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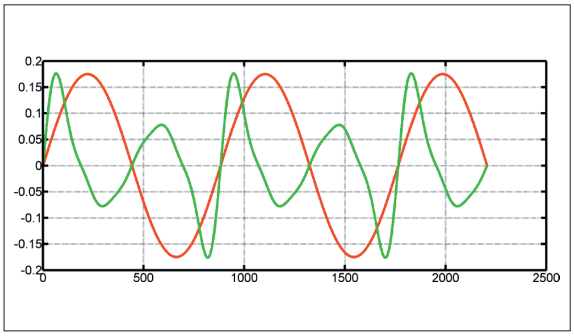
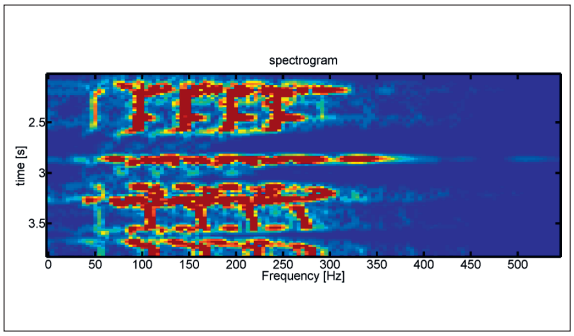
Subject Area	Digital Signal Processing
Project Partner	Illusonic GmbH, Uster, ZH

Psychoacoustic Audio Bandwidth Extension

Adaptive dynamic processing for psychoacoustic low-frequency enhancement of small speakers



An original sine wave (red) and the perceptual similar wave composed of its 2nd to 5th harmonic

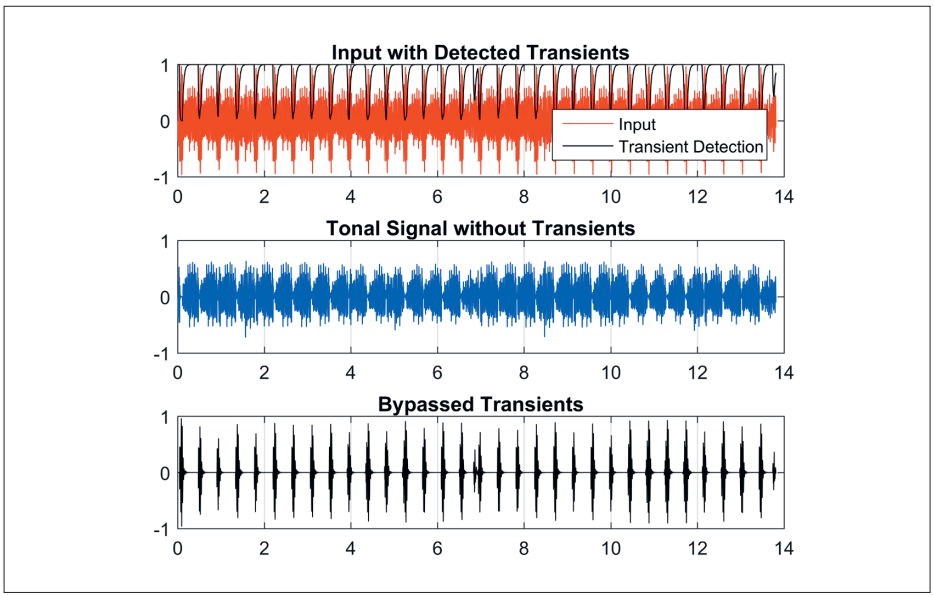


The spectrogram of a processed music signal: The weak green/yellow line at 55 Hz represents the fundamental, while the strong red lines are harmonics

Problem: Small speakers, such as used in smartphones or computer speakers, tend to have poor bass reproduction due to physical restrictions. This problem is often resolved by just supplying more power to the bass band, which may result in heavy distortion and damage to the speaker. An alternative approach to improving low-frequency perception without increasing power is to use a psychoacoustic effect: the human ear has the ability to hear a fundamental bass frequency, even if it is not present as long as its harmonics are. Therefore, fundamentals can be mapped into a higher frequency area, where the speaker is able to produce a distortionless sound.

Objective: Since these harmonics are not an existing part of the original input signal, they need to be generated. In order to introduce the new frequencies in the existing signal, a non-linear system has to be used. In this project, a simple non-linear algorithm developed by Illusonic GmbH was used as a basis and our goal was to improve it. Producing harmonics for a sinusoidal signal is a relatively simple task. This gets more complex as the signal becomes more dynamic and transients such as percussive attacks are introduced. Furthermore, because these transients are not tuned sounds, the signal does not have a clear pitch. Therefore, the psychoacoustic effect cannot be used because the fundamental frequency of such a signal is not defined.

Result: To solve this problem, an algorithm that offers multi-dimensional classification of an input signal and adaptive parameters for the psychoacoustic bass reproduction was developed. The result is a flexible algorithm for use on various target platforms that improves bass perception using a lower power signal. This allows for a high-quality audio output on small speakers while reducing stress and distortion.



The input signal is split into a tonal and a transient part. The tonal part gets processed while transients are bypassed and added back afterwards