BassBoost –
The power feature that boosts audibility

Summary

BassBoost is a powerful low frequency gain and output enhancer that allows for low to mid-frequency increase of +3 to +6 dB below 1000 Hz. Additional power in the low frequencies results in an immediate improvement in subjective loudness as well as sound quality of power instruments. But there is more...
BassBoost also facilitates speech perception and comprehension in quiet as well as noisy environments by making low-frequency speech cues more accessible. This document reviews the specific importance that these cues constitute for wearers with a moderately severe to profound hearing loss and their ability to provide significant benefit also for children with a moderately severe to profound hearing loss.

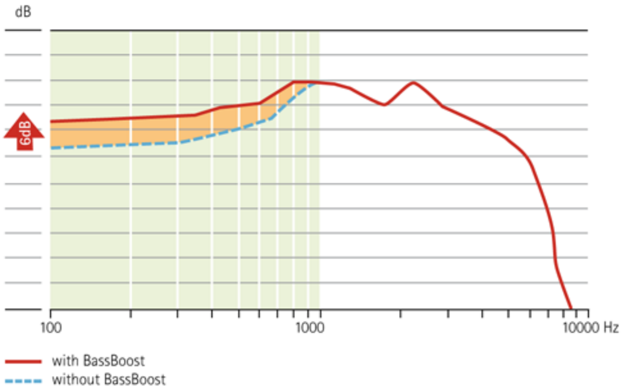

Fig.1
MPO shape of a power instrument without (blue line) and with BassBoost (red line).

Introduction

BassBoost was especially developed for wearers with a severe to profound hearing loss that need high audibility levels and were until now difficultly pleased by the overall sound experience of standard power digital hearing aids (Kochkin, 2005). For many long-term power users, the transition from analog to digital amplification was experienced as a rather disappointing and frustrating (r)evolution. Major complaints from this customer group account for relatively poor spontaneous acceptance and satisfaction levels as well as high return rates. Wearers with moderately severe to profound hearing loss, compared to other loss categories, are less satisfied by the clarity (-9 %), naturalness (-11 %), richness and fidelity (-12 %) of amplified sounds. BassBoost provides these users with a completely new, extremely satisfying, full and rich hearing experience.

Satisfaction boosted by an improved loudness experience!

BassBoost has an immediate and easily perceived impact on experienced loudness and sound quality. An increase in low frequency amplification results in proportionally more loudness perception than an equivalent increase in the high frequencies. This is easily explained by Moore's theory of the excitation pattern. It states that the recruitment level of hair cells along the cochlear basilar membrane will be broader for stimulation in the low frequencies than for comparable stimulation levels at high frequencies (see Fig. 2 and Robinson & Dadson, 1956; Moore,1982). A small increase in intensity at low frequencies will thus lead to a greater subjective loudness growth than an equivalent increase at high frequencies. Adding gain in the low frequencies will typically result in an immediate increase in perceived overall loudness of amplified sound. BassBoost will thus allow for immediate subjective loudness increase, without risk of feedback, leading to improved user satisfaction.

Loudness and cochlear encoding of sound

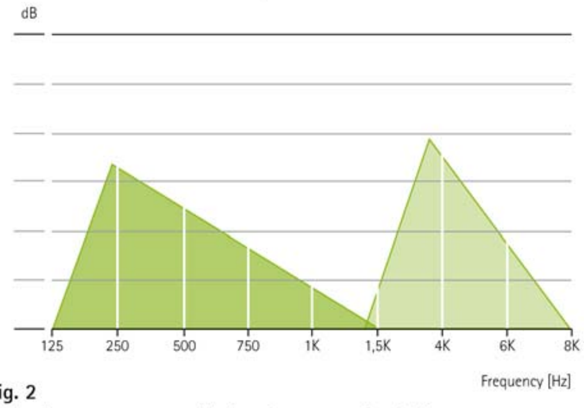

Fig. 2
Excitation patterns caused by low frequency stimulation and by corresponding high frequency stimulation. (Adapted from Moore, 1982 cited in Katz, 1994).

More Acceptance: A boost to sound quality!

Research has shown that judged naturalness of amplified sounds is closely associated with the smoothness and width of the frequency responses (Bucklein, 1062; Gabrielsson et al., 1990; 1991). Studying loudspeakers quality differences for example, Gabrielsson and collaborators (1991), showed that the subjective sound dimension "fullness" is associated with a broad and smooth frequency response with an emphasis in the low frequency range. In a more recent study, Moore and Tan (2003) demonstrated that an important proportion of acoustical information responsible for speech and music sounds, being rated as natural, was situated in a frequency domain below 200-250 Hz. The BassBoost feature in instruments from Phonak provides a powerful, clear and rich sound experience without increasing the risk of feedback. In this sense, BassBoost is a powerful tool designed to help people with significant gain needs and a narrow dynamic range to easily acclimatize to a new hearing solution. In addition, improving amplification in the low frequencies also provides additional significant benefits making it a must in the power domain.

The importance of low-frequency information for speech intelligibility

The frequency band conveying natural human speech information is rather broad. The well known "Speech Banana" (Fig. 3) extends from approximately 150 Hz up to more than 8000 Hz. It is well known that many important speech cues are in the high frequency range, such as sibilants and fricatives (/f/, /s/, or /sh/). It may therefore seem counter-intuitive that low frequencies are very important in speech comprehension. However, as clearly seen on the diagram, significant speech sounds have frequency spectra below 1 kHz. All of these speech sounds will benefit from the effective amplification range of BassBoost. This is especially important since many wearers with severe-to-profound hearing loss often have very poor high frequencies thresholds and do not get much high frequency speech cues at all.

Research has shown that these wearers compensate by relying more and more efficiently on the low frequency speech cues than normal hearing subjects (Hogan & Turner, 1998; Ching et al.; 1998; turner and Cummings, 1999). Providing low- to mid- frequency amplification to people with severe-to-profound sensorineural hearing loss has been shown to improve their speech comprehension abilities (e.g. Turner and Brus, 2001). The relevance of different frequency bands in the speech signal to intelligibility is relative and in fact, many crucial speech cues are present in the lower frequency range. A case in point is the fundamental frequency (F0) and the first formant (F1).

BassBoost Effective Range

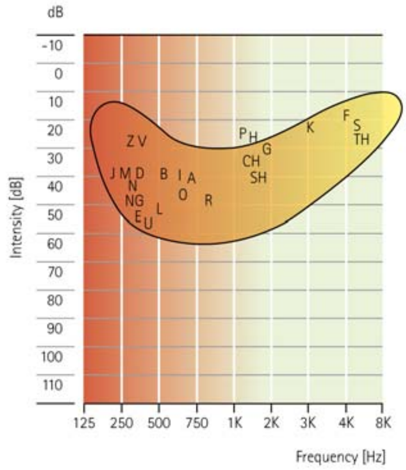

Fig. 3
The "Speech Banana": spectral and intensity distribution of human speech sounds (English language).

Better prosodic integration and syllable discrimination for improved word recognition

Formants (grey lines on Fig. 4) are regions of the spectrum where speech signals are more intense. In natural human speech there is one formant per 1kHz band and the most important ones for intelligibility are the first three. The fundamental frequency (blue lines on Fig. 4) is the perceived pitch of one's voice. It varies according to the gender and age of the speaker. The average value for a typical female voice is around 200 Hz with a range of 150 to 450 Hz. For a male speaker, the average is around 100 Hz ranging between 50 and 350 Hz (Ladd et al., 1995). Low frequency information significantly affects the accuracy of F0 perception. By increasing low frequency amplification with BassBoost, wearers with severe-to-profound HL are better able to extract and use F0 information. F0 extraction is important as it provides information regarding the rhythmic variations of the human voice. It is therefore of critical importance for the identification of word boundaries. The contribution of F0 information to speech comprehension is extremely important for power instruments users because such wearers heavily rely on lip reading to complement their auditory perception. In 1981, Rosen, Fourcin and Moore demonstrated that F0 information alone could improve the transmission rate of connected discourse, even in normal hearing subjects. Speech reading enhancements by the provision of F0 information was later demonstrated in studies done on both normal hearing subjects and subjects with various hearing loss configurations (e.g. Breeuwer & Plomp, 1986). Moreover, for certain consonant pairs, the most salient difference in the acoustic signal allowing for their discrimination is encoded in the F0 range. Fig. 4 displays the waveforms (upper panels) associated with two different syllables, /ba/ and /pa/, pronounced by the same male speaker, as well as their spectrograms (lower panels), showing the energy of the acoustic signal in the different frequency bands (vertical axis – range from 0 to 8 kHz), over time (horizontal axis – 0.5s examples). We have also added the variations of F0 over time (blue line) as well as the presence of the different formants (F1 to F3). The shadowed yellow area represents the effective range of the BassBoost feature. It is quite evident from this illustration that the major difference allowing for the discrimination between the two syllables is present in the low frequencies. BassBoost allows for intensified and better perception of F0 and F1 information, facilitating syllabic discrimination, leading to overall improvements in speech discrimination.

Boost perception of emotions and intentions in speech

F0 variations encode the gender but also reflect the age of speakers, the average F0 value of an infant's voice, for example, is typically around 270 Hz. Therefore, overall F0 information is crucial to identify speakers and recognize familiar voices.

F0 also varies as speech unfolds in time and listeners are able to track F0 information in order to follow a speaker in noisy environments, (Bronkhorst, 2000). In adverse listening situations, we mainly rely on surface information to identify the concurrent voices. These cues are individual rhythm, gender, accent or intonations and are mainly represented in F0 variations (Brungart, 2001; Brungart et al., 2001). Lastly F0 information is modulated by intonation, reflecting the state of mind and intentions of speakers. In Fig. 5, you can see the spectrogram of the sentence "The BassBoost Feature". In the lower panels, we extracted the information from four different recordings of that sentence. The ones on the left were pronounced by a male speaker asking the question "Is it the BassBoost feature?" and then answering (lower panel) this question by a neutral affirmation "Yes, it is the BassBoost feature."

The ones on the right were pronounced in the same situations by a female voice. Note that, in the 0 to 500 Hz range, where the F0 modulations mainly appear:

The average value of F0 for the female voice is higher than the male voice (~230 Hz vs. ~120 Hz respectively).

F0 values for questions show a progressive rise whereas for answers they show a progressive fall (dotted lines on Fig. 5).

In summary, extremely important speech cues are present in the low-frequency range and enhancing these cues by the use of BassBoost will help severe-to-profound wearers to extract and use these cues for a holistic speech comprehension.

Low frequency cues and syllable discrimination

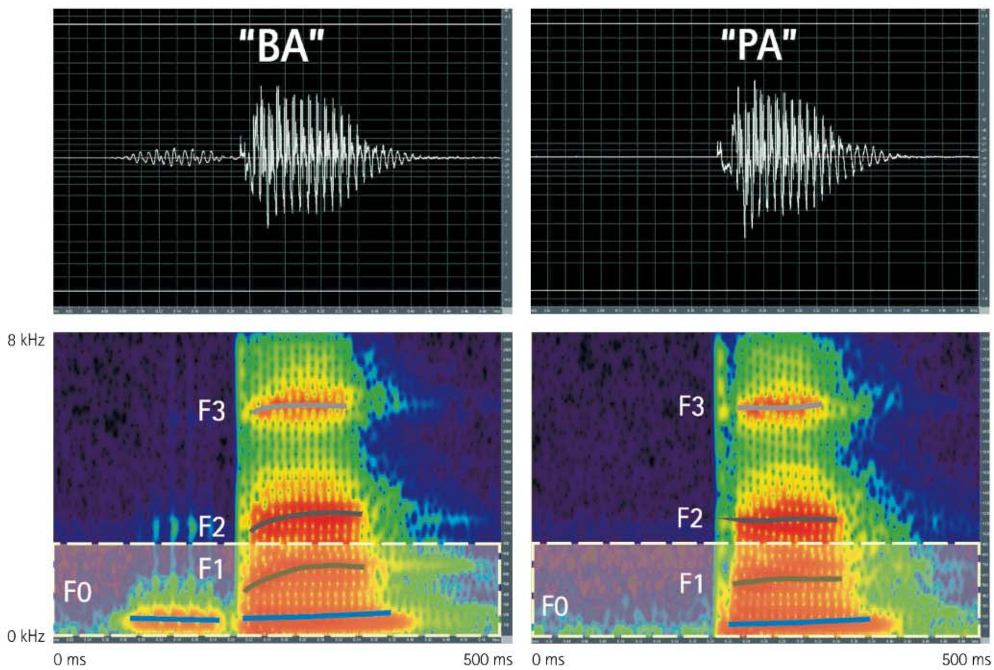

Fig. 4
Upper panel:
Waveform representations of the two syllables /ba/ (left) and /pa/ (right).
Lower panel:
Spectrographic representation of the same waveforms. F0 is highlighted in blue; the different formants are indicated in grey. The effective range of BassBoost is shown as a shaded area.

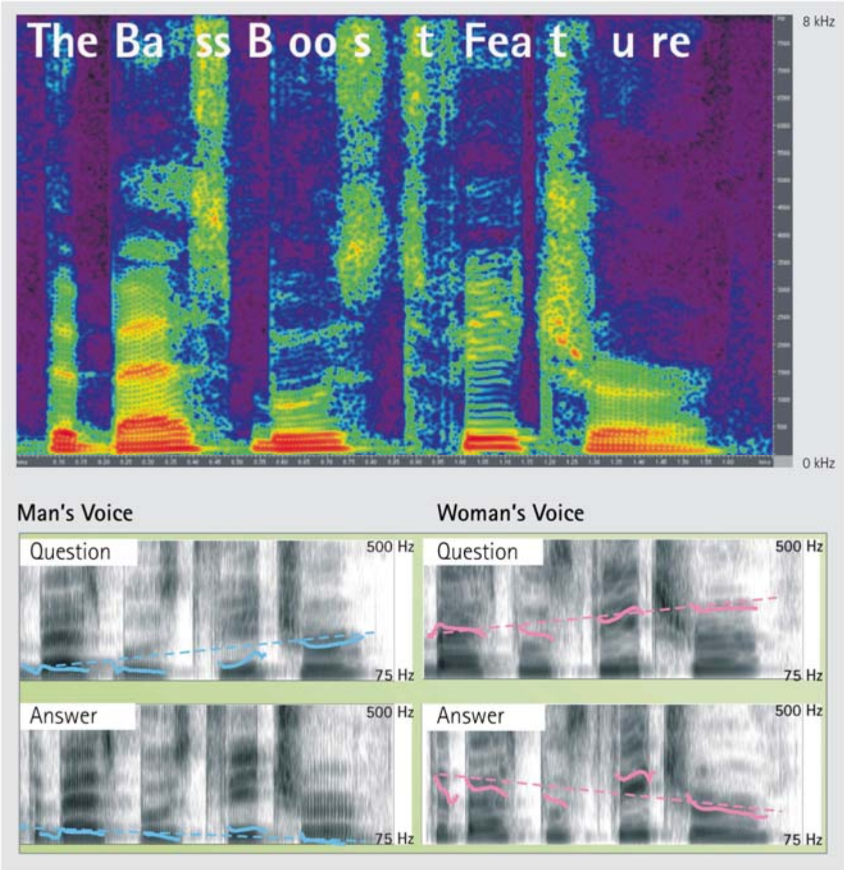

Fig. 5
Upper Panel: Spectrogram showing the distribution of energy in the signal amongst the different frequencies of speech. Note the important amount of energy present in the lower frequencies, as well as the general distribution of speech cues. Lower panel: The same sentence pronounced by speakers differing in gender and intonations, the F0 modulations (in the 0-500 Hz range) are shown against the spectrogram in its original scale (0-8,000 Hz). Note the rise and fall differentiating questions from answers and the average F0 values differentiating genders.

Pediatric relevance of the BassBoost feature

Reviving the original colours of Sounds for children with a significant hearing loss

During pregnancy the fetus starts to perceive sounds from the external world around the 20th week of gestation when the auditory system starts to mature. At that time, it perceives Sounds travelling through the placenta and the amniotic liquid. In-utero recordings of speech sounds have shown that the placental filter provides amplification to sounds below 250 Hz from +2 to +5 dB and then acts as a low-pass filter decreasing -6 dB per octave and ending up at an average attenuation level of –20 dB at 4 kHz. This low-pass filter essentially favours information in the low frequencies near the fundamental frequency range and is also reasonably intelligible (Smith et al., 2003). As a result newborns are very sensitive to the fundamental frequency of their mother's voice and can recognize and discriminate it from an unknown person's voice. They are also able to discriminate human speech in general from other sounds and prefer to listen to it, as well as discriminate the sounds belonging to their own mother's language from other languages. (Mehler et al., 1978; DeCasper and Fifer, 1980).

Fundamental Frequency information and language acquisition

This sensitivity of infants and children to F0 information is also used unconsciously, but naturally, by mothers speaking to their children. This is called "motherese" or "child directed speech". When speaking to their children, mothers (and sometimes fathers too) modify their voice producing exaggerated utterances like :"Ooooh, the liiitle baaaby... It's Muumy's baaby...". What could be thought of as a childish regression has a crucial importance: it amplifies fundamental frequency modulations that can thus be better identified and recognized by children (e.g. Kemler et al., 1989).
Because fundamental frequency provides prosodic information it has an extremely important role for infants and children supporting their phonemes and syllables recognition in the continuous speech stream (Christophe et al., 1994; Eimas, 1994; 1999; Jusczyk & Aslin, 1995; Jusczyk, 1997).
Finally, good rendering of fundamental frequency information is highly relevant to the extraction of intentional and emotional content of speech. Children learn from F0 information to recognize and discriminate moods and emotions in voices. BassBoost is therefore ideally suited for power pediatric applications as it provides clear fundamental frequency information to hearing impaired infants supporting their language acquisition and recognition of emotional expression of others.

What Phonak products offer BassBoost?

BassBoost is available in most BTE and ITE power solutions from Phonak (Exélia, Naída, Versáta, Certéna, SaviaArt, Eleva, eXtra and Una).

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