Sound and Music Science

Masking and Pitch

Masking

- When the ear is exposed to two or more different tones, it is common that one may mask the other
- Masking can be explained as an upward shift in the hearing threshold of the weaker tone by the louder tone and depends on the frequencies of the two tones

Masking continued

- Masking sometimes occurs for a split second
- Pure tones close together in frequency mask each other more than tones widely separated in frequency
- Pure tones of a higher frequency more effectively mask tones of a lower frequency

Masking continued

- The greater the intensity of the masking tone, the broader the range of frequencies it can mask
- Masking by a narrowband noise shows similar characteristics to masking by pure tones

Masking continued

- Masking by a broadband ("white") noise shows an approximately linear relationship between the degree of masking and noise level
- White noises can mask tones of all frequencies
- Forward masking refers to masking of a tone by a sound that ends a short time (20 or 30 ms) before the tone begins

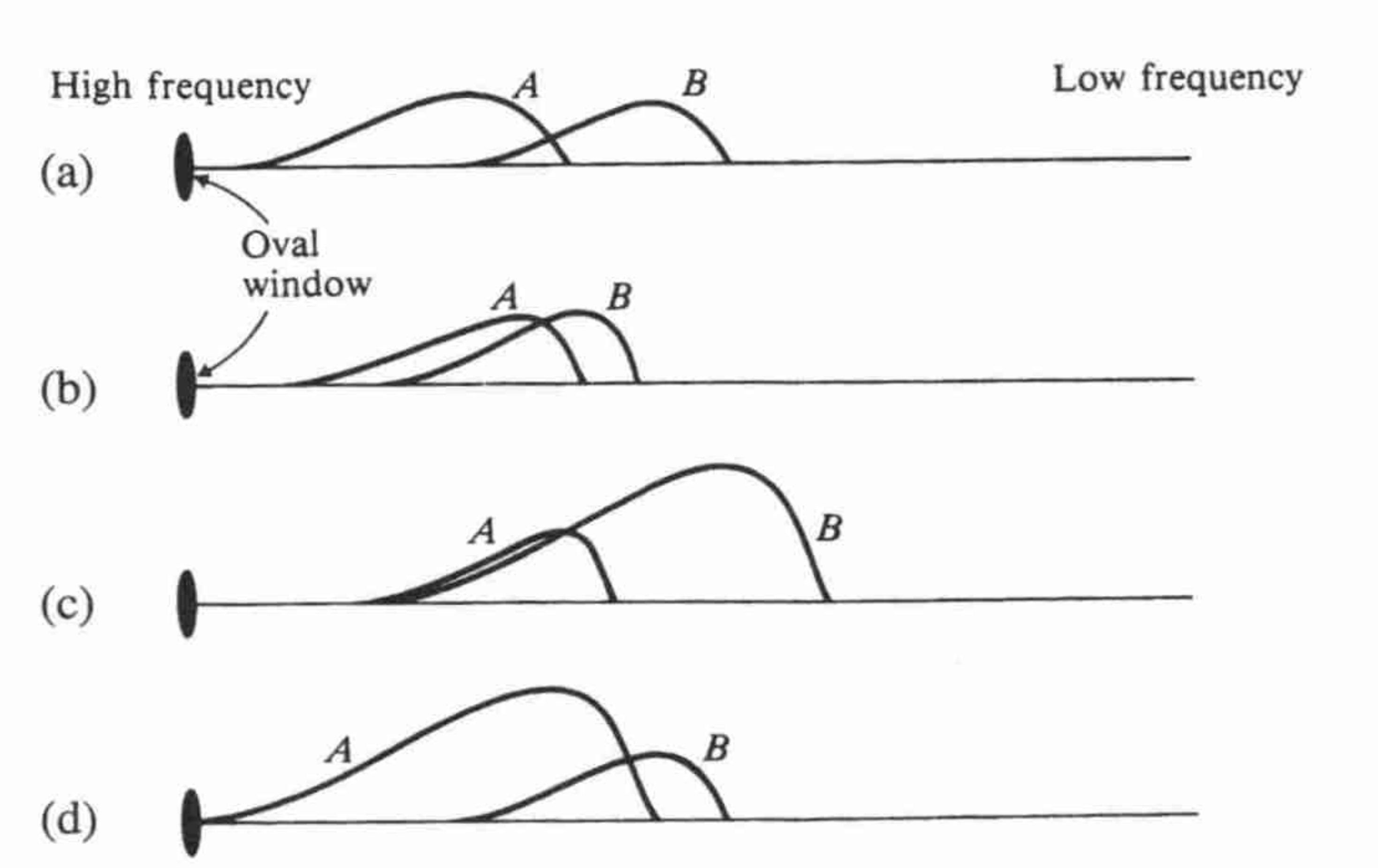
Masking continued

- Forward masking suggests that recently stimulated cells are not as sensitive as fully rested cells
- Backward masking refers to the masking of a tone by a sound that begins a few milliseconds later (up to 10 ms)

Masking continued

- Backward masking apparently occurs at higher centers of processing where the later occurring stimulus of greater intensity overtakes and interferes with the weaker stimulus
- Central masking is where masking of a tone in one ear can be caused by noise in the other ear (under certain conditions)

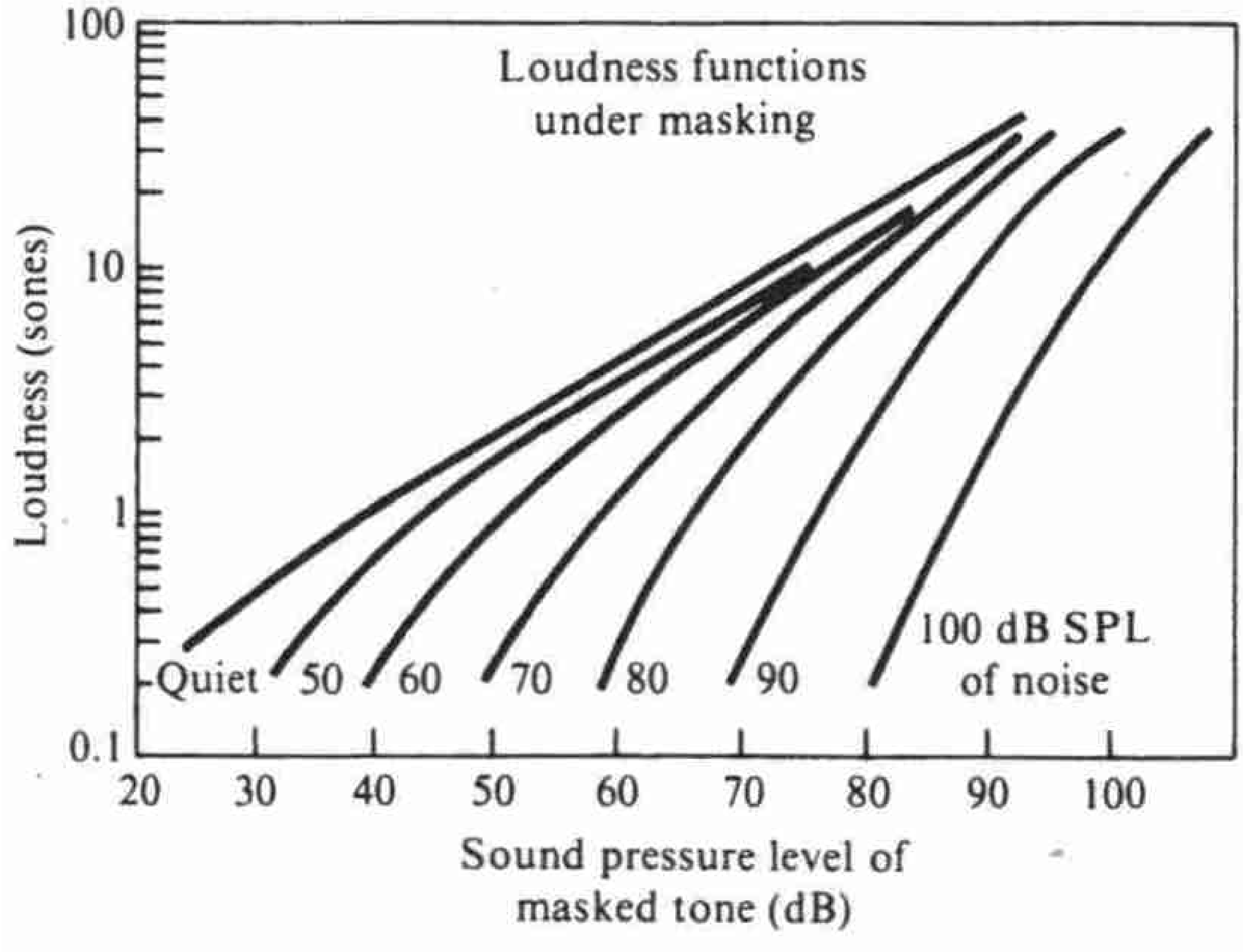
Masking continued



Loudness reduction by masking

- The presence of other sounds not only raises the threshold of hearing for a given sound but generally reduces its loudness as well (partial masking)
- This is quite evident for tones in the presence of background noise, where the loudness curve gets steeper with the increase in the level of the noise

Loudness reduction by Masking continued



Loudness and Duration

- Numerous experiments have shown that loudness level increases by 10dB when the duration of the sound is increased by a factor of 10
- The loudness level of broadband noise seems to depend somewhat more on the stimulus duration than the loudness level of pure tones

Acoustic Reflex

- The acoustic reflex occurs when the ear is exposed to sounds of 85 dB and more
- It does not occur until 30-40 ms after the sound overload occurs and full protection does not occur for another 150 ms
- Exposure to loud impulsive sounds (gunshot) causes the injury to the ear which cannot be prevented

Loudness and Duration continued

- Prolonged exposure to loud sounds causes adaptation
- It also affects our ability to hear another sound at a later time
- This is called fatigue and may result in both a temporary loudness shift (TLS) and a temporary threshold shift (TTS)
- TLS and TTS is greatest at a frequency a ½ octave higher than the fatiguing sound

Pitch

- Pitch is defined as that characteristic of a sound that makes it sound high or low or that determines its position on a scale
- A pure tone is a determined by a frequency
- A complex tone depends on the spectrum (timbre) of the sound and its duration

Pitch continued

- Pitch is a subjective the sensation
- Some listeners even assign pitch differently depending upon whether the sound was presented to the right or left ear (binaural diplacusis)
- The basic unit is the octave

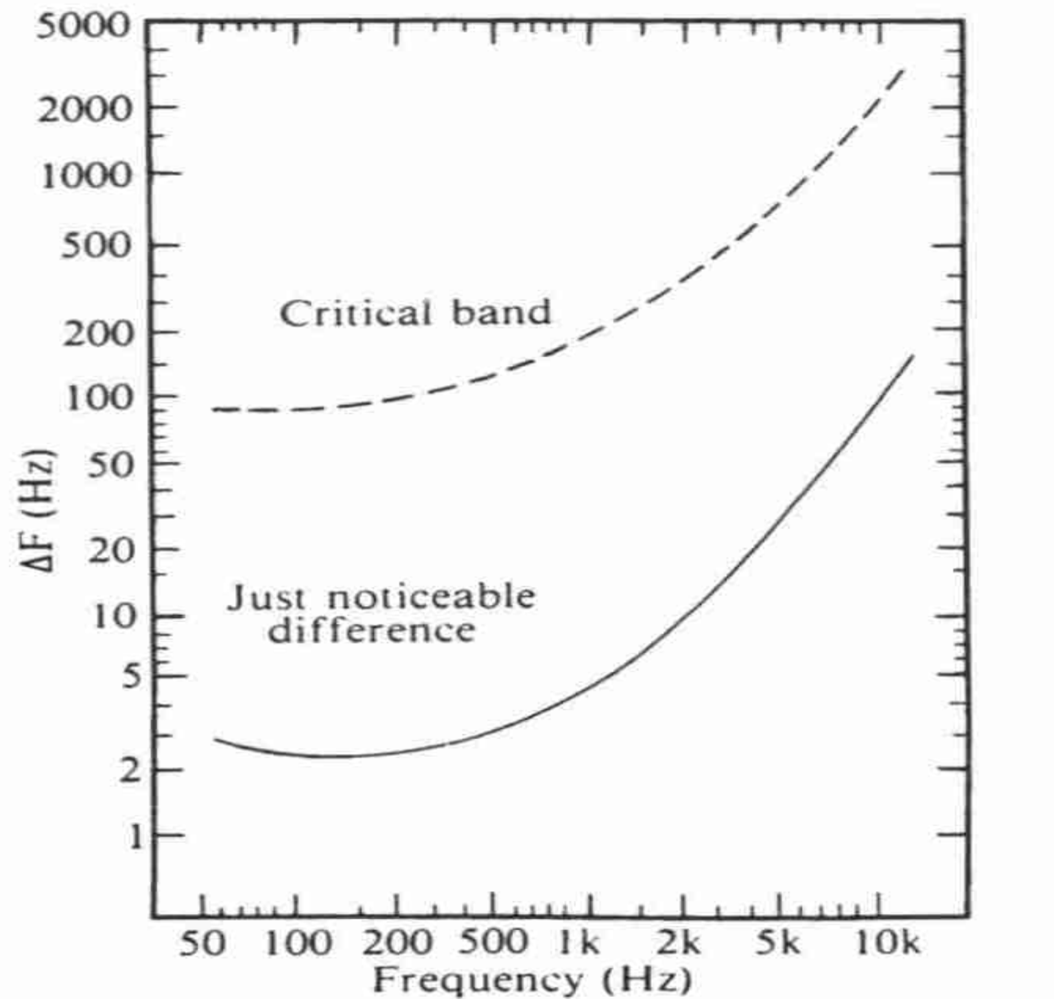
Pitch Discrimination

- Two sounds are judged the same if they differ by less than a **difference limen** or **just-noticeable difference** (jnd)
- The jnd for pitch depends on the frequency, sound level, duration and the suddenness of the frequency change
- It also depends on the training of the listener and the method of measurement

Pitch Discrimination continued

- The jnd is sometimes denoted as the **frequency resolution** (Δf/f)
- Comparing the critical band to the jnd curves reveal that they are similar and are off by 30 limens at all frequencies
- This suggests that the ear has a similar mechanism
- 10 octaves are covered by 5000 jnd

Pitch Discrimination continued



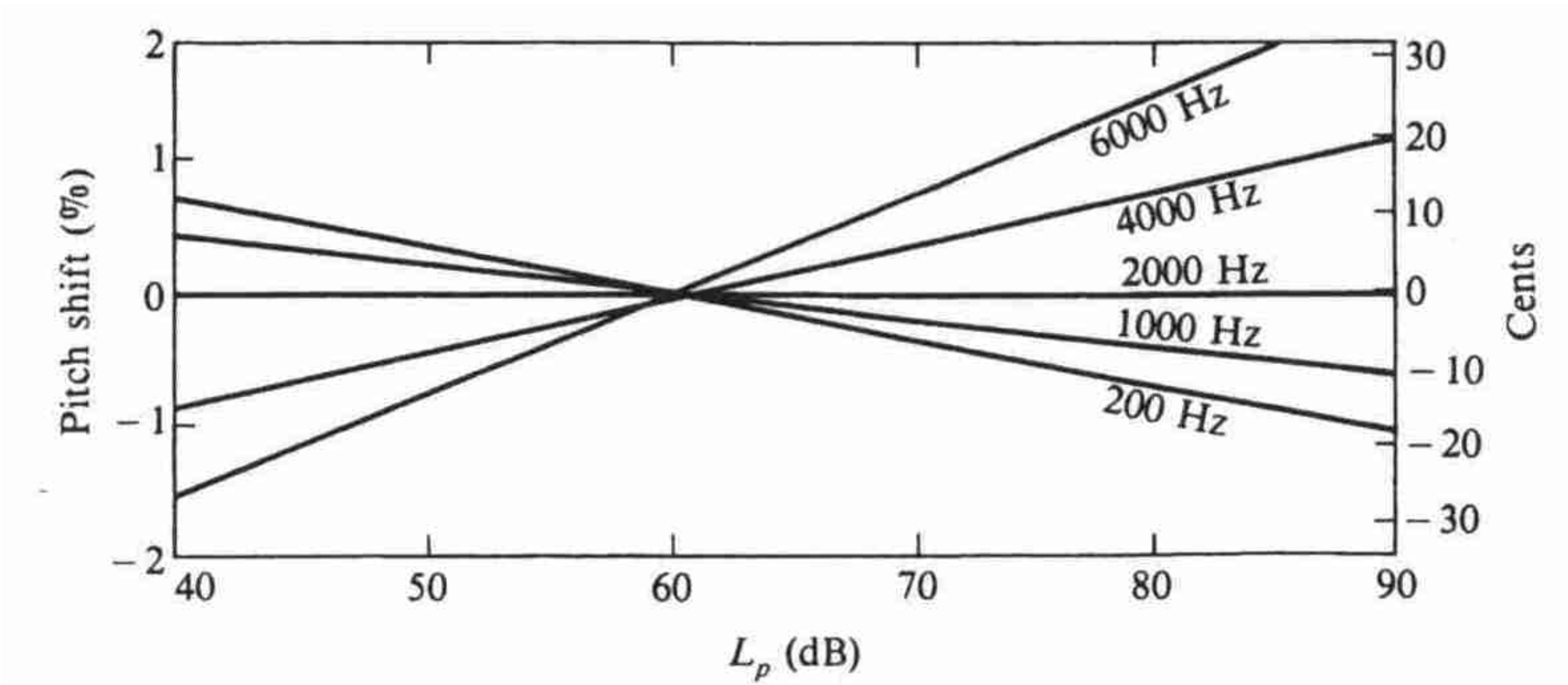
Pitch and Sound Levels

- Experiments show that there are slight pitch changes (perceived) when sound level changes
- Tones of low frequency fall with increasing intensity, whereas tones of high frequency rise with increasing intensity
- The maximum downward shift occurs at 150 Hz and the largest upward shift occurs at 8000 Hz
- No shift occurs for middle frequencies (1-2 kHz)

Pitch and Sound Level continued

- The shift for pure tones is between 0- 75 cents when a 250 Hz tone is increased from 40 to 90 dB
- It is about 17 cents for an increase of 65 to 95 dB for a complex tone
- Whether the pitch of a complex tone rises or falls with increasing intensity depends on which partials (above 1000 Hz) are predominant

Pitch and Sound Level continued



Pitch and Sound Level continued

- Increasing the amplitude of a short tone burst causes a downward shift in pitch over a wide range of frequency
- Pitch change has also been observed during reverberant decay, which is due in part to a change in sound level
  - e.g. A pipe organ's pitch seems to rise when the sound level diminishes after a loud chord ends in churches with substantial reverberation

Pitch and Duration

- Being able to identify pitch accurately depends on the duration of the note as well as the intensity
- It takes the ear about 3 ms to recognize a pitch if the tones does not begin abruptly
- The ear is sensitive to changes in the pitch of a pure tone and even more sensitive to pitch changes of narrow band noises

Pitch and Duration continued

- The ear is extremely sensitive to frequency changes in pure tones
- The jnd for frequency changes in pure tones is less than for noise, provided that the amplitude of the pure tone remains constant
- The jnd for a narrow band noise (10 Hz with center frequency of 1500 Hz) is 6 times greater than that of a pure tone

Pitch and Envelope

- The perceived pitch of a short exponentially decaying sinusoidal tone is found to be higher than a simple sine tone with the same frequency and energy
- Same is true for sinusoidal tones rising exponentially
- Pitch change depends on sound pressure level as well as rate of rise or fall of the envelope

Pitch and Envelope continued

- For a pure tone in the presence of an interfering tone/noise the following applies:
  - If the interfering tone has a lower frequency, there is an **upward** shift
  - If the interfering tone is above, a **downward** shift is observed at low frequencies

Pitch and Envelope continued

- For interfering noises always cause an upward shift if they have a lower frequency, but if it has a high frequency, shift can go in either direction
- The pitch shift increases with the amount by which the interfering tone/noise amplitude exceeds that of the test tone

Virtual Pitch

- If the a tone comprised of exact harmonics are presented, the ear perceives the missing fundamental (the lowest common factor)
- The perceived missing fundamental is called a virtual pitch
- This is very evident in the use of undersized loudspeakers such as those found in portable radios

Virtual Pitch continued

- Strong fundamentals are not essential for perceiving the pitch
- Experiments have shown that for fundamentals up to 200 Hz, the fourth and fifth harmonics are essential for determining the fundamental frequency
- As the frequency of the fundamental increases, the number of dominant harmonics decreases

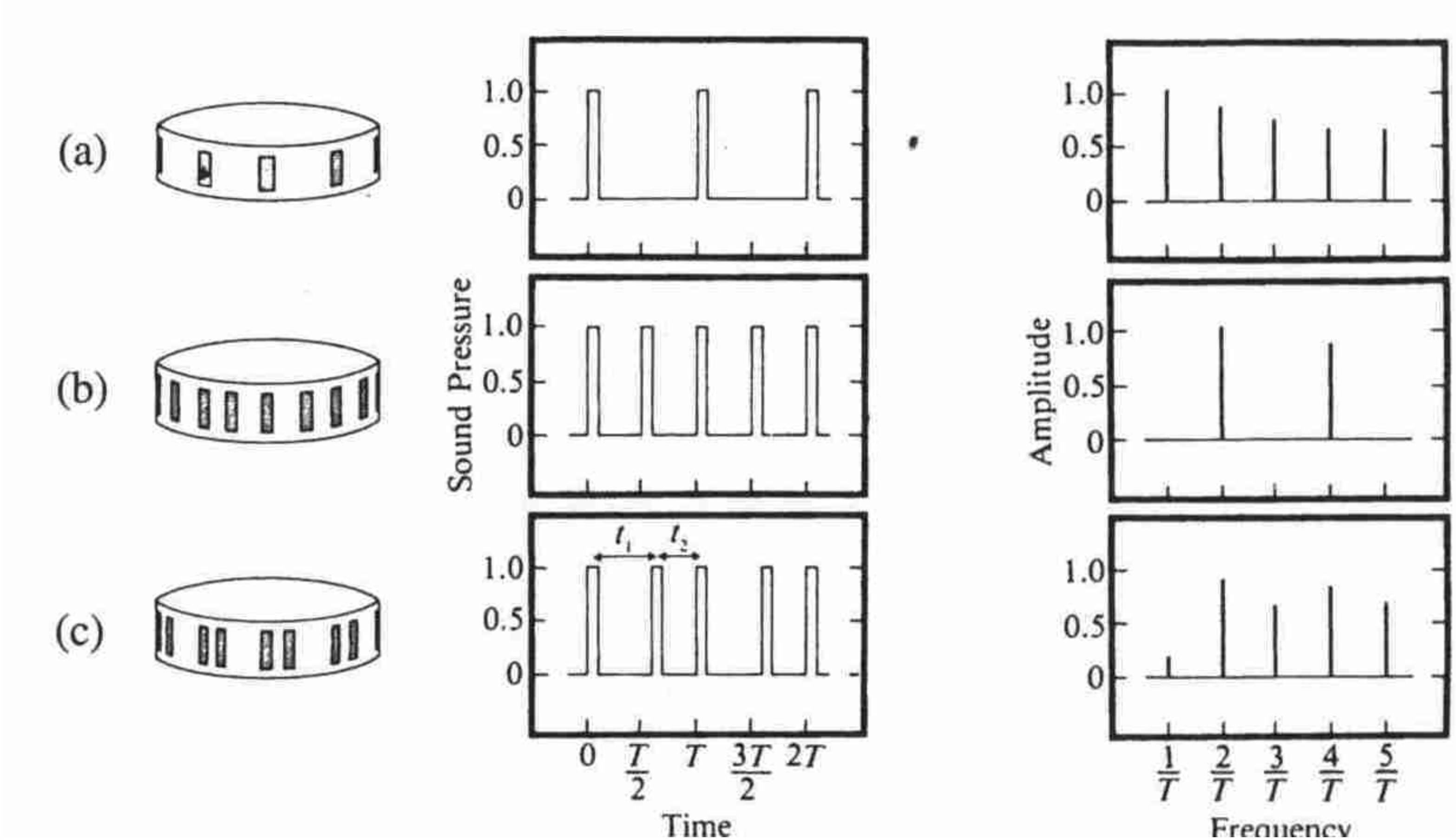
Virtual Pitch continued

- For A_3 for example, if you increase the frequency of the fourth and fifth harmonics, the pitch appears to rise even though the fundamental remained at 220 Hz

Seebeck's Siren

- Seebeck performed a series of experiments on pitch perception that produced some significant but surprising results
- The siren consisted of a rotating disc with periodically spaced holes that created puffs of compressed air at regular intervals

Seebeck's Siren continued



Seebeck's Siren continued

- This produced a very strong pitch corresponding to the time between puffs of air
- Doubling the number of holes raised the pitch by exactly an octave
- However, using a disk with unequal spacing of holes produced an unexpected result

Seebeck's Siren continued

- As shown in (c) on the figure, the pitch matched that shown in (a)
- By looking on the spectrum, it is clear that they have the same harmonics, with different values
- The period in (c) is $T = t_1 + t_2$
- The harmonics are therefore the same, however, the fundamental is weaker

Seebeck's Siren continued

- If we repeat the experiment using an electronic pulse generator, the lower tone is heard an octave lower, becoming softer as t_2 approaches t_1
- The lower tone disappears at $t_2 = t_1$
- The upper tone remains relatively constant in loudness