

# ConnexxFit

## Rationale, Implementation, & Evaluation

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### **Abstract**

ConnexxFit is Siemens' proprietary fitting strategy which applies modifications to NAL-NL1 based on device specific properties and ear canal acoustics in order to optimize spontaneous acceptance. In open fittings, ConnexxFit utilizes OPEN and OPEN4FLAT formulas to reduce the risk of feedback. In closed fittings, ConnexxFit considers the degree of hearing loss and the selected instrument to determine the default acclimatization levels applied to NAL-BALL. Finally, for severe to profound hearing losses, ConnexxFit defaults to SuperPower-Fit to offer the perception of loudness preferred by this target group. Various studies have shown that ConnexxFit is preferred by most patients without degradation of speech intelligibility.

The most critical moment in a hearing instrument fitting process is undoubtedly when the hearing instruments are placed in the ears for the first time, and the patient finally hears the first sounds with the new hearing instruments. That first impression of amplification sets the stage for the continuation of the fitting process. A positive reaction can increase the success of the fitting session, the perception of the selected instrument, and even the assessment of the hearing care professional's capabilities. Likewise, a negative reaction can negatively impact all of those same areas. As is often the case, the deciding factor in how the instrument will perform for this first impression is the selected fitting algorithm, which is usually implemented with the click of a button.

### Traditional Fitting Formulas

When we think about the purpose of a fitting algorithm, we can generally agree that this is a fitting tool that aims to optimize audibility and speech intelligibility, match preferred loudness levels, avoid loudness discomfort, and provide good sound quality. This complex set of goals has naturally generated a variety of different prescriptive formulas over the years.

With the regular use of non-linear amplification, two formulas in particular have emerged as the defaults for clinical use: DSL (Desired Sensation Level), with the current version being the *m* [i/o] 5.0 (Scollie et al, 2005, Seewald, et al, 2005) and NAL-NL1 (Dillon, 1999). NAL-NL2 will be released in 2010 and preliminary parameters have been described already (Keidser & Dillon, 2009). These traditional prescriptive fitting algorithms have several strengths. There is a sound theoretical basis leading to their development. And as part of that development, there is extensive evaluation supporting the algorithms and demonstrating the effectiveness of the algorithms. And, perhaps most importantly, they are repeatedly proven in practice as part of many clinical fitting protocols.

Traditional prescriptions, however, still have their limitations. There are a number of variables which also interact with the fitting result but are not taken into account. These variables include the dynamic effects of adaptive signal processing, device specific properties, ear canal acoustics, and the spontaneous acceptance of the fitting. Additionally, traditional prescriptions do not take hearing aid experience and acclimatization into account. A first time hearing aid wearer may find the prescribed target initially too

loud, so consequently, an appropriate fitting may be negatively received. Whereas an experienced user would often prefer more gain to be prescribed.

### **Siemens ConnexxFit**

If the existing prescriptive formulas can be a foundation onto which corrections for the individual patient and selected instrument can be added, then a successful initial fitting for each individual patient may be more likely. This is the philosophy governing Siemens ConnexxFit, the fitting algorithm implemented for Siemens hearing instruments. Since ConnexxFit is meant to be primarily used for adult users, NAL-NL1 is chosen as the base formula.

Rather than a specific fitting formula, ConnexxFit is a selection algorithm which determines the best fitting rationale for each individual fitting. The ConnexxFit approach first analyses the selected acoustic parameters, more specifically, whether it is an open or closed fitting. While a patient with an open fitting may not need any more or less gain than a closed fitting, there may be challenges in achieving intelligibility with appropriate high frequency without creating feedback from the open fitting. Therefore, open fittings, defined as having vent sizes larger than 2.5mm, are considered separately under the ConnexxFit selection process. At the next level, the patient's audiometric information and the selected hearing instrument are used to determine which acclimatization level is selected. Specific instrument characteristics are then considered to further individualize the fitting for the wearer. The decision matrix for ConnexxFit is summarized in Figure 1. In the following, we will explain the rationale, implementation, and verification of the fitting formulas selected by ConnexxFit in more detail.

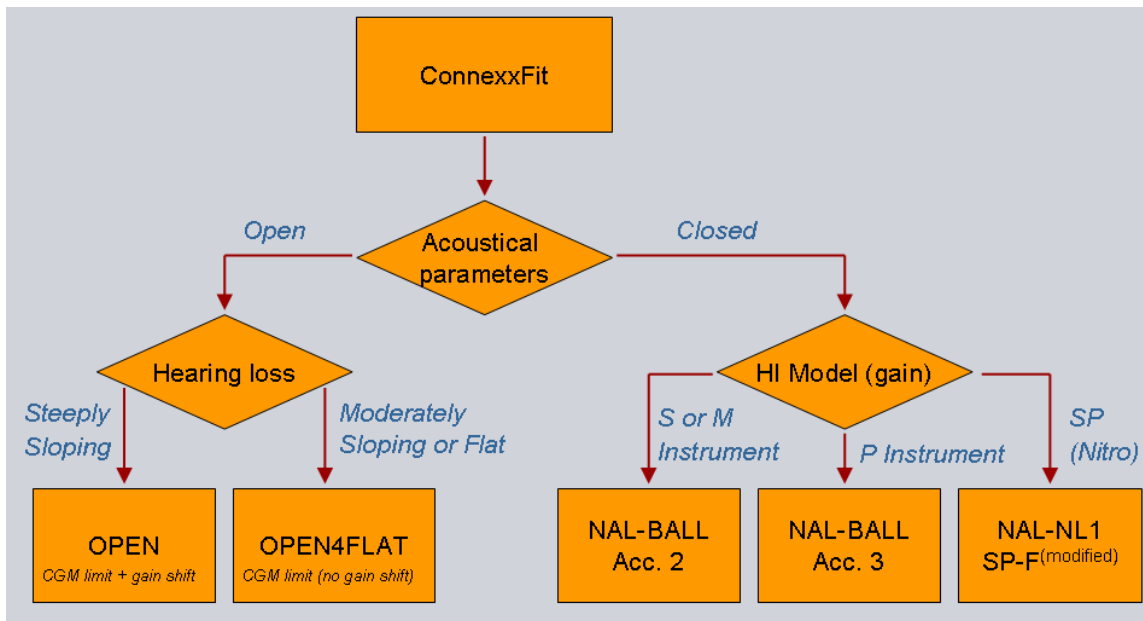


Figure 1. Based on the designated acoustic parameters, audiometric information, and the chosen hearing instrument, ConnexxFit selects a fitting rationale most suitable for each patient.

### Open Fittings:

Open fittings pose special challenges in terms of finding the most appropriate gain prescription. Despite the latest advancements in feedback cancellation, it is often possible for traditional prescriptive algorithm to require gain at a level that can cause feedback. Again, this would result in an unsatisfactory impression at the first fit. To address this issue, during an open fitting, ConnexxFit prompts the hearing care professional to perform a critical gain measurement (CGM) to determine the amount of stable gain possible without feedback. Note that ConnexxFit will use statistical CGM in case no individual measurement data are valid for the target calculation. Then, ConnexxFit considers the configuration of the hearing loss to determine the applicable fitting rationale. An additional factor considered for open fittings is whether the instrument employs an external receiver (RIC instruments) to account for the acoustic differences between RIC and thin tube fittings.

### Open fittings: OPEN

If the hearing loss is categorized as steeply sloping (i.e.: slope steeper than 25 dB per Octave and the hearing loss is better than 30 dB HL at 500 Hz and below), ConnexxFit defaults to the Connexx OPEN formula. Based on the CGM information, if the prescribed target for NAL-NL1 is achievable without feedback, then the OPEN target is equal to NAL-NL1. If meeting the NAL-NL1 target would induce feedback,

however, then OPEN determines the maximum possible stable high frequency gain. The high frequency target is then set slightly below this critical gain level to allow some margin for feedback-inducing variables (e.g. hats, scarves, close proximity to walls). When the gain for the higher frequency region has to be reduced due to the risk of feedback, OPEN applies some additional gain in the mid-frequency region to maximize the audible speech cues as determined by the Speech Intelligibility Index.

The effectiveness of the ConnexxFit OPEN formula was evaluated in two separate studies conducted at the University of Munich and the Hörzentrum Oldenburg (Chalupper & Kasanmascheff, 2008). In the first study, the results showed that speech intelligibility was not reduced when using the OPEN formula as compared to the NAL-NL1 formula (Figure 2).

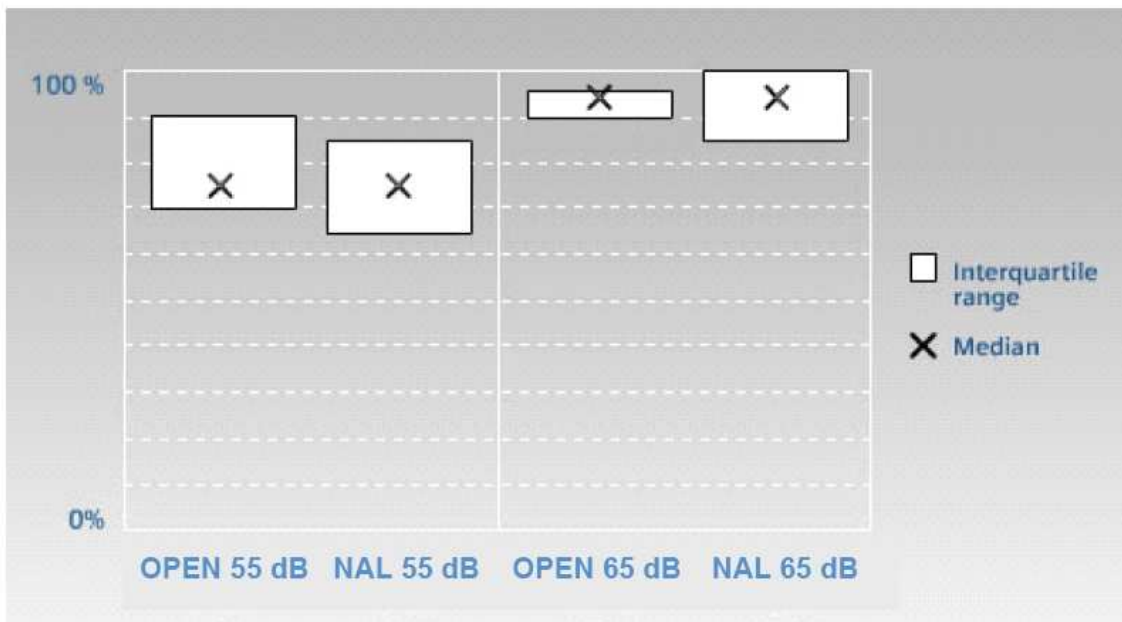


Figure 2. Speech intelligibility scores did not differ for patients who were fit with the ConnexxFit OPEN formula and the traditional NAL-NL1 formula.

In the second study, the subjects were asked to rate the OPEN formula in terms of annoyance from feedback, sound quality, and speech intelligibility after a two-week home trial. Results show that the subjects rated all three factors highly (Figure 3). Most importantly, despite the fact that OPEN often results in lower high frequency gain due to feedback risks, speech intelligibility was still rated very high.

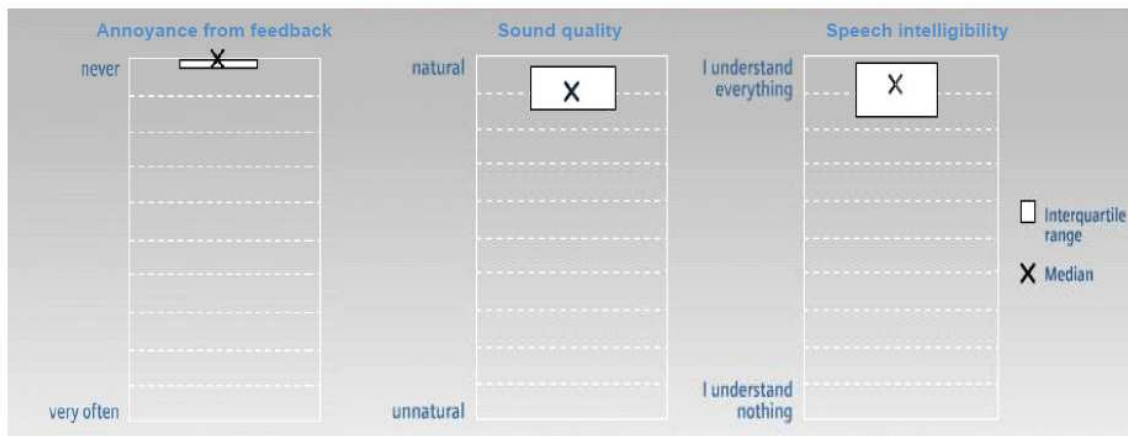


Figure 3. Subjects rated fittings with the OPEN algorithm favorably in terms of annoyance from feedback, sound quality, and speech intelligibility.

#### Open Fittings: OPEN4FLAT

While the OPEN formula was developed for open fittings with steeply-sloping hearing losses, more and more audiologists are also prescribing patients with flat and moderately severe hearing losses with an open fitting. In those cases, there are special challenges regarding the spontaneous acceptance after First Fit, and increased risk of feedback. Therefore, ConnexxFit takes not only the acoustic coupling into the account, but also the patient's hearing loss. When the hearing loss is not categorized as steeply sloping, then ConnexxFit defaults to another open fitting rationale for flat and more severe hearing losses: OPEN4FLAT. Compared to the OPEN formula, OPEN4FLAT provides more mid-frequency (1 – 3 kHz) gain for more speech understanding, and less gain at the low and high frequencies to improve the sound of own voice and to improve spontaneous acceptance. To evaluate the effectiveness of OPEN4FLAT, a field trial was conducted with 25 audiologists in 6 countries around the world. Their responses show that ConnexxFit using OPEN4FLAT is rated to be equal or better than what they consider the best competitor fitting formula in all areas considered, including feedback stability and spontaneous acceptance (Figure 4).

## How would you rate ConnexxFit in comparison with the best alternative fitting formula

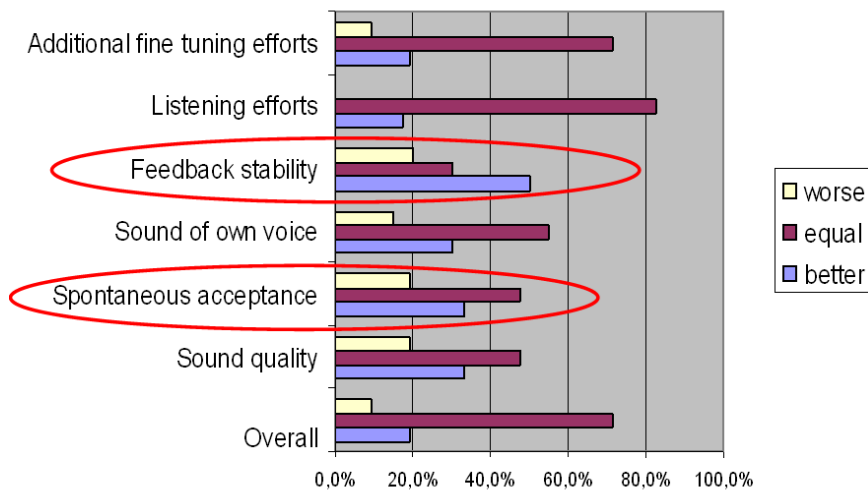


Figure 4. A field trial with audiologists from six countries shows ConnexxFit to be rated better or equal to the best alternative fitting formula.

### Closed Fittings:

For closed fittings, ConnexxFit selects the appropriate fitting rationale based on the chosen hearing instrument. A bigger hearing instrument is most likely chosen in order to accommodate a more severe hearing loss and that the patient is most likely an experienced user. First time users, on the other hand, usually have less severe hearing loss and tend to require smaller hearing instruments. To ensure optimal initial acceptance of the sound quality, ConnexxFit defaults to acclimatization level 2 when the smaller S and M housing instruments are selected. For the bigger P instruments, the acclimatization level 3 is chosen. Additionally, ConnexxFit for closed fittings also considers the size of the vent used to ensure an accurate match to target in the low frequencies.

### NAL-BALL

One significant modification made for closed fittings in ConnexxFit is referred to as Broadband Increase at Low Levels (BALL). BALL is a modification of the NAL-NL1 formula. The rationale behind BALL is that based on pilot studies and anecdotal experiences from practitioners, spontaneous acceptance of NAL-NL1 can be increased without compromising speech intelligibility. Specifically, subjects often prefer a more broadband response for low input levels and a more narrowband response for high levels. As a result, BALL is implemented so that for softer input signals, the low and high frequencies are increased from the NAL prescription to provide a more even broadband response (Figure 5). ConnexxFit applies

NAL-BALL with acclimatization level 2 for closed fittings with S and M housing instruments, and NAL-BALL with acclimatization level 3 for closed fittings with P housing instruments.

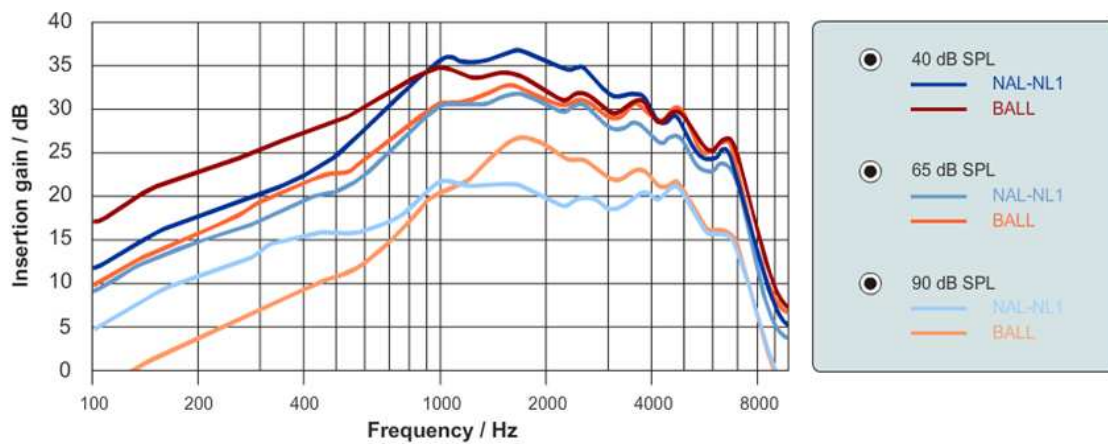


Figure 5. Resulting insertion gain responses for 40, 65 and 90 dB SPL LTASS inputs using both NAL-NL1 and NAL-NL1 BALL targets.

To investigate the performance of the ConnexFit fitting formula in terms of wearer satisfaction and speech intelligibility, twenty-one hearing impaired individuals in a study conducted at the University of Northern Colorado compared ConnexFit NAL-BALL acclimatization level 2 to the traditional NAL-NL1 formula. Using the same hearing instruments, the subjects were fit with these two formulas and asked to perform a speech intelligibility in noise test with HINT. Additionally, they listened to speech in three different levels of background noise and were asked to choose their preferred fitting formula in terms of “speech quality/intelligibility.” The results showed that while there was no significant difference between the HINT scores for the two fitting formulas, for all three noise conditions tested, the subjects overwhelmingly preferred ConnexFit over NAL-NL1 (Figure 6). Together, these results show that for closed fittings, ConnexFit does not degrade speech intelligibility when compared with NAL-NL1, but is much more preferred by patients.

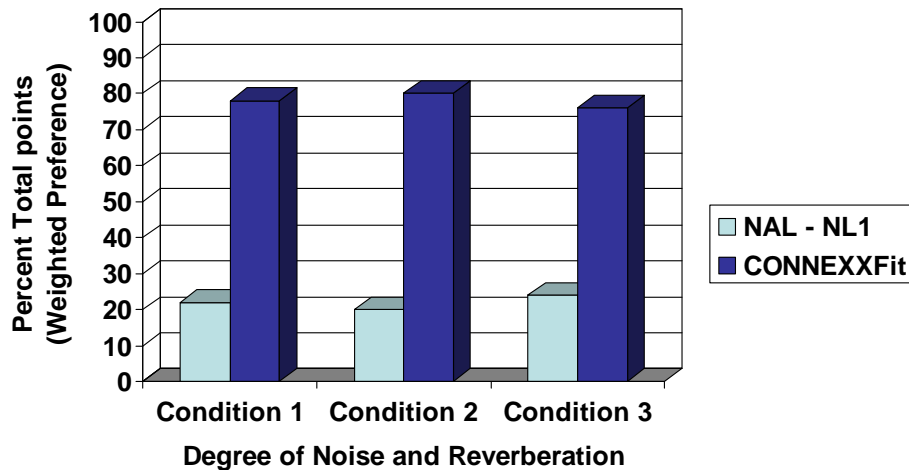


Figure 6. For all three noise conditions tested, ConnexxFit was preferred over NAL-NL1.

#### SuperPower-Fit (SP-F)

Research has shown that patients with severe to profound hearing losses often prefer less compression and more amplification in the low frequencies (Brokx et. al., 1997, Souza & Bishop, 1999). Based on in-house studies, a modified version of NAL-NL1, called SuperPower-Fit was developed for this target group. Specifically, SuperPower-Fit employs a high compression kneepoint ( $\geq 65$  dB) with a low compression ratio ( $\leq 2$ ). In addition, slower time constants are also employed (dual) in order to provide the sufficient perception of loudness preferred by this population. Additionally, SuperPower-Fit was further modified to maximize spontaneous acceptance.

In a study conducted at the Hörzentrum Oldenburg, SuperPower-Fit was compared to a number of fitting prescriptions considered for this target group including the original NAL-NL1 and DSL i/o formulas (Hies, 2002). Twenty subjects with severe to profound hearing loss were fit with six different fitting algorithms and were asked to rate their speech intelligibility in three different listening environments. Results show that SuperPower-Fit based on NAL was the algorithm rated to result in the highest speech intelligibility in all three conditions (Figure 7). In a final preference task, the majority of patients also preferred SuperPower-Fit over the other fitting formulas.

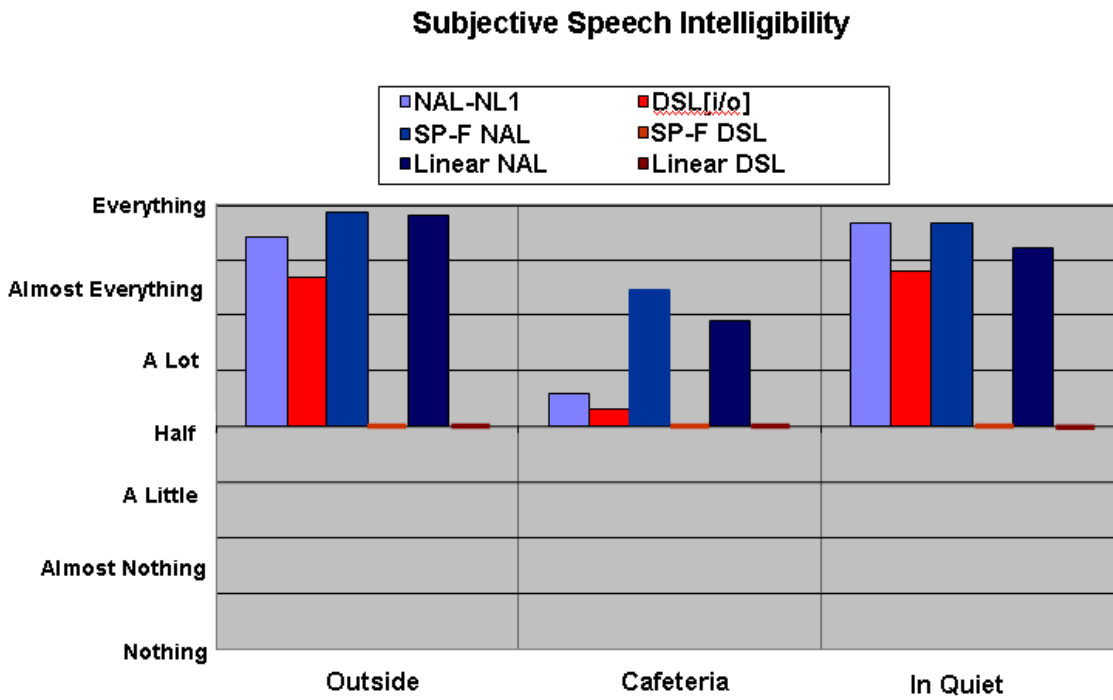


Figure 7. In three different listening environments, subjects with severe to profound hearing loss rated SuperPower-Fit (SP-F NAL) to be the optimal fitting formula for subjective speech intelligibility.

### Comparison with Competitor First Fit

ConnexFit was compared with the First Fit algorithms of other competitors. Results show that for the same hearing loss and acoustic parameters, the proprietary fitting algorithms of various hearing instrument manufacturers calculate very different gain prescriptions. Figure 8 shows the frequency responses for 65 dB input generated by different manufacturers for the same ISMADHA (International Standards for Measuring Advanced Digital Hearing Aids) 1 audiogram.

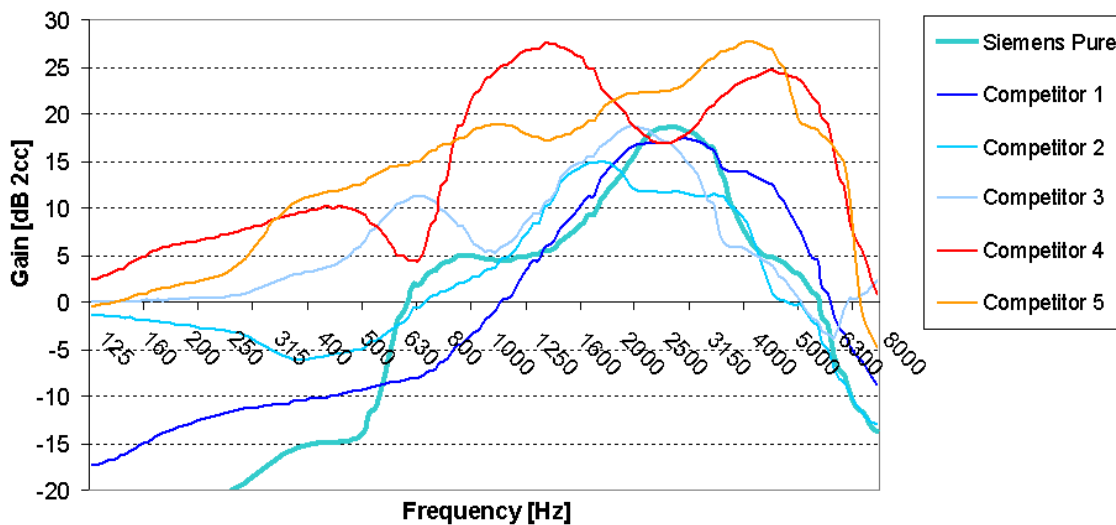


Figure 8. For the same hearing loss, the First Fit algorithms of various manufacturers result in very different frequency responses.

While most of our competitor's First Fit algorithms resulted in similar gain responses, Competitor 4 has a very different frequency shape. Therefore, to compare the spontaneous acceptance of ConnexxFit and Competitor 4, 15 subjects were asked to choose which fitting they preferred. Results show that a significant majority prefer Siemens over Competitor 4 (Figure 9).

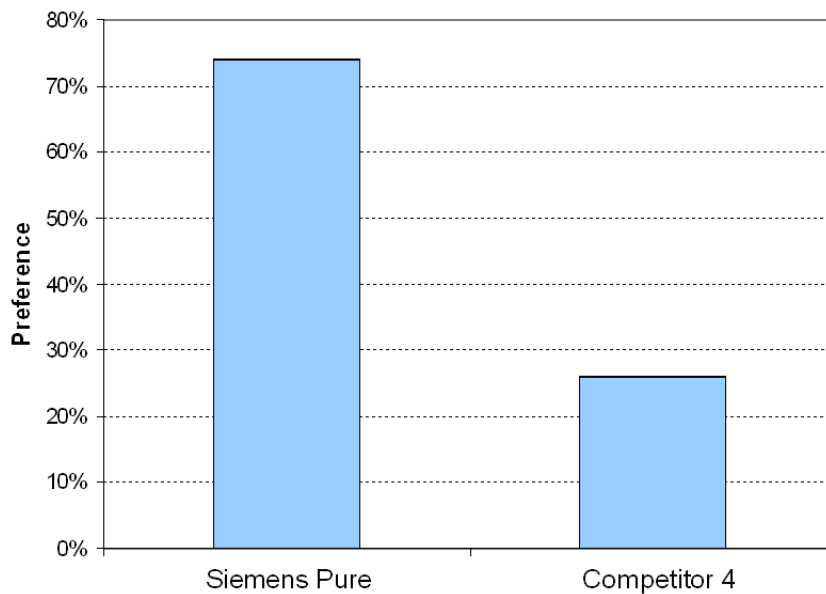


Figure 9. Siemens Pure fit with ConnexxFit was significantly preferred over Competitor 4, which prescribes a very different frequency response after First Fit.

## Conclusion

While traditional prescriptive formulas have been proven to restore audibility (DSL i/o) or maximize speech intelligibility (NAL-NL1), modifications to traditional prescriptions are required to account for device specific properties and individual differences. ConnexxFit is not a new fitting formula, but rather applies modifications to NAL-NL1 based on device specific properties and ear canal acoustics in order to optimize spontaneous acceptance. In open fittings, ConnexxFit utilizes OPEN and OPEN4FLAT formulas to reduce the risk of feedback. In closed fittings, ConnexxFit considers the degree of hearing loss and the selected instrument to determine the default acclimatization levels applied to NAL-BALL. Finally, for severe to profound hearing losses, ConnexxFit defaults to SuperPower-Fit to offer the perception of loudness preferred by this target group. All these various algorithms have been developed and tested with their respective target groups in mind. It is possible, therefore, that when different hearing instruments are used for the same hearing loss, different targets may be calculated by ConnexxFit. Various studies have shown that ConnexxFit is preferred by most patients without degradation of speech intelligibility.

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