Benefits of probe-mic measures with CROS/BiCROS fittings

By John Pumford

The management of clients presenting with "unaidable" unilateral hearing loss is a challenging task that hearing healthcare professionals frequently confront. One method commonly chosen to address this issue is a CROS (contralateral routing of signals) or BiCROS (bilateral CROS) hearing instrument fitting. Both CROS and BiCROS fittings attempt to overcome the adverse effects of the head shadow effect by providing awareness of sound from all directions around an individual, even if sound originates from the side of an ear with little or no usable hearing. This goal is achieved by positioning a microphone over the unaidable ear that transfers all sound via wires or radio frequency (RF) transmission to a receiver located at the better hearing ear.

As with any hearing instrument technology, it is important to evaluate the functionality of the CROS/BiCROS system and, if required, perform adjustments to meet the unique auditory needs of the individual being fitted. Probe-microphone measurements represent an invaluable tool for achieving these goals.

"...probe-microphone measurements represent an ideal method of ensuring that CROS/BiCROS hearing instruments are fitted and functioning appropriately so as to maximize the potential benefit to the wearer..."

These measurements can be used to inform clients about the impact of the head shadow effect and to demonstrate how the selection of CROS/BiCROS technology can overcome it. Furthermore, probe-microphone measurements represent an ideal method of ensuring that CROS/BiCROS hearing instruments are fitted and functioning appropriately so as to maximize the potential benefit to the wearer.

Given the unique manner in which these devices function, it should come as no surprise that the fitting and verification protocols used with CROS/BiCROS hearing instruments vary somewhat from those used with the typical hearing instrument. This article will discuss a number of issues and techniques that should be considered when fitting and verifying CROS/BiCROS hearing instruments using probe-microphone systems.

CANDIDACY AND IMPLEMENTATION

CROS hearing instruments are typically provided to patients with unaidable hearing loss in one ear and normal hearing to mild high-frequency hearing loss in their other ear (see Sandlin for a description of the unaidable ear).[1] A microphone (transmitter) is placed on the unaidable ear that sends signals by wire or RF transmission to a hearing instrument (receiver) fitted on the ear with normal (or near-normal) hearing. Processed signals from the receiver in a CROS fitting are usually delivered via a nonoccluding earmold (with BTEs) or shell (with ITEs) such that the better ear receives both the naturally occurring sound (i.e., from the better side) and sound from the transmitter (i.e., from the poorer side).

BiCROS hearing instruments are usually fitted on patients with unaidable hearing loss in one ear and a significant degree of hearing loss in the better ear. With the BiCROS, a microphone (transmitter) is again placed on the unaidable ear, sending signals via wire or RF transmission to a hearing instrument (receiver) on the aidable ear.

However, unlike the typical CROS candidate, the BiCROS user also requires amplification for the better ear, given the hearing loss on that side. Thus, to provide audibility of sound originating from all azimuths around the individual, a second microphone is activated and placed on the better ear. Sound from both microphones is processed by the hearing instrument on the better ear and delivered to that ear through tubing and a closed earmold or shell.

Expected benefits

The primary benefit expected for patients fitted with CROS/BiCROS technology is increased awareness of sound arising from their unaided side (i.e., reduction of the head shadow effect). It follows that there is potential for improving speech intelligibility in environments where speech is directed toward the worse ear. While localization and speech intelligibility in noise typically remain of concern, it has been reported that some CROS users find they can improve their localization abilities by comparing the differences in signal characteristics for sound arriving from the transmitter/receiver (i.e., the unaided side) and via the unoccluded ear canal (i.e., the better side).[2]

PROBE-MIC ISSUES

Given the implementation differences described above, it follows that there must be unique issues to consider during the fitting and verification process with CROS/BiCROS hearing instruments.

The general probe-measurement principles to keep in mind with these systems, as outlined by Dillon,[3] Tecca,[4] and Mueller and Hawkins,[5] include:

(1) The probe-tube microphone must always be located in the ear canal of the better ear.

(2) The reference microphone should be located on the same side of the client as the speaker. If the reference microphone cannot be separated from the measuring probe microphone, it should be deactivated and the substitution method used.

(3) The loudspeaker can be moved within the range of +/-90° relative to the front of the client, depending on the stage in the fitting process. A step-by-step illustration of how these issues are considered in the fitting and verification process follows below.

Demonstrating the impact of head shadow effect

Educating clients about how a CROS/BiCROS hearing instrument may provide benefit by overcoming the head shadow effect can be difficult. Some clients may find it hard to understand how aiding their better ear could possibly address their listening difficulties. In this regard, probe-microphone systems can serve as a valuable educational tool by allowing the clinician to demonstrate the advantage to be expected from a CROS/BiCROS system for a patient with an unaidable ear.[4,5]

Here is the recommended approach for demonstrating the magnitude of the head shadow effect (shown in Figure 1), as outlined by Tecca:[4]

(1) Measure the real-ear unaided response (REUR) for the better side.
   (a) Position the speaker at 45°-90° to the better ear.
   (b) Position the reference microphone at the better ear (i.e., same side as speaker).
   (c) Insert the probe tube into the better ear.

(2) Measure the REUR with sound directed towards the poorer (i.e., unaidable) side.
   (a) Position the speaker at 45°-90° to the poorer ear.
   (b) Position the reference microphone at the poorer ear (i.e., same side as speaker).
   (c) The probe tube remains in the better ear.

(3) The difference between the two measures (for the same input level) obtained in steps 1 and 2 represents an estimate of the head shadow effect for that client.

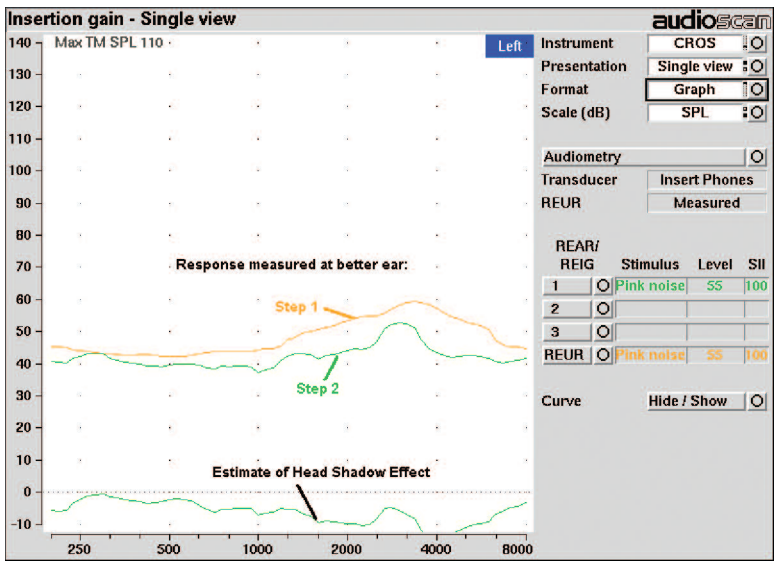

Figure 1. *Example of the head shadow effect measurement. The top (yellow) curve represents the real-ear unaided response (REUR) measured at the better (left) ear for step 1. The upper green curve represents the REUR measured at the better (left) ear for step 2. The lower green curve represents the difference between steps 1 and 2, which provides an estimate of the head shadow effect for this client.*

Determining functionality and directing the fitting

Having decided to fit a CROS/ BiCROS hearing instrument, the clinician must determine the functionality and appropriateness of the fitting. The clinician cannot rely solely on client feedback, as patients sometimes find it difficult to report reliably if a CROS hearing aid is operational, particularly if their better ear is at or near normal.[5] In this regard, probe-microphone measurements represent an ideal method of determining that the CROS/BiCROS system is functional and overcoming the head shadow effect. Furthermore, probe-microphone measurements can also direct the fitting of the CROS/BiCROS system to ensure that the appropriate level of amplification is being provided.

CROS fitting protocol

With CROS systems, the goal of the fitting process differs from that of more conventional hearing instrument fittings. In general, the primary aim of a CROS fitting for those with normal hearing in their better ear is not to amplify sound, but to transfer sound from the unaidable side of the head to the better ear so as to minimize the head shadow effect.[3]

To achieve this objective, the clinician should adjust the output from the receiver to match the resonance characteristics of the better ear (i.e., real-ear unaided gain: REUG) such that the CROS fitting sounds transparent to the individual.[3,4] Should hearing loss be present in the better ear of the CROS user, traditional target gain rules could be used to guide the amount of gain required similar to what is done in a conventional fitting.[5]

The use of a non-occluding earmold (BTE) or open vented shell (ITE) serves to achieve the goal of a CROS fitting by allowing sound originating from the "good" side to pass around the earmold and be heard naturally while minimizing occlusion. The frequency response of the CROS system must be carefully

adjusted to provide comfort as well as benefit. Should the receiver provide too much gain, the user will likely complain about internal noise and tinniness. In fact, overamplification of sound is the primary reason for CROS fitting failures.[4]

Probe-tube measurements are a useful tool for ensuring that the CROS output matches the REUG of the better-hearing ear. Here is the recommended approach for fitting CROS systems (shown in Figures 2, 3, and 4), as described by Dillon and Tecca:[3,4]

(1) Measure the response for the *better side*.
   (a) Position the speaker at 45° to the better ear.
   (b) Position the reference microphone at the better ear (i.e., same side as speaker).
   (c) Insert the probe tube into the better ear.
   (d) Position the CROS instruments (receiver/transmitter) on (in) the ears and turn them on.
   (e) The measured response should approximate the usual REUR. If it does not, the ear may not be fully open and the CROS fitting may be compromised by occlusion.

(2) Measure the response for the *poorer (i.e., unaidable) side*.
   (a) Position the speaker at 45° to the poorer ear.
   (b) Position the reference microphone at the poorer ear (i.e., same side as speaker).
   (c) The probe tube remains in the better ear.
   (d) The response measured in step 2 should match that obtained in step 1 for the same input level. If it does not, adjust the CROS response and repeat step 2 until the poorer-side real-ear aided response (REAR) matches the better-side REAR.

(3) Measure the REAR from in front of the client.
   (a) Position the speaker at 0° azimuth.
   (b) Position the reference microphone at the poorer ear or at the better ear.
   (c) The probe tube remains in the better ear.
   (d) The goal is to obtain a smooth REAR. An irregular response may indicate phasing problems with the hearing instrument or may be the result of reflections from nearby objects.

BiCROS fitting protocol

The fitting principles used with BiCROS systems vary somewhat from those used with CROS systems. As the better ear has a hearing loss, it is important to provide appropriate amplification to any signal received by that ear if audibility is to be achieved. The amount of amplification provided for the better ear can be determined by using a prescriptive fitting formula (e.g., NAL-NL1, DSL i/o). However, no binaural correction should be applied, as the amplified output is still delivered to only one ear.[3]

The initial steps involved in fitting a BiCROS system follow those typically performed during a conventional unilateral hearing instrument fitting. Once the instrument's characteristics have been determined for signals presented to the better ear, output measurements are conducted for signals presented to the unaidable ear (transmitter) as mentioned in the previous section on CROS fitting. Here the goals are to ensure that the transmitter is functional and to determine the settings at which the output approximates that obtained in the hearing instrument only condition. The recommended approach for fitting BiCROS systems, discussed by Dillon and Tecca,[3,4] is described below:

(1) Measure the response for the better side.
   (a) Position the speaker at 0°-45° to the better ear.
   (b) Position the reference microphone at the better ear.
   (c) Insert the probe tube into the better ear.
   (d) Position the BiCROS hearing instrument receiver/transmitter on (in) the ears and turn them on.
   (e) The measured REAR should be adjusted to approximate the

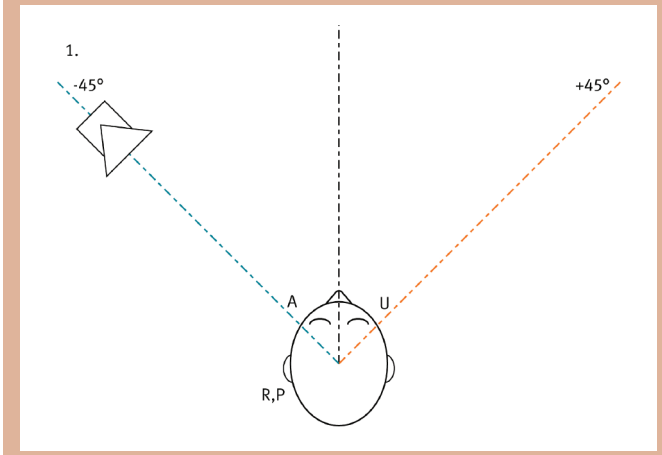

Figure 2. *Example of the "better side" measurement setup used in step 1. The left ear is better/aidable (A) while the right ear is poorer/unaidable (U). The probe microphone (P) and the reference microphone (R) are both located at the better ear. The loudspeaker is positioned at 45° azimuth relative to the better ear.*

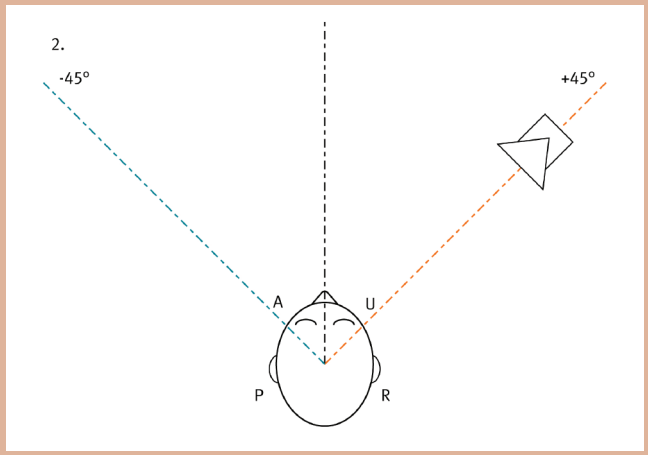

Figure 3. *Example of the "poorer side" measurement setup used in step 2. The probe microphone (P) is located at the better/aidable ear (A) while the reference microphone (R) is positioned at the poorer/unaidable ear (U). The loudspeaker is positioned at 45° azimuth relative to the poorer ear.*

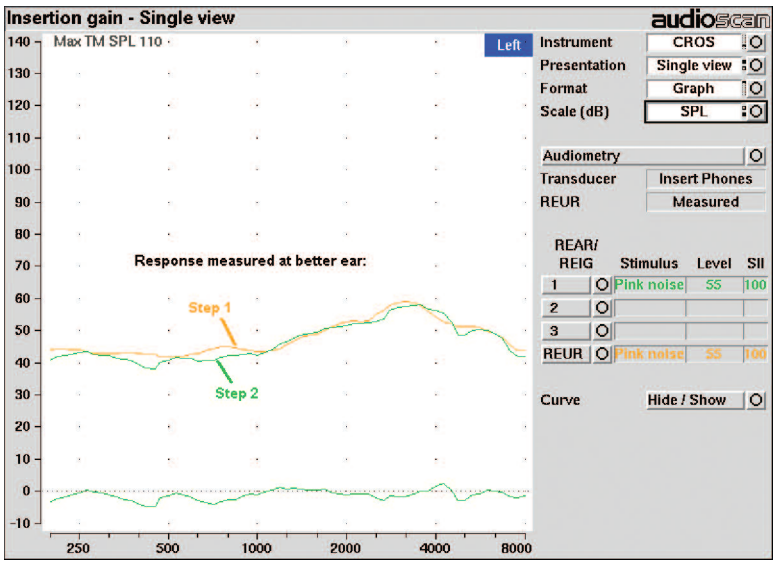

Figure 4. *Example of CROS hearing instrument fitting measurements. The yellow curve represents the real-ear aided response (REAR) measured at the better (left) ear for step 1. The upper green curve represents the REAR measured at the better (left) ear for step 2. The lower green curve represents the measured difference between step 1 and step 2.*

real-ear targets provided by the prescriptive formula you are using for the better hearing side.

(2) Measure the response for the poorer (i.e., unaidable) side.

(a) Position the speaker at 0°-45° to the poorer ear.

(b) Position the reference microphone at the poorer ear.

(c) The probe tube remains in the better ear.

(d) The measured REAR should approximate that achieved in step 1 for the same input level.

SUMMARY

Individuals with unaidable unilateral hearing loss present with many difficulties due to their inability to access binaural cues. The desire to assist these patients led to the development of CROS/BiCROS hearing instruments. The use of a transmitter microphone that transfers sound to the better ear can assist those with unaidable unilateral hearing loss by overcoming many of the difficulties associated with the head shadow effect. Yet, as with any hearing instrument technology, it is important for the clinician to ensure that the CROS/BiCROS system is functional and has been fitted so as to provide the maximum possible benefit to the wearer.

Probe-microphone measurements represent an ideal way of achieving these goals while also providing clinicians with a method of informing clients with unaidable unilateral hearing loss about the benefits they can expect from a CROS/BiCROS hearing instrument.

John Pumford, MClSc, Aud(C), is a Corporate Audiologist with Unitron Hearing. He has been involved with direct patient care and hearing aid dispensing as a clinical audiologist in both hospital and private-practice settings. He can be reached at Unitron Hearing Corporate, 20 Beasley Drive, Kitchener, ON N2G 4X1, Canada; e-mail john.pumford@unitron.com.

REFERENCES

1. Sandlin RE: Fitting binaural amplification to asymmetrical hearing loss. In Valente M, ed., *Strategies for Selecting and Verifying Hearing Aid Fittings*. New York: Thieme, 1994: 207-227.
2. Valente M, Valente M, Meister M, et al.: Selecting and verifying hearing aid fittings for unilateral hearing loss. In Valente M, ed., *Strategies for Selecting and Verifying Hearing Aid Fittings*. New York: Thieme, 1994: 228-248.
3. Dillon H: CROS, bone conduction and implanted hearing aids. In Dillon H, ed., *Hearing Aids*. New York: Thieme, 2001: 434-450.
4. Tecca JE: Use of real-ear measurements to verify hearing aid fittings. In Valente M, ed., *Strategies for Selecting and Verifying Hearing Aid Fittings*. New York: Thieme, 1994: 88-107.
5. Mueller HG, Hawkins DB: Assessment of fitting arrangements, special circuitry, and features. In Mueller HG, Hawkins DB, Northern JL, eds., *Probe Microphone Measurements: Hearing Aid Selection and Assessment*. San Diego: Singular, 1992: 201-225.