# Tensor tympani contraction produces frequency-dependent changes in middle ear sound transmission in gerbil

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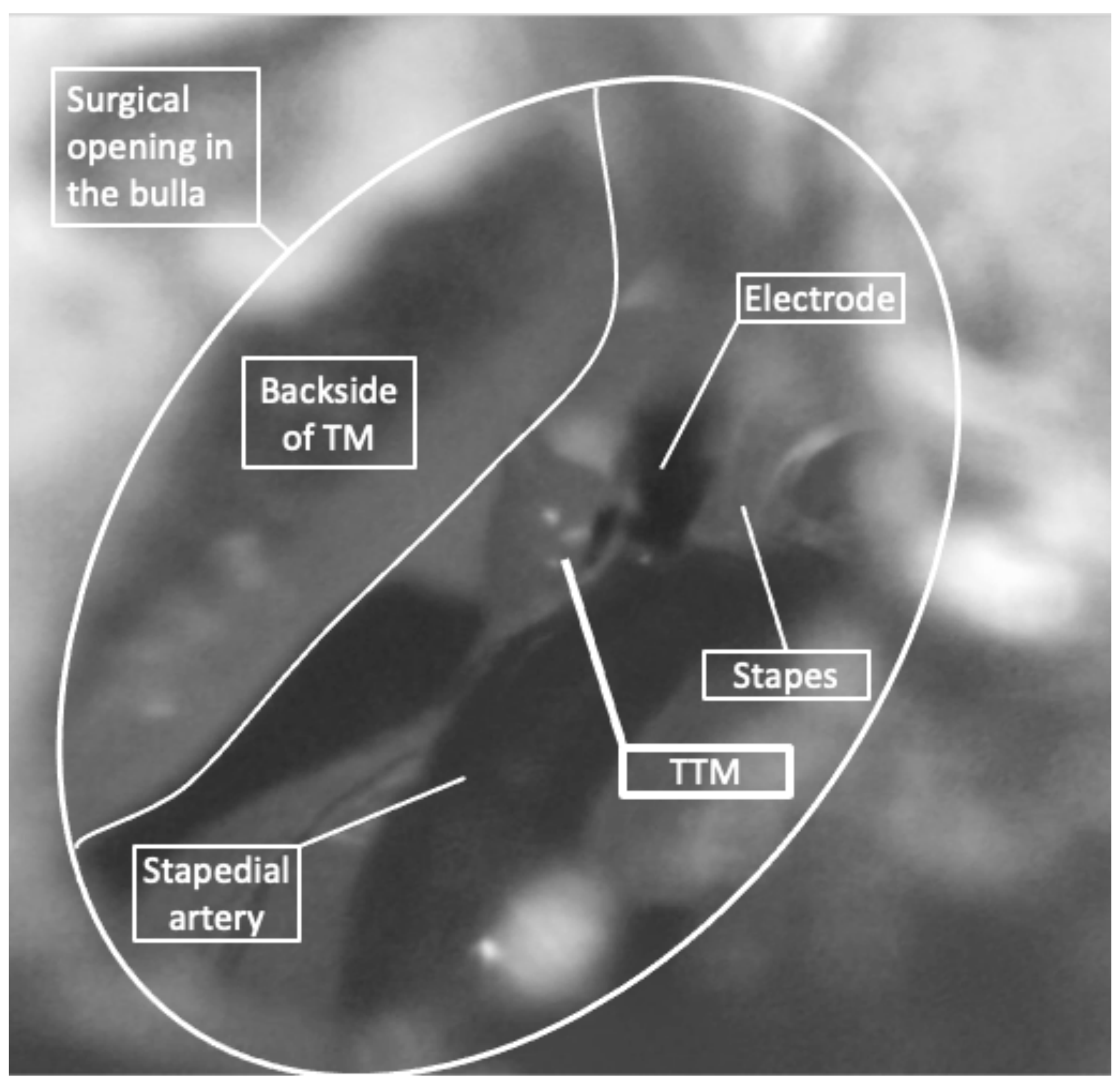
## Abstract

The middle ear is a high-fidelity, broadband impedance transformer that transmits acoustic stimuli at the eardrum to the inner ear. It is home to the two smallest muscles in mammalian species, which modulate middle ear transmission. Of this pair, the function of the tensor tympani muscle (TTM) has remained obscure. We investigated the acoustic effects of this muscle in young adult gerbils. Using Laser Doppler Vibrometry, we measured changes in middle ear vibration to multitone Zwuis stimuli produced by electrical pulse-train-elicited TTM contraction. There were consistent patterns of attenuation and enhancement in the velocity responses at the umbo and ossicles. The TTM produced a narrow band of enhancement around 6 kHz (maximally ~5dB) that can be modeled with an increased stiffness of an overdamped spring-mass resonance. At frequencies below 2 kHz and above 35 kHz, TTM contraction attenuated middle ear vibrations by as much as fivefold, and by comparable degrees at low and high frequencies.




The TTM appears as a dome shape tapering to a tendon that inserts on the manubrium (contact point is obscured by the TM in this view). A pulse train (100us 4V at 100Hz) delivered through the electrode produced a strong and repeatable contraction of the muscle. The surgical opening was occluded after electrode placement to allow probing of low frequencies. Video can be viewed upon request.

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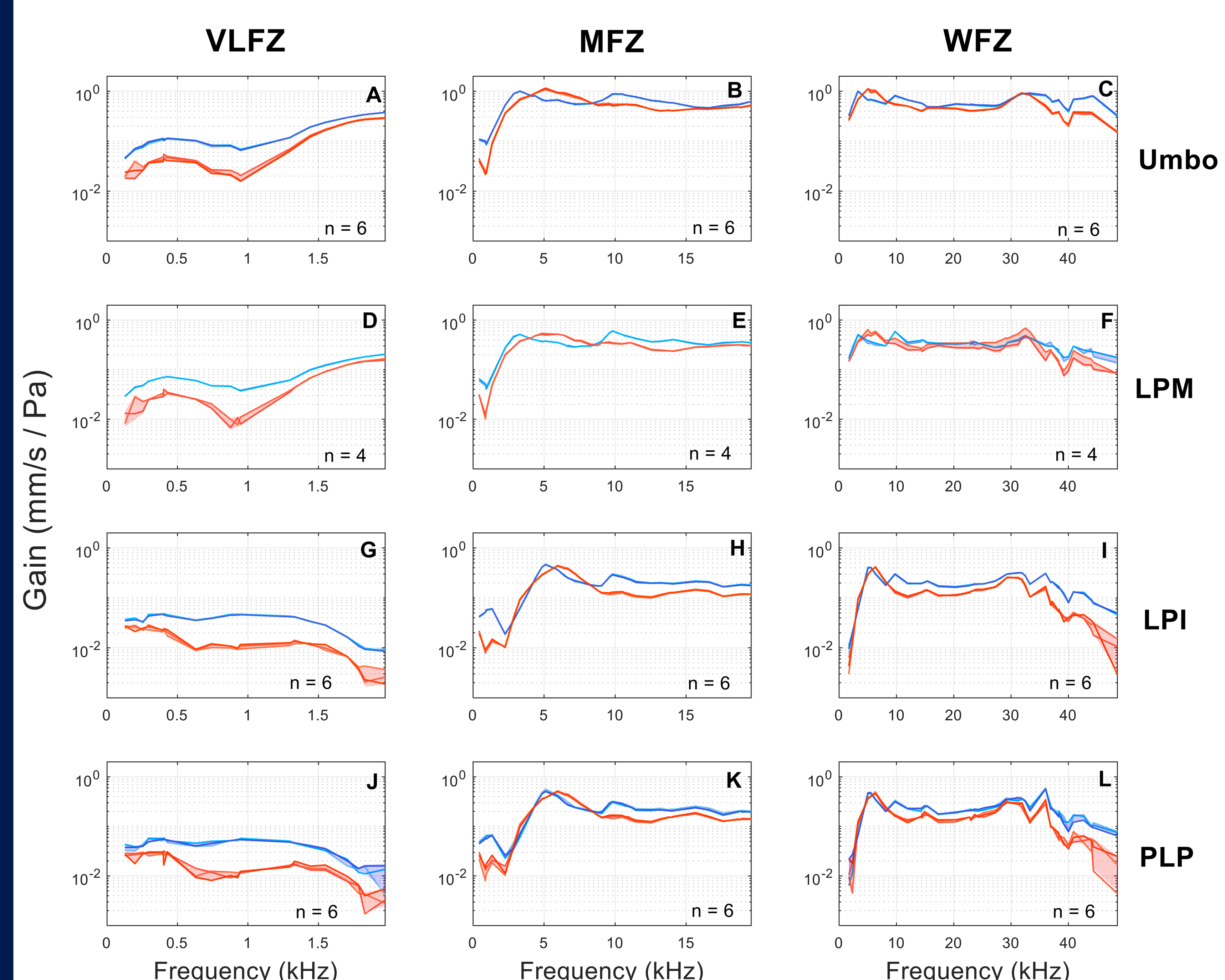
## Results

*Changes in middle ear transmission*

- ❖ Motion represented as normalized velocity, gain in mm/s/Pa
- ❖ Alternating stimulus demonstrates highly repeatable changes in gain
- ❖ Gain was greatest at umbo, decreased downstream
- ❖ PLP serves as a proxy for footplate motion, middle ear output



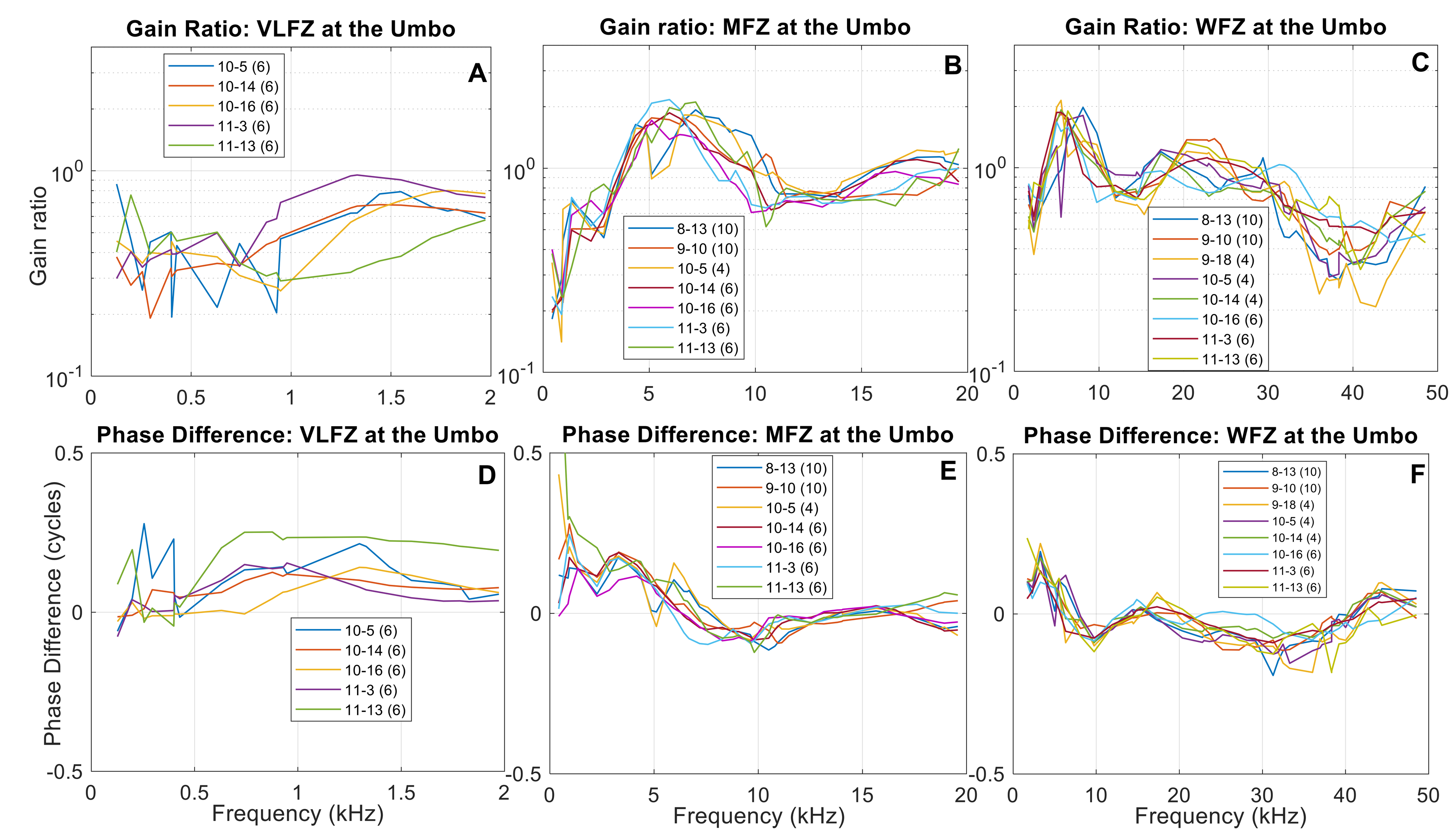

*Consistent frequency dependent structure*

Amplitude

- ❖ Gain ratio presents average ratio from one alternating series
- ❖ Below 4kHz and above 35kHz, TTM attenuates motion by as much as 5x
- ❖ TTM enhance umbo motion over a narrow band 4-10kHz
- ❖ Relatively minor effects on motion from 15-30kHz

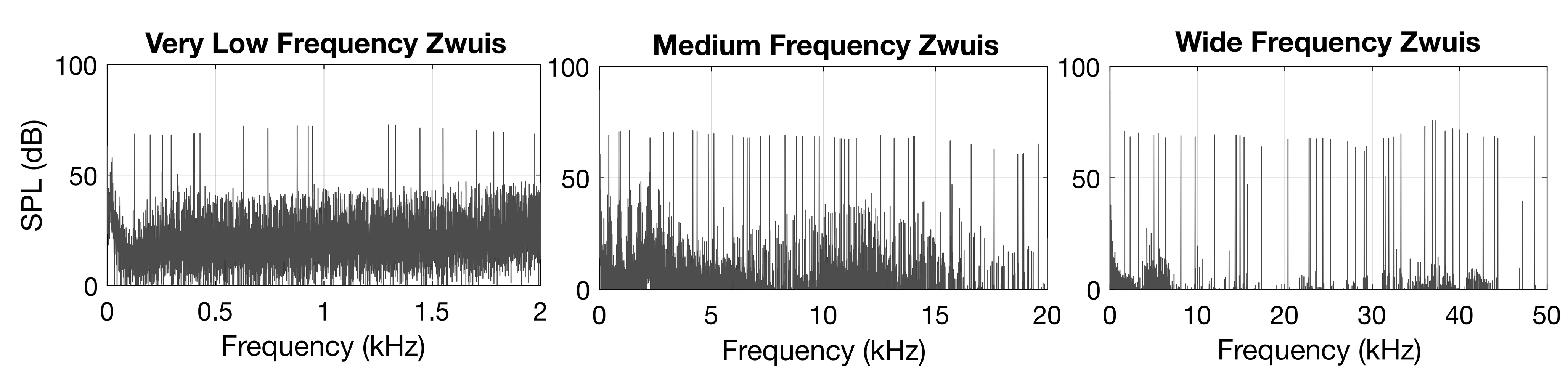
Phase

- ❖ TTM produced a lead that grew to almost 0.2 cycles at ~ 4 kHz
- ❖ Passed through zero at ~ 6 kHz with two mild variations from 6 to 50 kHz




## Methods

- ❖ Three overlapping Zwuis multi-tones probed a wide range of acoustic frequencies (VLFZ, MFZ, WFZ, see below)
- ❖ Sound stimuli were delivered open-field with alternating TTM electrical stimulus; relaxed and contracted. TTM contraction was visually confirmed for every stimulated run
- ❖ Ossicular motion was measured through the open ear canal
- ❖ Surgical bone wax closure reversed changes produced by opening the bulla
- ❖ LPI and PLP measurements required opening of pars flaccida.




## Discussion

- ❖ TTM produces repeatable changes in middle ear transmission, which at low frequencies can be explained by an increased stiffness
- ❖ Degree of attenuation was comparable at lower and higher frequencies, 2-5X
- ❖ Using bone wax to close the surgical opening the bulla reversed the effects of opening and may be a useful technique in surgical investigations of the middle ear
- ❖ Frequency-dependent effects suggest TTM might act as a tuning muscle or assist in spatial attention