

Audiologic Evaluation of the Tympan Open Source Hearing Aid

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Metrics Evaluated

1. Throughput delay
2. Internal noise
3. Total harmonic distortion
4. Maximum output
5. Compression parameters
 - Input/output function: CT, CR
 - Attack/release times
6. Frequency response
7. Audiometric fitting range
8. Directionality

ANSI S3.22, Annex C

“Guidelines for additional optional tests to characterize hearing aids”

- C.1 Characteristics of the **gain control**
- C.2 Characterization of **battery current** as a function of quiescent current and maximum current
- C.3 Effect of **tone-control** setting on frequency response
- C.4 Effect of **output limiting** control setting on OSPL90 and full-on frequency response
- C.5 Effect of gain control setting on **frequency response**
- C.6 Effect of power supply **voltage variation** on acoustic gain and OSPL90
- C.7 Effect of power supply **impedance variation** on acoustic gain and OSPL90
- C.8 Hearing aid output **noise spectrum**
- C.9 **AGC** hearing aids
- C.10 Total harmonic **distortion** in acoustic mode as a function of input SPL
- C.11 Total harmonic **distortion** in acoustic mode as a function of frequency
- C.12 Maximum **induction coil** sensitivity measurement
- C.13 Total harmonic distortion for **induction coil** mode as a function of input magnetic field strength
- C.14 **Difference frequency distortion**

Hardware and Software

- Arduino Software v1.8.3



- Teensy 3.6 audio processing board



- Sony ECM-CS10 Lapel Electret Microphone



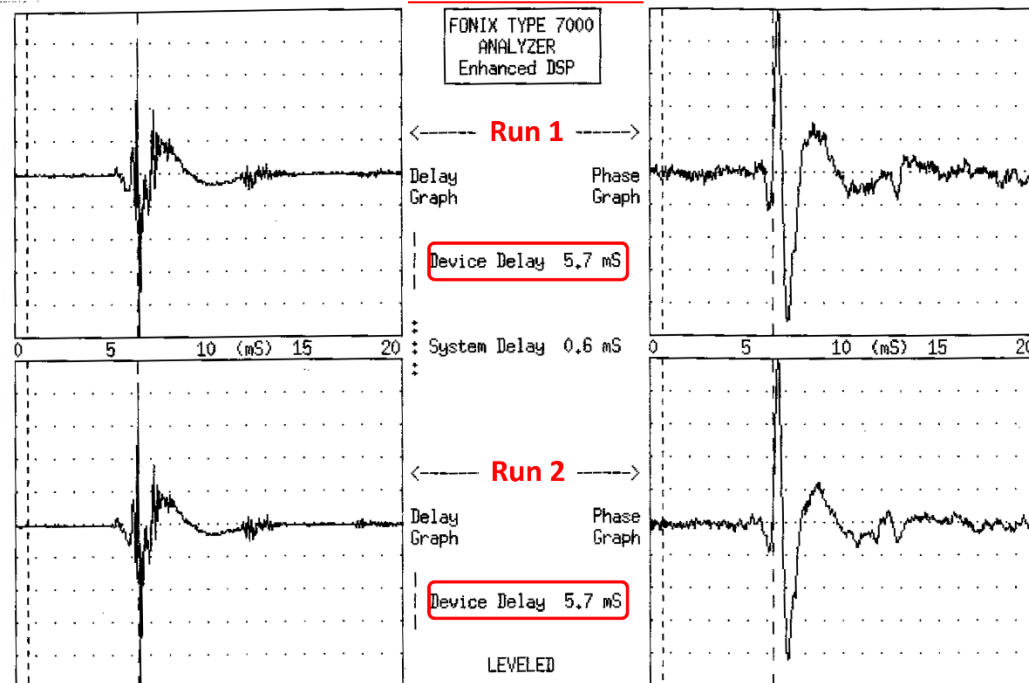
- Klipsch S4 earphones



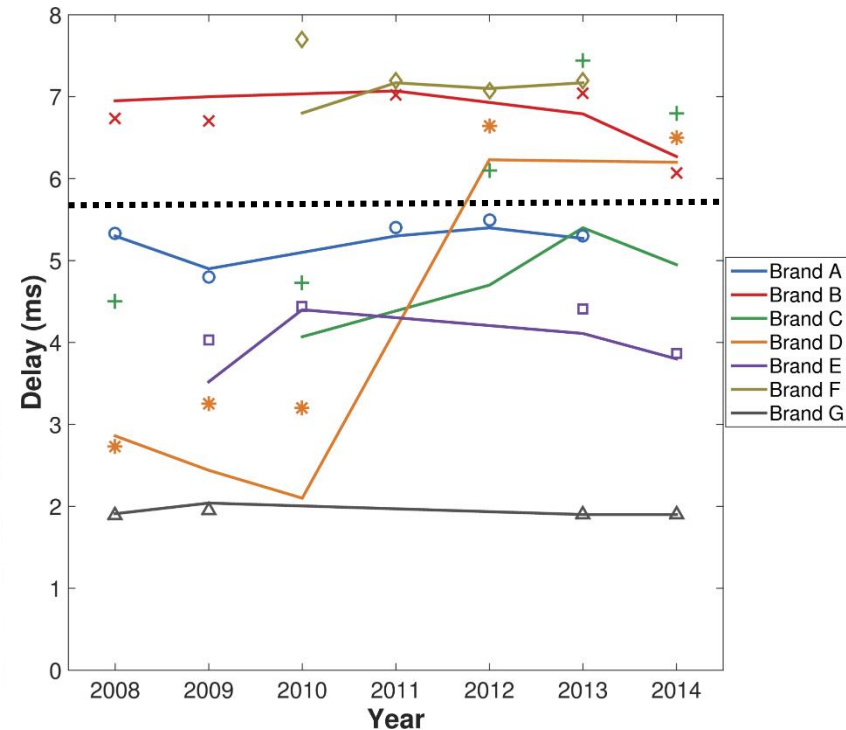
Throughput Delay

- **5.7 sec** as measured using a Frye Fonix 7000 hearing aid analyzer

Volume = +10 dB

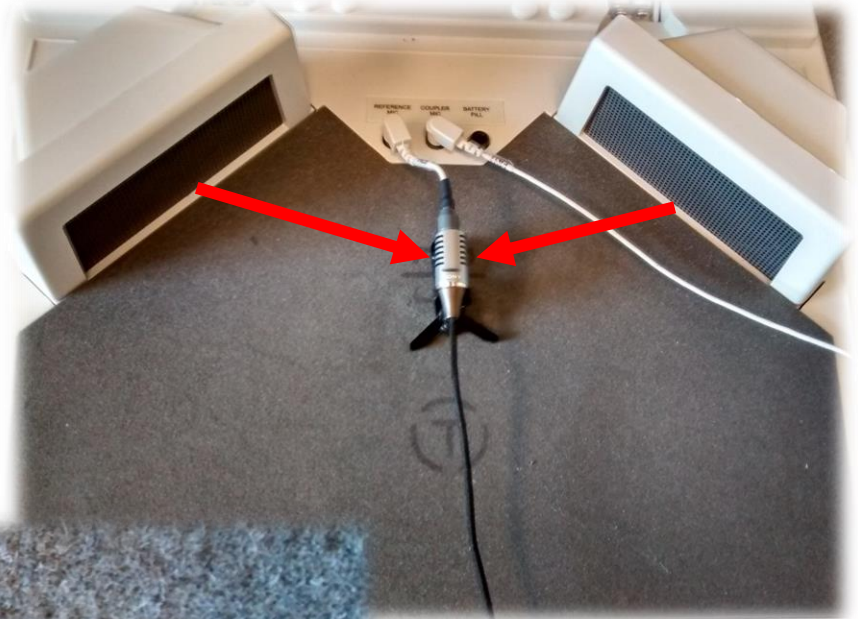


Alexander (2016)



Hearing Aid Test Box Set Up

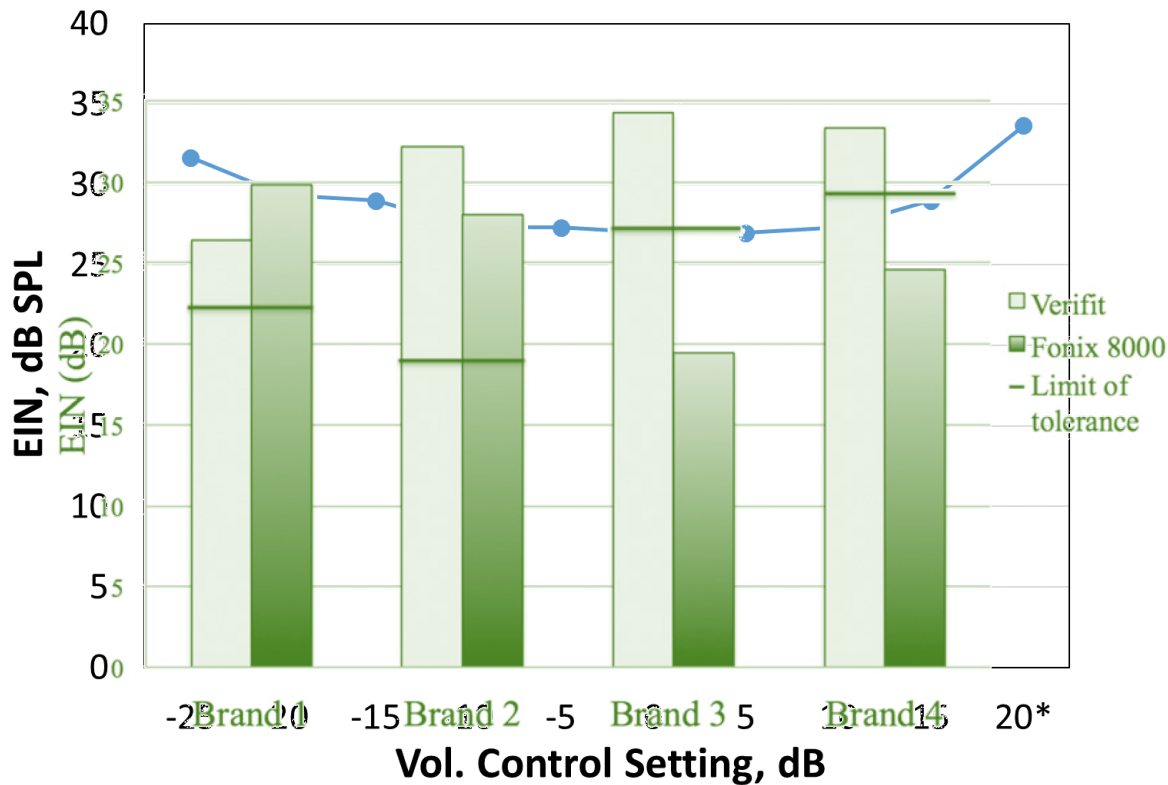
- Audioscan Verifit 1



2 cc (HA-1 coupler)

Internal Noise

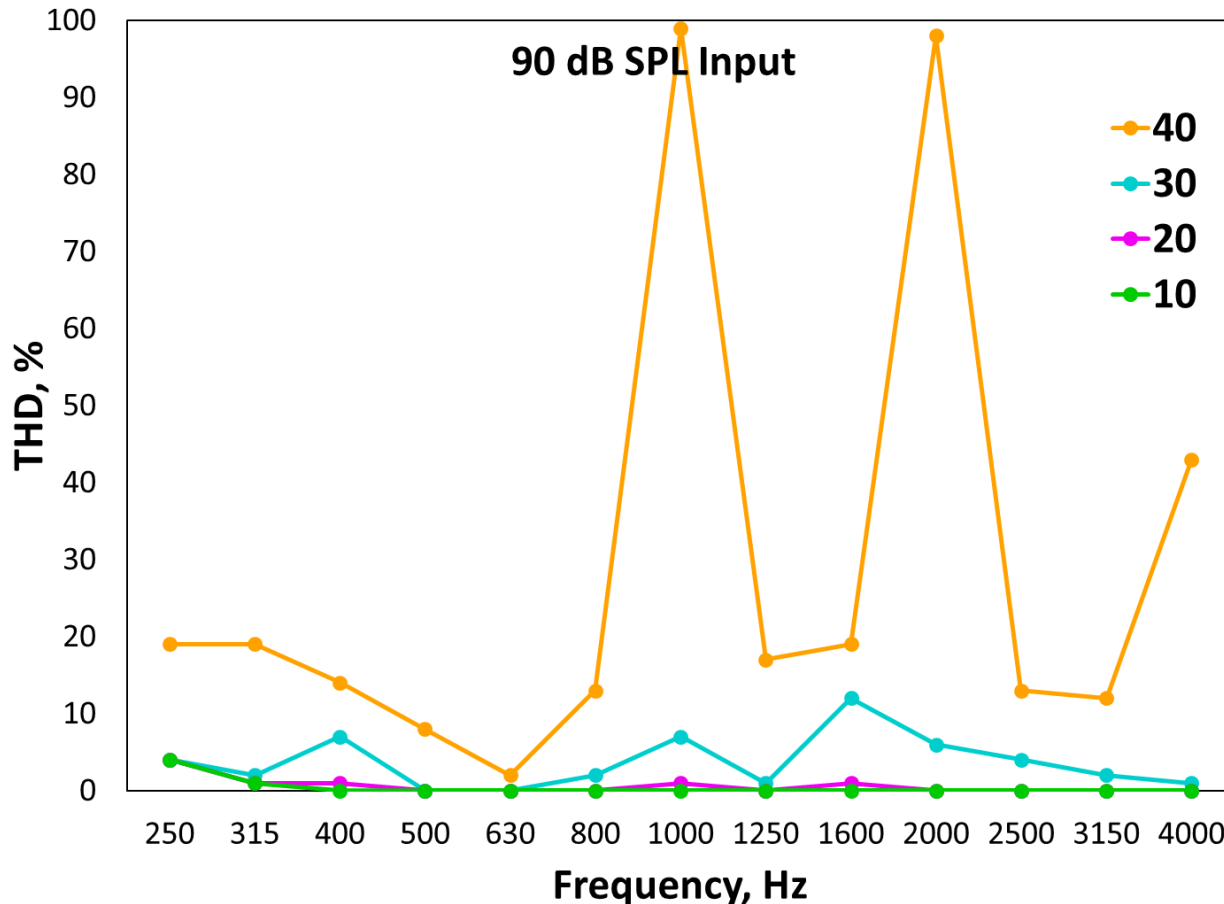
- Equivalent Input Noise (EIN)
- Expansion activated



Holder, Picou, Gruenwald, Ricketts (2016).
J Am Acad Audiol, 27, 619-627.

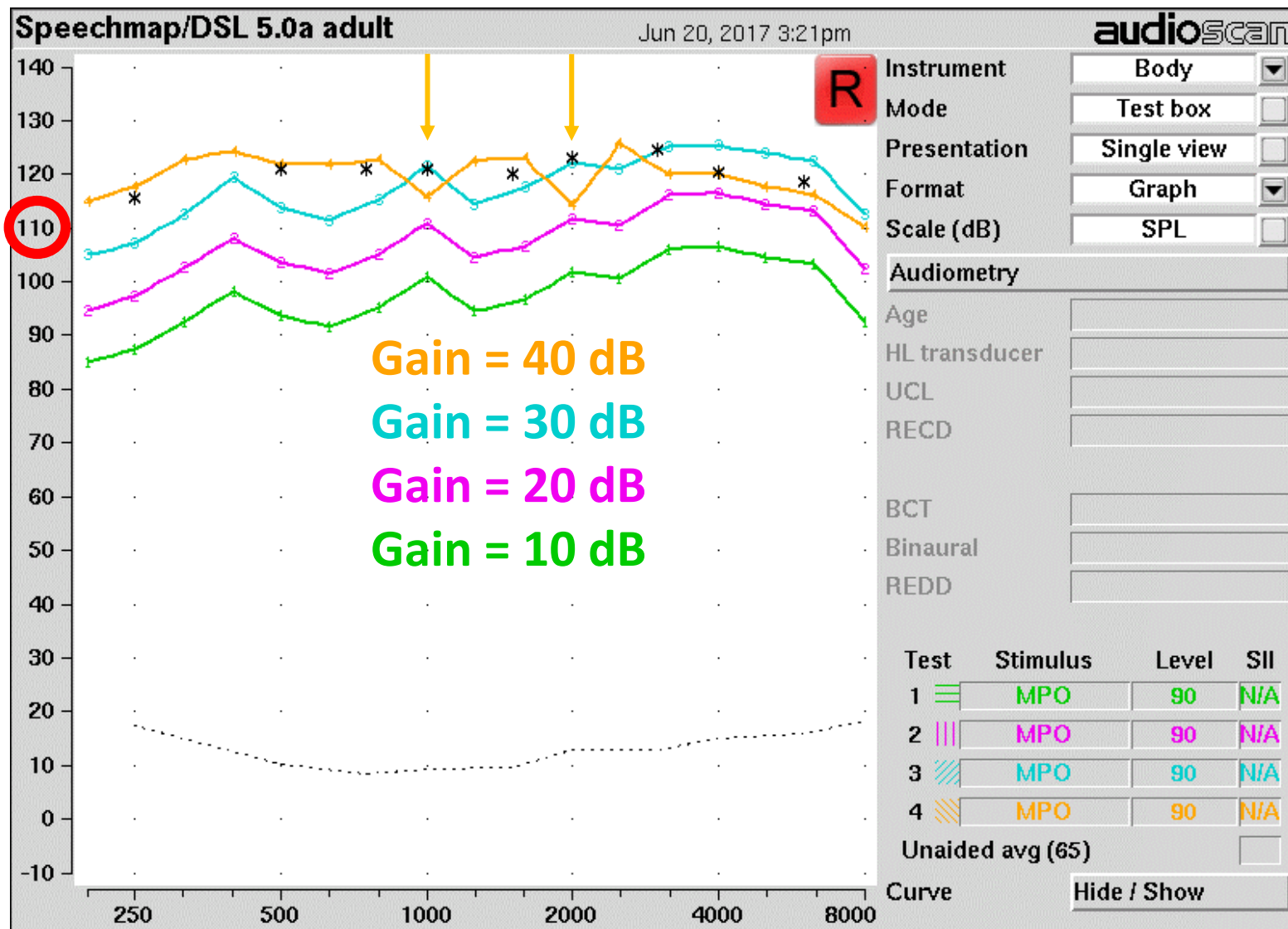
Total Harmonic Distortion (THD)

- Flat 10-40 dB **linear** gain
- Distortion only when **output** level is high
- Indicates that the front-end components (microphone, ADC, etc.) are not in saturation with high **input** levels



Maximum Output

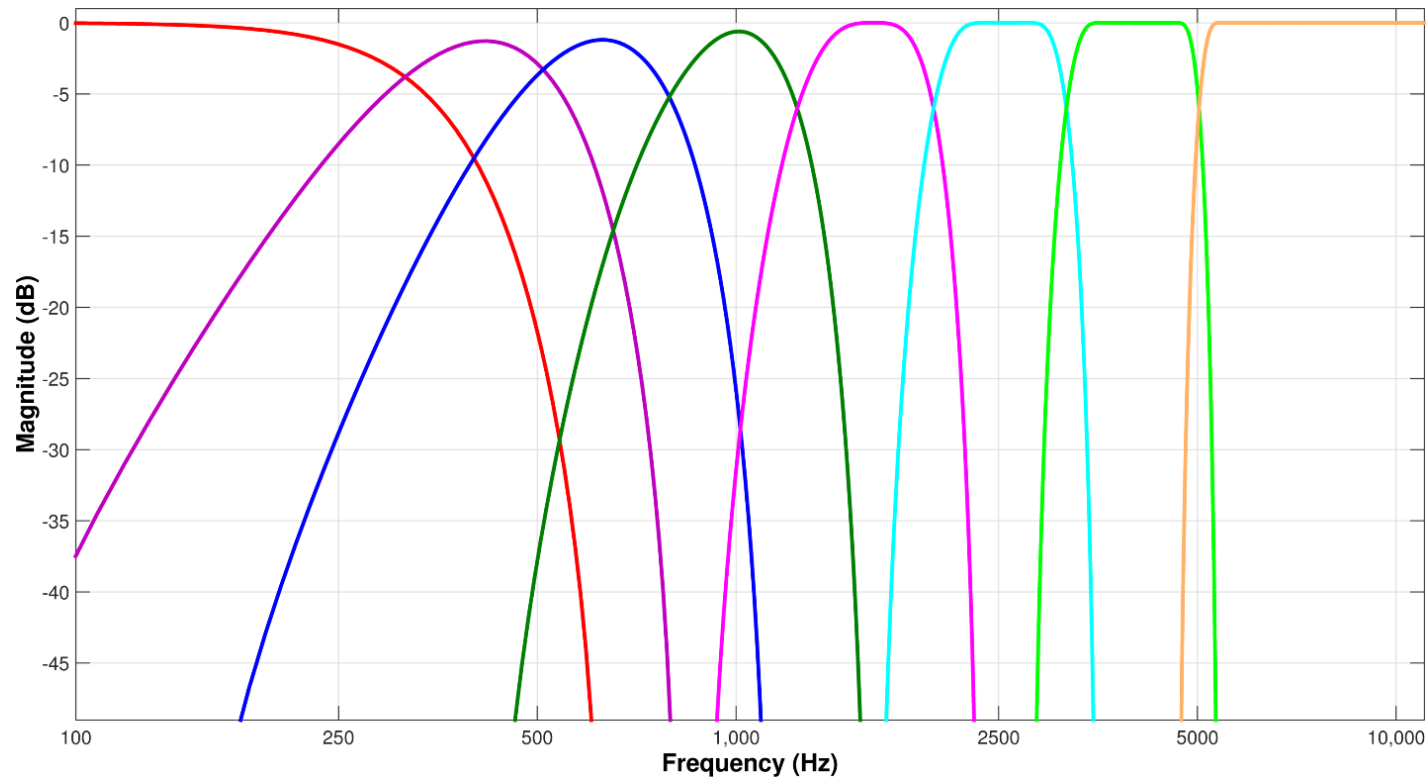
- 90-dB SPL tones; flat 10-40 dB linear gain



Settings for Moderate Hearing Loss

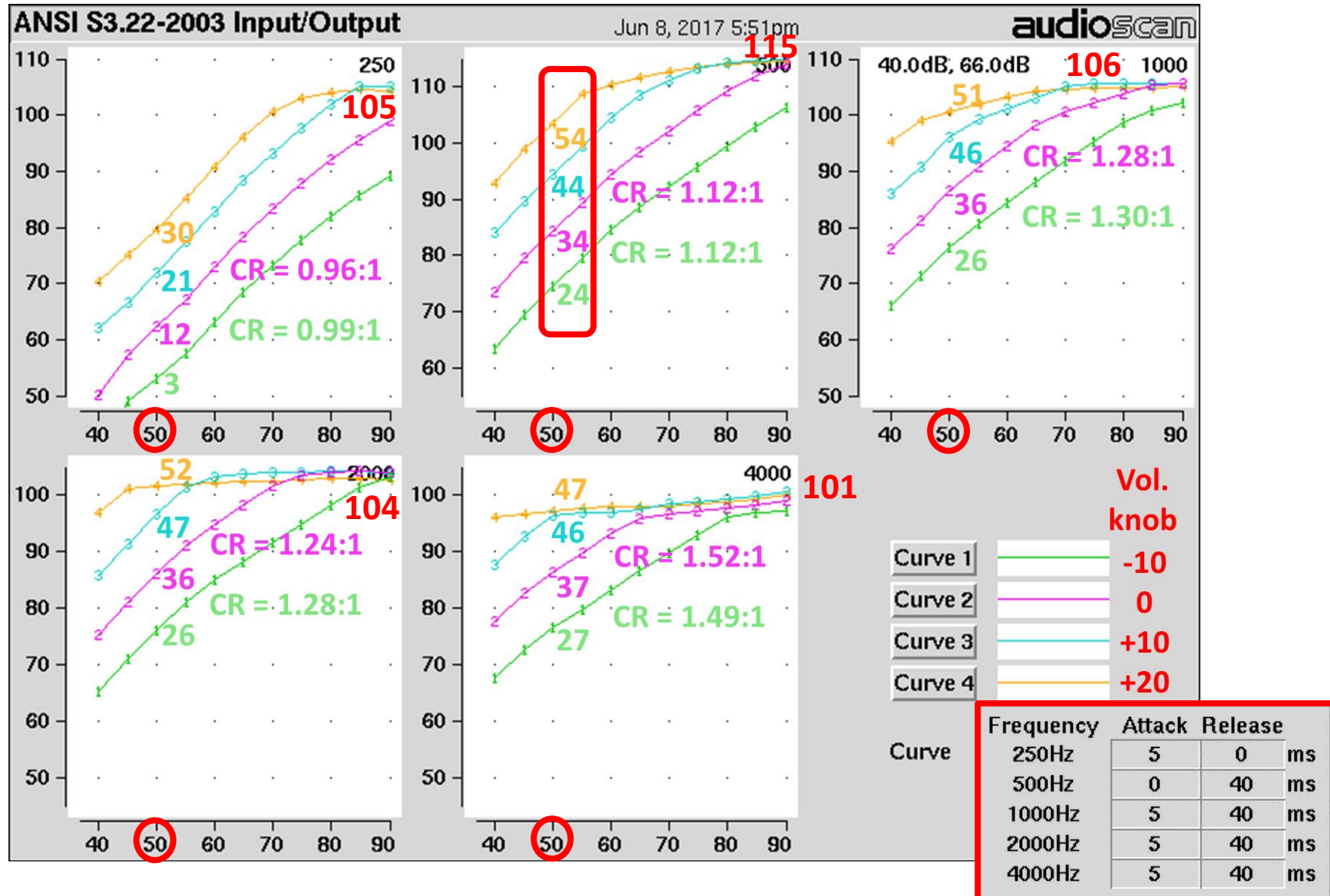
- 8-channel WDRC, 20-30 dB gain

Stage	Kneepoints	Ratios	Attack	Release
Expansion	32-45 dB SPL	1:1.75	40 ms	5 ms
Compression	50 dB SPL	1.5:1	5 ms	40 ms
Output-limiting	90/105 dB SPL	10:1	5 ms	40 ms

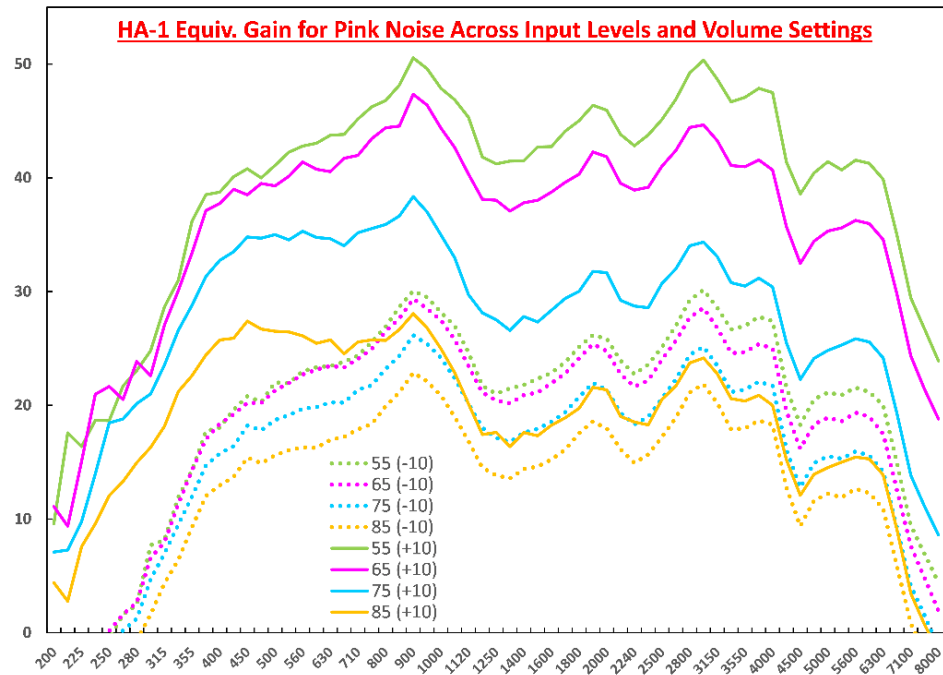
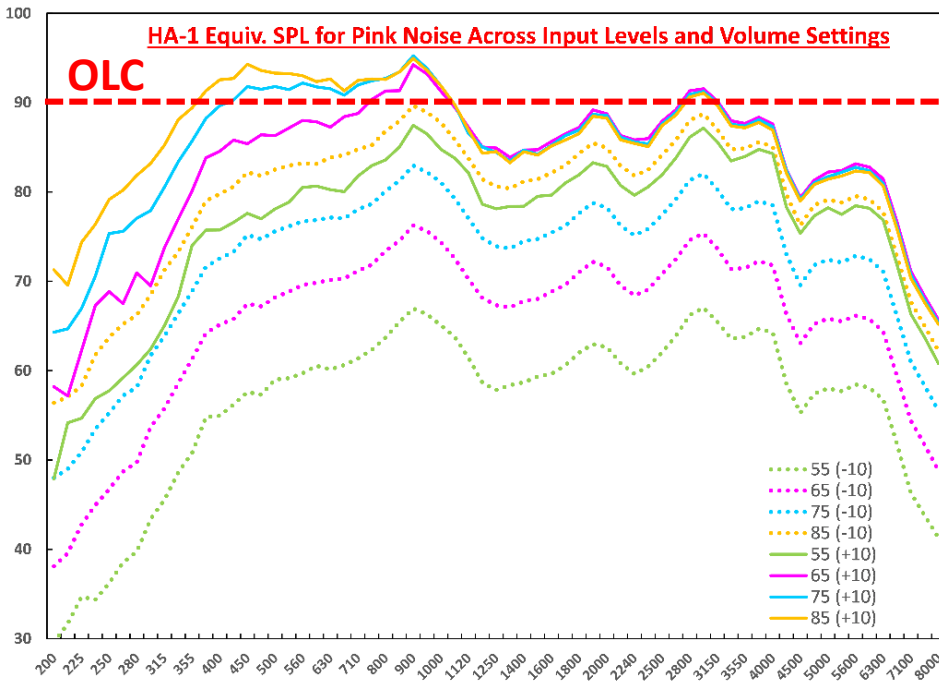


Compression Characteristics

- WDRC CT = 50 dB SPL, CR = 1.5:1; **OLC = 105 dB**



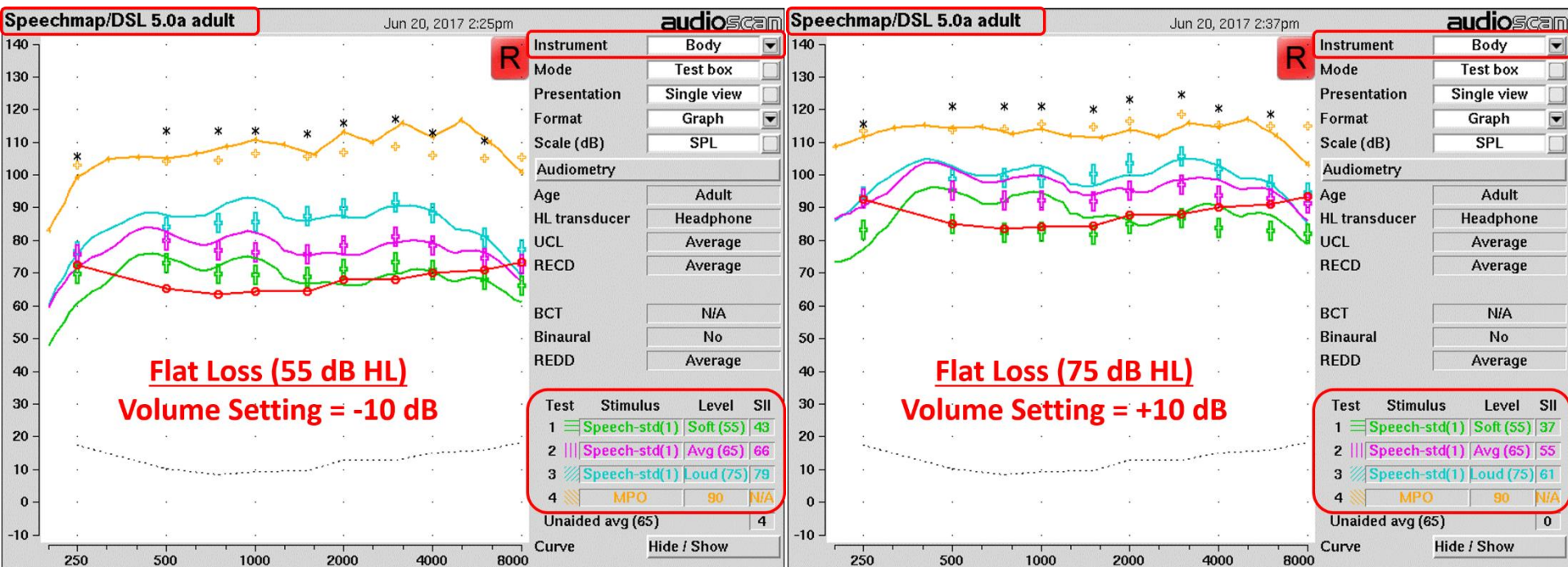
Frequency Response



- **Relatively flat** (300-4000 Hz), unvarying across changes in gain and input level
- **Output levels are effectively limited** by OLC
- Gain decreases with increasing input level (WDRC)
 - **Distortion 'free' gain at least up to 40-50 dB**

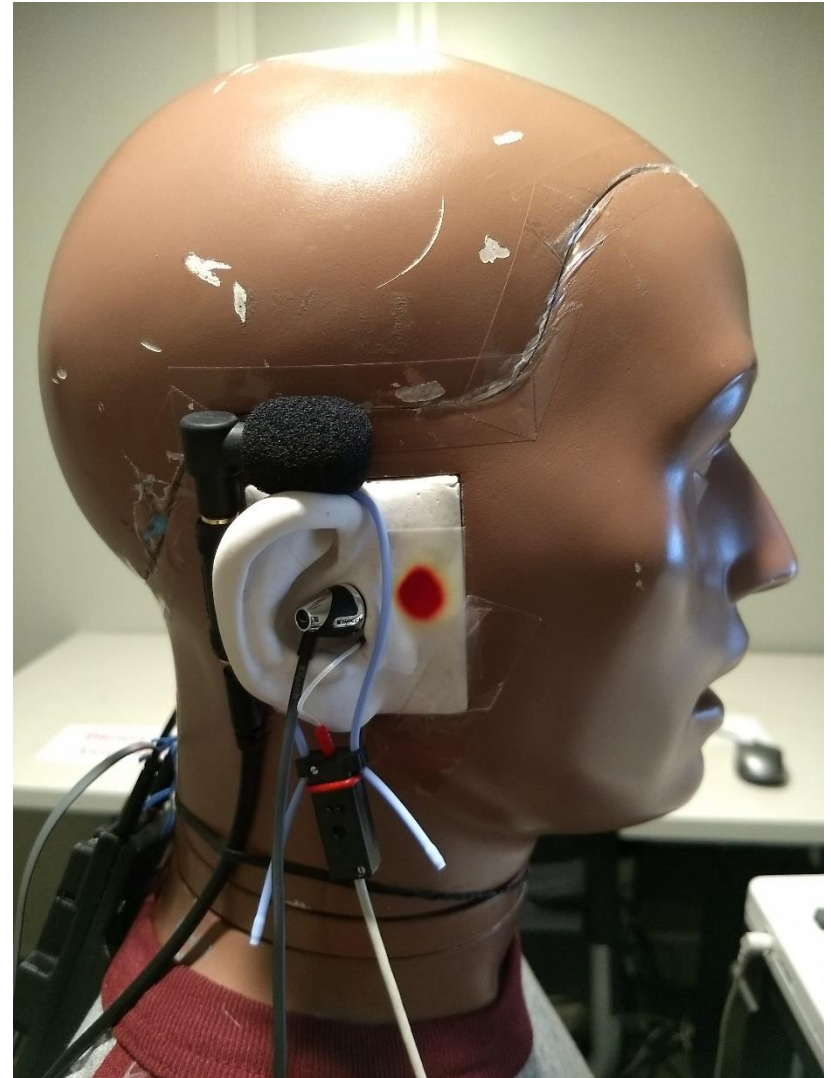
Audiometric Fitting Range

- Hearing losses up to 70-75 dB HL can easily be accommodated
 - Can amplify soft speech with relatively modest internal noise and amplify high-level narrowband sounds with relatively low distortion for these losses



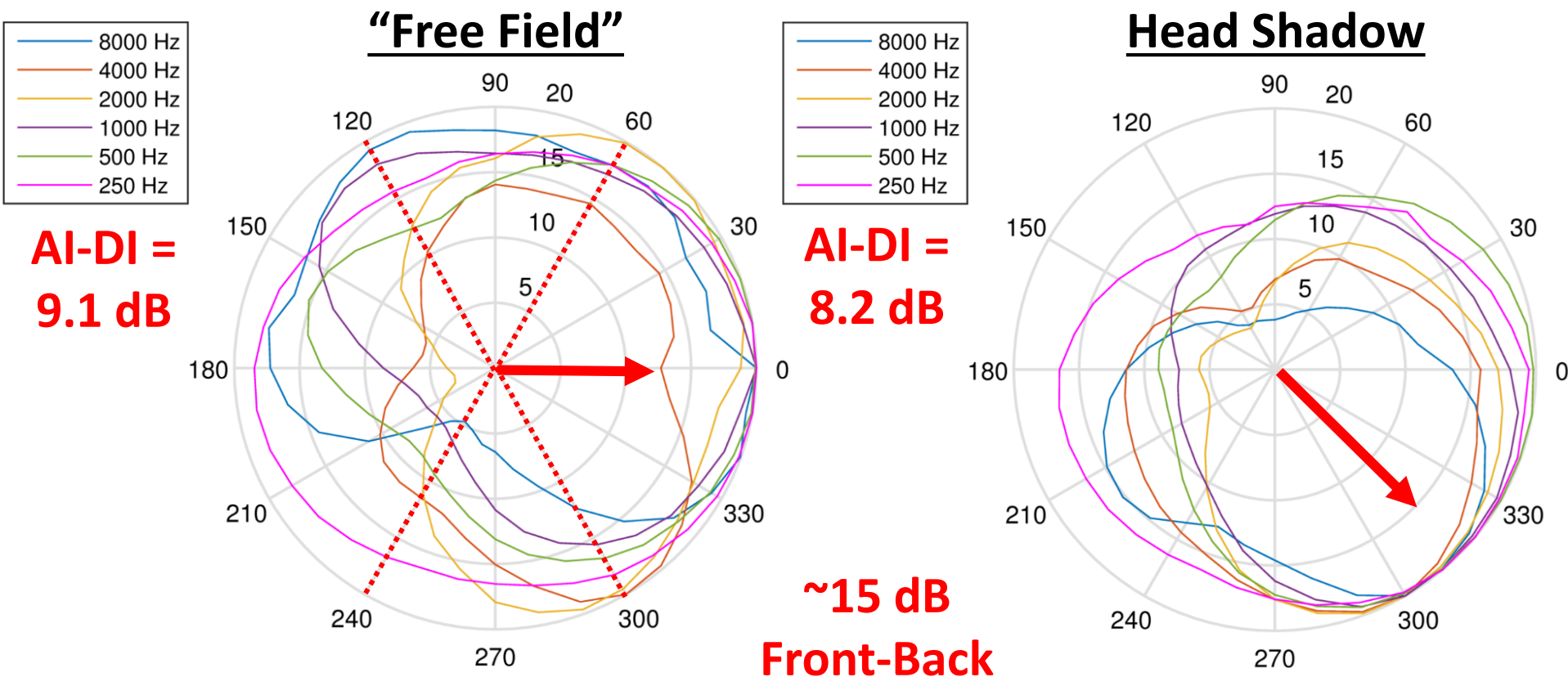
Directionality

- Generic mini boom mic



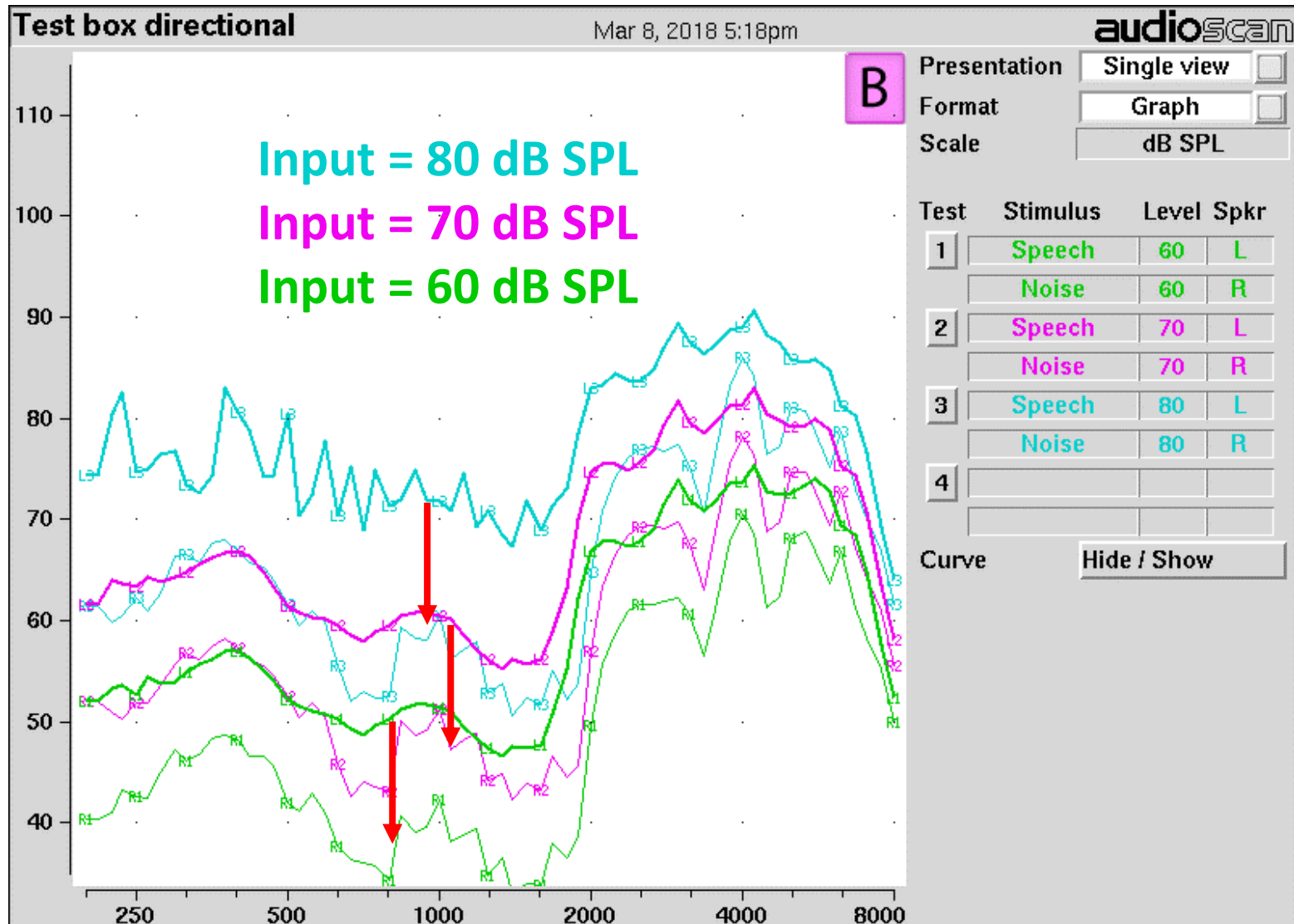
Directionality: KEMAR

- Mounted on right ear; flat 20 dB linear gain



Directionality: Test Box

- WDRC for a mild to moderate hearing loss



Summary

1. **Throughput delay:** acceptable with basic WDRC
2. **Internal noise:** expansion needed to make acceptable
3. **Total harmonic distortion:** 90 dB SPL input; 50 dB gain
4. **Maximum output:** ~110 dB SPL w/ minimal distortion
5. **Compression parameters:** WDRC parameters as advertised; OLC able to control max output
6. **Frequency response:** smooth with gain/input changes
7. **Audiometric fitting range:** ≤ 70 -75 dB HL
8. **Directionality:** basic using mini boom mic

An aerial photograph of the Purdue University campus in West Lafayette, Indiana. The image shows a dense collection of brick buildings with red roofs, interspersed with trees displaying vibrant autumn foliage in shades of yellow, orange, and red. A prominent clock tower is visible in the upper left quadrant. The overall scene is captured from a high angle, providing a comprehensive view of the university's architecture and landscaping.

Thank You!

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