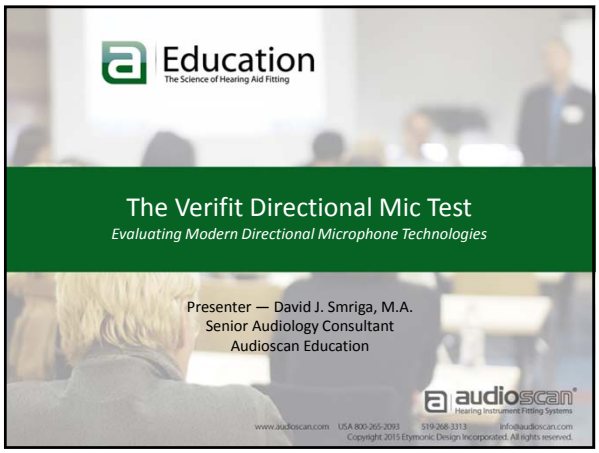

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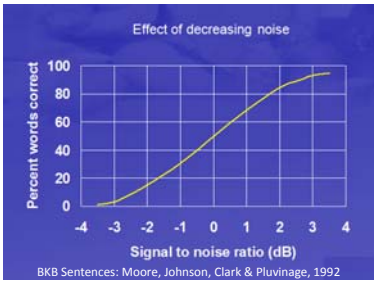
Directional Microphone Technology

- Directional technology has been available in hearing aids since 1969
- Remains to this day the single most effective "head-worn" approach to improving signal-to-noise ratio for certain listening conditions

Lybarger, S.F. & Lybarger, E.H. (2000). A historical overview. In R. Sandlin (Ed.), *Textbook of hearing aid amplification: Technical and clinical considerations, 2nd edition*. San Diego, California: Singular Thomson Learning.

SNR Impact on Intelligibility



From Dillon, H., "Hearing Aid Technology & The Future", ASA Presentation, April 2006

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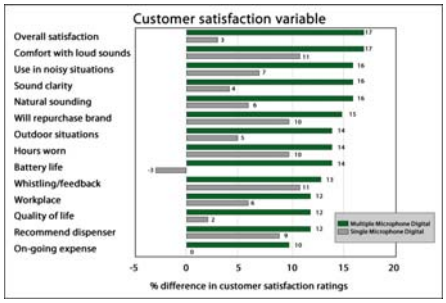
Directional Microphones Make A Difference On Key Satisfaction Factors



Kochkin S. On the issue of value: Hearing aid benefit, price, satisfaction, and brand repurchase rates. Hearing Review. 2003;10(2):12-26

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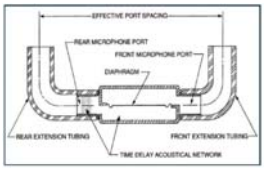
Directional Microphone History

circa. 1970's to app. 1995

- The pressure-gradient directional microphone
  - Two mic ports
    - One "front-facing"
    - One "rear-facing"
  - Ports directed to opposite sides of mic diaphragm
  - Port distance = external delay
  - Baffle in RP = internal delay
  - Polar pattern is function of ratio between external and internal delays



Described in *Knowles Electronics Technical Bulletin 21*

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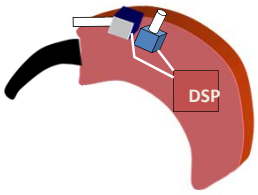
Directional Microphone History

App. 1995 to present

- Two omni-directional microphones
- Internal delay is part of DSP algorithm
  - Allows for different polar patterns
  - Allows directional mic to be "On" or "Off"
  - Facilitates automated directional mic activation



H. Dillon; NAL, CRC for CI and HAI

Modern Directional Mic Design Possibilities

Activation \ Polar Pattern	Fixed	Adaptive*
Manual	**Fixed**	**Manual/Adaptive**
Automatic	Automatic	Adaptive

** Includes broad-band and multi-band adaptive directionality*

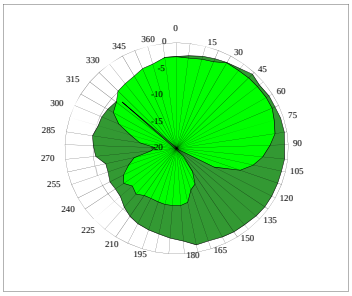
Fabry, D., "Adaptive Directional Microphone Technology and Hearing Aids: Theoretical and Clinical Implications", The Hearing Review, April 2, 2005

Remote Microphone

www.oticon.ca

Standard Specification of Directionality

Polar Plots



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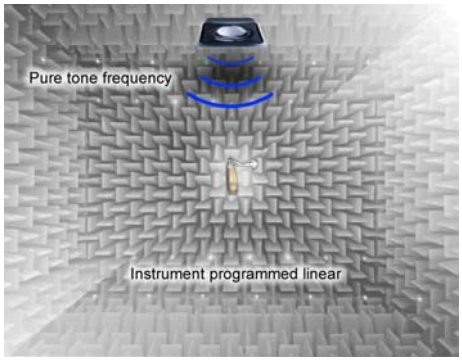

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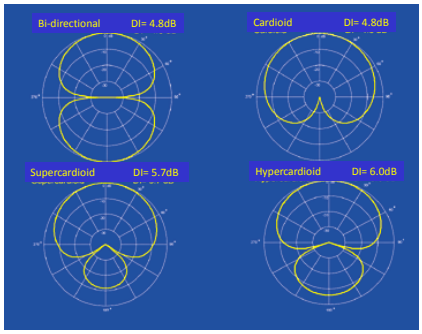

Fabry, D., "Adaptive Directional Microphone Technology and Hearing Aids: Theoretical and Clinical Implications", The Hearing Review, April 2, 2005

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KEMAR

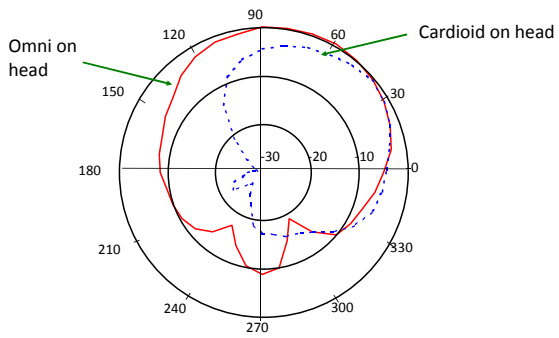

Figure 2.8 Directional sensitivity of (a) an omnidirectional (solid line) and (b) a directional (dotted line) microphone, mounted on the head at 2 kHz. Data adapted from Knowles, TB21.

Source: Dillon (2001): *Hearing Aids*

Considerations Regarding Conventional Polar Plot Testing

- Polar plots are obtained in the presence of a single pure tone frequency
- Polar plots do not measure in the presence of multiple input sources
- Polar plots can be less robust in the presence of non-linear (compression) amplification

Methods of Quantifying Directional Advantage

- Research Lab
  - The Directivity Index (DI)
    - Compares output for sounds originating from the front to output for sounds originating from all other locations
    - Expressed in dB
      - Omni directional aid would have a 0dB DI
      - Two-mic array devices can have as much as a 6dB DI
  - The AI-DI*
    - An AI (or SII) weighted version of the DI, taking into account the effects of the DI on certain speech frequencies

*Killion, M., et. al., "Real World Performance of an ITE Directional Microphone", The Hearing Journal 51(4), 1998 pp 24-38

Methods of Quantifying Directional Advantage

- Clinical
  - The Front-to-Back Ratio (FBR)
    - Comparison of output curves for the same broadband stimulus obtained with the hearing instrument at 0^o and 180^o orientation to the stimulus
  - Speech In Noise Tests
    - Fixed SNR approach: Difference between omni-directional and directional % correct = directional advantage
    - Variable SNR approach: Difference in SNR required to reach 50% correct = directional advantage
    - SIN, QuickSIN, HINT tests (and others) can be used for this purpose

Effects of Compression on FBR

TABLE 2. Single-source traditional and two-source modified front-to-back ratio values averaged within two hearing aid brands and across the four test frequencies of 500, 1000, 2000, and 4000 Hz.

	Traditional	Modified
Type B (compression off)	7.7 dB	7.7 dB
Type B (compression on)	3.9 dB	7.7 dB
Type C (compression off)	11.2 dB	11.2 dB
Type C (compression on)	3.7 dB	11.1 dB

Ricketts, T., "Directivity Quantification in Hearing Aids: Fitting & Measurement Effects"' Ear & Hearing, 2000; 21; 45-58

Education
The Science of Hearing Aid Fitting

A Unique Way of Measuring Directional Mic Performance

Multiple Input Locations
FFT Analysis

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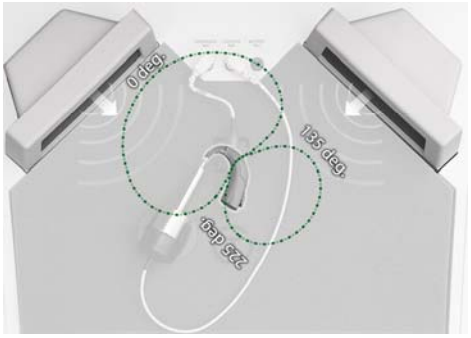
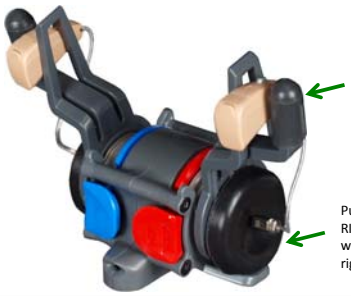
Hearing Instrument Fitting Systems

Recommended Positioning - Verifit

Recommended Positioning - Verifit



Verifit 2 Binaural Coupler



HA stabilizer can be "rocked" until front and rear mic ports of each instrument are aligned parallel to the floorboard of the text box

Putty-less TRIC adapter couples RIC and Thin Tube products to wideband .4cc coupler on both right and left coupler mics

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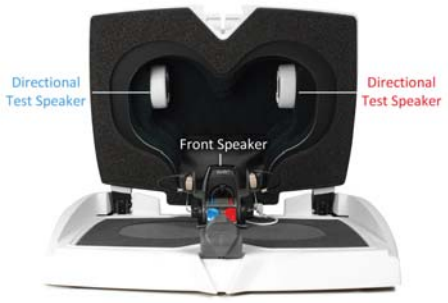
Recommended Positioning – Verifit2



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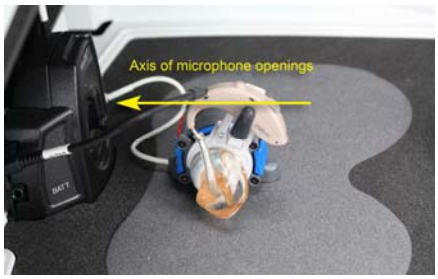
Directional in Test-box - BTE

Front speaker

Rear speaker



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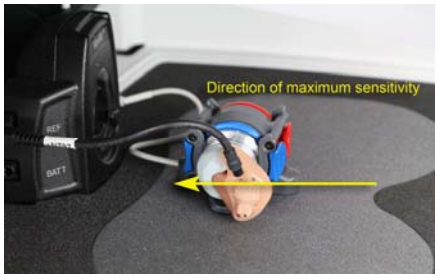
Directional in Test-box - ITE

Front speaker Rear speaker



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Directional testing

- Stimulus presented simultaneously from front and rear to condition hearing instrument directional operation.
- Periodically, short burst from only front speaker and only rear speaker used for measurement.
- Duration of measurement bursts short enough to not affect HI output.
- Two versions – Noise + Noise, Noise + Speech

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Noise + Noise Directional Test

- Simultaneous composite noise signals
- Alternates for measurement
- Rear stimulus presented longer to condition adaptive directional instruments.

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Noise + Speech Directional Test

- Speech from front speaker, noise from rear to condition speech activated directionals
- Alternating short noise bursts during measurement intervals

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DEMONSTRATION ONE:

OMNI DIRECTIONAL SWITCHING TO DIRECTIONAL

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DEMONSTRATION TWO:

DIRECTIONAL RESULTS AS A FUNCTION OF LEVEL

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DEMONSTRATION THREE:

DIRECTIONAL RESULTS AS A FUNCTION OF SIGNAL TO NOISE RATIO

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DEMONSTRATION FOUR:

ADAPTIVE DIRECTIONAL INTERACTION

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DEMONSTRATION FIVE:

TESTING A DIRECTIONAL MIC IMBEDDED IN A REMOTE MIC

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Remote Mic Considerations

- Remote microphone options (often connected to paired hearing instruments via blue tooth) can be either hand held (table top) or talker worn
- It can be a separate device or integrated into a wireless remote control
- If the remote microphone contains a directional mic, it too can be tested with the Verifit D-Mic test construct

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Positioning Remote Mic In Test Box for Directional Testing of Right HA

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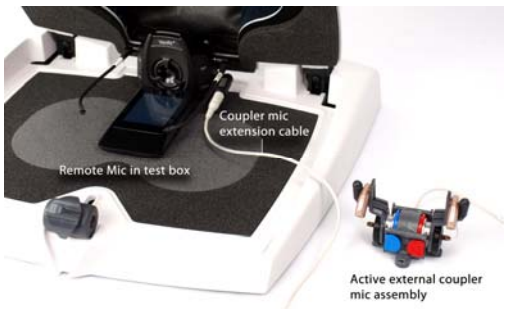
Placement of Coupler Mic Assembly Outside of the Test Box



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Omni-directional Remote Mic Setting

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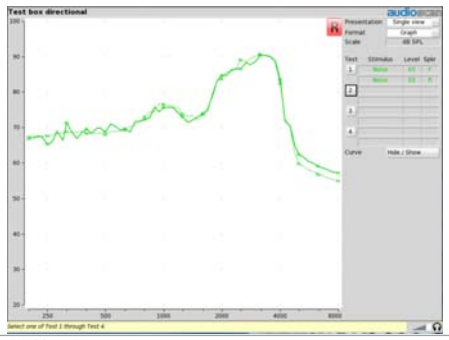
Directional Mic Test Result



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Directional Remote Mic Setting

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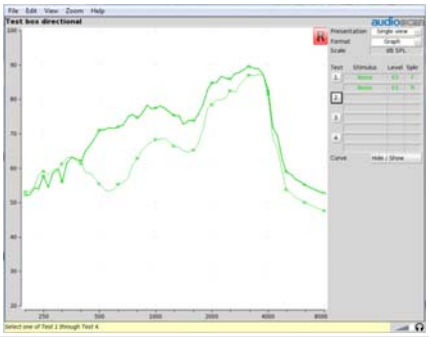
Directional Mic Test Result



DIRECTIONAL MEASUREMENT TROUBLESHOOTING

No Curve Separation

- Possible Causes:
  - Intensity level may be inadequate
  - SNR may need to be decreased
  - HA placement may be incorrect
  - The directional mic feature of the aid has not been activated
  - One or more mic ports are plugged with debris
  - The directional mic is not working

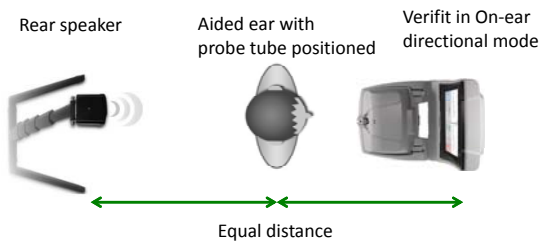
Curves Are Reversed (when not expected)

- Possible Causes:
  - HA placement may be incorrect (backward)
  - Directional mic is incorrectly wired

Poorer Curve Separation Than Initially Benchmarked

- Possible Causes:
  - HA placement may be incorrect or different
  - Current coupling ≠ original coupling
    - Slit leak
  - One or more mic ports are compromised by debris
  - Microphone drift

Directionality Test (REM)

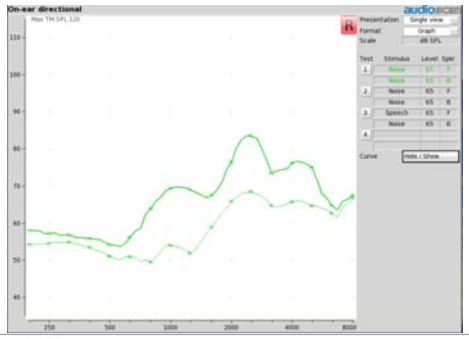


CONSIDERATIONS REGARDING ON-EAR DIRECTIONAL MIC TESTING

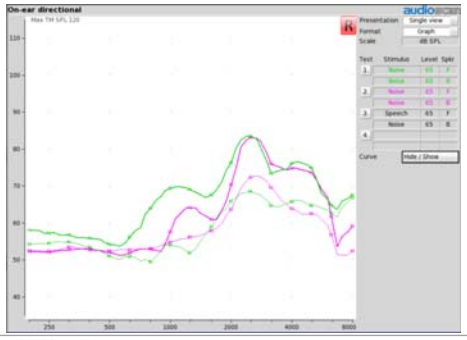
Venting

- Venting does effect directivity, especially at the low frequencies
  - Best directivity with no vent
- Low frequency sounds pass through the vent w/out attenuation

RIC w Power Dome (On-Ear)



RIC w Open Dome (On-Ear)



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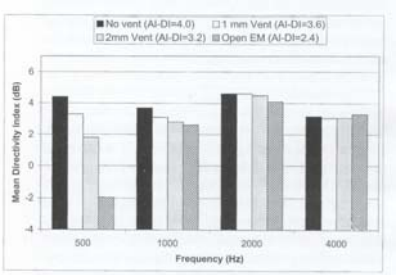

Figure 15. The average frequency specific DI and AI-DI for eight hearing aids (four each of two different models) calculated for closed earmold (closed), 1 mm, 2 mm, and open earmold (OM) venting conditions (data from Ricketts, 2000a).

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What is the impact of Venting?

- Data suggest that largest impact of vent in low frequencies (500 & 1000 Hz)
- Largest effect seen for open mold (OM)
- OM condition still resulted in significantly greater directivity than omnidirectional hearing aid
- Listeners receive significant directivity from many directional aids, regardless of venting
  - unless aid only provides directivity mainly in low frequencies

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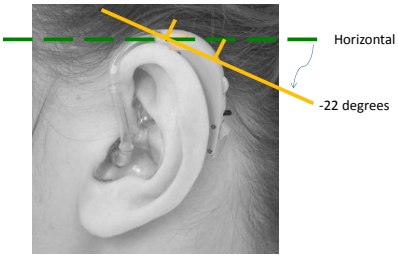
Mic Port Orientation

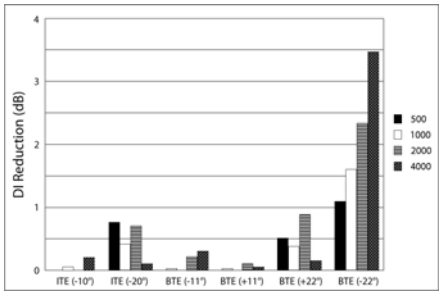
- Custom Products:
  - Modeled (or marked) representation of the horizontal plane for mic port placement on faceplate
  - May be difficult to achieve in some ears
- BTE Products:
  - Horizontal positioning will be influence by:
    - Earmold tubing length (BTE)
    - Receiver wire length (RIC)
    - Thin tube length (Thin tube)

Quantifying Mic Port Orientation



Ricketts, T., "Directivity Quantification in Hearing Aids: Fitting & Measurement Effects"' Ear & Hearing, 2000; 21; 45-58

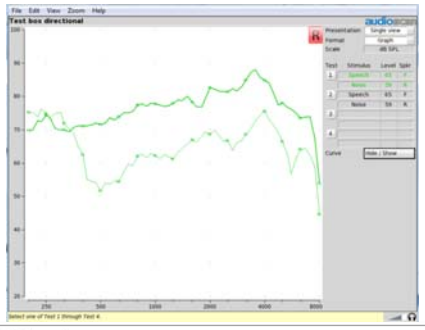
Mic Orientation Effects on DI



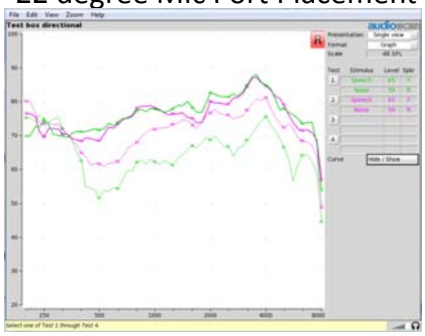
Relative to optimal (horizontal) mic port orientation

Ricketts, T., "Directivity Quantification in Hearing Aids: Fitting & Measurement Effects"' Ear & Hearing, 2000; 21; 45-58

Test-Box Directional Test
Horizontal Mic Port Placement



Test-Box Directional Test
-22 degree Mic Port Placement



Summary

- D-mics remain the most effective approach to "headworn" SNR improvement
- Through Audioscan's unique real-time independent analysis test, a great deal of practical clinical information can be obtained about D-mic functionality
- Test-box D-mic testing is both stable and robust
- On-Ear D-mic testing can be done with consideration of additional factors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