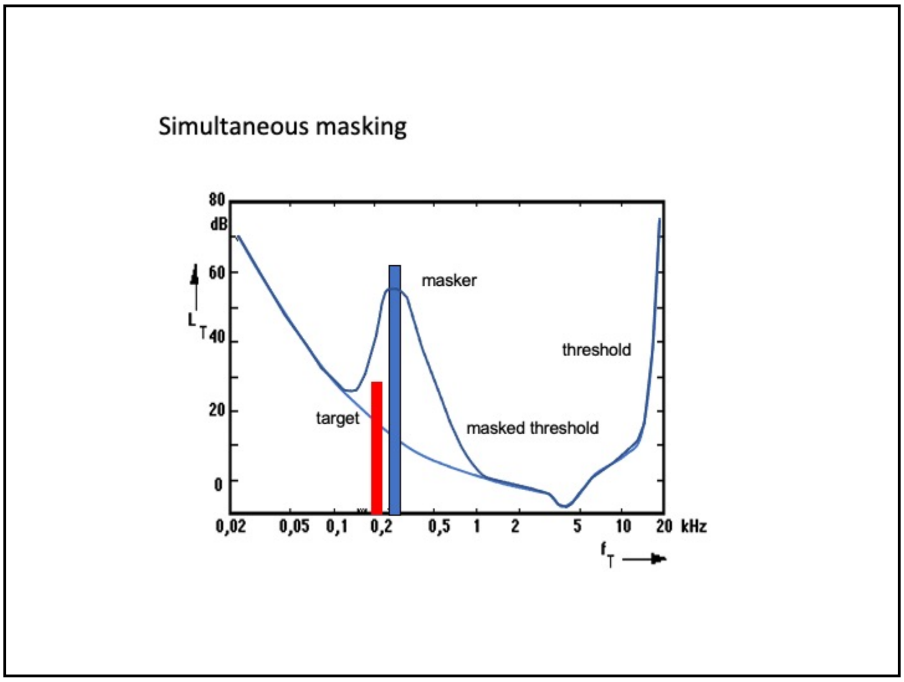
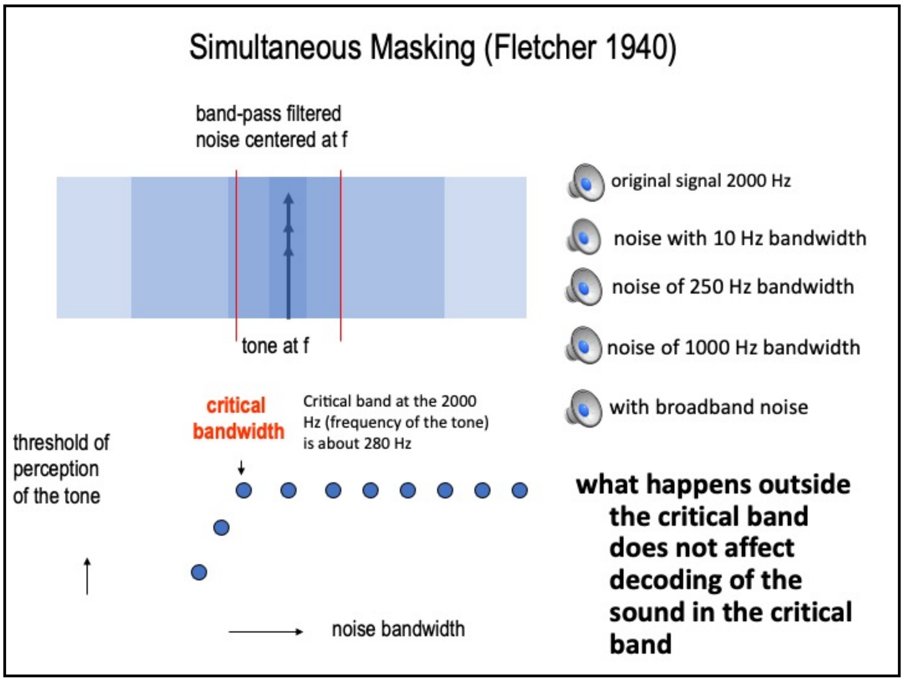
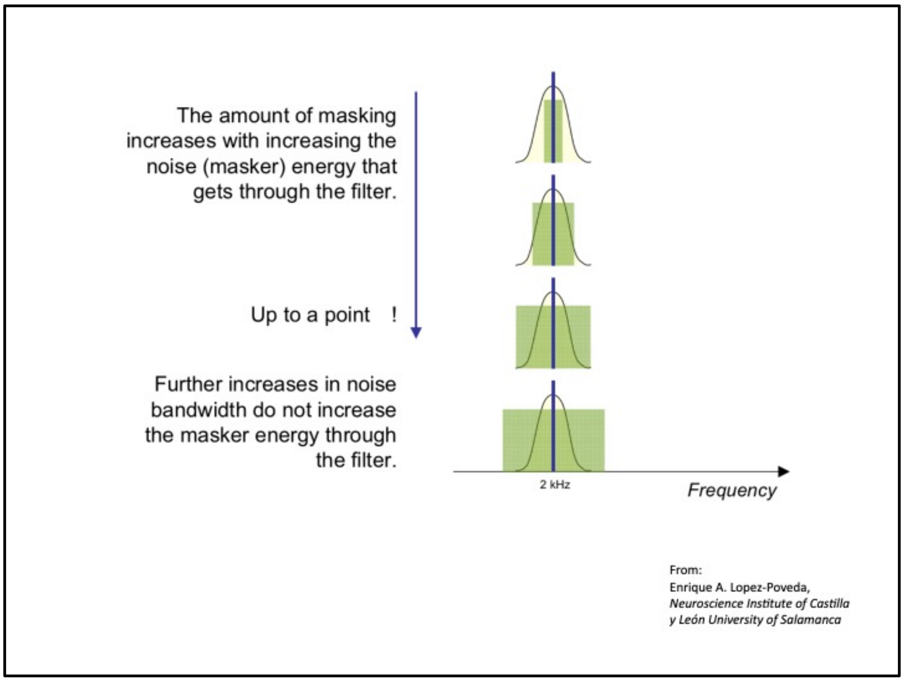


Listening to more than one tone induces yet another phenomenon of critical importance – the auditory masking. In masking, one signal (a probe) could be masked by another signal (a masker). The masker is always heard, the probe may not be heard. In effect, the presence of the masker modifies threshold of hearing for another signal. This masking phenomenon can be very important in applications like signal coding since it indicates that some disturbing elements (in this case in place of probes) may not be heard if a masker (in this case it is the signal which is being coded) is present. Understanding the masking phenomenon is a key to efficient coding schemes such as is MP3!



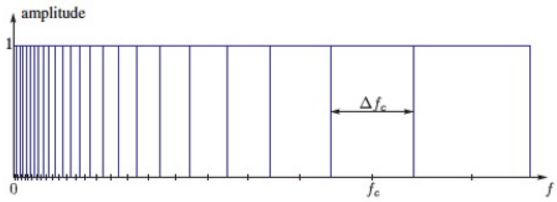
Let's try the method of limits but to save the class-time, let's inly do the first experiment to determine the threshold of hearing of a pure tone .
And to have more fun, let's add some bandlimited noise around the tone and change the noise bandwidth.

This original riginal experiments by Harvey Fletcehr and his group at Bell Labs in the thirties of the last century revealed existence of critical bandwidth were masking experiments where a tone of a certain frequency was masked by band-pass filtered noise with varying bandwidth, centered on the frequency of the probe. The masking increased with the increasing bandwidth of the noise, up to certain noise bandwidth, after which the masking did not increase anymore. More noise energy is being added but it has no effect on the detection of the probe anymore!

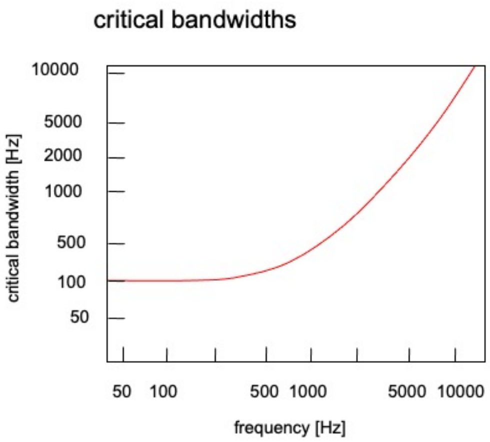


One way to imagine what is happeningas as the bandwidth of the basker signal increases is shown here. Once the masker bandwidth is wider than the bandwidth of the hypothetical cochlear filter, it does not contribute to masking if the signal within the filter.

Critical bands of hearing



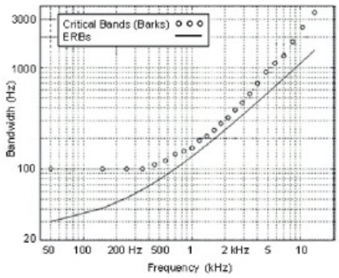
Critocal

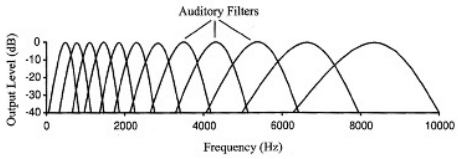


Critical band: whatever happens within it, is processed jointly
whatever happens outside it is processed independently

These critical bands of hearing are approximately constant (constant bandwidth) up to about 600 Hz, and after 600 Hz they increase approximately with logarithm of frequency.

Critical bands

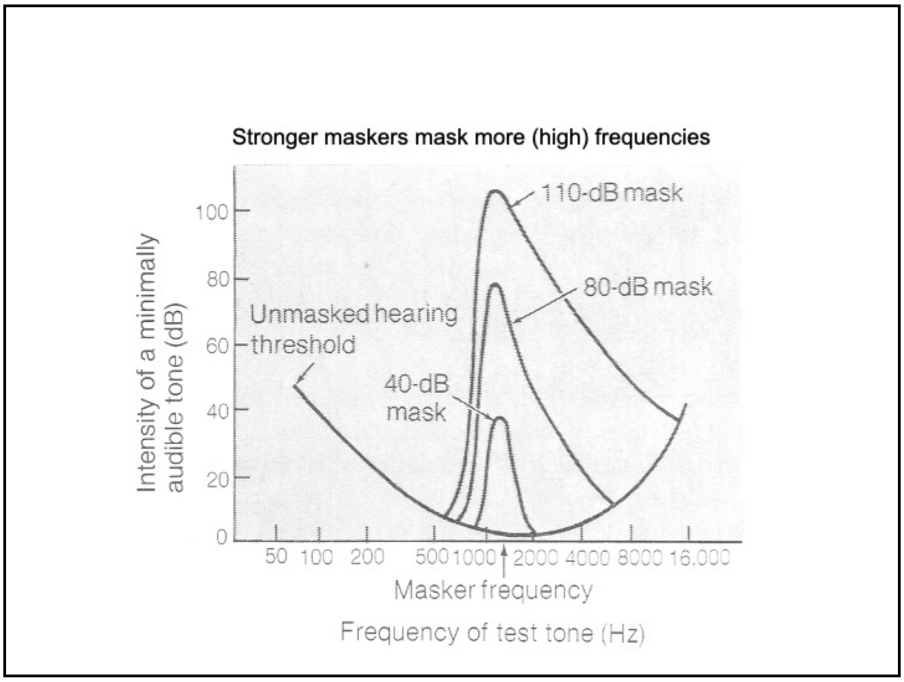




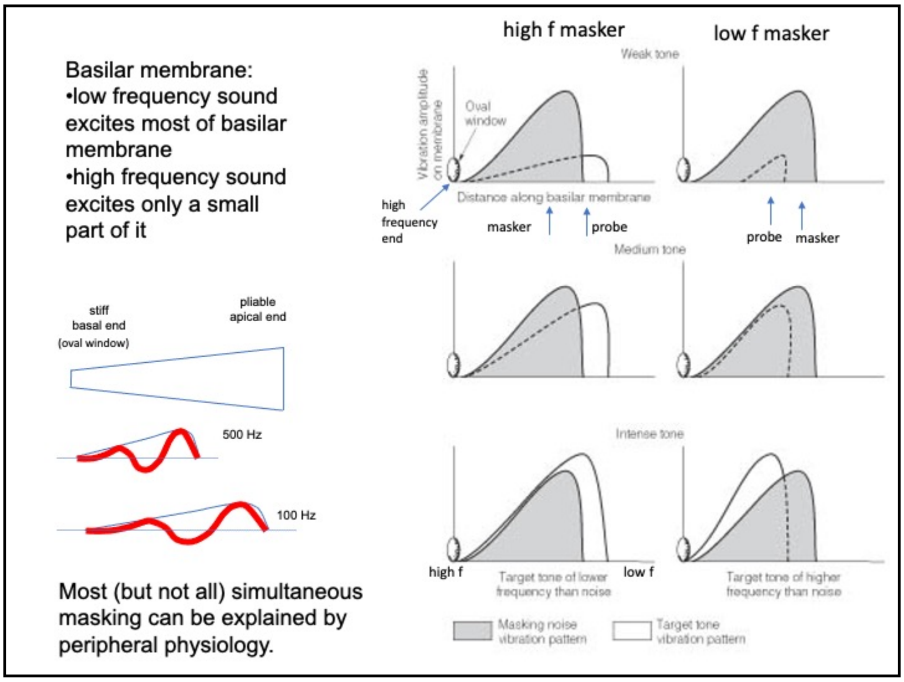
Actual values not well established but always broader towards higher frequencies

Each critical band covers approximately same length on basilar membrane (1.3 mm long, and each contains approximately 1300 neurons (Scharf, 1970).

Critical bands are one of the least disputed phenomena in hearing. Their existence is supported by a number of hearing experiments, masking being just one of them.

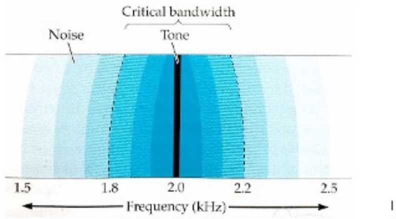


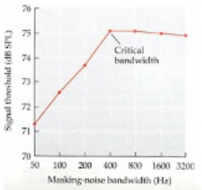
Excitation pattern for a tone can be derived by considering the tone as a masker and probing by another narrow-band signal (typically a narrow-band noise) to estimate how the tone lifts-up the hearing threshold for these noises. Notice that for higher probe levels, there is more masking towards higher frequencies. The low frequency slope of the excitation pattern is about 27 dB/Bark (1 Bark is one critical band), and is approximately constant for all excitation levels. The high frequency slope is for reasonable sound levels shallower (this comes from the fact that the low frequencies influence high frequency end of the basilar membrane more that the high frequencies influence the low frequency end). This slope is level-dependent and change between 27 dB/Bark at 40 dB to 5dB/Bark at 100 dB. Notice that for the 40 dB level, the excitation pattern is symmetric. When plotted on the critical-band (Bark) scale, the patterns for different frequencies are similar.

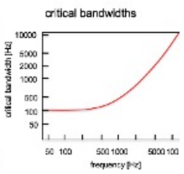


Here we have an explanation why the masking patterns have sharp edge towards low frequencies and much shallower slope towards highher frequencies. Remember that on a basilar membrane, pattern of activity depends on frequency and low frequencies influence positions at higher frequencies. So when the low frequency tone comes, the whole membrane may become active.

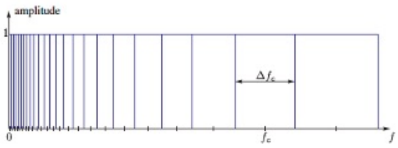
Notice that for higher probe levels, there is more masking towards higher frequencies. This is because the excitation pattern of a probe (target) spreads on basilar membrane towards high frequencies (forwards the basal part where the oval window is) more that it does towards the apical end.

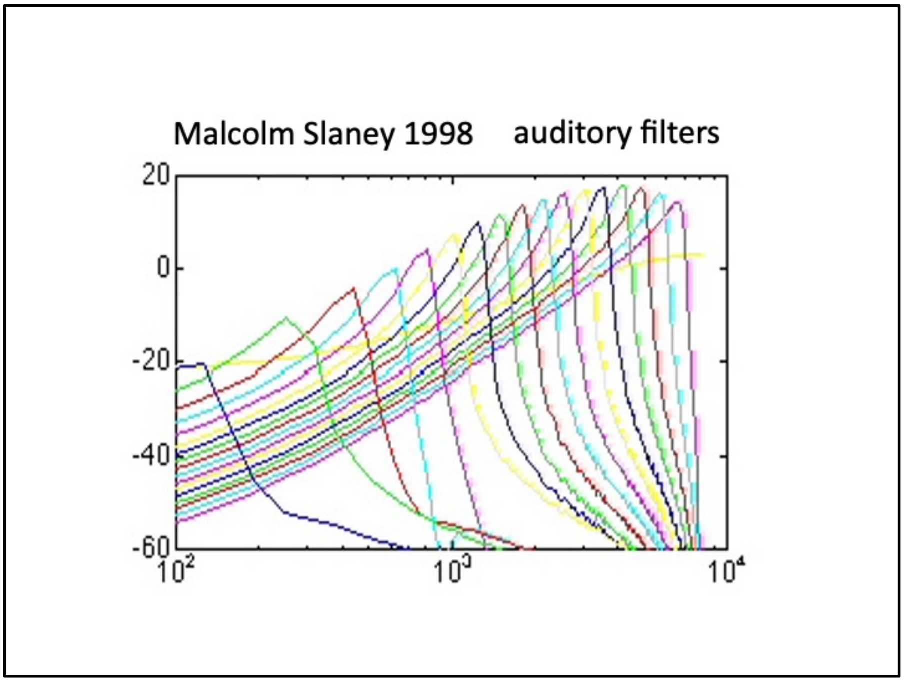




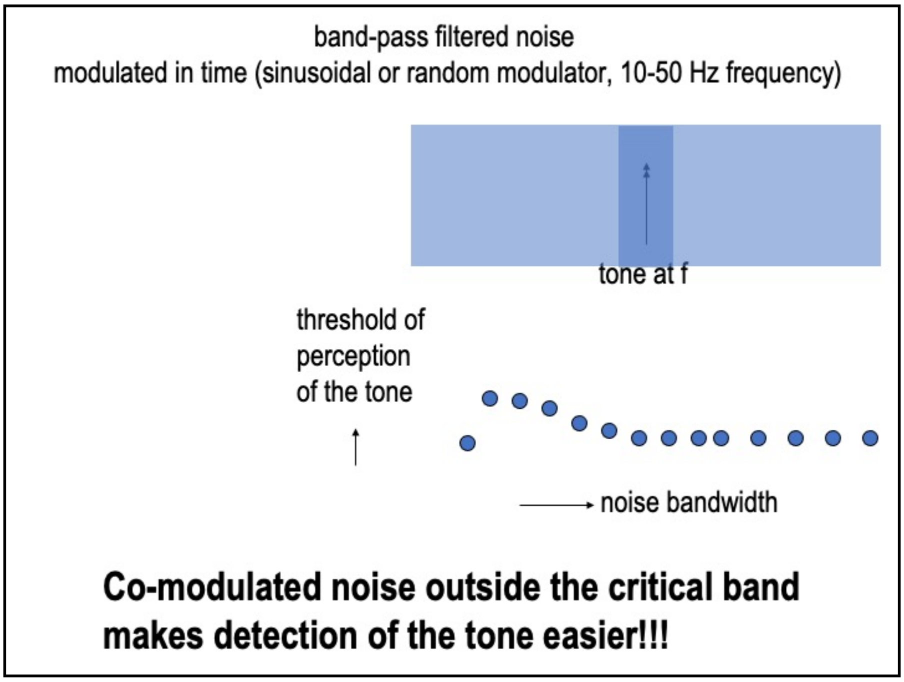


Critical bands of hearing

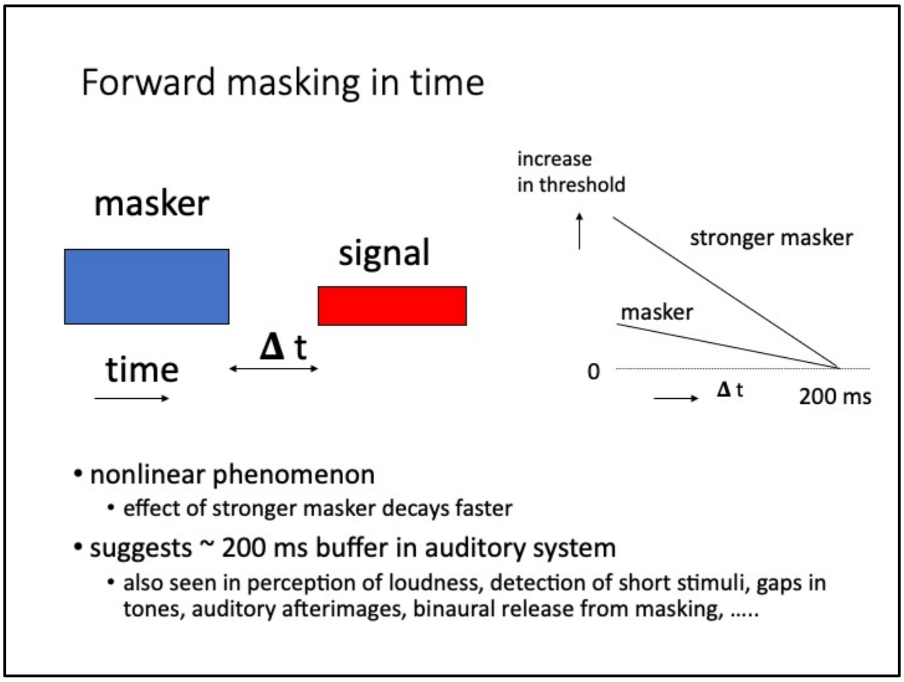




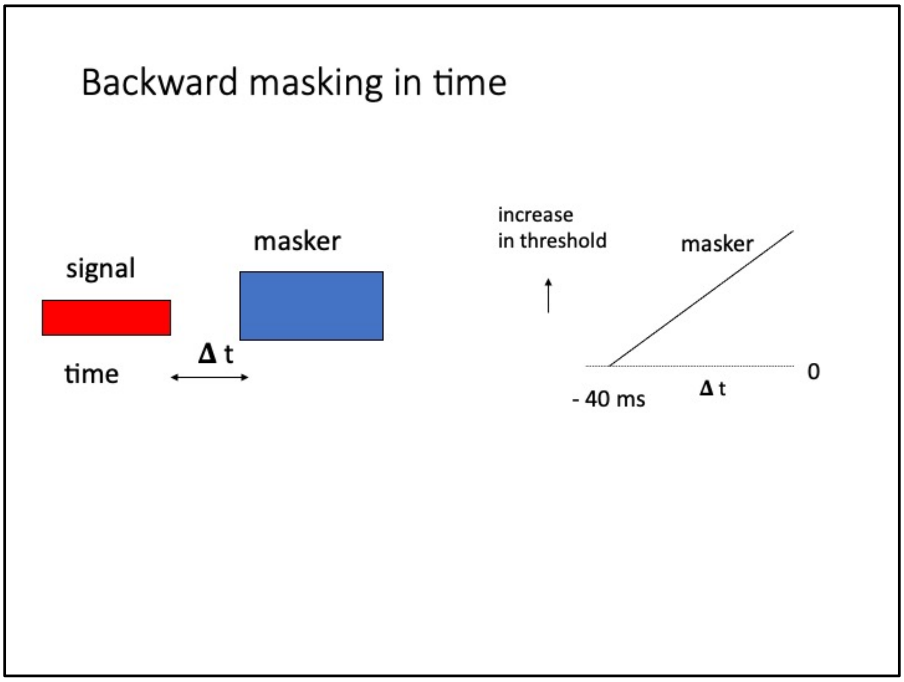
The most important function of the periphery is to bandpass filter the signal..The implied cortical filters have similar shapes on log frequency scale (i.e., they are getting broader towrds higher freuencies. They are asymmetric, slopes towerds lower frequncies are much shallower to account for the upward sperad opf masking (low frequencies influence higher frequencies and not vive versa).



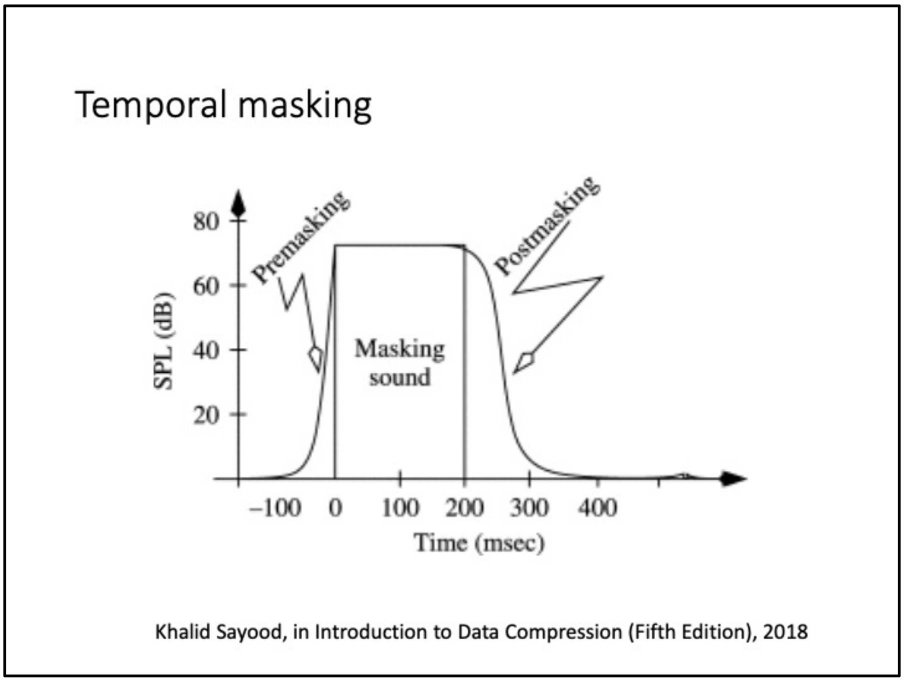
Anomalous situation arises when the masking noise is modulated. In this case, increasing the noise bandwidth beyond a certain point actually decreases the effect of the masking. More masker energy is added but this indices less masking !!!



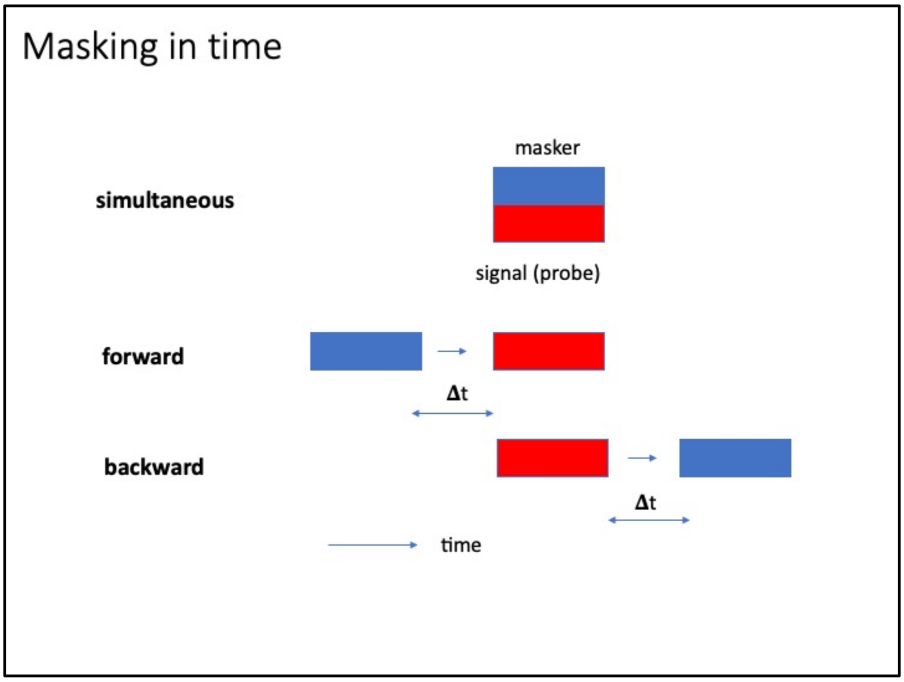
Forward masking is a nonlinear phenomenon. The masking is stronger for stronger maskers but is also declines faster, so regardles of the masker level, its effect on the probe is always gone after about 200 msec. We see similar temporal interval in a number of other hearing phenomena where use of temporal buffer may be postulated.



Forward masking is a nonlinear phenomenon. The masking is stronger for stronger maskers but is also declines faster, so regardles of the masker level, its effect on the probe is always gov=ne after 200-300 msec. We see this 200-300 msec temporal interval in a number of other hearing phenomena where use of temporal buffer may be postulated.



This figure summarizes what we have said about temporal masking.



Masker occuring at the same time as the signal (probe) has obviously larges effect on the probe threshold (simultaneous masking). However, when the masker is presented befor the probe, the masking effect is still there, as long as the interval between the msaker and the probe is not too large (forward masking). Even the masker presented after the probe has some effect on the probe threshold (backward masking). The forward masking last longer (about 200-300 msec.) The significant backward masking interval is shorter (not more than 40 msec).