ADVANCED BIONICS
POWERFUL CONNECTIONS

CLINICAL RESEARCH

Marvel CI Technology

Leveraging natural ear acoustics to optimize hearing performance

INTRODUCTION

The function of the outer ear (pinna) is to capture and funnel sound waves into the ear canal, and to naturally amplify frequencies between approximately 2 and 8 kHz,[1-4] which are known to be critical for speech understanding. Due to the shape and contours of the pinna (figure 1a), this amplification changes based on the direction of incoming sounds. Sounds from the front are amplified while others from behind are acoustically attenuated or "shadowed" by the pinna. This directional effect helps listeners identify whether a sound source is located in front of them or behind them, and improves their ability to understand speech in noise.[5,6]

Typically, a behind-the-ear (BTE) hearing aid or cochlear implant (CI) sound processor has microphone inputs that are placed above the ear (figure 1b). This microphone location at the top of each ear is effective for sound reception but it does not take advantage of the natural directional effect of the pinna. The same is true for microphone locations that are off-the-ear including placement in the headpiece (figure 1c); or in off-the-ear (OTE) processors.

This article focuses on four innovative options available with Marvel CI (Naída™ CI M sound processor and Sky CI™ M sound processor): (1) T-Mic™ microphone, (2) Real Ear Sound (RES) algorithm, (3) Phone Detect algorithm, and (4) T-Mic Detect algorithm. Each of these technologies ensures that CI users can experience the benefits of real or simulated pinna acoustics supported by automatic systems that continuously evaluate and select the optimal microphone mode for any listening scenario.

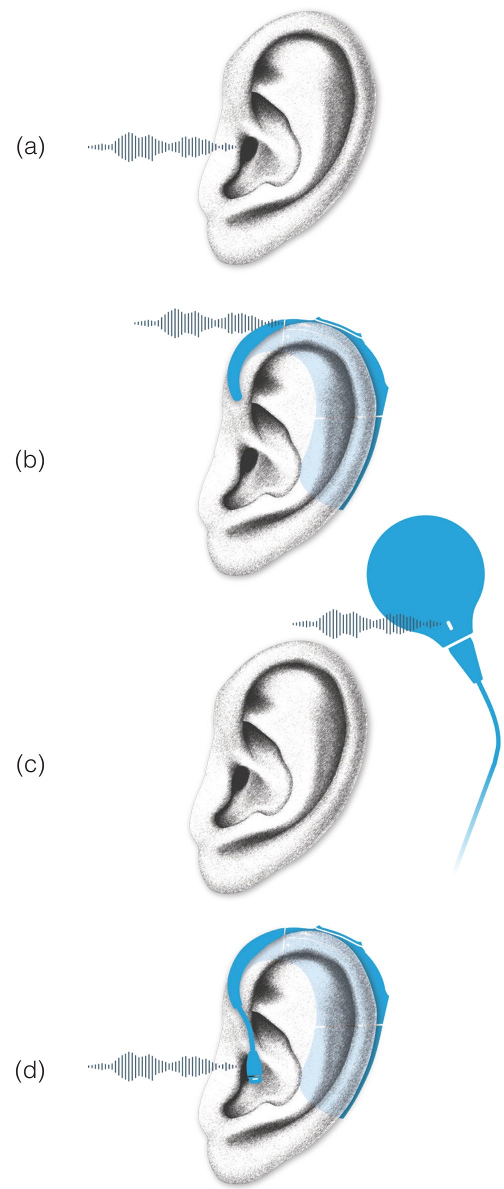


Fig. 1: (a) Outer ear (pinna) with natural acoustics. In blue, microphone locations of the Marvel CI sound processor: (b) behind-the-ear microphone (BTE mic), (c) Headpiece (Slim HP) microphone and (d) T-Mic.

THE T-MIC™ MICROPHONE

The T-Mic (figure 1d) is a dedicated microphone first developed by Advanced Bionics in 2001. While the T-Mic is an omnidirectional microphone, its placement at the entrance of the ear canal allows it to capture the pinna's natural acoustic characteristics. Comparisons of head-related transfer functions (HRTFs) from normal hearing adults and CI users show that the T-Mic placed at the entrance of the ear canal provides similar signal-to-noise ratio (SNR) improvements as the pinna.[7,8]

The SNR improvement with the T-Mic translates into significantly improved speech perception for CI users in spatially separated noise environments, as compared to omnidirectional microphones located on the processor or on the headpiece.[9-14] T-Mic benefit has been observed across multiple generations of AB sound processors with an average improvement in speech recognition that ranges from 2.3 dB to 4.4 dB, or 11.95% to 15%. The data from one such study are described in the following section and shown in figure 3. The positive impact of the T-Mic on speech understanding is also subjectively reported by CI users.[11,15,16] Study participants reported that the T-Mic is comfortable to wear and, due to its location, the T-Mic can also help CI recipients localize sounds more accurately than when using the BTE mic.[8,16-19]

Finally, the T-Mic allows the CI user to hold a phone in a natural position over the ear during phone calls. Holding the phone at the pinna imparts a SNR improvement from the 'sealed volume' created between the phone and the pinna/concha as well as an attenuation of external background noises.[16] Listeners report a better sound quality when using the T-Mic (when compared to a T-Coil) for phones calls in quiet and in noise[11,15,16] while still achieving equivalent levels of speech understanding with the two technologies.[16,20,21] Figure 2 shows T-Mic vs. BTE mic sound quality ratings obtained from 8 participants who had no prior experience with the T-Mic and then used it for two weeks in their everyday environments.[16]

SOUND QUALITY RATINGS: T-MIC VS. BTE MIC

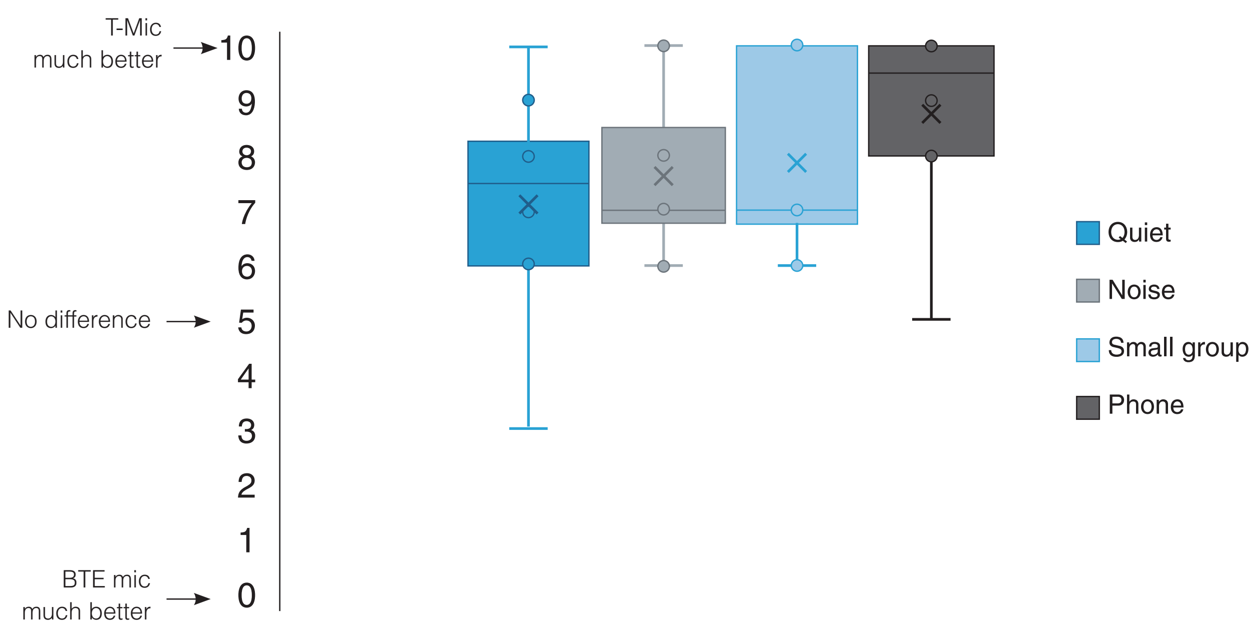


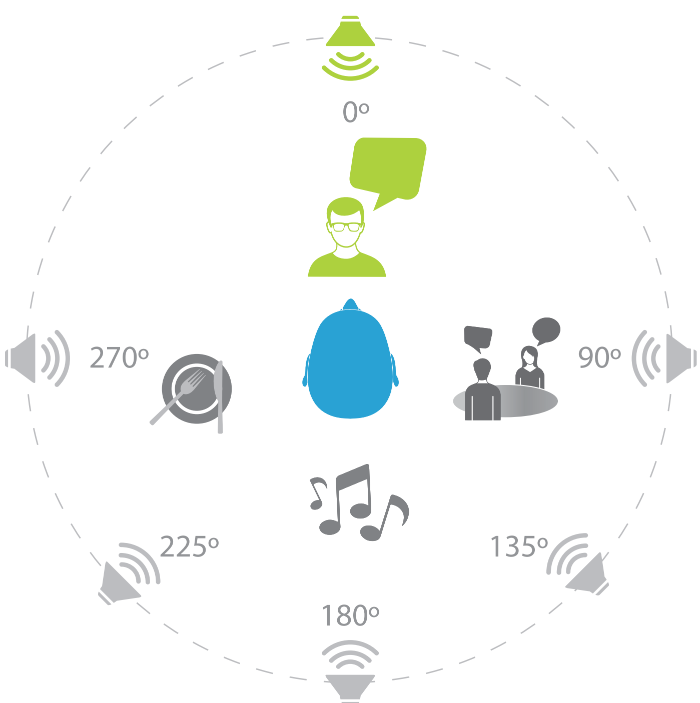
Figure 2: Relative sound quality ratings obtained in four listening domains: quiet, noise, small groups, and on the phone from eight CI recipients. A rating of 10 indicates the T-Mic was judged as much better than the BTE microphone, 5 indicates a neutral opinion (i.e., no difference) and 0 indicates the BTE microphone sound quality was much better.

REAL-EAR SOUND

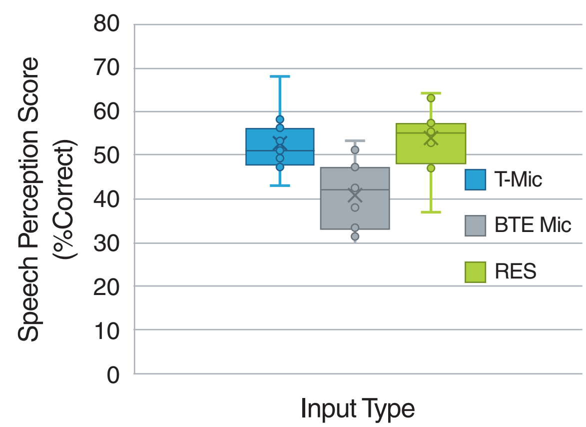
Real-Ear Sound (RES) is a microphone mode first introduced in Phonak hearing aids in 2005 to simulate the pinna's natural frequency response. This is accomplished by using the front and back BTE microphones to form a directional microphone response that is biased towards the high frequencies. In the Marvel CI sound processor, RES simulates the high-frequency pinna response when a T-Mic is not prescribed (i.e., Marvel CI fit with a standard earhook or an acoustic earhook), or if the T-Mic is not functioning.

In a study conducted at Advanced Bionics,[14] the effect of input type (RES, T-Mic, or BTE mic) on speech understanding in noise and on front/back localization was evaluated in CI recipients. For testing speech understanding, TIMIT sentences[22] were presented at 60 dBA from a single loudspeaker located in the front. Restaurant-type noise was presented from five loudspeakers arranged in a semi-circle around the participant (figure 3a). Noise levels were set individually for each participant such that their speech perception score in noise with the BTE mic was approximately half of that in quiet. For the bilateral listeners (9 participants, figure 3b), speech perception scores significantly improved when listening with the T-Mic ($p=0.0011$) and with RES ($p=0.00081$) as compared to the BTE mic. No difference was found between scores with the T-Mic and RES ($p=0.71$). In the unilateral group (7 participants, figure 3c), while there was a trend towards better outcomes with the T-Mic and RES as compared to the BTE mic, the scores were not different statistically.

3a.



3b. SPEECH PERCEPTION IN NOISE (BILATERALS)



3c. SPEECH PERCEPTION IN NOISE (UNILATERALS)

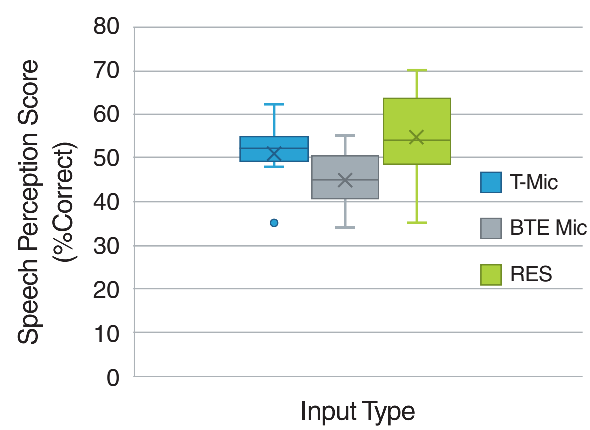
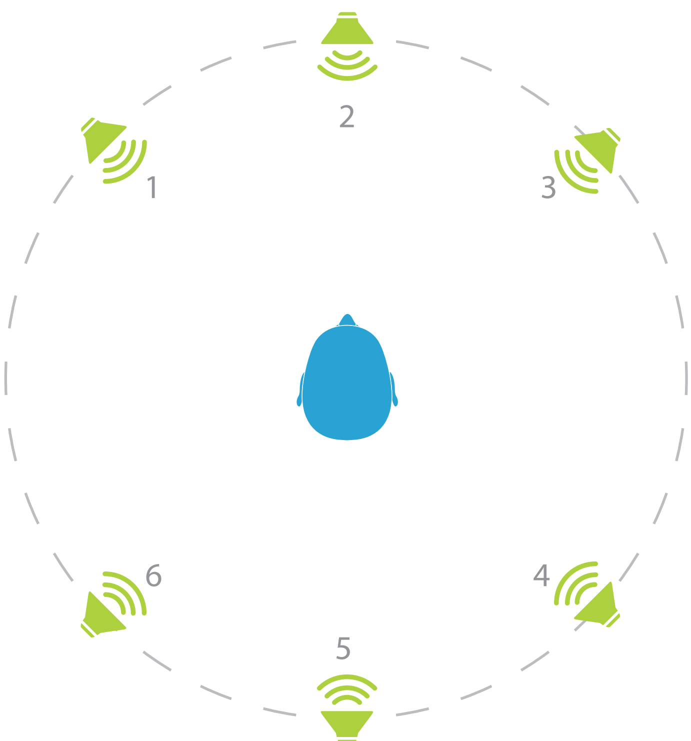


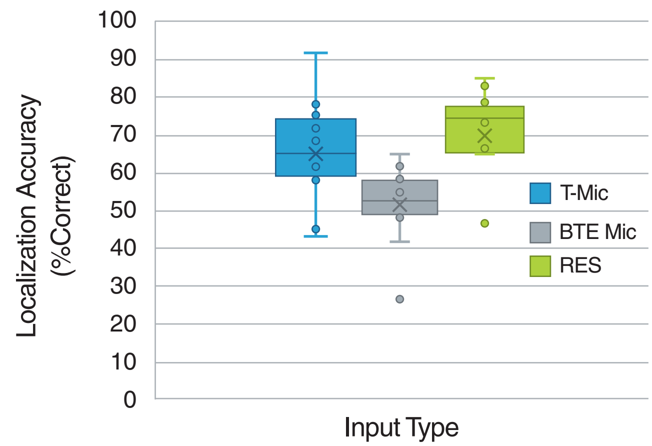
Figure 3: Speech perception in noise with T-Mic, BTE mic and RES algorithm. The test set-up is shown in 3a. As displayed in 3b and 3c, CI recipients showed improved speech perception (statistically significant or a trend) when listening with T-Mic and RES as compared to BTE mic.

Front/back localization was assessed using a sound field of six loudspeakers, three in the front (-45°, 0°, and 45°) and three in the back (135°, 180°, and 225°) (figure 4a). Participants heard a series of 4 pink noise bursts (170 ms duration each, 10 ms rise/fall time, 50 ms inter-burst interval) presented at 50 dB SPL (+/-5 dB). The task for the recipients was to identify the speaker number from which they perceived the sound had originated. Figures 4b and 4c show localization accuracy scores from 10 bilateral and 8 unilateral listeners with the three input types. Both groups of listeners demonstrated significantly higher localization accuracy when listening with the T-Mic (p=0.026 for bilaterals, p=0.009 for unilaterals) and RES (p=0.003 for bilaterals, p=0.02 for unilaterals) as compared to the BTE mic. Again, no difference was found in the scores with RES and T-Mic. These findings indicate that RES can improve speech perception and localization outcomes for CI recipients when compared to the BTE mic, while also providing performance levels similar to those achieved with the T-Mic. RES has also been shown to improve sound localization abilities in experienced BTE hearing aid users.[23] It is available on the Naída CI M90 and Sky CI M90 sound processors and Naída Link M and Sky Link M hearing aids.

4a.



4b. FRONT/BACK LOCALIZATION (BILATERAL RECIPIENTS)



4c. FRONT/BACK LOCALIZATION (UNILATERAL RECIPIENTS)

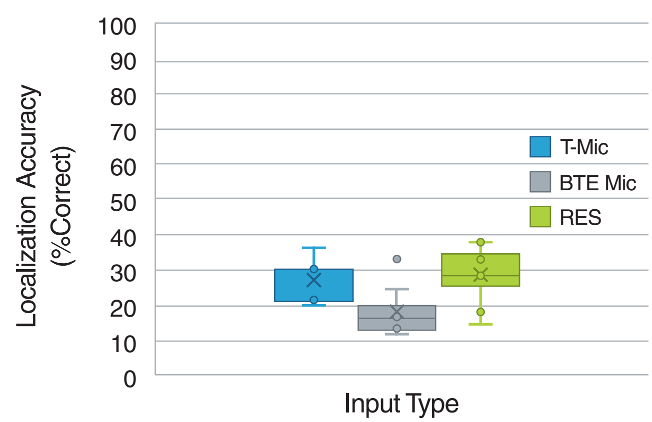
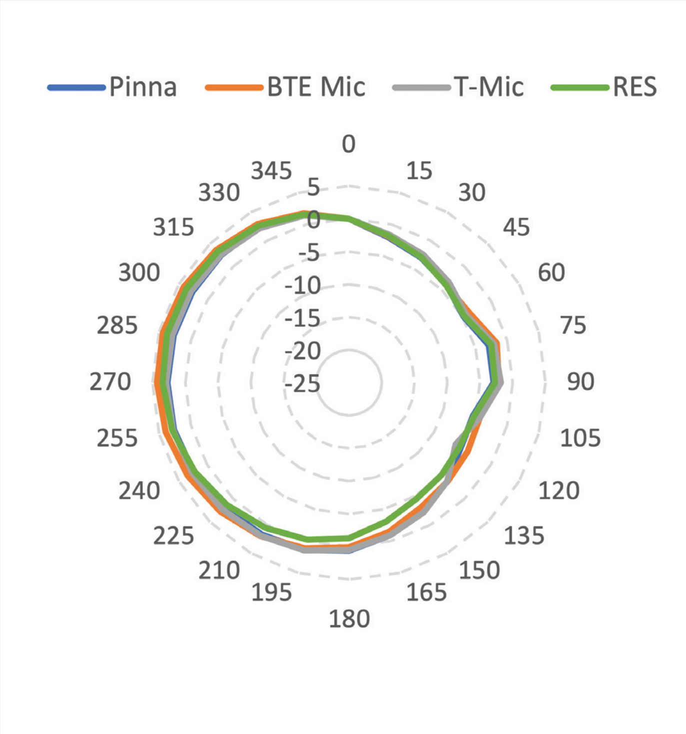


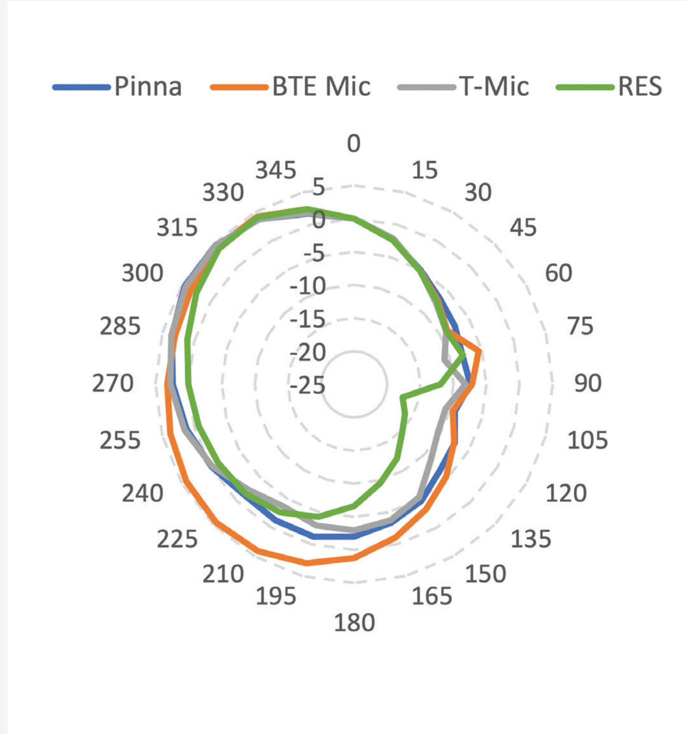
Figure 4: Front/back localization with T-Mic, BTE mic and RES algorithm. The test set-up is shown in 4a. Chance performance for this setup is 16.67% correct. As displayed in 4b and 4c, CI recipients showed improved front/back localization when listening with T-Mic and RES as compared to BTE mic.

Fig. 5 shows the 2D polar frequency response measured with a KEMAR (Knowles Electronics Manikin for Acoustical Research), a life-like head and torso simulator designed especially for acoustic research. Figure 5a shows the average response at 0.5, 1, and 2 kHz for pinna (unaided ear), BTE Mic, T-Mic, and RES. Figure 5b shows the same at 3, 4, and 5 kHz.

5a. 0.5 TO 2 KHZ AVERAGE



5b. 3 TO 5 KHZ AVERAGE



Note that the approximately omnidirectional response is expected and observed at frequencies up to 2 kHz for the four input types. At the higher frequencies, the response becomes directional, displaying an attenuation of sounds from the contralateral side. There is also an attenuation of sounds from the back with the pinna, T-Mic and RES, unlike the BTE mic. The frequency response of the T-Mic closely resembles the pinna. RES shows a similar response as the T-Mic and pinna with additional attenuation of input from the contralateral side.

PHONE DETECT

Marvel CI sound processors allow listeners to leverage a classifier-based operating system (AutoSense OS™ operating system 3.0 in Naída CI M and AutoSense Sky OS 3.0 in Sky CI M; hereafter referred to as AutoSense OS) that automatically steers sound processing features based on the listener's sound environment to provide optimal and comfortable hearing without needing to switch programs manually.[24-29] When AutoSense OS determines that the user is listening to speech in a noisy situation, it automatically deactivates the T-Mic and enables beamformers such as UltraZoom and StereoZoom,[30-33] which are designed to further improve speech perception in noise by improving the signal-to-noise ratio. One convenience of the T-Mic is the option to hold a phone over the ear canal to take calls instead of elevating it to cover the processor microphones. However, in noisy situations, the T-Mic may be disabled in favor of the directional microphones located on the sound processor. For this reason, Phone Detect[34] will automatically detect the presence of a phone over the T-Mic and enable the T-Mic, ensuring audibility of the acoustic phone output. Any active beamformer and SNR Boost are disabled while the phone is in this position covering the T-Mic. Phone Detect works by acoustically comparing the signals from the T-Mic and the back microphone of the processor. When a CI recipient holds a phone up to their T-Mic, it creates a comparatively different acoustic response between the T-Mic and the processor's back microphone. Note that Phone Detect only works if a functional T-Mic is installed and the recipient is in the AutoSense OS program. Phone Detect is available on all Naída CI M and Sky CI M sound processors.

T-MIC DETECT

The T-Mic Detect algorithm[35] allows for a seamless integration of the T-Mic in AutoSense OS. When a T-Mic is detected, it is automatically used in all quiet and low-noise conditions. While the T-Mic is in use, T-Mic Detect monitors the functioning of the T-Mic. If the T-Mic should fail or is removed from the sound processor, T-Mic Detect automatically switches to RES. The clinician doesn't need to specify whether a T-Mic is present in each program in the fitting software or create any back-up programs. By automatically responding to changes in the T-Mic response, the algorithm helps to simplify troubleshooting while ensuring a consistent and reliable listening experience. T-Mic Detect is available on all Naída CI M and Sky CI M sound processors. Since RES is not available with the Naída CI M30 sound processor, the T-Mic Detect algorithm switches to the BTE microphone instead of RES.

SUMMARY

The Marvel CI (Naída CI M and Sky CI M) combines AB's proven sound processing with Phonak's hearing aid technology to improve hearing performance of CI recipients of all ages, lifestyles, and listening needs. AutoSense OS 3.0 and AutoSense Sky OS 3.0 constantly monitor and automatically optimize listening experience in changing sound environments. T-Mic and Real Ear Sound leverage natural ear acoustics and improve speech recognition and localization. T-Mic Detect and Phone Detect go beyond AutoSense OS 3.0 to ensure a consistent and reliable listening experience. The Marvel CI system, thus, offers the recipient peace of mind with an uninterrupted listening experience that allows them to confidently connect with the world.

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