



Final Master's project advised by Jiri Tichy on architectural acoustics

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Acoustics Virtually Everywhere
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Penn State M.S. Project

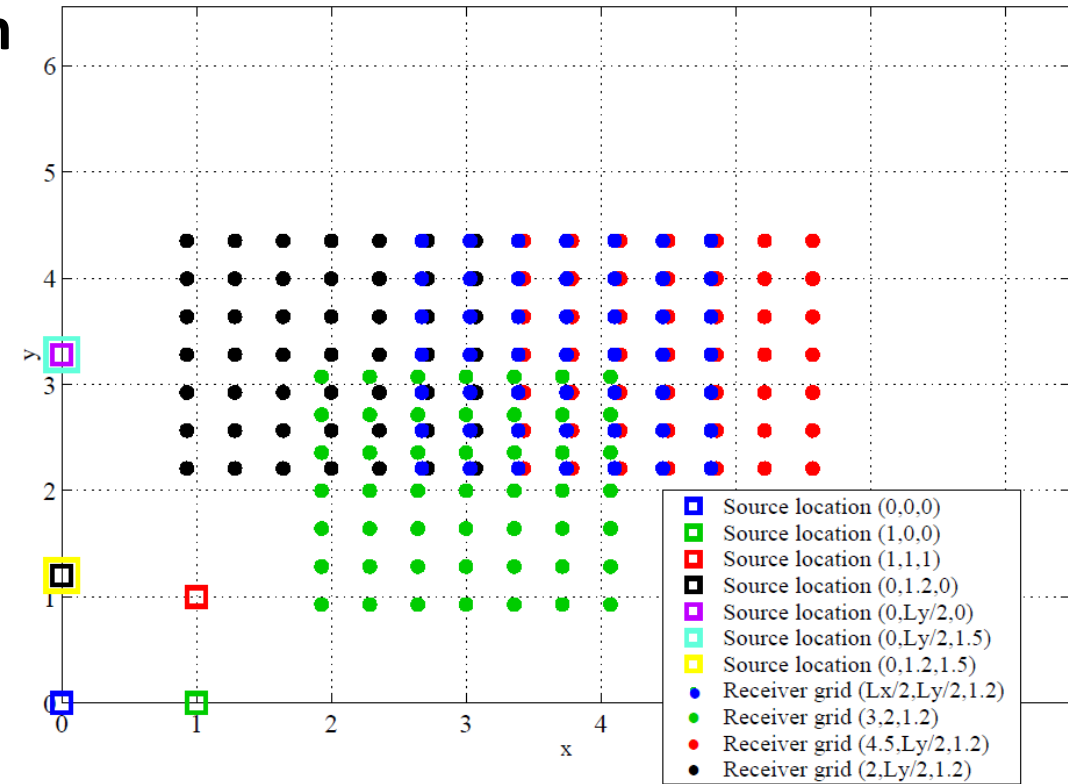


- **Conducted in 2001-2003**
- **Computational study in architectural acoustics**
 - Examined the effect of constant sound power radiation from a loudspeaker on the sound field variability with frequency in a small room
- **Research was funded by the Applied Research Lab at Penn State**

Low-frequency Sound Pressure Variability



- **Examine low-frequency sound field in a small room ($V \approx 150 \text{ m}^3$) through computational studies**
- **Obtain smoother frequency response**
 - Frequency range 20 – 80 Hz
 - Investigate constant sound power radiation effects
 - Based on data from the source
- **Investigate effects of absorption, source position, and receiver position**
 - $\delta_N/c = 0.0075, 0.015, 0.03$
 - Seven point source locations
 - Four receiver grid locations



Constant Sound Power Radiation Theory



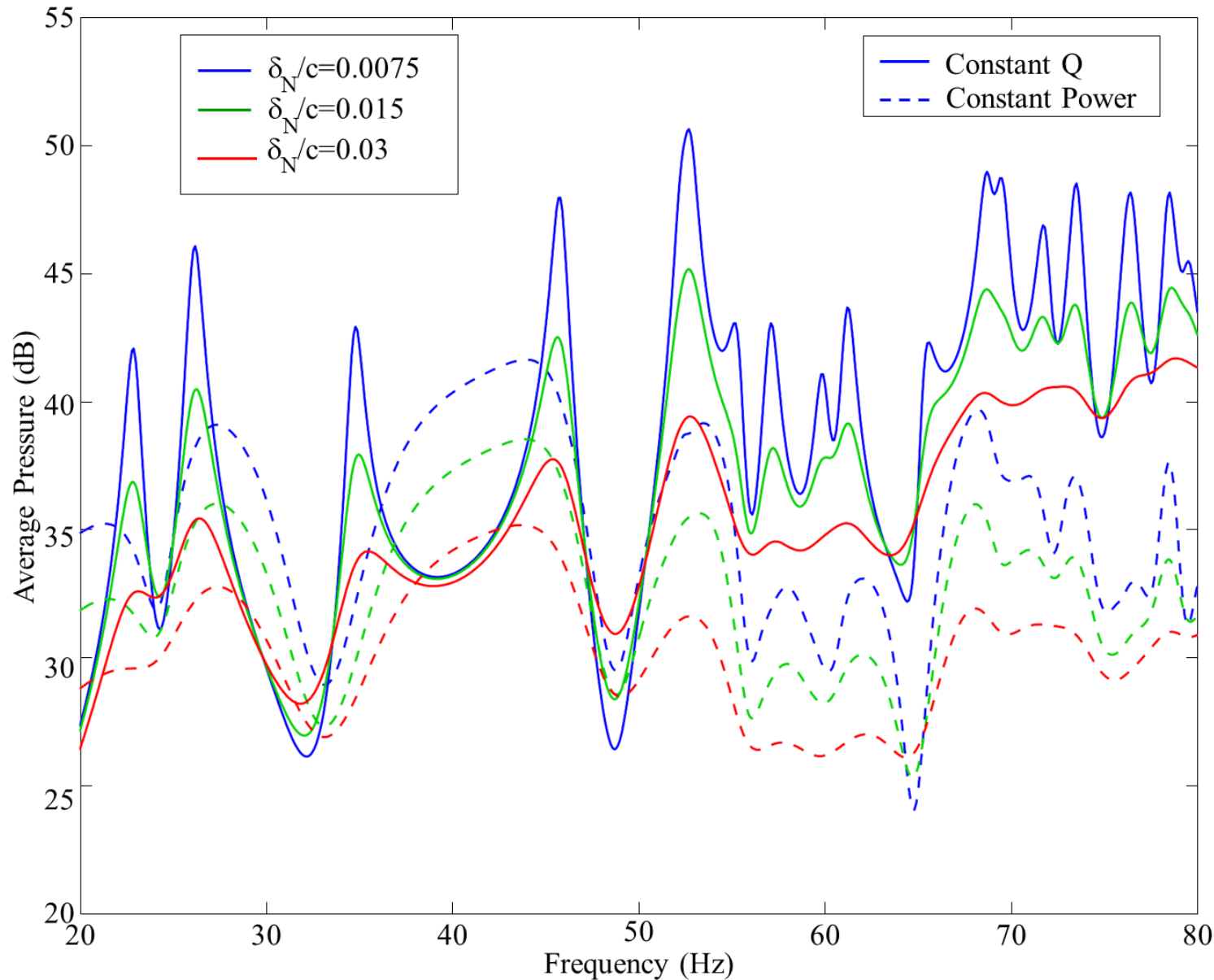
- For constant sound power output

$$P = \frac{1}{2} \operatorname{Re}\{Z_{rad}\} Q^2 = P_0$$
$$Q^2 = \frac{2P_0}{\operatorname{Re}\{Z_{rad}\}}$$

- Substitute expression for Q into pressure equation

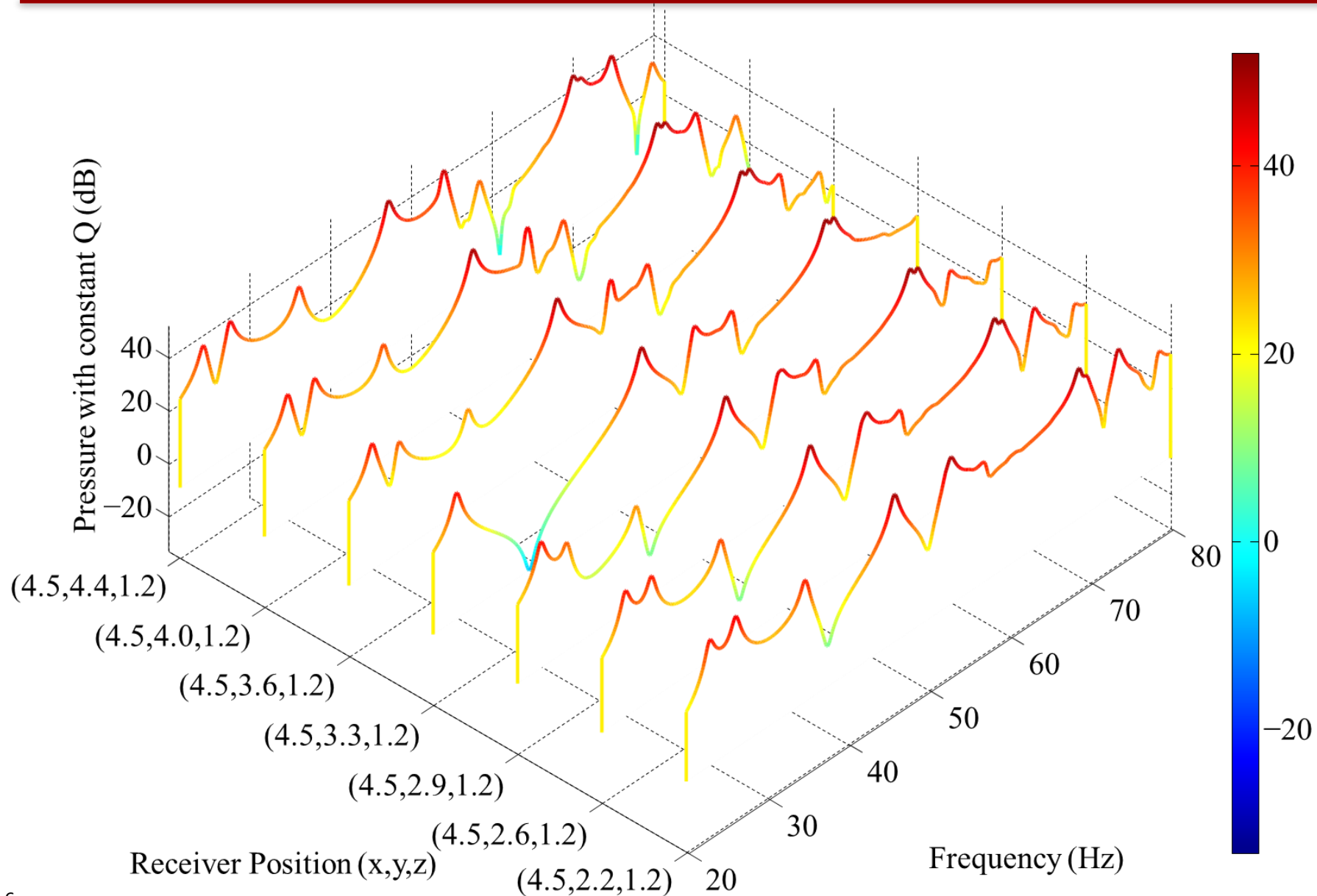
$$p(r, \omega) = -\frac{j\omega\rho_0}{V} \sqrt{\frac{2P_0}{\operatorname{Re}\{Z_{rad}\}}} \sum_N \frac{\varphi_N(r)\varphi_N(r_0)\varepsilon_N}{k^2 - k_N^2 - j2k_N\delta_N/c}$$

Damping Term Comparison



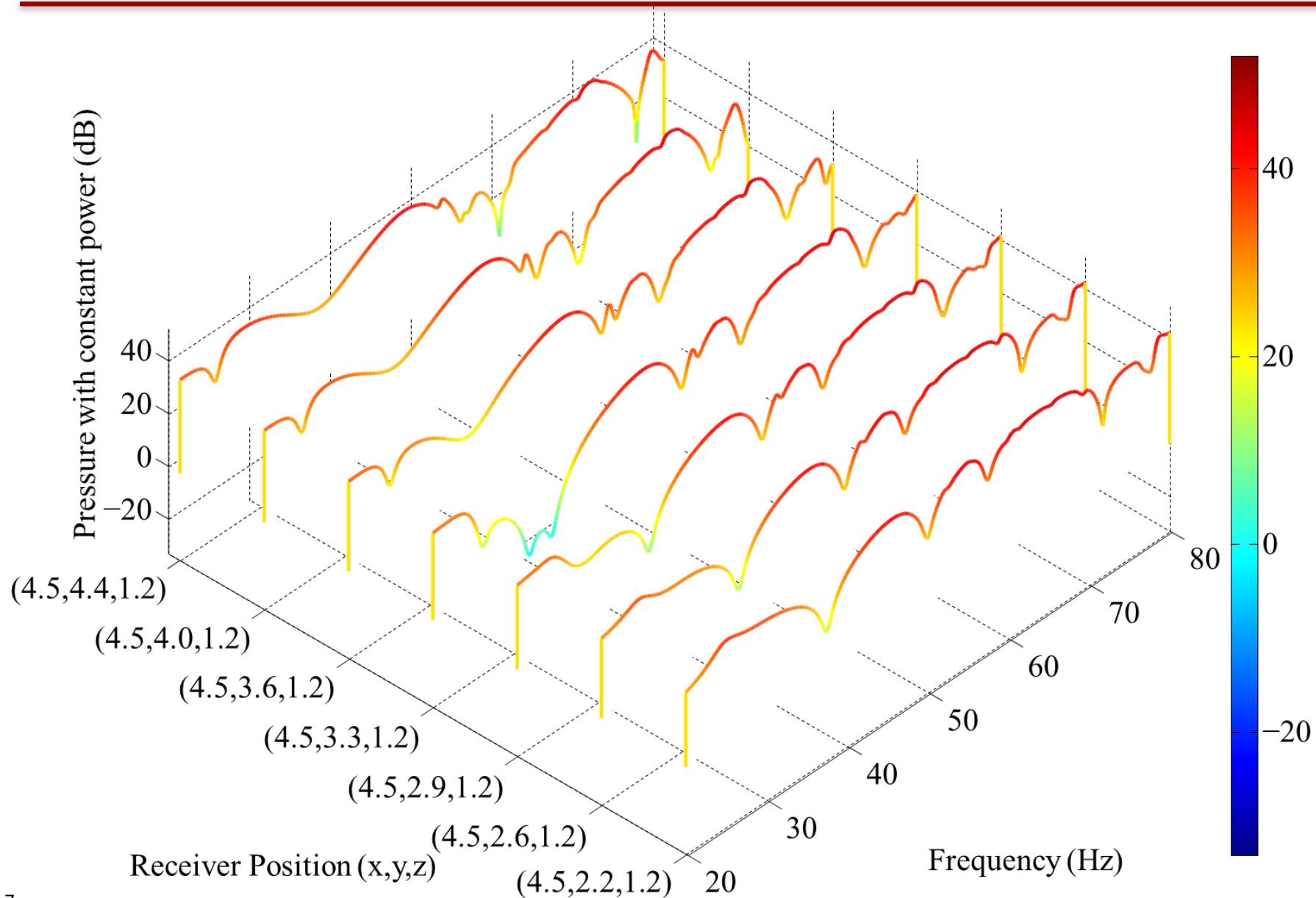
➤ **Source (0 ,0, 0)**
Receiver Grid (3, 2, 1.2)

Constant Volume Velocity



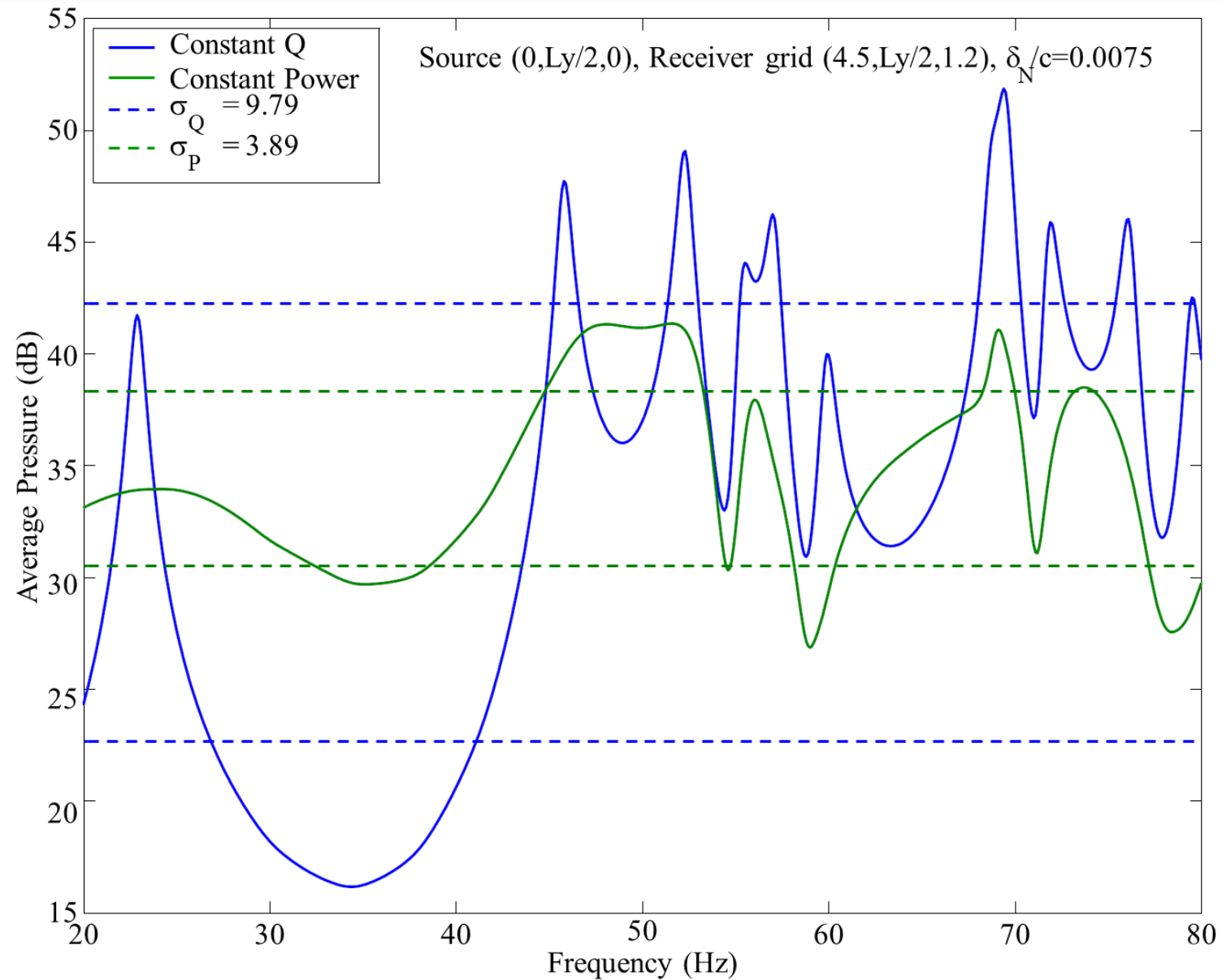
➤ **Source (0, 1.2, 1.5)**
 $\delta_N/c = 0.0075$

Constant Power



➤ **Source (0, 1.2, 1.5)**
 $\delta_N/c = 0.0075$

Standard Deviation



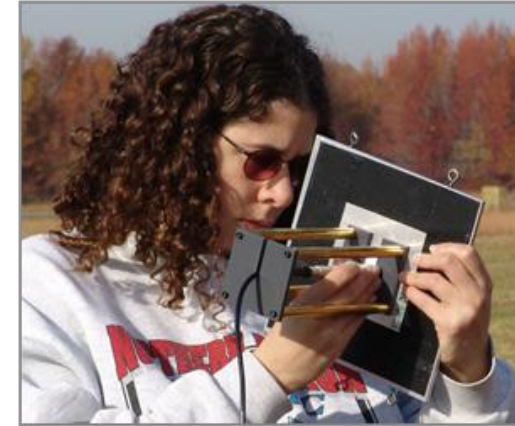
- **Most improvement due to constant power when σ_Q is high**
- **Frequency responses with constant Q**
 - High peaks
 - Large dips
 - Rising trend with frequency
- **Constant sound power radiation yields a smoother frequency response**
 - 3 dB average reduction in standard deviation
- **Completed work was presented at ASA meeting in 2003 and documented in M.S. thesis**
 - A. Loubeau and J. Tichy. Improvement of low frequency sound variability in a small enclosure by use of a source with frequency-independent radiated power. J. Acoust. Soc. Am., 114(4): 2315, 2003.
 - A. Loubeau. Reduction of low frequency sound pressure variability in a small enclosure by use of a source with frequency-independent radiated power. M.S. Thesis in Acoustics, The Pennsylvania State University, 2003.
- **Acoustics of Small Rooms book**
 - M. Kleiner and J. Tichy. Acoustics of small rooms. CRC Press, 2014.

Reflections and Following Work



➤ Explosion Noise – Ph.D. Penn State (Victor Sparrow)

- Numerical model for propagation of blast waves
- High-frequency measurements of blast wave propagation with comparisons to model predictions



➤ Sonic Booms – Postdoc IJLRDA (François Coulouvrat)

- Numerical model of sonic boom propagation for hypersonic aircraft
- Meteorological effects on sonic booms



➤ Sonic Booms – NASA Langley Research Center

- Human response in indoor spaces
- X-59 community testing to support the development of a new noise-based rule for supersonic flight
- Key data will be gathered on public perception of quiet supersonic flights in several cities across U.S.

