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# **Biomimetic Acoustic Sensors**

**Ronald N. Miles**  
**Department of Mechanical Engineering**  
**State University of New York**  
**Binghamton, NY**

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# Report Documentation Page

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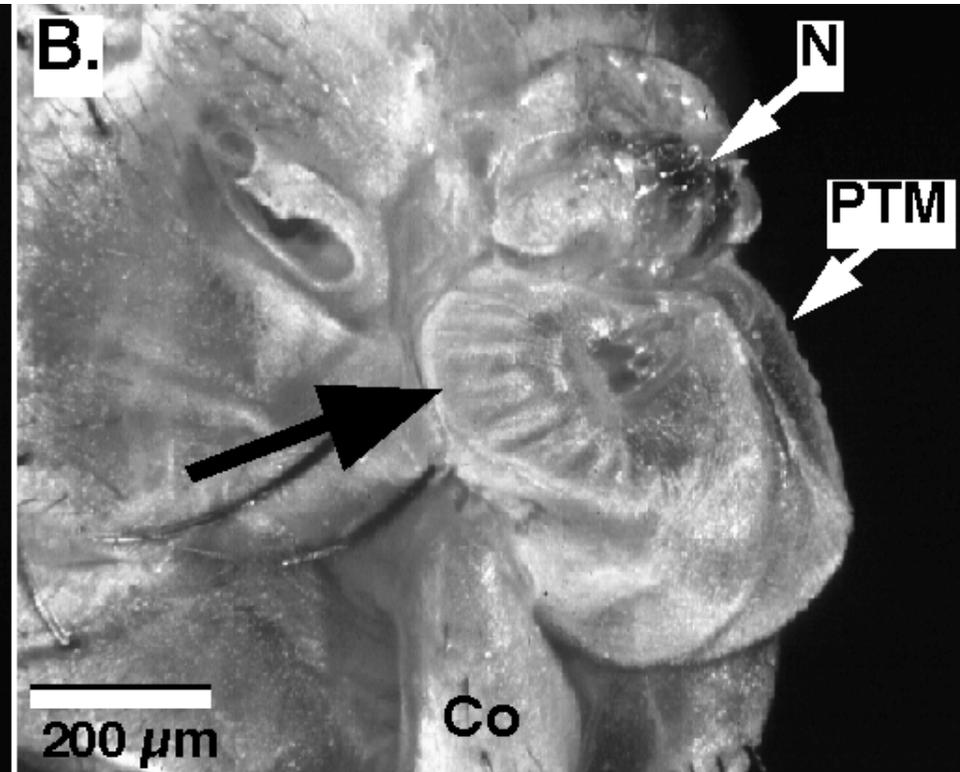
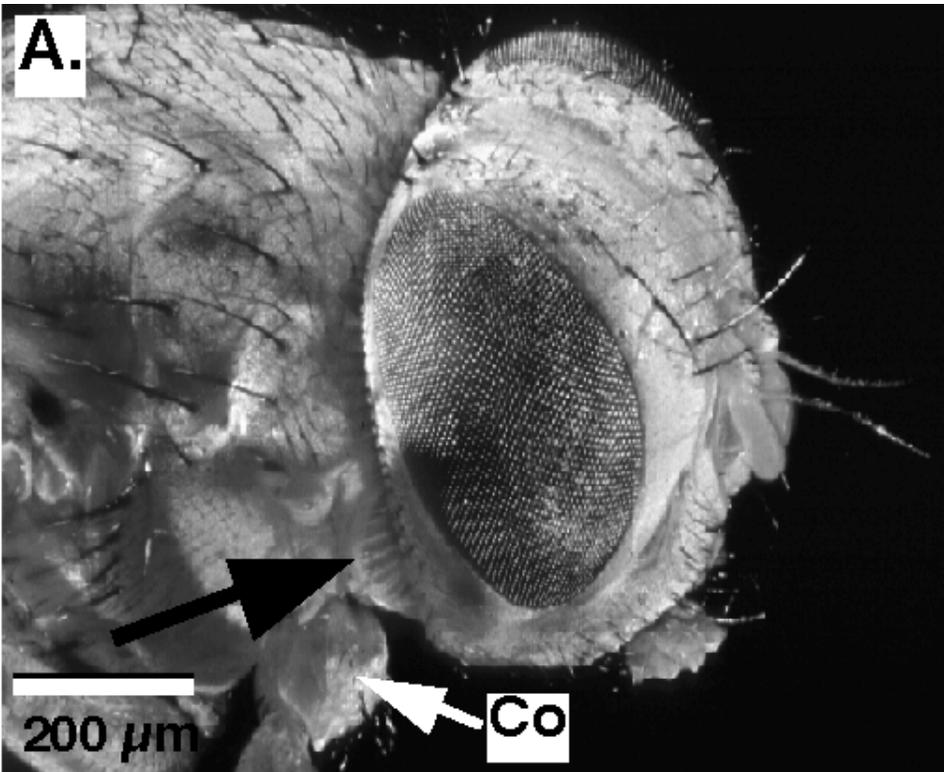
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# Outline

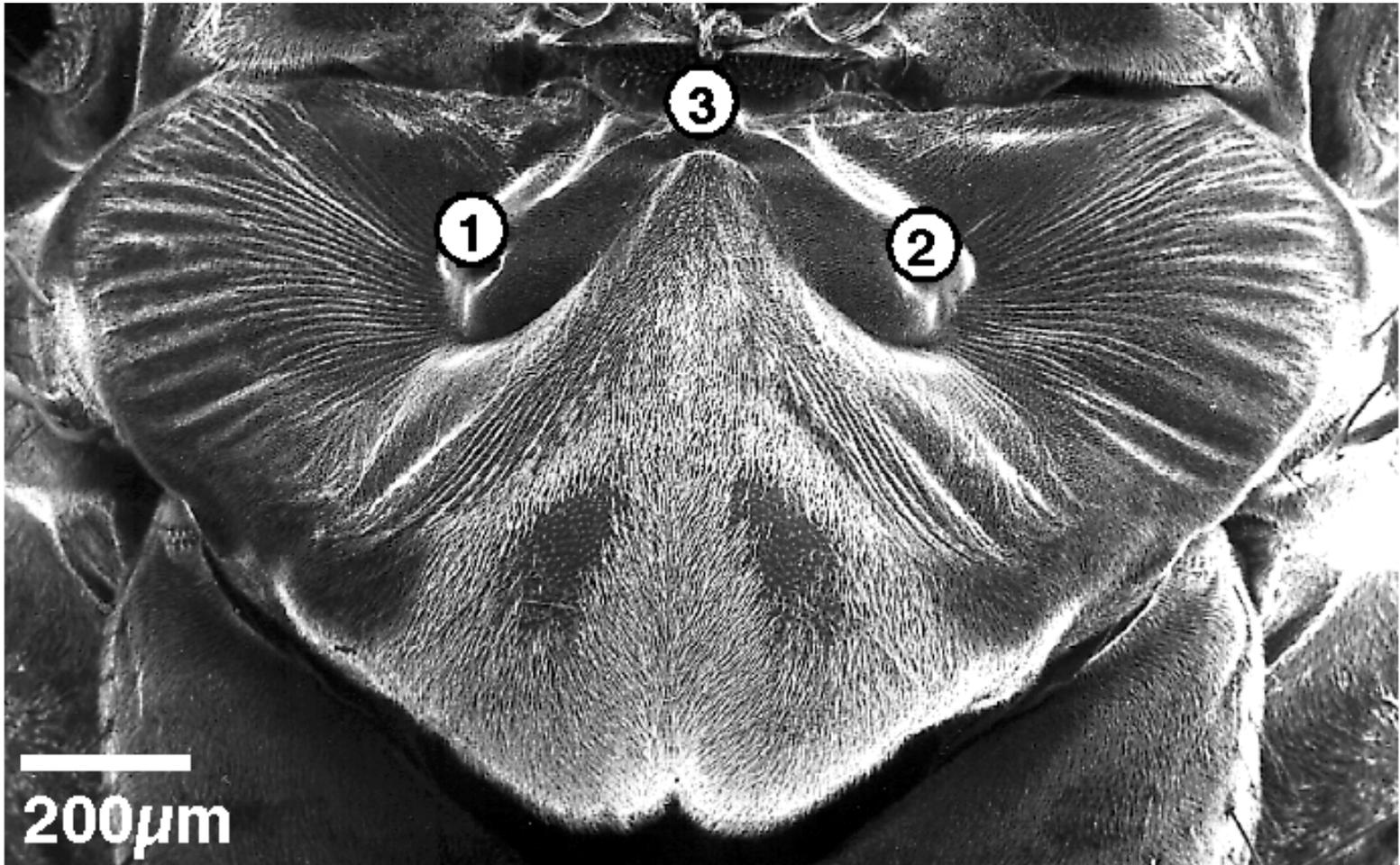
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- Mechanically coupled ears in a parasitoid fly:  
Novel mechanism for directional hearing
  - Biomimetic microphone for hearing aids
  - Directional vibration sensing in a treehopper
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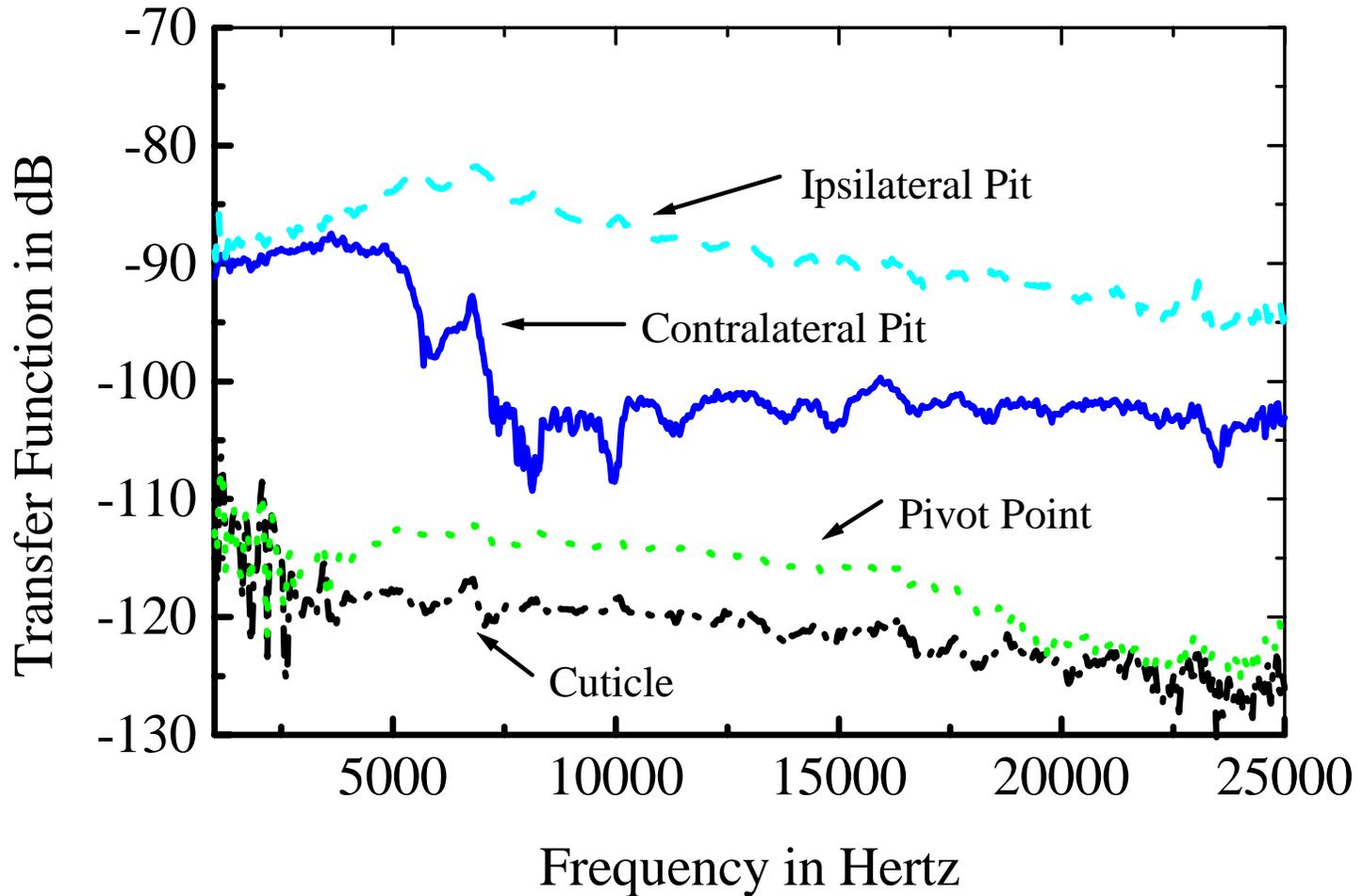
# External Anatomy of the Fly's Ears



## External Anatomy of the Fly's Ears



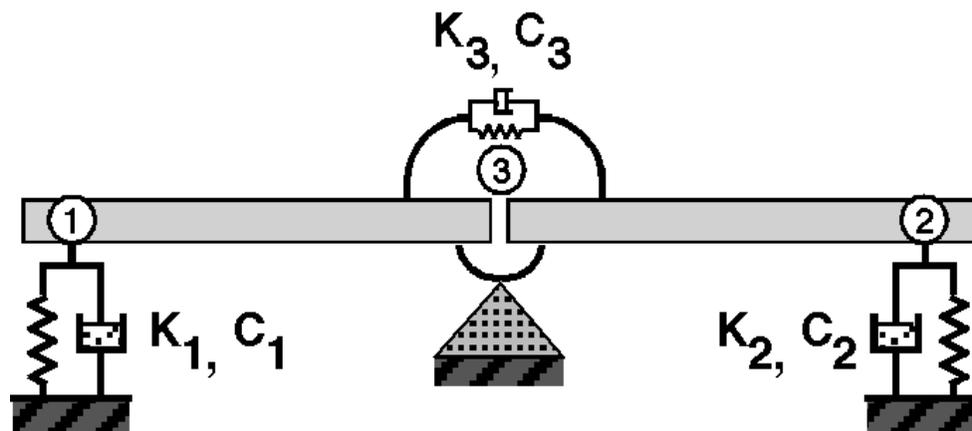
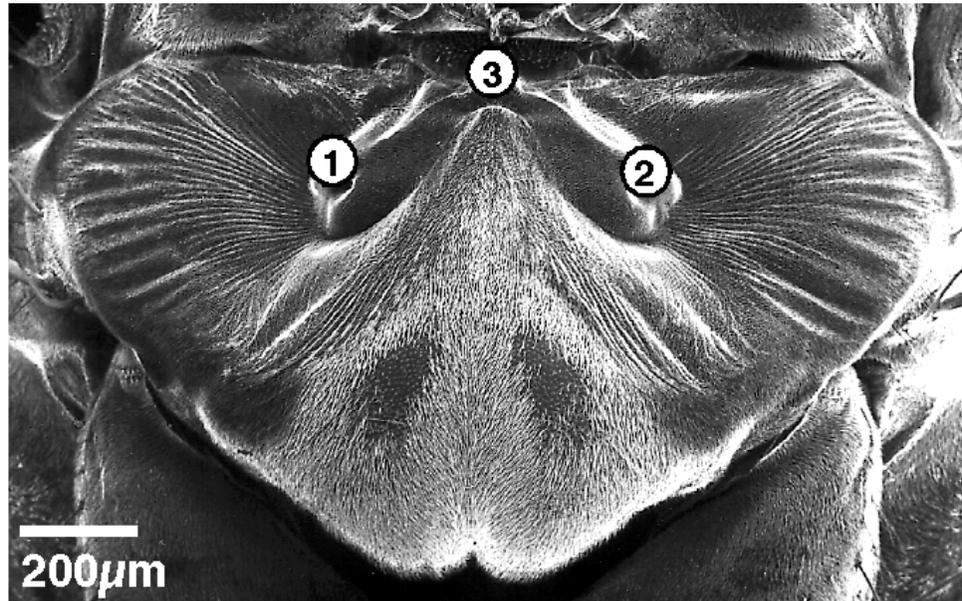
# Measured Response is Highly Directional



Female Ear Response

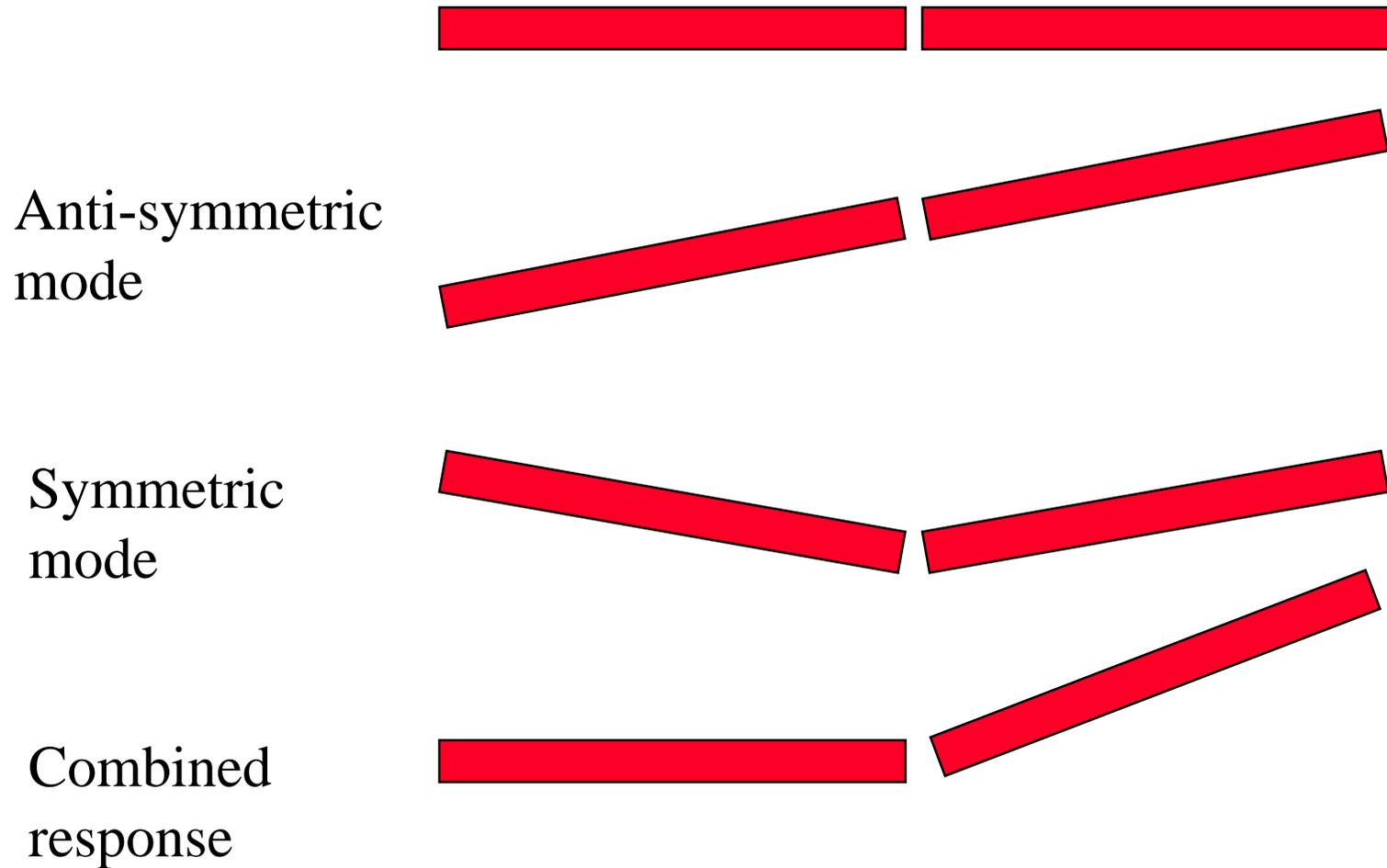
fig 3

# Mechanical Model of the Fly's Ears

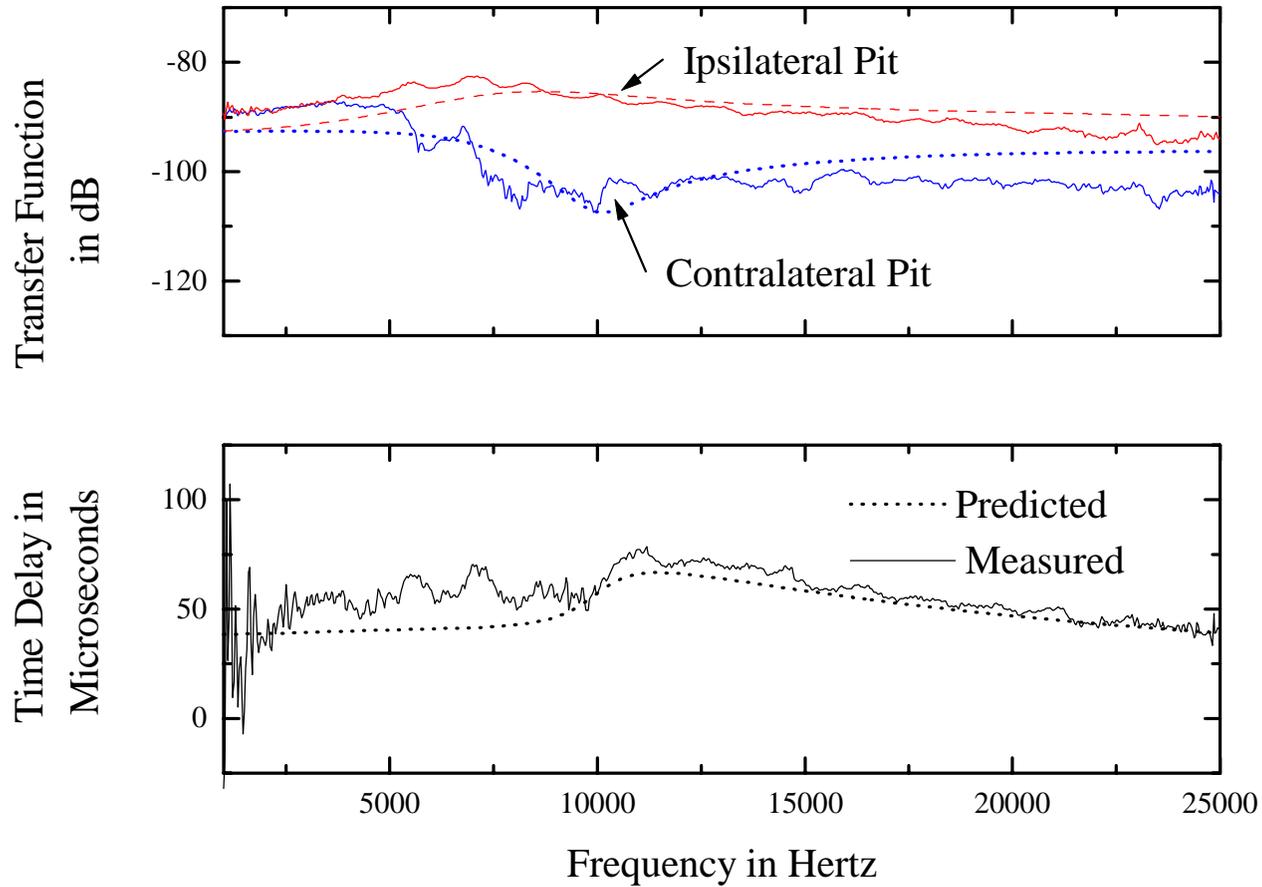


# Highly Directional Two-Mode Sensor

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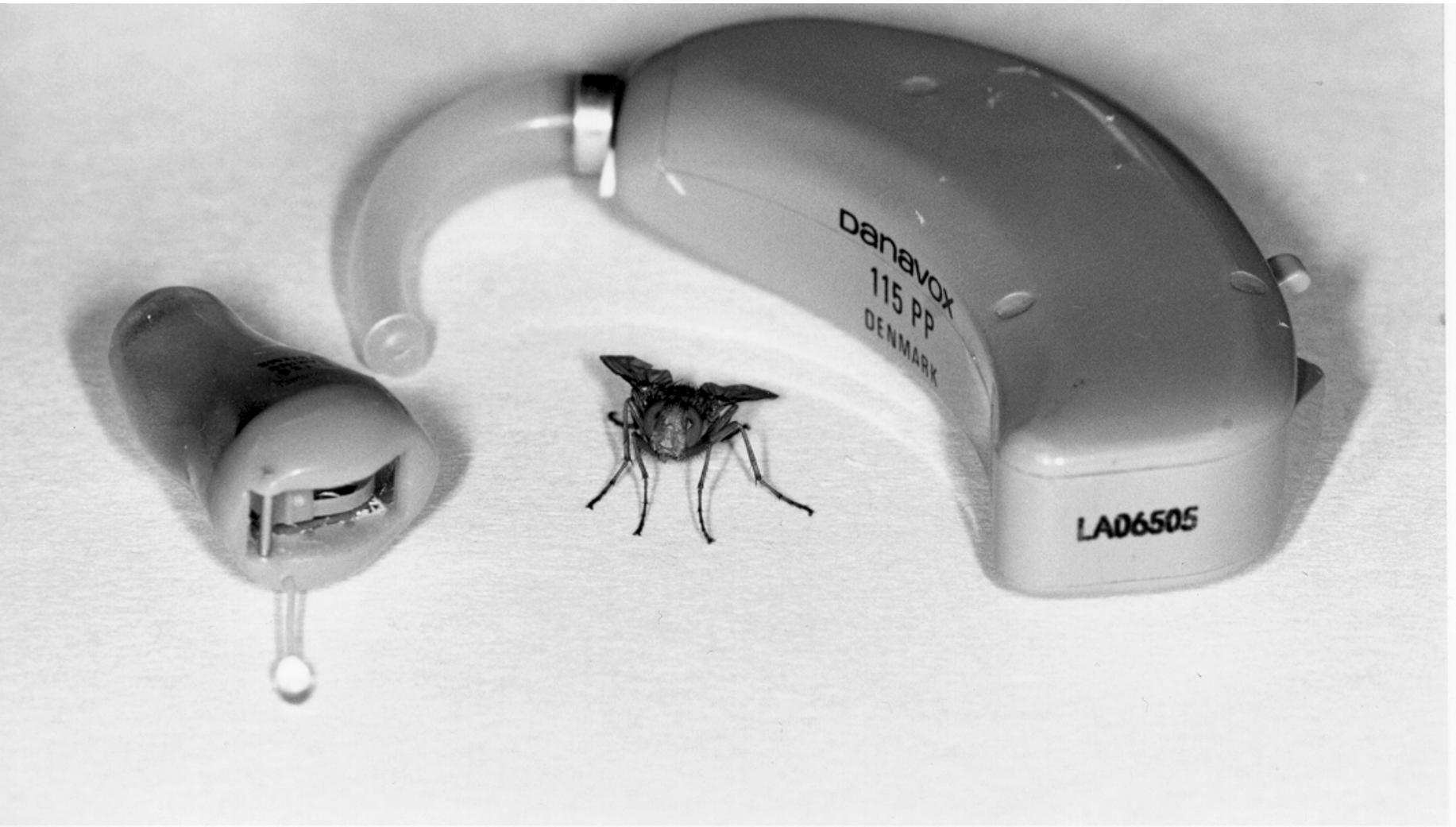


# Analytical Model Predicts Ear's Response



# Application: Directional Hearing Aid Microphone

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# Etymotic D-Mic

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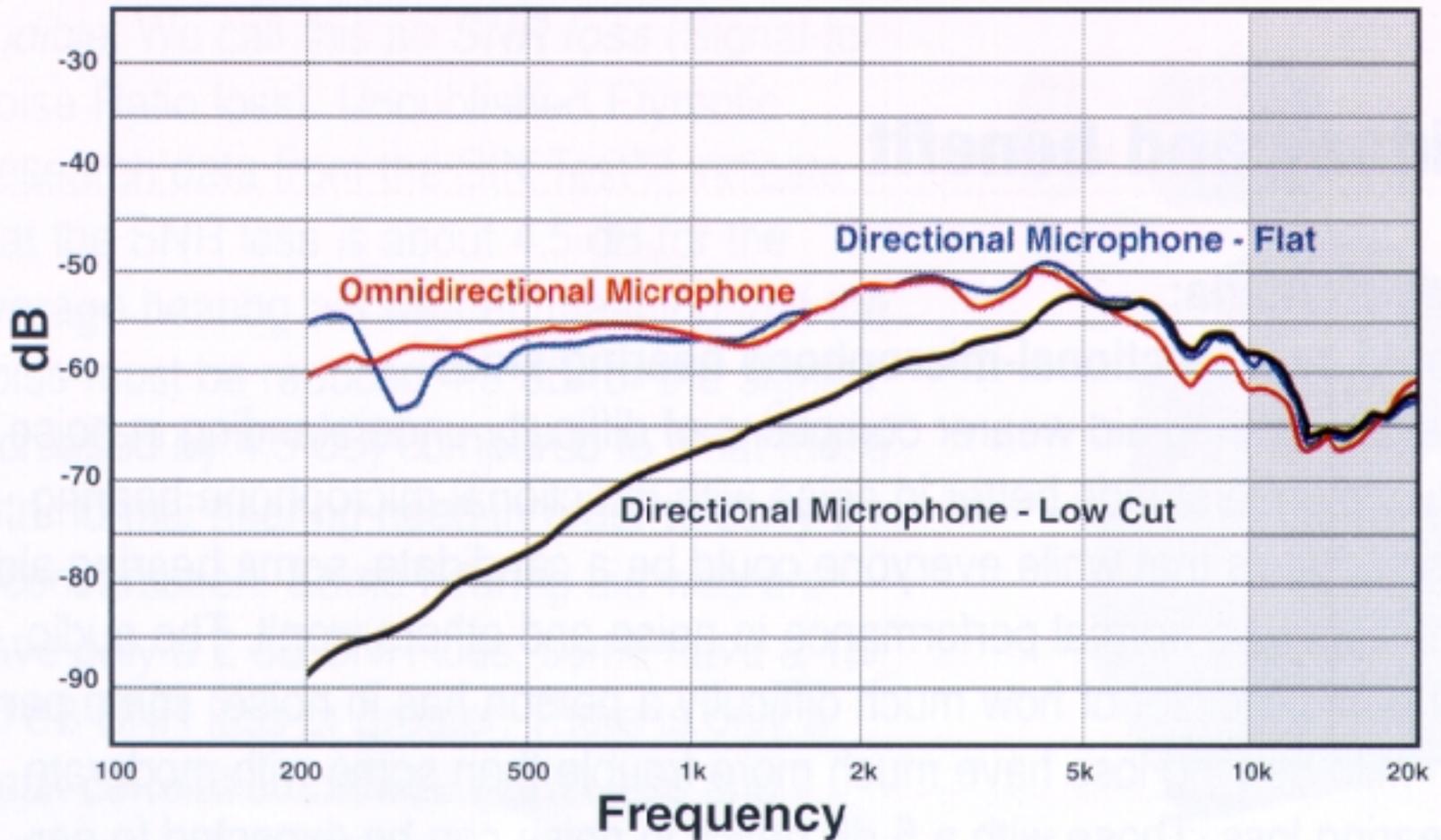


ETYMÖTIC  RESEARCH

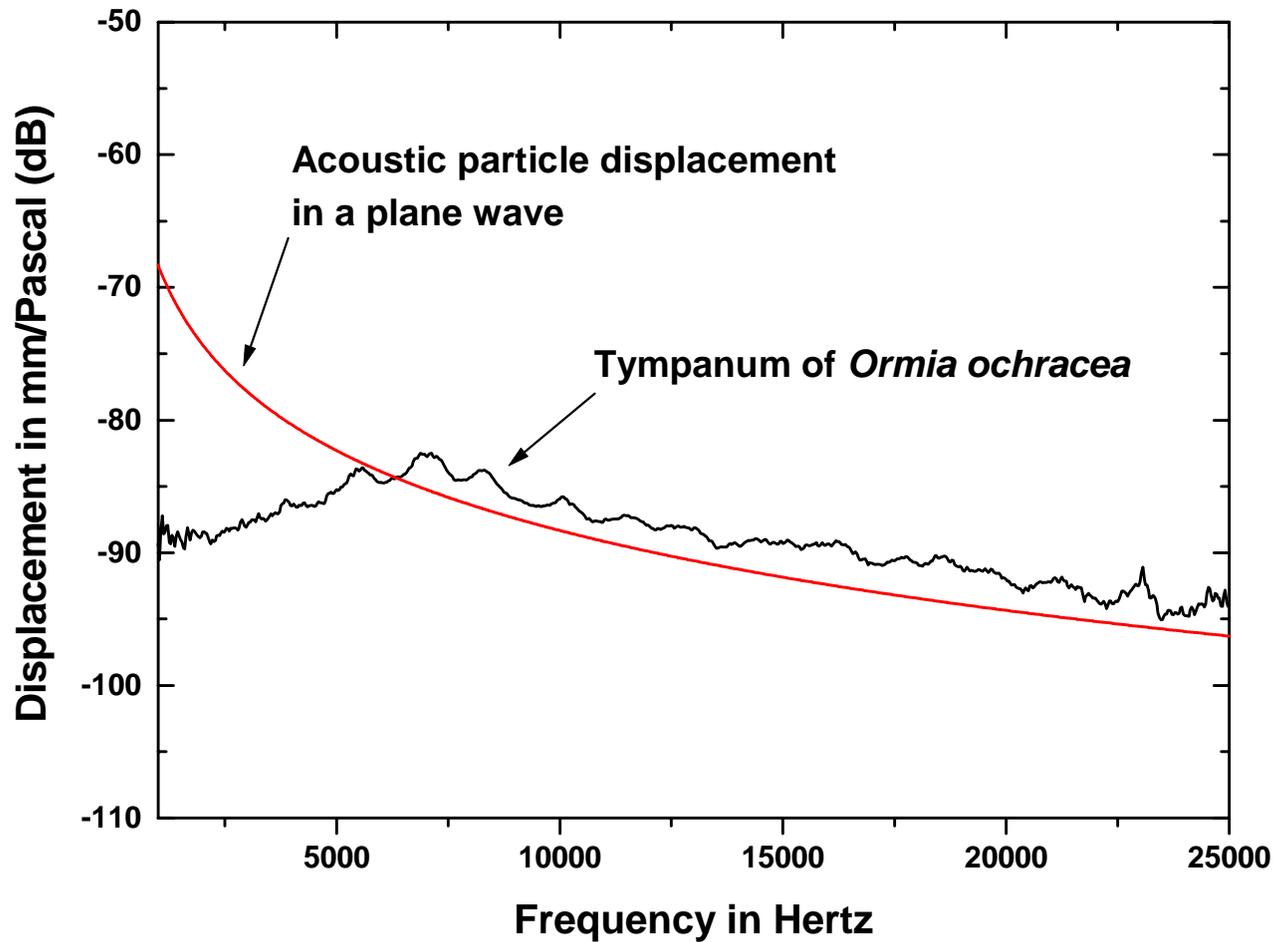


# Measured Response of D-Mic

FREQUENCY RESPONSE (KEMAR)

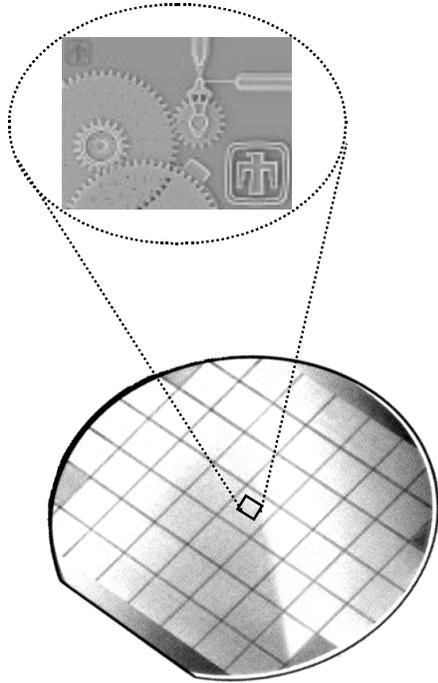


# The Fly's Ear is a Sensitive Acoustic Sensor



# MEMS

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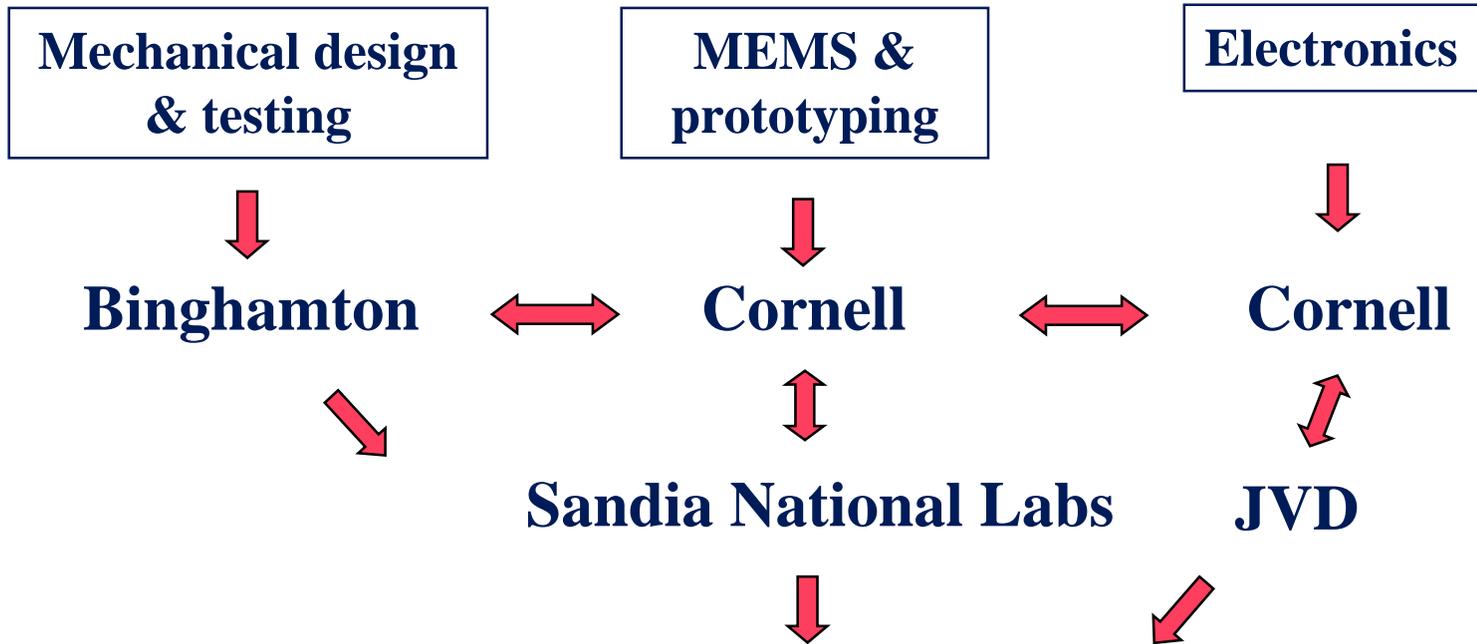
- **Microelectromechanical systems**
- **Mechanical devices with integrated circuits on silicon**
- **Batch fabrication using silicon IC technology**
- **New solutions that are low-cost**

\* **Can implement the fly's ear in a hearing aid using silicon MEMS technology**

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# Team Organization

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## Consultants:

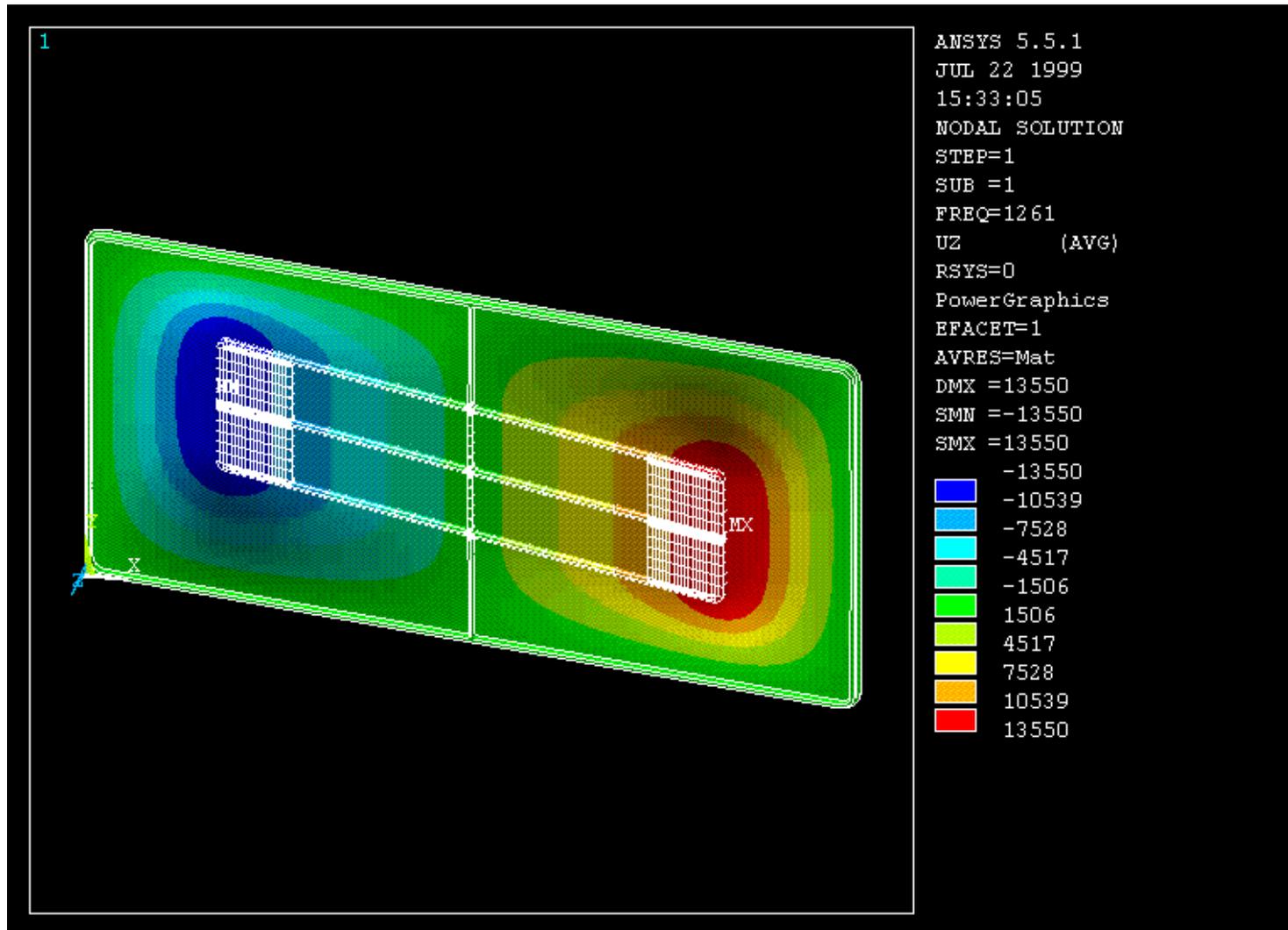
**Bob Young**  
**Ron Hoy**



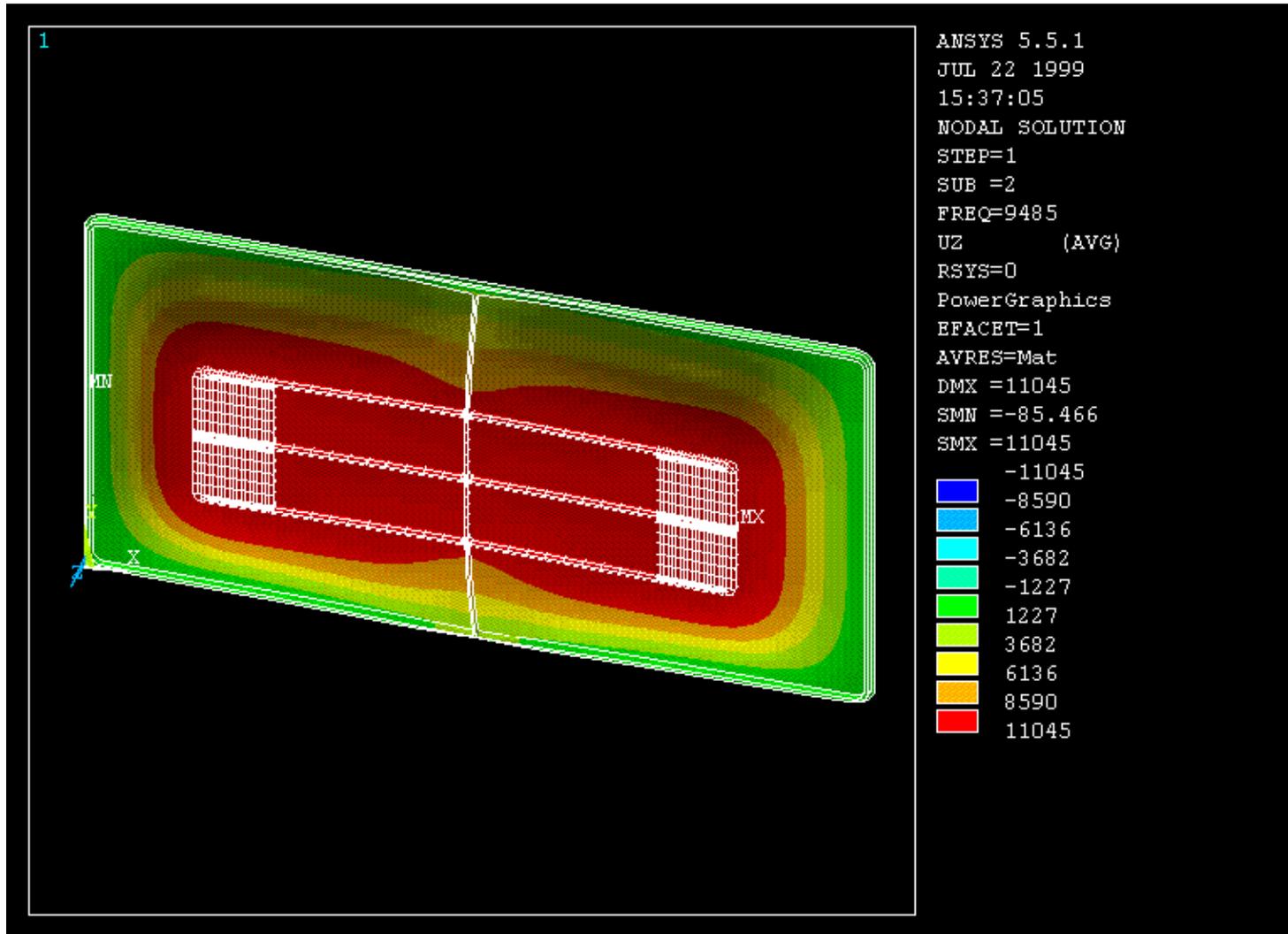
**Toward commercialization**

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# Membrane Design using FEM

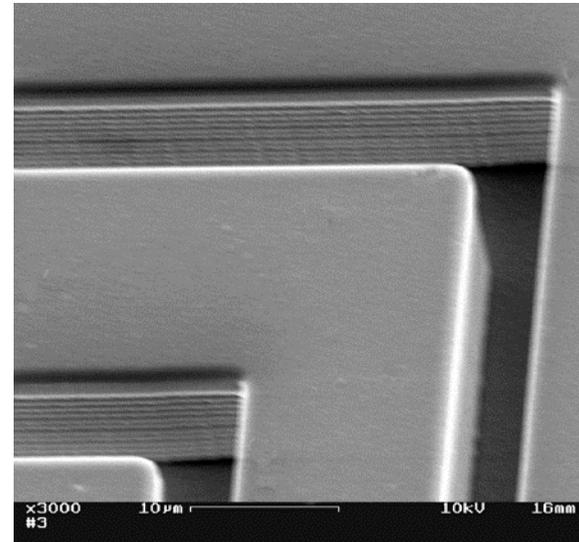
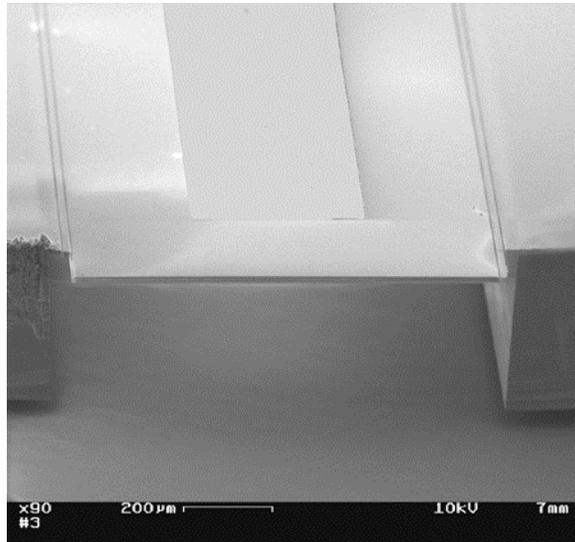


# Membrane Design using FEM



# Polysilicon membranes

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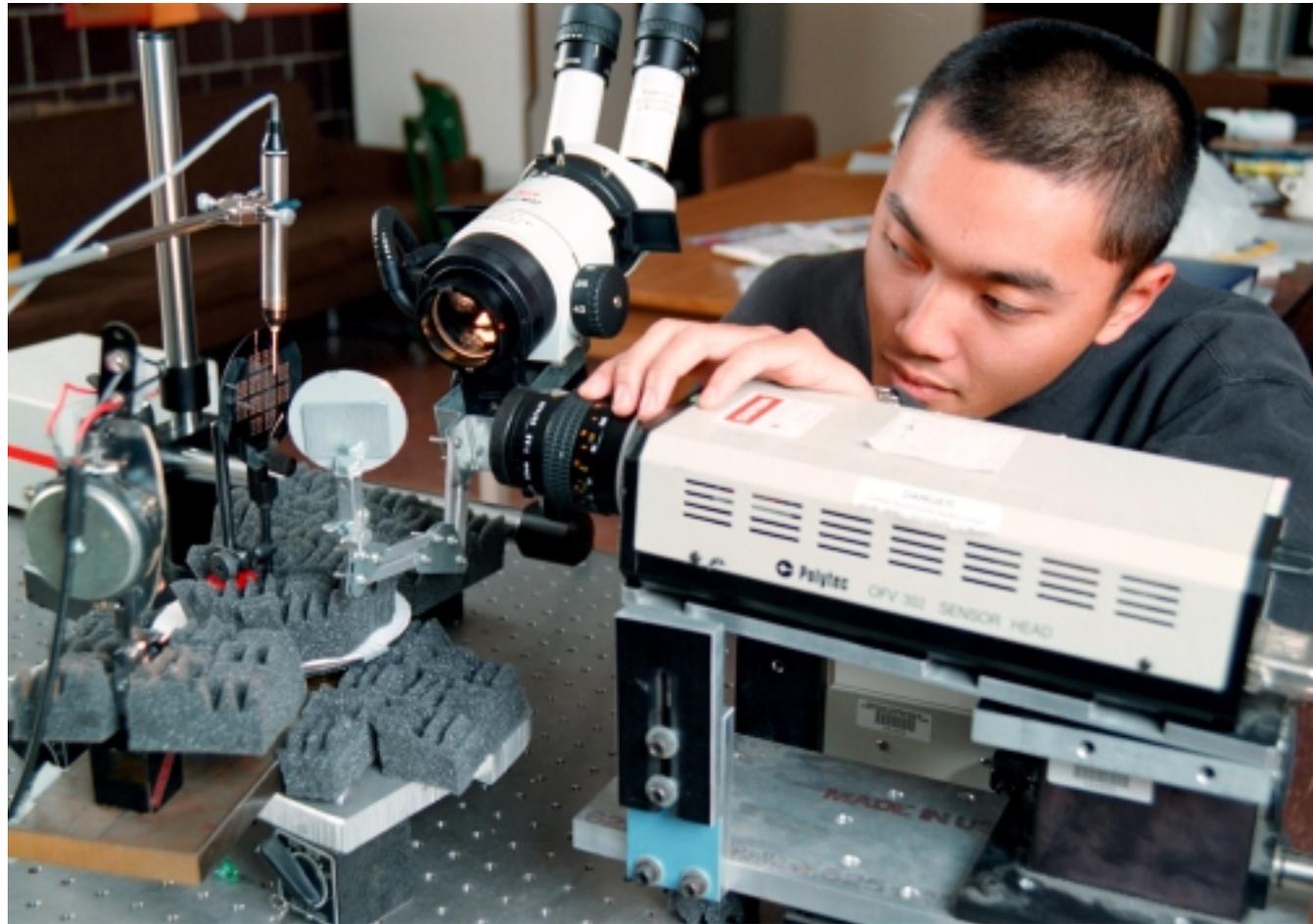


Close-up of the corrugation

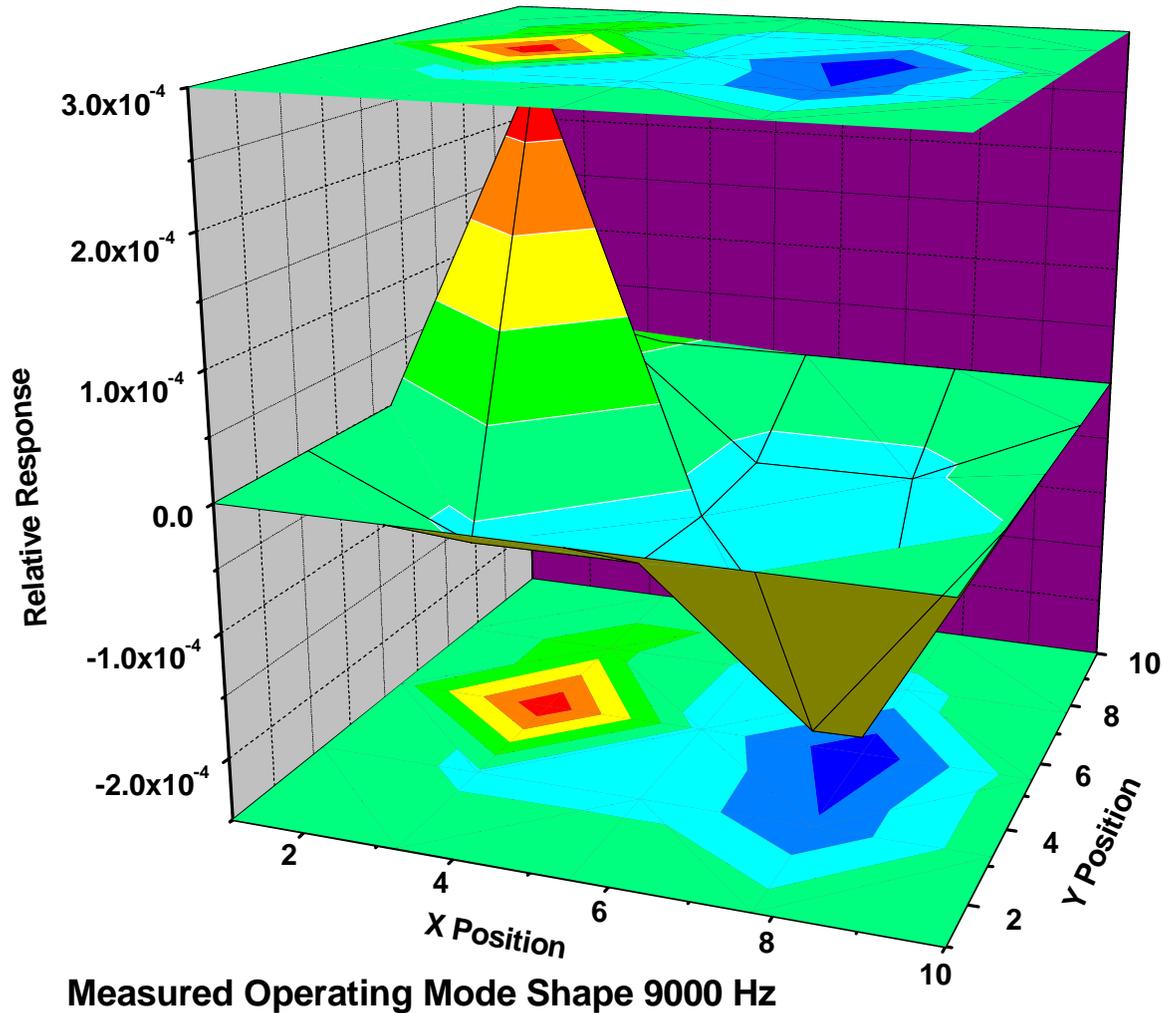
**Cross-section of the 1.0 x 0.5 mm<sup>2</sup> polysilicon membrane. The membrane is 0.5 μm thick with 10 μm deep corrugations.**

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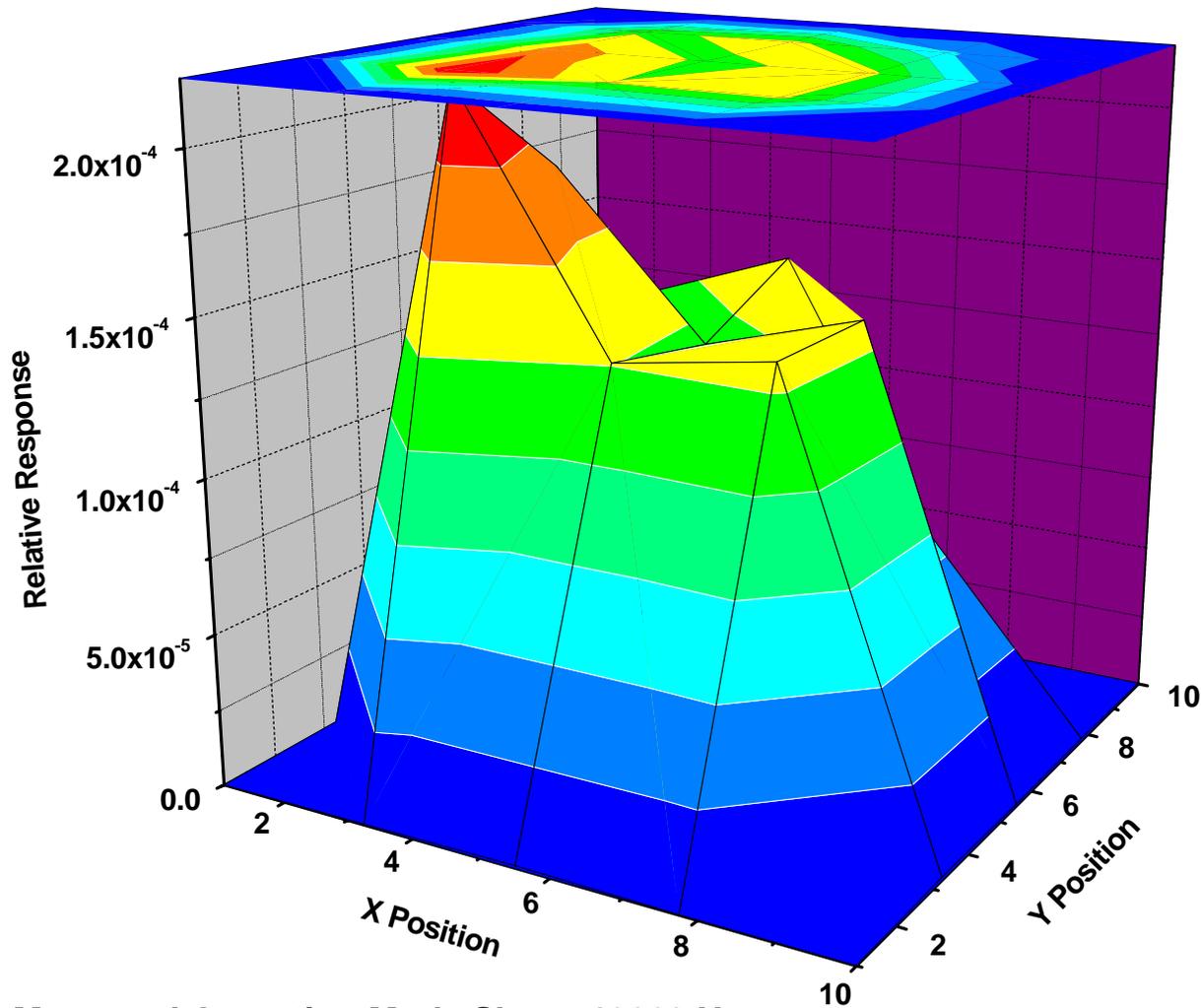
# Measurement of Mechanical Sensitivity



# Measured Anti-symmetric Mode



# Measured Symmetric Mode



Measured Operating Mode Shape 13063 Hz

# Vibrational Communication in a treehopper

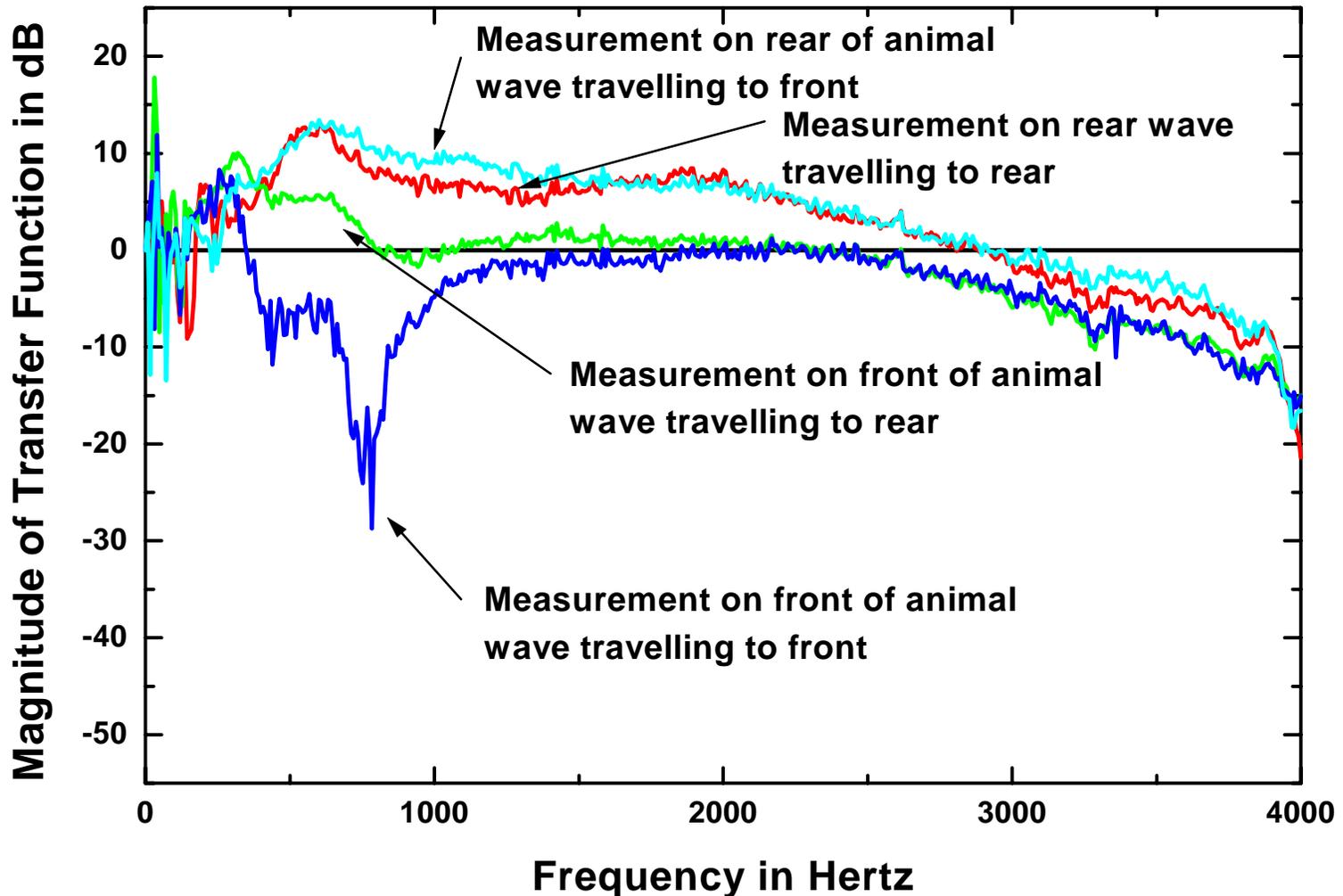


# Bending Wave Simulator

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# Vibration Depends on Wave Direction



# Proposed Biomimetic Sensors

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- Miniature acoustic particle velocity and pressure sensor for sound intensity measurement
  - Higher-order miniature directional microphones- Passive, low-cost
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## References

- [1] R. N. Miles, D. Robert, and R. R. Hoy 1995 *Journal of the Acoustical Society of America* **98**, 3059-3070. Mechanically coupled ears for directional hearing in the parasitoid fly *Ormia ochracea*.
  - [2] D. Robert, R. N. Miles, and R. R. Hoy 1996 *Journal of Comparative Physiology* **179**, 29-44. Directional hearing by mechanical coupling in the parasitoid fly *Ormia ochracea*.
  - [3] R. N. Miles, T. D. Tieu, D. Robert and R. R. Hoy (1997), "A mechanical analysis of the novel ear of the parasitoid fly *Ormia ochracea*," in *Proceedings: Diversity in Auditory Mechanics*. E. R. Lewis, et. al. (Eds.), (World Scientific, Singapore), pp. 18-24.
  - [4] Robert, D., Miles, R. N. and Hoy, R. R. 1999 *The Journal of Experimental Biology* **202**, 1865-1876. Tympanal hearing in the sarcophagid parasitoid fly *Emblemasoma* sp.: the biomechanics of directional hearing.
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