PEP-II longitudinal feedback and the low group-delay woofer

Dmitry Teytelman

Outline

I. PEP-II longitudinal feedback and the woofer channel

II. Low group-delay woofer topology

III. Why do we need a separate woofer processor?

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V. User interface features

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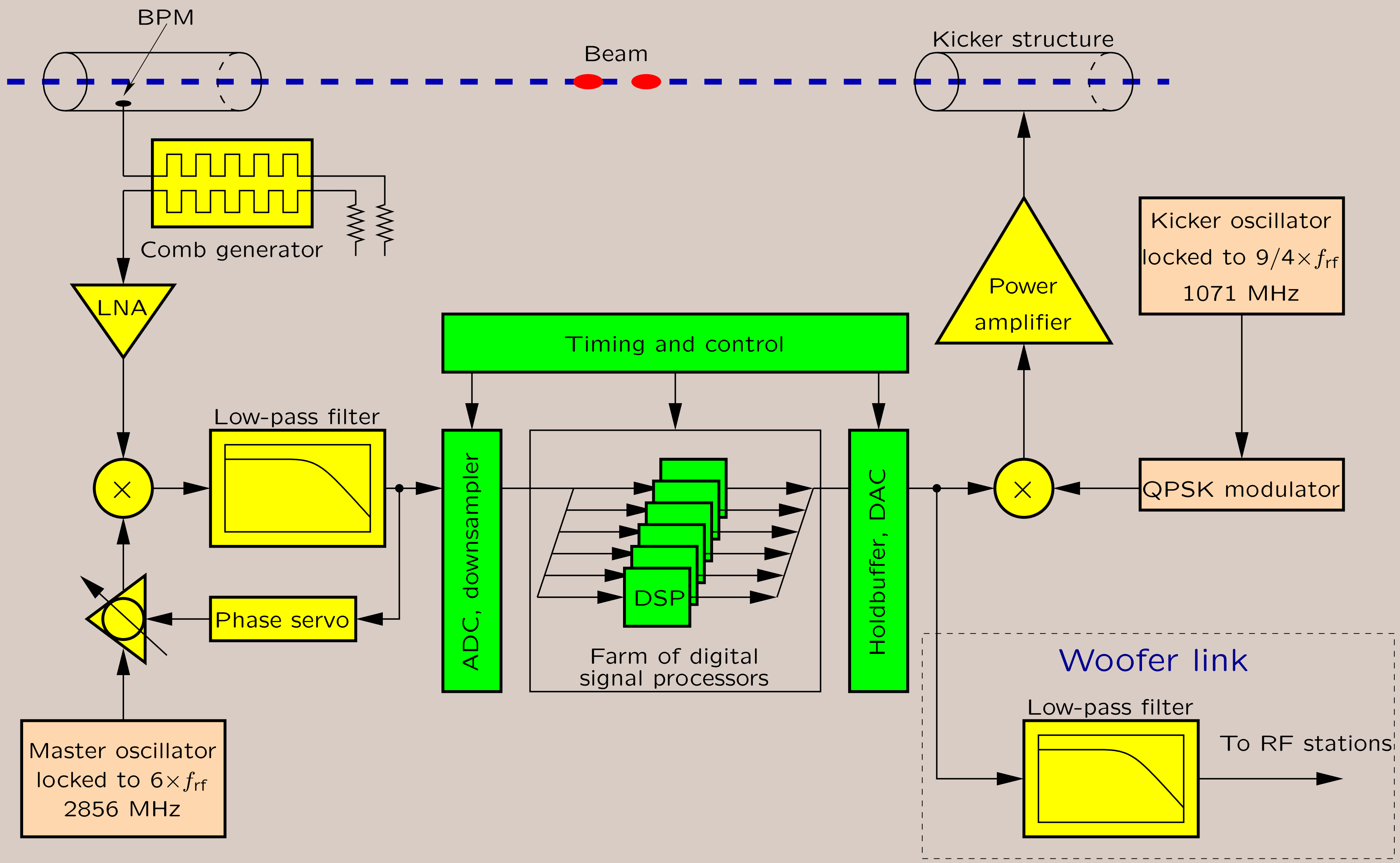
VII. Production LGDW: system description

VIII. Summary

PEP-II LFB and the woofer channel: original configuration



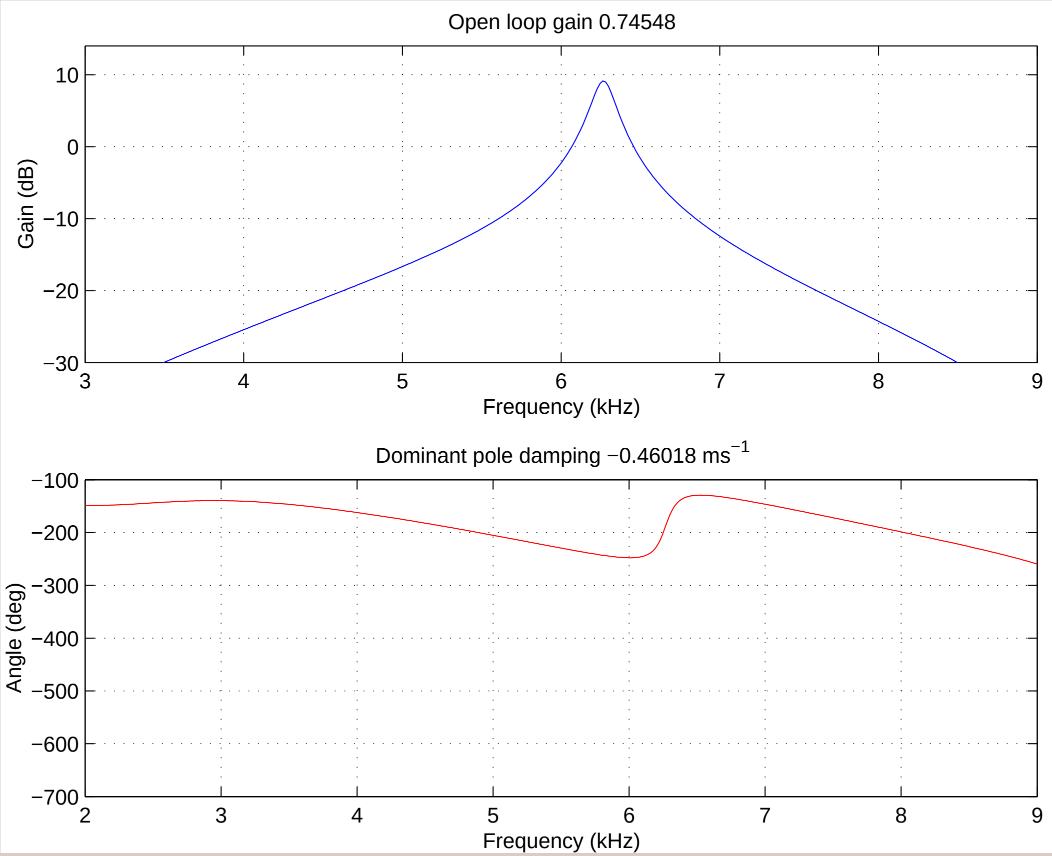
Why do we need a separate woofer processor?

Any feedback system is limited - concepts of minimum and maximum gain.

Minimum gain is important in instability control - below that value the system is unstable

Maximum gain is defined by the gain margin of the feedback loop. Above the maximum gain the system again becomes unstable.

Initially, as the loop gain is increased from the minimum value, the system becomes more stable (better damped).



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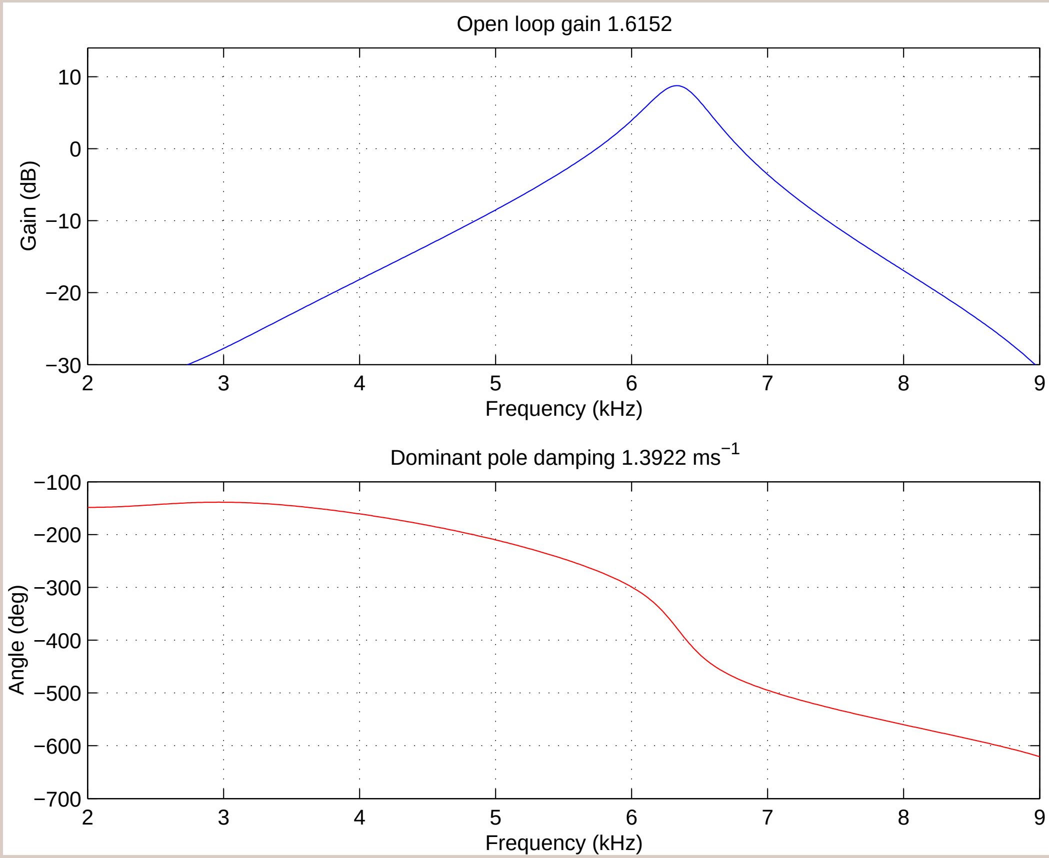

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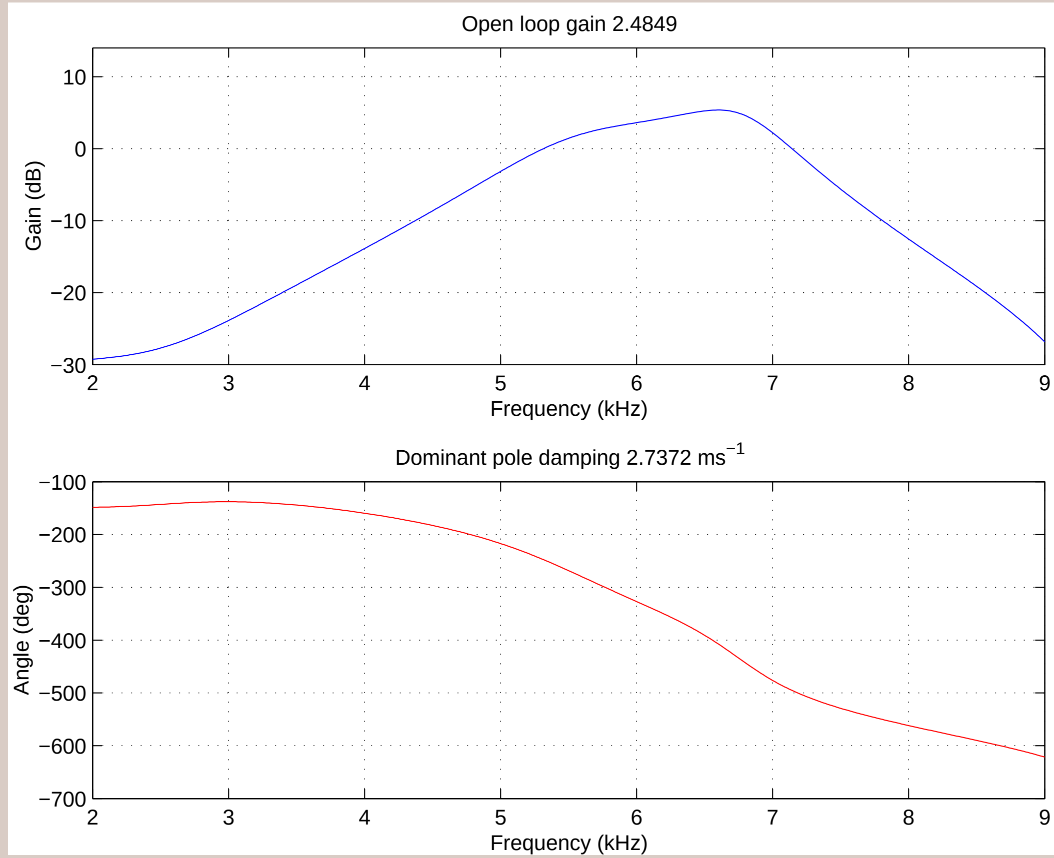

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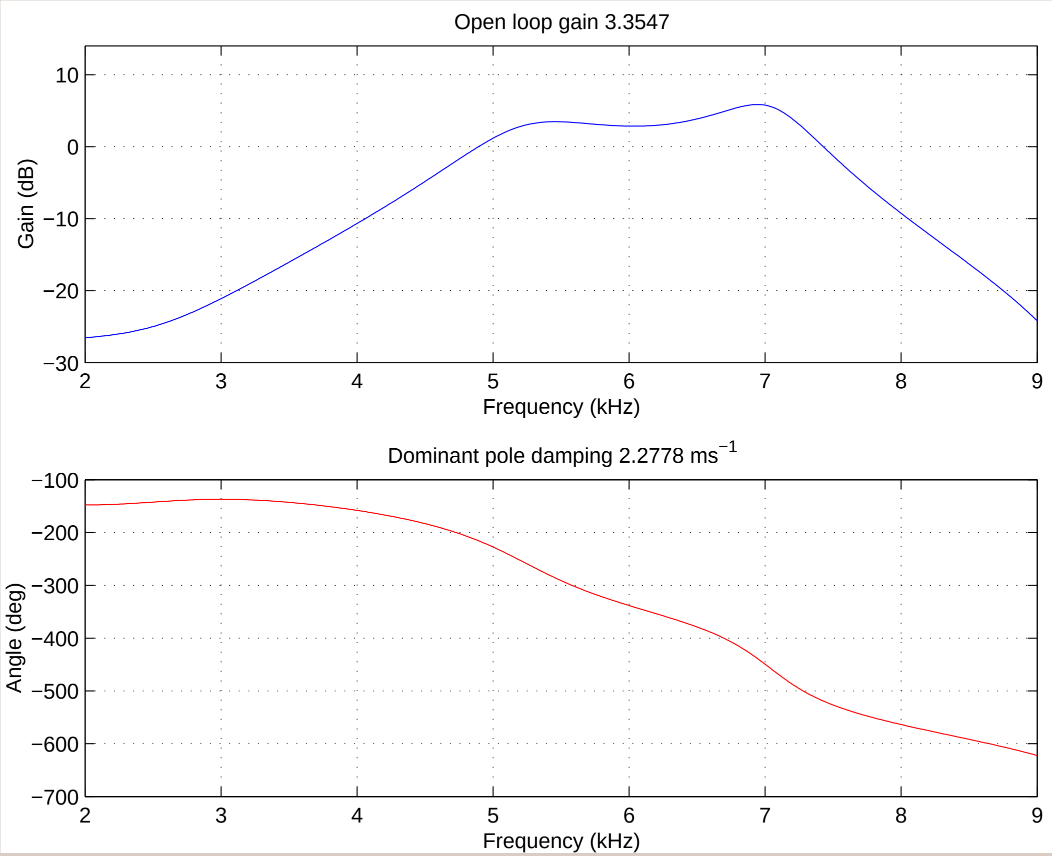

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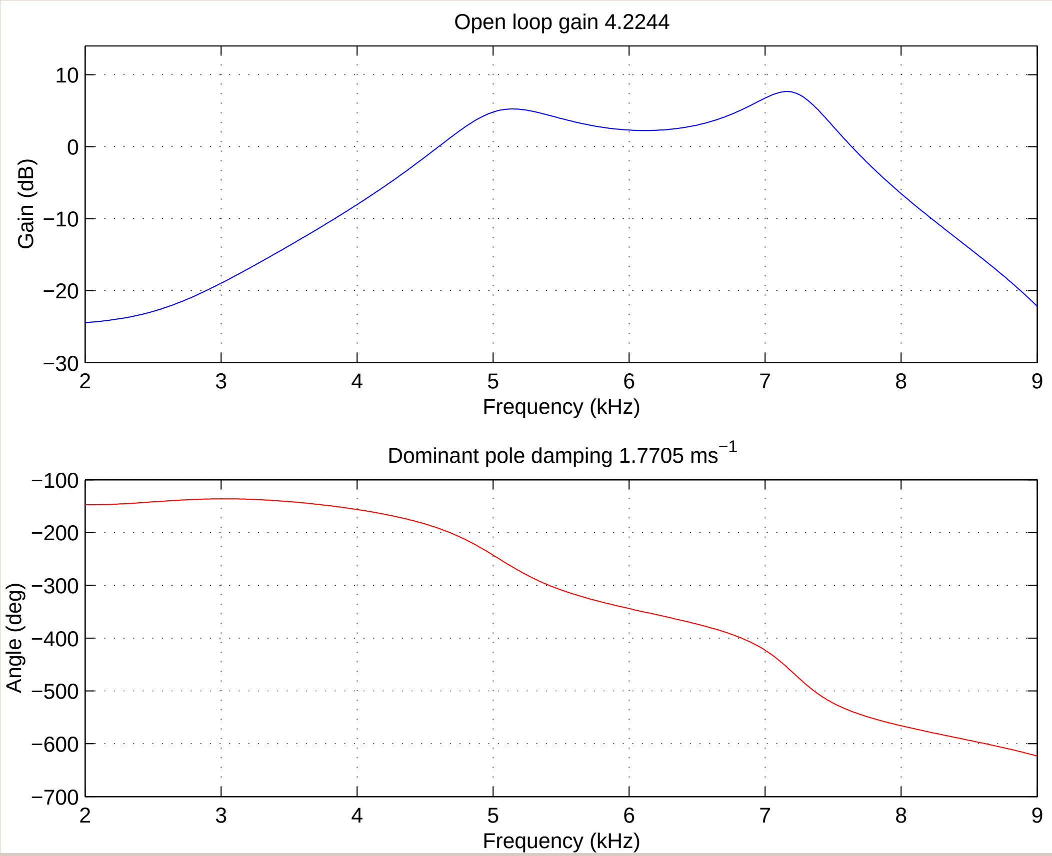

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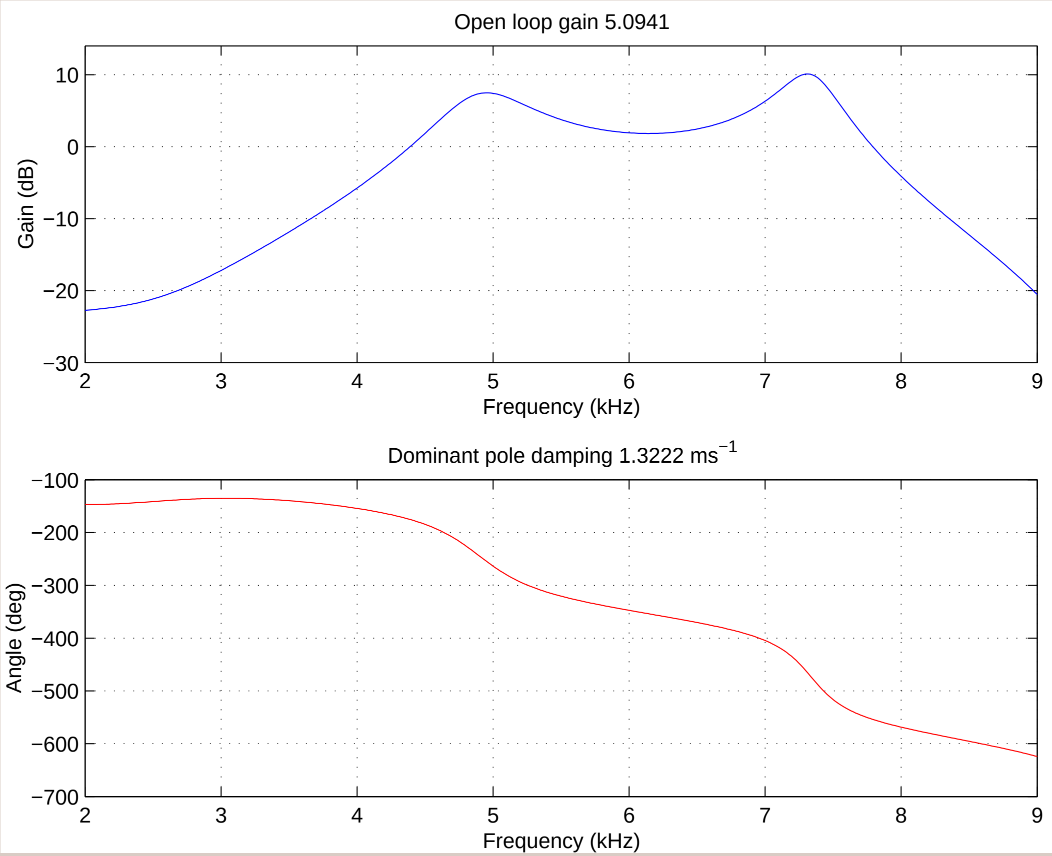

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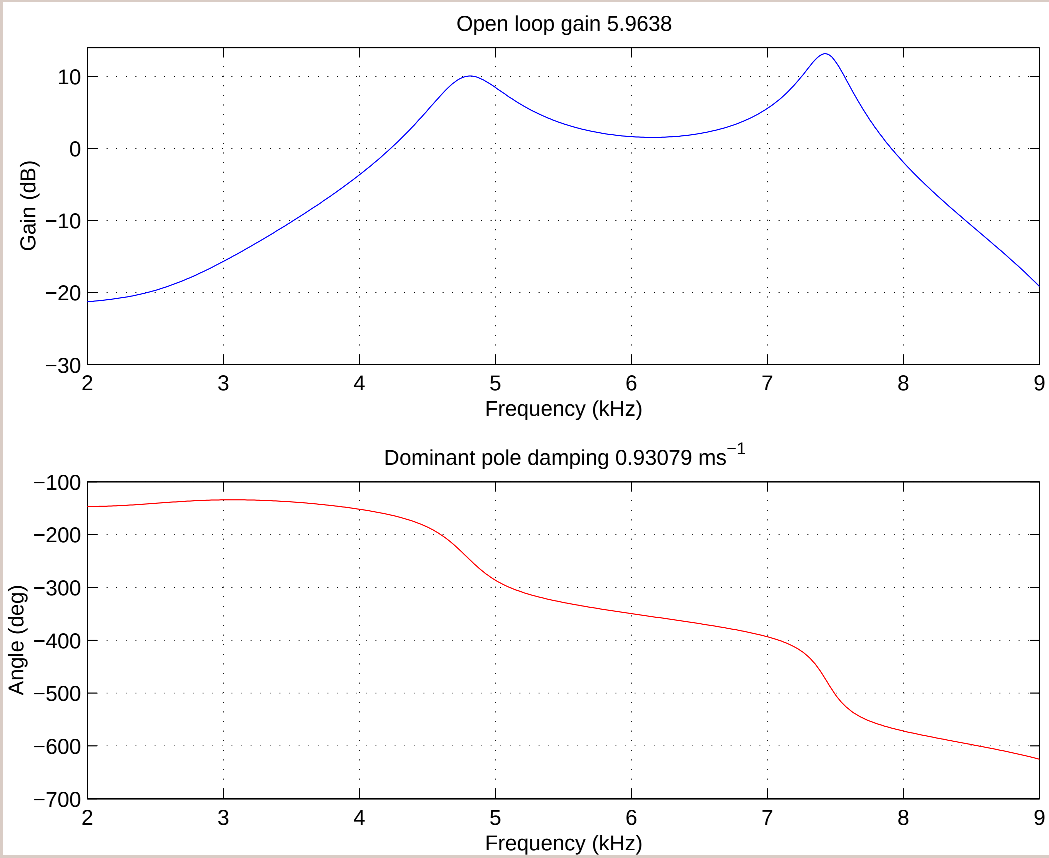

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Filter response: downsampled LFB

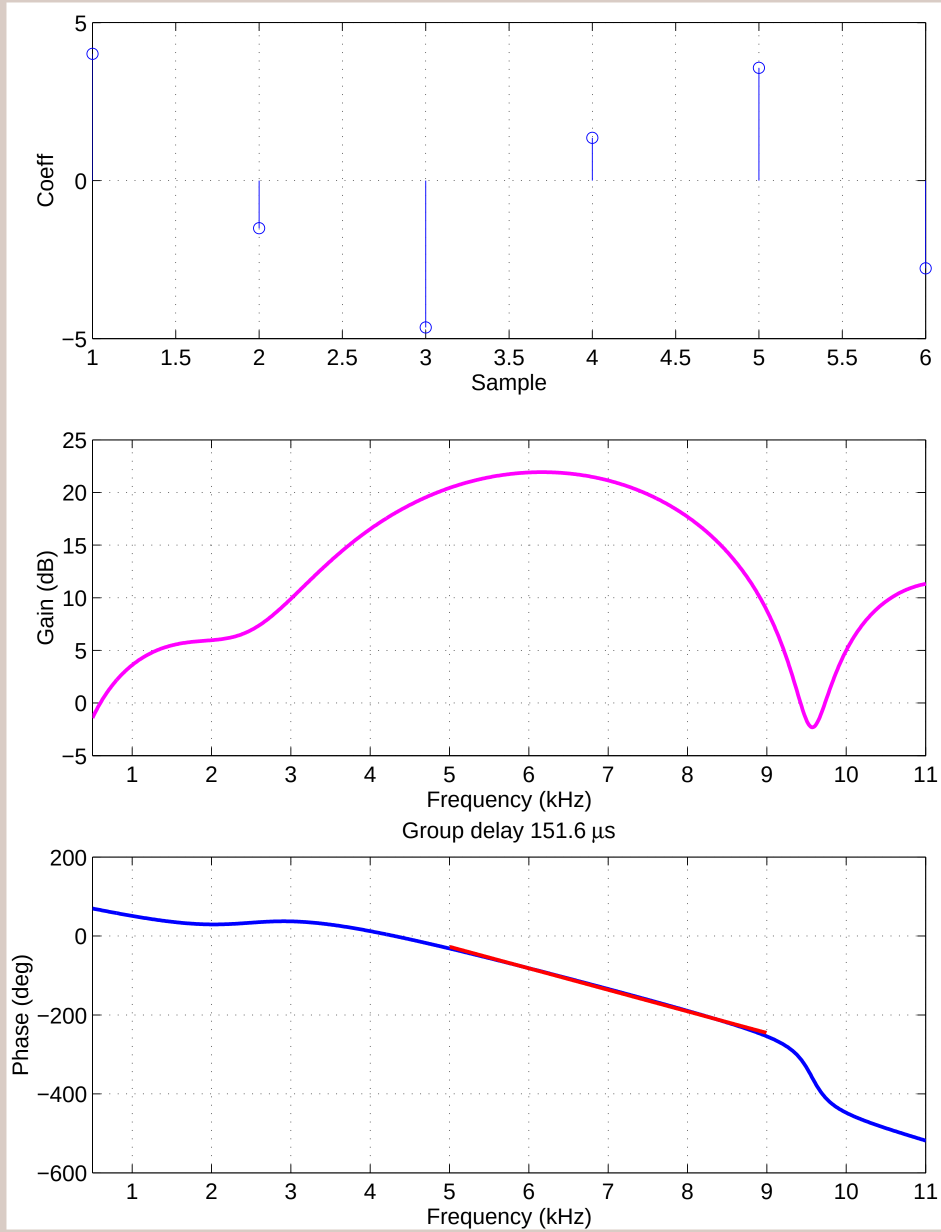
PEP-II LFB system processes bunch motion every 6 turns.

A 6-tap FIR filter has 3 taps * 6 turns = 18 turns of delay. With cable and sampling delays we get 152 μs

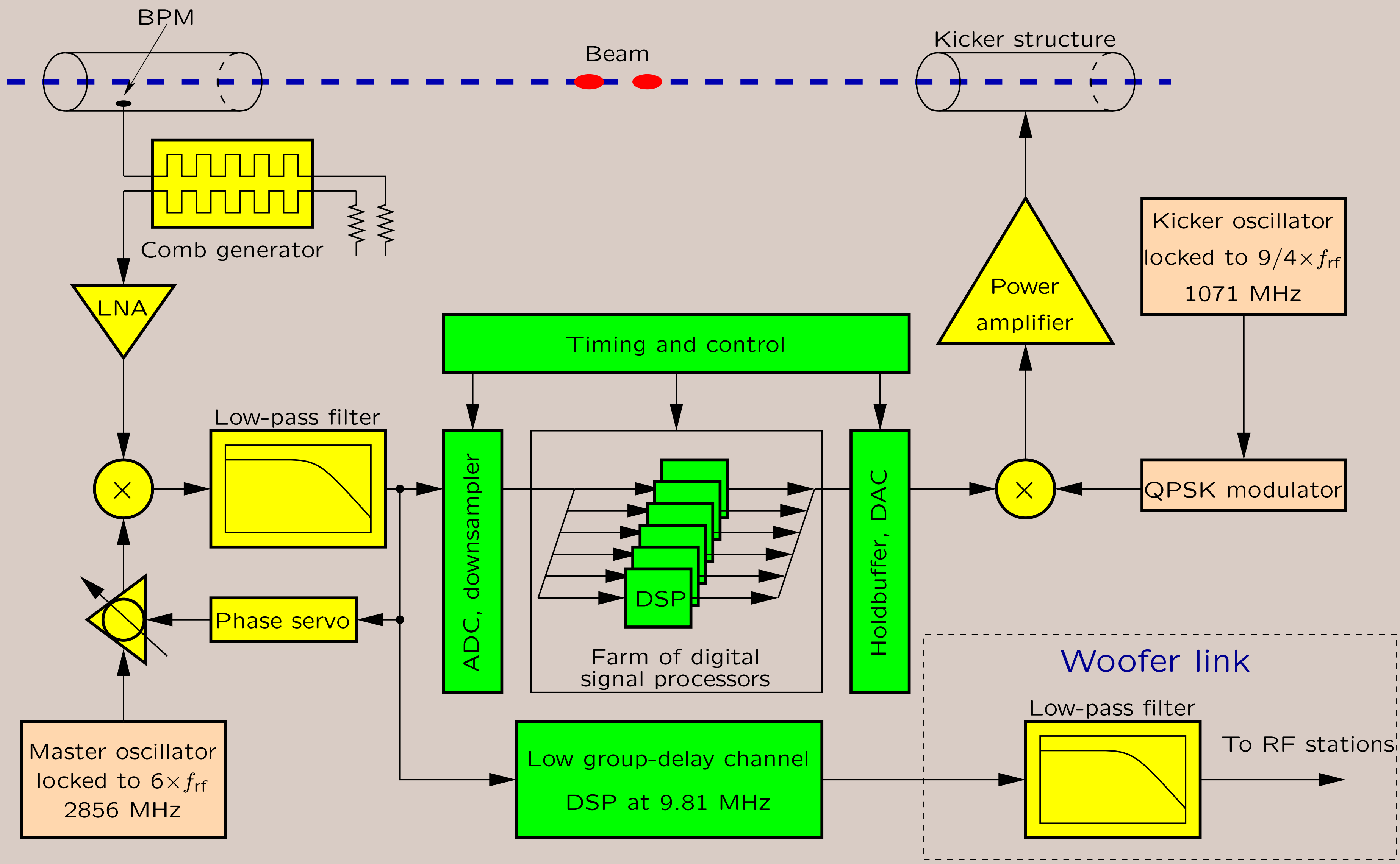
Relatively large phase slope around the synchrotron frequency leads to limited gain margins.

How can the situation be improved? Clearly, if we process beam motion on every turn the delay will be reduced. However the LFB has limited processing power and cannot be pushed beyond 6 turns downsamping.

We built a separate processing channel just for the woofer signal that computes corrections on every turn!



LFB and the low group-delay woofer channel

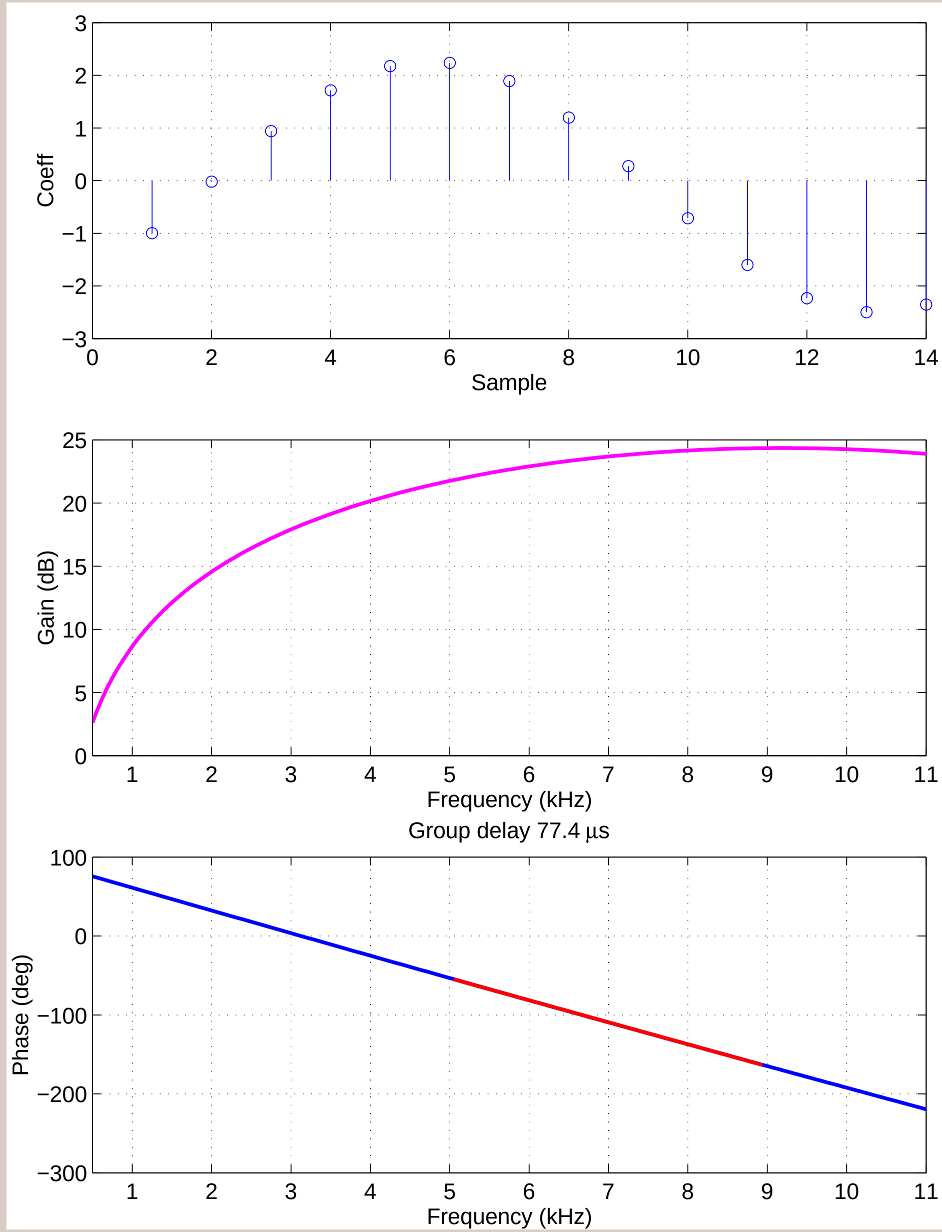


Filter response: low group-delay woofer

Group delay is reduced by a factor of 2

Note the wider filter bandwidth - directly related to a shorter time-domain response.

Still a very straightforward sampled sinewave design - more advanced filters need further work.



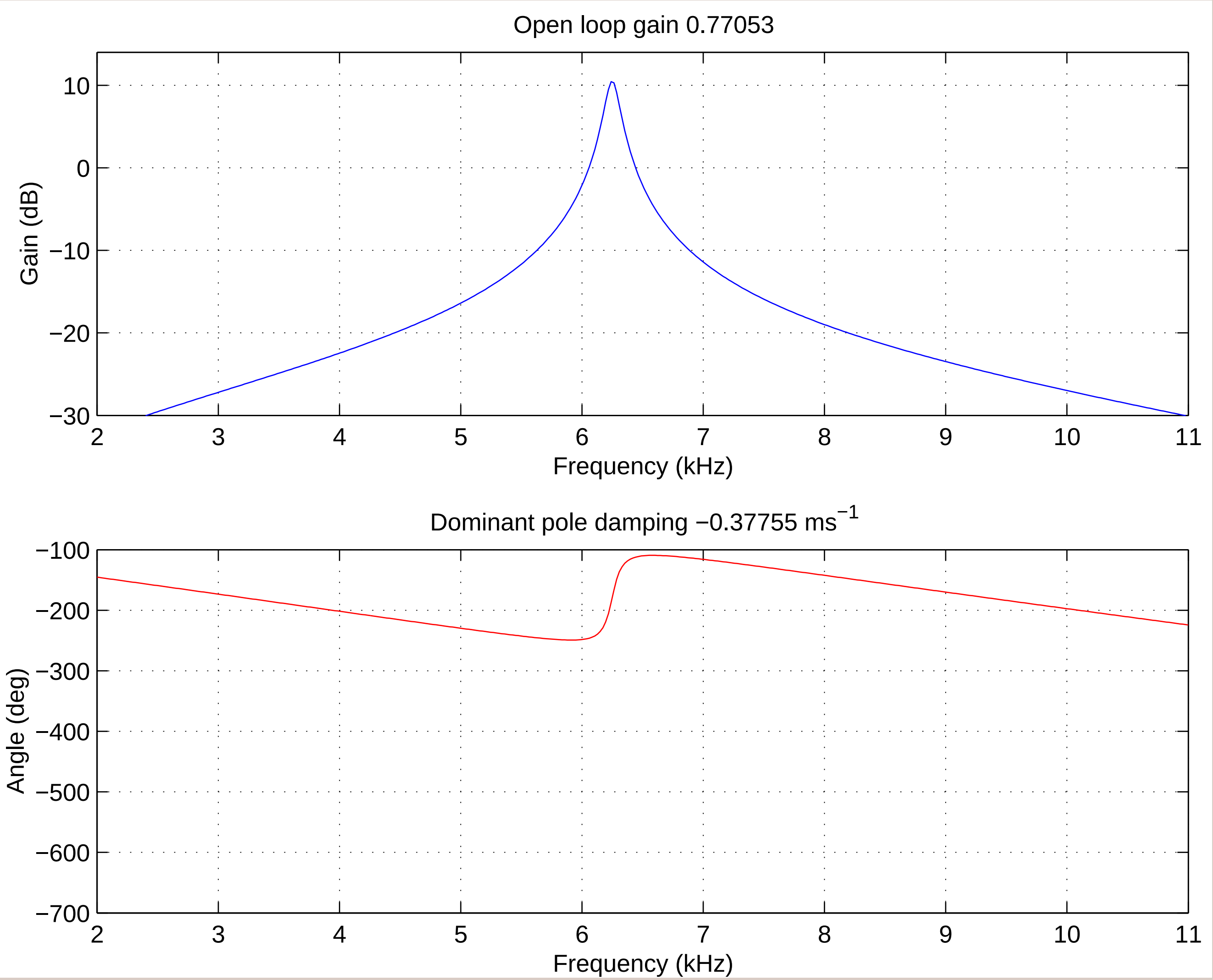
Damping provided by LGDW

With the lower group delay the new woofer can achieve much faster damping, than the LFB.

While the gain margin is an issue for both systems, the LGDW runs into the margin at higher loop gains

Due to lower group delay the closed-loop bandwidth is higher.

Peaking in the response happens further from the synchrotron frequency.



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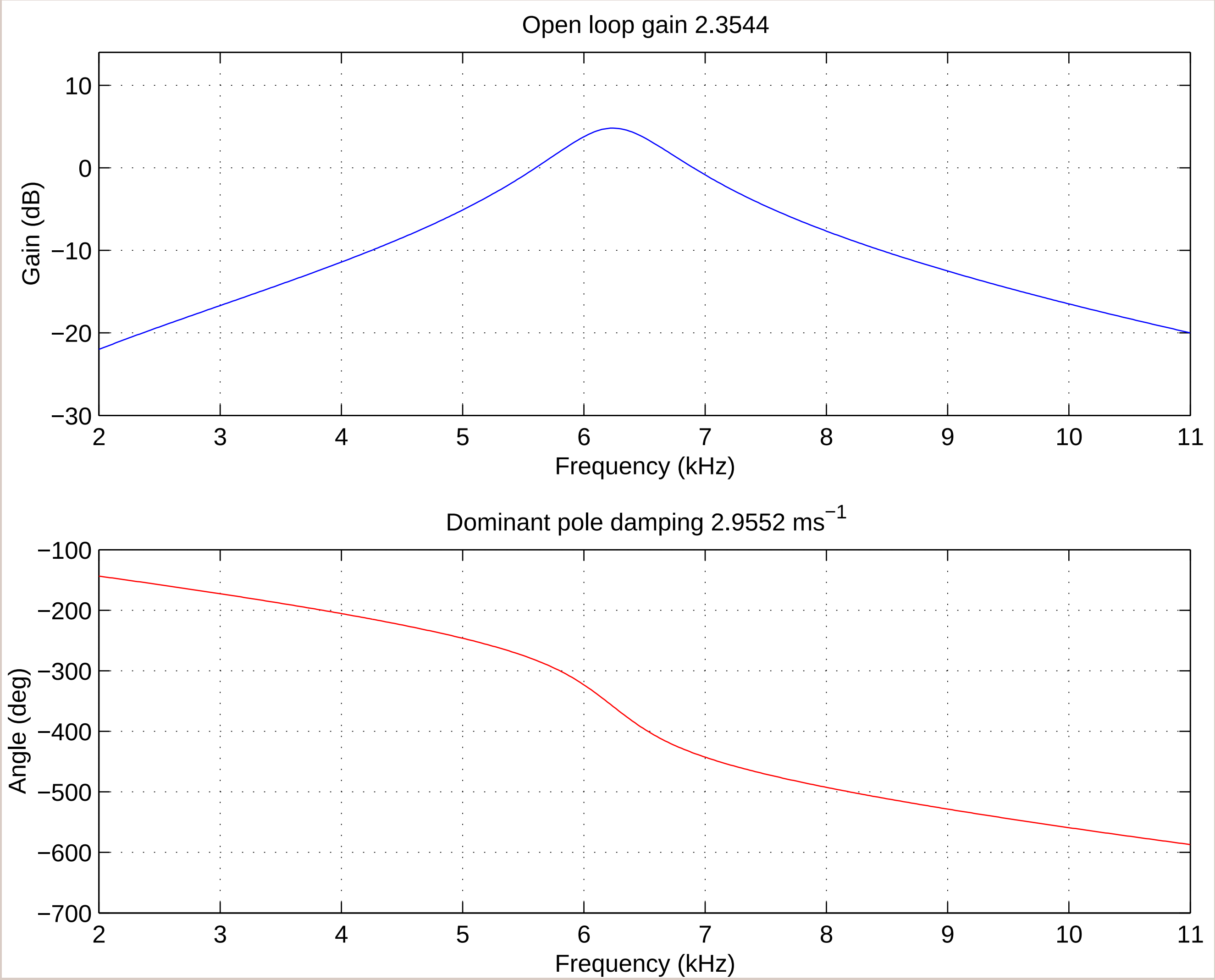

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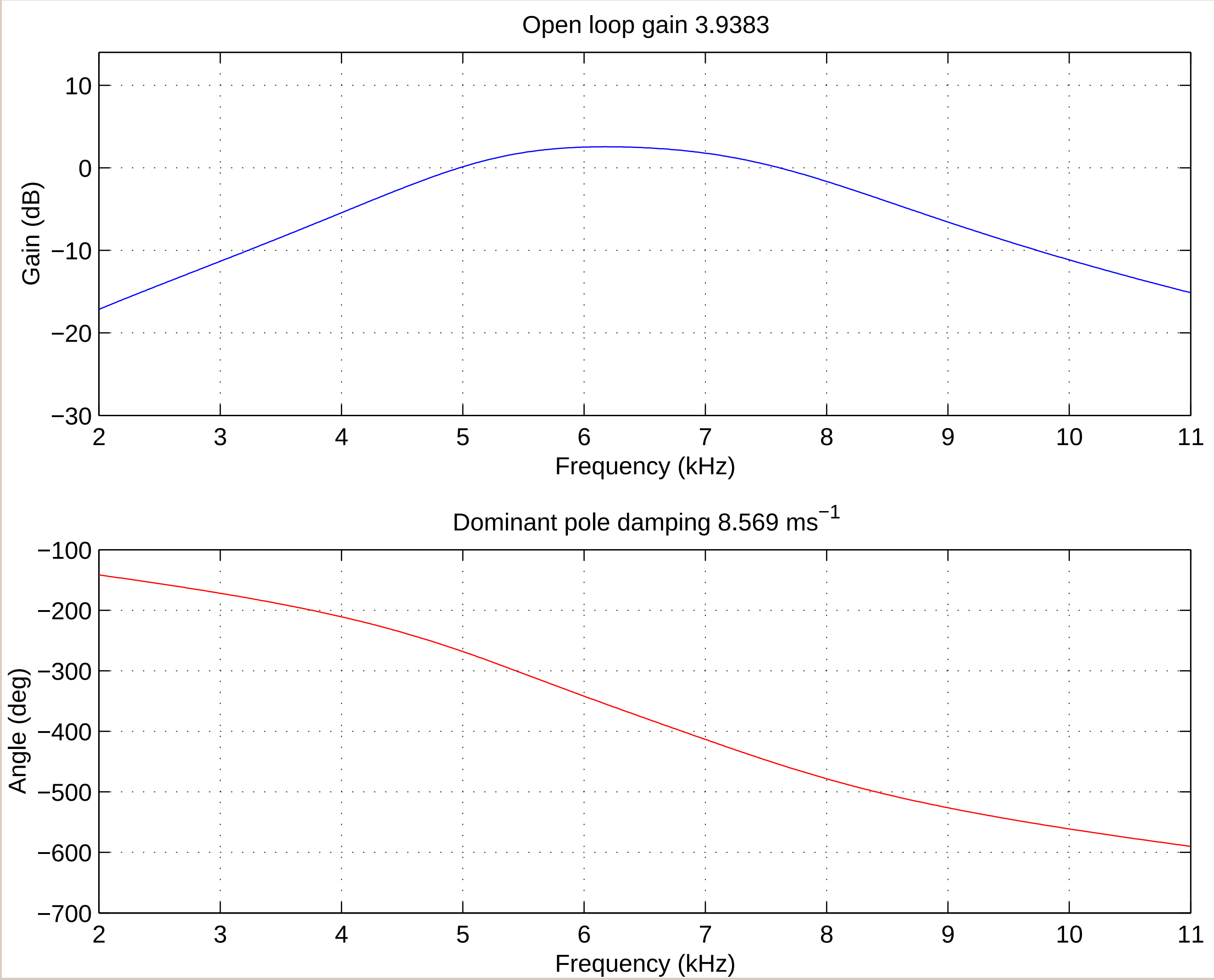

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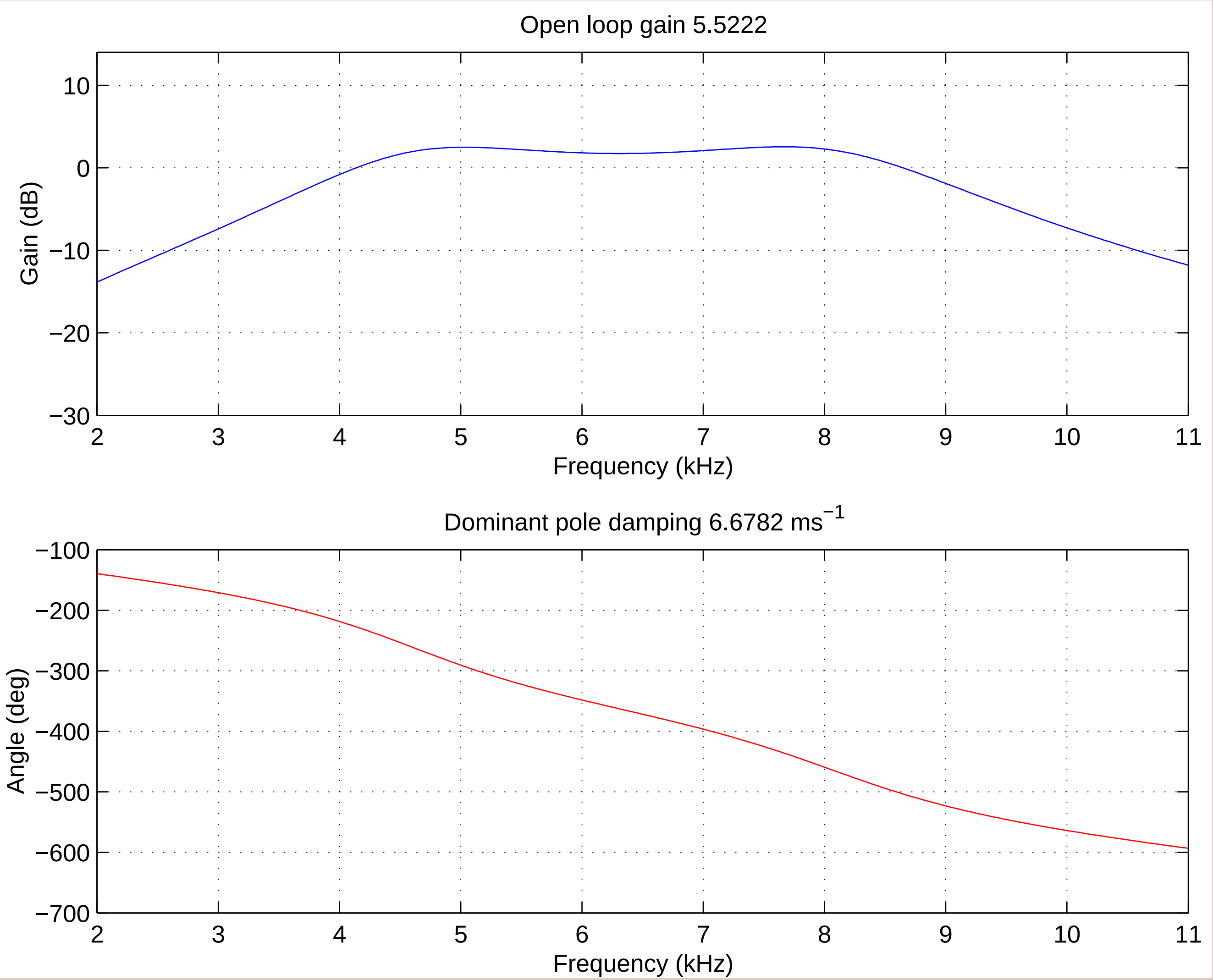

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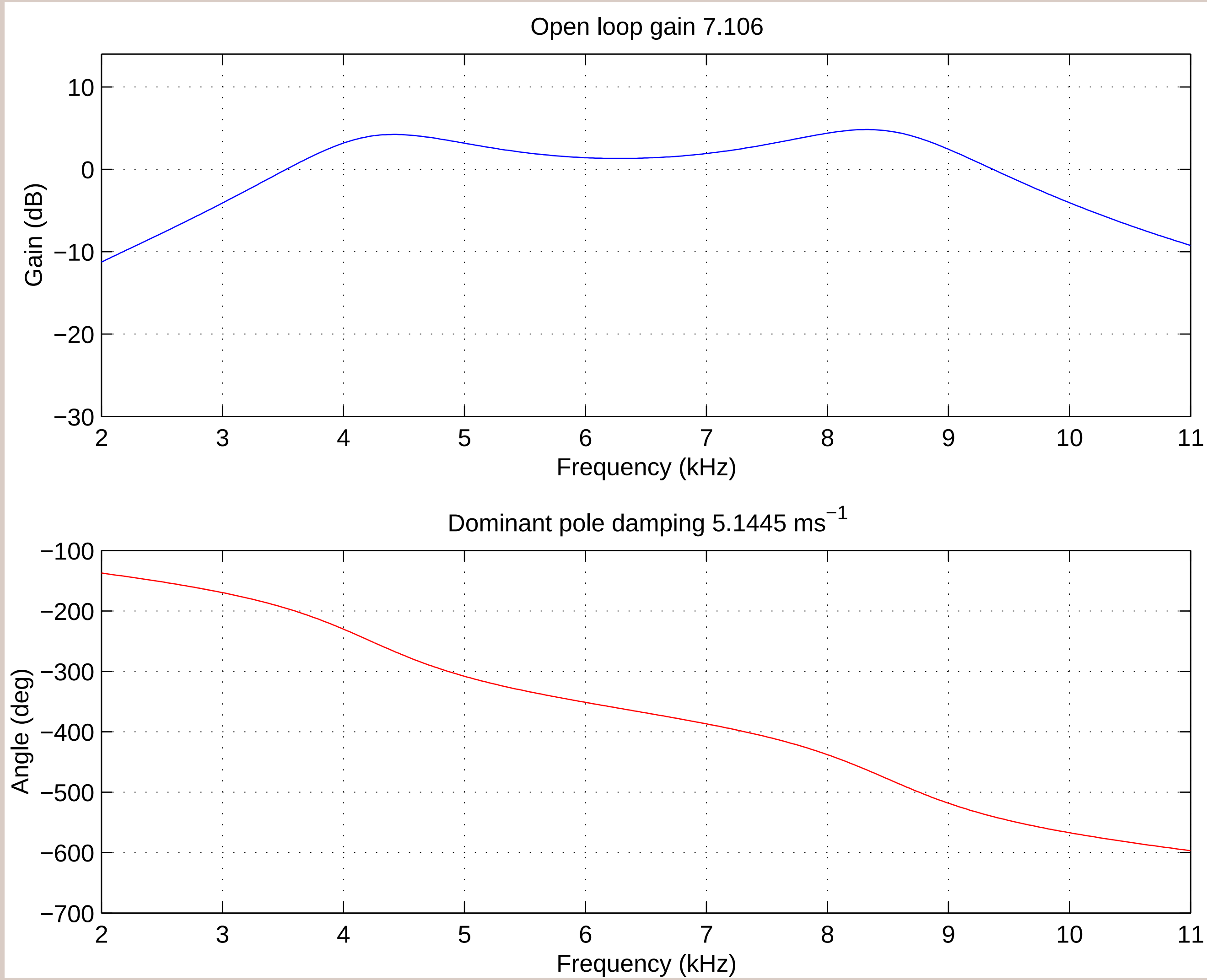

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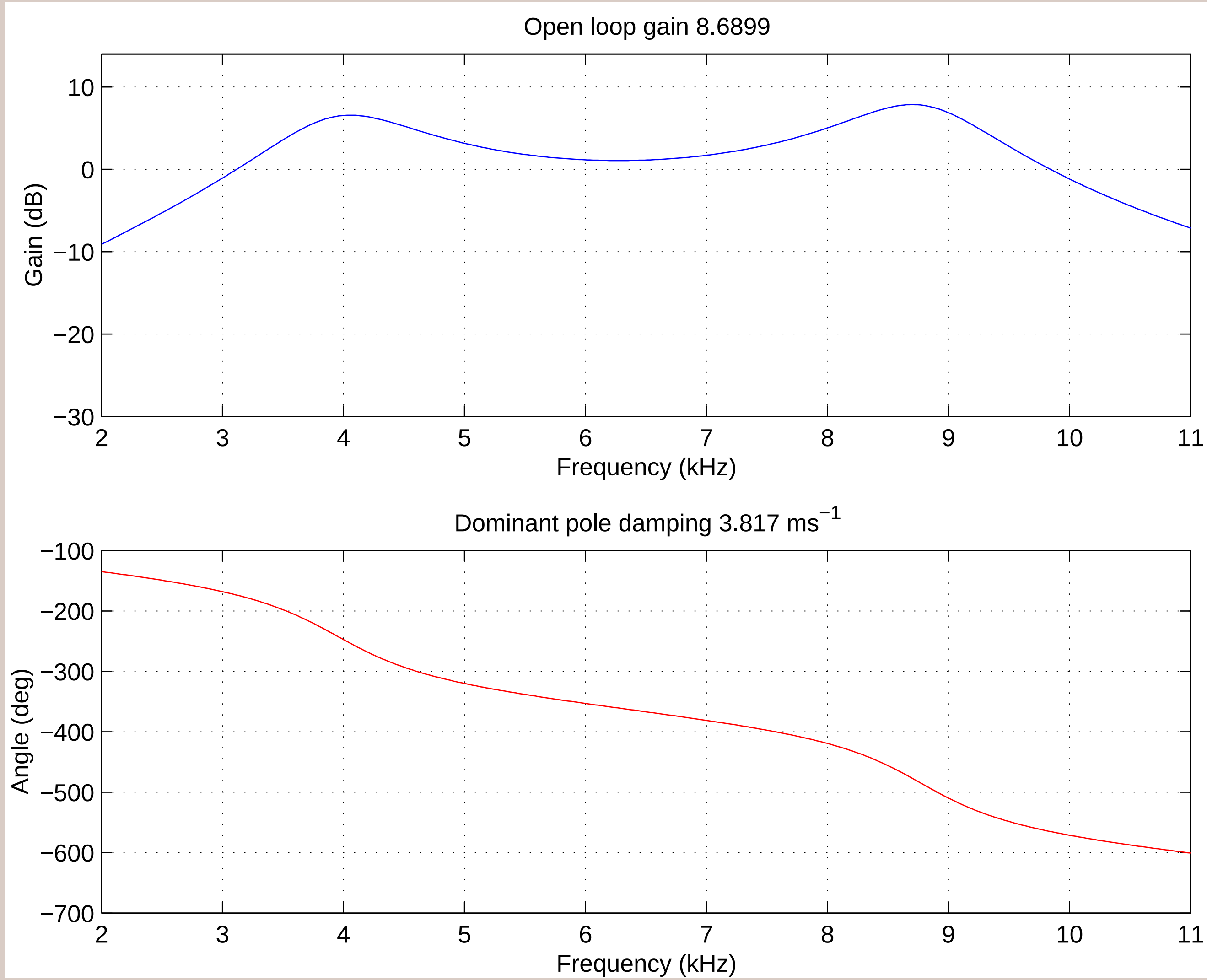

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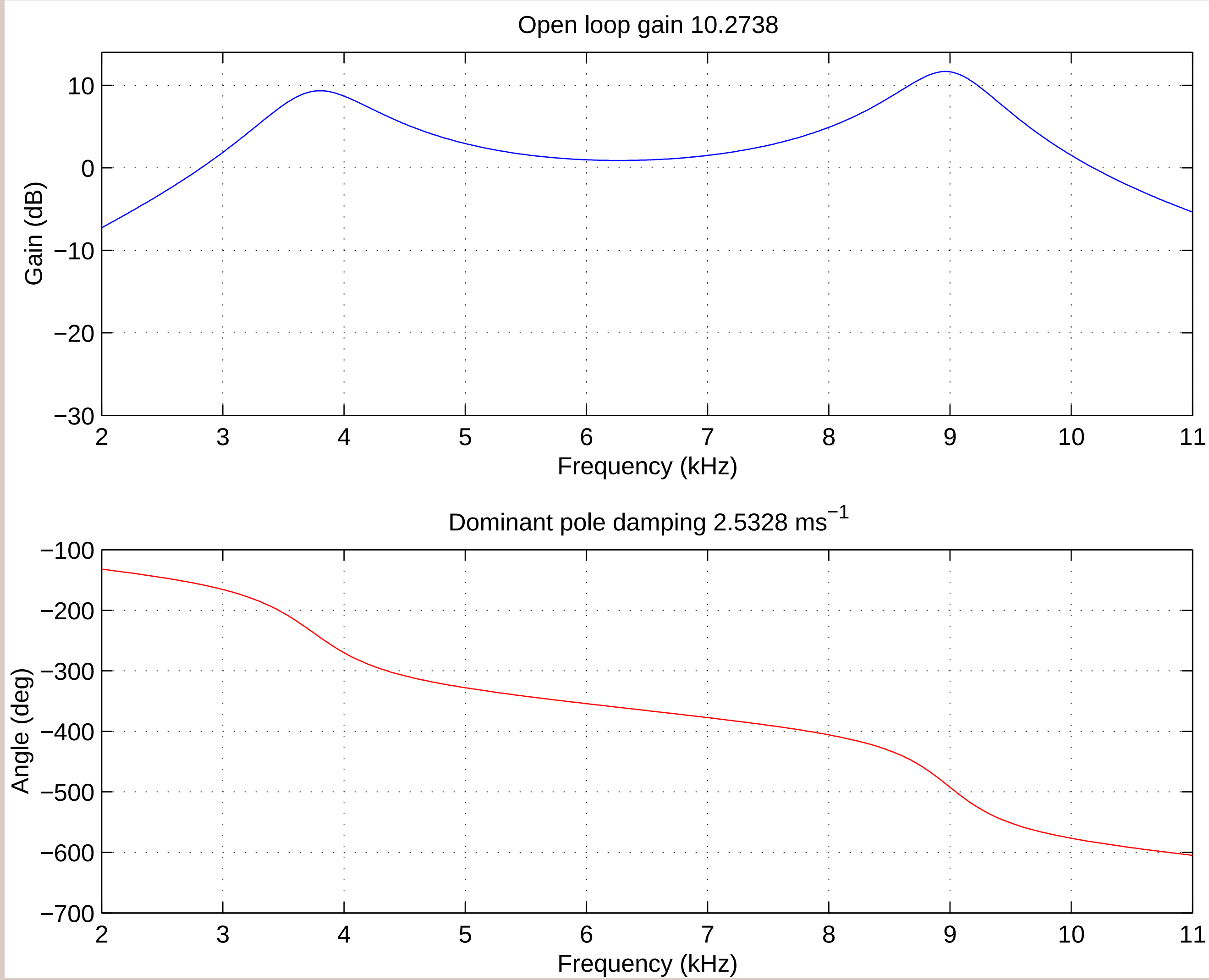
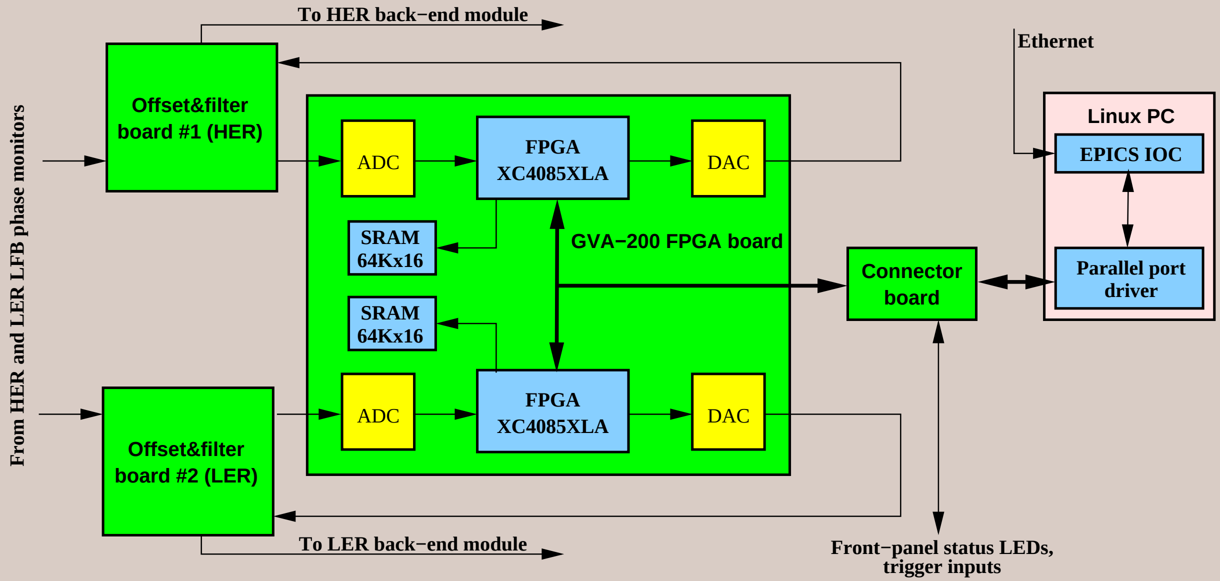


Low group-delay woofer: prototype system

The prototype is based on a off-the-shelf FPGA DSP board. It uses the existing LFB front-end monitor signal and the woofer output is passed to the existing back-end LFB module which drives the RF systems via fiber optic links.



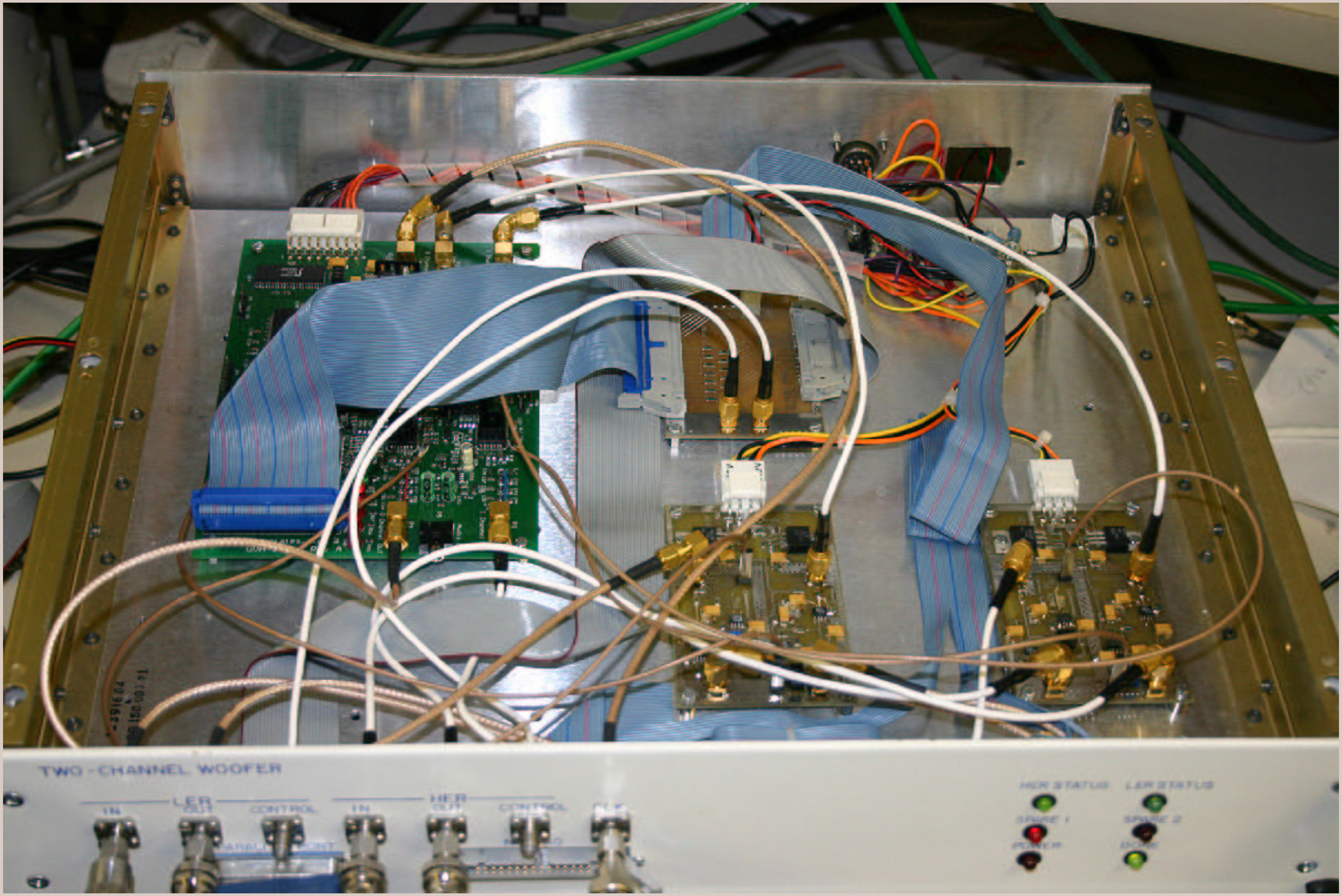
The LGDW prototype implements a 14 tap FIR filter, with a 9.81 MS/s processing rate.

Only one working channel due to signal coupling in the DSP board.

HER system was commissioned on May 6, 2004.

The low group-delay woofer allowed us to push the HER current from 1380 mA to 1560 mA while significantly reducing the rate of longitudinal instability aborts.

LGDW prototype



LGDW: user interface

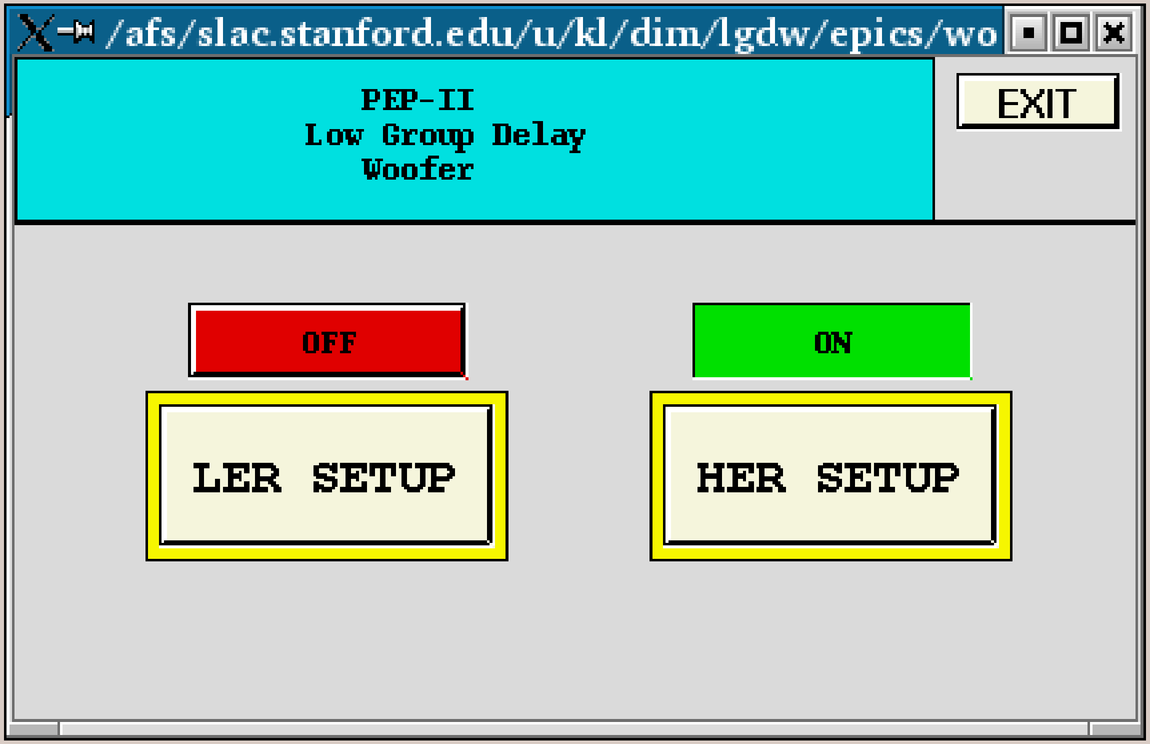
LGDW uses a soft IOC running on a Linux PC

User interface via EPICS and EDM display manager

Top level panel: on/off control for both rings and status summary.

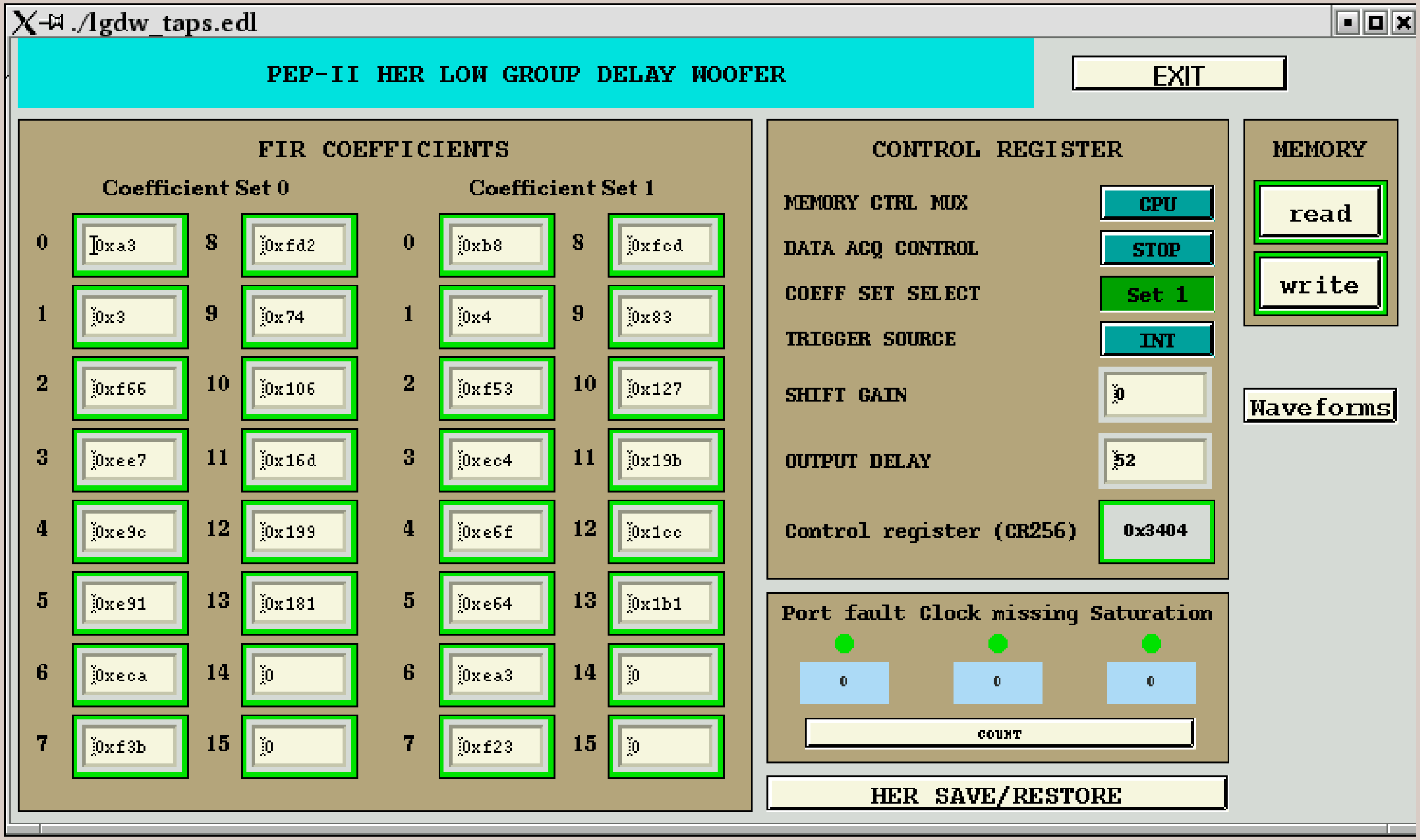
Status colors:

Green	No alarm
Yellow	Channel saturation
Orange	Register verify error
Red	Missing clock or interface fault



Main control panel

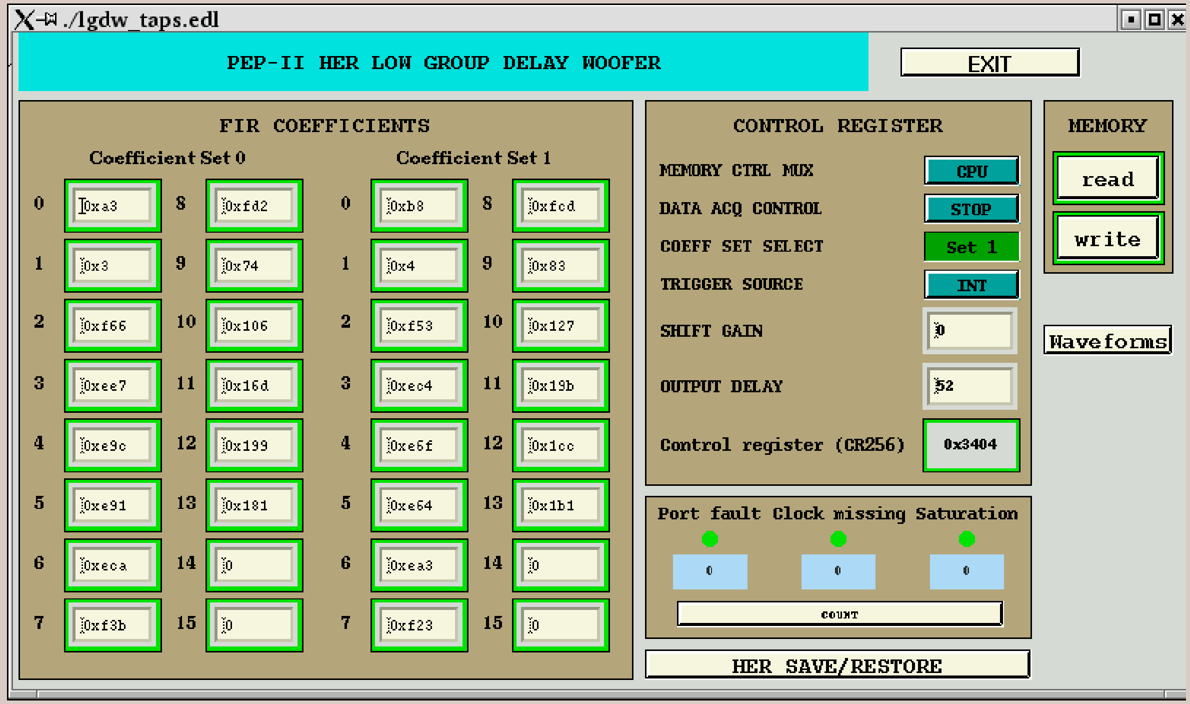
Two sets of 16 filter coefficients. Prototype used only the first 14.



Control register:

- Memory control mode
- Data acquisition state
- Coefficient set select
- External trigger enable
- Shift gain
- Output delay

Main control panel - continued



Memory control mode: *CPU* for EPICS access and *ADC* for data acquisition

Data acquisition state: *Stop* and *Run*. When *Run* is selected memory is filled with input data, then acquisition stops

Coefficient set select: modifying a coefficient in the active set is undesirable. Normally we modify the second set, then switch.

External trigger enable: allows one to control the coefficient set and trigger data acquisition

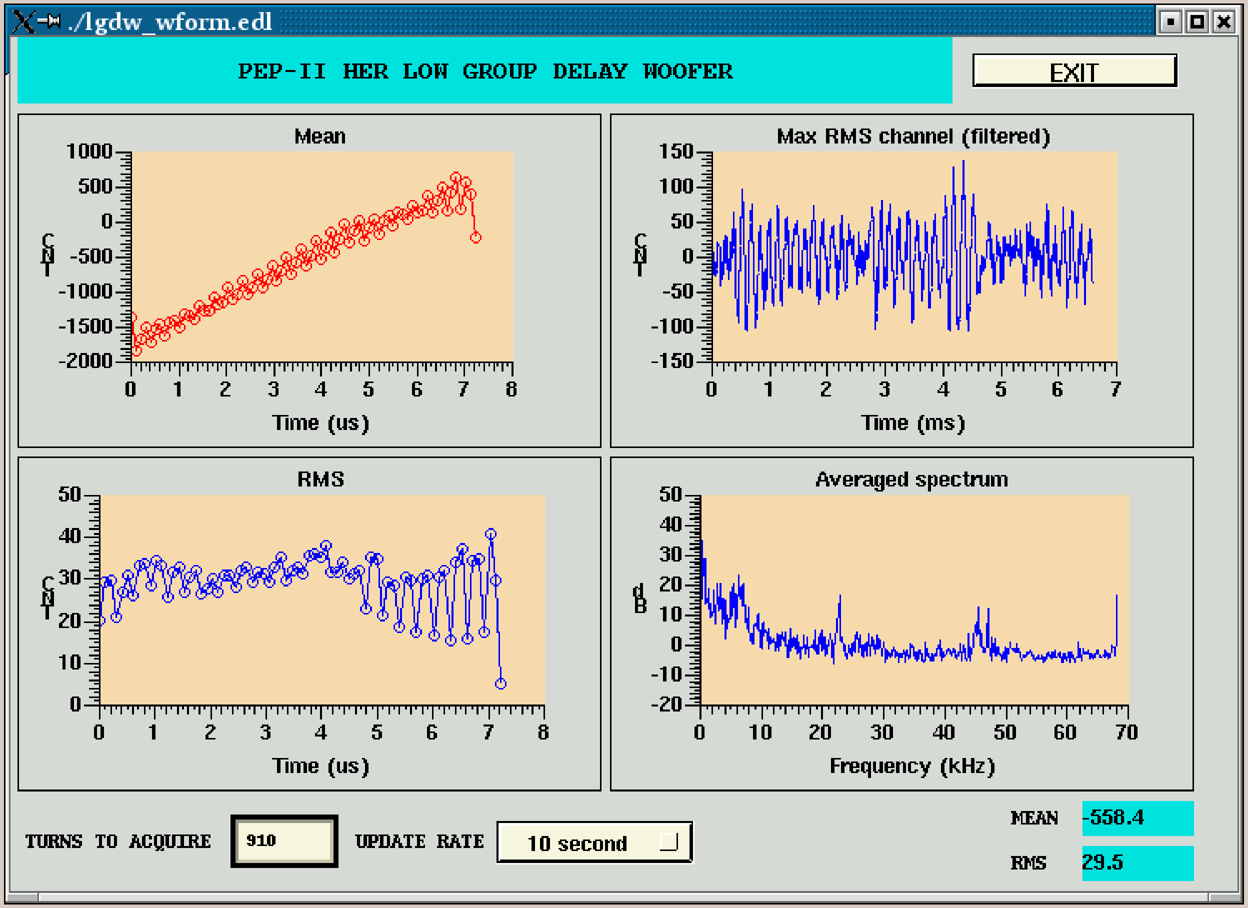
Shift gain: number of bits the output of the filter is shifted left (gain of 2^N)

Output delay: delay buffer length to time the kick to the beam

User interface features: beam diagnostics

Diagnostic waveform panel. IOC can be configured to periodically acquire beam data and present it in 4 plots:

- mean signal over a turn,
- RMS (filtered) over a turn,
- filtered time domain record of the channel with the highest RMS,
- averaged spectrum



The overall mean and rms values are also computed and can be stripcharted

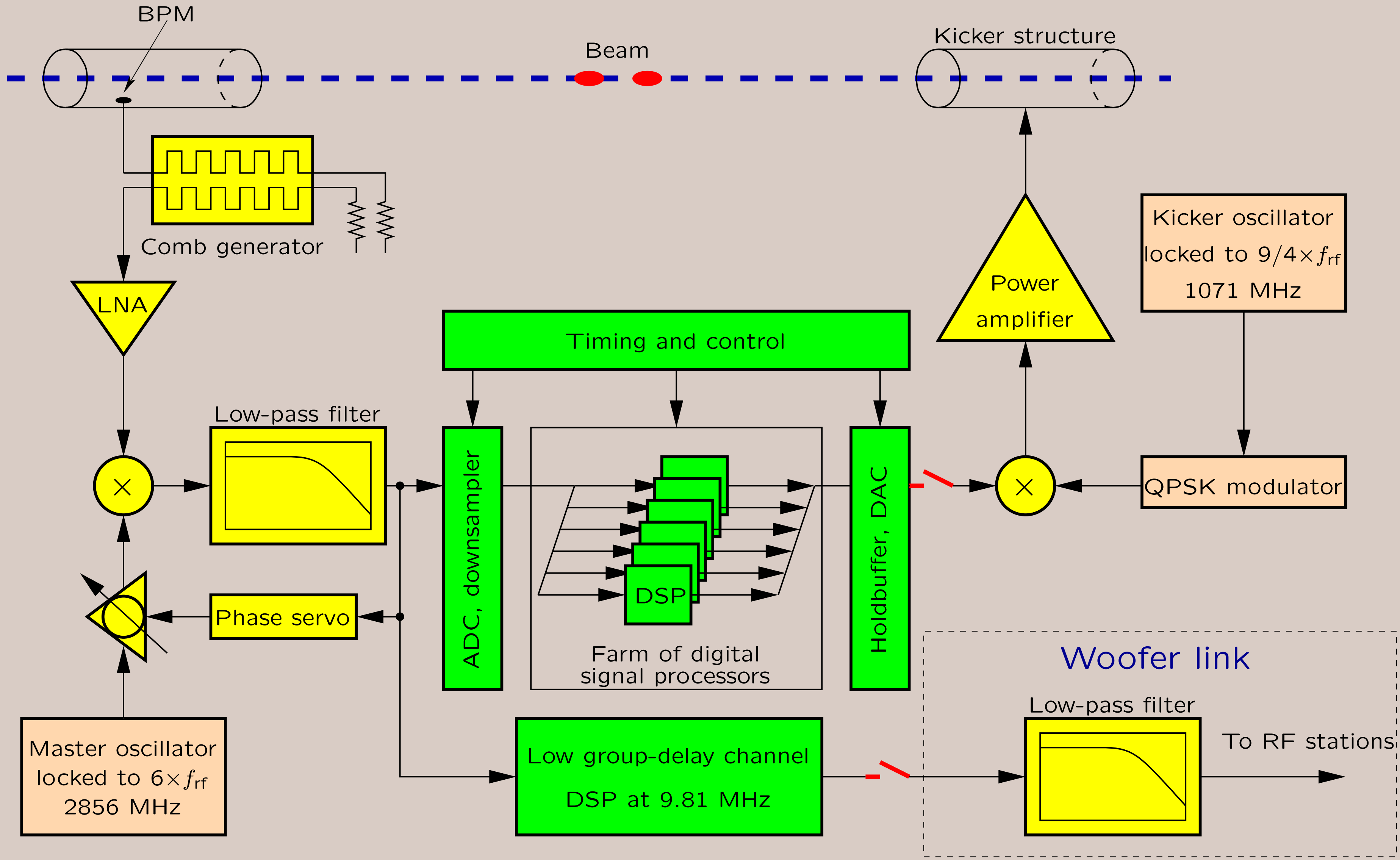
User interface: save/restore

Save and restore functions with confirm

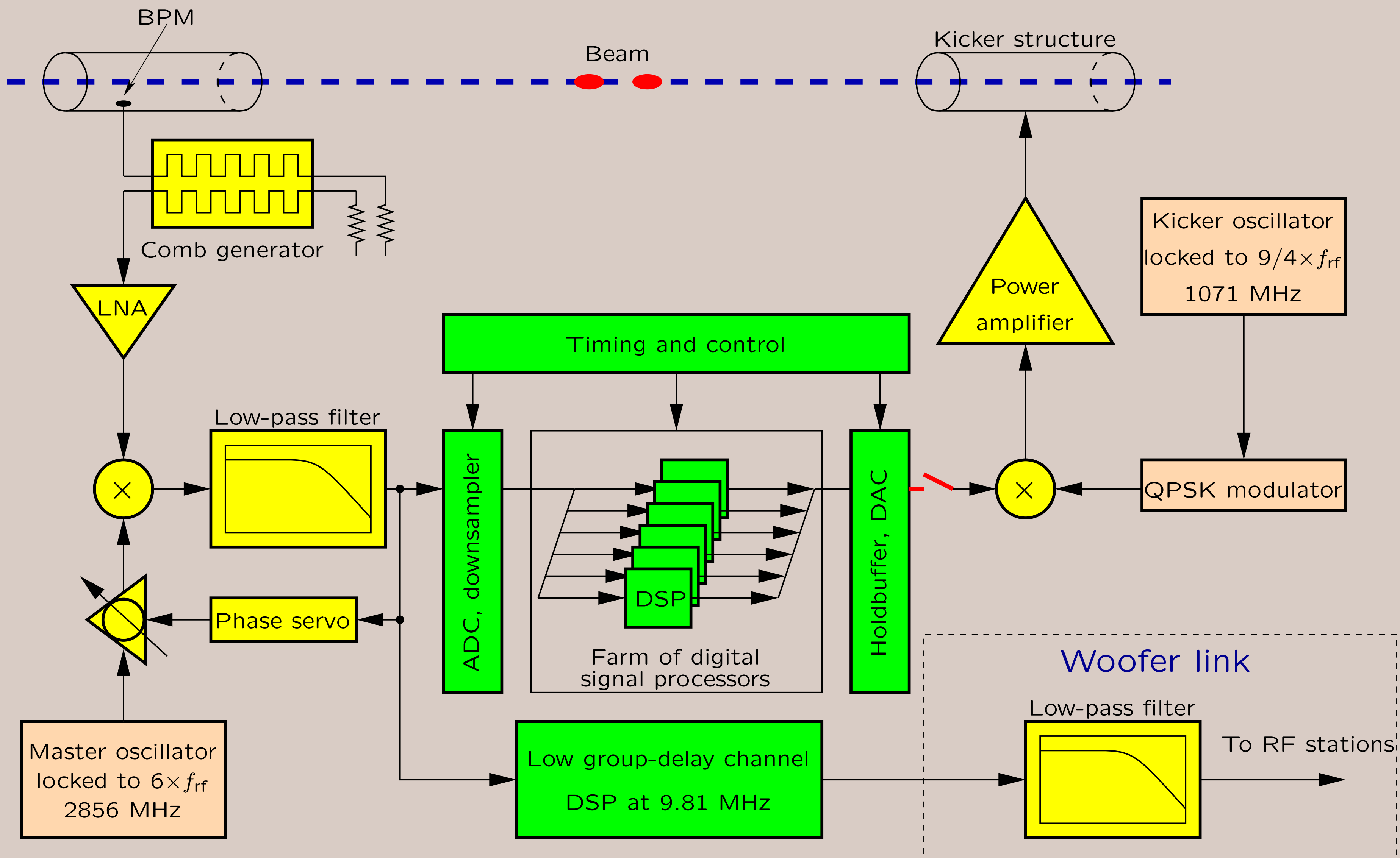
Clicking on the file name brings up a file selection dialog.

Restore function is invasive and will disrupt the feedback for a short while, even if the restored settings are the same as current values.

Two types of grow/damp measurements: all modes



Two types of grow/damp measurements: HOMs only



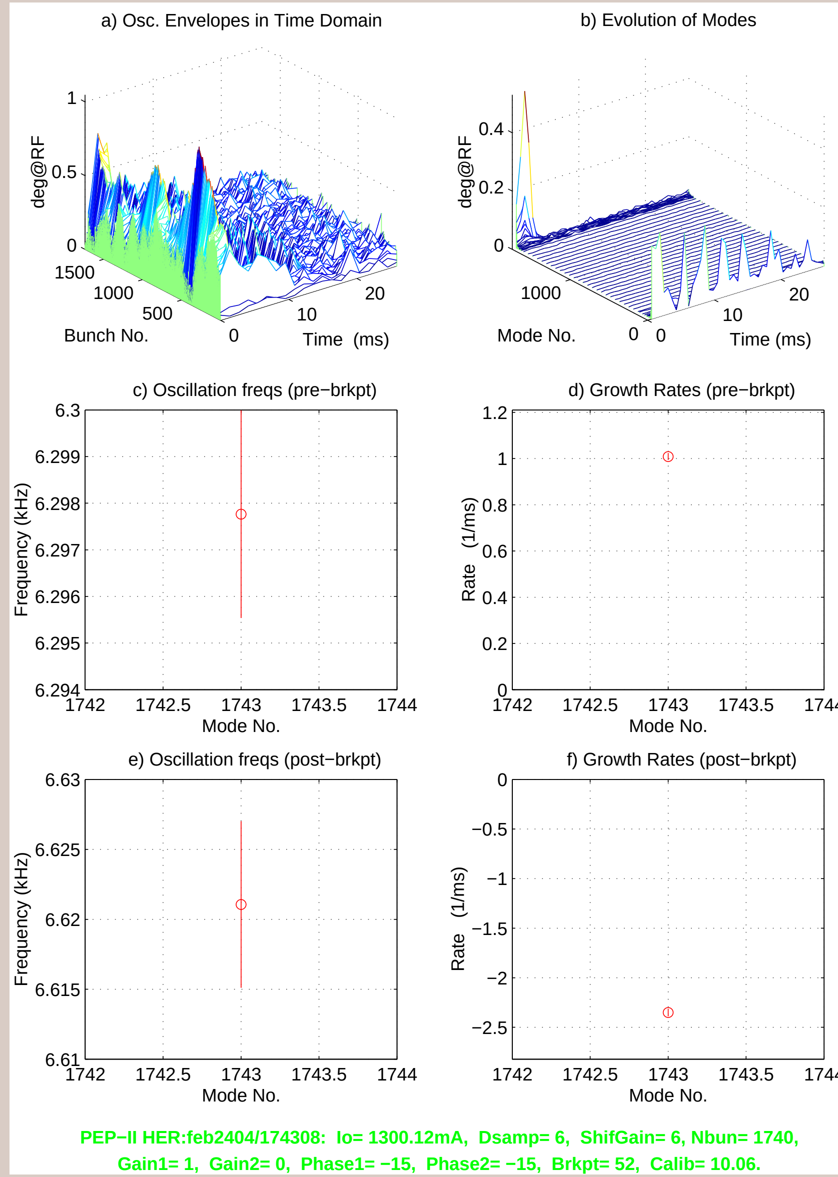
Grow/damp measurements for the low modes

During these measurements we turn off both wideband (LFB) and narrowband (LGDW) channels.

Measures open-loop growth and closed-loop damping for the fundamental driven modes

Due to optimized gain partitioning the system can recapture beam motion at larger amplitudes. For the grow/damp measurements this allows longer growth intervals and better SNR.

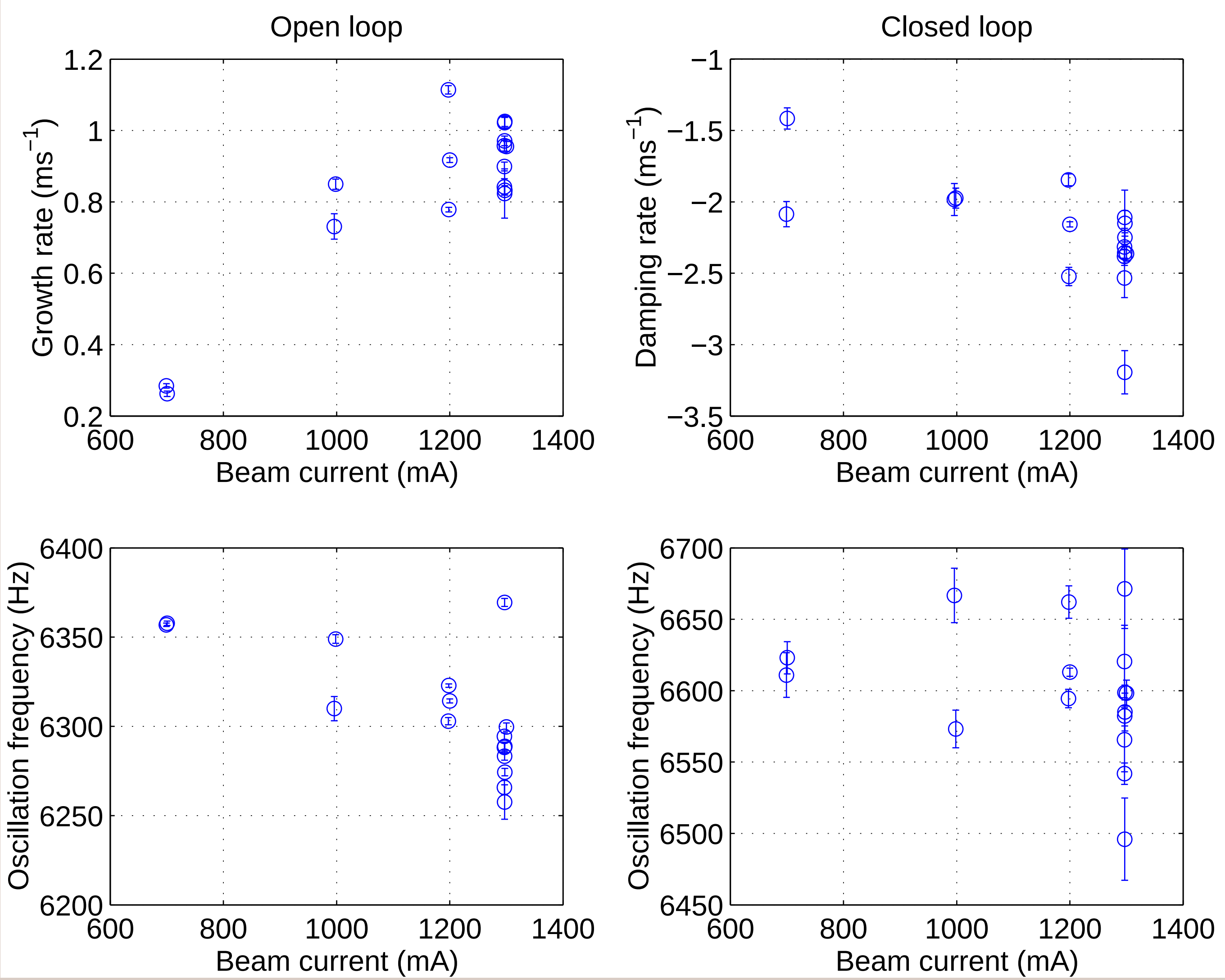
Larger dynamic range of the new woofer will allow it to handle significantly larger beam transients due to injection, RF, etc.



Growth and damping rate summary (mode -3)

Growth rates are similar to what we have seen historically.

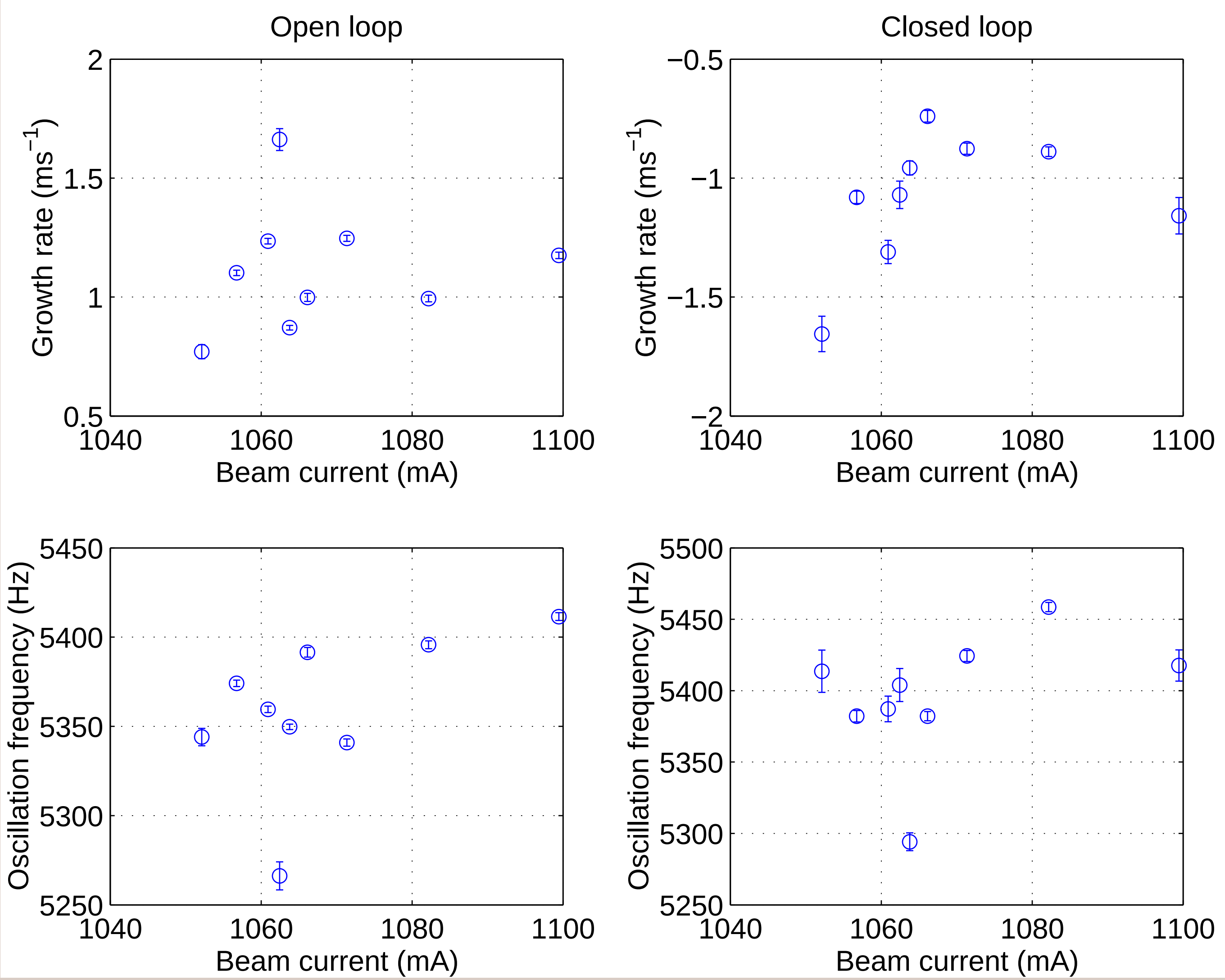
At 1300 mA the new low group-delay woofer provides 3 to 3.5 ms^{-1} of net damping.



Rates from 6/19/2003 for comparison: standard woofer

Net damping with the standard woofer configuration is around 2 ms^{-1}.

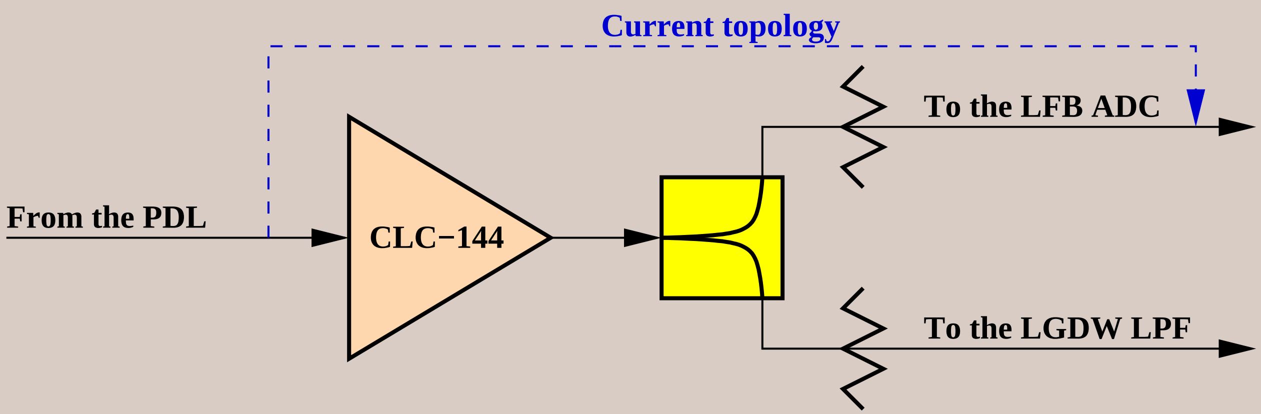
Even with the preliminary filter design the low group delay woofer improves low mode damping by 50%.



Production woofers: hardware description

What are we adding to the LGDW?

- Wideband amplifier to boost the LFB ADC signal and split the output into LFB and LGDW channels



- A PLL to generate the processing clock locally
- A slow multi-channel DAC for offset trimming
- Migrate from IEEE-1284 parallel port to USB using FT245BM USB FIFO chip on an off-the-shelf daughterboard module

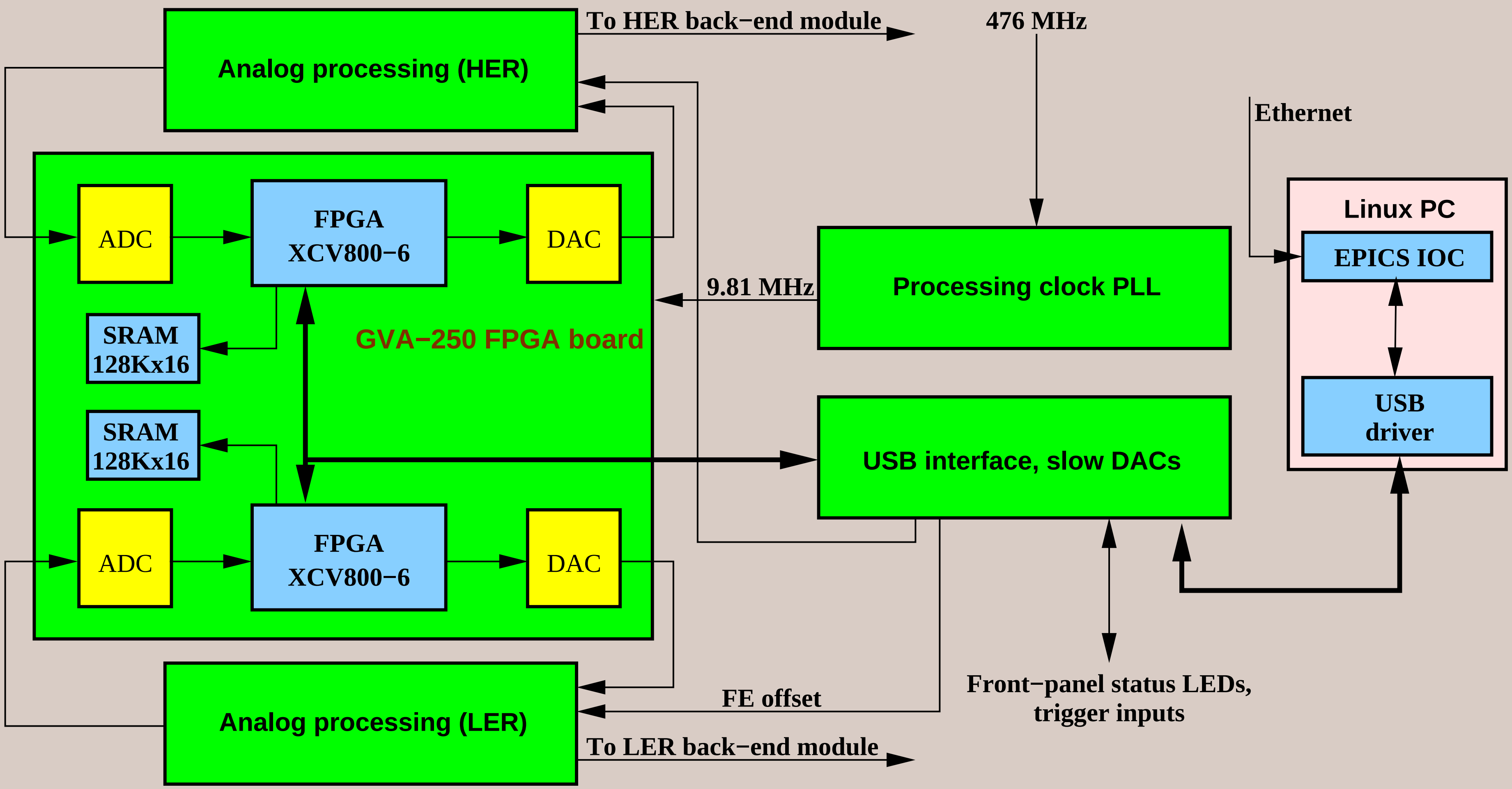
Production LGDW is based on bigger and better FPGA board (3x the logic capacity, 2x the memory) than the prototype.

Minimal changes to the software - faster data readout, larger coefficient sets, possibly a peak kick level detector.

New low group-delay woofer: block diagram

Integrates existing analog processing functions and digital interconnect board with USB functionality, PLL module, and slow DACs.

Wideband amplifiers and splitters are not shown on this diagram



Summary

Performance of PEP-II longitudinal stabilization systems is limited by the group delay and bandwidth considerations.

Low group-delay woofer channel helps achieve high damping of the low-order modes excited by the RF cavity fundamental.

The prototype system operated reliably and performed as expected. Low group-delay woofer allowed us to significantly raise HER beam current.

Final long-term systems are in production.

LGDW is equipped with a simple, yet functional EPICS interface. Diagnostic information from the soft IOC can be routed to stripcharts, warning panels, etc.

With separated control of low modes and HOMs new types of instability measurements become feasible. In addition the separation aids in tuning and optimizing the overall system damping.