

Pitch vs. Frequency

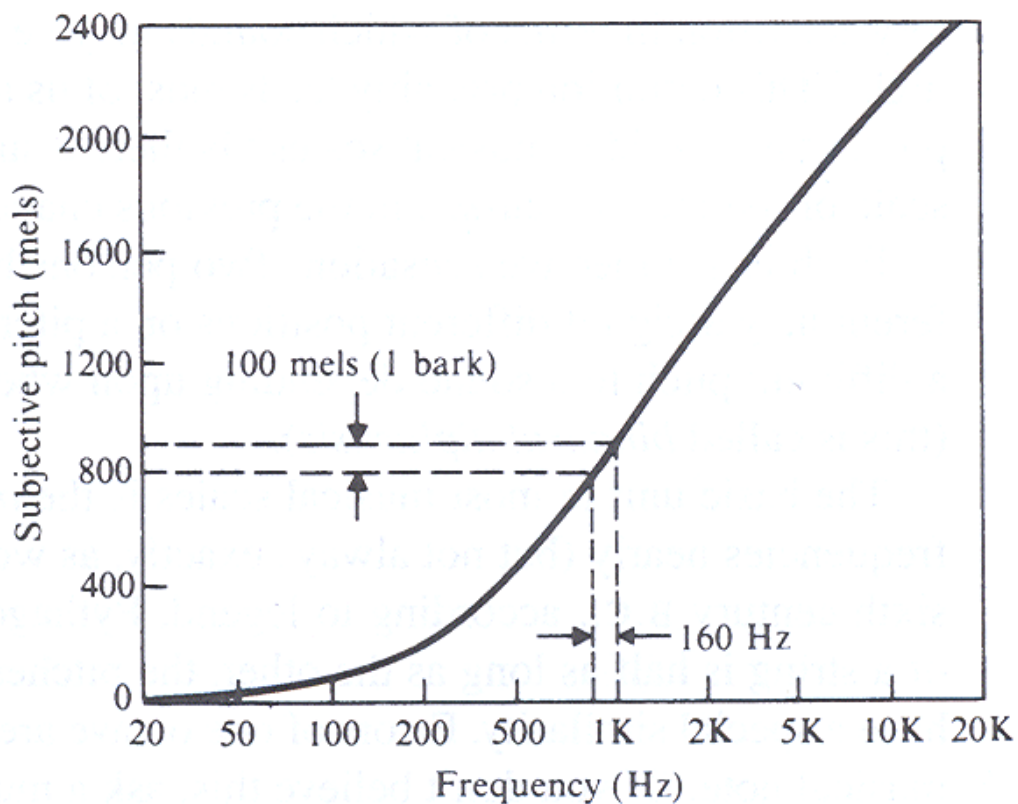
Pitch = human ear's *perception* of frequency of a sound vibration

Low pitch \Leftrightarrow low frequency of vibration/oscillation

High pitch \Leftrightarrow high frequency of vibration/oscillation

Is the relation between {perceived} pitch vs. frequency linear
e.g. a straight line $y = mx + b$ relation? No... see figure below:

Define "units" associated with *subjective* pitch = *mels* \Leftrightarrow analogous to *Hz*.



The Audible Frequency Range of Human Hearing (when young):

$$20 \text{ Hz} < f < 20 \text{ KHz} \quad (\simeq 3 \text{ orders of magnitude})$$

As we grow older, the dynamic range of frequencies we can hear decreases (both high and low frequencies – mostly on the high frequency end...)

Frequency ranges of musical instruments typically ~ 100 Hz to ~ few KHz

e.g. guitar Low E = 82 Hz
 High E = 330 Hz

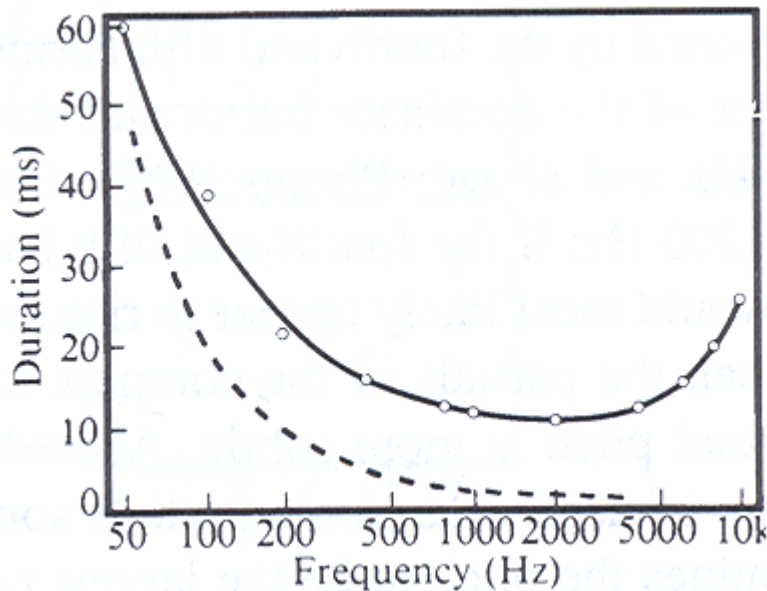
Piano highest note is ~ 4200 Hz

Very little above ~ 10 KHz (squeals & scrapes)

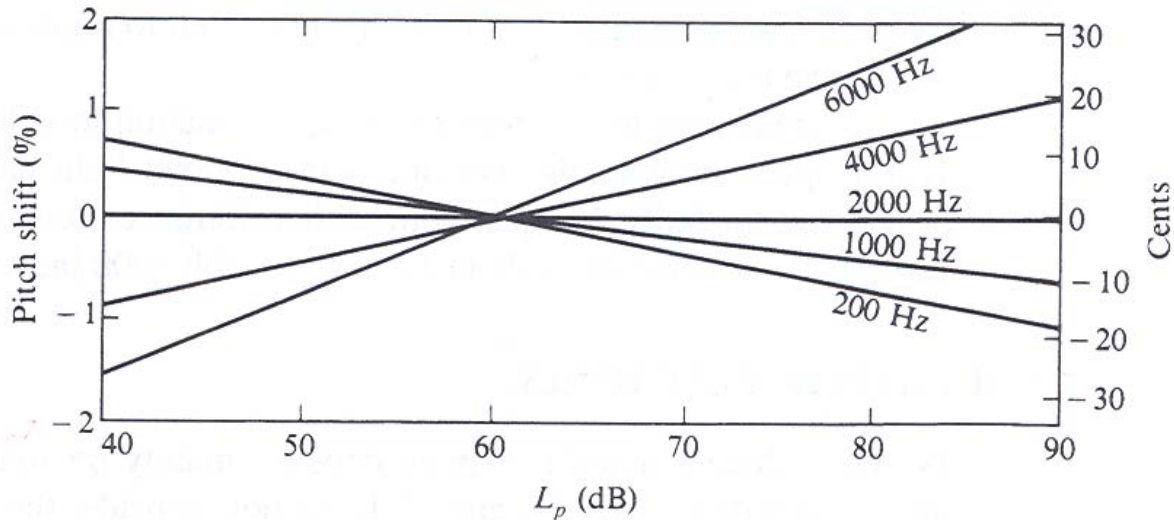
The human ear needs to be able to perceive a sound for minimum length of time. In order to determine pitch – this minimum time depends on frequency:

For $f \sim 100 \text{ Hz}$ ($\tau \sim 10 \text{ msec}$): $t_{\min} \sim 40 \text{ msec}$ (~ 4 cycles)

For $f \sim 1000 \text{ Hz}$ ($\tau \leq 1 \text{ msec}$): $t_{\min} \sim 13 \text{ msec}$ (~ 13 cycles)



- Perceived pitch also depends to some extent on the **loudness** of the sound.
- Effect arises due to non-linearities in the response of the ear.
 - Pitch appears to **decrease** slightly as loudness increases.
 - Effect exists only for pure/simple tones (!!!)
 - Complex tones show **no** perceived pitch changes with intensity! (why??)



Two ears of same person may **NOT** perceive sound of a given frequency as having the same pitch!!! = DIPLACUSIS – happens only for diseased, or injured ears. For **normal** musical purposes, frequency and pitch are synonymous (usually) — Applies to **periodic** sound vibrations.

Sound **pulses** are made up of a **continuum** of frequencies, sound **pulses** are thus **anharmonic** and hence have **no** characteristic frequency and/or pitch.

The human ear can discriminate **changes** in sound intensity levels of **JND** $\sim 1/2$ dB; Our ability to do so depends on frequency **and** sound pressure level/loudness:

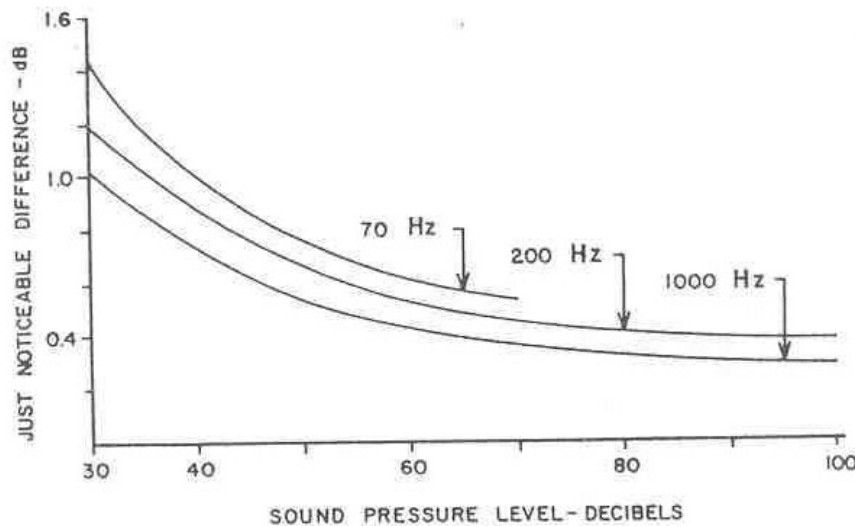
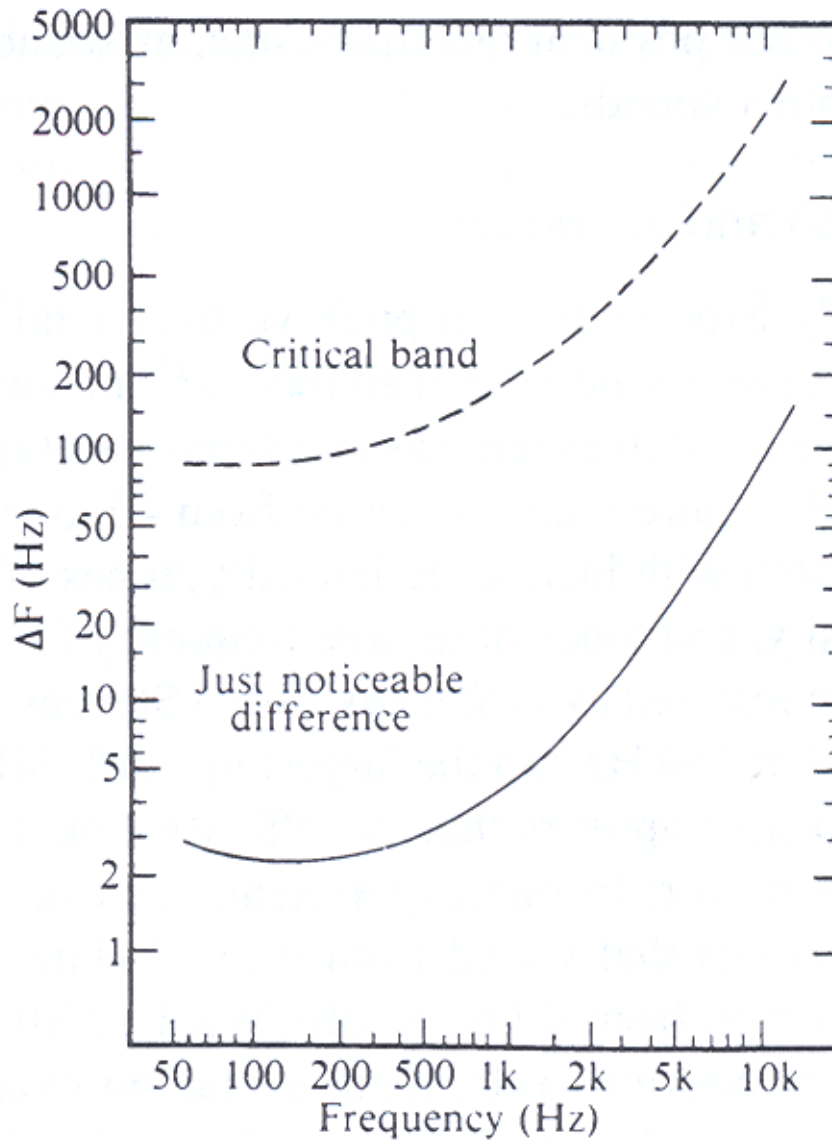


FIG. 2. Just noticeable difference in sound pressure level for three frequencies.

A *JND* $\sim 1/2$ *dB* change in sound intensity level corresponds to a fractional change in sound intensity of $\Delta I / I \sim 12\%$. Thus, due to its \sim logarithmic response, the human ear is not terribly sensitive to changes in the loudness of sounds.

The typical human ear can discern changes in pitch/frequency at the $\Delta f \sim 3$ Hz level in the frequency range $\sim 30 \leq f \leq 1000$ Hz. Again, has frequency dependence:



Note that:

At low frequencies: $\Delta f / f = 3/30 = 10\%$ ($\simeq 2$ semitones),

Whereas at higher frequencies: $\Delta f / f = 3/1000 = 0.3\%$ ($\simeq 0.1$ semitones)

A good musician can actually discern frequency changes that are ***much*** smaller than this – e.g. above $f \geq 500 \text{ Hz}$: ≈ 0.03 semitone!!!

\therefore The human ear/brain is capable of detecting small changes in frequency!!!

The human ear/brain is capable of perceiving a fundamental even when ***no*** fundamental is actually present!!!

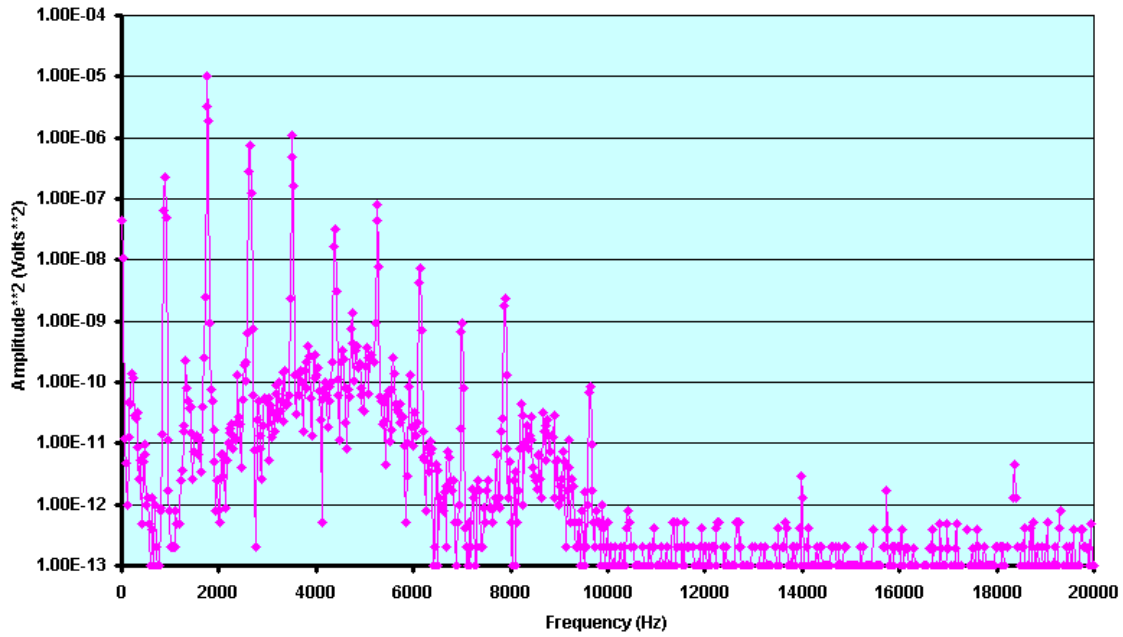
— This is the so-called ***missing fundamental effect***.

— This effect is consequence of effect of the non-linear response in/inside the human ear itself, and/or a non-linear response in the human brain's ***processing*** of frequency information – e.g. whenever a quadratic non-linear response exists (in any system), if two signals A and B with frequencies f_A and f_B are input to that system, sum and difference frequencies ($f_A + f_B$) and $|f_A - f_B|$ are produced! Thus a 2nd harmonic, $2f_1$ and a 3rd harmonic, $3f_1$ can produce a “missing” fundamental from the difference frequency, $|3f_1 - 2f_1| = f_1$!!! For further details on distortion, read e.g. Professor Errede's UIUC P498POM lecture notes on “Theory of Distortion I & II” – available on the web at:

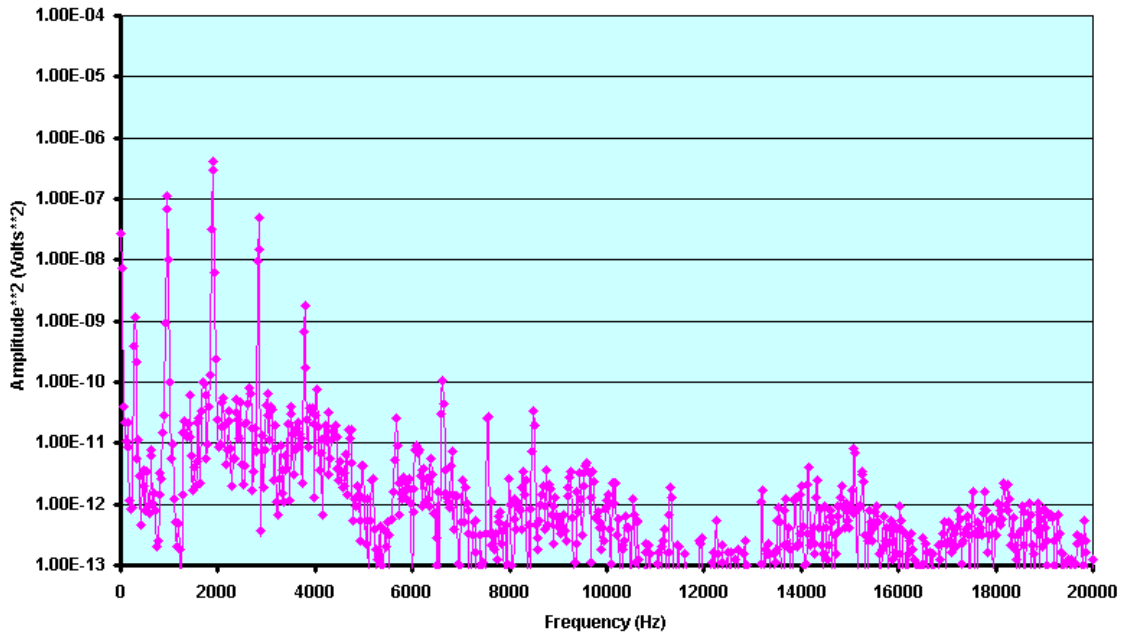
http://online.physics.uiuc.edu/courses/phys498pom/498pom_lectures.html

— For some musical instruments – e.g. the trumpet, the oboe and/or the bassoon – the 2nd (even 3rd) harmonics have a ***larger*** amplitude than that of the fundamental, however we perceive the “note” that is played on the trumpet (and/or oboe, bassoon) as that of the fundamental!!!

**Oboe A5
A**2 vs Frequency**



**Bassoon B5b
A**2 vs Frequency**



Note that the vertical axes are displayed on a logarithmic scale.

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