

TRL 3 — Analytical and Experimental Proof of Concept

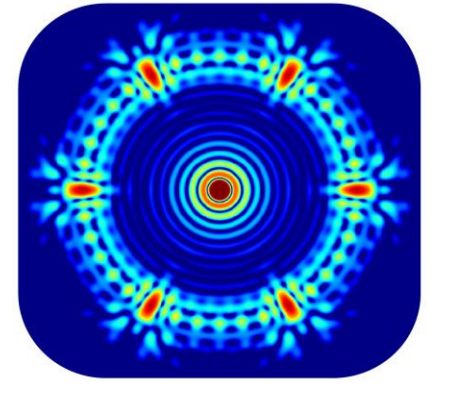
- The acoustic unit-cell concept has been defined using established resonator, damping, and microperforated-panel physics.
- COMSOL simulations predict measurable resonant behavior near the 500 Hz design target.
- Physical prototypes have been fabricated and evaluated in laboratory impedance-tube and grazing-flow experiments.
- Testing demonstrates measurable configuration-dependent acoustic behavior.
- The current experiments establish feasibility, but do not yet constitute standardized component validation in a controlled, mission-representative environment.

# Acoustic Metamaterial Composite Panel (AMP) for Spacecraft Noise Suppression



Meghan Cephus, Ezekiel Anguiano, Sergio Cantu, and Jingfei Liu  
 Department of Mechanical Engineering  
 Texas Tech University

Biomedical Acoustics  
 RESEARCH LAB



## Abstract

This project proposes a passive Acoustic Metamaterial Panel (AMP) to decrease ECLSS noise in spacecraft habitats. The sandwich composite design combines a resonator/metamaterial layer, rubber damping layer, and aluminum backing layer to target low-to-mid frequency noise without an added power demand. The current proof-of-concept focuses on 500 Hz, with COMSOL predicting resonance near 510 Hz and impedance tube testing showing resonance around 511–514 Hz. The close agreement supports the AMP as a compact, modular, and effective noise-reduction concept for future lunar and Mars missions.

## Introduction

The Human Lander supports Artemis missions and depends on the Environmental Control and Life Support System (ECLSS) to maintain a safe and habitable environment. However, ECLSS components such as fans, pumps, compressors, and ventilation ducts can create continuous background noise in the habitat. This noise can negatively affect crew comfort, communication, concentration, and quality of sleep during long-duration missions. Because spacecraft systems are limited by mass, power, and space, a compact and efficient noise-reduction solution is needed.

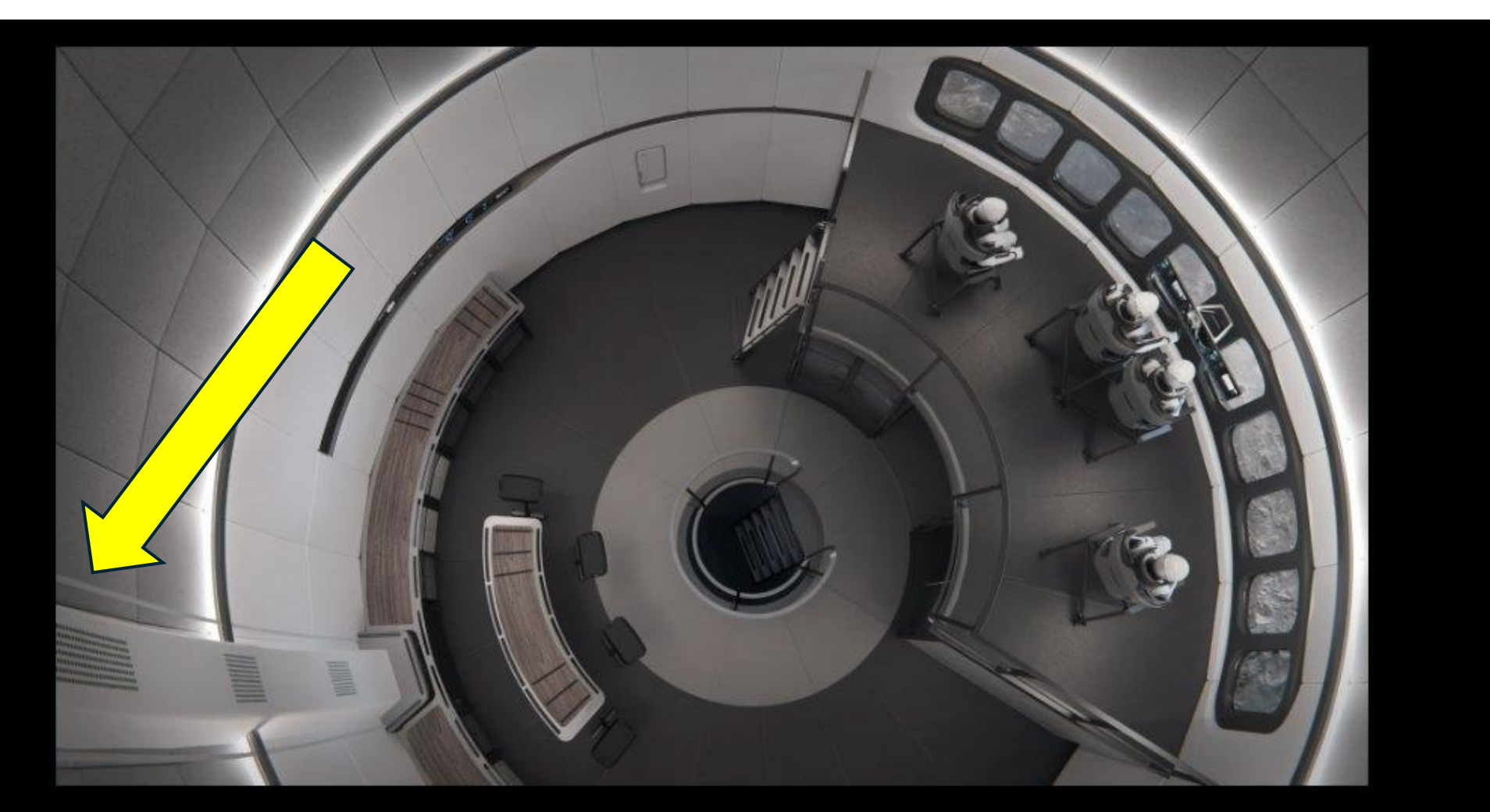


Figure 1. Human Lander interior view  
 Source: SpaceX, *To the Moon and Beyond*, 2025.

## Methodology

- Identify Target Frequency**
  - ECLSS-related noise bands were researched
  - 500 Hz was selected as the proof-of-concept target.
- Design AMP Prototype**
  - Resonator/metamaterial geometry was designed to target 500 Hz.
  - Layered structure combines resonator body, rubber damping layer, and aluminum backing plate.
- Simulate in COMSOL**
  - Frequency-domain acoustic simulation was used to predict resonance behavior.

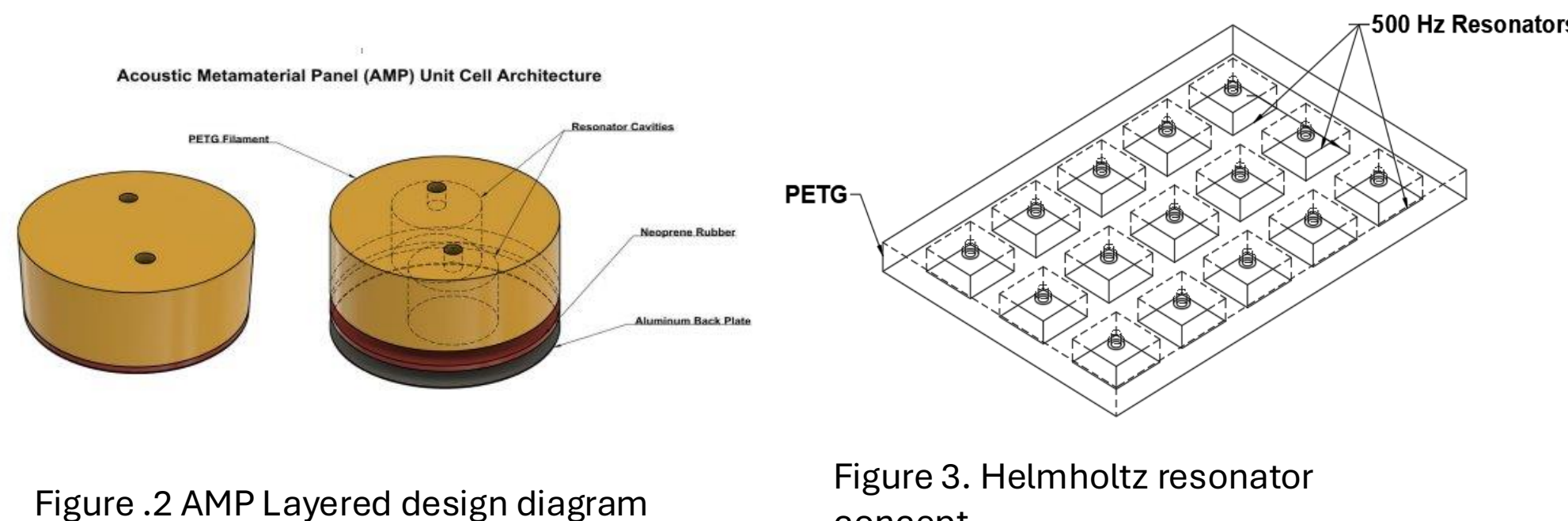


Figure 2. AMP Layered design diagram  
 Figure 3. Helmholtz resonator concept

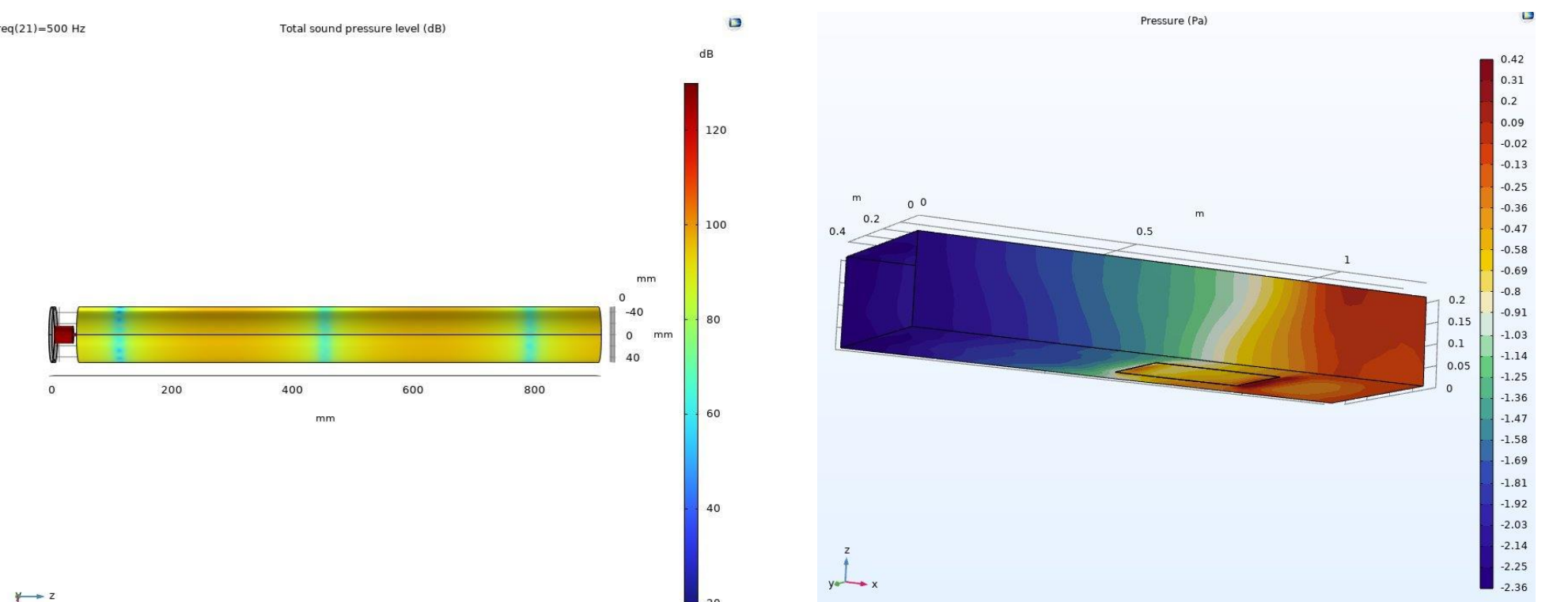


Figure 4: COMSOL Impedence pipe simulation  
 Figure 5: COMSOL grazing duct simulation

- Validate Experimentally**
  - Prototype was tested using a custom impedance tube.
  - Results were compared to COMSOL predictions.

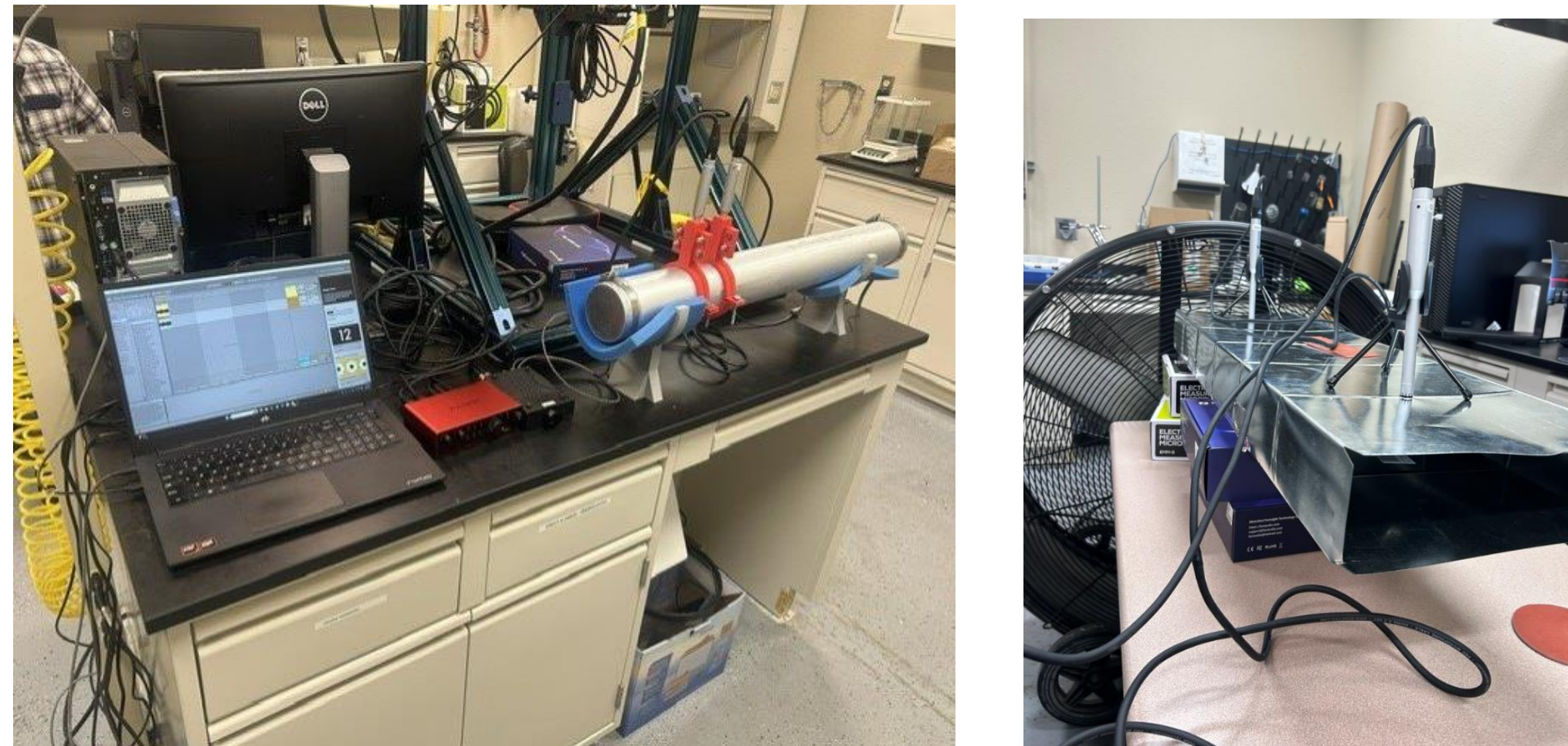


Figure 6. Impedance test setup  
 Figure 7. Grazing Flow Test set up

## Results

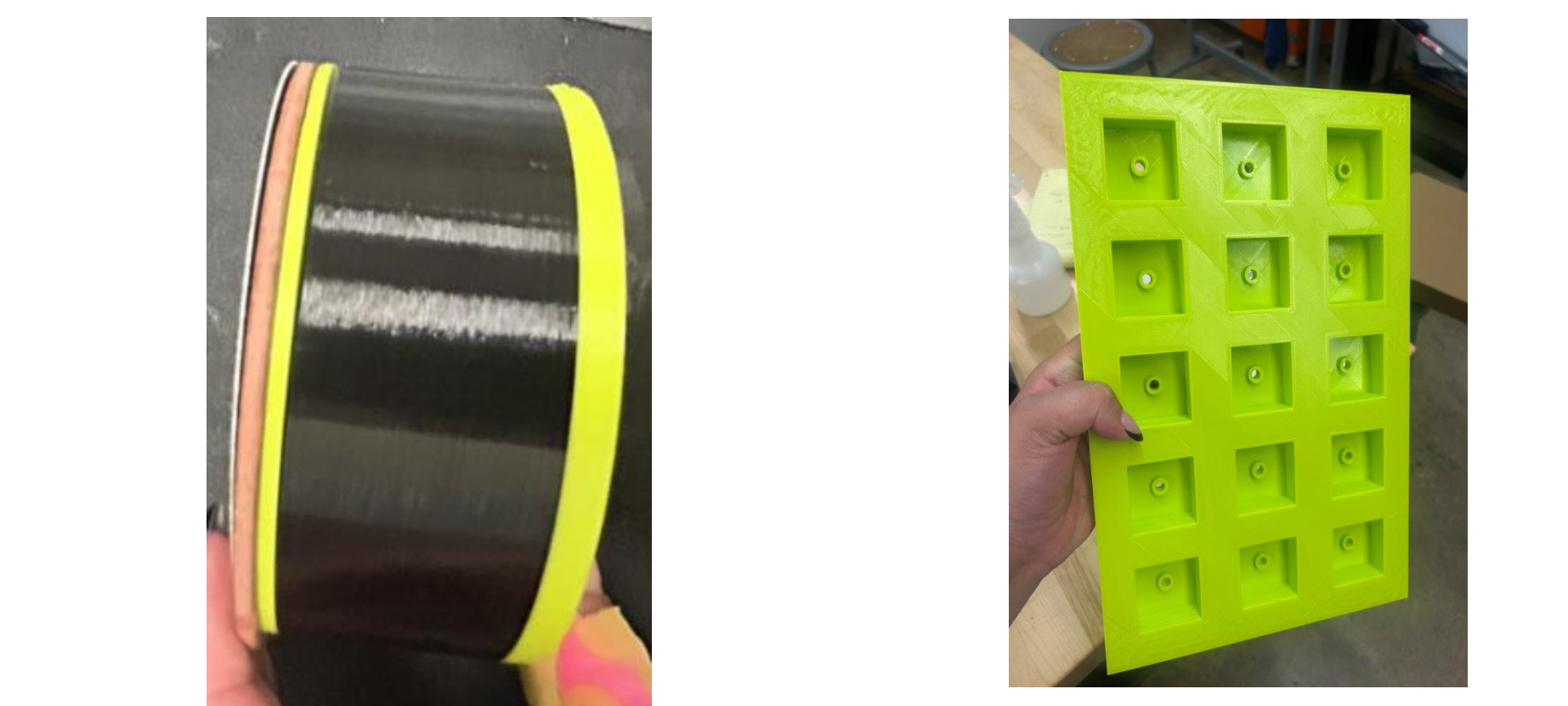


Figure 5: Assembled layered resonator puck  
 Figure 6: 500hz resonator layer

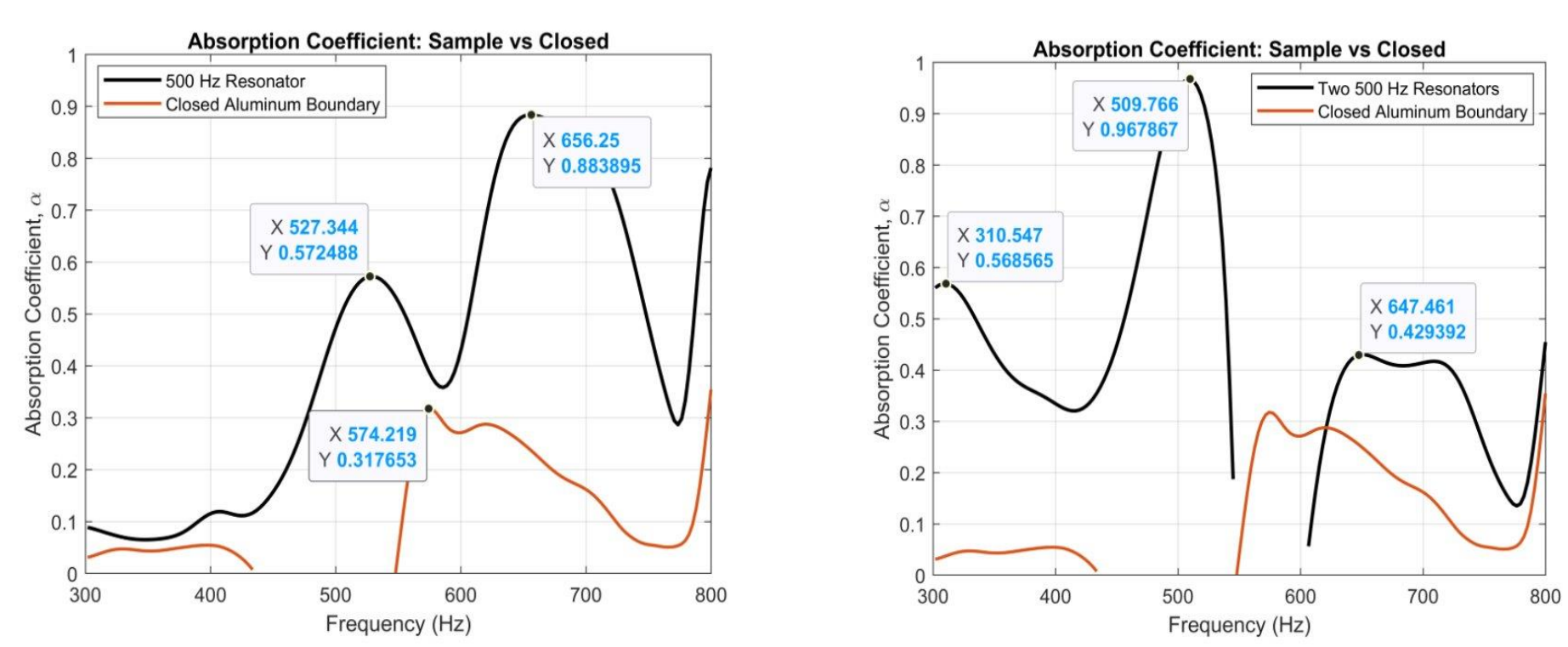


Figure 7: Absorption 500hz  
 Figure 8: Absorption with 2 500Hz resonators

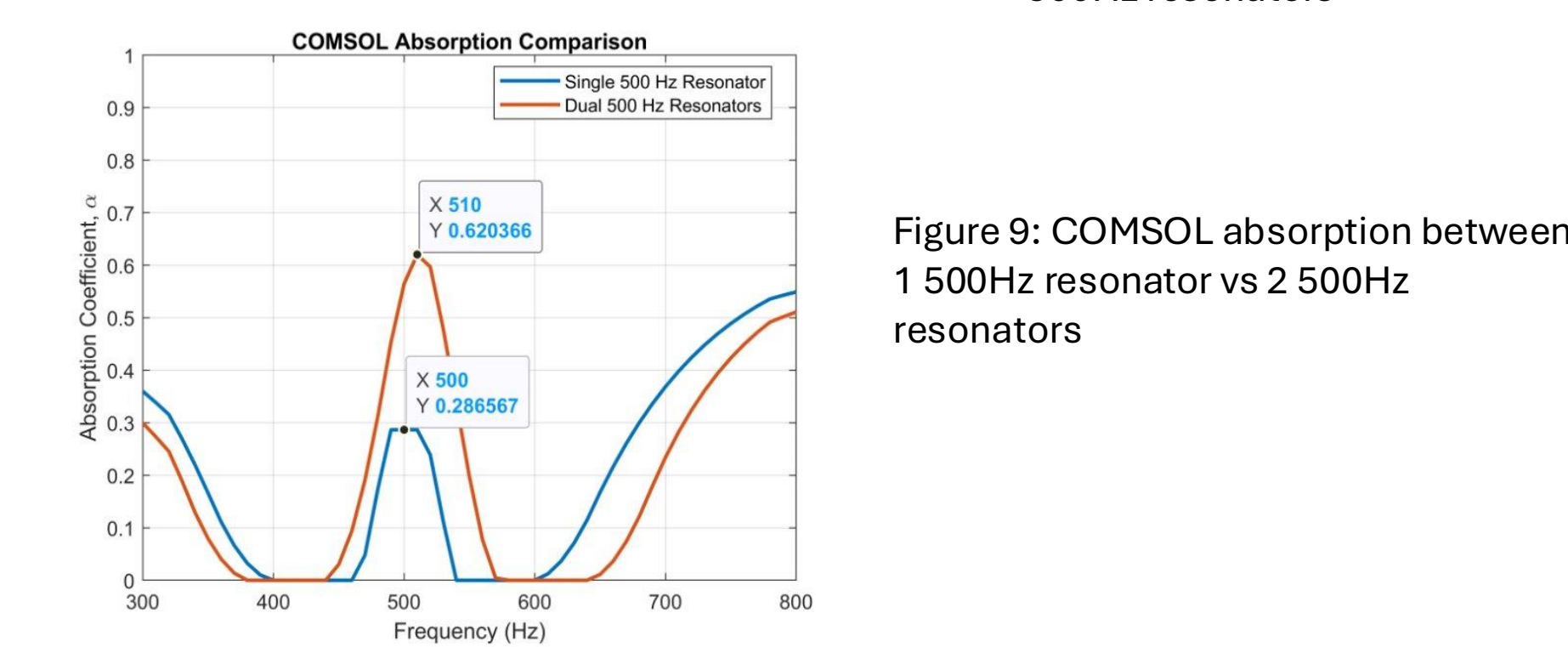


Figure 9: COMSOL absorption between 1 500Hz resonator vs 2 500Hz resonators

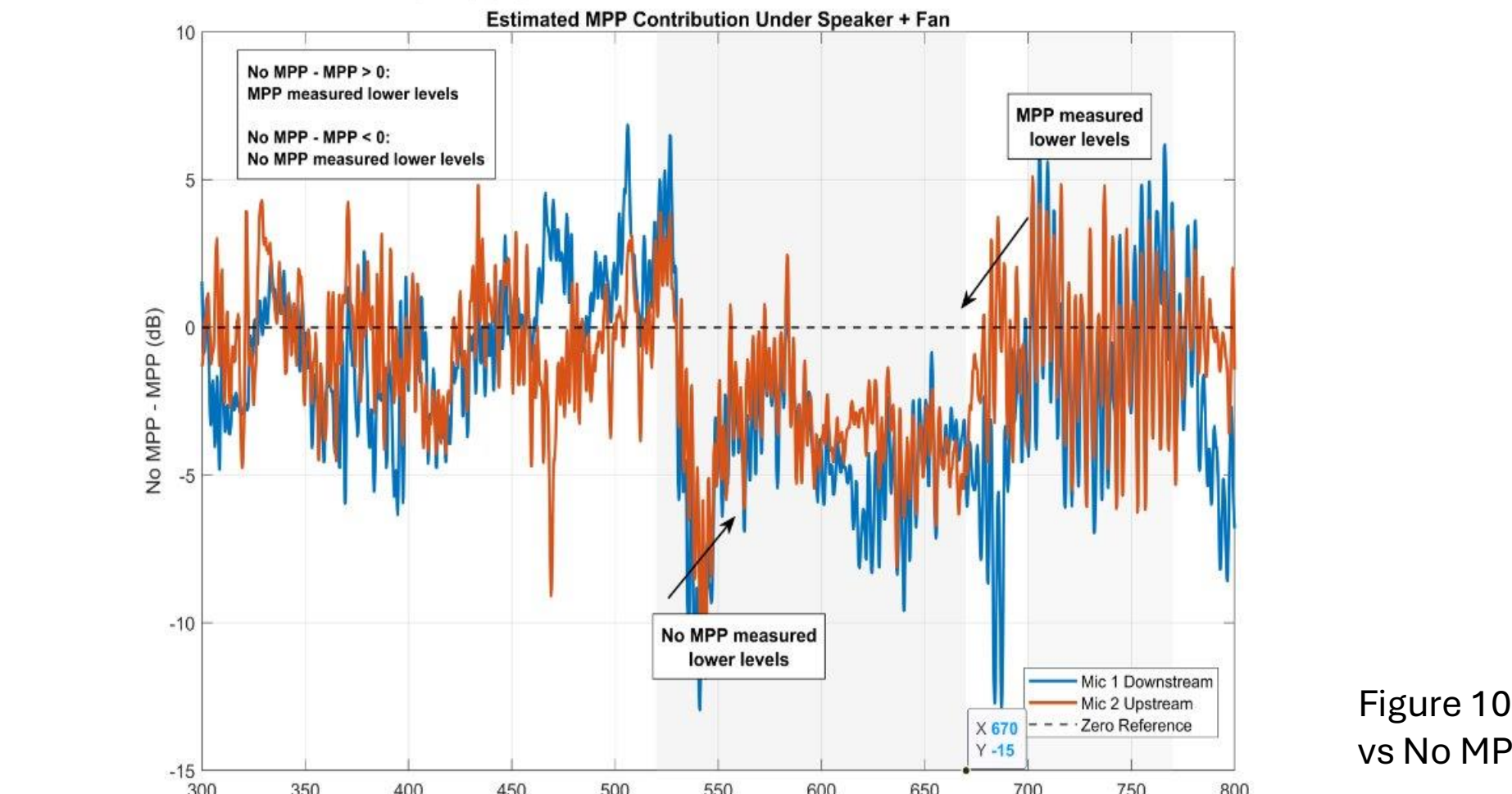


Figure 10: MPP vs No MPP

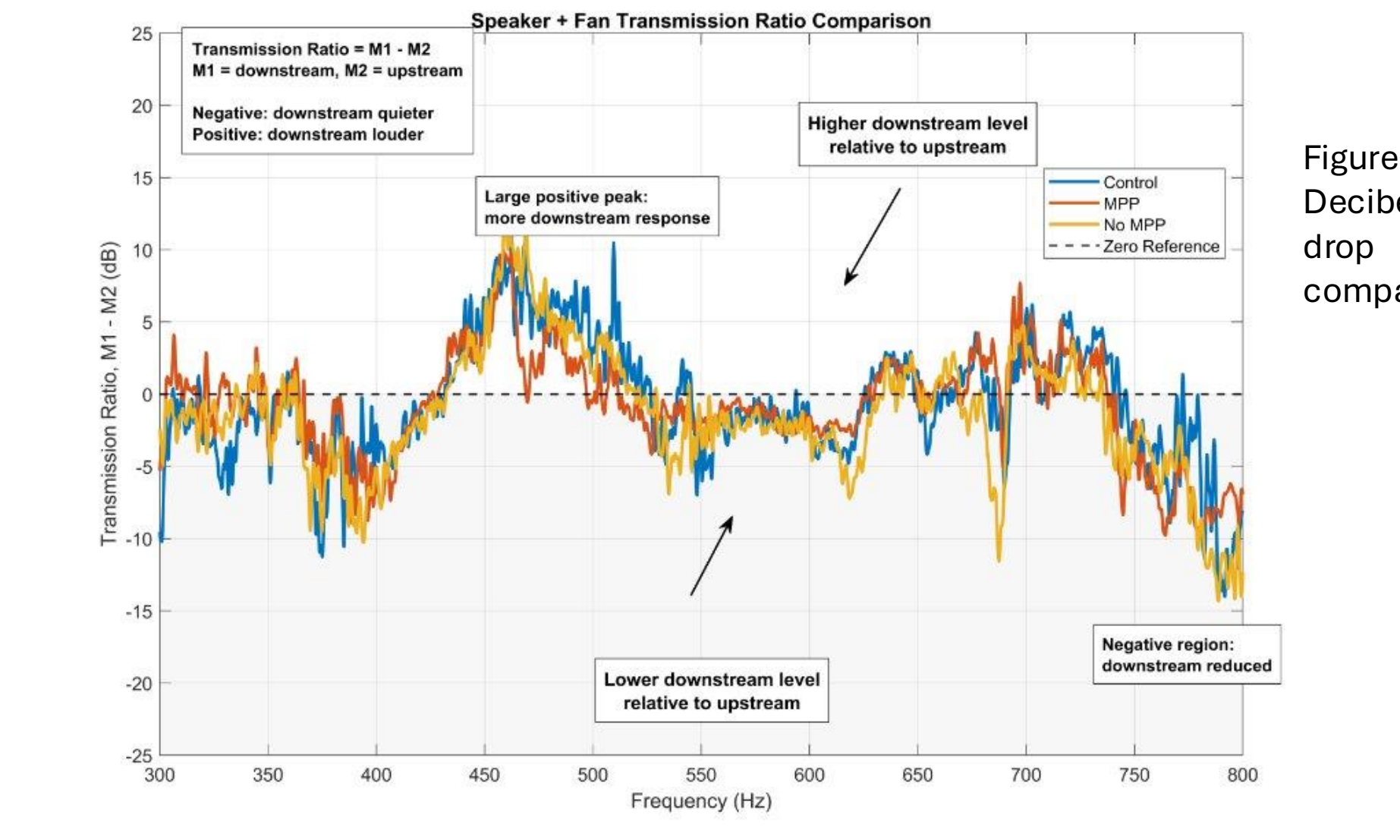


Figure 11: Decibel drop comparison

## Conclusion

- AMP showed strong simulation-to- real experiment agreement.
- The 500 Hz proof-of-concept supports the resonator design.
- The design is passive, compact, modular, and scalable.
- Future work includes multi-frequency testing, full-panel development, and spacecraft integration

TRL 3 — Analytical and Experimental Proof of Concept

- The acoustic unit-cell concept has been defined using established resonator, damping, and microperforated-panel physics.
- COMSOL simulations predict measurable resonant behavior near the 500 Hz design target.
- Physical prototypes have been fabricated and evaluated in laboratory
- Testing demonstrates measurable configuration-dependent acoustic behavior.

The current experiments establish feasibility, but do not yet constitute standardized component validation in a controlled, mission-representative environment.



## Acknowledgements

- Biomedical Acoustics Research Lab, Texas Tech University
- Faculty Advisor: Dr. Jingfei Liu
- NASA Human Lander Challenge / National Institute of Aerospace