Evaluating ME Function via an Acoustic Power Assessment

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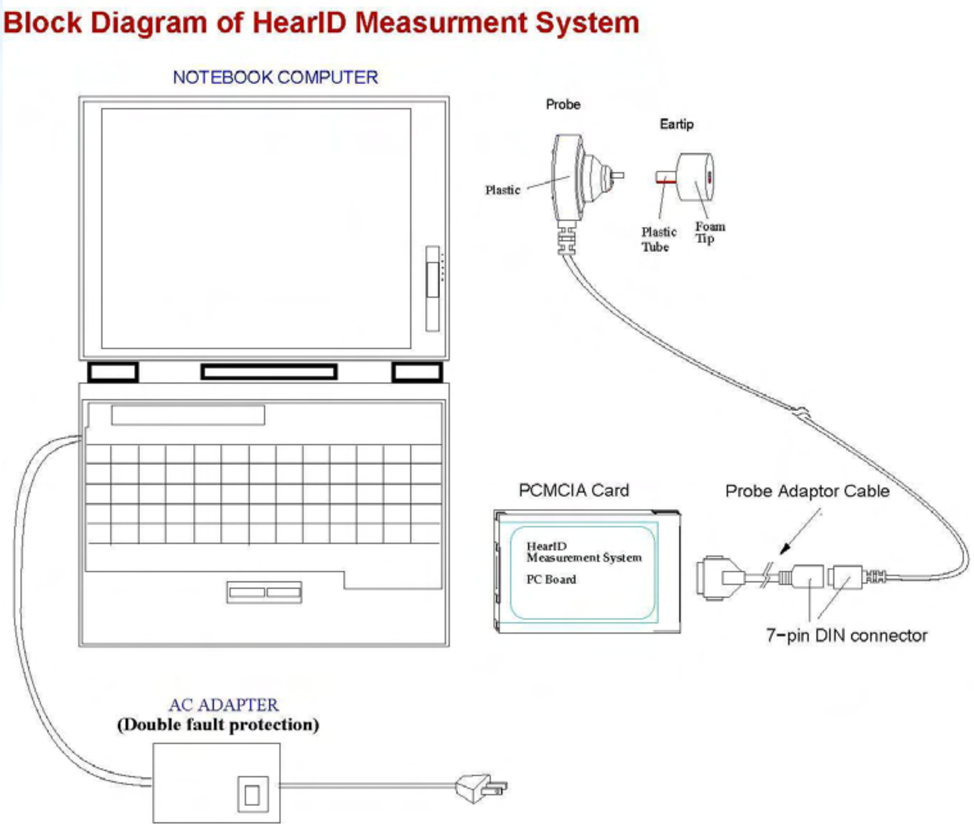
wbMEPA – the device

- PC board
- Ear probe
- Lap-top computer
- MEPA program



A clinical diagnostic tool - wbMEPA

- Mimosa's middle ear power analyzer (MEPA)
  - RMS – reflectance measurement system
  - WBR – wideband reflectance
  - Otoreflectance
- Sponsored by NIH SBIR grant R43/44 DC03138
- FDA 510(k) #053216

MEPA

- Principles of the wbMEPA measurement
- Demonstration of wbMEPA measurement
- Clinical applications
- Hands-on demonstration

The middle ear is the gateway to the auditory system

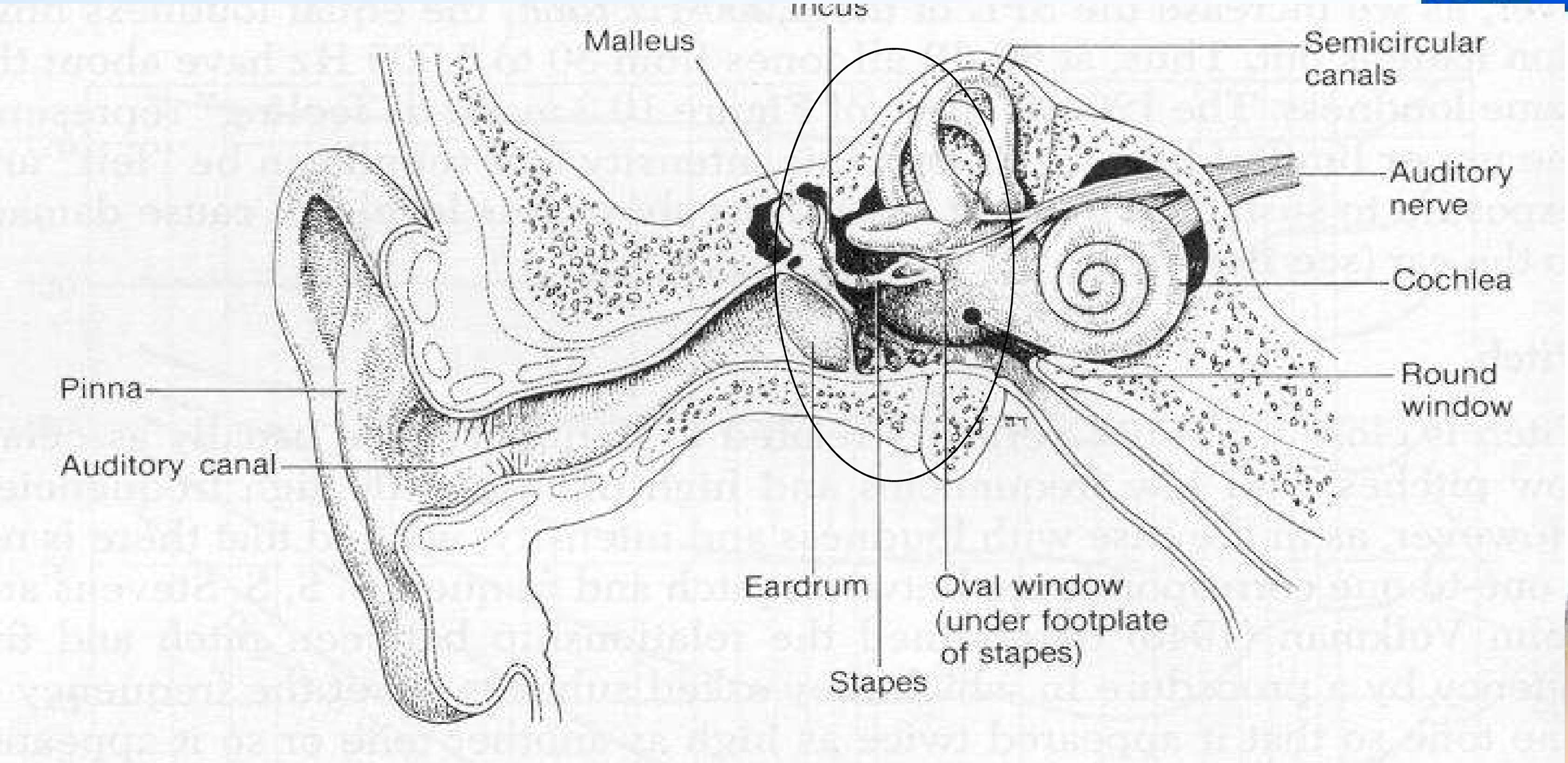
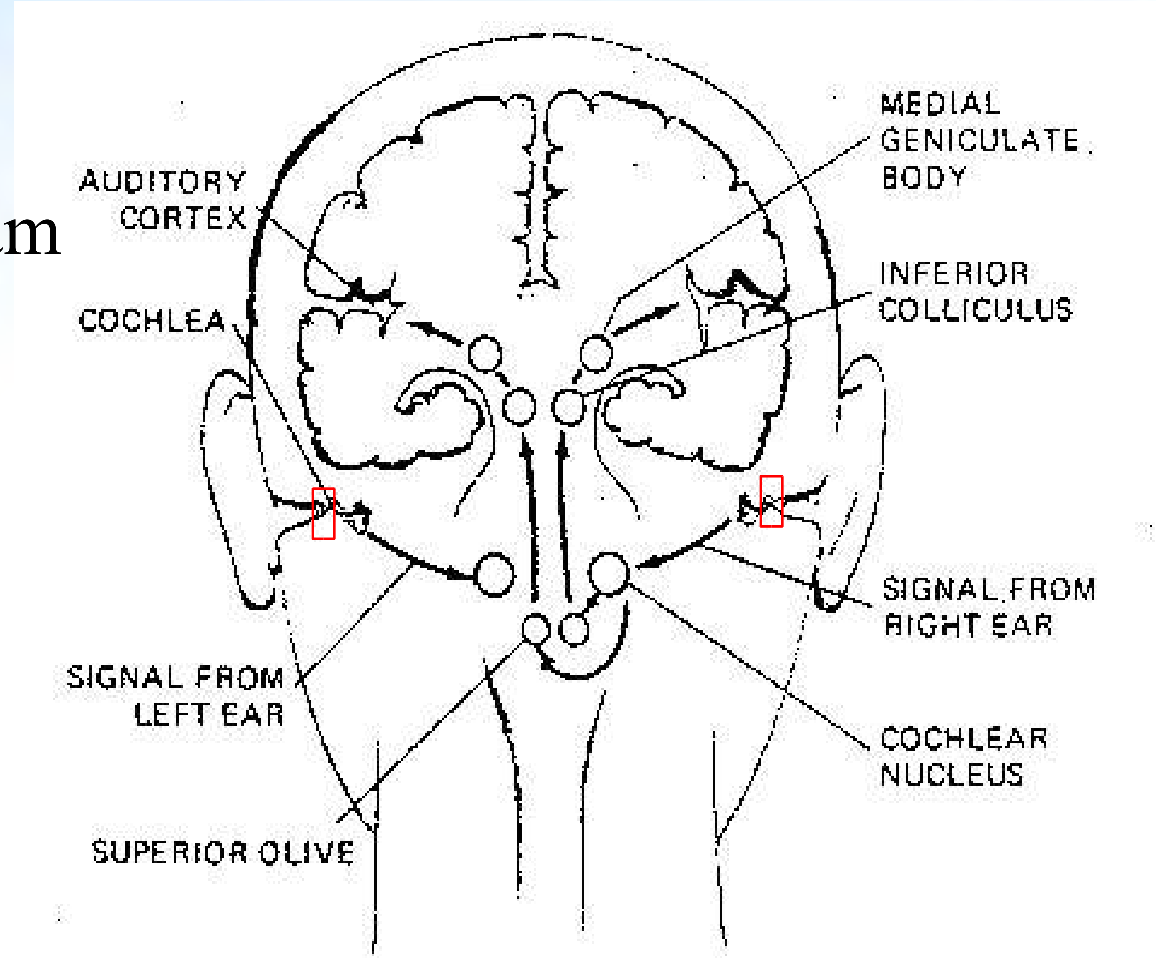


Figure 10.4

ME – **Gateway** to the auditory paths

- Audiogram
- OAE
- ABR



What is the Problem?

- The ME is the window into the cochlea
  - ME diagnostic tools are few
- Key application areas:
  - Neonate hearing screening
    - The “False-positive” problem
  - Middle ear disease diagnosis
  - Predicting the conductive component of hearing-loss vs. frequency, in dB

How can we evaluate the ME?

- In a normal ear the acoustic power is absorbed by the cochlea.
  - *Power reflectance* is a measure of ME inefficiency
- Acoustic power measurement objectively quantifies ME function and malfunction.

What is "acoustic power flow?"

- Demonstration: a wall that reflects the ball
- A middle ear with OME is like the wall.
- The ball is like the sound energy

- Demonstration: a cloth absorbs the ball's energy
- A normal middle ear is like the cloth
- Some of the ball's energy is transferred through the cloth

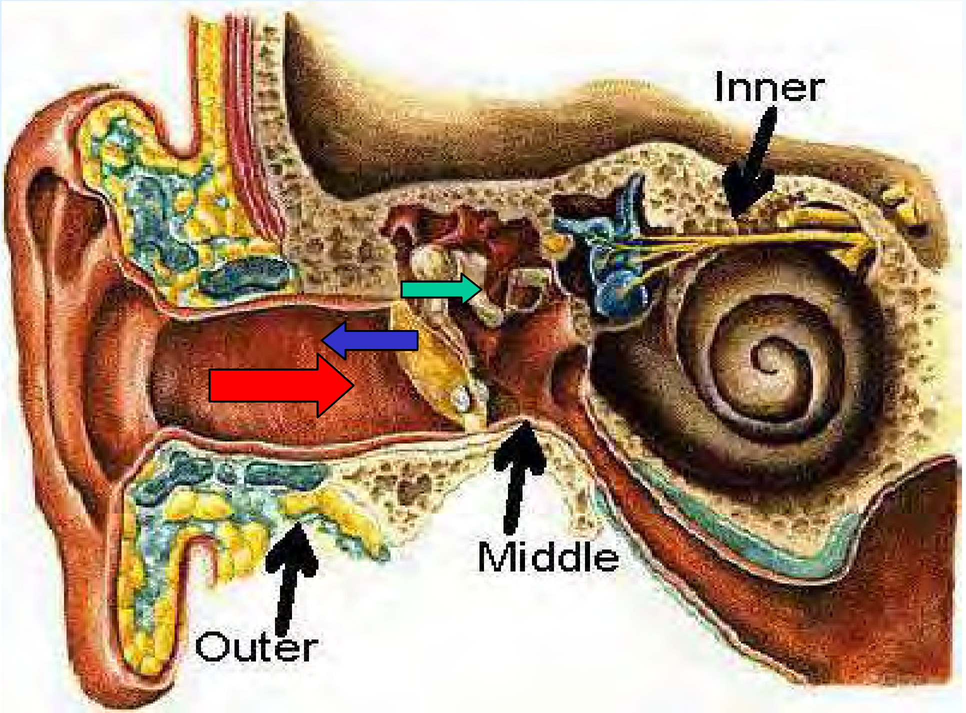
What is Power Reflectance?

- Sound enters ear canal, propagates down the ear canal, and is partially reflected from the ear drum.

$$\text{Reflectance} = \frac{\text{Reflected power}}{\text{Incident power}}$$

  – Power reflectance = energy reflectance

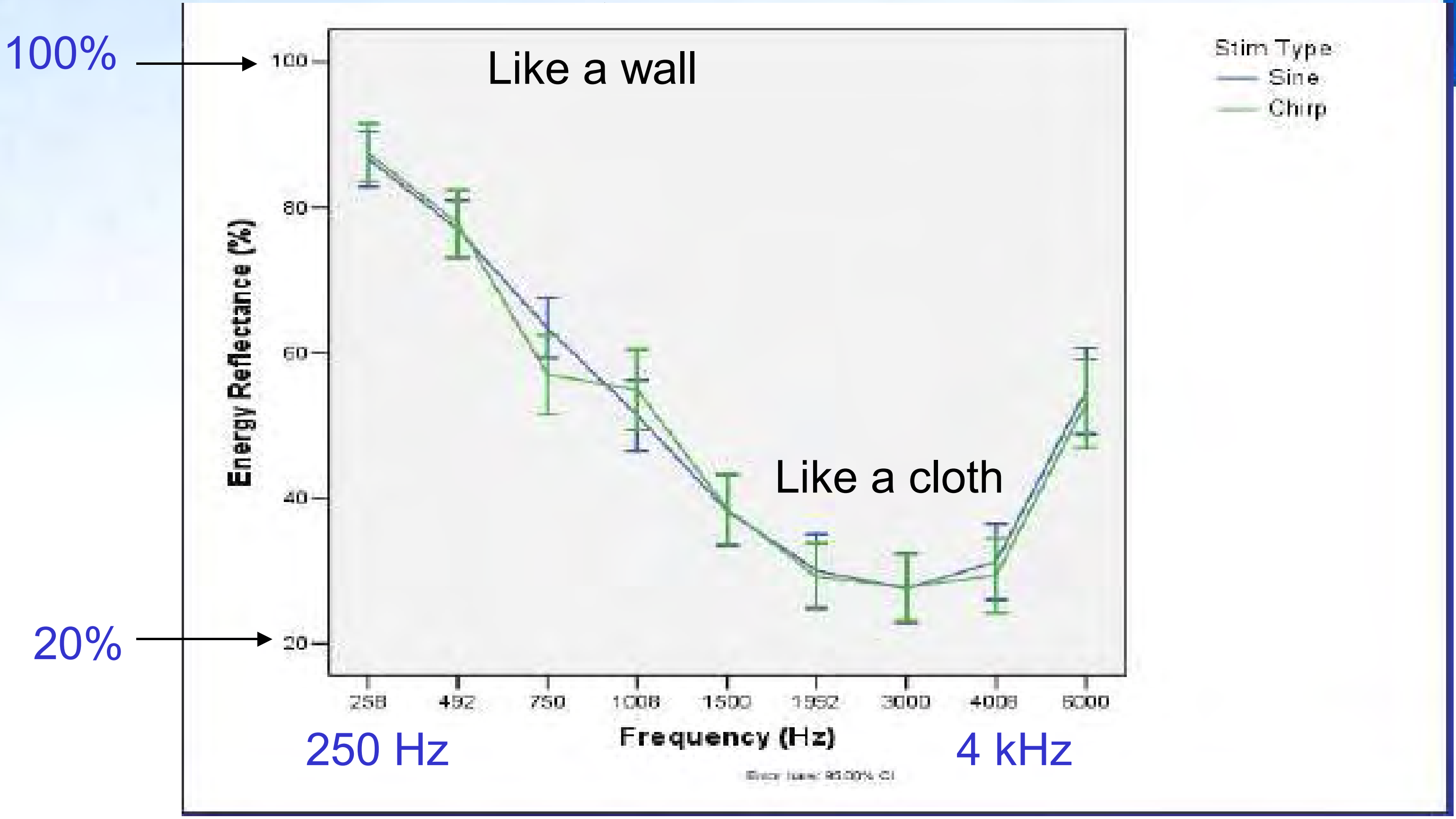
What is Power Reflectance?



$$\text{Reflectance} = \frac{\text{Reflected Power}}{\text{Incident Power}}$$

Transmittance = Absorbed Power

Wideband Reflectance |R(f)|



R(f) depends on frequency

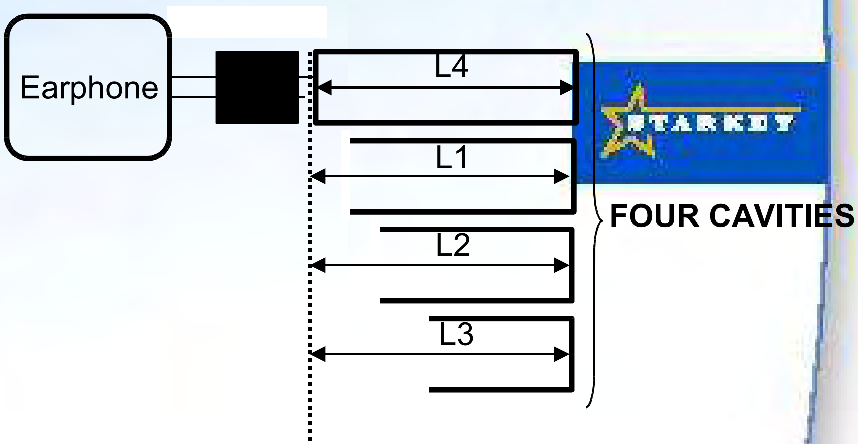
Hunter, AAA convention 2005

Reflectance Measurement

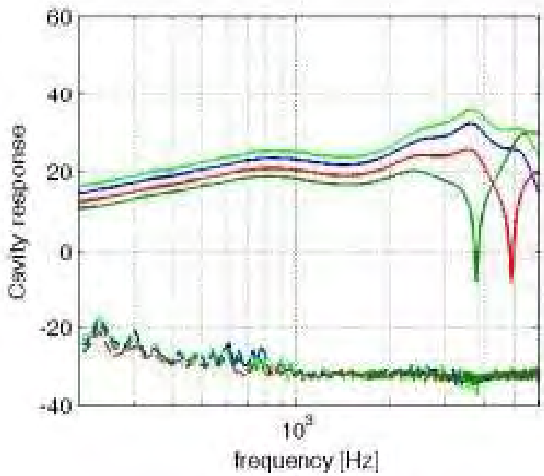
1. Probe calibration
2. Obtain patient measurement
3. Evaluation of results

1. Probe Calibration

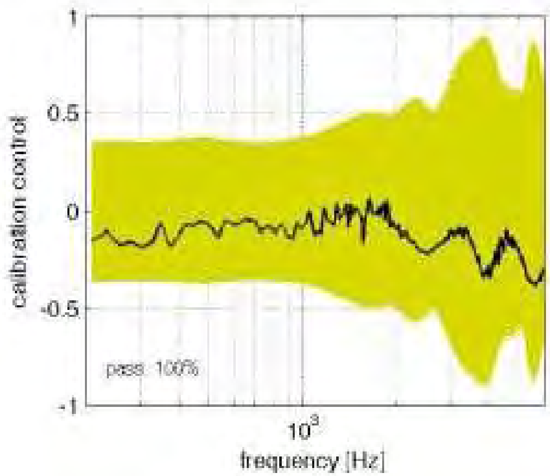
Characterize the probe acoustics properties via four cavities



Cavity pressures



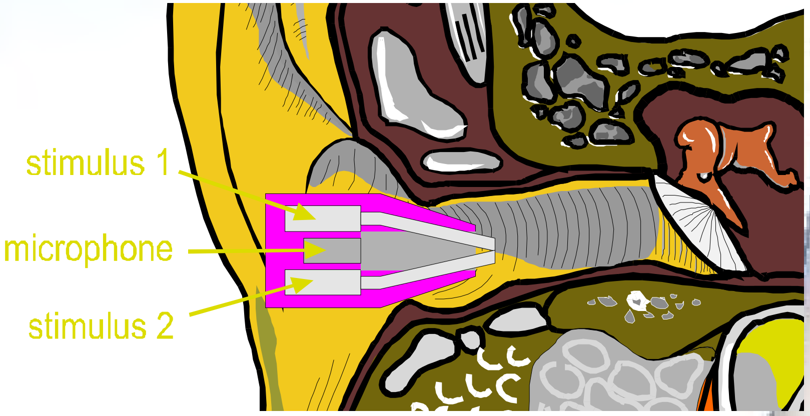
Calibration pass



Cavity set

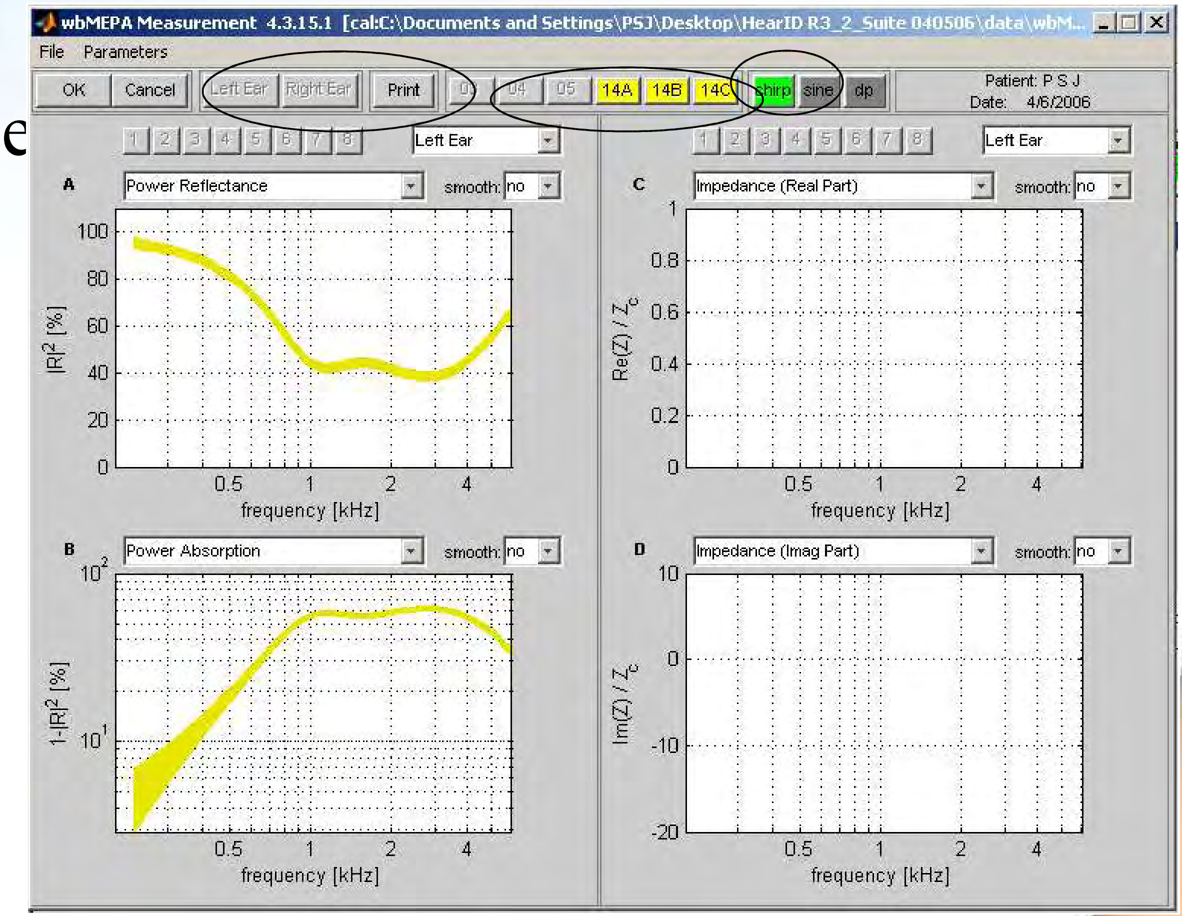
2. Obtain patient measurement

a. Select the probe tip
b. Place the probe in the patient's ear canal
c. Specify the probe tip size
d. Initiate the canal pressure measurement
e. Parameters:
   – Stimulus type (Chirp or tone)
   – Stimulus duration (sec)



Measure Reflectance

- Ear tip size
- Stimulus type
- Ear to be measured
- Reflectance plot



Application – UNHS

Why Reflectance?

mg

Why Reflectance?

A central goal of any UNHS (Universal Newborn Hearing Screening) program is to correctly identify ears with hearing loss and correctly identify ears with normal hearing.

Keefe, Ear and Hearing 2000

	PASS	REFER
Normal Hearing	100%	0%
Hearing Loss	0%	100%

Why Reflectance?

In the newborn population, the incidence of conductive hearing loss is greater than sensorineural hearing loss. Usually, the conductive component is transient.

Why Reflectance?

Boone, R.T, et al (2005) review 76 newborns whom failed the UNHS. Approximately 66% had OME and only 33% required BMT. SNHL was confirmed via EP in 11% following resolution of OME. SNHL was confirmed in the majority of patients without OME.

(International Journal. Of Ped. Otorhinolarygoloy)

Why Reflectance?

- Boone, 76 newborns whom failed the UNHS.
- 50 (66%) had OME
  - 17 (33%) required BMT.
  - SNHL was confirmed via EP in 5 (11%) following resolution of OME.
- Of the remaining 26, SNHL was confirmed in the majority of patients without OME.

(Boone, R.T., International Journal. Of Ped. Otorhinolarygoloy 2005)

Why Reflectance?

Boone, R.T, et al (2005) review 76 newborns whom failed the UNHS. Approximately 66% had OME and only 33% required BMT. SNHL was confirmed via EP in 11% following resolution of OME. SNHL was confirmed in the majority of patients without OME.

OME is a common cause of a 'false positive' failed UNHS, but the presence in the face of a failed hearing screening does not necessarily rule out a SNHL.

(International Journal. Of Ped. Otorhinolarygoloy)

Why Reflectance?

Keefe, Gorga,et al tested 2638 neonatal ears and these authors concluded that information on the middle ear status improves the ability to correctly predict hearing status

Keefe, JASA 2003

Why Reflectance?

- Keefe et al tested 2638 neonatal ears
- Concluded that information on the middle ear status improves the ability to correctly predict hearing status

Keefe, Gorga, JASA 2003

Why Reflectance?

Keefe, Zhao, et al, evaluated 1405 neonatal ears. OAE levels decreased and ABR latencies increased with increasing high frequency reflectance. Up to 28% of the variance in OAE levels and 12% of the variance in ABR wave V latencies where explained by these factors

Keefe, JASA, 2003

Why Reflectance?

- Keefe evaluated 1405 neonatal ears.
- High frequency reflectance approaching 1 implies abnormal OAE levels and abnormal ABR latencies.
- Up to 28% of the variance in OAE levels and 12% of the variance in ABR wave V latencies where explained by these factors

Keefe, Zhao, JASA, 2003

Why Reflectance?

It is possible to obtain abnormal 220 Hz. tympanograms in infants less than 4 months when indeed their middle ear system is normal.

- Keefe, 1996

Why Reflectance?

Tympanometry results where normal (Type A) in infants below 4 months of age even though middle ear effusion was present.

Paradise 1976, Meyer 1997

Why Reflectance?

In newborns with “normal” middle ear systems (as defined by normal TEOAE results) has an error rate of 8% for the 1000 Hz tympanogram.

Kei, JAA

Why Reflectance?

To decrease the false positives

Cost (Testing and Patient’s Opportunity Cost)
Validity of UNHS

Why Reflectance?

- The problem with tympanometry is that static pressurization of the ear canal produces large changes in the ear canal volume due to changes in the ear canal diameter.

Keefe, Ear and Hearing 2000

Why Reflectance?

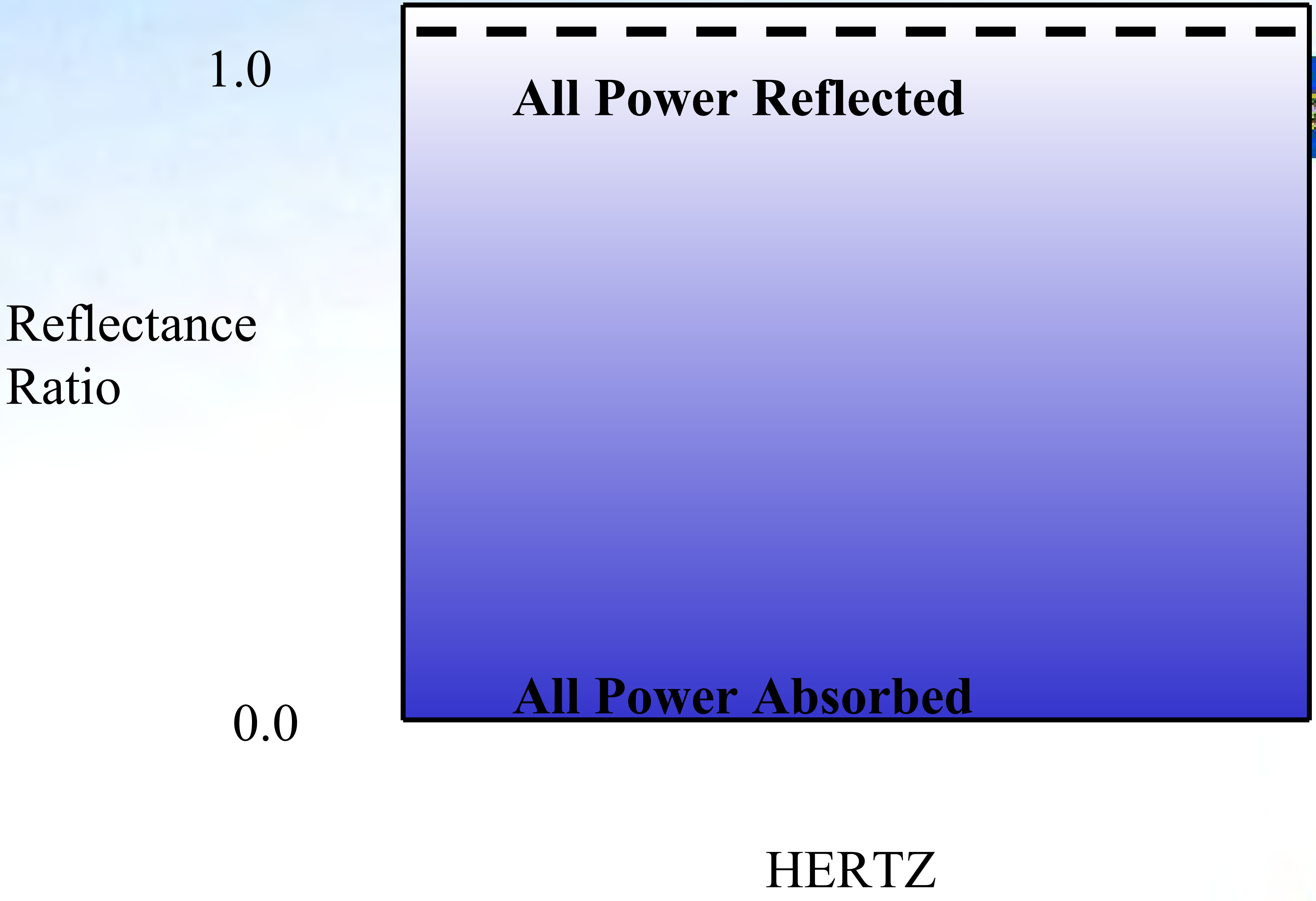
- There does not currently exist a clinically accepted acoustic test of middle ear status applicable to the neonatal population.
- The problem with tympanometry is that static pressurization of the ear canal produces large changes in the ear canal volume due to changes in the ear canal diameter.
- In a compliant infant ear canal, the diameter can change as much as 70% (Holte, 1991)

Keefe, Ear and Hearing 2000

Why Reflectance?

With proper calibration techniques WBR can be measured to 6 kHz.

WBR does not require the use of a pressurized E.A.C.


1.0
All Power Reflected
Reflectance
Ratio
0.0
All Power Absorbed
HERTZ

Application – ME pathology

Why Reflectance?

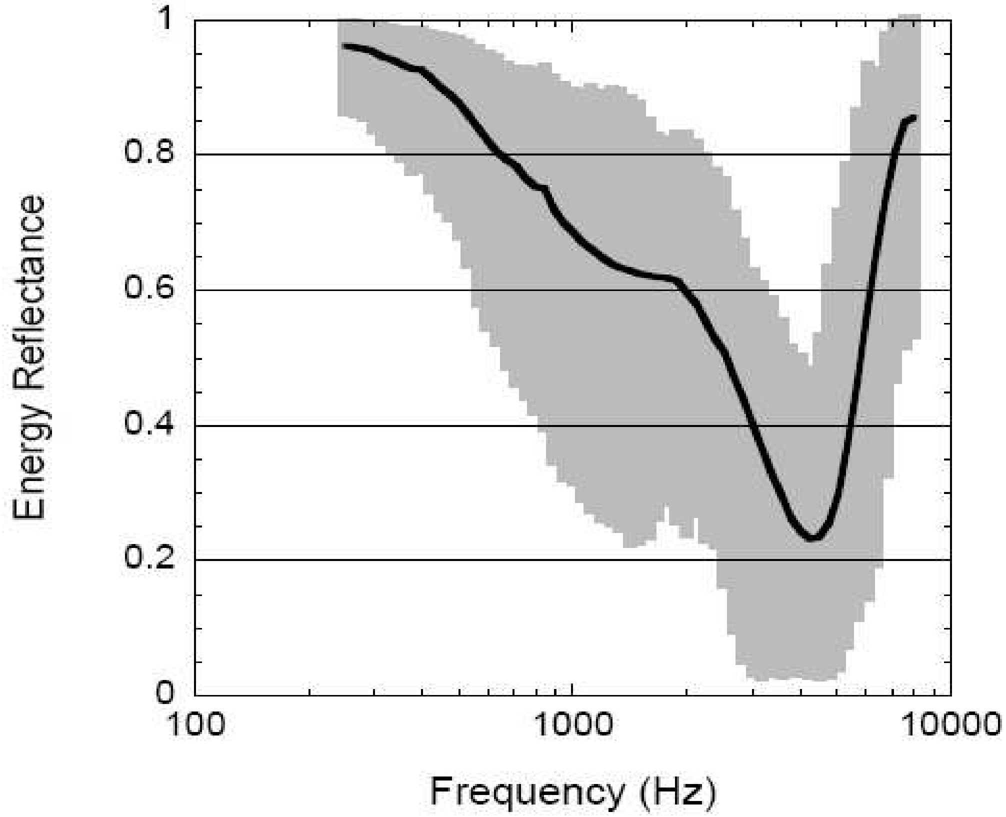
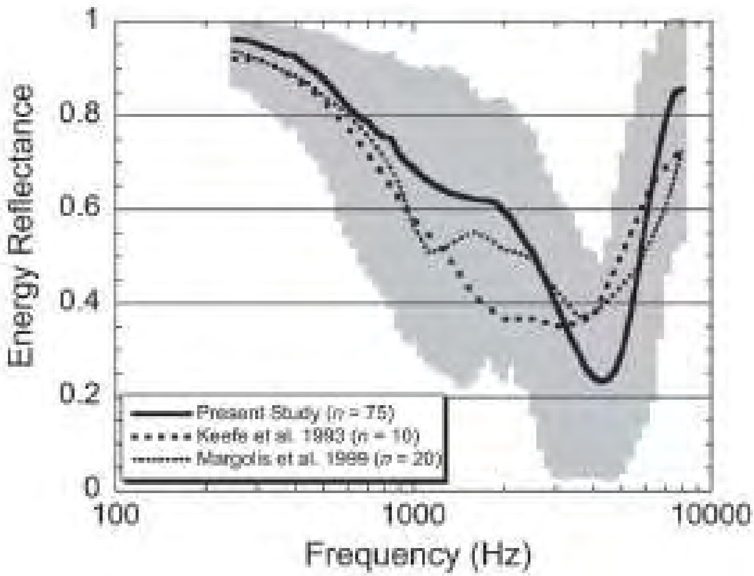


Figure 4. The mean 1/12 octave energy reflectance for 40 young-adult subjects with normal hearing. The shaded area represents the 5th percentile to the 95th percentile of the data. [From Feeney, P. (October, 2004). Current and Emerging Tools for the Assessment of Middle-Ear Function, ASHA Division 6, Perspectives on Hearing and Hearing Disorders Research and Diagnostics].

Feeney, ASHA Leader, 2005

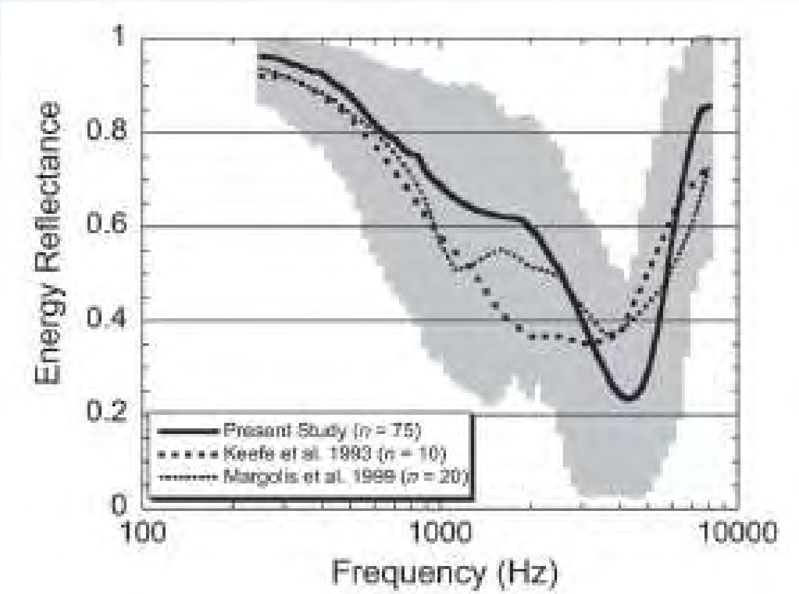


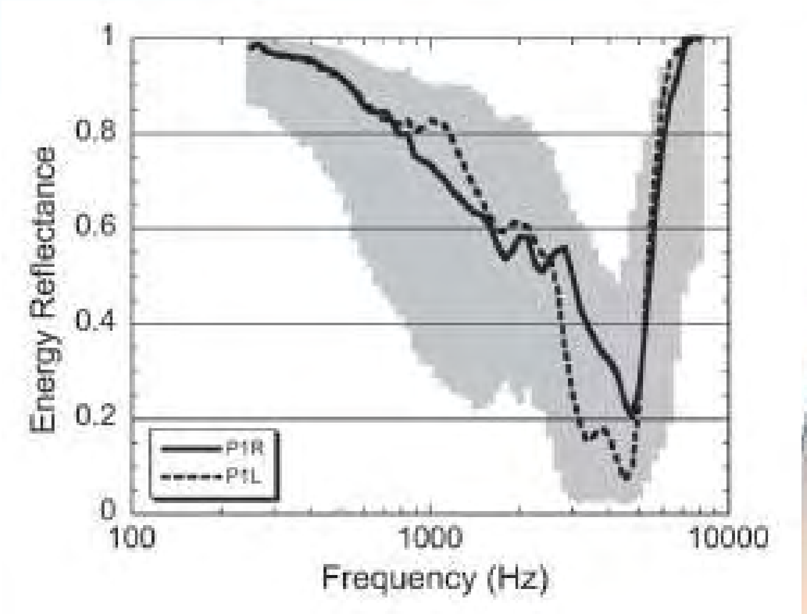
Feeney, JSHR, 2003

- The group mean one-twelfth-octave ER for the 75 ears of the young-adult participants (solid line) as a function of frequency. The shaded area represents the 5th percentile to the 95th percentile of the ER values. The group mean one-third-octave ER for 10 adult ears (thick dashed line) from Keefe et al. (1993) and the group mean one-sixth-octave ER for 20 adult ears (thin dashed line) from Margolis et al. (1999) are shown for

Normal

Reflected

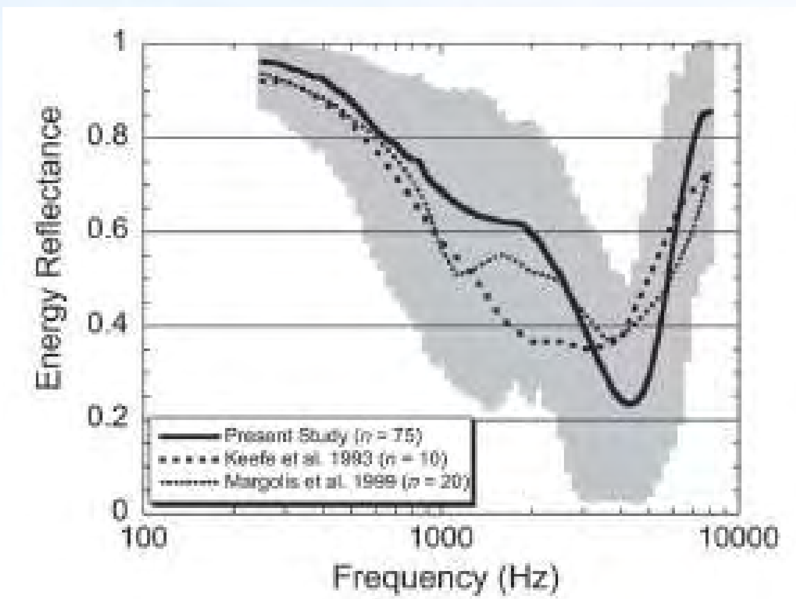


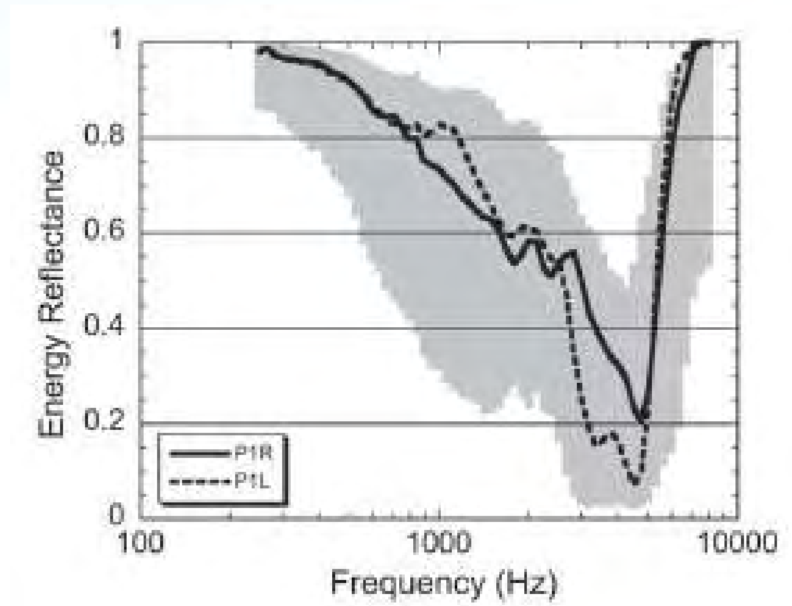


Absorbed

Feeney, JSHR, 2003

Bilateral SNHL

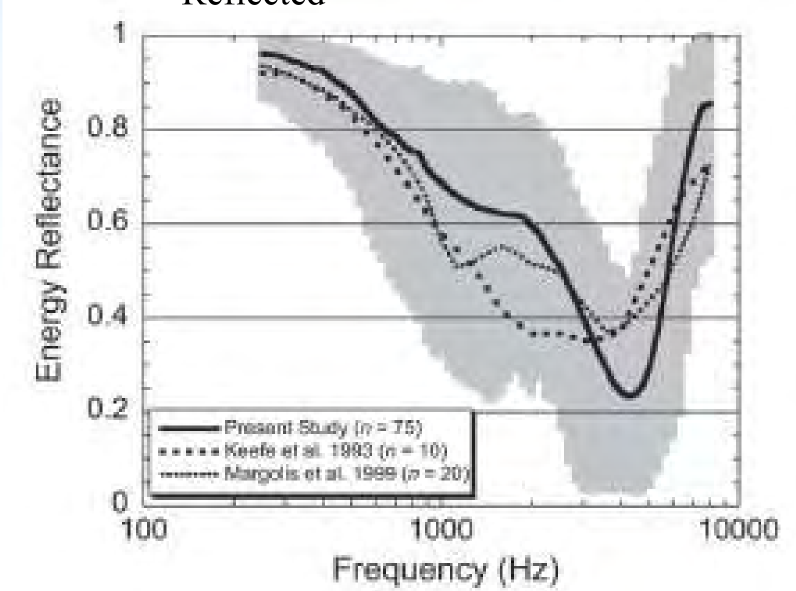




Feeney, JSHR, 2003

Normal

Reflected



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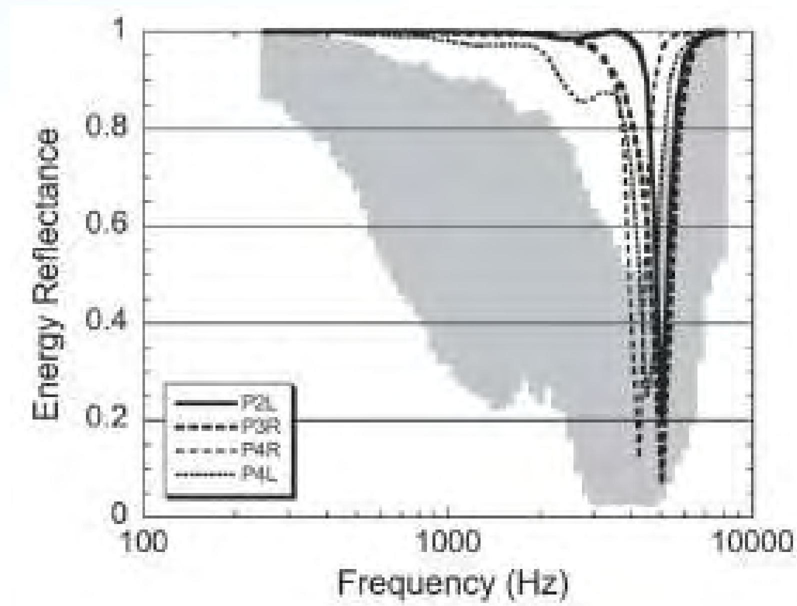
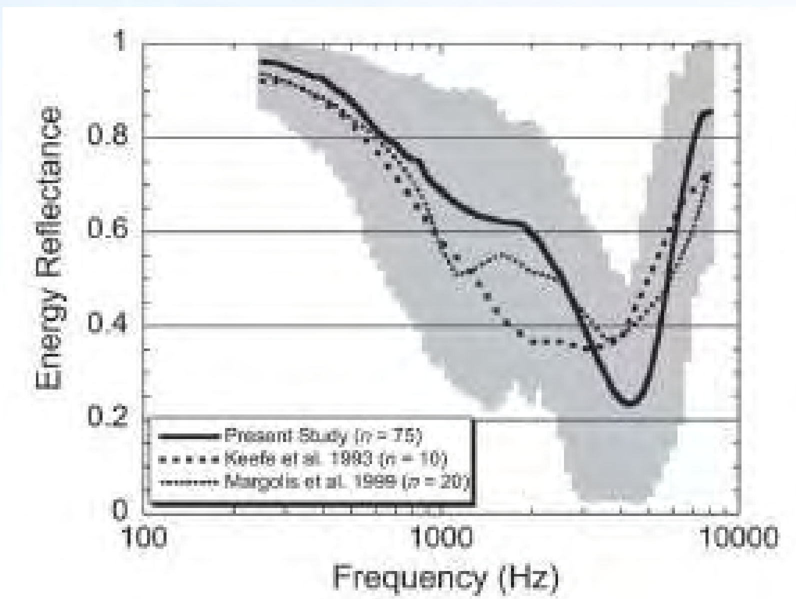
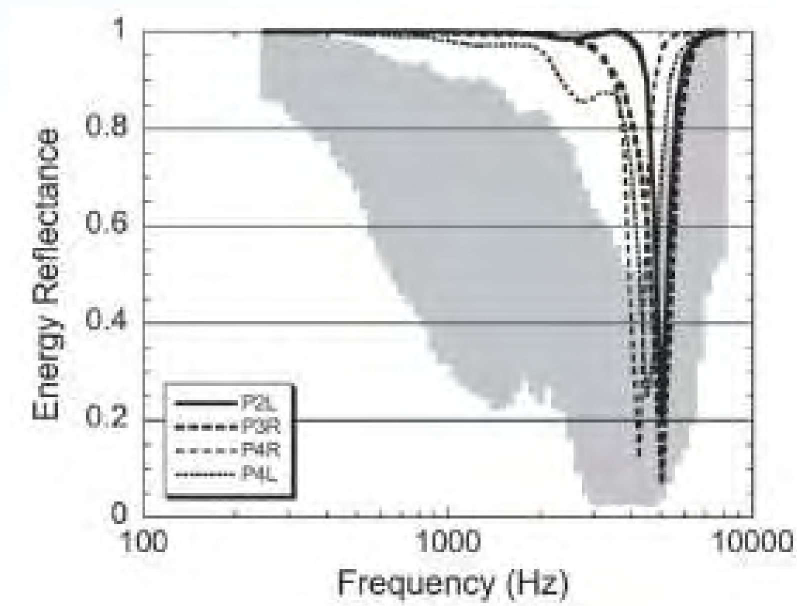


Feeney, JSHR, 2003

Four Ears with OME

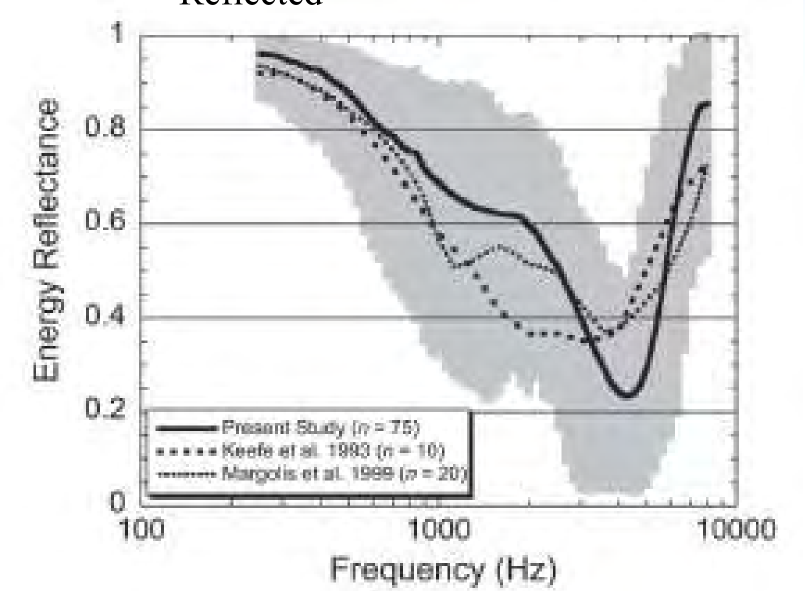


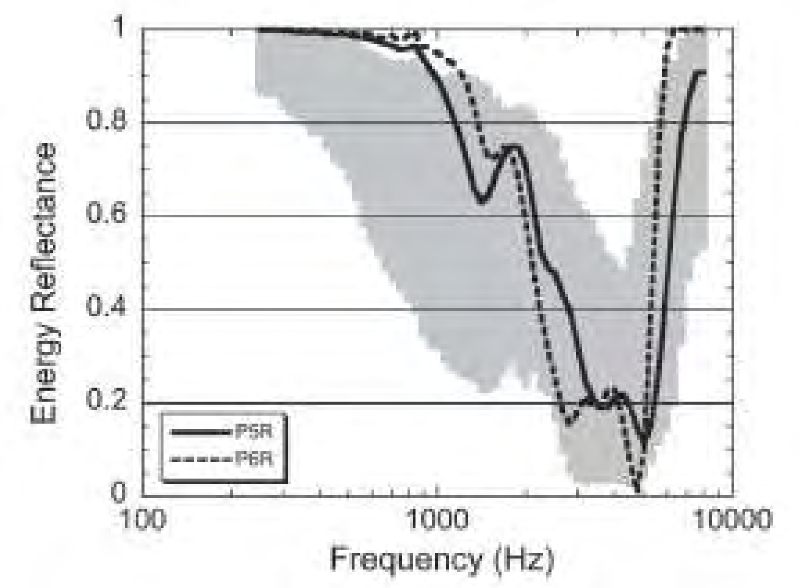


Feeney, JSHR, 2003

Normal

Reflected





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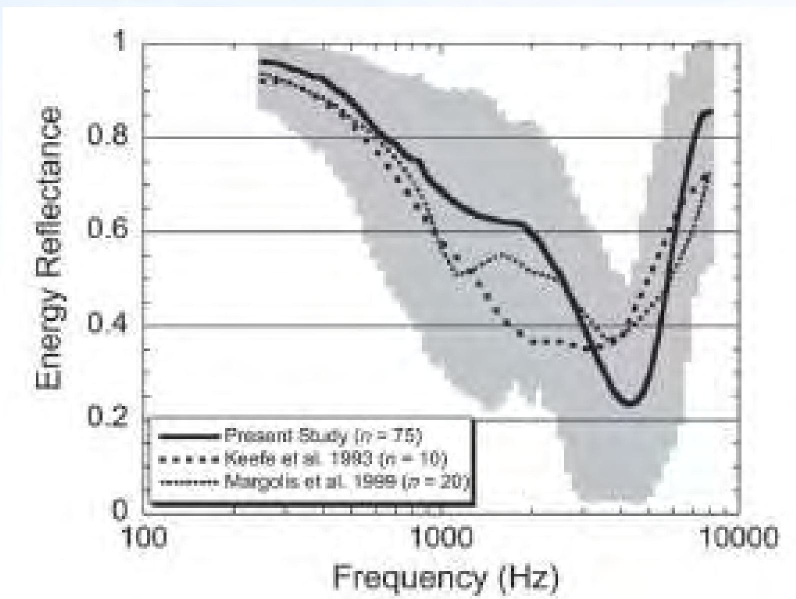
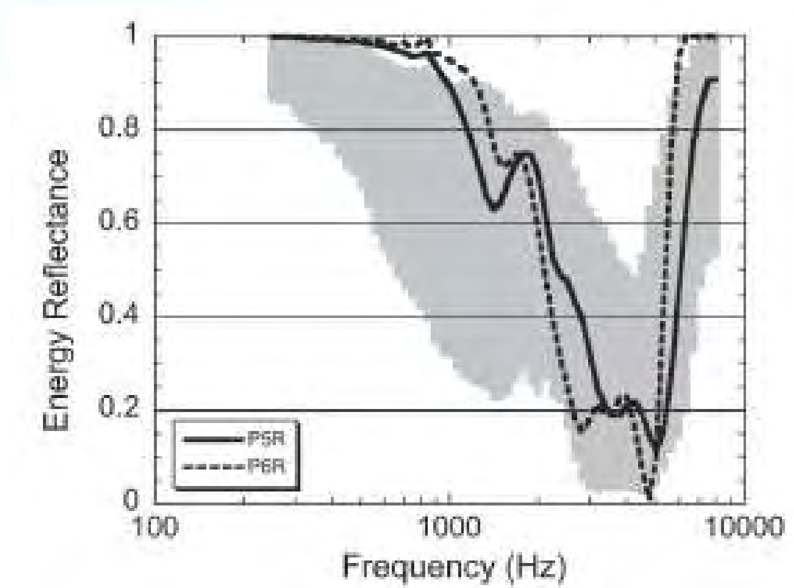
Feeney, JSHR, 2003

Two Ears with Otosclerosis

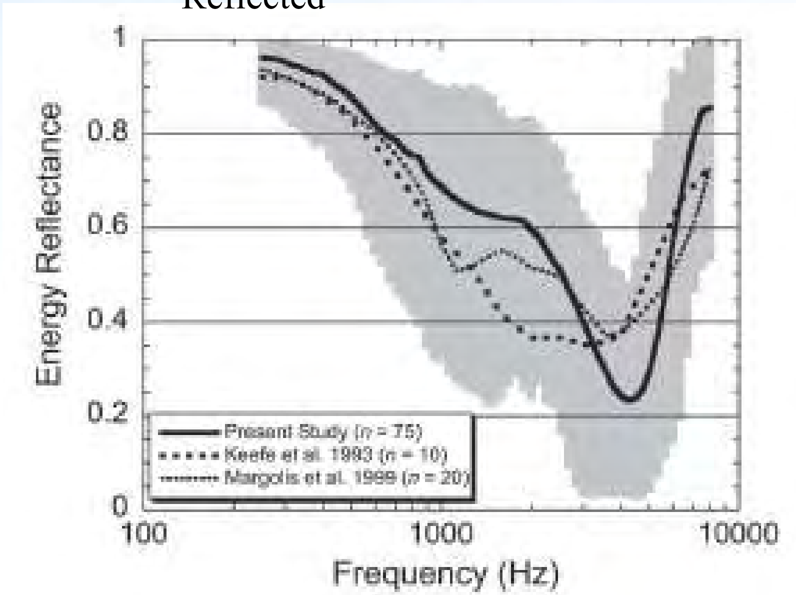


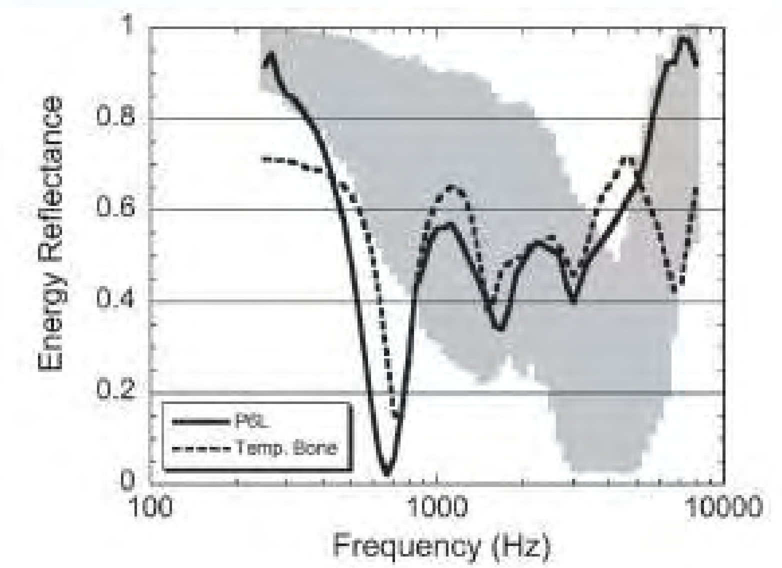


Feeney, JSHR, 2003

Normal

Reflected





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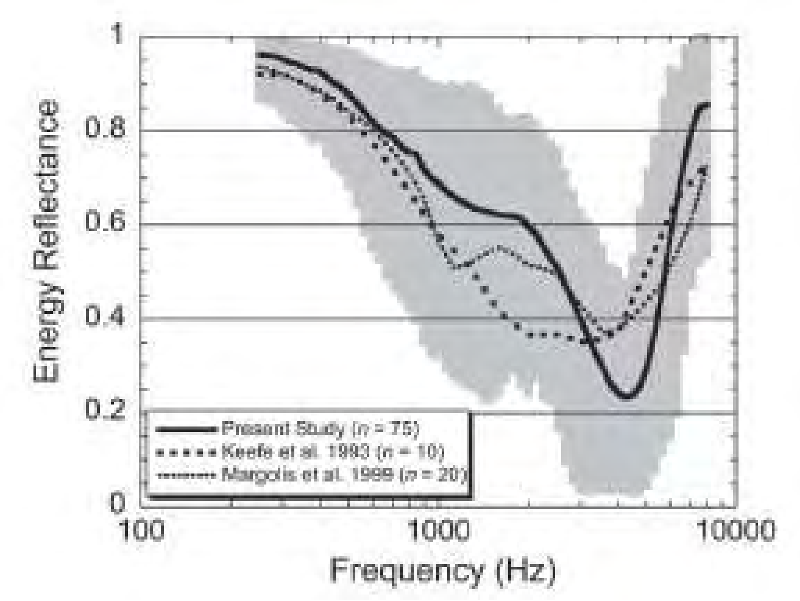
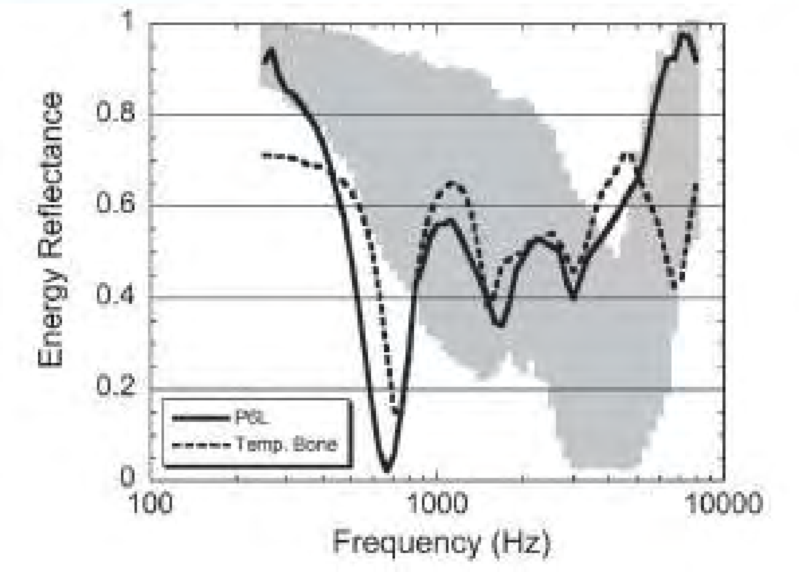
Feeney, JSHR, 2003

Ossicular Discontinuity

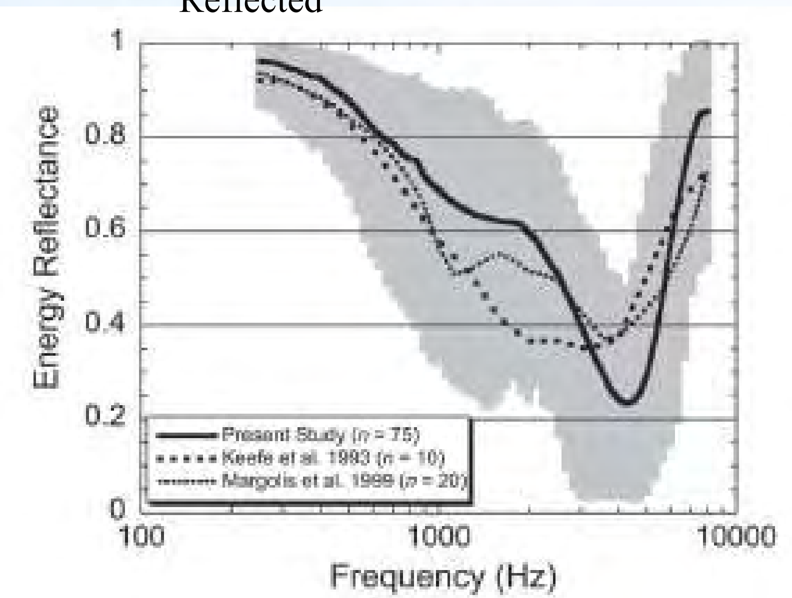


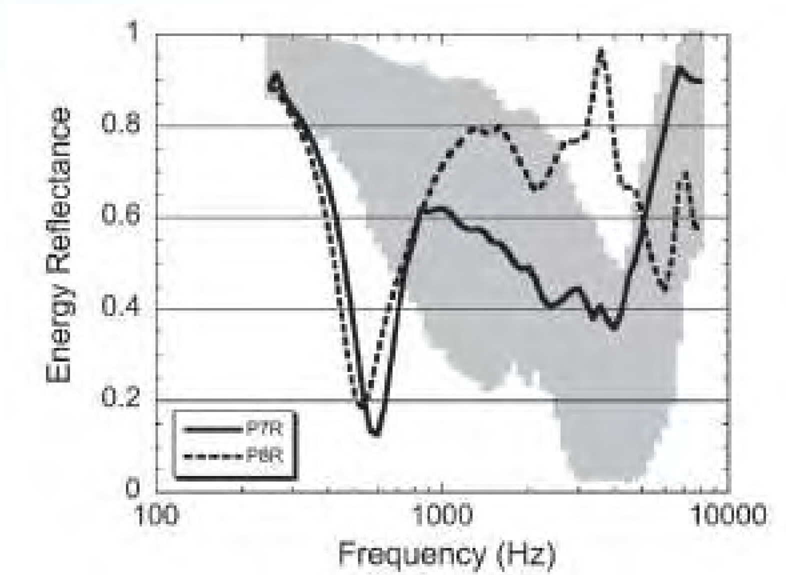


Feeney, JSHR, 2003

Normal

Reflected





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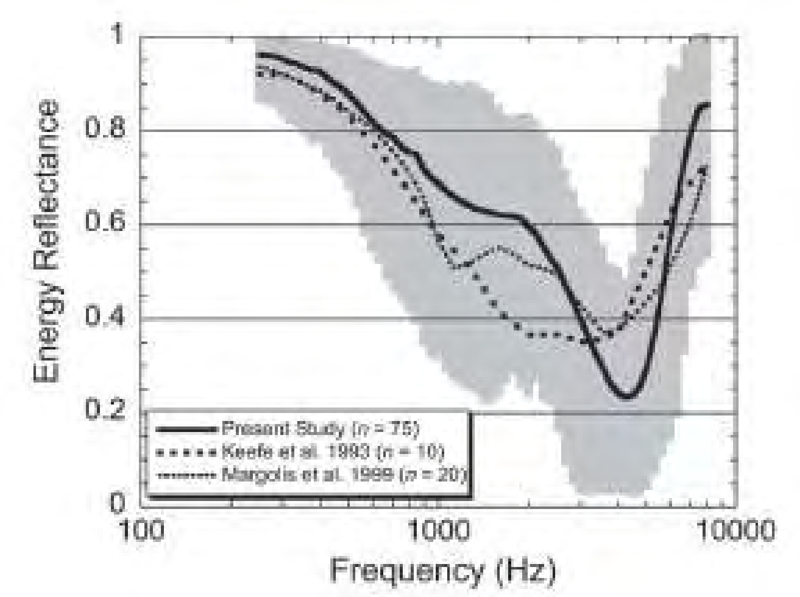
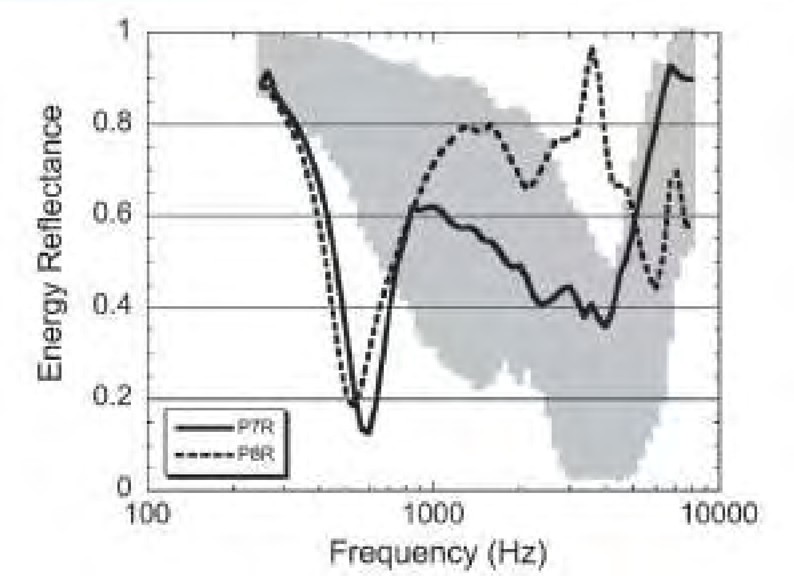
Feeney, JSHR, 2003

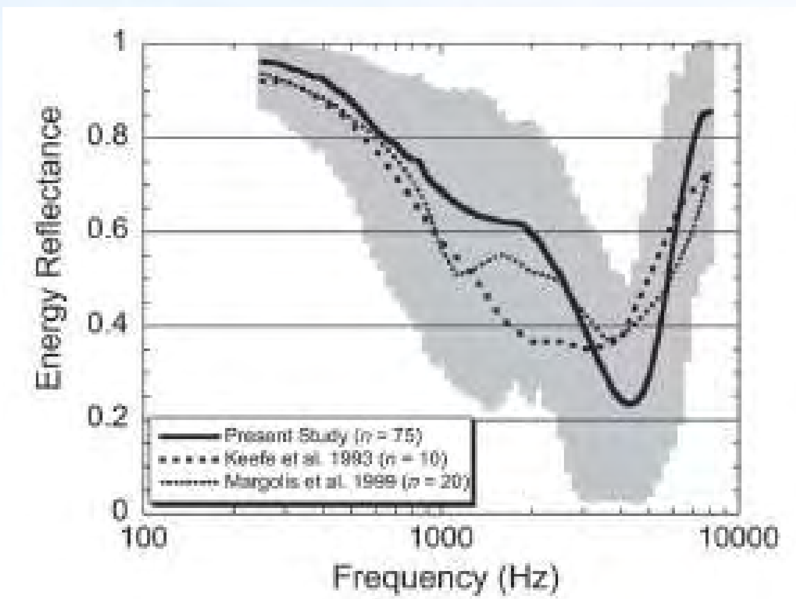
Two Hypermobile TM with normal hearing

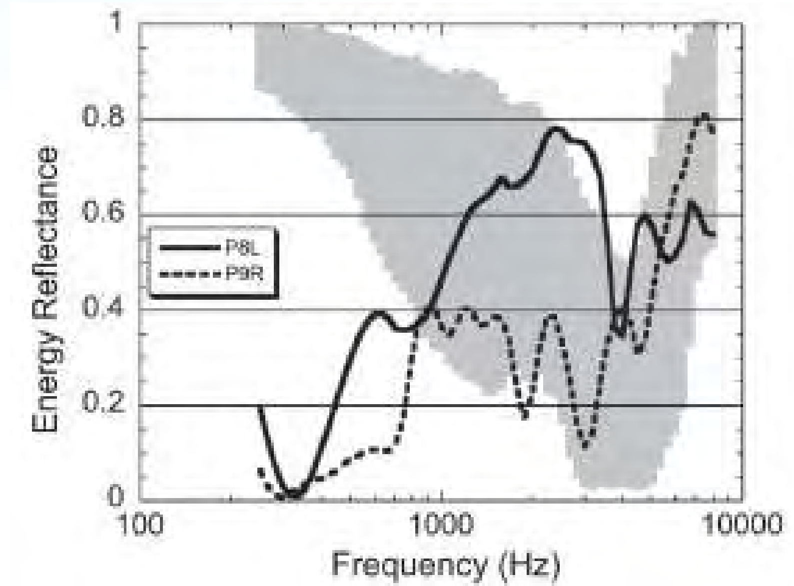




Feeney, JSHR, 2003

Normal





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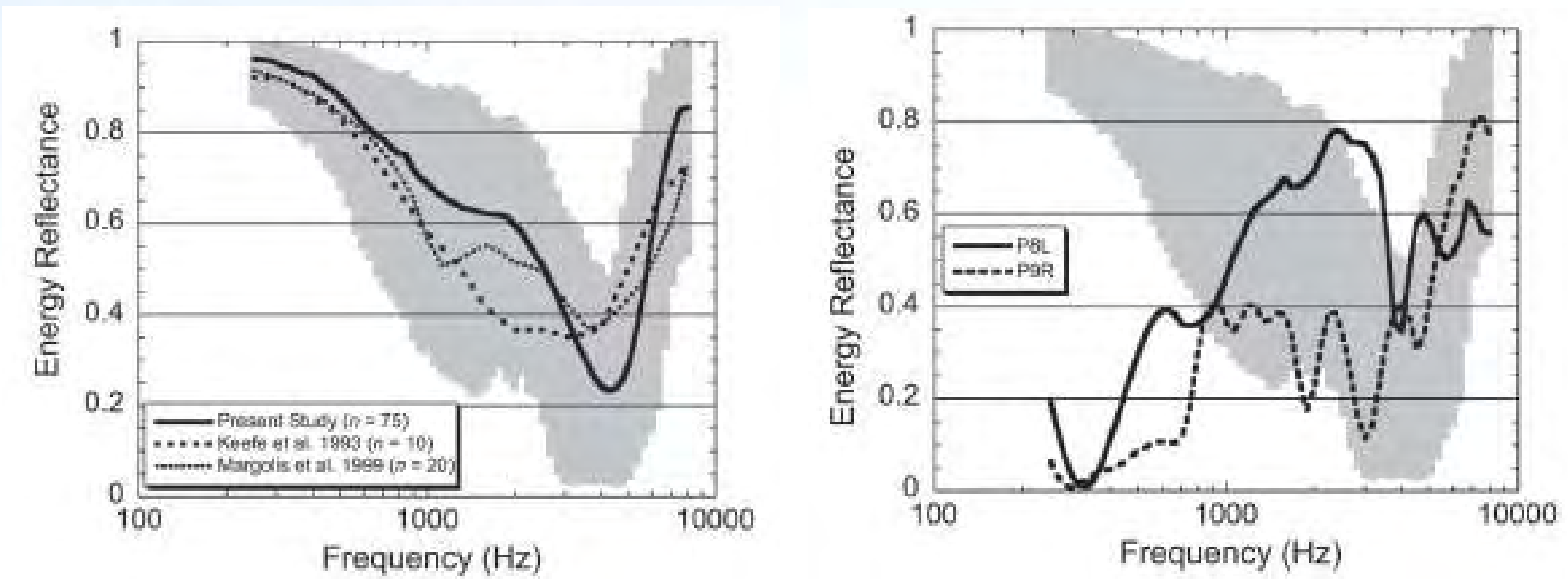
Feeney, JSHR, 2003

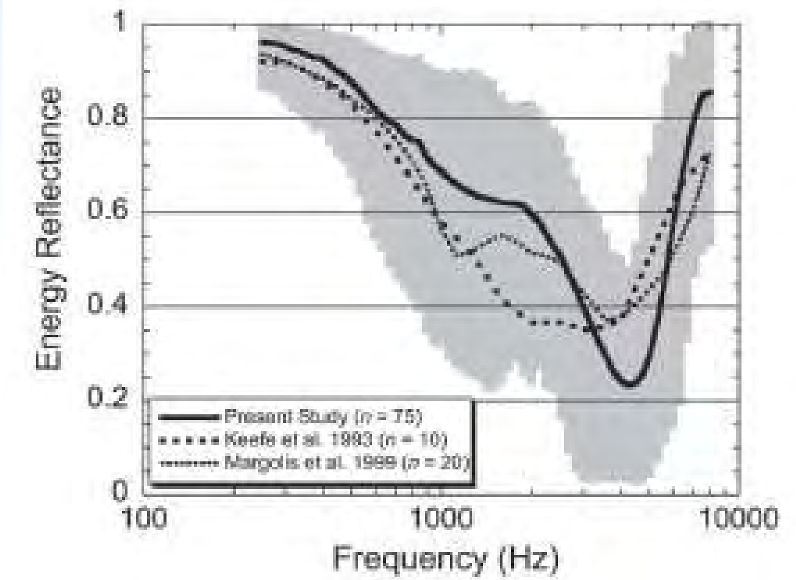
Tympanic Membrane Perforation

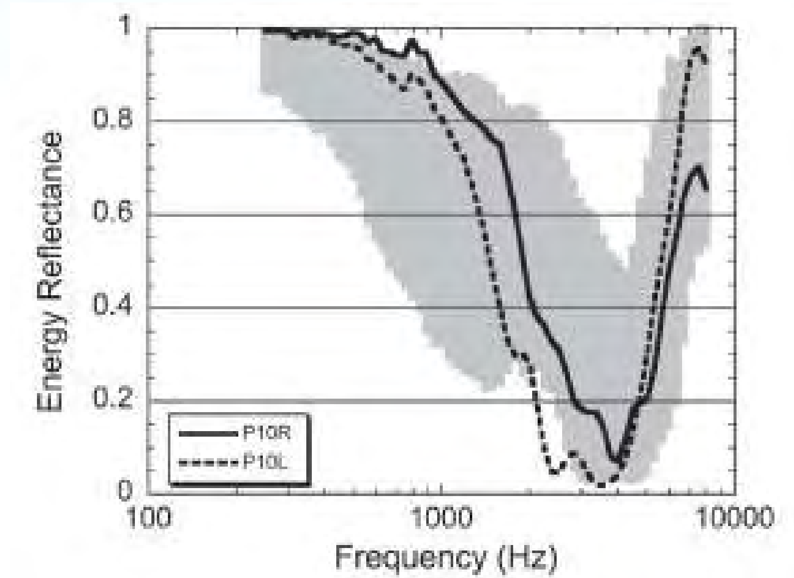


Feeney, JSHR, 2003

Normal

Reflected





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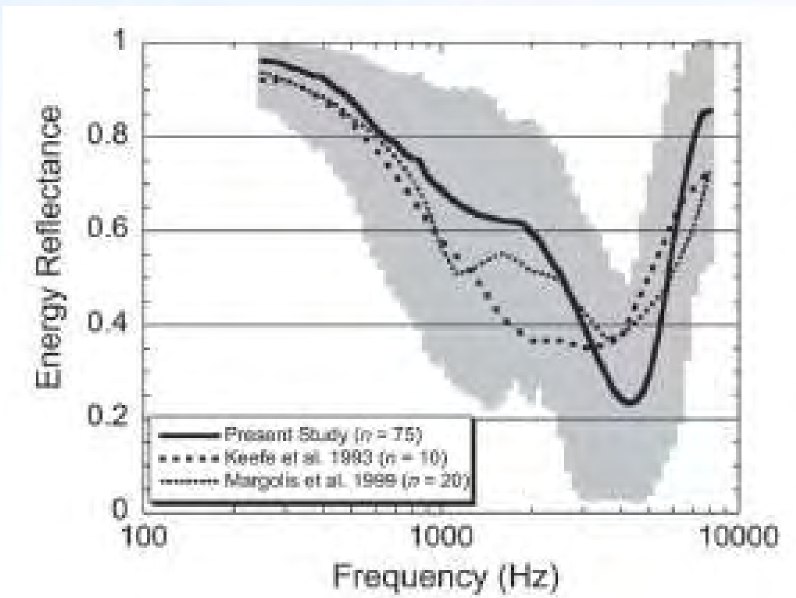
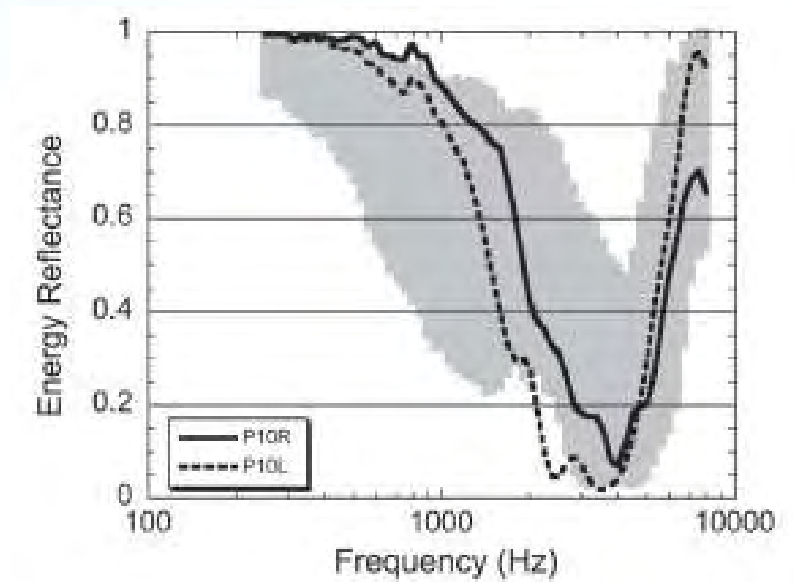
Feeney, JSHR, 2003

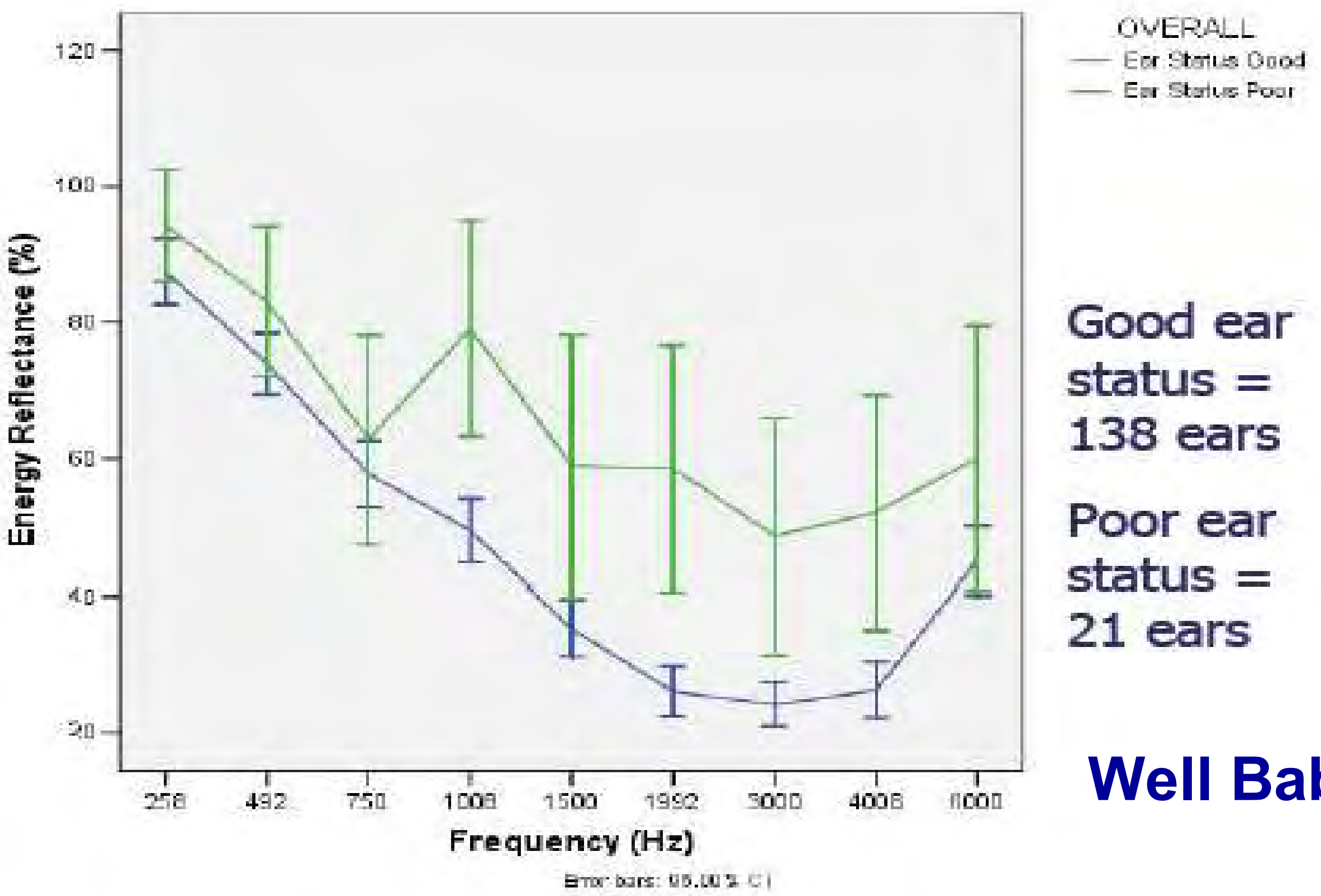
Negative Pressure Ears





Feeney, JSHR, 2003

Why Reflectance?



Good ear status = 138 ears

Poor ear status = 21 ears

Well Baby Clinic

Hunter, AAA convention, 2005

Why Reflectance?

- “No significant differences were found in WBR based on gender”

Hunter, AAA convention, 2005

Why Reflectance?

- “No significant differences were found in WBR based on gender”
- “No significant correlation was found between WBR and age, except at 6000 Hz.”

Hunter, AAA convention, 2005

Why Reflectance?

A central goal of any NHS program is to correctly identify ears with hearing loss and correctly identify ears with normal hearing.

Evoked otoacoustic emissions (EOAE) and Auditory Brain stem Responses (ABR) becomes difficult to assess without verifying the status of the middle ear system through independent means

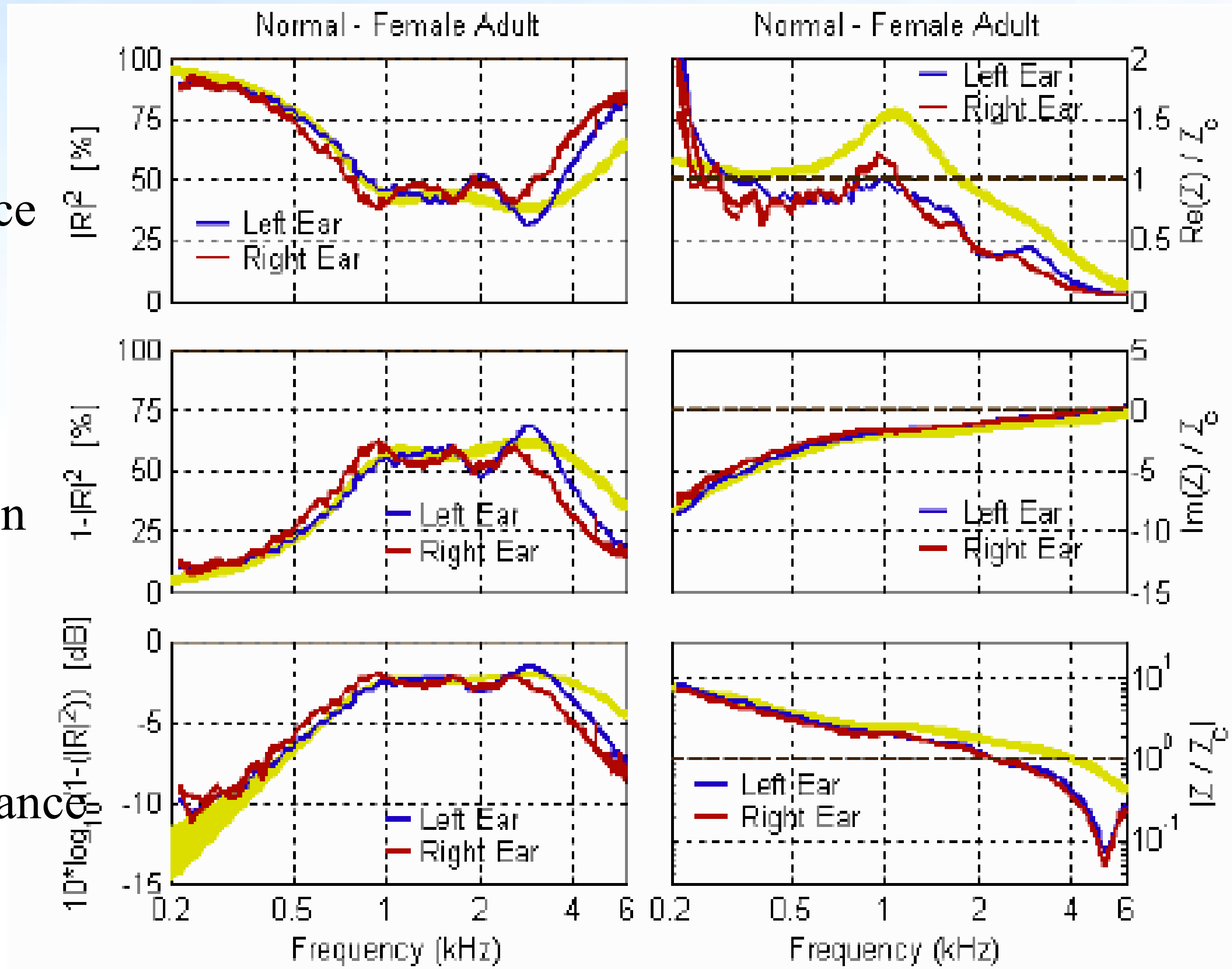
Keefe, Ear and Hearing 2000

RMS results - normal

Power Reflectance

Power Absorption

Power Transmittance



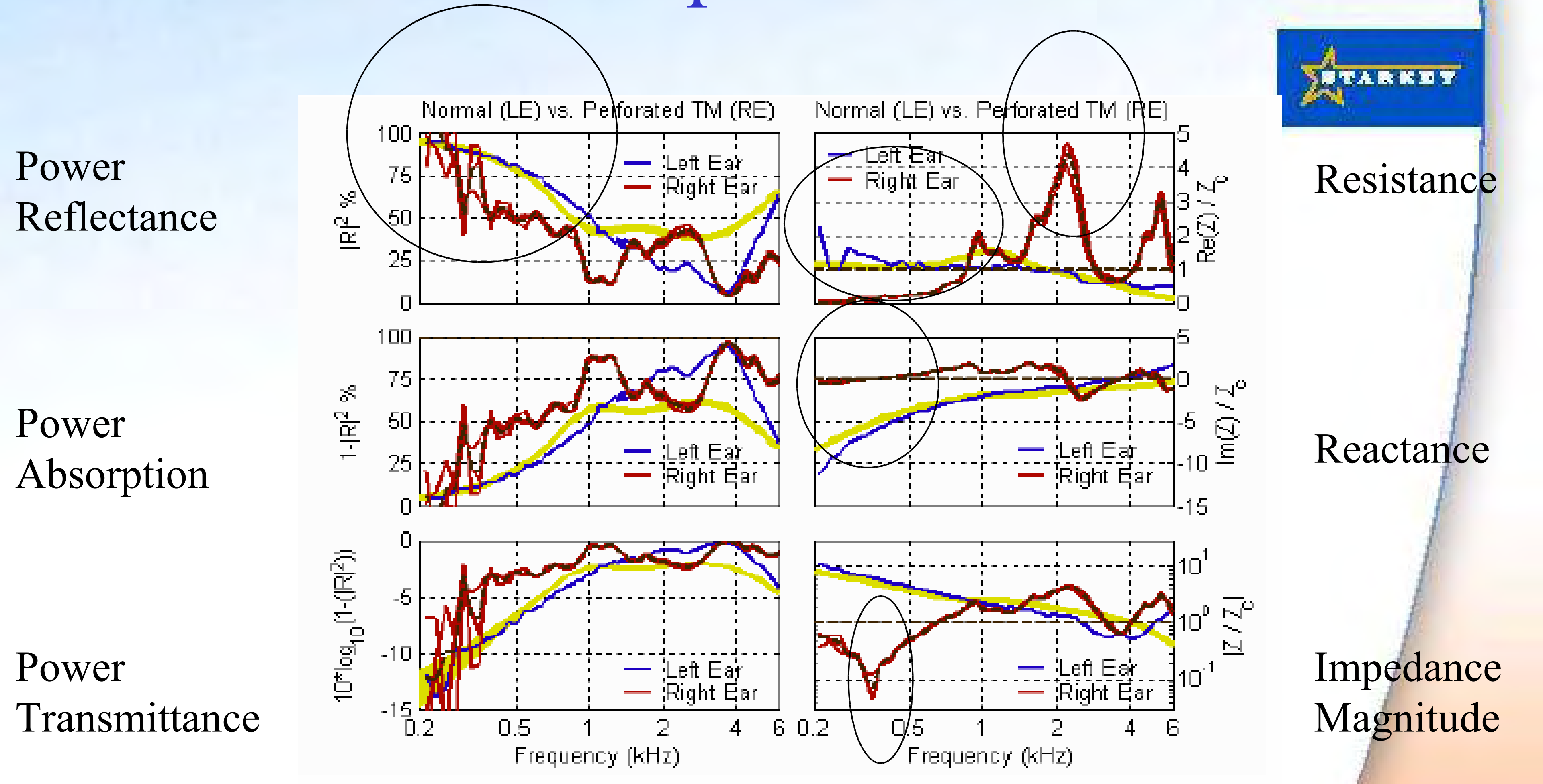
Resistance

Reactance

Impedance Magnitude

(Allen et al., JRRD, 2005)

RMS results – perforated ear drum



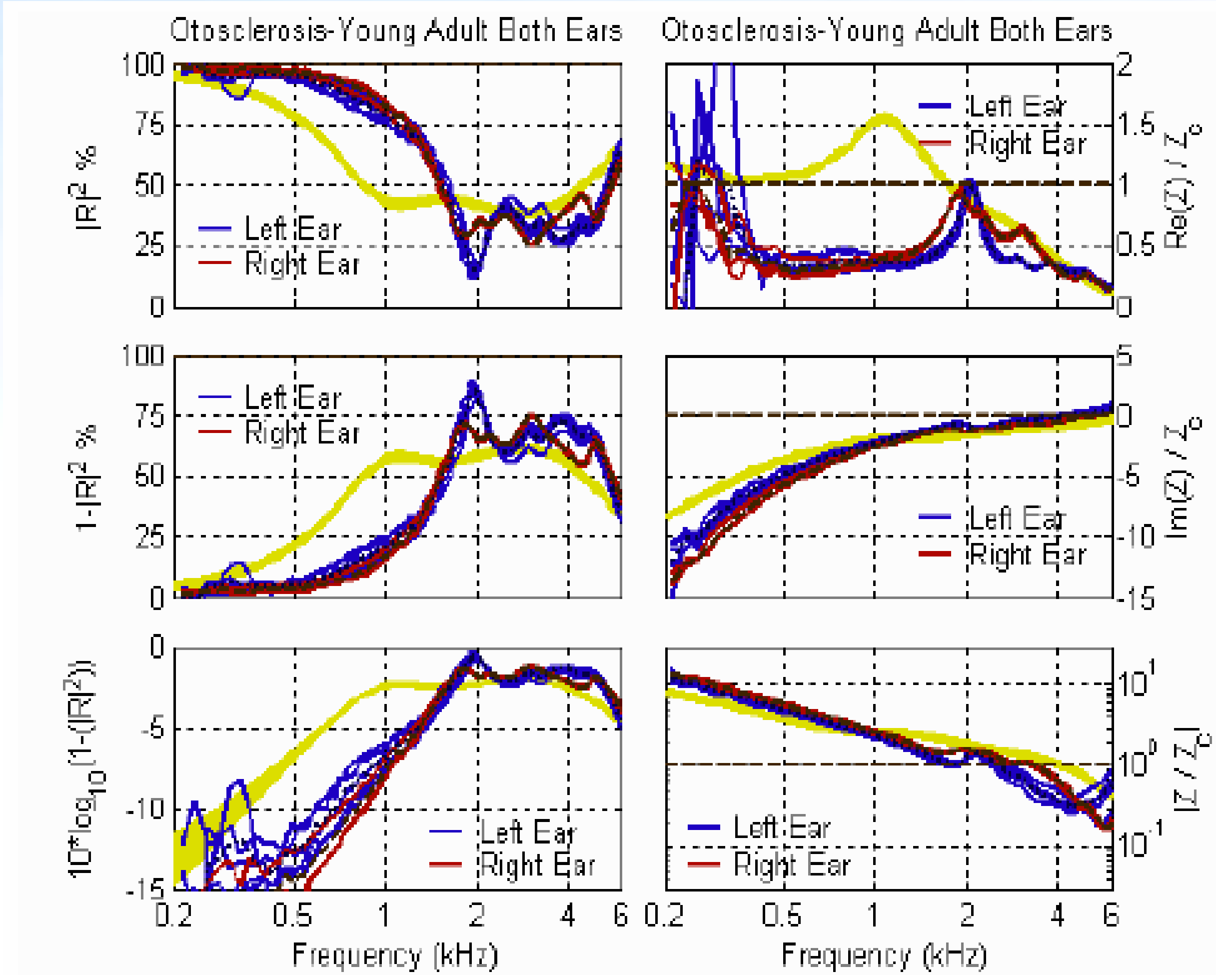
(Allen et al., JRRD, 2005)

RMS results – Otosclerosis

Power Reflectance

Power Absorption

Power Transmittance



Resistance

Reactance

Impedance Magnitude

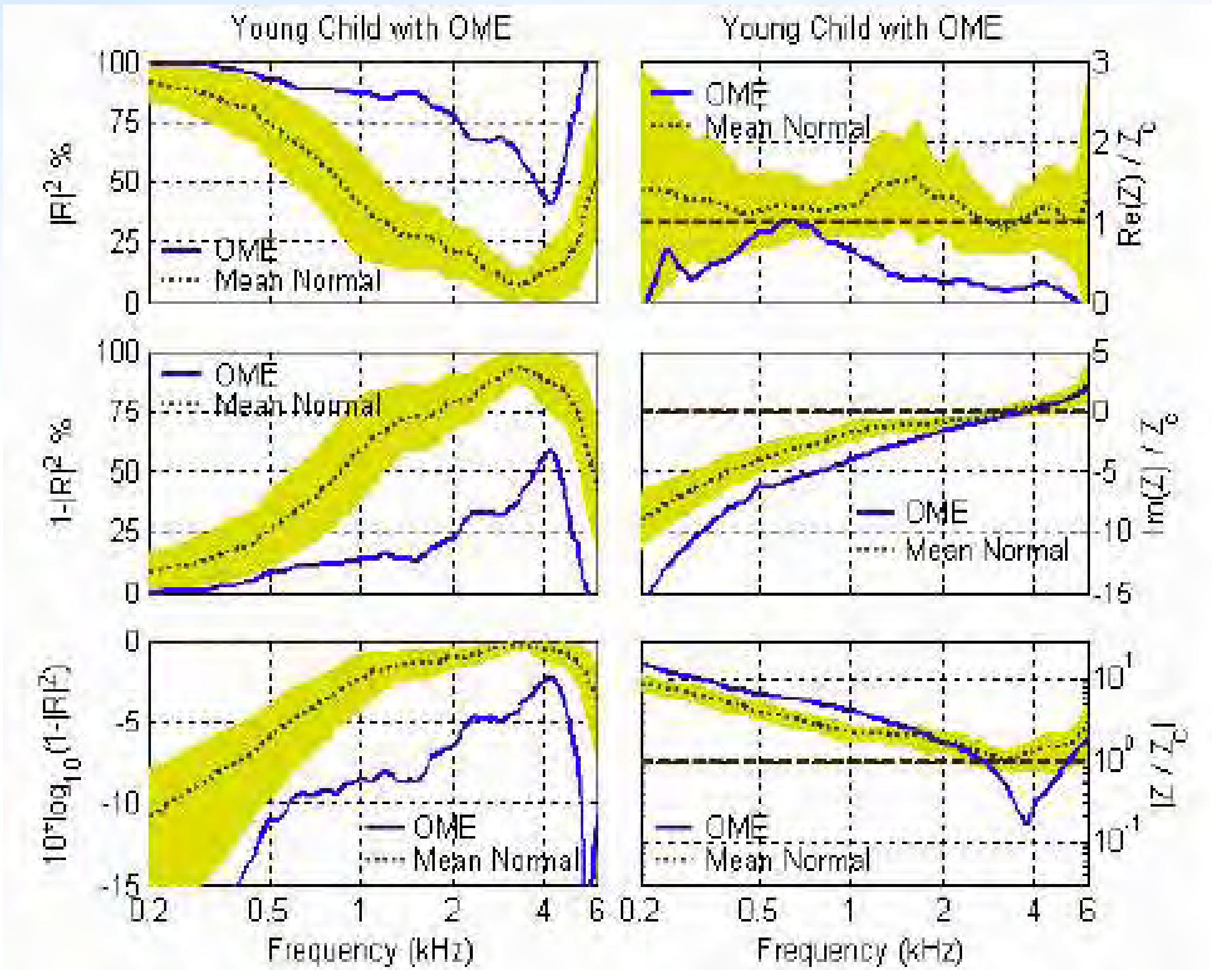
(Allen et al. JRRD, 2005)

RMS results - OME

Power Reflectance

Power Absorption

Power Transmittance



Resistance

Reactance

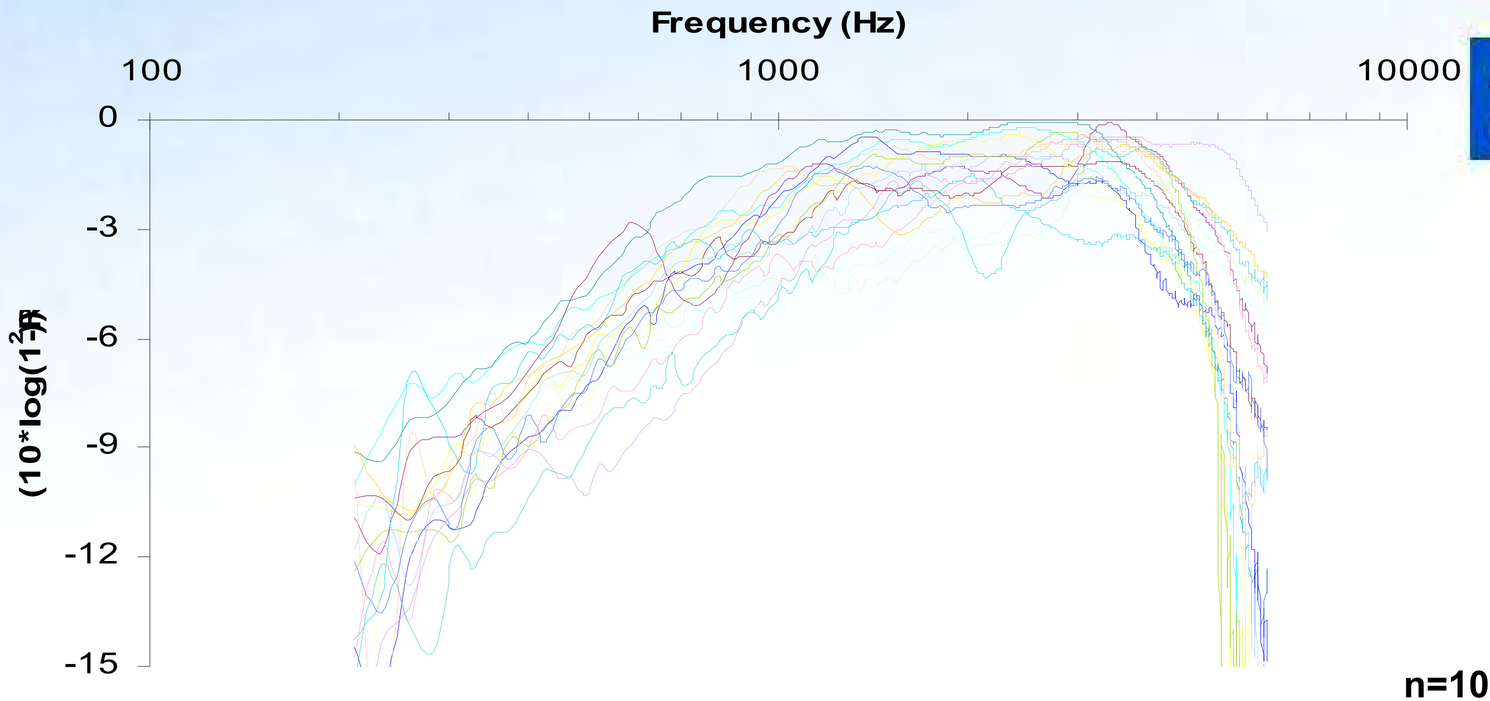
Impedance Magnitude

(Allen et al., JRRD, 2005)

Application -Transmittance

Predicting the conductive component hearing loss vs. frequency, in dB

Energy Transmittance across all subjects

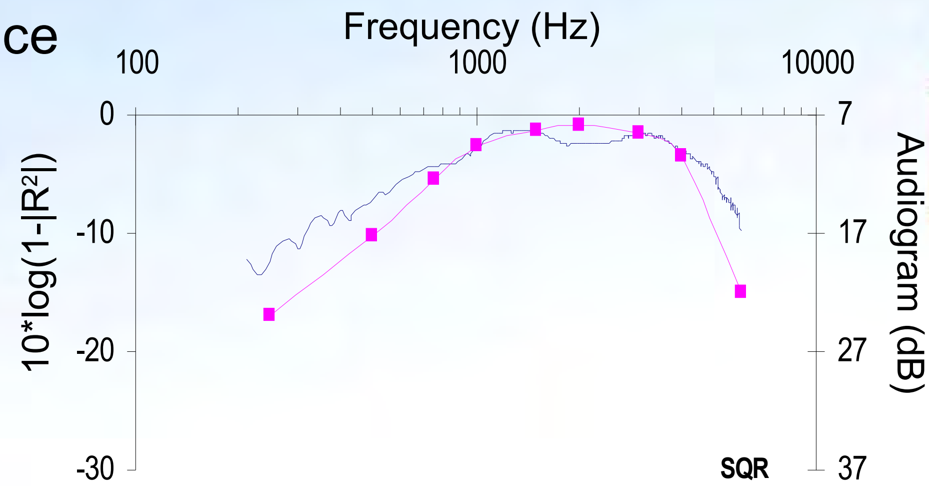


- 10 adult subjects
  - normal hearing
  - normal tympanometry
- **High pass cut-off frequency** ~ 1.2 kHz in all subjects
- **Low pass cut-off frequency** varies across subjects

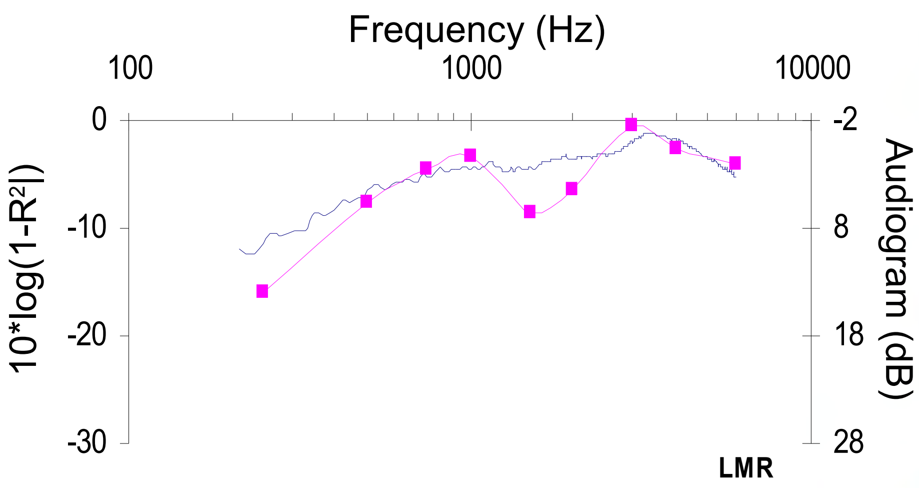
(Hazlewood et al., AAS, 2006)

Reflectance vs. audiogram in dB

- energy transmittance
- audiogram



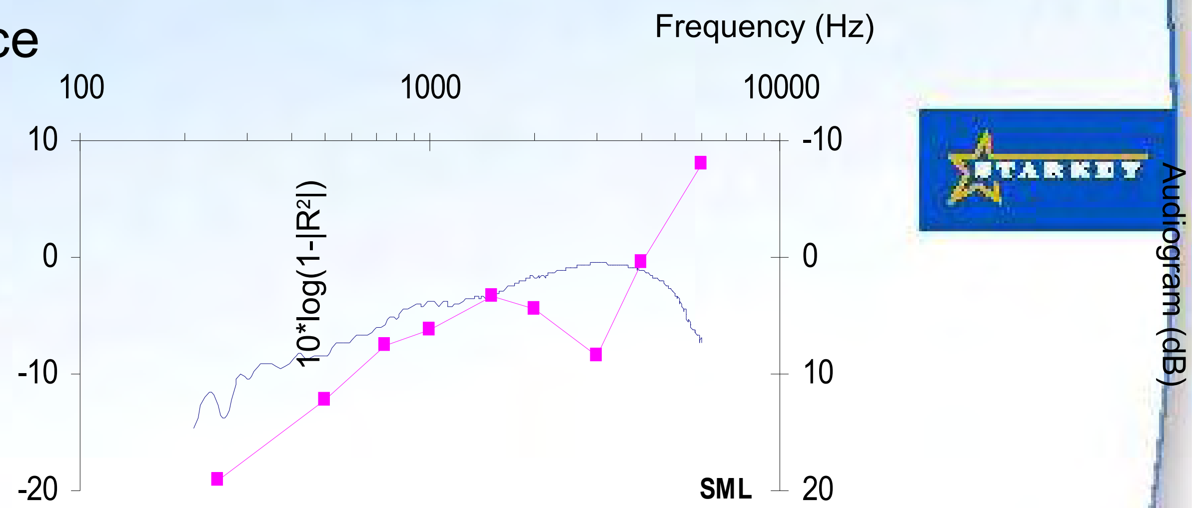
Audiogram shows *similar* frequency response as middle ear transfer function

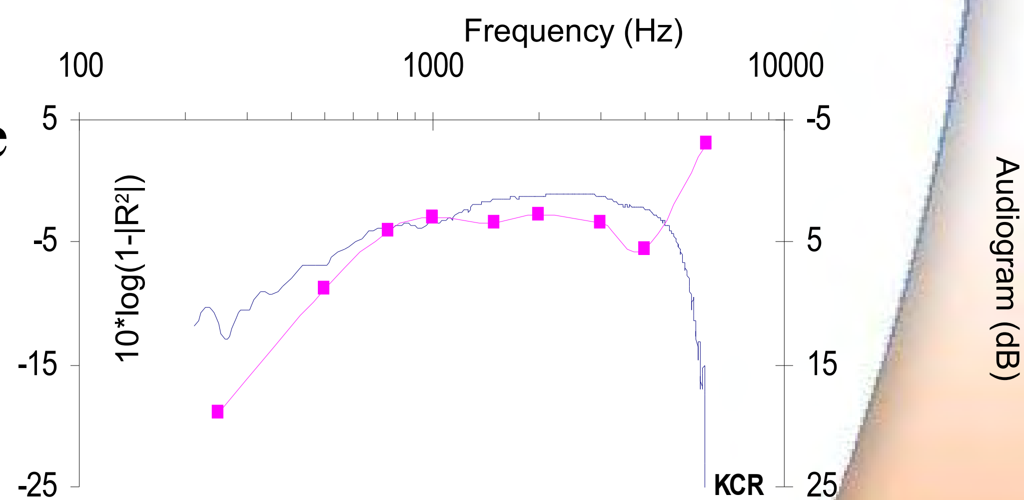


*Audiograms smoothed up to 3 kHz using a 3 point moving average.

Reflectance vs. audiogram in dB

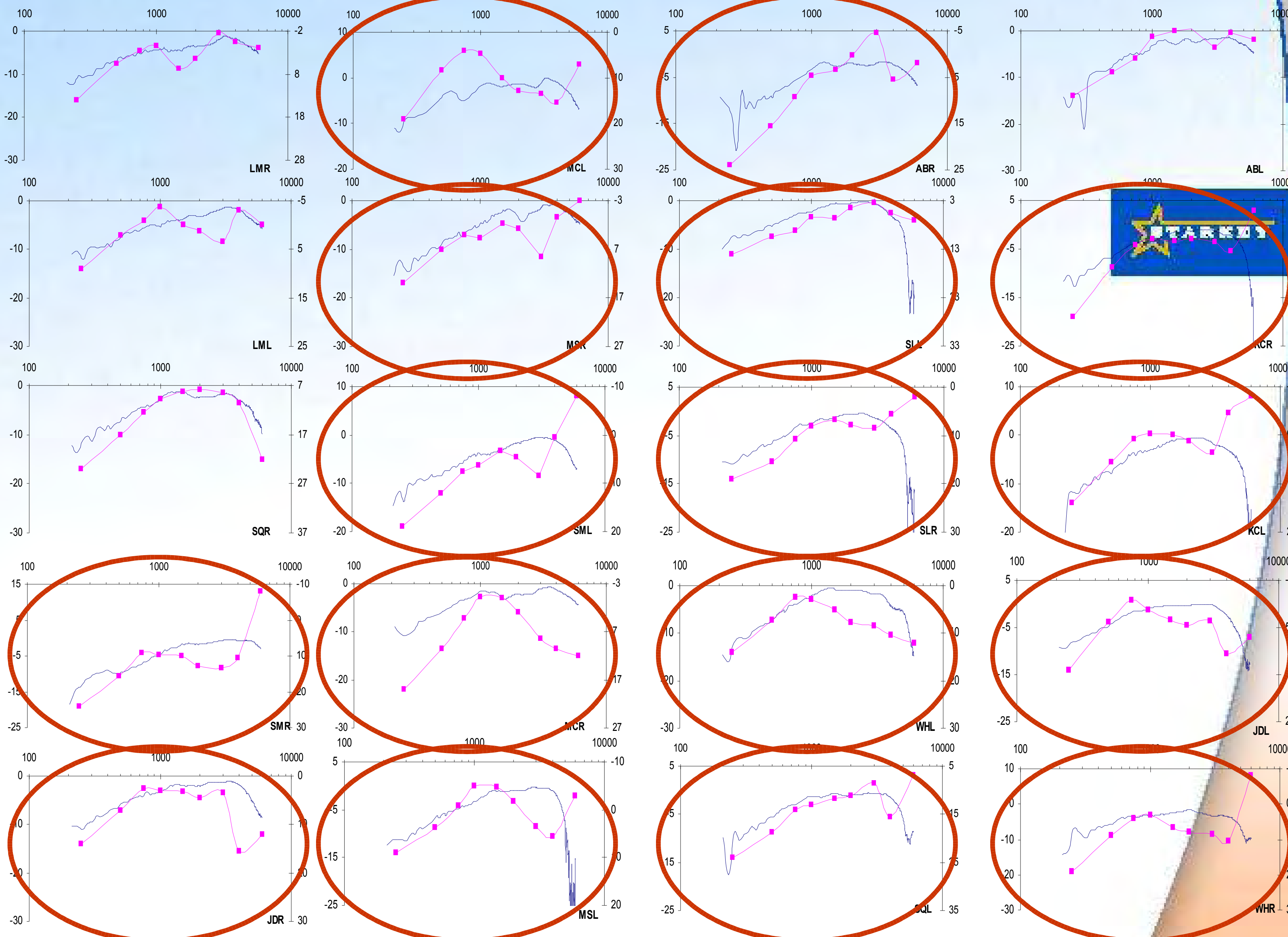
energy transmittance
audiogram





Audiogram ***does not*** show the same frequency response as middle ear transfer function

– High frequency disagreement


LMR
MCL
ABR
ABL
LML
MSR
SLL
KCR
SQR
SML
SLR
KCL
SMR
MCR
WHL
JDL
JDR
MSL
SQL
WHR

Does the middle ear transfer function determine hearing sensitivity?

- 90% agreement between low-frequency slope of audiogram and low-frequency slope of middle ear transfer function
- Reflectance may provide "objective air-bone gap"
  - Conductive hearing loss in children typically occurs in low frequencies
    - Changes to energy transmittance estimate of the middle ear function (low frequency slope and plateau region) should correlate with changes to the audiogram

Take Home Message

Energy transmittance data suggests

Cochlea is an acoustic detector of power over the frequency range 200-5000 Hz

Hands-on demo

- 3 stations to try out
- Exhibits at Starkey’s booth – for more questions and demo
- Contact information
  - mimosa@MimosaAcoustics.com
  - mel_gross@starkey.com

Question?

Evaluating ME Function via an Acoustic Power Assessment

Thank you