Beam Transfer Function Studies in SPEAR3

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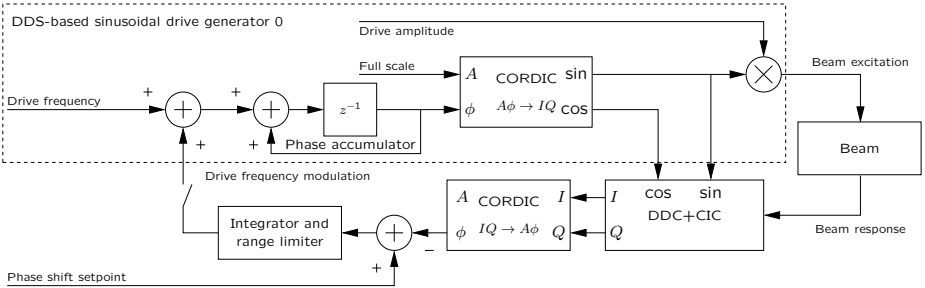
Single Bunch Phase Tracking



- A single bunch is excited with a sinusoidal excitation;
- Response is detected relative to the excitation to determine the phase shift;
- In closed loop, phase tracker adjusts the excitation frequency to maintain the desired phase shift value;
- Adjustable integration time, tracking range, loop gain.

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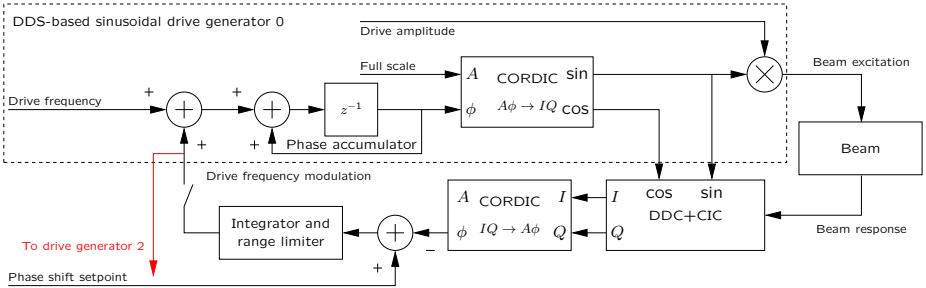
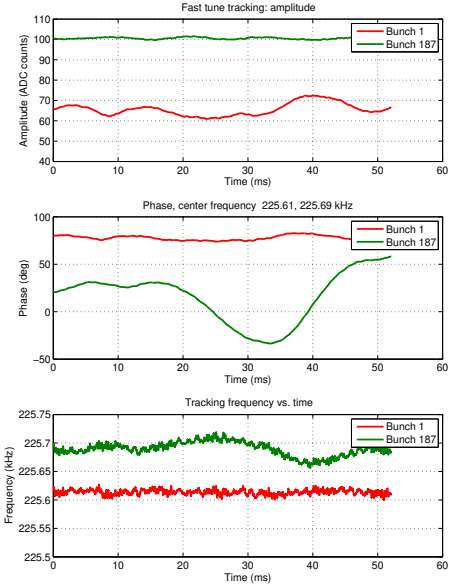


- Dual drive generators, each exciting one bunch;
- Drive generator 0 is under closed-loop tracking;
- Drive generator 2 can be configured to follow the tracking signal;
- Allows for adjustable offset in drive 2 while following common-mode tune jitter.

Tracking Behavior



- Closed-loop tracking on bunch 187;
- Pure sinusoidal excitation of bunch 1;
- Significant amplitude variation;
- Drive 2 following enabled;
- Amplitude is stabilized for both bunches;
- Can measure beam transfer function magnitude for bunch 1 by scanning drive frequency.

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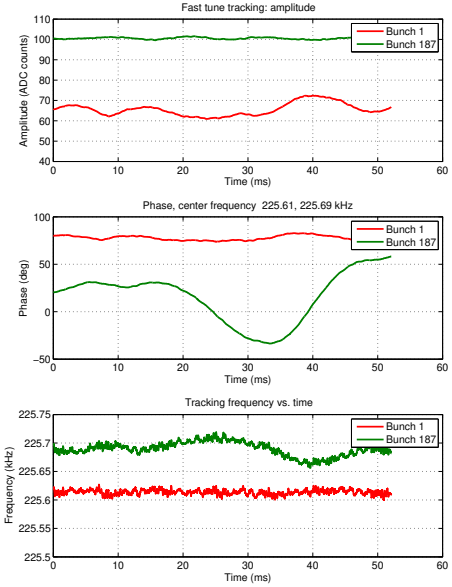

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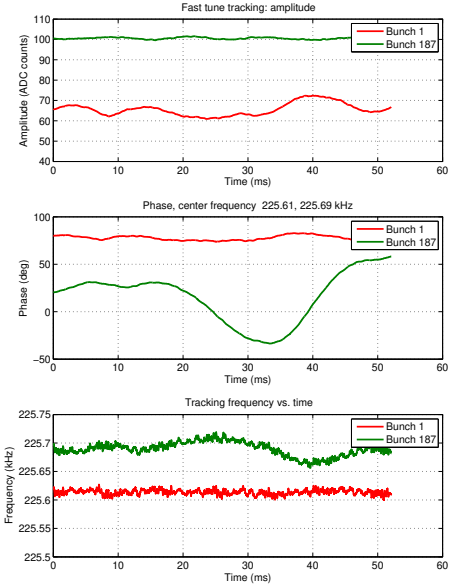

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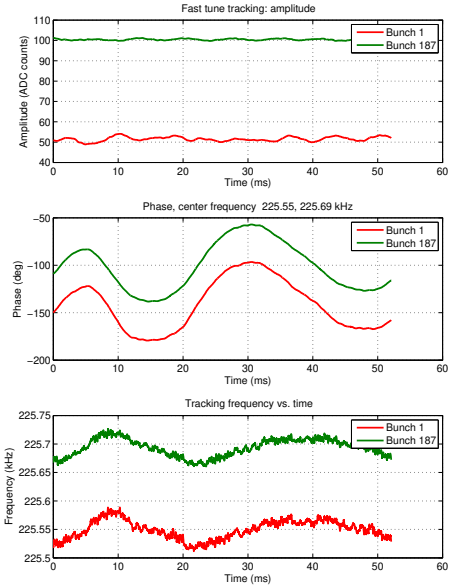

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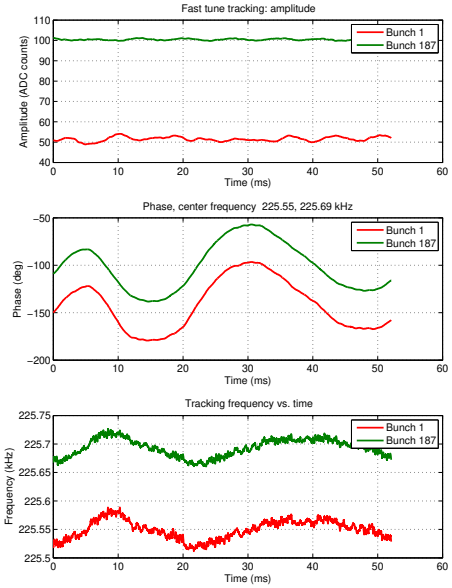

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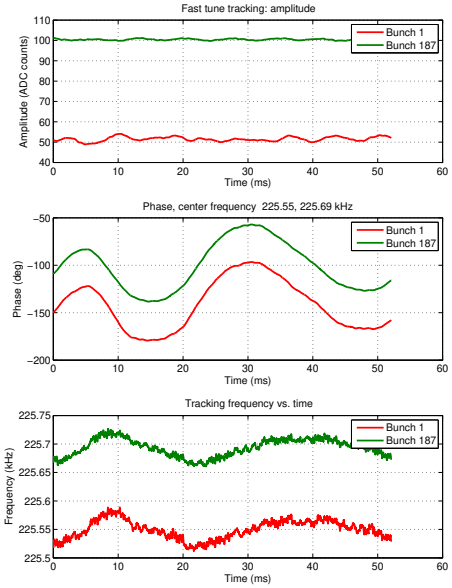

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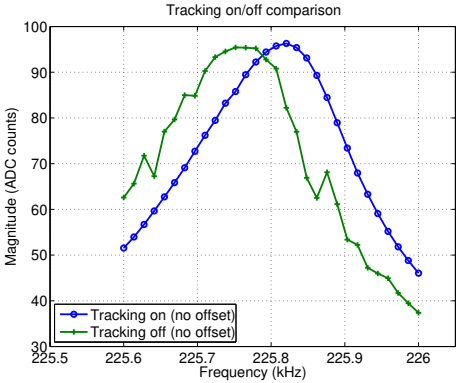
Extracting the Response



- Average magnitude plotted vs. drive frequency;
- Offset due to DC average in tune tracker correction;
- Drive 0 is set to 225.744 kHz, closed loop 225.69 kHz;
- Add average tracker offset to drive 2 frequency in tracking on state;
- Drive 2 tracking off correction:
  - Estimate how much the tune moved away from the average (tracking frequency offset without DC);
  - Subtract that value from drive 2 frequency.

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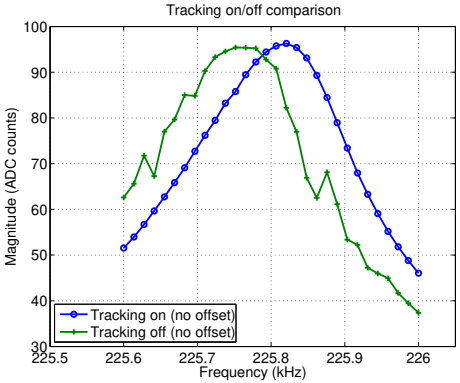

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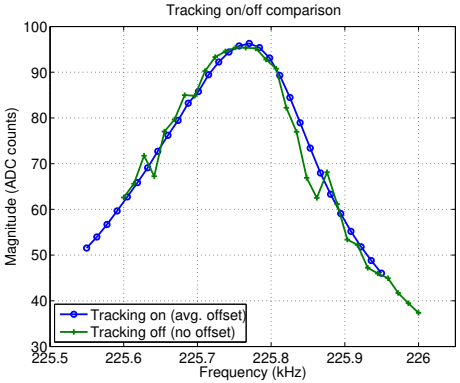

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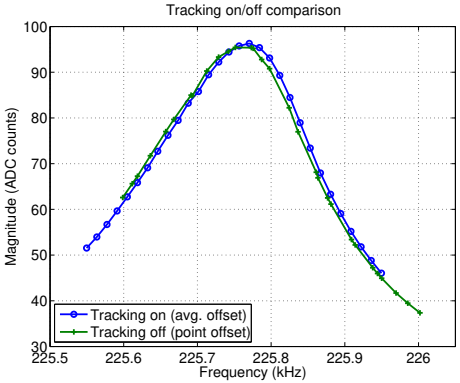

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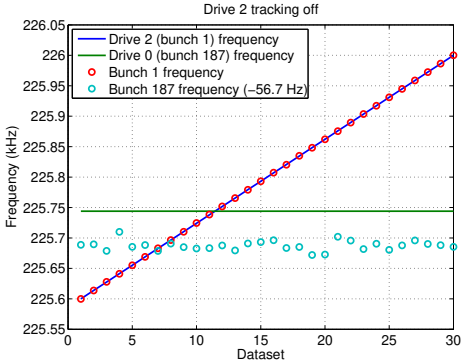

- Drive 2 tracking is off;
- Algorithm extracts the same frequency for bunch 1 as drive 2 setting;
- Drive 2 tracking is on;
- Very good estimation still, standard deviation of the frequency shift difference between 1 and 187 is 0.08 Hz.

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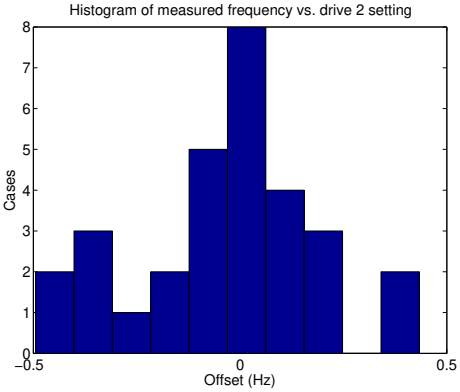

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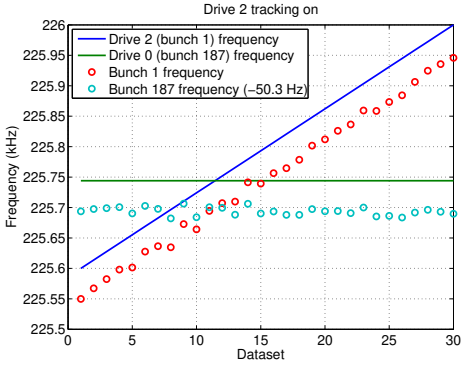

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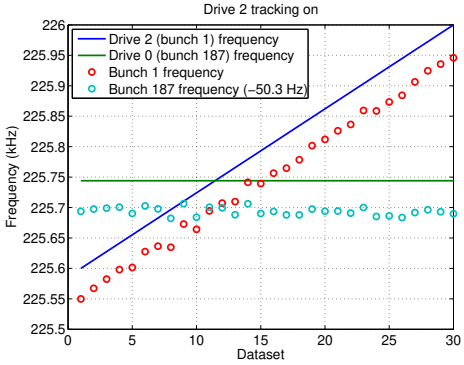

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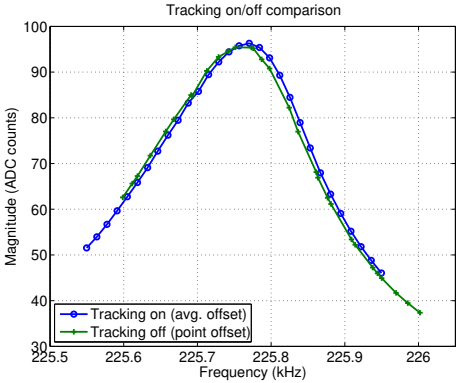

- Average tracker offset changes from -50.3 to -56.7 Hz between the two scans;
- Slow tune drifts?
- Corrected the drive 2 tracking off scan by 6.4 Hz;
- Almost on top of each other, some loss near the peak;
- Fast tune jitter in SPEAR3 is relatively small;
- Dual tracking is still critical to remove sensitivity to slow common-mode drifts.

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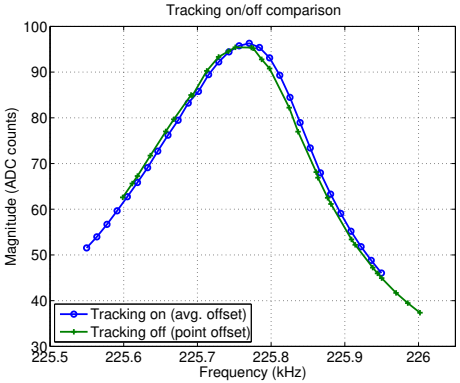

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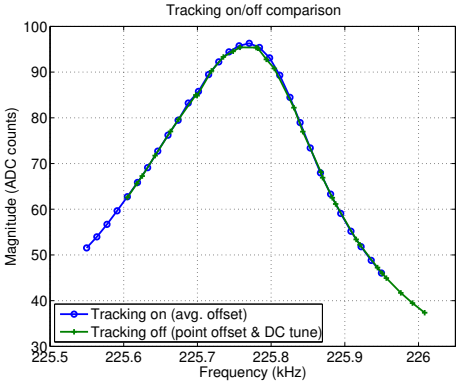

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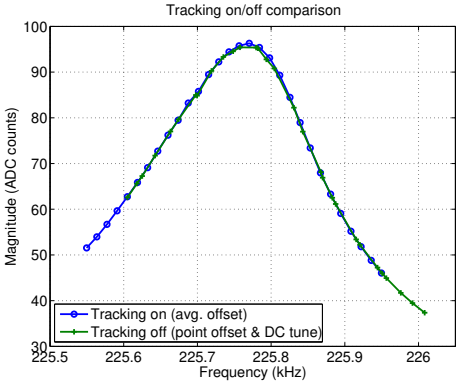

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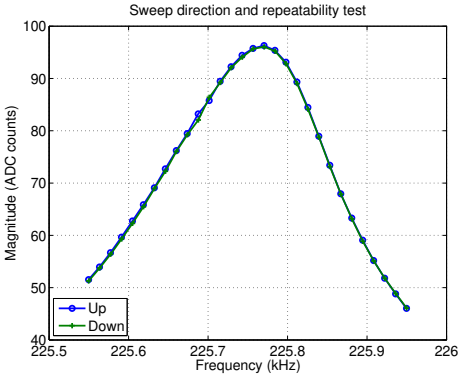
Sweep Direction Test



- Good agreement between the two scans;
- No clear systematic difference between sweep directions;
- Noisy data when crossing bunch 187 tracking point;
- Coupling between the bunches leads to beating;
- Source of the coupling is unclear.

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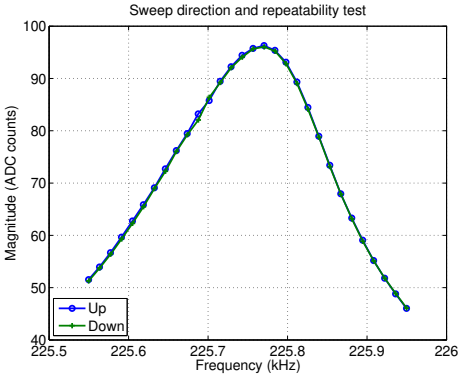

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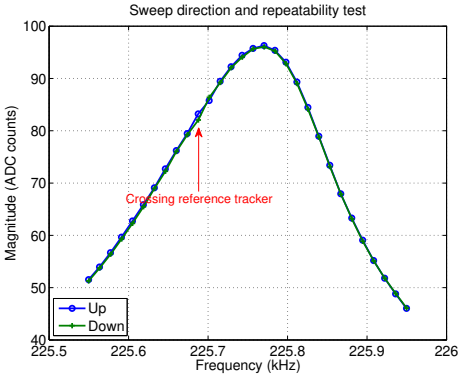

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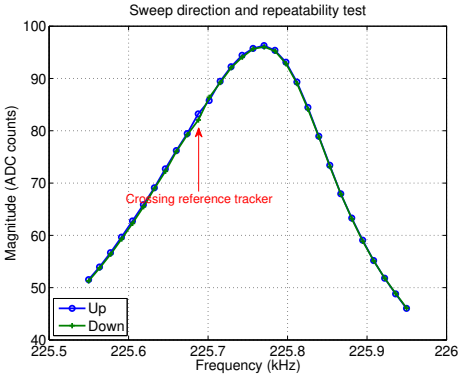

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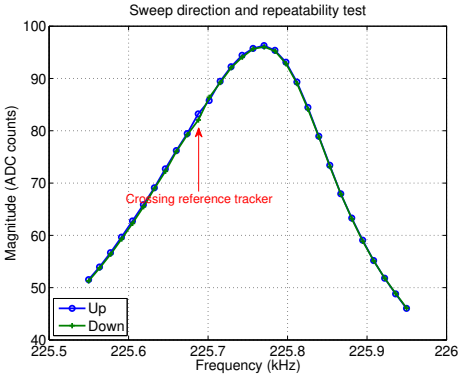

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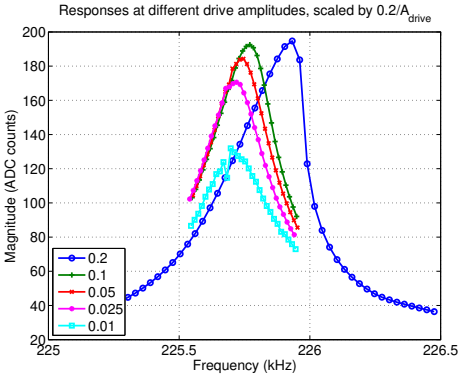
Beam Transfer Function Vs. Drive Amplitude



- Frequency scanned up in each case;
- Responses in agreement below resonance at amplitudes from 0.025 to 0.1;
- Nonlinear oscillator behavior with strong amplitude dependent tune shift at 0.2 drive level;
- Fairly symmetric response at 0.01 drive, noisy point near tracker crossing (amplitude imbalance).

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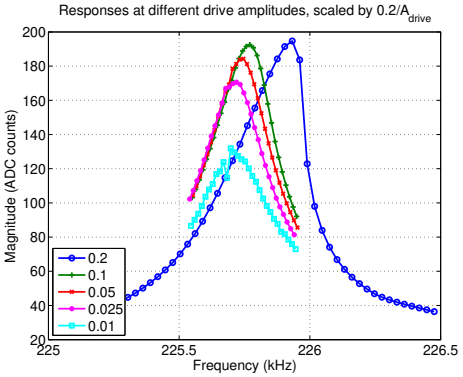

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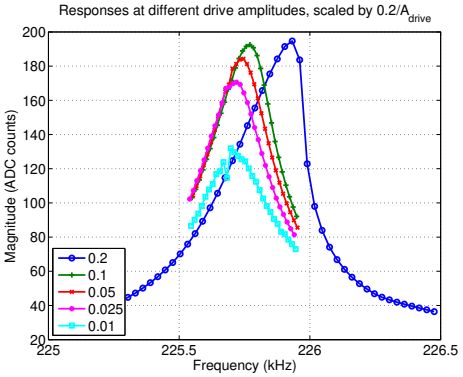

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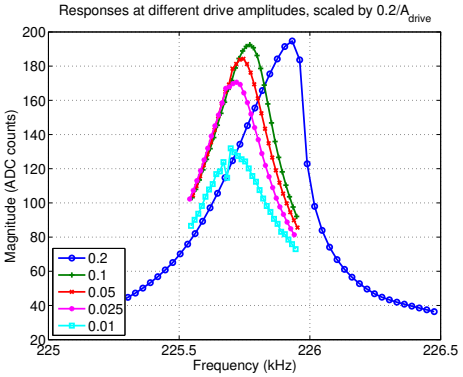

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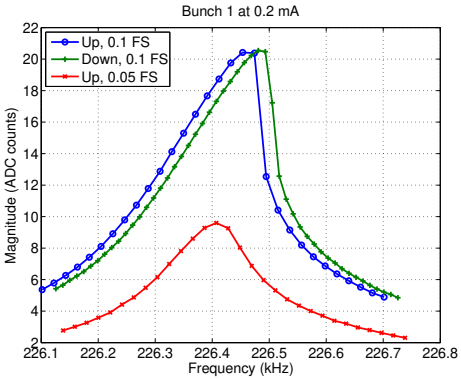

- Filled bunches 1 and 187 to 0.2 and 2 mA;
- Hysteresis vs. sweep direction;
- More symmetric at lower amplitude;
- Need to check more carefully response vs. drive amplitude (fitting?).

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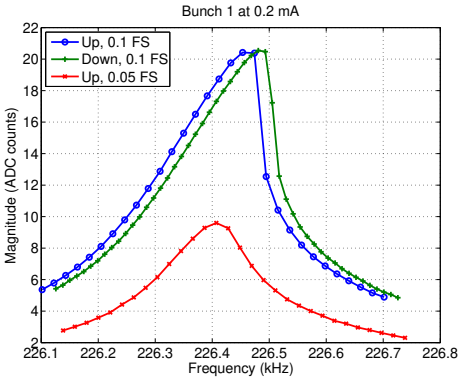

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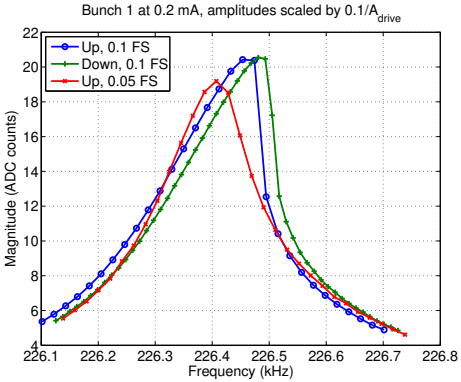

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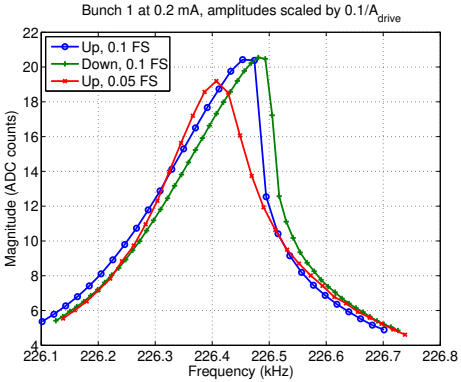

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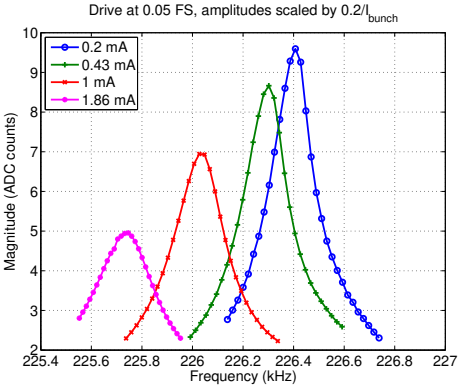

- Downward tune shift vs. current;
- Wider peak at higher currents;
- From the amplitude scan at 1.86 mA we know that 0.05 drive level is too high.

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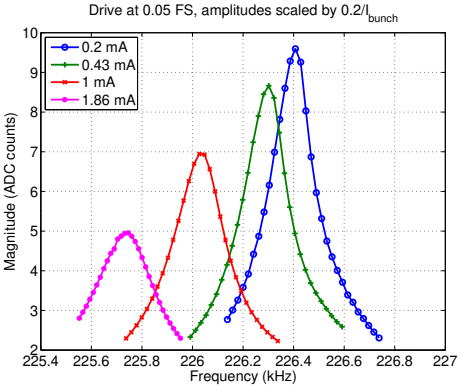

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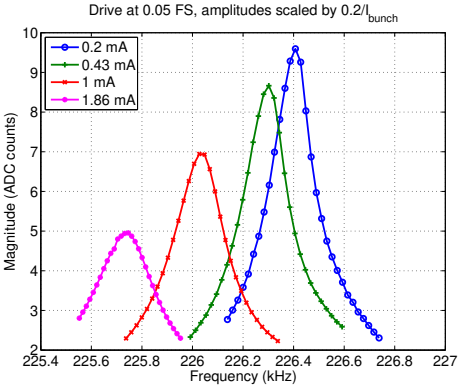

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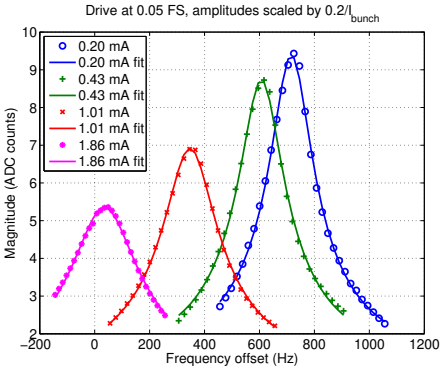

- The only meaningful frequency axis is the difference between the two drive sources;
- Fit harmonic oscillator response with noise floor;
- All fits show asymmetry — drive level too high?
- Extract center frequency, magnitude, damping time vs. bunch current;
- Error sources:
  - Four fills, reference bunch (187) current changes;
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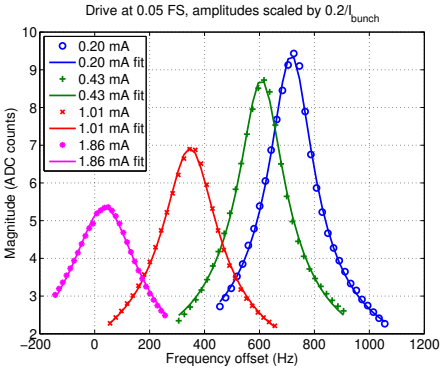

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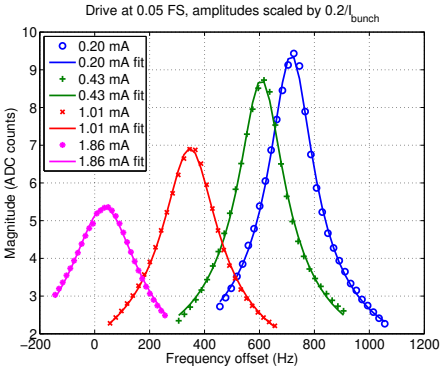

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- Extract center frequency, magnitude, damping time vs. bunch current;
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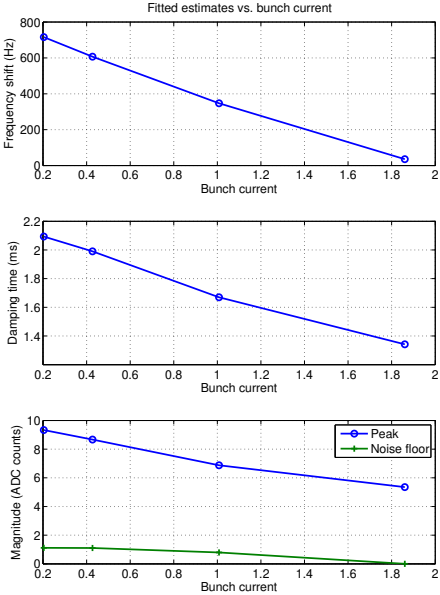
  - Four fills, reference bunch (187) current changes;
  - Bunch 1 current estimated;
  - Amplitude dependent shifts.

Beam Transfer Function Fits Vs. Current



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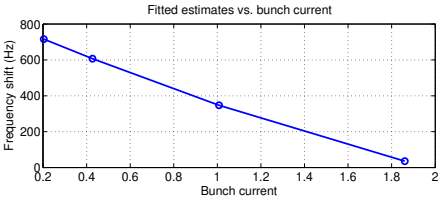

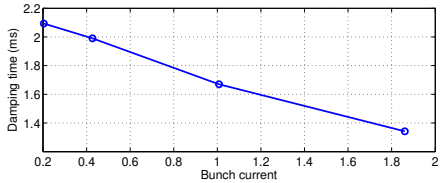

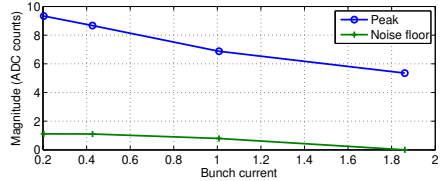

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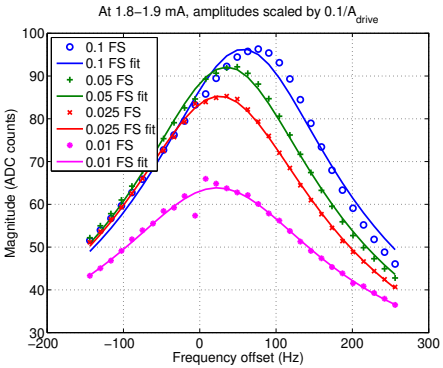

- Clear asymmetry at 0.1 and 0.05;
- Reasonably symmetric at 0.025 and 0.01;
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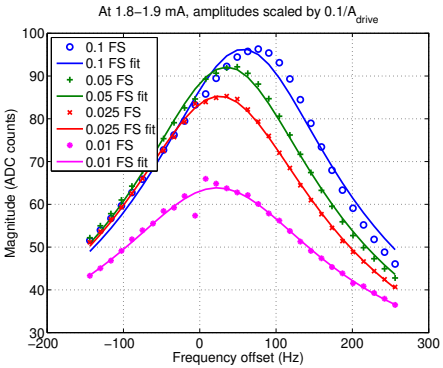

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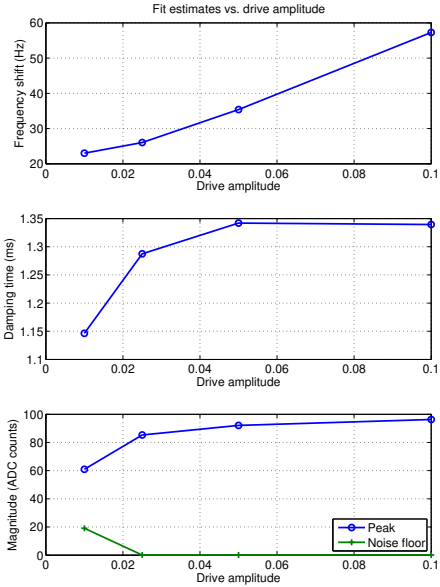

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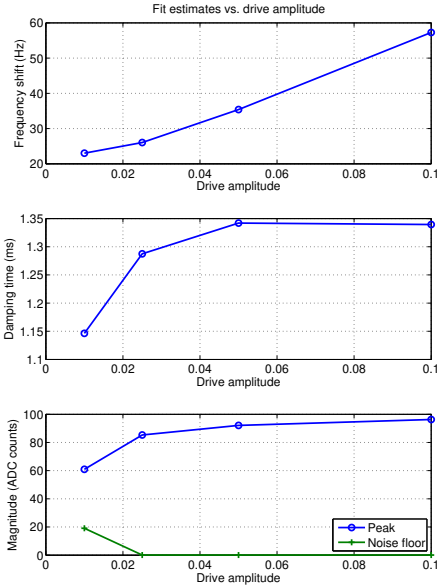

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Summary

- Successfully tested "follow the tracker" mode;
- Different information vs. dual tracker tests;
- Changes of the beam transfer function with amplitude and bunch current mean that dual tracker mode is sensitive to mismatches in gain;
- Avoiding systematics:
  - Keep bunch current low;
  - Measure at different drive levels to project to zero drive point;
  - Dual trackers miss complex BTF evolution, likely source of systematic errors.
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