Lecture 3

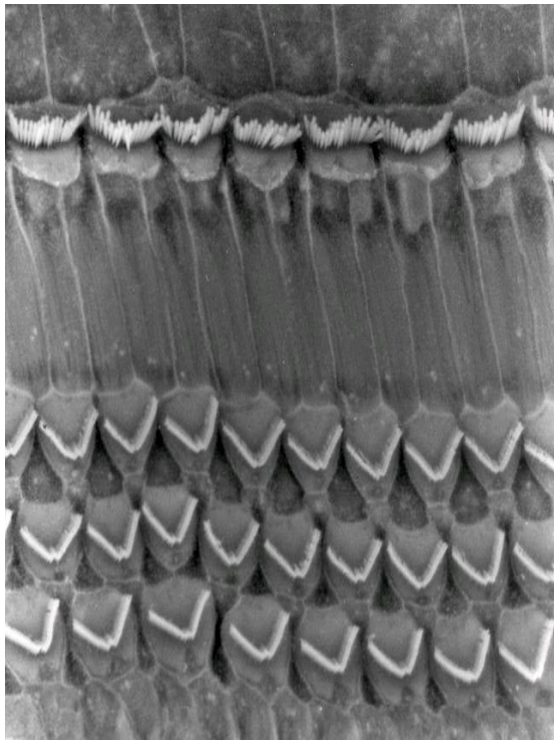
Issues faced by people with a Sensorineural Hearing Loss

Outline

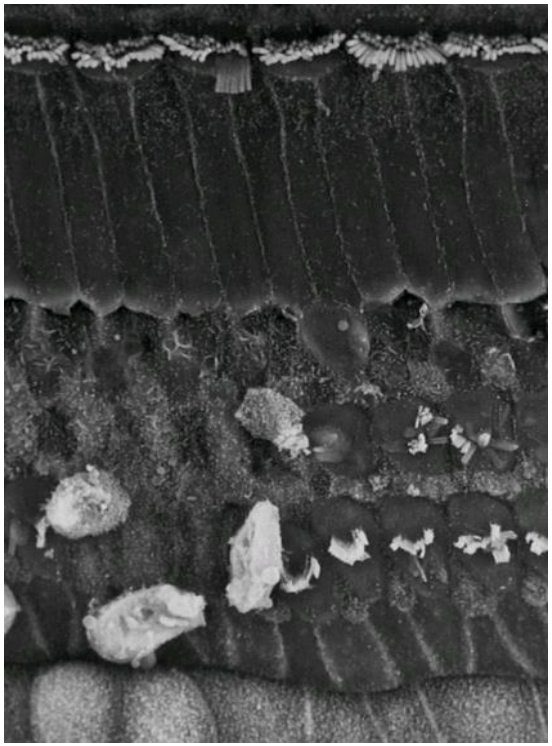
- Issues faced by people with a Sensorineural Hearing Loss

1. Decreased Audibility
2. Decreased Dynamic Range
3. Decreased Frequency Resolution
4. Decreased Temporal resolution

Damage to cilia of the hair cells



a) Normal hearing



b) Severe hearing loss

1. Decreased Audibility

- Hearing impaired people do not hear some sounds at all.

- People with severe or profound hearing loss may not hear any speech sounds, unless they are shouted at close range.

1. Decreased Audibility

- Hearing impaired people also have trouble understanding speech because essential parts of some phonemes are not audible.
- Sounds are recognized by noting which frequencies contain the most energy.
- The vowel oo for example, is differentiated from the vowel ee by the location of the second intense region or formant.

1. Decreased Audibility

- If for example, a hearing loss caused all frequencies above 700 Hz to be inaudible, as indicated by the shaded region.

- Although both sounds could be detected, the similarity of their first formants would make them sound almost identical.

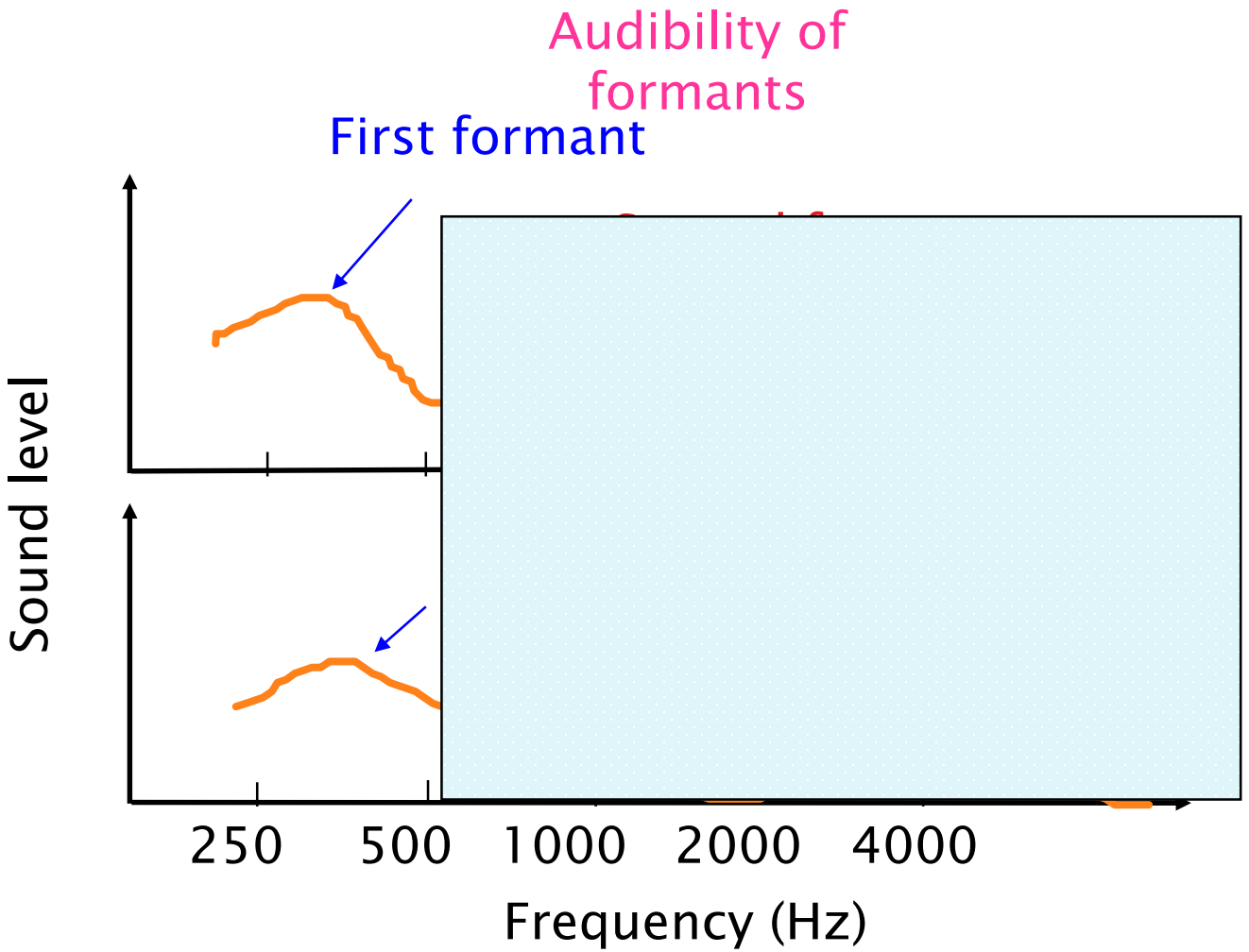


Figure 1.1 Similarity of the two vowels *oo* and *ee* when the second formant is inaudible because of hearing loss (grey area).

Source: Dillon (2001): *Hearing Aids*

1. Decreased Audibility

- The high frequency components of speech are weaker than the low frequency components.

- Furthermore, for approximately 90% of hearing impaired people, the degree of impairment worsens from 500 Hz to 4000 Hz.

1. Decreased Audibility

- To help overcome this difficulty, a hearing aid has to provide more amplification for frequencies where speech has the weakest components and where hearing loss is the greatest.

Dynamic Range of Hearing

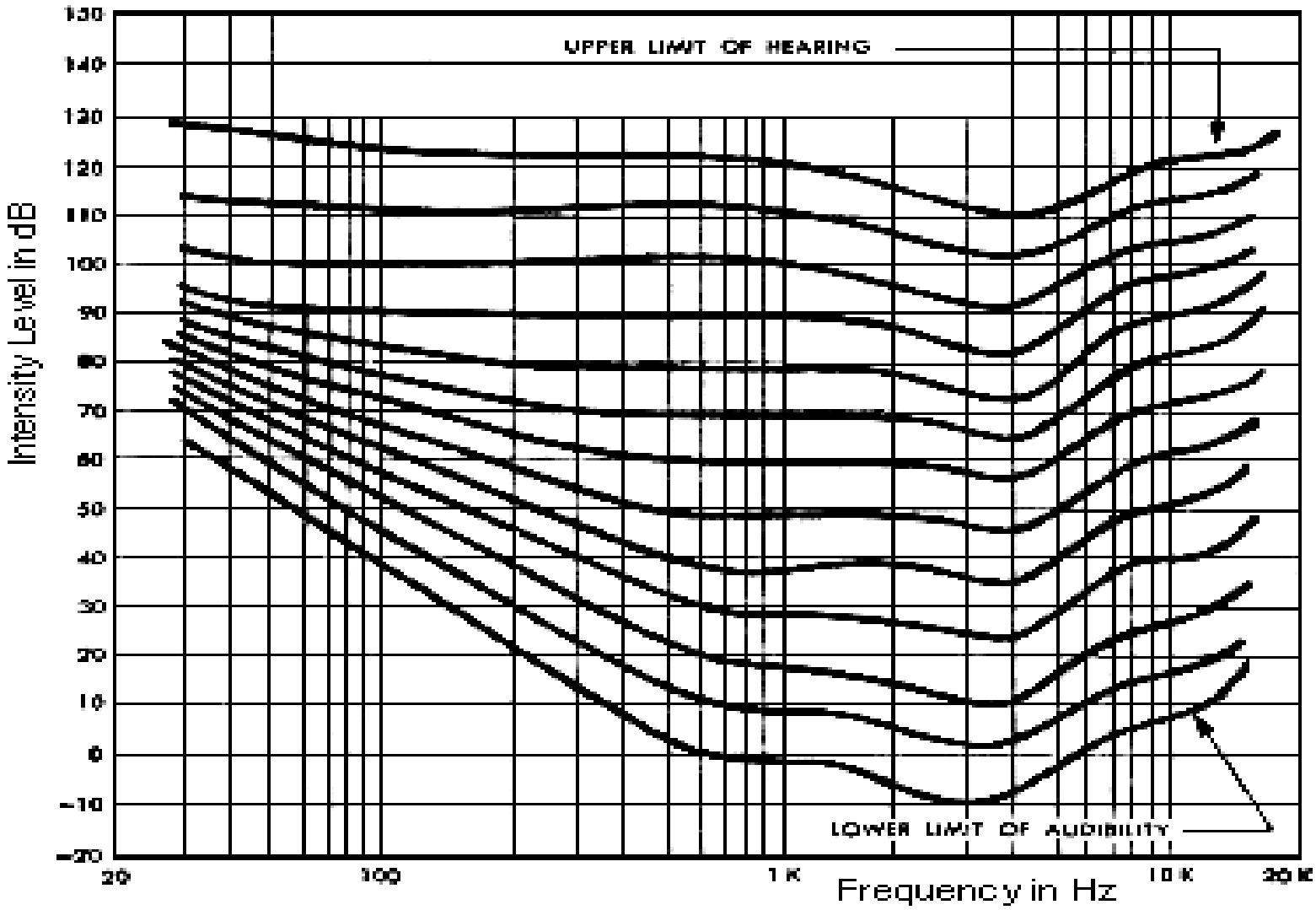
- The practical dynamic range could be said to be from the threshold of hearing to the threshold of pain

- Sound level measurements in decibels are generally referenced to a standard threshold of hearing at *1000 Hz* for the human ear which can be stated in terms of sound intensity.

Equal Loudness Contours

- An **equal-loudness contour** is a measure of sound pressure (dB SPL), over the frequency spectrum, for which a listener perceives a constant loudness when presented with pure steady tones.

Equal Loudness Contours



Equal Loudness Contours

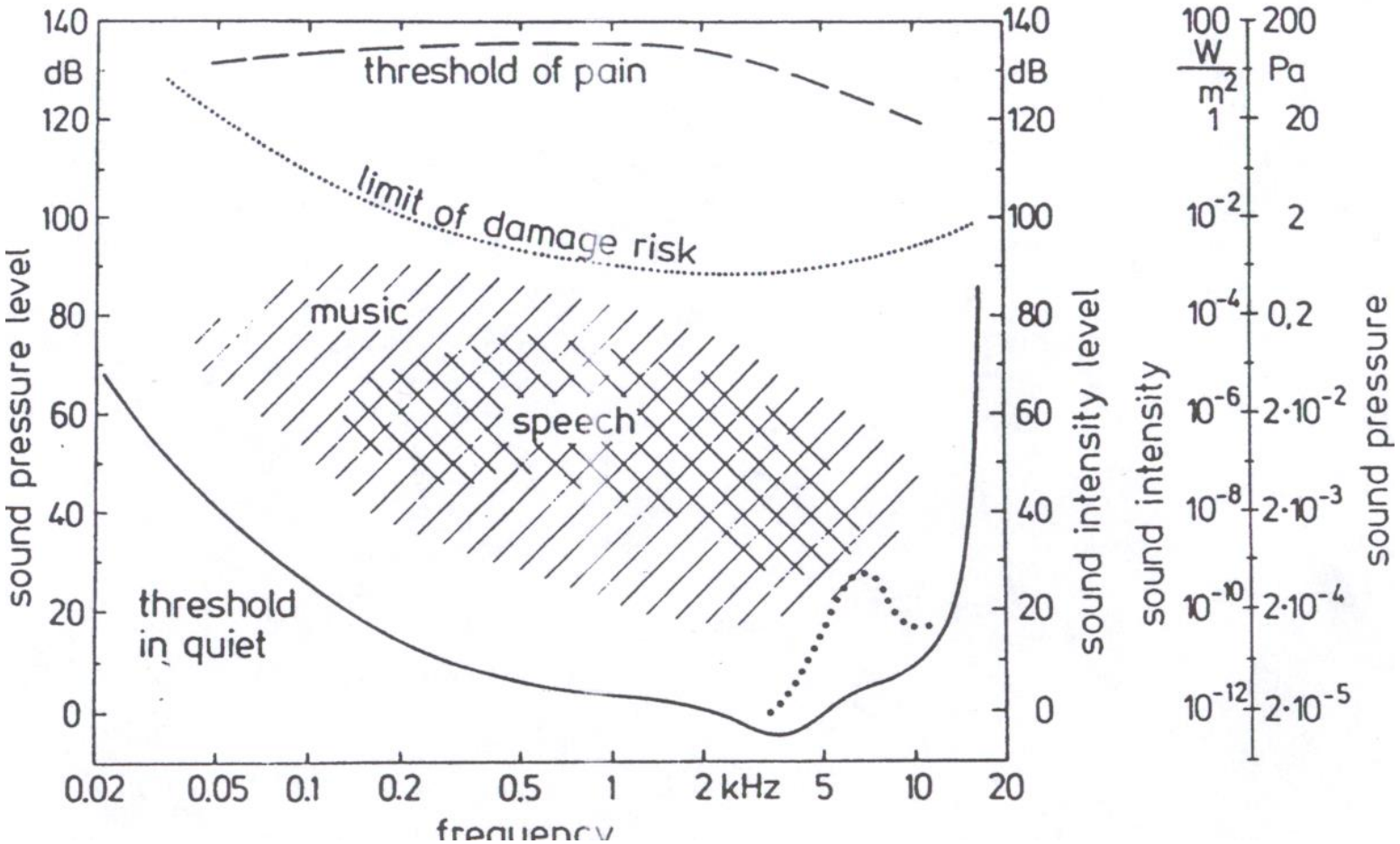
- The hearing curves show a significant dip in the range 2000-5000 Hz with a peak sensitivity around 3500 -4000 Hz. This is associated with the resonance of the auditory canal.

2. Decreased Dynamic Range-

- Threshold of Hearing 0dB
- Threshold of Pain 130 dB

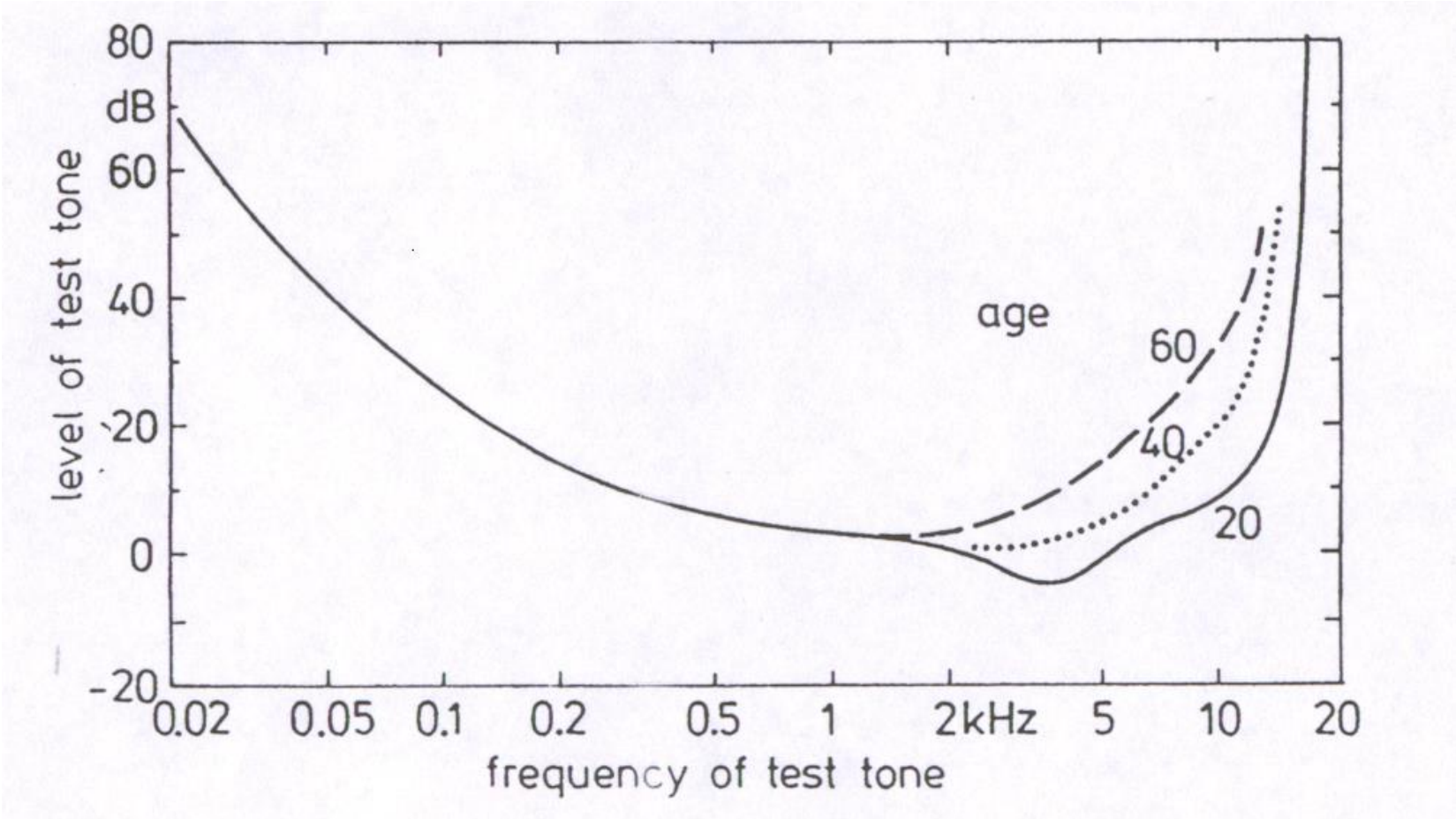
- A sensorineural hearing loss increases the threshold of hearing much more than it increases the threshold of loudness discomfort.

Threshold of hearing



Threshold of hearing at 1,000 Hz is 0 dB

Decreased Dynamic Range/Recruitment



2. Decreased Dynamic Range–

- Consequently, the dynamic range of an ear, the level difference between discomfort and the threshold of audibility, with a sensorineural impairment will be less than that of a normal hearing ear.

Reduced dynamic range

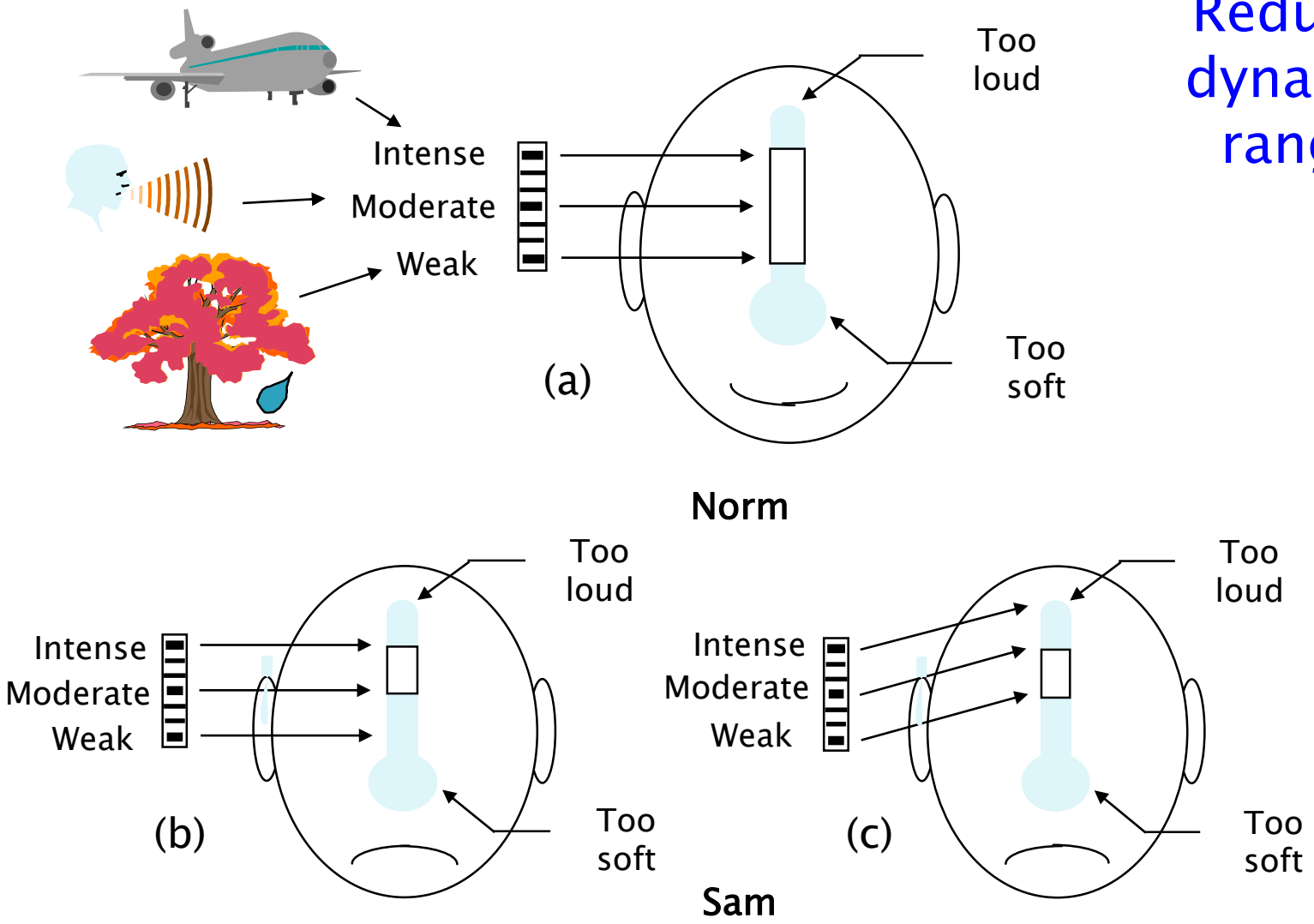


Figure 1.2 The relationship between the dynamic range of sounds in the environment and the dynamic range of hearing for: (a) normal hearing, (b) sensorineural hearing loss without amplification, and (c) sensorineural hearing loss with a constant amount of amplification for all input levels.

Source: Dillon (2001): *Hearing Aids*

Decreased Dynamic Range/Recruitment

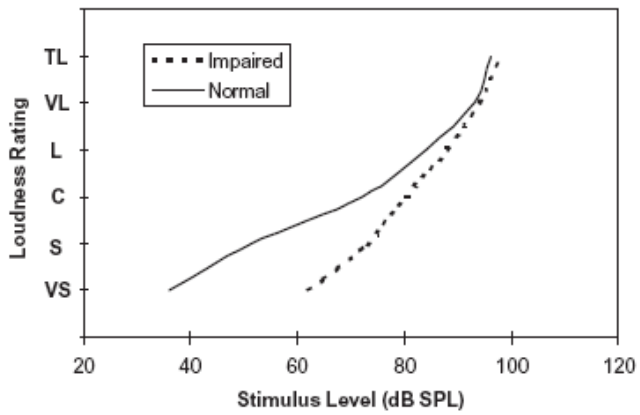


Figure 7.1. Typical loudness growth functions for a normal-hearing person (solid line) and a hearing-impaired person (dashed line). The abscissa is the sound pressure level of a narrowband sound and the ordinate is the loudness category applied to the signal. VS, very soft; S, soft; C, comfortable; L, loud; VL, very loud; TL, too loud.

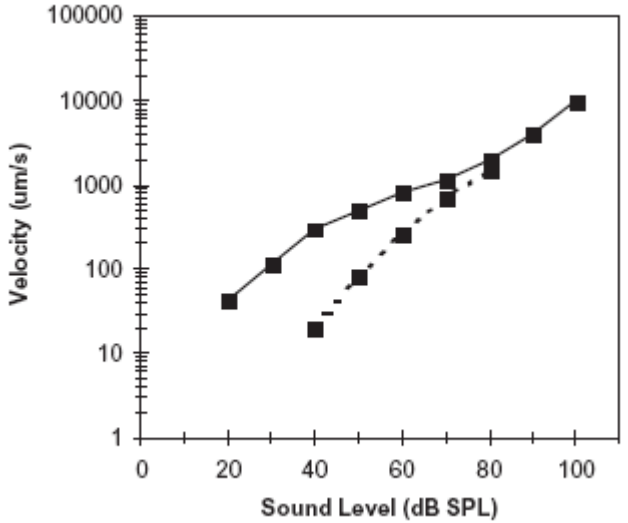


Figure 7.2. The response of a healthy basilar membrane (solid line) and one with deadened outer hair cells (dashed line) to best-frequency tone at different sound pressure levels (replotted from Ruggero and Rich 1991).The slope reduction in the mid-level region of the solid line indicates compression; this compression is lost in the response of the damaged cochlea.

Decreased Frequency Resolution-

- Another difficulty faced by people with sensorineural hearing loss is separating sounds of different frequencies. Different frequencies are represented most strongly at different places within the cochlea.

- In an unimpaired cochlea, a narrow band sound produces a clearly defined region of relatively strong vibration at one position on the basilar membrane.

Decreased Frequency Resolution-

- If a background noise contains some energy at a nearby frequency, the normal hearing ear can do a good job of sending separate signals to the brain, one signal for each region of intense activity in the cochlea.

- The ear has frequency selectivity or frequency resolution, which enables the brain to separate speech from noise.

Decreased Frequency Resolution-

- A person with sensorineural hearing loss has decreased frequency resolution.
- This occurs because the outer hair cells lose their ability to increase the sensitivity of the cochlea.

Decreased Frequency Resolution-

- Psychoacoustically, this shows up as flatter masking curves and tuning curves.
- The significance of this is that even when a speech component and a noise component have different frequencies, if these frequencies are close enough, the cochlea will have a single broad region of activity rather than two finely tuned separate regions.
- Consequently, the brain is unable to untangle the signal from the noise.

Reduced spectral resolution

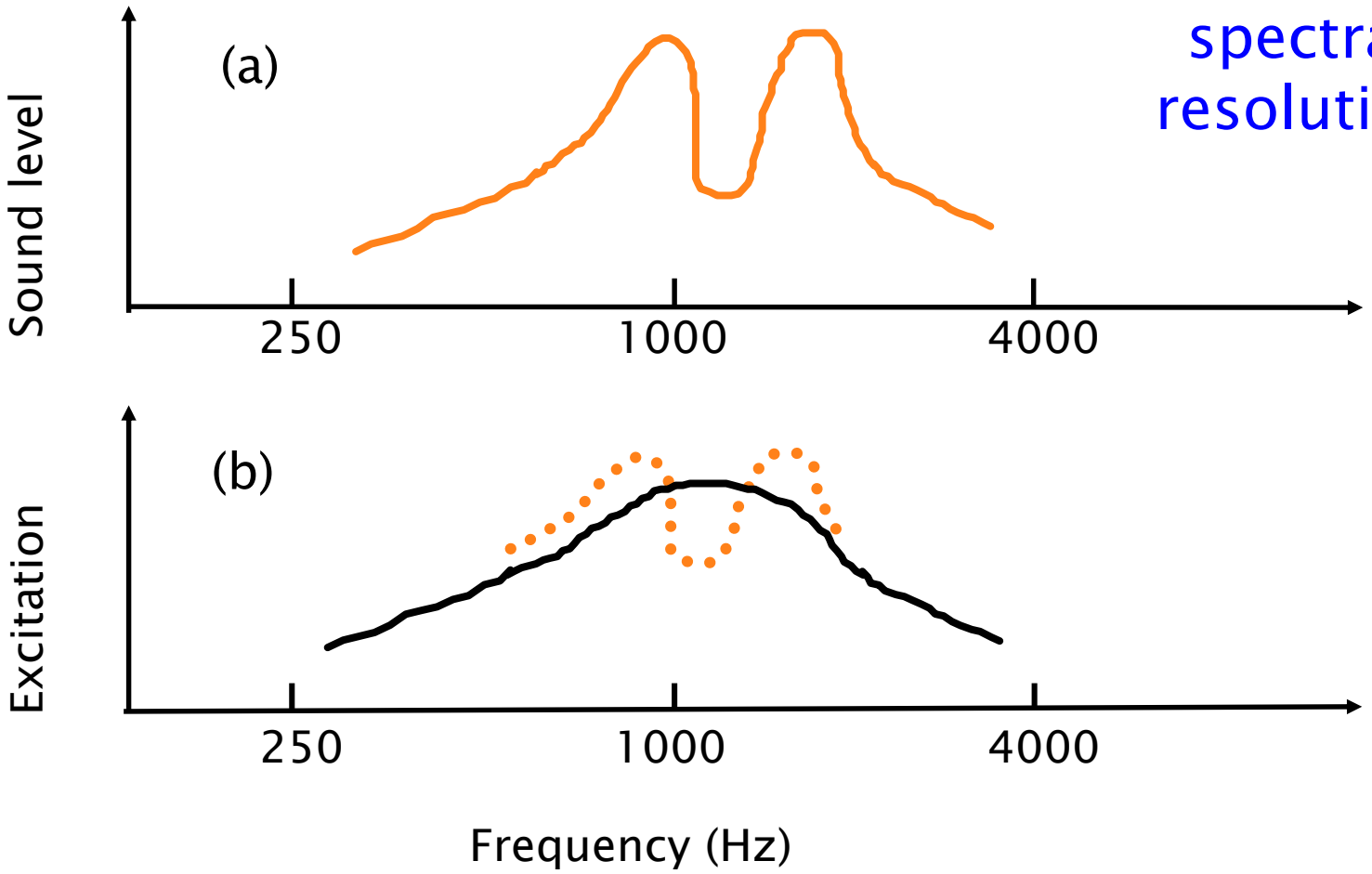


Figure 1.3 (a) Sound spectrum, and (b) representation in the auditory system for normal hearing (dotted line) and sensorineural hearing impairment (solid line).

Source: Dillon (2001): *Hearing Aids*

Decreased Frequency Resolution-

- There does not even need to be any noise for decreased frequency resolution to adversely affect speech understanding.
- If frequency resolution is sufficiently decreased, relatively intense low frequency parts of speech may mask the weaker higher frequency components.
- This is referred to as upward spread of masking.

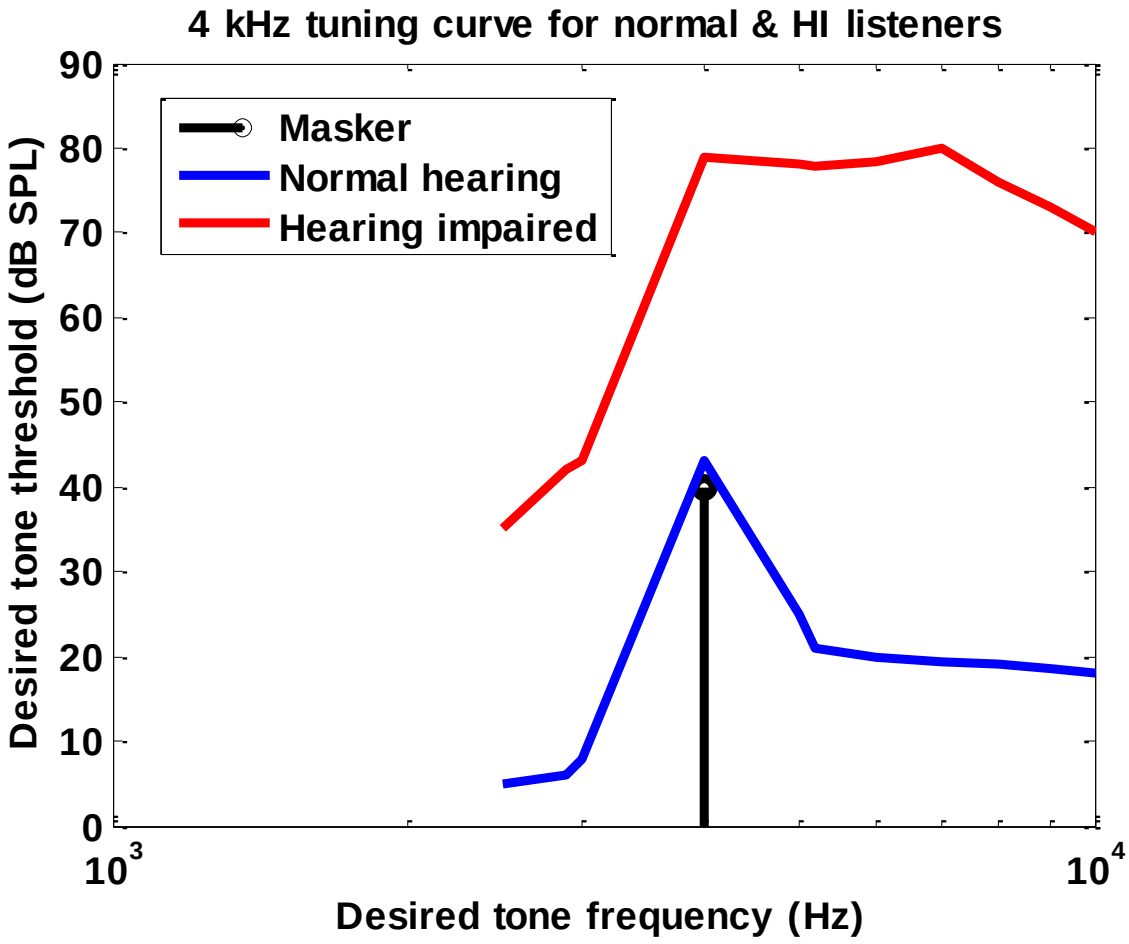
Decreased Frequency Resolution-

- There is a second reason why decreased frequency resolution is a problem.
- Even normal hearing people have poorer resolution at high intensity levels than at lower levels.
- Hearing impaired people, especially those with severe and profound hearing loss, have to listen at high levels if they are to achieve sufficient audibility.

Decreased Frequency Resolution-

- Consequently, hearing impaired people difficulty in separating sounds is partly caused by their damaged cochlea and partly due to their need to listen at elevated levels.

3) Frequency resolution



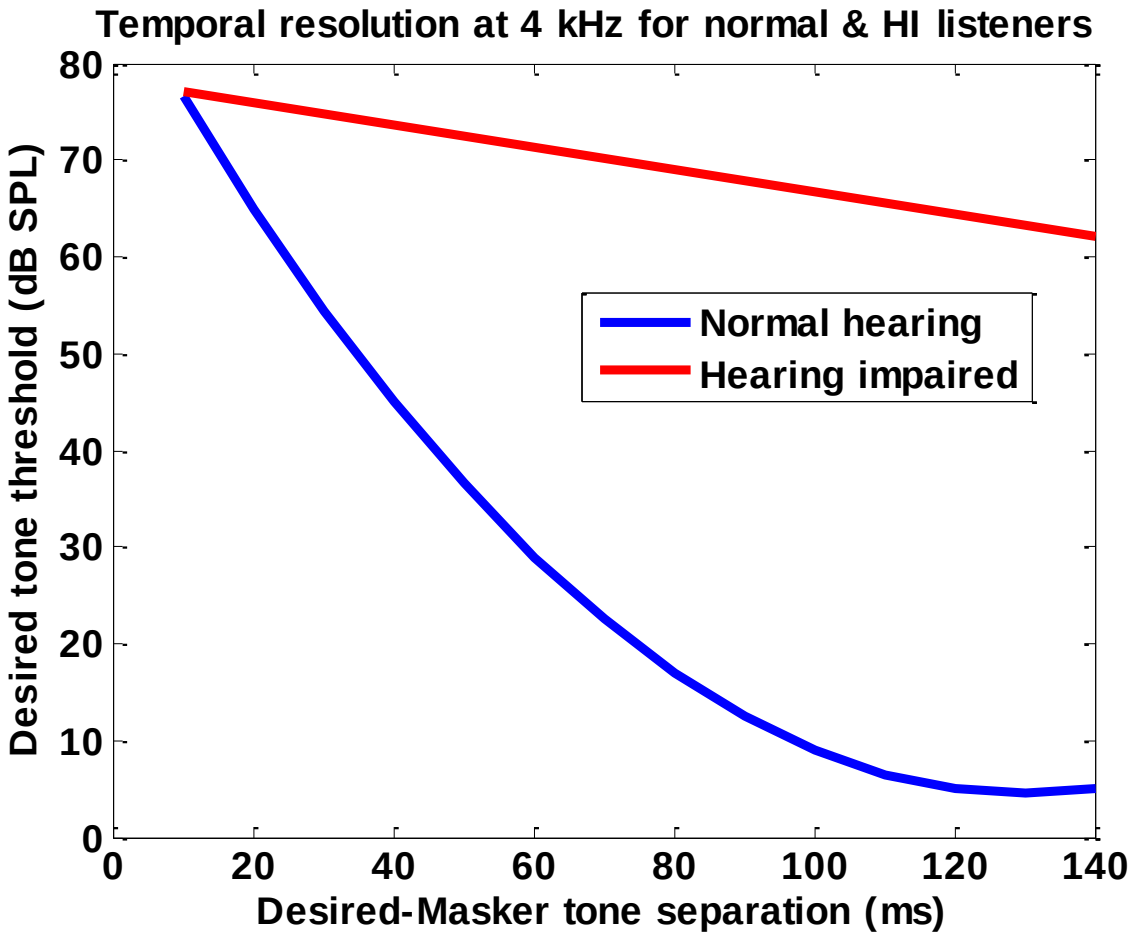
Decreased Temporal Resolution-

- Intense sounds can mask weaker sounds that immediately precede them or immediately follow them. This adversely affects speech intelligibility.

- Many real life background noises fluctuate rapidly, and normal hearing people extract useful pieces of information during the weaker moments of the background noise.

- Hearing-impaired people partially lose this ability to hear during the gaps in a masking noise, particularly if they are elderly.

4) Temporal resolution



Deficits in combination:

- Each of the above aspects of a hearing loss (decreased audibility, dynamic range, frequency resolution and temporal resolution) can cause a reduction in intelligibility.

- In combination, they can cause a hearing-impaired person to understand much less than a normal hearing person in the same situation, even when the hearing impaired person is wearing a hearing aid.

Deficits in combination:

- Looked at another way, the hearing-impaired person needs a better signal-to-noise ratio (SNR) than does a normal-hearing person, if both people are to understand the same amount of speech.

Deficits in combination:

- On average, the SNR required for a given level of speech intelligibility increases as the amount of sensorineural hearing loss increases.

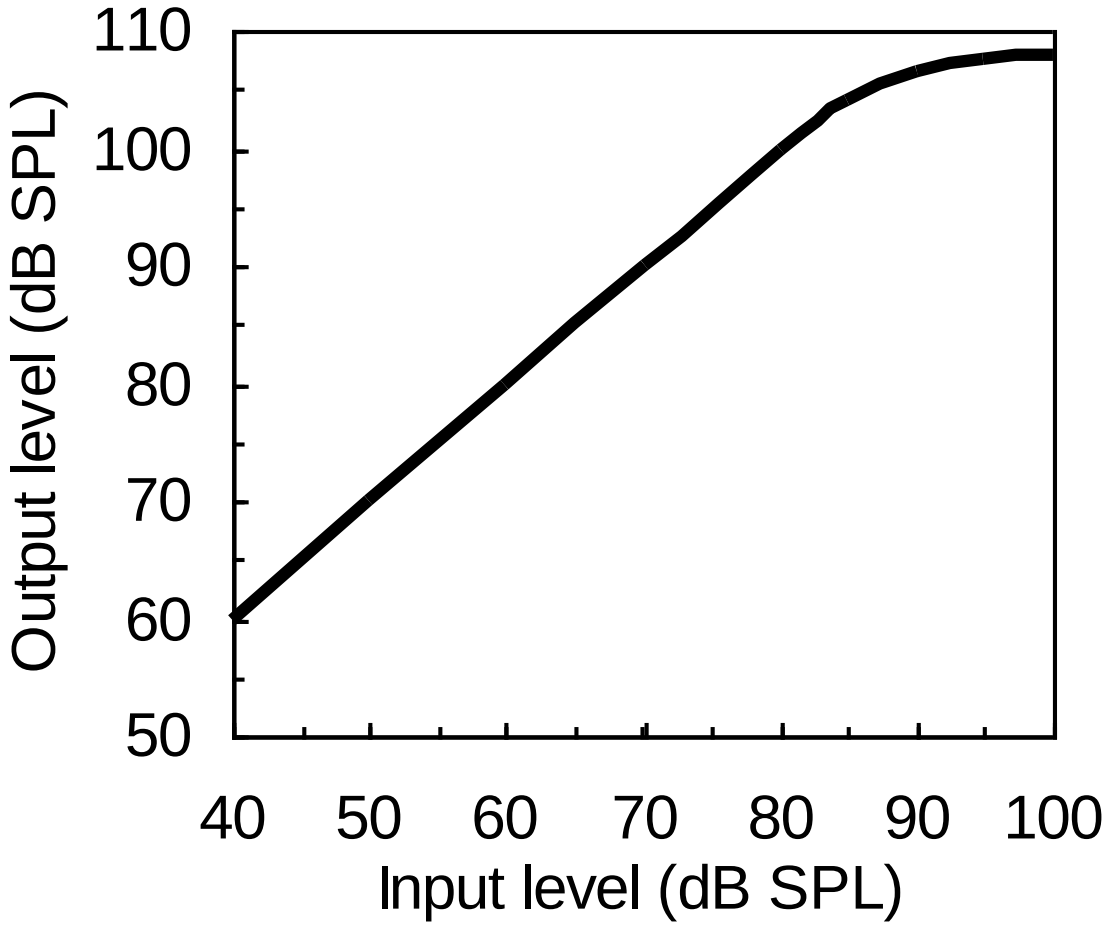
- The average SNR deficit associated with a mild hearing loss is estimated to be about 4 dB, and the average deficit associated with a severe hearing loss is estimated to be about 10 dB.

Deficits in combination:

- Despite these average trends, some individuals require a far higher or lower SNR than others with the same pure tone hearing loss.

- The situation is far simpler with conductive losses. These appear to cause a simple attenuation of sound, so that provided the hearing aid can adequately amplify sound, the normal cochlea can resolve sounds entering it just as well as the cochlea of someone with normal hearing.

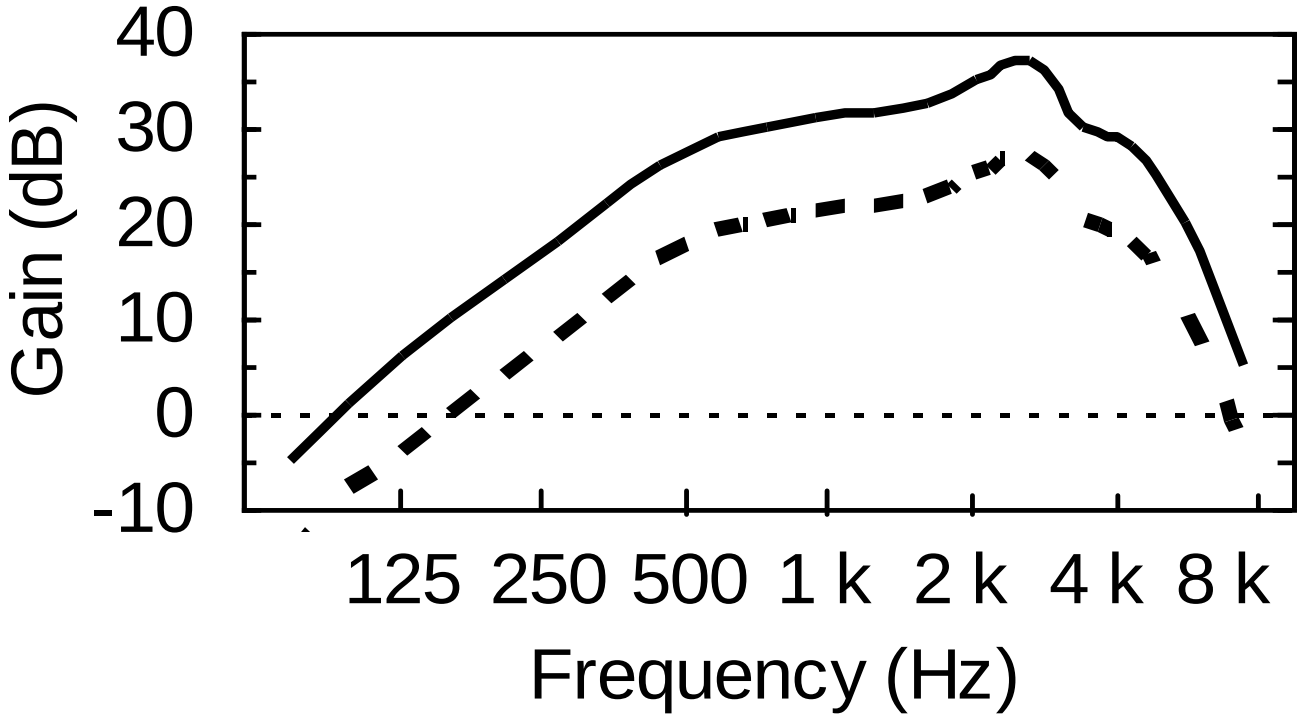
I–O diagram



Input–output diagram for a hearing aid with 20 dB gain, showing how the output SPL depends on the input SPL, for a particular signal or frequency.

Source: Dillon (2001): *Hearing Aids*

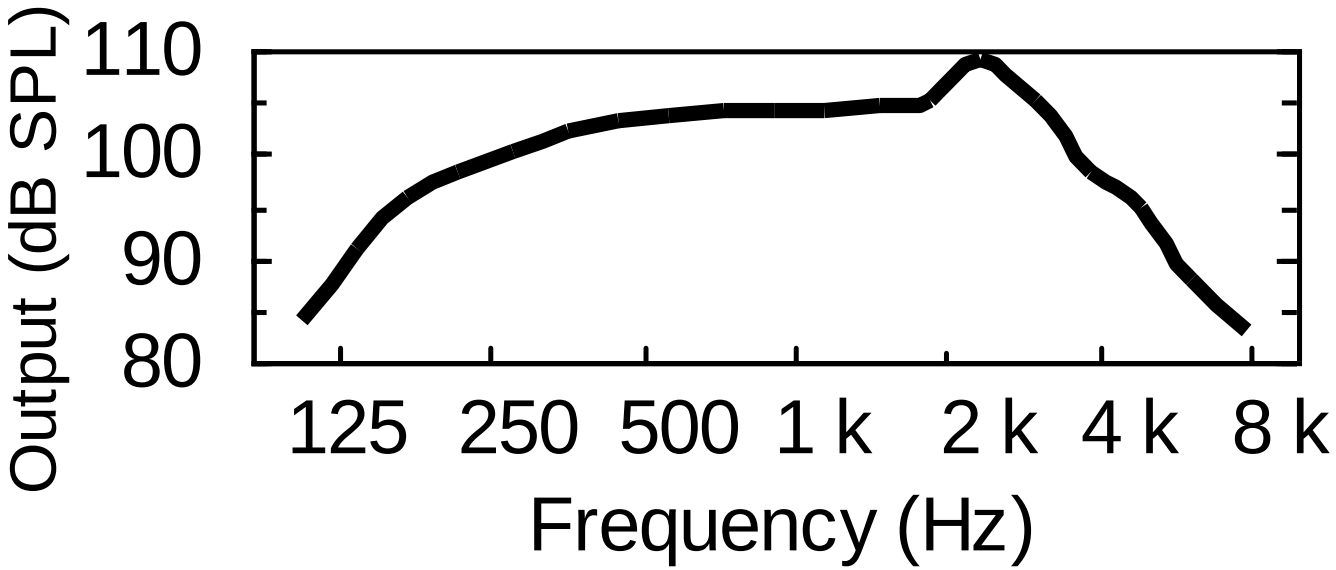
Gain-frequency response



Gain-frequency response of an in-the-ear hearing aid at maximum volume control position (solid line) and reduced volume control position (broken line).

Source: Dillon (2001): *Hearing Aids*

SSPL or OSPL90



Saturated sound pressure level frequency response of an in-the-ear hearing aid.

Source: Dillon (2001): *Hearing Aids*