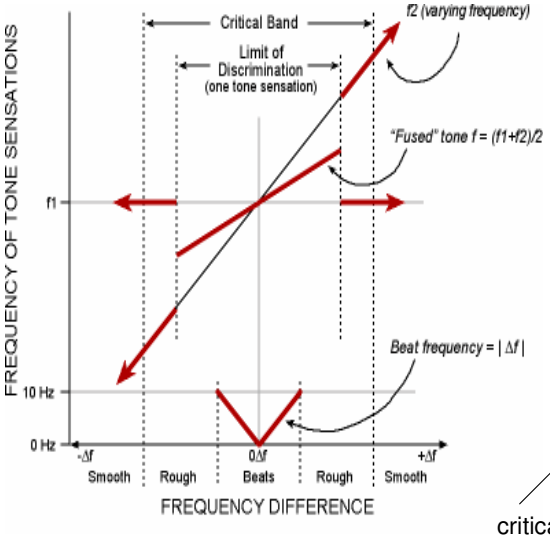
Superposition of complex tones: dissonance and consonance

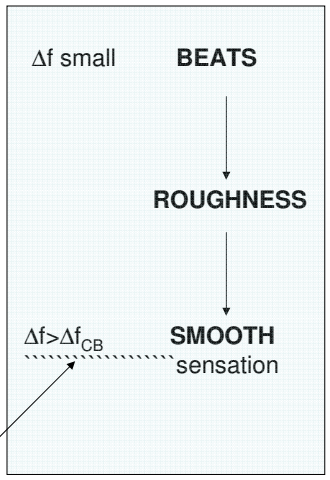
Overview

- Critical band Δf_{cb} - a reminder (Lecture 6)
- Helmholtz theory of consonance
- Plomp theory
- Quantitative evaluation of the degree of consonance. Examples
- Factors influencing degree of consonance of musical interval

First order superposition effects for pure tones



$$\Delta f = f_2 - f_1$$

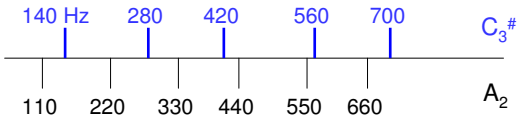


critical band

Superposition of complex tones – two different situations

• The fundamental of the higher tones **<u>is not equal</u>** to any of the harmonics of the lower tone

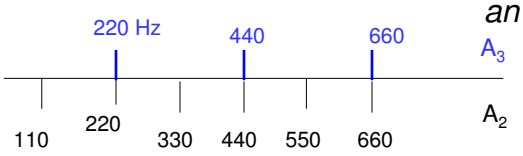
major third separation



There is a possibility of beats and roughness between any two neighbouring partials

•The fundamental of the higher tone **<u>is equal</u>** to one of the harmonics of the lower tone

an octave separation



Why tones do not fuse into one?

Dissonant and consonant musical intervals- just facts

Consonance occurs when the fundamentals of the tones are in a simple integer ratio relationship such as 1:2 (an octave) or 2:3 (a fifth).

"Perfect" consonance	1:1	Unison	C-C
	1:2	Octave	C-C
	2:3	Perfect fifth	C-G
"Imperfect" consonance	3:5	Major sixth	C-A
	3:4	Perfect fourth	C-F
	5:6	Minor third	C-E^{b}
	4:5	Major third	C-E
	5:8	Minor sixth	C-A^{b}

Degree of consonance

Earlier theories

"Agreeable consonances are pairs of tones which strike the ear with a certain regularity. This regularity consist in the fact that the pulses delivered by the two tones, in the same time, shall be commensurable in number, so as not to keep the eardrum in perpetual torment, bending in two different directions in order to yield to the ever-discordant pulses"

Galileo Galilei

Theory of Helmholtz

Hermann von Helmholtz, "On The Sensations of Tone: As a Physiological Basis for the Theory of Music" (1862)

Consonance arises from two sensory factors:

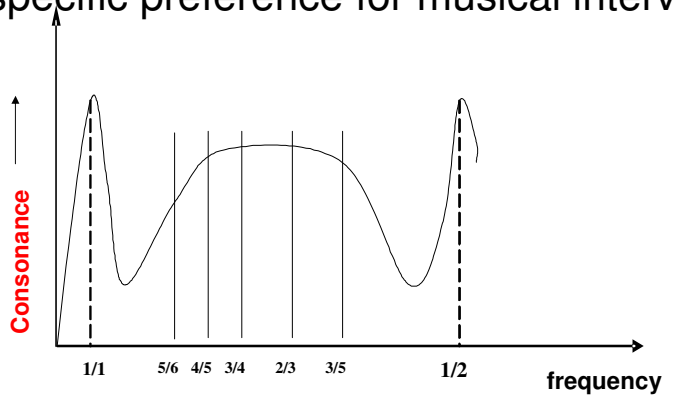
•the alignment of the upper partials of two or more tones

greatest between two tones whose frequency ratios yield simple integers, such as 2:3 (the fifth) or 4:5 (the major third)

•the lack of beats between these partials

avoid partials to be too close to each other. Frequency separation of 30-40Hz sounds most unpleasant.

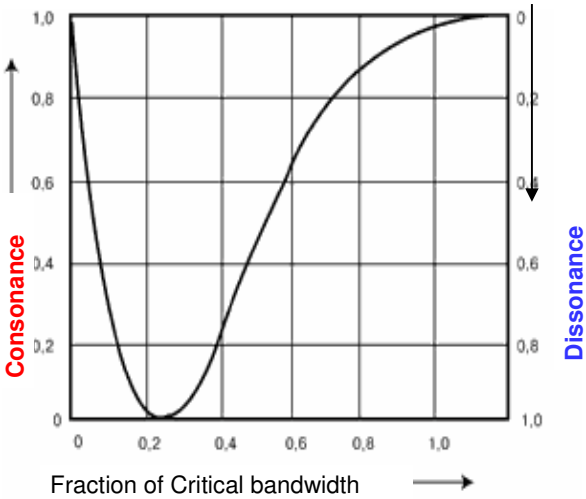
Perceived consonance and dissonance of **2 pure tones –** no specific preference for musical intervals



Experimental procedure: The subjects (20 y.o. male adults) judged each tone interval on a 7 point scale (1 – most dissonant, 7 – most consonant). Experiments in anechoic room. 5 values of the mean frequency in the interval 125-1000Hz. Each subject judged 12-14 intervals with various frequencies around these means.

(R.Plomp, W.J.M.Levelt J.Acoust Soc.Am, 1965)

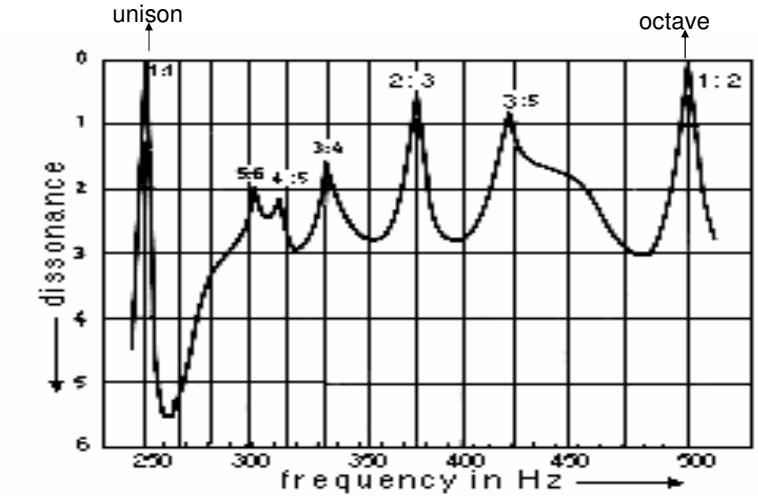
Perceived consonance and dissonance of **2 pure tones –** dependence on the critical band



- **Perfect consonance** – unison and octave
- **Dissonance** – separation of 5-50% of critical band
- **Maximum dissonance** – 25% of critical band separation

(R.Plomp, W.J.M.Levelt J.Acoust Soc.Am, 1965)

Consonance and dissonance of two superimposed **complex tones**



Common musical interval have frequency ratio close to that of maximum consonance

(***Plomp and Levelt***, *1965)*

Sounds are consonant when no or few partials fell within the same critical bandwidth Δf_{cb}

Quantitative analysis of the consonant properties of superimposed tones

Look at the harmonic pairs with frequency difference Δf :

C (perfectly consonant) $\Delta f = 0$

c (consonant) $\Delta f > \Delta f_{CB}$, here Δf_{cb} is critical band of the frequency midway between harmonics

D (highly dissonant) $\Delta f < 0.5\Delta f_{cb}$

d (dissonant) $0.5\Delta f_{CB} < \Delta f < \Delta f_{CB}$

The degree of consonance depends on the value of the lower tone fundamental

This is because critical band varies with frequency

Example: major third (4/5) with the lower tone fundamental f_0=55Hz is more dissonant than the same interval with f_0=110Hz and f_0=220Hz

f_0=55Hz	D d D C D D
f_0=110Hz	d d D C D d
f_0=220Hz	c c D C D d

(see Howard and Angus, p.143 -144)

The degree of consonance depends on tones timbre

- Dissonance/consonance between paired harmonics contributes more to the overall degree of consonance when their amplitudes are high (*they carry more energy*).

- The effect of dissonance/consonance between lower harmonic pairs is more 'important' than between higher harmonics (*usually in musical tone the higher the harmonic the lower its amplitude*)

Consonant properties of the intervals with frequency separation bigger than an octave

Project the upper tone down by octaves until the interval smaller than an octave is obtained and then analyse the interval

This cyclic property of intervals is called
CHROMA OF MUSICAL TONES

Further reading

- D.M.Howard, J.A.S.Angus Acoustics and psychoacoustics pp.138-144
- J.G.Roederer The physics and psychophysics of music pp.162-171