Disappearing Derivatives

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In order for an audio system to have excellent sound quality, the measurement of *any* given parameter with respect to *any* other parameter should have no abrupt change as the parameters are varied – this is the concept of "disappearing derivatives".

The reason for this deals with the nature of our nervous system. We are responsive to *changes* in stimuli, rather than any sort of *constant* stimuli. For example, the application of pressure to the skin will very quickly go unnoticed, until that pressure is released (an example of a change, or a derivative). Our hearing is much the same, with a constant tone quickly disappearing from our notice until it suddenly ceases, at which time our attention is once again drawn back to it.

An audio system that does not introduce any abrupt changes of its own (no higher-order derivatives) will allow the natural transitions of the source material to be interpreted without taxing our brain with additional analysis. This is the cause of the often mentioned "listener fatigue" – our brain is in a sense inherently lazy and it is difficult to relax and enjoy when extra processing is required.

Remember: the outer ear itself generates copious quantities of low-order harmonic distortion (i.e. low-order derivatives), so any present in the transfer function of the audio system is quite effectively masked. To put it into the context of this principle, the transfer function of the outer ear has disappearing derivatives. Here are some examples of the application of this principle to typical audio measurements:

THD+N versus amplitude:

A gentle rising curve with increasing level is fine (low-order derivatives), while a sharp increase as clipping is approached in not (high-order derivatives). For example, typical high-feedback linear amplifiers do not satisfy this requirement, as the THD+N increases abruptly when approaching clipping, while typical vacuum tube amplifiers do, as the onset of clipping is much more gradual.

Amplitude versus frequency:

Gradual rolloff is acceptable (low-order derivatives), while peaks or nulls are not (high-order derivatives). For example, class-D amplifiers without feedback taken after the output filter may have abrupt peaking toward the upper end of the audio band with light loads.

THD+N versus frequency:

Gradual change in THD+N versus frequency is acceptable (low-order derivatives), while an abrupt rise at higher frequencies is not (high-order derivatives). For example, this is often seen in linear amplifiers (and some class-D amplifiers) where the dominant pole is at a frequency much lower than 20kHz.

Noise floor versus amplitude:

Gradual rise in noise floor with increasing amplitude is acceptable (low-order derivatives), while an abrupt change in the amplitude or the nature of the noise floor with increasing amplitude is not (high-order derivatives). For example, some types of digital processing may exhibit the effect of a noise floor modulated by amplitude.