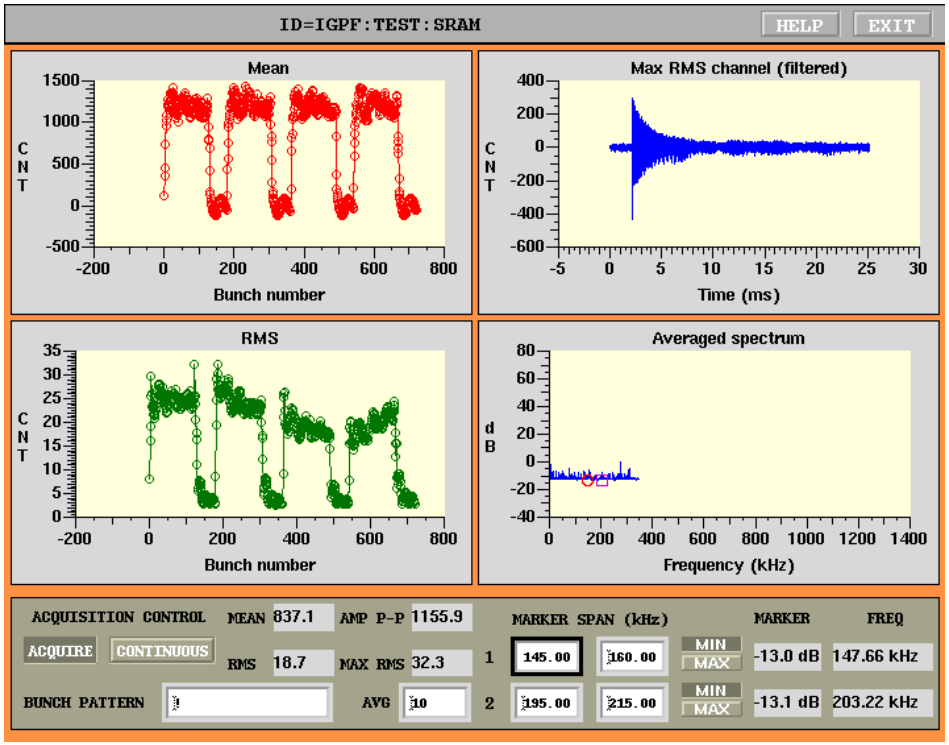

- Trigger derived from the feedback unit output;
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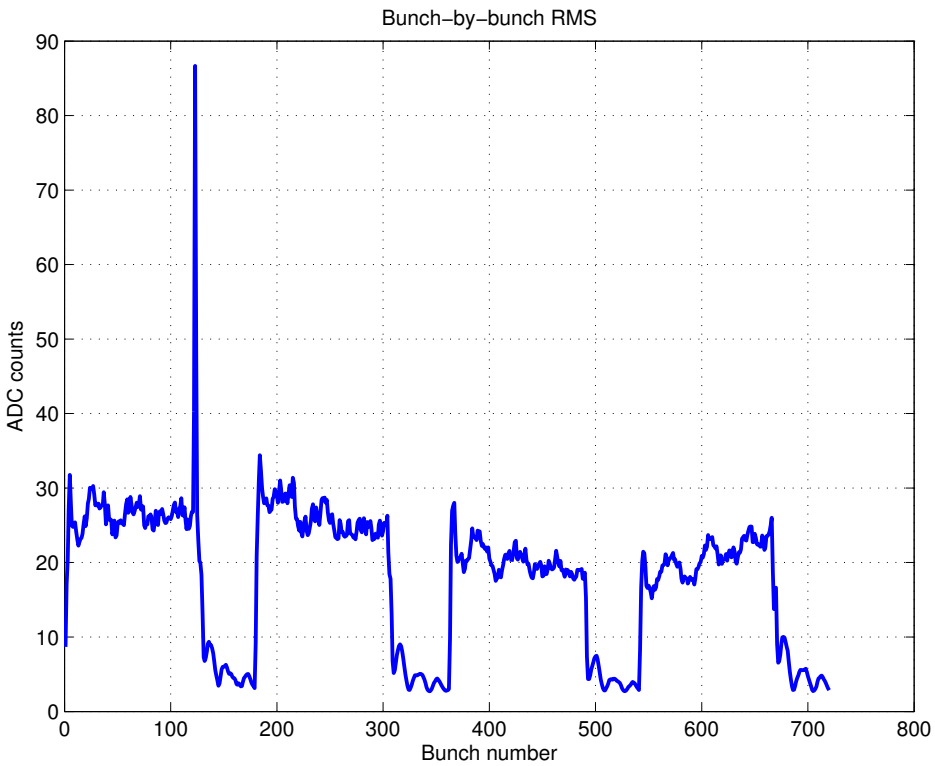

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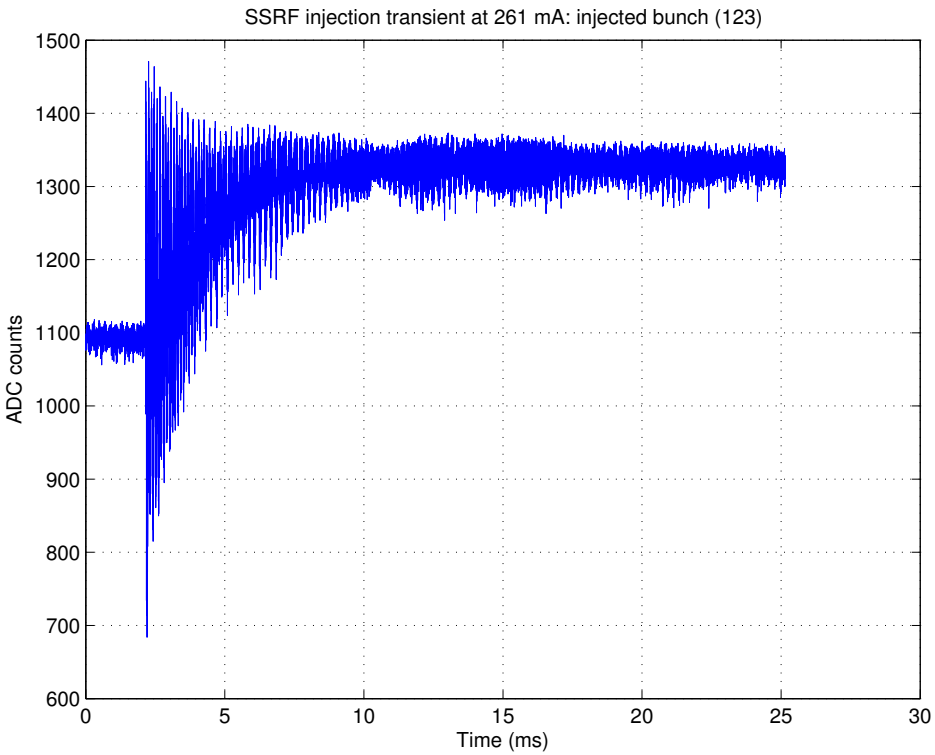

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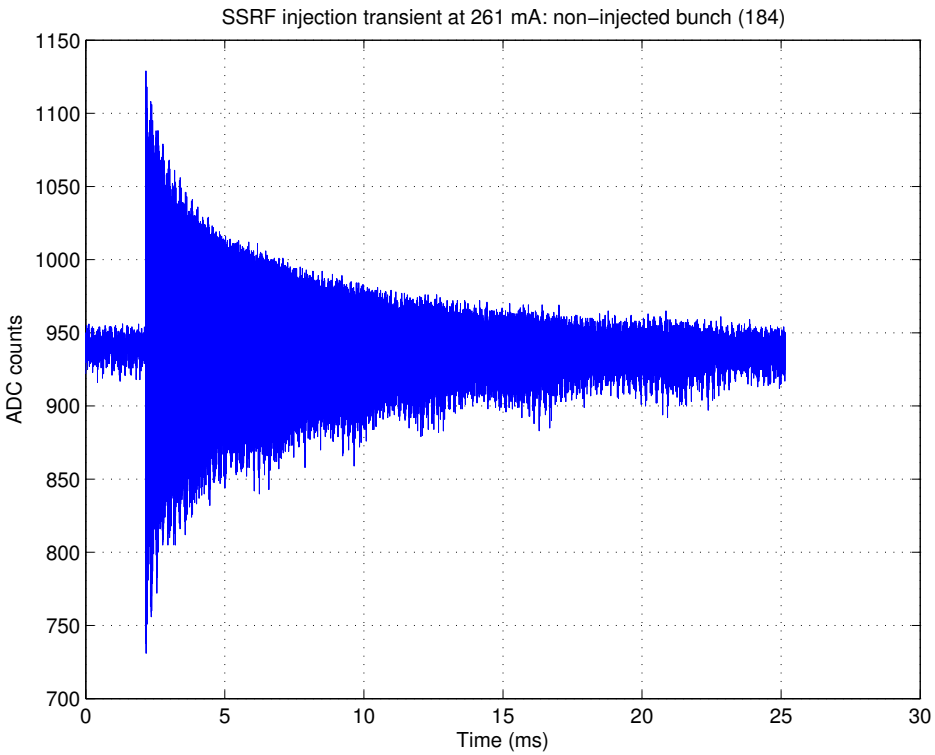

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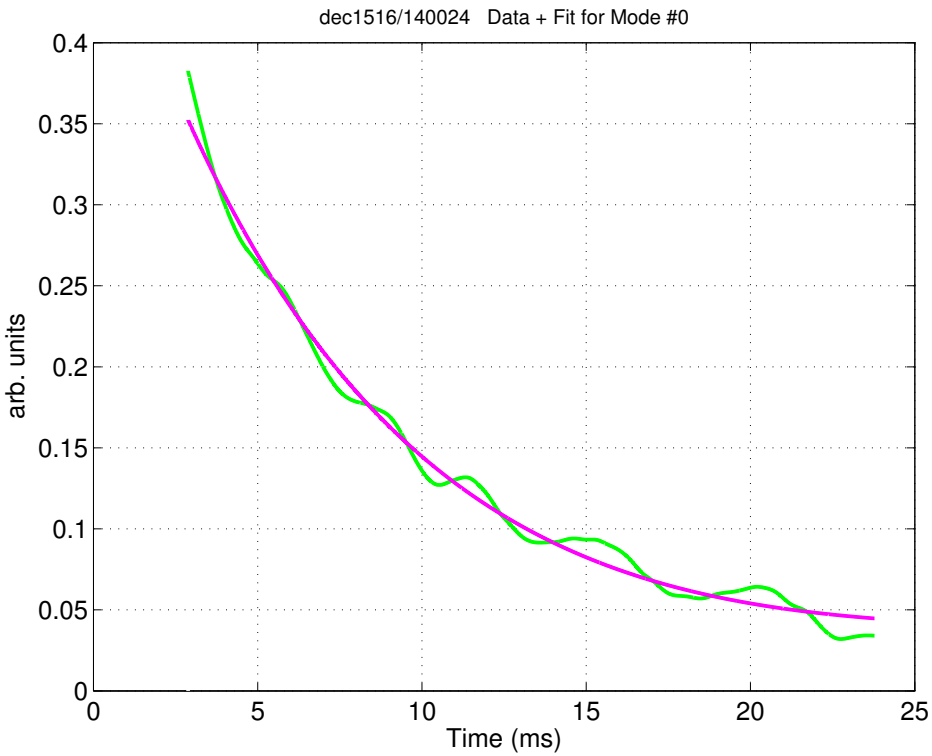

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Summary

- Successfully operated Dimtel bunch-by-bunch systems in SSRF;
- At 250 mA observed mild horizontal instabilities due to the resistive wall, no vertical instabilities;
- Smaller ion-driven motion could be obscured by the noisy reference;
- Measured beam transfer functions, tested fast and slow tune tracking;
- Bunch cleaning was attempted, but had insufficient voltage to sufficiently excite the beam;
- I'd like to thank everyone who helped to make this a successful test in spite of challenging circumstances!

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