

Less internal noise with ReSound CROS

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Abstract

People who are fit with wireless CROS systems have one ear that is unaidable with conventional hearing aids and normal or near-normal hearing on their better ear. Because of their hearing status in the better ear, they may be sensitive to any noise in a CROS system and may ultimately choose not to wear the CROS system as a result. CROS systems that use digital wireless streaming are the most convenient compared to legacy wired technology, but have the disadvantage of low-level noise added in the transmission that could be audible in some environments. Therefore, techniques to reduce this noise are of great importance. The ReSound wireless CROS uses a compander to substantially reduce added internal streaming noise while preserving environmental sound. A compander boosts the transmitted signal and then reduces it at the receiving device. Lab measurements show the effectiveness of the ReSound CROS solution compared to CROS systems from other premium hearing aid brands.

Wireless Contralateral Routing Of Signals (CROS) is a non-invasive hearing solution for people with unaidable hearing on one ear and normal or near-normal hearing on the other. By routing sound picked up on the poor ear side to the better ear, lack of audibility caused by the head shadow effect is improved. While CROS does not allow for higher order binaural hearing that requires individual input to the brain from each ear, it is still a convenient, low-risk way to help improve functional hearing in daily life. Notable benefits include better speech understanding for speech on the poor ear side as well as environmental awareness and safety (see Stewart & Woodward¹ for a review of benefits).

Modern CROS systems are wireless and use digital audio streaming to transmit sound from the transmitter device on the poorer ear to the receiver device on the better ear. While this type of solution offers greater convenience to users, an important consideration when fitting wireless CROS is the possibility of internal device noise becoming audible to the user. We know that low level internal noise from microphones and directional microphone systems in hearing aids can be audible and bothersome to those with milder hearing loss severity.² With digital wireless CROS systems, the desired environmental sound from the poor ear side is delivered to the better ear along with noise added by the ear-to-ear transmission. This noise is a by-product of digital audio streaming that arises from different sources. People fit with CROS have sound delivered to an ear with normal or near-normal hearing and may be sensitive to this internal device noise. When the environmental sound is not very loud and does not mask internal noise of the system, the added

noise may become audible and affect sound quality in the better ear side. In the worst case, a user may judge this to outweigh the benefits of the system and abandon use of the CROS. In designing the ReSound CROS system, a clever technique was implemented to minimize extraneous noise being transmitted to the good ear. As we will show, this technique effectively minimizes internal noise due to digital wireless transmission regardless of whether the receiving device has its microphones active. This adds fitting flexibility for the Hearing Care Professional and allows the user to control microphone status according to their preference without the risk of a degradation in sound quality.

Influence of the microphones on the receiving device

A factor that affects the level of digital transmission noise is whether the receiver device microphones are active. In a CROS fitting, it is not unusual to program the receiver device with the microphones deactivated. Assuming an open fitting, this practice makes sense because the environmental sound on the normal or near-normal hearing ear can enter the unoccluded ear canal and be heard naturally. However, digital wireless CROS systems with deactivated microphones have the disadvantage of higher noise levels on the receiver side compared to BiCROS systems where the microphones are active on the receiving hearing aid. This may seem counterintuitive but there is a simple explanation for why this can happen.

The reason for higher residual transmission noise with inactive receiver microphones has to do with the way the sound level is adjusted in the receiver device. When the microphones on the receiver side are not active, there is only one signal passed to the amplifier on the receiver side. All sound from the transmitter device and transmission noise contained in this signal are delivered to the receiving device amplifier. But when the microphones on the receiver side are active, the total signal equals the signal from the transmitter device, the transmission noise and the signal from the receiver device. To provide the correct level for the receiver device amplifier, this total signal must be divided by two, which conveniently also halves the noise level since this noise is not present in the signal from the receiving device microphones. Recall that this transmission noise is not environmental noise that can be detected by the microphones of the receiver device.

The effect of deactivating the receiver device microphone is illustrated in Figure 1. This figure shows the level of digital audio transmission noise embedded within the signal delivered to the receiver device with the microphones turned off versus on. We were able to calculate this noise level by comparing output in the receiver device with the receiver microphones on versus off. When the receiver device microphones are turned on, the noise decreases by one half, which in this figure is represented by a 0 dB baseline, for easy comparison.

In the ReSound design, all CROS fittings have the receiver microphones active. In essence, this means that there is no practical difference between CROS and BiCROS fittings. However, the user can mute the receiver microphones via the ReSound Smart 3D™ app. This allows users to experiment with the sound quality in their daily lives. People with minimal hearing loss in particular may or may not prefer to receive sound picked up from the receiver device in addition to the transmitter device. Even people who have hearing thresholds within normal limits may enjoy the sound quality with both the transmitter and receiver device microphones on. Leaving this option open to users requires that the system design manage reduction of transmission noise such that muting and unmuting the receiver device microphones does not result in noise levels changing.

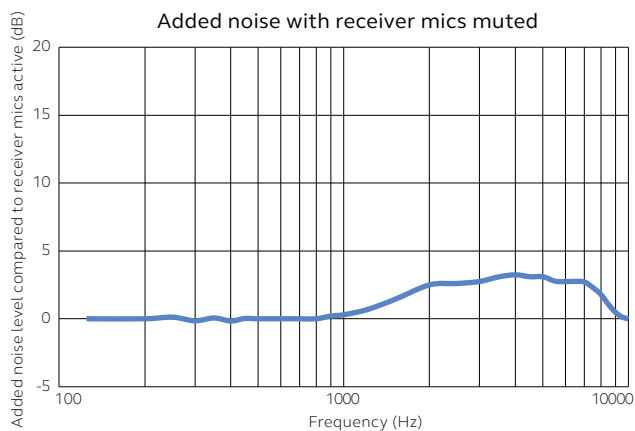


Figure 1. The increase in internal noise when the CROS receiver is turned off, compared to keeping the the CROS receiver microphones on (which essentially makes it a BiCROS fitting). This halves residual noise that results from digital wireless transmission of the sound from the transmitter device. Users may be sensitive to this noise level difference, so it is important to apply a noise management strategy that does not rely on microphone status.

How internal noise is reduced in ReSound CROS

The ReSound approach to reducing the transmission noise added in the digital audio streaming from ear-to-ear is the use of an audio processing technique commonly called a “comparator”. It involves strategically compressing, then expanding, the signal from the transmitter device to reduce the noise introduced in wireless transmission. Note that the name “comparator” comes from the combination of these two techniques, in that order: compressor + expander.

How does the comparator work in detail? First, let’s look at what happens if no noise management is applied. In Figure 2, the environmental sound picked up by the transmitter is represented by the black sound wave. This sound is then digitally streamed to the receiver device. The green curve in the top middle of the figure represents the transmission noise added during this process. At the receiver device represented on the right, the environmental sound is mixed with the transmission noise. This noise may be audible to the user.

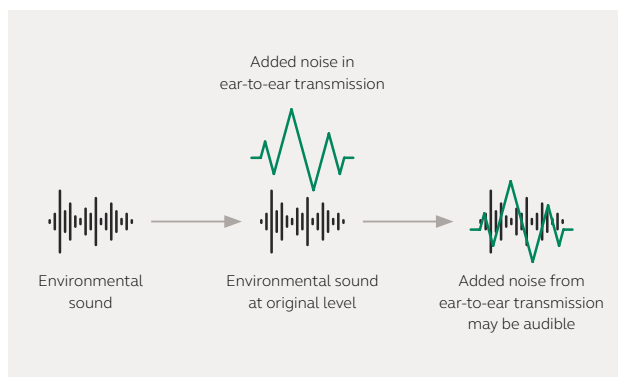


Figure 2. If no noise management is used, the noise added during the digital transmission of the signal will be added to the desired environmental sound. The transmission noise may be audible to the user

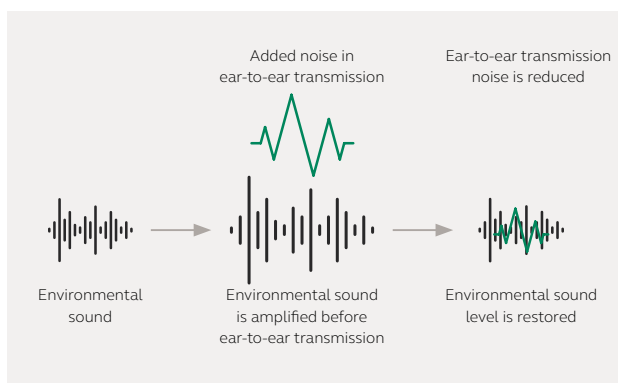


Figure 3. CROS transmission with comparator. Environmental sound is amplified before ear-to-ear transmission and compressed to prevent peak clipping. The signal is expanded to the original sound level at the receiver device. Because added transmission noise was not in the original signal, it is reduced in the sound delivered to the ear

Figure 3 illustrates what happens when the comparator is applied. First, the level of the sound being sent from the transmitter over to the receiving device on the other ear is increased. This desired, but boosted, sound combines with the unwanted noise from the digital wireless transmission.

Because the original signal from the transmitter is increased, there is a more favorable signal-to-noise ratio when combining the signal with the wireless transmission noise – the signal is louder in comparison to the noise. Next, the entire signal, including noise, is turned back down so that the desired environmental sound is presented at the original level. Because the noise wasn't in the original signal, it too is turned down below what was added during the transmission.

A risk in the first step of the compander process is that, since we are increasing the level of the transmitted signal, we could exceed the dynamic range of the transmission and peak clipping could occur. Therefore, we apply compression at this stage. The compression allows us to turn up the level of the transmitted signal but keep it within the dynamic range of the ear-to-ear transmission capability. This prevents artifacts and peak clipping.

The compression of the digitally streamed signal needs to be reversed before being delivered to the receiver ear amplifier. Thus, we turn the levels back down. As illustrated in Figure 3, this lowers the level of the added noise, but it will also expand the dynamic range back to what it was originally. Due to the effectiveness of this technique, the transmission noise level with the receiver microphones on is nearly identical to with the receiver microphones off, ensuring consistent sound quality across both conditions.

Comparison to other wireless CROS

The compander technique used to reduce the noise introduced by digital wireless streaming in a CROS solution is effective. To illustrate how it compares to typical wireless CROS products, the internal noise levels for a ReSound CROS solution and CROS systems from two other premium brands were measured. The methodology for measuring Equivalent Input Noise (EIN) was used, but the hearing aids were programmed to provide 10 dB flat linear insertion gain rather than set to their reference test gains. EIN is calculated by subtracting the gain from the measured output. In this case, there is no external sound entering the devices, so the “gain” would be the internal noise of the device that becomes amplified as output and measured by the test. This way of quantifying the internal noise was carried out in third octave bands from 200 to 6300 Hz. As shown in Figure 4, the noise was lower in all bands for the ReSound system compared to the other brands. The average EIN in the ReSound system was 10 dB SPL compared to 20 dB SPL for Brand A and 19 dB SPL for Brand B. Furthermore, the EIN in the ReSound system was lower in each measured third octave band than the other systems.

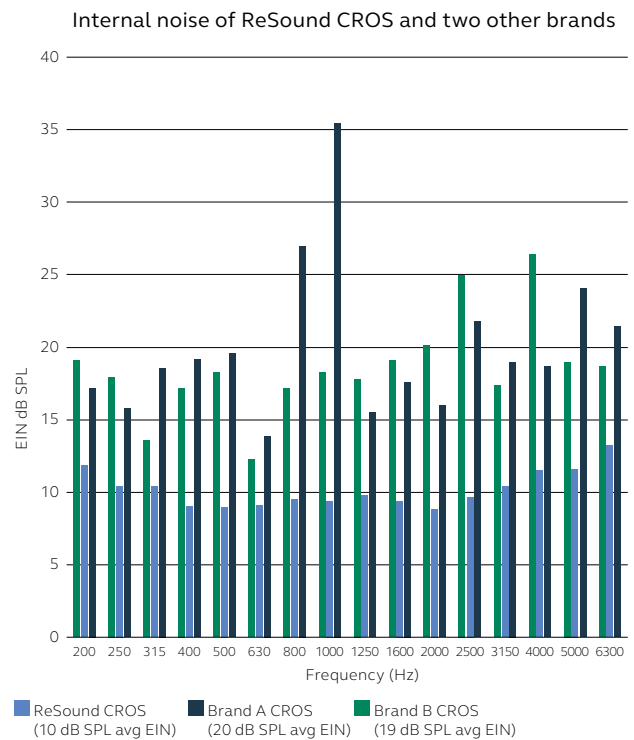


Figure 4. EIN measurements demonstrate that the ReSound CROS system has less internal noise than two other premium brand CROS systems. This is likely due to the effectiveness of the compander.

Conclusion

The method developed by ReSound for reducing internal noise in digital wireless CROS is not only effective but results in lower measured internal noise than in comparable systems from at least two other premium hearing aid brands. The compander approach substantially reduces added transmission noise by boosting the original signal level without exceeding headroom, and then expanding the signal back to its original level. This results in the correct level for the transmitted signal and a significantly lowered level of noise added by the transmission. This approach is so effective that transmission noise level differences when the receiver microphones are on versus off are negligible, and users can be in control of microphone status without risk of sound quality differences due to added noise.

Additional tips for ensuring the best CROS listening experience

Although internal noise due to transmission is minimized in the ReSound CROS system, internal noise in any hearing aid can still be a user complaint due to normal or near-normal hearing on the ear fit with the receiving device. Tips for dealing with a complaint of internal noise for CROS user are the same as for any hearing aid fit to someone with minimal hearing loss:

1. Make sure the receiver device is fit open³.
2. Keep gain in the receiver device very low, especially in the lower frequencies, where noise is more likely to occur³. The goal is to not amplify sound, but just allow the microphones to be activated, to help reduce transmission noise.
3. Activate or increase expansion in the receiver device.
4. Set Directional Mix to Low or Very low in the receiver device, if the microphones are activated and directionality is applied.

References

1. Stewart E, Woodward J. Out of the (head) shadow: A systematic review of CROS/BiCROS literature. The Hearing Review. 2021;28(8):22-5.
2. Thompson SC. Internal noise in hearing aid microphones: Its causes and consequences. The Hearing Journal. 2003 Oct 1;56(10):46-7.
3. Dillon, H. CROS, bone-conduction, and implanted hearing aids. In: Hearing Aids. 2nd edition. New York: Thieme Publishers;2012;p. 513-519.

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