Microphonics and Transient Effects

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LCLS II Microphonics Workshop 1

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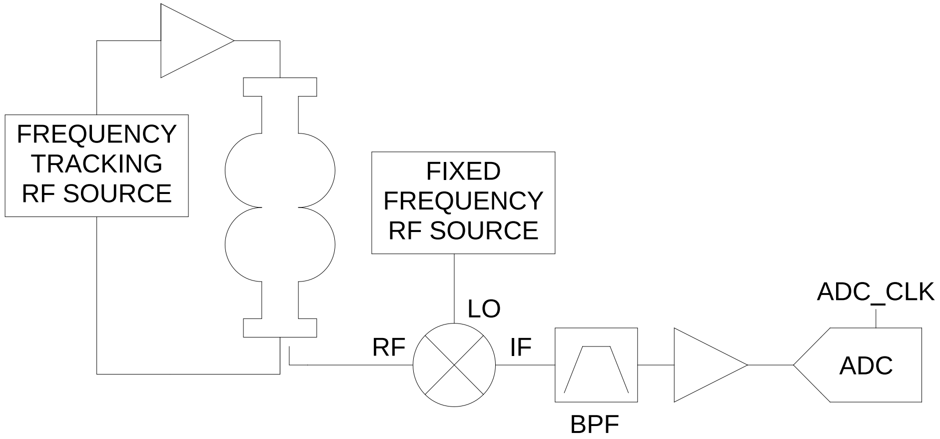
Simple Microphonics Acquisition Scheme

If the RF IF frequency is not precisely related to the sample frequency by the ratio 4, 1/1.25, 1/2.5, 1/5 . . . the I and Q signals will have the form:

$$I(t) = V_{Peak}cos(\omega_1 t + \varphi(t)) \qquad Q(t) = -V_{Peak}sin(\omega_1 t + \varphi(t))$$

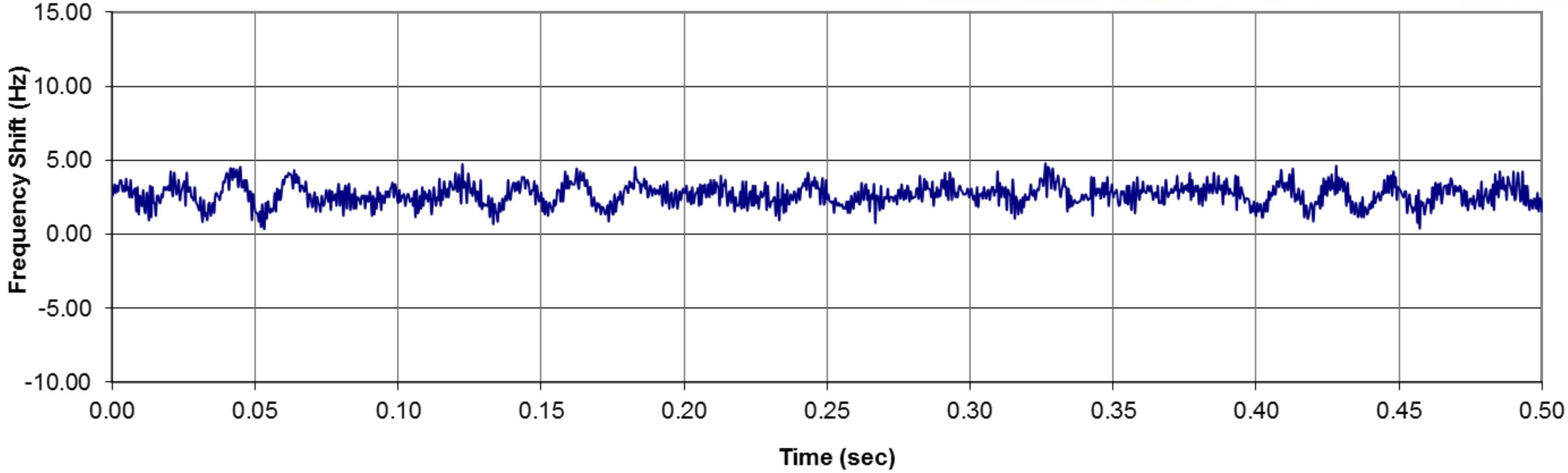
Where ω_1 is the difference frequency between the ideal IF frequency and the actual IF frequency. One can implement such a system using a simple mixer to down convert the RF signal to an IF frequency as shown below to collect the data.

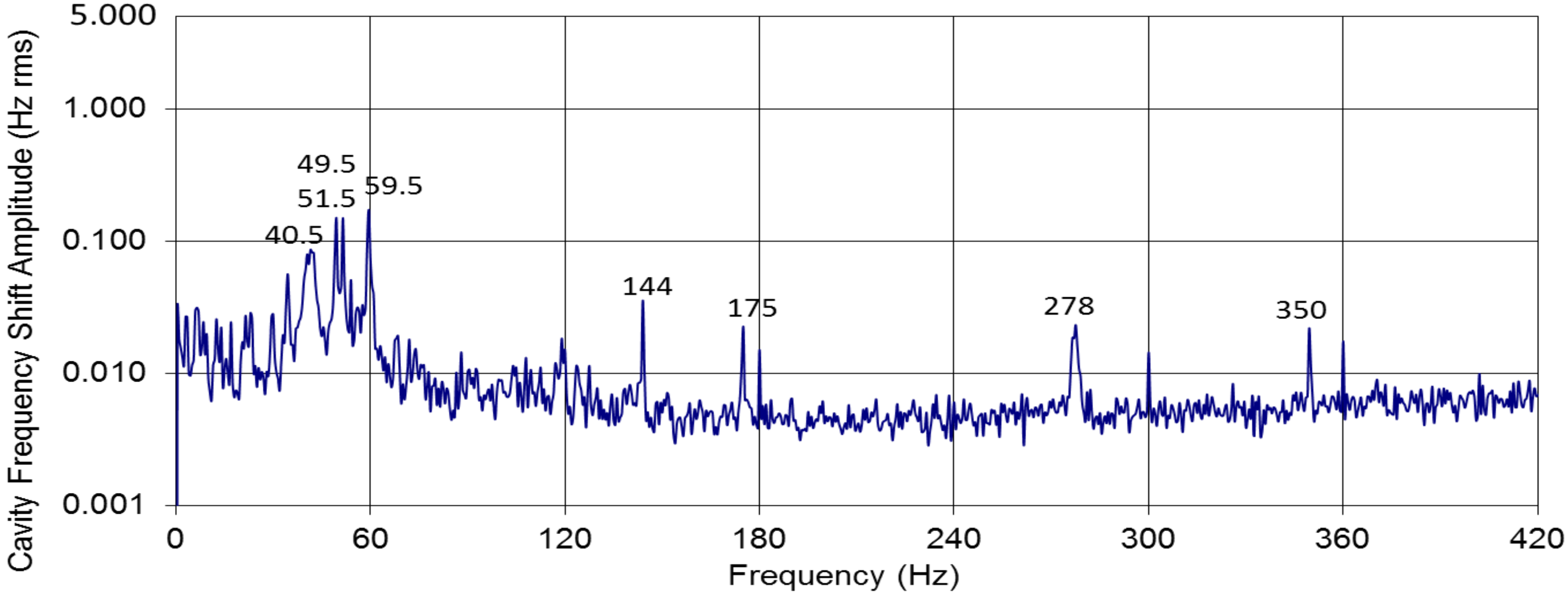


Example Parameters:
IF = 400 kHz,
ADC clock = 320 kHz
Filter BW = 200 kHz

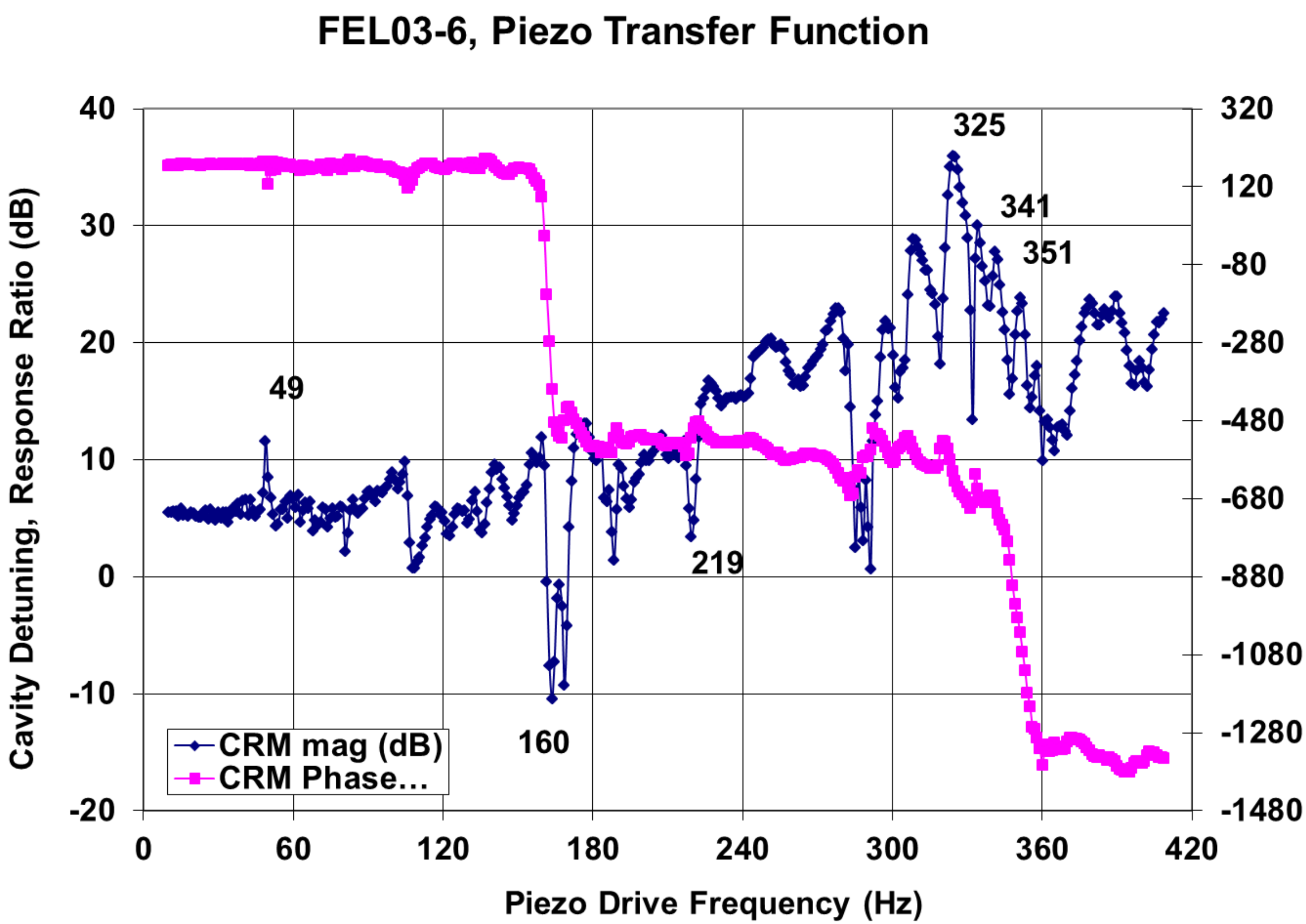
OR
IF 25 kHz
ADC clock 100 kHz
LPF 5 MHz (for high freq.)
LPF 40 kHz

FEL3-6 Microphonics

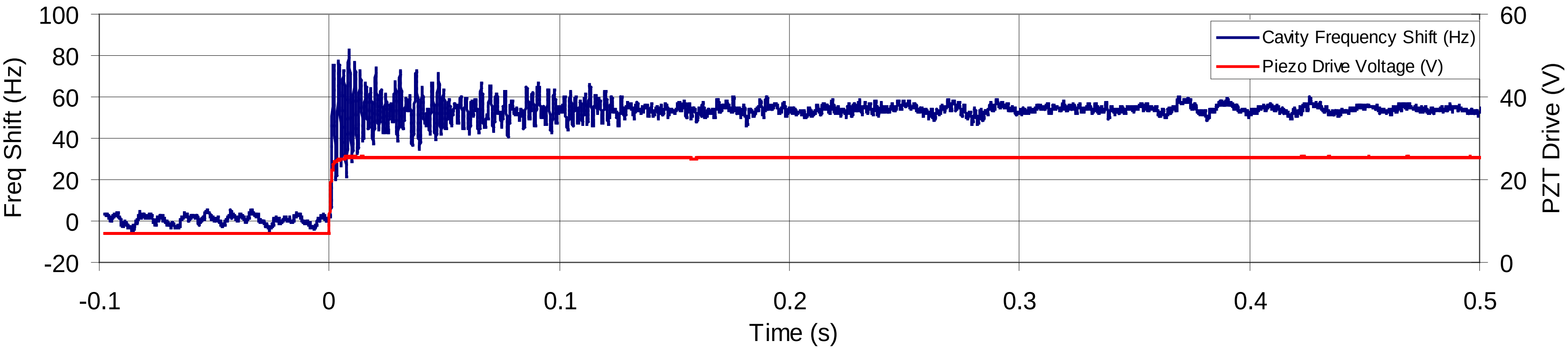


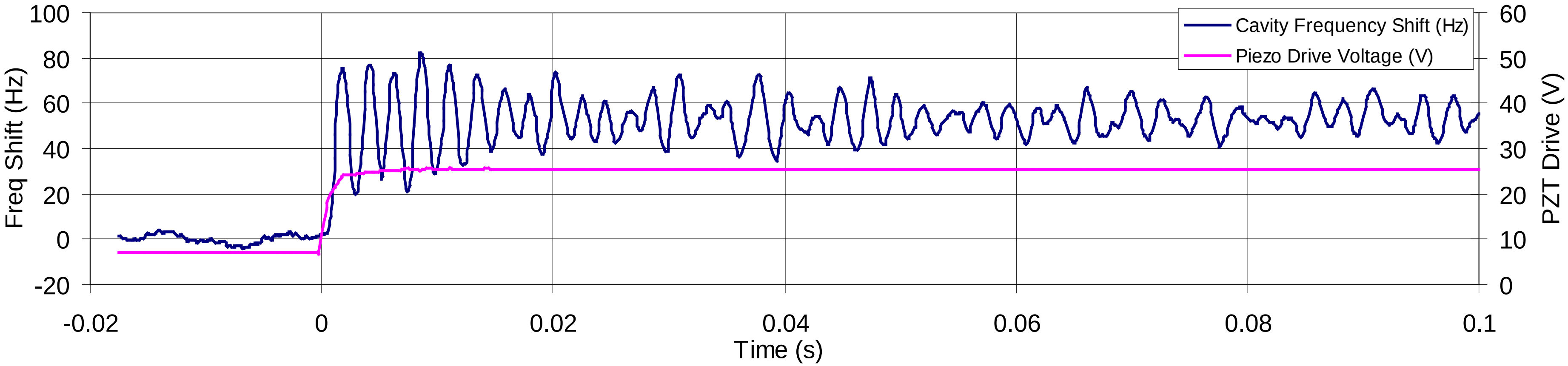


FEL03-6, Piezo Transfer Function



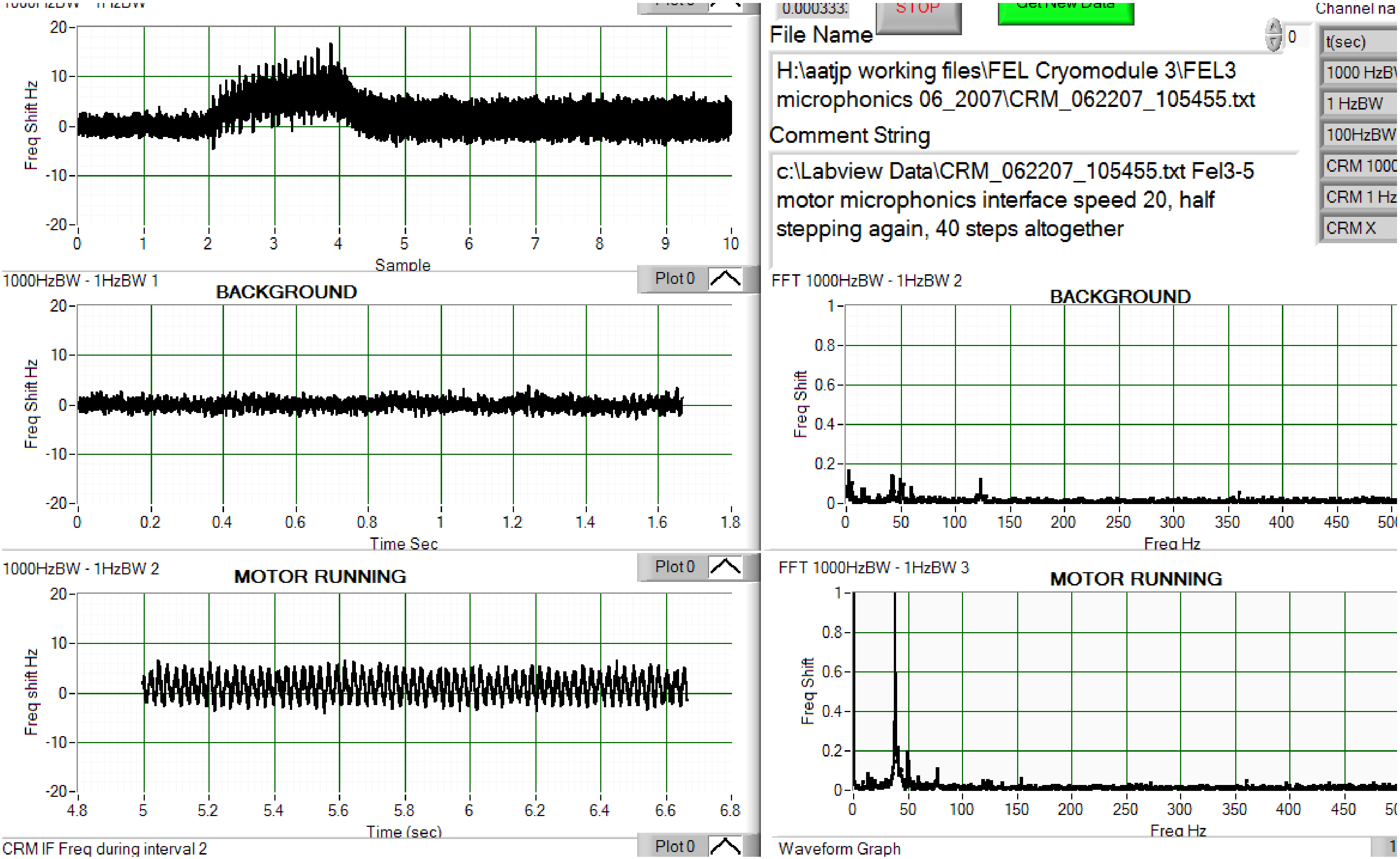
FEL3 PZT Step Response



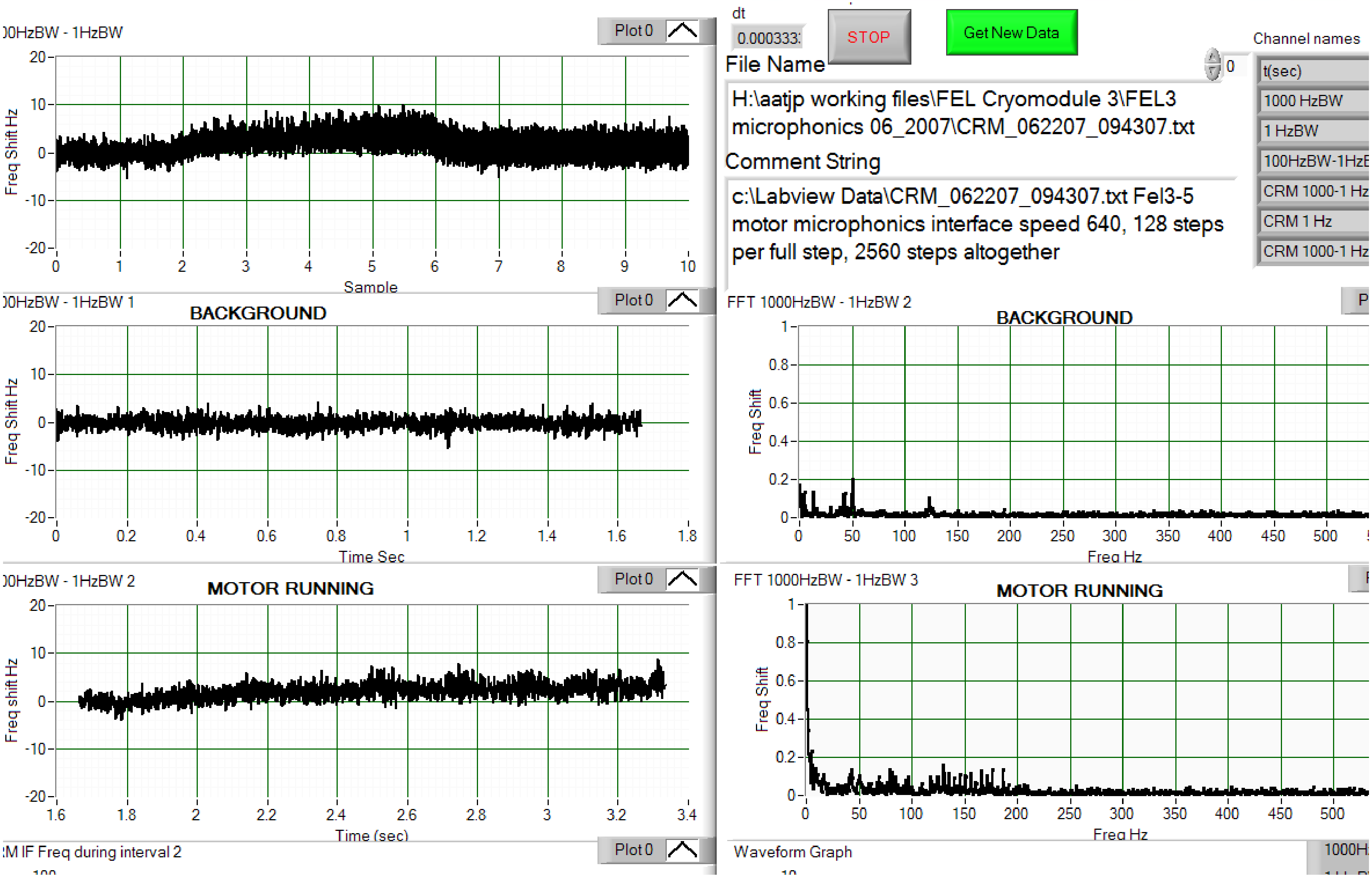


Step response of a cavity excited by a by a 50 Hz step in the piezo tuner controls. The total range of this tuner was 550 Hz.

FEL3-5 Tuner Running 2 steps/full step



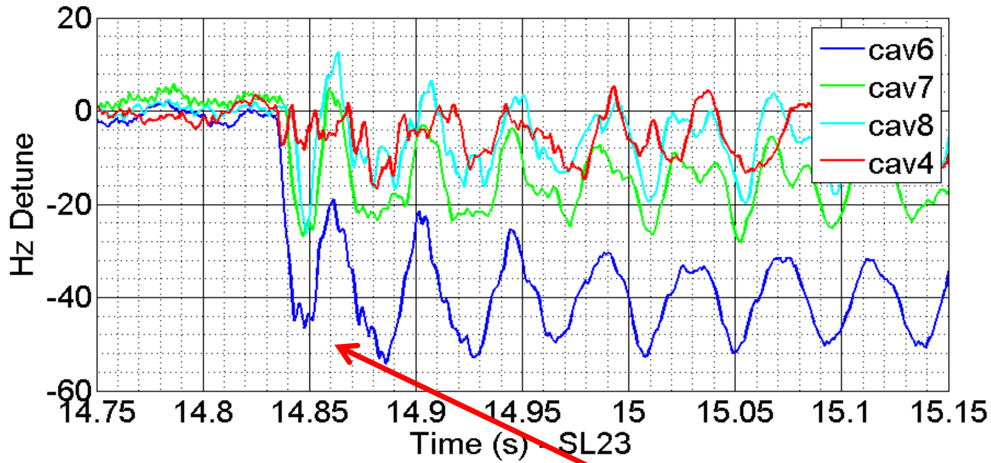
FEL3-5 Tuner Operations 128 microsteps/step

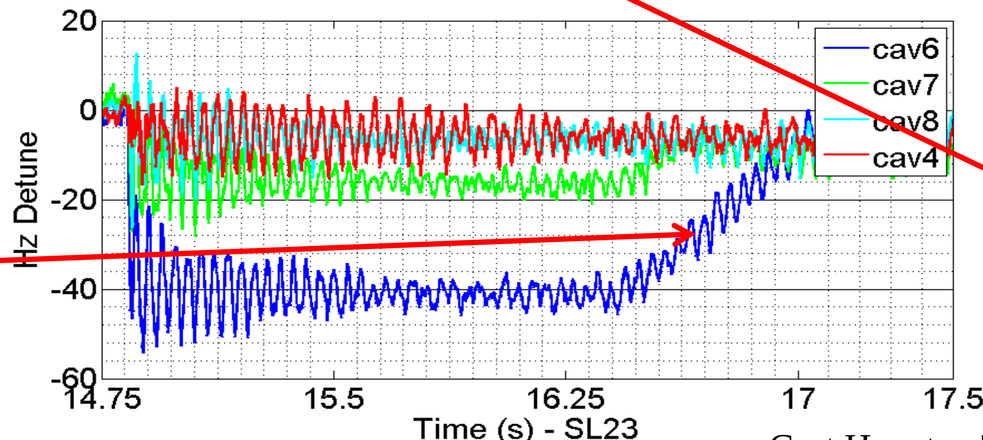


DYNAMIC COUPLING BETWEEN CAVITIES

C100-4 Cavities 4, 6, 7, 8 responding to an applied PZT step control voltage change from 52 to 39 volts (130 Volt range) in cavity 5

- Cavity 5 PZT moved 460 Hz.
- Locked in GDR Mode
- Because of 10 MV/m operating point, the klystron had the overhead to keep cavities locked
- Stepper Motor operated to tune the cavities

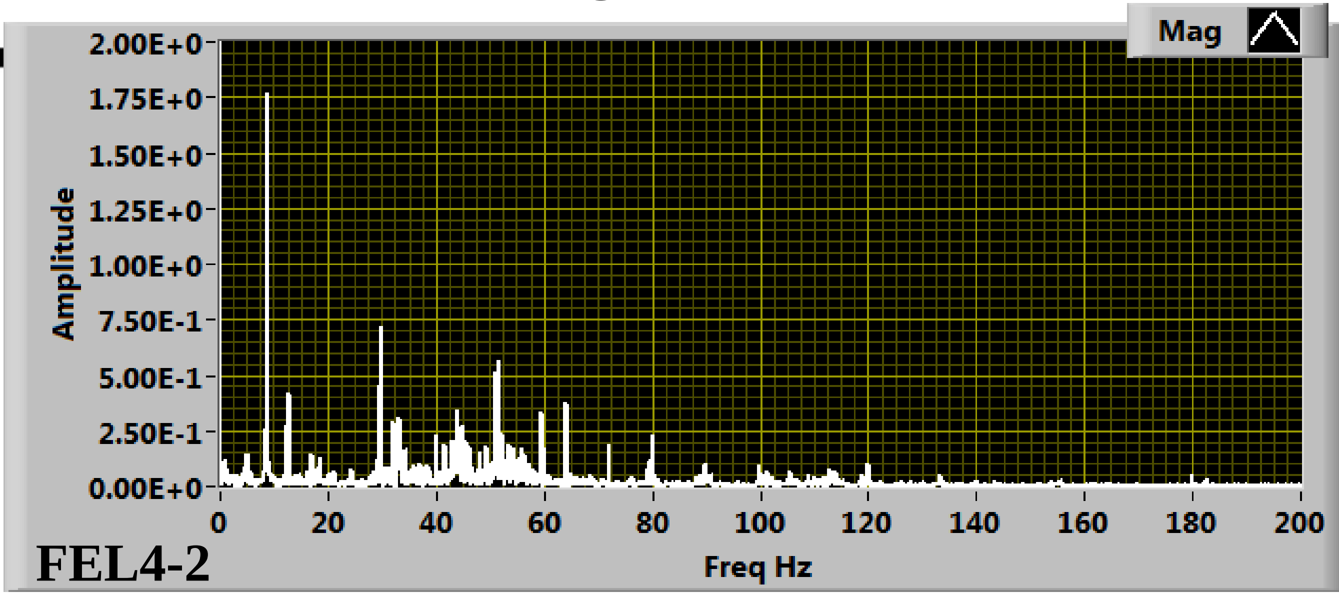


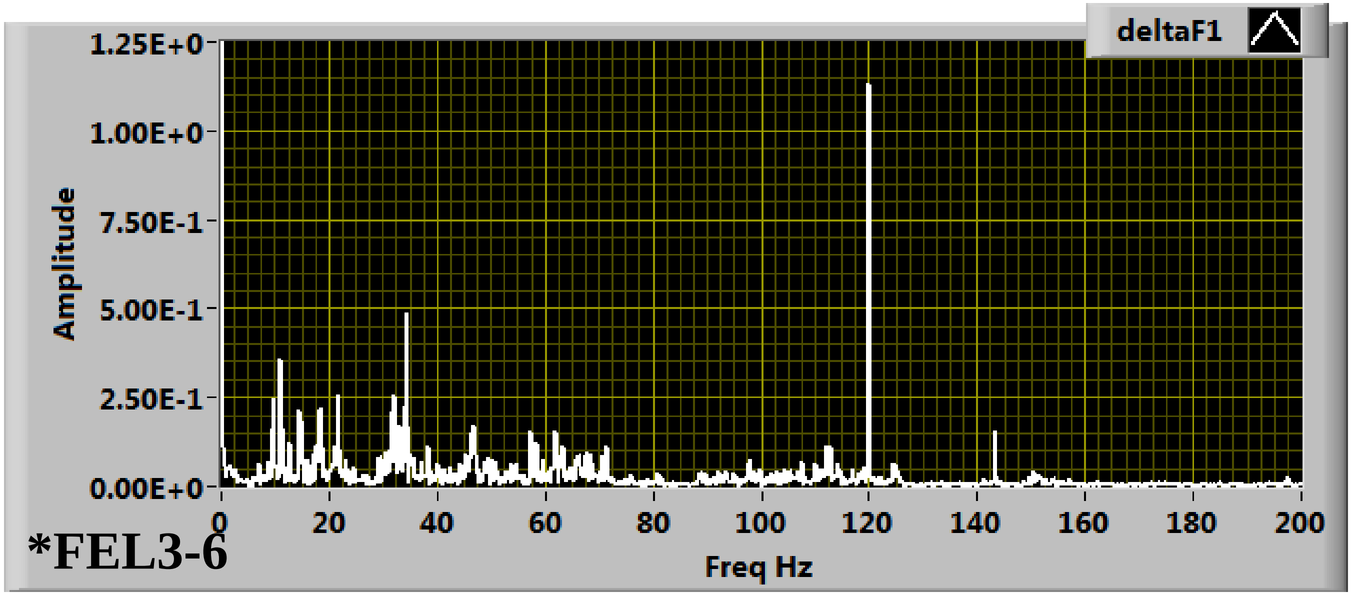


- **Adjacent Cavity coupling is ~ 10% between 1-4 and 5-8 cavities**
- **Cavities 4 and 5 have a "quasi" mechanical support between them.**
- **Ringing is the 21 Hz mechanical Mode**

Curt Hovater, Tomasz Plawski,, Michael Wilson, Rama Bachimanchi

Excessive Background microphonics

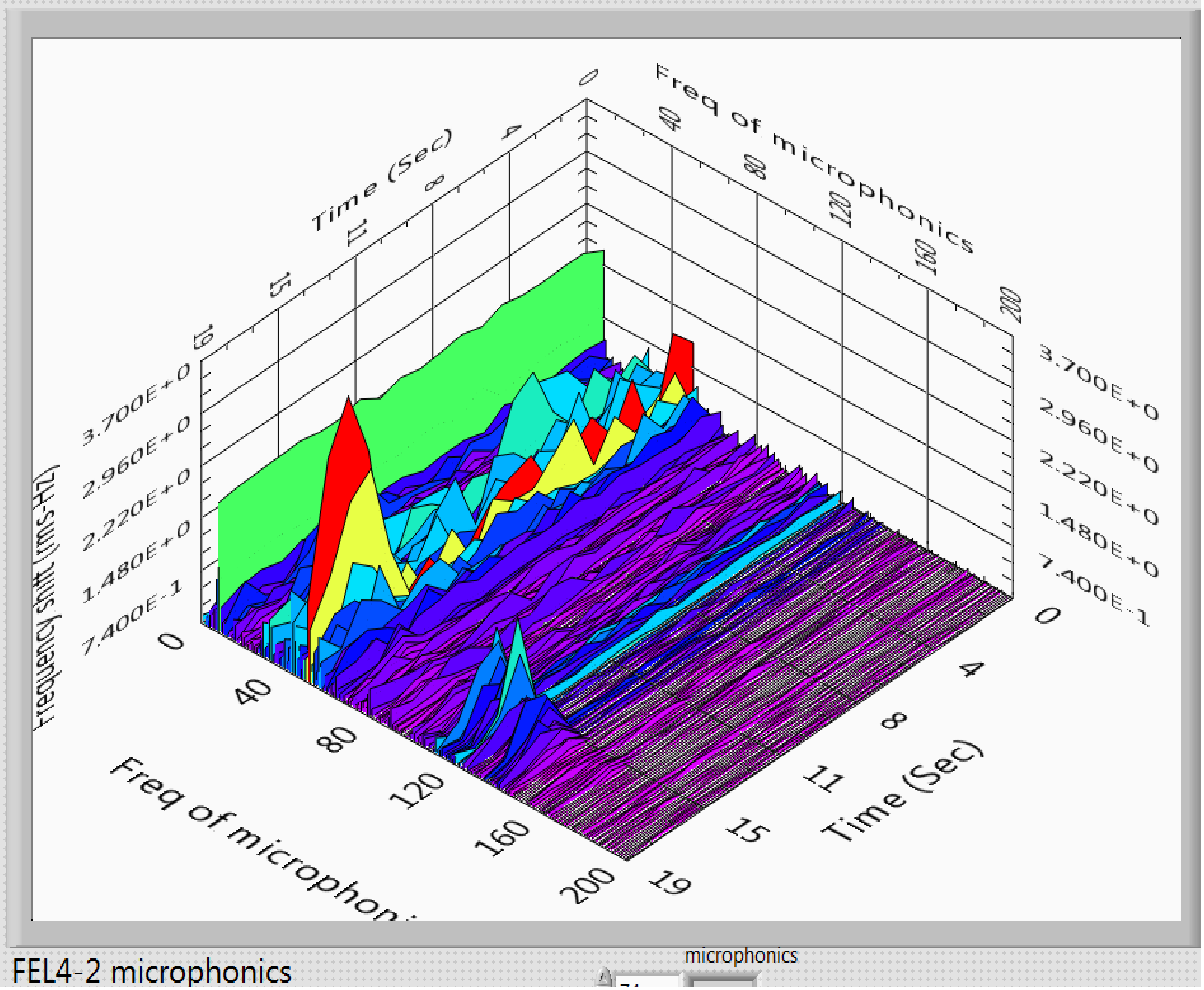




*Cryomodule replaced with former SL21 CM

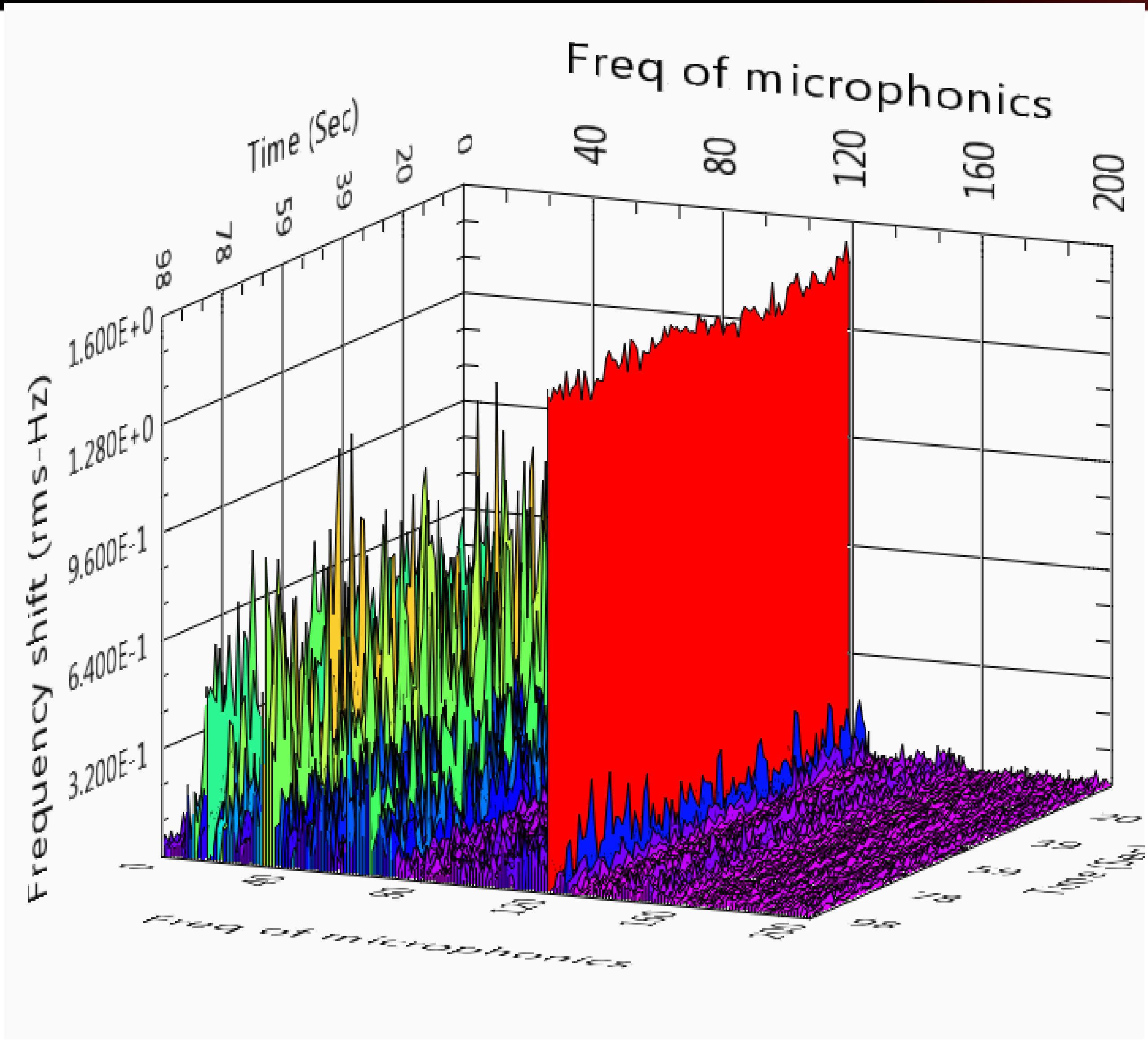
- Data taken during USPAS school.
- FEL4-2 Data taken with kystron at a few MV/m.
- FEL3-6 data taken with a 1W amplifier and a top hat.

FEL4-2 Frequency vs Time data



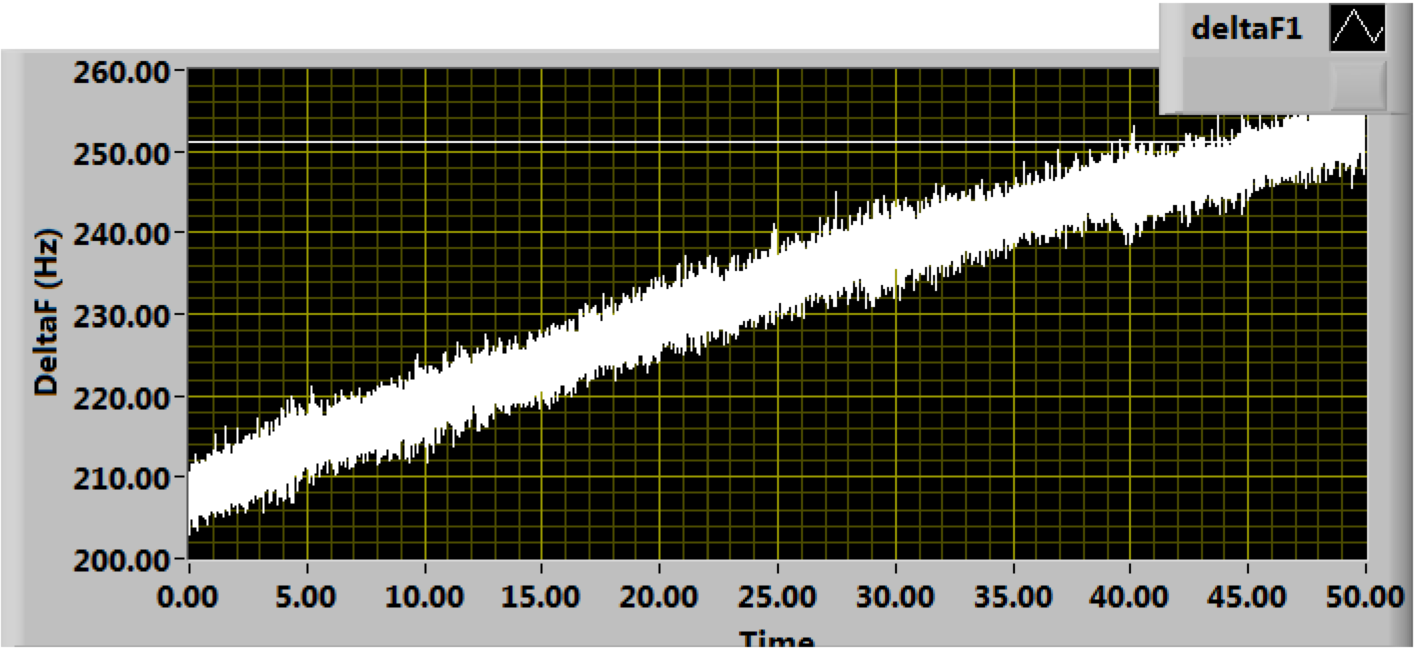
8 Hz perturbation due to poorly mounted beam line ion pump (over extended jack stand).

FEL3-6 Frequency vs Time Data



120 Hz noise due to insulating vacuum turbo pump backing pump coupled in through corrugated hose.

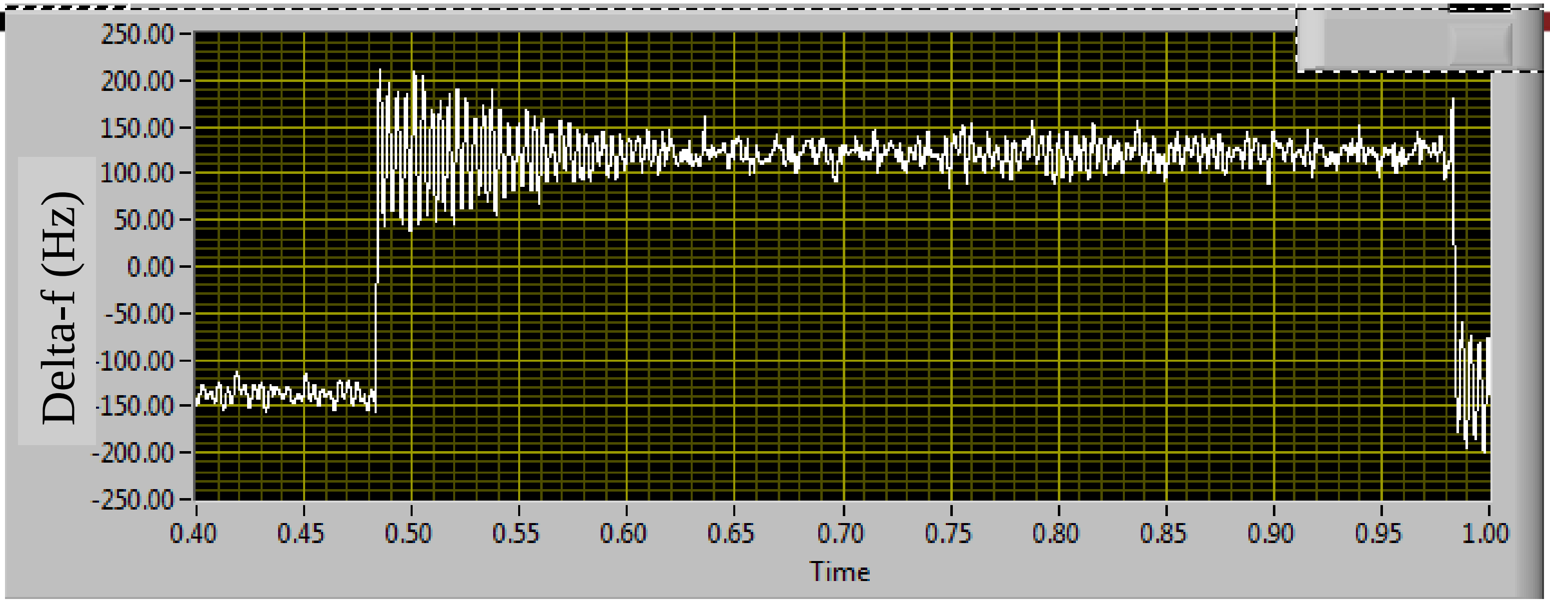
FEL3-6 with fan blowing on beam line



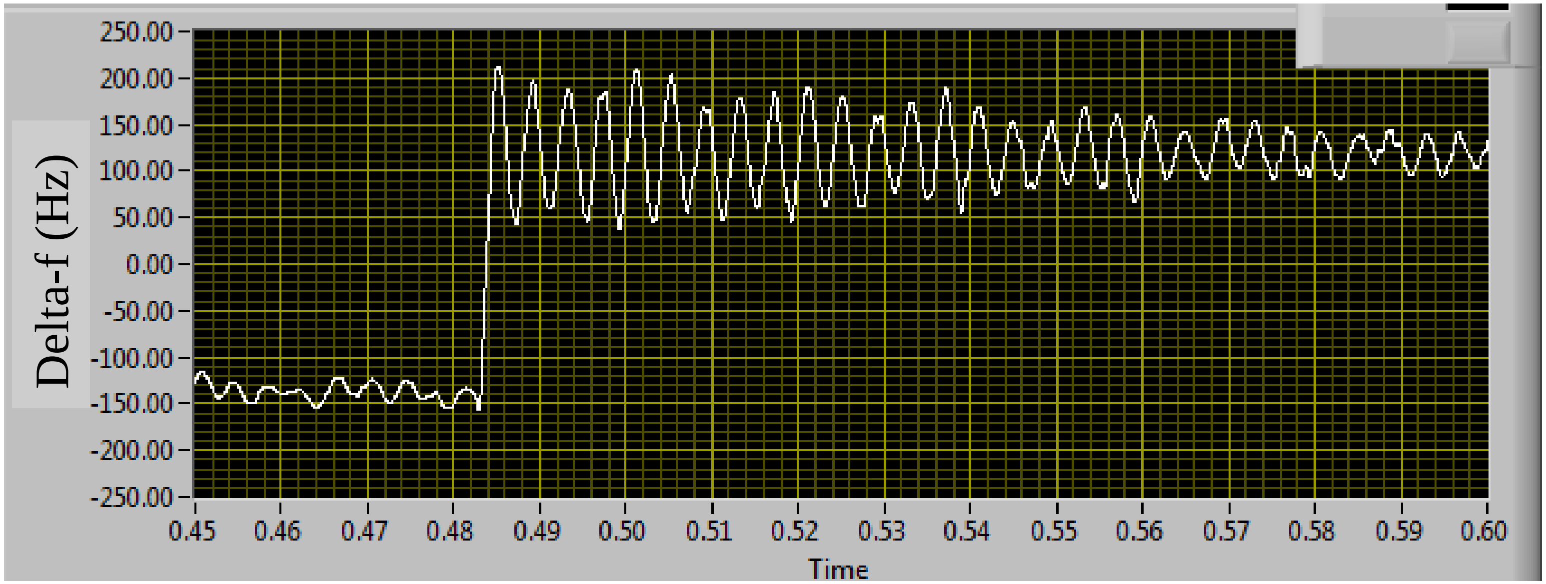
Time (seconds)

- Fan blowing on inner cryomodule girder caused slow temperature shift of about 200 Hz. Removal of the fan caused the frequency to restore to the previous value.
- Similar continuous (hours and hours) detuning has been seen in cryomodules operated at constant gradient overnight.

Transient Frequency Shift Oscillation Due to Step Change in Gradient

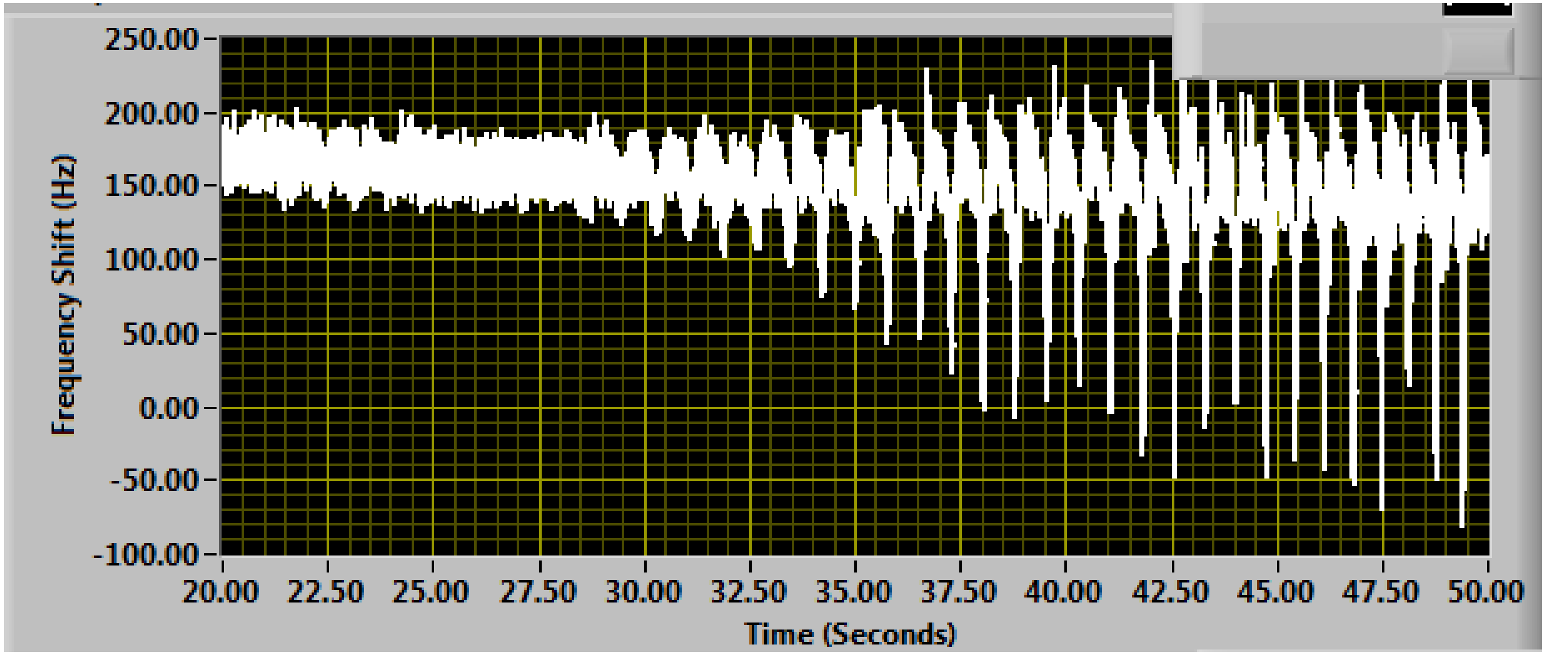


IHEP HWR structure



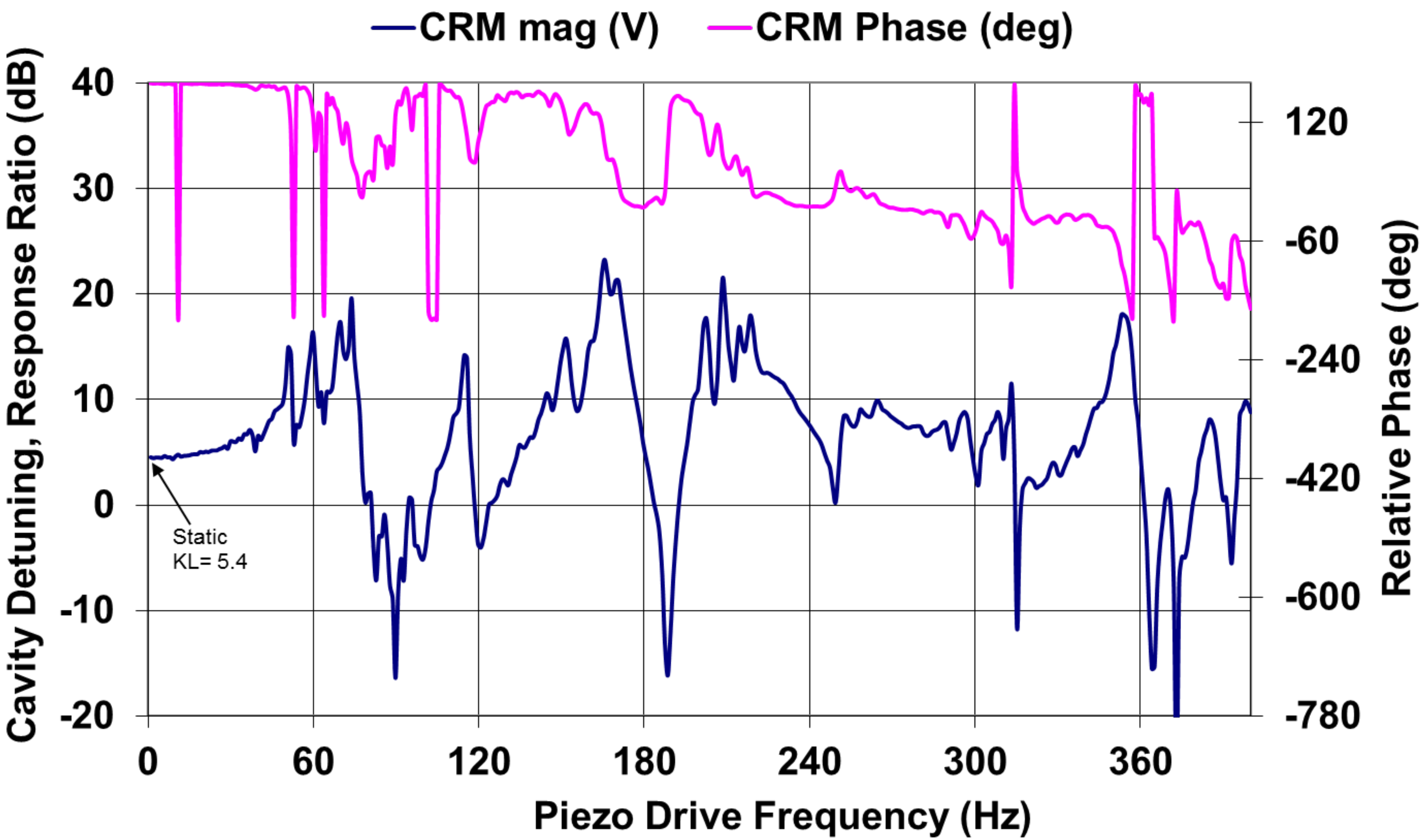
Frequency of oscillation is appx. 250 Hz

Construction Noise Source

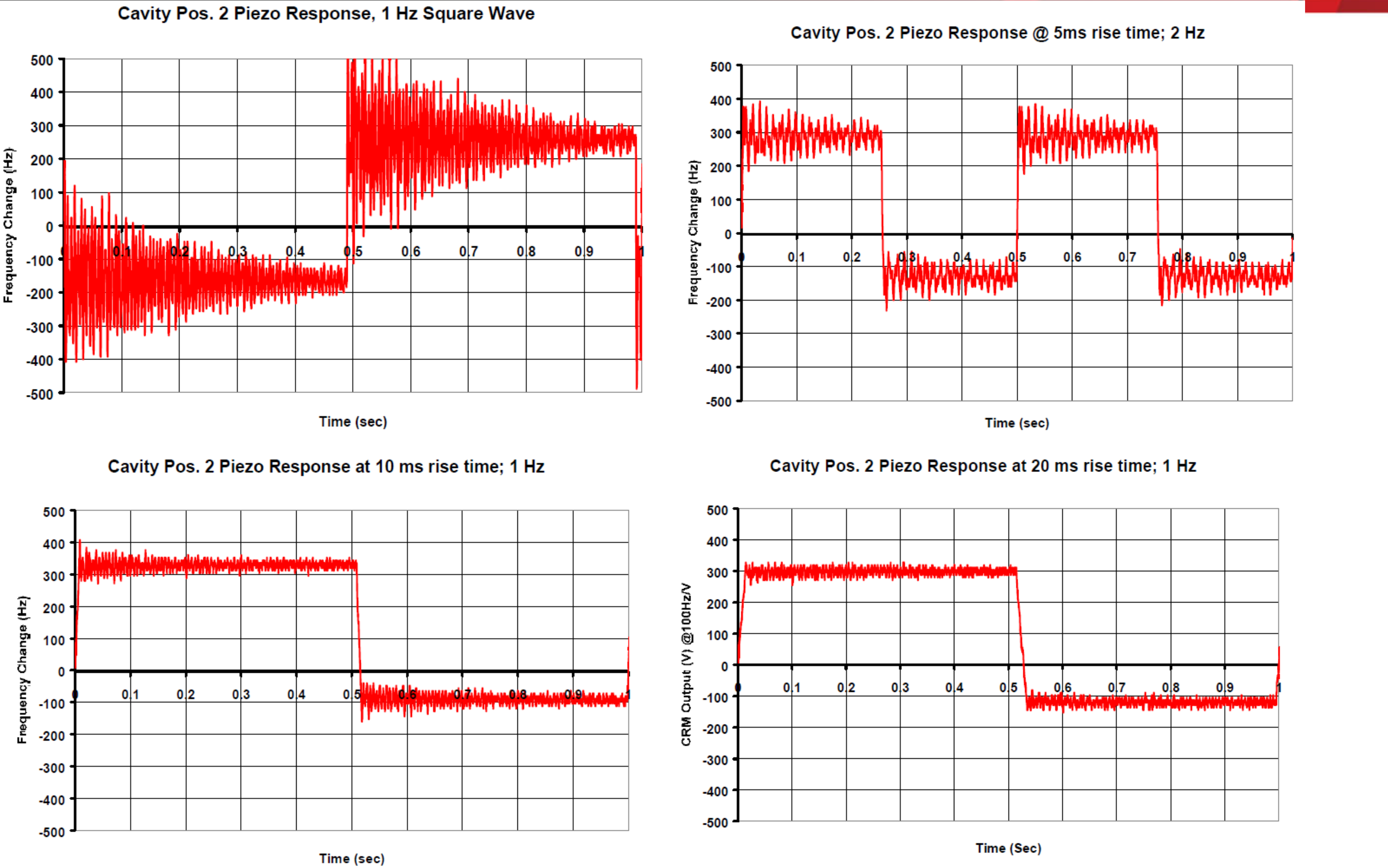


IHEP spoke cavity 1 excited by jack hammer on roof of building

SNS MB1 Cavity 2, PZT Transfer Function



Varying PZT ramp time SNS MB Cavity



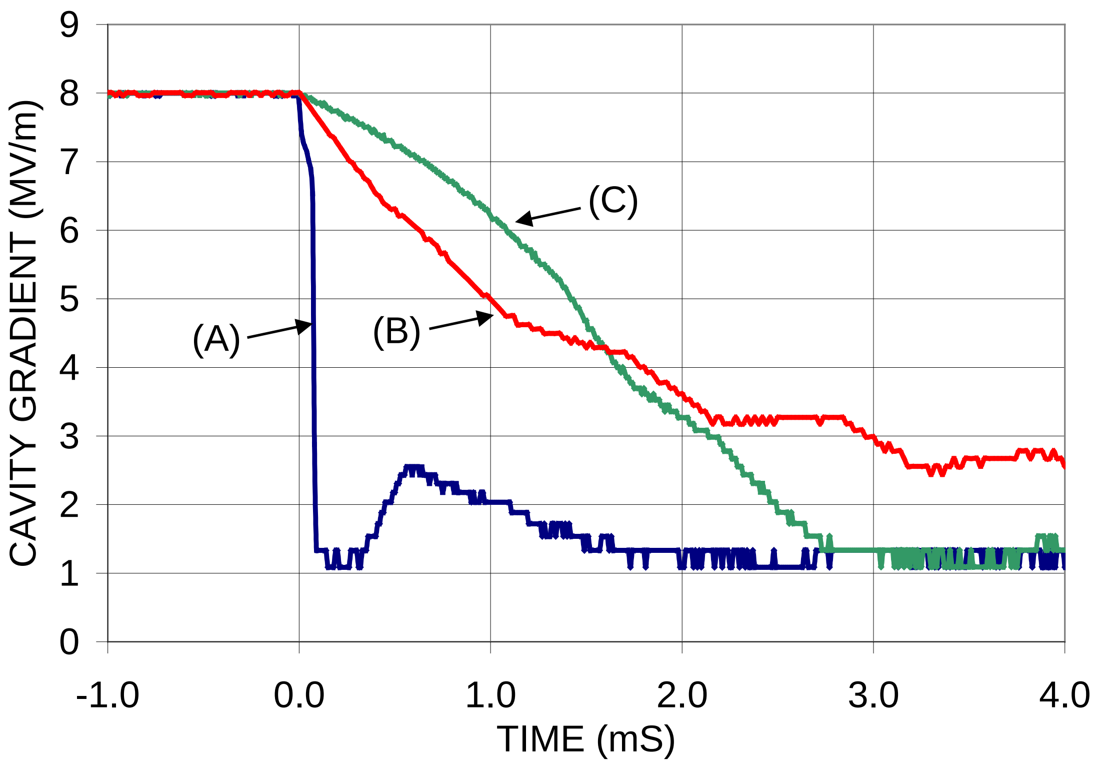
JLAB TN-02-049, Delayen, et. al. Frequency Measurements on Prototype SNS Medium-β Cryomodule Under Pulsed and CW operations.

Types of Arc Events

1. Waveguide Arc
   - Occur in the vacuum space between warm and cold windows
   - Gradient decay time ~1 – 2 msec

2. “Electronic Quench”
   - Occur in vacuum space on the cavity side of the cold window
   - Gradient decay time < 200 μsec

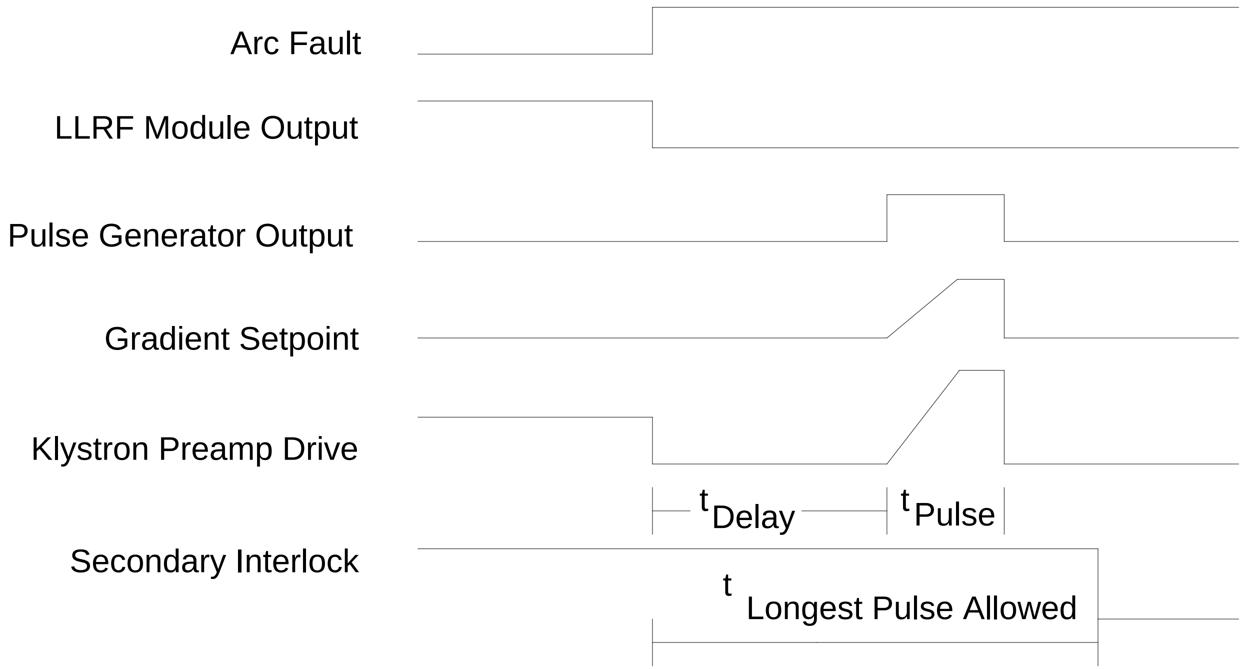
System Response to Arc Events



A. “Electronic Quench”
B. Waveguide Arc
C. Normal Response

Experimental Overview

- Induce arc events using the existing LLRF system
- Apply a secondary RF pulse following a delay
- Measure system response
- Vary delay and ramp-up time of secondary RF pulse
- Maintain machine protection via hardware interlocks



Open Loop Test Results at 7.7 MV/m

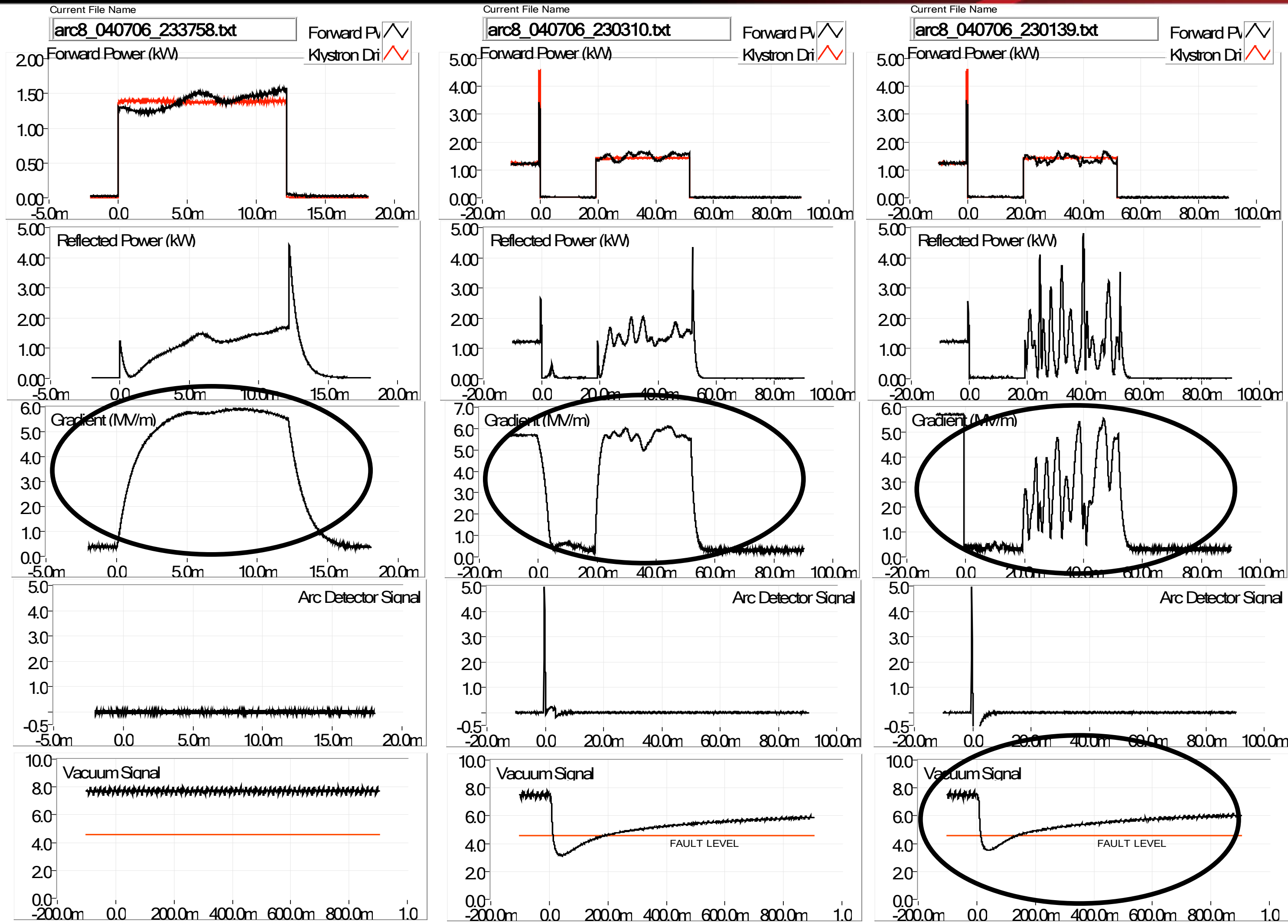
Forward Power

Reflected Power

Gradient

Arc Detector

Vacuum



Normal Pulse (no event)

Pulse following Waveguide Arc

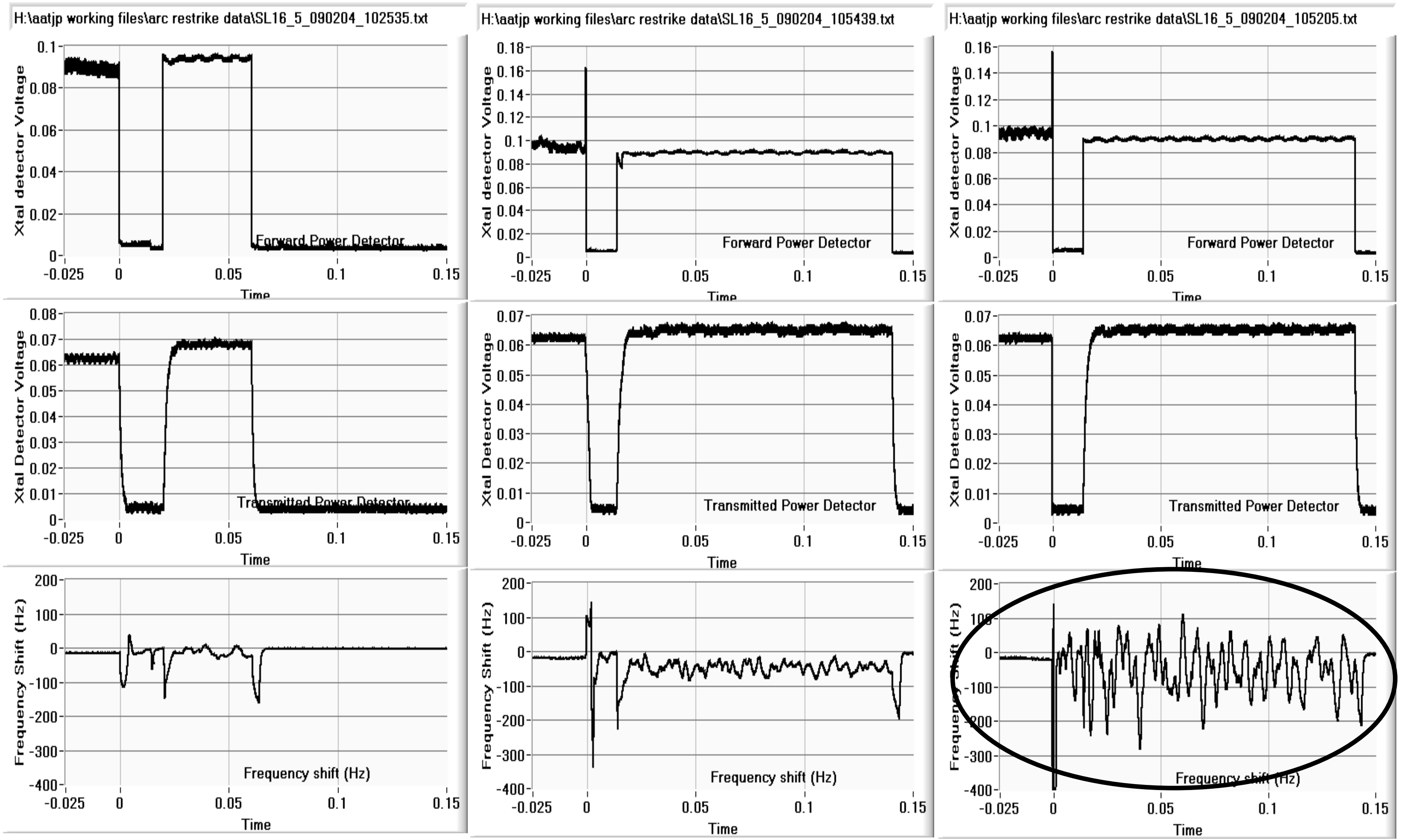
Pulse following "Electronic Quench"

Frequency Shift Measurements at 7.7 MV/m

Forward Power

Transmitted Power (Gradient)

Frequency Shift



Normal Pulse (no event)

Pulse following Waveguide Arc

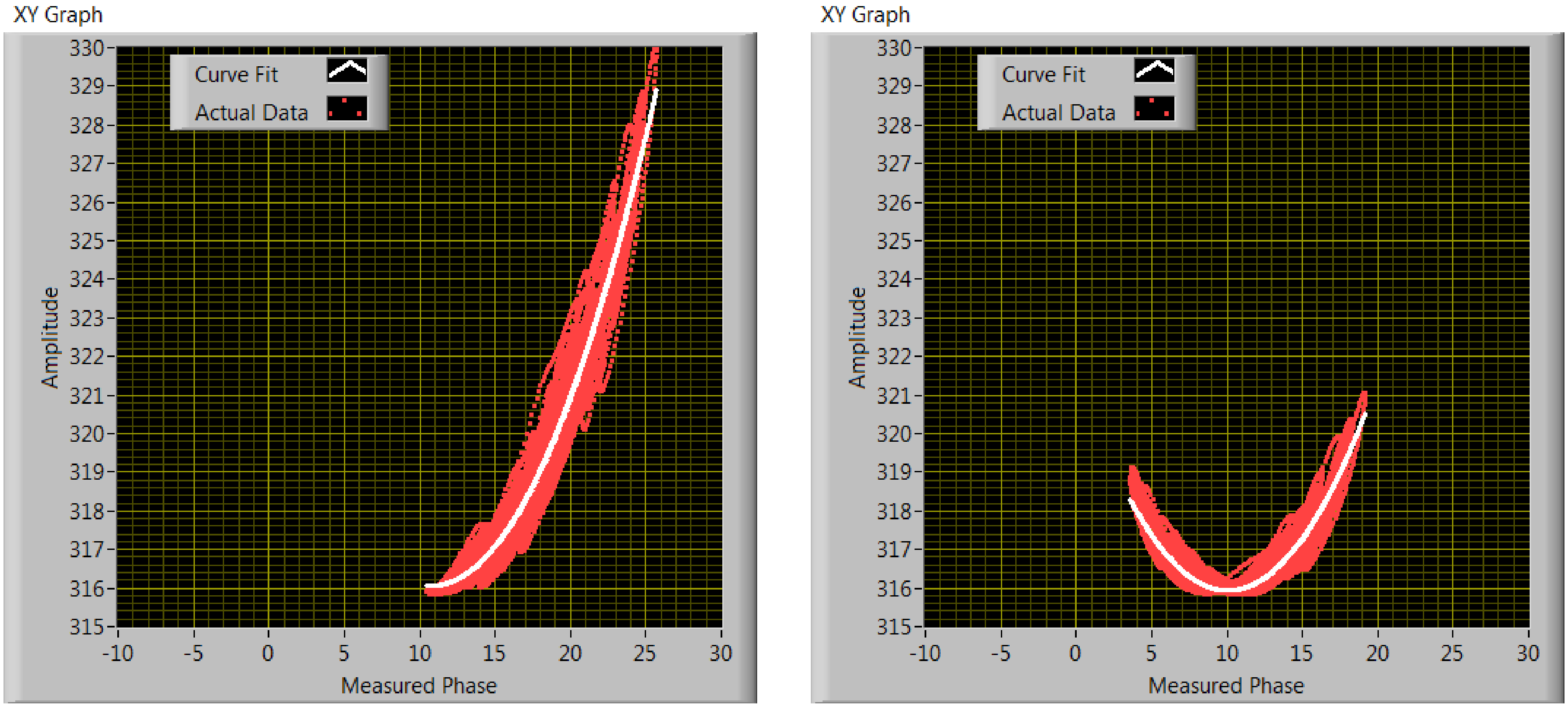
Pulse following "Electronic Quench"

Backup Slides

Automatically Determining TPOFF

- Using a digital LLRF system one can record the forward RF voltage (magnitude of the I/Q signal) and the difference between the transmitted power phase and the forward power phase for several seconds.
- The microphonics noise in the system will introduce spread in the data.
- If a second order fit (X value is the phase difference and the Y value is the RF voltage) is applied to the data the minimum will occur when TPES = TPOFF.
- This process is valid in GDR mode both with and without CW beam.
- It not valid during pulsed beam operation.

Maintaining Proper Value of TPOFF

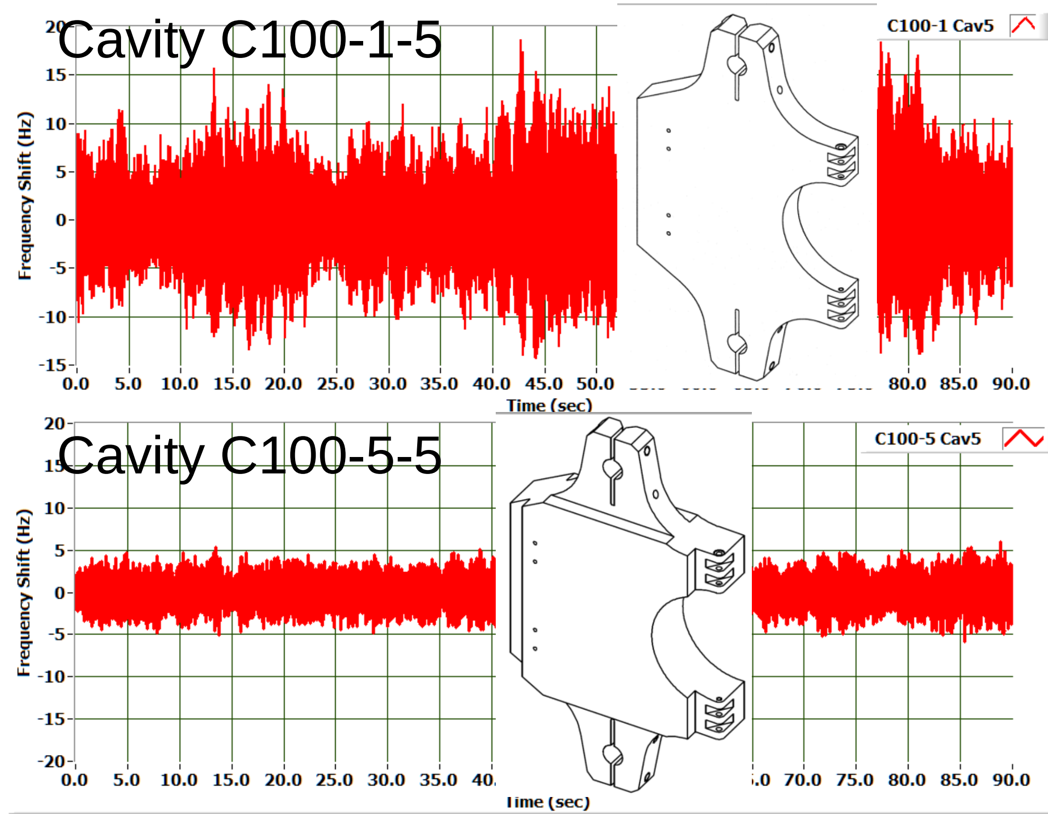


Curve fitting for measured microphonics data with a peak to peak value of 15 Hz and a cavity that off resonance with a detune offset of 10° and (right) curve fitting for measured microphonics data with a peak to peak value of 15 Hz and a cavity that is close to on resonance. In both cases the data indicates that the proper detune offset is approximately 10°.

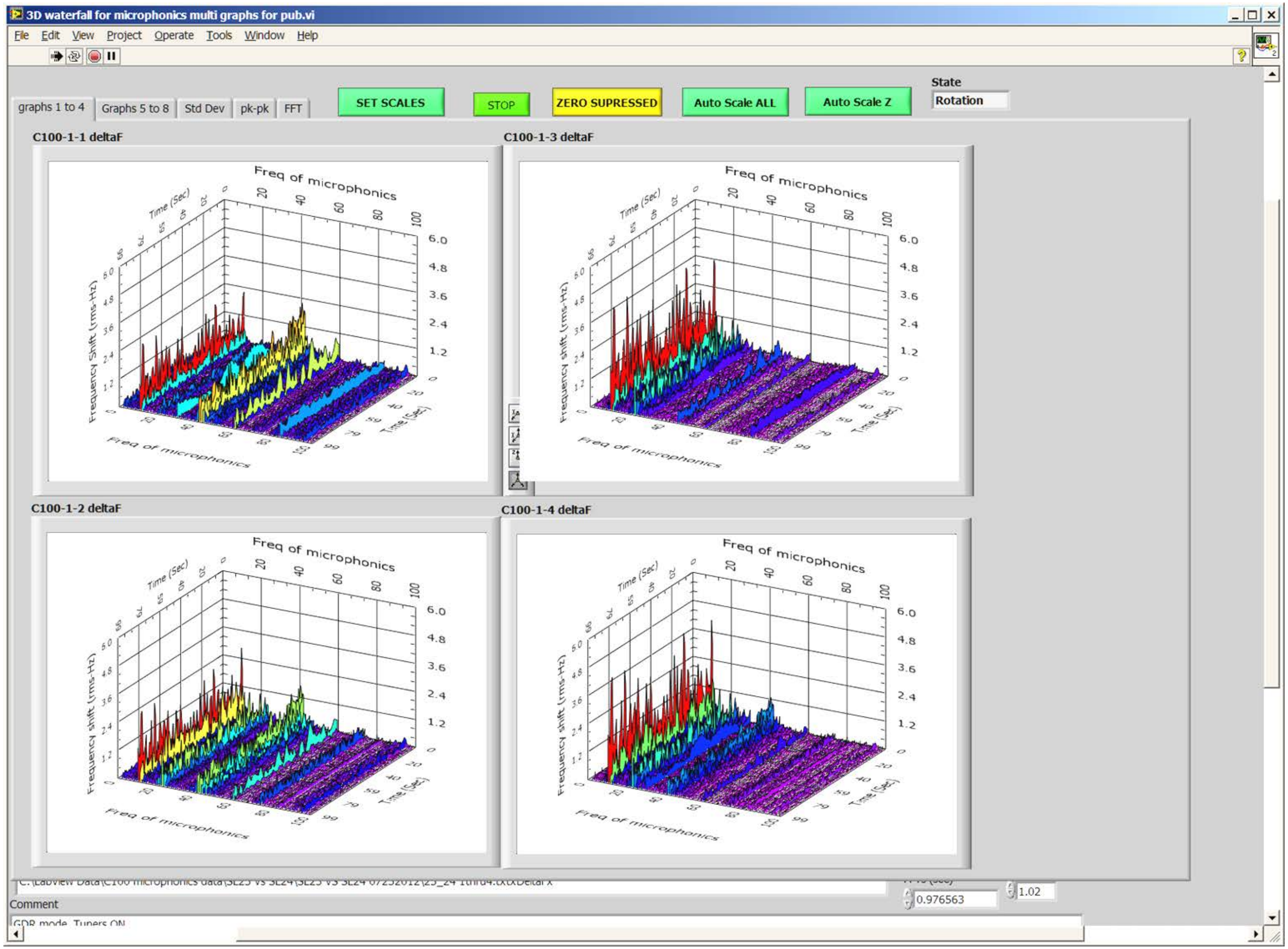
C100 Cryomodule Fix

- Design allows for 25 Hz Peak Detuning
- Actual peak detuning **(21 Hz)** was higher than expected in first cryomodules
- A detailed vibration study was initiating which led to the following design change.
- A minor change to the **tuner pivot** plate substantially improved the microphonics for the CEBAF C100 Cryomodules.
- While both designs meet the overall system requirements the improved design has a larger RF power margin

Microphonic Detuning*	C100-1	C100-4
RMS (Hz)	2.985	1.524
6σ(Hz)	17.91	9.14

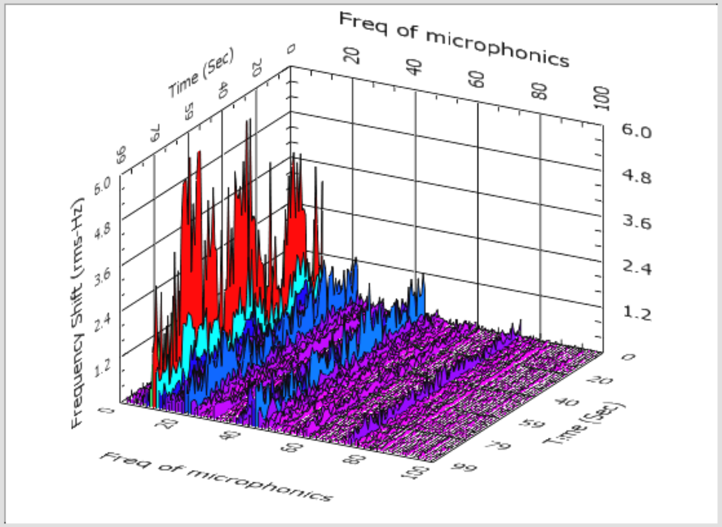


C100-1 Microphonics

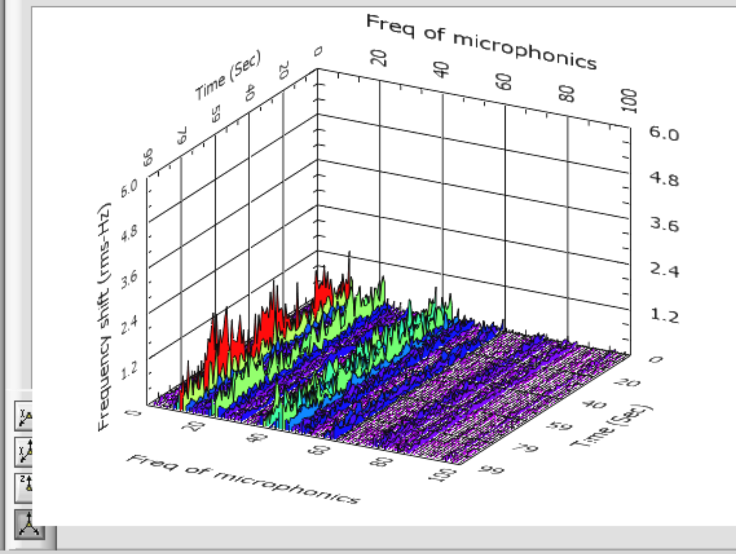


C100-1 Microphonics

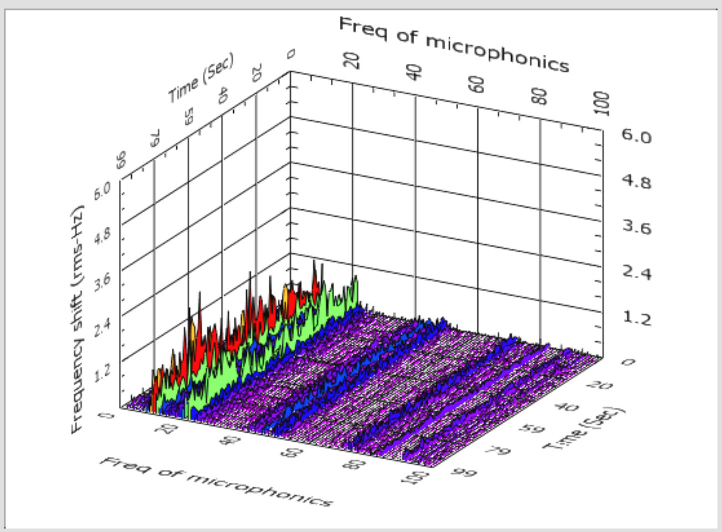
C100-1-5 deltaF



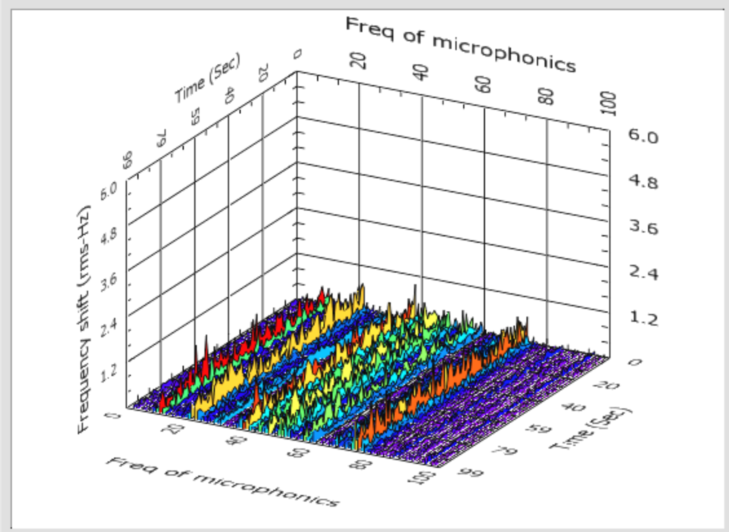
C100-1-7 deltaF



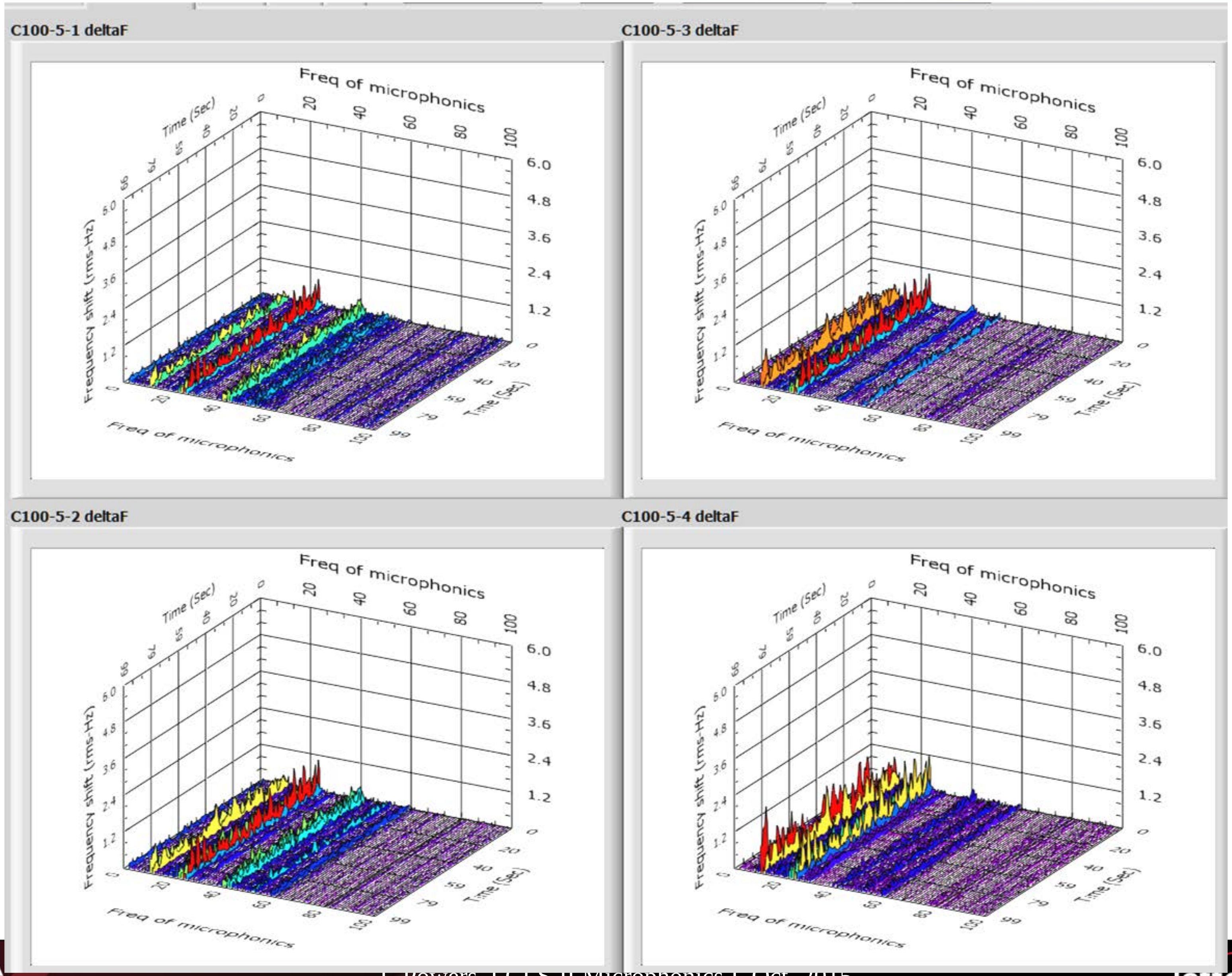
C100-1-6 deltaF



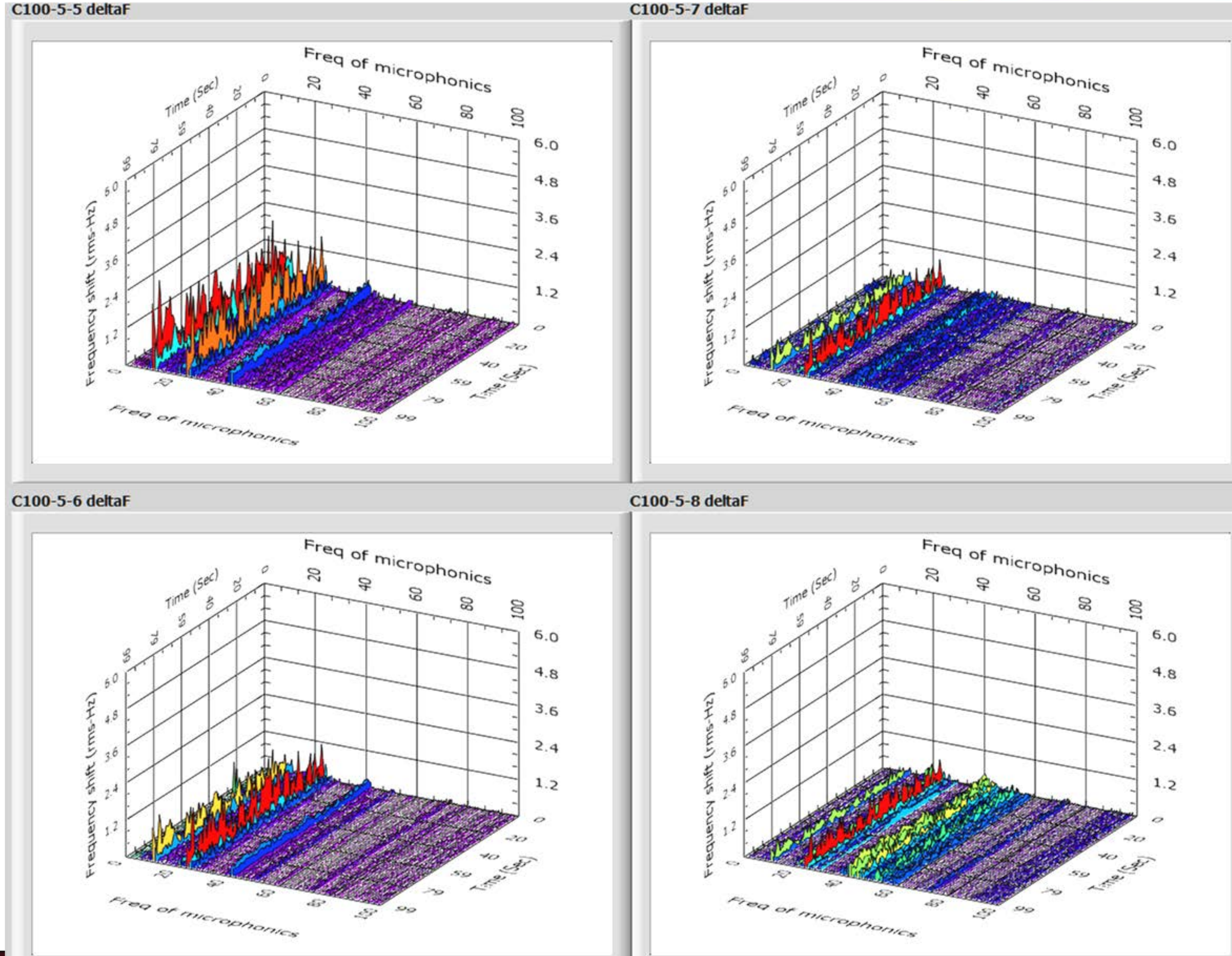
C100-1-8 deltaF



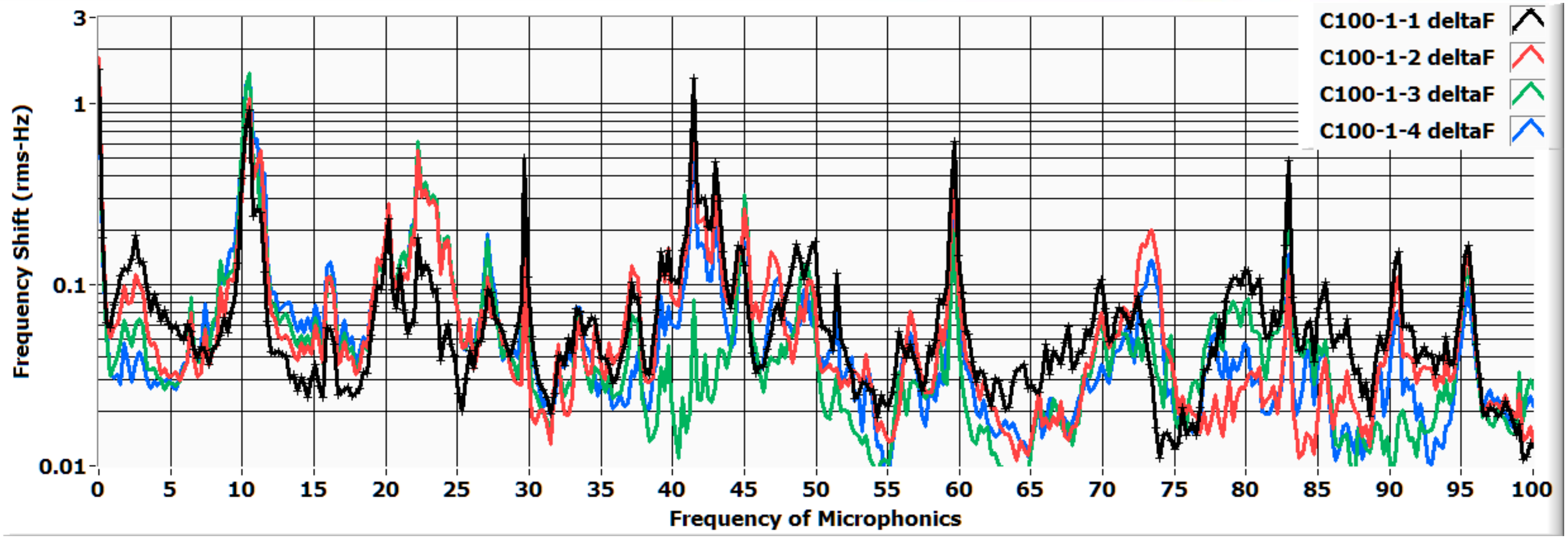
C100-5 Microphonics

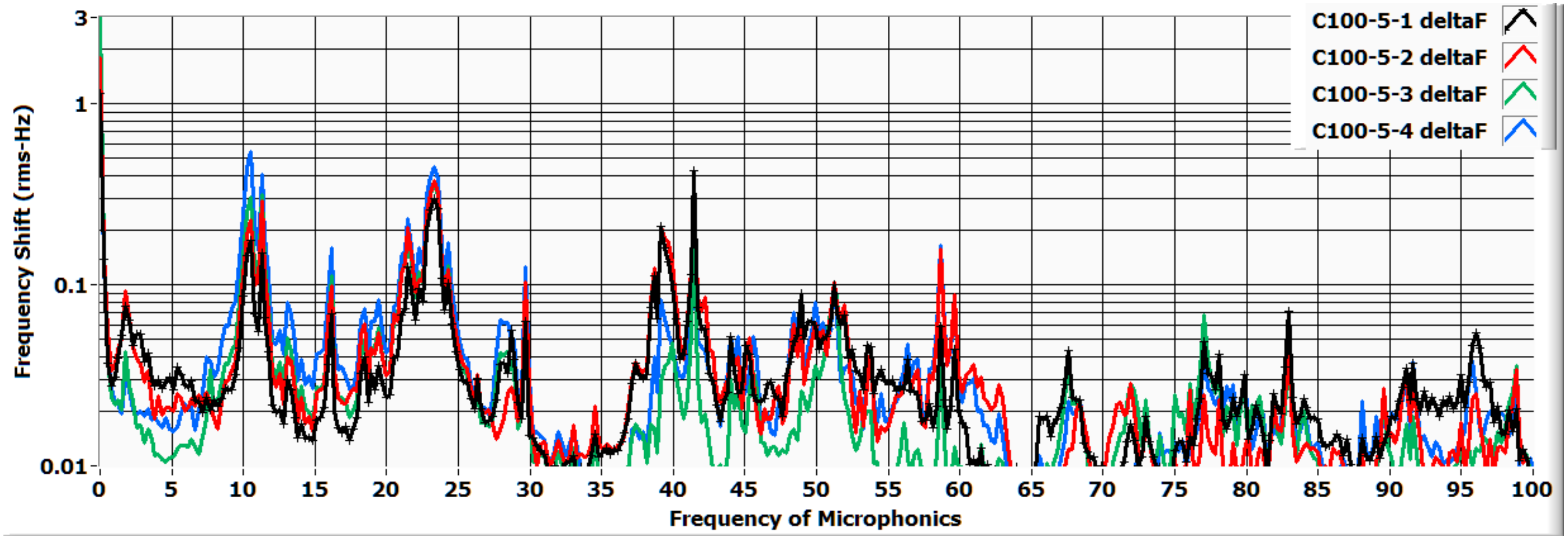


C100-5 Microphonics

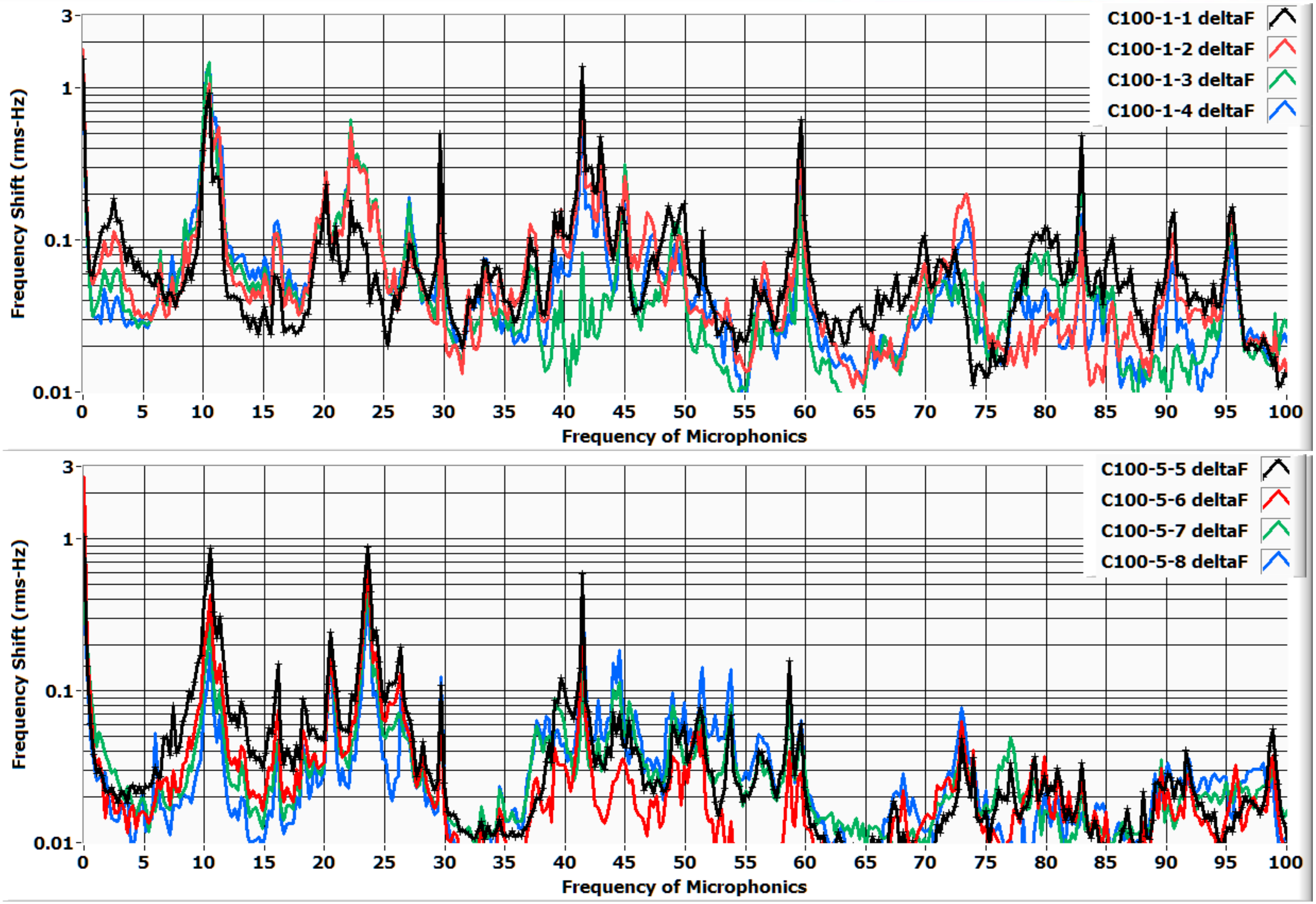


Background spectrum for Original (C100-1) and Stiffened (C100-5)

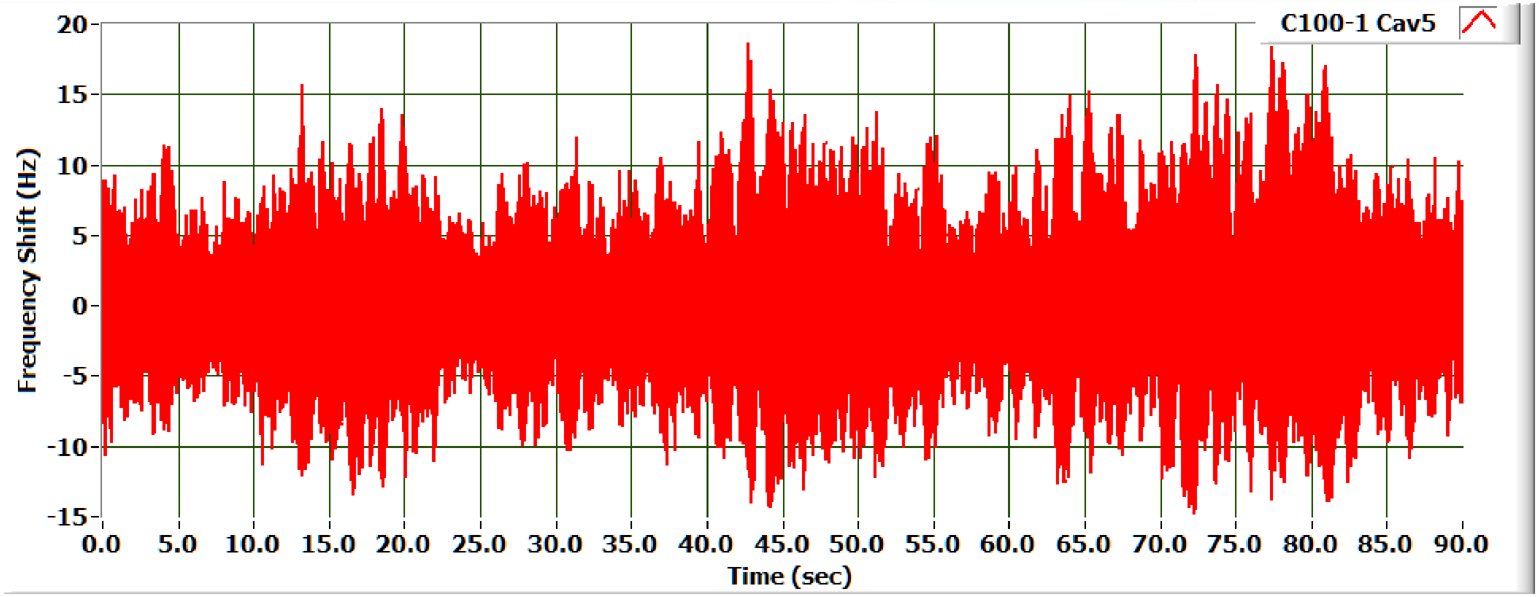


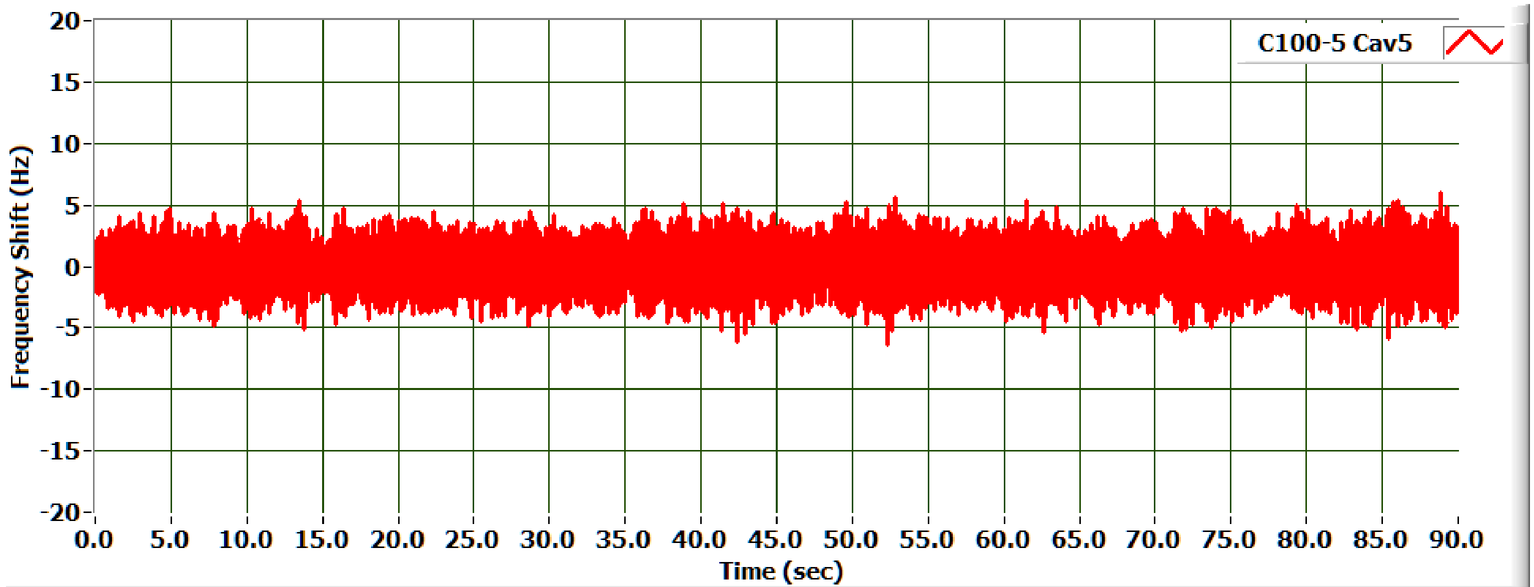


Background spectrum for Original (C100-1) and Stiffened (C100-5)



Background Time Domain for Original (C100-1) and Stiffened (C100-5)





Background spectrum for Original (C100-1) and Stiffened (C100-5)