Technical Note

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Transient Steepness Analysis

NTI's PureSound™ option for RAPID-TEST is a completely new analysis method that measures the steepness of signal transients. It allows detecting Rub & Buzz defects as well as checking the correctness of audio signals.
The document explains the terms "transient", "steepness" and the backgrounds of the PureSound™ technology.

1. Definitions

1.1 Transient & Steepness

Transient: A temporary change of the signal level (also called "slope").

Steepness: The amount by which the signal level rises or falls within a certain period of time.

Fig. 1 shows a time signal to explain the meaning of transients and steepness (green triangles).

A simple steepness definition is voltage change ΔV per time interval Δt:

$$Steepness_n = \frac{\Delta V_n}{\Delta t_n}$$

Unfortunately, this formula is only applicable on signal segments with "linear" transients, i.e. a constant steepness over a certain time period Δt. To get all steepness values of the continuous signal, another method must be applied.

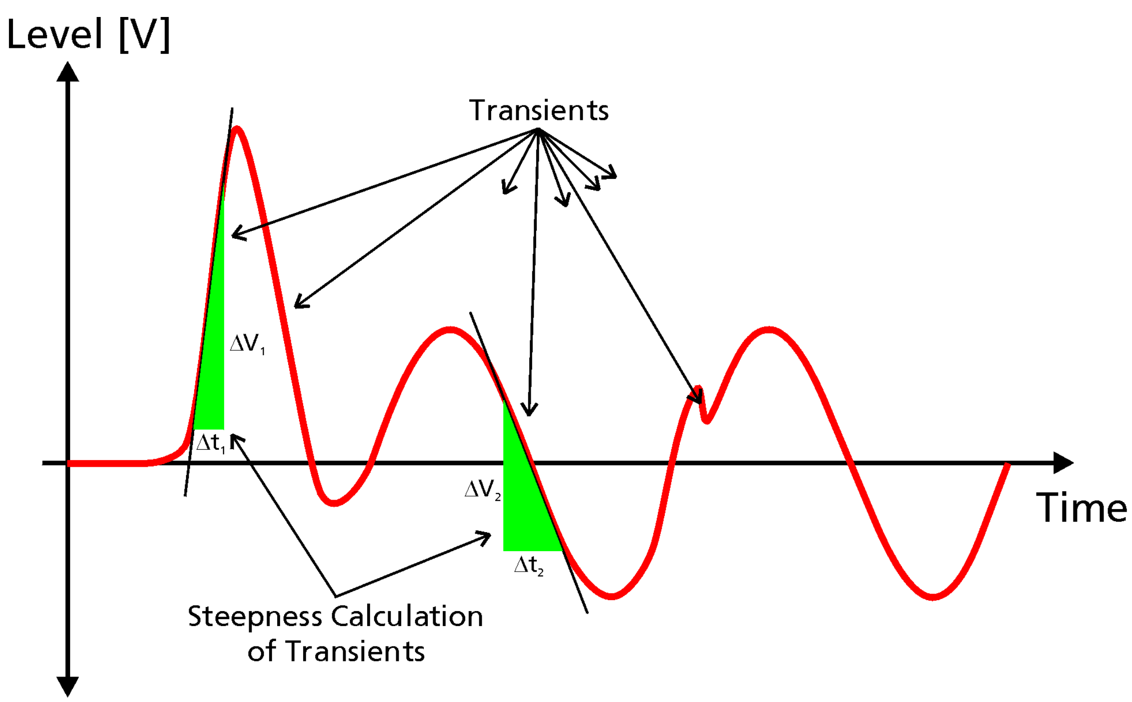

Fig. 1 Transients and Steepness Calculation

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PureSound™ calculates the countinuous steepness in two steps, by differentiation and rectifying the time signal:

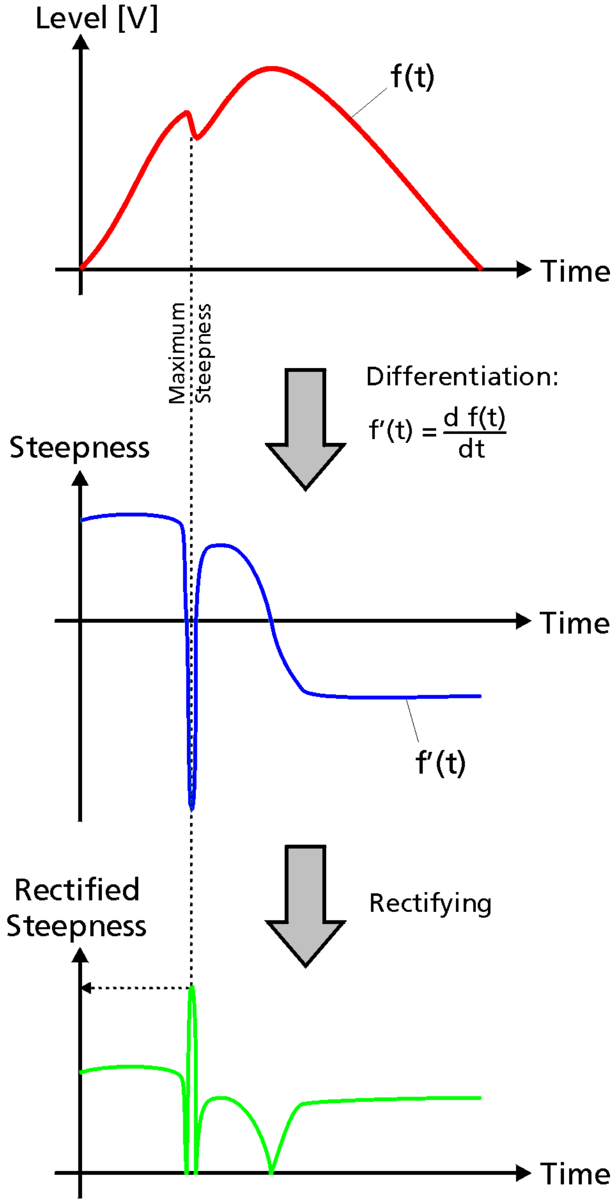

Fig. 2 Time Signal f(t) and Steepness Curve f'(t)

Fig. 2 shows an excerpt of a speaker signal with a typical Rub & Buzz distortion (red, on top), the differentiated signal, i.e. the steepness curve (blue, in the middle) and the rectified result (green, below).

It is cleary visible that the small "defect" in the time signal f(t) with its steeply falling edge results in the highest value of the rectified steepness curve.
In other words, the PureSound™ calculation makes the small - but most annoying - defects of the signal detectable.

1.2 Units

Steepness corresponds to a level change per time period. Applied on electrical signals, it is epressed in [V/s], i.e. Volt per second. In addition, RAPID-TEST allows expressing the steepness [Pa/s], if the signal has been acquired through a microphone.

- V/s is the normally used unit to express the steepness of an electrical signal.
- Pa/s (Pascal per second): Pascal is a unit for air pressure that is also used to quantify the sound pressure level (SPL) of an acoustical signal. If the sensitivity of the microphone (i.e. the conversion factor Pa → V, expressed in [V/Pa]) is known, RAPID-TEST allows expressing the signal steepness in [Pa/s].

2. Applications

The direct correlation between the shape of a time signal and its transient steepness plot has an essential consequence. It provides the possibility of the following applications:

- The detection of Rub & Buzz distortions, caused by non-linearities of speakers.
- The characterization or identification of a sound signal.

Both applications are implemented in NTI's PureSound™ option and will be explained hereunder.

2.1 Rub & Buzz Analysis

Detecting Rub & Buzz of electroacoustic transducers (e.g. woofers, drivers, tweeters, speakers, headphone capsules etc.) is a very challenging demand, mainly due to the very low energy content of this kind of distortion. If a speaker is defective, it typically creates short pulses that have a very low energy content but are most annoying to the human ear.

Unfortunately, due to the very low energy content of these short pulses they cannot be detected by using traditional RMS-FFT techniques (refer to NTI's application note "PureSound™ for Rub & Buzz Detection" for further details).

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On the other hand, such pulses show large changes in the instantaneous energy that can be detected easily with an appropriate transient analyzer. For this reason, the PureSound™ approach processes the waveform in a way that isolates all transient components from the signal. It extracts all short-lived pulses and calculates the steepness of the leading and trailing edge for each pulse.

As part of the PureSound™ analysis, six input filters are applied to simulate the perception of the human ear. Therefore, the analysis results correlate directly to the human perception of Rub & Buzz. *Fig. 3* shows the characteristics of these filters.

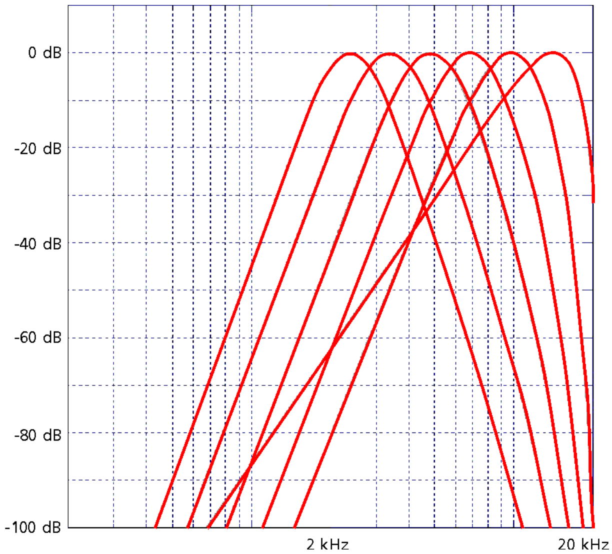

Fig. 3 Analyzer Input Filters

NOTE	**The PureSound™ approach processes the input signal in a way that reflects the perception of the human ear.**

To stimulate the DUT (device under test) for a Rub & Buzz test, a gliding sweep (i.e. "chirp") must be used. This is the only type of sweep that truly comprises all possible frequencies between its start and stop frequency.
This is essential since Rub & Buzz distortions typically have very sharp and individual resonance frequencies so that the test signal must not lack of any such frequencies (as it would be the case e.g. with a stepped sweep).

An important aspect of the PureSound™ Rub & Buzz test is that the signal generation and analysis are executed in two separated frequency bands:

a) 5 Hz - 6 kHz for the stimulus signal.
b) 2 kHz - 20 kHz for the signal analysis.

In other words, the RAPID-TEST analyzer only calculates the steepness of those signal components that have a higher frequency than the stimulus.

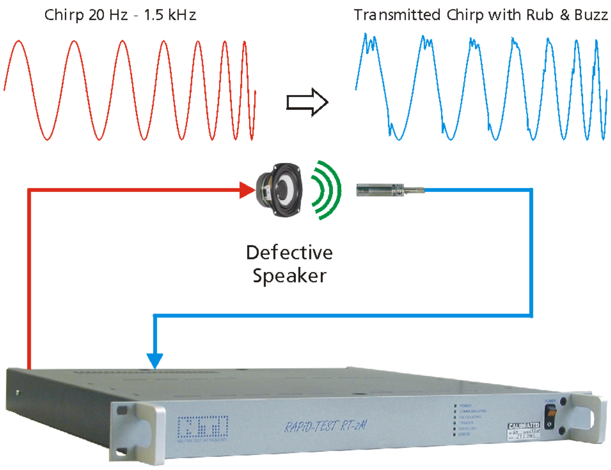

Fig. 4 Chirp vs. Rub & Buzz Frequencies

Fig. 4 shows the reason for the separated frequency bands of stimulus and signal analysis: Rub & Buzz distortions always have higher frequencies than the stimulus signal, i.e. the chirp.

Practice has shown that all applications can be solved with a stimulus signal that has a frequency range of 5 Hz - 6 kHz. In other words, all kinds of electroacoustic transducers (woofers, drivers, tweeters, speakers, headphone capsules etc.) can be checked reliably for possible Rub & Buzz defects.

2.2 Sound Correlation

The verification of the correctness of sound sequences has been a problem for decades. Distortions, level changes, missing or corrupted parts, extensive frequency shifts or clicks due to lost samples amend the signal in a clearly audible way, but are hardly detectable with audio test instruments that are based on RMS or FFT analysis.

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Actually, conventional approaches failed because of the very small energy differences between good and corrupted samples. Only a signal analysis in the time domain, i.e. the steepness results allow identifying reliably corrupted samples.
Therefore, the only solution is to analyze the transients of the signal and to compare it against a previously recorded reference, i.e. the transient pattern of a "golden sample".

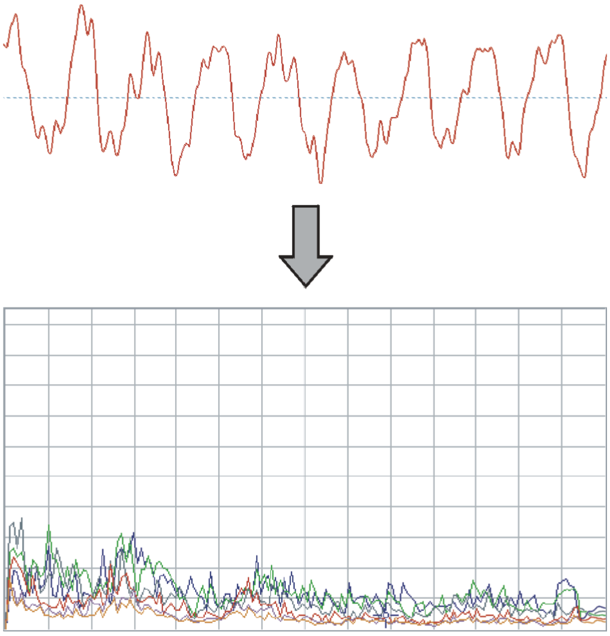

Fig. 5 Time Plot & Steepness of Golden Sample

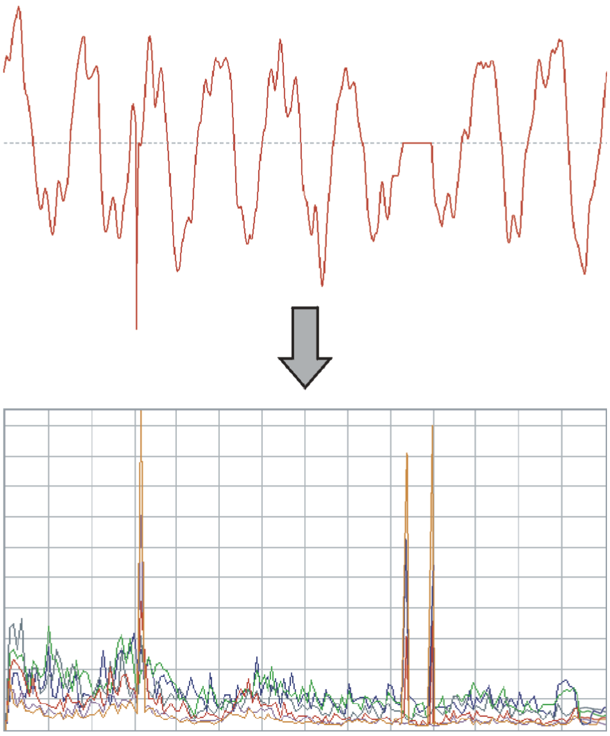

Fig. 6 Time Plot & Steepness of Corrupted Sample

Fig. 5 & 6 show an excerpt of a sound sequence as "golden sample" (above) and as corrupted sample (below). Although several differences are clearly visible in the time plot, neither the RMS or peak level results nor the spectrum of the two signals would show meaningful discrepancies.

Fortunately, the PureSound™ analysis allows detecting even slight differences because it operates in the time domain by simulating the perception of the human ear. In other words, the differentiation process singles out the "defects" of the corrupted signal and lets the RAPID-TEST unit identify the differences to the "golden sample" (refer also to NTI's application note "Sound Verification & Noise Analysis with RAPID-TEST and PureSound™").

3. Summary

The patented transient analysis method of Frank Leonhard is a unique tool for the detection of Rub & Buzz defects and for the verification of sound samples.

The principle transforms a signal into a new curve, representing the steepnesses of the transients in the signal. Thereby, signal components with small energy content but steep slopes (e.g. short, but sharp peaks or pulses) are "amplified", thus becoming detectable.
Since these peaks have a direct impact on the perception of the signal by the human ear, the steepness results provide essential information about the quality of the signal itself.