



DTS Enhance™: Smart EQ and Bandwidth Extension Brings Audio to Life

White Paper

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Executive Summary

When listeners turn down audio volume on a variety of electronic devices — TVs, sound bars, automotive audio systems, phones, PCs, etc. — they often cannot hear low and high frequencies well enough. To remedy this, listeners typically increase the bass and treble. Later, when they turn up the volume, low frequencies often sound too heavy and the high frequencies too shrill. DTS Enhance™ ensures the consistency and quality of the listening experience by maintaining the perceived spectral balance at an ideal monitoring level. When the volume is adjusted, it intelligently maintains that balance through dynamic loudness equalization. In addition, DTS Enhance applies spectral bandwidth enhancement to help restore high frequency content from band-limited audio material, such as low bit rate streaming audio, MP3 recordings, and Internet TV.

Spectral Audio Issues, Partial Solutions

The following factors can cause listeners to perceive an imbalance in high and low frequencies during audio playback with a variety of consumer electronics systems:

- Human hearing sensitivity varies by frequency and sound pressure level (SPL)
- Human hearing deteriorates with damage and age
- Band-limited or low-bit rate audio may have insufficient high frequency content, creating a dull or muffled sound
- Equalization can only be properly “tuned” for a particular SPL. Standard equalization technology does not keep up with changing levels, which can lead to dramatic over- or under-compensation.

“Loudness” boosting buttons and/or “Smiley Face” EQ presets are common solutions created for consumer electronics to manage high- and low-frequency imbalance.

Named after the “smile” shape it yields on octave band EQ sliders, Smiley Face equalization settings became popular for “turning up” frequencies that listeners could not hear. Loudness compensation circuitry provides a similar remedy, boosting lows and highs without increasing midrange power.

The simple Smiley Face EQ adjustment is successful, to a limited degree, when the volume level is fixed. This is because it boosts frequencies in a manner that roughly compensates for the listener's ability to hear different frequencies, as described by the standard Equal Loudness Contours (see Fletcher-Munson or Robinson-Dadson).

Today, many listeners continue to rely on some form of Smiley Face EQ setting. Some engineers have even used it as a basis for audio mixing during recording sessions. However, any adjustment to volume invalidates these EQ settings. For this imprecise compensation to remain relevant, the Smiley face EQ would need to be re-tuned each time the volume is changed. If not, the audio is likely to become overwhelming at higher listening levels and underwhelming at lower levels. This limits the effective range in which consumer electronics products sound their best.

The audio encoding process creates further spectral audio issues. When perceptual coders are pushed to extremely low bit-rates, one compromise they make is to reduce the effective sample-rate of the audio signal, thus limiting the bandwidth. This process renders low-pass filtered and down-sampled audio that may be perceived as less bright or muffled.

Smiley Face EQ adjustment cannot compensate for spectral audio issues introduced by audio encoding because it cannot replace content removed by band limiting or re-sampling for low bit-rate transmission. High frequency equalization can only correct for problems in the existing audio spectrum. If the audio has been band-limited, it can still sound muffled. Increasing the EQ will either do nothing or increase audible noise in the system.



Figure 1: Audio Listeners Need More than Just Another “Smiley Face” EQ

Clearly, audio listeners need a solution that dynamically compensates for a) variances in “actual” human hearing as volume changes, b) issues introduced by heavy processing of audio for low bit rate transmission, and c) personal preference in equalization based on the unique hearing of the listener.

A Better Way

New EQ technologies are now available to support a much more sophisticated, automated solution to spectral audio issues. For audio to be heard as the producer intended, dynamic equalization must adjust for typical variances in hearing (based on the equal-loudness contour), especially at SPL levels lower than those intended by content creators. As the SPL reaches the intended listening level, the frequency curve should gradually flatten to match the intended experience.

Furthermore, EQ technology can be combined with other technologies to yield better results. For example, spectral equalization and bandwidth extension can be combined in one technology package. Ideally, bandwidth extension should be applied before loudness equalization so that it has something to equalize. This approach does more than dynamically equalize audio. It also restores high frequency

audio content lost during audio encoding. By continuously analyzing playback level and signal bandwidth, it is possible to only process the signal where required.

The DTS Enhance Solution

DTS Enhance is an equalization breakthrough; a smart version of the Smiley Face EQ setting that automatically adjusts frequencies as the SPL changes. It dynamically enhances high and low frequency content to yield the same perceived spectral balance at all volume levels. For low bit rate encoded audio, DTS Enhance automatically extends the bandwidth to restore missing high-frequency audio components.

DTS Enhance dynamically compensates for perceived loss in audio quality through a combination of:

- Low Frequency Loudness Equalization
- High Frequency Loudness Equalization
- Bandwidth Extension

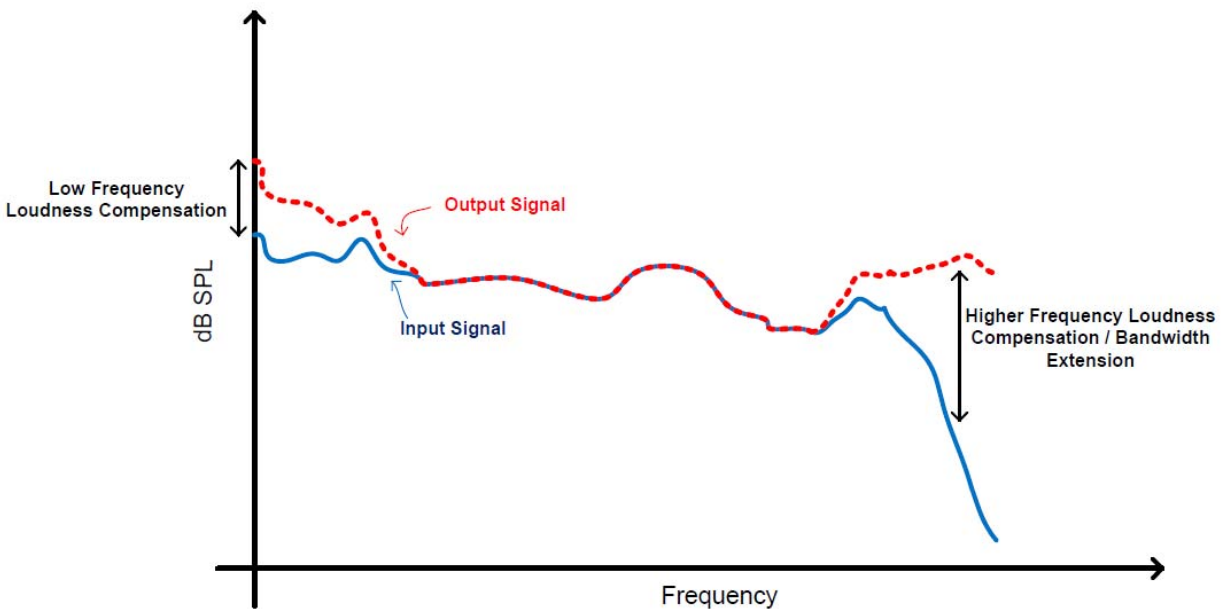


Figure 2: DTS Enhance Compensates for Perceived High/Low Frequency Loss



Low Frequency Loudness Equalization

Lowering the volume can yield a dramatically lower “perceived” bass level, often to the extent that low frequencies below 100 Hz are hardly perceptible. DTS Enhance compensates by adapting the frequency spectrum based on a calculation of the difference between the equal loudness curve generated for the assumed intended listening level and the actual listening level achieved by the system. The greater the difference, the more DTS Enhance adjusts the low-frequency EQ to compensate for perceived bass loss.

To maintain the perceived spectral balance of an ideal monitoring level, DTS Enhance continuously adapts low frequency equalization based on the current volume settings (output level) and the actual content being processed. The listener can also increase the amount of desired compensation, based on preference, using the Low Frequency Enhancement Level slider.

High Frequency Loudness Equalization

High frequency loudness adjustments by DTS Enhance are based on the inverse of the typical hearing loss trend line. Listeners also have the ability to increase compensation using a High Frequency Enhancement Level slider.

To avoid applying too much high frequency enhancement, DTS Enhance decreases the high frequency gain as the level is increased, so the listener is able to naturally hear the high frequencies as intended.

Bandwidth Extension

To compensate for audio encoding, DTS Enhance analyzes the bandwidth of incoming audio and extends it, only where required. This process can create the perception of higher fidelity audio for material that has been band limited or downsampled for low bit rate transmission, such as streaming audio, MP3s, and Internet TV.

Bandwidth extension derives additional high frequency audio content by regenerating missing harmonics from the existing lower frequency content. Since DTS Enhance applies this before equalization, the dynamic equalizer has a broader frequency spectrum of audio to work with. Consequently, the benefits of applying both dynamic high/low frequency loudness equalization and bandwidth extension together are greater than applying either technology alone.

Optimal Equalization at Any Volume - DTS Enhance

A listener turns down the volume and quickly notices that the bass line is inaudible and hi-hats are not crisp. In short, most of the audio sounds midrange and muddled. With DTS Enhance, highs and lows are restored automatically — even at low volumes — and the audio comes to life again. Additionally, when the listener turns the volume back up, the spectrum is balanced right back to where it was. Even when listening to heavily compressed and/or band-limited audio, a noticeable improvement is achieved.

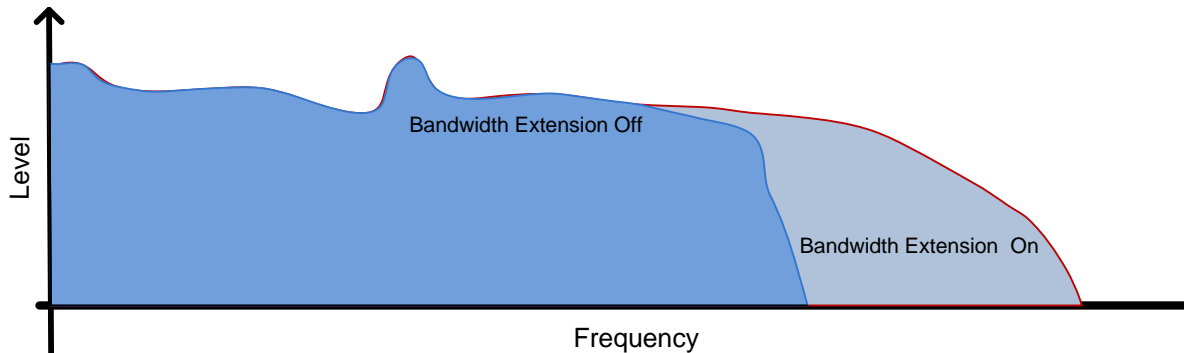


Figure 3: DTS Enhance Expands Bandwidth for LBR Content

Conclusion

DTS Enhance significantly improves the perceived quality of audio played on TVs, sound bars, automotive audio systems, phones and PCs by intelligently adjusting audio to achieve the optimal spectrum for any volume level.

Taking a giant step beyond the popular Smiley Face EQ, DTS Enhance is a high and low frequency loudness equalization algorithm that dynamically adjusts audio to the perceived spectral balance that would be heard at an ideal monitoring level. It applies a formula based on the equal-loudness contour to compensate for variance in “actual” human hearing due to volume changes. It also enables the listener to tailor the experience to his or her own unique hearing.

DTS Enhance also applies spectral bandwidth extension to compensate for audio encoding for very low bit rate transmission. Together, dynamic high/low frequency loudness equalization and bandwidth extension produce a more superior audio effect than if either were applied alone.

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