Interpreting WBR in terms of middle ear mechanics and contrasting Tympanometry with WBR

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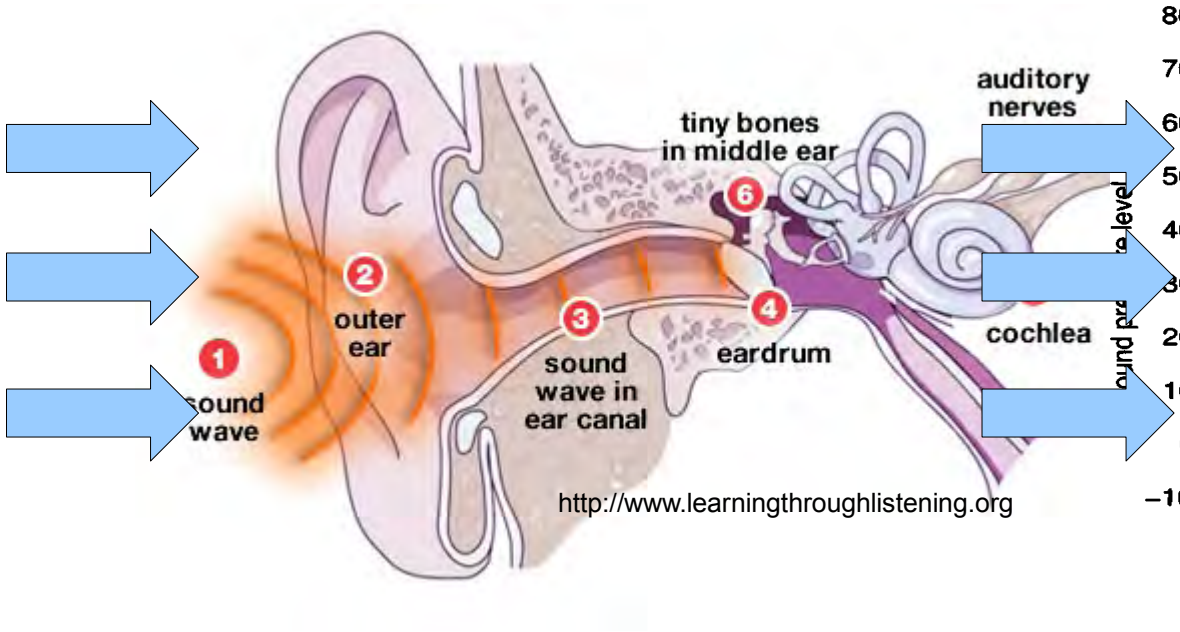
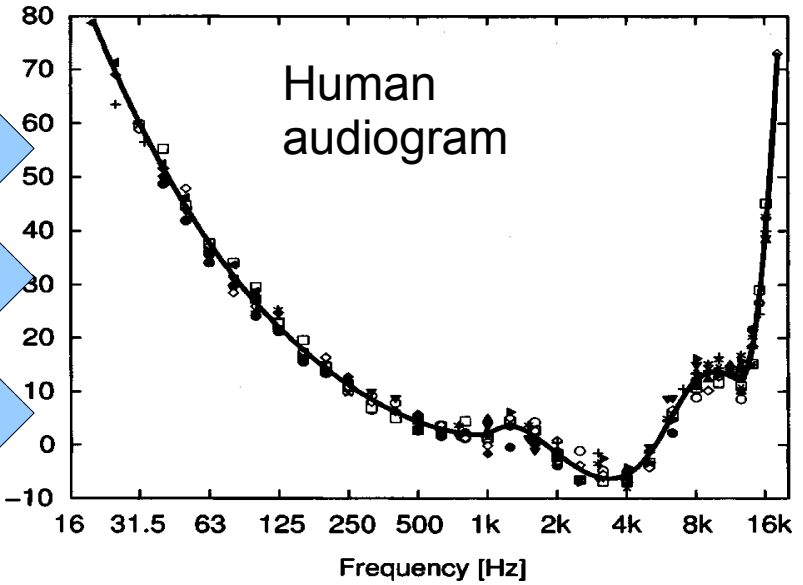
ABSTRACT

Wideband reflectance (WBR) and tympanometry both provide a measure of the impedance of the middle ear. Tympanometry has been the standard tool for assessing middle ear function for many years. WBR provides a precise, broad spectrum assessment of middle ear function. WBR patterns can be interpreted in terms of the mechanics of the middle ear, pathology producing predictable alterations in WBR patterns. WBR and tympanometry will be discussed in terms of i. how they work, ii. what they measure, and iii. the relationship between WBR and tympanometry.

The Human Ear



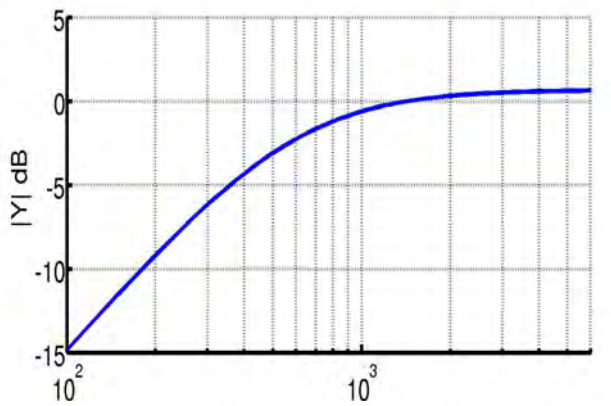


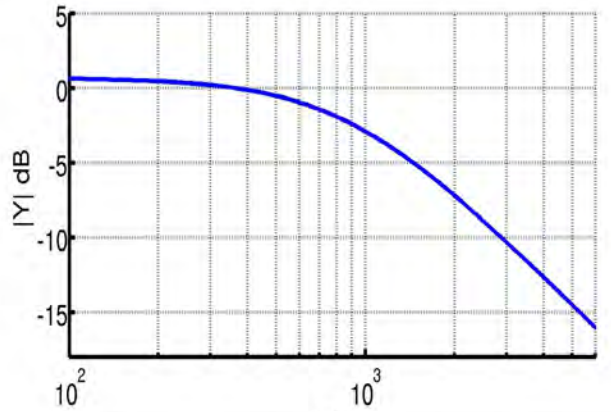
Suzuki & Takeshima, 2004, JASA, 116(2)

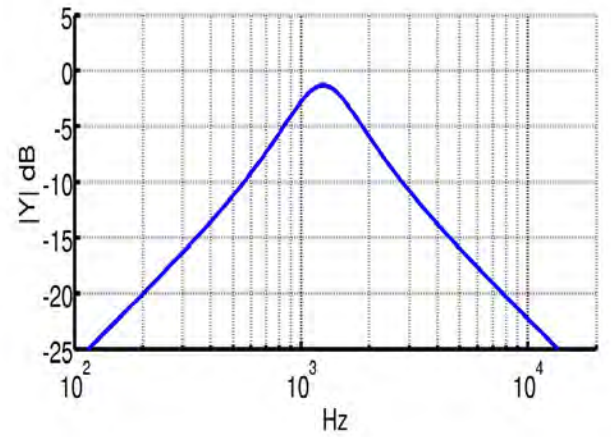
- Hearing thresholds are frequency-dependent
- Outer and middle ear contribute significantly to this frequency-dependence (Dallos, 1971)
- Sound is **filtered** by the outer and middle ear before being received by the cochlea

Filtering Sound

- High-pass filter
  - spring + friction
  - e.g., eardrum = spring, motion of eardrum in air produces friction
- Low-pass filter
  - mass + friction
  - e.g., ossicles = mass, motion in air of middle ear space = friction
- Tuned filter
  - mass + spring + friction
  - e.g., middle ear of lizard







The Lizard Middle Ear

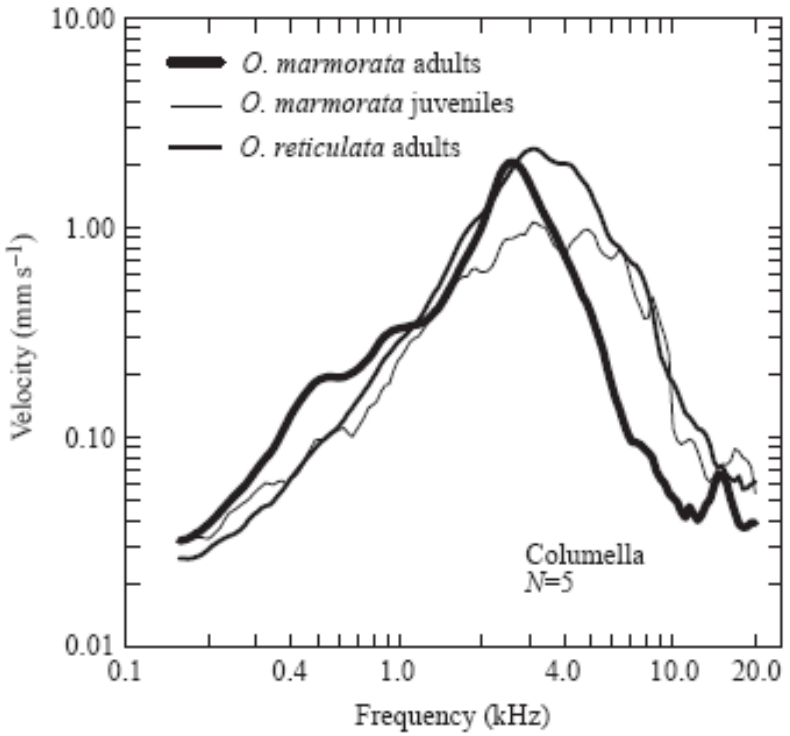
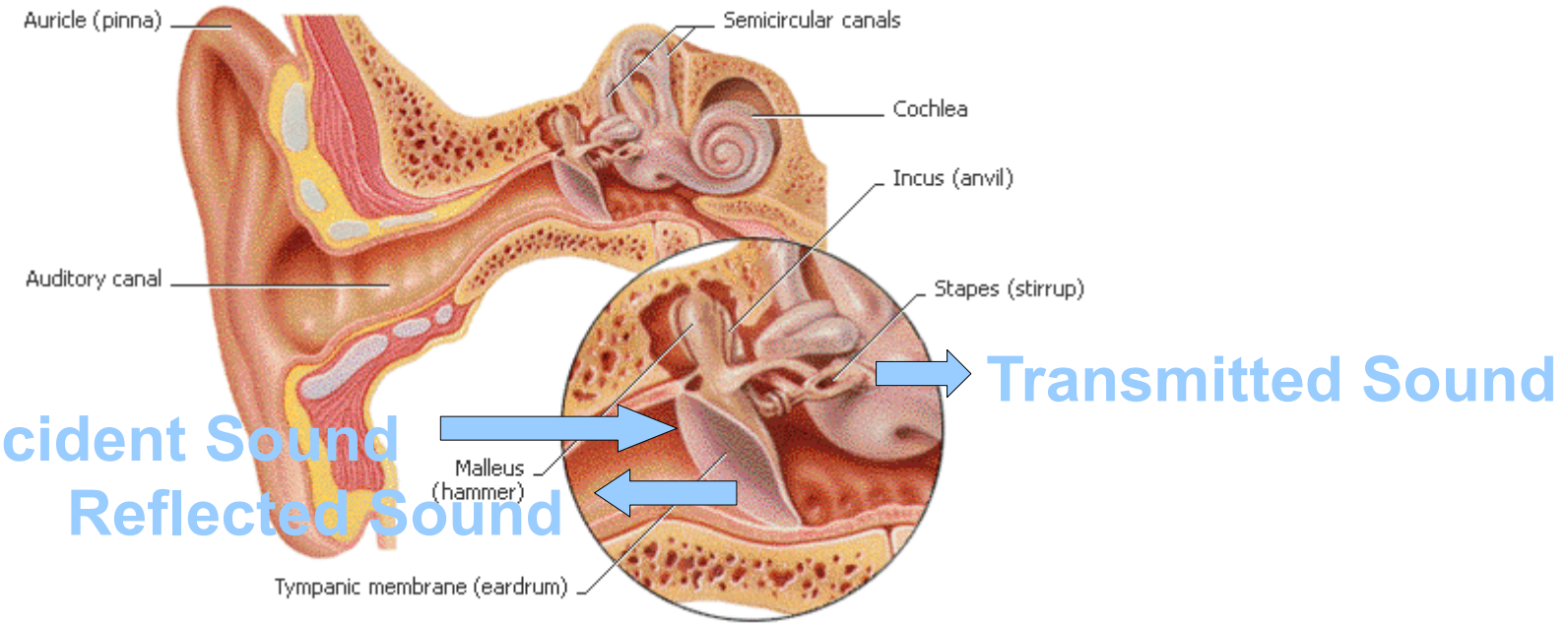


Fig. 6. Averaged peak-to-peak velocity functions of the tympanic membrane, measured at the junction of the columella, for the diplodactyline triad.

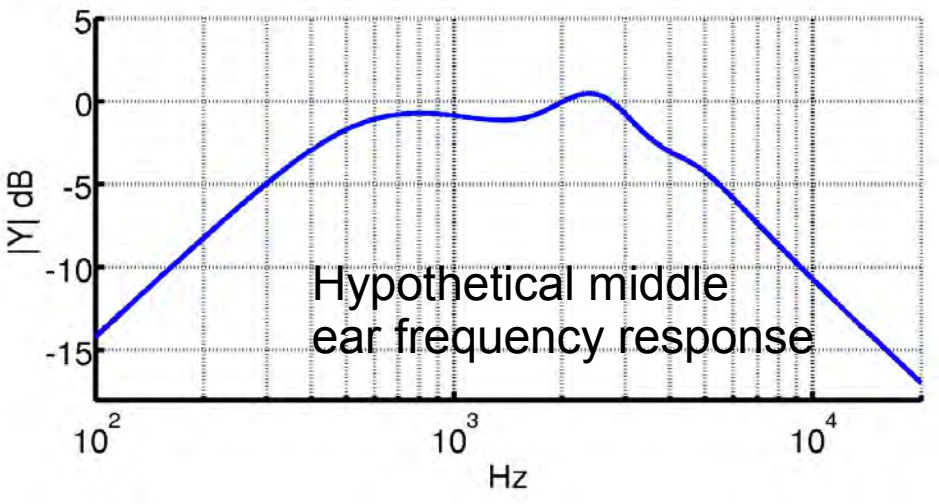
Werner et al, 2002, J. Exp. Biol. 205

- A simple mass-spring system with a single resonant frequency
- Lizard middle ear consists of only one ossicle (not three)
- Lizard middle ear simpler than human middle ear with a narrower frequency response

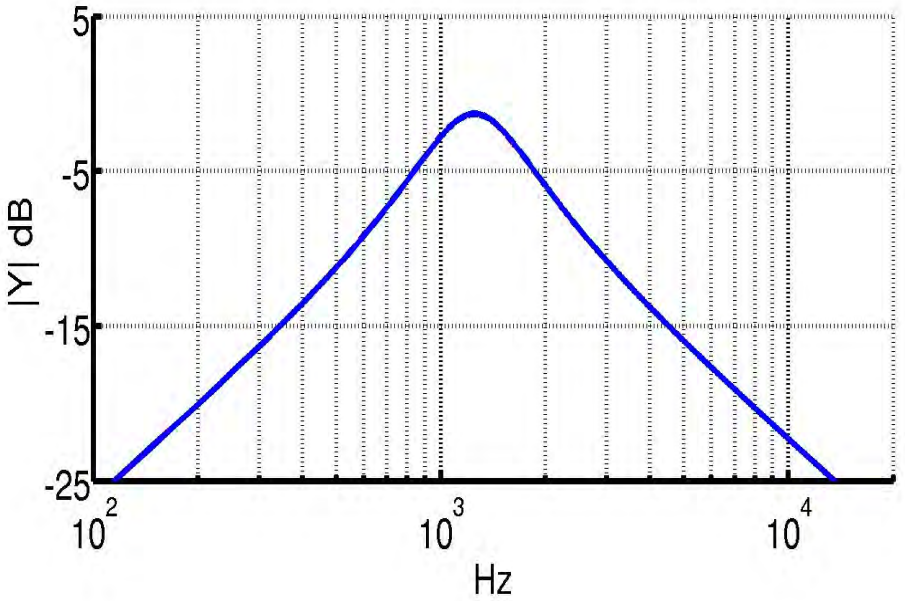
The Human Middle Ear

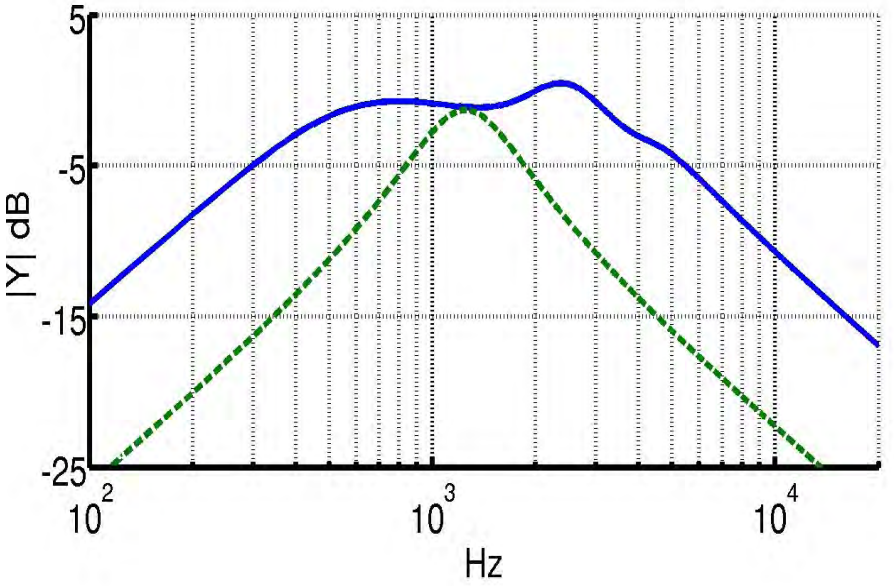


- A broad-band frequency response



How do we get from



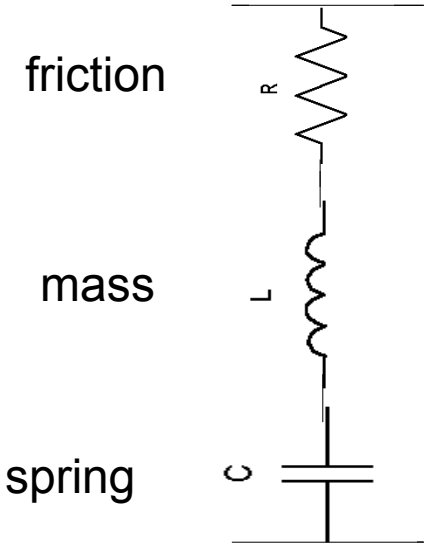


here to here ?

A simple interpretation

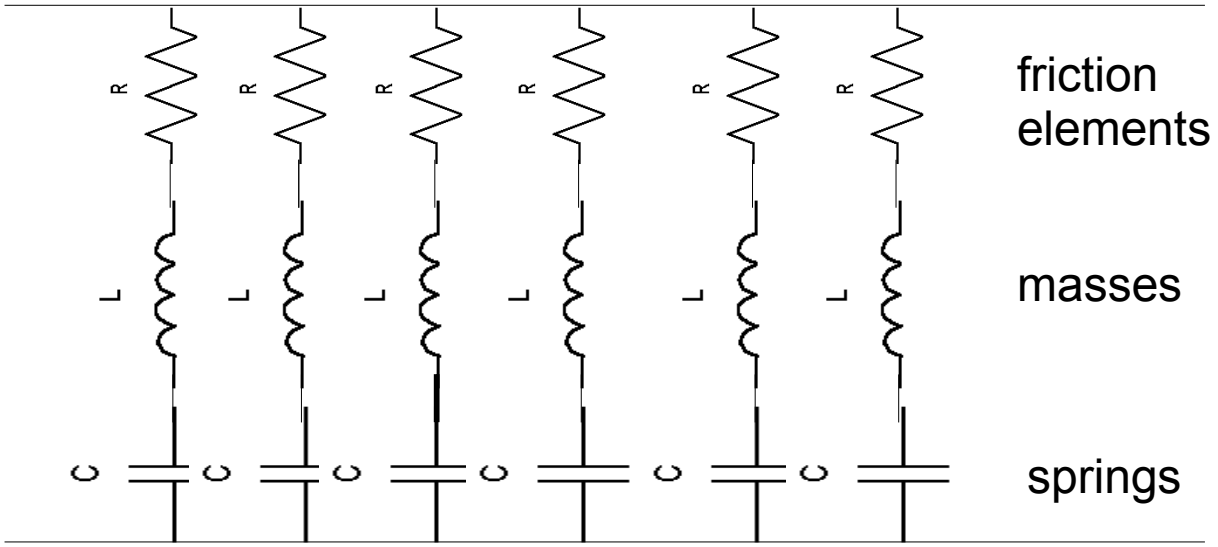
Lizard Middle Ear

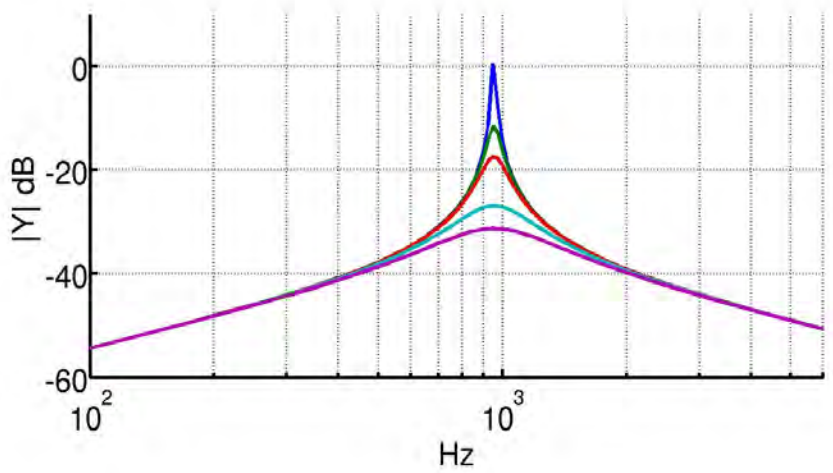
A tuned filter

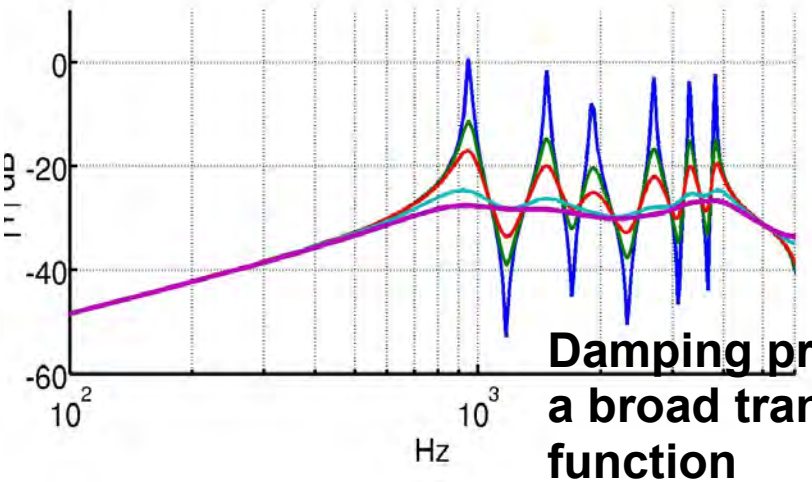


Human Middle Ear

A bank of tuned filters



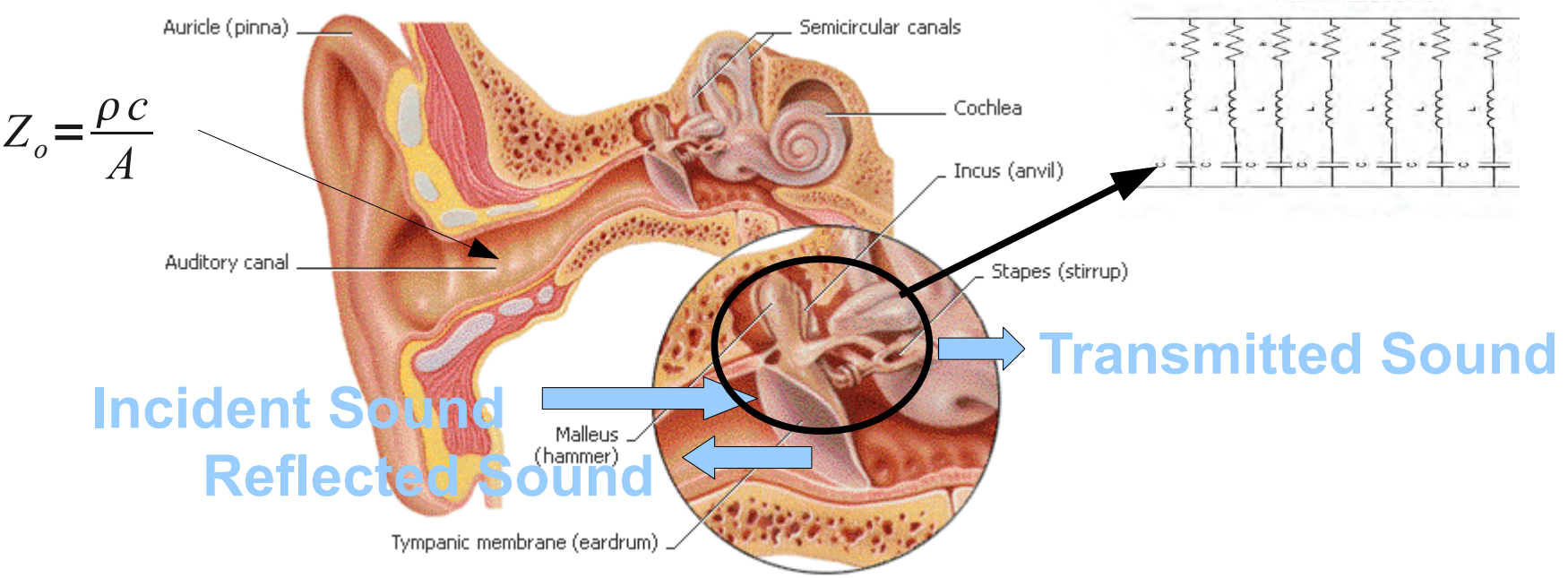




Damping produces a broad transfer function

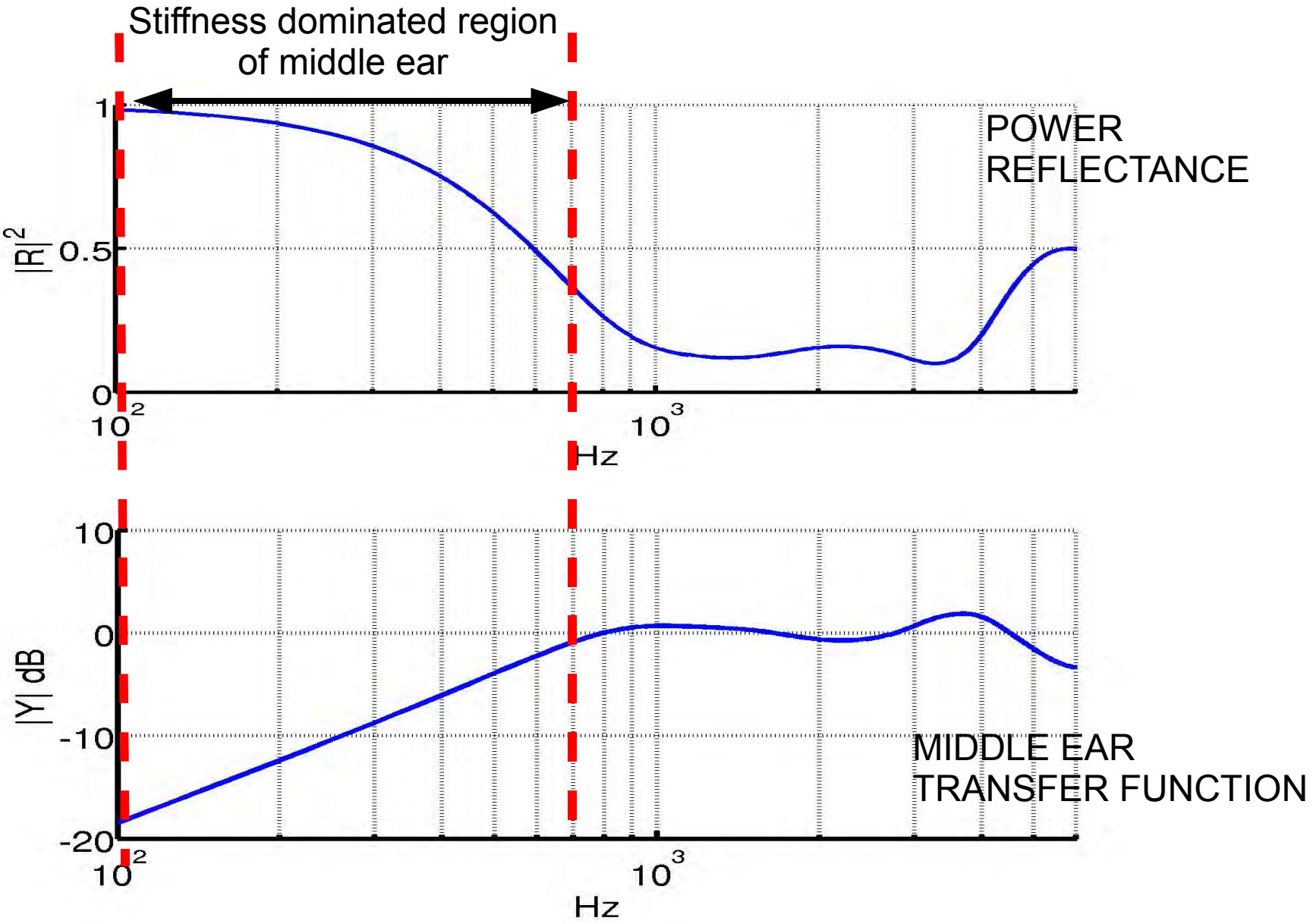
The Middle ear and Reflectance

$$Z_o = \frac{\rho c}{A}$$

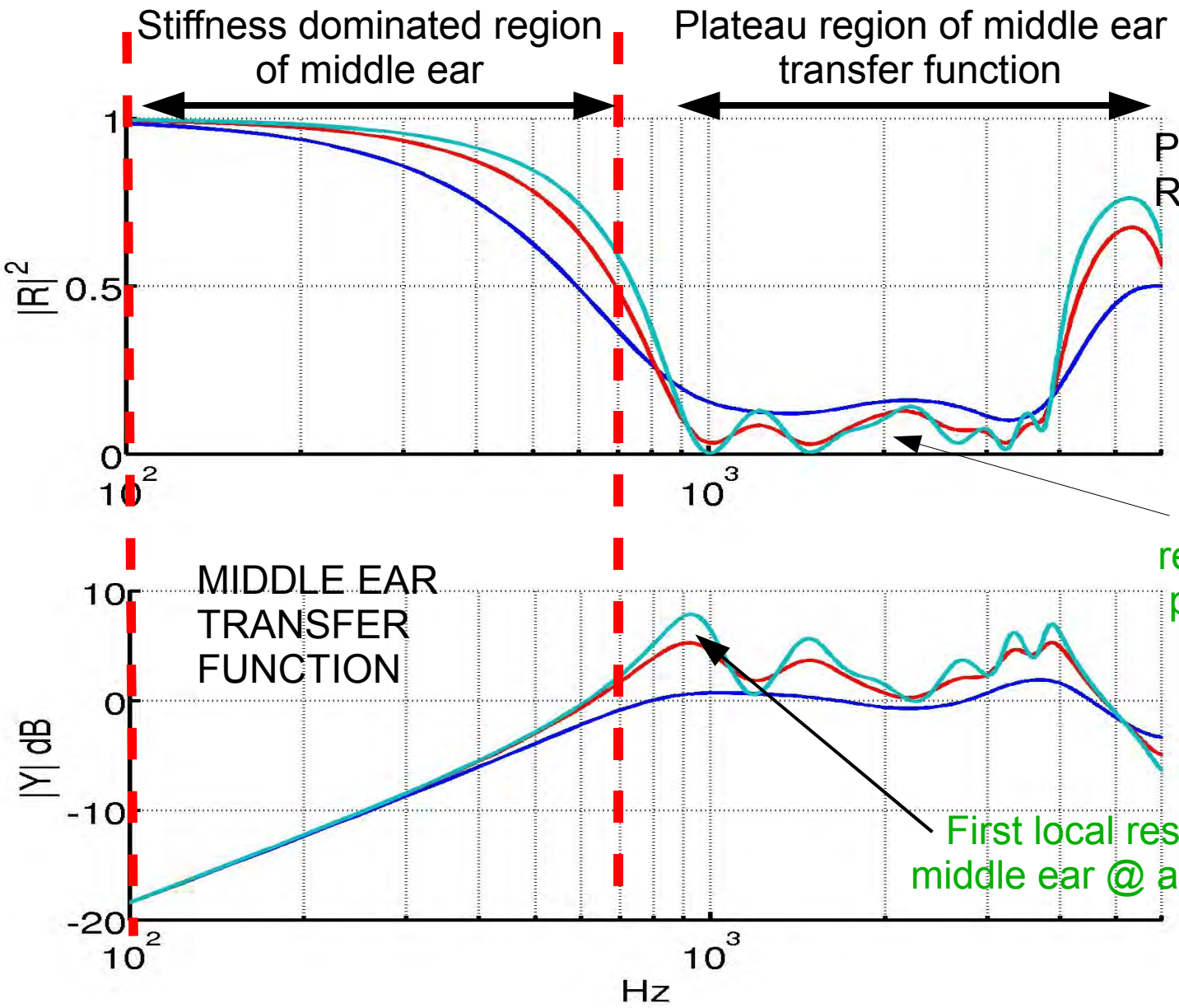


- The amount of sound reflected from the eardrum is determined by the **impedance mismatch** between the ear canal and the middle ear
- We can examine this reflected sound energy using
  - **Power Reflectance**
    - with our middle ear model (and a value for Zo)

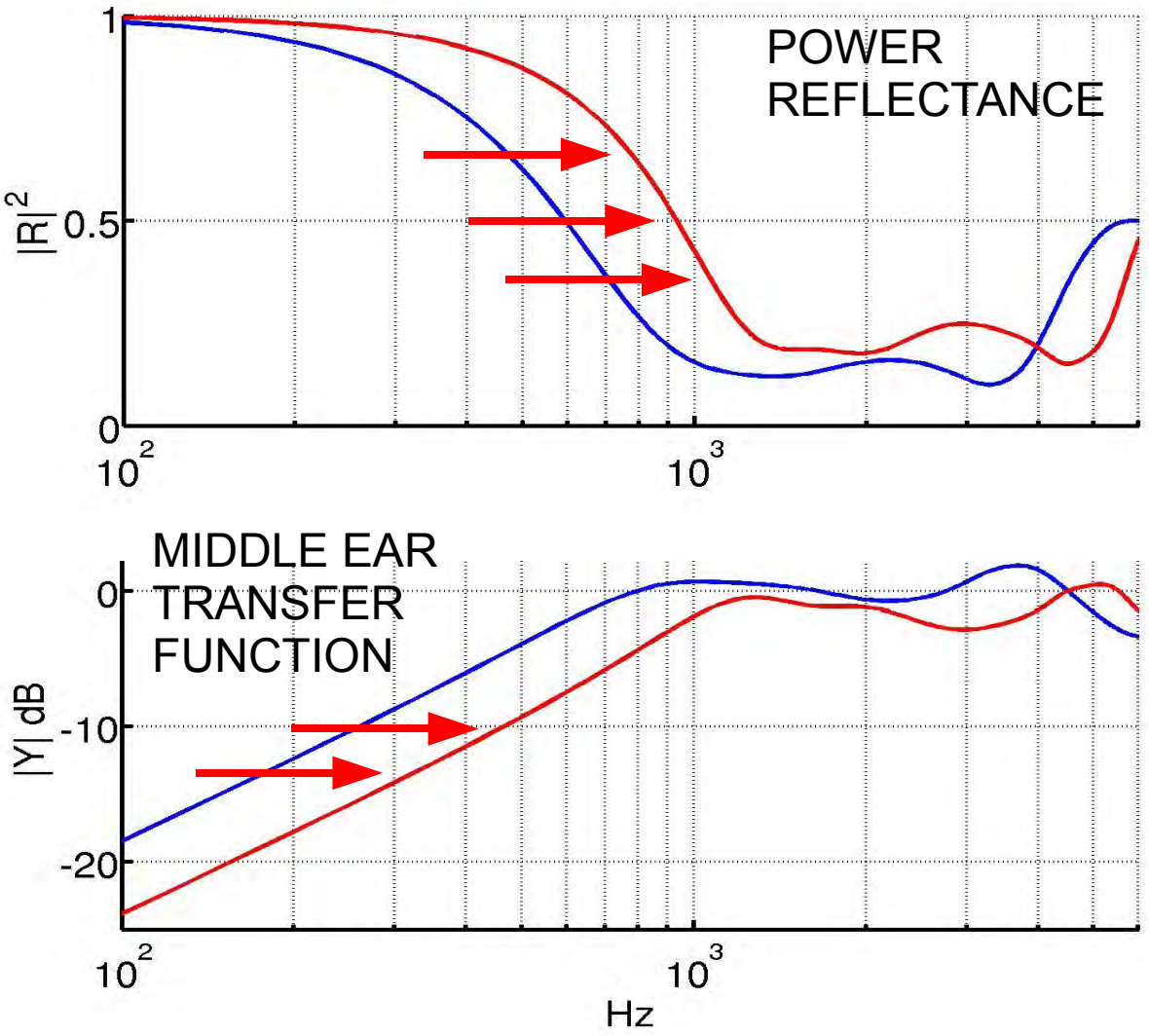
Power Reflectance

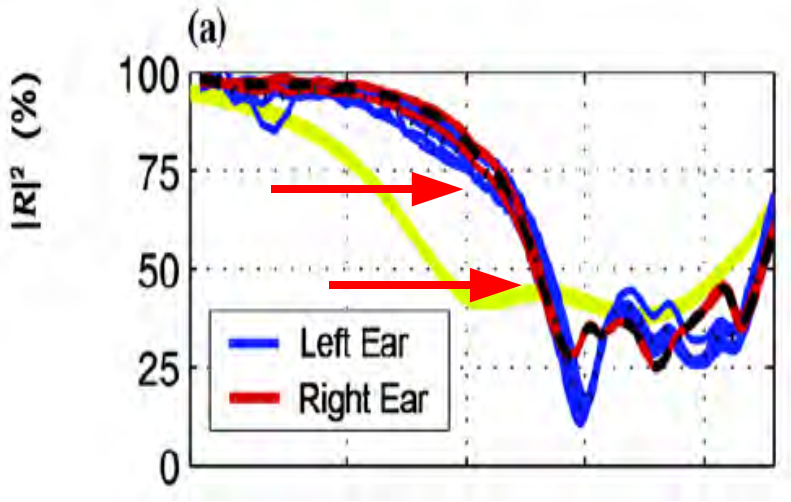


Power Reflectance
- role of damping in the middle ear -



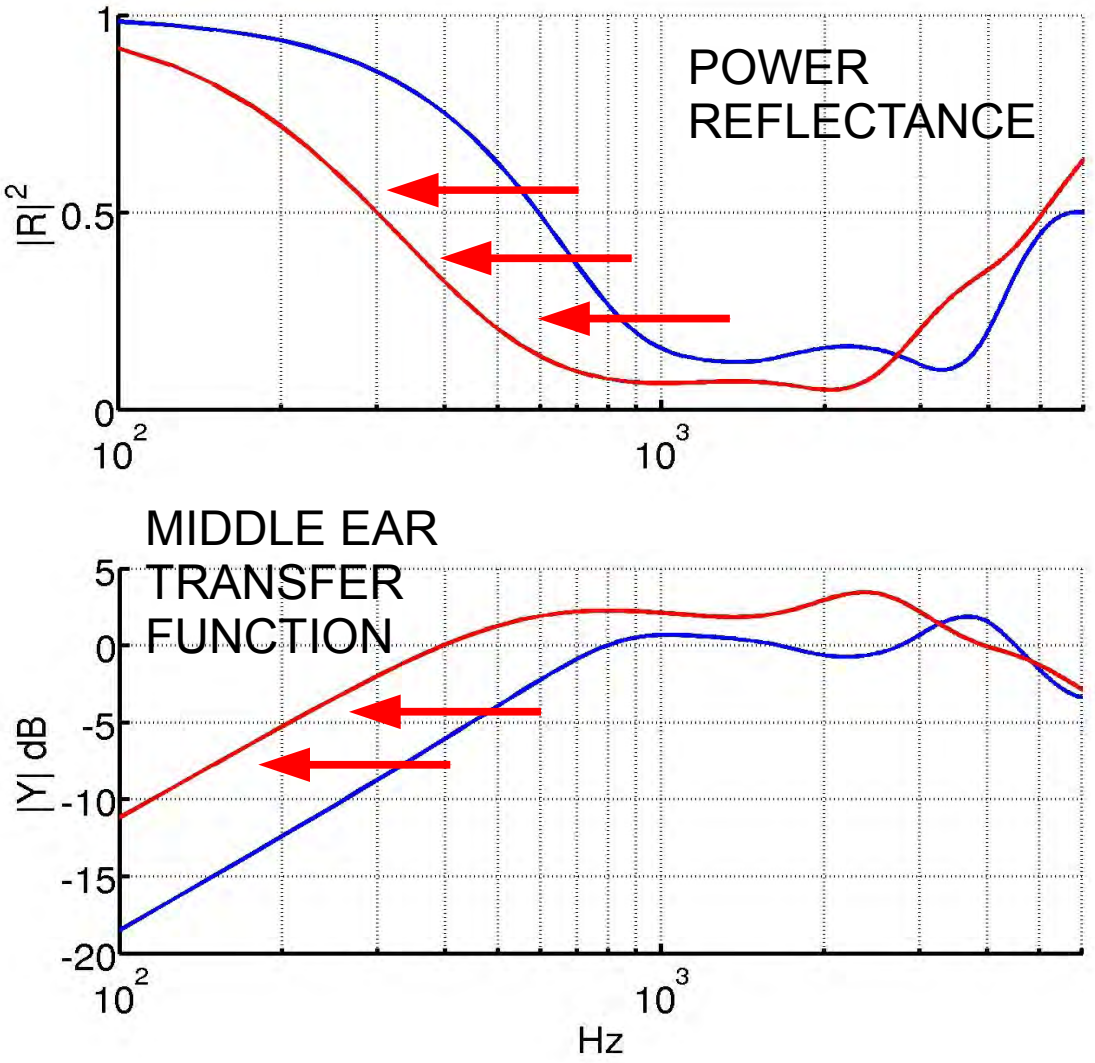
Power Reflectance
- increase in stiffness of middle ear -

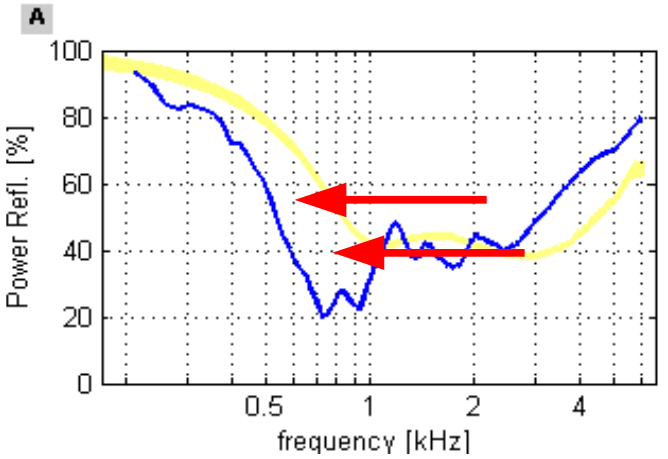




Power reflectance results from a subject with otosclerosis (Allen et al., 2005)

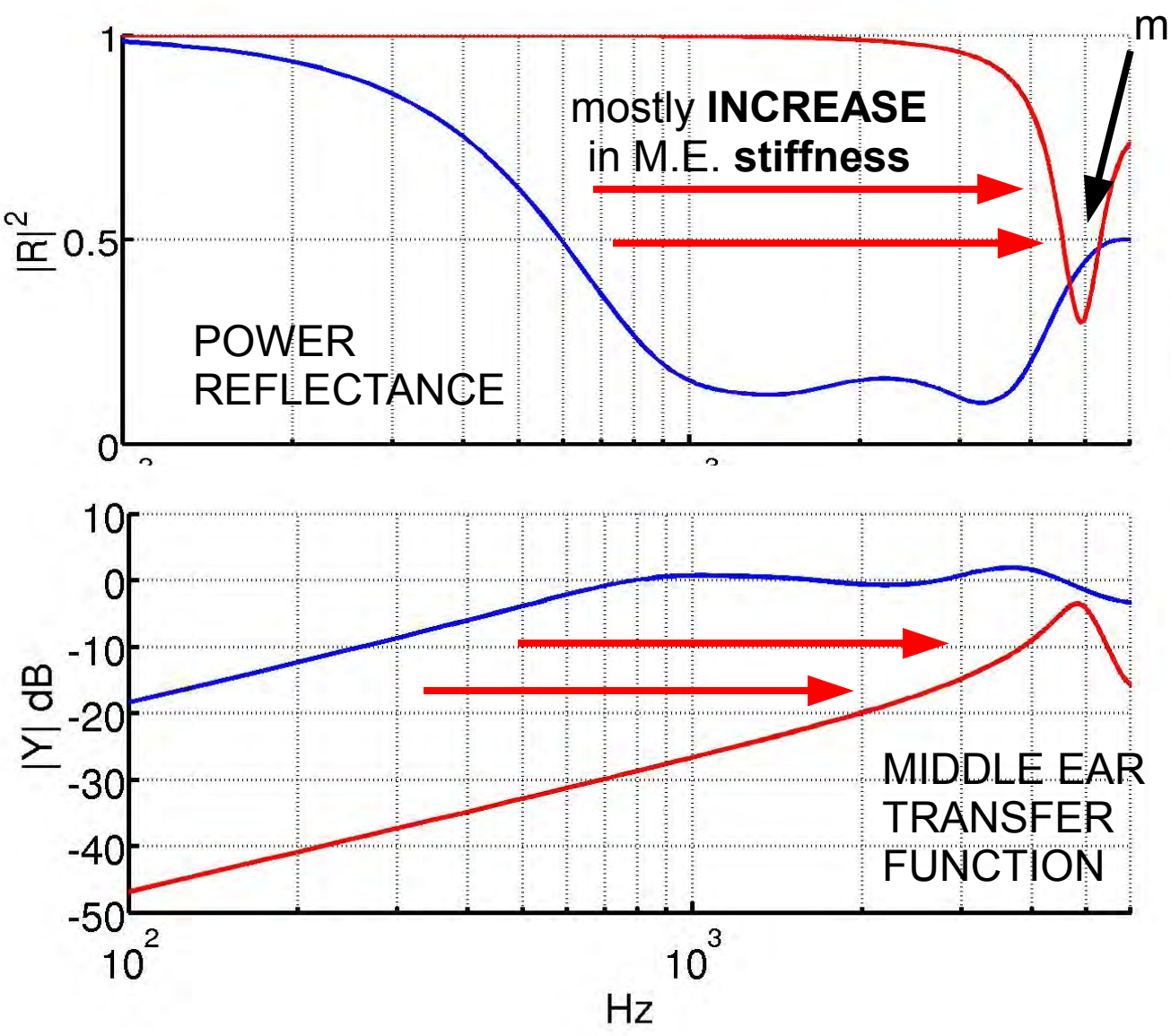
Power Reflectance
- decrease in stiffness of middle ear -

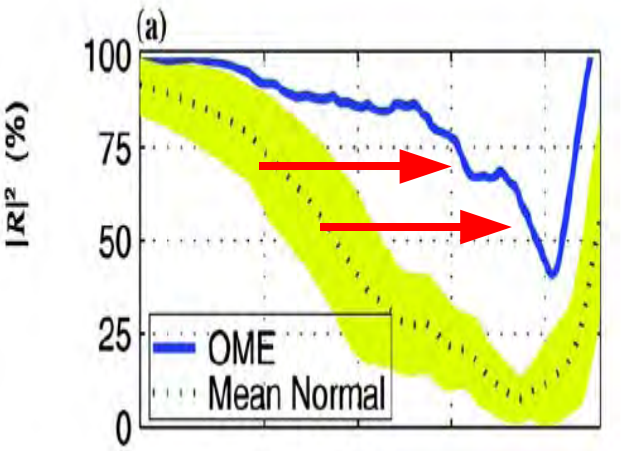




Power reflectance results from a subject with middle ear disease as a child (Mimosa data)

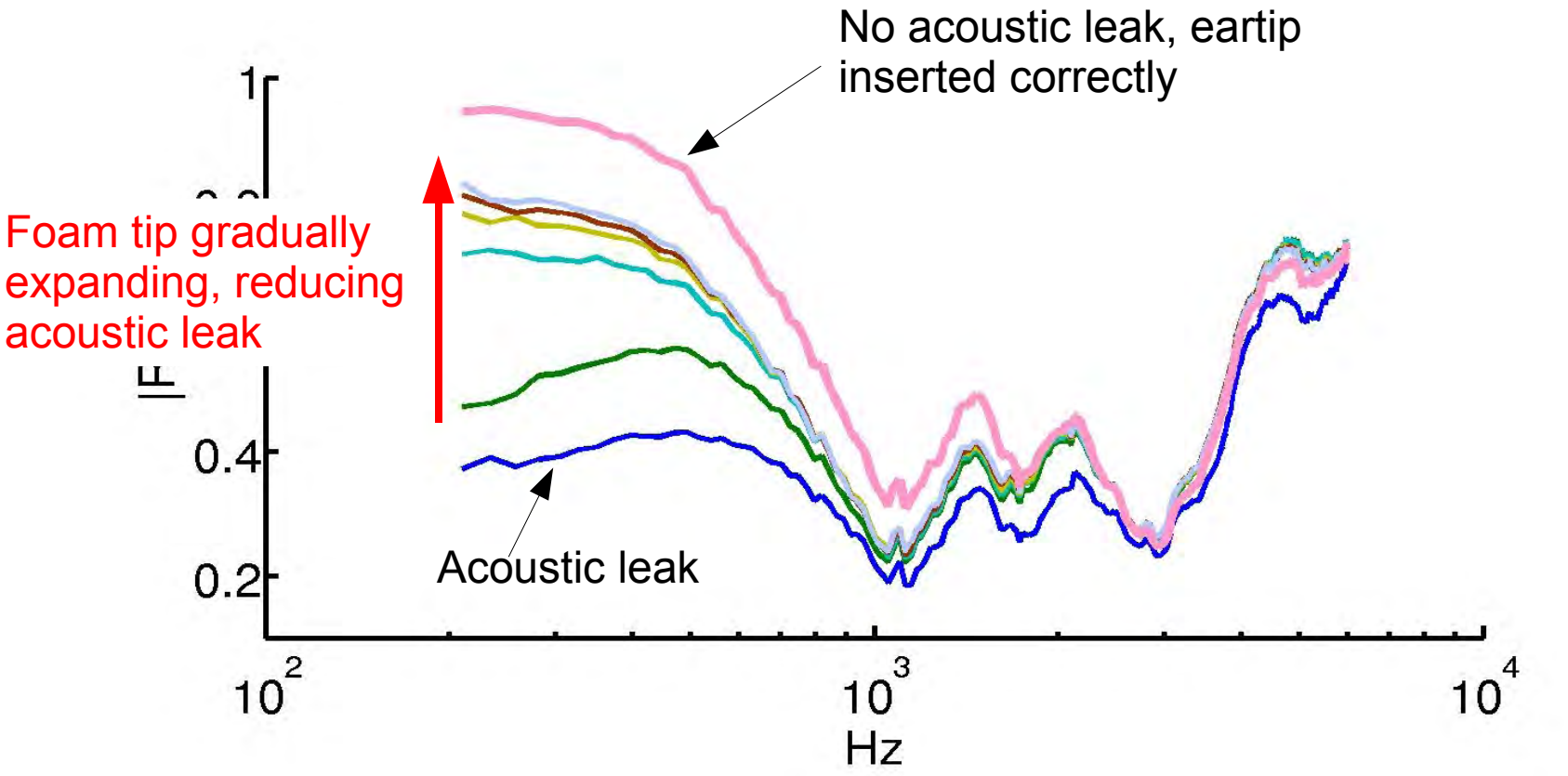
Power Reflectance
- what about OME? -





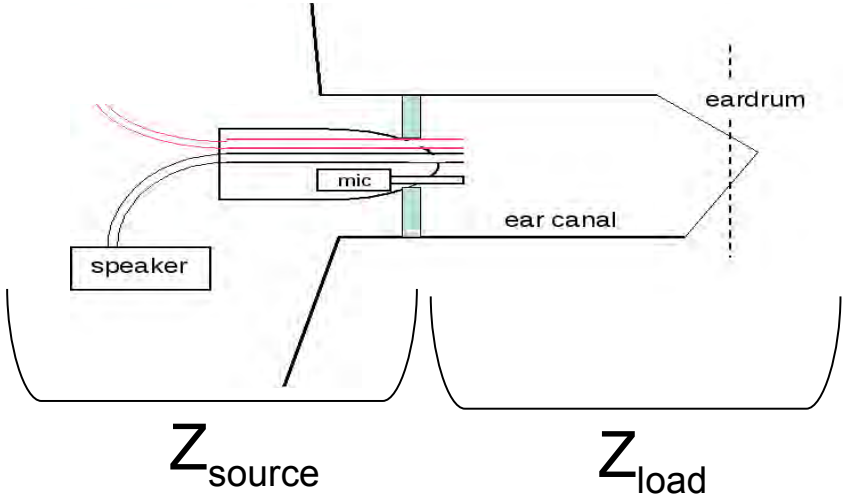
Power reflectance results from a subjects with otitis media with effusion (Allen et al., 2005)

Power Reflectance
- Acoustic Leak -

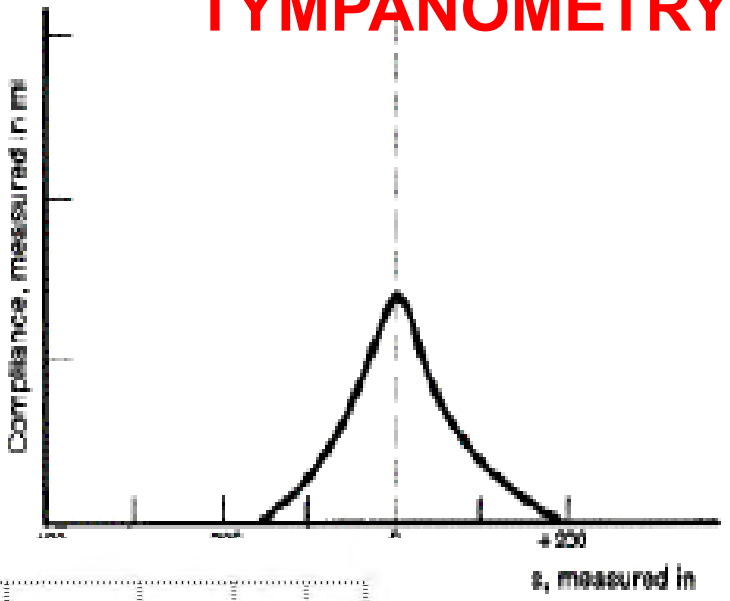


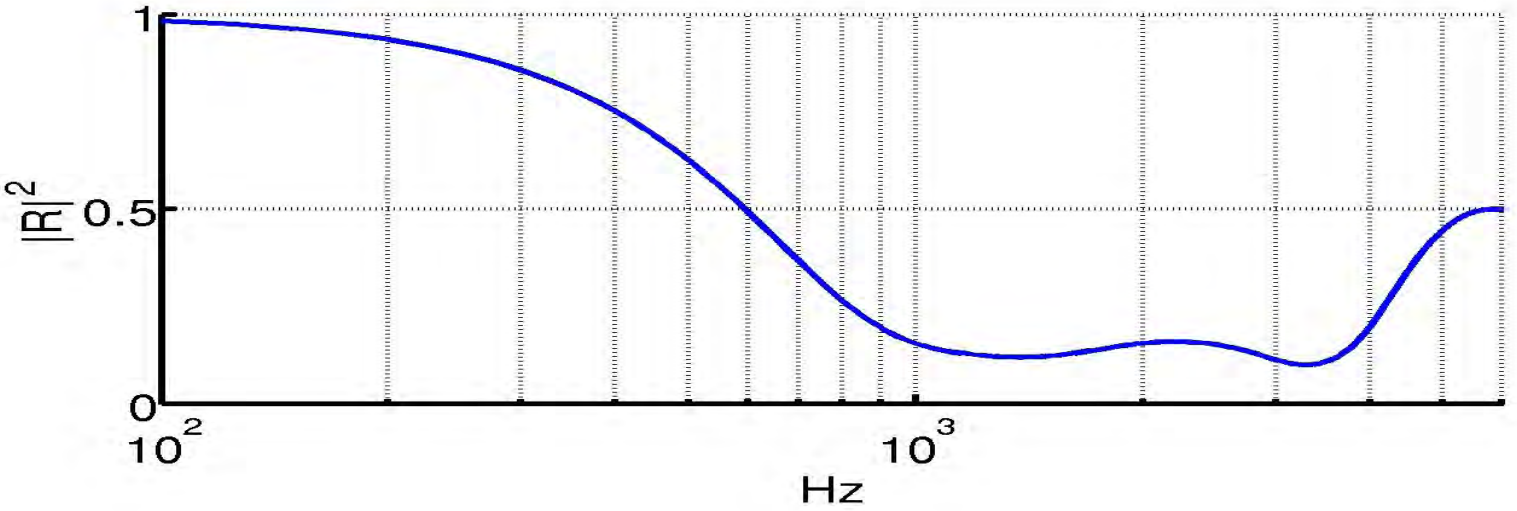
If eartip is not acoustically sealed in ear canal, sound at low frequencies leaks out, affecting the calculation of reflectance

Measuring the impedance mismatch between the ear canal and middle ear

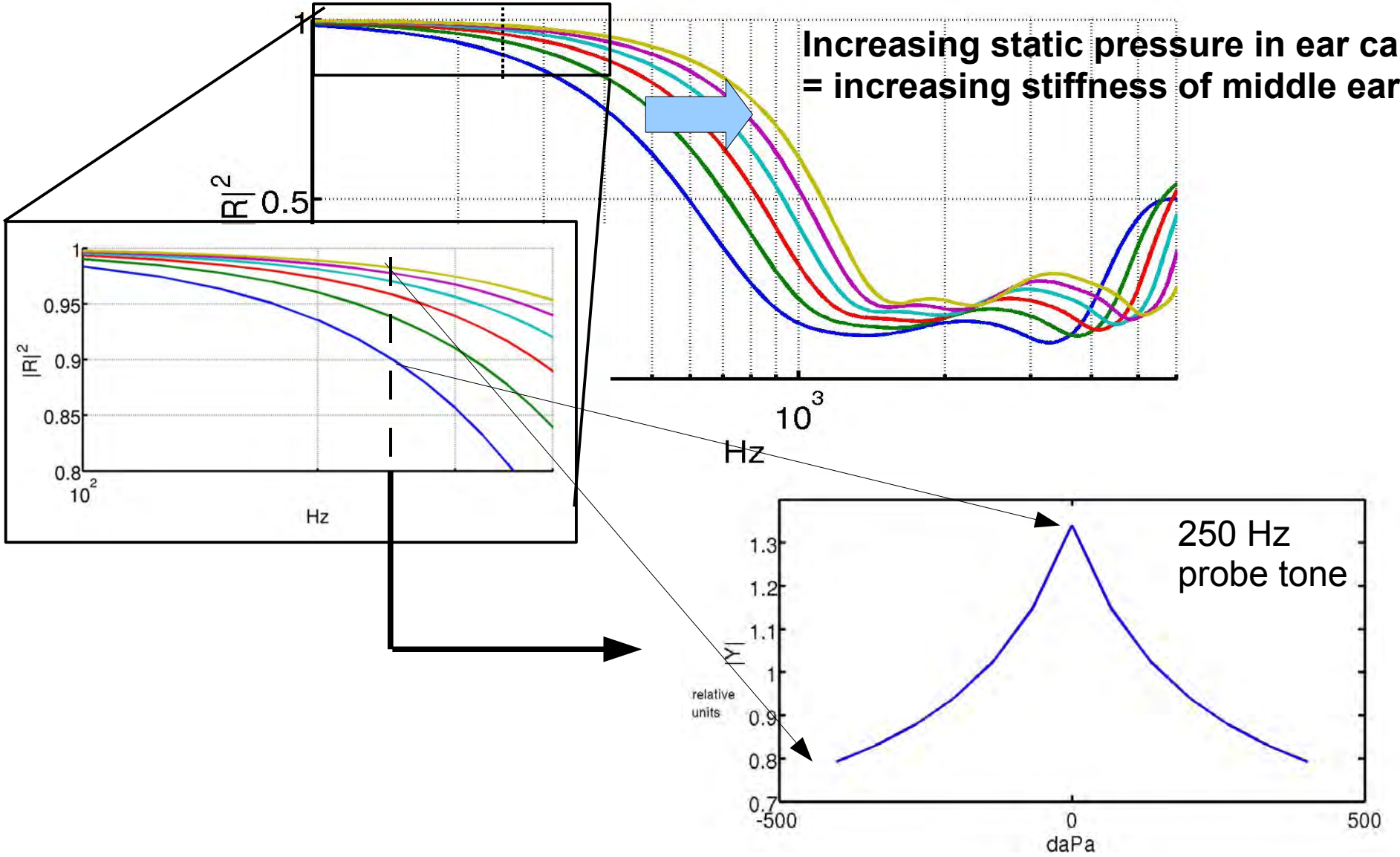


TYMPANOMETRY

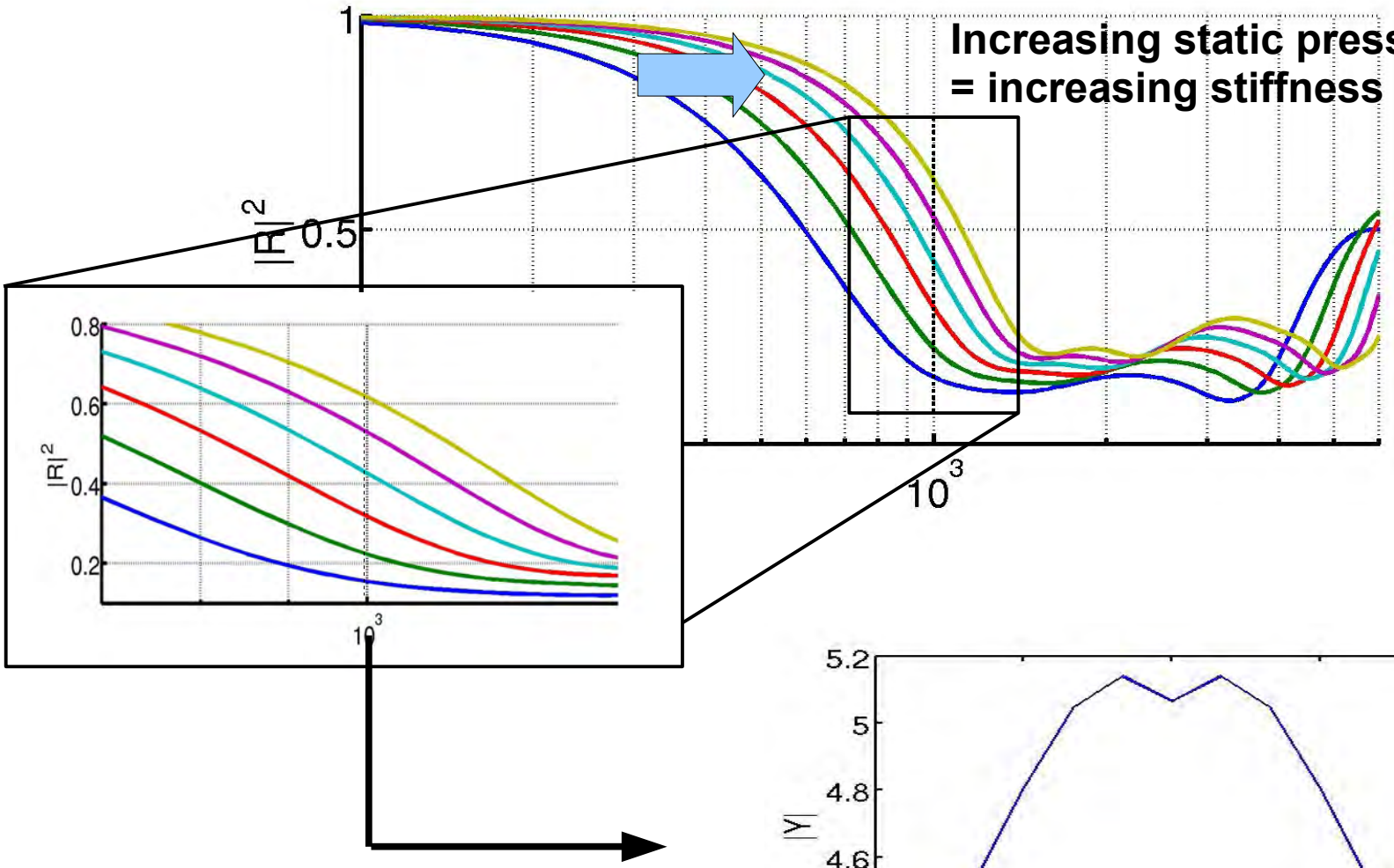


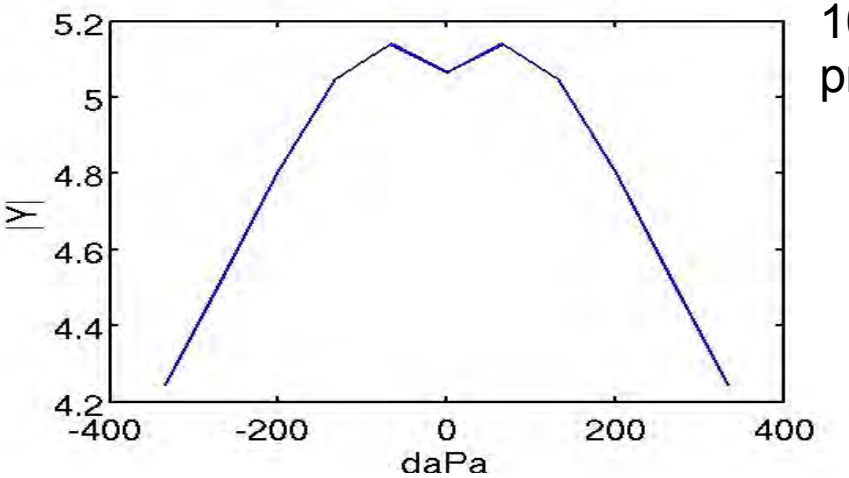


WBR vs Tympanometry



WBR vs Tympanometry





1000 Hz
probe tone

Power Reflectance

- Provides a broad spectrum measure of the impedance mis-match between the ear canal and middle ear
- Does not require static pressure changes in the ear canal
- The reflectance transfer function alters predictably with middle ear pathology