Field Study News

August 2015

Phonak CROS II

Electroacoustic measurements look at key performance aspects of two wireless CROS systems

The Contralateral Routing of Signal (CROS) device is one recommended solution for individuals with Single-Sided Deafness (SSD). BiCROS is the adaptation for individuals who also need amplification in the better ear. Phonak Audiology and Research Center (PARC) took an in-depth look at the sound quality, sound cleaning and general usability of the Phonak CROS II compared to a competitive CROS device. Technical measurements of the noise floor of the two systems revealed lower noise levels for the Phonak CROS II compared to the competitor's CROS device. Further, results revealed the potential for better speech understanding in background noise for the Phonak device, due to more advanced noise management and automatic activation of settings that facilitate optimal hearing performance.

Introduction

Contralateral Routing of Signal (CROS) devices are an accepted and effective intervention for individuals with Single-Sided Deafness (Ryu et al, 2013, Schafer et al, 2013, Williams, et al, 2012, Hol et al, 2010). In spite of advances in this technology, significant challenges still exist for this population, with many users reporting poor overall satisfaction (Cashman et al, 1984; Ericson et al, 1988; Hayes et al, 2005). Previous dissatisfaction with (Bi)CROS devices has been reported in the areas of usability, difficulty in background noise and appearance (Williams et al, 2012). Individuals with Unilateral Hearing Loss (UHL) lose binaural functions including binaural summation and binaural squelch. Therefore, the need for good audibility as well as noise management are of utmost importance. The needs of CROS users extend beyond speech understanding in noise. Due to their hearing acuity in the better ear, these users may be sensitive to sound quality issues such as interference, distortion and high noise levels in the devices. This investigation was designed to evaluate how modern (Bi)CROS devices perform in these challenging areas.

This investigation compares the new Phonak CROS II device to a CROS competitive device on a series of technical measures including noise floor levels, directional microphone functionality, and general ease of use.

Methodology

Several measurement tools were used for the current investigation at the Phonak Audiology Research Center (PARC). The first was a Signal-to-Noise Ratio (SNR) analysis tool developed in Matlab. To perform this measurement, (Bi)CROS devices were placed on a low-metal version of the Knowles Electronic Manikin for Acoustic Research (KEMAR). This low-metal KEMAR prevents any interference or interruption of the wireless transmission from the CROS transmitter to receiver. In the measurement, speech and noise signals are presented simultaneously via loudspeakers and recorded with KEMAR (with built-in ear simulators). By analyzing these recordings, an effective output SNR can be computed and referenced to the known SNR of the input signals. This way an SNR-improvement can be measured objectively for realistic speech in noise conditions (Hagerman, Olofsson & Nästén, 2002). The SNR measurement shows the benefit in reference to the input signal-to-noise ratio. Therefore the higher the output bar, the greater the benefit in SNR, and higher expected performance. Adobe Audition (Adobe Systems Incorporated, 2007) was used to record noise floor levels and stimuli through KEMAR. These recordings could then be visualized in a spectral domain to assess noise floor levels across frequency.

The Verifit II verification system was used for all test box measurements. These measurements were completed using 2-cc couplers and average adult RECDs. Due to the binaural transmission inherent to a CROS system, both the receiver and transmitter were coupled to the binaural coupler of the Verifit II. All responses throughout the investigation were measured on the receiver hearing aid side of the CROS system. To ensure that the

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measurements were isolating only the sound being delivered to the receiver by the transmitting device, and not sound being picked up and amplified by the receiver microphone itself, only the transmitter was placed inside the test box during measurements. The response of the transmitted signal was measured on the receiver, which was coupled to the Verifit II but kept outside the test box during measurements.

A Phonak Venture Bolero Behind-The-Ear (BTE) hearing aid and a Phonak CROS II BTE transmitter were used for this investigation. A competitor's BTE hearing aid and CROS transmitter were used for comparison to the Phonak system. Devices were coupled to KEMAR's ears using the standard KEMAR BTE couplers.

Hearing Instrument Programming

The manufacturers' proprietary fitting strategy was applied for each fitting, respectively. Frequency lowering, feedback cancellation and any sound cleaning features were disabled. Standard tubing and an occluded standard earmold without venting was selected in both Phonak Target and the competitor's software. For the measurements, the CROS devices were programmed for 0 dB hearing thresholds in the better ear. The BiCROS devices were programmed for a flat 60 dB HL hearing loss across all frequencies in the better ear. These settings were used for all measurements described below.

Results

Internal and external noise

Research by Nabelek (1991) suggests that the presence of background noise, and ability to tolerate this noise, is an extremely important consideration in successful hearing aid use, with higher noise tolerances correlating with increased wearing time. (Nabelek et al, 1991). In 2006, Nabelek et al found that Acceptable Noise Level (ANL) is an even more accurate predictor of hearing aid use than speech understanding in background noise. Furthermore, there is a large percentage of the population that can be considered more sensitive to noise, and therefore may be susceptible to hearing aid rejection if noise reaches levels that are too high above threshold. In a study of 191 participants, 64% had lower ANLs (Acceptable Noise Levels) (i.e. less tolerance for noise) as compared to consistent hearing aid users and reported inconsistent or no hearing aid use. Additionally, Agnew (1997) described that internal noise of hearing instruments became objectionable to the user when the level exceeded their hearing thresholds by 4 dB. These findings support the notion that external environmental noise as well as internally-produced noise may play a critical role in the comfort and ultimate success of a Bi(CROS) device.

Noise floor

Figure 1 and 2 show the noise floor levels by frequency for the Phonak (green) and the competitor (red) CROS and BiCROS systems. In both configurations, the Phonak CROS II system revealed a consistently lower noise floor. The noise floor of the system could have several implications for the user. With CROS candidates often presenting with thresholds better than 20 dB HL in the 'good' ear, noise levels between 20 and 35 dB SPL, as seen with the competitive device (right) in Figure 1, would be audible and possibly interfere with audibility for soft sounds. The results of this investigation indicate that CROS users would not hear the noise floor with the Phonak CROS II device. In an example BiCROS fitting, the noise floor level of the Phonak CROS II was 10-35 dB lower compared to measurements with the competitive device. Using the 60 dB HL reference line (blue), it could be anticipated that individuals with mild, moderate and sloping hearing losses would find the noise floor in the competitive device to be clearly audible. These measurements provide additional value and applicability beyond the standard specifications (i.e. Equivalent Input Noise (EIN)) shown on hearing aid data sheets due to the ability to observe the impact of internal noise in a realistic fitting.

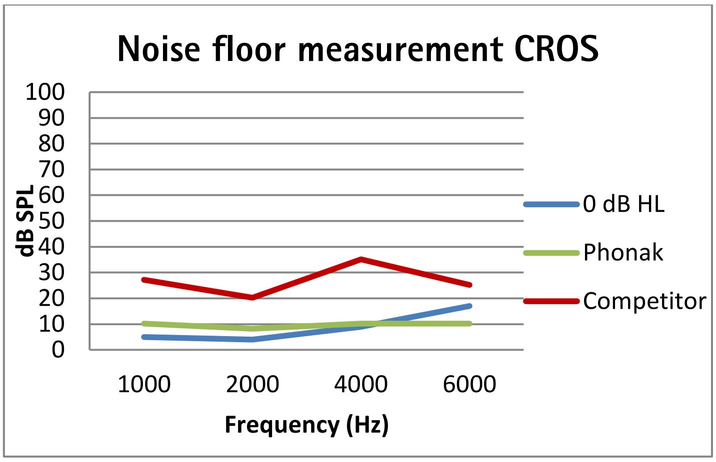

Figure 1: Frequency spectrum of the noise floor for CROS competitor (red) and the Phonak CROS II system (green). The blue line indicates normal hearing thresholds at 0 dB HL across all frequencies as a reference for audibility of the noise floor.
*** noise floor values for the Phonak CROS II at 1000 and 2000 Hz may be lower than what is indicated due to limitations of the measurement system.**

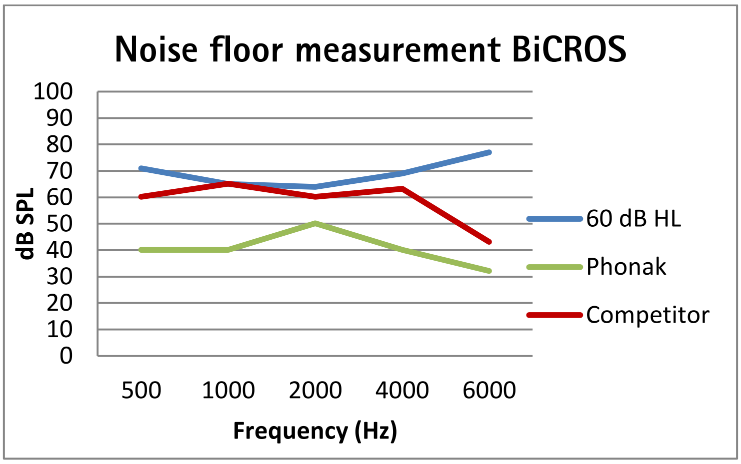

Figure 2: Frequency spectrum of the noise floor for the CROS competitor (red) and the Phonak CROS II system (green) when programmed as a BiCROS with a 60 dB HL hearing loss across all frequencies in the better ear. The blue line indicates 60 dB HL thresholds across all frequencies as a reference for audibility of the noise floor.

It is important to also consider the impact of the noise floor on the ability to understand soft speech information. Figure 3 shows the frequency spectrum of an average speech sample presented at 40 dB SPL (blue) and the frequency spectrum of the noise floor for the competitor's device. The overlap between these two curves suggests potential interference of the noise floor that could be detrimental to soft speech audibility. Figure 4 shows the same frequency spectrum of an average speech sample presented at 40 dB SPL (blue) and the Phonak CROS II noise floor in red. In this figure it is notable that the noise floor and speech signal curves maintain separation across a wide frequency bandwidth. Further, it important to note that the audibility of the noise floor for any hearing aid can be significantly affected or mitigated by the adjustment of the knee point thresholds. However, by raising the knee point threshold(s) to lessen the perceptibility of the noise floor, the audibility of soft speech is also affected. The Phonak CROS II system demonstrates a low noise floor, eliminating the need for any change or increase in kneepoint threshold and resulting decrement to soft sound audibility.

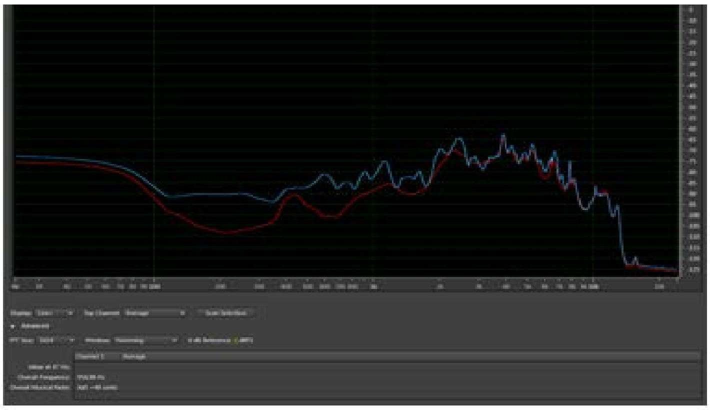

Figure 3: Frequency spectrum of an average speech sample presented and recorded at 40 dB SPL to represent the level of soft speech is shown in blue. The noise floor recorded from the competitor's CROS device is shown in red. The degree of overlap between these two curves suggests potential interference of the noise floor with soft speech perception.

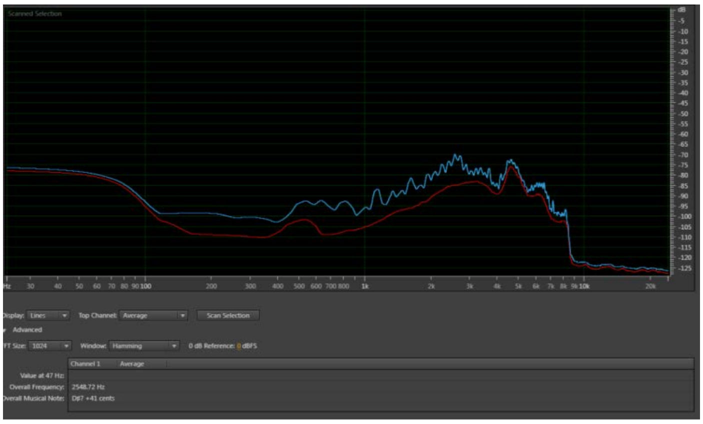

Figure 4: Frequency spectrum of an average speech sample presented and recorded at 40 dB SPL to represent the level of soft speech is shown in blue. The noise floor recorded from the Phonak CROS II device is shown in red. The degree of separation between these two curves through 4000 Hz suggests higher potential for soft speech audibility.

Directional microphone functionality

The difficulties associated with unilateral hearing loss and the loss of binaural function may be underestimated based on the assumption that the individual can rely on the better ear. However, many critical functions including localization and understanding speech in competing noise require binaural input. In fact, Valente et al (2002) noted that unilateral hearing loss can present a 13 dB SNR deficit compared to that experienced by individuals with normal hearing. In a study by Chiossoine-Kerdel et al (2000), 86% of subjects with unilateral hearing loss reported a significant hearing handicap on the Hearing Handicap Inventory for Adults (HHIA). While the CROS solution does not restore binaural function, significant efforts have been directed at employing sound cleaning schemes to improve everyday function and reduce perceived handicap.

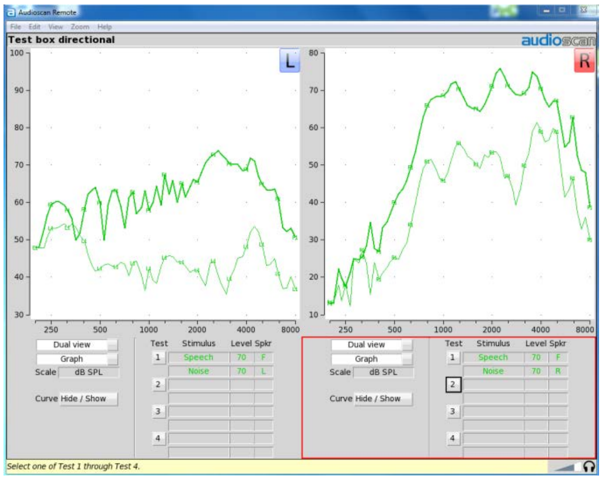

Figure 5 : The Verifit II measurements of directionality for the CROS devices. Phonak CROS II system in Adaptive StereoZoom (left) and the competitor's CROS system in an adaptive directional mode (right). Both systems were fitted as a CROS device with 0 dB hearing thresholds across all frequencies in the better ear. The Phonak CROS II device (left), demonstrates an average front-to-side directional difference at 500 Hz, 1k, 2k, and 4 kHz of 18 dB SPL. The competitive system demonstrated an average of 12 dB SPL.

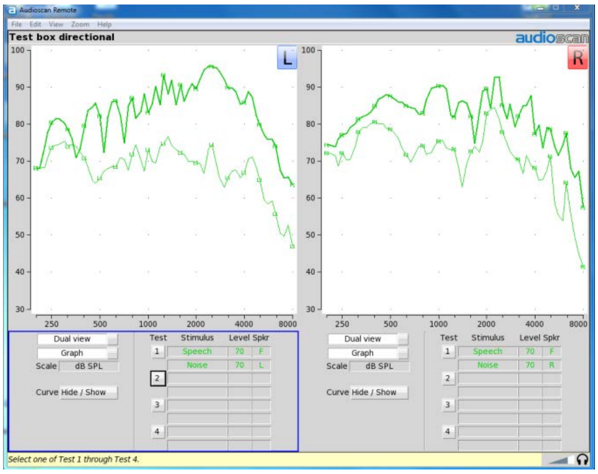

Figure 6: The Verifit II measurements of directionality for both systems fitted as BICROS devices with hearing thresholds of 60 dB HL across all frequencies in the better ear. An average front-to-side directional difference at 500 Hz, 1k, 2k, and 4 kHz of 19.5 dB SPL was measured for the Phonak BiCROS fitting, and an average of 8.5 dB SPL was measured for the competitor's device.

Figures 5 and 6 show the results of a Verifit II measurement of directionality for both the CROS and BiCROS fittings. The Phonak CROS II system is shown on the left side in both figures, and the competitor's CROS system on the right. Results for both the CROS and BiCROS fittings show a greater average separation between speech and noise for the Phonak CROS II system across 500 Hz, 1, 2, and 4 kHz.

The results of greater separation between speech and noise, particularly for the CROS fitting, could be attributed to a significant difference in the amount of gain prescribed in the low frequencies between the Phonak CROS II and the competitor device. The reduced amount of low frequency gain prescribed for the competitor's CROS fitting, may limit the performance of directional microphones. See Figure 7 below for the Verifit output response showing the difference in prescribed gain between the Phonak and competitor's BiCROS systems.

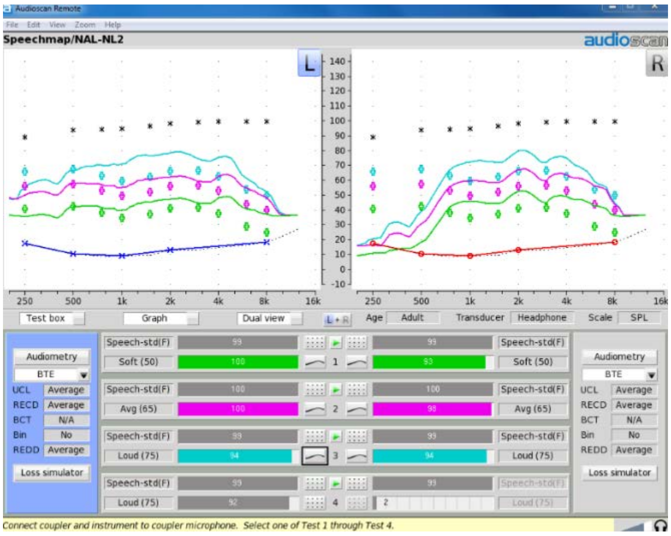

Figure 7: Verifit output for soft, medium, and loud input levels. The Phonak CROS II system is shown on the left, the competitor CROS system is shown on the right. Output reveals a drop-off in low frequency gain for the competitor's CROS device. This could limit the benefit provided by gain-dependent features such as directional microphones.

Usability

Hayes et al. (2005) also cite ease of use as a potential source of dissatisfaction with Bi(CROS) devices. Devices were described as "not user friendly" if they required manipulation of push button or switches to ensure functionality. Additionally, Williams et al (2012) found that manual adjustments of a Bi(CROS) device were within the top five concerns for CROS users when evaluating this type of device. The Phonak CROS II system utilizes an advanced automatic system that analyzes the acoustics of the listening environment, and adjusts both the receiver and hearing aid signal processing, accordingly. The competitor CROS system defaults to the CROS transmitter turned off, and relies on the user to turn the CROS transmitter on or off when the situation dictates.

The two figures below show the resulting SNR with the Phonak CROS II system (left) and the competitor CROS system (right) with the transmitter turned on and off in three types of challenging listening situations. The figures also indicate the actions required to optimize listening in each condition with the Phonak CROS II system (green) and competitor CROS system (red).

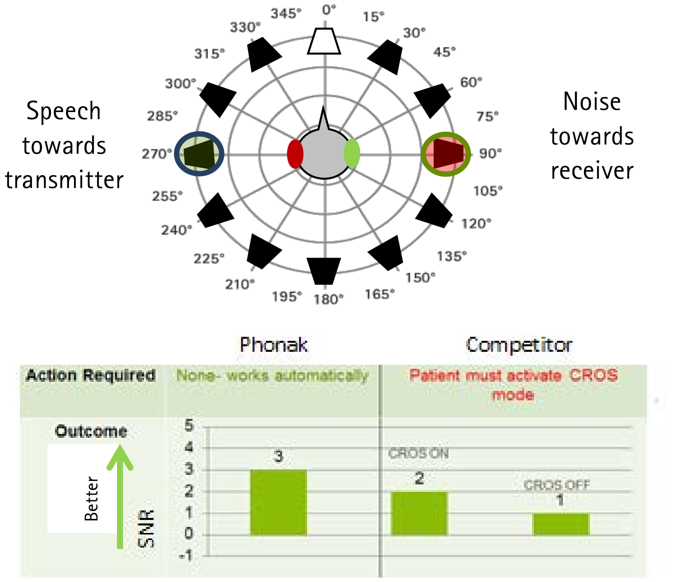

Figure 8: Listening environment with speech towards the transmitter and noise towards the receiver. Phonak CROS II system (left) and competitor CROS system with transmitter on/off (right).

Figure 8 shows the SNR results when speech is directed toward the transmitter (poorer ear) and noise towards the receiver (better ear). In this example, the user benefits from the Phonak automatic adaptive system which allows the transmitter side to stay in Real Ear Sound while the receiver side can assist in noise supression utilizing the UltraZoom directional mode. The competitive system, after the CROS device is engaged, detects noise and activates a binaural directional microphone mode, which obviously results in some target cancellation since the signal is lateralized to the poorer ear.

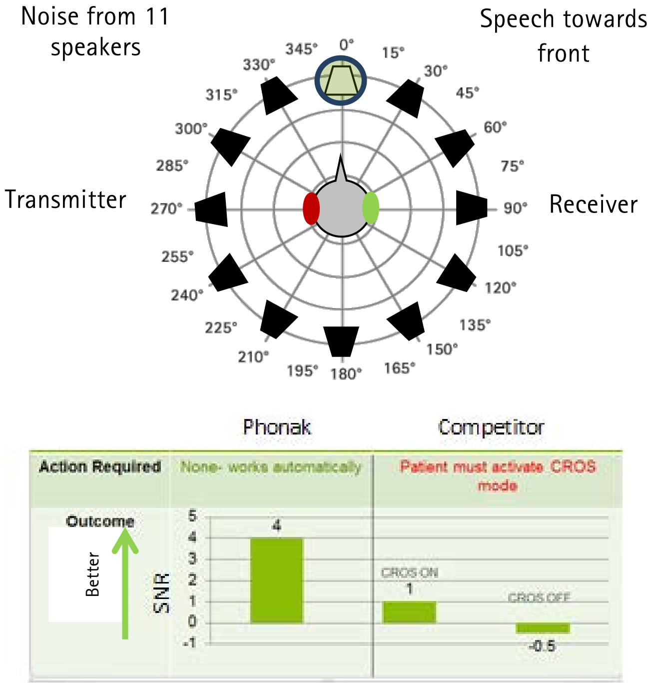

Figure 9: Listening environment with speech towards front, and multitalker babble noise from all other 11 speakers. Phonak CROS II system (left) and competitor CROS system with transmitter on/off (right).

SNR measures in a diffuse noise environment with speech to the front are displayed in Figure 9. In this case, the adaptive narrow directionality of Phonak StereoZoom, is activated. This feature narrows the beam of focus, allowing the user to benefit from maximum noise attenuation. The Phonak solution offered the only fully automatic functionality (CROS needed to be manually activated in the competitor's system) and the most effective SNR improvement.

Figure 10 and Figure 11 show the difference in output frequency response from the receiver hearing aid with input signal from the CROS transmitter (purple) and the output of the receiver hearing aid when the CROS transmitter is turned off (orange).

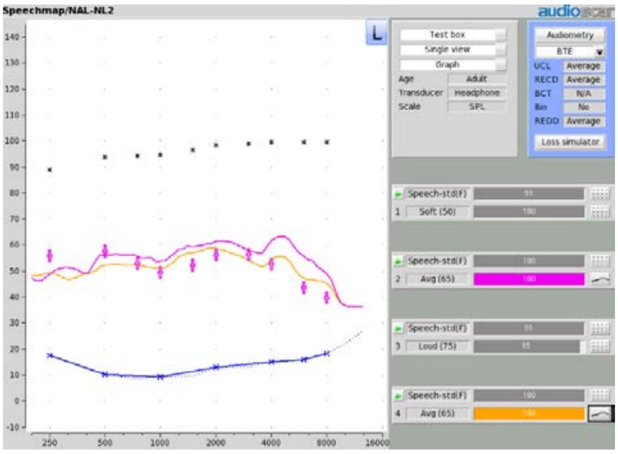

Figure 10: Output of the Phonak Bolero receiver hearing aid with the input signal from the Phonak CROS II transmitter (purple). Output of Phonak hearing aid receiver alone with transmitter turned off (orange).

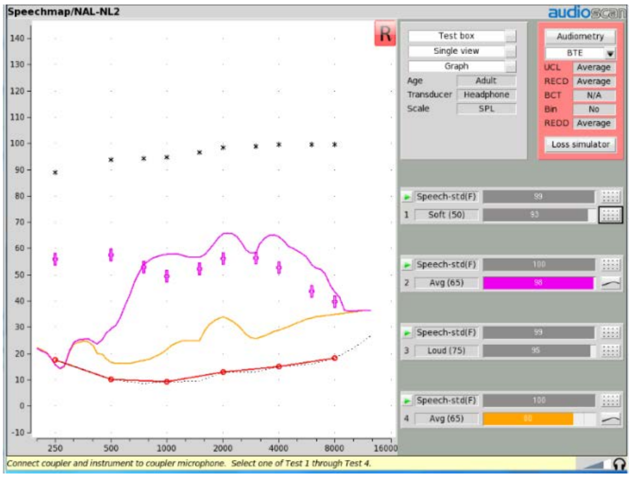

Figure 11: Output of competitor CROS receiver hearing aid with input signal from CROS transmitter (purple). Output of competitor hearing aid receiver alone with transmitter turned off (orange)

Results reveal consistent function of the Phonak receiver-side hearing aid, even when the CROS transmitter is turned off. The competitor system, however, switches off the receiver-side hearing aid when the transmitter is switched off. Although the CROS user does not need amplification on the better ear, the sensation of a disabled or "dead" hearing aid placed in a normal hearing ear may be uncomfortable for CROS users.

Conclusion

The results from this investigation indicate that the Phonak CROS II delivered superior sound quality, based on the predicted audibility of the noise floor in the CROS and BiCROS configurations of the competitive device. Additionally, as a result of the full bandwidth directionality and the narrow directionality StereoZoom feature, Phonak CROS II is able to provide a better SNR in the presence of background noise. Finally, the Phonak CROS II did not require manual activation or manual program switching on the part of the CROS user in order to activate the settings that deliver optimum performance. As a result of this experiment, the Phonak device is expected to deliver industry-leading sound quality, noise management and hearing performance delivered automatically.

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