

# MAKING THE MOST OF MUSIC WITH RESOUND DFS ULTRA II AND MUSIC MODE

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## Abstract

For the audiophile or extreme music enthusiast, hearing aids often fall short of expectations when aiming for high fidelity reproductions of musical inputs. The reasons for these shortfalls have been documented in the literature<sup>1,2</sup> and are often associated with several key aspects of basic hearing aid function. Moreover, the perception of music, be it through amplification or via the unaided ear, is truly subjective in nature. As such, while a one-size-fits-all solution for improved music fidelity in hearing aids is attractive, the reality of creating such a solution is highly unlikely. Therefore the clinician fitting musicians or music-lovers must have a keen grasp of the tools available to limit the impact of hearing aid processing on the musical signal and create the highest fidelity reproduction of sound quality as possible. This paper reviews some of the inherent issues when listening to music via hearing aid processing, and how the processing affects sound quality. A new solution to improve the music listening experience, ReSound's Music Mode setting in DFS Ultra II, is also detailed. Introduced in the feature package for the ReSound Verso, Music Mode controls feedback while maintaining a truer representation of music. The development of Music Mode is discussed, as well as practical information when fitting patients with the new Music Mode feature.

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Music is a completely unique auditory experience. While speech and other environmental sounds are essential to verbal communication and awareness in one's surroundings, music often encompasses a more emotional role. Music can elicit intense feelings of joy, sadness and love. It can bring people together when it is shared. It can evoke memories of yesteryears. It can fill people with excitement, inspire through evolving genres, and open minds to other cultures. Music is truly a special auditory phenomenon – and as such, deserves special treatment when it comes to hearing aid processing.

Traditionally, music is treated the same as other sounds by hearing aid processing. A music program may be set up for a patient with slightly different gain settings, but often times the features – such as digital feedback suppression – are set identically to the speech programs. Yet music does not behave exactly like speech, and has distinct properties that separate it from other sounds in the environment.<sup>1</sup> While speech has a generally controlled spectrum, the music spectrum is highly variable, based on the musical instrument. Music also has a wider, more variable range of dynamics than speech, and can reach higher intensities as well. The crest factor (the difference between the peaks in the spectrum and the average values) are about 6-8 dB higher for music than for speech. Fur-

ther, tonal qualities in music can occasionally mimic pure tones when processed by the hearing instrument. These pure tones can be confused as feedback by some feedback management systems, and the system may attempt to cancel them. This erroneous feedback designation and cancellation leads to artifacts, or additional, tonal sounds emitted from the hearing aid. These artifacts, as they are unnatural to the sound environment, are often annoying to the hearing aid user and detract from the overall listening experience.

## RECOMMENDATIONS FOR BETTER MUSIC SOUND QUALITY WITH HEARING AIDS

The topic of hearing aids and music reproduction has received good exposure over the last several years within the trade journals and academic literature. Some general findings can be divided into information that is utilized by hearing instrument manufacturers in their design process, or into techniques clinicians can use to manipulate output characteristics of the devices they are fitting. Table 1 outlines aspects of hearing aids that can be altered to enhance the perception of music. The left column shows techniques that may be implemented by manufacturers, and the right column shows fine-tuning and programming adjustments that may be done by clinicians.

Manufacturer Action	Clinician Technique
<b>Increase peak input limiting level to at least 105 dB SPL<sup>1,3</sup></b>	<b>Disable feedback cancellation,</b> OR if feedback cancellation can be altered, <b>use slower time constants</b> to differentiate from true feedback and transient musical harmonics
<b>Decrease microphone sensitivity or attenuate microphones<sup>1</sup></b>	<b>Disable noise reduction</b>
<b>Wide dynamic range compression<sup>1,4</sup> with a low compression ratio (1.3-1.5)<sup>1</sup></b>	<b>Enable expansion</b>

Table 1. Possible techniques to improve the representation of music in hearing aids, divided by manufacturer concerns (left column) and clinician programming options (right column), as described by Chasin<sup>5</sup> unless otherwise stated.

Each of these proposed actions has the potential of improving the music listening experience for the hearing aid user. From the manufacturer-responsibility column in Table 1, an increase in the peak input limiting level will reduce distortion at the front end of the hearing aid processing. A high input range up to 105 dB SPL will allow the forte dynamics and peaks in most music to pass into the hearing aid processor without distortion. If the hearing aid has a low input limiting threshold of less than 100 dB SPL, an input signal of 105 dB SPL will enter the hearing aid processing already distorted or clipped, and attempts to clean or optimize the signal will not be able to restore the original signal integrity. Many hearing aids on the market have traditionally had an input limit of 85-90 dB SPL.<sup>1</sup> Raising the input level will reduce the occurrence of distortion due to clipping or limiting loud input signals. Similarly, decreasing the microphone sensitivity will result in a lower overall output level from the microphone to the analog-to-digital converter, thereby reducing the amount of distortion at the input stage of the processing.

While improving the dynamic range will help provide the listener with a clean signal, other approaches to handling music include a “do-no-harm” strategy that increases the transparency of the hearing aid processing for the end user. Such strategies include enabling expansion, which will reduce the internal noise of the hearing aid. Other recommendations include disabling noise reduction and feedback control.<sup>5</sup> For this reason, the default setting in the music program for these two features is “off” for some hearing aids. However, the feedback cancellation feature is often the trickiest

to disable and still ensure a successful, feedback-free fitting. This is especially true when considering the frequency characteristics of a typical music-induced hearing loss, which may include a high-frequency noise notch. These hearing losses typically require their peak amplification in the 3-4 kHz region, which, coincidentally, is precisely the same frequency range where feedback is likely to occur. Thus, to reduce the occurrence of feedback while maintaining the integrity of the music signal, it is important to implement a feedback cancellation system designed especially for music.

## RESOUND DFS ULTRA II AND MUSIC MODE

ReSound recognizes the importance of excellent sound quality for music. For this reason, ReSound technology incorporates several parameters that are recommended for high fidelity music listening (Table 2). First, the peak input limiting level is high for the industry, at around 106 dB SPL. This allows for a larger dynamic range than other products can offer, and is also at the recommended level in the literature (at least 105 dB SPL). The improved ReSound Range II chip allows for better sound fidelity. WARP processing affords low distortion and frequency resolution that is similar to and based on the human cochlea. Wide dynamic range compression (WDRC) is used to determine gain settings, and longer release times are implemented for low frequencies to prevent audible artifacts. In the default Music Program in Aventa, other parameters are set to optimize the music listening experience. Gains for soft input levels are lower as compared to speech-based programs, and the compression ratio is lower, typically around 1.5:1 for a mild sloping to severe sensorineural hearing loss. An omnidirectional response is utilized to give the fullest sound representation possible. Feature settings such as NoiseTracker II and WindGuard are set to “Off.” In addition, DFS Ultra II (an improved version of DFS Ultra introduced with ReSound Verso that has better precision and scaling to more accurately cancel feedback) is set as a default to Music Mode.

ReSound Technology for High Fidelity Sound	ReSound Aventa Music Program Defaults
<b>Peak input limiting level of 106 dB SPL</b> , allowing peaks of music to enter the hearing aid without distortion	<b>Gains pre-set to a lower compression ratio</b> than in speech-based programs
<b>Improved ReSound Range II chip</b> for better sound fidelity	<b>Omnidirectional microphone response</b> for the fullest sound representation for music
<b>WARP signal processing</b> for low distortion and frequency resolution modeled after the human cochlea	<b>Noise control features such as NoiseTracker II and WindGuard pre-set to "off"</b>
<b>Wide dynamic range compression</b>	<b>DFS Ultra II Music Mode</b> to differentiate from true feedback and transient musical tones

Table 2. ReSound core technology (left column) and Aventa fitting software defaults (right column) to maximize sound fidelity for music.

Music Mode is distinct from other settings of DFS Ultra II because it analyzes the input sound over a longer period of time. This allows for better accuracy in distinguishing true feedback from other tonal input sounds, such as those commonly found in music. Music often incorporates signals such as flute and piano notes that can seem very pure-tone-like, and can be confused as feedback by the hearing aid. Traditional feedback systems will try to cancel these sounds, thereby introducing a disturbing, often tonal sound artifact. Music Mode was designed to effectively reduce this artifact occurrence. As a result, the feedback cancellation component of Music Mode is less likely to adapt to rapid changes in the feedback path. Music Mode is considered a less-aggressive feedback cancellation setting than other settings of DFS Ultra II, and was designed exclusively to enhance the music-listening experience.

## EVALUATING MUSIC MODE

DFS Ultra II Music Mode was developed to give music a cleaner, truer, more authentic representation for the hearing aid listener. The feature was tested both in the lab and with individuals with hearing loss. Lab testing was completed on an artificial ear and KE-MAR. Responses to music were modeled in Music Mode, standard DFS Ultra II settings (mild, moderate and strong), and a no-DFS option. These responses were then evaluated for predictive sound quality judgments through the Hearing Aid Speech Quality Index (HASQI).<sup>6</sup> The HASQI is based on the “coherence” between the input sound and the output of the hearing aid. This provides a physical measure of the added

noise and distortion relative to the original signal. The HASQI has been found to correlate well with subjective quality judgments by normal-hearing and mild-to-moderately hearing impaired listeners. For the experiment, gains were set to the maximum stable gain level without DFS activated. This would be a common DFS setting for the Music program in actual fittings, many of which are open. Individuals with open fittings often have spontaneous or sub-oscillatory feedback without DFS activated, and are frequently those who have sound quality complaints when listening to music. A 10% improvement in sound quality was observed between DFS Ultra II settings and the no-DFS option. This finding alone indicates the effectiveness of DFS Ultra II in eliminating feedback without causing sound quality issues, which is no small feat. However, Music Mode further improved the sound quality by nearly 3% as compared to the DFS Ultra II setting results (Figure 1). The results support ultimate sound quality with Music Mode.

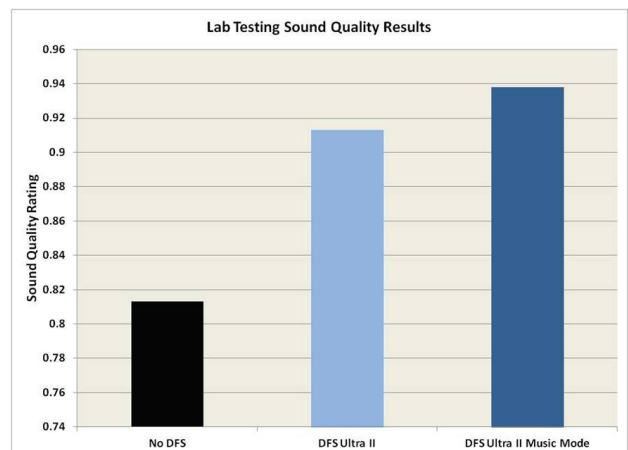


Figure 1. Laboratory testing of sound quality comparing Music Mode to other settings of DFS Ultra II and a condition without feedback suppression.

A research trial was also conducted with hearing aid users who expressed enjoyment listening to or playing music. Each participant was fitted with two programs: one with Music Mode and the other program with a typical setting of DFS Ultra II. Each program was identical in gains and feature settings with the exception of the feedback suppression feature. Subjects were blinded to which program contained which feedback suppression feature setting, and the program order was counterbalanced among subjects. Subjects were asked to listen to a familiar musical piece and/or play an instrument with which they have experience before rating the sound quality in both programs on a five-point scale. Overall, subjects reported good sound

quality with both Music Mode and standard settings of DFS Ultra II. As suggested by the HASQI results, it was an expected finding that sound quality would generally be rated as good when listening to or playing music. In addition, other music enhancing ReSound features likely contributed to this positive result. These include the high peak input limiting level, WARP processing, and other characteristics of the Surround Sound by ReSound signal processing strategy. However, more subjects expressed preference for the sound quality with Music Mode.

Subjects who expressed a preference for sound quality with Music Mode over other settings of DFS Ultra II had reported listening to classical, rhythmic and other types of music over their home stereos. One subject had also attended a live 1980's pop music concert. Table 3 shows direct subject comments about Music Mode and the settings in which they occurred. These comments demonstrate that Music Mode performed well in several distinct auditory environments.

Music Mode Sound Experience Comment	Listening Environments or Music Types
Fine reproduction of the nuances and frequencies of music	Attending a live pop music concert and listening to music on the home stereo
Good perception of phrasing, and high and low pitches are maintained	Listening to Whitney Houston songs on the home stereo
Very clean and clear sound	Listening to classical music on the home stereo
Sound is fantastic	Playing digital organ
Little to no distortion at loud levels	Attending a live pop music concert
Overall good sound experience at both high and low pitches as well as loud and soft levels	Listening to violin music
Good sound quality	Movie soundtrack in a theater

Table 3. Research trial subject comments about the listening experience with Music Mode activated, with the corresponding auditory environments pertaining to each comment.

### FITTING MUSIC MODE FOR PATIENTS

Music Mode is enabled through Aventa 3.4 fitting software for both the ReSound Verso 9 and 7 product families. Once feedback calibration is completed, Music Mode can be chosen as the DFS Ultra II setting in any program. It is set as the default option exclusively in the Music program, since it was designed specifically for music. Figure 2 shows the DFS Ultra II options available in the drop-down menu in Aventa.

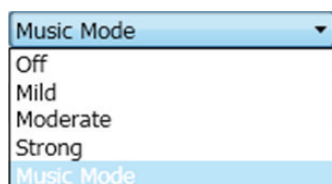


Figure 2. DFS Ultra II options in Aventa 3.4 for the Verso product families.

Since Music Mode prioritizes accuracy over fast analysis of the input sound, it is recommended for music listening. Other modes of DFS Ultra II, which were designed for speech inputs, are preferable for other programs.

### SUMMARY

Although most hearing aid technology is designed for optimal speech intelligibility, other sound inputs such as music can have a significant impact on the user's experience. Music is different from speech in that it comprises a greater dynamic range and often contains tonal qualities. These pure-tone-like sounds can be easily mistaken for feedback by traditional feedback control systems, which may then attempt to cancel them. This erroneous feedback cancellation results in sound artifacts that are detrimental to the overall sound quality. ReSound's technology, with its high peak input limiting, extraordinary Surround Sound by ReSound signal processing strategy and new DFS Ultra II Music Mode feature, provides excellent sound quality without tonal artifacts for hearing aid users who enjoy or play music.

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