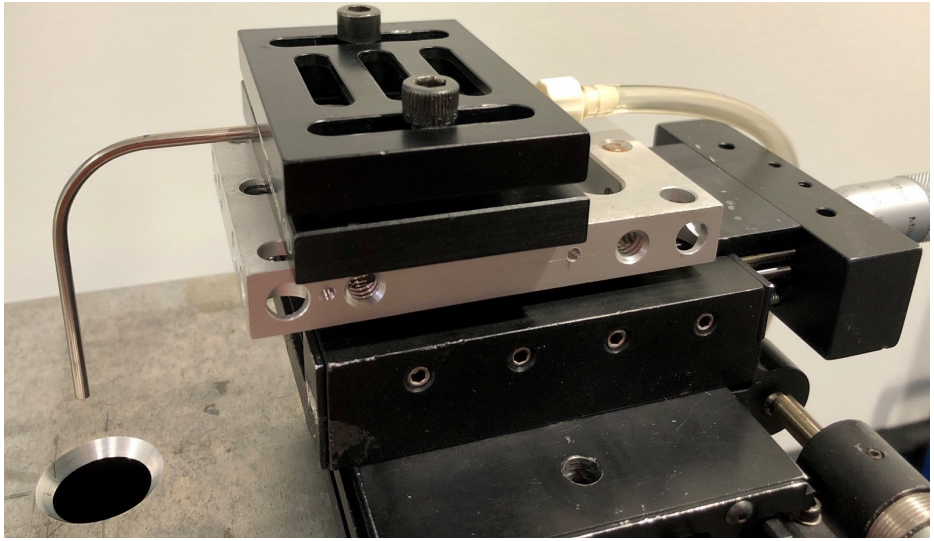
Stanford University

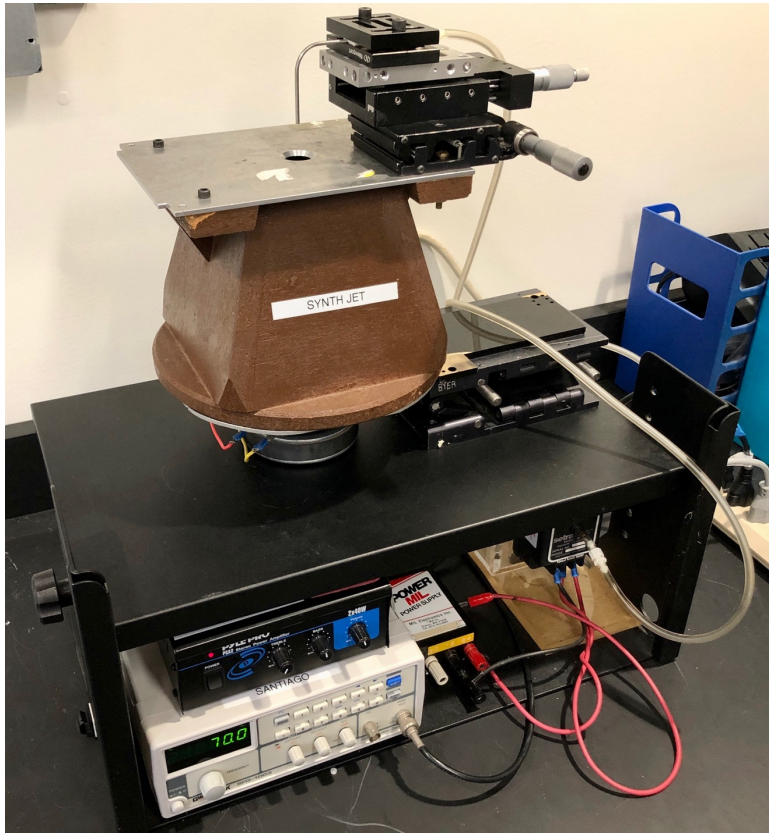
Velocity Profile and Frequency Characterization of Synth-Jet

Mar. 23, 2023

Project Overview

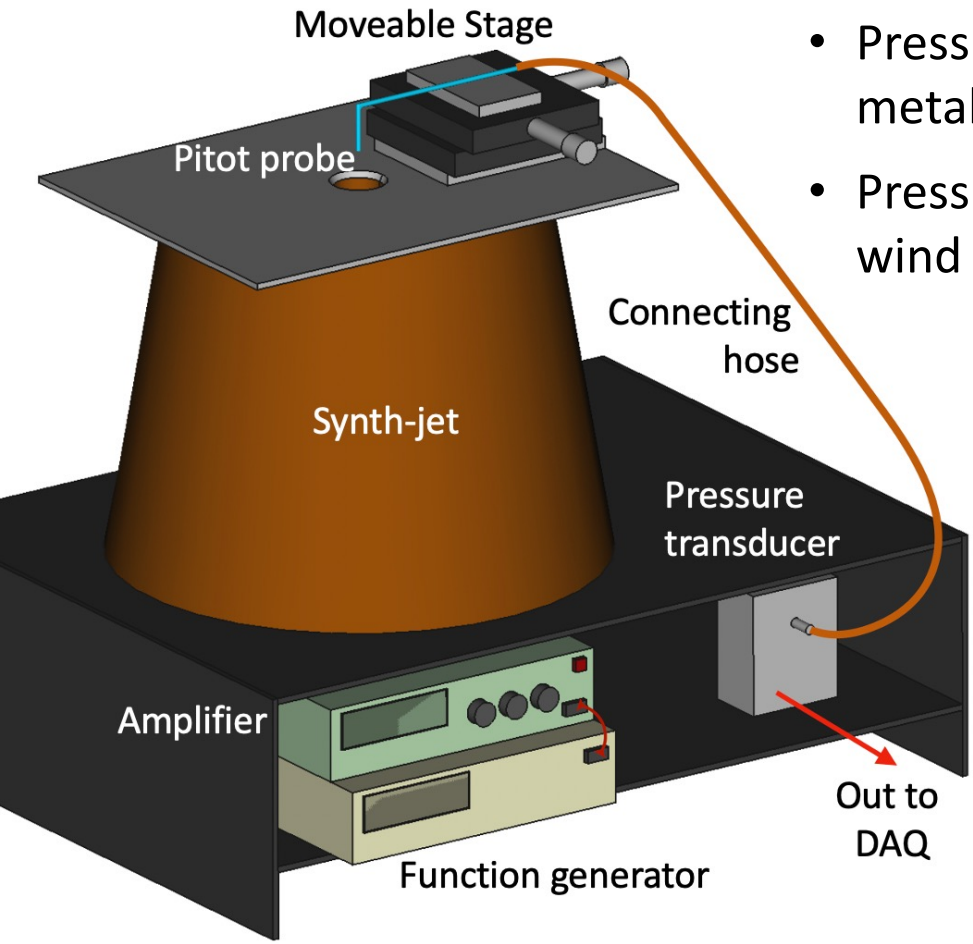
- Built a robust test rig that samples pressure data at different locations across synth-jet outlet
- Performed experiments and data analysis to characterize the velocity profile and frequency response of the system

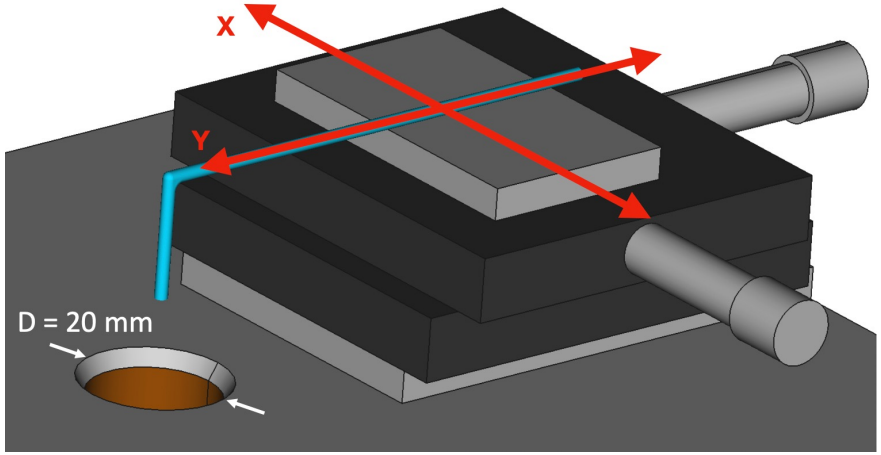




Experimental Setup

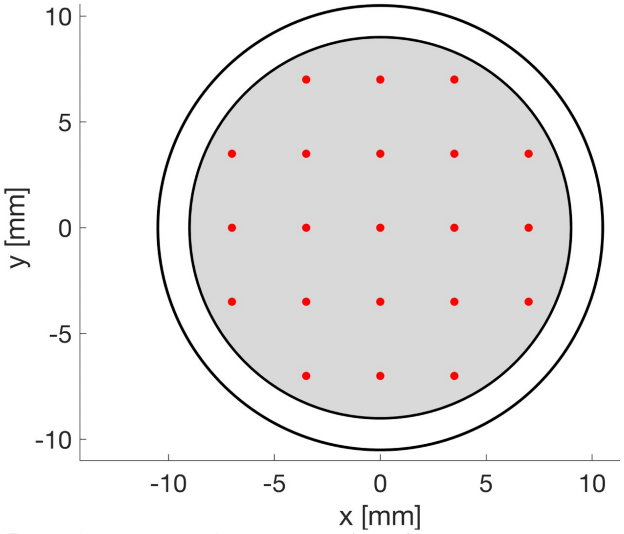
- Interfaces with existing DAQ for data collection
- Precise positioning of Pitot probe in 2D plane
- Pressure transducer shielded from speaker by metallic shelf to minimize EMF interference
- Pressure transducer and probe calibrated using wind tunnel, linear fit MSE is 0.344 Pa^2

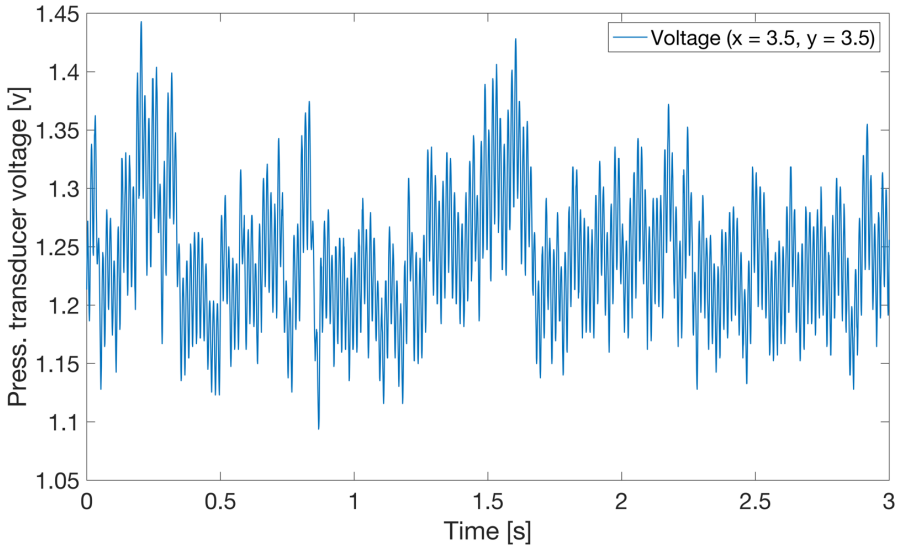


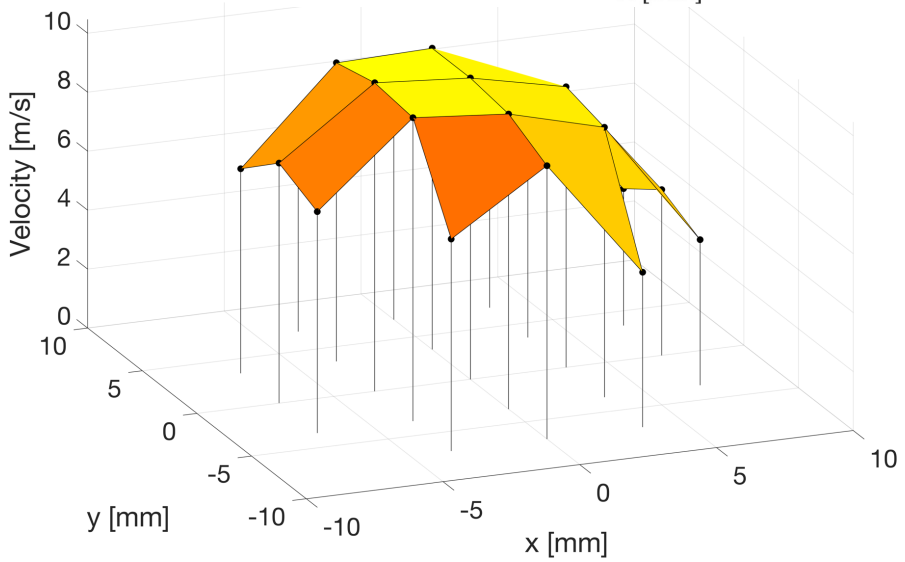


Experiment 1: Velocity Profile

- Synth-jet driven at constant 70 Hz
- Pressure sampled at 21 locations (F_S = 1kHz, N = 10k)
- Pressure varies sinusoidally with time at driving frequency of jet speaker
- Velocity related to pressure at each location using Bernoulli's equation

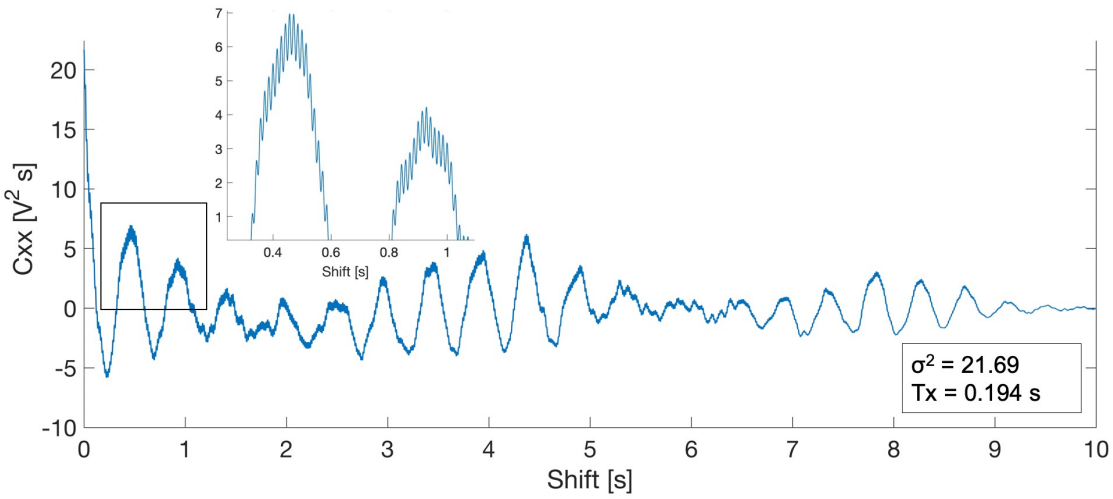


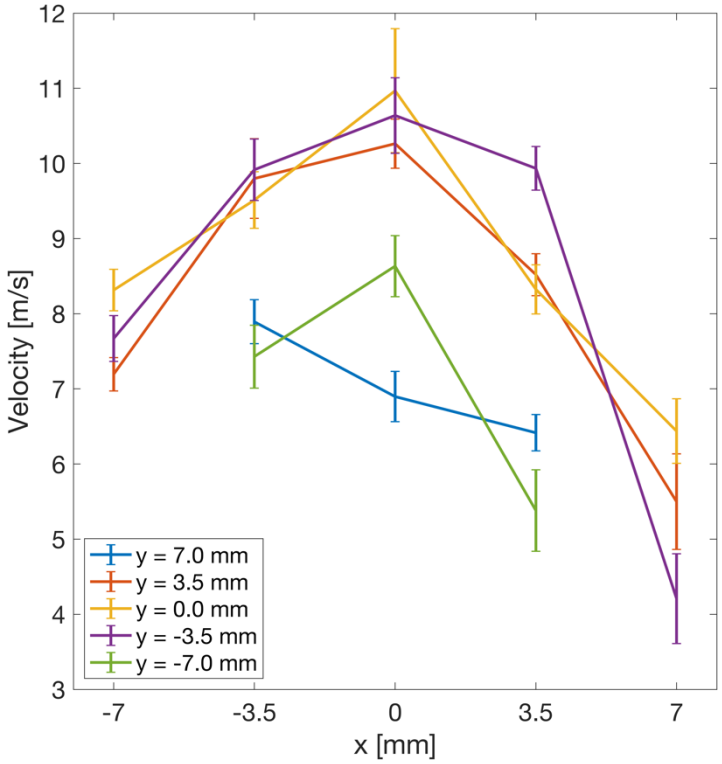




Experiment 1: Velocity Profile

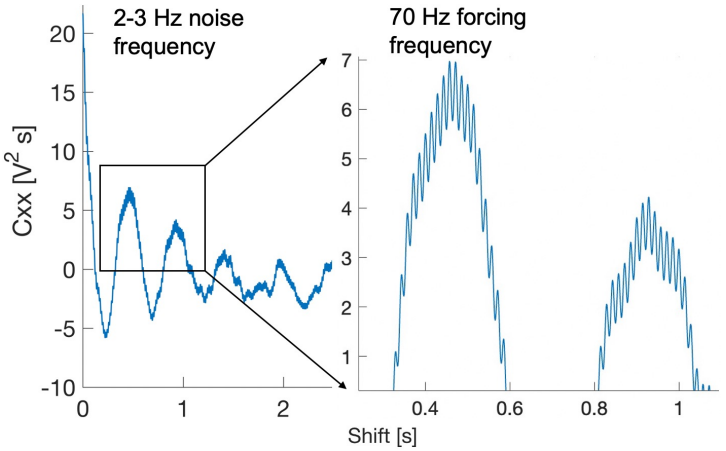
- Auto-covariance yields Tx = 0.19 s using full set of 10000 datapoints
- For good statistics, sample every 500 points to avoid correlated data
- Uncertainty bars reflect 95% confidence on mean estimates
- Mean velocity accurate to within +/- 1 m/s
- Strong 2 Hz background frequency detected in addition to 70 Hz driving frequency

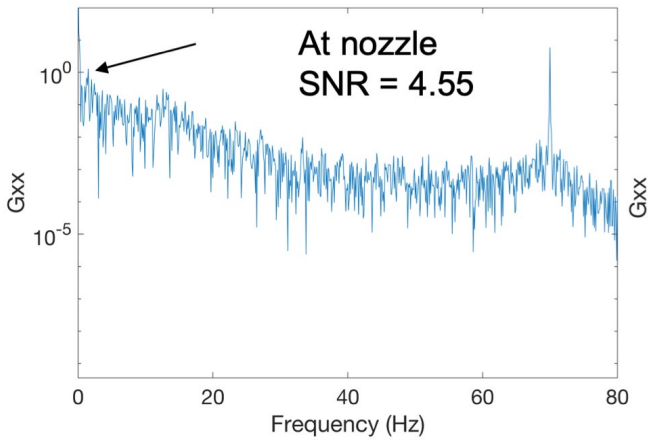


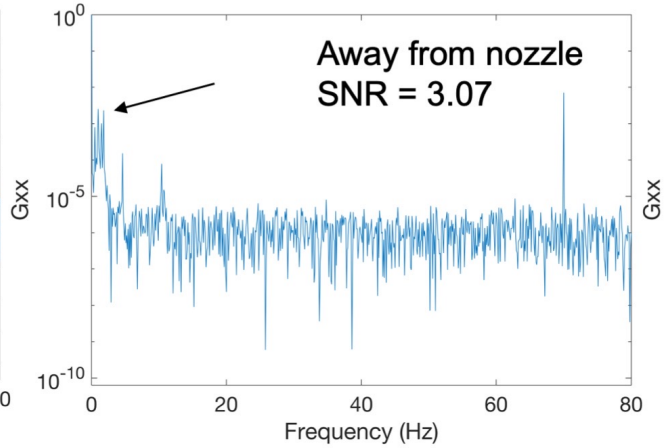


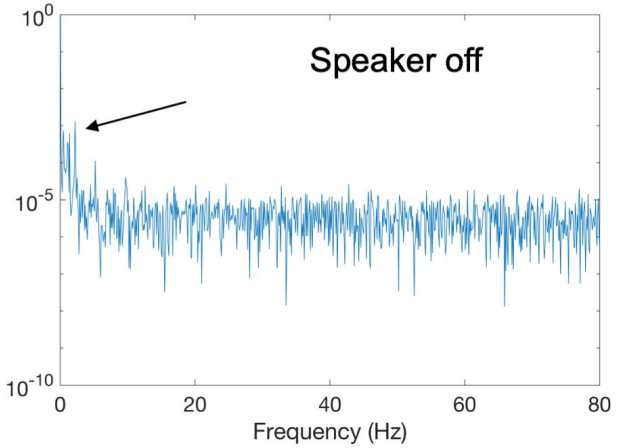
Background Noise in Data

- 2-3 Hz noise frequency was detected after FFT, signal-noise ratio at nozzle center is 4.55
- Repeated experiment with Pitot probe held away from jet outlet, signal-noise ratio is 3.07
- Suspected LabView could be sampling in bursts, but analysis of timestamps disproved this
- Source of noise remains a mystery for now



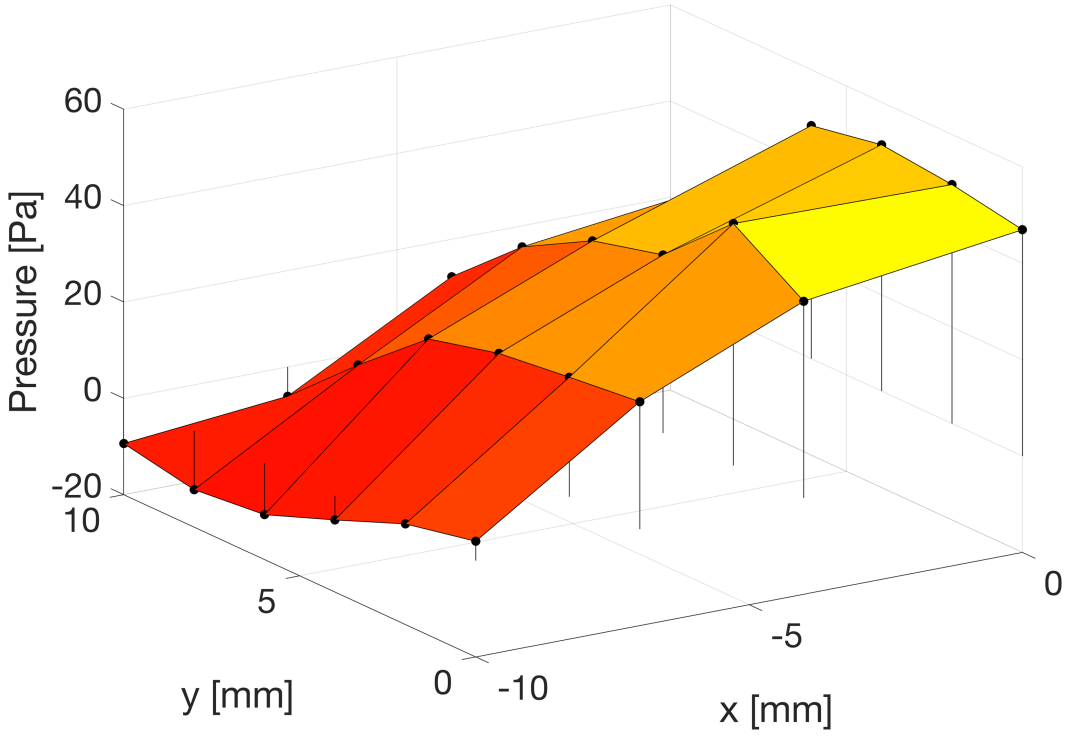


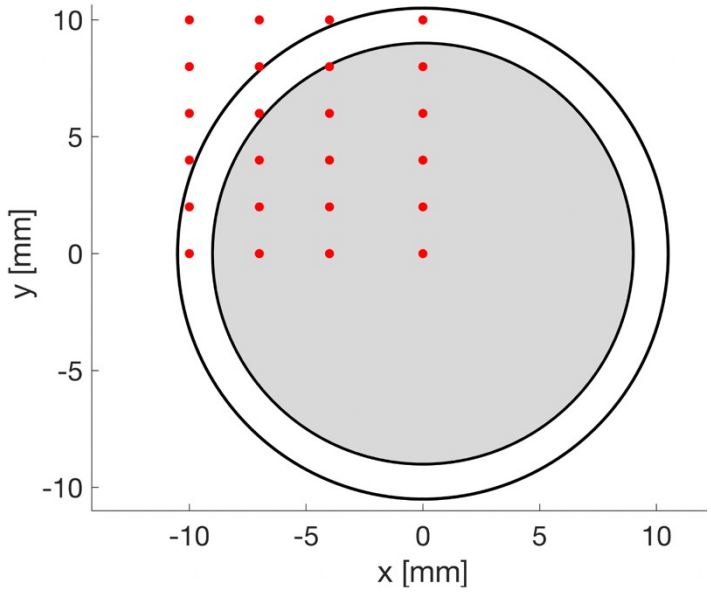




Experiment 2: Pressure Distribution

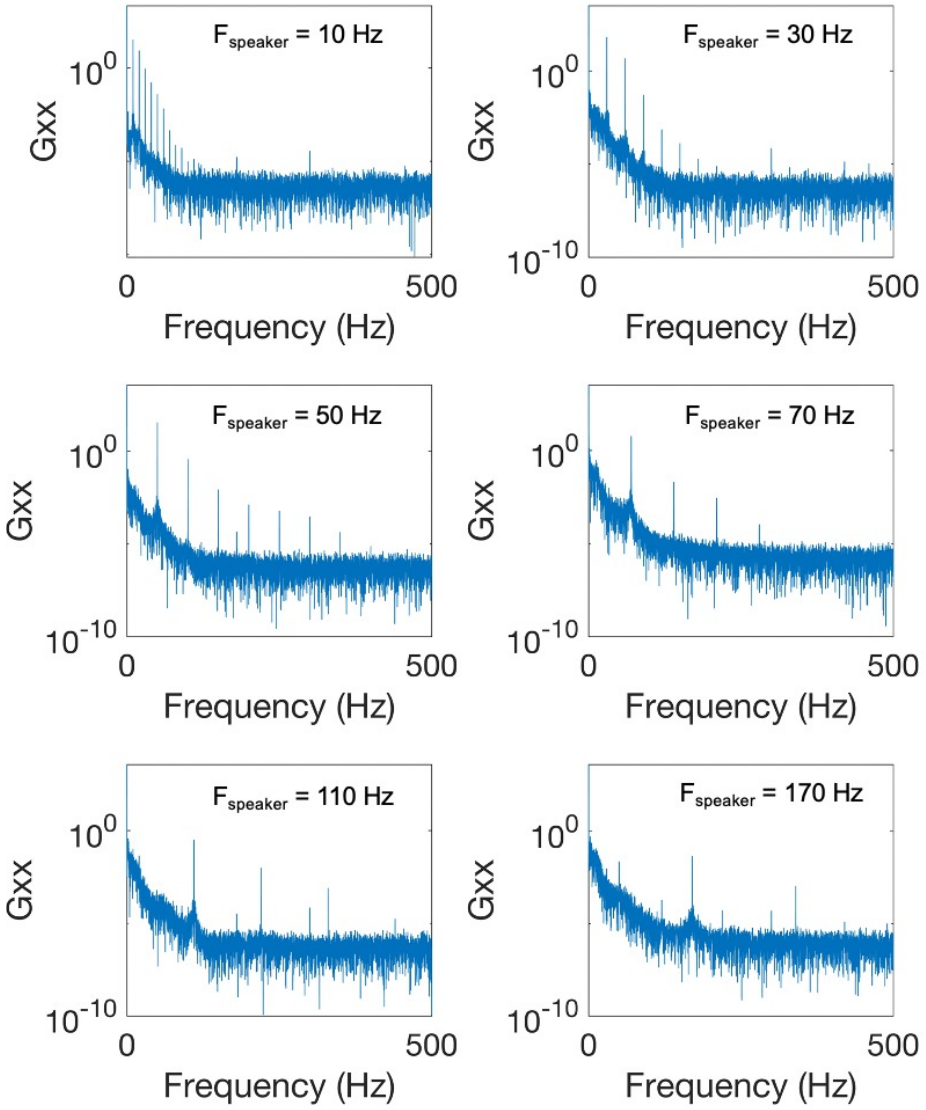
- Synth-jet driven at constant 70 Hz
- Pressure sampled at 24 locations (F_S = 1kHz, N = 10k)
- Region of negative pressure detected at the corner of outlet potentially due presence of significant velocity component not directed at Pitot tube, causing a drop in local pressure





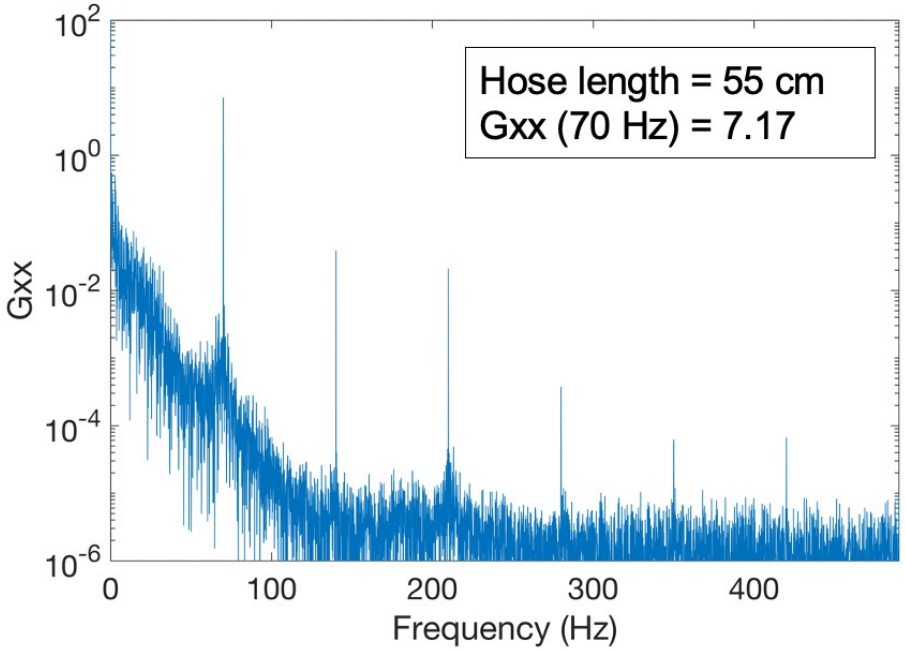
Experiment 3: Frequency Analysis

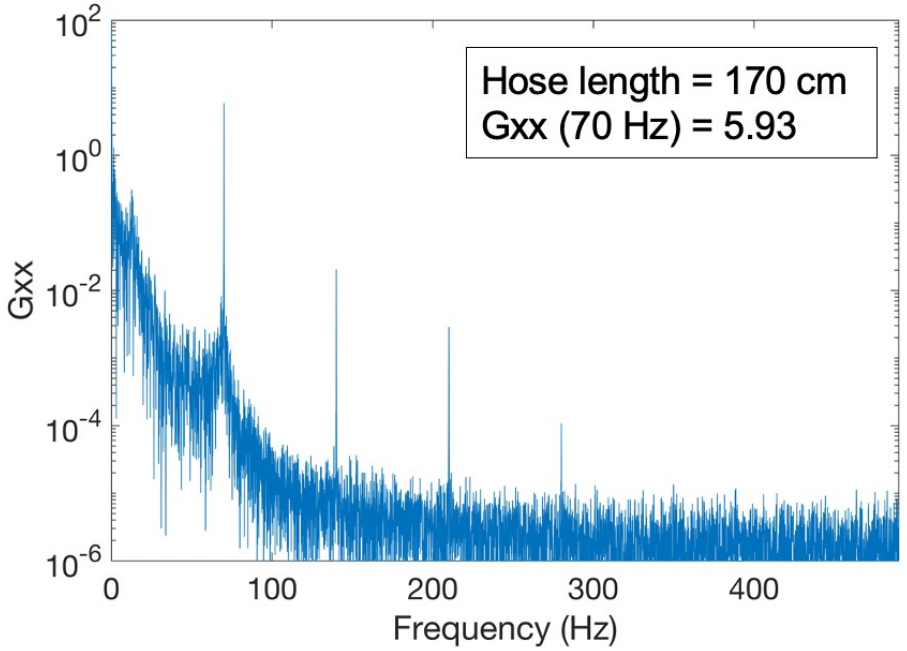
- Synth-jet driven at 6 frequencies ranging from 10 Hz to 170 Hz
- FFT of time-series signal computed, and power spectrum peaks are extracted
- System has a dominant peak at the speaker driving frequency
- Harmonics are integer multiples of the driving frequency
- Power of harmonics diminishes with increasing frequency



Experiment 4: Viscous Damping

- Synth-jet driven at constant 70 Hz
- Used two different connecting hose lengths (55 cm and 170 cm)
- FFT of time-series data computed to obtain power spectrum
- Amplitude of dominant peak and harmonics decrease with increasing hose length
- Amplitude attenuation attributed to effect of viscous damping within hose

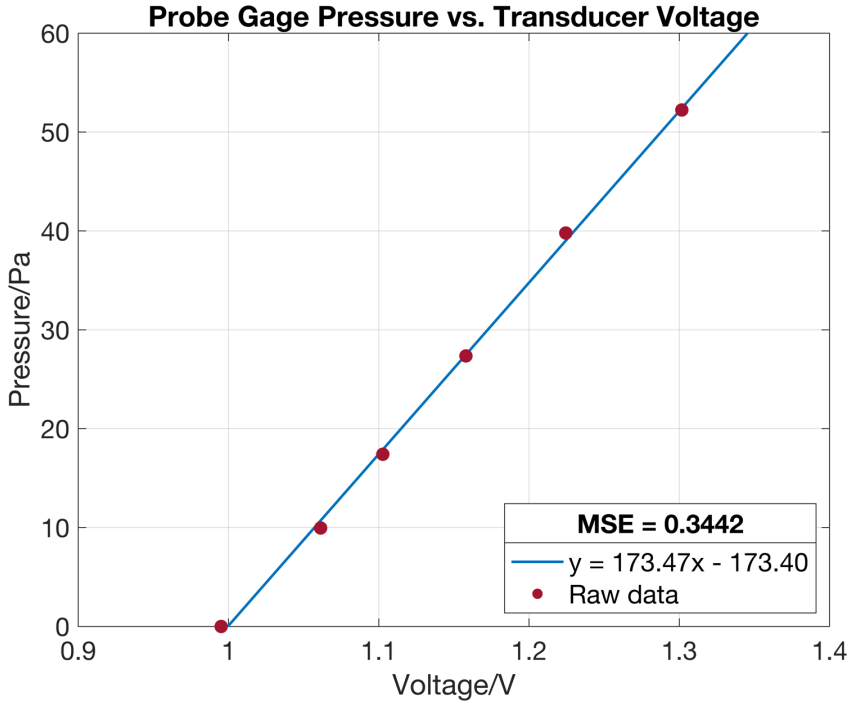




Thank You
Any Questions?

Appx. 1: Calibration of Pressure Transducer

- Kiel probe and pressure transducer calibrated using wind tunnel
- 6 different wind tunnel velocities used ranging from 0 to 9.2 m/s
- Calibration curve MSE is 0.344 Pa^2

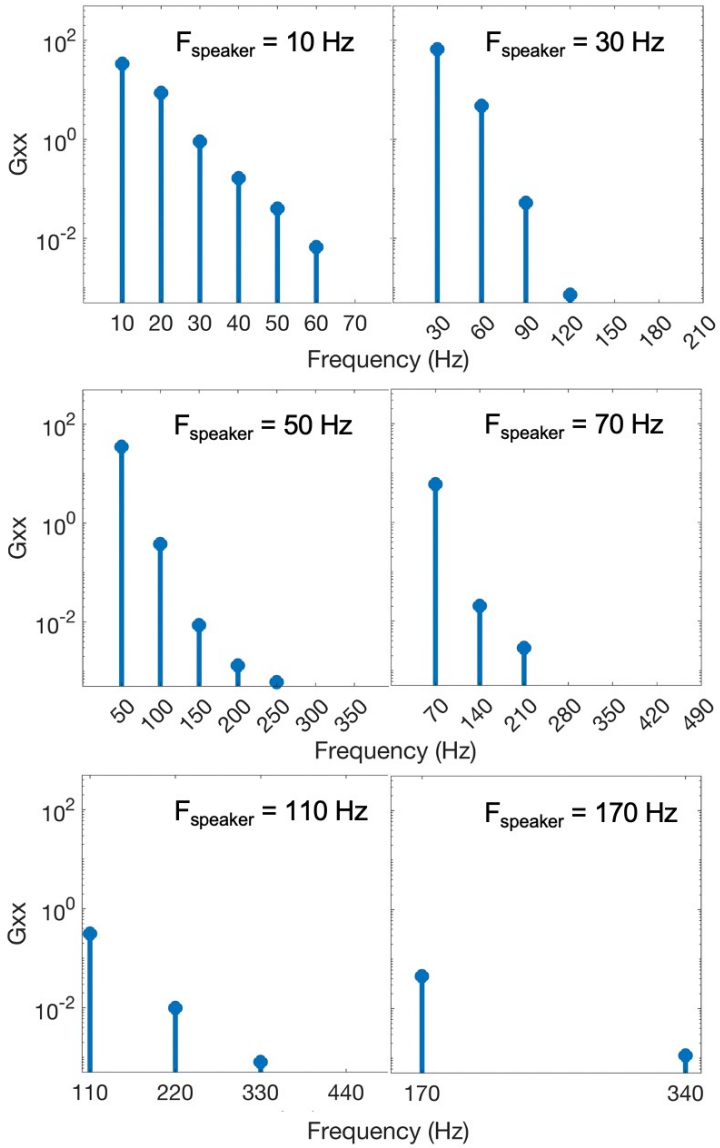


Appx. 2: LabView Timestamps

- It was suspected that the 2 Hz background frequency was an artifact of the data collection process
- Background process could be interrupting data collection
- Regular timestamp intervals provided by LabView suggest that this is not the case

Time [s]	Voltage [V]
0.000000	0.983887
0.001000	0.981445
0.002000	0.983887
0.003000	0.981445
0.004000	0.983887
0.005000	0.986328
0.006000	0.988770
0.007000	0.986328
0.008000	0.988770
0.009000	0.986328
0.010000	0.986328
0.011000	0.983887
0.012000	0.981445
0.013000	0.986328
0.014000	0.981445
0.015000	0.983887

Appx. 3: Extracted Peaks Freq. Analysis



Appx. 3: Extracted Peaks Viscous Damping