Information

Dolby Evaluates DTS

Part 1

November 2000

Introduction

Some audio industry members and consumers have compared Dolby Digital and DTS tracks on DVDs, and found that they sound different. Some say DTS sounds better. Until recently, it was difficult to prove or disprove this point, since DTS did not make encoders commercially available. Now that DTS encoders are finally being sold, Dolby has conducted a full set of measurement and listening tests on DTS technology.

Our findings—combined with other research we have conducted—explain the differences some listeners have reported between Dolby Digital and DTS soundtracks, and reveal some interesting results.

Coder Evaluations

Based on the recent availability of the DTS CAE-4 encoder and CAD-4 decoder in mid 2000—five years after the launch of DTS for laserdisc and three years after DVD-V—it is now, for the first time, possible to conduct a legitimate series of tests on DTS. The tests discussed here include basic electrical measurements using laboratory test equipment, subjective evaluations using standard "coder killer" test material, and extended listening sessions using high quality music and movie material in mastering studios in London and Los Angeles, using professional recording engineers as test subjects.

These tests were done with DTS at both the 1509 kilobit/second (full rate) and the 754 kbps (half rate) data rates, and with Dolby Digital at 448 and 384 kbps. Three different units of the CAE-4 encoder were tested; the results were consistent among the three. The results of these tests may be generalized as follows:

1. Measurements of DTS at the full data rate shows performance commensurate with a well-designed audio codec, but at the 754 kbps data rate, the audio bandwidth of the main channels maxes out at 15 kHz. Also, at both rates, the LFE channel response gently rolls off 1 dB at 50 Hz and 3 dB at 90 Hz relative to 0 dB at 20 Hz.

In comparison, Dolby Digital maintains full 20 kHz bandwidth at 448 kbps and achieves an 18 kHz bandwidth at 384 kbps. LFE response is flat (less than 0.1 dB rolloff) to 120 Hz.

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2. On difficult test material, audible artifacts were found to varying degrees in the subjective tests with both coders and at all data rates, but 754 kbps DTS exhibited the most.

Before we detail the results of the subjective listening tests, it should be noted that the magnitude of audible differences found in the critical environment of the studio sessions, while real and consistent, would normally be characterized as small or insignificant to most listeners, and in many home playback systems such differences might go unnoticed altogether.

Here are the rankings from each of the three studio tests:

Studio One
1. Dolby Digital 448
2. DTS 1509/Dolby Digital 384 (tie)
4. DTS 754

Studio Two
1. Dolby Digital 448
2. DTS 1509
3. Dolby Digital 384
4. DTS 754

Studio Three
1. DTS 1509
2. Dolby Digital 448
3. Dolby Digital 384
4. DTS 754

Overall, Dolby Digital 448 clearly performed best in these tests. Half rate DTS was found to be distinctly below the other three options.

While full-rate DTS greatly outperforms the half-rate mode, the studio sessions revealed that DTS full rate imparts subtle audible colorations compared to the source. These may be summarized as an emphasis in the 800 Hz to 1 kHz region; a dulling of the very top octave, a sense of compression on percussive transients, and an emphasis in the frequency region of 8-10 kHz. Listeners also described a loss of ambience or “air” and spatial dimensionality compared to the source. The LFE channel lost some of its punch and loudness apparently due to the rolloff characteristics of the low-pass filter. These types of alterations were not present in Dolby Digital at either data rate.

Soundtrack Mastering

The magnitude of differences heard under these carefully controlled conditions is significantly less than have frequently been described between DTS and Dolby Digital versions of movie and music titles on DVD. What can explain these sorts of stark differences?

1. Loudness. Dolby Digital includes a dialog normalization feature designed to keep the level of dialogue consistent in all Dolby Digital software. (DTS does not include this feature.) The most common setting of dialnorm reduces movie loudness 4 dB. However, there are some movies on which dial norm is not used, including *Air Force One*, *Twister*, *Interview with the Vampire*, and *Lethal Weapon 1, 2,* and *3*. These movies should play at the same level whether in Dolby Digital or DTS. However, even on titles without dialnorm, the loudness can differ significantly due to two factors: occasional differences in mastering levels, and a 0.6 dB difference in overall level caused by a characteristic of some DTS encoders.

   Until recently, DTS encoders added 0.6 dB gain to broadband audio program content, even though they measured 0 dB gain for 1 kHz calibration tones. Most listeners would not detect this small gain as an increase in loudness, but would describe the louder sound as having more "punch" or dynamics when compared with the source. This encoding characteristic has recently been removed from the CAE-4, but many DTS DVDs currently available (including *Twister* and *Interview with the Vampire*) exhibit the 0.6 dB increase in level.

   Thus, attempts to perform level-matched comparisons between Dolby Digital and DTS may be flawed even if the test compensates for dialnorm.

2. Mastering. DTS and Dolby Digital versions of a DVD are often released at different times. In these cases, a different master is often used, which can cause significant sonic differences between the two soundtracks.

   The first step in the mastering process includes transferring from the original analog source elements to a digital version. This digital source is then used for encoding the final soundtrack in Dolby Digital or DTS. When a new digital master is requested, the studio will usually go back to the original analog source. Often, a different transfer facility is used. But even if the same facility is used, a different signal chain may be employed, using a different mastering machine and different analog-to-digital converters. All of these factors can produce disparities between two masters – disparities that carry through into the final DVD.

   Once transferred to digital, a soundtrack is often "mastered" or "sweetened" to make it sound better by adjusting various aspects of the sound, such as equalization, channel

balance, or spatial properties. Dolby Digital soundtracks are sometimes changed during mastering – some, most notably *Saving Private Ryan* and other Dreamworks titles, have had portions of the LFE signal redirected to other channels to help improve compatibility for stereo listeners. DTS soundtracks are also changed sometimes. For example, in the case of *Jurassic Park*, the soundtrack on the original DTS laserdisc differs considerably from the later version released on DVD.

It has been found that some music recordings released on DTS have been sweetened prior to encoding, whereas the Dolby Digital version usually has not. One example of this practice is Steely Dan's *Two Against Nature* DVD. And in the case of Dave Grusin's *West Side Story* DVD, an LFE channel was added to the DTS version.

3. Mixes. There are cases where different mixes of the same movie are released. The Dolby Digital version of *The Haunting* DVD was the original Surround EX soundtrack, while the later DVD with DTS ES was a new mix to add the separate Bs channel. *Terminator 2* was also substantially remixed to add Surround EX for the later special edition DVD compared to the earlier DVDs and laserdiscs.

Conclusion

It should not be a surprise that many listeners report the existence of differences when comparing DTS and Dolby Digital soundtracks. However, the many factors mentioned above show that such differences cannot be solely attributed to the core audio coding technology.

With all things being equal in the preparation of source masters, the huge differences reported between DTS and Dolby Digital essentially disappear. The remaining comparison of the two technologies shows that Dolby Digital not only equals DTS, but in fact outperforms it. Even though DTS uses a higher data rate than Dolby Digital, greater sophistication and efficiency gives Dolby Digital superior sound quality.

Of course, it is not expected that the audio industry will accept without question this view of a competing product. But now that DTS encoders are available, anyone with proper equipment in the audio industry can repeat these tests, and it is encouraged for them to do so.

Dolby Reviews DTS's Position
Part 2
March 2001

Introduction

Dolby has been selling encoders and decoders ever since Dolby Digital was adopted by consumer formats, to support the creation of content. DTS has issued various reports and statements reflecting their tests and opinions of Dolby coding going back to at least 1995. They have also issued a CD intended to compare the audio quality of DTS and Dolby coding to the source signals. Some of their published findings showed obviously flawed measurement practices. Dolby issued a detailed reply with correct data in October, 1995.

In 2000, Dolby purchased the DTS CAE-4 and CAD-4 encoder/decoder units, performed various measurement and listening tests, and published a summary of its findings in a paper called "Dolby Evaluates DTS," issued October of that year. As this was the first time DTS openly sold these units, it was Dolby's first opportunity to conduct such tests.

On November 21, DTS issued a response called "DTS Position Paper on 'Dolby Evaluates DTS'." While DTS agreed with several of our points, they also took exception to some of Dolby's measurements and listening tests. However, DTS provided no data or meaningful evidence to support their comments.

Dolby would like to take this opportunity to provide some additional information on its tests so the reader may be in a better position to understand the original claims.

Further Details

1. Dolby stated that "the audio bandwidth of the main channels maxes out at 15 kHz."

   DTS responded that DTS has *"response to 19 kHz at 754 kbit/s."*

   While Dolby's original statement was given in a somewhat casual style as opposed to engineering terms, audio bandwidth is universally understood to be the –3 dB point of a frequency response. The graph shows DTS is flat only to 15 kHz. However, the response does reach 19 kHz, albeit at a reduced level. See Figure 1.

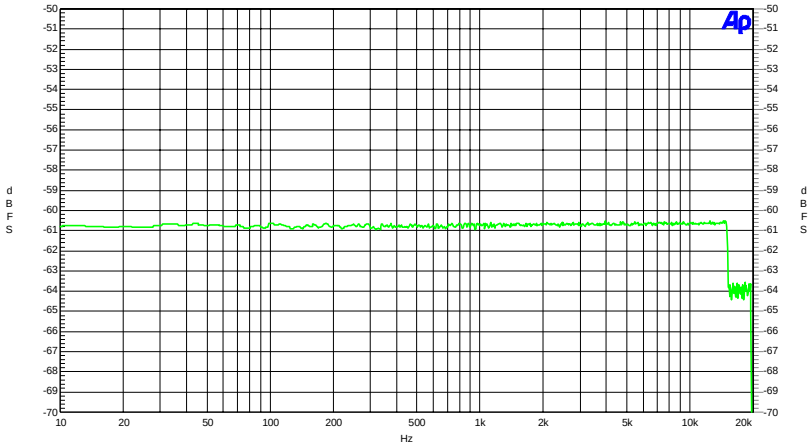

Fig. 1. DTS CAE-4, CAD-4 response with wideband signals

2. Dolby stated "the LFE channel response gently rolls off 1 dB at 50 Hz and 3 dB at 90 Hz."

   DTS responded that *"the response of the CAE-4 encoder is: flat to 100 Hz, –3 dB at 116 Hz, –6 dB at 125 Hz. All CDs and DVDs encoded with the CAE-4 exhibit this characteristic."*

   The graph in Figure 2 shows that DTS's LFE response rolls off as Dolby originally stated. Furthermore, an example of actual DTS content reflects the exact same filter response, as shown in Figure 3.

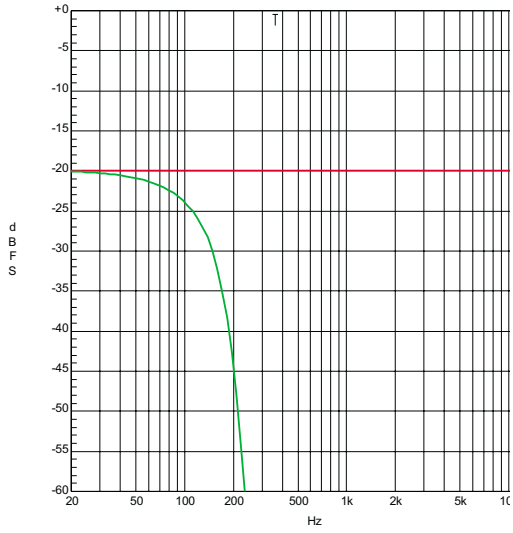

Fig. 2. Measured LFE response of DTS encoder/decoder

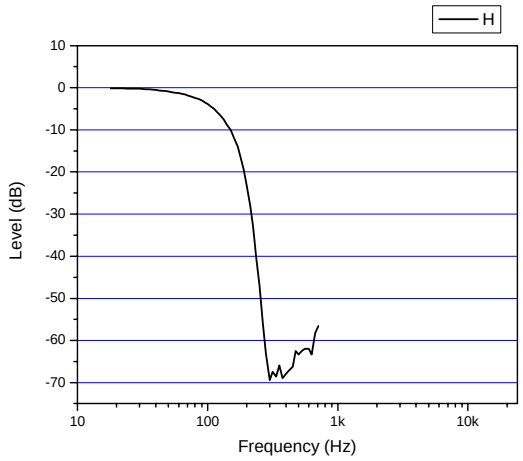

Fig. 3. Response rolloff of DTS LFE channel derived from "Peg"

3. Dolby stated that "DTS encoders added 0.6 dB gain to broadband audio program content, even though they measured 0 dB gain for 1 kHz calibration tones." ". . . DTS DVDs currently available (including *Twister* and *Interview with the Vampire*) exhibit the 0.6 dB increase in level."

   DTS responded that *"the CAE-4 has not been changed. Dolby themselves note that prior to the CAE-4, they had no opportunity for testing a DTS encoder. Therefore this statement contradicts both the facts and itself." "This measurement is irrelevant and would have no correlation with instantaneous perception of 'punch' or anything else."*

   As stated, Dolby found the 0.6 dB level difference in *Twister* and *Interview with the Vampire*. Dolby used a long-term cumulative measurement method (L_{Aeq}) over identical program segments from one-off test discs provided by the encoding studio. These titles are now readily available and can be independently measured and confirmed. DTS provided no data to refute our measurements, nor any evidence that a 0.6 dB difference in level is inaudible in an A/B listening session.

   To confirm these gain issues at the time, the studio that prepared the encoded masters was asked to check the calibration of the actual DTS and Dolby encoders used to make the discs. They confirmed the same result we measured: 0.0 dB gain with 1 kHz tone from both systems, 0.0 dB gain with noise from Dolby Digital, and 0.6 dB gain with noise from DTS. It was reported by the studio that when this information was forwarded to DTS, they "updated" the code in that unit, and Dolby was later advised by the studio that the gain error was no longer present.

It may be of further interest to note that the demonstration CD prepared by DTS in 1995 provided the stereo source programs and the versions encoded/decoded in DTS and Dolby Digital for comparison. The Dolby Digital versions matched the source program level exactly, while the DTS version was 0.6 dB louder than the source.

DTS is correct in saying that Dolby does not possess a DTS encoder with the 0.6 dB gain characteristic. All we have are ostensibly identically encoded programs made five years apart which exhibit this same specific difference in level; one made by DTS themselves; the other made by a respected studio.

4. Dolby stated that "The Dolby Digital version of *The Haunting* DVD was the original Surround EX soundtrack, while the later DVD with DTS ES was a new mix to add the separate Bs channel."

   DTS responded that *"The Dolby Digital Surround EX format, which adds a back channel to 5.1, is compromised by the fact that the back channel is not discrete, but rather matrixed into the left and right surround channels. DTS, in contrast, is able to deliver the back channel as fully discrete. If a discrete 6.1 master has not been archived for a particular title, it is necessary to restore such a master prior to encoding. Note that this task does not involve making subjective changes to the 'mix', and it is always done under the direction and with the approval of the original mixing engineers, the task being simply to provide optimum separation without disturbing artistic intent."*

   a) Dolby Digital Surround EX was the format used to mix, monitor, encode, deliver, and reproduce the original soundtrack of *The Haunting* to the cinema industry. When Dolby Digital is used to deliver that soundtrack on DVD, it is the same mix as used for the theatre, and so cannot be considered a compromise to that reference. It is exactly what the filmmakers produced. Furthermore, if the video company optimizes the mix for home use, such as removing clicks or pops, or improving the equalization, it is again exactly representative of their wishes, not a compromise.

   b) The act of "restoring" a 6.1 master quite obviously makes subjective changes to the mix, since there is no way to exactly duplicate the mixer's original actions. And by definition, the results in the surround channels will be different between the Surround EX and discrete 6.1 versions. Hence they can sound different even when using the same surround playback mode.

   c) In the case of *The Haunting*, the final 6.1 composite EX master was either non-existent or was not used for the DTS ES version. For that version, the discrete 6.1 stems were reportedly reassembled at a different studio, with a different console, and matrix-encoded with a different "ES" encoder than that used for the original Surround EX version. Hence, there is the clear possibility that the two versions will sound different, as originally stated.

5. Dolby stated “it has been found that some music recordings released on DTS have been sweetened prior to encoding, whereas the Dolby Digital version usually has not. One example of this practice is Steely Dan’s *Two Against Nature* DVD.”

   DTS responded that *“According to Image Entertainment, there was no ‘sweetening’ of the DTS track on* Two Against Nature. *The Dolby Digital and DTS tracks were encoded directly from the same master by Buena Vista Sound.”*

   Dolby would like to clarify its original statement. The conclusion that *Two Against Natur*e was sweetened prior to DTS encoding was based on listening tests which revealed rather obvious differences between the two versions, with the DTS version exhibiting what was described as “tighter, deeper” bass. Since both DTS and Dolby Digital are well able to deliver prodigious bass, this conclusion seemed plausible at the time. Upon further investigation, the actual reasons for the audible difference became obvious.

   The LFE channel in the Dolby Digital version contains significant bass energy to around 700 Hz, as shown in Figure 4. The LFE lowpass filter in Dolby Digital encoders normally cuts off steeply above 120 Hz. With the LFE filter turned off, the LFE response remains flat to around 700 Hz. Based on measured LFE spectrum, it is apparent that Dolby’s LFE filter was turned off when the program was encoded.

   The LFE response of the DTS version is much narrower as shown in the same figure.

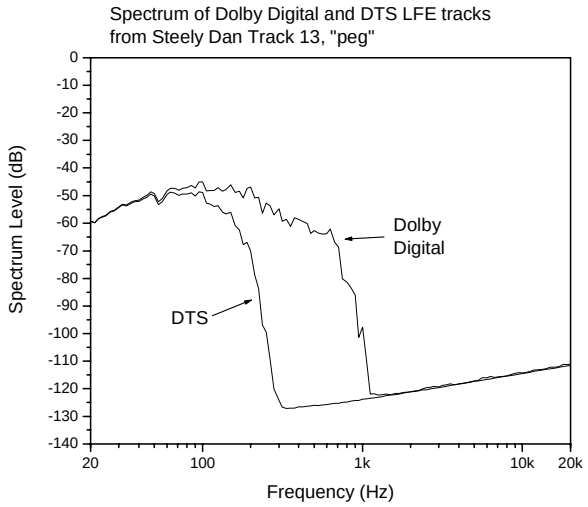

Fig 4. Long-term LFE spectral plots from “Peg”

To determine the origin of the response difference between the two versions, the two curves in the above figure were calculated as a ratio (Dolby/DTS), and plotted in Figure 3, shown earlier. Where the two curves are the same (20 to 50 Hz), the ratio is 0 dB. Where the DTS response rolls off compared to Dolby, the amount of rolloff is shown.

The direct response of the LFE channel in a DTS studio encoder was plotted with a sine wave sweep, as shown by the green line in Figure 2 above. If the above two plots are superimposed with the same scale factors, something interesting happens: They match perfectly. This proves that the entire rolloff seen in the DTS version's LFE channel is attributable solely to the DTS encoder's LFE filter. Figure 5 demonstrates this superimposition.

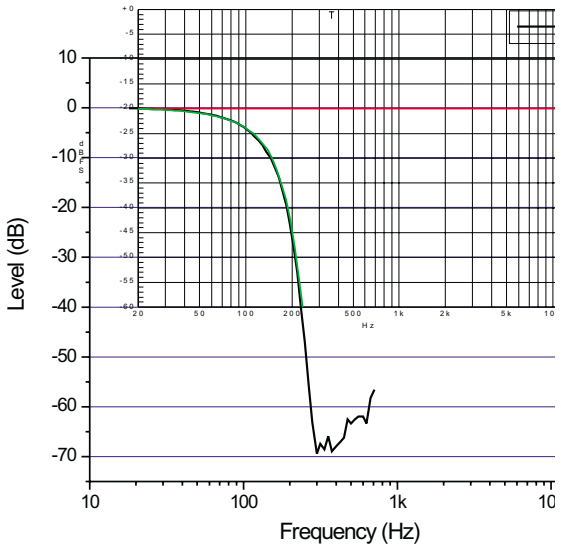

Fig. 5. Superimposed LFE responses

This rolloff of bass energy changes the subjective character of the bass, which also affects the perception of the overall musical spectrum. While one might subjectively prefer "deeper, tighter" bass, the original source master obviously contained audibly more bass than the DTS version delivered. One might reasonably conclude that the Dolby Digital version therefore sounds closer to the source master. However, since the LFE signal is usually directed to the subwoofer, any frequencies above the cutoff point (usually 80 Hz or lower) are attenuated. The degree is unpredictable and depends on the specific playback system used.

In the end, no one apparently "sweetened" or otherwise manipulated the two versions to achieve the audible differences that resulted. It appears to be an inadvertent result of creating an LFE track that contained much more spectrum than the DTS coder could deliver, compounded by failing to use the LFE filter in the Dolby Digital encoder. The Dolby Digital system should not be asked to carry such wideband LFE signals, as it can lead to aliasing components and variability of results depending on decoder filter design or the capabilities of the subwoofer.

The remedy is to ensure that the LFE filter is activated, or to filter the LFE signal on the master tape to a point that both DTS and Dolby can deliver in common (less than 80 Hz), or better yet,

to omit the LFE signal altogether so that all the bass in the recording can be carried in the full bandwidth channels and reproduced with highest accuracy from the playback system.

Conclusion

While none of these tests prove that DTS and Dolby Digital sound identical to each other, or to the source master, they do show that there are many reasons, some more subtle than others, why there *ought* to be audible differences between DTS and Dolby Digital versions of the "same" soundtrack. That consumers can hear these differences should not come as any surprise. That all such differences can be attributed solely to the coding technologies should not come as an automatic conclusion.