

Nonlinearity and Psychoacoustics

Do We Measure What We Hear?

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- Attempt to explain why “conventional” measurement methods may not provide information well correlated with subjective sound quality.
- Discuss possible future developments of nonlinearity measurement in transducers and sound systems.

What is nonlinear distortion?



**Perceived
deterioration
of sound
quality?**

**Nonlinear
physical
effects?**

**Measured
objective
parameters
and
responses?**

THD versus sound quality

Quiz 1: Which system has less distortion?

Undistorted
musical signal



Click this button!

Nonlinear
system 1



THD = 22.6

Nonlinear
system 2

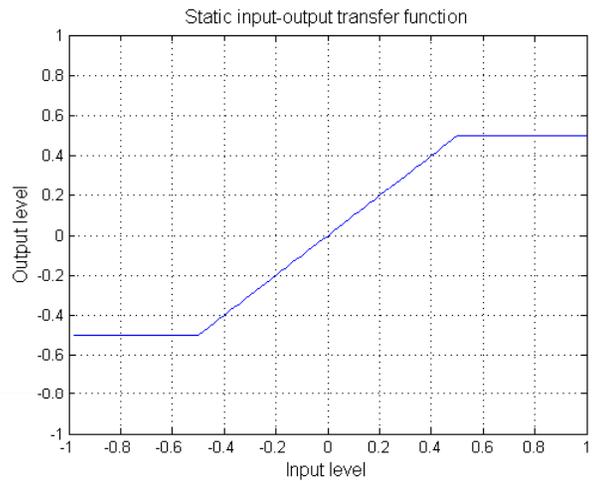


THD = 2.8 %

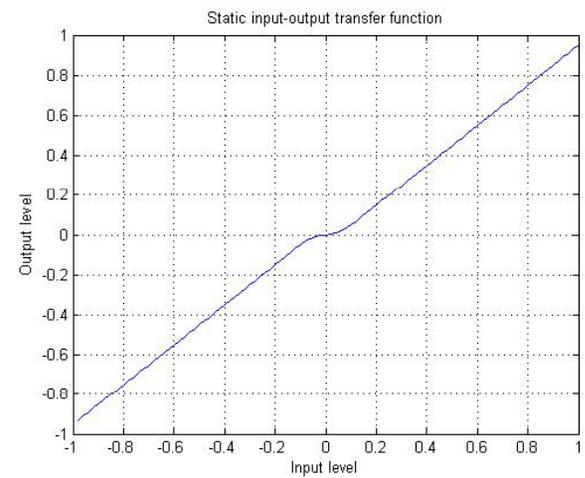
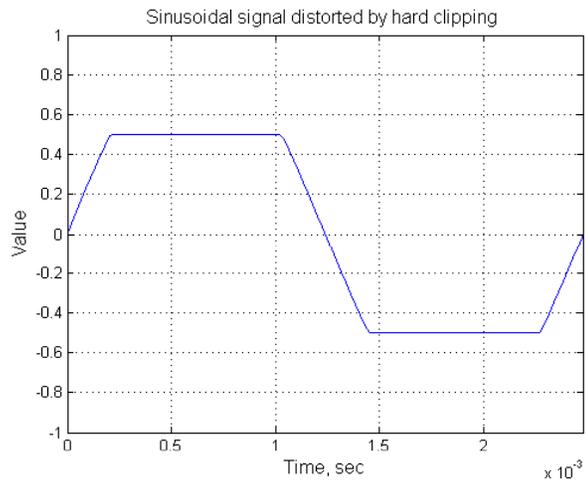
Common sense: the system 2 sounds worse, it must have higher harmonic distortion.

Musical excerpt from Paul Anka "It's My Life" (by Jon Bon Jovi), CD "Rock Swings", Verve Records, 2005

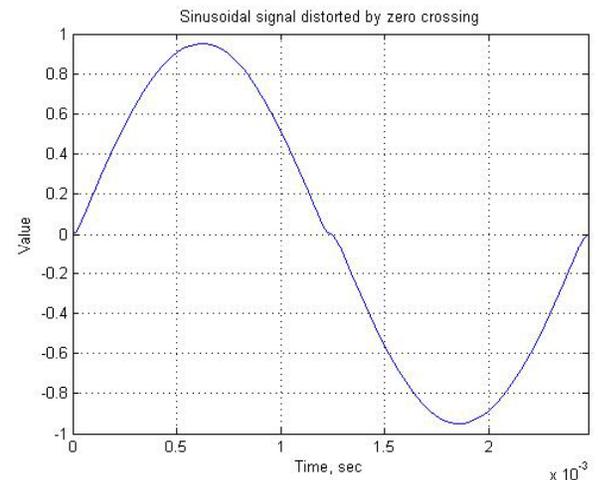
THD versus sound quality



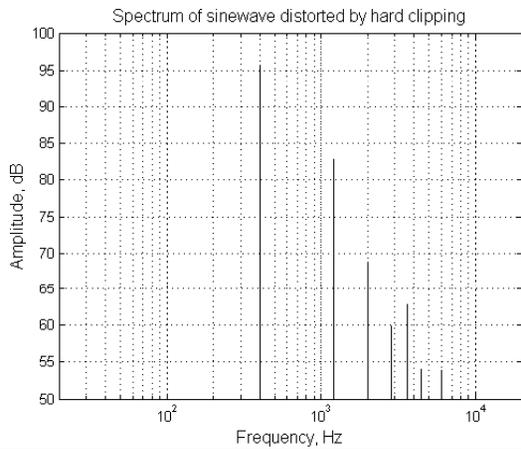
Hard clipping THD = 22.6 %



Soft zero crossing THD = 2.8%

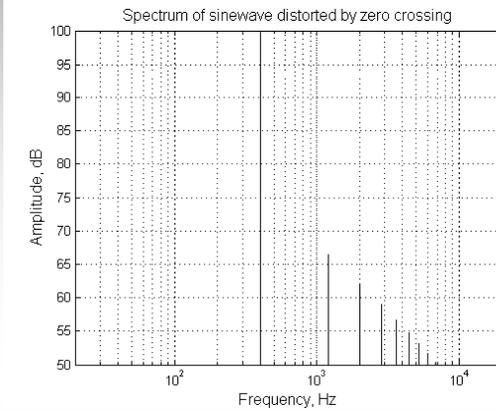


THD versus sound quality



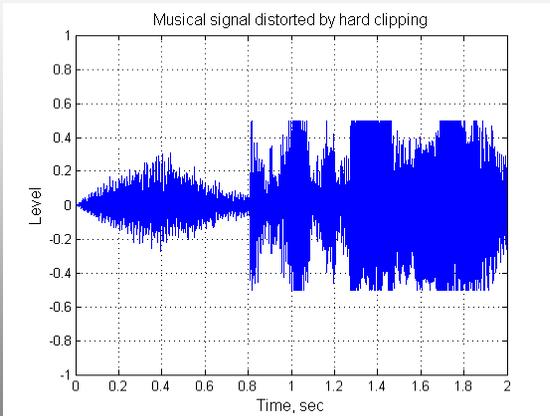
Hard clipping THD = 22.6 %

Spectra of distorted sinusoidal signals

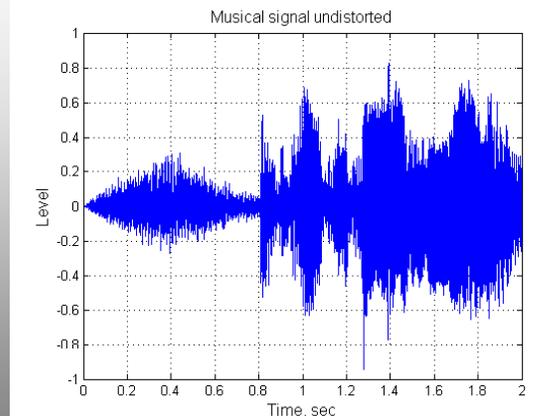


Zero crossing THD = 2.9 %

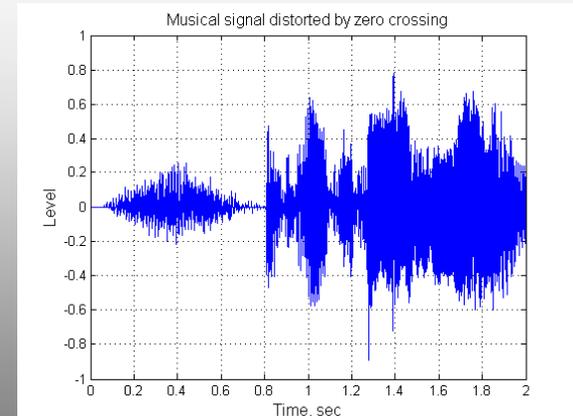
Waveforms of musical signal



Hard clipping



Original signal



Zero crossing

Quiz 2: Why do we measure harmonic distortion?

Answer:

Because we can!

Philip Newell, "Recording Studio Design",
Focal Press, 2003

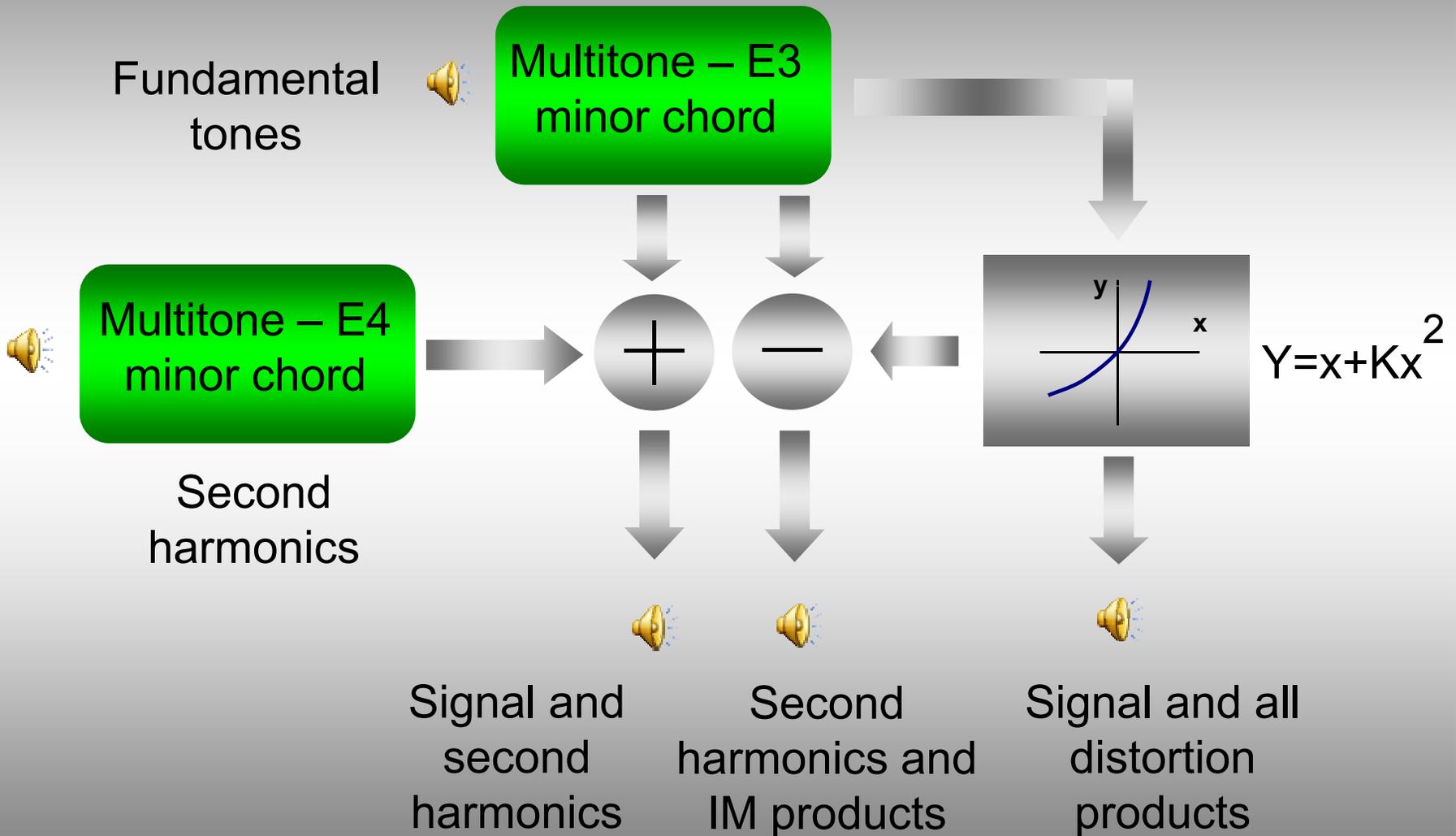
Popular believe: second harmonic distortion is benign

Second harmonics
are in octave
consonance with
fundamental tones

Second harmonics
are masked by the
musical instruments'
overtones

Does a system that
generates second
harmonic distortion still
sound good?

Second harmonic distortion versus second order distortion



Background

Why don't "conventional" measurement methods correlate well with subjective sound quality?

Complexity of nonlinear systems

Complexity of human hearing system

Complexity of musical signal

Reaction to simple testing signals does not convey sufficient information

Hearing system is not a mere spectrum analyzer

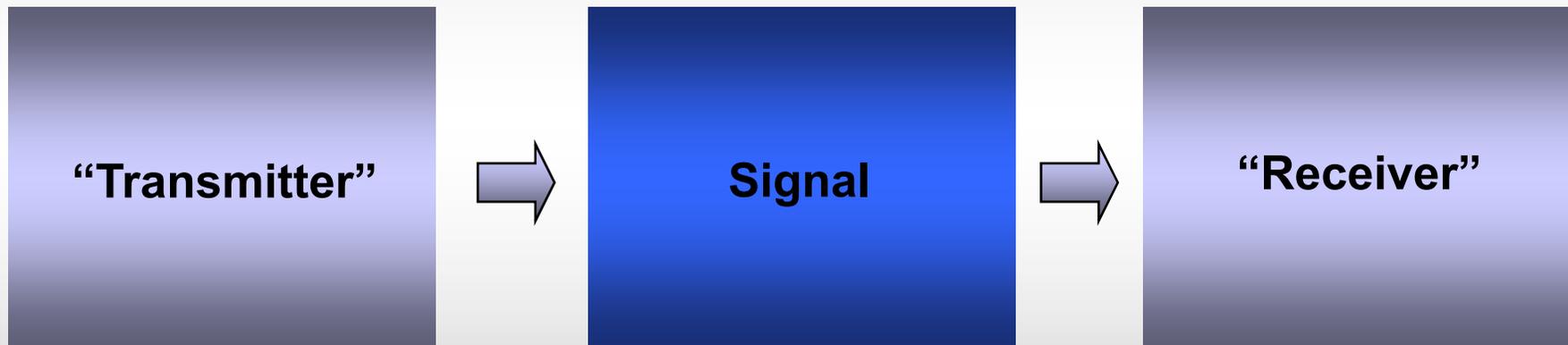
Musical and tonal signals differ statistically, in time and frequency domains

Sound reproduction as a communication system



Sound reproduction as a communication system

What we often think about this system is not what it really is



Sound reproduction as a communication system

We typically think that:

**“Transmitter” –
loudspeaker
produces
harmonics and
IM distortion**



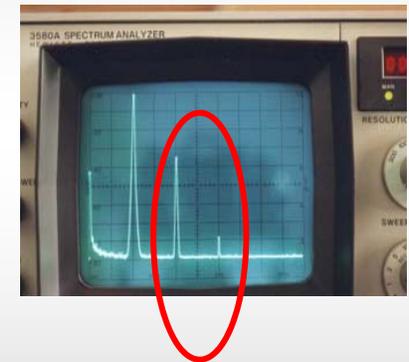
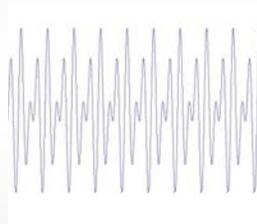
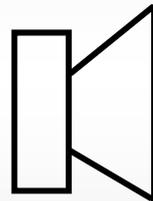
**Musical signal is
accompanied by
harmonic and IM
products**



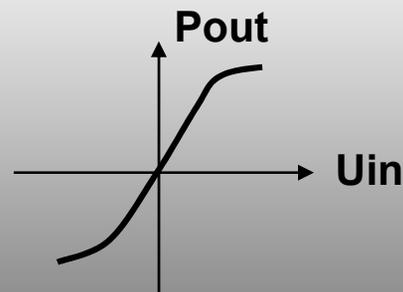
**We hear these
irritating
harmonic and
intermodulation
products**

Sound reproduction as a communication system

Stereotypical picture of loudspeaker distortion measurements

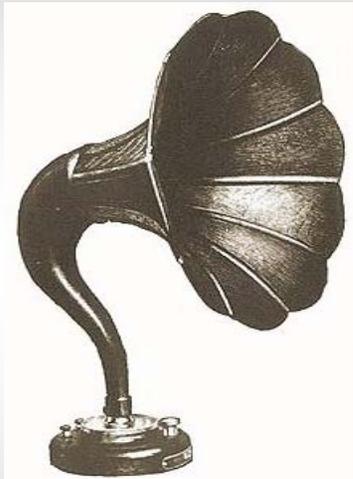


Culprits

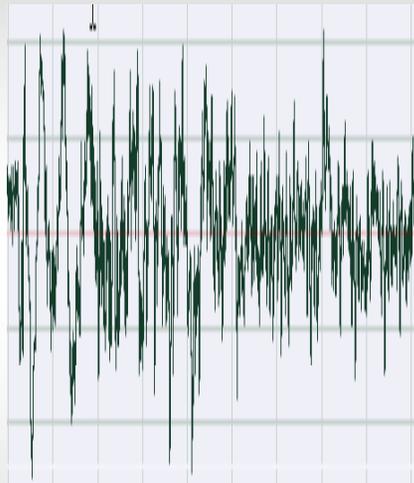


Sound reproduction as a communication system

In reality:



Extremely complex dynamic system with plethora of nonlinear and parametric electromagnetic, mechanical and acoustical effects



Very complex dynamic signal with instantaneously changing level, waveform, and spectrum. Far cry from sinusoidal signal including totally different statistical distribution. Distortion signal is just as complex



Enormously complex nonlinear time-variant system characterized by numerous physiological, psychoacoustical and cognitive effects