PsychoAcoustics Intro

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(also Music)

Views of Sound

- ***Sound is a recorded waveform***
  PCM playback is all we need for
  digital sound manipulation and <u>creation</u>
- ***Time Domain*** ***x(t)*** ***(from physics)***
- ***Frequency Domain*** ***X(f)*** ***(from math)***

- ***Production*** ***what caused it***
- ***Perception*** ***our image of it***

Views of Sound

Time Domain
is most closely related to
Production

Frequency Domain
is most closely related to
Perception

we will see that many hybrids abound

Views of Sound: Time Domain

Sound is produced/modeled by physics, described by quantities of

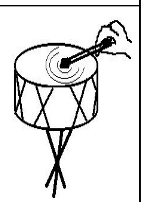
- Force — force = mass * acceleration
- Position — x(t) — actually < x(t), y(t), z(t) >
- Velocity — Rate of change of position dx/dt
- Acceleration — Rate of change of velocity dv/dt

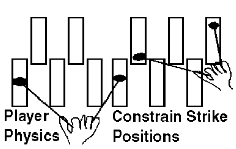
Examples: ***Mass+Spring+Damper***
Wave Equation

Views of Sound: Production

Throughout most of history, some physical mechanism was responsible for sound production.

From our experience, certain <u>gestures</u> produce certain audible results





Examples:
Hit harder --> louder AND brighter
Can't move instantaneously
Can't do exactly the same thing twice

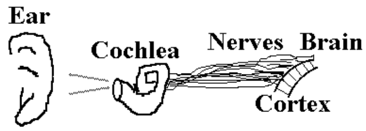
Sound Views: Frequency Domain

Frequency Domain:

- Many physical systems have <u>modes</u>
  (damped oscillations)
- Wave equation (2nd order) or
  Bar equation (4th order) need 2 or 4
  "boundary conditions" for solution
- Once boundary conditions are set
  solutions are sums of exponentially damped sines
  the sinusoids are Modes

Views of Sound: Perception

Human sound perception:



Brain:
Higher level cognition, object formation, interpretation

Ear:
receive 1-D waves

Cochlea:
convert to frequency dependent nerve firings

Auditory cortex:
further refine time & frequency information

Psychoacoustics

Limits of Human Hearing

- **Time Domain Considerations**
- **Frequency Domain (Spectral) Considerations**
- **Amplitude vs. Power**
- **Masking in Time and Frequency Domains**
- **Sampling Rate and Signal Bandwidth**

Limits of Human Hearing

Time and Frequency

Events longer than 0.03 seconds are resolvable *in time*

shorter events are perceived as *features in frequency*

20 Hz. < Human Hearing < 20 KHz.
(for those under 15 or so)

"Pitch" is <u>PERCEPTION</u> related to <u>FREQUENCY</u>
Human Pitch Resolution is about 40 - 4000 Hz.

Limits of Human Hearing

Amplitude or Power???

- **"Loudness" is <u>PERCEPTION</u> related to <u>POWER</u>, not <u>AMPLITUDE</u>**
- **Power is proportional to (integrated) square of signal**
- **Human Loudness perception range is about 120 dB, where +10 db = 10 x power = 20 x amplitude**
- **Waveform shape is of little consequence. Energy at each frequency, and how that changes in time, is the most important feature of a sound.**

Limits of Human Hearing

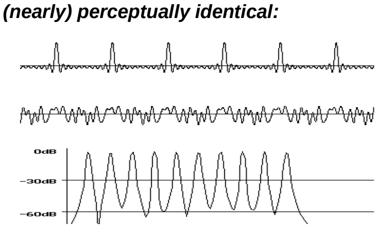
Waveshape or Frequency Content??

Here are two waveforms with identical power spectra, and which are (nearly) perceptually identical:

Wave 1

Wave 2

Magnitude Spectrum of Either



Limits of Human Hearing

Masking in Amplitude, Time, and Frequency

- **Masking in Amplitude: Loud sounds 'mask' soft ones. Example: Quantization Noise**
- **Masking in Time: A soft sound just before a louder sound is more likely to be heard than if it is just after. Example (and reason): Reverb vs. "Preverb"**
- **Masking in Frequency: Loud 'neighbor' frequency masks soft spectral components. Low sounds mask higher ones more than high masking low.**

Limits of Human Hearing

Masking in Amplitude

Intuitively, a soft sound will not be heard if there is a competing loud sound. Reasons:

- **Gain controls in the ear**

  stapedes reflex and more

- **Interaction (inhibition) in the cochlea**
- **Other mechanisms at higher levels**

Limits of Human Hearing

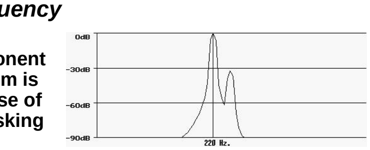
Masking in Time

- **In the time range of a few milliseconds:**
- **A soft event following a louder event tends to be grouped perceptually as part of that louder event**
- **If the soft event precedes the louder event, it might be heard as a separate event (become audible)**

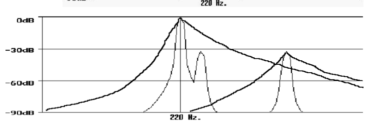
Limits of Human Hearing

Masking in Frequency

Only one component in this spectrum is audible because of frequency masking



Each component exhibits a "masking curve"



Waveform Sampling and Playback

- *Sample and Hold*

  Sample Rate vs. Aliasing

- *Quantize*

Word Size vs.

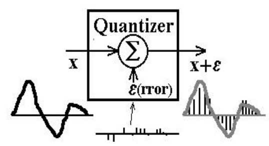
Quantization Noise

- *Reconstruct: (filter)*

  Hold and Smooth

  Filter Order vs.

  Error and Latency



References and Resources

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References and Resources

Critical Bands and Masking

Old Views

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Newer Views

Moore and Glasberg, "Suggested Formulae for Calculating Auditory-Filter Bandwidths and Excitation Patterns," JASA, 7, 4(3) 1983.