Compensation of microphonics in CW operation at CMTB

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for the MSK LLRF Team

ARD-ST3 Mini-Workshop
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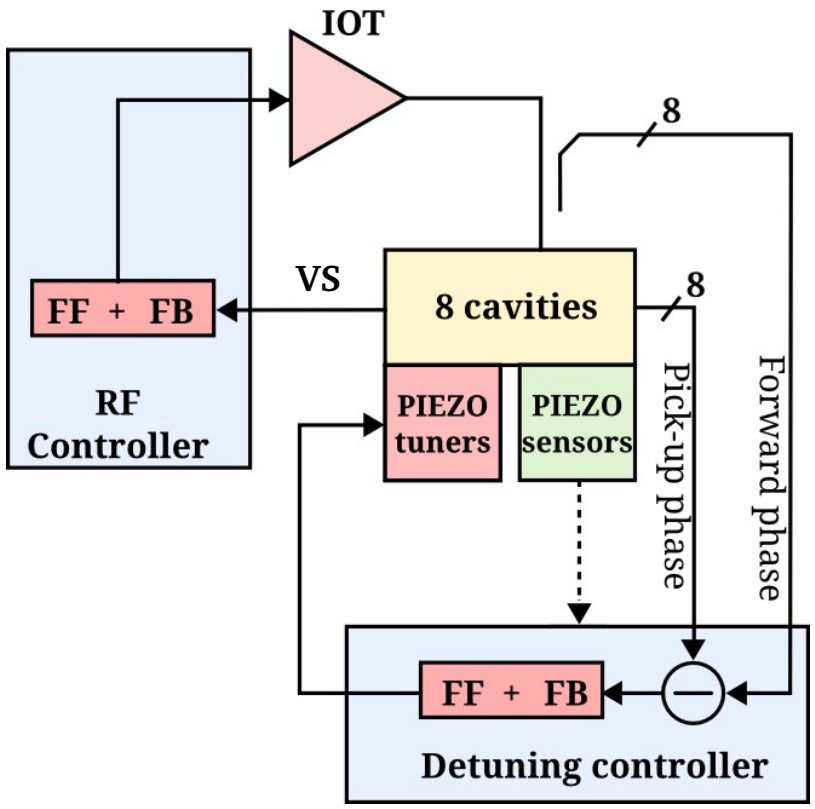
HELMHOLTZ ASSOCIATION

LLRF CMTB overview

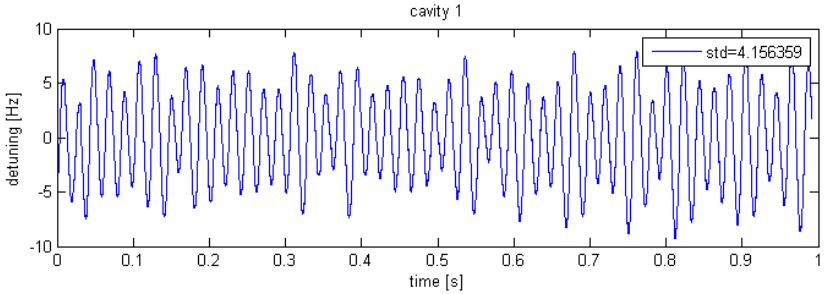
- Cryo Module Test Bench
  - one superconducting module
  - 8 TESLA cavities 1.3 GHz
  - currently QL=1.5e7 → BW=86 Hz
- MTCA.4 LLRF
- IOT RF power amplifier
  - Vector Sum stabilization
  - CW
  - LP mode
    - max. 2kW per coupler
    - 20W/module
- Detuning controller
  - Pickup,forward phase difference

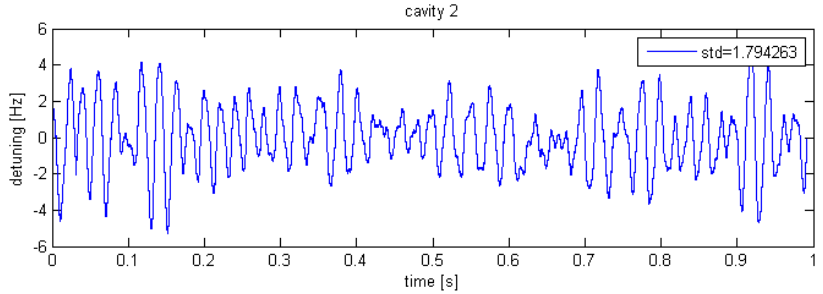


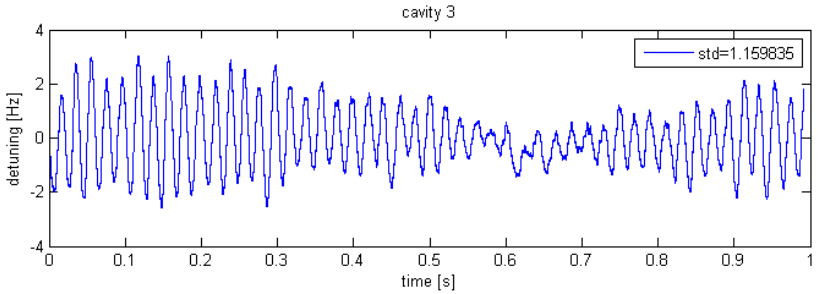
Microphonics

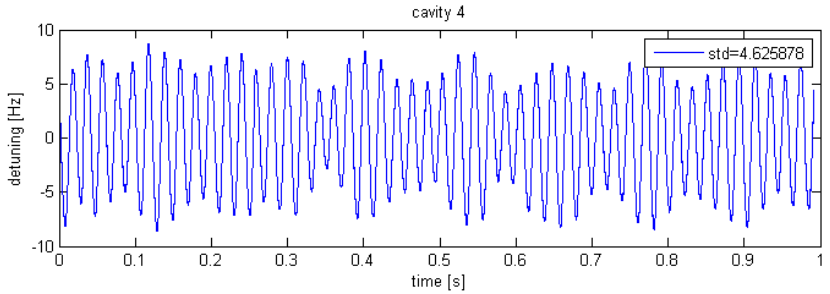
- Cavitites detuning caused by mechanical interferences
  - helium pressure change
  - vacum pumps
  - other sources
- More RF power needed to stabilize accelerating gradient
- Piezo tuners can be used to compensate for it
- RF signals can be used as a source of information
  - probe forward phase difference
  - model based cavity detuning
  - alternatively piezo sensor readout
- Vibration control methods can be used for controlling the microphonics
  - Vibration isolation
  - Active tuning with piezo

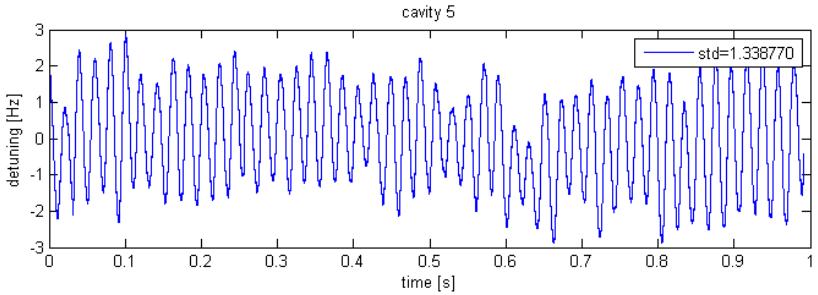
Microphonics noise measurement – Vac. Pumps turned on

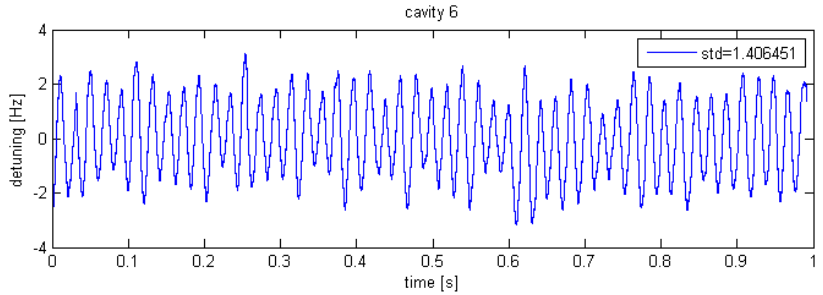


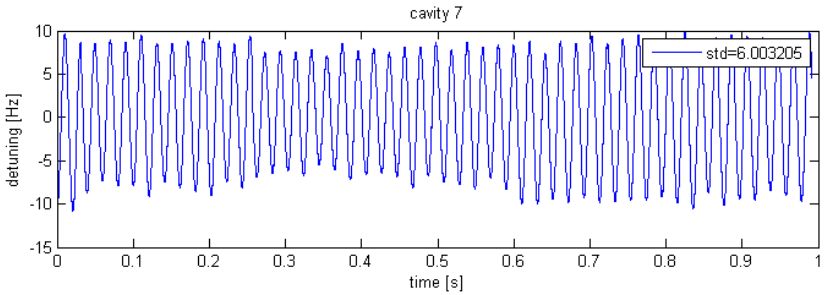


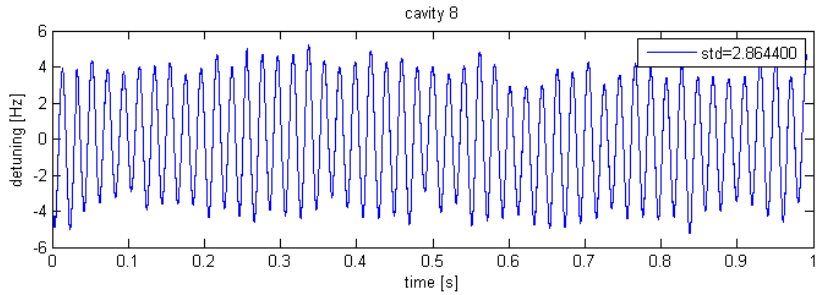




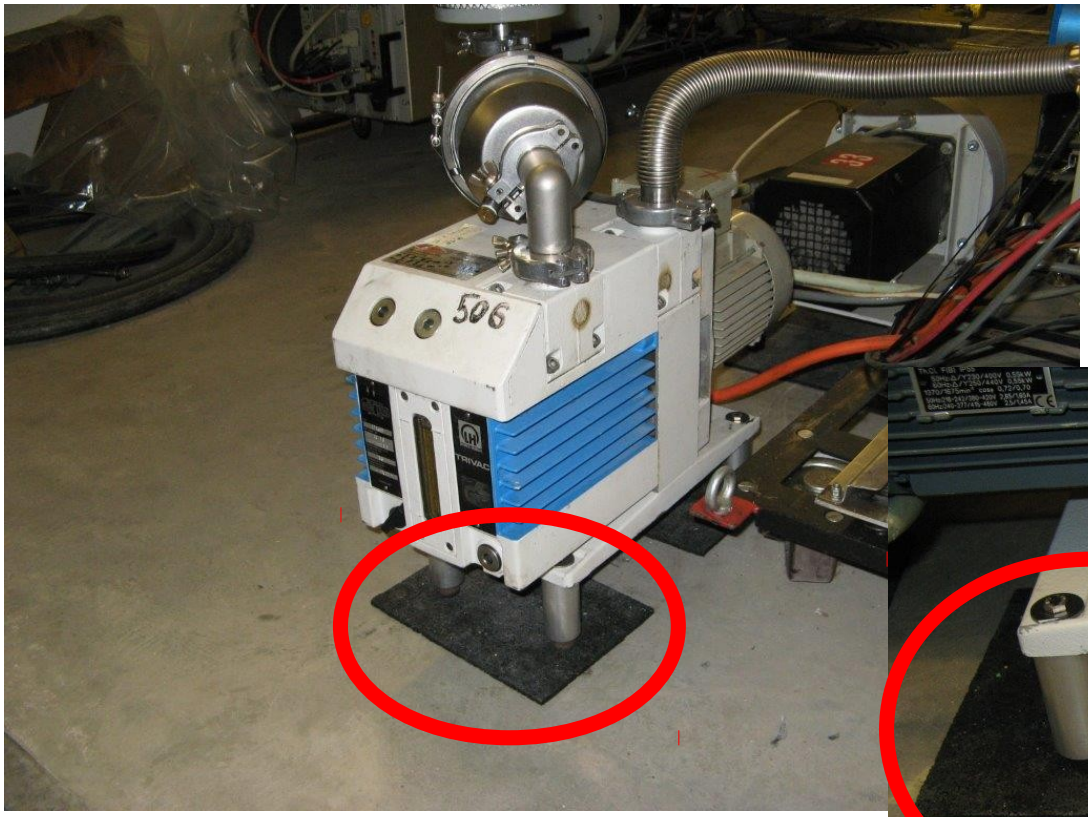








Vacum pumps vibration isolation



Courtesy of: Jurgen Eschke

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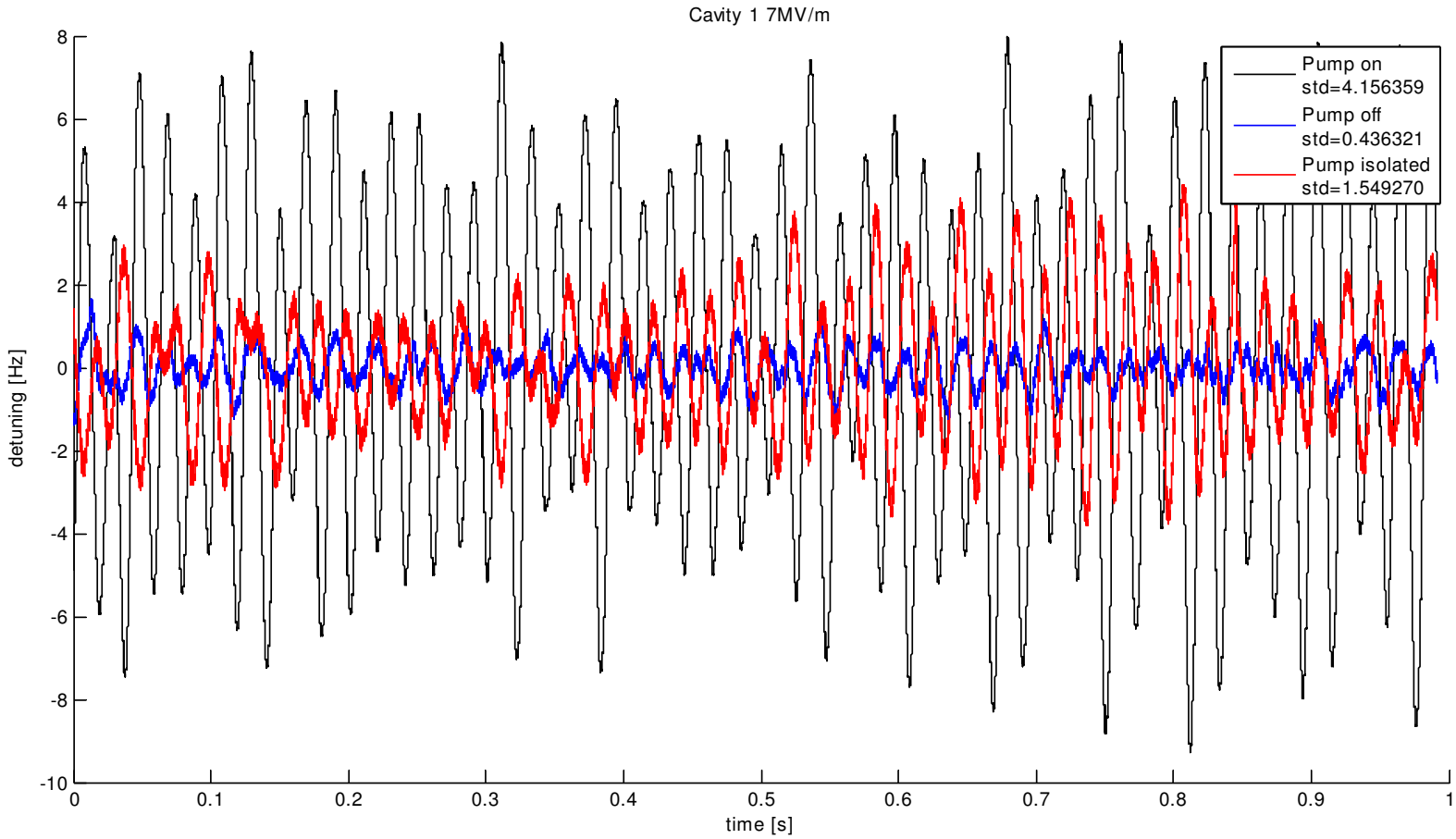
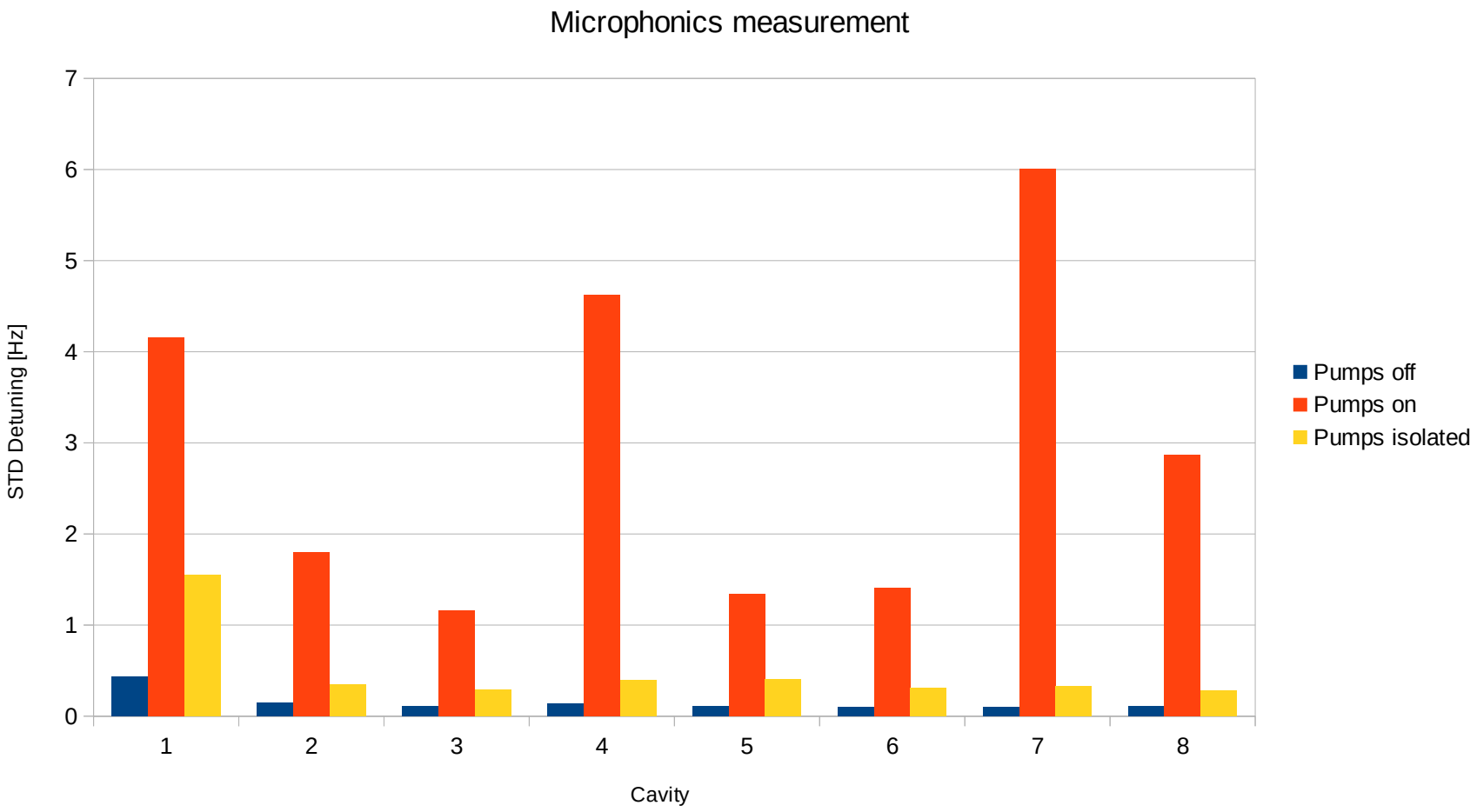
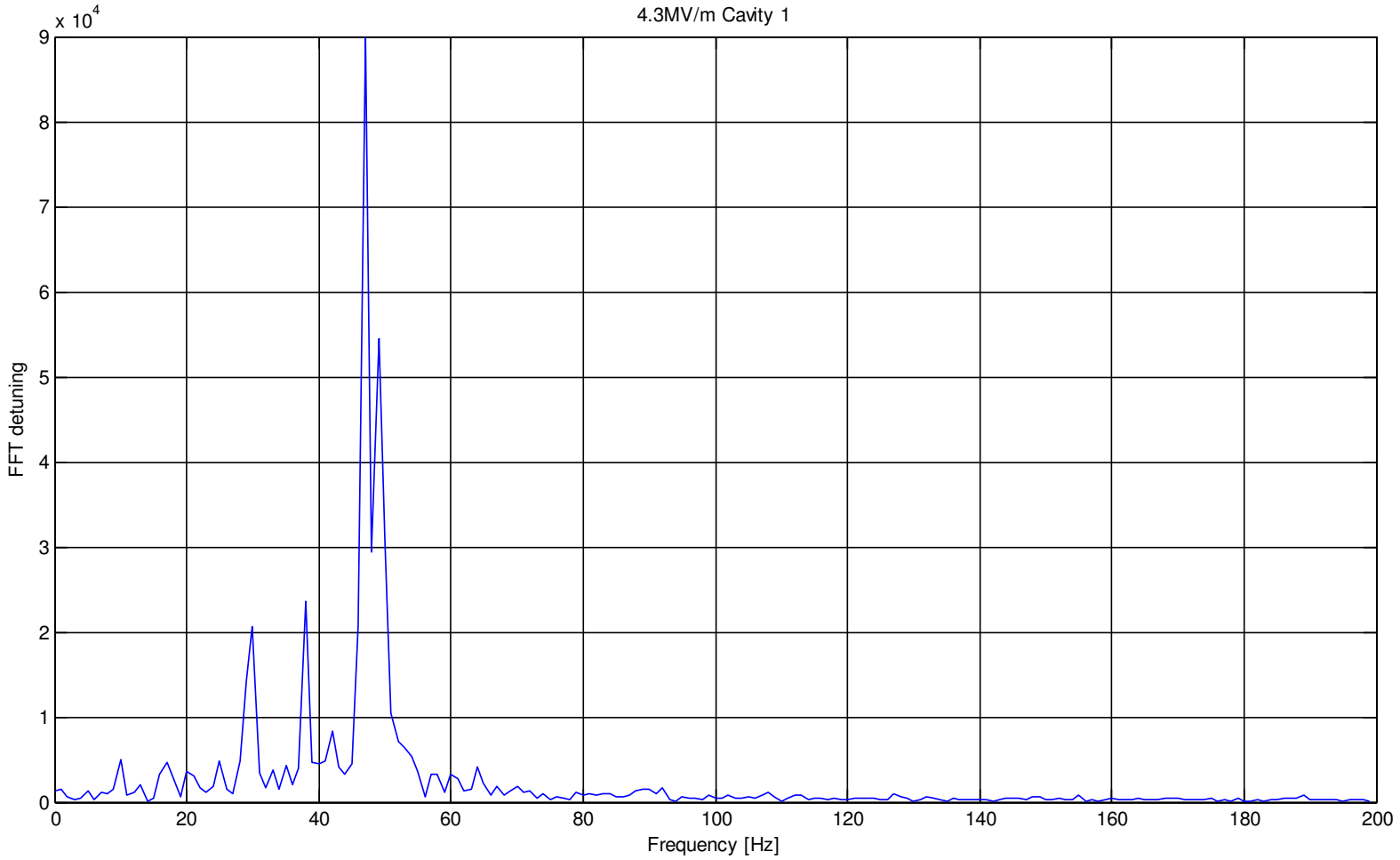


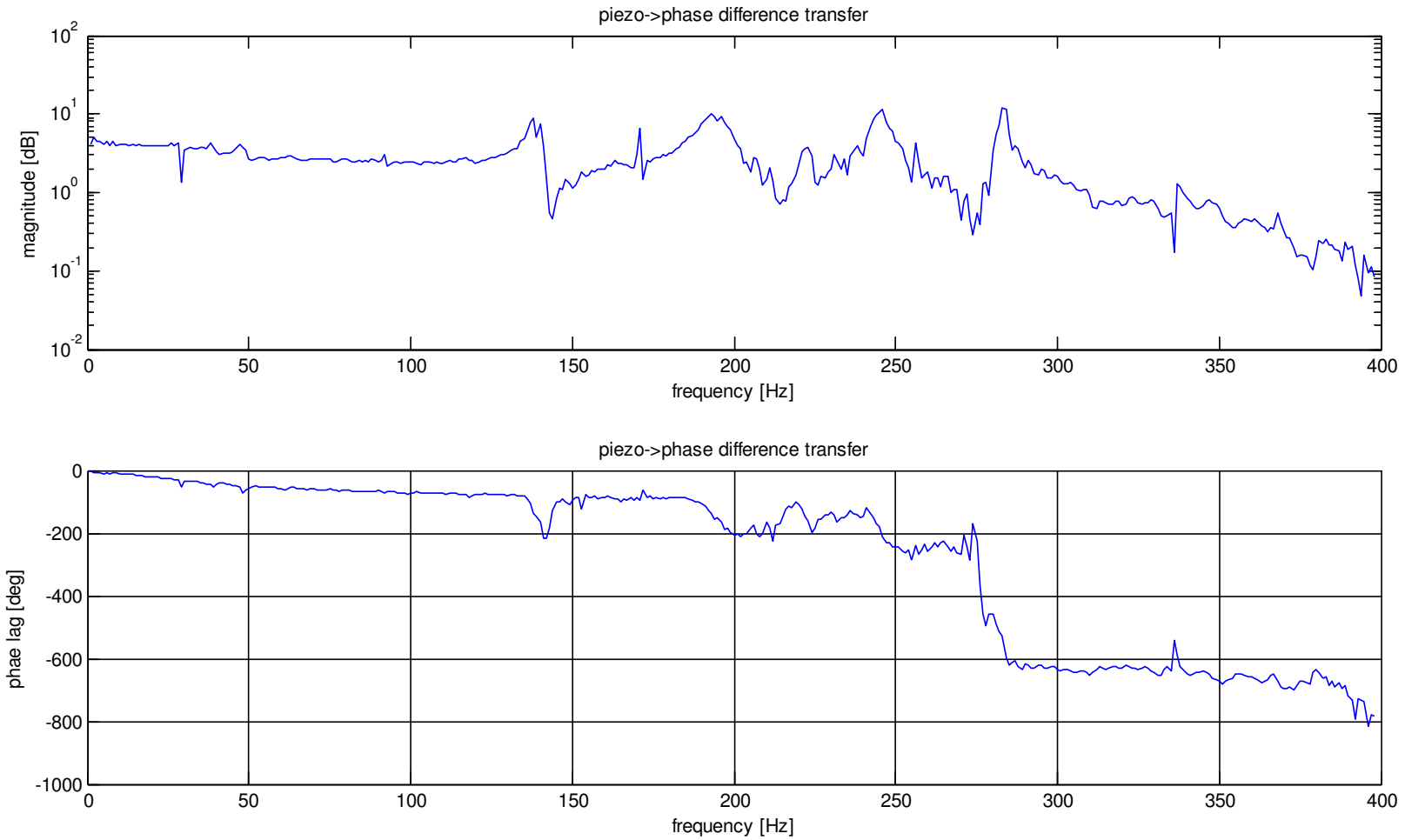
Microphonic noise statistics



Microphonics frequency distribution



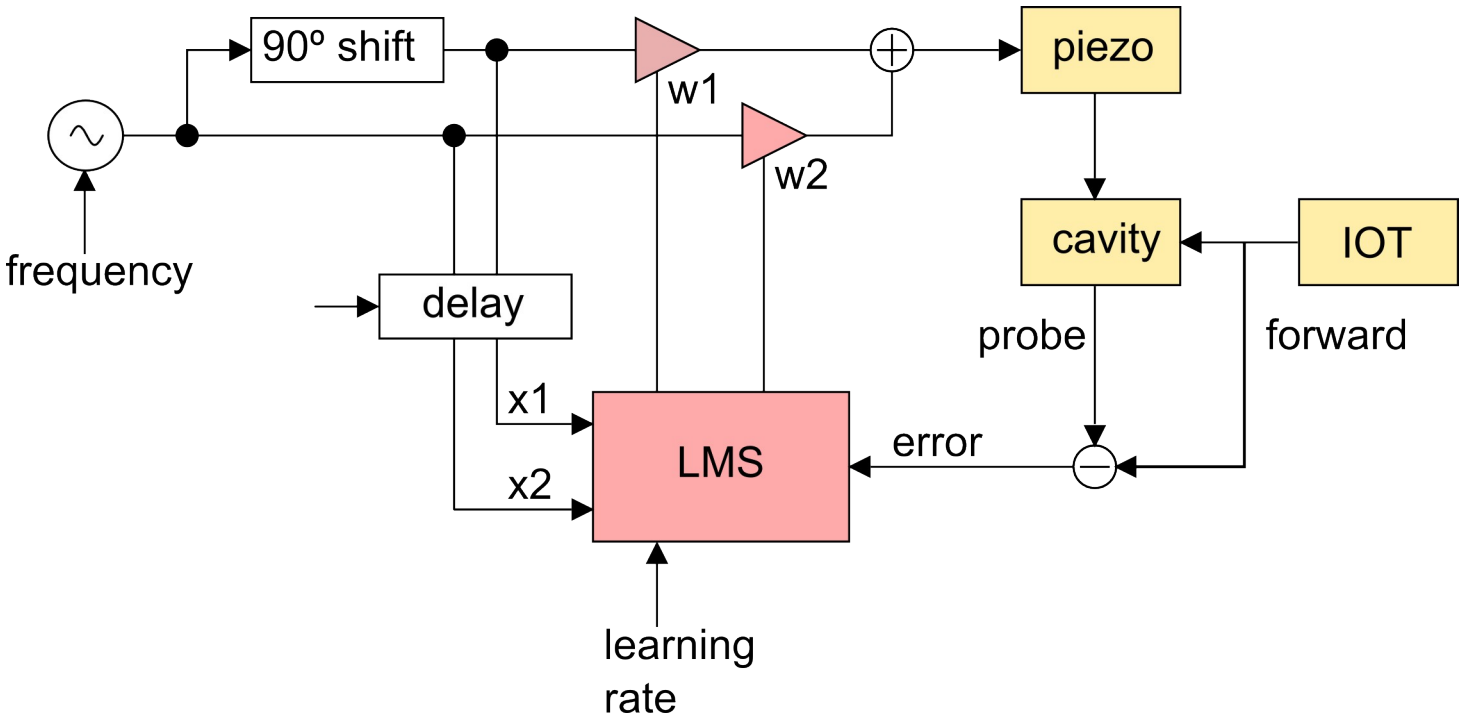
Piezo actuator → Pickup - Forward phase transfer function



0-400Hz sin wave chirp

Narrowband Active Noise Canceler

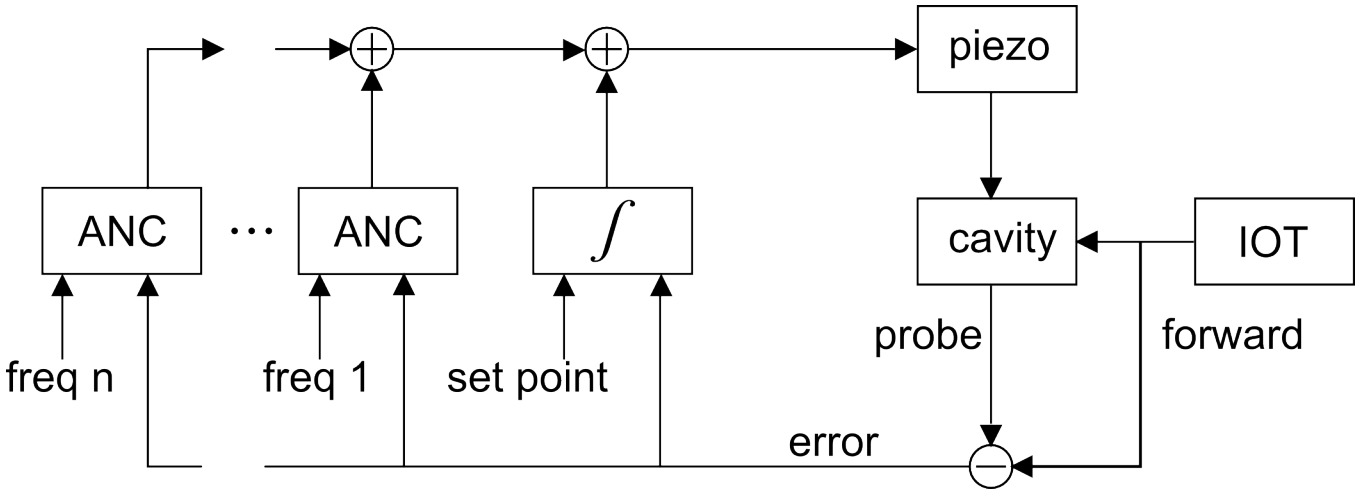
- Adaptive feed forward algorithm
- Band-pass filter



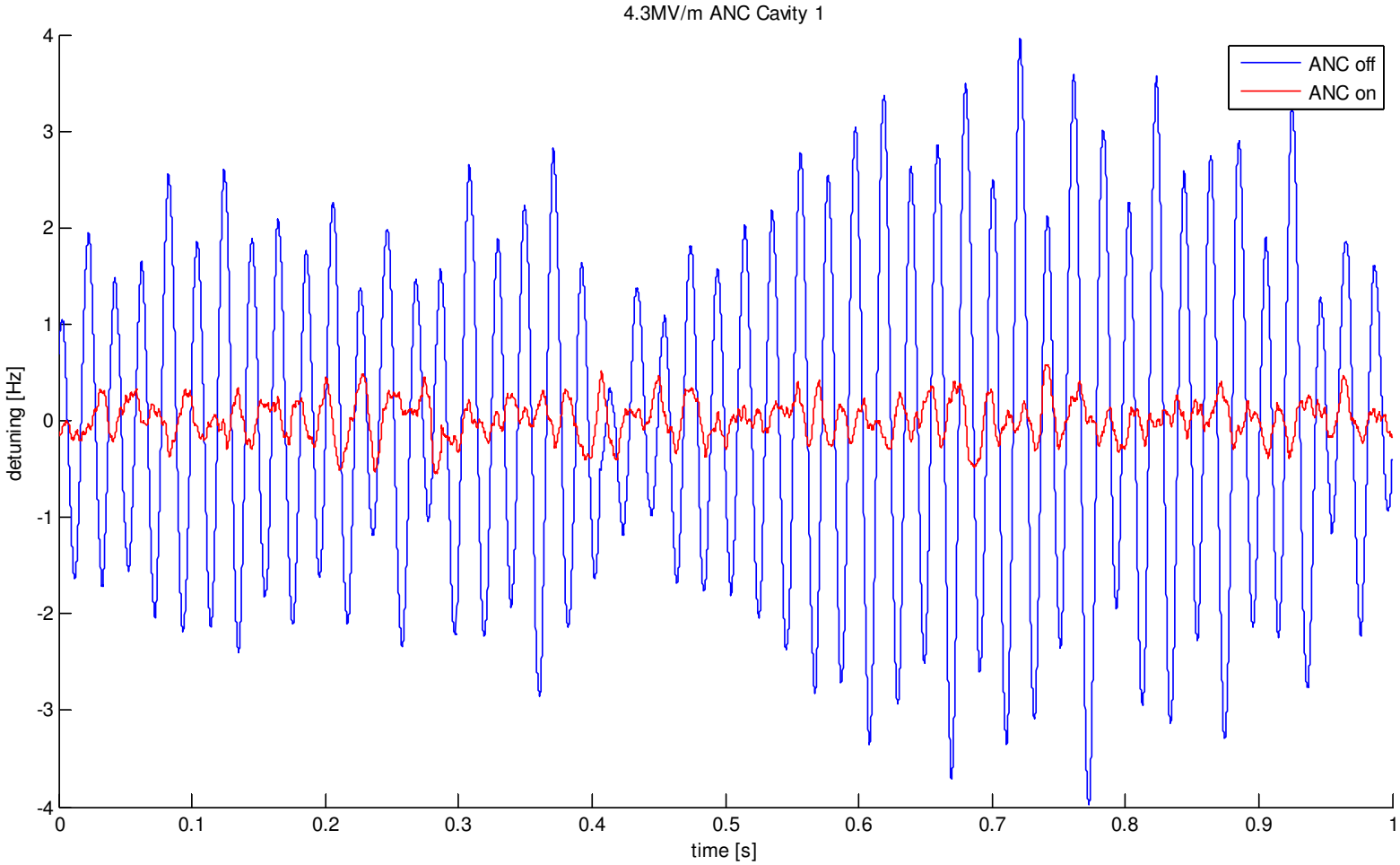
w1=w1+learning_rate*error*x1
w2=w2+learning_rate*error*x2

Microphonics compensation strategy

- PI controller available only for frequencies < 10 Hz
- Most dominating disturbances at 30 and 49 Hz
- Integral feedback controller for slow drifts (Helium) compensation
- Active Noise Control for the 30 and 49 Hz disturbances
  - multiple frequencies per cavity



ANC (30&49Hz) + I controller results



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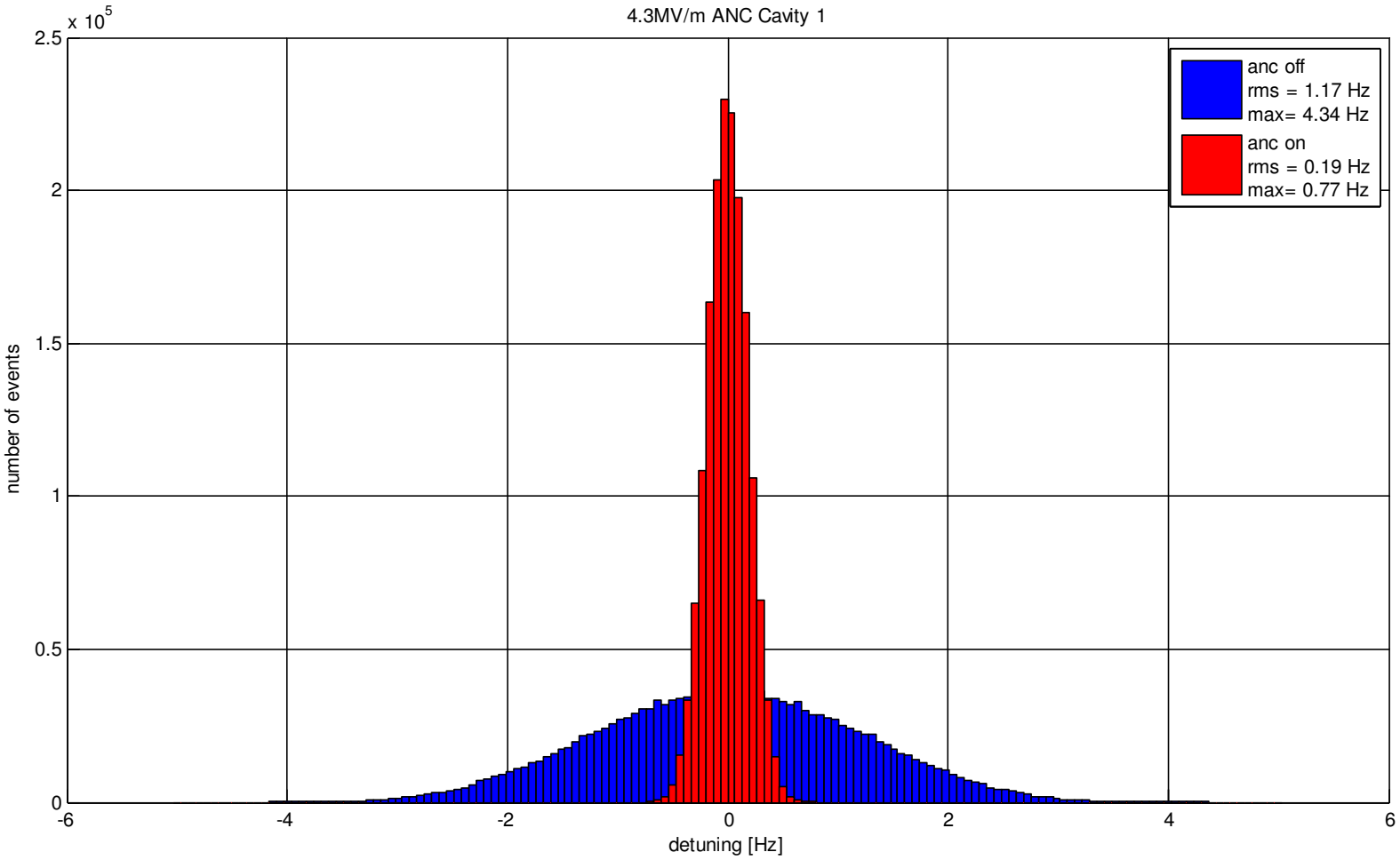

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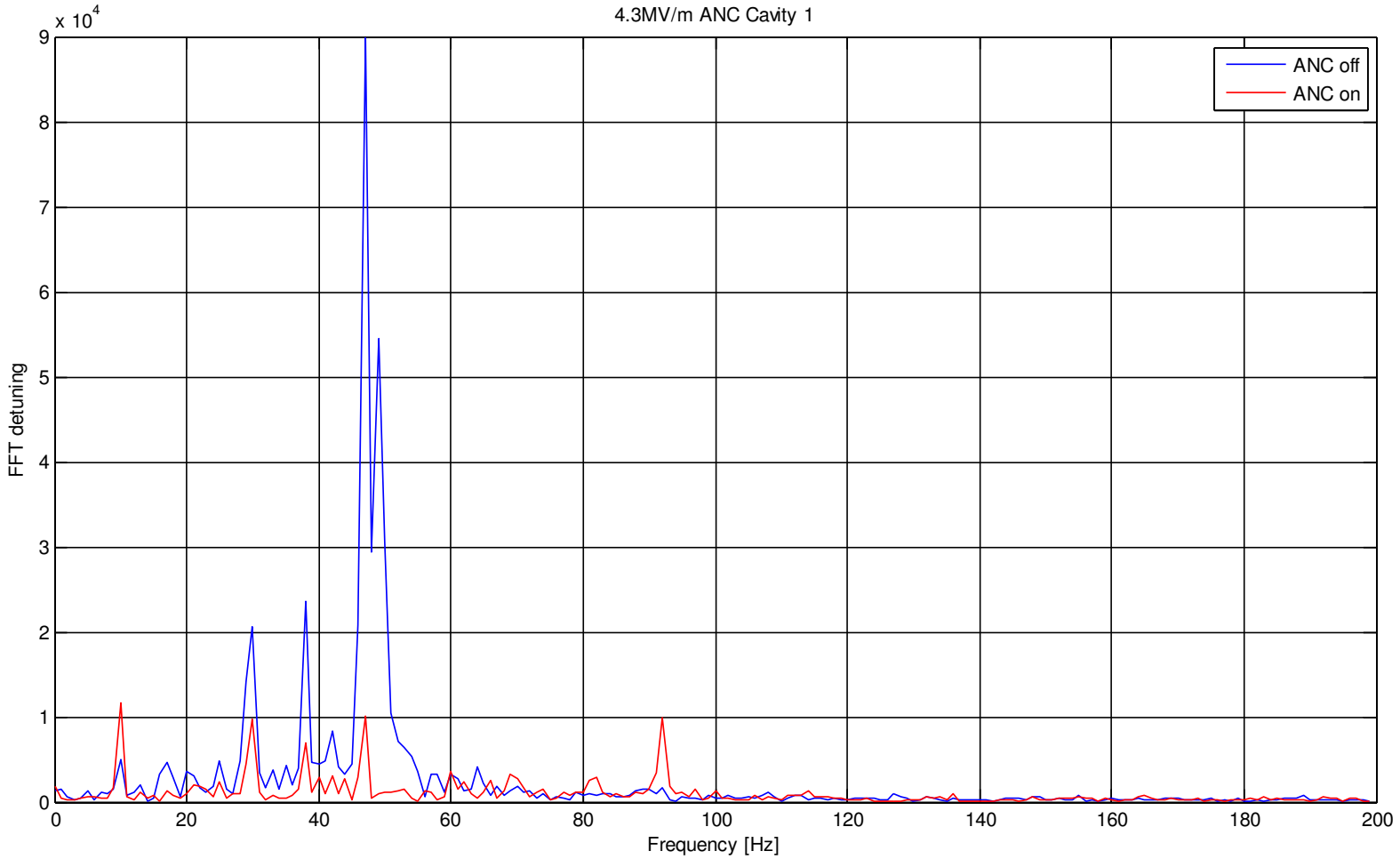
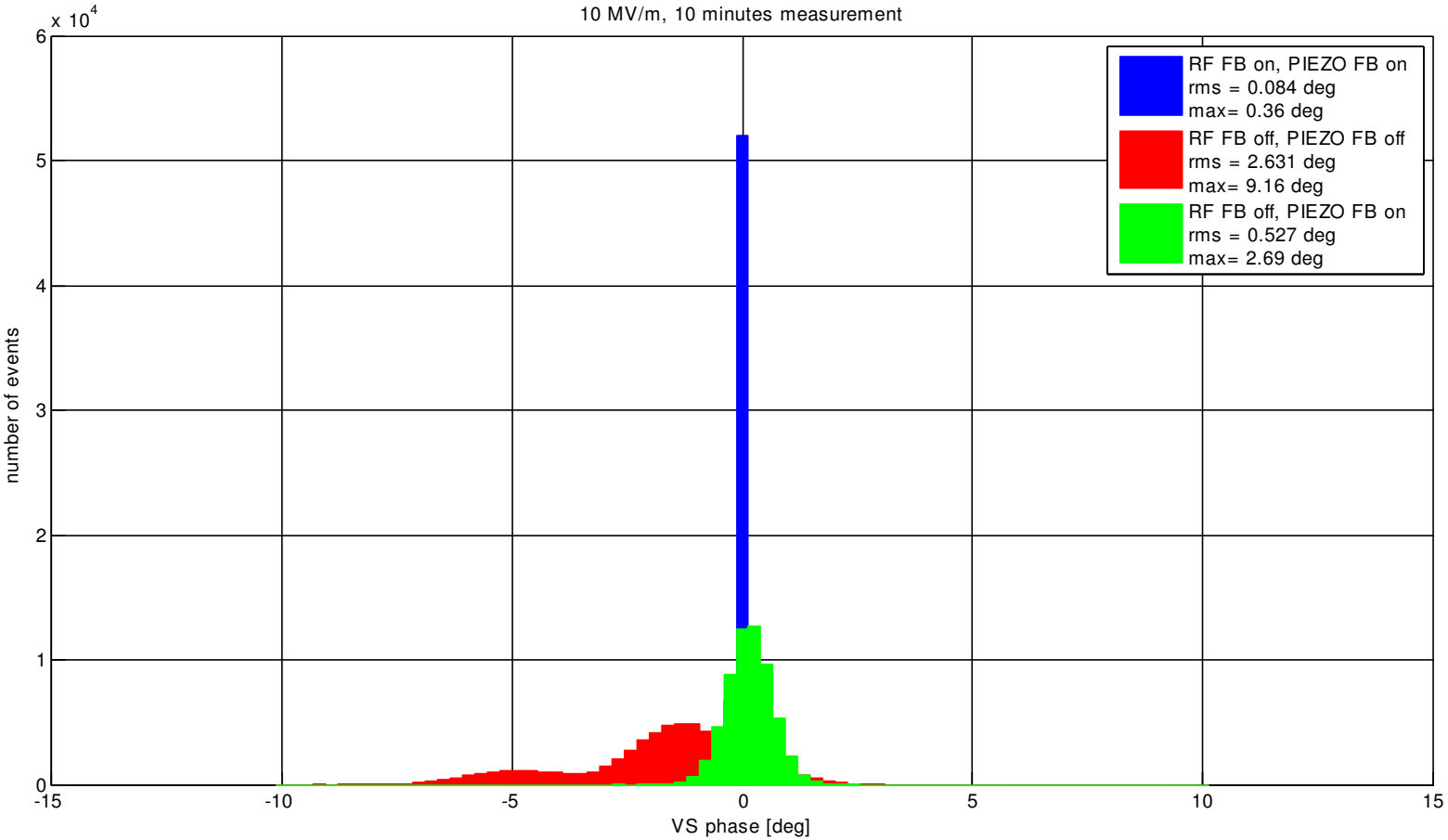


ANC resource utilization

- 8 cavities 4 frequencies per cavity

Device Utilization Summary (estimated values)			[-]
Logic Utilization	**Used**	**Available**	**Utilization**
Number of Slice Registers	2662	521200	0%
Number of Slice LUTs	2673	260600	1%
Number of fully used LUT-FF pairs	2259	3076	73%
Number of Block RAM/FIFO	4	835	0%
Number of BUFG/BUFGCTRLs	1	32	3%
Number of DSP48E1s	11	1680	0%

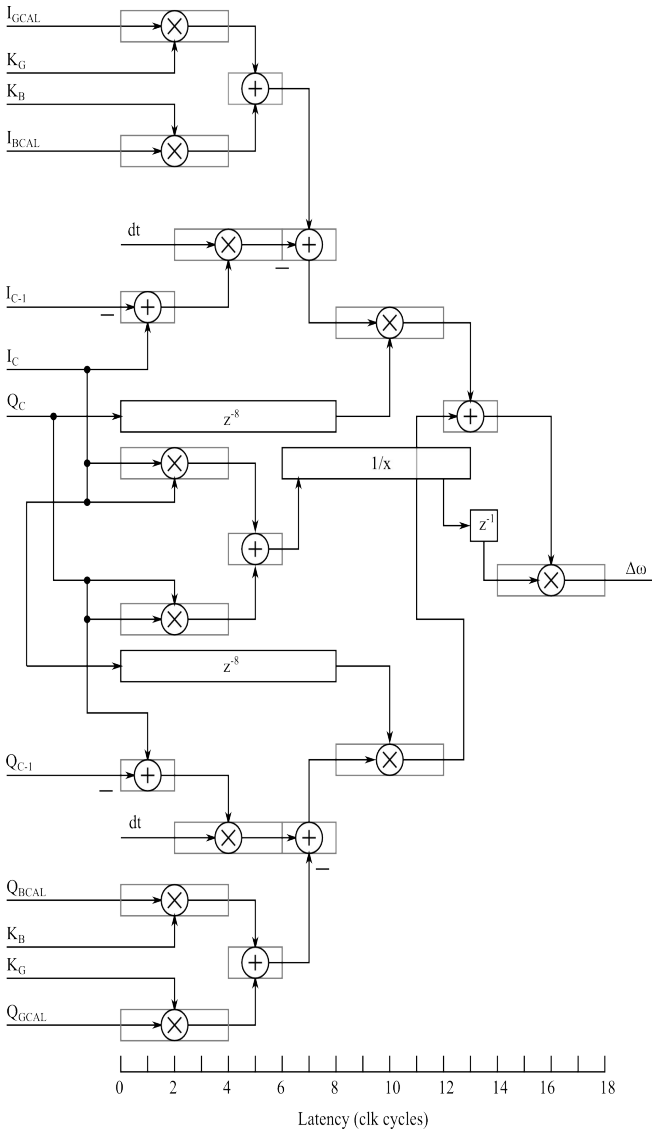
Vector sum stabilization



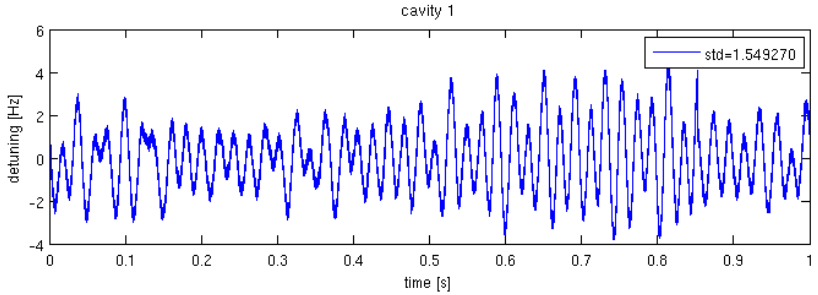
Future plans

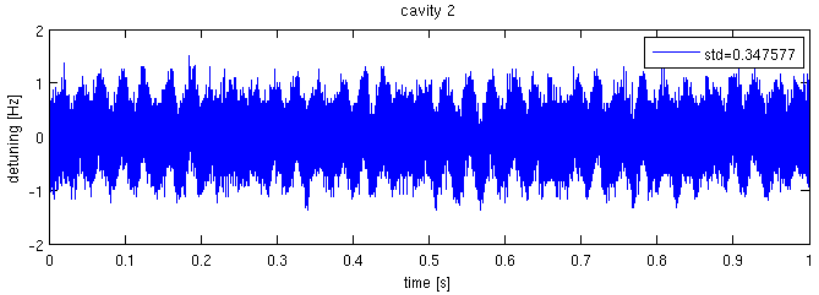
- Validate the model based detuning computation
- Apply presented methods for Long Pulse operation
- High Level Software update
  - automation
- Further ANC tests

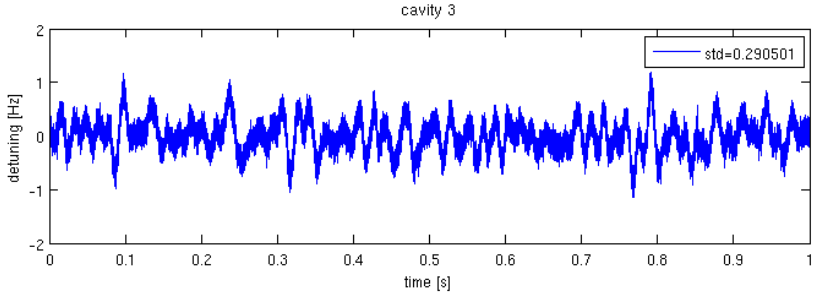
- Thank you for attention!

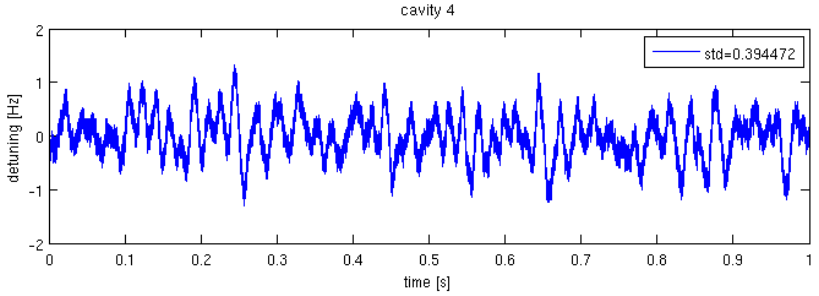


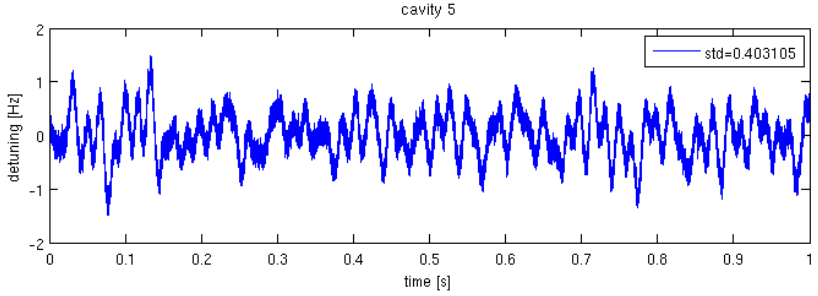
Microphonics noise measurement – Vac. Pumps Isolated

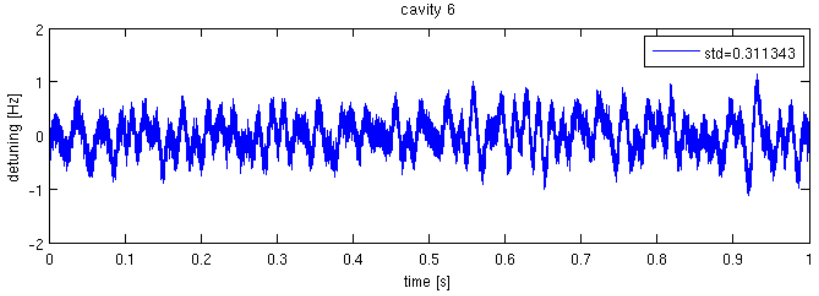


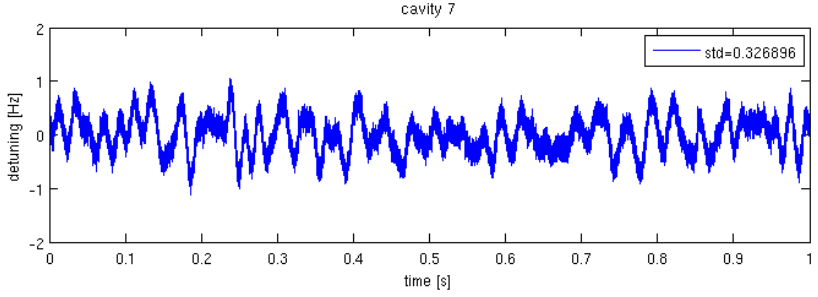


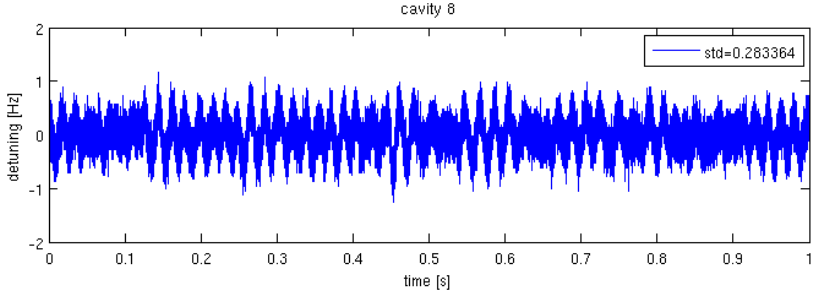












Microphonics noise measurement – Vac. Pumps turned off