SpeechFocus – A new automatic directional microphone system for special listening situations

Josef Chalupper[1], Yu-Hsiang Wu[2], Jennifer Weber[3]

www.siemens.com

SIEMENS

[1] Siemens Audiologische Technik, Erlangen, Germany

[2] University of Iowa, Iowa, USA

3 University of Northern Colorado, Greeley, USA

Abstract

The new Siemens SpeechFocus, which includes a reverse directional polar pattern, was introduced to improve speech understanding for listening environments where speech may not originate from the front. Clinical trials at two independent research sites with this new technology compared SpeechFocus with two alternative microphone choices: omnidirectional and conventional frontal adaptive directional. The findings showed a significant benefit for SpeechFocus for understanding speech in background noise. This paper explains how SpeechFocus works, provides details about behavioral studies with SpeechFocus and shows how to fit and demonstrate SpeechFocus with Connexx 6.4.

Introduction

Directional microphone technology has been used in hearing instruments since the late 1960s, and has been shown to effectively improve speech understanding in background noise (e.g., see evidence-based review by Bentler[1]). For many years, this technology was considered to be a "special feature", and was only available in select models. All this has changed in the last 15-20 years, and today manufacturers offer directional technology in most of their hearing instruments.

In modern day instruments, the directional effect usually is accomplished using two omnidirectional microphones, and Siemens was the first to introduce digital hearing instruments with dual-directional microphones in 1997 ("TwinMic"). Research with this new technology revealed encouraging findings[2,3]. In 2002, Siemens was again the first to add automatic-adaptive functionality to the polar patterns of directional microphones[4,5,6]. Automatic meaning that based on the analysis results of the situation detection system, the algorithm "automatically" switched from omnidirectional to directional, or back to omnidirectional. "Adaptive" meaning that the directivity was focused to the front, but the null of the polar pattern could be steered to correspond with the loudest sound from the rear hemisphere, which allowed for the maximum attenuation of background noise in this general region. Or, if a diffuse noise field was detected, the adaptive algorithm would select the polar pattern that provided the best directivity.

This adaptive functionality was expanded to a multi-channel function in 2004—that is, the maximum direction of attenuation could be varied for different frequency regions. While this meant that more noise sources could be attenuated, the directivity was still adjusted to provide maximum gain for signals from the front.

While multi-channel automatic/adaptive directional hearing instruments already offer a high level of sophistication in terms of improving speech intelligibility in noisy situations, this technology still has its limitations. The intrinsic nature of traditional directional microphones implies that attenuation of noise can only occur in the rear hemisphere and that directivity can only be aimed towards the front of the hearing instrument wearer. This application is of course desirable, since in most circumstances the wearer faces the speaker of interest. Even if the talker is not located in front of the wearer when he or she starts speaking, it is expected that the listener will turn to face the talker.

The only situation when traditional directional microphones are not effective, therefore, is when the wearer is not able to face the speaker. One such specific, but commonplace, situation is when the wearer is driving a car and a passenger in the backseat speaks. In this case, speech comes from the back while the noise comes from the sides and front, but the wearer cannot turn to face the speaker while driving. A similar situation is when the hearing instrument wearer is walking side by side with a group of people. In this case, the speech is coming from the side, which the directional microphone cannot account for, and the wearer cannot always turn towards the speaker.

An ideal microphone system therefore, should be able to steer maximum directivity towards speech, regardless which direction it originates – even it originates from behind the listener.

A New Innovation in Directionality

A new "full-directional" algorithm has been developed for steering directionality, which has been labeled SpeechFocus. The SpeechFocus algorithm overcomes the limitations of traditional directional microphones, as more unique polar patterns have been added as options for certain listening environments. In addition to having all the functionalities of a four-channel adaptive directional microphone, when necessary, SpeechFocus automatically also can suppresses noise which occurs from the front of the wearer, and focus on speech coming from a different direction, such as behind the wearer. SpeechFocus continuously scans sounds in the listening environment for speech patterns. When speech is detected, then SpeechFocus selects the directivity pattern most effective in focusing on that speech source, which would include selecting an omnidirectional pattern if noise is not present at a significantly high level.

SpeechFocus: How it works

SpeechFocus works by operating simultaneously three different directivity patterns: omnidirectional, adaptive directional, and a reverse directional (anti-cardioid) pattern. Unlike typical directional microphone patterns (e.g., cardioid, hypercardioid, etc.), which only attenuate sounds coming from the sides and the back, this backward directional microphone pattern works like an acoustic rear-view mirror and focuses on speech which originates from the back while suppressing noise from the front hemisphere.

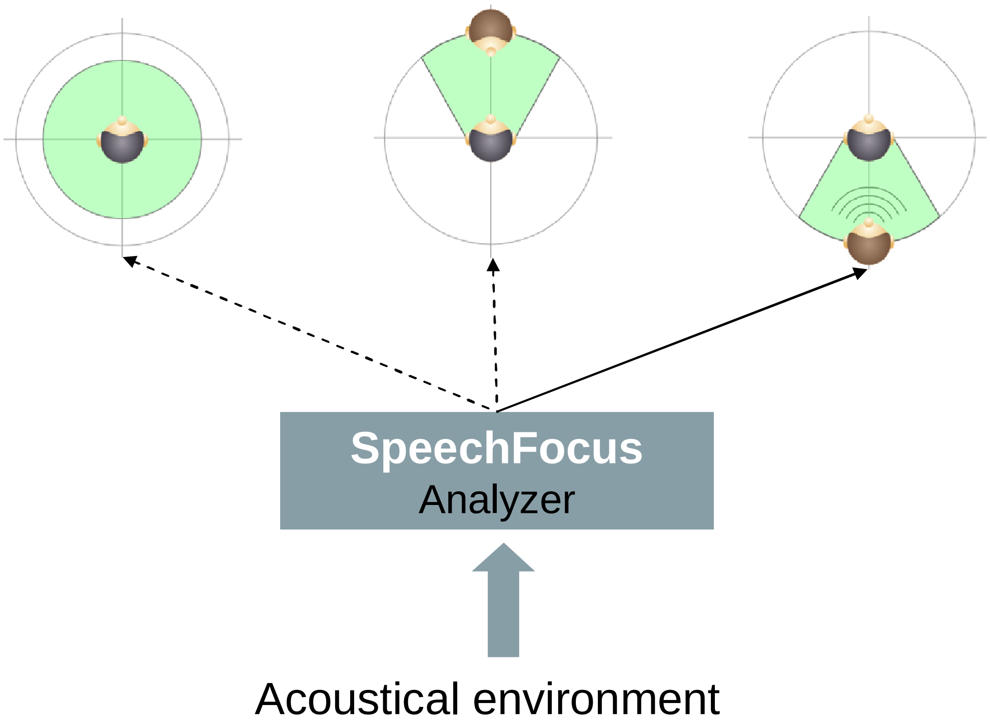

Figure 1: Illustration of how the acoustic scene analysis system monitors the acoustic environment to create effective steering for SpeechFocus

When speech is present, and background noise is also detected, the signals from all directivity patterns are then analyzed for speech patterns (see Figure 1). The microphone pattern which results in the greatest output for the speech signal is then chosen as the appropriate microphone mode. This means that when speech is detected from the front hemisphere, the traditional frontal adaptive directional microphone polar patterns are employed, reducing noise from the side and the back. When speech is detected as originating from the back, the backward directional microphone pattern is selected, and noise from the front hemisphere is reduced. When speech is detected directly from the left or the right side, then the omnidirectional directivity pattern is engaged. As this would happen only for exactly +/- 90°, in the real world usually either the frontal or backward directionality will be active in noisy situations.

The decision-making process in SpeechFocus depends upon the detection of speech patterns, in particular the modulations present in human speech. Since the typical modulation frequency of speech is approximately four Hz (i.e., 4 peaks/second), accurate detection of speech requires at least a one second window of analysis. Therefore, the SpeechFocus algorithm has an attack time of approximately one second. That is, when speech is detected from a particular direction, it takes about one second for the appropriate polar pattern to be chosen. In some listening situations, however, this detection time might not be fast enough for optimum speech understanding. For maximum effectiveness, therefore, SpeechFocus should be activated in a separate program for more static listening situations, especially situations where it is anticipated that speech will be originating from behind the listener, such as when driving a car with passengers in the back.

SpeechFocus will select an omnidirectional pattern whenever the background noise is ~65 dB SPL or lower. As described by Branda and Hernandez[7], there are listening situations where soft-level directionality is desired, which is available in the traditional frontal-directional automatic/adaptive setting. For many patients, therefore, it probably would be most effective to use the standard automatic/adaptive directionality in the universal program, and SpeechFocus in a different program.

Electro-acoustic evaluation

Prior to the behavioral study of the SpeechFocus algorithm, first a laboratory electro-acoustic analysis was conducted by the University of Iowa to assure that the automatic steering and resulting adaptive polar patterns were correct. The following polar patterns were obtained in an anechoic chamber with the Siemens Pure 701 BTE.

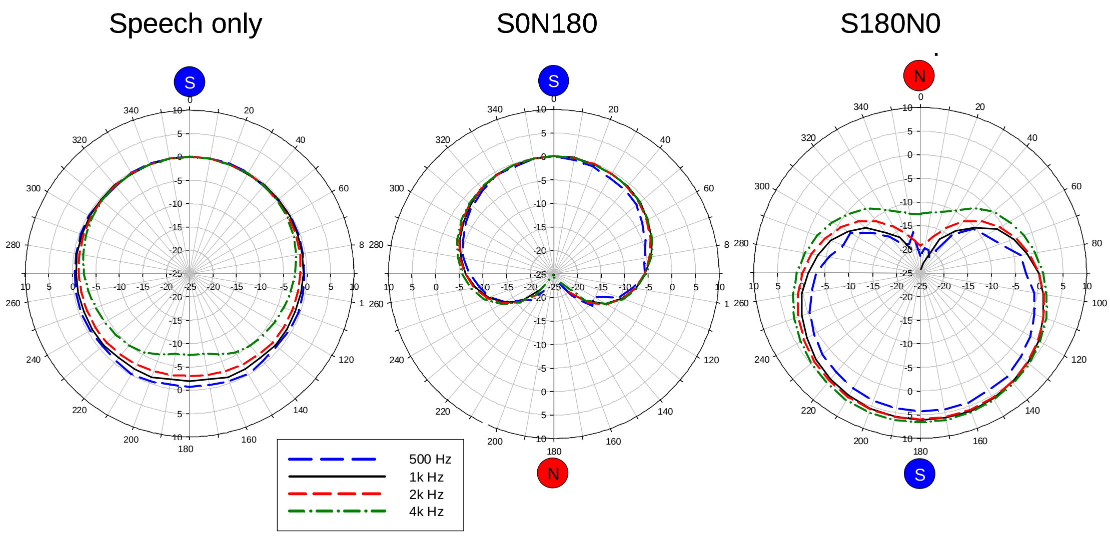

Figure 2: SpeechFocus automatically selects the most appropriate directivity pattern in different acoustic environments: Omnidirectional for speech only, frontal directional for speech from front and noise from the back (S0N180) and reverse directional for speech from back and noise from front (S180N0). Measurements obtained at the Hearing Aid Lab of the University of Iowa.

Figure 2 shows the results of speech presented at a 0 degree azimuth at 75 dB SPL (left), with no noise present. The resulting pattern is omnidirectional. In the middle plot, we show the resulting polar pattern when a background noise signal (multi-talker babble) from 180 degree azimuth was added. As expected, a frontal directional cardioid pattern was selected. We then switch the location of the speech and noise signals, so that speech is now from the back and noise is from the front. The results of this paradigm result in a reverse directional (anti-cardioid) pattern (right). To summarize, when the SpeechFocus mode is selected, the automatic/adaptive directional feature works essentially the same as in the standard universal directional mode, except that in addition the option of an anti-cardioid pattern is available.

Behavioral testing with SpeechFocus

To examine the effectiveness of the SpeechFocus algorithm for improving speech understanding in background noise, clinical studies were conducted at two different sites: Site 1 was the University of Iowa, Iowa City, IA, and Site 2 was the University of Northern Colorado, Greeley, CO. The same protocol was used at both sites.

The participants were individuals with downward sloping sensorineural hearing loss, all experienced hearing aid users (n=15 at Site 1, n=21 at Site 2). The participants were fitted bilaterally with the Siemens Pure 701 BTE instruments using closed domes. The CONNEXX 6.4 software was used to program the hearing instruments to the NAL-NL1 prescriptive fitting. The calibrated real-speech signal ("carrot passage") of the Verifit probe microphone system was used to verify the match to targets; minor adjustments to gain and compression were made to obtain a closer fit when necessary. This prescribed gain and output was then stored in three different memories of the hearing instruments. The three memories only differed in terms of the microphone mode setting: Memory #1: fixed omnidirectional, Memory #2: conventional frontal automatic/adaptive directional, and Memory #3: SpeechFocus (fully automatic/adaptive directional including the anti-cardioid pattern). All special features (e.g., noise reduction, adaptive feedback suppression, low-level expansion, etc) remained active for all microphone modes at default settings.

Testing was conducted in an audiometric sound suite, with speech delivered from the back (180° azimuth) and noise from the front of the listener (0° azimuth). The speech material used was the Hearing in Noise Test (HINT), delivered via CD. The standard HINT material was modified slightly: the quiet interval between sentences was filled with the HINT noise, and the carrier phrase "Please repeat the next sentence" was inserted before each sentence. The standard HINT noise was presented at a constant level of 72 dB(A); the level of the sentences was adaptive.

Participants were tested for each of the three microphone modes using two HNT lists (20 sentences). The HINT was scored in the conventional manner, resulting in a reception threshold score (RTS) for sentences in noise for each participant for each microphone setting. The ordering of the microphone modes was counterbalanced.

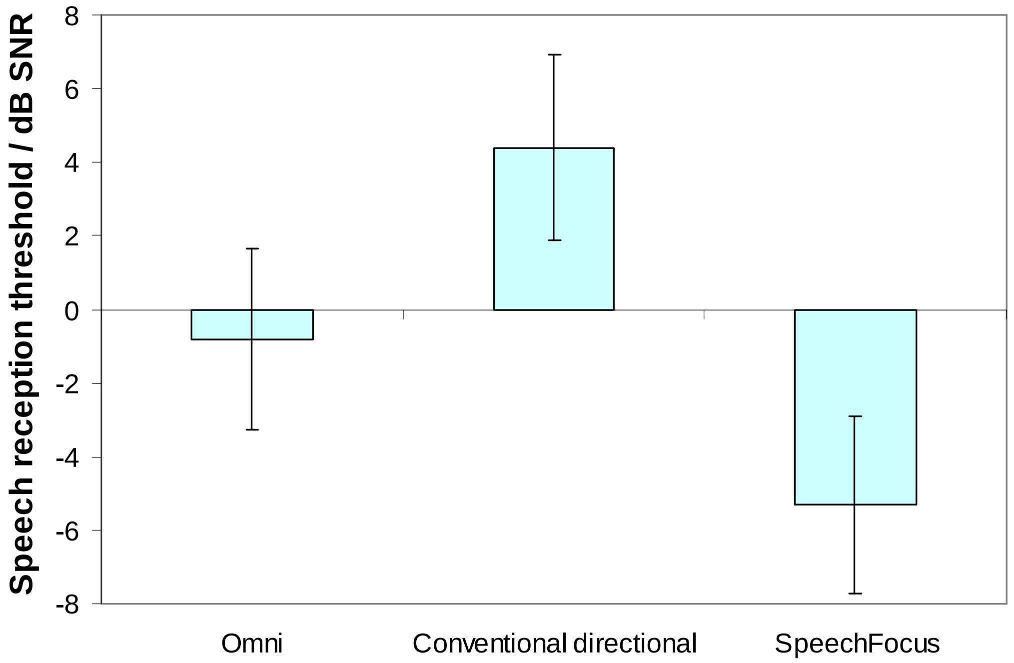

Figure 3: HINT results (mean and standard deviations) from Site 1 (University of Iowa) for SpeechFocus compared to omnidirectional and conventional adaptive directional microphones.

The results for Site 1 are shown in Figure 3. The three conditions shown are the fixed omnidirectional, adaptive directional (which adapted to a hypercardioid pattern) and SpeechFocus (which adapted to an anti-cardioid pattern). Note that there were large differences in the resulting mean HINT RTS scores. Repeated-measure ANOVA was conducted to determine the effect of microphone mode with the HINT RTS score as the dependent variable. The main effect of microphone mode was significant ($F(2, 28) = 85.36$, $p < 0.0001$). The follow-up tests (with Bonferroni correction) showed that the performance between all microphone modes was significantly different ($p<0.0001$):

Omni was better than adaptive frontal directional, SpeechFocus was better than adaptive directional and omni. Looking at individual data and simply comparing SpeechFocus to omni, there was a benefit for SpeechFocus of at least 2 dB for 100% of the participants, and 67% of the participants had a SpeechFocus benefit of at least 4 dB.

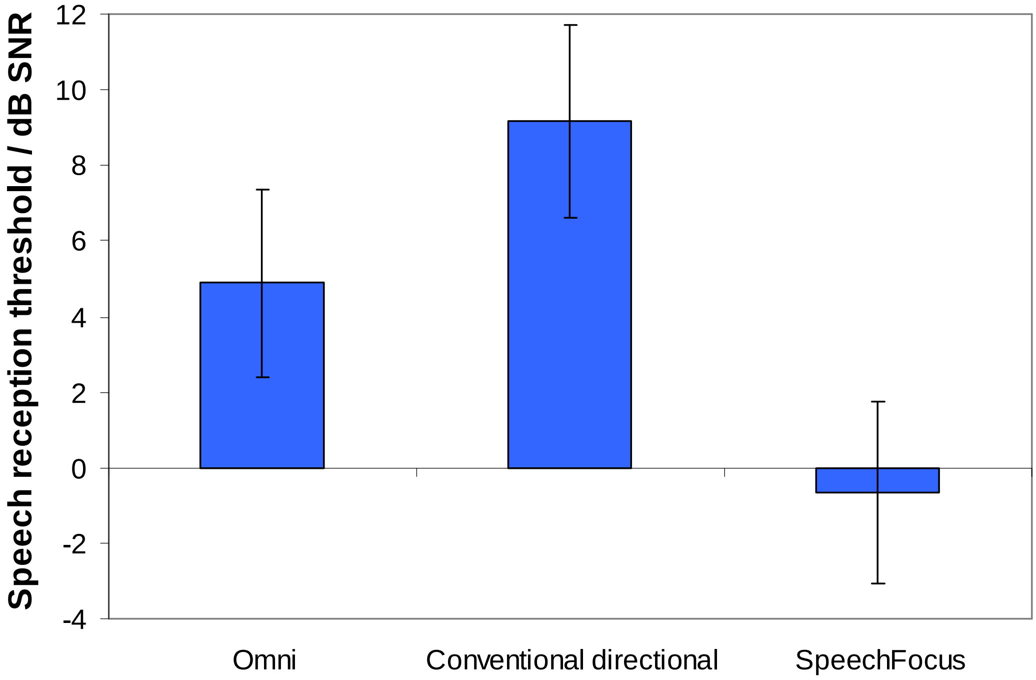

Figure 4: HINT results (mean and standard deviations) from Site 2 (University of Northern Colorado) for SpeechFocus compared to omnidirectional and conventional adaptive directional microphones.

The findings for Site 2 are shown in Figure 4. The overall mean HINT RTS scores were somewhat poorer at this site, presumably because the participants had greater hearing loss, but the pattern of findings was very similar to that of Site 1. Repeated-measure analysis of variance was performed to determine the effect of microphone mode, and the main effect was significant ($F(1.7, 33.7) = 151.85$; $p < 0.0001$) . The follow-up tests (Bonferroni correction) showed that the HINT performance between all the microphone modes differed significantly ($p<.0001$). At this site, 95% of the participants had a SpeechFocus benefit of at least 2 dB (when compared to omni) and 81% had a benefit of at least 4 dB; 3 of the 21 participants had a SpeechFocus benefit of over 9 dB.

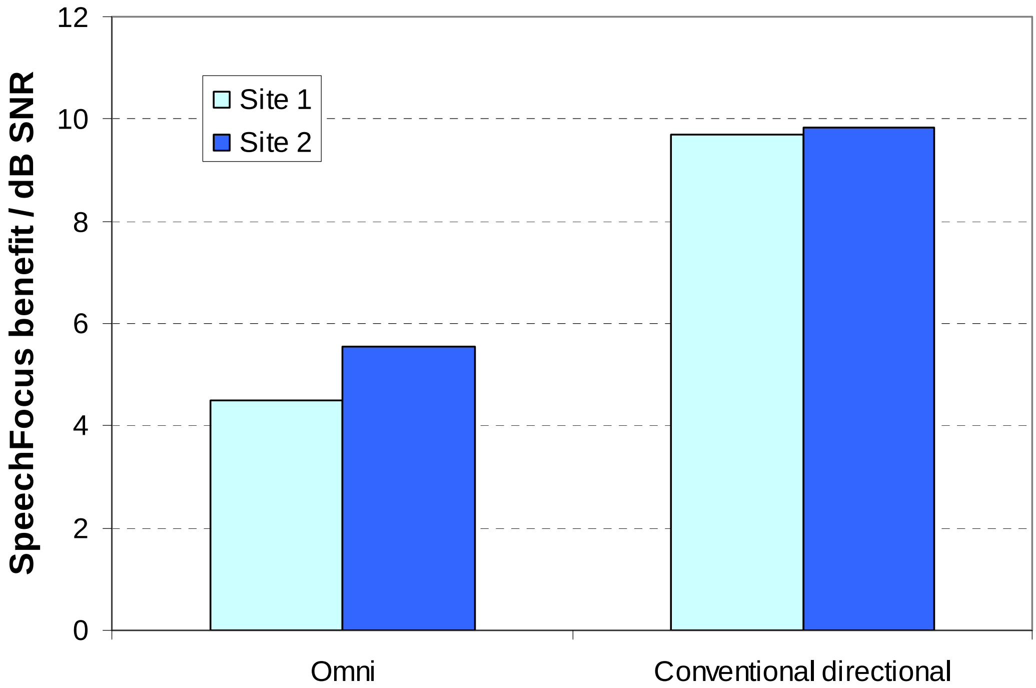

Figure 5: Mean benefit of SpeechFocus at two different research sites.

Figure 5 shows the results from the two experimental sites plotted as a function of mean SpeechFocus benefit. Observe that although the overall mean HINT RTS scores were somewhat different for the two sites (Figures 3 and 4), the *benefit* for SpeechFocus was nearly identical when compared to the two other microphone mode options. As shown in this figure, the SpeechFocus benefit is about 10 dB when compared to adaptive directional, and about 5 dB when compared to omnidirectional.

Fitting Tips for SpeechFocus

In the CONNEXX 6.4 software, SpeechFocus is offered as a separate directional microphone setting under the *Microphone/Bluetooth* tab. It also is the default setting in the “SpeechFocus” Program. We recommend that SpeechFocus be used whenever setting up programs for the patient to use when speech may be originating from different directions other than the front, and the wearer cannot turn his or her head to face the speaker.

While patients could use SpeechFocus as their primary program, recall that the automatic activation to directional occurs at a higher noise level for this algorithm, and therefore we continue to recommend the standard automatic/adaptive directional mode for everyday listening. We also recommend that the fixed omnidirectional microphone mode should be used for music and outdoor programs, as well as in a mixed input mode, such as with DAI or the Tek Transmitter.

The function of the SpeechFocus algorithm easily can be tested *real time* using the Connexx software. This is useful for the dispenser for understanding the operation of this feature, and also is useful for patient demonstration. Figure 6 is an example of what is shown in the "Connexx Real Time Display." This specific recording was obtained for a speech-in-noise situation, with speech originating from the back.

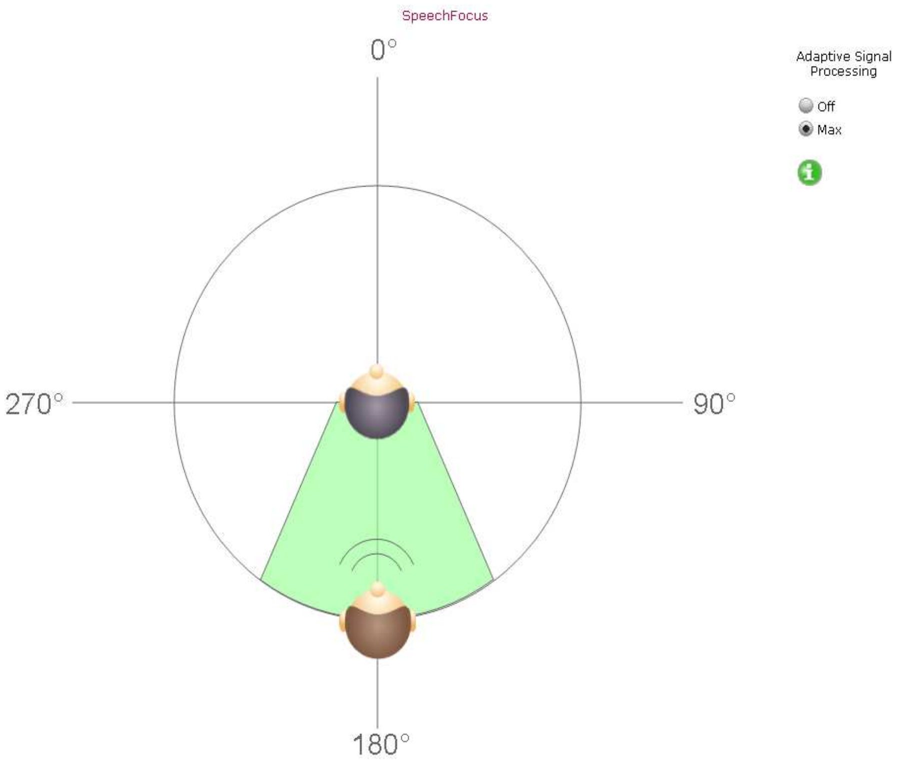

Figure 6: Demonstrating SpeechFocus with the CONNEXX Realtime Display

The diagram shown in Figure 6 represents an aerial view of the hearing instrument wearer facing front (0° azimuth). Depending on the direction from which speech originates, the green field indicates the focus of directivity. By simply holding the hearing instrument and presenting speech and/or noise from different azimuths, the automatic operation of the algorithm can be observed. Importantly, this is real time, not a simulation, so the automatic switching which is observed is the same as what the patient will experience during real-world use.

During the fitting process, informational counseling is facilitated by having the patient wear the instrument so that he or she can *hear* as well as *see* the effects of SpeechFocus. Here is a protocol that we have found successful:

- Fit the hearing instruments bilaterally to the desired gain and output settings.
- Select the SpeechFocus setting under the *Microphone/Bluetooth* tab.
- Play the selected sound files from the CONNEXX software utilizing two loudspeakers. Select a presentation level around 70 dB SPL.
- First, position the loudspeaker playing the speech signal in front of the wearer and the loudspeaker playing noise behind the wearer. For this listening situation the frontal adaptive directional polar pattern will be engaged, and the green field will be focused to the front.
- Then, exchange the position of the speakers (or rotate the patient) so that speech is now coming from the back and the noise is coming from the front. In this listening situation, the adaptive anti-cardioid directional polar pattern will be activated and the green field will appear behind the wearer (as shown in Figure 6).
- Finally, move the speakers playing either speech or noise to different locations to observe the automatic/adaptive behavior.

Summary

While directional microphone technology has been used in commercially available hearing instruments for over 40 years, there continues to be significant advances. Until now, one listening situation in which directional technology was not successful was a speech-in-noise condition, with speech being presented from behind the listener. The new Siemens SpeechFocus, which includes a reverse directional polar pattern, was introduced to improve speech understanding for this type of listening environment.

Clinical trials at two independent research sites with this new technology compared SpeechFocus with two alternative microphone choices: omnidirectional and conventional frontal adaptive directional. The findings showed a significant benefit for SpeechFocus for understanding speech in background noise. This microphone mode provided an average improvement of ~5 dB compared to omnidirectional, and ~10 dB compared to frontal adaptive directional. To facilitate the understanding of SpeechFocus, for both the hearing health care provider and the patient, a "real time" observation of its function can be observed in the CONNEXX fitting software.

As has been pointed out in several MarkeTrak reports, overall satisfaction with hearing aids often is related to the number of listening situations in which patients report that the instruments provide benefit. With SpeechFocus, we believe we have just added one more listening situation where patients will now say that a significant improvement in speech understanding is present.

References

1. Bentler RA. Effectiveness of directional microphones and noise reduction schemes in hearing aids: a systematic review of the evidence. *J Am Acad Audiol*, 2005; 16(7): 473-484.
2. Powers T, Wesselkamp M. The use of digital features to combat background noise. *Hearing Review*: High Performance Hearing Solutions 1999; 3:36-39.
3. Ricketts T, Dhar S. Comparison of performance across three directional hearing aids. *J Am Acad Audiol*, 1999; 10:180-189.
4. Powers T, Hamacher V. Proving adaptive directional technology works. *Hear Rev* 2004; 11(4): 46-50.
5. Bentler R, Palmer C, Mueller H. Evaluation of a second-order directional microphone hearing aid I: Speech perception outcomes. *J Am Acad Audiol*. 2006; 3: 179-189.
6. Palmer C, Bentler R, Mueller H. Evaluation of a second-order directional microphone hearing aid II: Self-report outcomes. *J Am Acad Audiol*. 2006; 3:190-201.
7. Branda E, Hernandez A. New directional solutions for special listening situations. Paper presented at the 2010 annual meeting of the American Academy of Audiology, April, 2010, San Diego.