Mistakes on Real Ear Measures Clinicians Often Make

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There are two national guidelines (ASHA, 1998; AAA 2006) stating the need to use REM to verify the performance of hearing aids in order to achieve best practice

Kirkwood
Hear J (2010)

"How often do you do REM?

	0%	Occasionally	<50%	50%	Most of Time	Almost Always
Audiologist	29.9	19.5	13.2	7.1	11.5	19.2
HIS	27.0	21.1	8.9	8.9	13.0	21.1

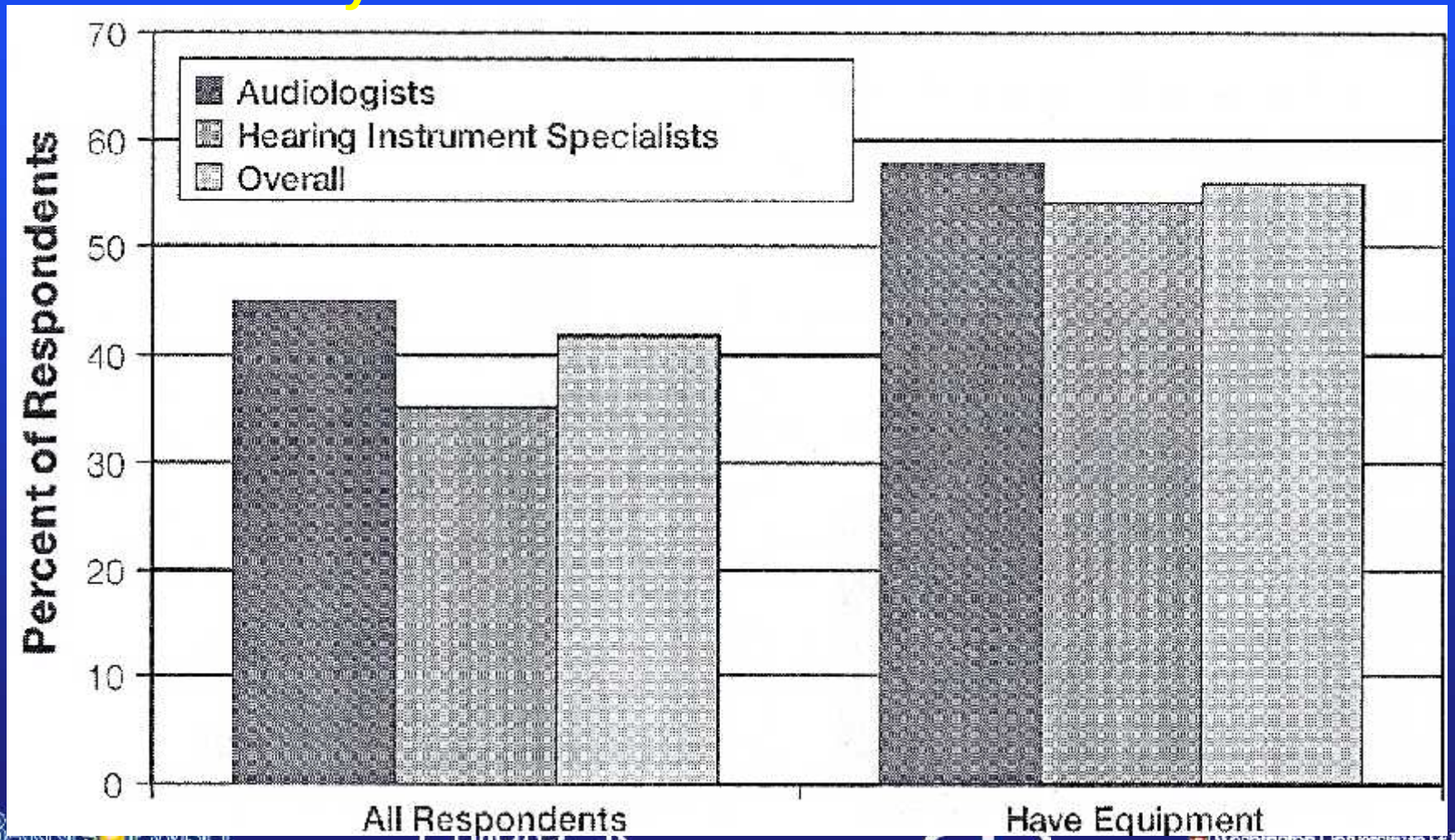
Mueller and Picou Hear J (2010)

"How often do you do REM?

		Seldom or Never	Sometimes	50%	Usually	Almost Always
Audiologist and HIS		34%	18%	6%	12%	30%

Mueller and Picou (2010)
"How often do you use REM to verify and adjust on the day of the fitting"

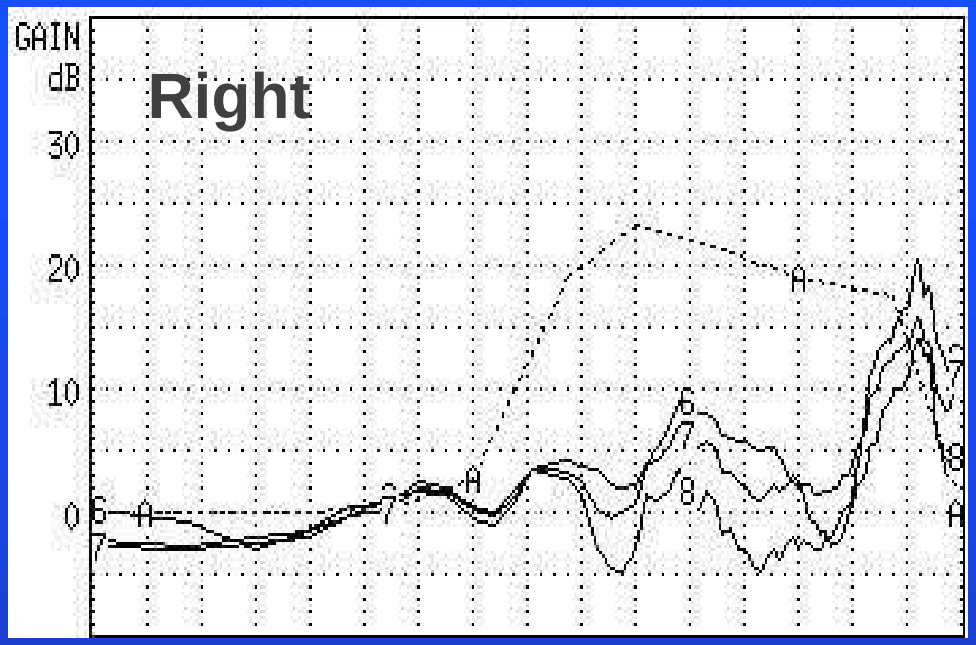
Nearly 50% who have REM don't use it!

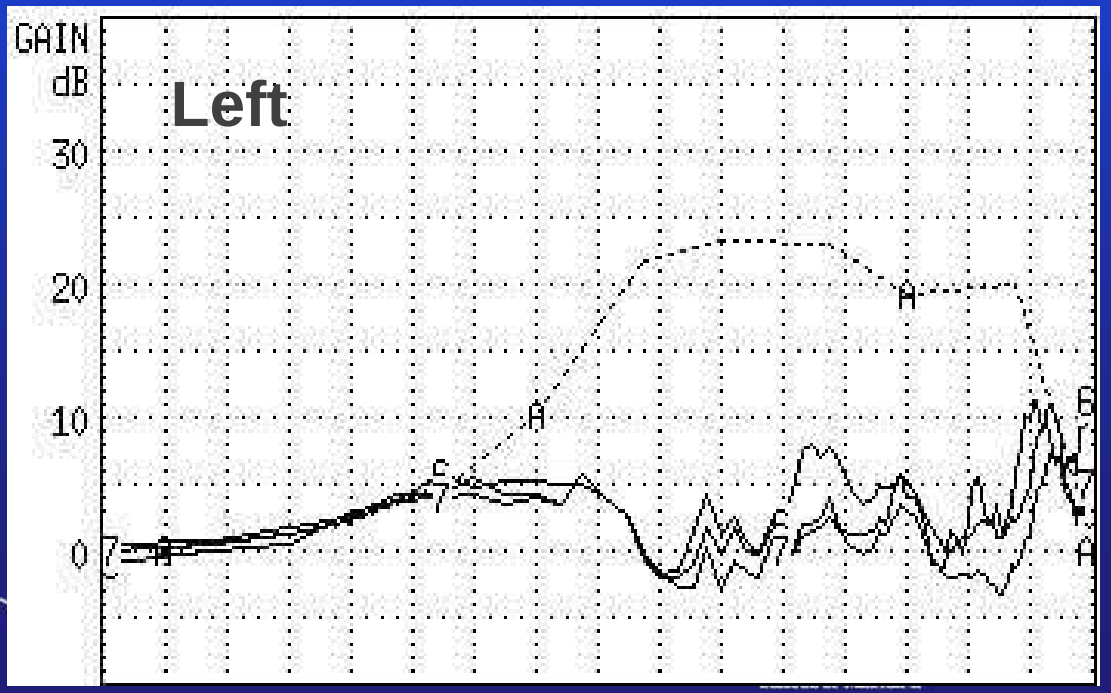


There is overwhelming evidence that manufacturer "first-fit" under amplifies the needs of patients and the reduced amplification occurs most often in the high frequencies which is most often needed to improve speech recognition.

First-Fit Does Not Reach Target

- **Swan and Gatehouse (1995):** in 76% of 319 ears the measured response differed from predicted response @ 250-4000 Hz.
- **Hawkins and Cook (2003):** as much as a 20 dB difference
- **Bentler (2004):** as much as a 15 dB difference
- **Aarts and Caffee (2005):** measured REAR less than predicted REAR in all 41 participants for two audiometric configurations and two input levels.
- **Bretz (2006):** as much as 20 dB difference
- **Aazh and Moore (2007):** only 36% of 42 ears were within 20 dB of NAL-NL1
- **Byrne (1992):** a difference of as little as 3-4 dB were judged to be significantly different





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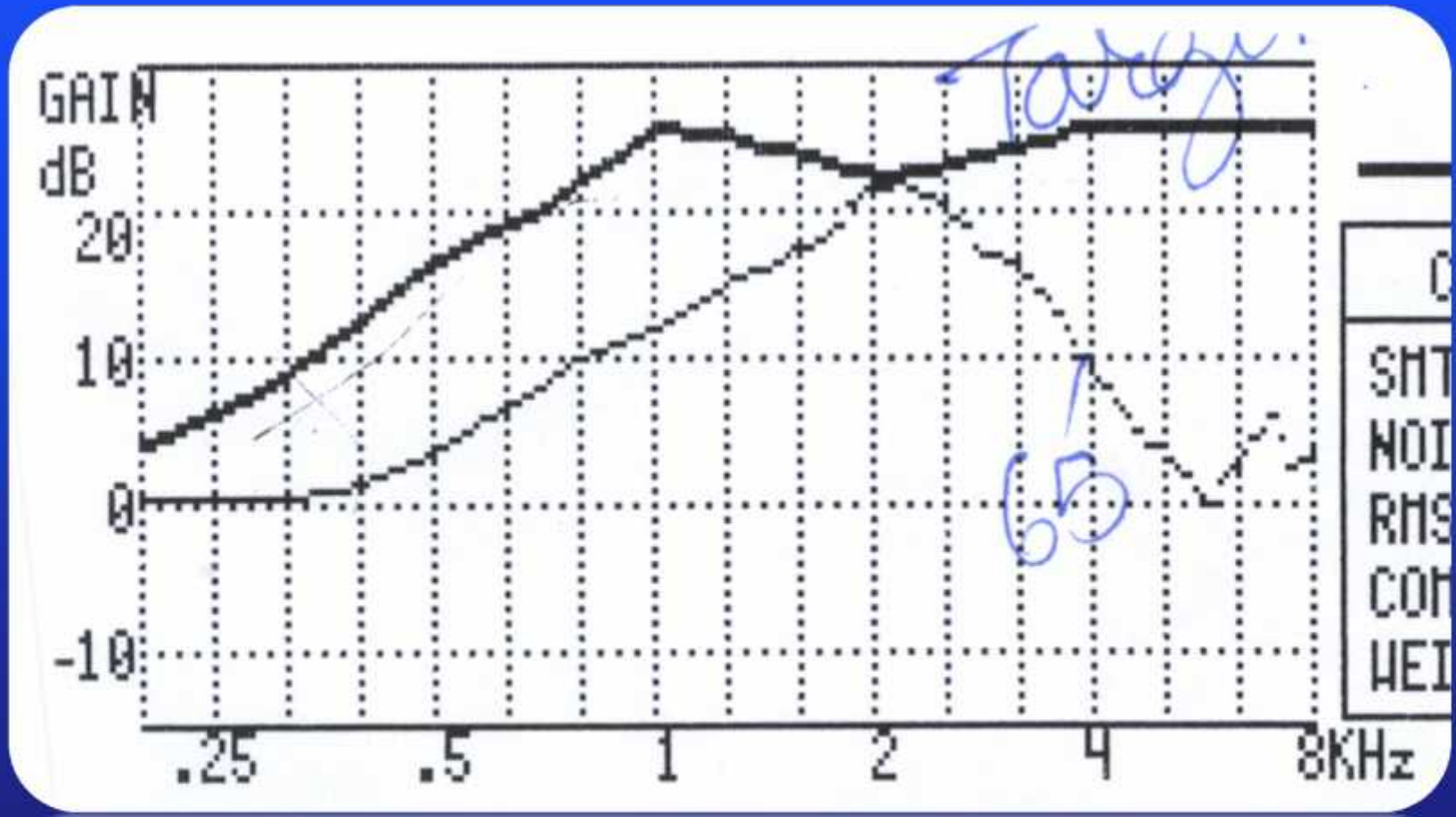
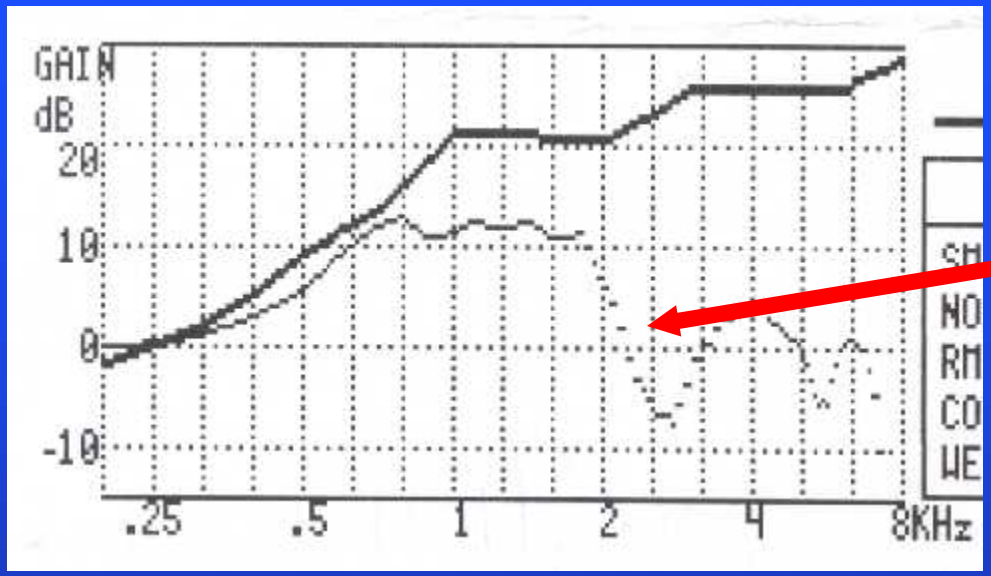
Typical “First-Fit” Real Ear Insertion Gain (REIG) w/o Verification



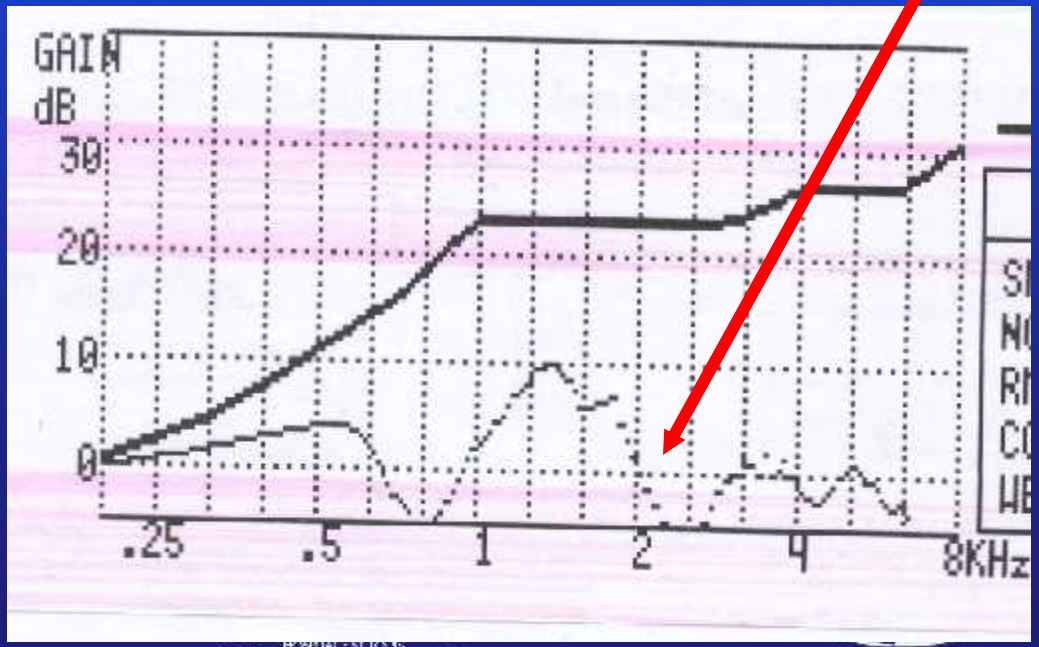
First-Fit

Left

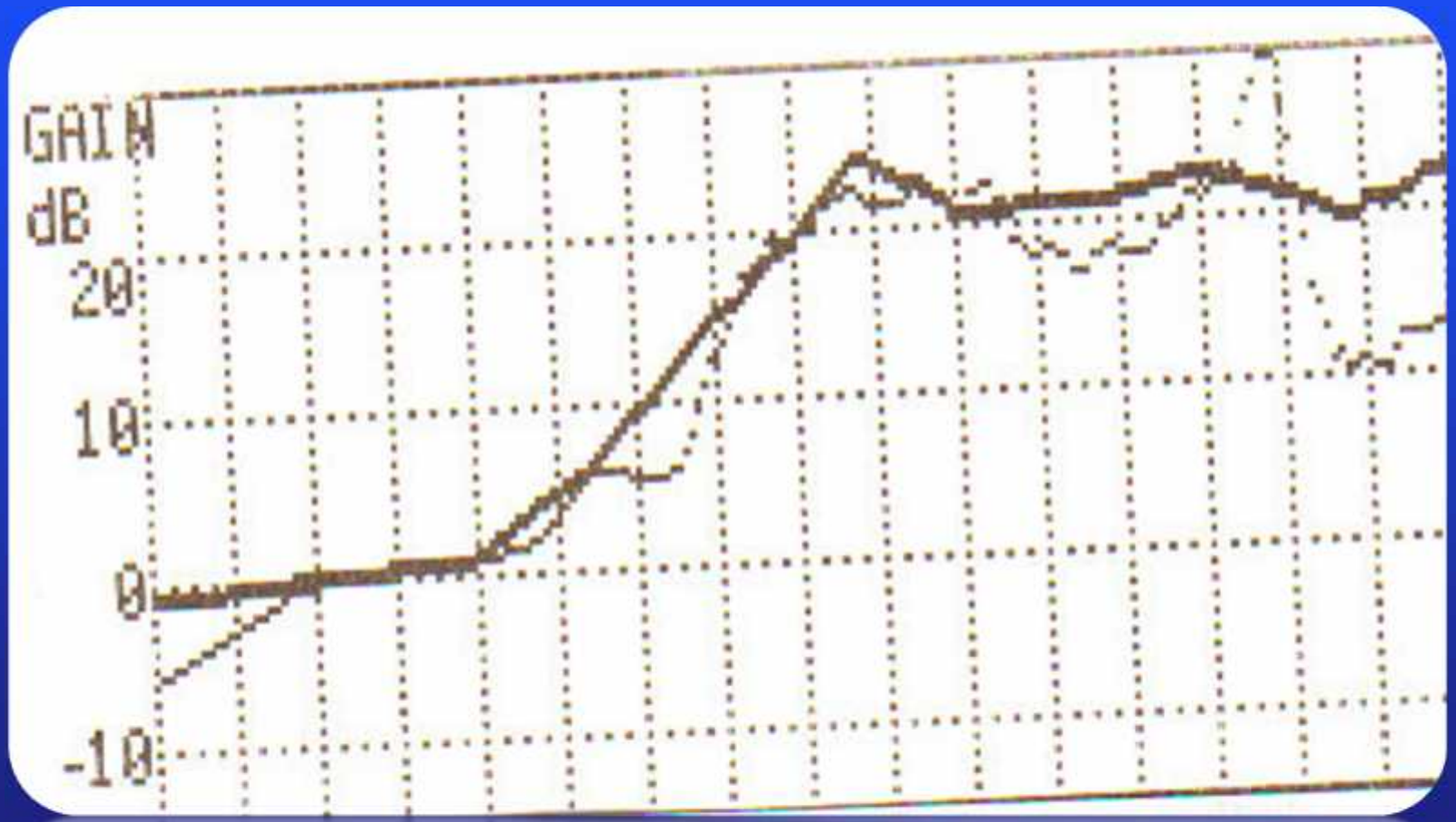
Feedback Management



Right



REIG With Verification



Abrams et al (2012)

- First-Fit
- REM using NAL-NL1
- APHAB
- N = 22 experienced HA users
- Cross-over (randomized block) design
- Blinded to method
- EC, RV and BN benefit scores for REM were significantly higher than First-Fit
- 15 subjects preferred REM and 7 preferred First-Fit

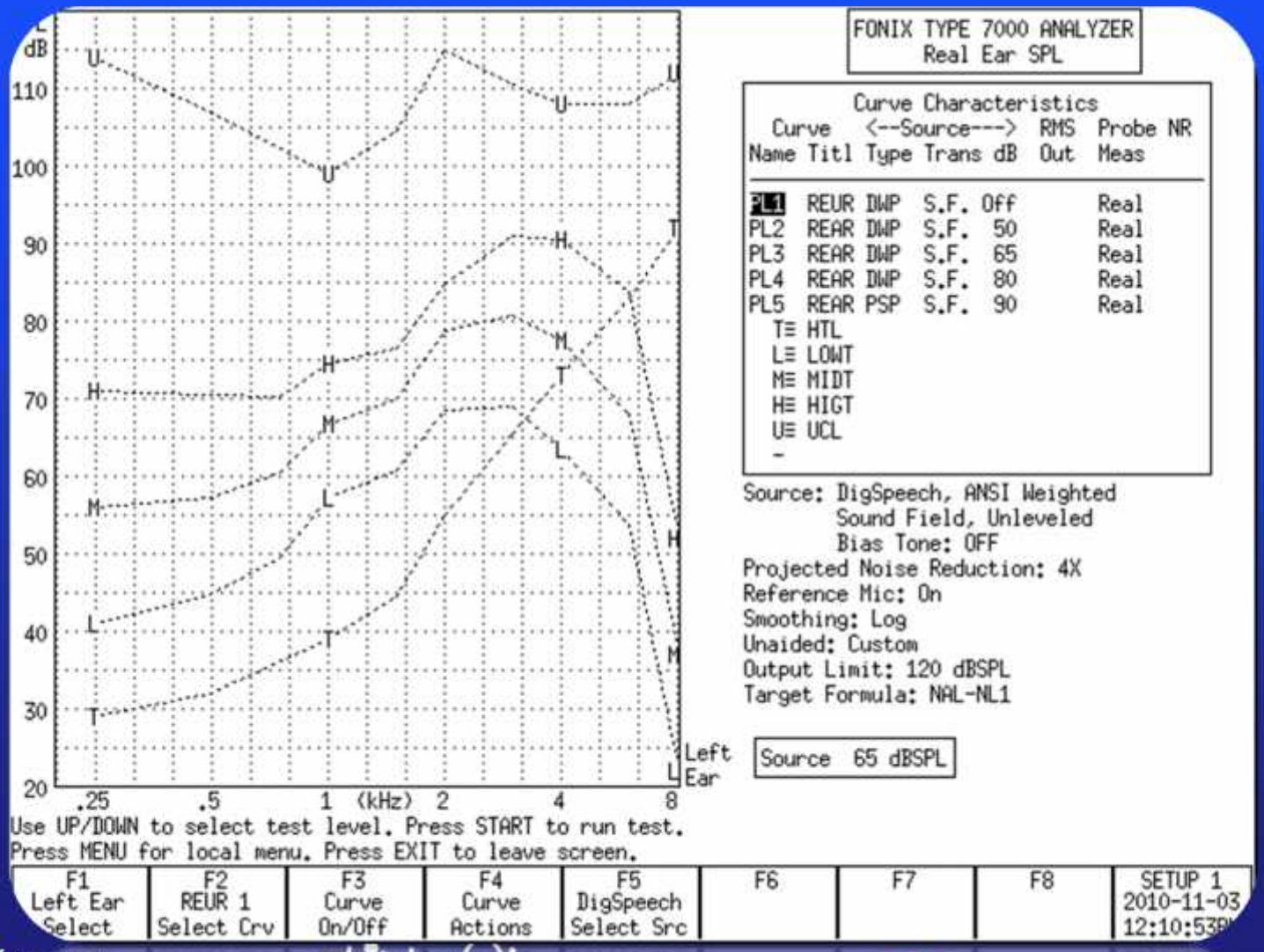
Mueller and Picou (2010)

- **Consumer Reports (2009):** 66% of HA's not fitted correctly and audiologists and HIS do not routinely conduct REM.
- **Palmer (2009):** failure to use REM is unethical based on AAA Code of Ethics to "maintain high standards of professional competence."
- **Kochkin (2010):** HA satisfaction related to testing conducted @ the fitting and more testing leads to greater satisfaction and REM is one of the tests that impact results

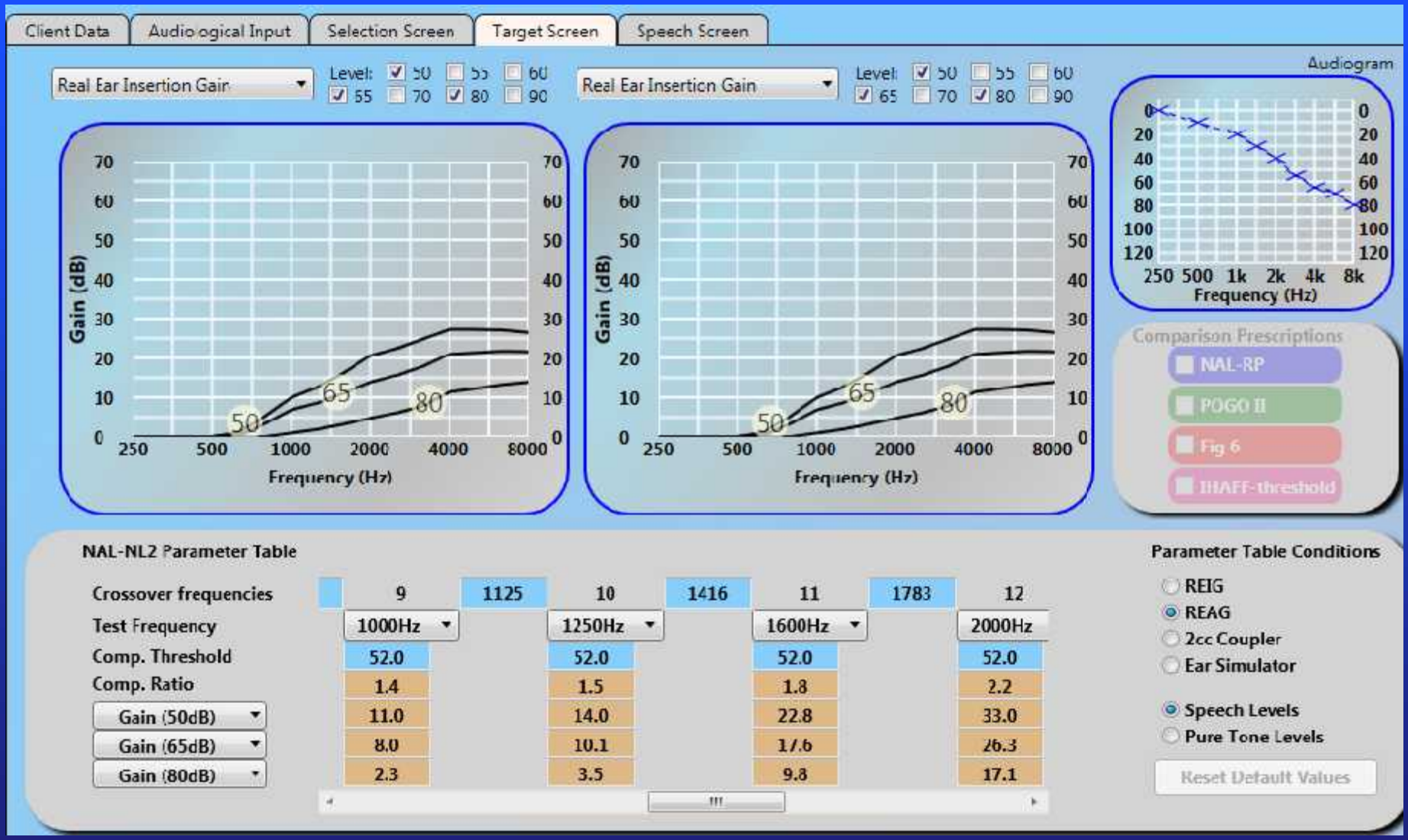
Mueller and Picou (2010)

- For those who do use REM:
  - REAR: used by 78%
  - Verify REAR 50-65-80 is within the residual dynamic range. Threshold is converted to dB SPL from the audiogram (dB HL) using <u>average</u> transformations (Real Ear to Dial Difference (REDD).
  - Loudness Discomfort Level$_{\text{dB SPL}}$ (upper segment of the residual dynamic range) based on Pascoe (1988) + average REDD
- REIG: used by 22%
- REUG: 9% use “average” and 91% use “individual”

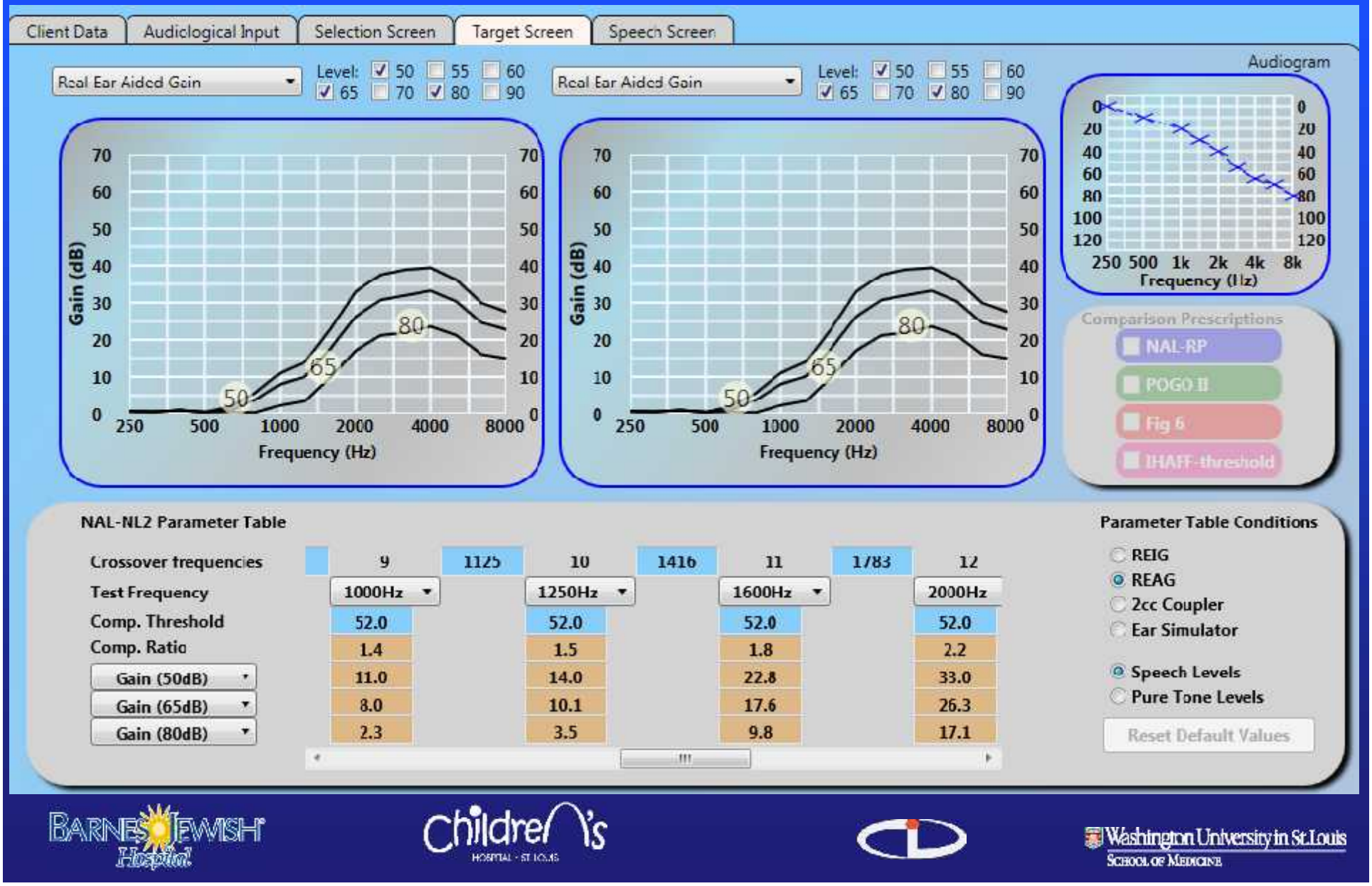
Frye equipment creates multiple REAR targets on one screen, but not for REIG and there are no targets for REAG



NAL-NL2 REIG



NAL-NL2 REAG



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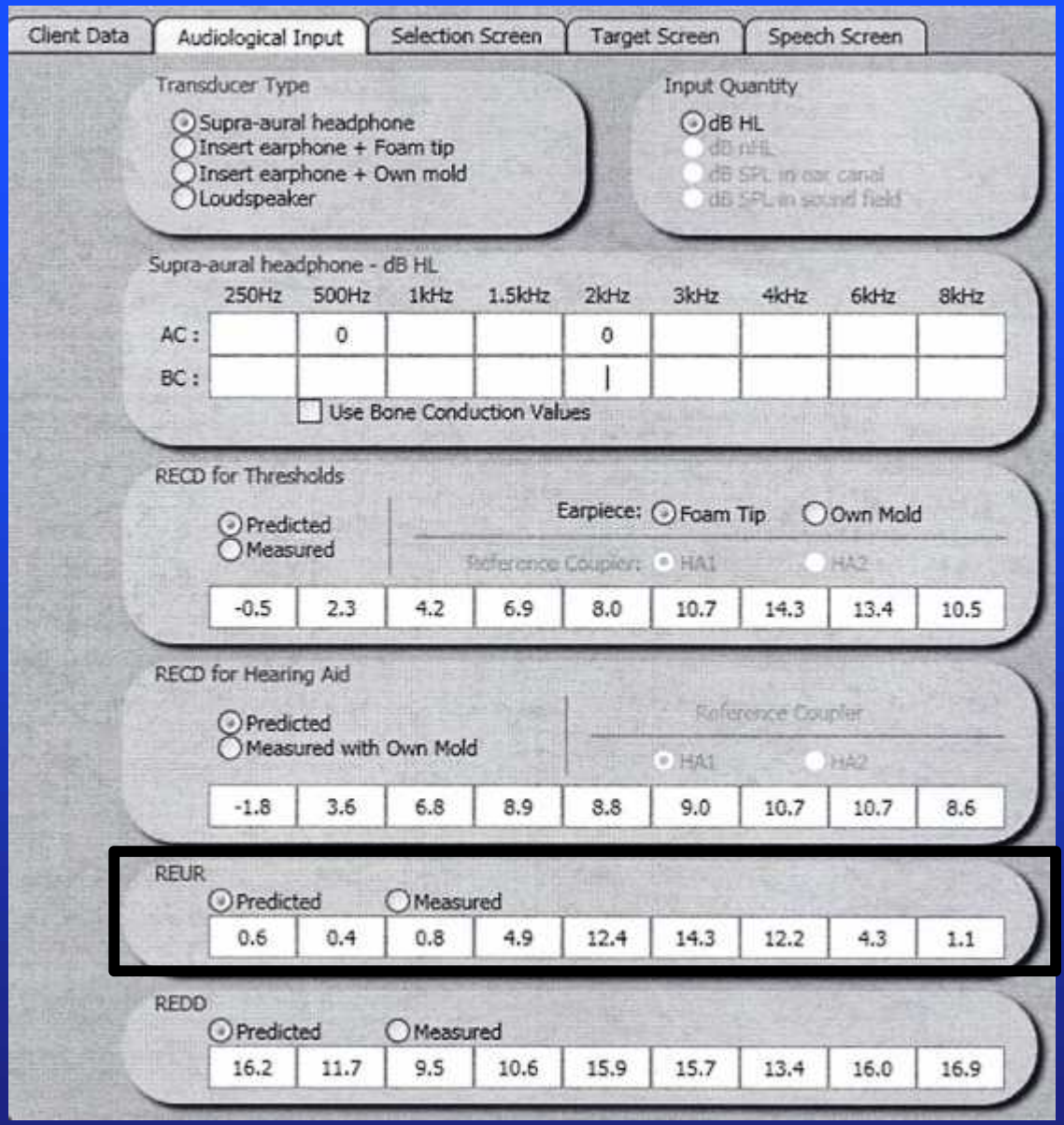
Impact of REUG

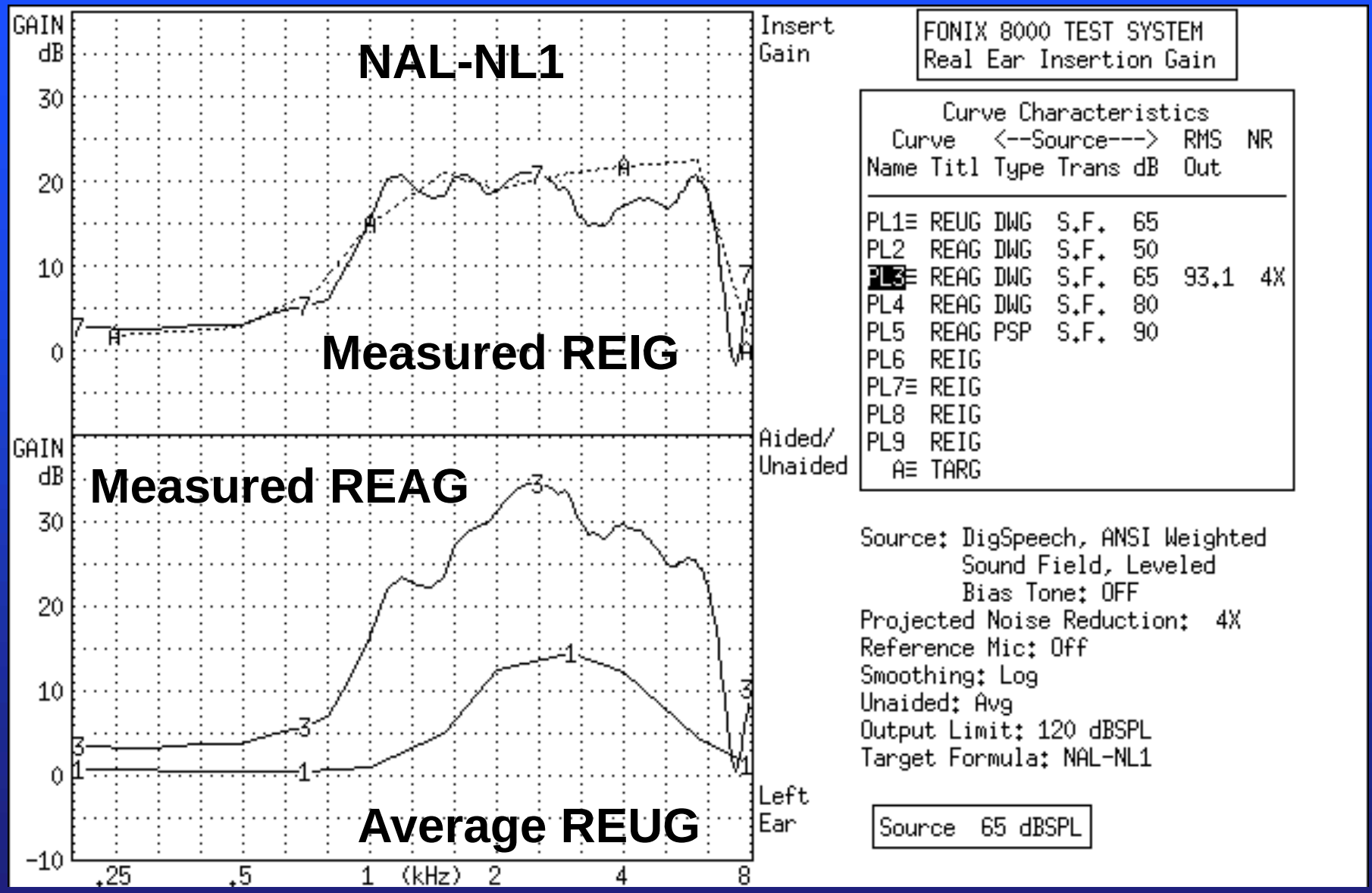
NAL-NL2



REUG
DSL i/o and NAL-NL-1

Frequency	DLS i/o	NAL-NL1 /Frye	Verifit
250	2.2	0.5	1.0
500	5.0	0.4	2.0
1000	6.4	0.8	3.0
1500	8.8	4.9	5.0
2000	15	12.4	12.0
3000	19.8	14.3	13.0
4000	18.3	12.2	14.0
6000	14.4	4.3	7.0
8000	-	1.1	-

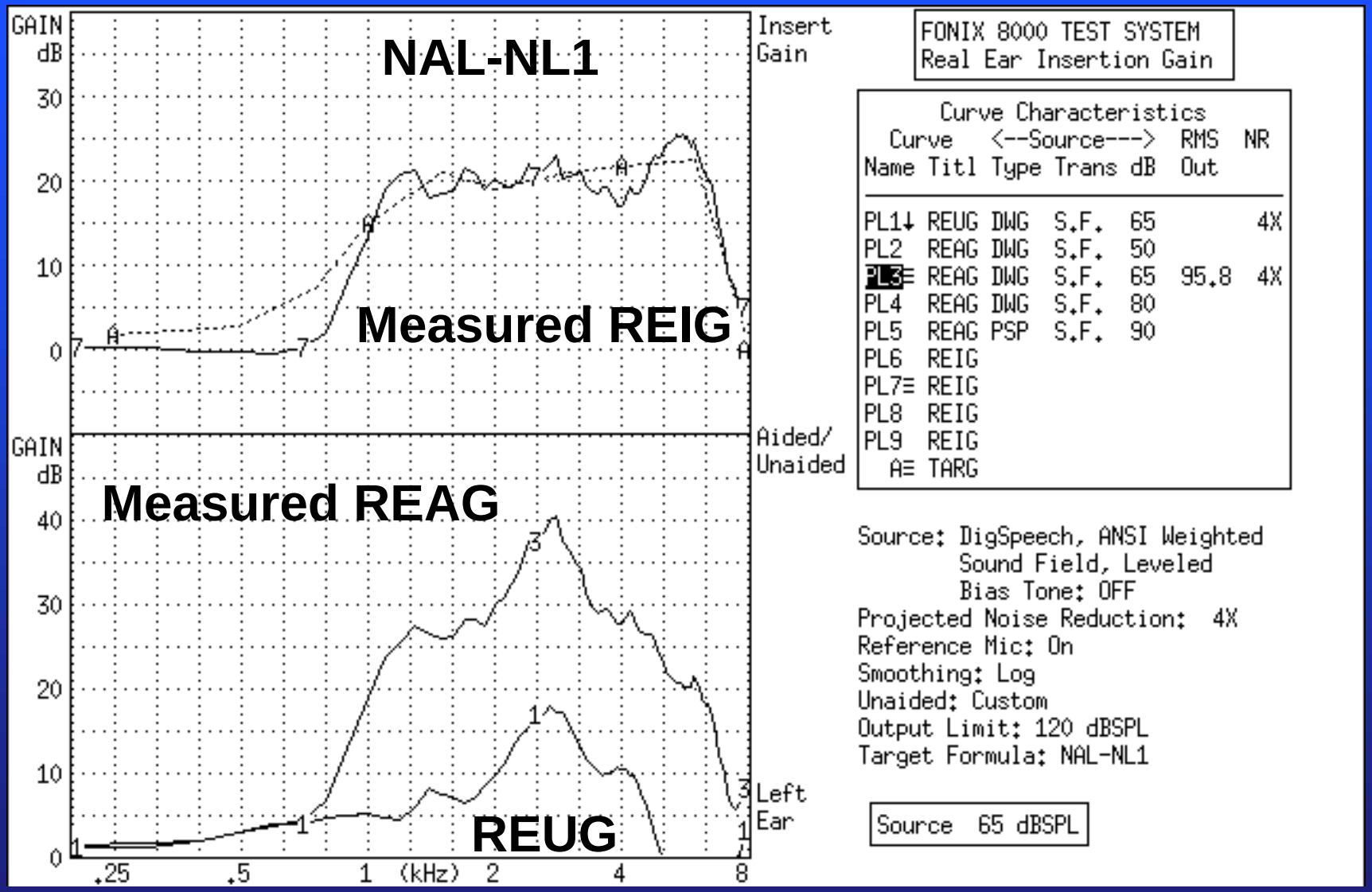
REIG Using Average REUG



Probe Left REAG3

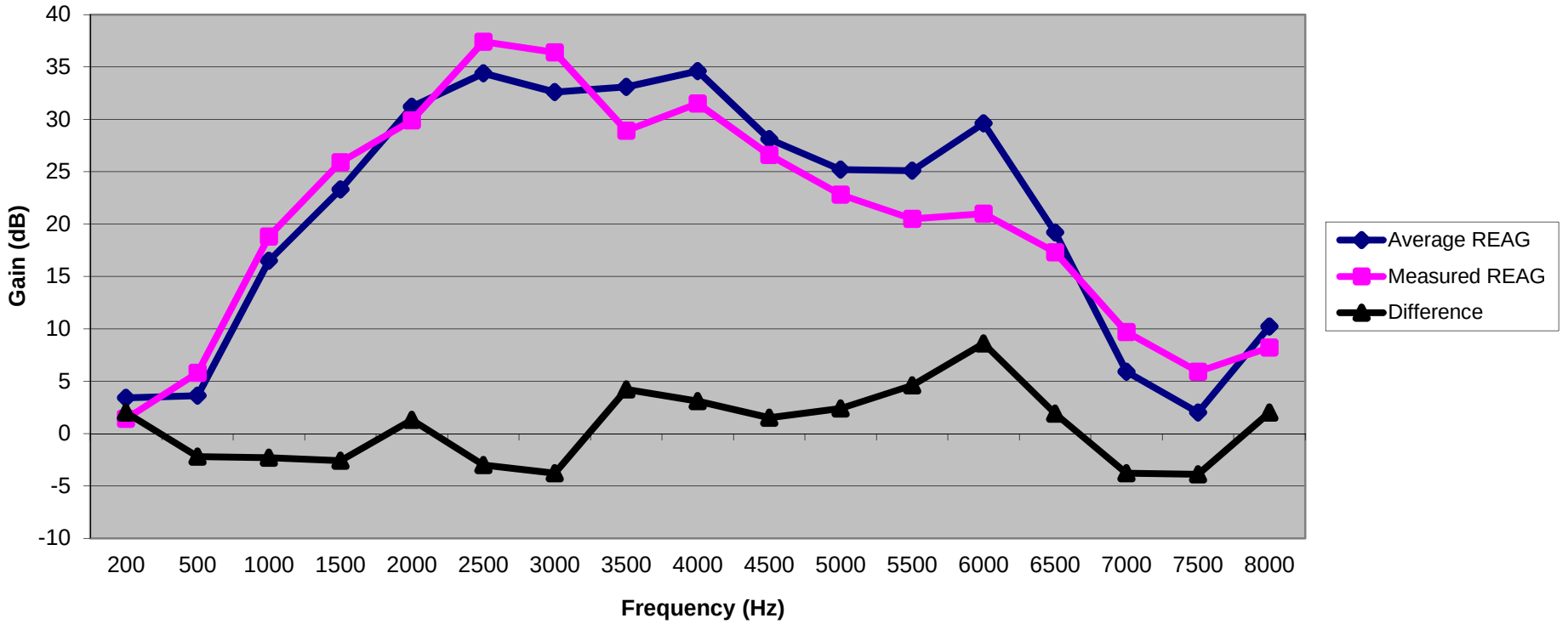
Freq Hz	Gain dB	Freq Hz	Gain dB	Freq Hz	Gain dB	Freq Hz	Gain dB
		2100	32.4	4100	29.2	6100	24.3
200	3.4	2200	33.5	4200	29.1	6200	23.4
300	3.2	2300	34.1	4300	29.0	6300	22.2
400	3.5	2400	34.3	4400	28.9	6400	20.7
500	3.6	2500	34.4	4500	28.1	6500	19.2
600	5.0	2600	34.1	4600	27.9	6600	17.3
700	5.7	2700	33.8	4700	27.2	6700	14.8
800	6.8	2800	33.0	4800	26.7	6800	11.9
900	11.2	2900	33.6	4900	25.9	6900	9.1
1000	16.5	3000	32.6	5000	25.2	7000	5.9
1100	21.9	3100	30.4	5100	24.8	7100	3.9
1200	23.3	3200	29.4	5200	24.7	7200	1.9
1300	22.4	3300	28.5	5300	24.7	7300	0.5
1400	22.2	3400	28.7	5400	25.1	7400	1.4
1500	23.3	3500	28.1	5500	25.1	7500	2.0
1600	27.1	3600	28.0	5600	25.3	7600	3.5
1700	28.7	3700	28.3	5700	25.6	7700	5.9
1800	29.4	3800	29.3	5800	25.5	7800	6.7
1900	29.6	3900	29.3	5900	25.3	7900	7.9
2000	31.2	4000	29.6	6000	24.6	8000	10.2

REIG Using Individual REUG

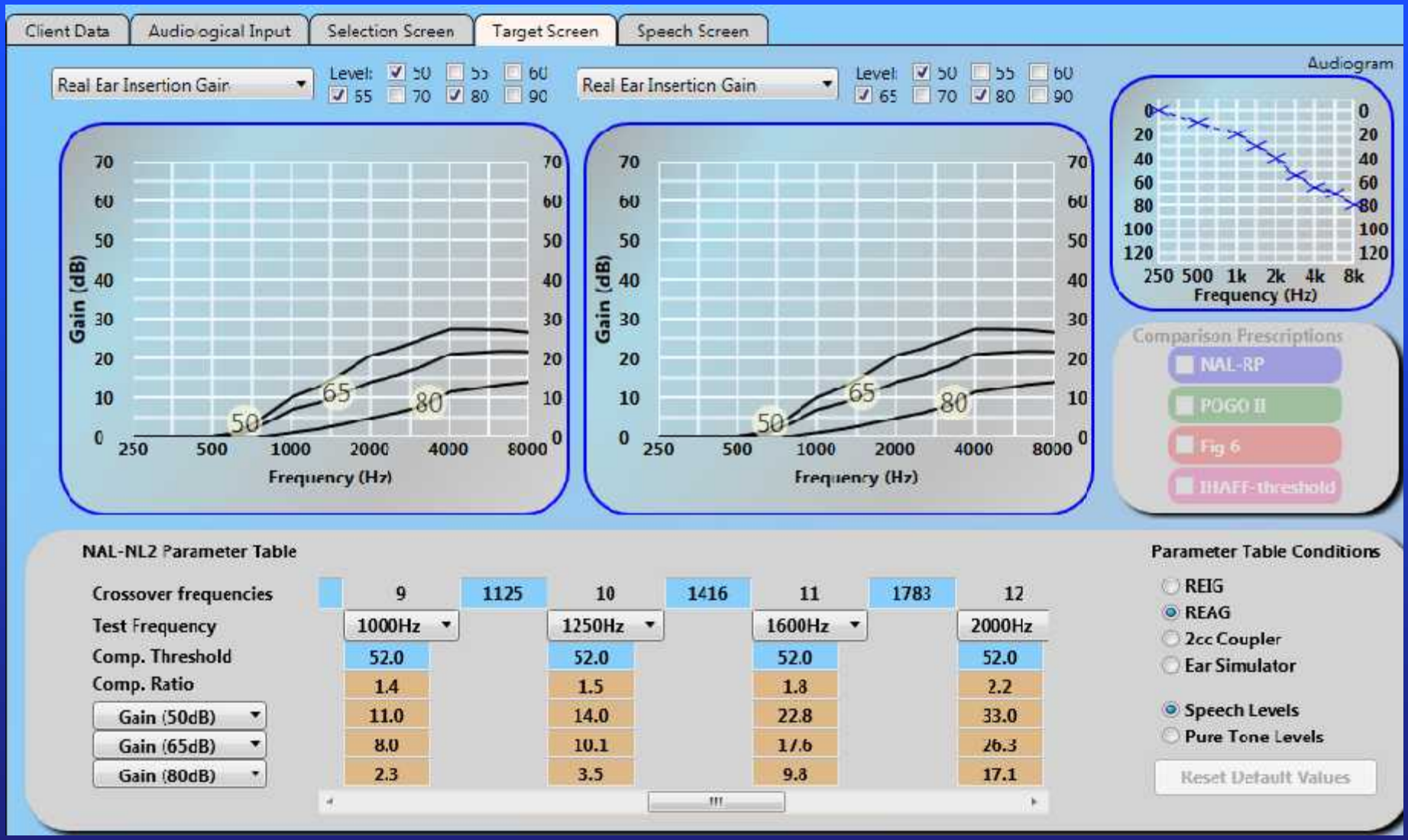


Probe Left REAG3

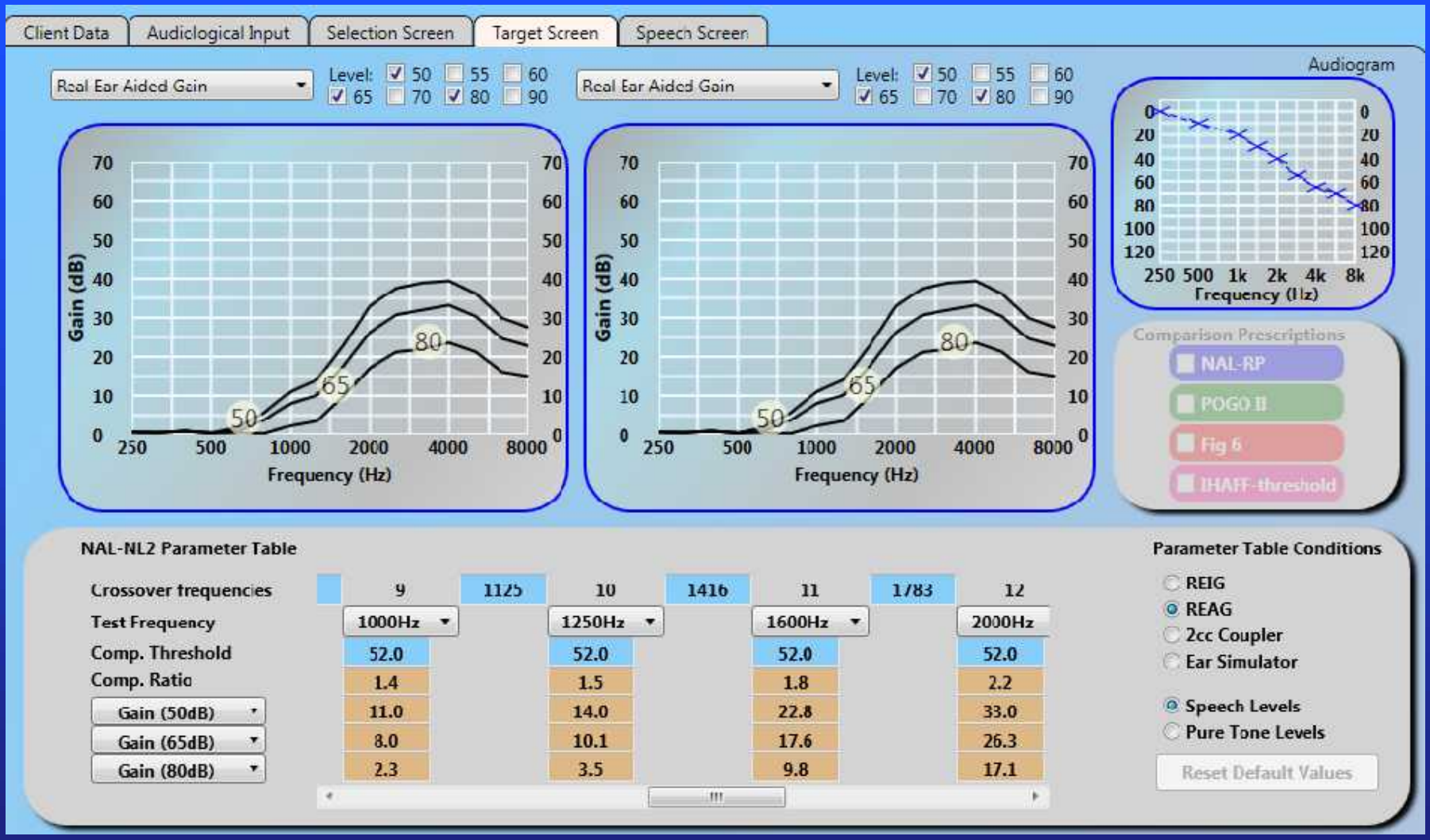
Freq Hz	Gain dB	Freq Hz	Gain dB	Freq Hz	Gain dB	Freq Hz	Gain dB
		2100	30.6	4100	28.4	6100	20.2
200	1.4	2200	32.4	4200	29.0	6200	18.7
300	1.5	2300	34.4	4300	28.2	6300	18.1
400	1.8	2400	37.5	4400	27.0	6400	18.0
500	2.8	2500	37.4	4500	26.6	6500	17.3
600	3.7	2600	38.3	4600	26.5	6600	15.5
700	4.4	2700	40.0	4700	26.5	6700	13.7
800	6.7	2800	40.3	4800	25.4	6800	12.2
900	13.0	2900	37.5	4900	23.9	6900	10.7
1000	18.8	3000	36.4	5000	22.8	7000	9.7
1100	23.7	3100	34.9	5100	21.9	7100	7.7
1200	25.3	3200	34.1	5200	21.3	7200	6.7
1300	27.4	3300	31.5	5300	21.0	7300	6.0
1400	26.3	3400	29.7	5400	20.7	7400	5.7
1500	25.9	3500	28.9	5500	20.5	7500	5.9
1600	26.0	3600	29.0	5600	20.2	7600	6.6
1700	28.1	3700	29.3	5700	20.2	7700	7.0
1800	28.1	3800	28.3	5800	20.2	7800	7.7
1900	27.4	3900	27.7	5900	21.3	7900	7.9
2000	29.9	4000	27.5	6000	21.0	8000	8.2


40
35
30
25
20
15
10
5
0
-5
-10
Gain (dB)
200
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
7500
8000
Frequency (Hz)
Average REAG
Measured REAG
Difference

NAL-NL2 REIG

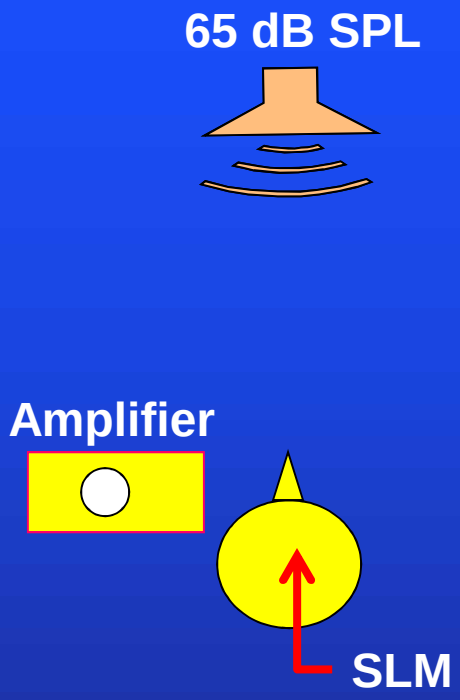


NAL-NL2 REAG



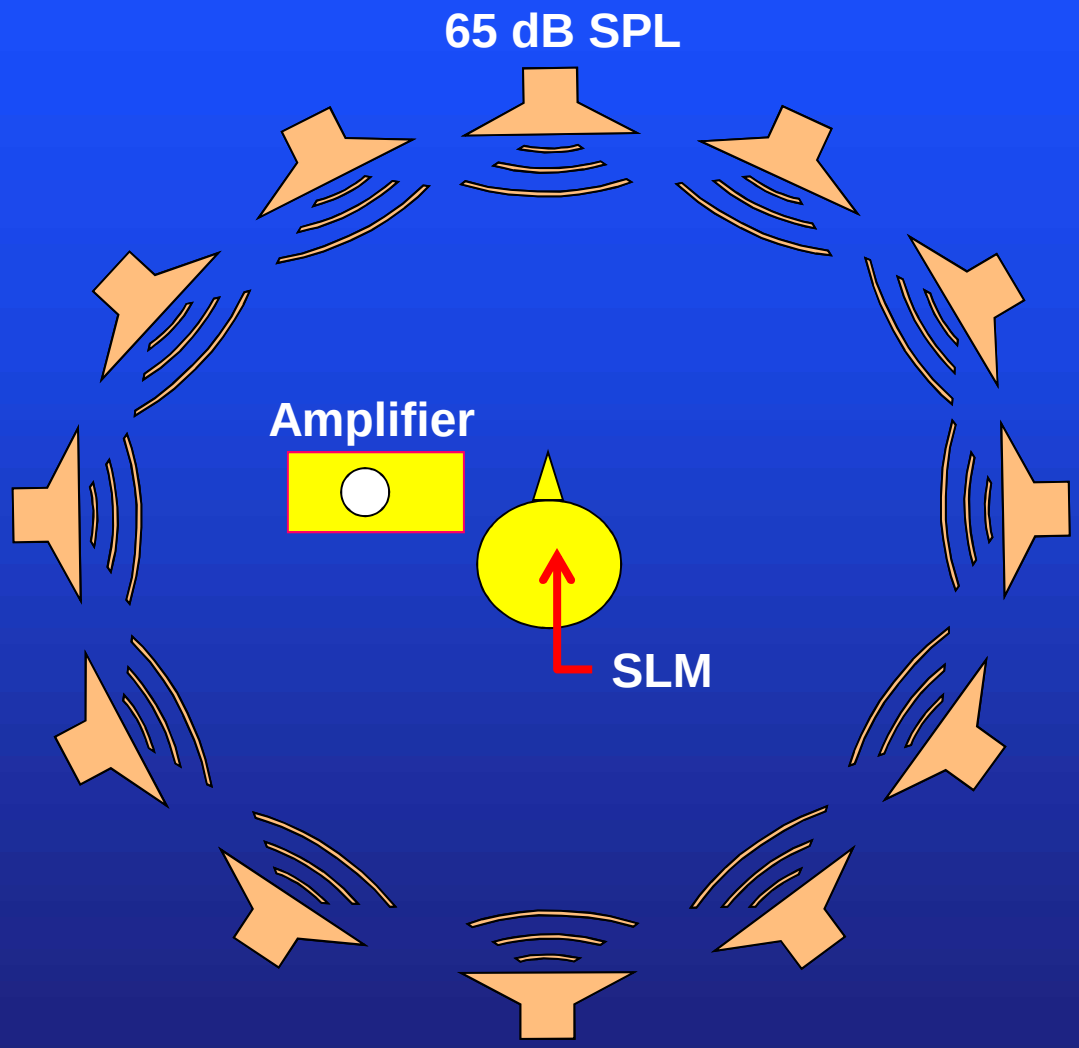
Impact of Bilateral and Power (Channel) Summation

An Analogy to Help Explain Channel/Power Summation



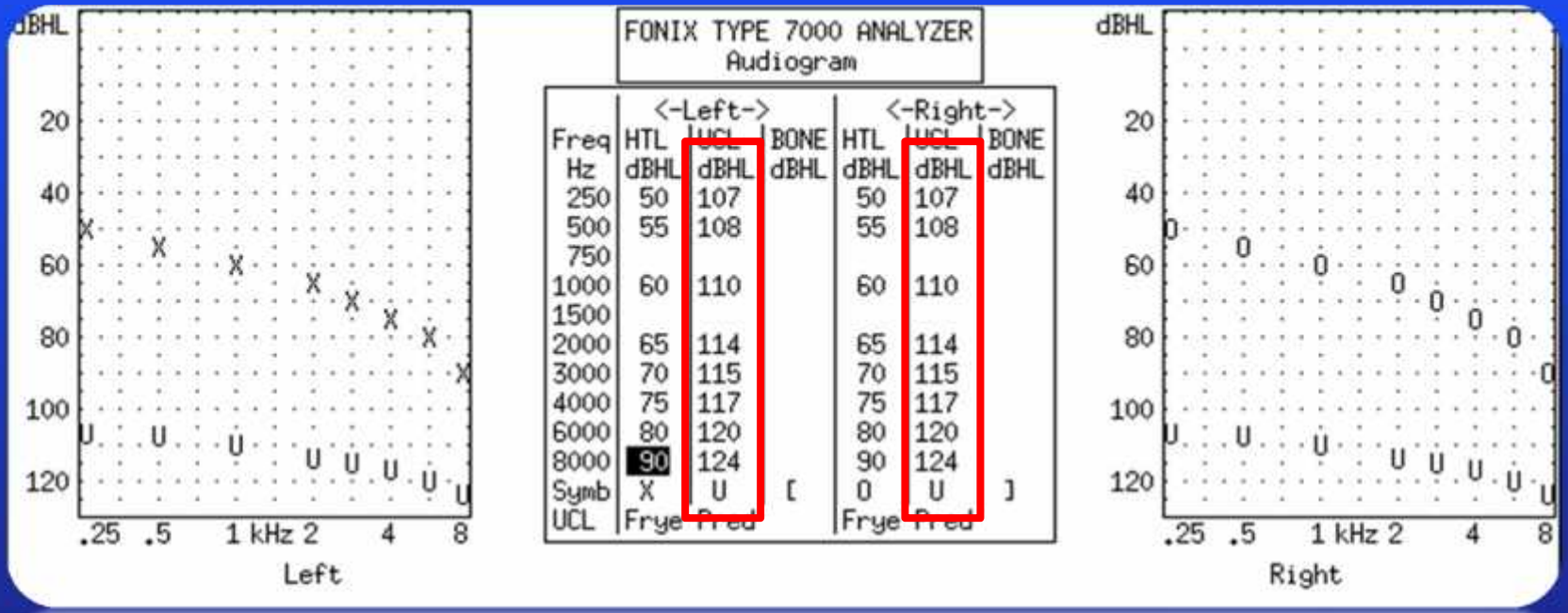
Now, add 11 loudspeakers and keep the selected input level to each loudspeaker the same

An Analogy to Help Explain Channel/Power Summation



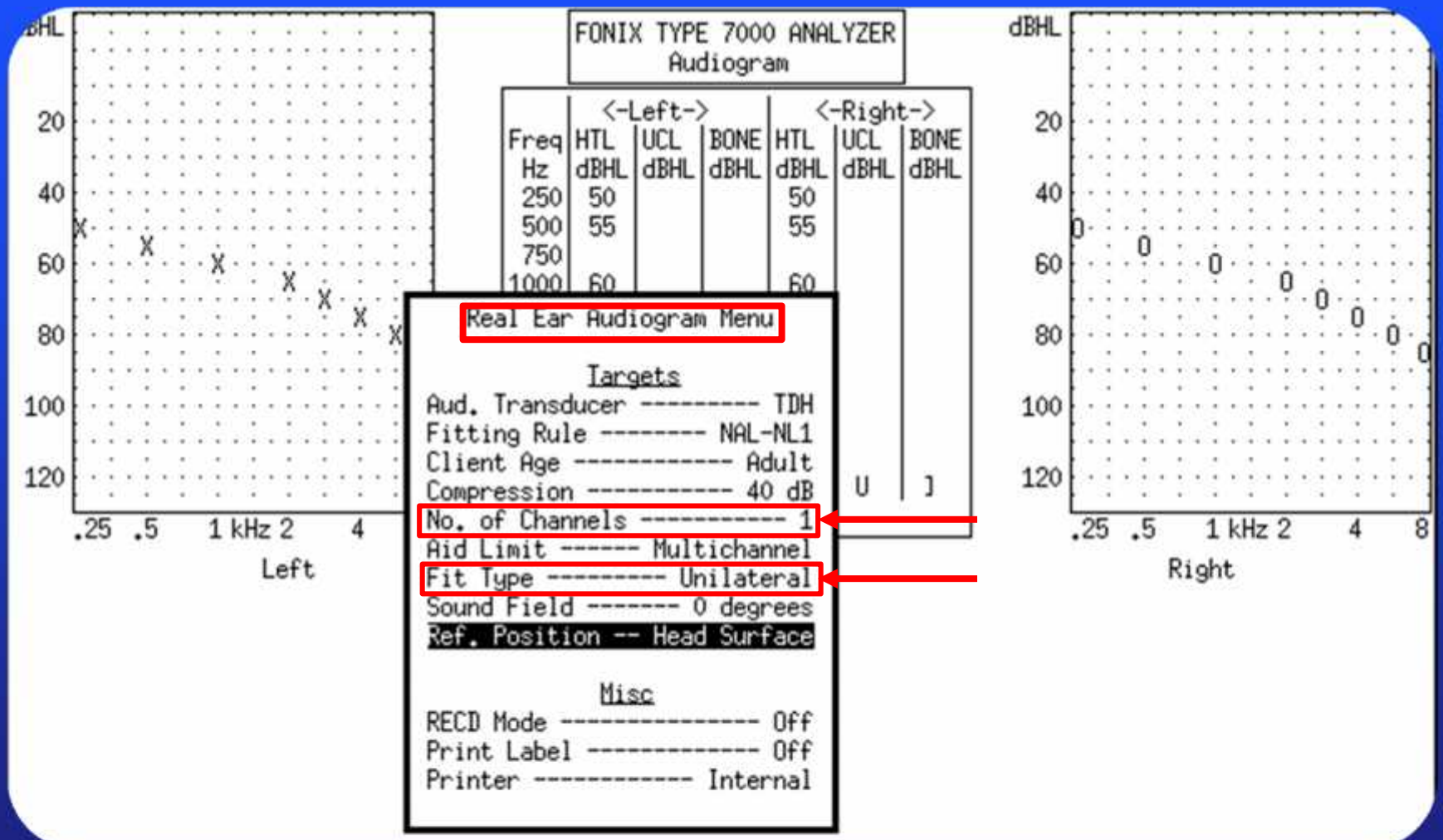
Example of Correcting for Bilateral and Channel Summation in a Hearing Aid Fit Using the Frye 7000 or 8000

Entered audiogram for fitting bilateral hearing aids with 20 channels of signal processing.

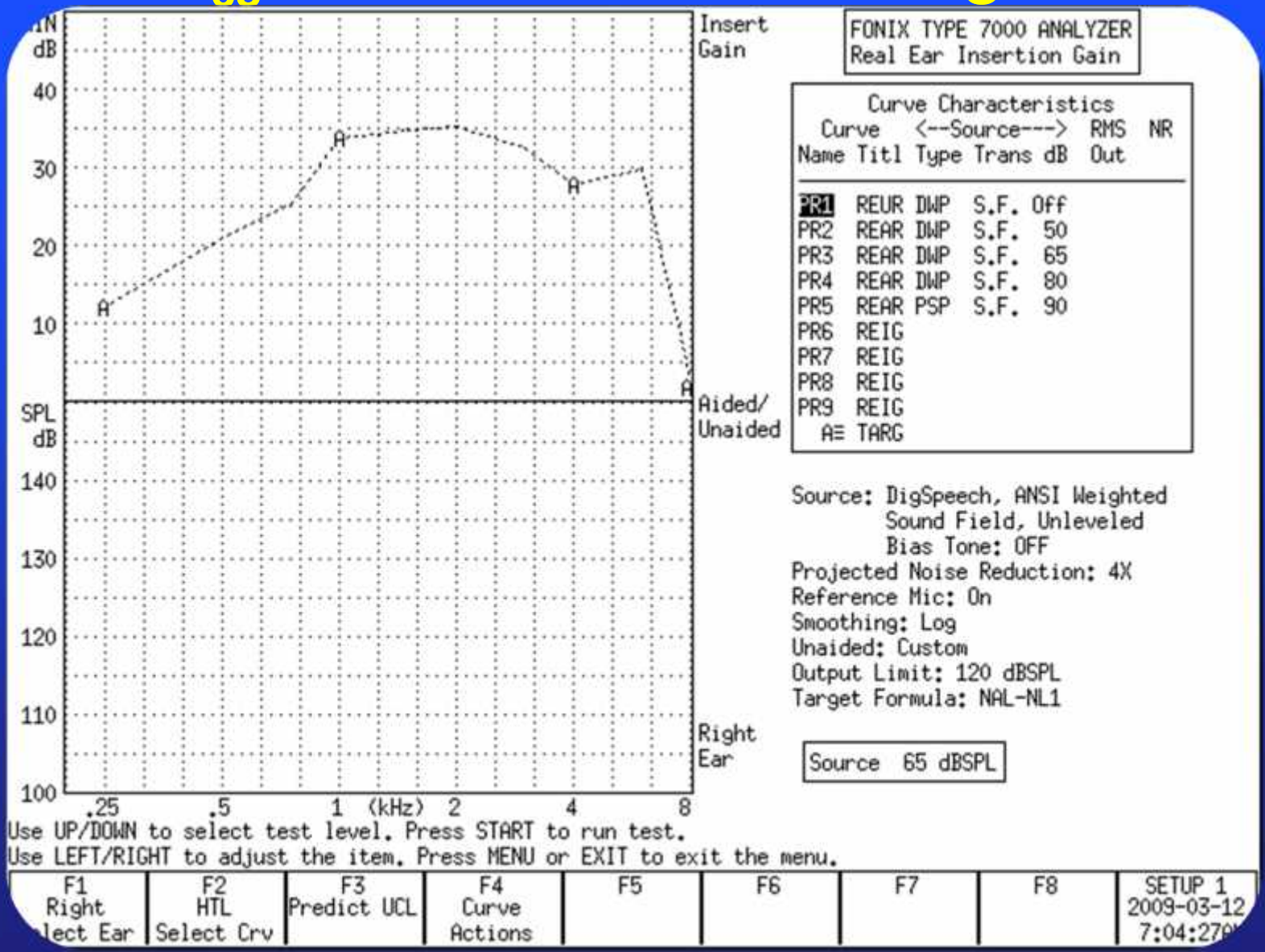


As a sidebar....notice the predicted LDL's in dB HL.

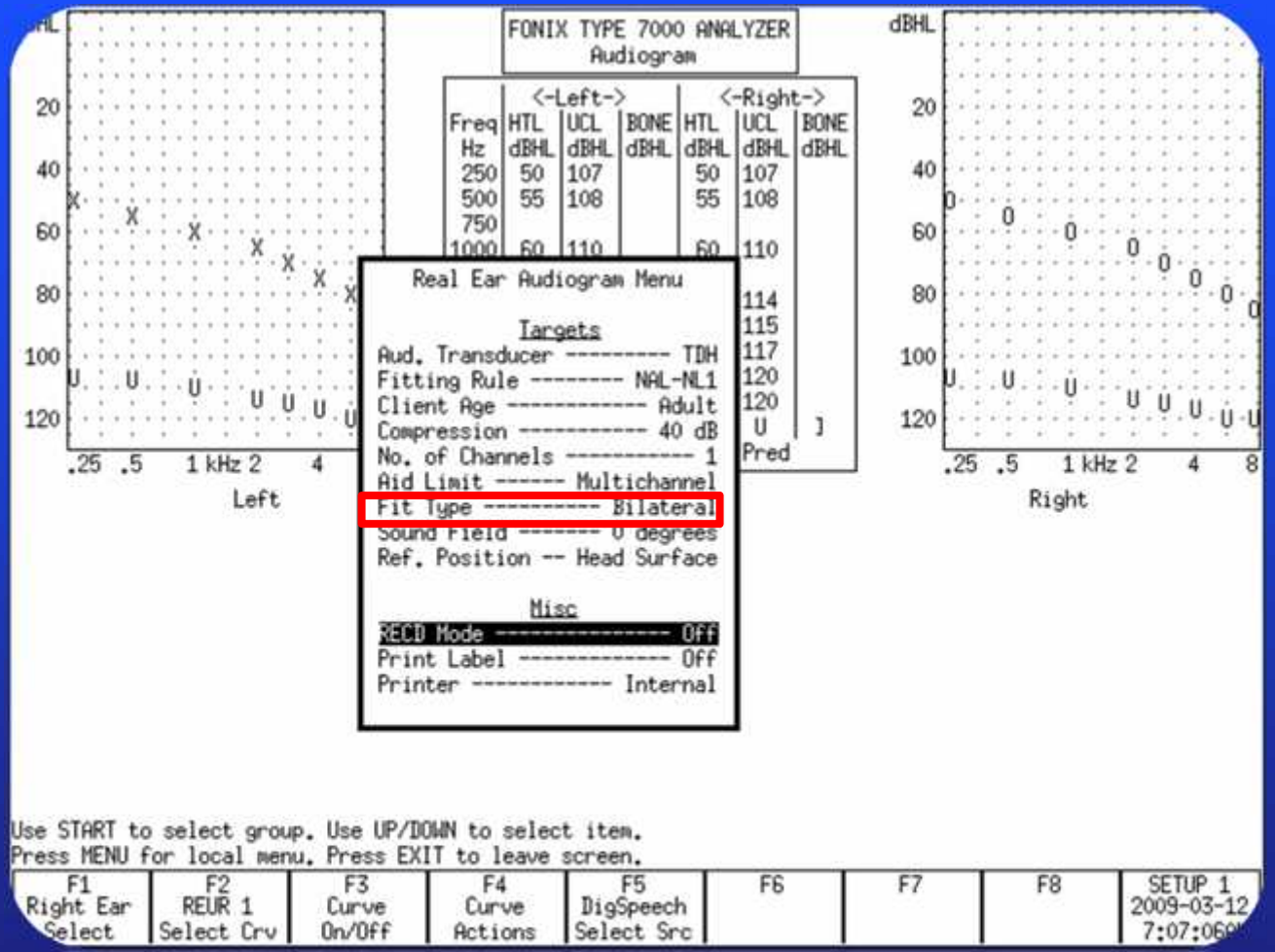
Frye default is monaural and 1 channel, but audiologists typically do not “see” this.



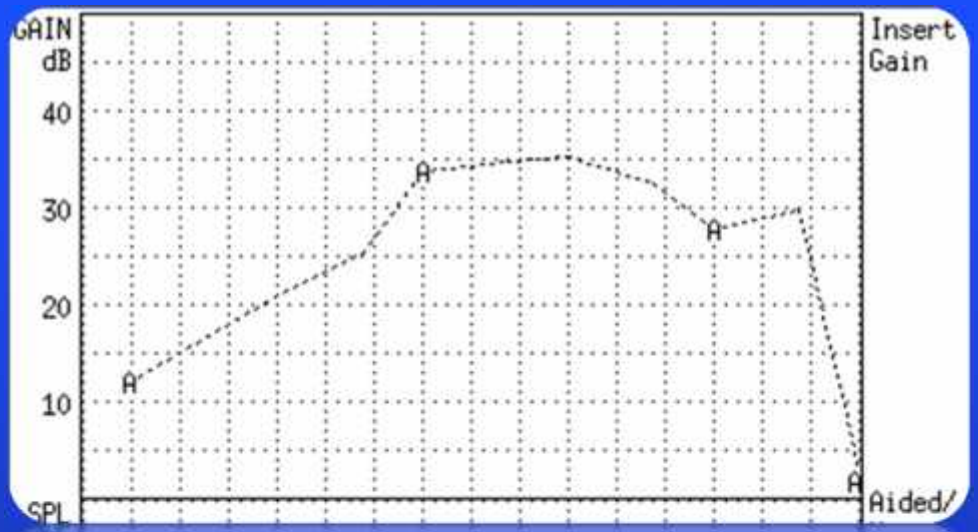
$REIG_{65}$ for the entered audiogram



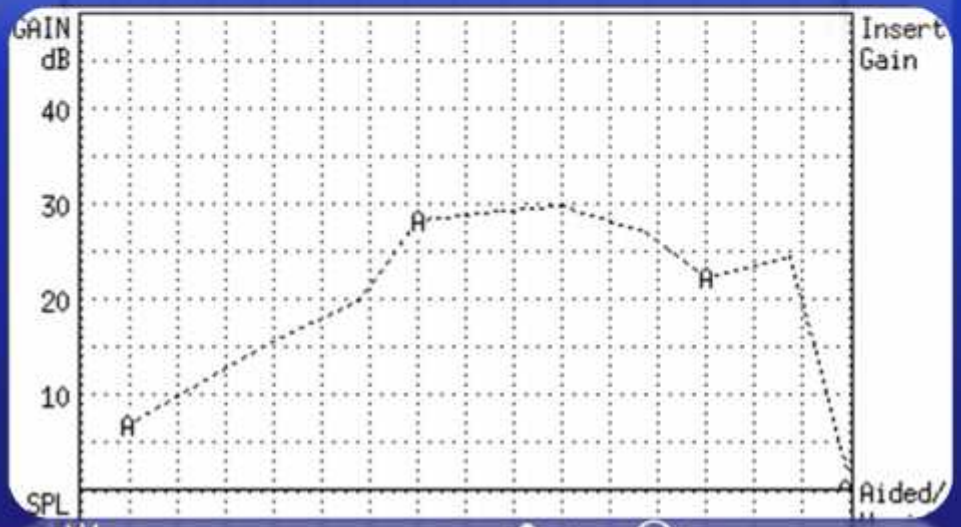
Correct for bilateral summation



REIG for bilateral summation

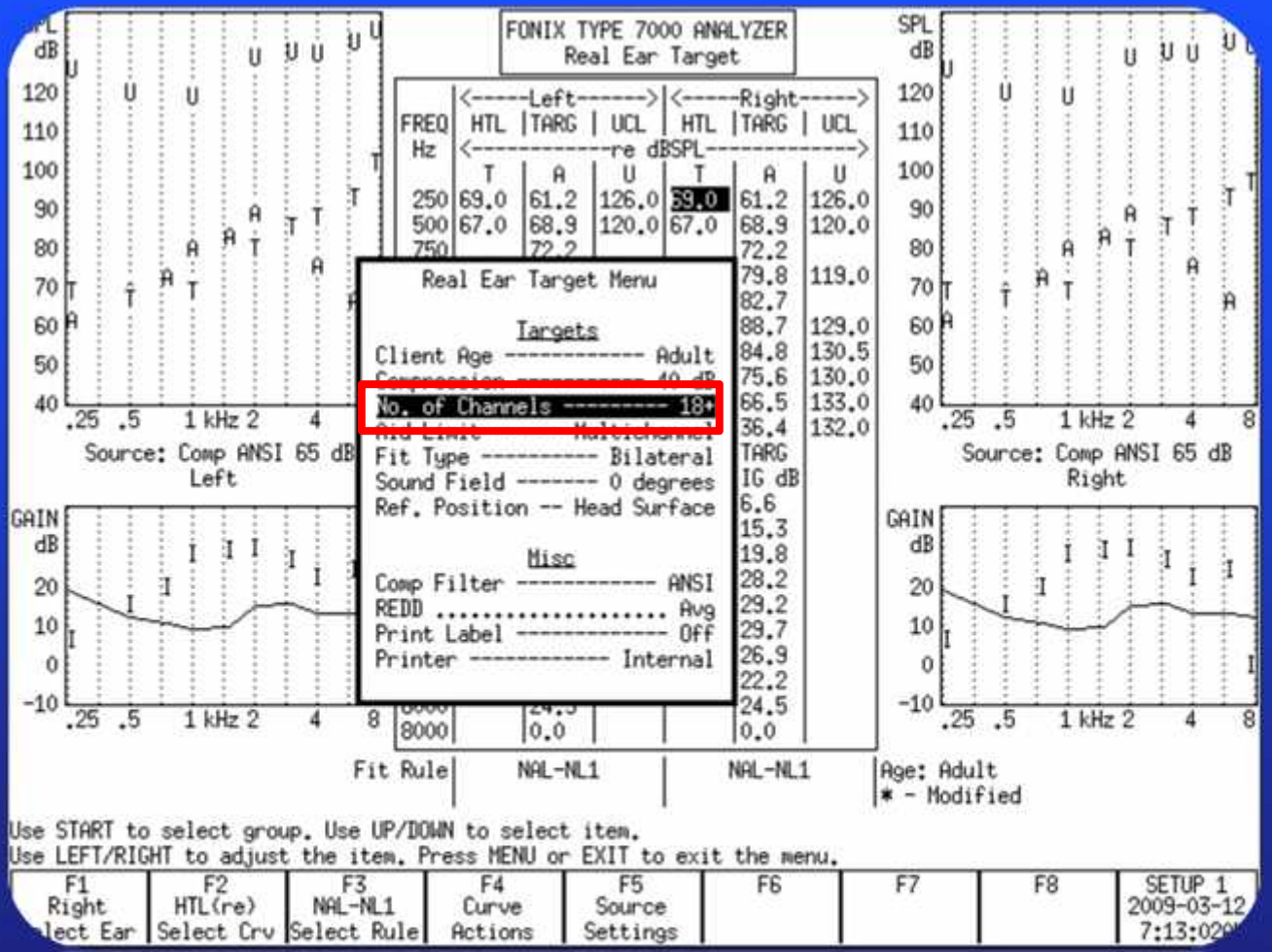


Default

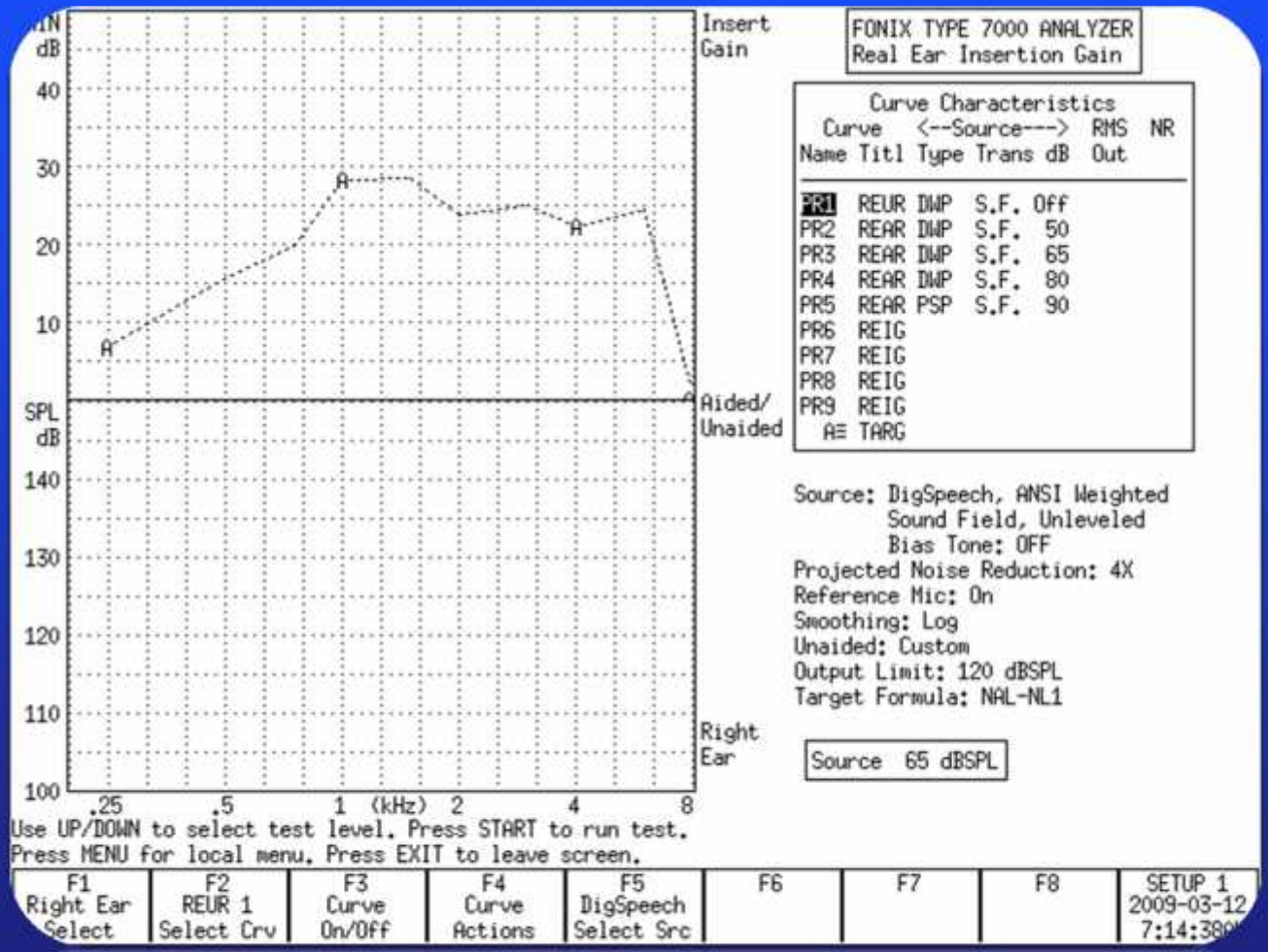


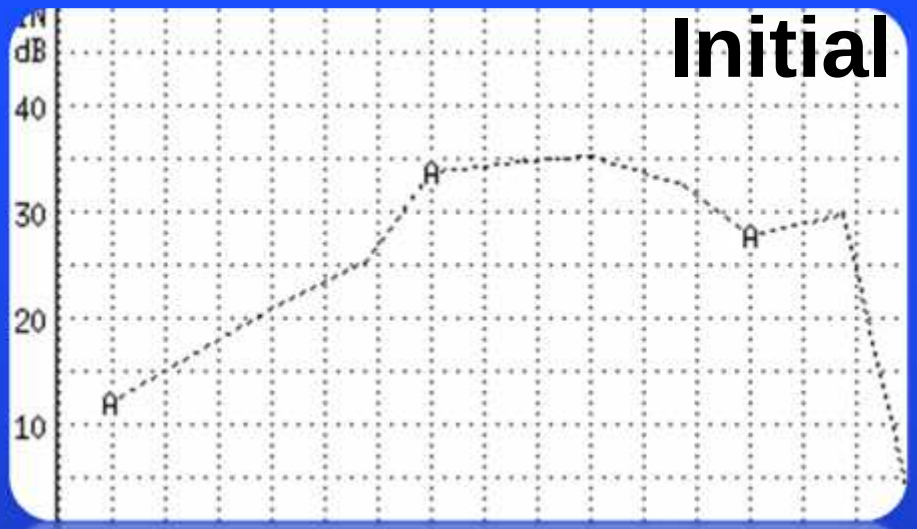
Corrected

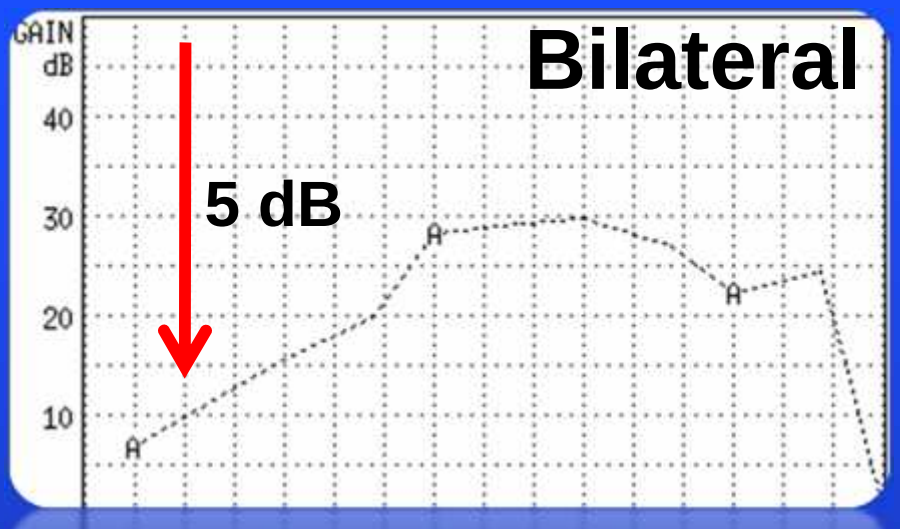
Correct for channel summation



Resulting REIG for bilateral and channel summation

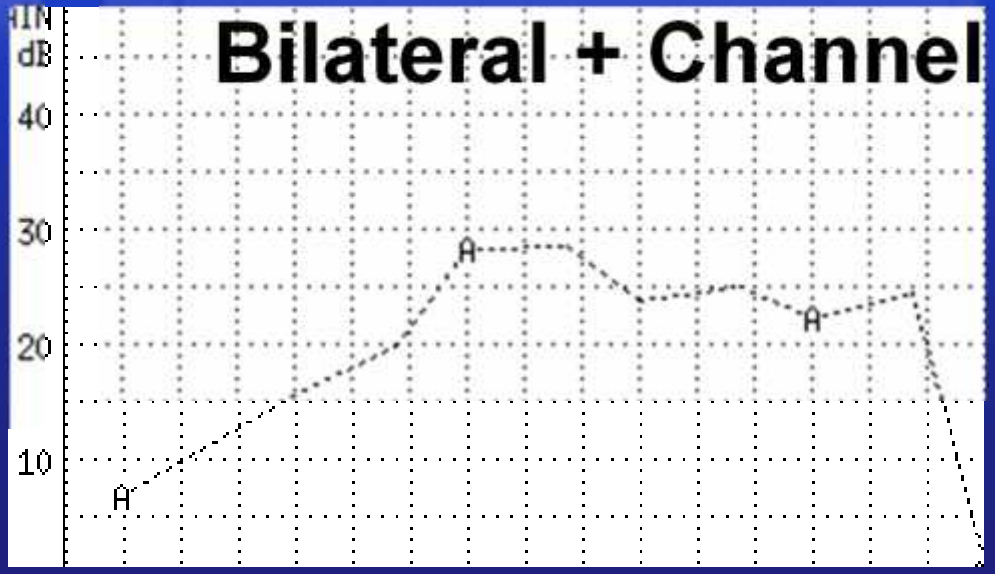






Difference

250	5
500	5
1000	7
2000	11
4000	6
6000	6



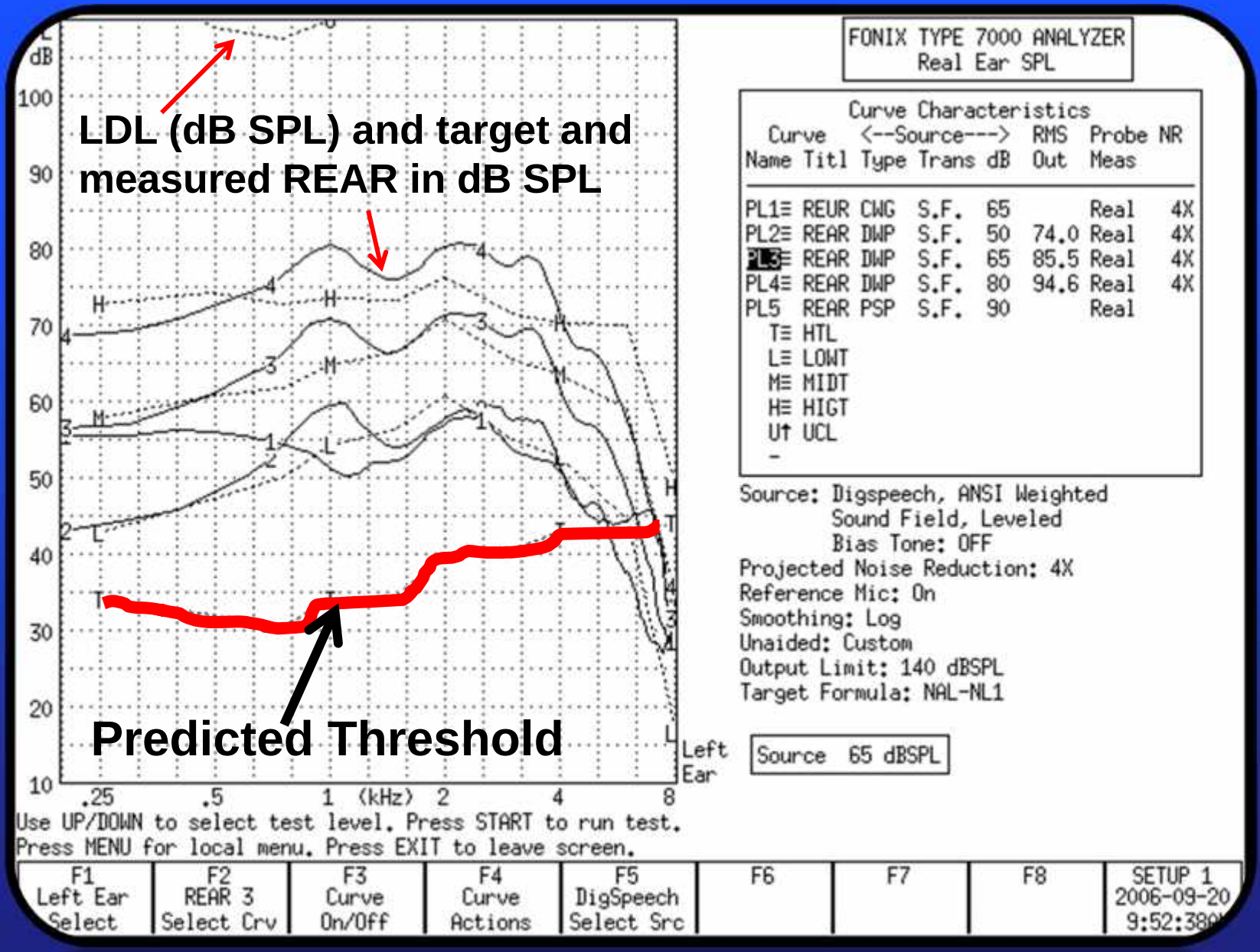
Correction for REAR measures

First, Need to Know a Little About the Real Ear to Dial Difference (REDD)

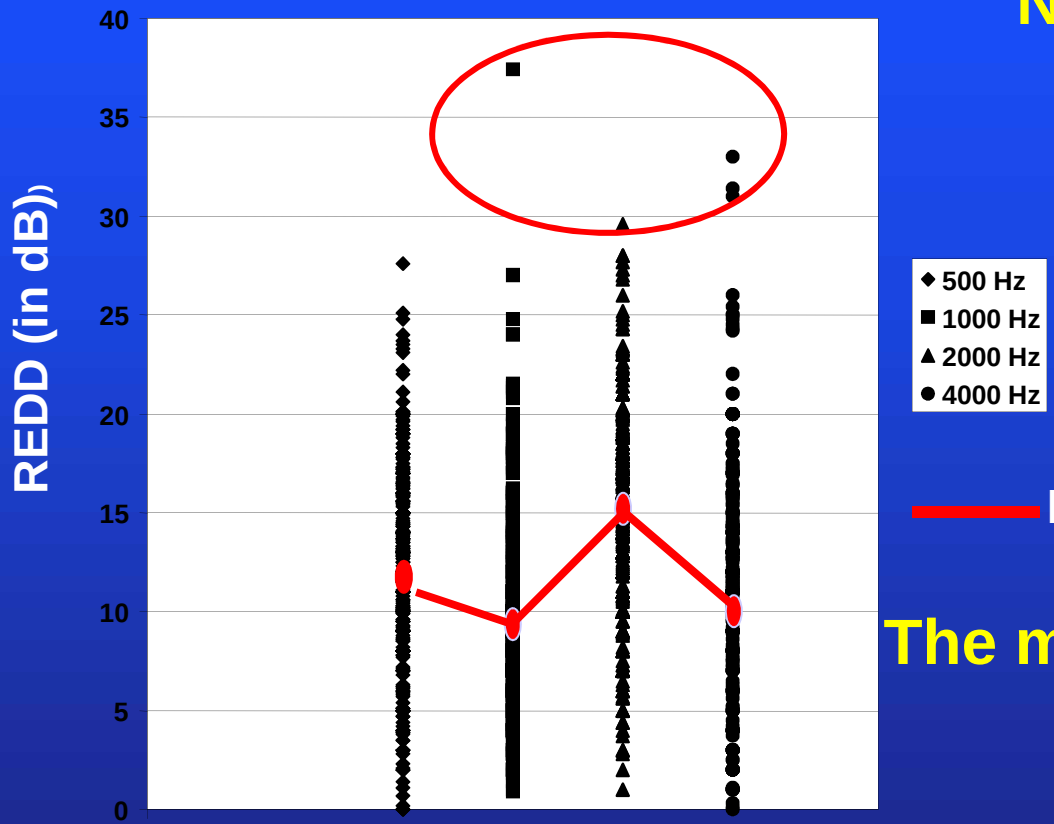
When completing REAR measures you may not be aware….

As mentioned earlier, when you enter the audiogram in dB HL, the REM software will convert the threshold (dB HL) to dB (SPL) by adding the average REDD from ANSI S3.6-1989 to calculate the *predicted* threshold in dB SPL:

250	19	3000	15.5
500	12	4000	13
1000	9	6000	13
2000	15	8000	14


LDL (dB SPL) and target and measured REAR in dB SPL
Predicted Threshold
dB
100
90
80
70
60
50
40
30
20
10
.25
.5
1
(kHz)
2
4
8
Left Ear
FONIX TYPE 7000 ANALYZER
Real Ear SPL
Curve Characteristics
Curve Name Titl
<--Source---> Type Trans dB
RMS Out
Probe Meas
NR
PL1≡ REUR CWG S.F. 65 Real 4X
PL2≡ REAR DWP S.F. 50 74.0 Real 4X
PL3≡ REAR DWP S.F. 65 85.5 Real 4X
PL4≡ REAR DWP S.F. 80 94.6 Real 4X
PL5 REAR PSP S.F. 90 Real
T≡ HTL
L≡ LOWT
M≡ MIDT
H≡ HIGT
U↑ UCL
Source: Digspeech, ANSI Weighted
Sound Field, Leveled
Bias Tone: OFF
Projected Noise Reduction: 4X
Reference Mic: On
Smoothing: Log
Unaided: Custom
Output Limit: 140 dBSPL
Target Formula: NAL-NL1
Source 65 dBSPL
Use UP/DOWN to select test level. Press START to run test.
Press MENU for local menu. Press EXIT to leave screen.
F1 Left Ear Select
F2 REAR 3 Select Crv
F3 Curve On/Off
F4 Curve Actions
F5 DigSpeech Select Src
F6
F7
F8
SETUP 1
2006-09-20
9:52:38

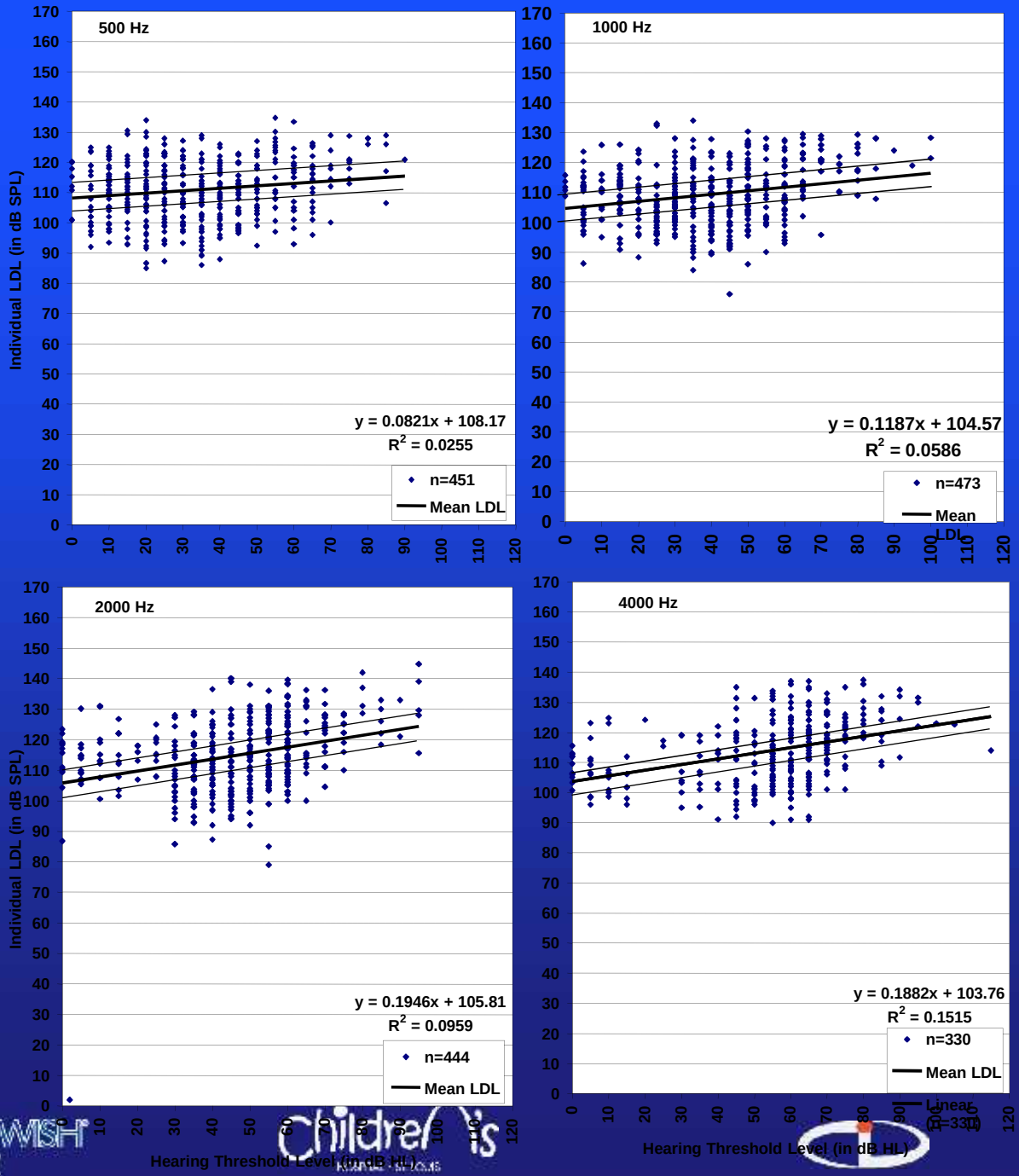
Keller and Valente (2006)



REDD as a function of frequency

N = 451 ears @ 500
444 ears @ 1000
473 ears @ 2000
330 ears @ 4000

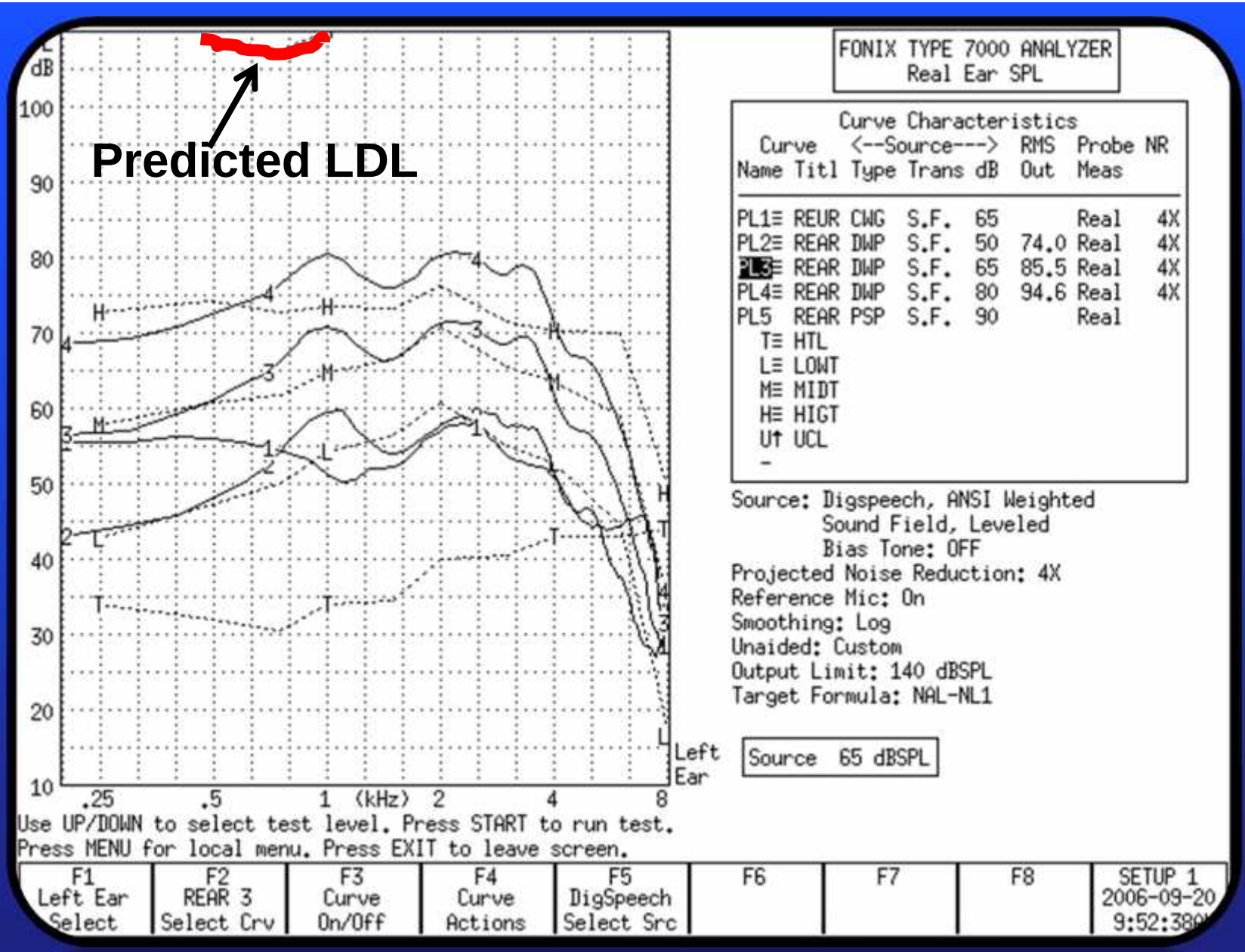
The mean is equal to ANSI 1989!

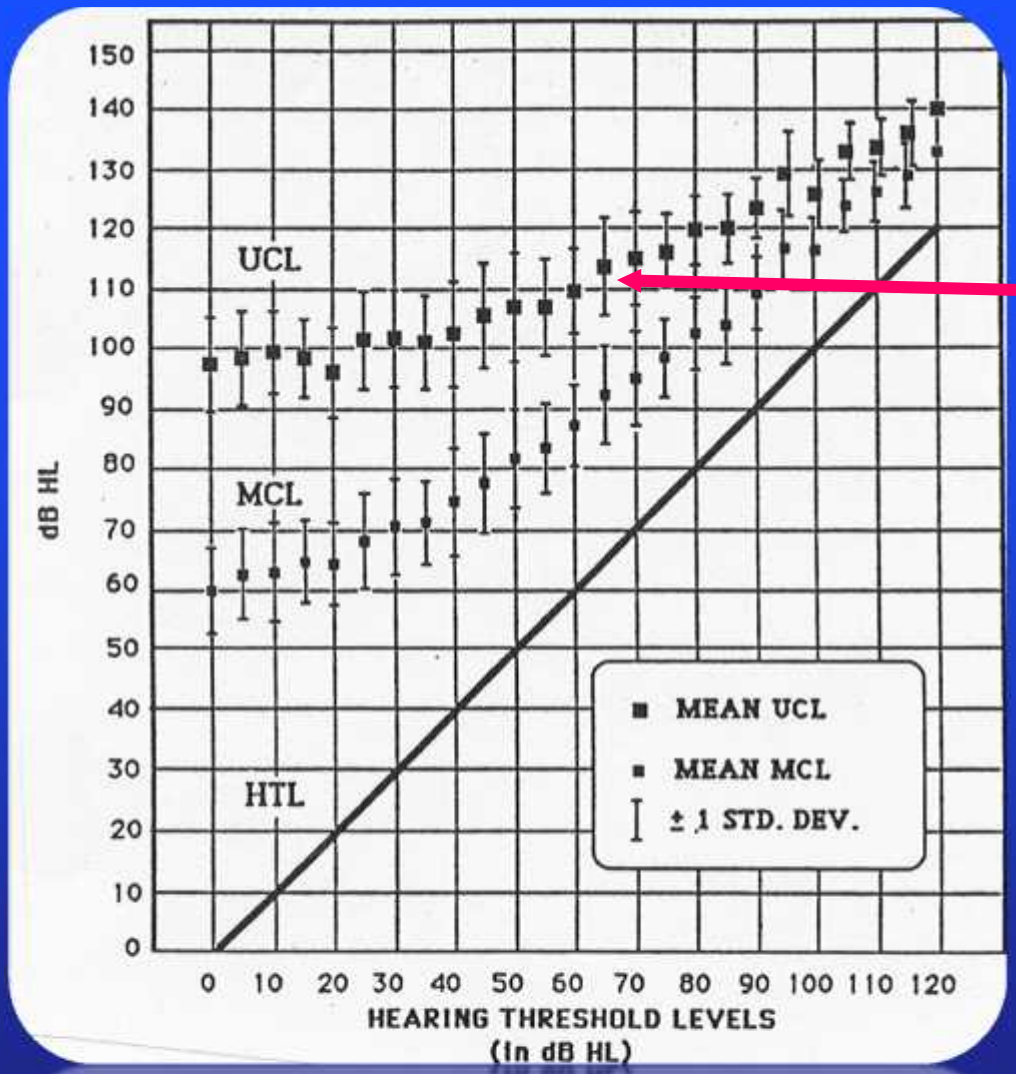


	dB (HL)			dB (SPL)		
	% below 5 dB	% within +/-5 dB	% above +5 dB	% below 5 dB	% within +/-5 dB	% above +5 dB
500	0.26	0.45	0.29	0.25	0.45	0.30
1000	0.20	0.60	0.20	0.23	0.53	0.24
2000	0.22	0.56	0.22	0.27	0.44	0.29
4000	0.18	0.62	0.20	0.27	0.50	0.23
Grand	0.22	0.56	0.23	0.26	0.48	0.26

Elberling (1999) reported that measured and predicted LDL would be within +/- 5 dB in 70% of the cases.

Next, the software *predicts* LDL in dB HL from Pascoe (1988) and adds the average REDD to convert the LDL in dB HL to LDL in dB SPL


Predicted LDL
dB
100
90
80
70
60
50
40
30
20
10
.25
.5
1
(kHz)
2
4
8
Left Ear
FONIX TYPE 7000 ANALYZER
Real Ear SPL
Curve Characteristics
Curve Name Titl
<--Source---> Type Trans dB
RMS Out
Probe Meas
NR
PL1≡ REUR CWG S.F. 65 Real 4X
PL2≡ REAR DWP S.F. 50 74.0 Real 4X
PL3≡ REAR DWP S.F. 65 85.5 Real 4X
PL4≡ REAR DWP S.F. 80 94.6 Real 4X
PL5 REAR PSP S.F. 90 Real
T≡ HTL
L≡ LOWT
M≡ MIDT
H≡ HIGT
U↑ UCL
Source: Digspeech, ANSI Weighted
Sound Field, Leveled
Bias Tone: OFF
Projected Noise Reduction: 4X
Reference Mic: On
Smoothing: Log
Unaided: Custom
Output Limit: 140 dBSPL
Target Formula: NAL-NL1
Source 65 dBSPL
Use UP/DOWN to select test level. Press START to run test.
Press MENU for local menu. Press EXIT to leave screen.
F1 Left Ear Select
F2 REAR 3 Select Crv
F3 Curve On/Off
F4 Curve Actions
F5 DigSpeech Select Src
F6
F7
F8
SETUP 1
2006-09-20
9:52:38



TOO LOUD!	RED	9
VERY LOUD		8
LOUD		7
OK (LOUDER)	GREEN	6
OK!		5
OK (SOFTER)		4
SOFT	YELLOW	3
VERY SOFT		2
TOO SOFT!		1
NOTHING	WHITE	0

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Frye 6500, 7000 and 8000

LDL + REDD = LDL dB SPL

HTL dBHL	UCL HL	HTL dBHL	UCL HL
0	97	65	114
5	99	70	115
10	99	75	117
15	98	80	120
20	97	85	120
25	101	90	124
30	102	95	130
35	101	100	127
40	103	105	133
45	105	110	134
50	107	115	137
55	108	120	140
60	110		

FREQ (Hz)	dB
250	19.0
500	12.0
750	10.5
1000	9.0
1500	12.0
2000	15.0
3000	15.5
4000	13.0
6000	13.0
8000	14.0

HL	250	500	1000	1500	2000	3000	4000	6000	8000	Pascoe (1988)	
0	116	109	106	109	112	113	110	110	111	97	
5	118	111	108	111	114	115	112	112	113	99	
10	118	111	108	111	114	115	112	112	113	99	
15	117	110	107	110	113	114	111	111	112	98	
20	116	109	106	109	112	113	110	110	111	97	
25	120	113	110	113	116	117	114	114	115	101	
30	121	114	111	114	117	118	115	115	116	102	
35	120	113	110	113	116	117	114	114	115	101	
40	122	115	112	115	118	119	116	116	117	103	
45	124	117	114	117	120	121	118	118	119	105	
50	126	119	116	119	122	123	120	120	121	107	
55	127	120	117	120	123	124	121	121	122	108	
60	129	122	119	122	125	126	123	123	124	110	
65	133	126	123	126	129	130	127	127	128	114	
70	134	127	124	127	130	131	128	128	129	115	
75	136	129	126	129	132	133	130	130	131	117	
80	139	132	129	132	135	136	133	133	134	120	
85	139	132	129	132	135	136	133	133	134	120	
90	143	136	133	136	139	140	137	137	138	124	
95	149	142	139	142	145	146	143	143	144	130	
100	146	139	136	139	142	143	140	140	141	127	
105	152	145	142	145	148	149	146	146	147	133	
110	153	146	143	146	149	150	147	147	148	134	
115	156	149	146	149	152	153	150	150	151	137	
120	159	152	149	152	155	156	153	153	154	140	

1. Pascoe (1988) dB HL to LDL (last column to right)

2. HL to SPL conversion (ANSI S3.6-1989 Table G-1) in each cell)

==========

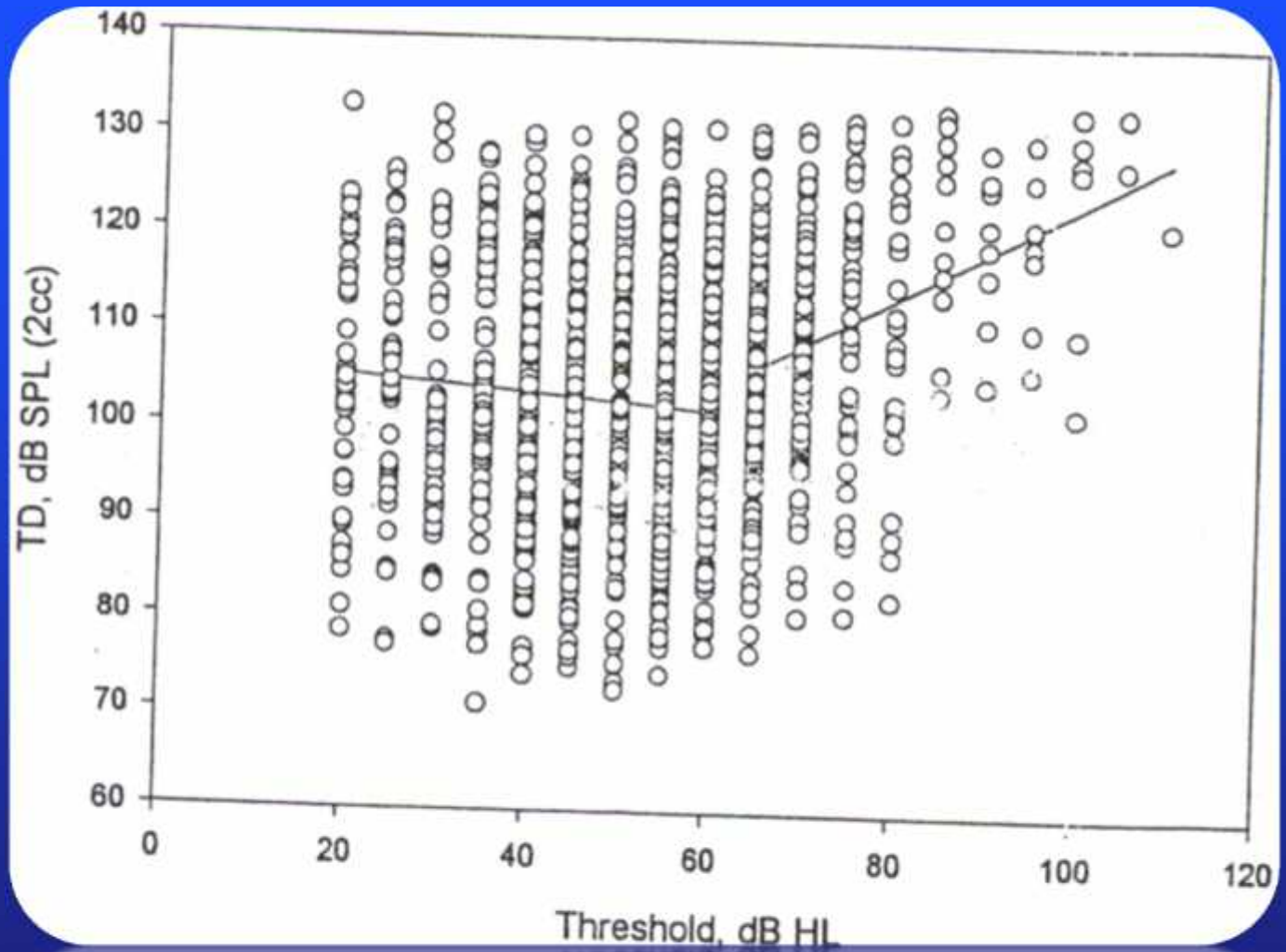
250	19
500	12
1000	9
1500	12
2000	15
3000	15.5
4000	13
6000	13
8000	14

==========

Predicted $RESR_{90}$ (Dillon, 2000)

HTL	250	500	1k	2k	4k
0	85	90	90	90	87
5	86	91	91	92	89
10	87	92	93	93	90
15	89	94	94	94	91
20	90	95	95	96	92
25	91	96	97	97	93
30	92	98	98	99	95
35	94	99	100	100	96
40	95	101	101	101	97
45	96	102	103	103	98
50	97	103	104	104	99
55	99	105	106	105	101
60	100	106	108	107	102
65	103	110	110	109	105
70	107	113	113	112	107
75	111	116	115	114	110
80	114	120	118	117	112
85	118	123	121	120	115
90	121	126	123	122	117
95	125	130	126	125	120
100	128	133	129	127	122
105	132	136	131	130	125
110	135	140	134	133	127
115	139	143	136	135	130
120	143	146	139	138	132

Bentler and Cooley (2001)



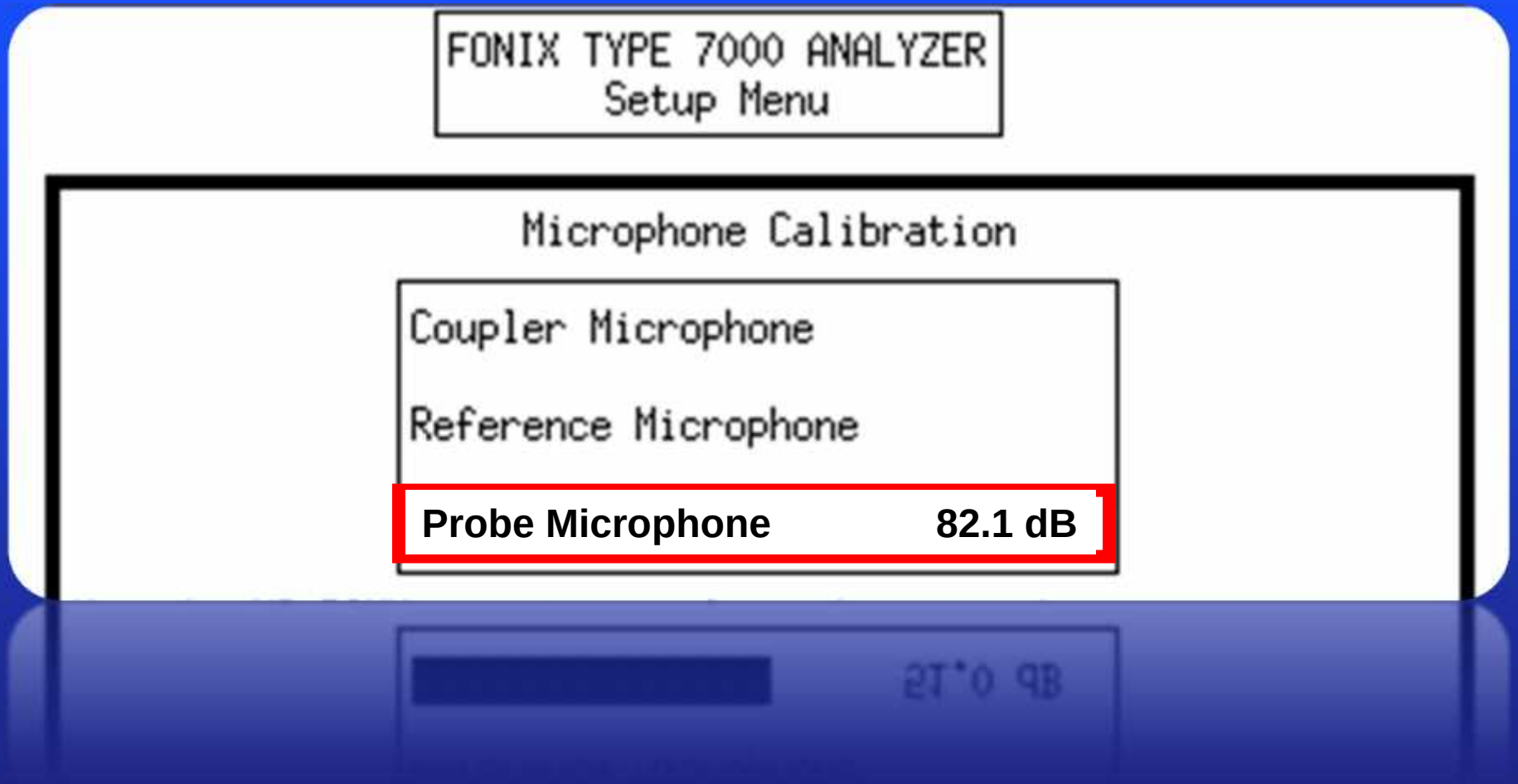
How does one measure the individual REDD?

Measuring REDD

Audiometer dial is 70 dB HL

Probe

Screen to measure REDD



FONIX 8000 TEST SYSTEM
Setup Menu

Calibrator (dB SPL): 90 94 110 *114*

Chamber	Mic	Model	Serial	RMS	Fixup
	Coupler	M1958E	005134		2.05
Probe Left					
	*Probe *	M767	005263	107.27	2.92
	Ref	M767	005263		2.27
Probe Right					
	Probe	M767	005255		5.41
	Ref	M767	005255		2.55

Use the LEFT-RIGHT arrows to select the appropriate calibrator amplitude.
Use the UP-DOWN arrows to select the microphone to calibrate.
Press START to start auto-calibration.
Press STOP to stop a calibration in process.

LEVELED

Error encountered during calibration. Please check that the calibrator is on.
If setup is correct, your microphone may need repair or replacement.

F1 Settings Selection	F2 Find Modules	F3 Set Time/Date	F4 Meas Earph in Coupler	F5 Save Cham Level	F6 Calibrate Microphones	F7 Load Setup Defaults	F8 Save Setup Defaults	SETUP 1 2013-09-30 6:41:01AM

Verifit

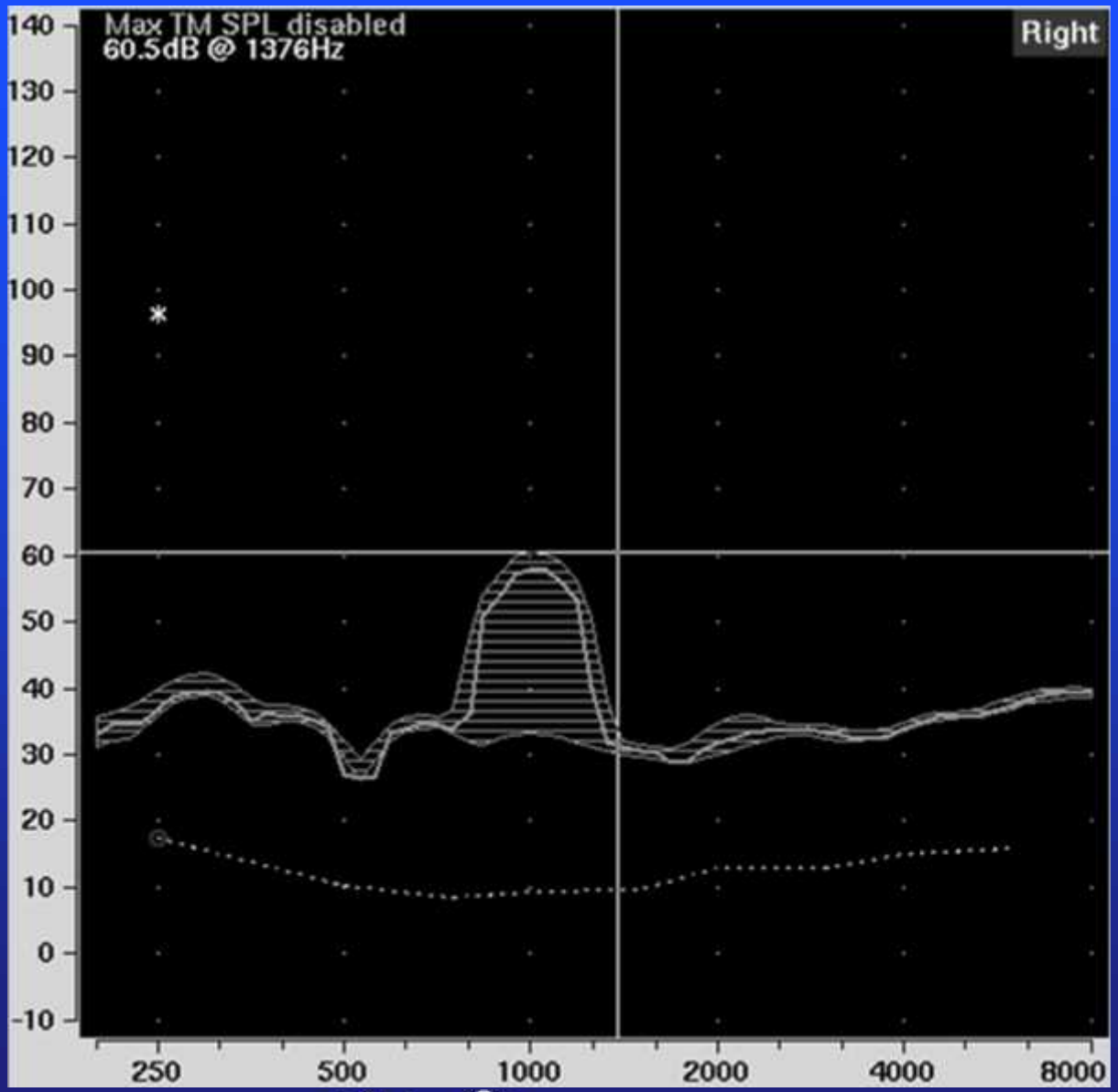


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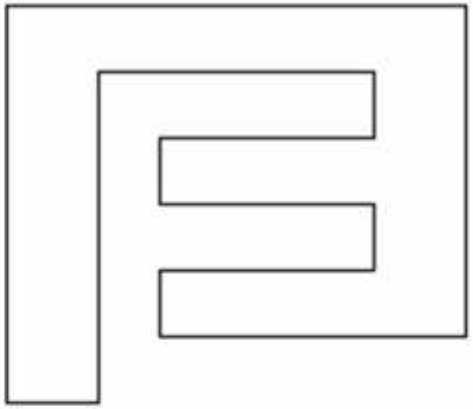
Table used to document REDD in SPL

	RT			LT		
	HL	SPL	REDD	HL	SPL	REDD
500	70	78	8			
1000	70	82	12			
2000	70	87	17			
3000	70	80	10			
4000	70	76	6			

Add REDD to audio threshold to convert to dB SPL @ TM.

Using the Dynamic Range of the Patient as the *Target*



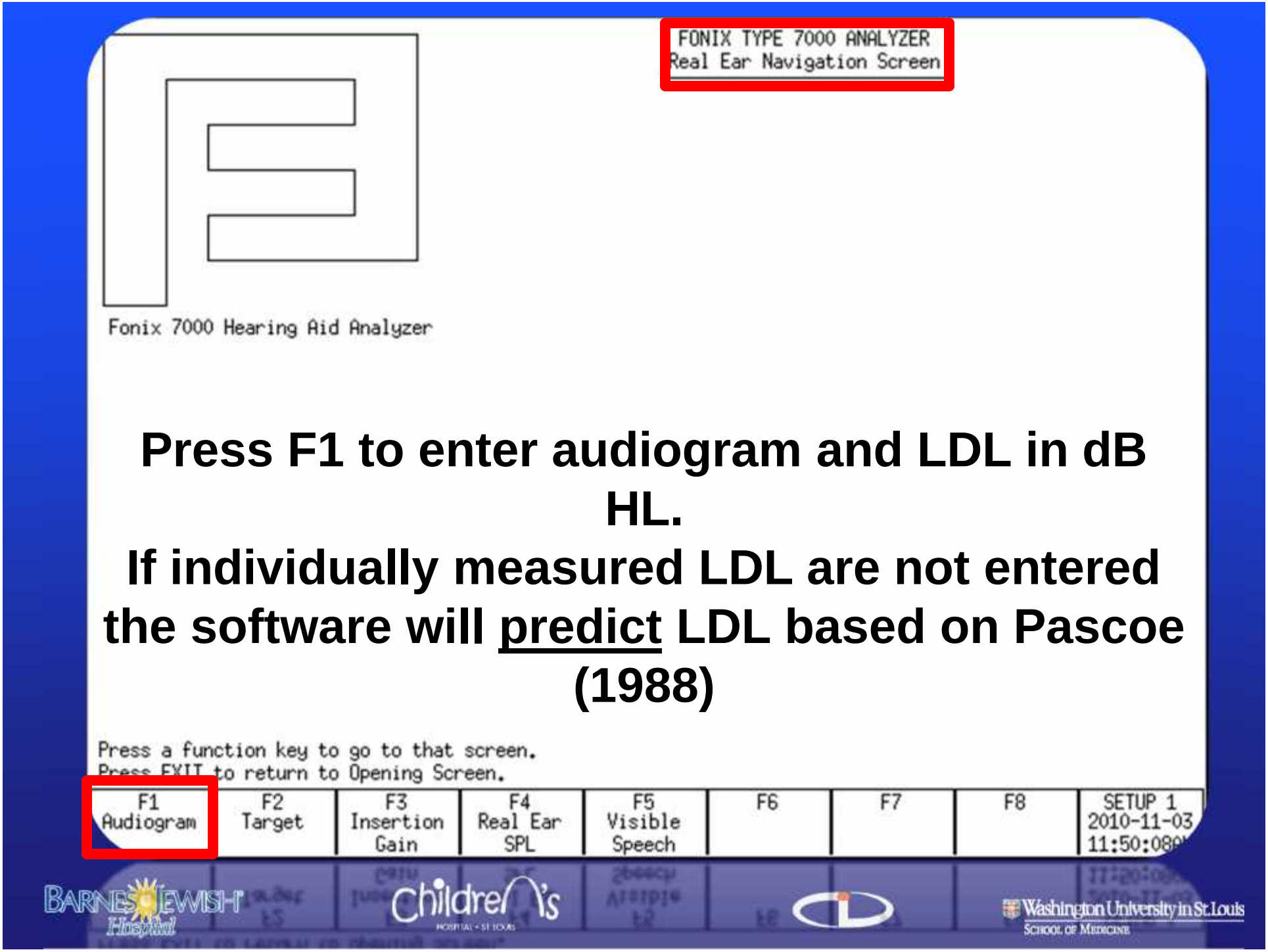
Fonix 7000 Hearing Aid Test System
Copyright @ 2003, 2004, 2005, 2006,
2007, 2008, 2009
Frye Electronics, Inc.
9826 SW Tigard St
Tigard, OR 97223

Phone: 503-620-2722
800-547-8209
Fax: 503-639-0128
Web: www.frye.com

Software Version **1.64**
Serial Number: **000780**
Available Options: **Probe, IEC 1994, IEC 2005, ANSI**

Press F2 from opening screen to open Real Ear Navigation Screen

F1	F2	F3	F4	F5	F6	F7	F8	SETUP 1
Coupler ulticurve	Real-Ear	Advanced Coupler	ANSI S3.22 2003	IEC 60118-7 2005		None	Load Setup Defaults	2010-11-03 11:47:52


FONIX TYPE 7000 ANALYZER
Real Ear Navigation Screen
Fonix 7000 Hearing Aid Analyzer
Press F1 to enter audiogram and LDL in dB HL.
If individually measured LDL are not entered the software will predict LDL based on Pascoe (1988)
Press a function key to go to that screen.
Press EXIT to return to Opening Screen.
F1 Audiogram
F2 Target
F3 Insertion Gain
F4 Real Ear SPL
F5 Visible Speech
F6
F7
F8
SETUP 1
2010-11-03
11:50:08
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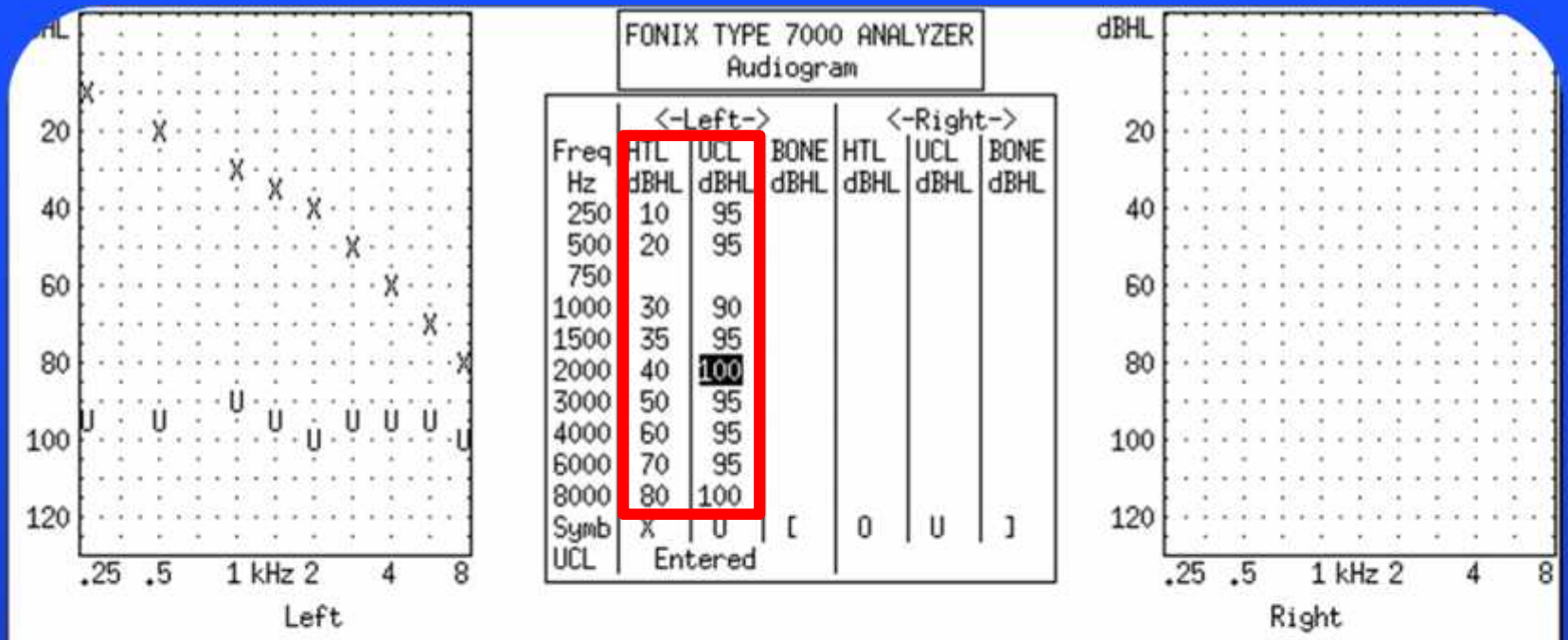
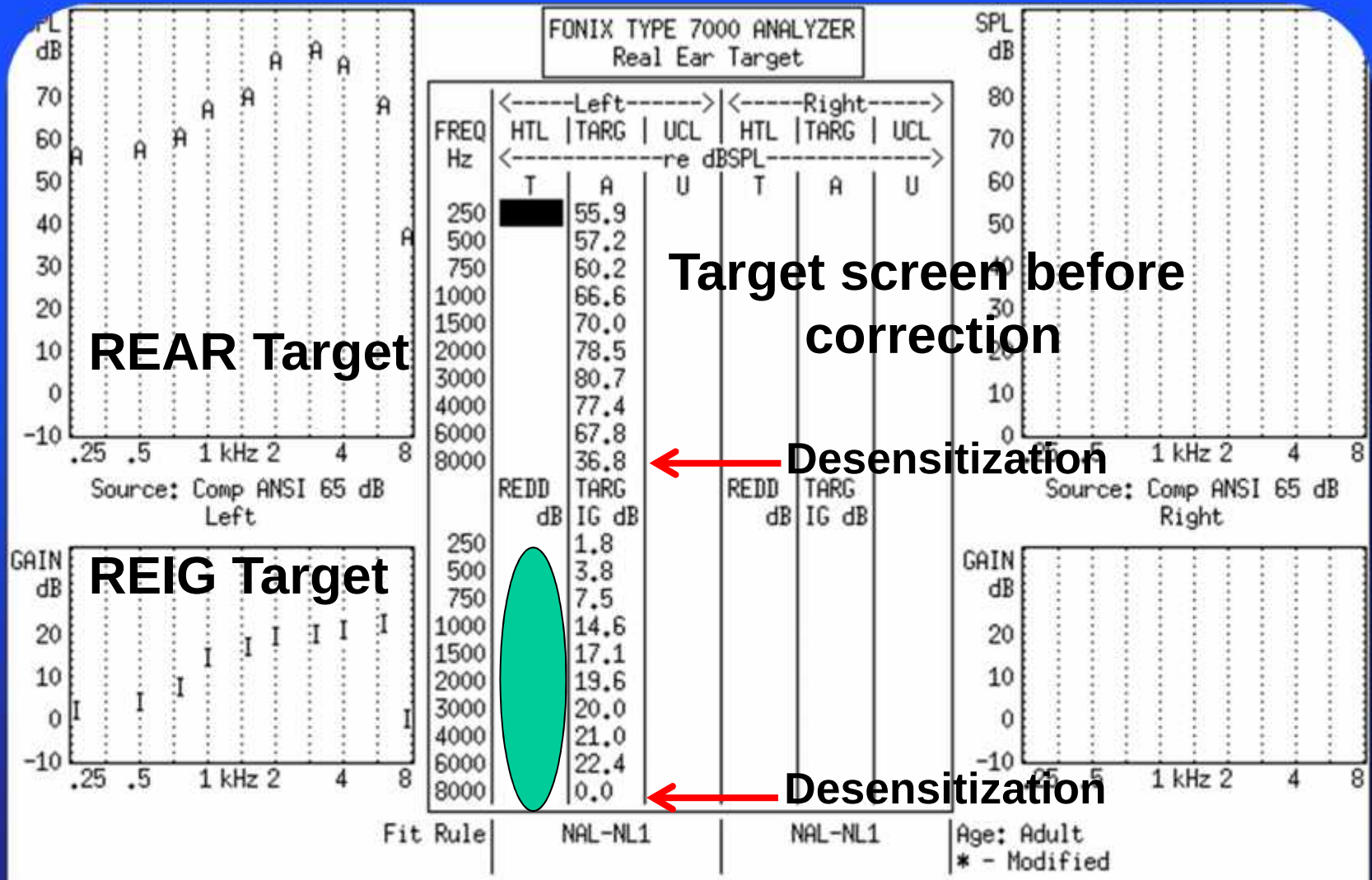


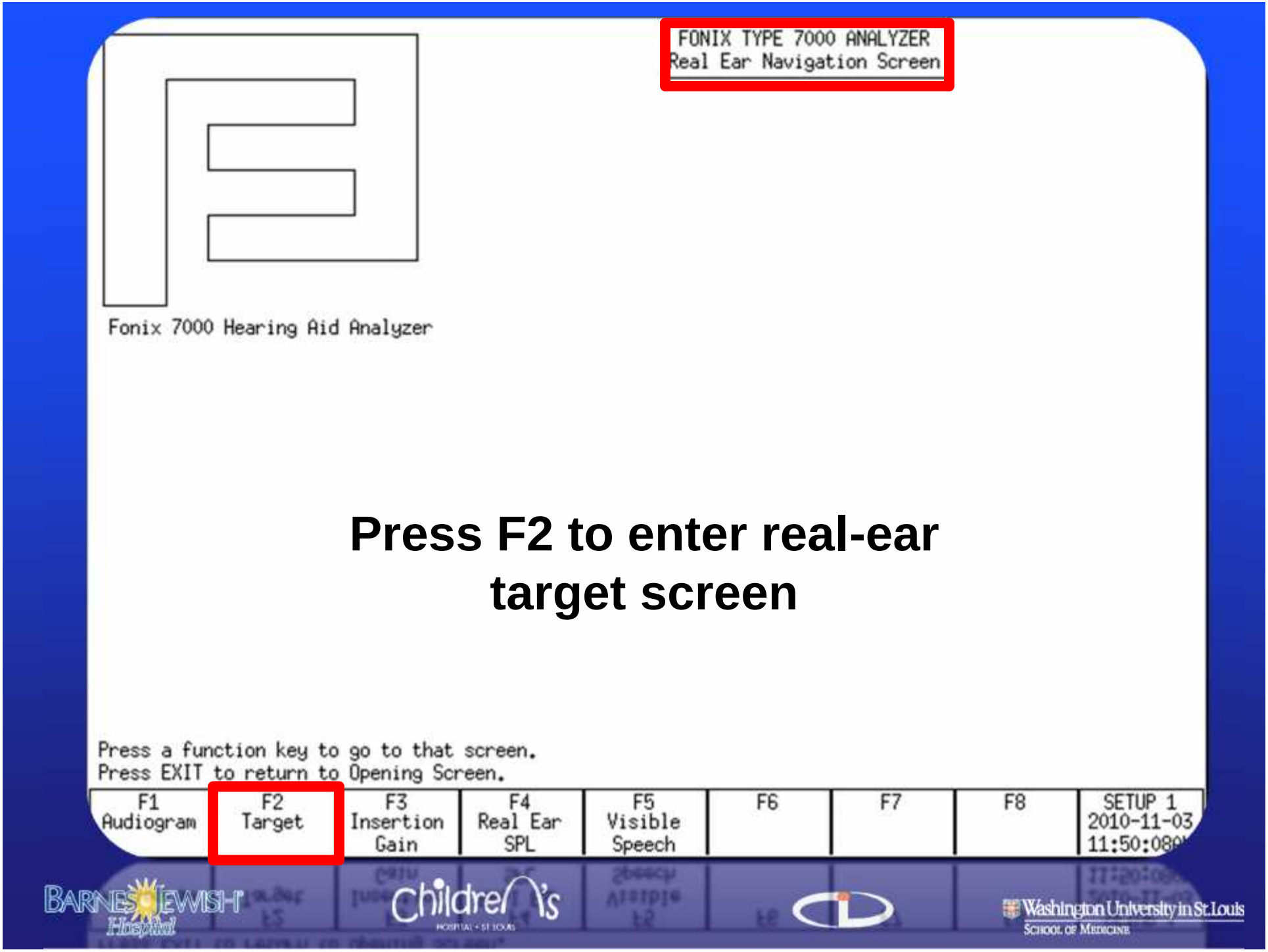
Audio + <u>measured</u> LDL of left ear in dB HL

Press a function key to go to that screen.
Press EXIT to return to Opening Screen.

F1 Audiogram	F2 Target	F3 Insertion Gain	F4 Real Ear SPL	F5 Visible Speech	F6	F7	F8	SETUP 1 2010-11-03 11:50:08

Frequency	ANSI S3.6-1989	My REDD (Left)	Difference	
250	19	13	-6	
500	12	15	+3	
1000	9	12	+3	
2000	15	16	+1	
3000	15.5	12	-3.5	
4000	13	2	-11	
6000	13	10	-3	
8000	14	12	-2	


FONIX TYPE 7000 ANALYZER
Real Ear Target
REAR Target
REIG Target
Target screen before correction
Desensitization
Desensitization
Source: Comp ANSI 65 dB Left
Source: Comp ANSI 65 dB Right
<-----Left------> <-----Right----->
FREQ Hz
HTL TARG UCL HTL TARG UCL
<-----------re dBSPL----------->
T A U T A U
250 55.9
500 57.2
750 60.2
1000 66.6
1500 70.0
2000 78.5
3000 80.7
4000 77.4
6000 67.8
8000 36.8
REDD dB
TARG IG dB
250 1.8
500 3.8
750 7.5
1000 14.6
1500 17.1
2000 19.6
3000 20.0
4000 21.0
6000 22.4
8000 0.0
Fit Rule
NAL-NL1
NAL-NL1
Age: Adult
* - Modified
Use UP/DOWN to select frequency. Use LEFT/RIGHT to enter the dB.
Press MENU for local menu. Press EXIT to leave screen.
F1 Left Select Ear
F2 HTL(re) Select Crv
F3 NAL-NL1 Select Rule
F4 Curve Actions
F5 Source Settings
F6
F7
F8
SETUP 1
2010-11-03


FONIX TYPE 7000 ANALYZER
Real Ear Navigation Screen
Fonix 7000 Hearing Aid Analyzer
Press F2 to enter real-ear target screen
Press a function key to go to that screen.
Press EXIT to return to Opening Screen.
F1 Audiogram
F2 Target
F3 Insertion Gain
F4 Real Ear SPL
F5 Visible Speech
F6
F7
F8
SETUP 1
2010-11-03
11:50:08
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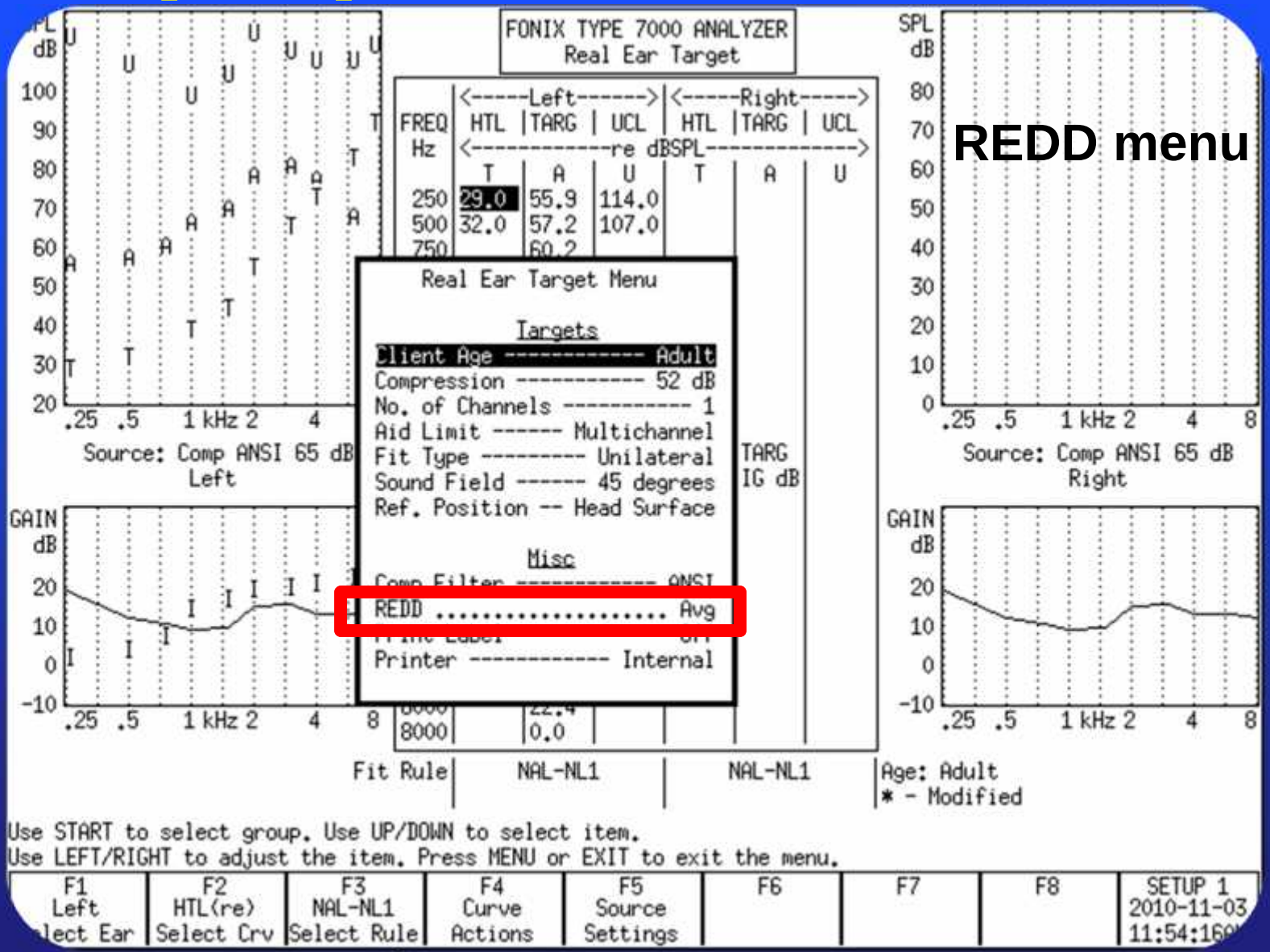
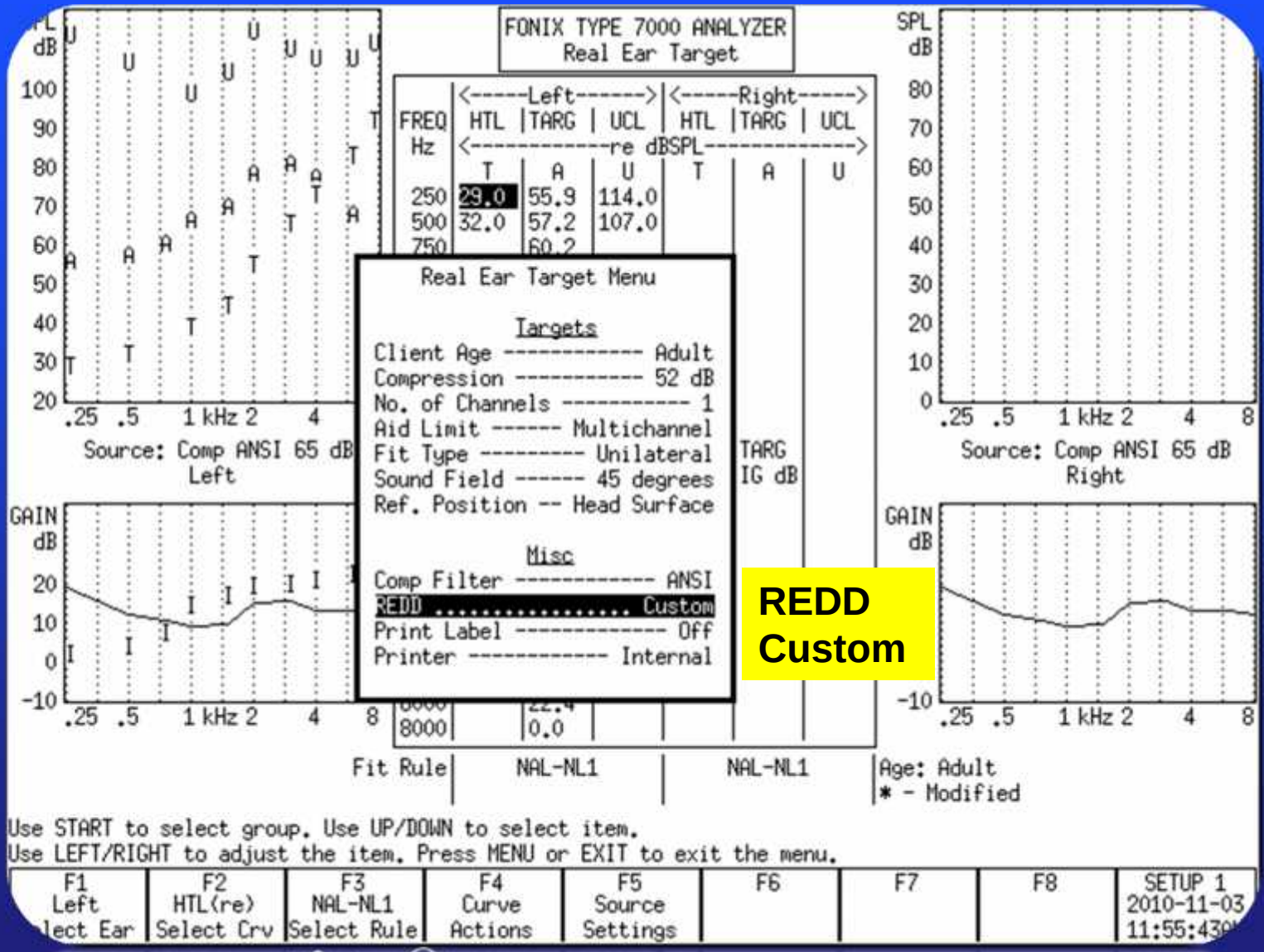
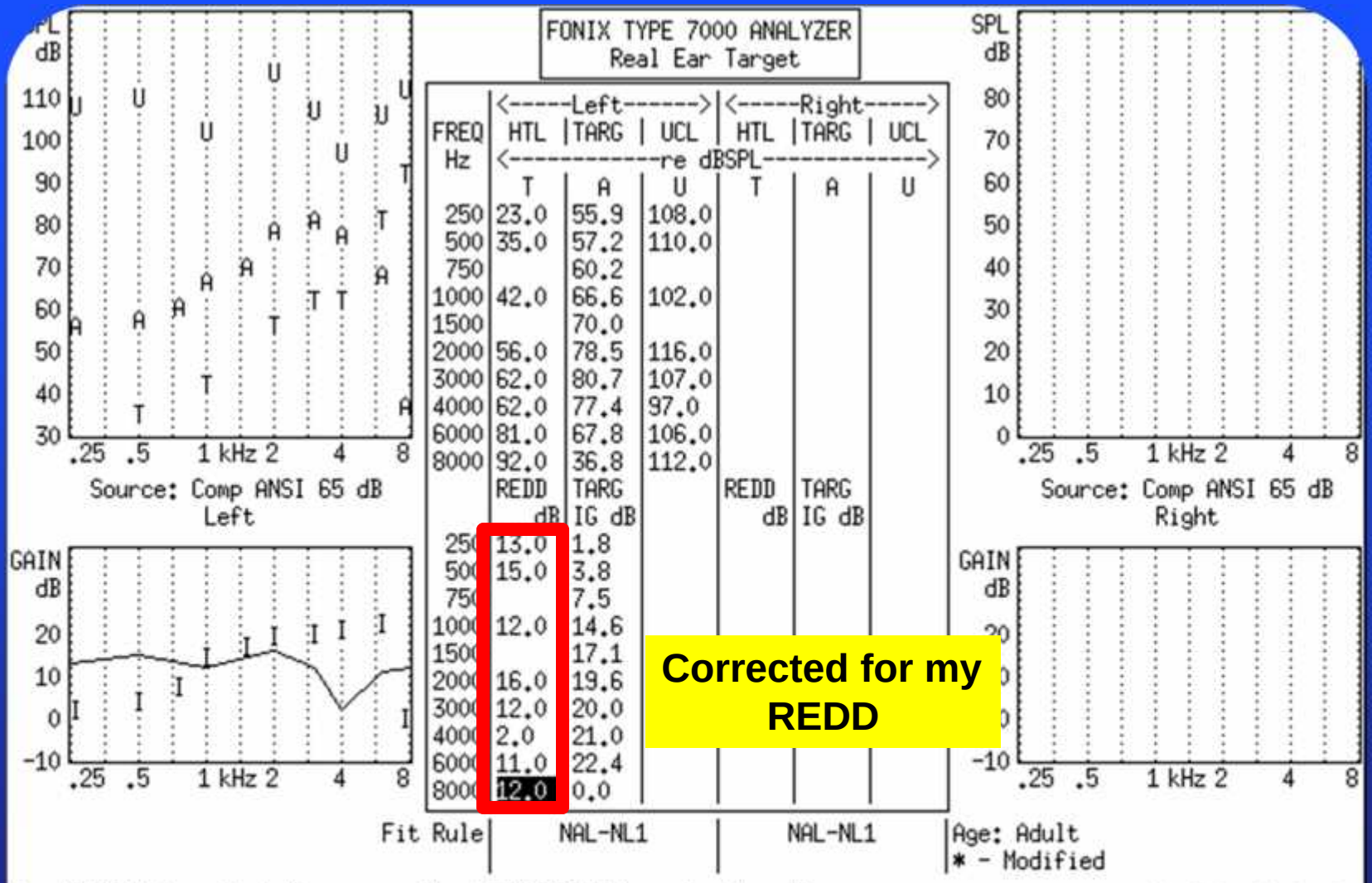
Press [Menu] and scroll down to REDD

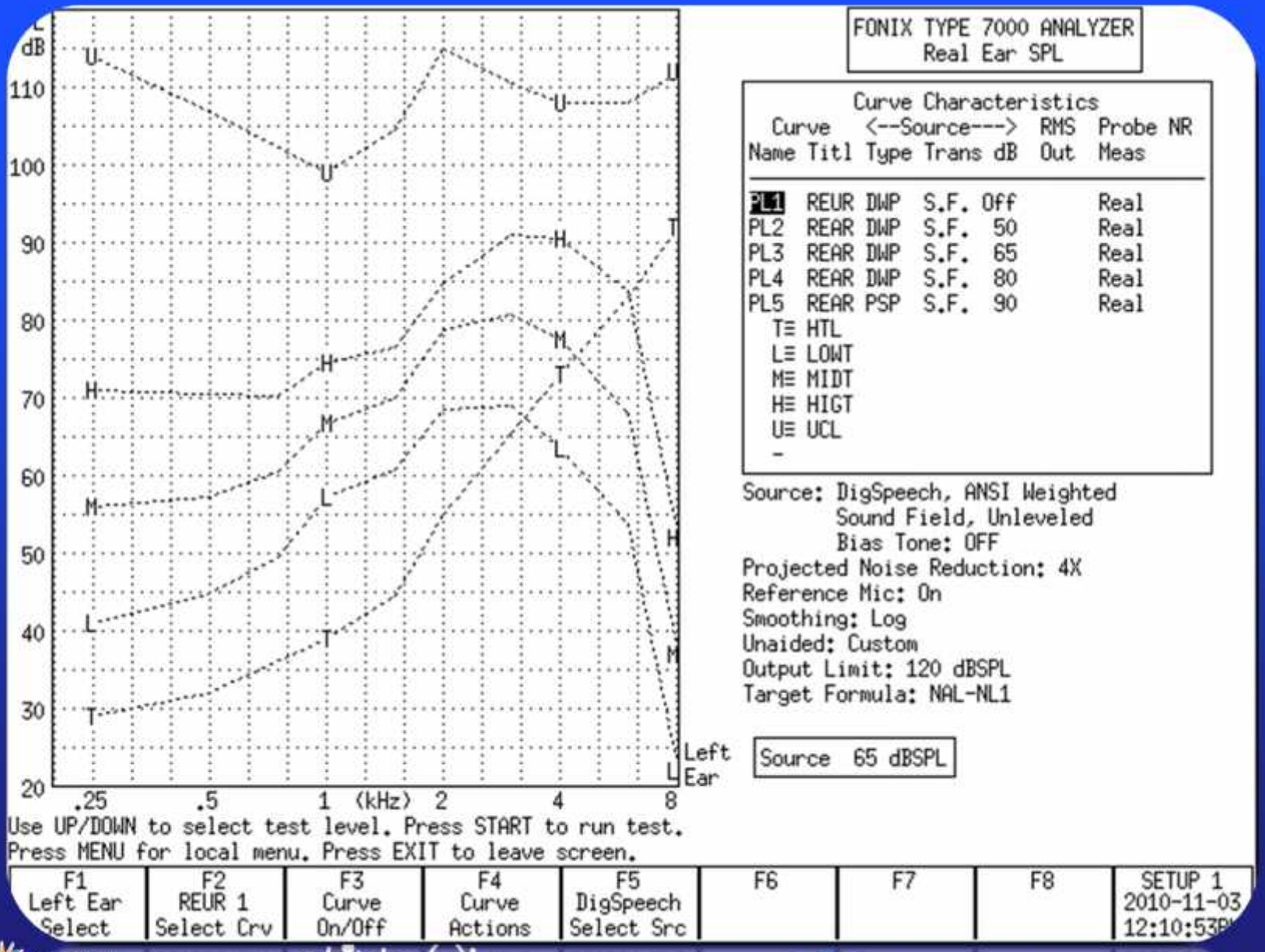


Press Right Arrow to “Custom”

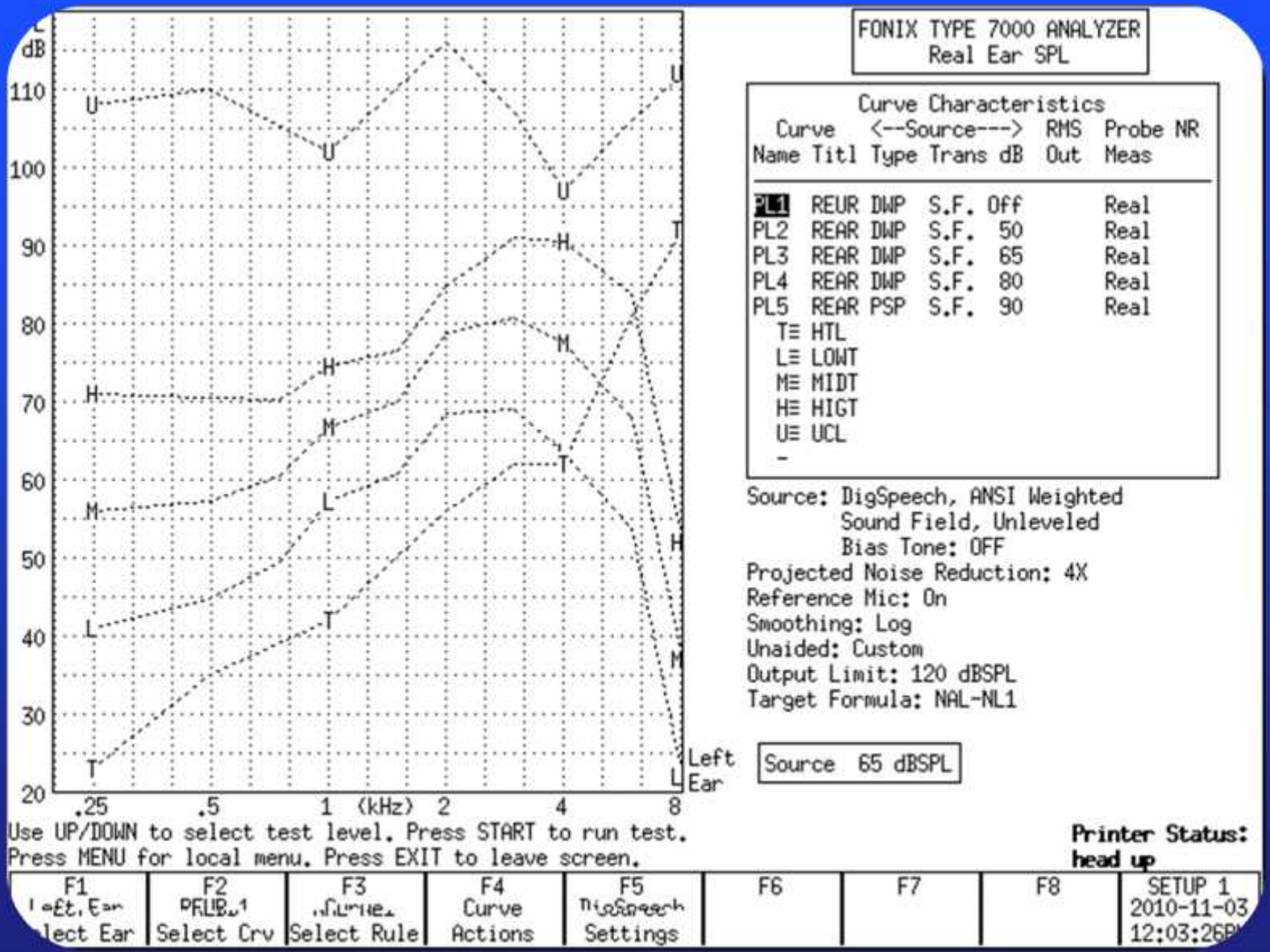



FONIX TYPE 7000 ANALYZER
Real Ear Target
<-----Left------> <-----Right----->
FREQ HTL TARG UCL HTL TARG UCL
Hz <----------re dBSPL----------->
T A U T A U
250 23.0 55.9 108.0
500 35.0 57.2 110.0
750 60.2
1000 42.0 66.6 102.0
1500 70.0
2000 56.0 78.5 116.0
3000 62.0 80.7 107.0
4000 62.0 77.4 97.0
6000 81.0 67.8 106.0
8000 92.0 36.8 112.0
REDD TARG REDD TARG
dB IG dB dB IG dB
250 13.0 1.8
500 15.0 3.8
750 7.5
1000 12.0 14.6
1500 17.1
2000 16.0 19.6
3000 12.0 20.0
4000 2.0 21.0
6000 11.0 22.4
8000 12.0 0.0
Fit Rule NAL-NL1 NAL-NL1
Age: Adult
* - Modified
dB
110
100
90
80
70
60
50
40
30
.25 .5 1 kHz 2 4 8
Source: Comp ANSI 65 dB
Left
GAIN
dB
20
10
0
-10
SPL
dB
80
70
60
50
40
30
20
10
0
Source: Comp ANSI 65 dB
Right
Corrected for my REDD
Use UP/DOWN to select frequency. Use LEFT/RIGHT to enter the dB.
Press MENU for local menu. Press EXIT to leave screen.
Printer Status:
head up
F1 Left lect Ear
F2 REDD Select Crv
F3 NAL-NL1 Select Rule
F4 Curve Actions
F5 Source Settings
F6
F7
F8
SETUP 1
2010-11-03
12:03:26

Uncorrected



Final correction



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Final Thoughts-1

- **Unfortunately, in the US, I do not see widespread use of REM unless financial penalties are adopted as occurs in some other countries (e.g., Canada, Brazil, Australia).**
- **The impact, if any, of using average versus individual REUG for REIG measures has not been investigated.**
- **For the most accurate REAR measures, it intuitively makes greater sense to use the individual's DR as the target and a target based on average transformations.**

Final Thoughts-2

- Unfortunately, in the US, I do not see widespread use of REM unless financial penalties are adopted as occurs in some other countries (e.g., Canada, Brazil, Australia).
- The impact, if any, of using average versus individual REUG for REIG measures have not be investigated.
- For the most accurate REAR measures, it intuitively makes greater sense to use the individual's DR as the target and a target based on average transformations.

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