ReSound GN

An overview of directional options in ReSound hearing aids

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ABSTRACT

Directional microphones in hearing aids were once a single component that provided an unchanging response. As technology advanced, users could manually select the directional response. Today's digital hearing aids provide much greater sophistication, both in the sound processing as well as in the way the directional response is automatically activated. This paper describes the many directional fitting options that ReSound offers across the product portfolio.

Directional microphones in hearing aids remain the only proven technology that improves speech recognition in noise[1-4] with evidence reaching back to the 1970s.[5] The principle on which this key benefit is based is the improvement in signal-to-noise ratio (SNR) for sound coming from a particular direction, usually in front of the user. Directional technology in hearing aids has evolved dramatically throughout the decades, while still preserving this fundamental benefit. There have been major technical advances that have optimised SNR improvement, improved sound quality, increased usability, and helped to make the technology more beneficial in everyday environments. As a result, ReSound offers a plethora of directional features and options in our product portfolio. This paper provides an overview of directional options available in ReSound hearing aids.

Because this paper is intended to be used as a reference, the directional options are organised and discussed according to their purpose. The directional options cover three broad categories, as shown in Figure 1. One category contains the set of holistic features which control the directional modes. These features follow a rationale to automatically apply different settings such that user benefit is optimised in everyday situations. They make it easier for users to benefit from the advanced technologies without needing to understand how they work. In simple terms, these represent the "how" that describes the way different modes are applied. Another category includes the actual directional modes, the sound processing strategies that create the directional response and result in an improved SNR for the hearing aid user. Each of these is the "what" that can be automatically controlled by the "how" features. The third category covers features that help in reducing or eliminating drawbacks of conventional directional processing (i.e. low frequency roll-off and compensation,[6] increased wind noise,[7,8] and poorer localisation[9]). These are the "facilitation" features that help users enjoy the benefits of directionality without having the distracting downsides.

AUTOMATIC CONTROL FOR EASE OF USE

- All Access Directionality
- Binaural Directionality III
- Binaural Directionality II
- Binaural Directionality
- Natural Directionality II
- Soft Switching

IMPROVED SNR

- Weighted binaural beamformer
- Ultra Focus
- Autoscope Adaptive Directionality
- Multiscope Adaptive Directionality
- Adaptive Directionality
- Fixed Directionality

SOUND QUALITY AND SPATIAL HEARING

- M&RIE
- Spatial Sense
- Directional Mix

Figure 1. ReSound directional options can be organised into three broad categories according to their purpose.

AUTOMATIC CONTROL FOR EASE OF USE

In everyday life, people naturally and subconsciously use different listening strategies depending on the characteristics of the environment and what their intentions and goals are in the given situation. Because the way a person listens is different depending on the situation and their listening goals, hearing aid technology should be designed to support different ways of listening rather than imposing rigid schemes. Although directional microphones can improve hearing in noise, they can also interfere with listening when desired sounds are moving or not directly in front of the user. ReSound continually refines its approach to using directional technology in a way that considers how a listener will experience it in real-life. A hearing aid user is not just the sum of their two ears. A person's ears work within the framework of the entire auditory system. Therefore, the entire human auditory system is considered in the design, from the acoustic effects of the shape and location of the external ears on the head to the power of binaural processing by the brain. The goal is for a hearing aid user to effortlessly engage in auditory social behaviors in the same way as a normal hearing individual, and thereby have a natural and transparent hearing experience.

ReSound developed an approach to automatically applying directionality based on binaural hearing that supports natural listening strategies. It uses analysis of the acoustic environment to steer bilaterally fit hearing aids among three different listening modes with the most optimum settings to support different listening strategies that people naturally use. We call these modes Spatial Cue Preservation, Binaural Listening, and Speech Intelligibility.

- The Spatial Cue Preservation mode emphasizes naturalness and overall sound quality. Although directional microphones help hearing in noise by improving SNR for speech in front of the user, they may not be preferred in less complex environments. This mode aims to provide the best and most enjoyable listening conditions in environments that are relatively quiet or with few overlapping sound sources.

- The Binaural Listening mode is based on the observation that a listener can take advantage of the location of the ears on each side of the head to either enhance or suppress sounds in the environment at will. When the environment is moderately complex, the listener shifts away from relying primarily on spatial cues, relying instead on the ear that has the best representation of the desired sound – the "better ear".

- The Speech Intelligibility mode is activated in complex listening environments where individual talkers blend into the mix of background sound. In that type of environment, it is likely that a listener would employ a listening strategy where they face a conversation partner to maximise visual cues as well as the audibility of the person's voice.

Support for these listening modes is the strategy ReSound has followed for more than a decade. Each successive generation has enhanced how well this could be done as new technologies became available. Table 1 provides an overview of how the strategy has evolved.

Feature	Introduced	Uses ear-to-ear communication	Spatial Cue Preservation	Binaural Listening	Speech Intelligibility
Natural Directionality II	ReSound Live (2009)	No	N/A	**Focus ear: Directional** **Monitor ear: Omnidirectional**	N/A
Binaural Directionality	ReSound Verso (2012)	**Yes**	**Omnidirectional**	Focus ear: Directional Monitor ear: Omnidirectional	**Bilateral directional**
Binaural Directionality II	ReSound LiNX2 (2015)	Yes	**Spatial Sense**	Focus ear: Directional Monitor ear: Omnidirectional	Bilateral Directional
Binaural Directionality III	ReSound LiNX 3D (2017)	Yes	Spatial Sense	Focus ear: Directional Monitor ear: **Enhanced omnidirectional**	Bilateral Directional
Binaural Directionality III	ReSound LiNX Quattro (2018)	Yes	**Spatial Sense***	Focus ear: Directional Monitor ear: Enhanced omnidirectional	Bilateral Directional
All Access Directionality	ReSound ONE (2020)	Yes	**M&RIE** or Spatial Sense**	Focus ear: **Weighted binaural beamformer** Monitor ear: Enhanced omnidirectional	**Weighted binaural beamformer**

*Binaural Compression performance was improved
**depending on receiver

Table 1. Overview of how the ReSound binaural hearing strategy for applying directional technology has evolved. The bolded text indicates the improvements for each successive generation.

All Access Directionality

Role

Adjusts hearing aid microphone patterns according to a binaural hearing strategy and based on acoustic analysis of the environment.

Benefit

Better hearing with less effort in all daily life situations.

Details

All Access Directionality is the most advanced version of the ReSound strategy for controlling directionality. Compared to previous versions, the improvements included in All Access Directionality include further improved SNR with a weighted binaural beamformer and improved sound quality and spatial hearing with the M&RIE receiver module.

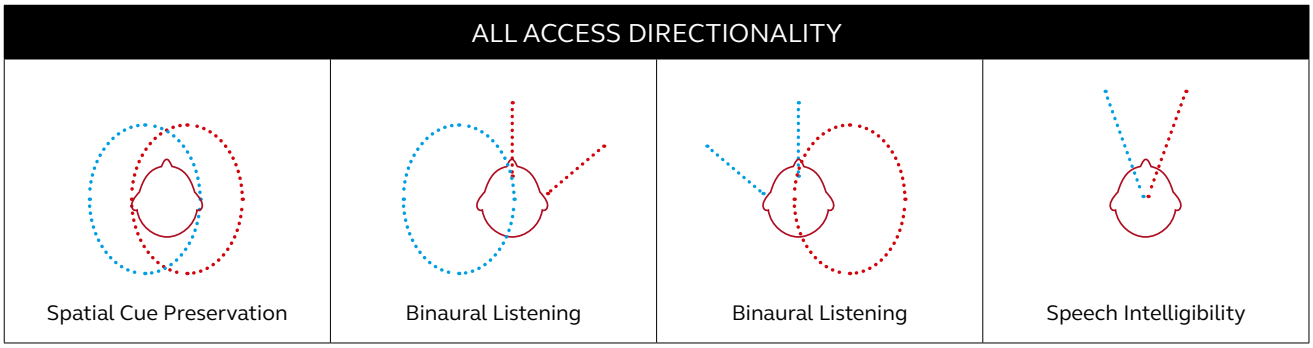


Figure 2. Three different listening modes are automatically applied to support the listening strategies that people naturally use in different types of environments. Ear-to-ear data exchange and a binaural connection enable this advanced processing.

How to use it

All Access Directionality is the default program in some premium hearing aids, such as the ReSound ONE.

Further reading

The evolution of the ReSound binaural hearing strategy: All Access Directionality and Ultra Focus white paper

Further reading on Binaural Directionality III

Binaural Directionality III: Directionality that supports natural auditory processing

Effect of directional strategy on audibility of sounds in the environment

Further reading on Binaural Directionality II

Binaural Directionality II with Spatial Sense

Hearing aid directionality with binaural processing

Further reading on Binaural Directionality

Binaural Fusion by ReSound: Technology optimized as nature intended

Proven benefits of ReSound Binaural Directionality

Further reading on Natural Directionality II

Natural Directionality II brings ReSound Key users the great hearing they deserve

Soft Switching

Role

Smoothly switches between omnidirectional and directional mode depending on the sound environment.

Benefit

Can provide directional benefit in noisy situations with the user needing to switch programs. Does not require a binaural fit so a user who wears only one hearing aid can benefit.

Details

Soft Switching is the most basic way of automatically controlling directionality. Depending on the specific product, it activates Adaptive Directionality, Multiscope Directionality or Autoscope Directionality whenever there is noise present and speech detected in front of the user. For devices with ear-to-ear communication, Soft Switching can be synchronised such that both hearing aids always switch at the same time. Soft Switching has slow transition times to ensure that the switching between the omnidirectional and directional modes is not distracting for the user.

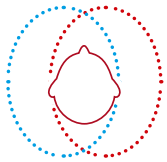
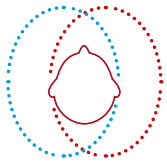
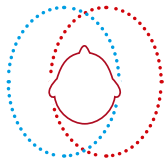
SOFT SWITCHING MICROPHONE MODES					
Signal in front	Speech	Speech	Speech	Noise	Noise
Signal behind	Quiet	Speech Babble	Noise	Noise	Speech
MICROPHONE RESPONSE	 Omni	Directional	Directional	 Omni	 Omni

Figure 3. Soft Switching follows a conventional approach for automatically controlling directional microphones.

OPTIONS THAT IMPROVE SNR
Weighted binaural beamformer with spatial cue preservation

Role

Improves SNR for sound in front of the user while preserving important localisation cues. Enhances the speech on the less noisy side in environments where the noise surrounding the user is not equal.

Benefit

Strikes a balance between maximizing SNR for speech in front of the user, preserving access to off-axis sound, and preserving spatial hearing cues to allow re-orienting to new or moving target speech.

Details

The weighted binaural beamformer uses the four microphones on bilaterally fitted hearing aids to form a narrow directional beam. Compared to other ReSound directional features that improve SNR, the binaural beamformer has the potential to increase articulation index-weighted directivity index (AI-DI)[10] by approximately 2 dB. The weighting of the signal from the side with the least noise provides better performance in environments where the noise background is not the same on both sides of the user. Figure 4 shows how binaural beamforming is limited to the mid frequency region to preserve some spatial hearing cues and sound quality.

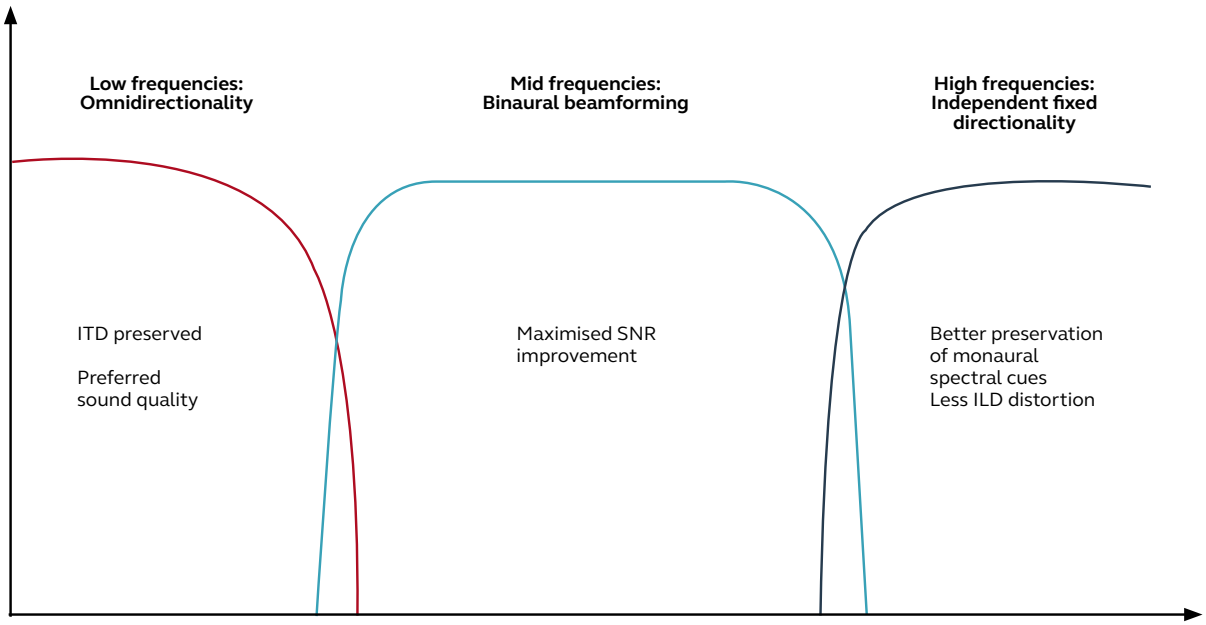


Figure 4. The ReSound binaural beamformer applies strong directionality in the mid-frequency range, while preserving spatial hearing cues in the low and high frequency bands.

How to use it
The weighted binaural beamformer is automatically incorporated in All Access Directionality. In addition, the user selectable Ultra Focus program is based on this technology.

Further reading
The evolution of the ReSound binaural hearing strategy: All Access Directionality and Ultra Focus

Ultra Focus

Role
Maximise speech understanding in noise.

Benefit
Gives the user a selectable option to override automatic control of microphone modes to get the best improvement in directional benefit for speech in front.

Details
Ultra Focus uses the weighted binaural beamformer with a high Directional Mix setting to provide the best possible SNR for speech in front. Other advanced features are also customised to preserve the clarity of the sound.

How to use it
Ultra Focus can be assigned as a dedicated listening program. Users can easily activate it via the on-board pushbutton, a remote control, or the ReSound Smart 3D app when they are in a situation where they only want to focus on what is in front of them.

Further reading
The evolution of the ReSound binaural hearing strategy: All Access Directionality and Ultra Focus

Autoscope Adaptive Directionality, Multiscope Adaptive Directionality, and Adaptive Directionality

Role
Improves SNR for speech in front of the user. Adjusts polar pattern shapes to cancel noise most effectively in the rear plane.

Benefit
Improves speech understanding in dynamic, noisy situations.

Details
The adaptive directional features are multiband, meaning that they apply different polar patterns depending on frequency. As an example of how this could be helpful, the adaptive directional features can adjust to effectively reduce the buzz of a group conversation occurring in the background while at the same time reducing the clatter of dishes and cutlery off to one side.

In addition to adaptation for sound coming from the rear plane, Autoscope Adaptive Directionality and Multiscope Adaptive Directionality offer adjustments of the focus to the front, called “beamwidth”. Autoscope Adaptive Directionality adjusts beamwidth as the intensity of speech in front of the user increases. Multiscope Adaptive Directionality offers three beamwidth settings, Narrow, Medium and Wide. Adaptive Directionality sets the beamwidth to Medium.

How to use it
Depending on technology level, one of these three adaptive directional features will be default in the Restaurant program. They are well-suited to any environment where the user will want to listen solely to speech coming from the front.

Further reading
Surround Sound by ReSound: The technical background

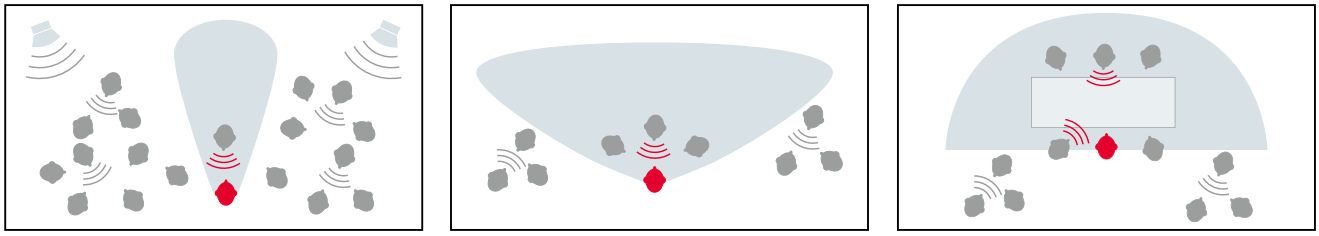


Figure 5. These illustrations show conceptually how different beamwidths may help improve listening in different types of noisy backgrounds. When listening to one person directly in front, a narrow focus is desirable (left panel). As the number and location of the participants in the conversation increases (middle and right panels), a wider beamwidth may be optimal. Autoscope Adaptive Directionality continually adapts the beamwidth according to the intensity of the speech directly in front. Multiscope Adaptive Directionality offers three beamwidth settings.

Fixed directionality

Role

Improves SNR for speech in front of the user.

Benefit

Improves speech understanding in noisy situations.

Details

Directional microphone systems in ReSound digital hearing aids are dual microphone systems, where two omnidirectional microphones are positioned on the device, and digital delays are applied to one of the microphones to create the desired spatial directivity patterns. Fixed directionality uses the dual microphones on the hearing aid to create a static hypercardioid response. This type of response would be observed with a traditional directional microphone with two sound ports. A key difference is that Directional Mix is also applied to balance sound quality and directional benefit. Fixed directionality is the simplest directional option in that the directional characteristics do not adapt to different noise environments.

How to use it

Fixed directionality may be a default setting in some lower technology products. It is an available option at all technology levels. Because of its invariant directional characteristics, it is well-suited for verification measurements of directionality in the test box or real ear.

SOUND QUALITY AND SPATIAL HEARING OPTIONS

M&RIE

Role

Places a microphone in the receiver module for receiver-in-ear devices to take advantage of the user's unique ear shape to filter and collect sound in the most natural location.

Benefit

An immersive an individualised hearing experience with greater depth and direction, sense of space and localisation.

Details

M&RIE, which means "Microphone-and-receiver-in-ear", is technically not a directional microphone. However, it preserves the natural directional hearing that occurs due to the acoustic effects of the outer ear, head and body. M&RIE can be used with compatible Receiver-in-Ear (RIE) hearing aids from ReSound. It is integrated in the All Access Directionality program, where it is active in quiet and moderately complex listening environments. M&RIE can also be selected for a customised listening program. Because the microphone location in the ear canal provides some natural protection from wind noise, M&RIE is a good choice for a listening program intended for outdoor use. When M&RIE is active in a binaural fitting, binaural compression is also applied. Binaural compression aligns the gains at the two ears to best preserve natural level differences between the ears resulting from the acoustic shadow created by the head. Known as Interaural Level Difference (ILD), this is a significant high frequency cue for localisation.

Figure 6. The M&RIE is a receiver module that includes a microphone in the ear canal that helps maintain the ear's natural directional characteristics and spatial hearing cues.

How to use it

The M&RIE is a hardware solution. When hearing aids are fit with M&RIE, the receiver is automatically recognised by the Smart Fit fitting software and incorporated in All Access Directionality. As mentioned, it can also be selected in a dedicated listening program.

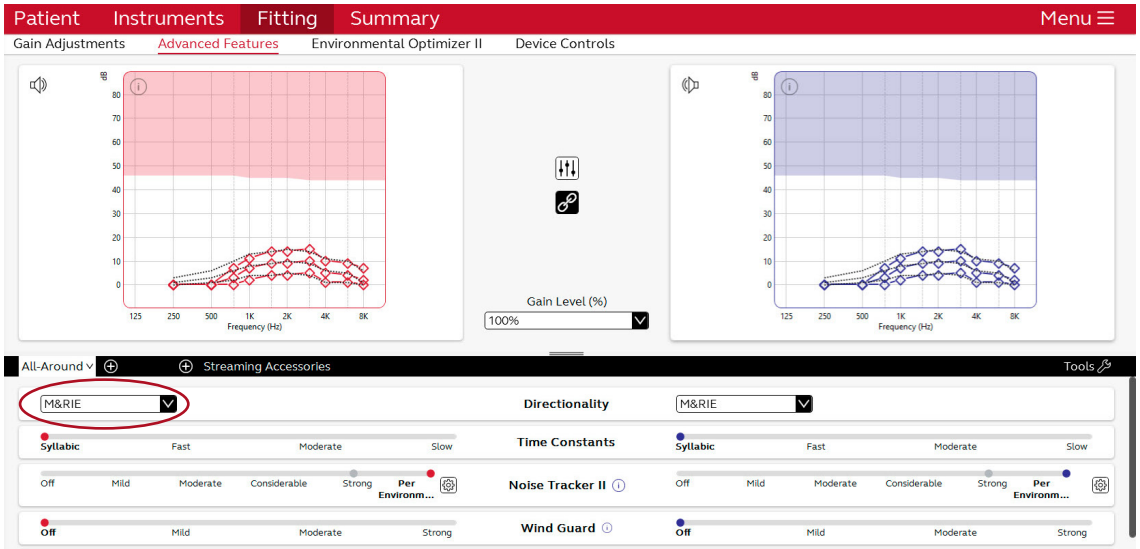


Figure 7. When fit with a M&RIE receiver, the canal microphone is active by default when in All Access Directionality. In other programs, "M&RIE" can be selected in the Advanced Features screen.

Further reading

An innovative RIE with microphone in the ear lets users "hearing with their own ears"

M&RIE receiver preferred for sound quality and localisation

Spatial Sense

Role

Emulates spatial hearing cues normally provided by the natural sound filtering of the outer ear that are disrupted when the hearing aid microphones are placed above the ear.

Benefit

Better localisation compared to omnidirectionality, especially for sounds in the horizontal plane, and improved sound quality.

Details

Spatial Sense was designed to compensate for the disadvantageous location of the microphones above the ear in RIE and Behind-the-Ear (BTE) hearing aids. It uses the directional microphone system to achieve a response for sounds in the horizontal plane that is similar to the average adult ear. This type of feature is generically known as "pinna compensation" or "pinna restoration" in reference to its purpose in compensating for lost acoustic cues from the pinna. Thus, it emulates the response of an omnidirectional microphone with placement within the ear canal. Spatial Sense is automatically incorporated in Binaural Directionality II and Binaural Directionality III, as well as in All Access Directionality in fittings where the M&RIE receiver is not used. Spatial Sense can also be selected as the directional setting in a dedicated program where natural sound quality is prioritised, such as a program for music listening or outdoor use. In a binaural fitting, Spatial Sense incorporates binaural compression as described above in the section on M&RIE. In dual microphone custom hearing aids with ear-to-ear communication, the pinna compensation is not needed, but binaural compression is still applied when Binaural Directionality II or Binaural Directionality III is selected.

How to use it

Spatial Sense is automatically incorporated in Binaural Directionality II, Binaural Directionality III, and All Access Directionality when not using M&RIE. Like M&RIE, Spatial Sense can be selected for a dedicated listening program.

Further reading

Binaural Directionality II with Spatial Sense

Directional Mix

Role

Splits the sound into low and high frequencies, applying directional processing only to the high band.

Benefit

Improved sound quality compared to full band directionality and preserved low frequency interaural timing differences (ITD), for improved localisation.

Details

All directional processing in ReSound hearing aids uses Directional Mix. This processing minimises the impact on sound quality of the inherent low frequency roll-off associated with directional microphones, which can cause a tinny sound quality. Directional processing is carried out in the frequency region that is most important for understanding speech. This provides directional benefit to the user without affecting sound quality compared to other microphone modes. This is critical for a seamless transition when an automatic switching feature is active, such as All Access Directionality or Soft Switching. Sound quality and directional benefit are balanced for each individual based on low frequency hearing threshold levels and the spacing between microphones on the device. People with worse low frequency hearing are prescribed more Directional Mix (a lower crossover frequency between the low and high bands; see Figure 8). Devices with closer microphone spacing have higher crossover frequencies for each Directional Mix setting than those with greater spacing. This is because the relationship between microphone spacing and wavelength of the sound affects the frequency at which the inherent roll-off occurs. Closer microphone spacing results in a higher frequency for the roll-off.

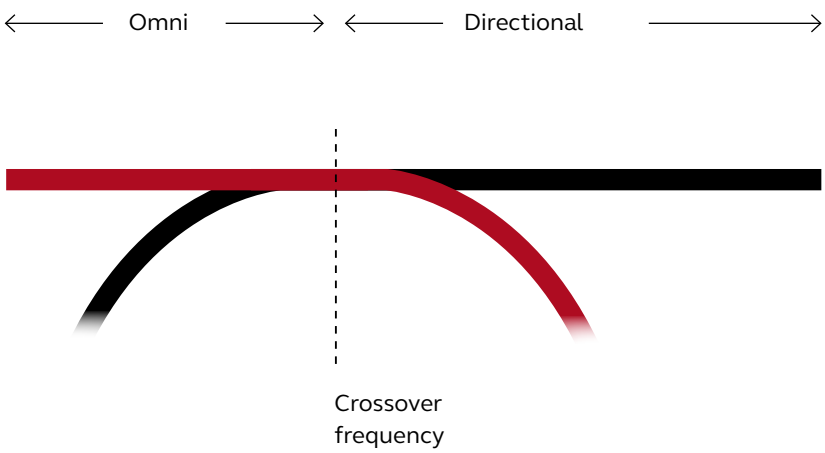


Figure 8. Directional Mix splits the sound into 2 bands. Directionality is applied to the high band.

In addition to balancing sound quality and directional benefit, Directional Mix also preserves low frequency ITD cues, which are disrupted by full-band directionality.[9]

How to use it

Directional Mix is automatically calculated for each individual. In some products, it is also available for fine-tuning in the Advanced Features screen of ReSound Smart Fit™. Although it is rare to change this setting, the user complaints that might prompt a change are:

- Limited benefit understanding speech in noisy situations: *increase* Directional Mix setting to lower the frequency where directional processing begins.
- Intermittent noisiness or tinny sound quality and the user is fit with a feature that automatically changes microphone modes, such as All Access Directionality or Soft Switching: *decrease* Directional Mix setting.

Further reading

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Surround Sound by ReSound: The technical background

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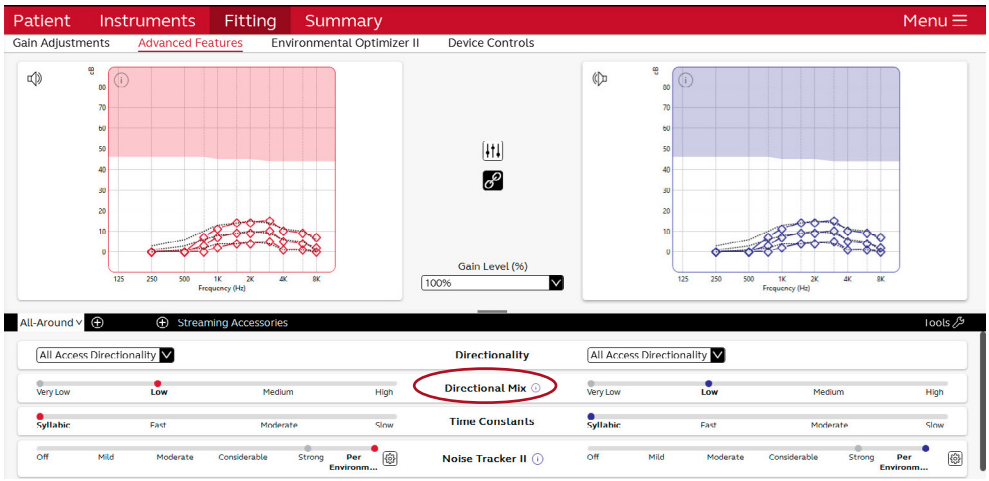

Figure 9. Some products allow adjustment of the Directional Mix in the Advanced Features screen.

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