

Nonlinearity and Psychoacoustics

Do We Measure What We Hear?

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Motivation

- 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

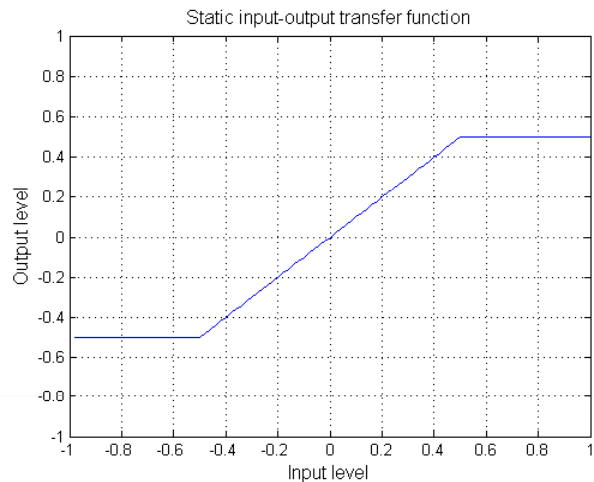


THD = 2.8 %

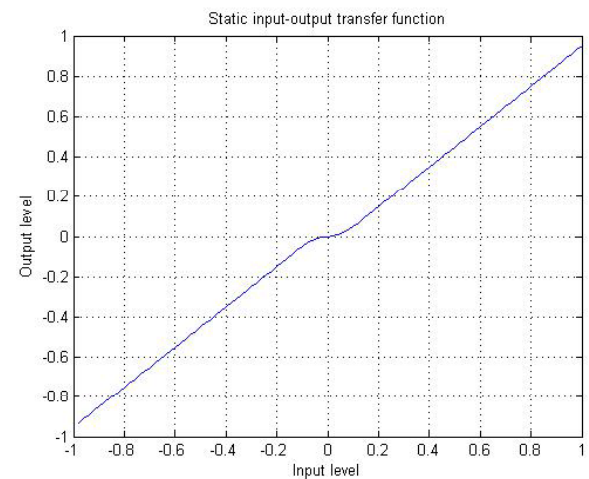
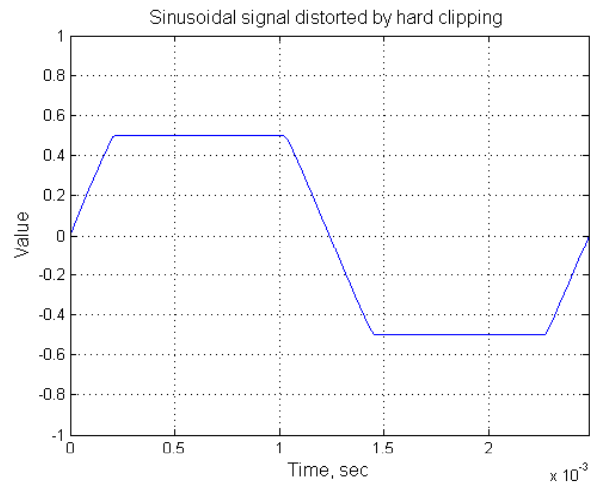
Common sense: the
system 2 sounds
worse, it must have
higher harmonic
distortion.

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

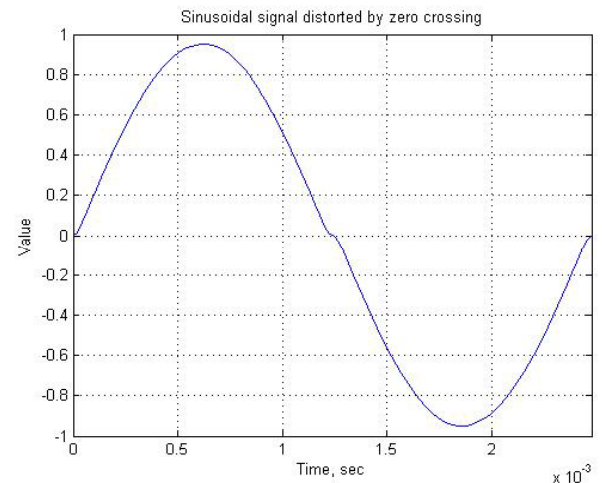
THD versus sound quality



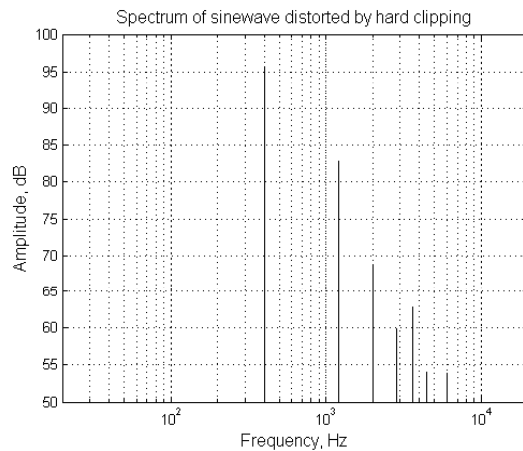
Hard clipping THD = 22.6 %



Soft zero crossing THD = 2.8%

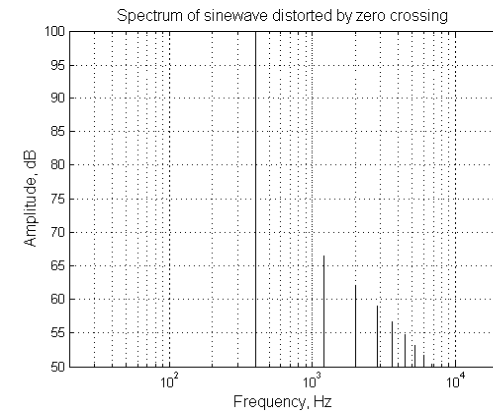


THD versus sound quality



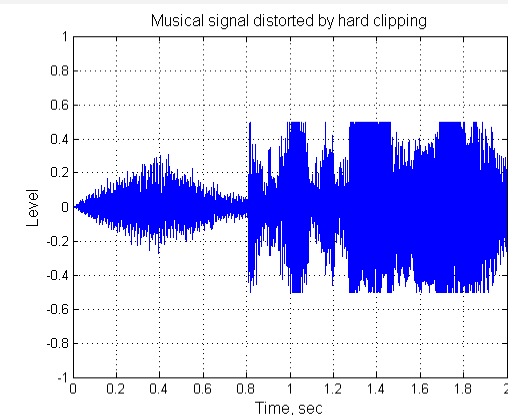
Hard clipping THD = 22.6 %

Spectra of
distorted
sinusoidal
signals

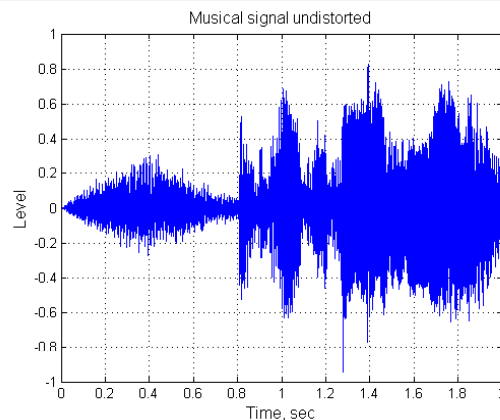


Zero crossing THD = 2.9 %

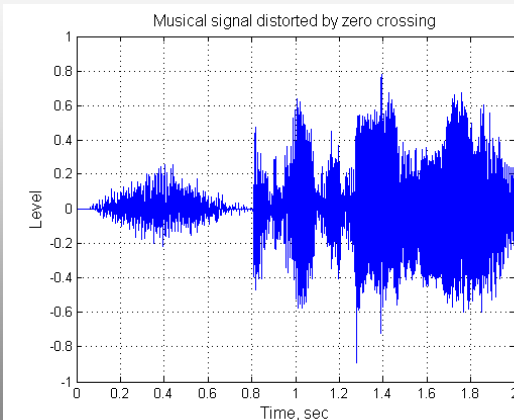
Waveforms of musical signal



Hard clipping



Original signal



Zero crossing

THD versus sound quality

Quiz 2: Why do we measure harmonic distortion?

Answer:

Because we can!

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

Background

Popular believe: second harmonic distortion is benign



**Second harmonics
are in octave
consonance with
fundamental tones**

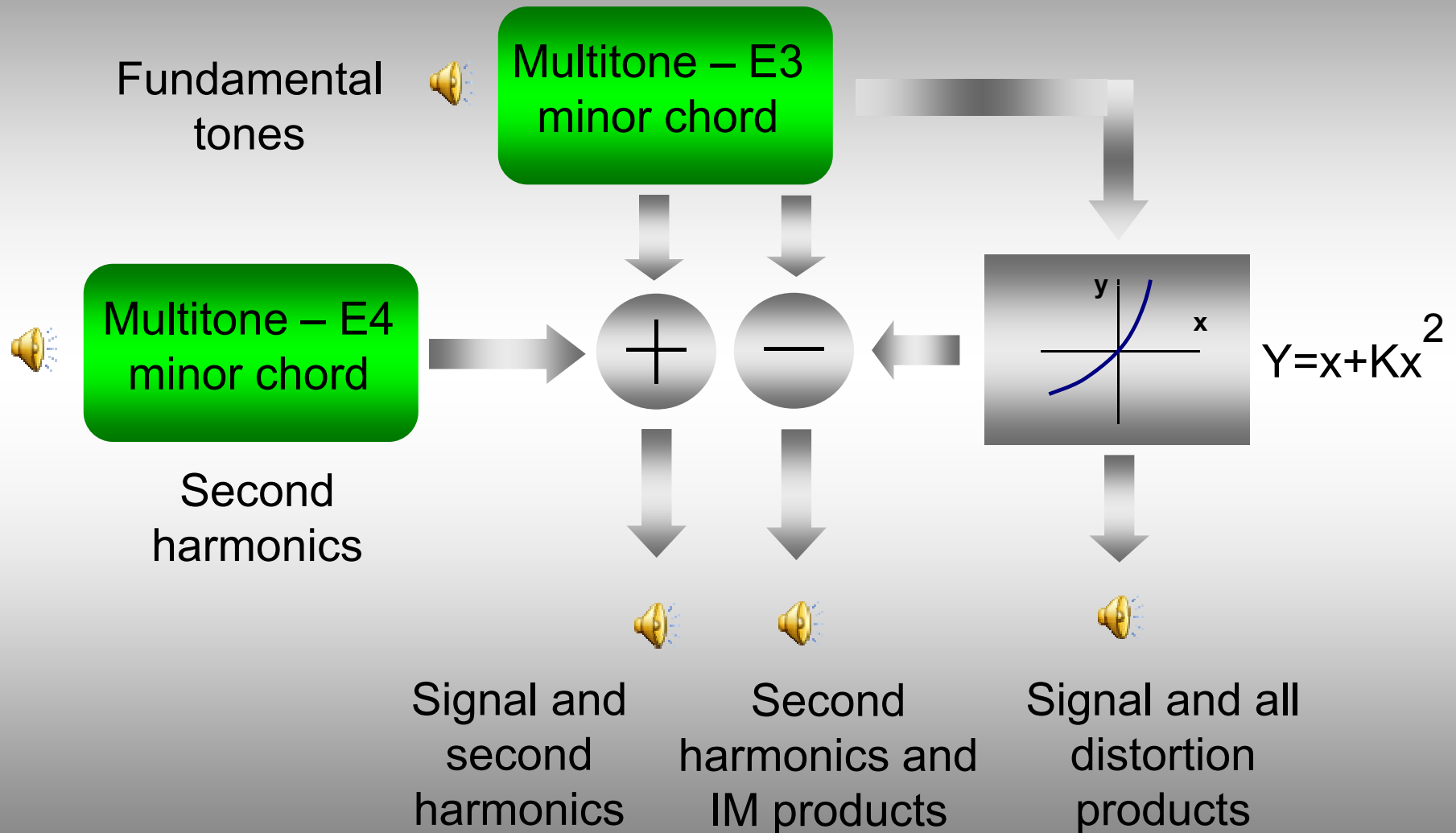


**Second harmonics
are masked by the
musical instruments'
overtones**



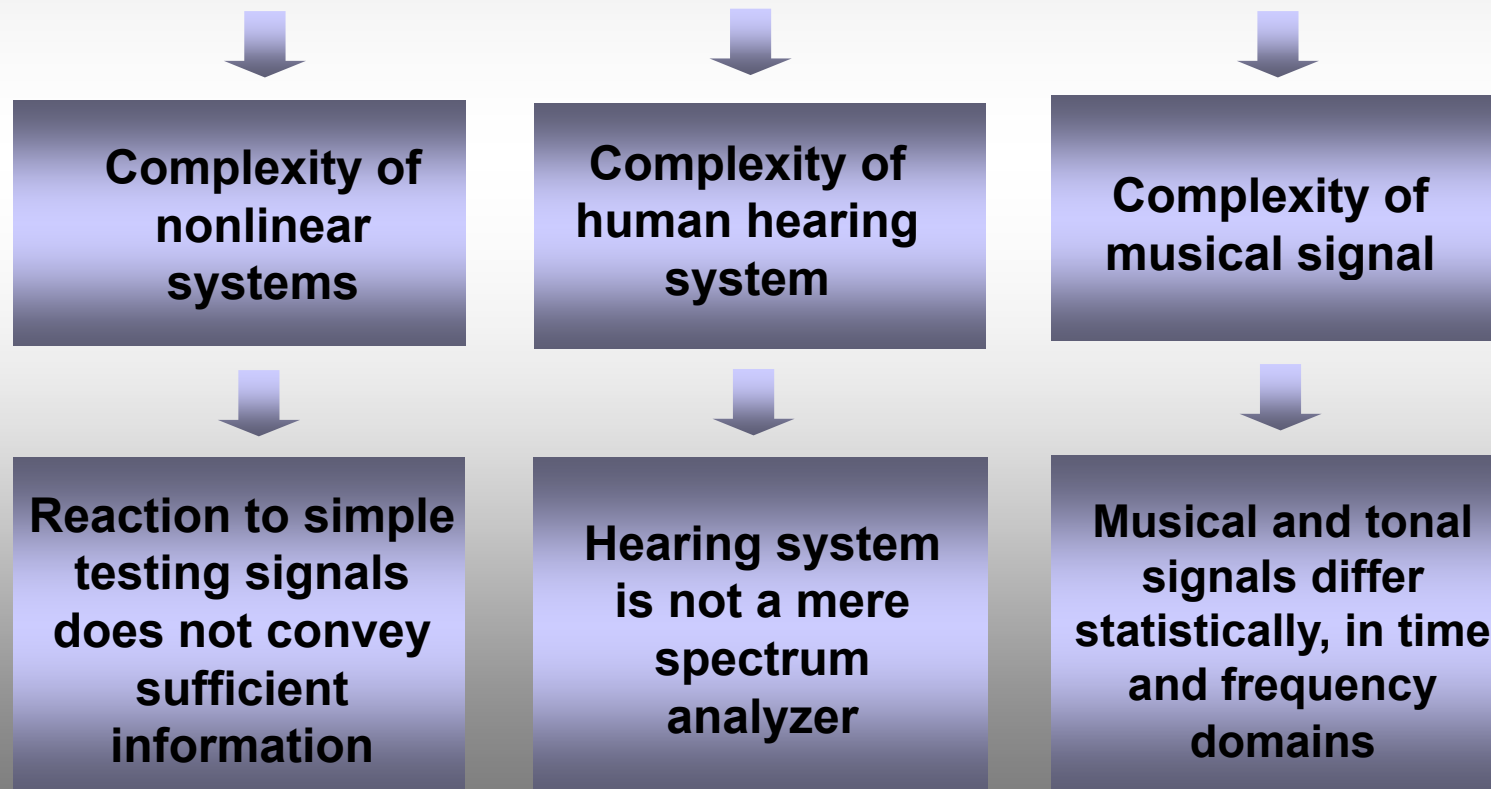
**Does a system that
generates second
harmonic distortion still
sound good?**

Second harmonic distortion versus second order distortion

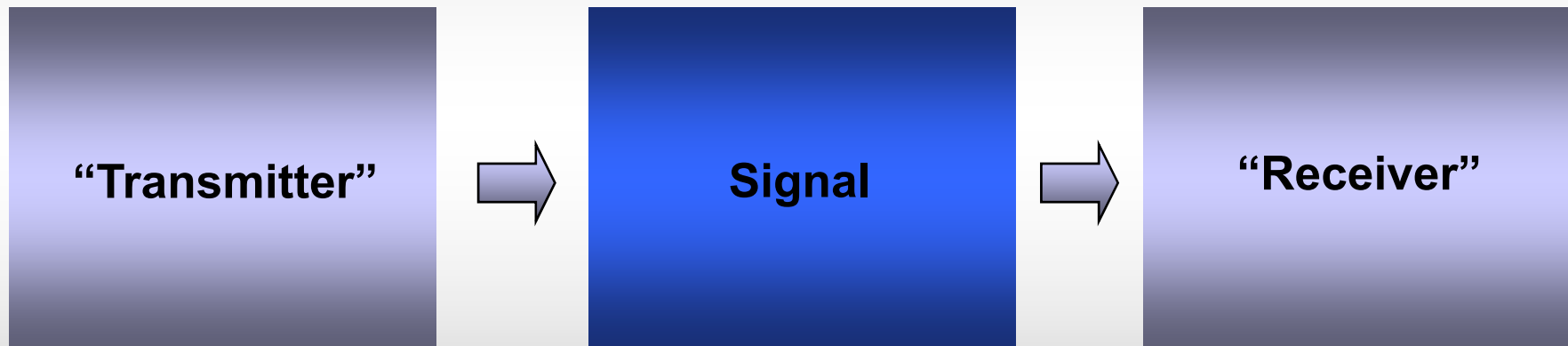


Background

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

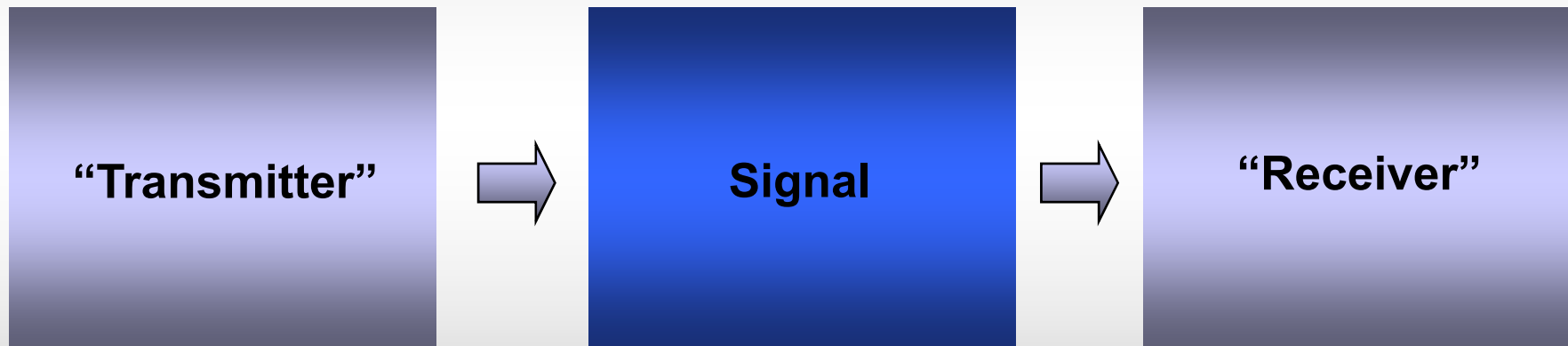


Sound reproduction as a communication system



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**



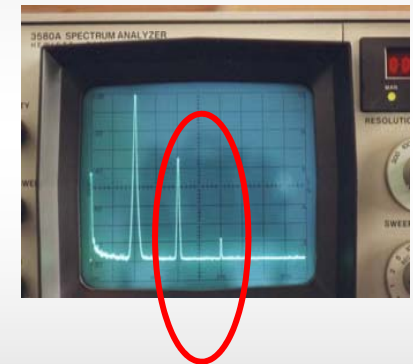
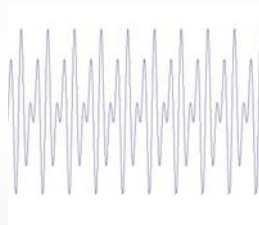
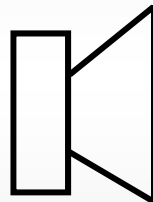
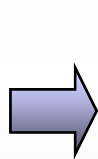
**Musical signal is
accompanied by
harmonic and IM
products**



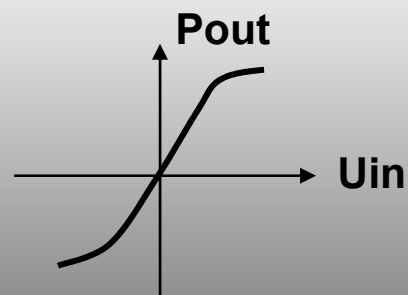
**We hear these
irritating
harmonic and
intermodulation
products**

Sound reproduction as a communication system

Stereotypical picture of loudspeaker distortion measurements

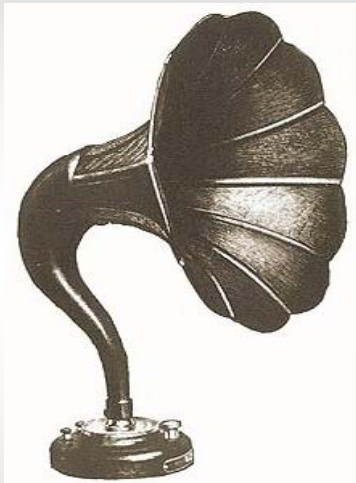


Culprits

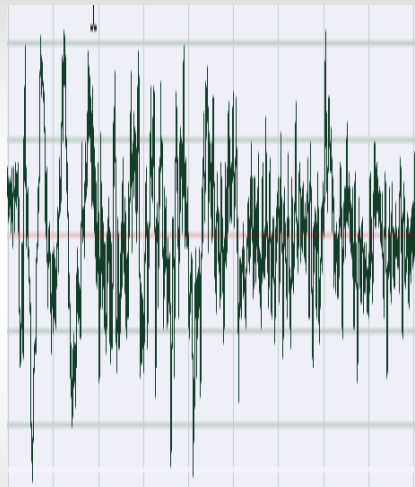


Sound reproduction as a communication system

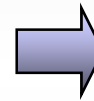
In reality:



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