

SoundRecover and its benefit for Hearing Instrument wearers with a moderately-severe to severe hearing loss

Summary

Frequency compression is a proven new technique for improving the ability of people with hearing impairment to detect and recognise high-frequency sounds. As difficulty perceiving such sounds is one of the most common characteristics of hearing loss, the practical success of frequency compression is a significant advance in the field of hearing instruments. SoundRecover, a Phonak proprietary algorithm implementing frequency compression, was introduced recently in Naída UltraPower hearing instruments. Extensive trials have demonstrated the benefits of SoundRecover for many adults and children with severe to profound hearing impairment. Similar benefits may also be obtained by users of SoundRecover who have less-severe losses. Results from preliminary studies with Naída users having moderate or worse bilateral hearing loss show, that SoundRecover is generally both readily accepted and reported to assist with sound perception. This article explains the importance of SoundRecover even to hearing-instrument users with a moderately severe to severe hearing loss.

Introduction

The recent introduction of frequency compression in Phonak Naída UltraPower hearing instruments has demonstrated significant benefits of frequency lowering for many children and adults with relatively severe hearing impairment. In the past, a wide range of frequency-lowering schemes have been developed and tested experimentally. At present, several kinds of hearing aids from a number of manufacturers provide various types of frequency lowering (McDermott, et al. 1999; Kuk, et al. 2006). However, those schemes are not all the same. The SoundRecover scheme in Phonak Naída hearing instruments is not only technically distinctive, but also perhaps the only widely-used scheme for which the perceptual benefits have been clearly evident in well-controlled independent trials (Simpson, et al. 2005).

The rationale for the development of these schemes is based on the common observation that most people with hearing impairment have poorer perception of sounds at high frequencies than at low frequencies. In many cases, high-frequency hearing sensitivity is so deficient that conventional

amplification cannot make all such sounds comfortably audible. Even when audibility can be achieved, it is often difficult for people with moderately severe or worse hearing loss to discriminate and identify high-frequency sounds (Hogan and Turner 1998). This is an important problem, because many complex sounds, including several phonemes that are often used in speech, contain dominant or significant high-frequency components. Furthermore, children who are learning spoken language experience particular difficulty when attempting to produce phonemes that they cannot hear adequately.

To some researchers in hearing and speech science, frequency lowering has seemed for many years to be a potentially feasible solution to this problem. Although numerous schemes have been devised and evaluated experimentally, the outcomes have been mixed. With some schemes, the recognition of certain speech phonemes has been improved, but at the expense of poorer identification of other phonemes. A few previous and existing schemes have been shown to improve high-frequency sound perception, but the quality of the processed signal is marred by 'artefacts' including clicks, other noises, and unintended changes in pitch. As a result, frequency-lowering schemes in general have not been widely accepted until recently. Even now, there is a belief that such schemes are probably appropriate and effective only for people with profound hearing loss in the high frequencies. However, recent research and technological developments have indicated that frequency lowering can be beneficial even for people with relatively good hearing sensitivity across most of the normally audible frequency range. To what extent a perceptual benefit can be obtained depends both on the technical function of the frequency-lowering scheme and on the way the variable parameters of the scheme are fitted to the individual user of a hearing instrument. These factors are discussed briefly below.

The importance of perceiving high frequencies

Not only speech but also environmental sounds often contain or are dominated by high-frequency components. Being able to detect and identify such sounds is at least as important for people with hearing impairment as it is for people with normal hearing.

Figure 1 shows a spectrogram of forest sounds including birds singing. In the spectrogram, time increases from left to right, and frequency from bottom to top, while lighter colours represent sound signals of higher intensity. In the birdsongs, the most intense acoustic components are at frequencies above about 2 kHz. Most of the sounds are concentrated in the range from 2 to 5 kHz, although there are some components at even higher frequencies. Such sounds can be difficult for many people with high-frequency hearing impairment to detect and discriminate.

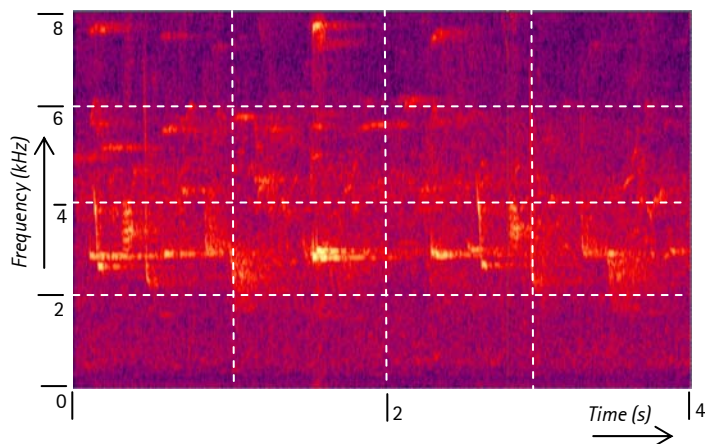


Figure 1: A spectrogram of forest sounds including birds singing. In the spectrogram, time increases from left to right, and frequency from bottom to top, while lighter colours represent sound signals of higher intensity.

A spectrogram illustrating two speech sounds that are dominated by intense high-frequency components is shown in Figure 2. The sequence of phonemes, which was produced by a female speaker, is /a-s-a-sh-a/. Note that the vertical frequency axis in this figure extends to 16 kHz. Although the vowels have most energy below about 4 kHz, the fricative consonants /s/ and /sh/ contain components that cover a wide range of generally higher frequencies. The /s/ sound has a broad peak from about 7 kHz to over 12 kHz, whereas the /sh/ sound covers a somewhat lower frequency range (approximately 3-8 kHz).

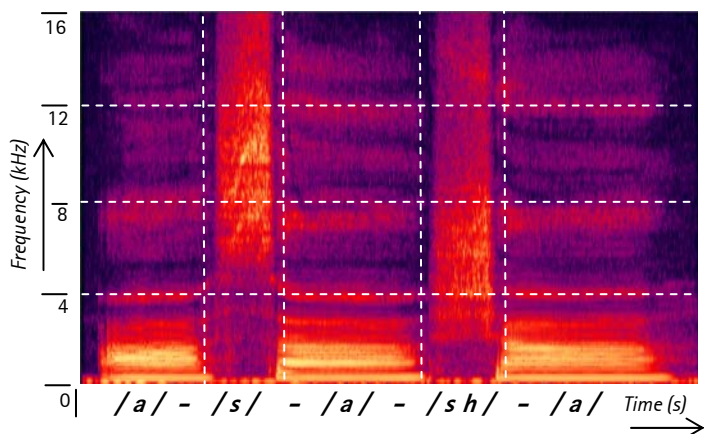


Figure 2: A spectrogram of the nonsense utterance /a-s-a-sh-a/, plotted as in Figure 1. The two consonants /s/ and /sh/ are dominated by intense high-frequency components.

The graph in Figure 3 summarises the results of a published study in which the spectral content of the phonemes /s/ and /z/ was analysed (Stelmachowicz, et al. 2002). The

consonants were spoken by a male and a female speaker, and the levels were measured in 1/3-octave bands as a function of frequency. As can be seen in the figure, most energy lay above 3 kHz for each speaker. Importantly, the broad energy peak for the female speaker had a lower edge at approximately 5 kHz, and an upper edge apparently above the highest frequency available in the analysis (8 kHz). The measurements shown in Figures 2 and 3 clearly reinforce the need for hearing instruments to deliver information about relatively high frequencies to people with hearing impairment in order to maximise their understanding of speech. They also illustrate that frequency regions well above 5 kHz often contain high levels of acoustic signals when the speaker is female, and other studies have reported similar observations for child speakers.

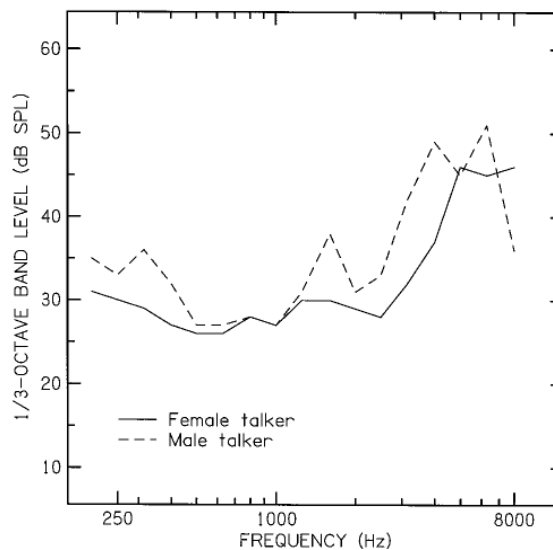


Figure 3*: Analysed spectral content of the phonemes /s/ and /z/ spoken by a male and a female speaker. Most of the energy lies above 3 kHz for each speaker. Importantly, the broad energy peak for the female speaker had a lower edge at approximately 5 kHz, and an upper edge apparently above the highest frequency available in the analysis (8 kHz).

*From Ear & Hearing

How do conventional hearing aids process high frequencies?

The importance of high-frequency audibility for adequate speech understanding has been understood since the early days of amplification. In general, both the design and the fitting of acoustic hearing aids result in the provision of more gain at high frequencies than at low frequencies. However, there are several practical limitations on the benefit available from high-frequency amplification, including:

- feedback whistling in the hearing aid;
- hearing sensitivity being too poor for amplification to be practicable;
- the discomfort sometimes experienced from amplified high-frequency sounds; and
- the presence of 'dead regions' in the cochlea.

The last point refers to a condition in which large numbers of certain hair-cells in the cochlea are absent or non-functional (Moore 2001). Such 'dead' regions are apparently more common in the more-basal parts of the cochlea, where high-frequency sound vibrations are detected and converted into neural activity, than in more-apical cochlear locations. This condition is often associated with severe or profound loss of hearing sensitivity, but may occur even at frequencies where the hearing thresholds seem appropriate for the amplification normally provided by a hearing aid. Individuals with extensive high-frequency dead regions may have abnormal perception of sounds containing high frequencies even when they are made audible, with the result that their ability to discriminate and identify such sounds is worse than would be expected based on their audiogram.

Application of frequency compression to less-severe hearing loss

If the deterioration of hearing sensitivity in the high frequencies is not extreme, conventional amplification should be able to make sounds audible. However, although audibility is a necessary condition for sound recognition, it is not a sufficient condition. As mentioned earlier, many people with sensorineural hearing impairment cannot easily discriminate or resolve high-frequency sounds even when they are fully audible. Therefore, the fundamental principle of frequency compression – i.e., that lowering significant frequency components will make them easier to perceive accurately – is applicable to a broad range of audiogram configurations, not just those showing minimal sensitivity at high frequencies. Furthermore, the preservation of sound quality achieved by Phonak's SoundRecover algorithm suggests that many users of hearing instruments who have relatively good high-frequency hearing would readily accept and benefit from frequency compression. In fact, ongoing studies are confirming that such hearing-instrument users often do find SoundRecover helpful, and that they generally prefer frequency compression to be enabled rather than disabled in 'blind' trials. The main challenge for successful use of SoundRecover is to ensure that the fitting is optimised for each individual.

Fitting of SoundRecover in Naída SuperPower

The initial fitting of frequency compression is based on the audiogram configuration of the hearing-instrument user. The two adjustable parameters – the cut-off frequency and the frequency-compression ratio – are preset within restricted ranges of 1.5 to 6.0 kHz, and 1.5:1 to 4:1, respectively. The values of these two parameters are automatically selected initially according to a rule that operates on the audiogram data. In brief, the cut-off frequency is set to a low value within the above limits if the audiogram shows relatively severe hearing impairment, or a relatively steep decline of hearing sensitivity towards higher frequencies. Conversely, the cut-off frequency has a relatively high initial setting when the hearing thresholds are not as severe, or the shape of the audiogram is flatter or slightly upward-sloping.

After initial fitting, the amount of frequency compression that is applied can be adjusted for each individual user by means of a single strength parameter. When the strength is varied, the cut-off frequency and the compression ratio are changed together following an inbuilt rule. For example, if the user's audiogram slopes fairly uniformly from a threshold level of 60 dB HL at 250 Hz down to 95 dB HL at 4 kHz, the automatic initial fitting will set the cut-off frequency to 2.5 kHz and the compression ratio to 1.8:1. Subsequently, if the strength is decreased, the cut-off frequency will increase, resulting in frequency compression being applied only across a narrower range of higher frequencies. Conversely, if the strength is increased, the cut-off frequency will decrease. For instance, an increase in strength by two steps from the initial default setting in the above example will lower the cut-off frequency to 1.8 kHz. In general, the compression ratio changes in the same direction as the cut-off frequency, resulting in a smooth variation in the perceptual effect of frequency compression when the strength is adjusted. However, when the cut-off frequency reaches one of the limits (1.5 or 6.0 kHz), further strength adjustments result in changes being made only to the compression ratio.

It is not yet clear whether there is a minimum limit to the degree of hearing impairment above which frequency compression is either not helpful or produces unacceptable sound quality. Current research suggests that even users of hearing instruments with mild losses find that SoundRecover can provide comfortable listening if the cut-off frequency is set relatively high (above 4 kHz). This is not surprising, because there is little or no harmonic pitch information present in most types of sound at the high frequencies affected by frequency compression with such settings. On the other hand, there is useful information present in some high-frequency sounds, particularly the fricative consonants of speech. It is certainly plausible that the perception of those sounds would be improved by limited application of frequency compression. In fact, even people with normal hearing could theoretically benefit under certain listening conditions. In particular, when using a telephone – which has an upper frequency limit below 4 kHz – it can be difficult to understand unfamiliar words, such as names, if they contain certain phonemes. For example, /s/ can easily be confused with /f/, and in many cases is not audible at all. Under these conditions, some frequency compression above a relatively high cut-off frequency could improve the listener's ability to hear and to discriminate such speech sounds. Therefore, it is highly likely that SoundRecover, when appropriately fitted, could provide benefits to almost all users of hearing instruments.

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