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Let's Start With Some Context

- Hearing Assistance Technologies (HAT)
  - Remote Microphone Hearing Assistance Technologies (subject of the AAA Guidelines For Children and Youth – April 2008, updated April 2011)
    - Sound-field Systems (Audio Distribution Systems)
    - Ear-level FM Systems (receiver integrated with HA)
    - Ear-level FM Systems (inductive loop)

FM System Illustration

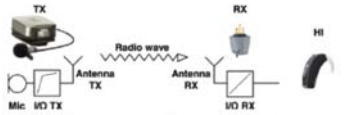

Figure 1. Illustration of an FM system, comprising a transmitter (TX) or remote microphone and a receiver (RX) connected to a hearing instrument (HI).

Platz, R., "SNR Advantage, FM Advantage and FM Fitting", Chapter 14 in ACCESS 2003 Phonak Proceedings *https://www.phonakpro.com/.../2003proceedings_**chapter14**.pdf*

FM System Purpose

- To help people better understand speech in noisy situations
  - The person speaking wears or holds a transmitter microphone, or this microphone is placed in the middle of a group
  - Radio waves send this signal to the listener who wears a receiver typically located behind the ear.

American Academy of Audiology Clinical Practice Guidelines – "Remote Microphone Hearing Assistance Technologies For Children and Youth From Birth To 21 Years", April 2008

FM System Uses

- In the classroom:
  - To create a favorable S:N ratio for the teacher's voice in comparison to environmental sounds
- For personal use:
  - To enhance the S:N ratio delivered to the listener's ear beyond what a head-worn directional microphone alone can do

Examples of FM Transmitters

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Other Wireless Remote Mics

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Examples of FM Receivers

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Goals When Fitting FM Systems

- Audibility of the person wearing the FM transmitter/microphone
- Audibility of self
- Audibility of others at a variety of distances

For this webinar, these goals will be demonstrated using the FM+HA mode

Lewis, D.E., "Electroacoustic Evaluation of Advanced FM Systems" AudiologyOnline, November 13, 2006

Reference Guidelines

FM SYSTEM VERIFICATION

ASHA 1994

"Guidelines For Fitting and Monitoring of FM Systems"

- "Equal Output Approach"
  - Output for FM system with 80 dB SPL input should be matched to the output of the hearing aid's environmental microphones with 65 dB SPL input
    - Can only be useful if FM and EM are used separately
      - If they are used together, this approach would eliminate the SNR advantage the FM system should provide

ASHA 2002

"Guidelines For Fitting and Monitoring of FM Systems"

- "Equal Gain Approach"
  - Measure HA output with a 65 dB SPL 1 kHz pure tone
  - Measure FM output with a 65 dB SPL 1 kHz pure tone
    - Adjust to match the FM output with HA result
- "FM Advantage Approach"
  - Measure FM output with a 80 dB SPL 1 kHz pure tone
    - Look for a 10 dB increase in output relative to above
  - After adjustment, run a full frequency response curve using speech-weighted input (set to 80 dB SPL at 1 kHz) and confirm that the desired FM advantage is maintained for octave frequencies 500 to 2000 Hz

Why 10dB?

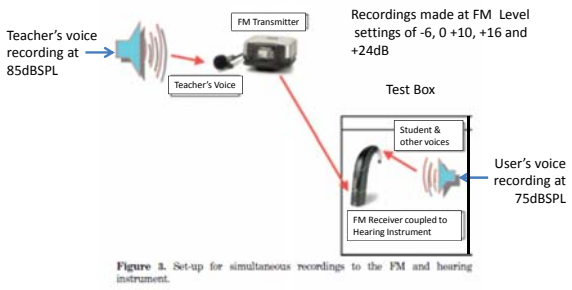
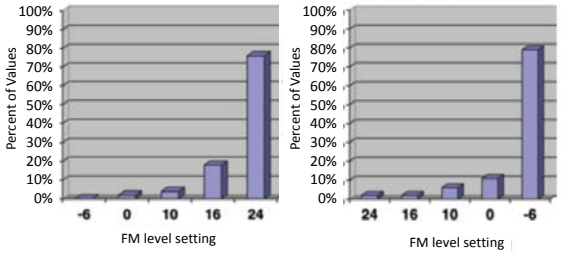


Figure 1. Set-up for simultaneous recordings to the FM and hearing instrument.

Lewis, D.E. & Eiten, L.E. (2004a). Assessment of advanced hearing instrument and FM technology. In D.A. Fabry and C. DeConde Johnson (Eds.), ACCESS: *Achieving Clear Communication Employing Sound Solutions-2003. Proceedings of the First International FM Conference*. (pp. 167-174). Phonak AG

Results

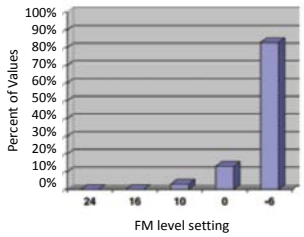


Voting results for audibility of teacher's voice by FM level setting

Voting results for audibility of self by FM level setting

Lewis, D.E. & Eiten, L.E. (2004a). Assessment of advanced hearing instrument and FM technology. In D.A. Fabry and C. DeConde Johnson (Eds.), ACCESS: *Achieving Clear Communication Employing Sound Solutions-2003. Proceedings of the First International FM Conference*. (pp. 167-174). Phonak AG

Results



Voting results for audibility of other voices by FM level setting

Lewis, D.E. & Eiten, L.E. (2004a). Assessment of advanced hearing instrument and FM technology. In D.A. Fabry and C. DeConde Johnson (Eds.), ACCESS: *Achieving Clear Communication Employing Sound Solutions-2003. Proceedings of the First International FM Conference*. (pp. 167-174). Phonak AG

FM Advantage Level Setting Recommendations

- Lecture = +16dB
- Classroom discussion = +10dB
- Conference – = +6dB
- **Compromise level = +10dB**

Lewis, D.E. & Eiten, L.E. (2004a). Assessment of advanced hearing instrument and FM technology. In D.A. Fabry and C. DeConde Johnson (Eds.), ACCESS: *Achieving Clear Communication Employing Sound Solutions-2003. Proceedings of the First International FM Conference*. (pp. 167-174). Phonak AG

SNR Advantage vs. FM Advantage

- SNR Advantage:
  - Compares the SNR of the FM signal to the SNR of the hearing instrument microphone signal and thus compares the SNR benefit with and without the FM.

Lavalier Mic

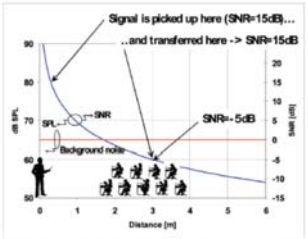


Figure 6. Speech level as a function of distance from the speech source (assuming a simplified 6 dB loss every doubling of distance) and resulting SNR values for a given background noise level of 65 dB-SPL.

Platz, R., "SNR Advantage, FM Advantage and FM Fitting", Chapter 14 in ACCESS 2003 Phonak Proceedings *https://www.phonakpro.com/.../2003proceedings_**chapter14**.pdf*

Boom Mic

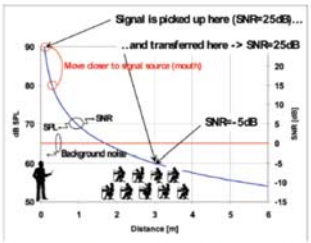


Figure 7. Speech level as a function of distance from the speech source (assuming a simplified 6 dB loss every doubling of distance) and resulting SNR values for a given background noise level of 65 dB-SPL.

Platz, R., "SNR Advantage, FM Advantage and FM Fitting", Chapter 14 in ACCESS 2003 Phonak Proceedings *https://www.phonakpro.com/.../2003proceedings_**chapter14**.pdf*

SNR Advantage vs. FM Advantage

- FM Advantage:
  - Measures relative loudness of both signals when FM mic signal and HA mic signal are active *at the same time.* This condition corresponds to the FM + HA Mode
    - Works well if HA is linear
    - If HA is not linear, the ASHA 2002 result will not reflect what happens when BOTH microphones are being stimulated with input

Which Highlights A Key Point

Can we use sequential measures to determine simultaneous performance?

- Sequential testing method:
  - Test HA output alone
  - Test FM output alone
- Simultaneous use:
  - Both HA and FM signals are being delivered simultaneously

The Answer is YES, if:

- The transmitter and HA microphones are manipulated by the same amount of compression:
  - This means inputs are of the same magnitude
- The input levels are below the kneepoint of the FM system
  - This is the kneepoint of the FM Offset feature

FM Offset Kneepoint Feature Defined

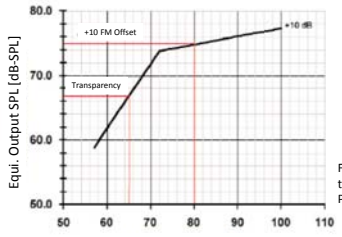


Fig. 1: Overall I/O of a Phonak transmitter combined with a Phonak MLxS receiver.

As long as the input level is below the offset kneepoint, transparency exists

2006 Phonak FM Offset Protocol from Phonak.com

Stimulus Options

- Constant level pure tones
- Speech-weighted pure tones
- Composite noise
- Speech-weighted composite noise
- ICRA signals
- Digital speech in noise signals
- Calibrated real speech
- Uncalibrated real speech (speech live)

- Because speech IS the signal of interest, test equipment with a real speech signal have been demonstrated to provide the best representation of the performance of both the FM and hearing instrument devices.

Lewis, D.E. & Eiten, L.E. (2004a). Assessment of advanced hearing instrument and FM technology. In D.A. Fabry and C. DeConde Johnson (Eds.), ACCESS: *Achieving Clear Communication Employing Sound Solutions-2003. Proceedings of the First International FM Conference*. (pp. 167-174). Phonak AG

Scollie, S.D. and Seewald, R.C. (2002). Evaluation of electroacoustic test signals I: comparison with amplified speech. *Ear and Hearing, 23(5), 477–487.*
Scollie, S.D. (2003). Hearing aid test signals: what's new and what's good for kids? *The Hearing Journal, 56(9),* 10–15.
Stelmachowicz, P.G., Kopun, J., Mace, A.L. and Lewis, D.E. (1996). Measures of hearing aid gain for real speech. *Ear and Hearing, 17(6), 520–527.*

AAA 2008

"Remote Microphone Hearing Assistance Technologies For Children and Youth From Birth to 21 Years" (April 2008)

- Supplement A (April 2011) "Fitting and Verification Procedures for Ear-Level FM"
  - Addresses the following user groups:
    - Children and youth with hearing loss who are actual or potential hearing aid users
    - Children and youth with cochlear implants
    - Children and youth with normal hearing sensitivity who have special listening requirements

The Other Supplements

- Supplement B: "Classroom Audio Distribution Systems: Selection and Verification", (July 2011)
- Supplement C: "Induction Loop System Fitting and Verification Procedures", (under development)

Fitting Goals of Supplement A

- To deliver an FM fitting that results in the following:
  - Speech recognition that is commensurate with performance in ideal (i.e., quiet, average speech) listening conditions
  - Full audibility of self and others (EM)
  - Reduced effects of distance, noise and reverberation (FM)

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Verification Priorities

- FM system should increase the level of speech in the listener's ear by at least 10 dB relative to HA only
- If system typically has both FM + HA mics active, then tests should be performed in the FM + HA position
- Assess electroacoustic performance with the same speech-weighted input signal for both HA and FM system (calibrated speech)
- MPO is assessed with HA microphone

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Steps That Are Outlined In Supplement A

- Electro-acoustic testing
  - Purpose: to verify transparency
    - Transparency (Operational definition): Transparency in an ear-level FM system is attained when inputs of 65dBSPL to the wireless and hearing aid microphones produce equal outputs from the hearing aid.
- Behavioral testing
  - Purpose: to confirm that the selected system functions as expected on a student/child
    - Speech-in-noise tests with HA alone and with wireless mic in place.

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Guideline Terminology

- E = Electroacoustic measurement
- R = Real Ear measurement
- B = Behavioral measurement
- HA = Hearing aid only
- FM = FM only
- FM/HA = FM evaluated in the FM+HA setting
- HA/FM = HA evaluated in the FM+HA setting
- DB_{SPL} = Input level specified in dBSPL
- DB_{HL} = Input level specified in dBHL
- $50/50_{HL}$ = Signal in noise presentation. Signal level is the first number

$EHA/FM65_{SPL}$

$BHA65/65_{SPL}$

Supplement A: Three Steps For

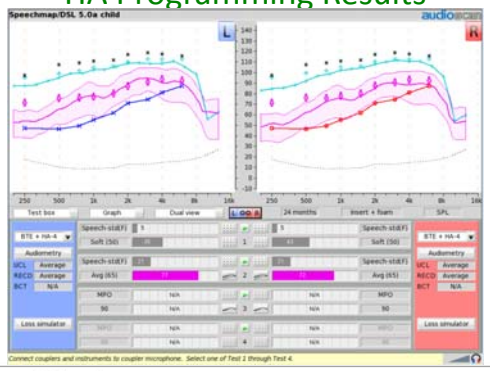
ELECTRO-ACOUSTIC TESTING OF TRANSPARENCY

Pre-test Considerations

- The hearing aids have already been adjusted to provide appropriate audibility and output prior to FM system verification
- Since the guideline outlines that transparency is being verified in a test box, a (W)RECD measurement should precede this verification testing to individualize the SPL audiogram and to simulate an on-ear result

JP34

HA Programming Results



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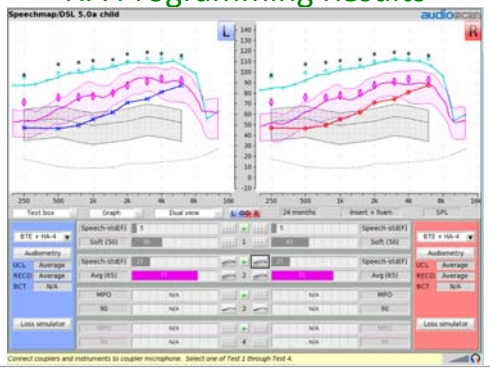
HA Programming Results



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STEP ONE:

EVALUATE EHA65$_{SPL}$ <u>WITHOUT</u> THE FM RECEIVER ATTACHED

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Procedure

1. Adjust hearing aid per typical approach for optimal audibility
2. Record HA response (65 dB SPL input) without FM receiver attached

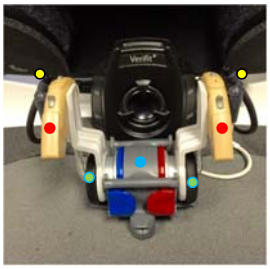
Picture of Test Box Setup

Reference Mics

Left & Right Hearing Aids (Standard Earhooks)

Bilateral Coupler Microphones

.4cc/HA-4 Couplers



Video Recording of Test One Process and Result

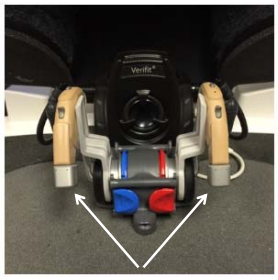
STEP TWO

EVALUATE EHA/FM65$_{SPL}$ WITH THE FM RECEIVER ATTACHED AND TRANSMITTER ON BUT MUTED

Procedure

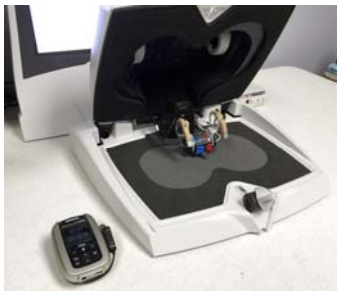
3. Attach FM receiver to HA
4. Turn on FM transmitter mic (at default FM Advantage) and set to “Mute”
5. Record HA + FM response (65 dB SPL input) . Should look virtually identical to Test 1 (HA only).

Picture of Test Box Setup



FM Receivers

Transmitter Setup



Video Recording of Test Two Process and Result

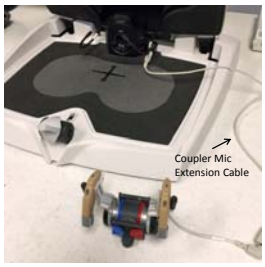
STEP THREE

EVALUATE EFM/HA65$_{SPL}$ WITH THE FM TRANSMITTER ON AND IN THE BOX AND THE COUPLER/HA OUTSIDE THE BOX

Procedure

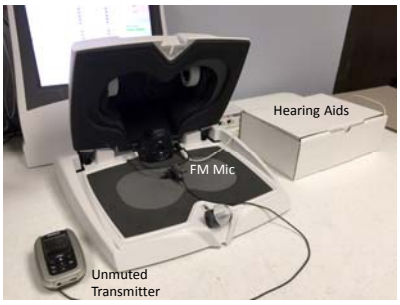
6. Move HA/coupler assembly outside test box (ideally in a sound isolating environment).
7. Unmute transmitter and place transmitter microphone in test box at appropriate test location
8. Record FM + HA response (65 dB SPL input) . Should look virtually identical to Test 2.

Coupler Microphone Setup



Transmitter Setup

Completed Setup



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Video Recording of Test Three Process and Result

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Results Calculation Worksheet

	750Hz		1000Hz		2000Hz	
	LE	RE	LE	RE	LE	RE
EFM/HA65$_{SPL}$	73	70	71	73	88	86
- EHA/FM65$_{SPL}$	74	73	70	70	86	86
Difference	-1	-3	1	-3	2	0
Average			LE = +.66 RE = -2			

If the average difference is ≤ ±2dB, do not change the FM setting
If the average difference is > ±2dB, change the FM setting and reevaluate EFM/HA65$_{SPL}$

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Video of the two LTASS displays and how the curser can be used to identify the values at each target frequency

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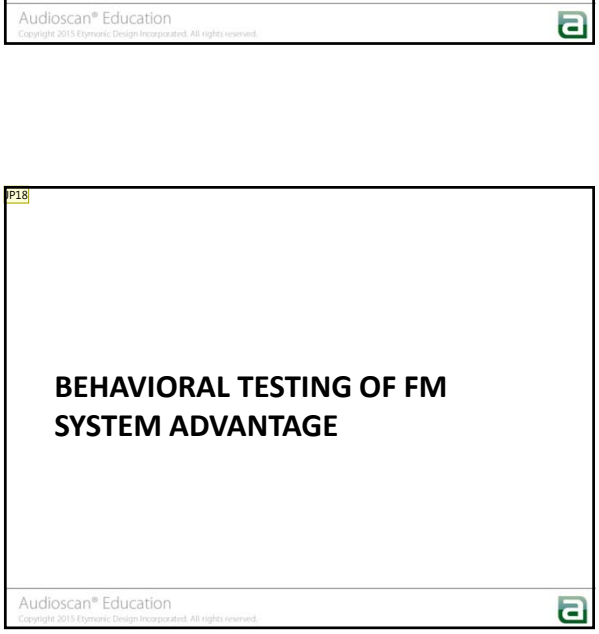

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BEHAVIORAL TESTING OF FM SYSTEM ADVANTAGE

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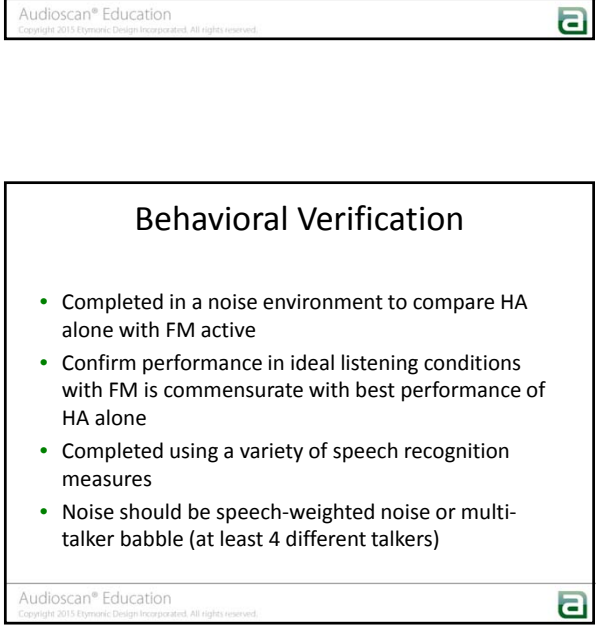

Behavioral Verification

- Completed in a noise environment to compare HA alone with FM active
- Confirm performance in ideal listening conditions with FM is commensurate with best performance of HA alone
- Completed using a variety of speech recognition measures
- Noise should be speech-weighted noise or multi-talker babble (at least 4 different talkers)

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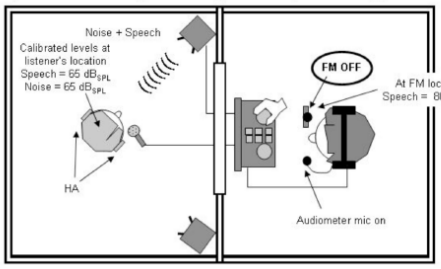
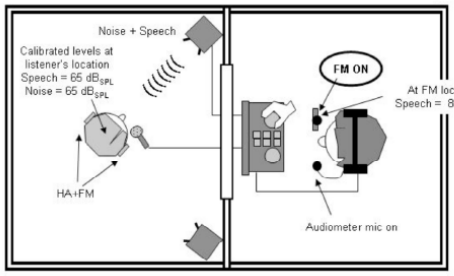
JP19 DS2

a) Behavioral testing via hearing aid alone (BHA65/65$_{SPL}$)



AAA "Remote Microphone Hearing Assistance Technologies For Children and Youth From Birth to 21 Years" (April 2008) Supplement A (April 2011) "Fitting Verification Procedures for Ear-Level FM"

b) Behavioral testing via hearing aids and FM (BHA65/65FM80$_{SPL}$)



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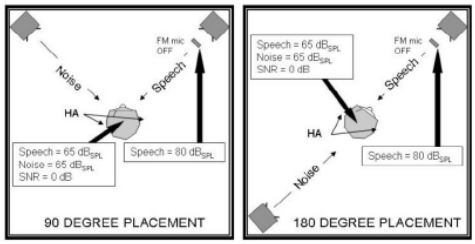

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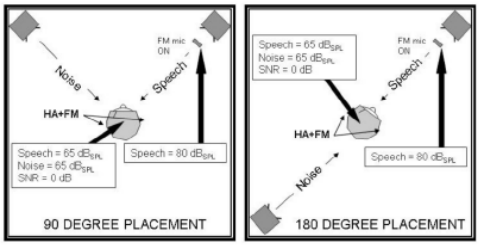

AAA "Remote Microphone Hearing Assistance Technologies For Children and Youth From Birth to 21 Years" (April 2008) Supplement A (April 2011) "Fitting Verification Procedures for Ear-Level FM"

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Results Analysis

- Speech recognition with FM in noise should be significantly improved over performance in noise with HA alone.
- Speech recognition results from the FM in noise should be commensurate with speech recognition performance in ideal listening conditions.

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Ideal Listening Conditions

- Evaluate performance of HA alone in quiet (BHA50HL)
  - FM microphone on mute or OFF
  - FM receiver on HA only or FM+M with FM microphone muted
  - Subject at 0 degrees azimuth to speaker presenting speech

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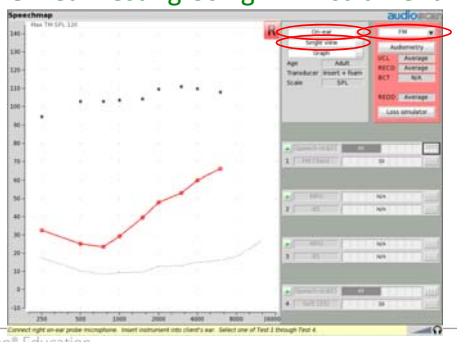
FM Microphone Placed in the Test Box

ON-EAR VERIFICATION OF FM ONLY

- Open Fittings
- Normal Hearing Assistance

Speechmap Screen Set Up To Do On-ear Testing Using FM Instrument



Test set up
FM transmitter in the test box
Patient wearing probe mic and FM receiver

JP38

Real-Ear Verification with FM Microphone Placed in Sound Chamber

- Select FM as instrument
- Complete RESR measures at maximum volume control setting

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Video of RESR measurement using DSL target

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Real-Ear Verification with FM Microphone Placed in Sound Chamber

- Select FM as instrument
- Complete RESR measures at maximum volume control setting
- Complete REAR measure at use gain setting
  - Input level chosen to correspond with FM microphone being used
    - FM Chest (84dBSPL)
    - FM Boom (93dBSPL)
  - Adjust gain to hit target in 1000Hz to 4000Hz range

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Video demonstration of REAR procedure

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Real-Ear Verification with FM Microphone Placed in Sound Chamber

- Select FM as instrument
- Complete RESR measures at maximum volume control setting
- Complete REAR measure at use gain setting
  - Input level chosen to correspond with FM microphone being used
    - FM Chest (84dBSPL)
    - FM Boom (93dBSPL)
  - Adjust gain to hit target in 1000Hz to 4000Hz range
- Repeat RESR at use gain setting

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Video demonstration of 2nd REAR procedure

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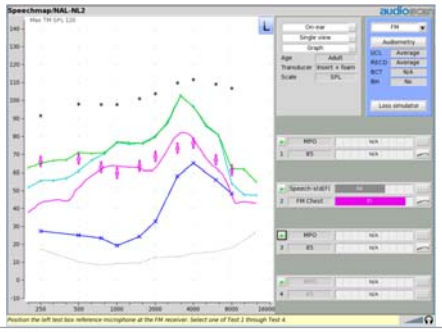
Final results screen



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Summary

- AAA 2008 guidelines, including the 2011 supplements, represent the most current thinking regarding FM system verification of modern (compression) systems
- Supplement A guideline includes:
  - An electroacoustic protocol for verifying transparency
  - A behavioral protocol for verifying FM advantage
  - An on-ear protocol for verifying FM only input signal audibility and target match

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Summary

- Speech (and ideally, calibrated speech) is the preferred stimulus to use when evaluating FM systems
- Much of this verification process can be used to verify any remote microphone technology

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