The Foundation of a Dynamic Fitting

Compression Overview

MELISSA JORDAN, Au.D. EDUCATION AND TRAINING AUDIOLOGIST

Hear better. Live better.

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Compression Overview

The Foundation of a Dynamic Fitting

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Learning Objectives

1. Define compression and give an example of what types of hearing losses are most likely to benefit from use of compression
2. Describe the difference between compression and expansion
3. Identify three scenarios where a more linear fit would be beneficial to the patient

The Foundation of a Dynamic Fitting

Compression Overview

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Starkey

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What is **Compression**?



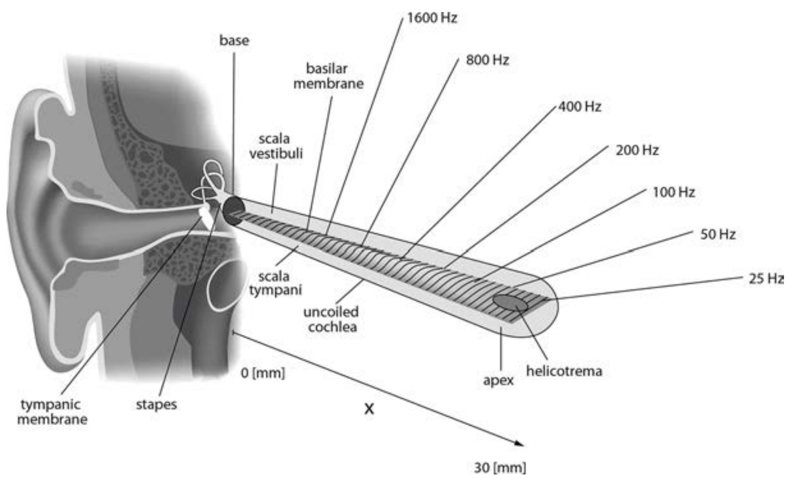



How are we able to hear all these sounds?

Physiological functions that specifically relate to compression:

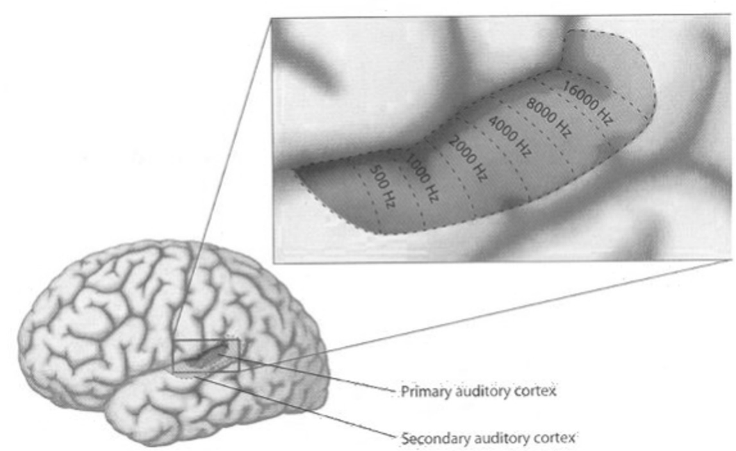
1

Non-linear functions of the cochlea

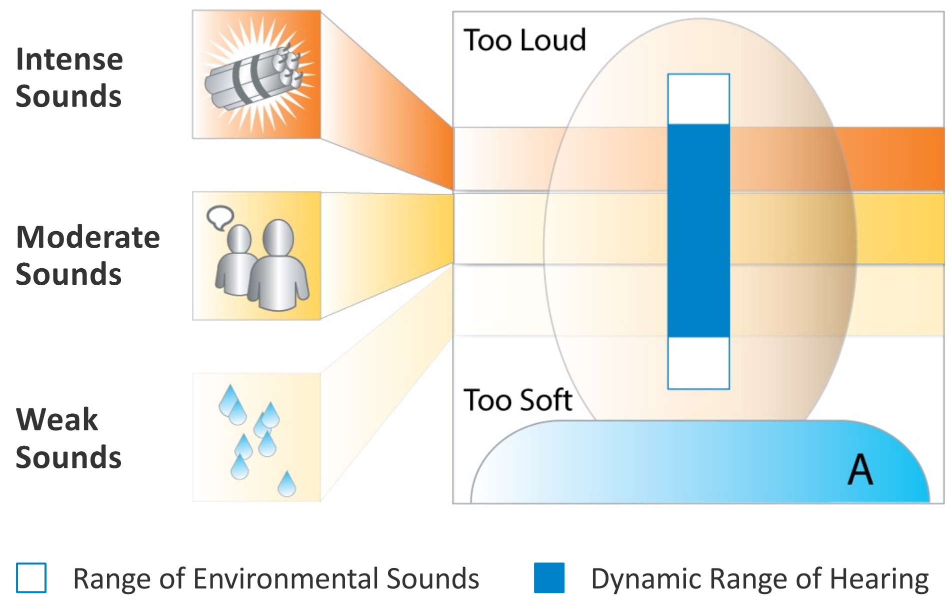


2

Tonotopic organization of the basilar membrane and central auditory pathways



Normal Hearing Dynamic Range



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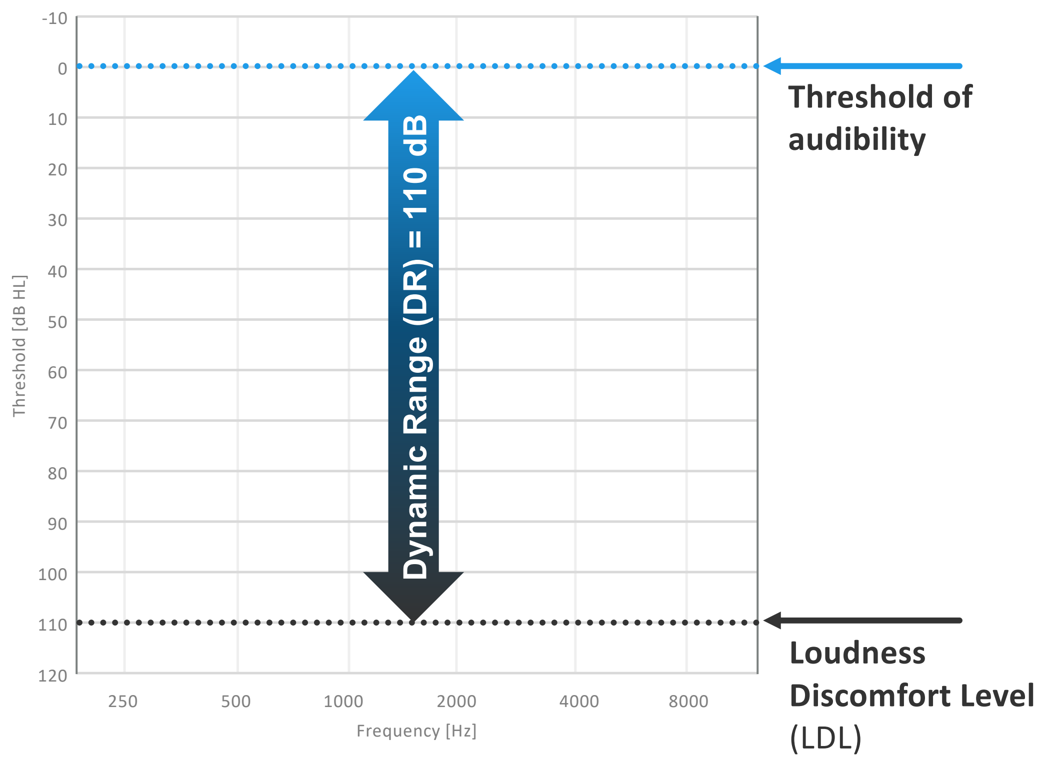
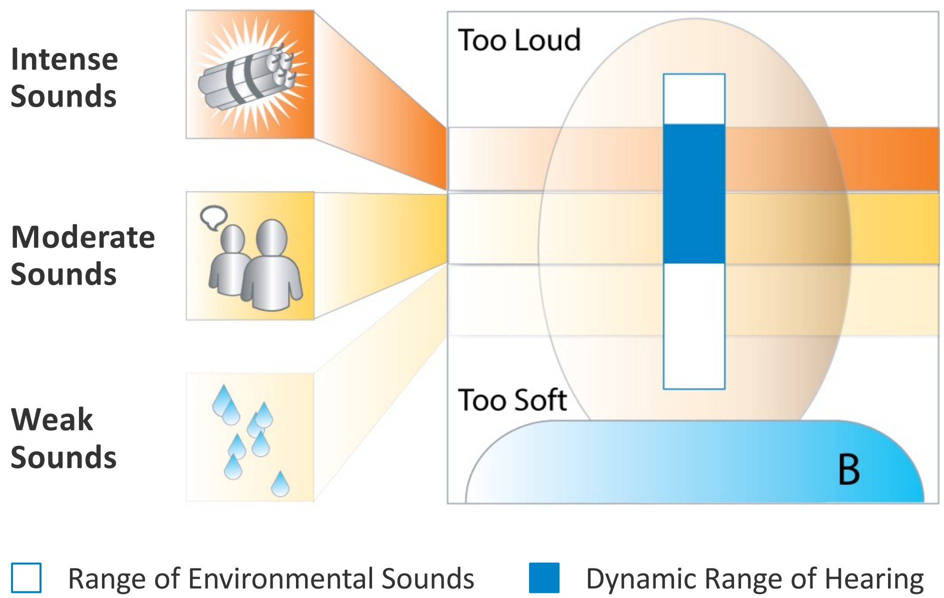
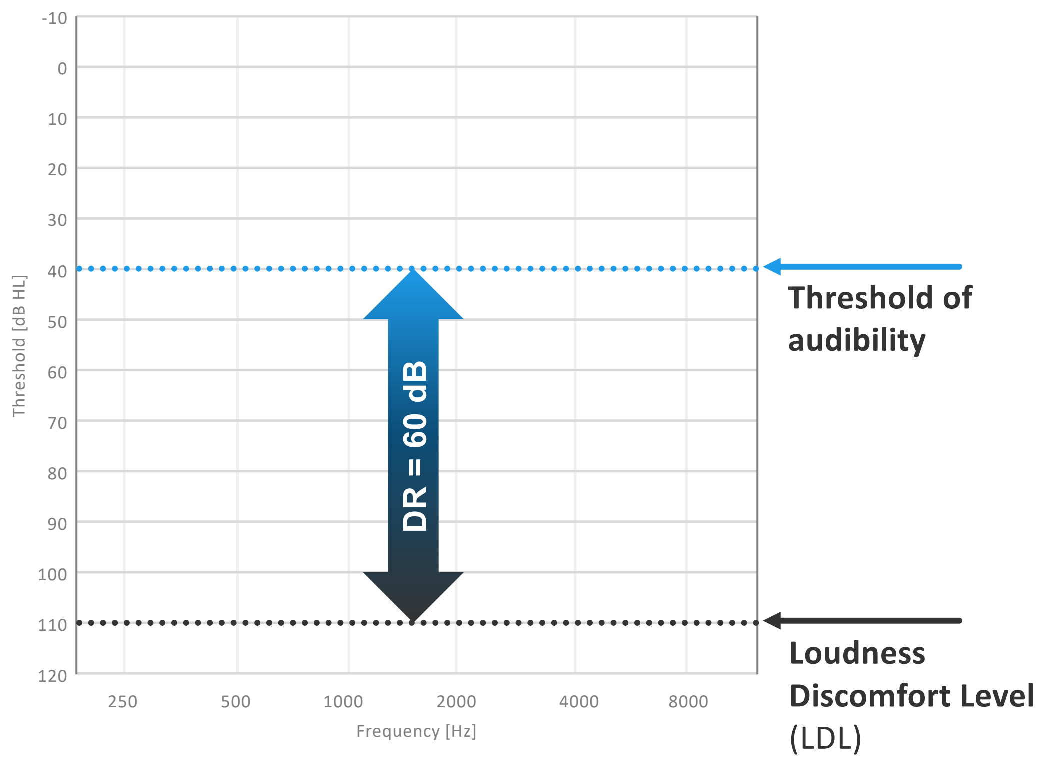


How does this change in the case of hearing loss?

Hearing Impaired Dynamic Range

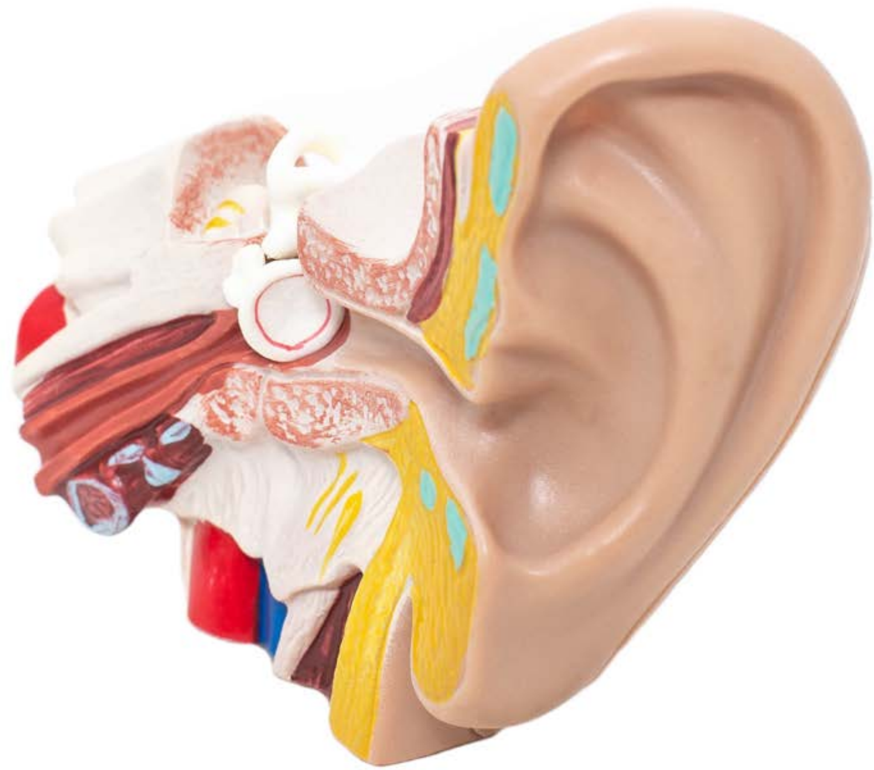


Hearing Impaired Dynamic Range



Recruitment

Sounds get louder more quickly for someone with sensorineural hearing loss

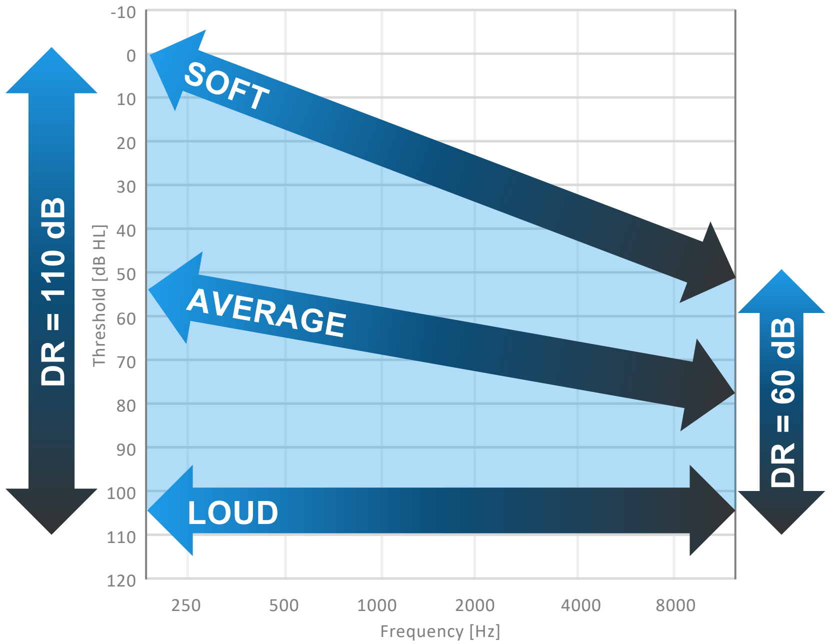


Mimicking the dynamic nature of the intact auditory system

Squeezing an elephant into a suitcase

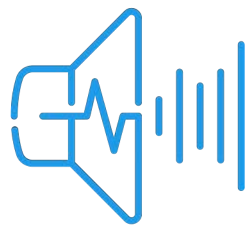
Goal

Fitting the world of sound *(the elephant)* into the dynamic range of the individual with hearing impairment *(the suitcase).*



Bottom Line

Soft sounds must be made audible



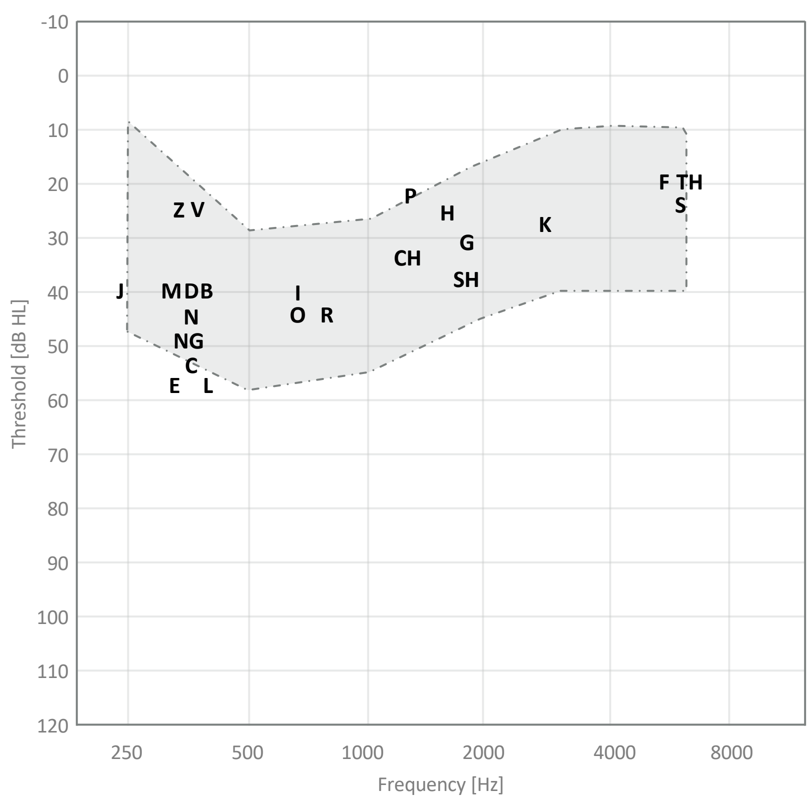
Loud sounds cannot become uncomfortably loud

Speech should remain at a comfortable level

What sounds do we **prioritize** when thinking of compression?

Average Conversational Speech

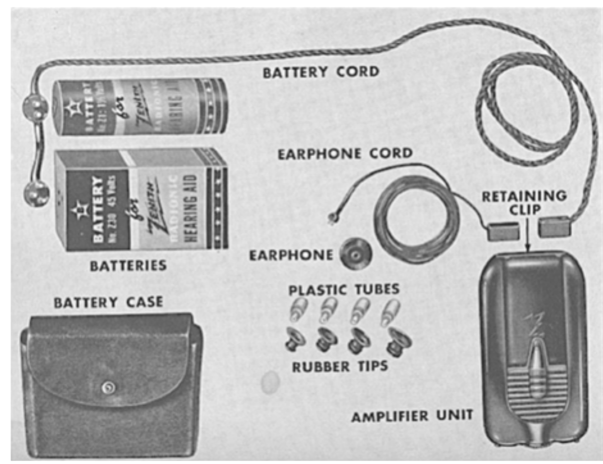
Spans a Range of 30dB



A Brief History

Early 1940s

Gain applied based audiometric thresholds/frequency specific.
Half-gain rule



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Comparative hearing aid evaluations based on speech recognition scores

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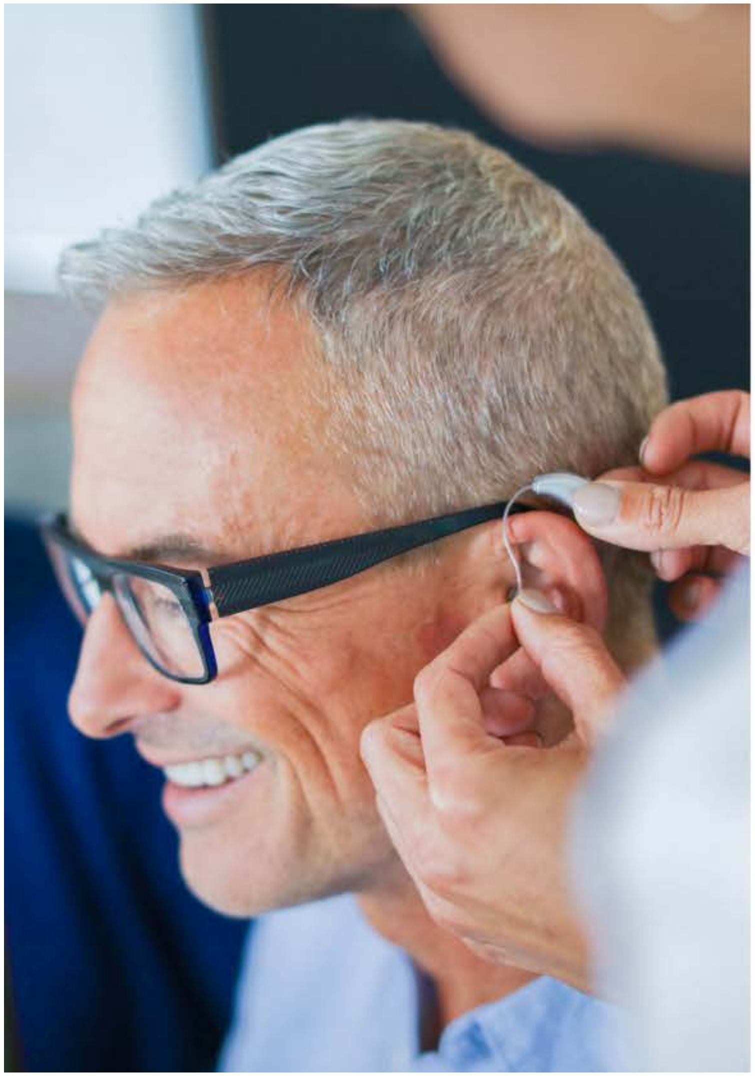
Early 1970s

Comparative hearing aid evaluations based on speech recognition scores

Late 1970s

Re-visited exploring the efficacy of applying various prescriptive formulas in hearing aid fittings



Signal processing approaches

Compression in the Modern Hearing Aid

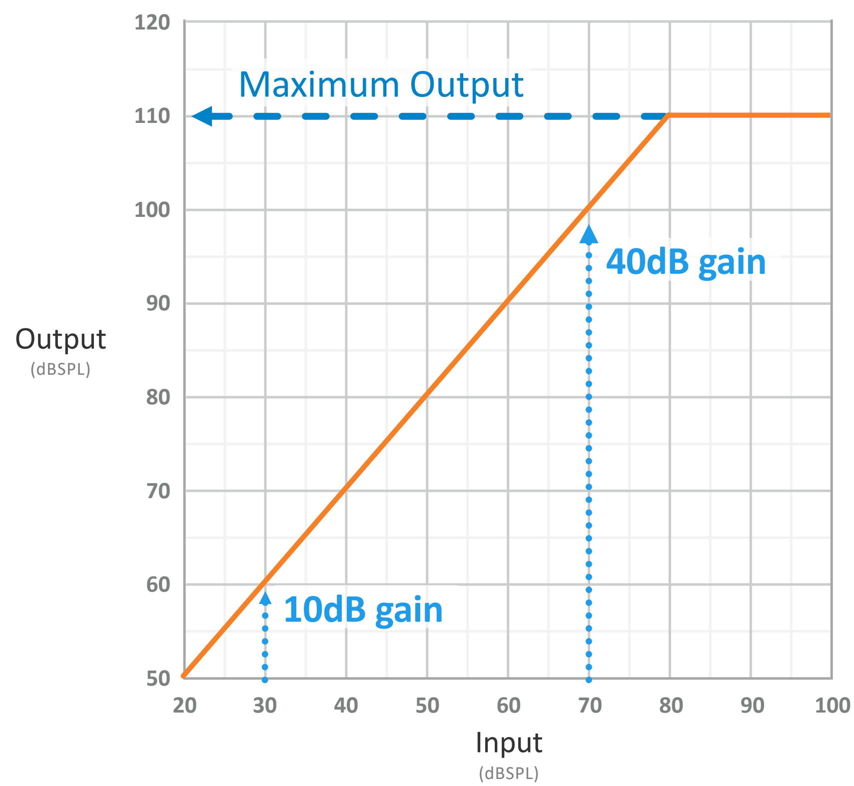
Hear better. Live better.

Linear approaches

Linear Amplification

A fixed amount of gain regardless of input level

1:1 Ratio (gain : output)

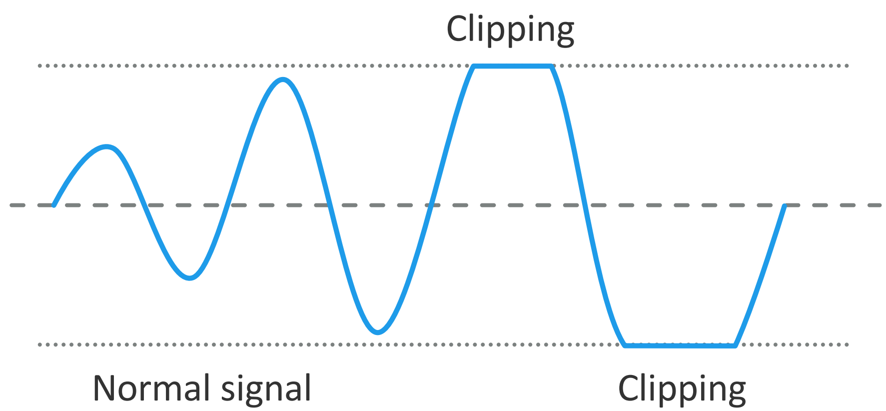


Maximum Output

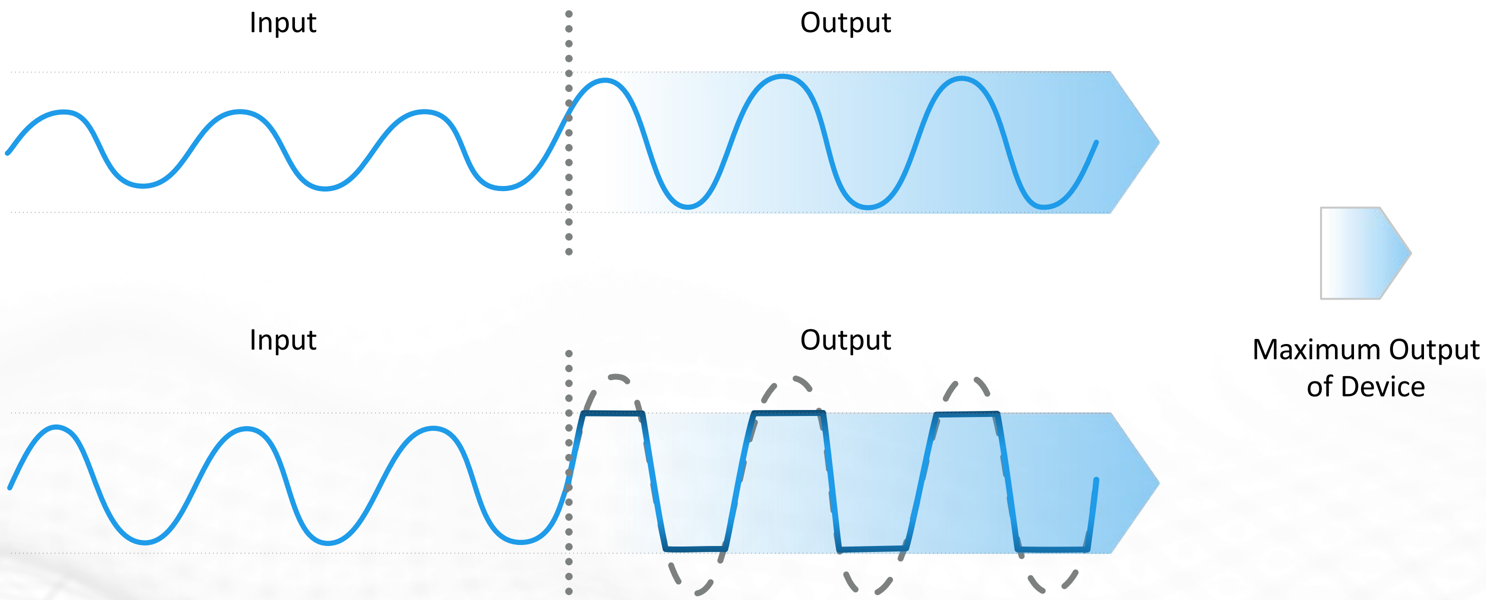
Highest possible signal that a hearing aid capable of delivering

Saturation (Peak Clipping)

Input level and gain exceed the maximum output



Peak Clipping



Limitations of Linear Approaches

Making soft sounds audible

Average conversational speech
is now loud

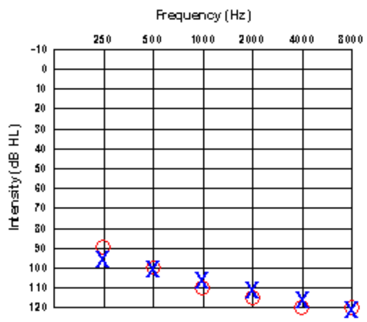
Intense sounds are amplified
beyond the upper end of the dynamic
range making them uncomfortably,
or even painfully, loud

Peak clipping is distortion

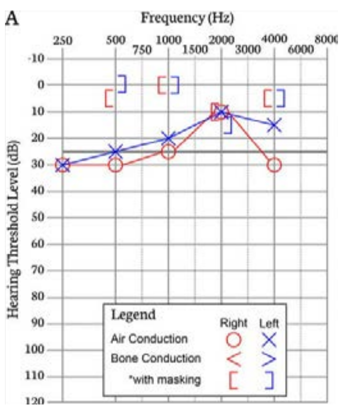
Cases in which linear approaches still apply

1. Long-time linear technology users

2. Severe to profound hearing losses



3. Conductive & mixed hearing losses



Non-Linear approaches

Compression Terms

- Threshold Kneepoint
- Output Compression Limiting
- Fast Acting Compression
- Attack and Release Times
- Compression Ratio
- Slow Acting Compression

Threshold Kneepoint
(TK)

Point at which compression is activated

Also referred to as Compression Threshold (CT)

*Advanced hearing aids have multiple kneepoints

Threshold Kneepoint
(TK)

Controls how long linear gain and/or expansion is in effect

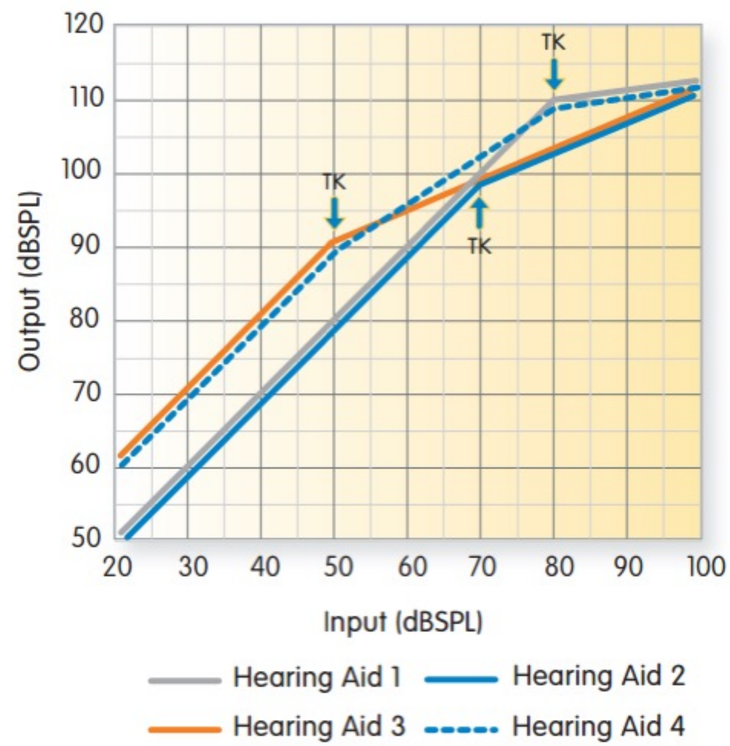


Figure 2-5
Sample input/output functions showing threshold kneepoints (TK) for four different hearing aids.

Threshold Kneepoint

CONSIDERATIONS

Higher TK

Linear longer

May be beneficial for more severe hearing losses and previous hearing aid wearers

Lower TK

In compression longer

May be beneficial to users experiencing recruitment

Compression Ratio
(CR)

Determines how much the signal will be compressed

Expressed in a ratio:

- **1:1 = Linear**
- **>1.1:1 = Compression**

Compression Ratio

(CR)

Determines how much the signal will be compressed

Expressed in a ratio:

- **1:1 = Linear**
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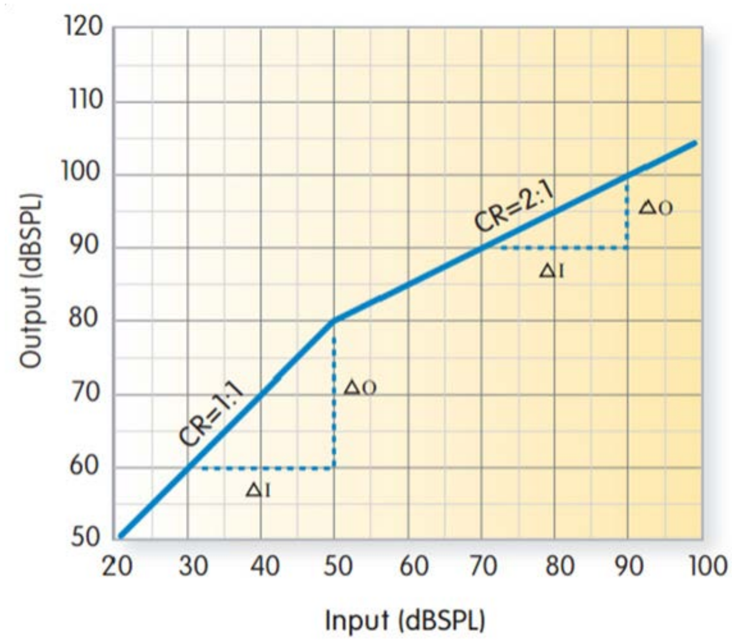


Figure 2-6
Calculating compression ratios (CRs) from an input/output function. ΔI = Change in input, ΔO = Change in output.

Compression Ratio (CR)

CONSIDERATIONS

Lower CR	High CR
Less than 5:1	Greater than 8:1
Improves audibility of the softer components of speech	Offers protection from loudness discomfort
Restores loudness perception	May be more beneficial for severe to profound hearing losses
May be beneficial for more mild hearing losses and new hearing aid wearers	

Compression Ratio (CR)

CONSIDERATIONS

Low CR

May over amplify softer, non-important environmental sounds

Higher CR

May adversely affect the clarity and pleasantness of the amplified sound

Attack and Release Times

Length of time it takes for a compression circuit to respond to intensity changes of input/environmental sounds

(Venema, 2006)

Attack and Release Times

Length of time it takes for a compression circuit to respond to intensity changes of input/environmental sounds

(Venema, 2006)

Attack Time

Length of time it takes a hearing aid to go into compression and reduce gain

Release Time

The length of time it takes for the hearing aid to come out of compression, and restore gain

Attack and Release Times

CONSIDERATIONS

Faster AT

The faster they benefit from compression – soft sounds audible, loud sounds not too loud etc.

BUT if too fast: can negatively impact sound quality

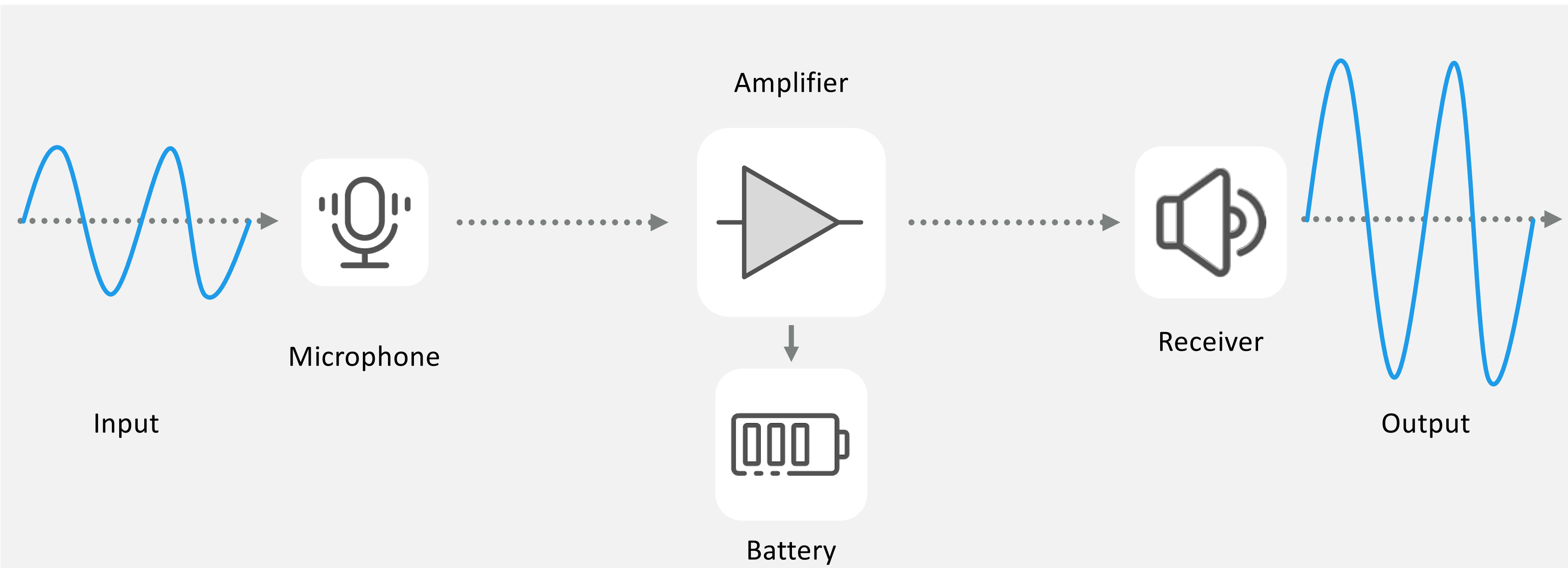
Longer RT

Ensure variability doesn't impact the processed signal

BUT if too long: can affect intelligibility of speech following transient sound

How does the volume control **interact** with compression settings?

Basic Hearing Aid Components

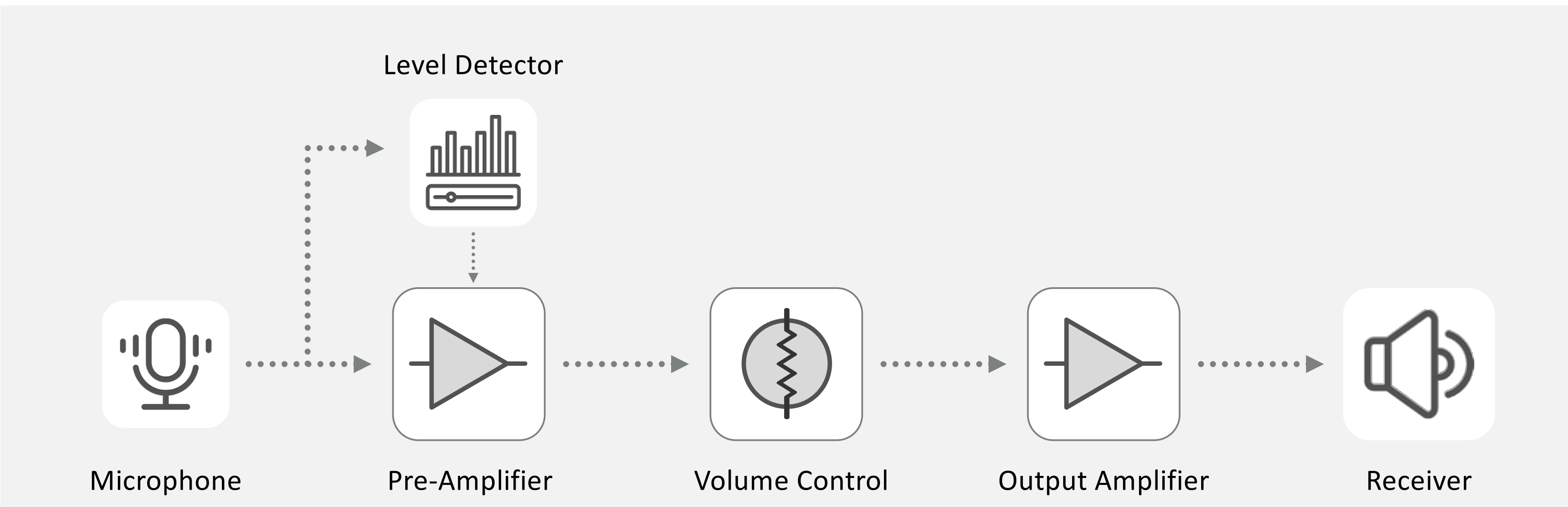


Input Compression (AGC-i)

Compression acts before the volume control

TK is not affected by volume control changes

Most commonly used with wide dynamic range compression*

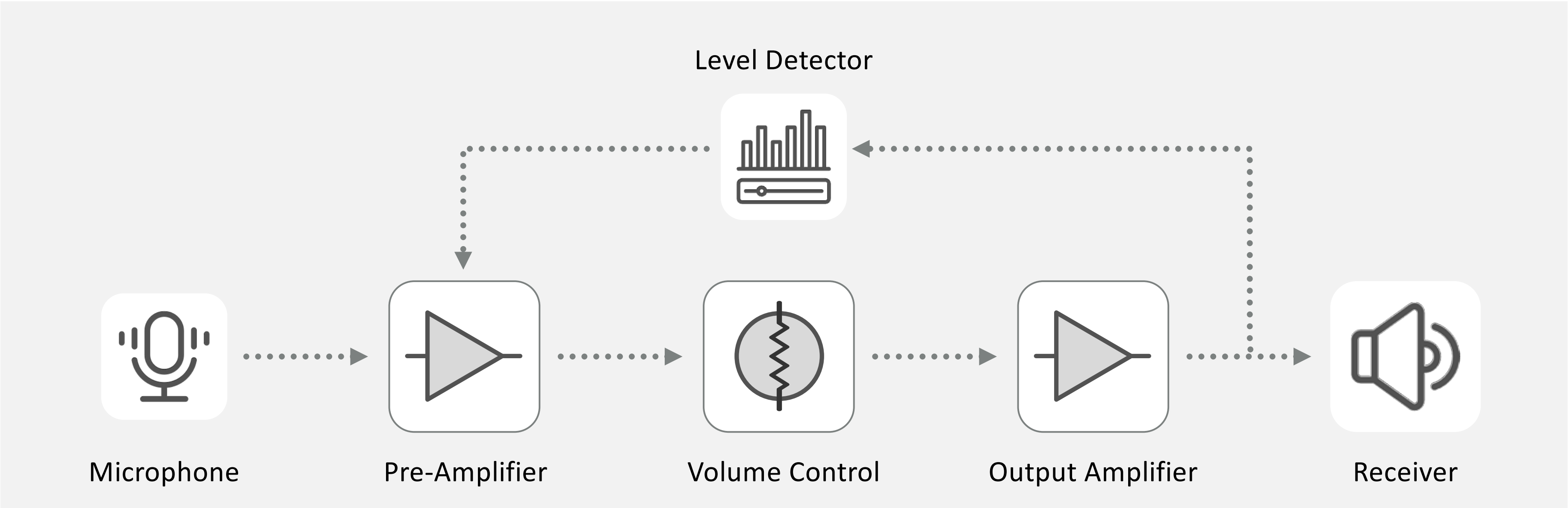


Output Compression (AGC-O)

Compression acts after the volume control

TK is affected

The volume control has no input on maximum output of hearing aid



Compression Limiting

Use of compression to control or limit loud sounds without causing distortion

High TK's

70dB or greater

High CR's

8:1 or greater

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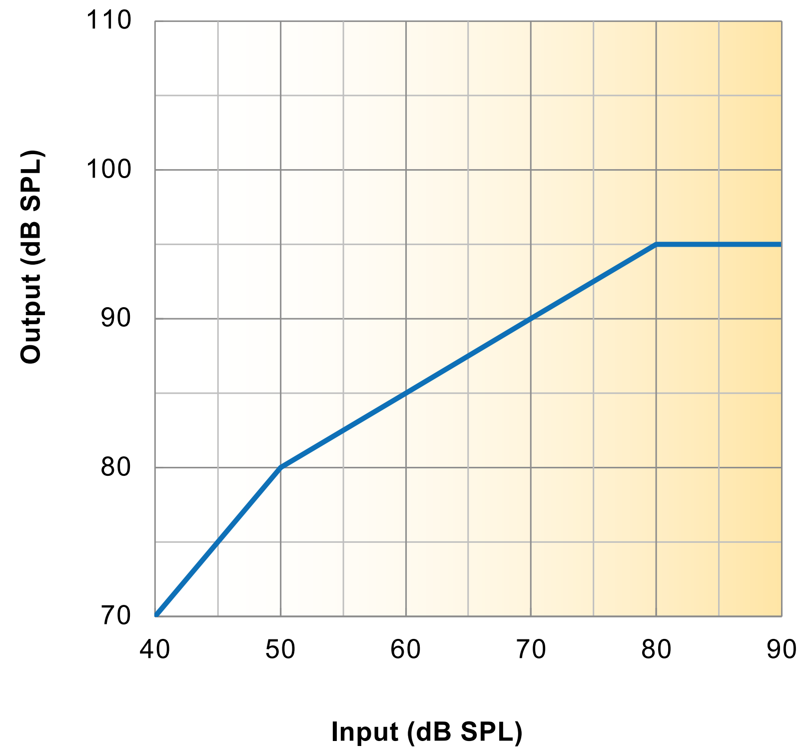

Wide Dynamic Range Compression (WDRC) and Expansion

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Dynamic Compression

The Dynamic behavior of hearing aids is related to the time constants for compressive processing: i.e., fast or slow acting compression

Faster Time Constants – More Compressive

- May provide enhanced audibility for those with smaller residual dynamic range
- Conversely, this advantage may be offset by distortion of speech intelligibility

Slower Time Constants – Less Compressive

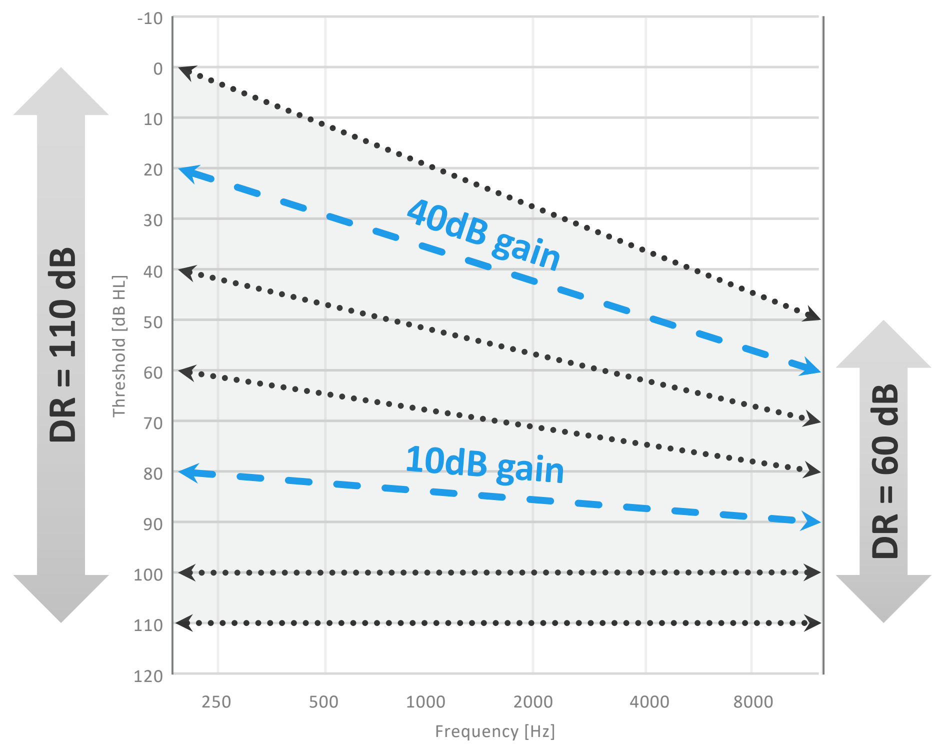
- May be better for patients with cognitive considerations

Wide Dynamic Range Compression

The hearing aid provides different degrees of amplification depending upon input level

Softer sounds are given more amplification than louder sounds

Attempts to reproduce the full dynamic range of the world into the reduced dynamic range of the listener



Expansion & Limitation of Compression

IN COMPRESSION

Weak sounds are amplified to a greater extent than moderate & intense sounds

This improves speech intelligibility

BUT... Unwanted sounds are made audible as well

Expansion

Principle

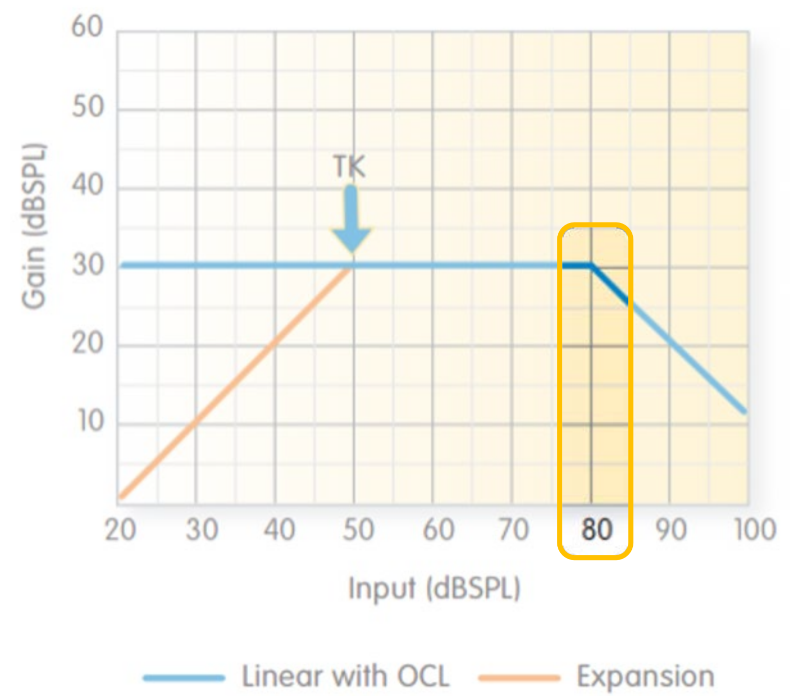
- Soft sounds are amplified less than louder sounds
- Ensure you do not provide any gain below a certain input level

How it functions

- It only applies to the weakest sounds in the environment
- Different amounts of gain are applied dependent on input level

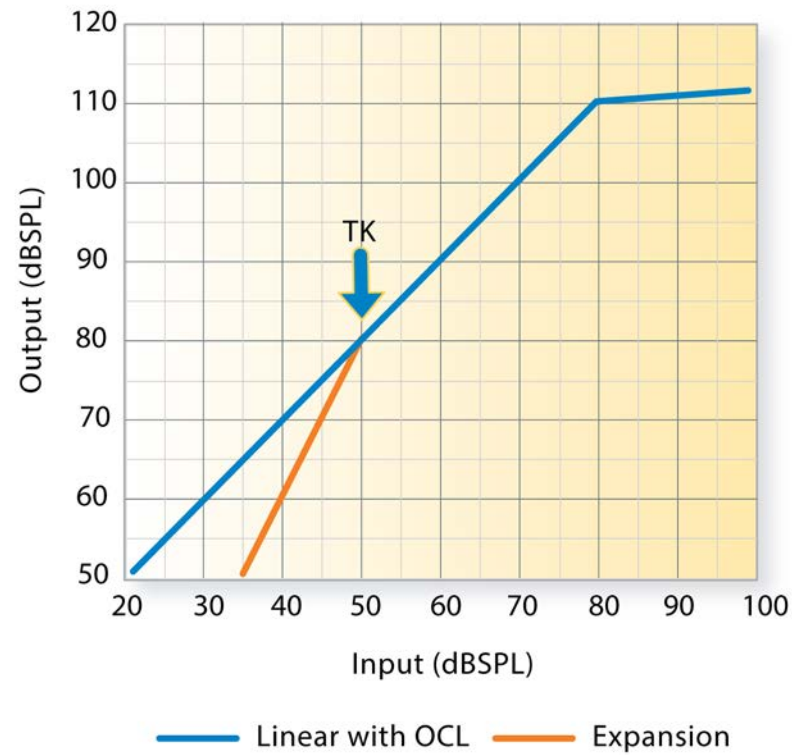
Expansion

Sample input/gain functions showing linear amplification and output compression limiting (OCL), with and without expansion below the threshold kneepoint (TK).



Expansion Threshold
(XT/TK)

- Input level below which expansion operates
- Expansion acts BELOW the TK/XT
- Frequently compression and expansion share the same TK



Expansion Thresholds

CONSIDERATIONS

Low XT/KP

40 dB SPL or lower

PRO
Ensures speech audibility at lower levels

CON
May still be a ‘noisy’ hearing device

High XT/KP

50 dB SPL or greater

PRO
Quieter hearing device

CON
Negative impact on speech audibility

Expansion Ratio
(XR)

Extend which an input signal is expanded

$$\mathbf{XR} = \frac{\Delta \text{ Input}}{\Delta \text{ Output}}$$

Expansion Ratio vs. Compression Ratio

Remember

- A CR of 1 is linear
- CR when compression is acting is always greater than 1

XR

- Always between 0 and 1 when expansion is being applied

Expansion Ratio

Lower XR

Closer to 0

Steeper the slope i/o function

Indicates a greater degree of expansion

If too low:
speech audibility may be reduced

High XR

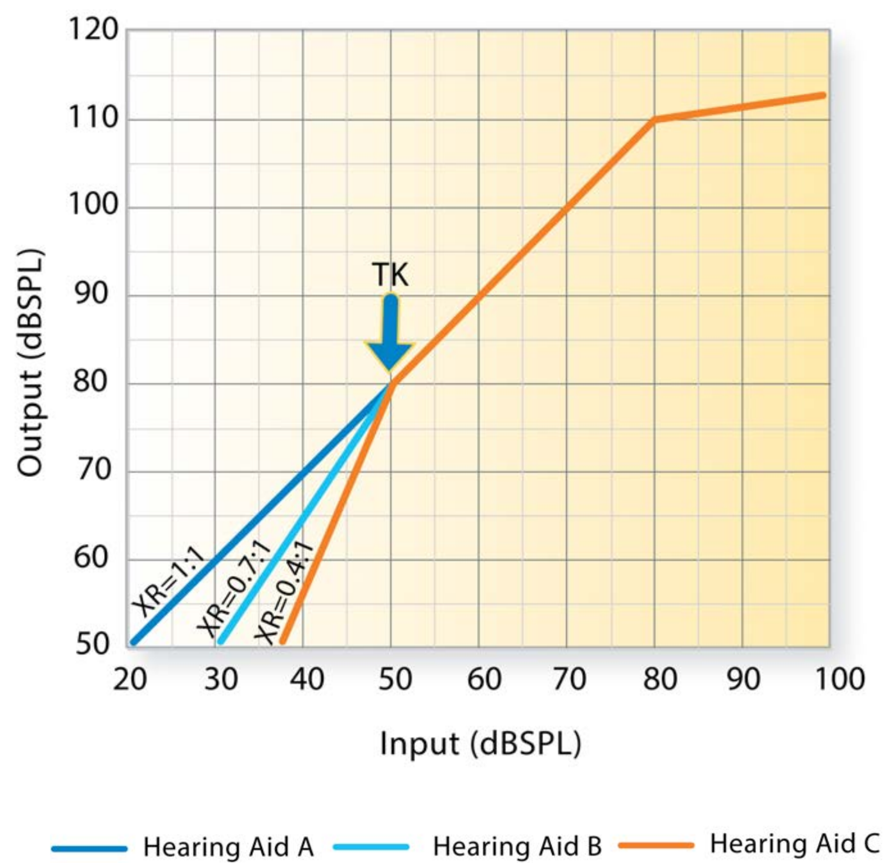
Closer to 1

Less expansion

If too high:
hearing device can be noisy

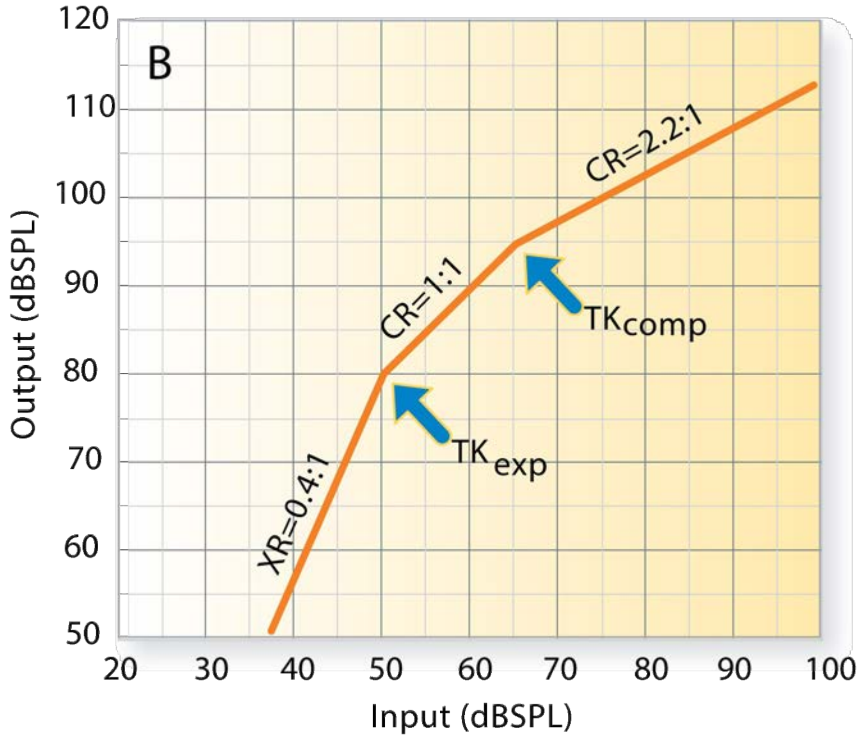
Expansion Ratio

The steeper the slope, the greater degree of expansion



Expansion

XR is typically separate from CR in hearing aids



Applications of Compression

Channels/Bands & Prescriptive Formulas

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Channels vs. Bands

Terms often used interchangeably

Specifics of how defined can slightly differ in the literature or between manufacturers

Bands

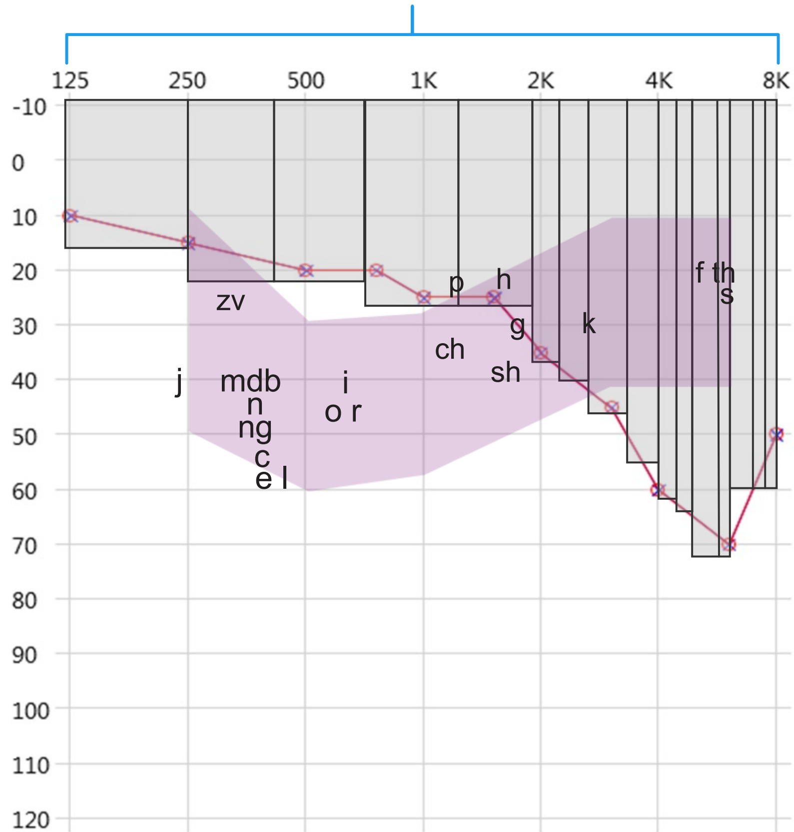
1

Shape frequency response of the hearing aid

2

Accommodate **loudness tolerances**

16 Bands



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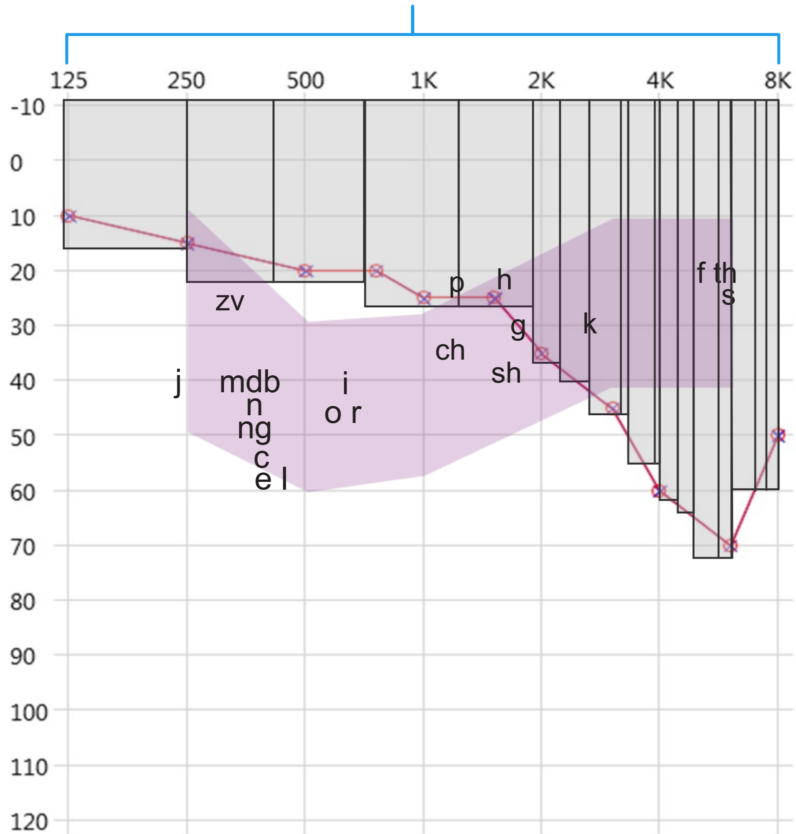
20 Bands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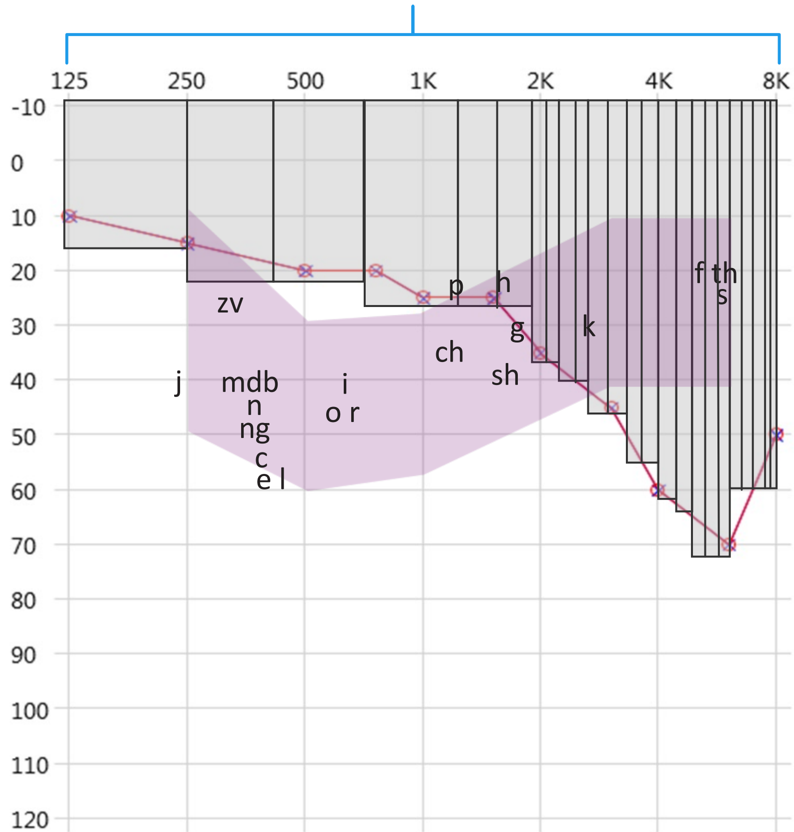
24 Bands



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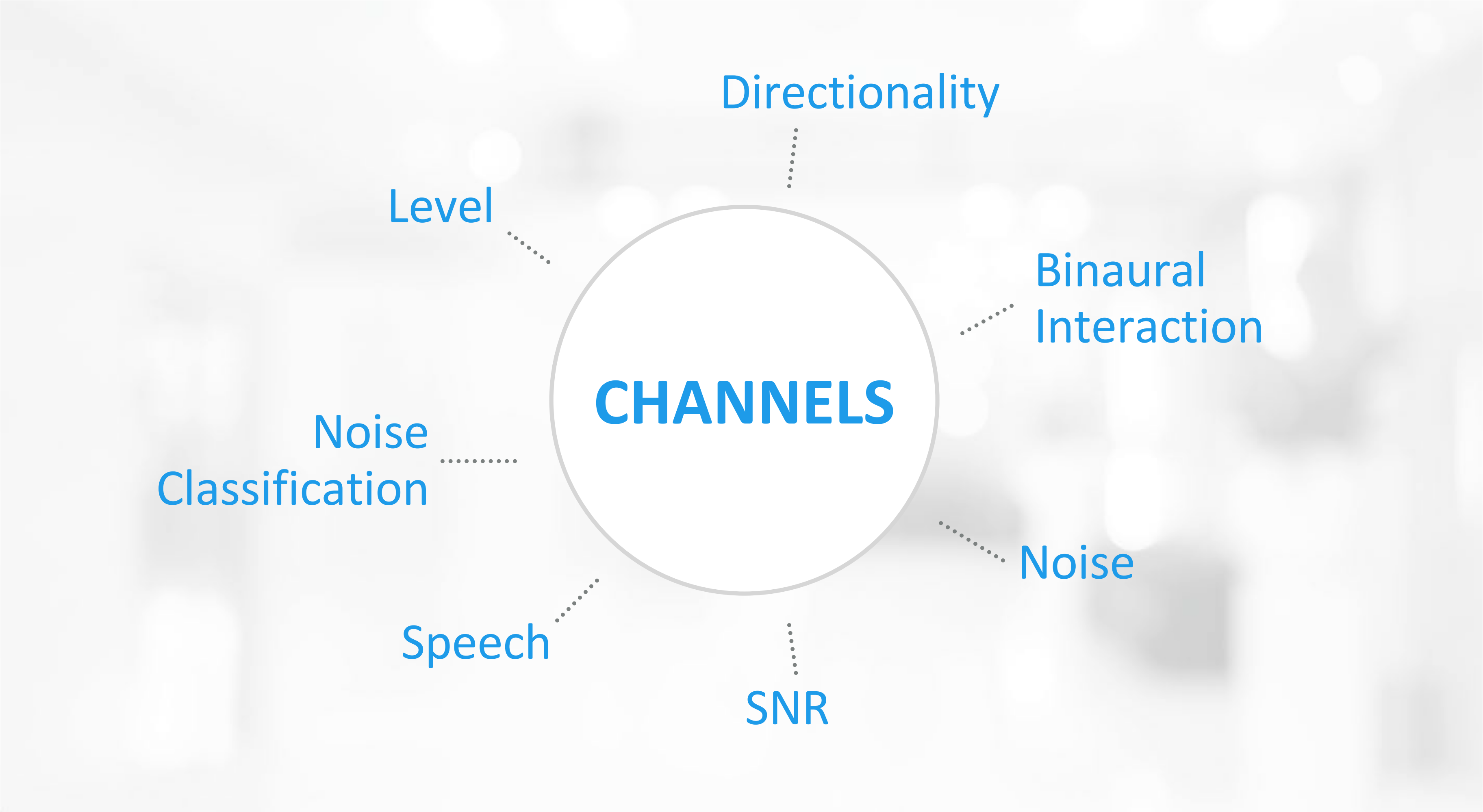
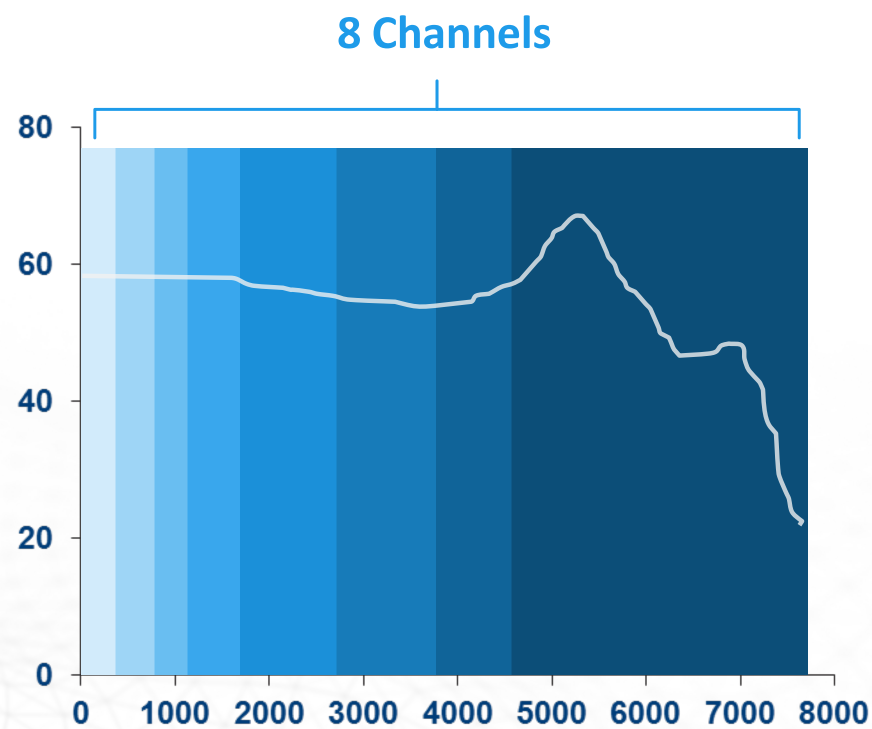
Implementation of **advanced features**
to provide more **precise noise control**


Directionality
Level
Binaural Interaction
CHANNELS
Noise Classification
Noise
Speech
SNR

Spectrum Over Time



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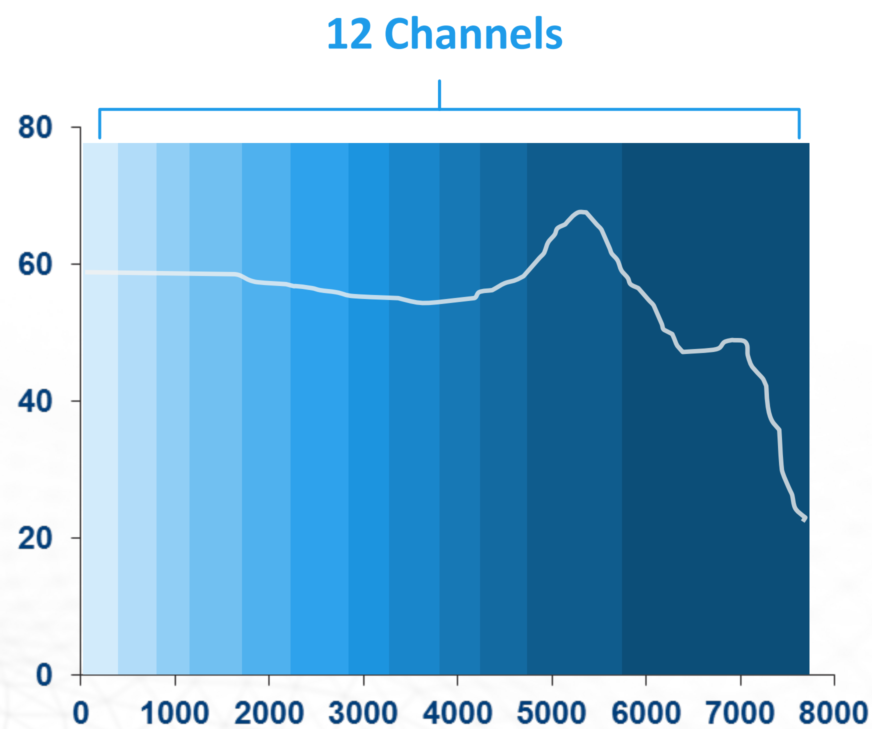

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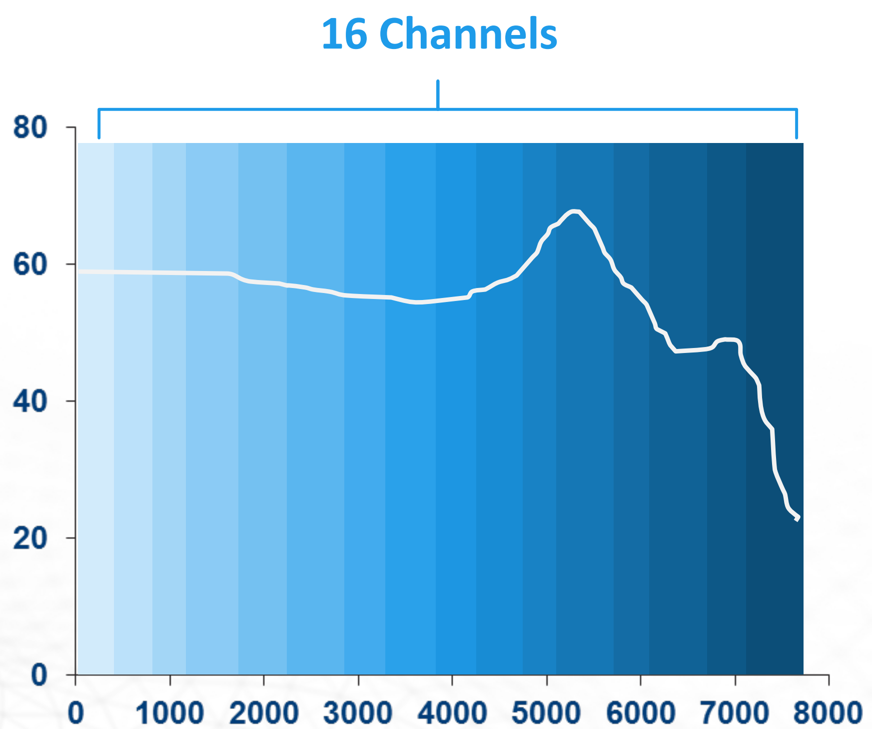


Prescriptive fitting formulas

Prescriptive Fitting Procedures and Fitting Formulas

The compression architecture

Proprietary Fitting Formulas

- Manufacturer specific

Generic Fitting Formulas

Not manufacturer specific

- NAL-1/NAL-2, NAL-R
- DSL

NAL-R

Linear formula

Utilizes a loudness equalization rationale

NAL-NL1

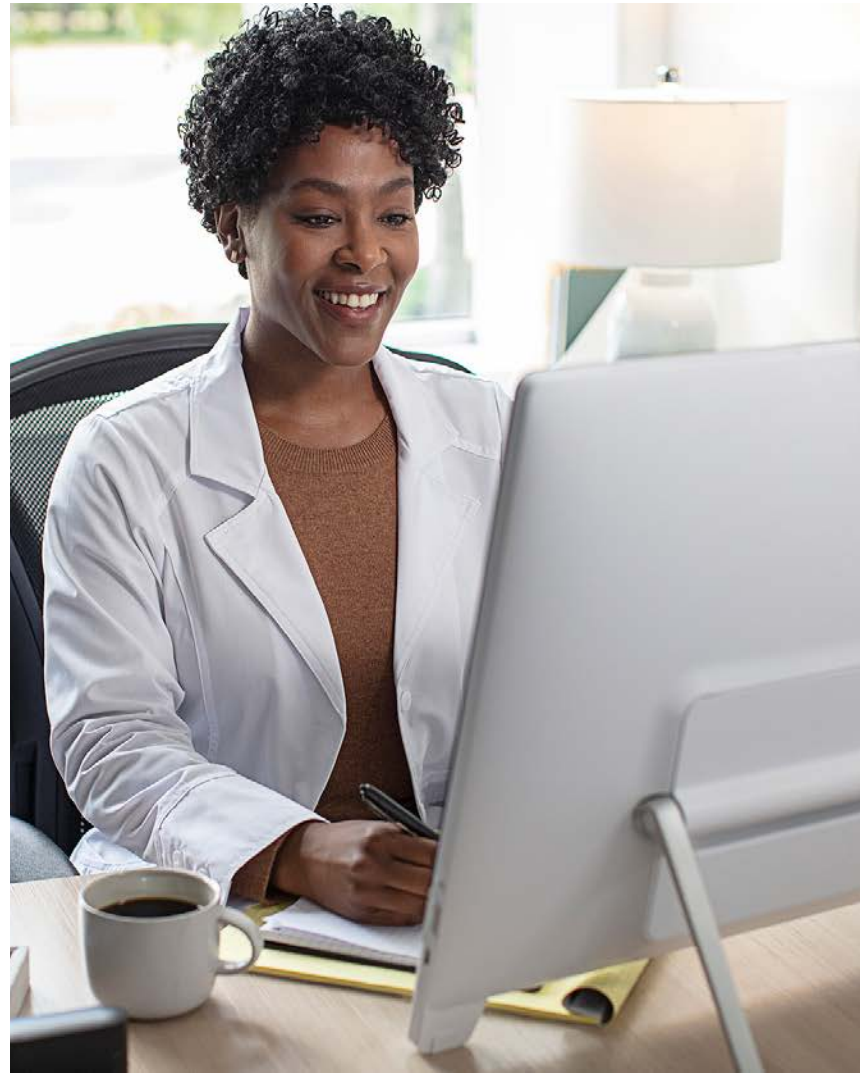
Development based of NAL-R

WDRC

Based upon predictive model for speech intelligibility

- Derived ANSI SII

Utilizes a loudness normalization rationale



NAL-NL2

Developed based on empirical data collected over a decade regarding NAL-NL1

Still WDRC

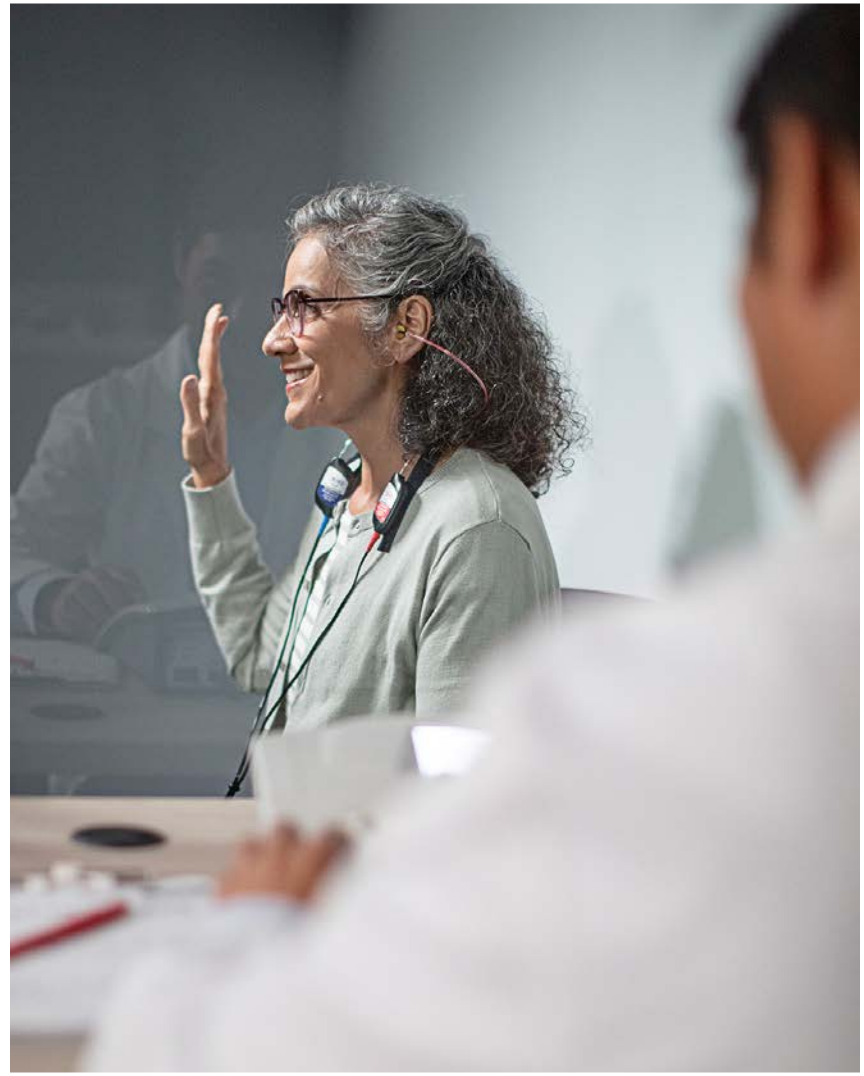
Primary goal remained the same

- Loudness normalization
- Predictive model of speech intelligibility

NAL-NL1 vs. NAL-NL2

Differences

Adults with mild to moderate hearing losses preferred less overall gain and higher CR’s that utilized in NAL-NL1



DSL v5.0

Desired Sensation Level

Developed for pediatric fittings

Compression Characteristics

- Dependent on the severity of loss
- Closer resembles a loudness equalization rationale: full audibility, including in quiet environments is the priority

e-STAT

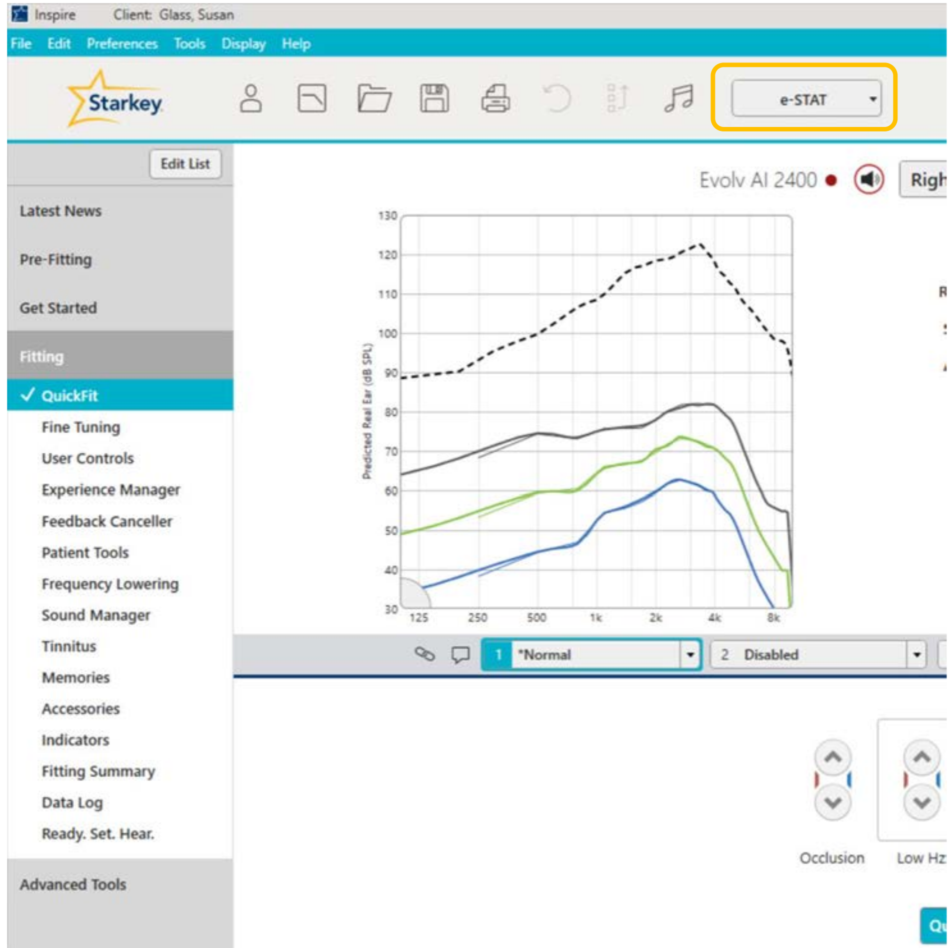
Starkey's Proprietary Fitting Formula

Emphasizes audibility for speech understanding

Developed for Starkey's proprietary compression architecture

Optimizes response modeling regardless of hearing aid style

Optimizes vent hearing aid interaction



e-STAT

Utilizes WDRC principles

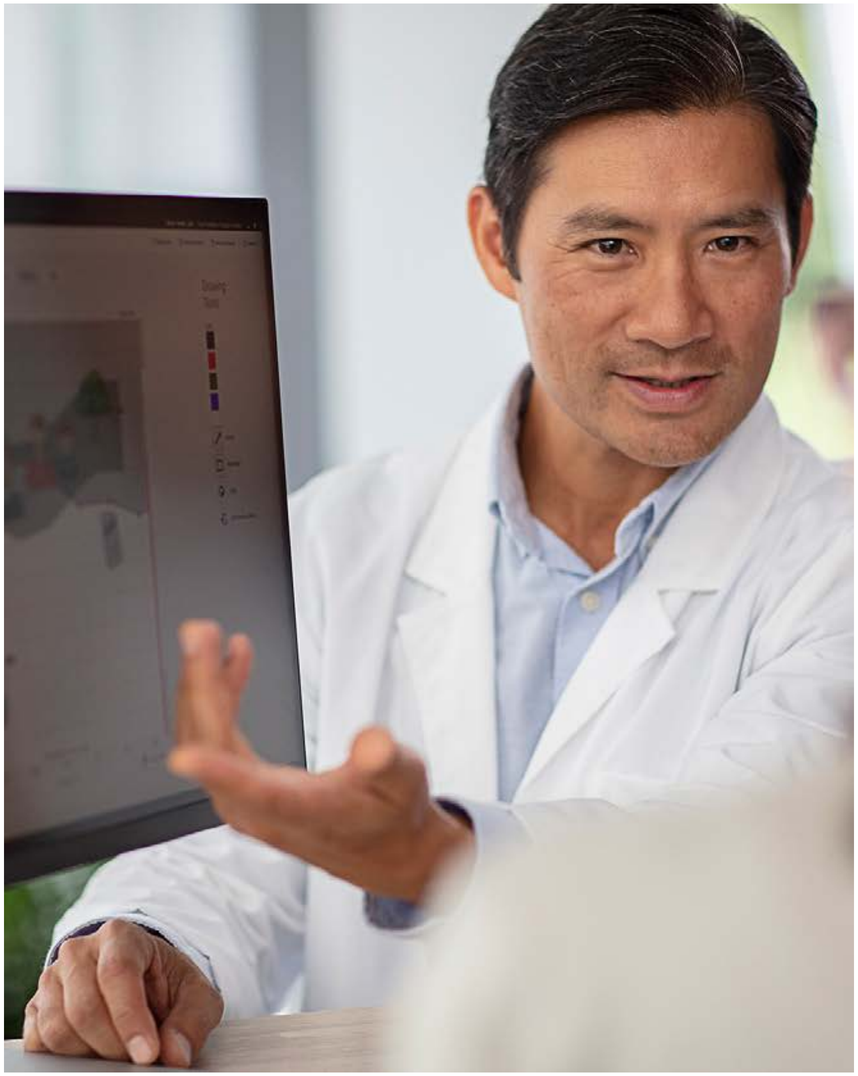
Low CRs

Low CTs

Fast-acting

Continues to be optimized for the best fitting starting point possible

- Based on clinical product research and professional input

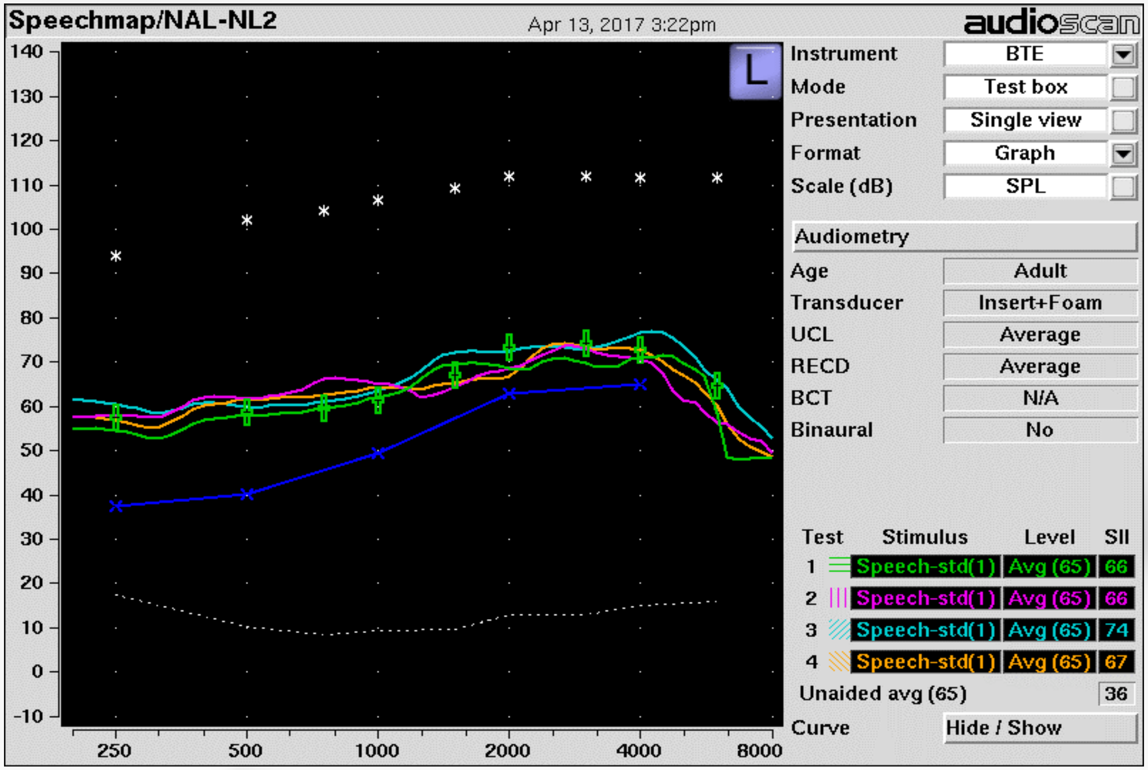


Independent Speech Optimization (ISO-C)

Goal

- Provide the best sound quality possible for soft speech
- Provide independent gain controls for soft vs. moderate vs. loud sounds within the Inspire software

Fitting Formulas:
Same in all manufacturers?



Manufacturer-specific approaches to signal processing impact hearing aid responses.

Universal fitting formulas do not produce equivalent results.

Starkey Compression Architecture

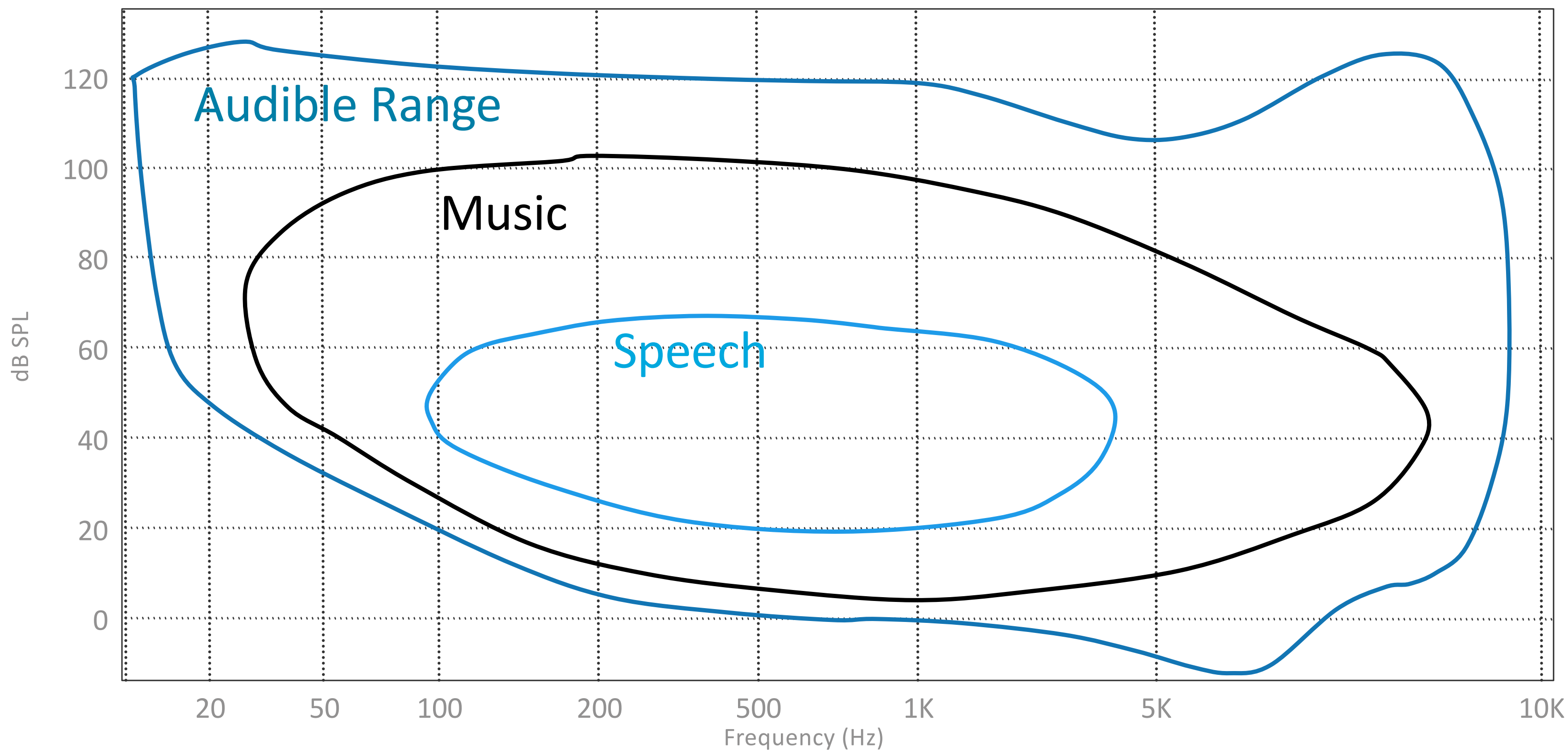
Hear better. Live better.

Compression **and** Music

Twin Compressor Technology

Multicore Twin Compressors

Giving speech and music the individual attention they deserve
for an exceptional listening experience

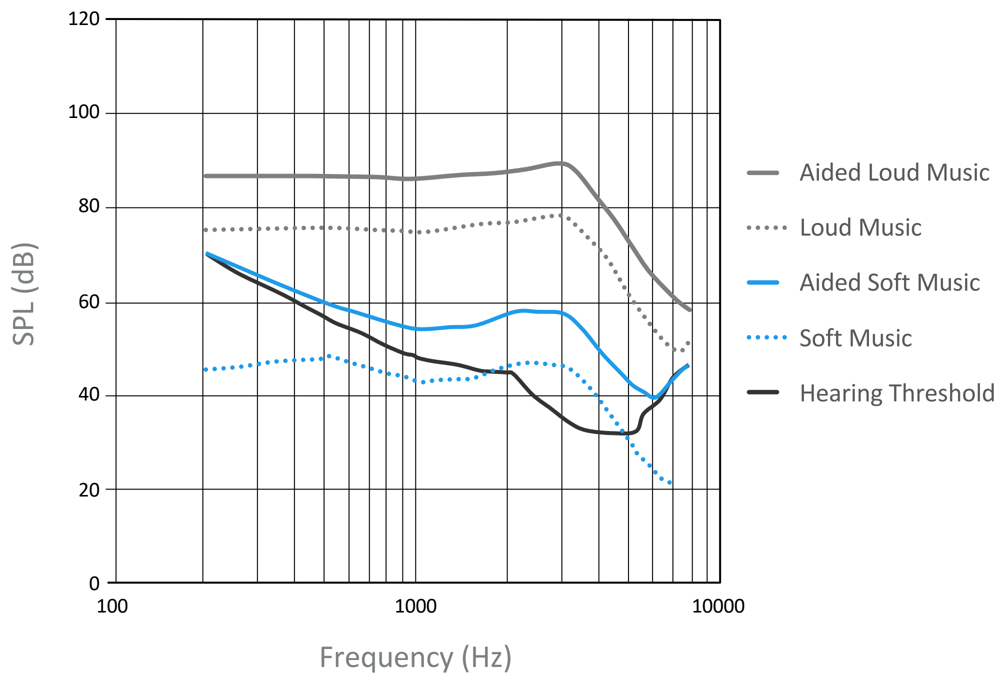


A New Proprietary Fitting Formula

Evidenced-based prescription optimized for music

Restores audibility for soft music

Restores desired loudness for loud music



Linear + Non-Linear

Processing of Music

Research has shown flat gain and a combination of compression and linear approaches, preserves fidelity of loud music.

Dedicated Music Memory

Unique music-centric fitting prescription

Shaped gain according to hearing loss for quiet music

Flat, linear, insertion gain for loud music

Effortless Intelligence

Our latest technology provides superior sound quality plus advanced features and capabilities

	Premium **2400**	Advanced **2000**	Select **1600**	Basic **1200**	Entry **1000**
Voice AI (iOS only)	●				
Translate	●				
Edge Mode: Tap Control	●				
Transcribe	●	●			
Edge Mode: Thrive app access	●	●	●		
Thrive Assistant	●	●	●		
Find My Phone	●	●	●		
Hear Share app compatibility	●	●	●	●	
Engagement Tracking	●	●	●	●	
Activity Tracking	●	●	●	●	
2-Way Audio	●	●	●	●	●
Fall Alert	●	●	●	●	
Reminders	●	●	●	●	●
Self Check	●	●	●	●	●
Auto On/Off	●	●	●	●	●
Tap Control	●	●	●	●	●
TeleHear	●	●	●	●	●
Tinnitus Technology	●	●	●	●	
REM Target Match	●	●	●	●	●
CROS system*	●	●	●	●	

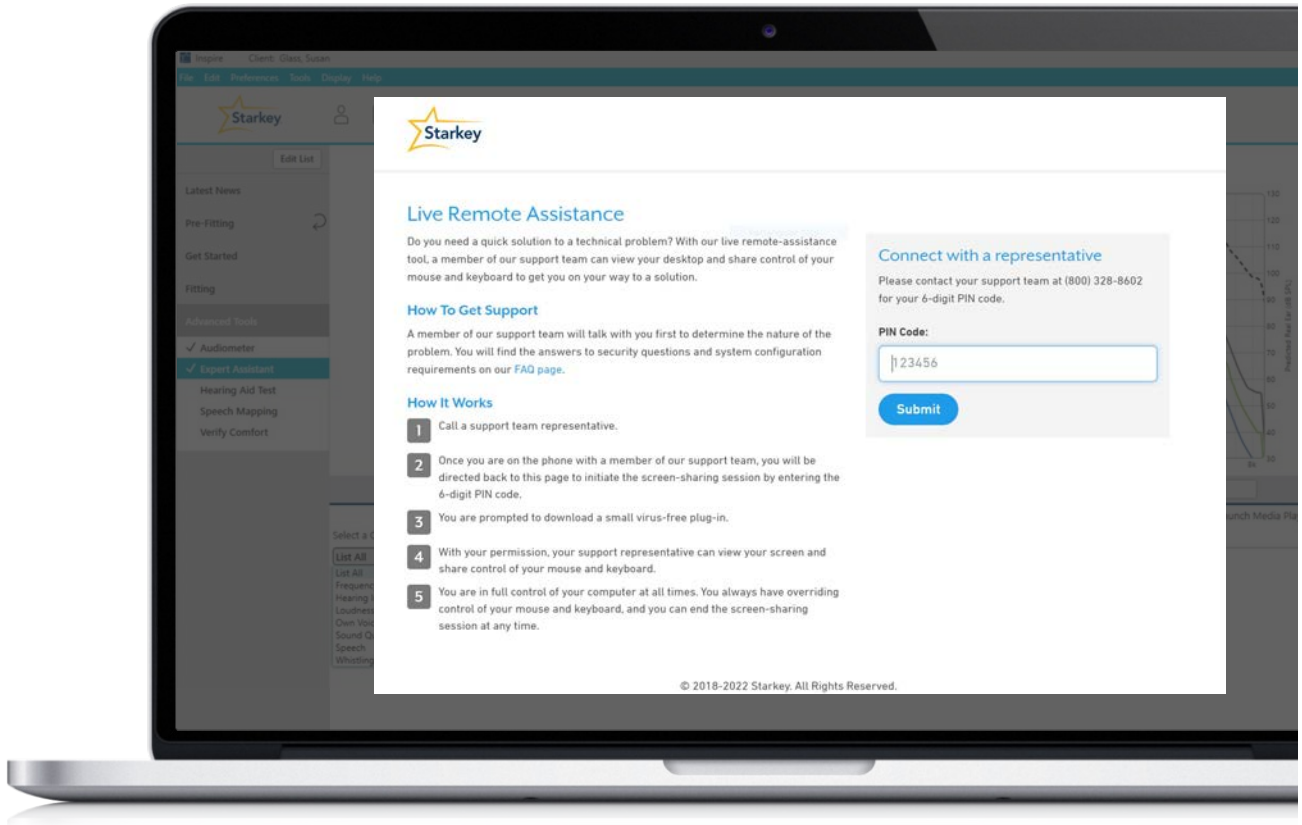
Wireless CIC | ITE R | ITC R | miniRIC | RIC 312 | RIC R | BTE 13 | BTE R | Power Plus BTE

BOLD indicates a feature new to this technology tier

Resources

Audiology On-Demand

Audiology support built directly into the software



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Thank you

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Hear better. Live better.