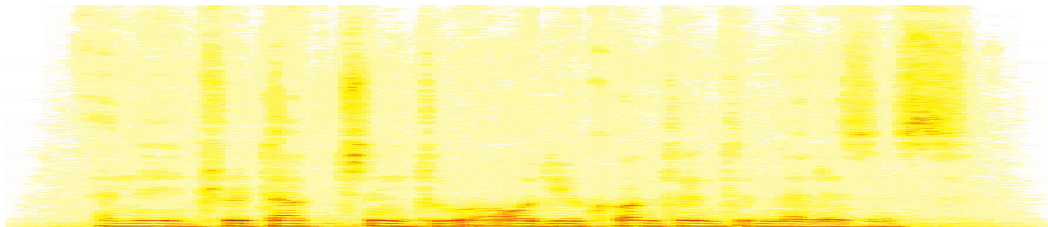


# Introduction to Audio Content Analysis

## Module 5.0: Human Perception of Pitch

alexander lerch



# introduction

## overview

### corresponding textbook section

Chapter 5 — Tonal Analysis: pp. 79–82

- **lecture content**

- pitch as perceptual phenomenon
- non-linear relation of frequency and pitch
- frequency content of a simple pitched sound
- dimensions of pitch perception

- **learning objectives**

- describe basic properties of models for pitch
- explain the two dimensions of pitch perception



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# tonal analysis

## introduction

- **pitch & pitch-based properties** belong to the most important parameters describing music
  - melody
  - harmony
  - tonality
  - tuning & intonation
- **related ACA tasks**
  - fundamental frequency detection
  - key detection
  - chord detection
  - tuning frequency & temperament estimation

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# pitch perception

## pitch definition

### definition (American Standards Association)

pitch is that attribute of auditory sensation in terms of which sounds may be ordered on a musical scale<sup>a</sup>

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- temporal variations in pitch give rise to a sense of melody
  - closely related to frequency, but **subjective**
- ⇒ assigning a pitch value to a sound means **specifying the frequency of a pure tone having the same subjective pitch** as the sound

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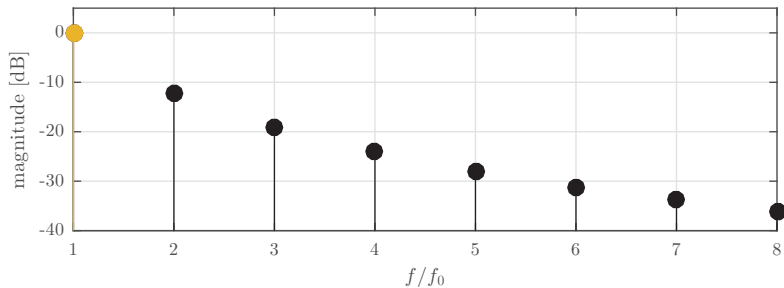
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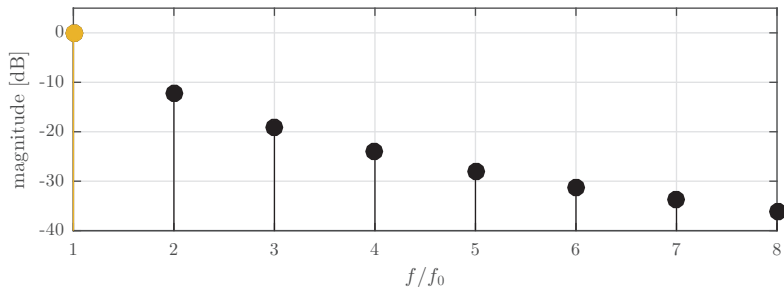
## fundamental frequency



- dominant *fundamental* frequency ( $f_0, 2f_0, 3f_0, \dots$ )
- higher fundamental frequency  $\Rightarrow$  higher pitch (mono-dimensional)

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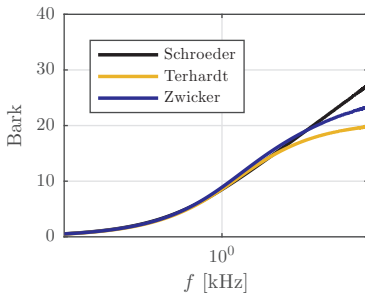
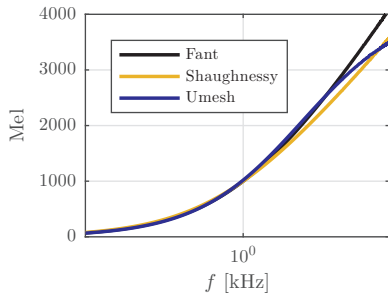
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## frequency & pitch

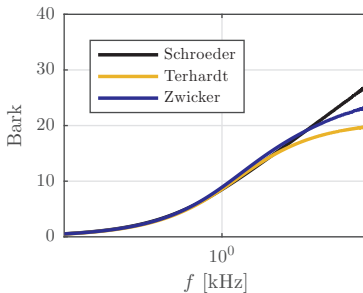
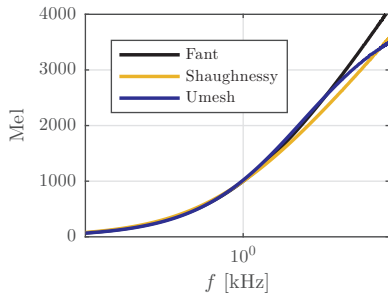


### non-linear pitch frequency relation:

- perceptual pitch distance  $\neq$  frequency distance
- ⇒ *models* for psycho-acoustic/physiological data
  - Mel scale (equal pitch distance)
  - Bark scale (critical band width)
  - physiological frequency location (basilar membrane)

# pitch perception

## frequency & pitch



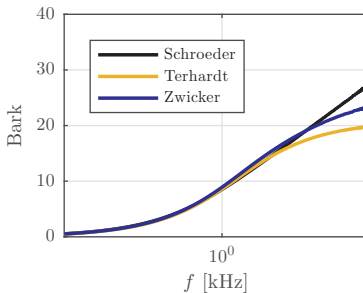
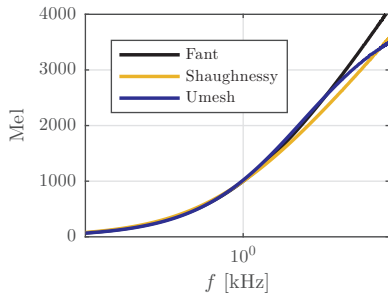
**Fant:**  $m_F(f) = 1000 \cdot \log_2 \left( 1 + \frac{f}{1000 \text{ Hz}} \right)$

**O'Shaughnessy:**  $m_S(f) = 2595 \cdot \log_{10} \left( 1 + \frac{f}{700 \text{ Hz}} \right)$

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## frequency & pitch



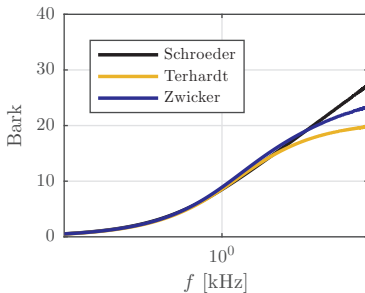
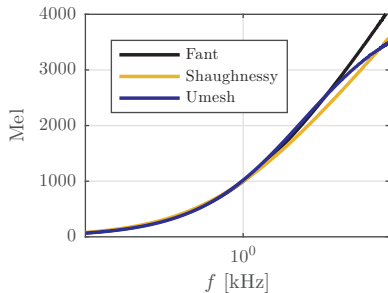
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## frequency & pitch



**Schröder:**

$$z_S(f) = 7 \cdot \operatorname{arcsinh} \left( \frac{f}{650 \text{ Hz}} \right)$$

**Terhardt:**

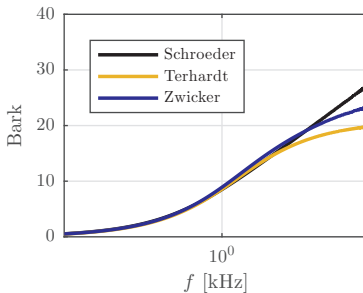
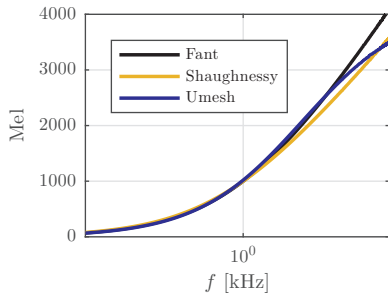
$$z_T(f) = 13.3 \cdot \arctan \left( 0.75 \cdot \frac{f}{1000 \text{ Hz}} \right)$$

**Zwicker:**

$$z_Z(f) = 13 \cdot \operatorname{atan} \left( 0.76 \cdot \frac{f}{1000 \text{ Hz}} \right) + 3.5 \cdot \operatorname{atan} \left( \frac{f}{7500 \text{ Hz}} \right)$$

# pitch perception

## frequency & pitch



$$\text{ERB: } \epsilon(f) = 9.26 \log \left( 1 + \frac{f}{228.7} \right)$$

$$\text{Cochlear Map: } \mathfrak{x}(f) = \frac{1}{2.1} \log_{10} \left( \frac{f}{165.4} + 1 \right)$$

# pitch perception

## pitch dimensions

## 2 dimensions of musical pitch

- **tone height**: monotonic relationship to frequency (increasing frequency  $\Rightarrow$  increasing pitch)
- **tone chroma**: two tones separated by octave sound similar (same *pitch class*)

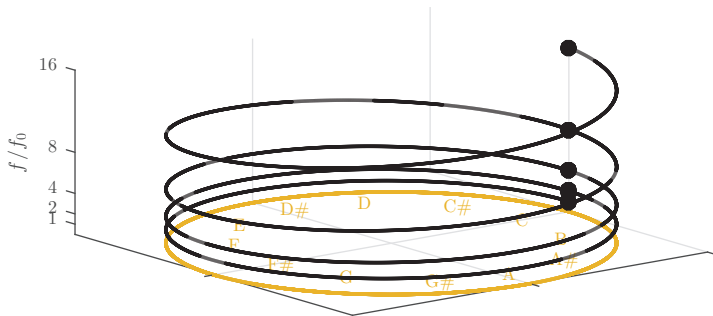


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# summary

## lecture content

### ● pitch

- subjective phenomenon
- non-linear monotonic relationship to frequency (tone height increases with fundamental frequency)
- pitch grouping based on powers of two: tone chroma perception

