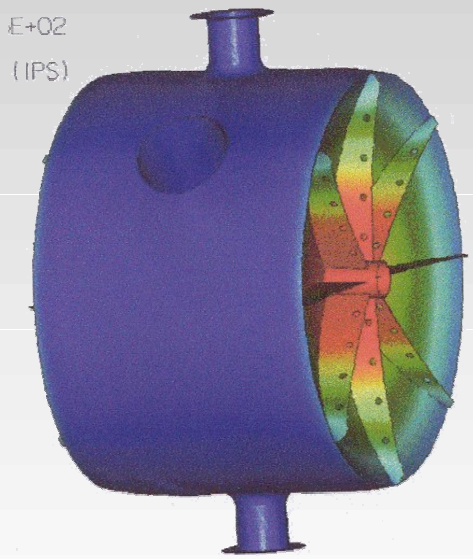
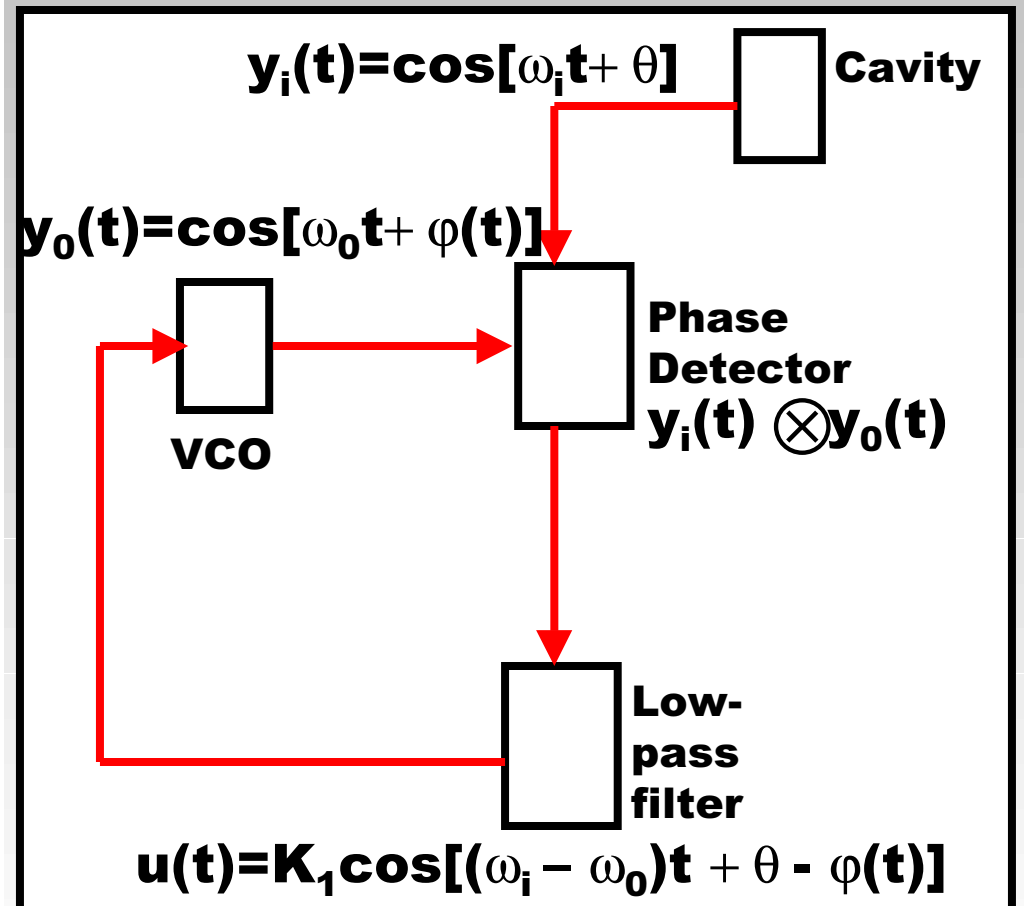
Microphonics Measurements in Spoke Cavities

Overcoupling + Negative Phase Feedback or Voltage Controlled Reactance?

- **Phase-locked loop; Cavity Resonance Monitor**
- **Phase noise**
- **Measurements**



Phase-locked loop



Ref. - A. Blanchard, Phase-locked Loops, 1976

Cavity Resonance Monitor

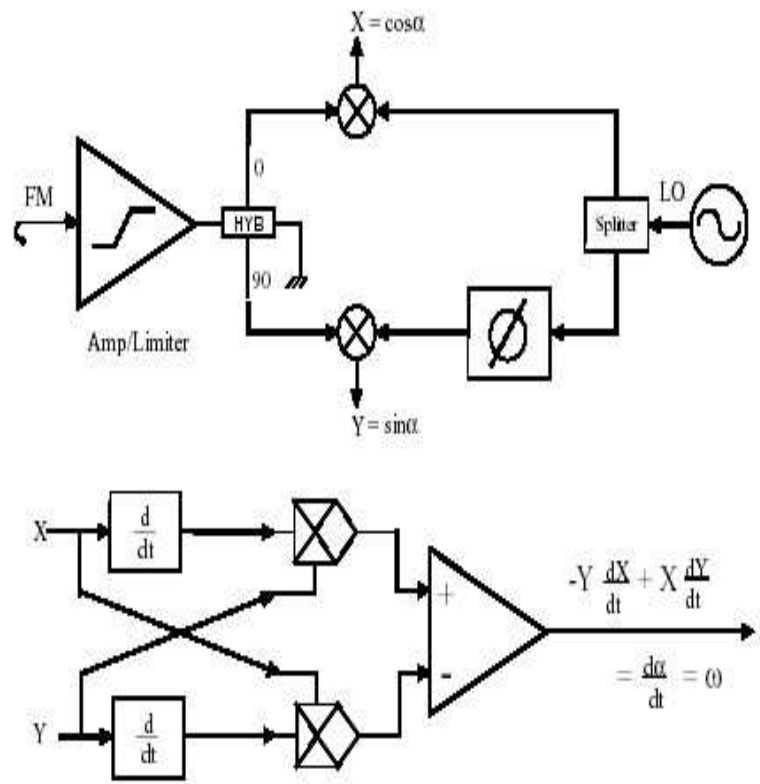


Figure 1: Cavity Resonance Monitor Block Diagram

G. Davis, J. Delayen et. al., PAC 2001

Cavity Resonance Monitor

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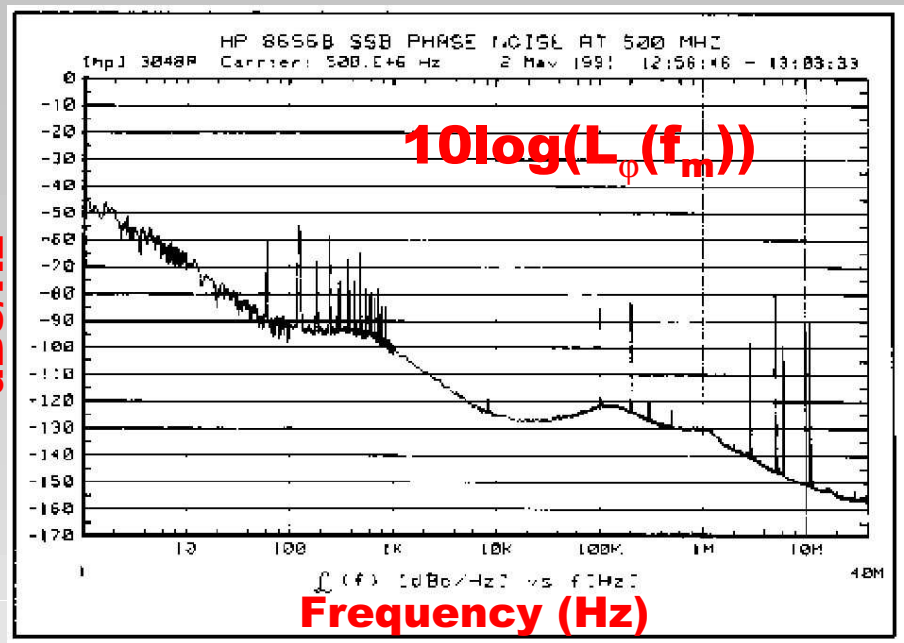
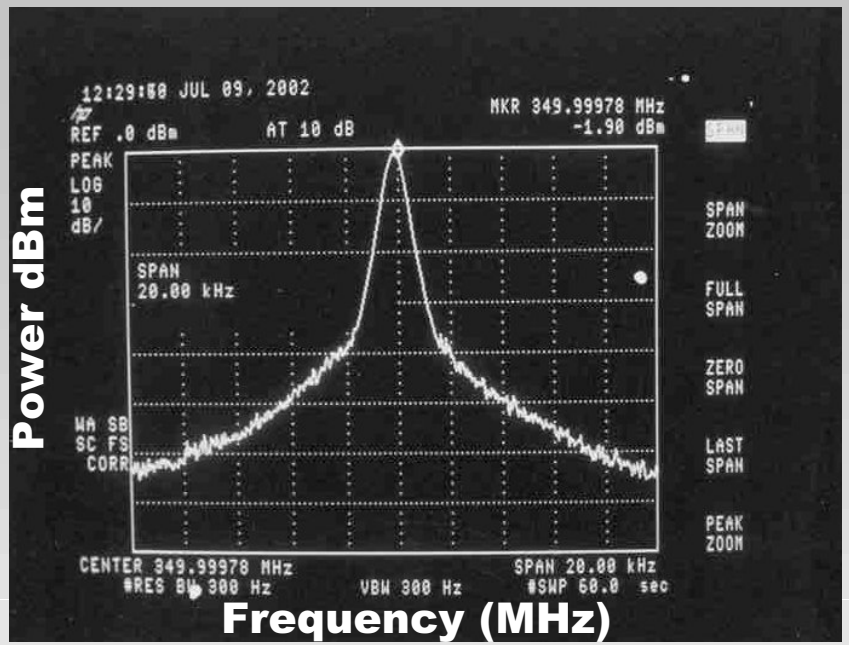
Phase Noise ⟷ Frequency Modulation





$$y_i(t) = \cos[\omega_i t + \varphi \sin \omega_m t]$$

φ is the peak amplitude of phase modulation for a modulating frequency ω_m

Cavity frequency = $\omega_i + \omega_m \varphi \cos \omega_m t$

$$\boxed{\omega_{peak} = \omega_m \varphi}$$

Frequency Modulation from Phase Noise

$$\omega_{peak} = \omega_m \varphi$$

Relates peak freq. modulation to peak phase modulation

$$S_f(\omega_m) = \omega_m^2 S_\varphi(\omega_m)$$

Power density of freq. oscillation vs. phase oscillations

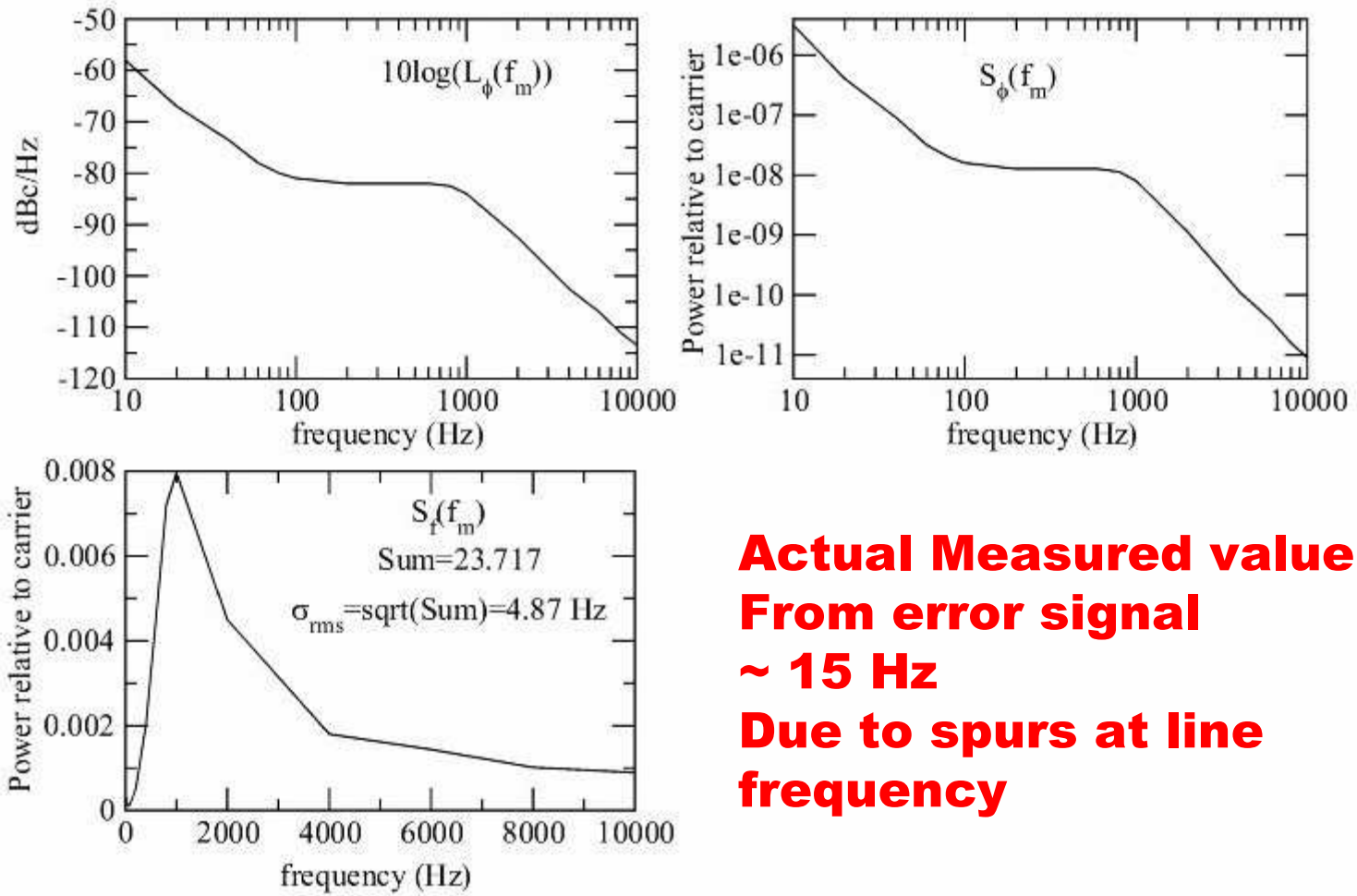
or

$$S_f(f_m) = f_m^2 S_\varphi(f_m)$$

$$\sigma_f = \sqrt{\int_{f_1}^{f_2} S_f(f_m)\, df_m}$$

RMS frequency deviation

HP 8656B FM from Phase Noise Spec

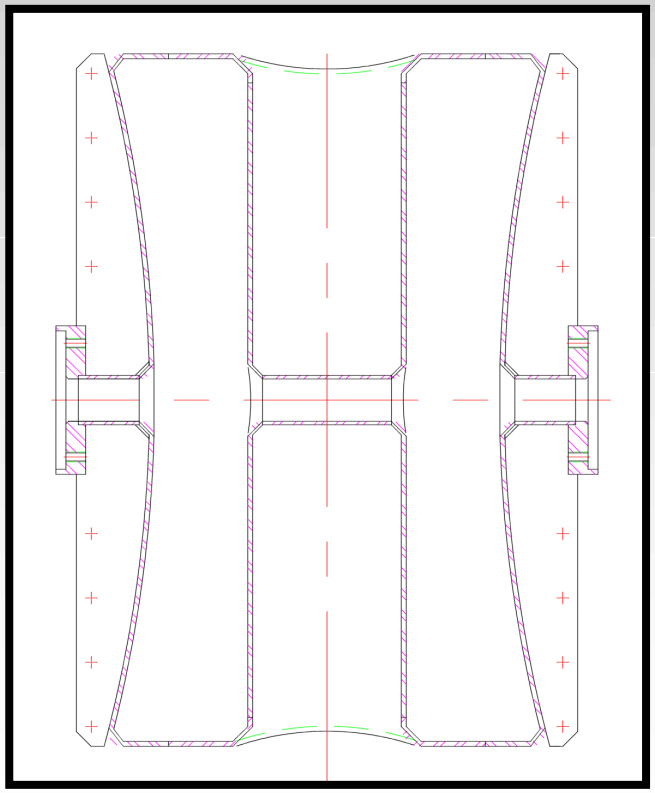


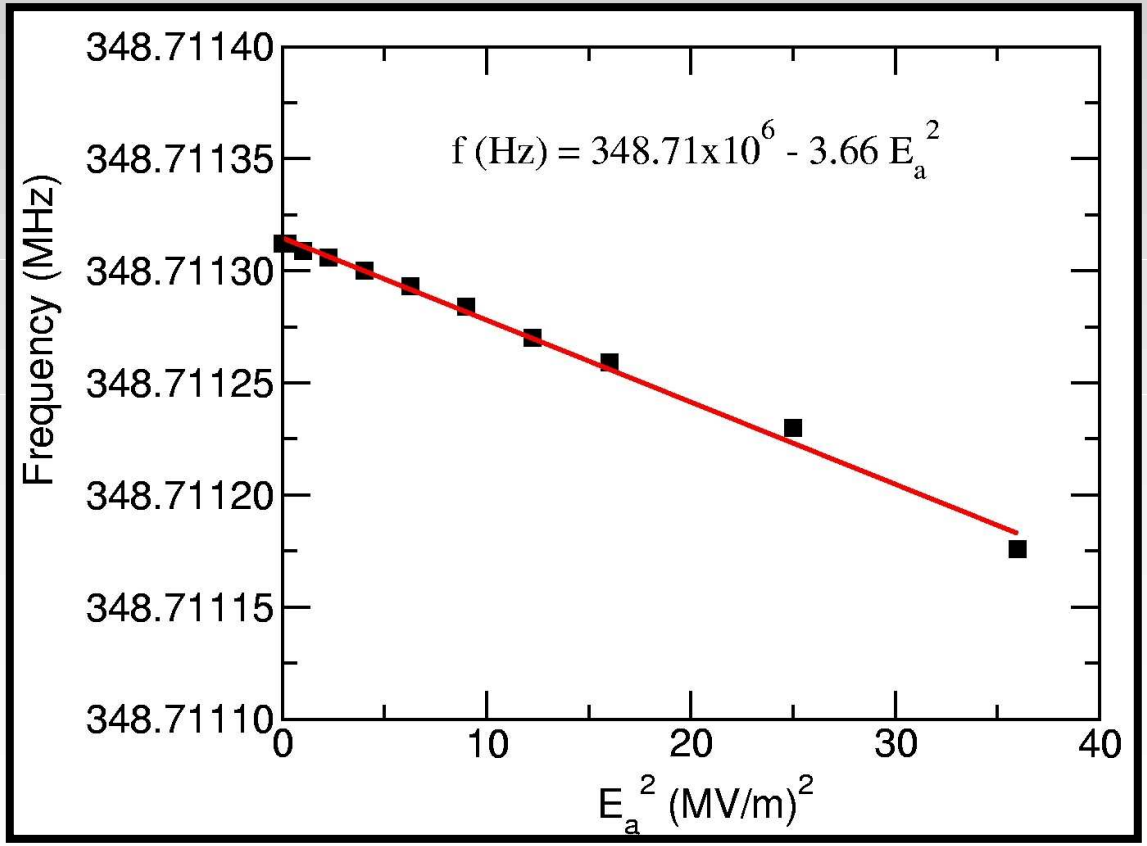
Actual Measured value
From error signal
~ 15 Hz
Due to spurs at line frequency

Agilent 8665 about factor of 10 better

Some β=0.4 Spoke Cavity Mechanical, EM Properties

- Stored Energy 82 mJ, E_{PEAK}=4 MV/m, B_{PEAK}=107 G at E_{ACC}=1 MV/m
- Active length 23 cm
- RRR~150, ~2.8 mm average thickness after processing
- Pressure sensitivity 120 kHz/atm at 4 K (~10% higher warm)
- Lorentz detuning 3.7 Hz/(MV/m)^2





Low-lying acoustic modes from FEA (J. Fuerst)

Spoke moving in and out

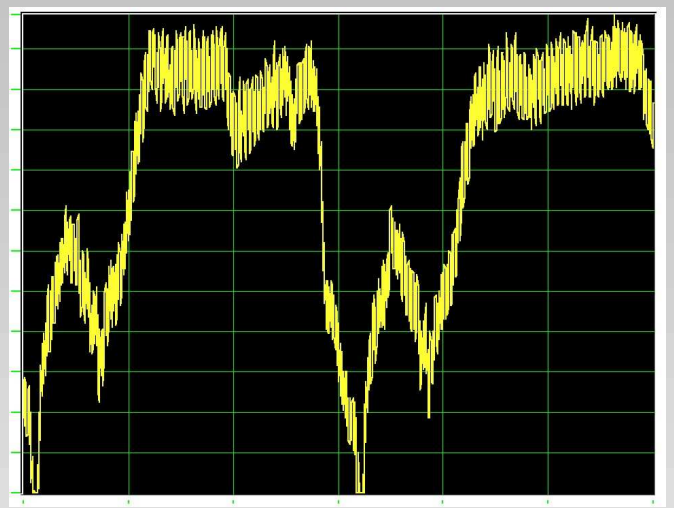
End wall vibration

Beam port vibration

Mode			Frequency (Hz)
1			259
2			279
3			315
4			360
5			398
6			422
8			461
11			488
16			723
17			727

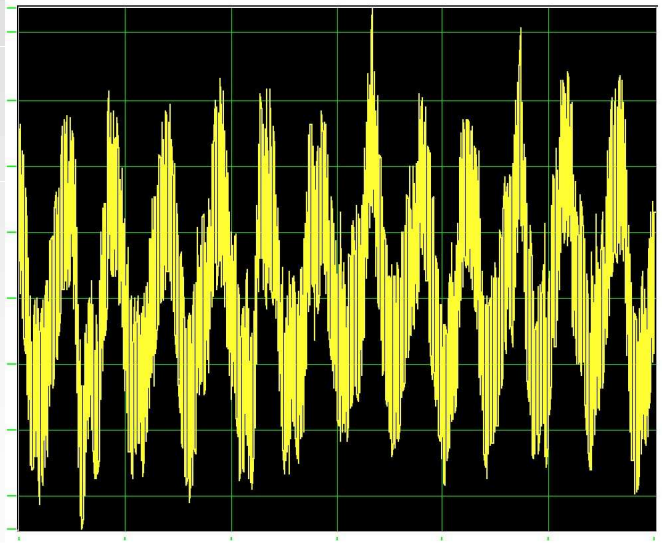
Refrigerator Effects: PLL Error Signal 6/28/02

Δf = 1150 Hz



2800W refrigerator set up with 2 watts excess capacity with 1S loaded at 2800 rpm and 8S unloaded. L dewar pressure 2.4 psig

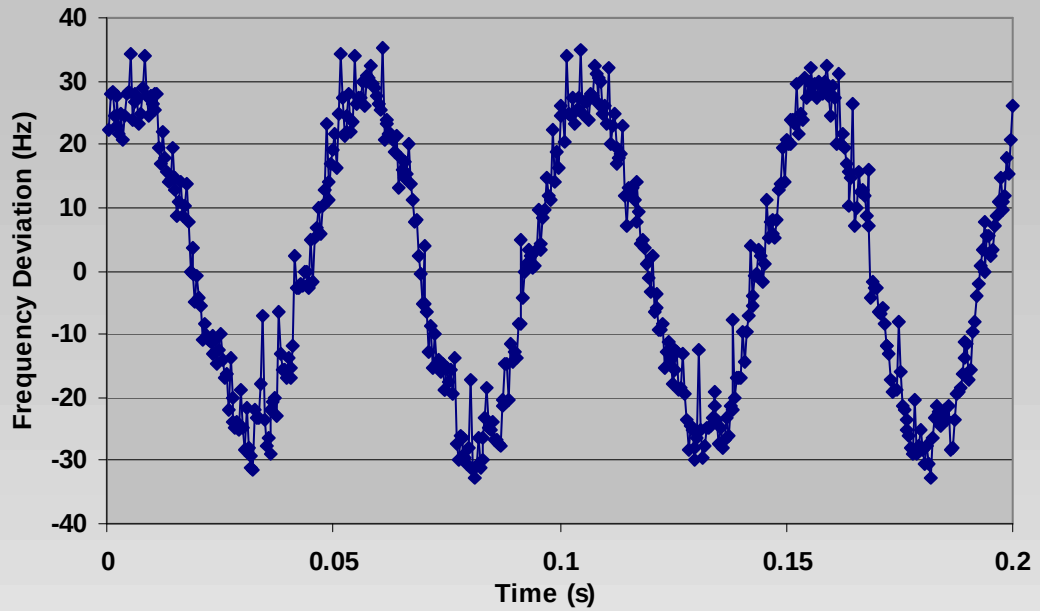
Δf = 280 Hz

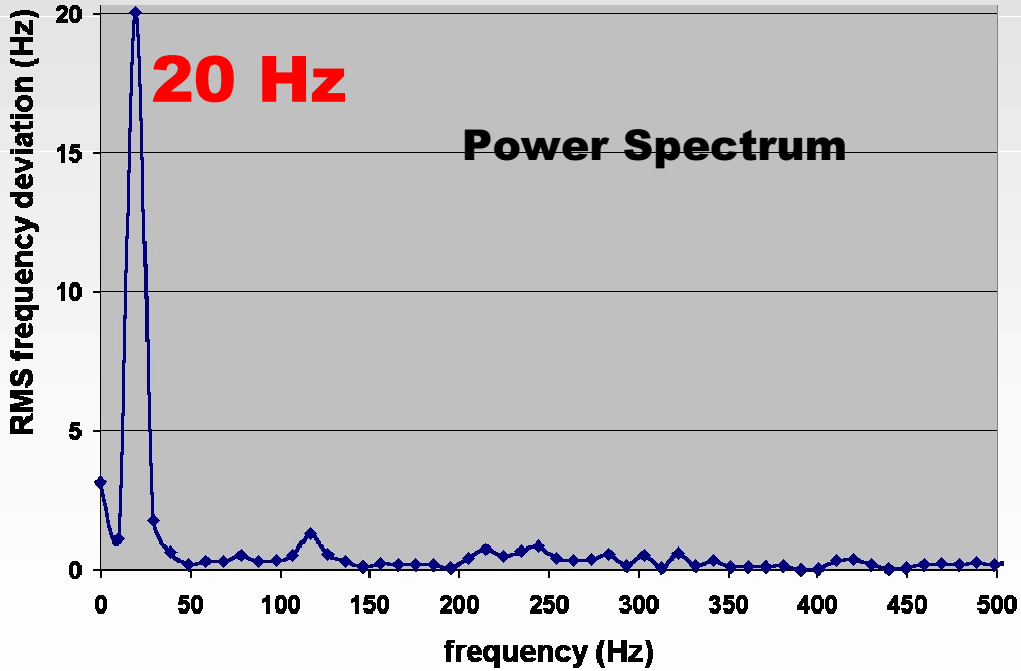


Refrigerator conditions are 60 watts excess capacity. L pressure = 2.8 psig. 1S loaded at 3600 rpm & 8S unloaded.

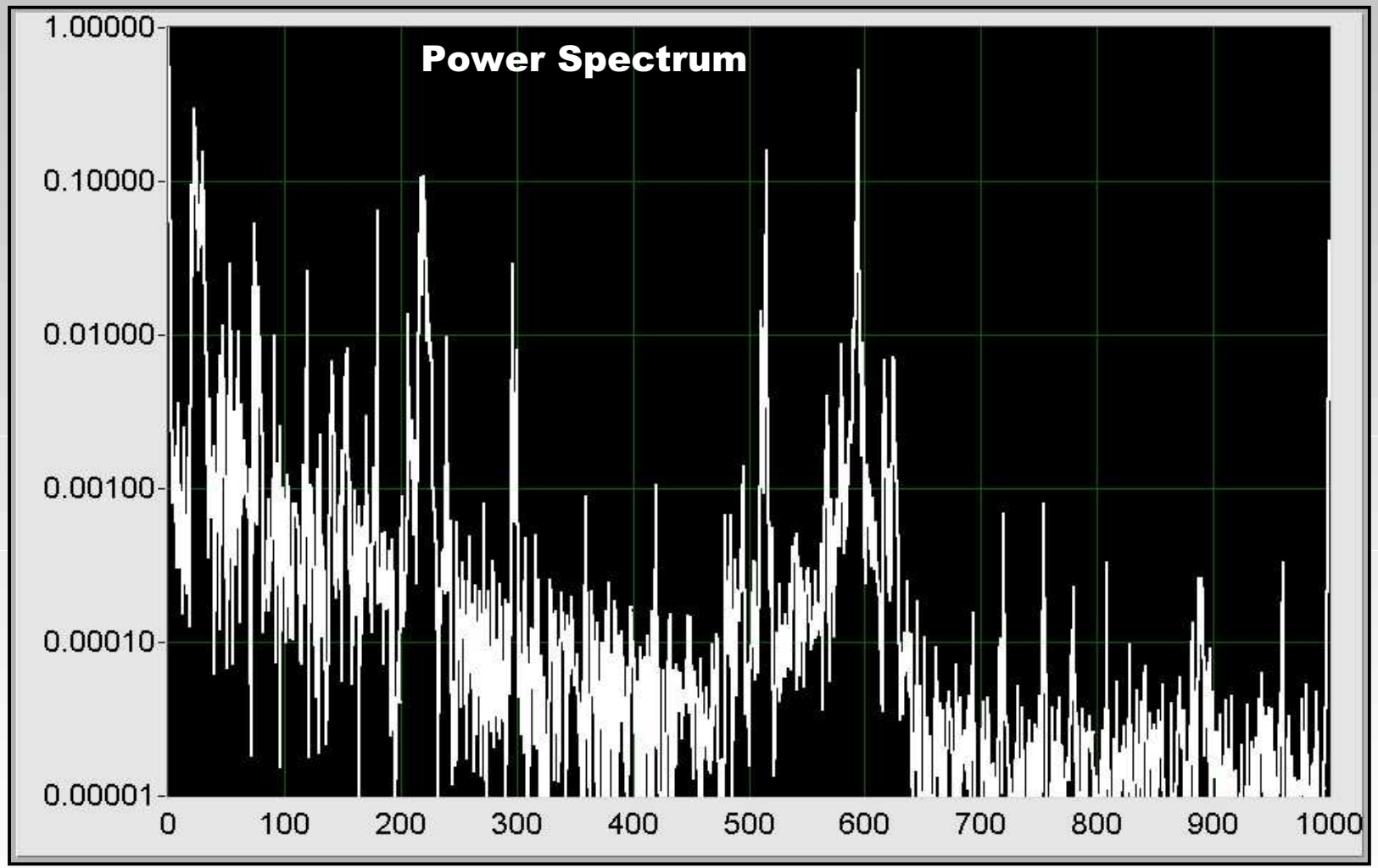
300 seconds

Spoke Cavity PLL Error Signal: Thermal-acoustic oscillation 6/24/02

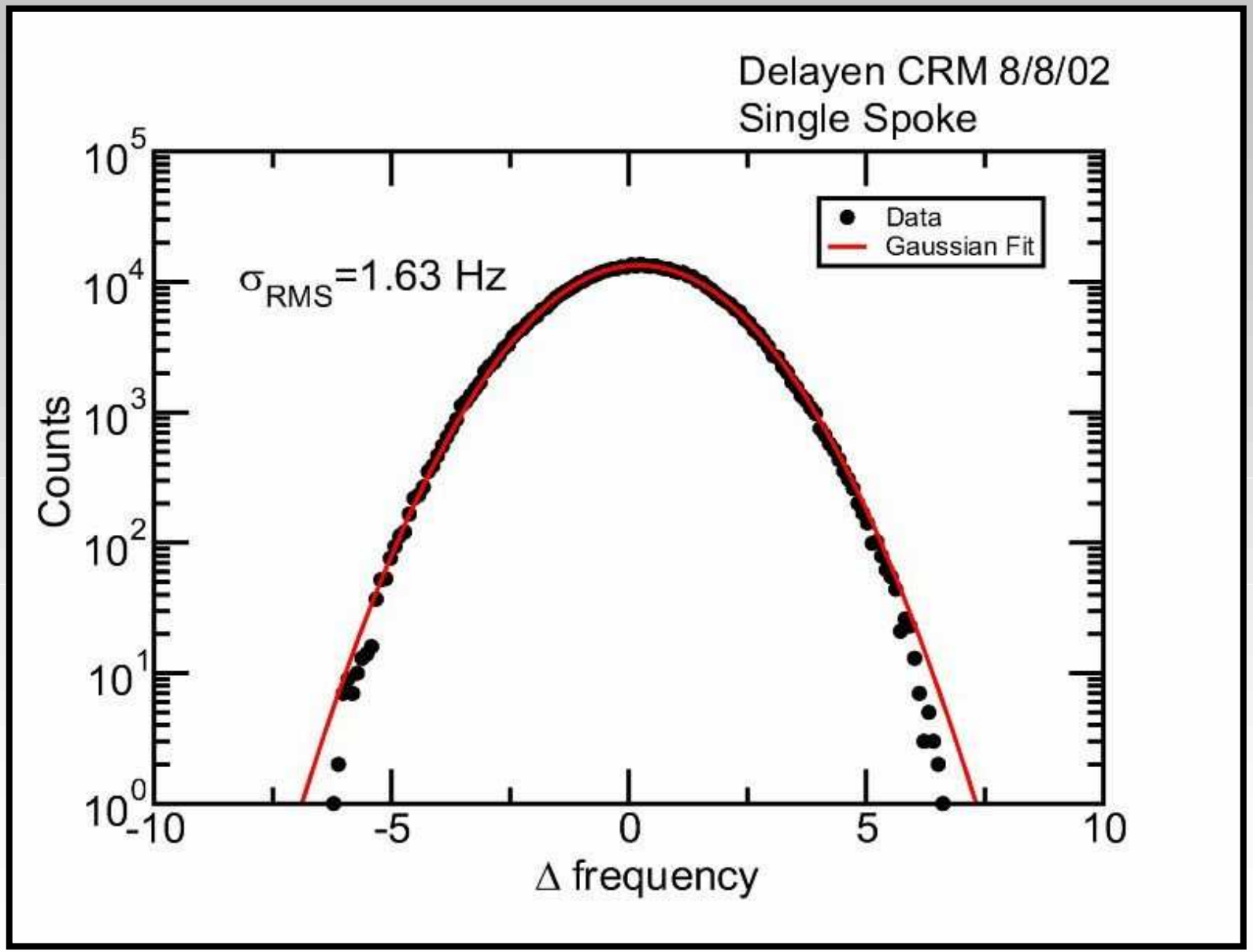




Single Spoke w/ Cavity Resonance Monitor 8/8/02



Modulation Amplitude (Hz)

Modulation Frequency (Hz)

Single Spoke w/ CRM: 50 sec. At 11 kHz