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# TOPICS IN AMPLIFICATION

## Benefits of Frequency Composition™

The purpose of a hearing instrument is to restore audibility so that a hearing-impaired person can hear speech and other sounds. As a hearing care professional, you achieve this goal most of the time by providing enough amplification. However, it becomes more difficult with increasing high-frequency hearing loss due to various limitations such as an increased risk of acoustic feedback, gain limits, etc. A solution to this problem is available with Bernafon's frequency-lowering system: Frequency Composition™.

Severe high-frequency hearing loss occurs rather often. In fact, Davis (1995) reported that 24 % of people over 60, included in his research, suffer from severe high-frequency hearing loss. His definition relates to an average of at least 75 dB HL, measured at 4, 6, and 8 kHz. With this type of hearing loss, there is an increased risk of cochlear dead regions (Vinay & Moore, 2007). Cochlear dead regions designate regions of the cochlea where the inner hair cells and/or neurons are no longer functioning (Moore & Glasberg, 1997). In this case, amplification alone may not provide sufficient audibility.

Without sufficient high frequency audibility, clients miss out on important speech cues, e.g. fricatives like /s/ and /z/ (Stelmachowicz, Pittman, Hoover, & Lewis, 2002; Stelmachowicz, Pittman, Hoover, Lewis, & Moeller, 2004). As a result, these clients often confuse words and find it hard to communicate even in quiet situations. Improving audibility is possible, in a different way, with Frequency Composition™. Its working principle is shown in Fig. 1.

Frequency Composition™ is a frequency-lowering system. As shown in Fig. 1, the system takes high-frequency signal components from the source range and superposes them on the mid-frequency destination range. In contrast to similar systems, it maintains the bandwidth of the audio signal. In this way, Frequency Composition™ improves high-frequency audibility and preserves sound quality. In addition, it also offers individualized settings.

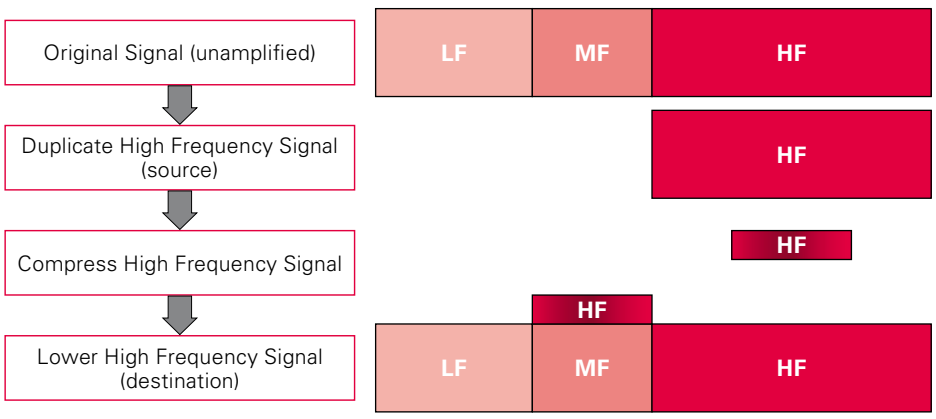


**Figure 1:** Working principle of Frequency Composition™

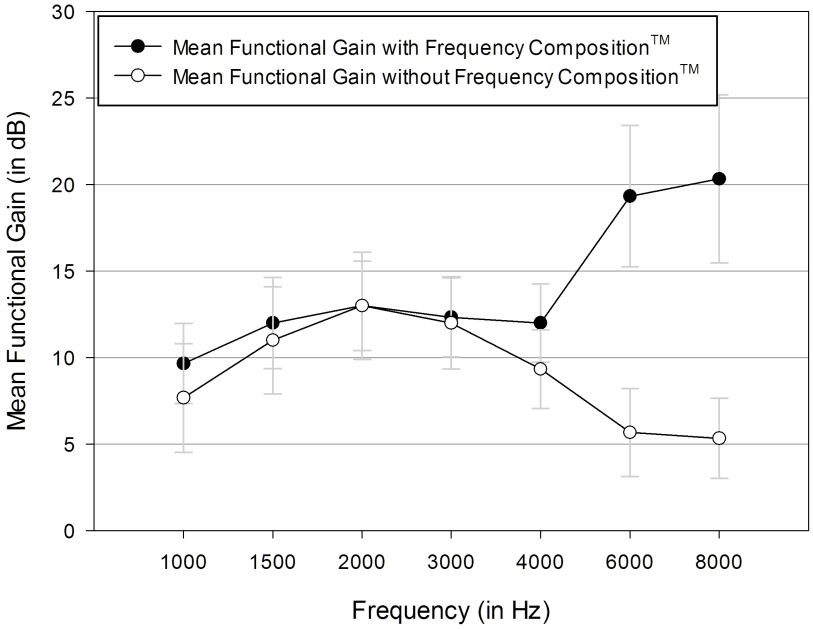


**Figure 2:** Functional gain with Frequency Composition™ on vs. off

## Improved High-Frequency Audibility

We verified high-frequency audibility using a functional gain procedure. As a hearing aid verification method, functional gain is currently used less frequently than real ear measurements (REM). However, in order to verify audibility, we need a procedure where the client confirms an audible signal – a feature which is not part of REM. In contrast to REM, functional gain shows more than just hearing aid output, it shows what the client perceives.

Functional gain involves sound-field measurements of hearing thresholds and is therefore well suited for detecting audibility. In more specific terms, functional gain is the difference between aided and unaided measurement values of hearing thresholds. Therefore, functional gain is able to reveal the effect of Frequency Composition™ on audibility, as shown in Fig. 2.

The diagram shows two curves of the mean functional gain for a group of 15 appropriately fitted clients. The curve with the black circles shows the mean functional gain with Frequency Composition™ on, whereas the curve with the white circles shows the mean functional gain with Frequency Composition™ off. The difference is an improvement of approximately 15 dB at 6 and 8 kHz. These frequencies are within the source range that is lowered by Frequency Composition™ to the destination range. In addition, Fig. 2 shows no significant difference below the source range, demonstrating that Frequency Composition™ provides audibility only where specified.

## Preserved Sound Quality

A signal processed with frequency lowering has added information in regions where it would normally not be present. This additional information has an effect on the way the signal sounds and can affect overall sound quality. However, Frequency Composition™ gives special attention to the original signal in order to maintain overall sound quality.

One important factor in maintaining sound quality is to avoid interference in the frequency region below 1.5 kHz. Changing spectral information below this frequency affects the harmonic structure of speech cues, which causes speech to acquire an unnatural quality (Dillon 2012). Frequency Composition™ consequently makes high-frequency information audible by superposing it on the mid-frequencies above 1.5 kHz. In addition, Frequency Composition™ maintains the full bandwidth. These aspects become evident with a differential spectrogram.

A differential spectrogram is derived from two standard spectrograms, which show spectral content of a signal over time. The differential spectrogram shows the difference between spectrograms over the same time period. As a result, the differential spectrogram allows you to see the difference between signals processed with and without Frequency Composition™. An example is shown in Fig. 3.

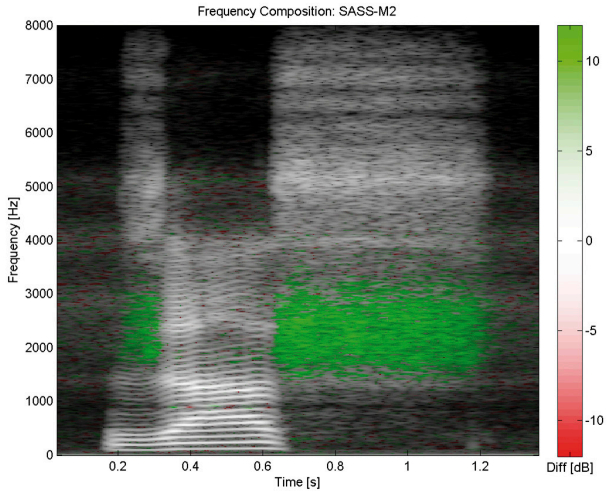


**Figure 3:** Differential spectrogram of a test signal

Fig. 3 shows the differential spectrogram of the test sound /zas/, processed with and without Frequency Composition™. White areas in the spectrogram indicate signal components that are the same in both signals, whereas the green areas indicate additional signal components added by Frequency Composition™. A red area would indicate signal components that were removed.

From Fig. 3, we demonstrate that Frequency Composition™ removes no signal components so all the information is available to the ear for maximum stimulation. Moreover, all signal components below 1.5 kHz are left untouched, which maintains the harmonic structure of speech cues in the low frequencies.

As shown by the green areas in Fig. 3, Frequency Composition™ added energy for the high-frequency consonants /z/ and /s/. However, in the case of the vowel /a/, the superposed energy is only marginal. This difference is due to the natural masking effect that results from the different levels of spectral energy between vowels and consonants. Vowels have more energy in low and mid-frequencies as compared to higher frequency consonants. Frequency Composition™ maintains this natural balance between consonants and vowels and preserves sound quality.

It is important to clients that what they hear with Frequency Composition™ sounds as natural as possible. To test overall sound quality, 14 clients completed a Speech, Spatial, and Qualities of Hearing questionnaire (SSQ) (Gatehouse & Noble, 2004) comparing the sound quality of signals processed with and without Frequency Composition™. Their ratings showed no significant difference between the two signals, supporting the finding that Frequency Composition™ preserves the sound quality.

## Individualized Settings

Frequency Composition™ is implemented in the fitting software Oasis. The new Frequency Composition™ algorithm automatically selects the best setting for your client. It evaluates and compares the audiometric data of each ear and then selects the optimal setting based on this data. To that end, Oasis creates individualized settings for your clients. An example is shown in Fig. 4.

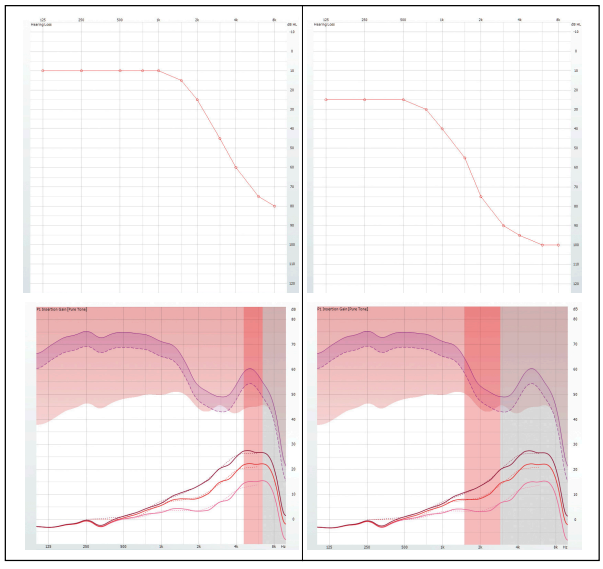

**Figure 4:** Hearing loss and destination frequency range

Fig. 4 shows two typical high-frequency hearing losses (top panel) that activate different Frequency Composition™ settings in the software (bottom panel). The red shaded column on the diagram indicates the Frequency Composition™ destination region, which is selectable in the software. The diagram refers to the right ear; in the case of the left ear, the shaded column is blue. For both the left and right ears, the grey shaded region indicates the source region from which the high-frequency information is lowered. This example illustrates the flexibility of the fitting software in providing individualized settings.

## Mature Solution for Severe High-Frequency Hearing Loss

Frequency Composition™ provides a new way of improving audibility, especially in the case of severe high-frequency hearing loss, and helps preserve the overall quality of sound. With individualized settings, the fitting software Oasis tailors Frequency Composition™ to your clients' needs. Let Frequency Composition™ help your clients hear what is important.

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