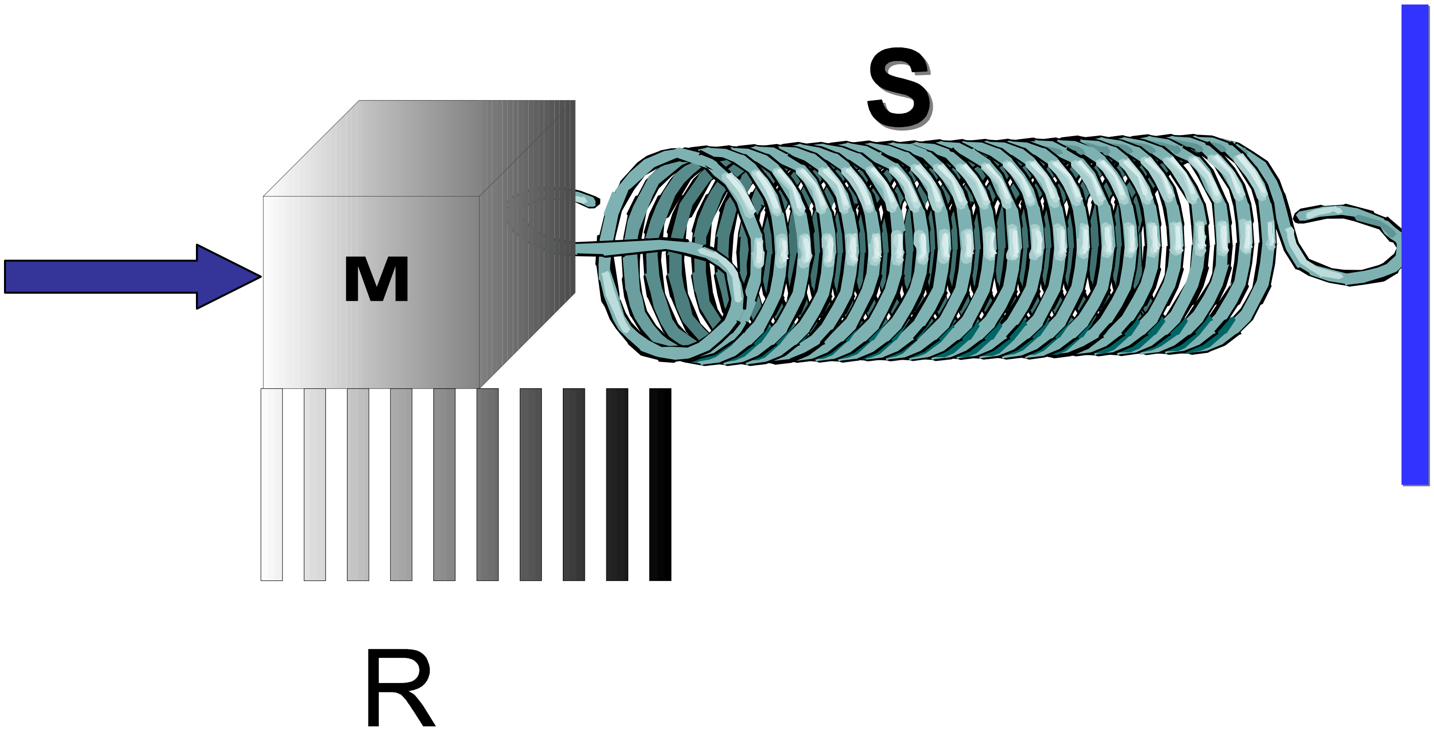
Immittance Audiometry

Terminology

- **Immittance**: Immittance is a generic term that encompasses impedance, admittance, and their components
  - **Impedance** (**Z** - in acoustic ohms) in the middle ear system is defined as the total opposition of this system to the flow of the acoustic energy.
  - **Admittance** (**Y** - in acoustic mmhos) is the reciprocal of impedance and is the amount of acoustic energy that flows into the middle ear system. Currently available immittance instruments typically measure admittance.

Simple Harmonic Motion

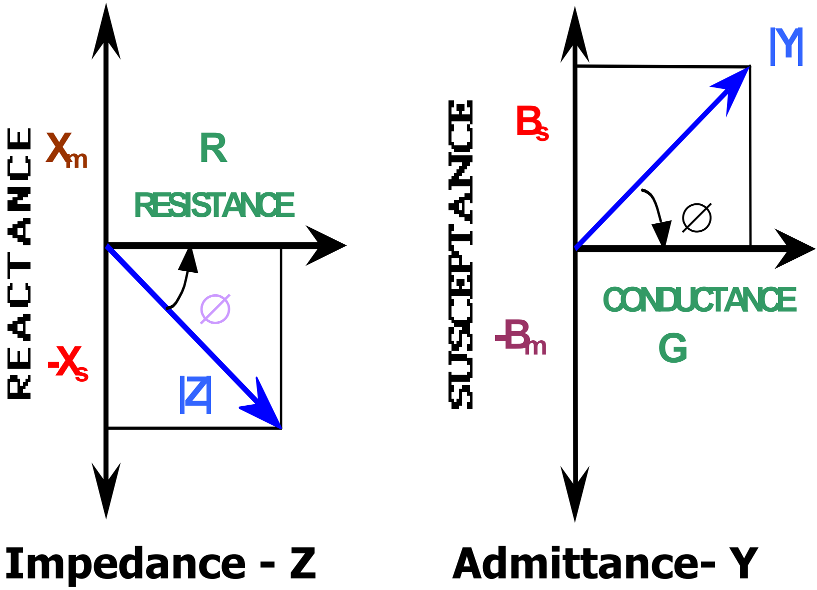


Variables That Determine Admittance

- **Compliance** (the inverse of the **stiffness**) – C/S : the admittance offered by stiffness elements in the middle ear system which is called compliant susceptance and is denoted by B_S (also stiffness reactance, negative reactance, or $-X_s$ in impedance terms)
- **Mass** – M: the admittance offered by mass elements in the middle ear system which is called mass susceptance and is denoted by B_m (also mass reactance, positive reactance, or X_m in impedance terms)
- **Friction or Resistance** – R:determines the absorption or dissipation of acoustic energy. In admittance terms, this element is called conductance and is denoted by G (also resistance, or R in impedance system).

Admittance Layout

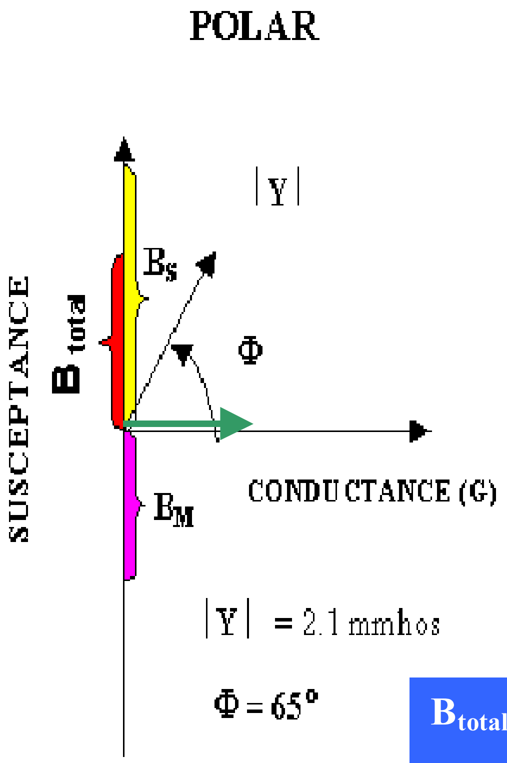
- Total susceptance (or total reactance in impedance terms) which store acoustic energy is the algebraic sum of the mass and compliance elements as plotted along the Y-axis
- the compliant susceptance (B_s) is on the positive axis that begins at zero and extends upward indefinitely, whereas the mass susceptance (B_m) is on negative axis that begins at zero and extends downward indefinitely. If the total susceptance is positive, a system is stiffness controlled; if this value is negative, the system is mass controlled
- Conductance (G) is plotted on the X-axis. The value of conductance is always positive.



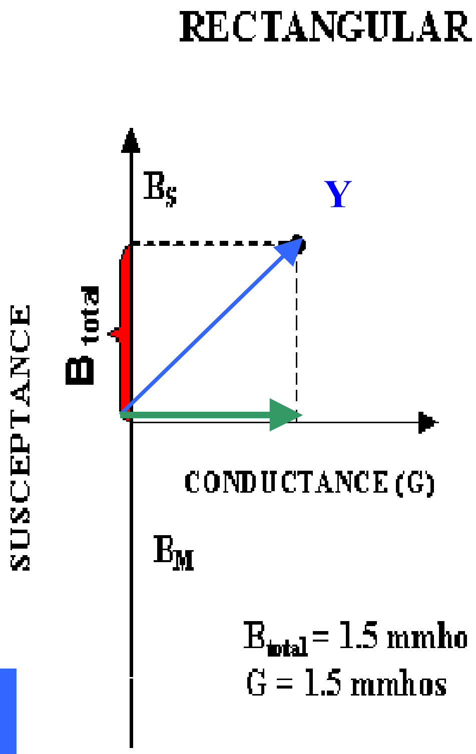
Admittance is a Complex Number

- The admittance of the system (|Y|) is a two dimensional quantity and is a vector sum of conductance (G) and the total susceptance (B_t).
- Mathematically, admittance can be expressed in rectangular notation or in polar notation.
  - In rectangular notation, admittance is expressed as the sum of its conductance (G) and susceptance (Bt) elements. $Y = G + jBt$
  - In polar notation admittance is expressed by its magnitude and phase angle. $|Y| \angle Øy$

Complex Acoustic Admittance



$B_{total} = B_s + B_m$



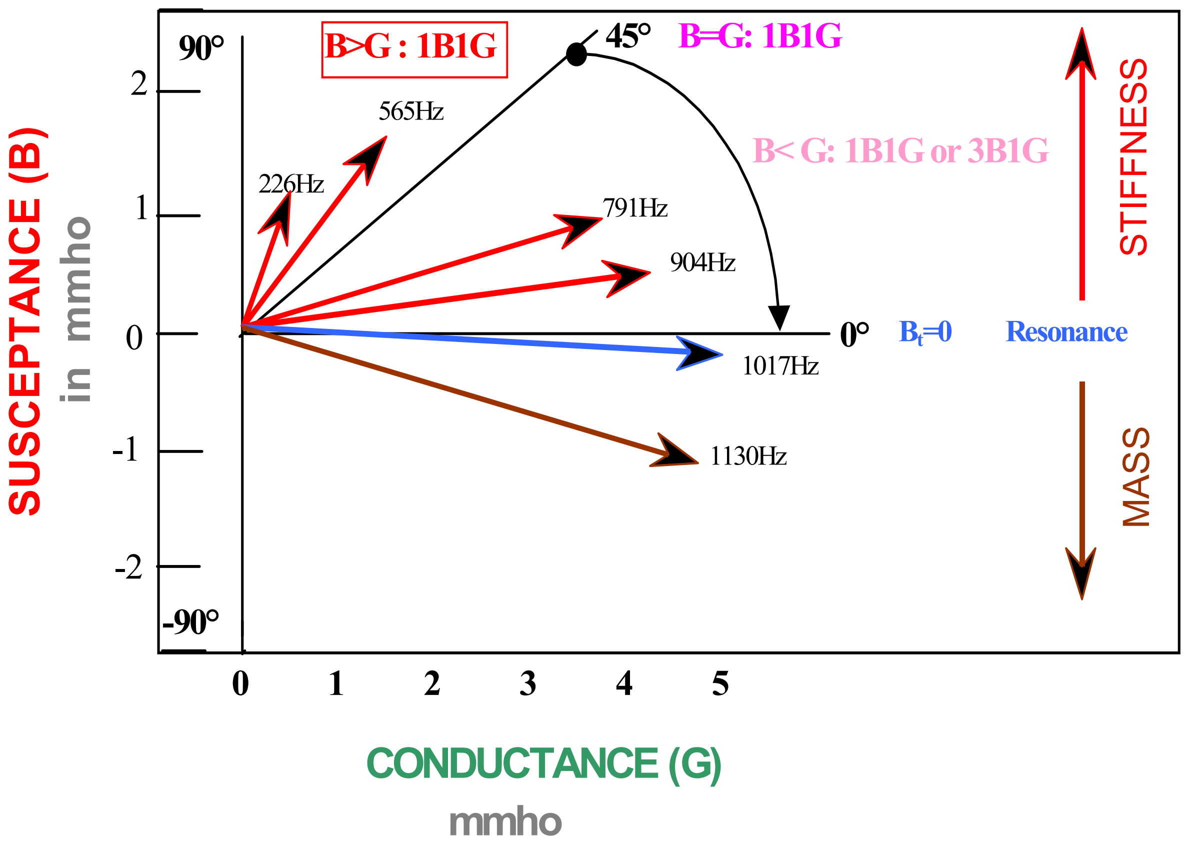
Mathematical Correlation Between Polar & Rectangular Notation

Admittance_Y
|Y| < Øy (Polar notation)
G + jB_t (Rectangular notation)
G= |Y| Cos Øy
B= |Y| Sin Øy
$Y_{tm} = \sqrt{G_{tm}^2 + B_{tm}^2}$
Tan Øy= B/G
Øy= arctan (B/G)

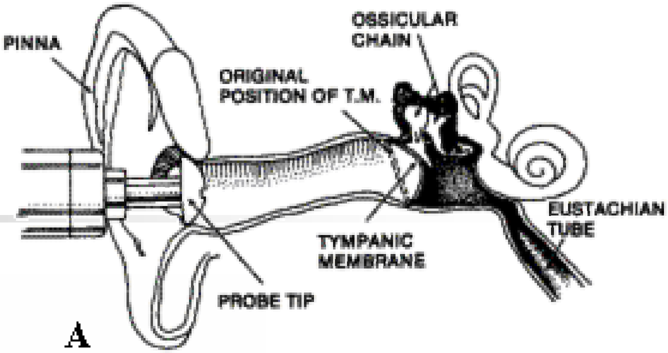
Relationship Between Admittance Components & Frequency

- Acoustic conductance (the frictional component) is independent of frequency
- compliance and mass susceptance are frequency dependent
  - Mass susceptance is directly proportional to frequency
  - compliance susceptance is inversely proportional to frequency
- Therefore, as frequency increases, the total susceptance progresses from positive values (stiffness controlled) toward zero (resonance) to negative value (mass controlled).
- Resonance of the middle ear system is achieved when the compliant and mass susceptance are equal, i.e., total susceptance is equal to 0 mmhos.

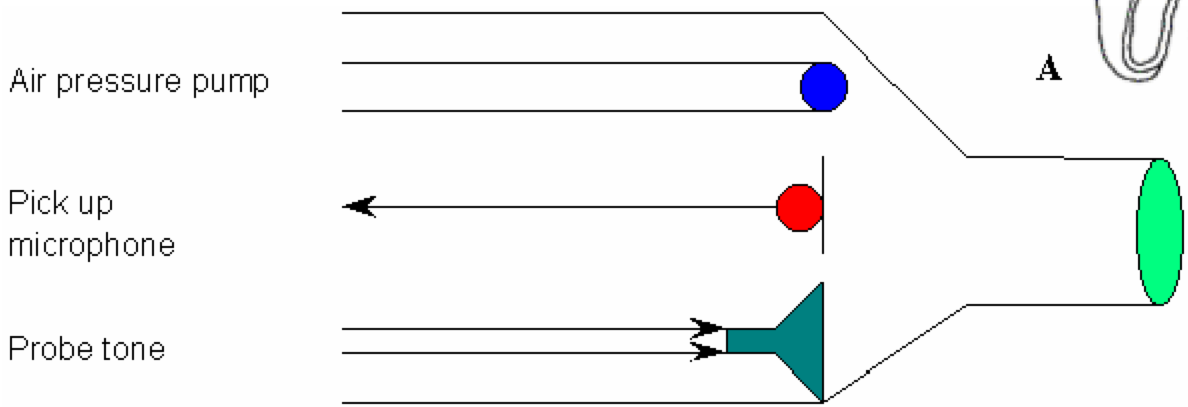
Relationship Between Admittance Components & Frequency

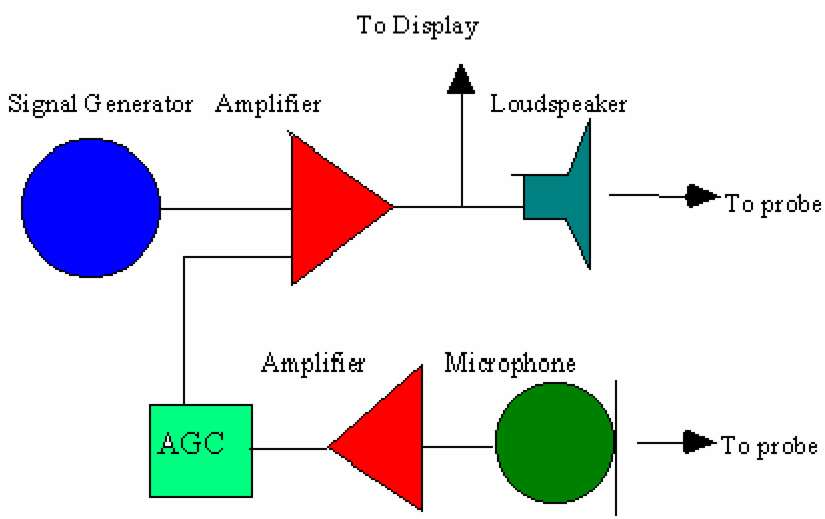


Admittance Meter



A





B

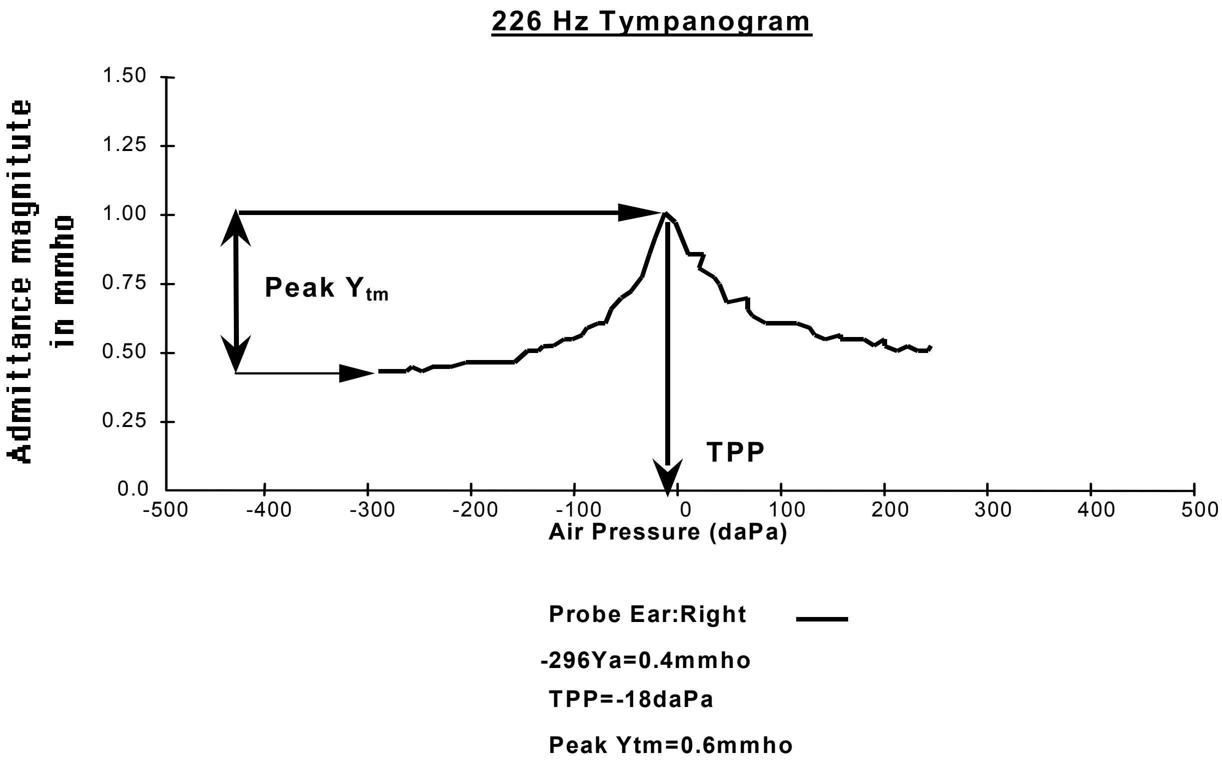
Standard Low Frequency Tympanometry

- Tympanometry is the measurement of the acoustic immittance of the ear as a function of ear canal air pressure (ANSI, S3.39-1987).
- For clinical purposes, the admittance of the middle ear is measured using tympanometry to gain information regarding middle ear function.
- Standard clinical tympanometry is performed using a low probe tone frequency, usually 220 or 226 Hz, and measures the admittance magnitude |Y| as a function of ear canal air pressure.
- The result is a graphic display called a tympanogram.
- At the low probe tone frequency used in standard tympanometry, the normal middle ear system is stiffness dominated and susceptance (the stiffness element) contributes more to overall admittance than conductance (the frictional element)

Standard Low Frequency Tympanometry

- Traditional parameters obtained from low frequency tympanometry:
  - Static admittance (SA)
  - Tympanometric Shapes
  - Tympanometric peak pressure (TPP)
  - Ear Canal Volume (ECV)
  - Tympanometric width (TW)

Tympanogram



Plane of The measurement

- Because the probe tip of the admittance measurement system is remote from the surface of the tympanic membrane, admittance measured at the probe tip jointly reflects the admittance of the external auditory canal and the admittance of the middle ear (plane of the measurement)
- The dimensions of the external auditory canal vary depending on the depth of insertion of the probe tip as well as individual differences in ear canal size. This produces substantial variation in the admittance due to the external ear
- Therefore, to derive a measure of middle ear admittance alone, it is necessary to subtract the admittance due to the external ear canal from the overall admittance measure.

Static Admittance (SA)

- Measuring admittance under changes in air pressure provides a way to derive an estimate of the admittance due to ear canal volume
- This is accomplished through placing the eardrum under sufficient tension by a high positive or negative pressure to drive the impedance of the middle ear toward infinity
- The admittance measured at the probe tip under these extreme pressures provides a reasonable estimate of the ear canal admittance alone
- This estimate (e.g., at -296Ya in previous figure) is then subtracted from the peak value (tympanometric peak pressure –TPP) which jointly reflects the admittance of the external auditory canal and the middle ear to arrive at a value that reflects only the admittance of the tympanic membrane and middle ear
- According to ANSI, (1987) the resulting value (Peak Y_{tm} in the previous figure) is properly referred to as the peak-compensated static acoustic admittance

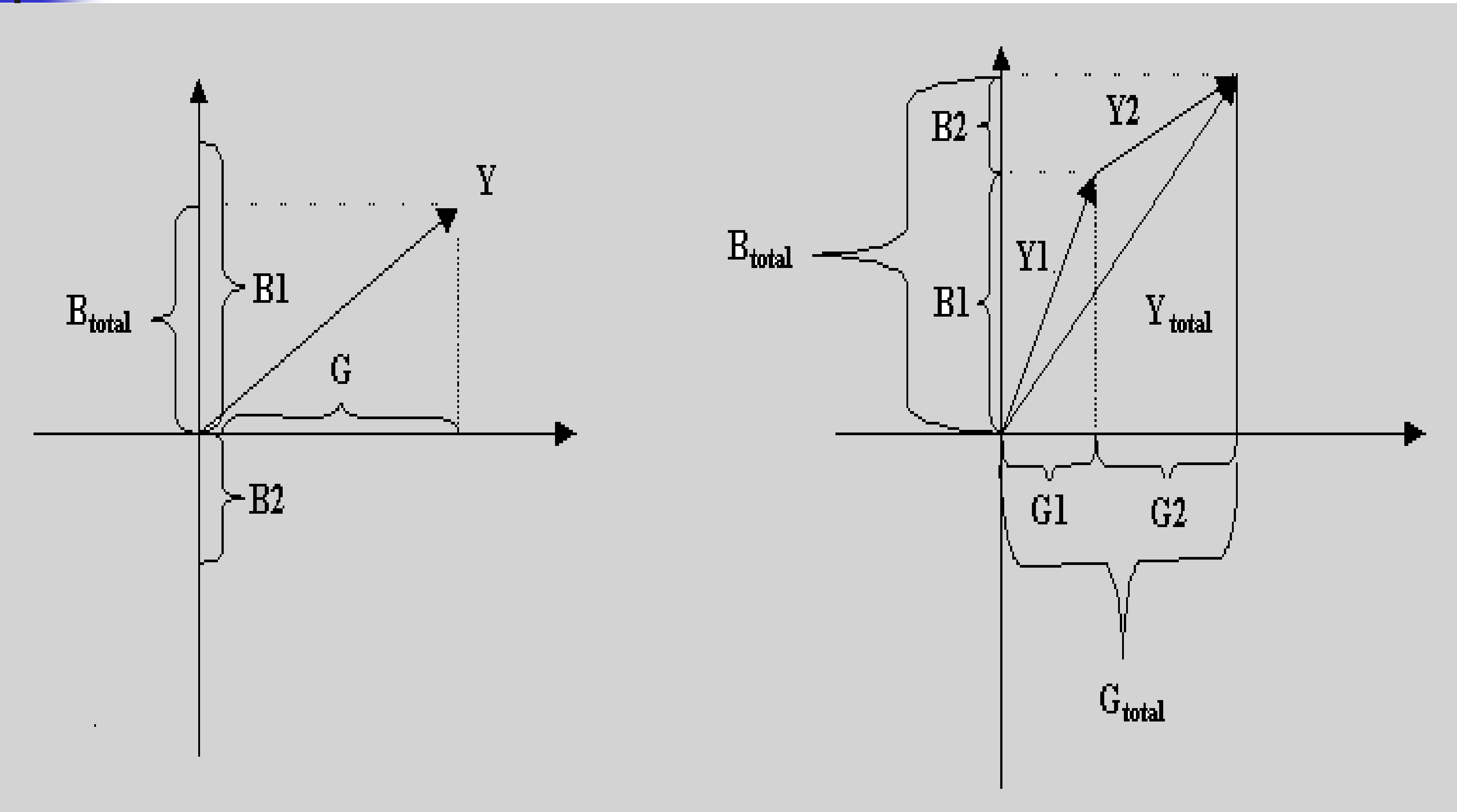
Variables Affecting SA

- The choice of pressure value for compensation of ear canal admittance: The compensated static admittance is typically higher when extreme negative (rather than extreme positive) pressure is used to estimate ear canal admittance (Margolis & Smith, 1977; Rabinowitz, 1981; Shanks & Lilly, 1981).). This asymmetry occurs because friction contributes less to admittance at extreme negative pressures than at extreme positive pressure (Margolis & Smith, 1977).
- The rate of ear canal pressure: Higher SA values for faster pump speeds (Van Camp, 1974)and more frequenct notching of high frequency tympanograms recorded at faster pump speeds (Van Camp et al., 1976)
- The direction of ear can pressure change: SA is greater for negative to positive (-/+)than for positive to negative (+/-) pressure change (Wilson et al., 1984). The incidence of notched tympanograms also is higher for -/+ (Margolis et al, 1978)

Variables Affecting SA

- Ear canal correction: Because admittance is a vector quantity, it cannot be added or subtracted unless the phase angle of the two admittance vectors is identical.
  - Subtracting admittance vector data at standard low probe tone frequency results in negligible error since the phase difference between the admittance vector of middle ear and the ear canal is small.
  - At higher probe tone frequencies a marked error occurs because a significant phase shift for the admittance vector takes place. Therefore, at higher probe tone frequencies it is necessary to compensate for the effect of ear canal from admittance rectangular components (susceptance and conductance), and then convert the data back to admittance vector (Margolis & Hunter, 1999; Shanks, Wilson, & Cabron, 1993).

Admittance Vectors (Phasor) additions



Variables Affecting SA

- Probe tone frequency: As probe tone frequency increases the SA also changes. At low probe tone frequency, regardless of the pathology tested, the middle ear system is stiffness dominated. One effect of the middle ear disease is to shift the resoonant frequency of the normal middle ear system. The greatest effect of the disease on on SA occurs near resonant frequency (Liden et al, 1974; Shahnaz & Polka, 1997). The superiority of higher probe tone frequency over 226 Hz has been shown both in low impedance pathologies (Van Camp et al., 1980) and high impedance pathologies (Shahnaz & Polka, 1997).

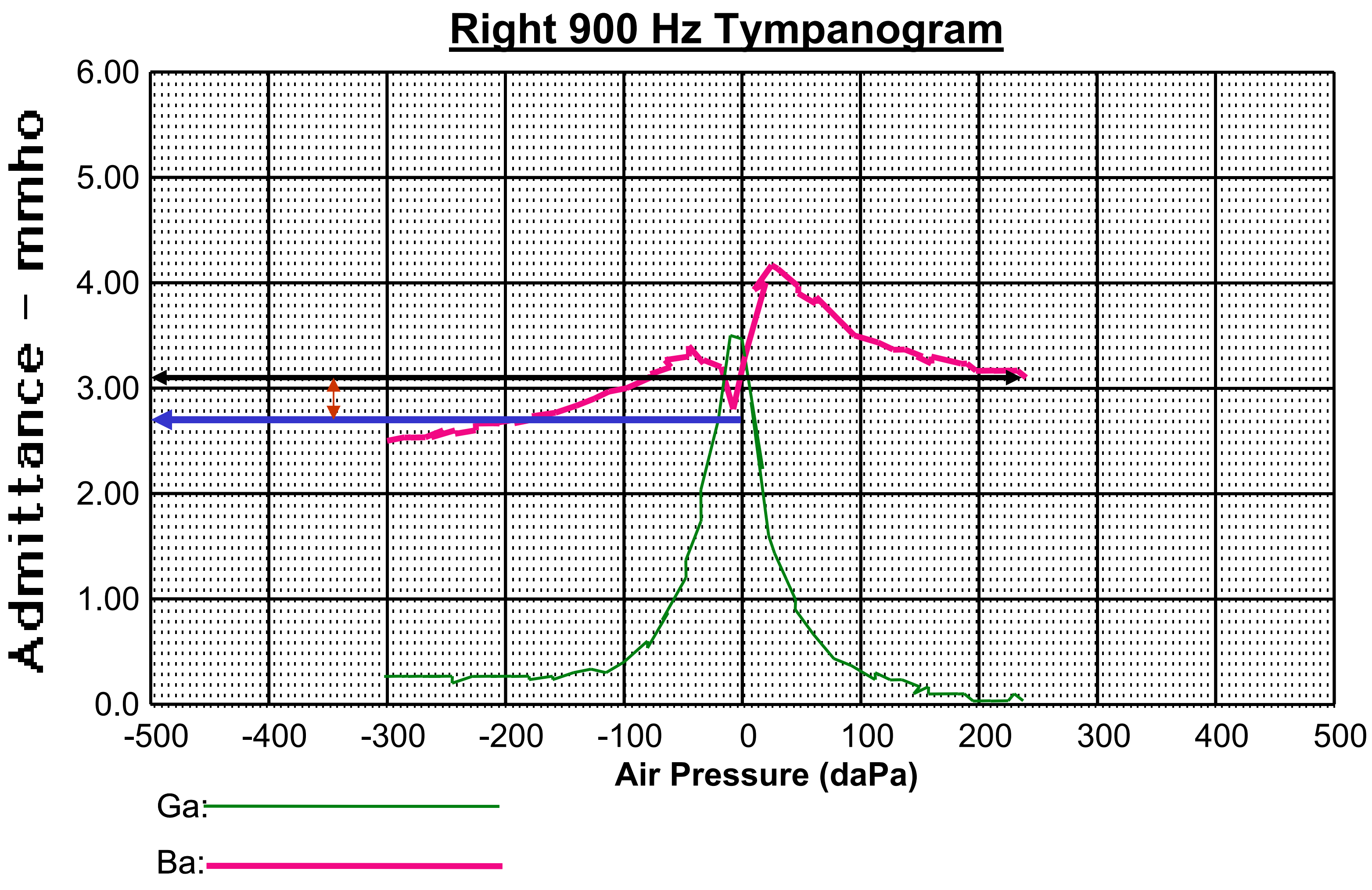
Guidelines for Measuring SA

- Ear canal volume should be estimated with the ear canal pressurized to the value that results in the minimum admittance value (MIN), however, if test re test reliability is an issue the + 200 daPa should be used.
- SA should be calculated at the ear canal pressure corresponding to the peak value for single peaked tympanograms (MAX). For notched admittance tympanograms, the static value should be calculated at the minimum in the notch. When susceptance (B) and or conductance (G) tympanograms are notched, Static susceptance should be calculated at the ear canal pressure corresponding to the minimum in the susceptance notch.

Guidelines for Measuring SA

- Either direction of ear canal pressure change can be used for tympanograms obtained with a low frequency probe (226 Hz). The decreasing (+/-) pressure direction, however, should be used with high frequency probe (e.g., 678 Hz) to minimize the occurrence of multipeaked tympanograms. In normal ears.
- Both admittance components (B & G) should be recorded simultaneously.

Calculating SA from Notched Tympanogram



SA Norms for Adults @ 226 Hz

	Normal (adults) N=68			
	Y+	**B+**	**Y-**	**B-**
Mean	0.65	0.59	0.74	0.69
SD	0.31	0.27	0.31	0.27
90% Range	0.32 | 1.28	0.3 | 1.11	0.39 | 1.26	0.39 | 1.15
95% CI	0.57 | 0.72	0.53 | 0.65	0.66 | 0.81	0.62 | 0.75

Descriptive statistics on *static immittance* (mmhos) for admittance (Y) and susceptance (B) using positive (+) and negative (-) compensation @ 226 Hz. The results are shown for the normal. Re.: Shahnaz & Polka (1997) and Shahnaz (Ph.D. dissertation)

Suggested Diagnostic Criteria for SA @ 226 Hz

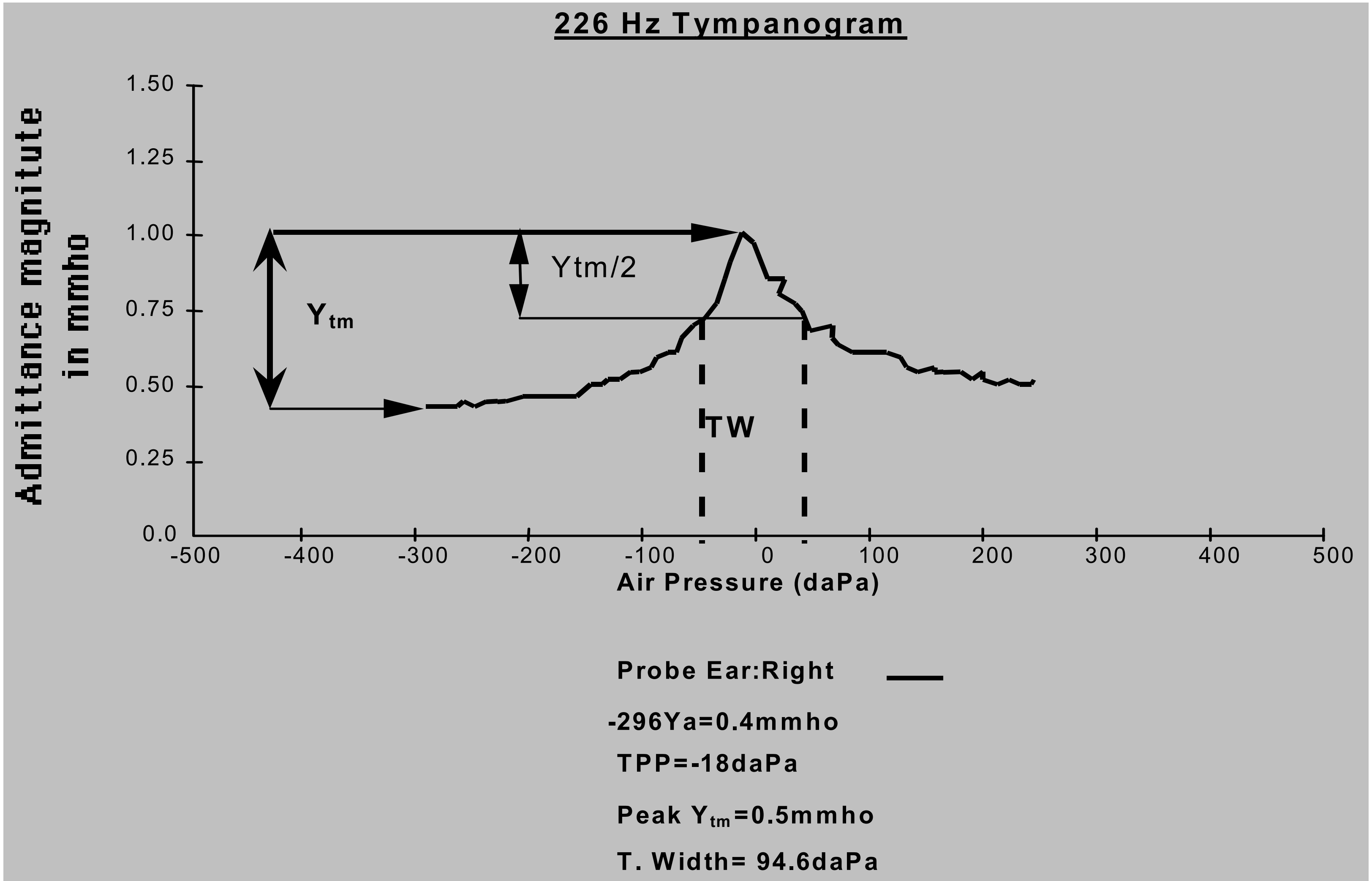
Group	*90% Normal Range mmho*	*Fail*
Adult (Shahnaz & Polka, 1997) (≥ 18 y)	0.30 -130	< 0.30 (+ 250 daPa compensation)
Adult (Margolis & Goycoolea, 1993)	0.30 – 1.70	< 0.30 (+ 200 daPa compensation < 0.40 (Negative compensation)
Children (Hunter, 1993) (3-10 years) (≥ 18 y)	0.25 – 1.05	< 0.20 (+ 200 daPa compensation) < 0.30 (Negative compensation)

Dreena's Thesis		SA					
		+ compensation			- compensation		
Investigator		Mean (mmho)	SD (mmho)	90% Range (mmho)	Mean (mmho)	SD (mmho)	90% Range (mmho)
Current Study (Caucasian)	M	0.70	0.34	0.24-1.46	0.76	0.36	0.32-1.59
	F	0.74	0.52	0.34-2.49	0.81	0.54	0.40-2.61
	C	0.72	0.43	0.34-1.55	0.79	0.46	0.39-1.69
Current Study (Chinese)	M	0.58	0.34	0.22-1.47	0.63	0.33	0.24-1.51
	F	0.43	0.28	0.14-1.22	0.47	0.28	0.17-1.17
	C	0.50	0.32	0.19-1.23	0.55	0.31	0.20-1.19
Wan & Wong (2002)	M	0.58	0.29	0.30-1.10	--	--	--
	F	0.52	0.28	0.20-1.30	--	--	--
	C	0.55	0.28	0.20-1.10	--	--	--
Roup et al. (1998)	M	0.87	0.46	0.30-1.80	--	--	--
	F	0.58	0.27	0.30-1.12	--	--	--
	C	0.72	0.40	0.30-1.19	--	--	--
Margolis & Heller (1987)	M	0.77	0.37	--	--	--	--
	F	0.65	0.21	--	--	--	--
	C	0.72	0.32	0.27-1.38	--	--	--
Wiley et al. (1996)		0.66	--	0.20-1.50	--	--	--
Holte (1996)		0.84	0.53	0.30-1.80	0.86	0.55	0.30-1.90
Shahnaz & Polka (1997)		--	--	--	0.85	0.47	0.40-1.60
Shahnaz & Polka (2002)		0.65	0.31	0.30-1.70	0.74	0.31	0.39-1.26
Margolis & Goycoolea (1993)		0.79	0.37	0.30-1.70	0.88	0.37	0.40-1.70
Shanks et al. (1993)		0.40	--	--	--	--	--

Tympanometric Width (TW)

- Tympanometric width (also referred to as tympanometric gradient) refers to the width of tympanogram (in daPa) measured at one half the compensated static admittance as illustrated
- This measure provides an index of the shape of the tympanogram in the vicinity of the peak
- It quantifies the relative sharpness (steepness) or roundness of the peak
- A large tympanometric width is measured when the tympanogram is rounded and a small tympanometric width results when the tympanogram has a sharp peak

TW Measurement



TW Norms

Group	*90% Normal Range daPa*	*Fail*
Adult (Shahnaz & Polka, 1997) (≥ 18 y)	30 – 125	> 125
Adult (Margolis & heller, 1987) (≥ 18 y)	51-114	> 115
Children (Hunter, 1993) (3-10 years)	80-159	> 160

		SA					
		+ compensation			- compensation		
Investigator		**Mean** (mmho)	**SD** (mmho)	**90% Range** (mmho)	**Mean** (mmho)	**SD** (mmho)	**90% Range** (mmho)
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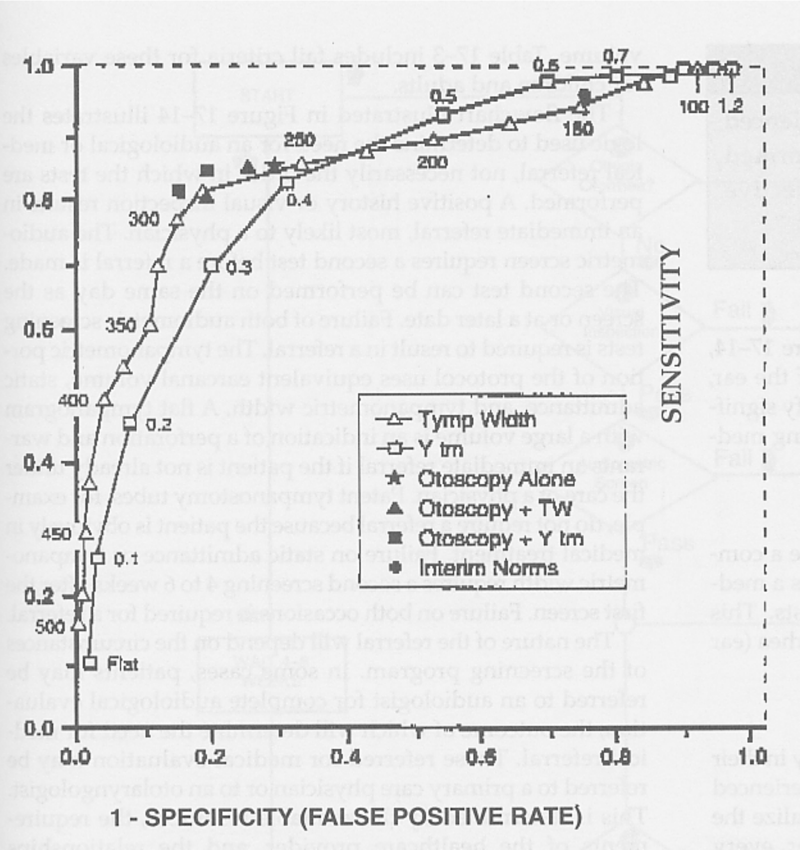
Shanks et al. (1993)		0.40	--	--	--	--	--

Sensitivity & Specificity of Tympanometry & Otoscopy

Variables	Criterion	Sens (%)	Spec (%)	PPV (%)	NPV (%)
OT		86	71	78	79
AR	Absent	86	65	76	77
Y_{tm}	≤ 0.2	46	92	88	58
TW	> 275	81	82	85	78



Nozza et al., 1994; N = 249; diagnosis of MEE; Gold Standard = Myringotomy

Multifrequency Tympanometry

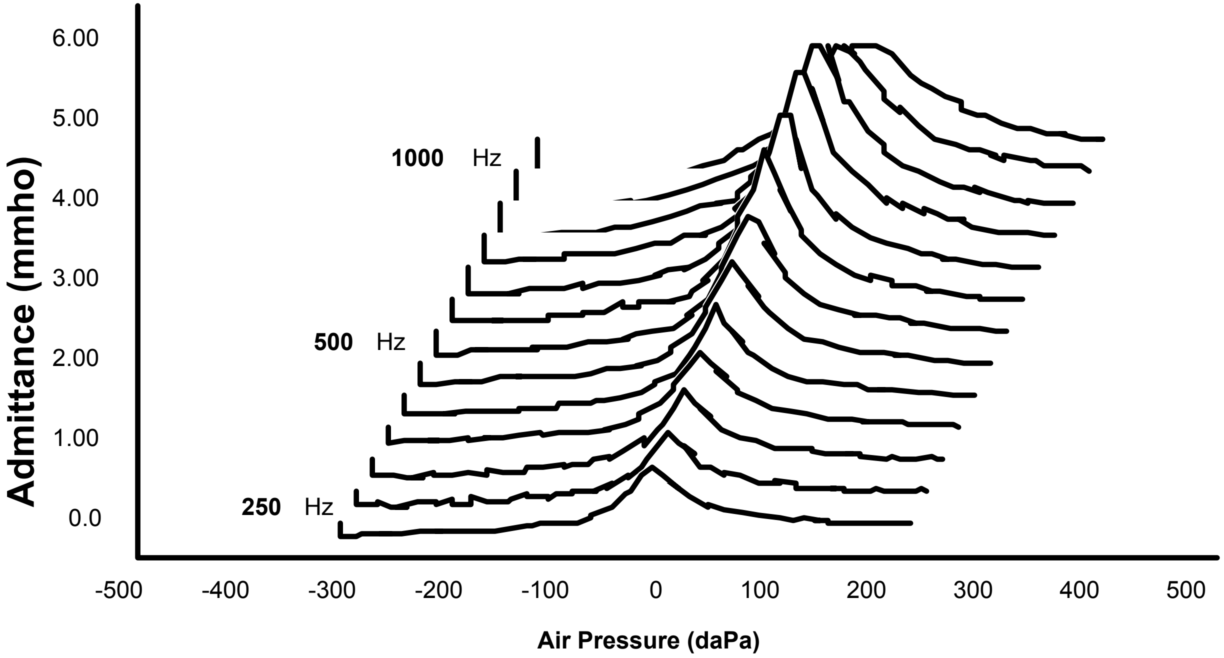
- The selection of 220 or 226 Hz probe tone frequency in standard tympanometry was partly for ease of calibration and not because it necessarily provided the most clinically useful information (see Terkildsen & Thomson, 1959)
- Now it is possible to record tympanograms at multiple probe tone frequencies and at multiple components (B & G)
- In normal ears, a low probe tone frequency tympanogram has a single peak. In contrast, tympanograms recorded at higher frequencies often have multiple peaks

Recording Methods

- **Sweep Frequency (SF):** pressure is held constant while frequency is swept across multiple frequencies

- **Sweep Pressure (SP):** frequency is held constant while the pressure is swept across a given range

Sweep Frequency (SF)



Multifrequency Tympanometry Parameters

- Tympanometric configuration - Vanhuyse Pattern
- Resonant frequency (RF)
- Frequency corresponding to admittance phase angle of 45 degree (F45°)

Multifrequency Tympanometry

- Vanhuyse, Creten, & Van Camp (1975) developed a model which predicts the shape of susceptance (B) and conductance (G) tympanograms at 678 Hz in normal ears and in various pathologies
- The Vanhuyse model categorizes the tympanograms based on the number of peaks or extrema on the susceptance (B) tympanogram and the conductance (G) tympanogram and predicts four tympanometric patterns at 678 Hz

Vanhuyse Model

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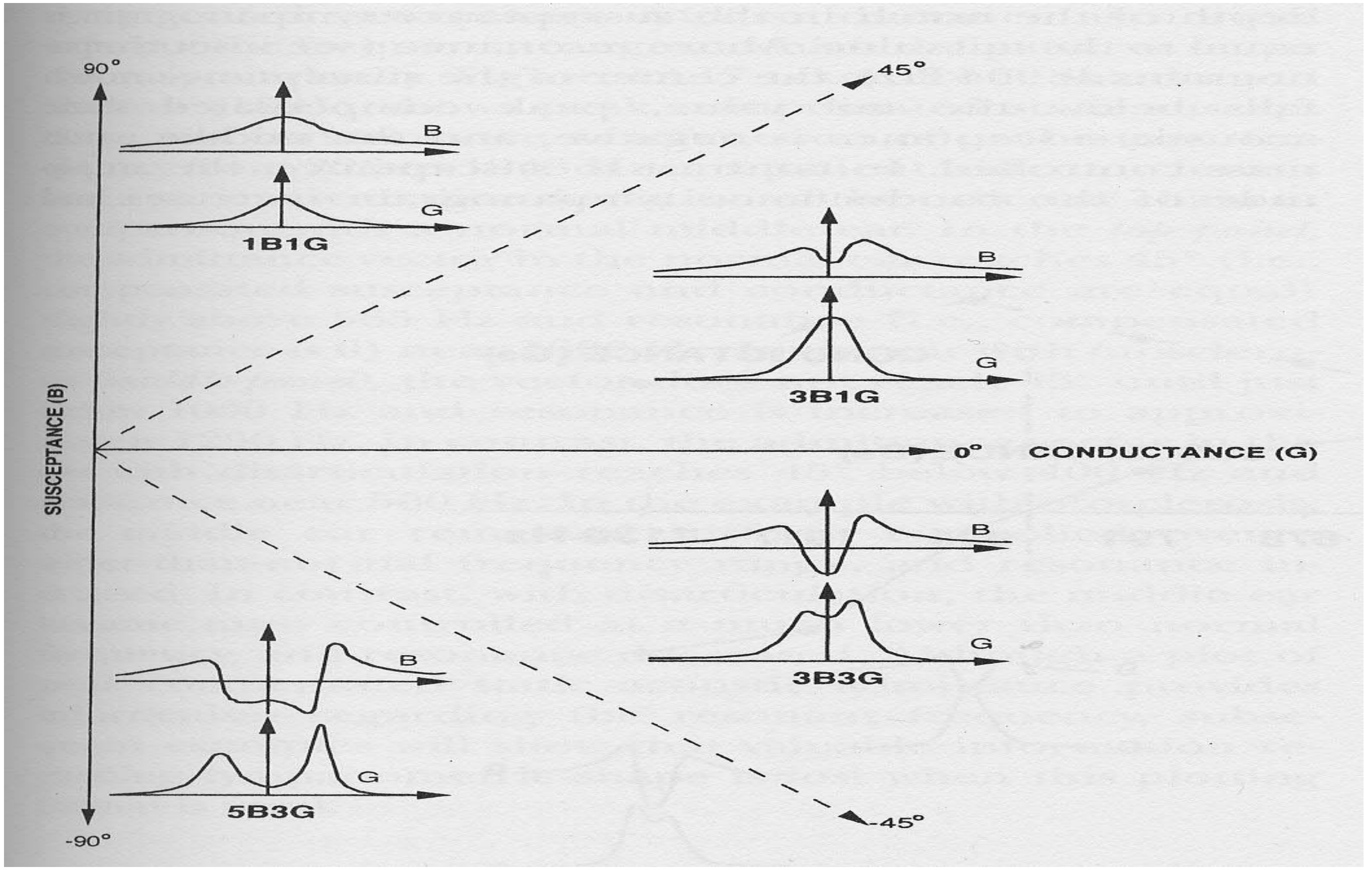
- The Vanhuyse model categorizes the tympanograms based on the number of peaks or extrema on the susceptance (B) tympanogram and the conductance (G) tympanogram and predicts four tympanometric patterns at 678 Hz

Vanhuyse Pattern & Frequency



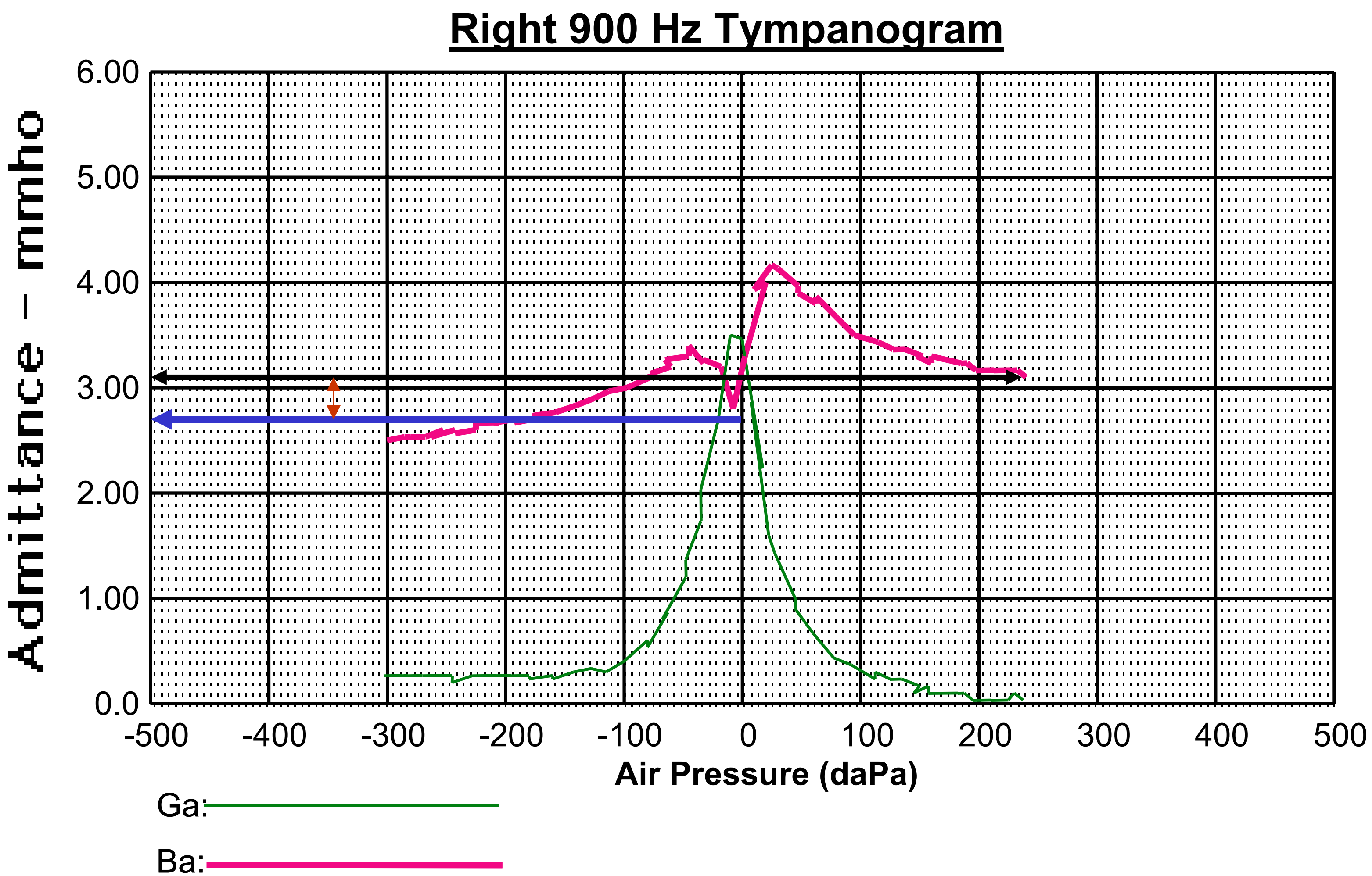
Vanhuyse Pattern Interpretation

- Except in neonates (< 4 months of age), notched tympanograms should always be considered abnormal at standard low probe tone frequency. With high probe frequency, a notched tympanogram should be considered normal if the following conditions are met:
  - The number of peaks (both maxima and minima) must not exceed five for B and 3 for G tympanograms.
  - The distance (in daPa) between the outermost G maxima must not exceed the distance between the B maxima
  - The distance between the outermost maxima must not exceed 75 dPa for tympanograms with three pekas (3B3G0 and must not exceed 100 daPa for tympanograms with five peaks (e.g., 5B3G)

Guidelines for Measuring SA

- Either direction of ear canal pressure change can be used for tympanograms obtained with a low frequency probe (226 Hz). The decreasing (+/-) pressure direction, however, should be used with high frequency probe (e.g., 678 Hz) to minimize the occurrence of multipeaked tympanograms. In normal ears.
- Both admittance components (B & G) should be recorded simultaneously.

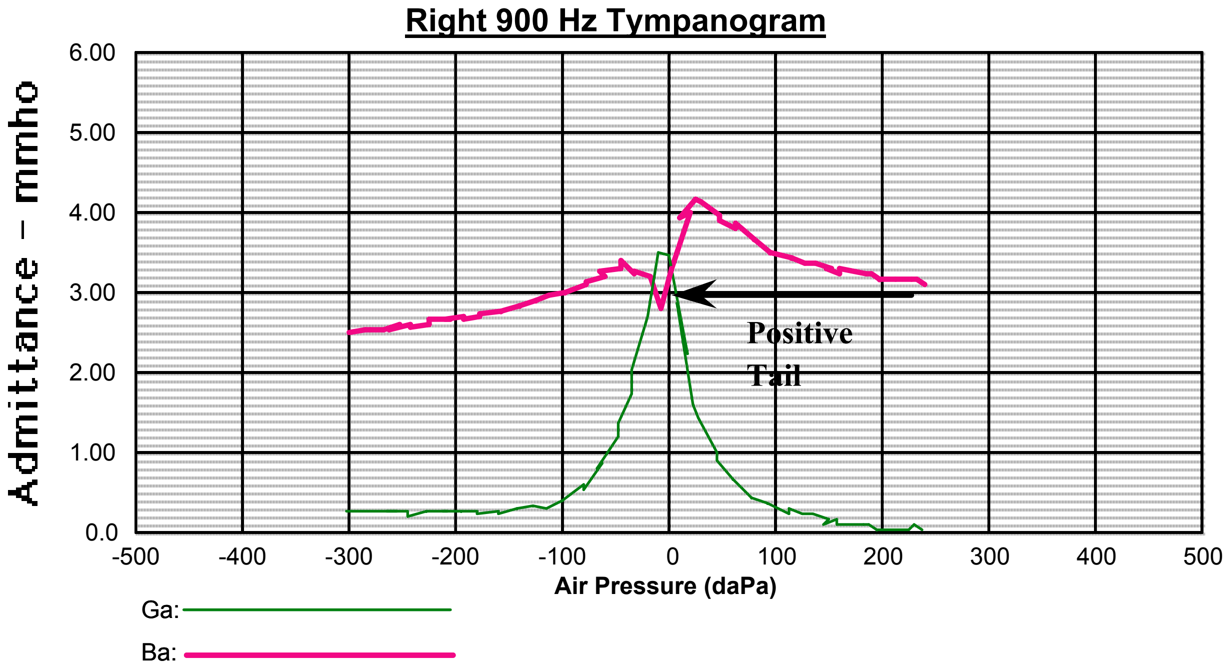
Calculating SA from Notched Tympanogram



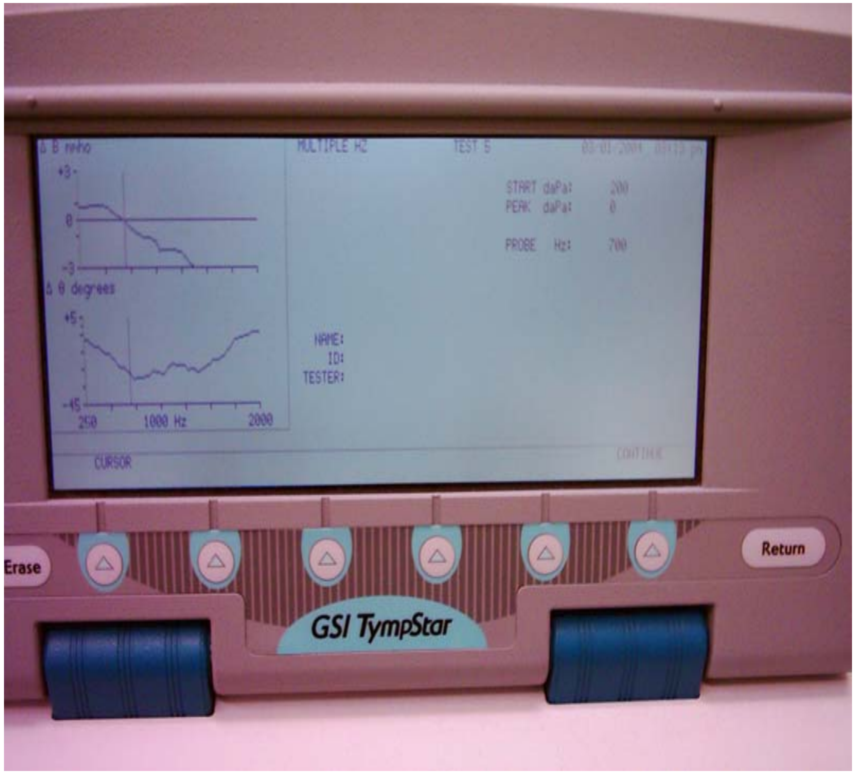
Resonant Frequency (RF)

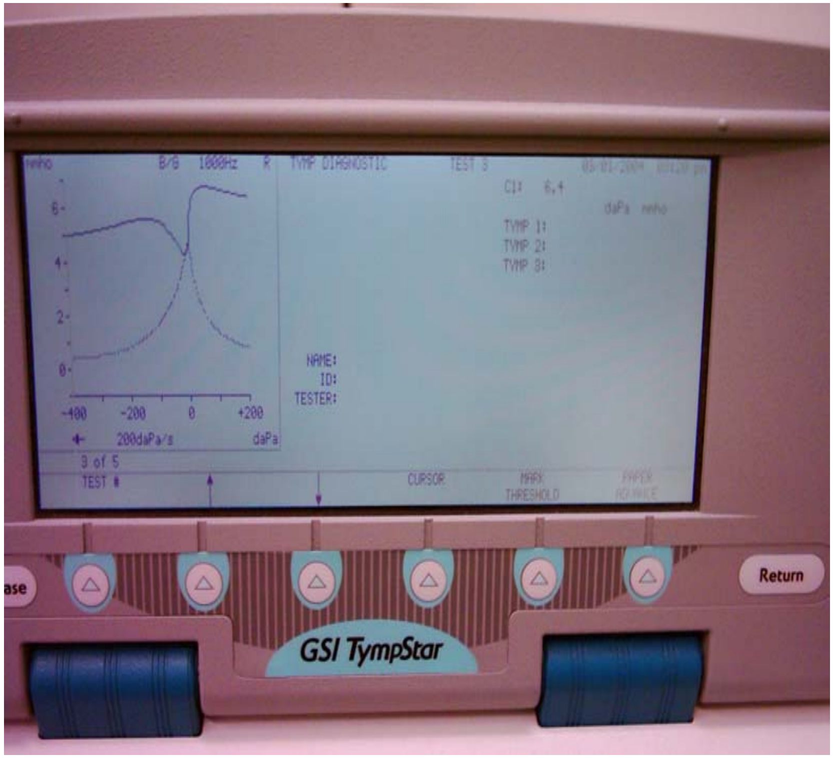
- Is the frequency at which the total susceptance is zero. The resonant frequency of the middle ear system may be shifted higher or lower compared to healthy ears by various pathologies
  - Resonant is directly proportional to the stiffness of the middle ear system, e.g., Otosclerosis increases the resonant frequency of the middle ear
  - Resonant is inversely proportional to the mass of the middle ear system

RF Estimation-Virtual or GSI



RF Estimation- GSI

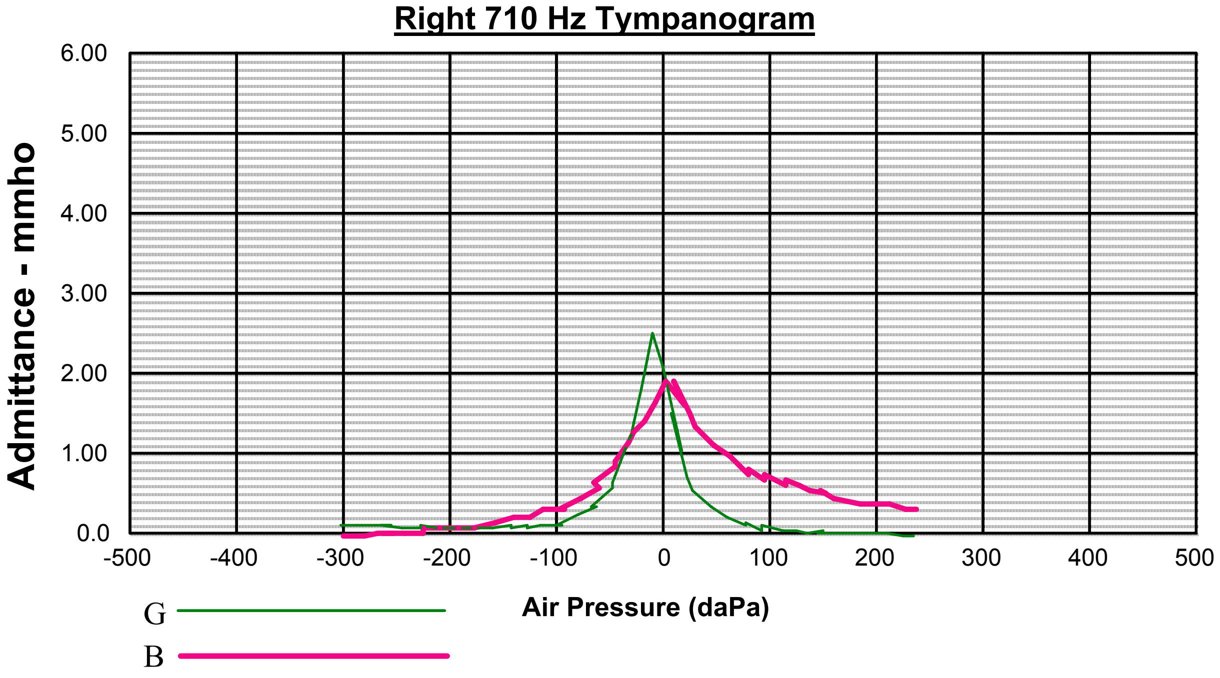




F45°

- This parameter may also be shifted higher or lower by various middle ear pathologies. Preliminary findings suggest that the frequency corresponding to a 45° phase angle may be a better index than resonant frequency with respect to distinguishing healthy ears from otosclerotic ears (Shanks, Wilson, & Palmer, 1987; Shahnaz, Polka, 1997).

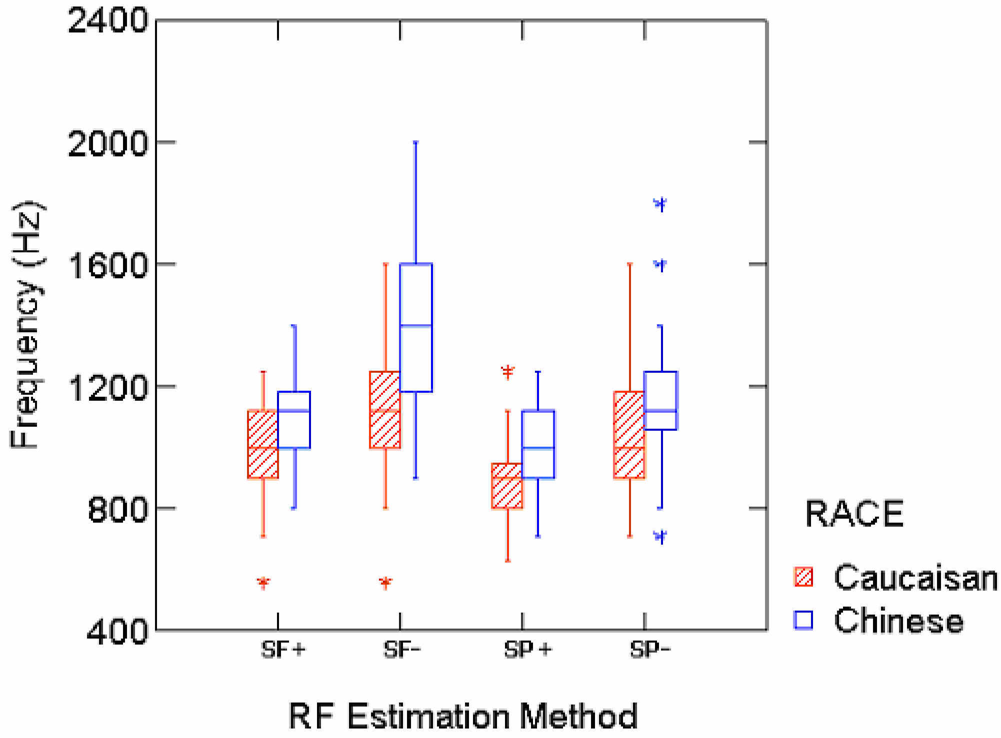
F45° Estimation



RF norm		SF					
		+ compensation			- compensation		
Investigator		Mean (Hz)	SD (Hz)	90% Range (Hz)	Mean (Hz)	SD (Hz)	90% Range (Hz)
Current Study (Chinese)	M	1084	168	805-1400	1377	298	905-1800
	F	1105	158	900-1400	1444	283	1120-2000
	C	1094	161	900-1400	1411	289	1000-1990
Current Study (Caucasian)	M	997	157	715-1250	1168	225	805-1600
	F	973	138	572-1120	1098	212	577-1400
	C	985	146	714-1250	1133	219	805-1590
Margolis & Goycoolea (1993)		1135	306	800-2000	1315	377	710-2000
Hanks & Rose (1993)		1003	216	650-1400	--	--	--
Shanks et al. (1993)		817*	--	565-1130	1100 *	--	678-1243
Valvik et al. (1994)		1049	261	650-1500	--	--	--
Holte (1996)		905	184	630-1250	1001	257	710-1400
Hanks & Mortenson (1997)		908	188	650-1300	1318	308	900-1750
Shahnaz & Polka (1997)		894	166	630-1120	1043	290	710-1400
Wiley et al. (1999)	M	826	146	--	993	259	--
	F	898	189	--	1076	297	--
	C	866	175	--	1039	283	--
Shahnaz (2000)		955	206	612-1347	1124	309	710-1600

Adult > 18 yrs

RF Norm		SP					
		+ compensation			- compensation		
Investigator		Mean (Hz)	SD (Hz)	90% Range (Hz)	Mean (Hz)	SD (Hz)	90% Range (Hz)
Current Study (Chinese)	M	990	148	810-1250	1141	243	810-1780
	F	1032	133	805-1250	1214	202	715-1600
	C	1011	141	800-1250	1177	223	800-1600
Current Study (Caucasian)	M	905	132	710-1244	1036	195	800-1393
	F	881	134	634-1120	1036	225	715-1590
	C	893	132	710-1120	1035	208	800-1400
Margolis & Goycoolea (1993)		990	290	630-1400	1132	337	710-2000
Hanks & Rose (1993)		--	--	--	--	--	--
Shanks et al. (1993)		--	--	--	--	--	--
Valvik et al. (1994)		--	--	--	--	--	--
Holte (1996)		--	--	--	--	--	--
Hanks & Mortenson (1997)		--	--	--	--	--	--
Shahnaz & Polka (1997)		615	148	400-870	508	127	355-686
Wiley et al. (1999)	M	--	--	--	--	--	--
	F	--	--	--	--	--	--
	C	--	--	--	--	--	--
Shahnaz (2000)		841	168	560-1120	974	253	630-1250



Box-and-whisker plot showing a significant race effect for resonant frequency with race (collapsed genders) as a between-subject factor and estimate (SF+, SF-, SP+, SP-) as a within-subject factor.

RF Norms – Children

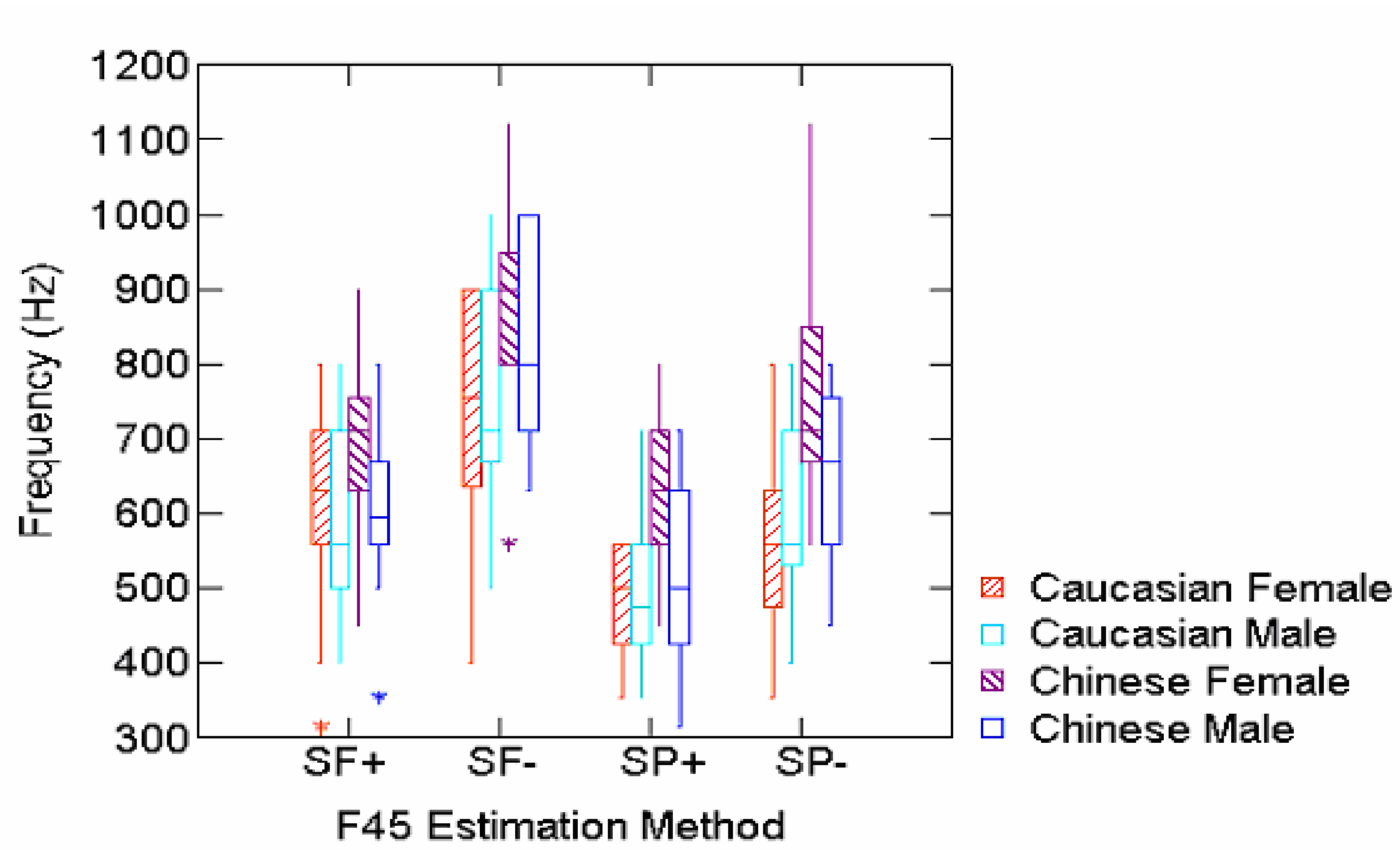
Table 12.4.

Mean Estimates of Middle Ear Resonance (in Hz) for Sweep-Frequency Tympanometry and Ear Canal Volume Compensation at +200/+250 daPa for Two Commercially Available Instruments

Investigator	Device	*N*	Age	Mean	SD	90% Range
Hanks and Mortensen (1997)	GSI	53	18–25	908	188	650–1300
Hanks and Rose (1993)	GSI	158	6–15	1003	216	650–1400
Holte (1996)	Virtual	144	20–90+	906	184	630–1250
Margolis and Goycoolea (1993)	Virtual	28	19–48	1135	306	800–2000
Shahnaz and Polka (1997)	Virtual	36	20–43	894	166	630–1120
Shanks et al. (1993)	Virtual	26	20–40	817		565–1130
Valvik et al. (1994)	GSI	100		1049	261	650–1500
Wiley et al. (1999)	Virtual	404	48–90	866	175	

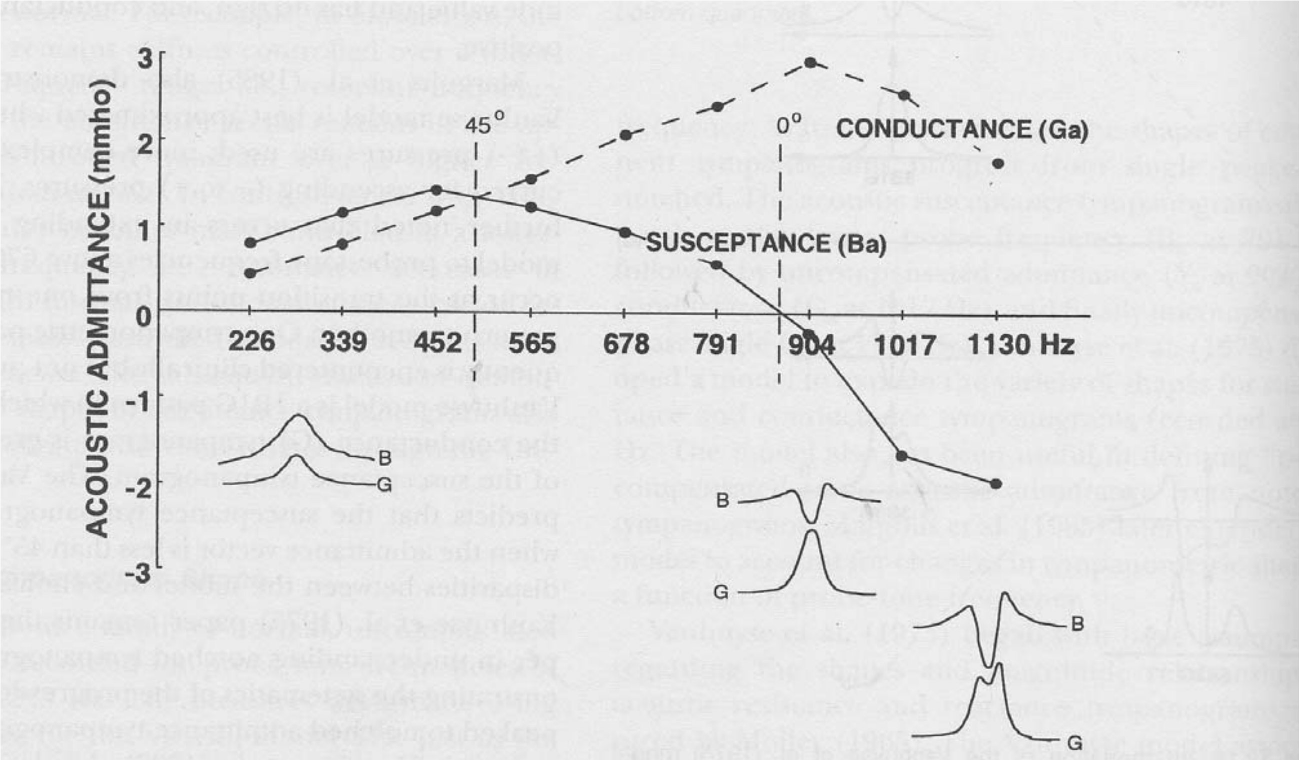
F45° Norms

Age Group	SF (Hz)	SP (Hz)
Adults > 18 yrs Shahnaz & Polka (1997)	Mean = 615 90 % range: 400-870 < 400 Hz & > 870 Hz	Mean = 508 90 % range: 355-686 < 400 Hz & > 870 Hz



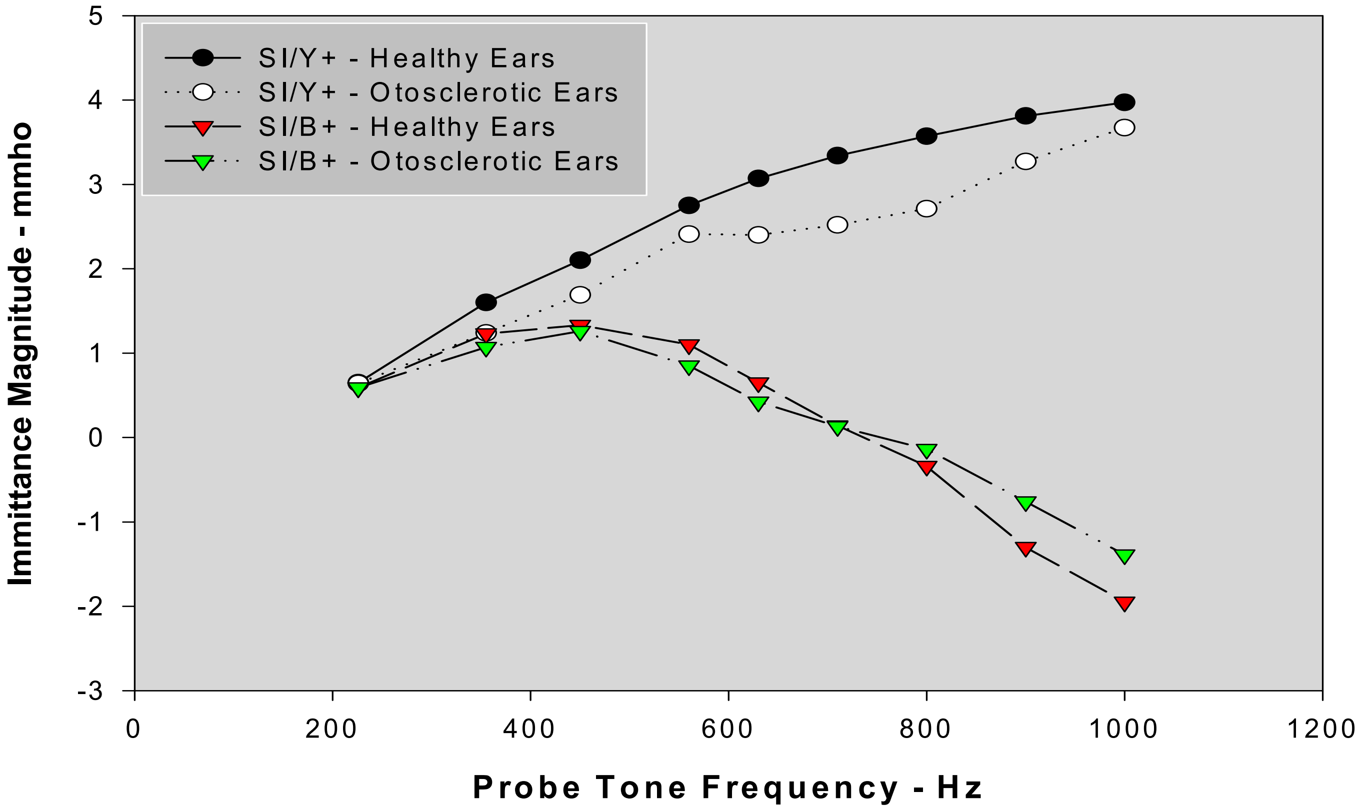
Box-and-whisker plot showing F45° by gender and race (between-subject factors) and estimate (within-subject factor). Genders are not collapsed as significant gender differences were found in the Chinese adults.

Compensated B & G as a Function O\of Frequency

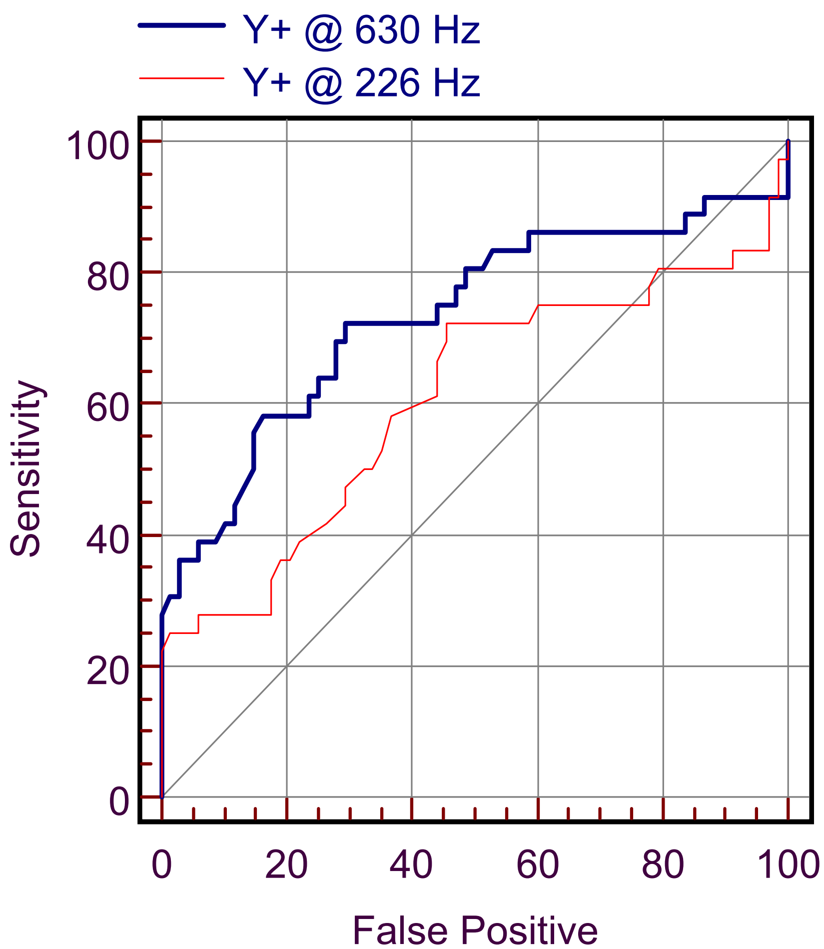


The Choice of Probe Tine Frequency For Measuring SA

Shahnaz & Polka (paper submitted for publication)



Low vs. High Probe Tone Frequency



SA Norms at Multiple Frequencies

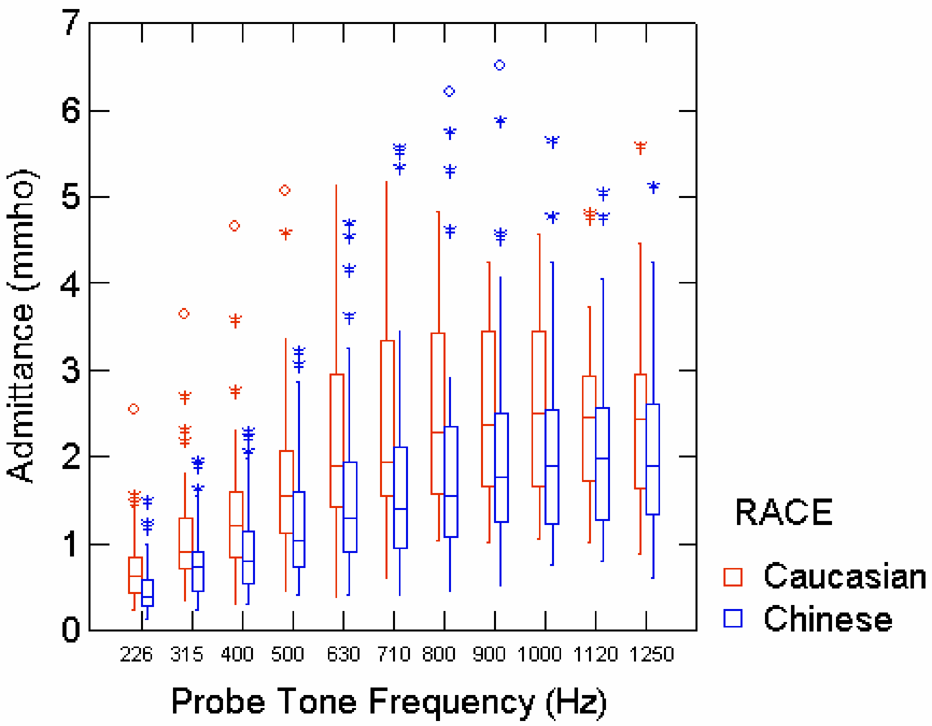
Freq. Hz	Y+ mmho			B+ mmho			Y- mmho			B- mmho		
	Mean	SD	90% Range	Mean	SD	90% Range	Mean	SD	90% Range	Mean	SD	90% Range
226	0.65	0.31	0.32-1.28	0.59	0.27	0.30-1.11	0.74	0.31	0.39-1.26	0.69	0.27	0.39-1.15
355	1.60	1.15	0.62-3.50	1.23	0.67	0.54-2.90	1.70	1.13	0.70-3.55	1.41	0.68	0.65-3.02
450	2.10	1.21	0.77-4.88	1.33	0.66	0.49-2.32	2.21	1.18	0.91-4.92	1.62	0.69	0.79-2.62
560	2.75	1.40	0.95-5.33	1.10	0.75	-0.22-2.17	2.78	1.34	1.05-5.00	1.56	0.62	0.73-2.60
630	3.07	1.54	1.14-5.64	0.65	1.03	-1.69-1.88	3.03	1.46	1.25-5.20	1.19	0.80	-0.33-2.25
710	3.34	1.50	1.33-5.83	0.14	1.33	-2.94-1.49	3.20	1.38	1.51-5.59	0.81	1.05	-1.60-1.84
800	3.57	1.44	1.53-6.04	-0.34	1.72	-3.84-1.30	3.00	2.61	1.19-5.75	0.63	1.25	-1.17-2.10
900	3.81	1.45	1.82-6.76	-1.30	1.65	-4.40-0.73	3.40	1.35	1.70-6.16	-0.30	1.30	-3.31-1.20
1000	3.97	1.52	1.75-6.78	-1.95	1.83	-5.71-0.21	3.47	1.24	1.55-5.87	-0.85	1.38	-4.08-0.85

Frequency		Y+ Mean (mmho)	Y+ SD (mmho)	Y+ 90% range (mmho)	Y- Mean (mmho)	Y- SD (mmho)	Y- 90% range (mmho)
226 Hz	**M**	0.70	0.34	0.24-1.46	0.76	0.36	0.32-1.59
	F	0.74	0.52	0.34-2.49	0.81	0.54	0.40-2.61
315 Hz	**M**	1.09	0.54	0.44-3.60	1.14	0.58	0.44-2.45
	F	1.11	0.78	0.35-3.60	1.18	0.80	0.44-3.76
400 Hz	**M**	1.40	0.62	0.54-2.74	1.49	0.66	0.64-2.94
	F	1.41	1.03	0.32-4.60	1.46	1.05	0.32-4.75
500 Hz	**M**	1.81	0.82	0.72-3.35	1.95	0.88	0.71-3.58
	F	1.75	1.16	0.47-5.04	1.82	1.17	0.43-5.13
630 Hz	**M**	2.37	1.12	0.96-4.36	2.49	1.18	0.86-4.44
	F	2.13	1.10	0.42-5.05	2.14	1.08	0.61-5.09
710 Hz	**M**	2.63	1.23	1.00-4.83	2.75	1.26	1.02-4.76
	F	2.23	1.14	0.61-5.12	2.23	1.15	0.52-5.05
800 Hz	**M**	2.66	1.16	1.07-4.80	2.76	1.20	0.99-4.99
	F	2.50	1.14	1.04-4.74	2.42	1.10	1.01-4.52
900 Hz	**M**	2.56	0.93	1.22-4.15	2.53	0.93	1.12-4.02
	F	2.58	1.08	1.02-4.25	2.48	1.03	0.98-4.02
1000 Hz	**M**	2.55	1.06	1.15-3.94	2.48	0.76	1.20-3.77
	F	2.62	1.06	1.07-4.55	2.49	0.96	1.04-4.15
1120 Hz	**M**	2.41	0.76	1.23-3.61	2.60	1.11	1.02-4.81
	F	2.31	0.65	1.27-3.29	2.41	0.98	0.99-4.48
1250 Hz	**M**	2.24	0.70	1.02-3.49	2.15	0.57	1.17-4.47
	F	2.56	1.16	0.91-5.52	2.30	0.93	1.00-4.47

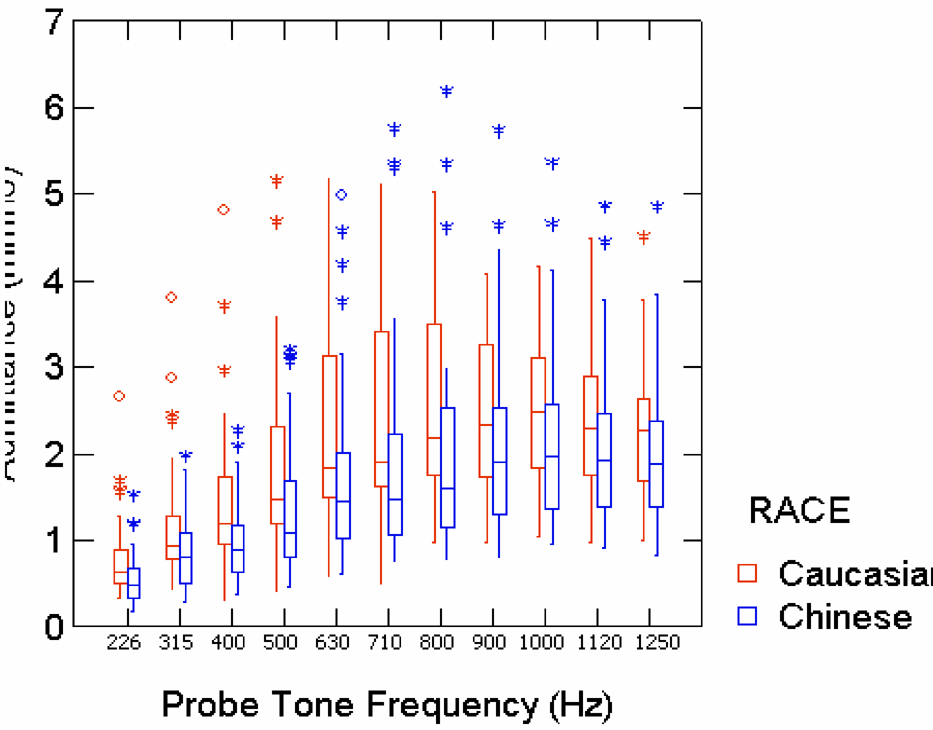
Caucasian

Frequency		Y+			Y-		
		Mean (mmho)	SD (mmho)	90% range (mmho)	Mean (mmho)	SD (mmho)	90% range (mmho)
226 Hz	M	0.58	0.34	0.22-1.47	0.63	0.33	0.24-1.51
	F	0.43	0.28	0.14-1.22	0.47	0.28	0.17-1.17
315 Hz	M	0.92	0.42	0.43-1.88	0.96	0.42	0.43-1.96
	F	0.67	0.42	0.25-1.92	0.75	0.43	0.29-1.80
400 Hz	M	1.12	0.59	0.49-2.28	1.19	0.56	0.56-2.27
	F	0.75	0.41	0.30-1.93	0.83	0.45	0.38-2.23
500 Hz	M	1.52	0.87	0.44-3.20	1.62	0.85	0.65-3.20
	F	0.99	0.54	0.41-2.53	1.11	0.60	0.46-3.00
630 Hz	M	1.85	1.23	0.41-4.66	1.94	1.16	0.76-4.55
	F	1.40	0.90	0.57-4.42	1.54	0.95	0.63-4.85
710 Hz	M	2.05	1.47	0.40-5.54	3.12	1.41	0.77-5.34
	F	1.58	1.07	0.71-5.36	1.71	1.09	0.82-5.58
800 Hz	M	2.25	1.61	0.45-6.19	2.31	1.52	0.78-6.15
	F	1.68	1.02	0.76-5.17	1.83	1.01	0.96-5.23
900 Hz	M	2.57	1.58	0.54-6.47	2.29	1.23	0.81-4.55
	F	1.81	0.91	0.77-4.50	1.93	0.86	1.00-4.55
1000 Hz	M	2.31	1.27	0.76-5.60	2.30	1.17	0.96-5.33
	F	1.90	0.84	0.94-4.19	2.01	0.78	1.18-4.07
1120 Hz	M	2.24	1.13	0.80-5.03	2.21	1.04	0.93-4.84
	F	1.91	0.78	1.07-4.00	1.95	0.69	1.13-3.74
1250 Hz	M	2.22	1.11	0.62-5.08	2.13	0.98	0.84-4.81
	F	1.91	0.78	1.07-3.98	1.91	0.64	1.19-3.50

Chinese



Positive compensation



Negative compensation

Case 1: OM (Fowler & Shanks, 2002)

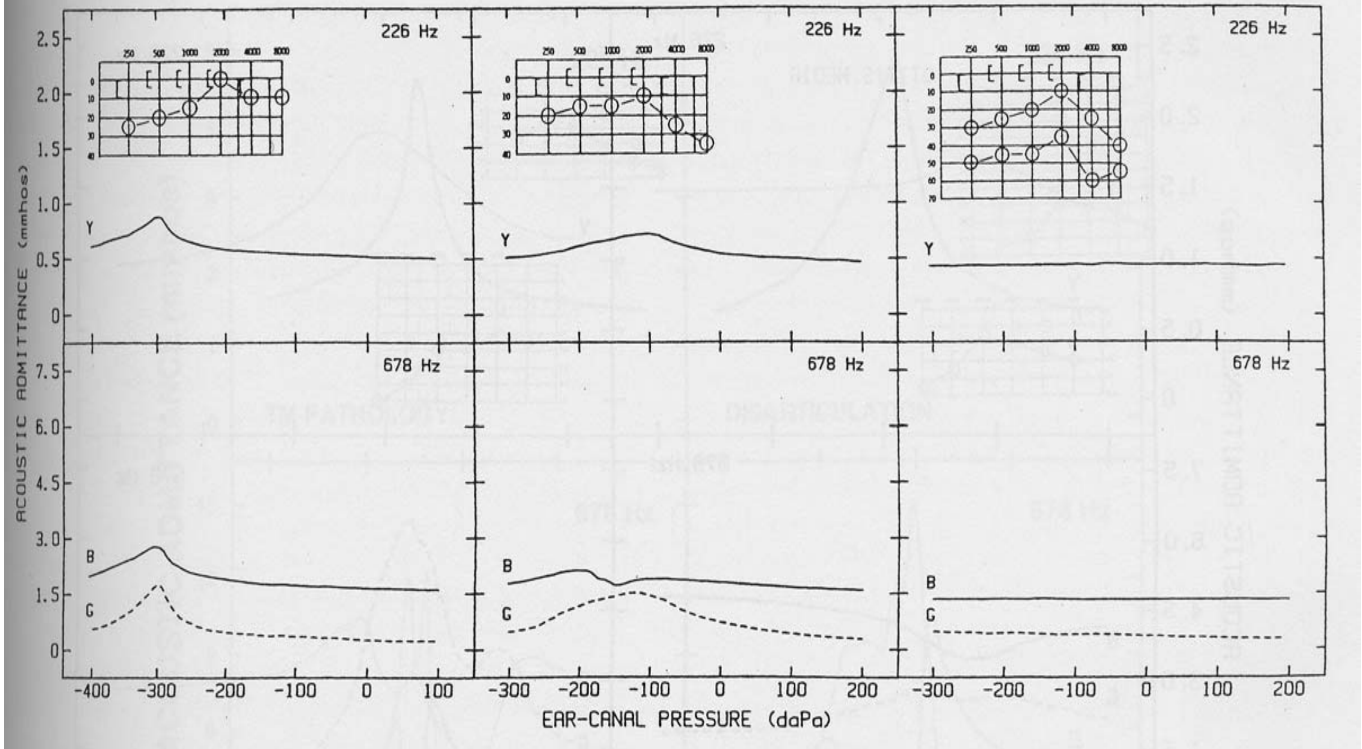


Figure 12.18. Three patterns of 226-Hz admittance *(Y)* tympanograms and 678-Hz susceptance *(B)* and conductance *(G)* tympanograms recorded from a 5-year-old child with otitis media. Puretone audiograms are shown as *inserts*. (From Shanks JE, Shelton C (1991) Basic principles and clinical applications of tympanometry. Otolaryngol Clin North Am; 24: 299–328, with permission.)

Case 2: OM (Fowler & Shanks, 2002)

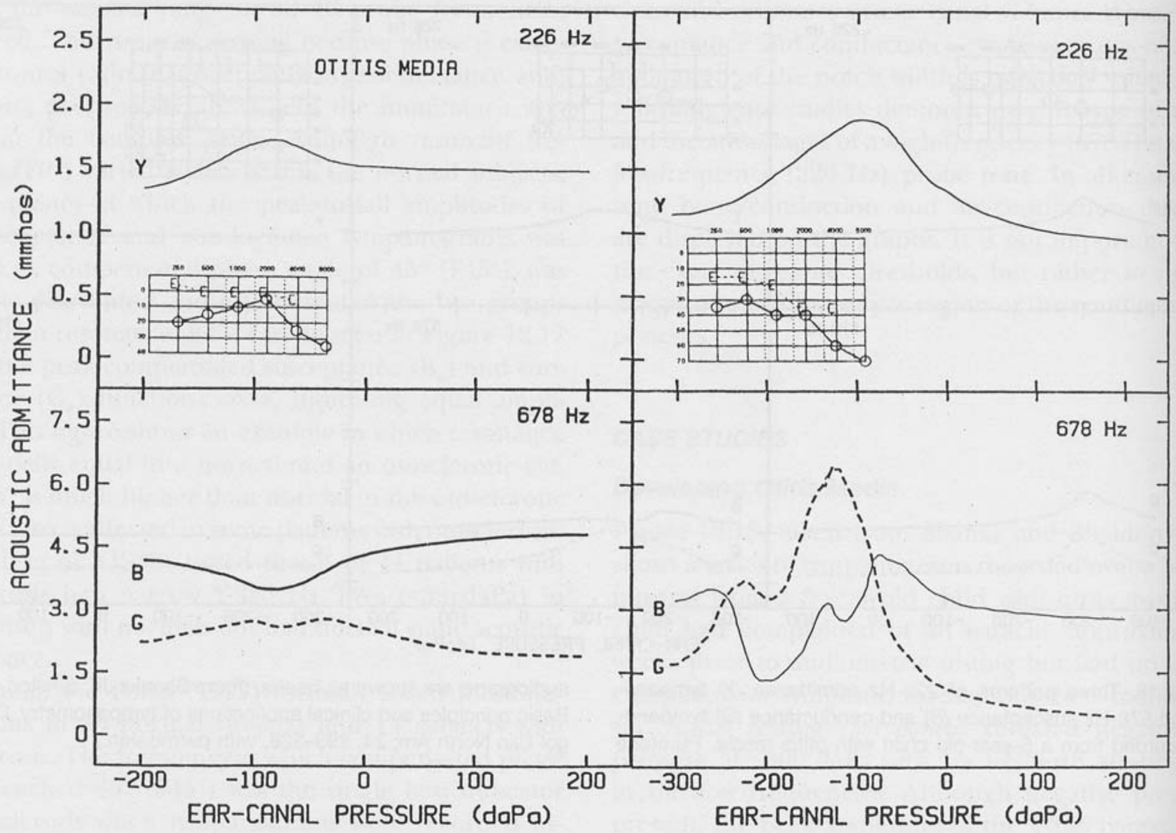


Figure 12.19. 226-Hz acoustic admittance *(Y)* tympanograms in comparison with 678-Hz susceptance *(B)* and conductance *(G)* tympanograms from two patients with small amounts of middle ear fluid. Puretone audiograms are shown as *inserts*.

Case 3: TM Pathology vs. Disarticulation (Fowler & Shanks, 2002)

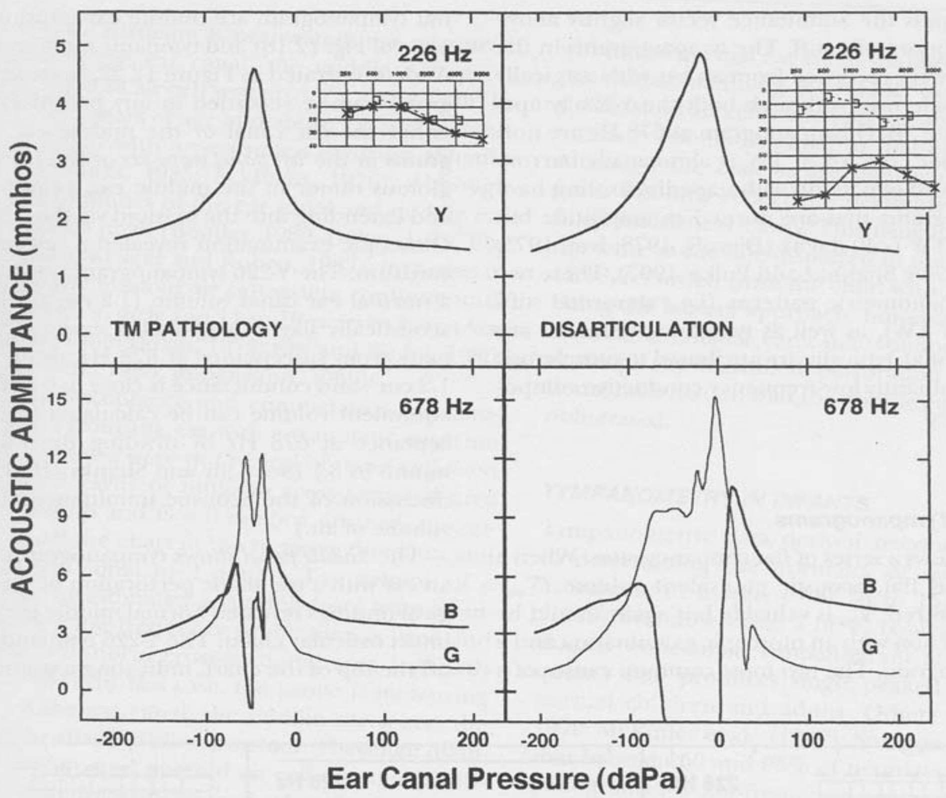


Figure 12.20. 226-Hz acoustic admittance *(Y)* tympanograms in comparison with 678-Hz susceptance *(B)* and conductance *(G)* tympanograms from an ear with atrophic scarring of the eardrum *(left panels)* and an ear with ossicular disarticulation *(right panels)*. Pure-tone audiograms are shown as *inserts*.

Case 4: Otosclerosis (Fowler & Shanks, 2002)

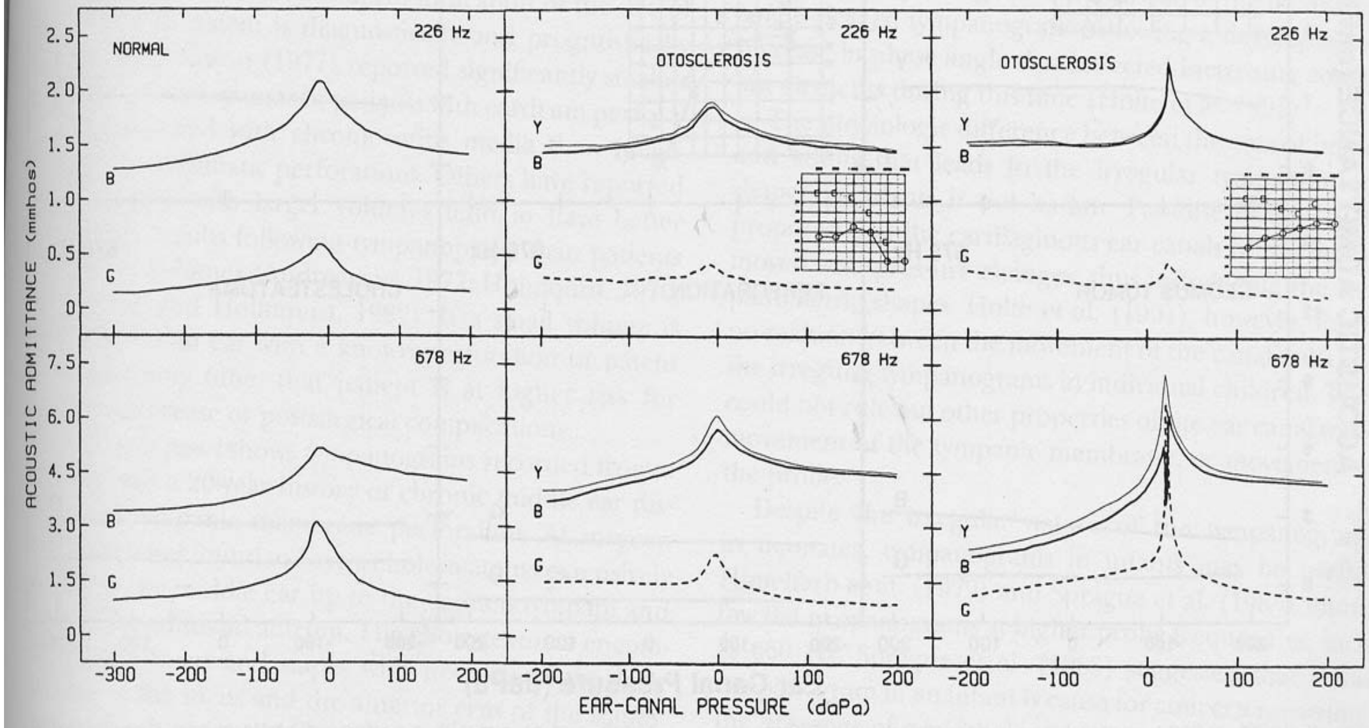


Figure 12.21. 226-Hz and 678-Hz acoustic admittance *(Y)*, susceptance *(B)*, and conductance *(G)* tympanograms from a normal middle ear *(left panel)* in comparison with two ears with surgically confirmed otosclerosis *(middle and right panels)*. Puretone audiograms are shown as *inserts*.

Case 5: Middle Ear Problems (Fowler & Shanks, 2002)

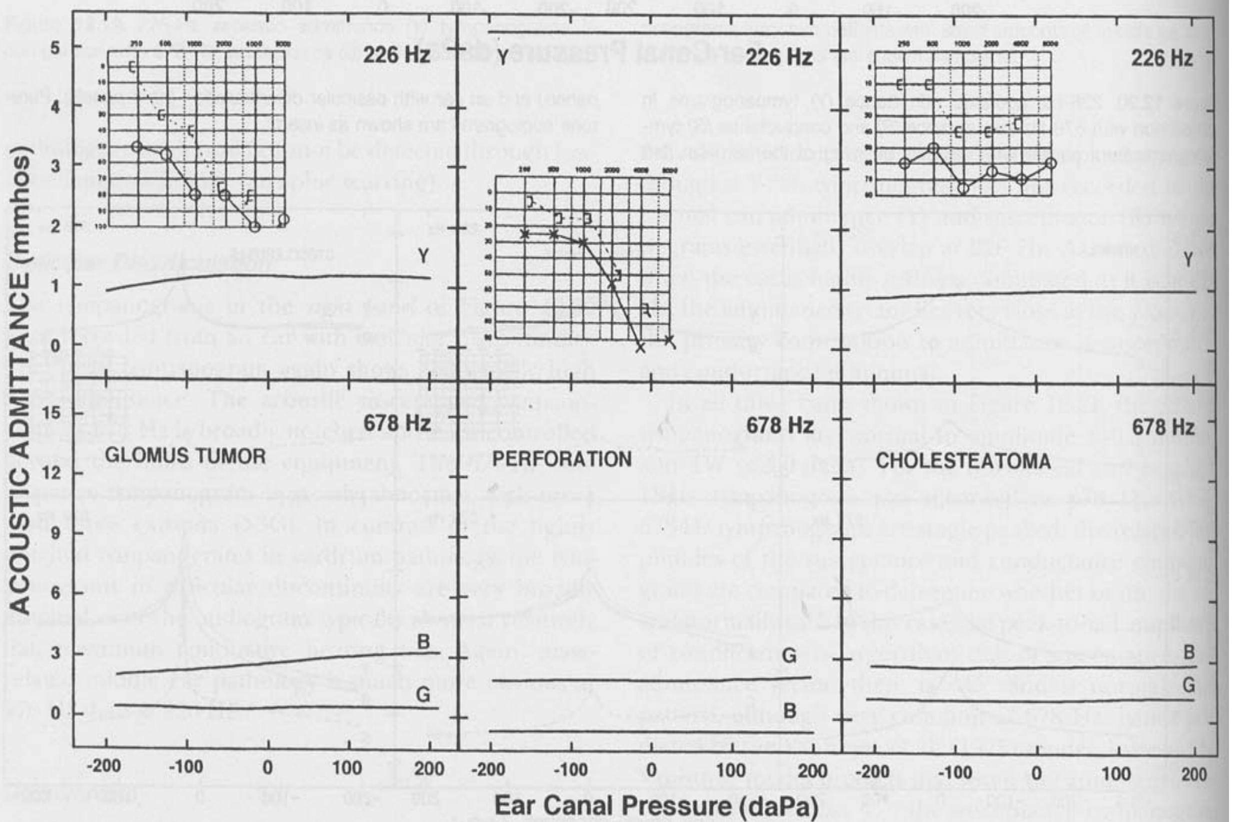


Figure 12.22. Y-226 tympanograms in comparison with 678-Hz susceptance *(B)* and conductance *(G)* tympanograms from an ear with a glomus tumor *(left panel)*, an ear with a perforated eardrum *(middle panel)*, and an ear with a perforated eardrum and a cholesteatoma completely filling the middle-ear space *(right panel)*. Puretone audiograms are shown as *inserts*.

Tympanometry in Infants

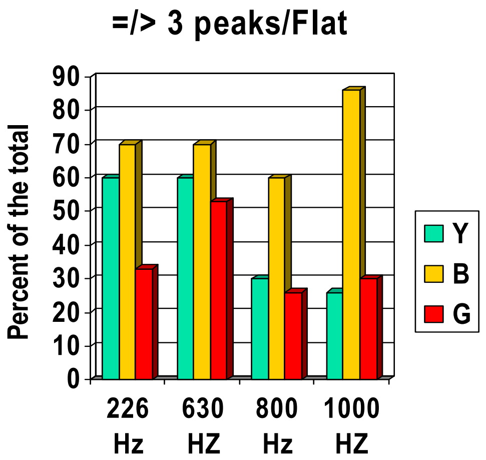
- The clinical value of standard and multifrequency tympanometry in infants under 4 months of age is controversial
- This is mainly due to the presence of mesenchyme (unresorbed fetal tissue), amniotic fluid, and other cellular debris (Eavey, 1993)

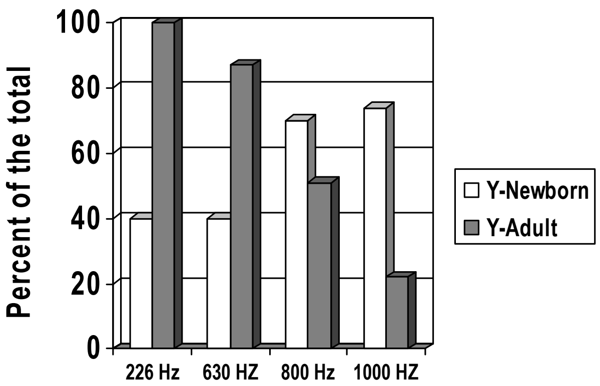
Method (Pilot study, Shahnaz 2001; Polka, Shahnaz, Zeitoni, 2001)

- Thirty ears of sixteen 3-weeks old infants were tested using Virtual 310 middle ear analyzer with EHF option
- Sweep pressure recording was used to record tympanograms at nine probe tone frequencies (226 – 1000 Hz) in roughly 100 Hz intervals
- All infants, except one, passed Algo-II automatic ABR protocol for both ears at the time of birth and at 3-weeks of age

Results

- While eighteen ears had multiple peak or irregular patterns on Y tympanogram at standard low probe tone frequency (226 Hz), 22 ears had a single peak and essentially normal shape tympanogram on G component at 800 Hz and Y @ either 800 or 1000 Hz.
- One infant who failed Algo-II protocol in both ears at the time of birth and at 3-weeks of age, had an irregular Y tympanogram at 226 Hz and single peak G tympanogram at 800 Hz. This infant was later diagnosed to have a moderate to severe bilateral sensorineural

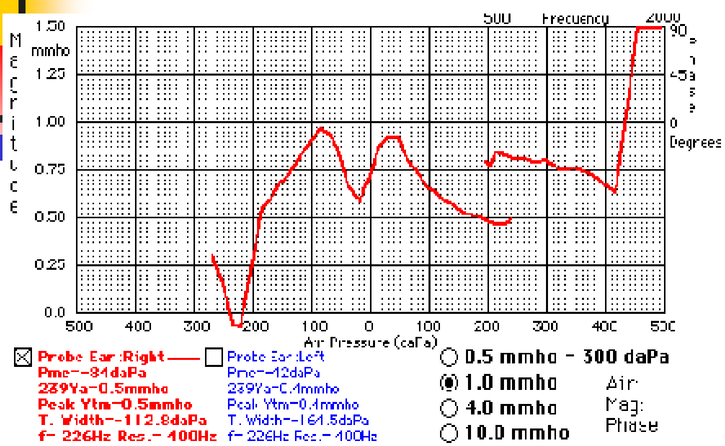


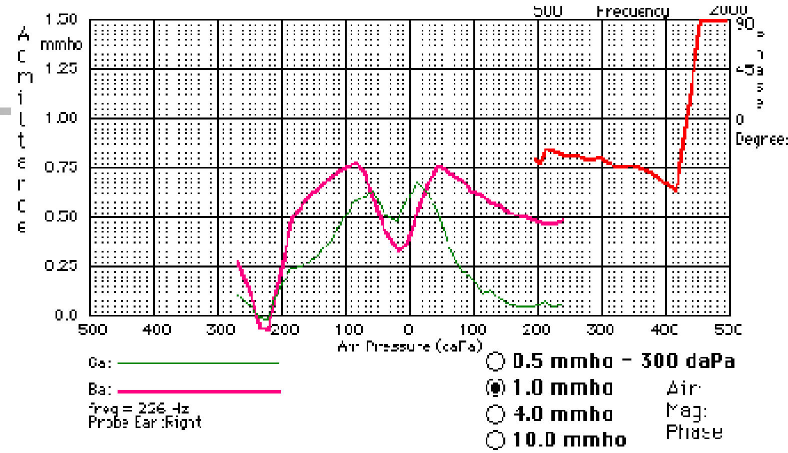


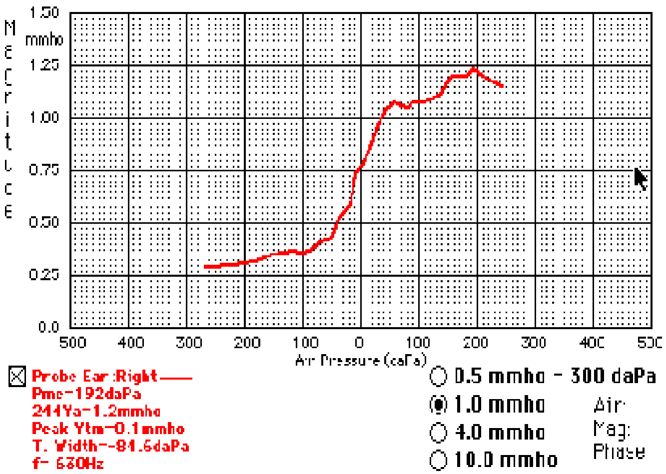
Results & Conclusions

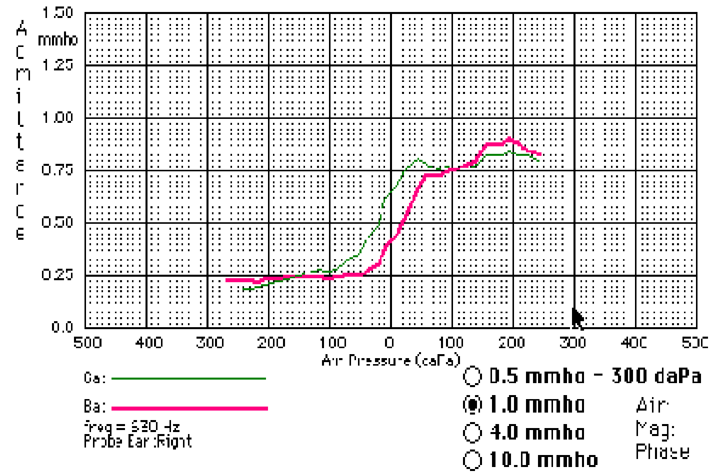
- The findings of the current study suggest the importance of multifrequency, multicomponent tympanometry in newborns and young infants
- Further studies are needed to seek out the optimum probe tone frequency and admittance component in measuring the middle ear status of newborns and young infants with documented conductive component.

Case II


1.50 mmho
Frequency
Air Pressure (daPa)
Probe Ear :Right
Pme--84daPa
239Ya-0.5mmho
Peak Ytm-0.5mmho
T. Width--112.8daPa
f- 226Hz Res.- 400Hz
Probe Ear :Left
Pme--12daPa
239Ya-0.4mmho
Peak Ytm-0.4mmho
T. Width--161.5daPa
f- 226Hz Res.- 400Hz
0.5 mmho - 300 daPa
1.0 mmho
4.0 mmho
10.0 mmho
Air
Mag:
Phase

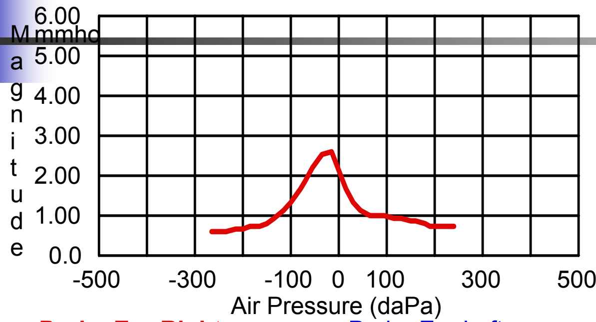

1.50 mmho
Frequency
Degrees
Air Pressure (daPa)
Ga:
Ba:
freq = 226 Hz
Probe Ear :Right
0.5 mmho - 300 daPa
1.0 mmho
4.0 mmho
10.0 mmho
Air
Mag:
Phase


1.50 mmho
Air Pressure (daPa)
Probe Ear :Right
Pme-192daPa
244Ya-1.2mmho
Peak Ytm-0.1mmho
T. Width--84.6daPa
f- 630Hz
0.5 mmho - 300 daPa
1.0 mmho
4.0 mmho
10.0 mmho
Air
Mag:
Phase


1.50 mmho
Air Pressure (daPa)
Ga:
Ba:
freq = 630 Hz
Probe Ear :Right
0.5 mmho - 300 daPa
1.0 mmho
4.0 mmho
10.0 mmho
Air
Mag:
Phase

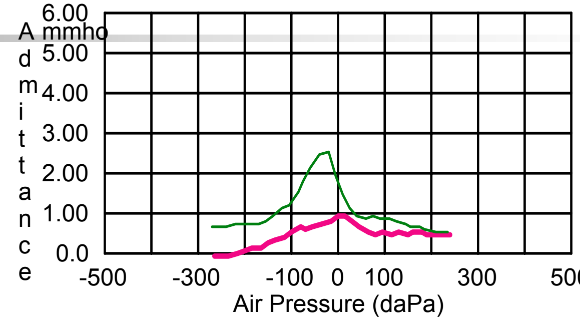
Case I

800 Hz Tympanogram



Probe Ear:Right Probe Ear:Left
Pme=-18daPa
239Ya=1.5mmho
Peak Ytm=1.6mmho
T. Width=-112.8daPa
f= 800Hz

800 Hz Tympanogram

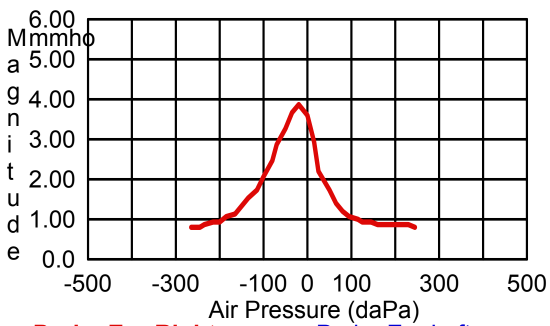


Ga:

Ba:

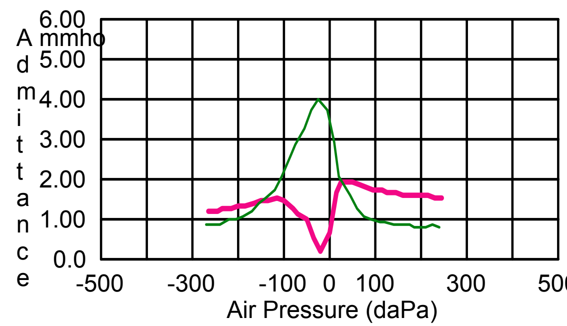
freq = 800 Hz
Probe Ear:Right

1000 Hz Tympanogram



Probe Ear:Right Probe Ear:Left
Pme=-23daPa
244Ya=1.8mmho
Peak Ytm=2.2mmho
T. Width=-150.4daPa
f= 1000Hz

1000 Hz Tympanogram

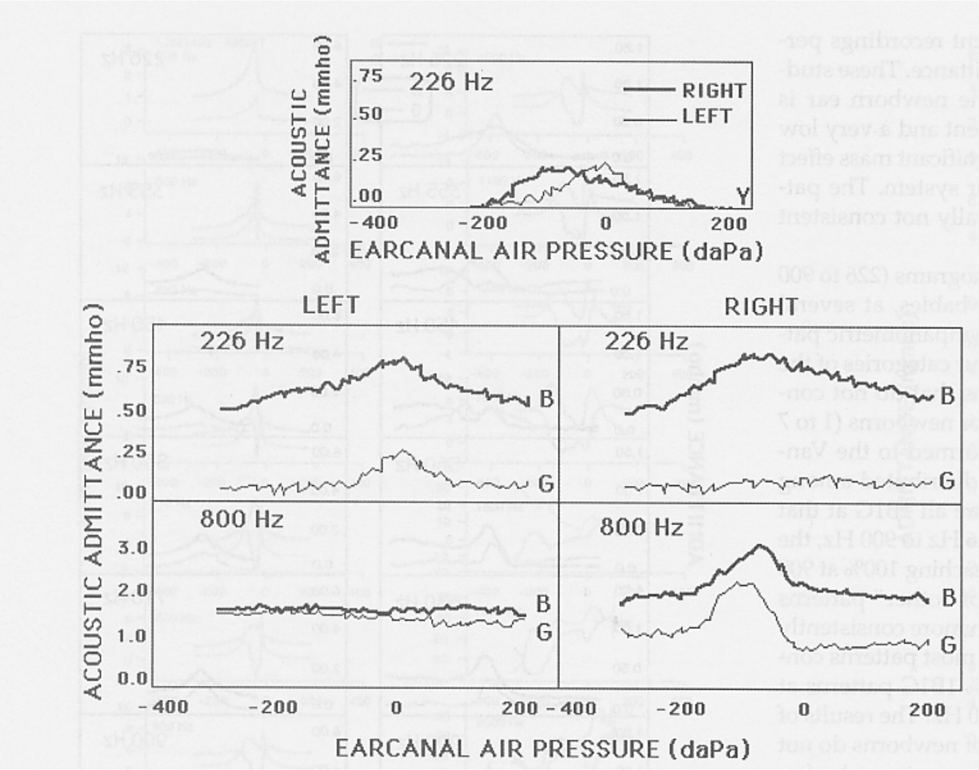


Ga:

Ba:

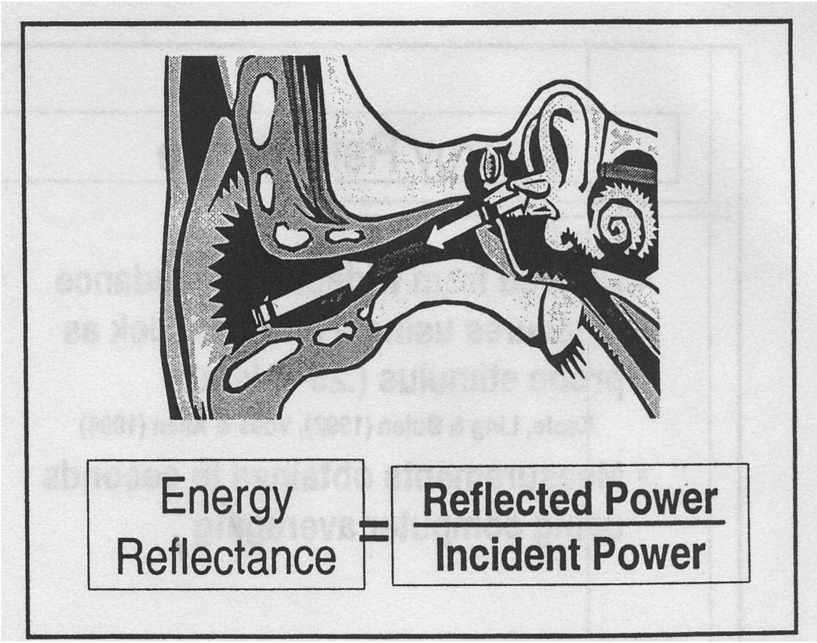
freq = 1000 Hz
Probe Ear:Right

Tympanometry in Infants



Wideband Reflectance

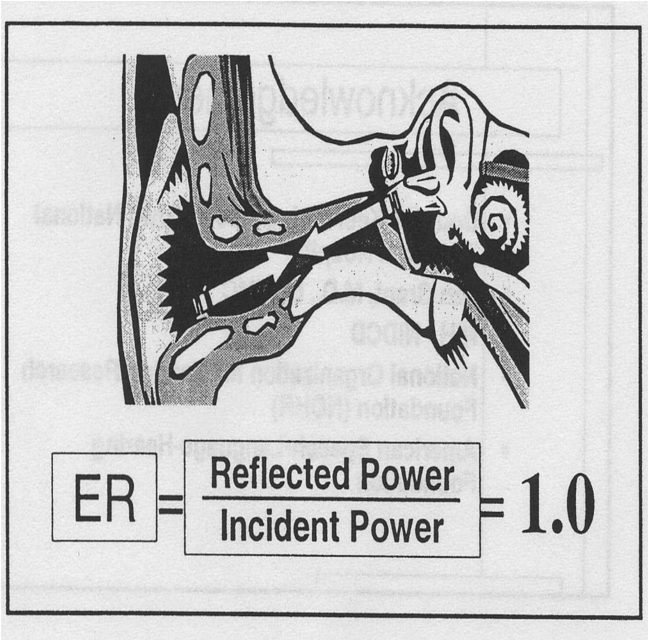
- Definition: is a ratio of energy reflected from a surface to the energy that strikes the surface (incident energy)



All the figures are from P. Feeney, 2001

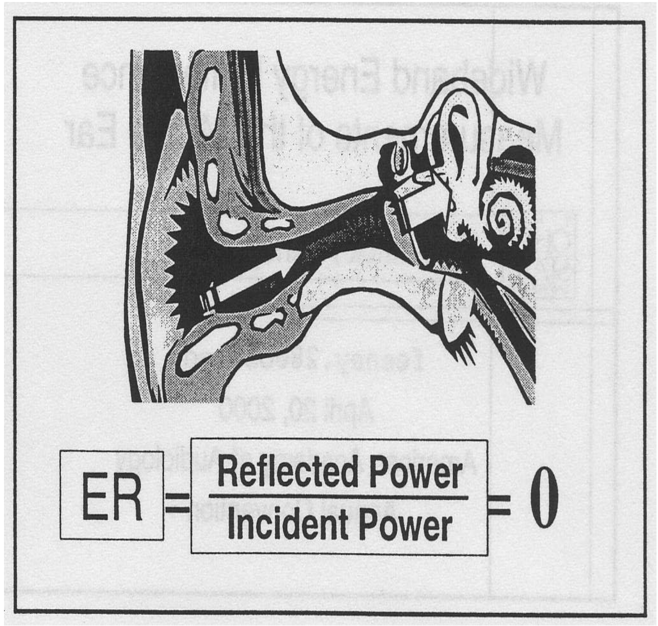
Wideband Reflectance

- If all the energy is reflected from the eardrum the energy reflectance (ER) would be 1.



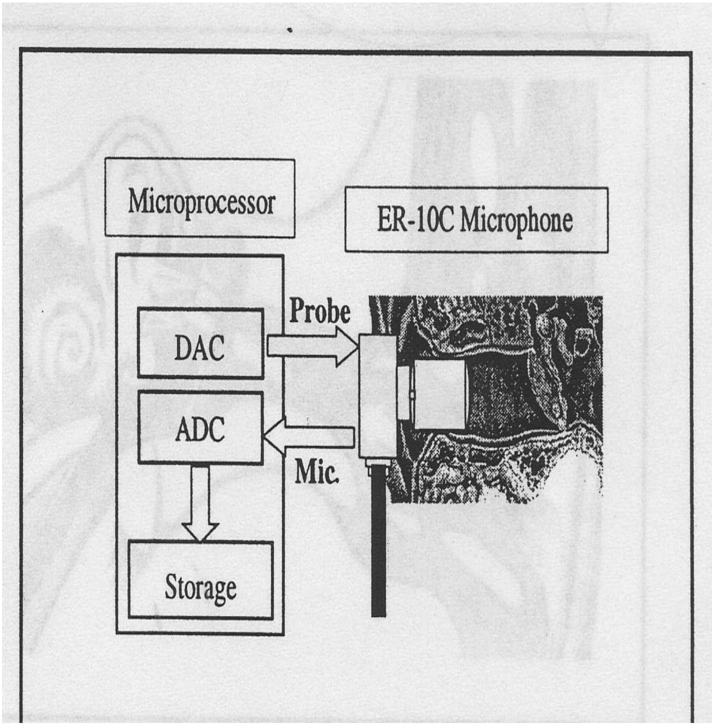
Wideband Reflectance

- If all the energy is absorbed by the middle ear, the ER would be 0.



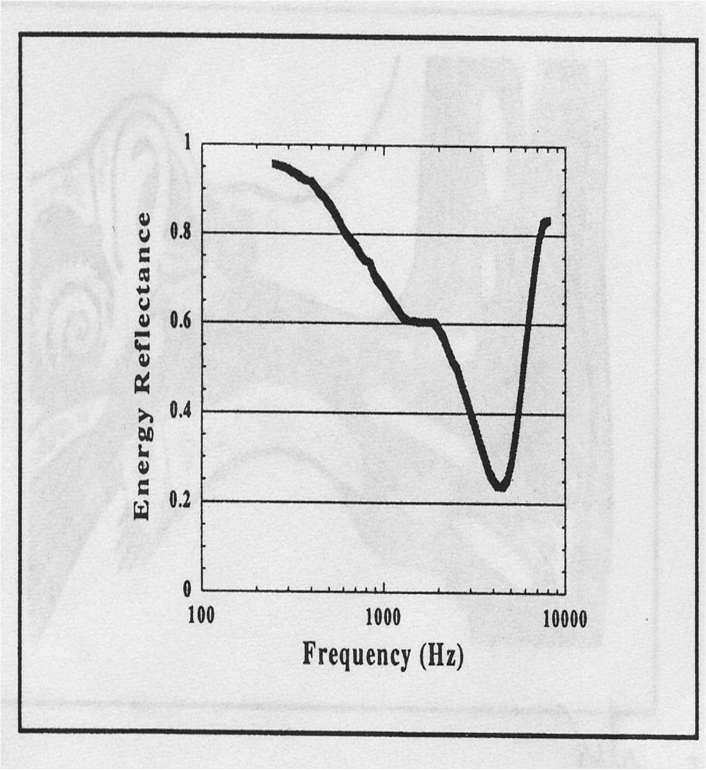
Wideband Reflectance

- ER is derived from wideband impedance measures using a chirp or click as probe stimulus (0.25-8 KHz)
- Measures obtained in seconds using computer averaging

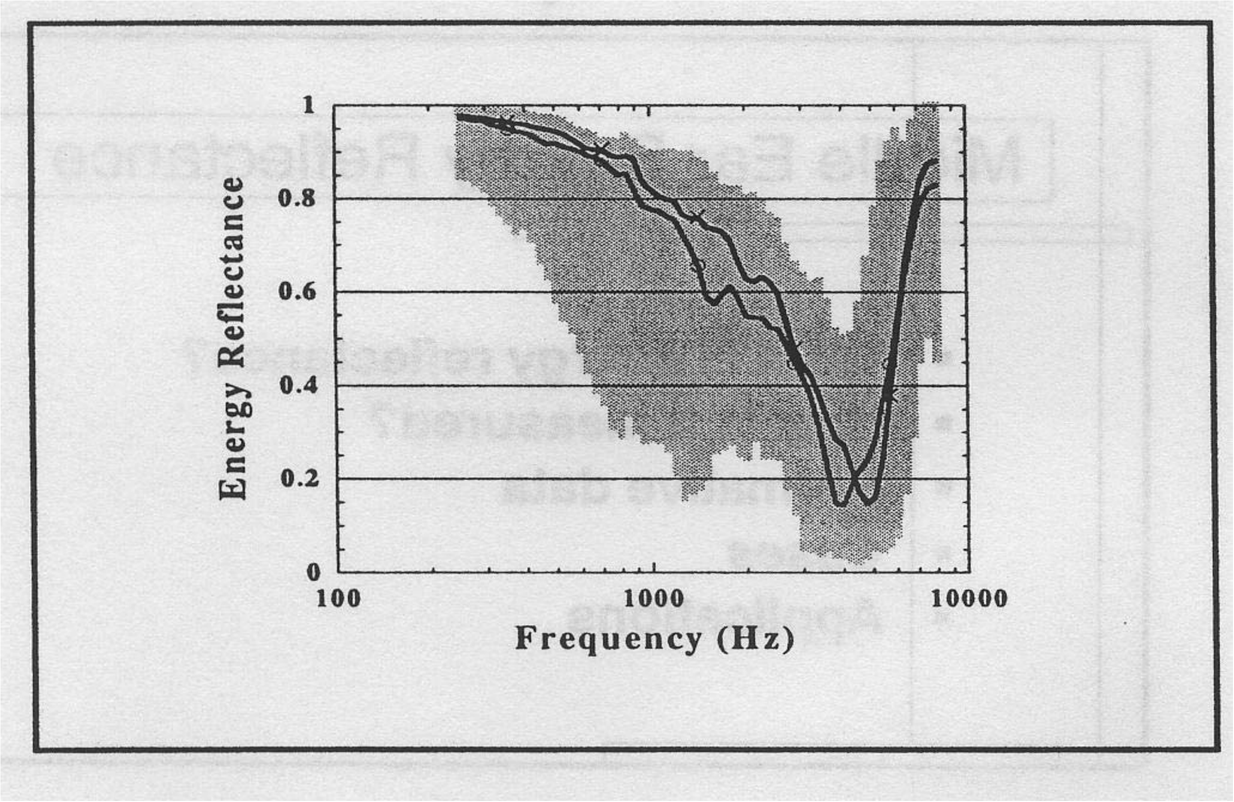


Energy Reflectance Graph

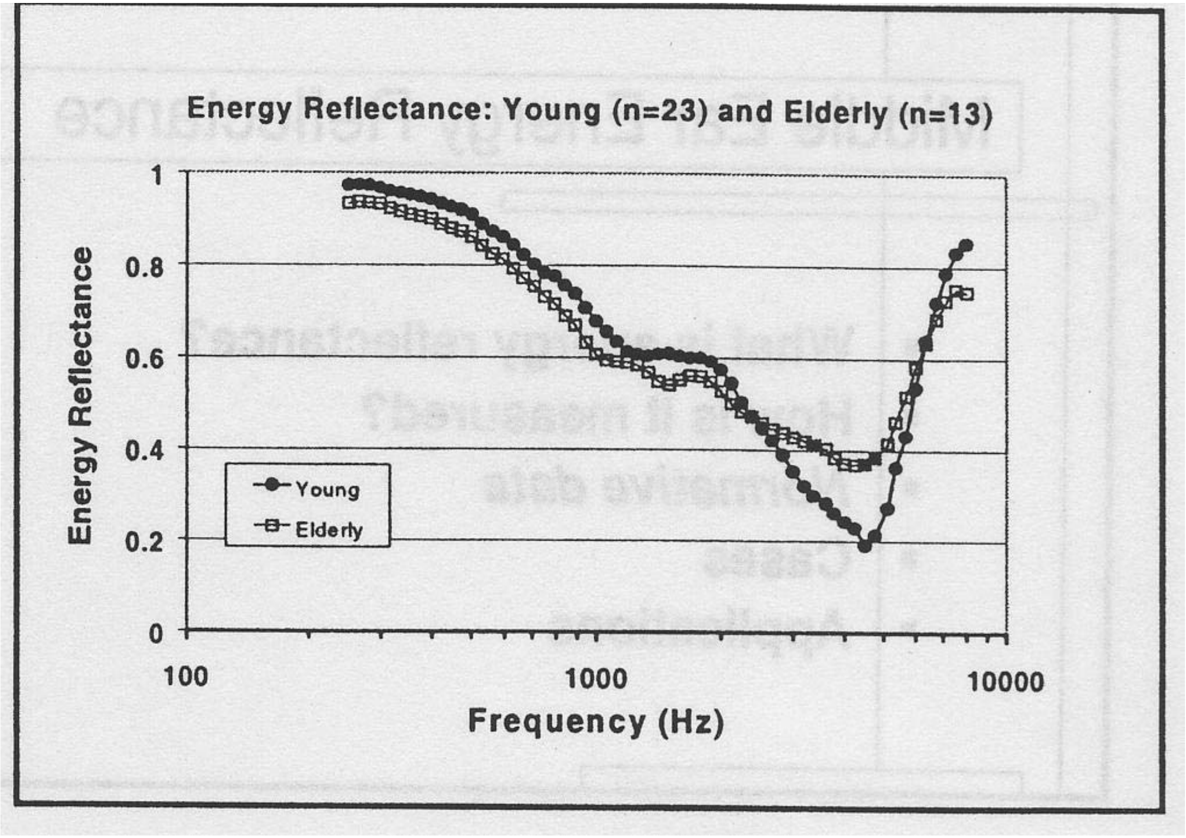
- In normal adults ears, more than 90% of low frequency energy is reflected
- The location of the notch corresponds to the range that energy is most effectively transmitted into the middle ear



Reflectance Norm



Reflectance & Age



Application of The Reflectance

- Reflectance tympanometry (Margolis et al, 1999)
- Prediction of CHL (Piskorski et al., 1999)
- Neonatal hearing screening programs (Keefe et al, 2000)