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Masking

Aug 29, 2019 · Community Article

ARTICLE BODY

Masking is an auditory phenomenon in which one sound alters the perception of another sound, sometimes making that other sound inaudible.

There are two forms of masking: spectral masking and temporal masking.

Spectral Masking

Spectral masking is a phenomenon in which *frequency* content that is normally audible becomes inaudible due to the presence other frequency content.

When no other noise is present, most humans can hear sounds that fall within the hearing domain below. The lower threshold is called the hearing threshold or the "threshold in quiet".

1.png

Figure 1: The human hearing domain.

When noise is present, the threshold of human hearing can change. Essentially, the presence of noise in the hearing domain makes some portions of the hearing domain more difficult to hear. This is called spectral masking.

There are many ways that spectral masking can take form. This article will discuss the following two:

- Tones masked by broadband noise
- Tones masked by tones

Tones masked by broadband noise

The presence of broadband white noise raises the threshold of human hearing. The higher the overall level of the white noise, the higher the masked threshold becomes.

The graphic below compares the threshold in quiet (blue line) to the masked thresholds caused by different levels of white noise (pink dotted curves). For example, the uppermost pink curve is the new threshold of hearing caused by white noise playing at an overall level of 93dB.

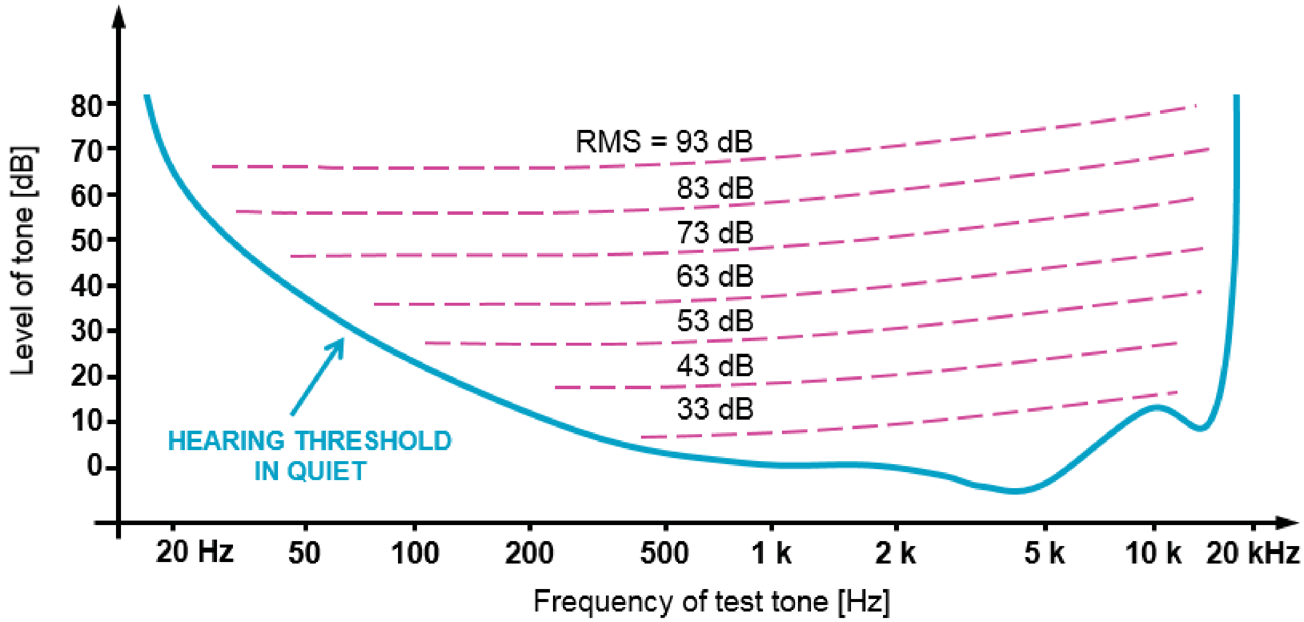


Figure 2: Level of tone just masked by the white noise.

The level of the tone must increase to be heard over increasingly loud broadband noise. **

Example of masking a tone with broadband noise:

Assuming only a 5000Hz tone at 40dB is playing, the tone should be audible as it is above the hearing threshold in quiet.

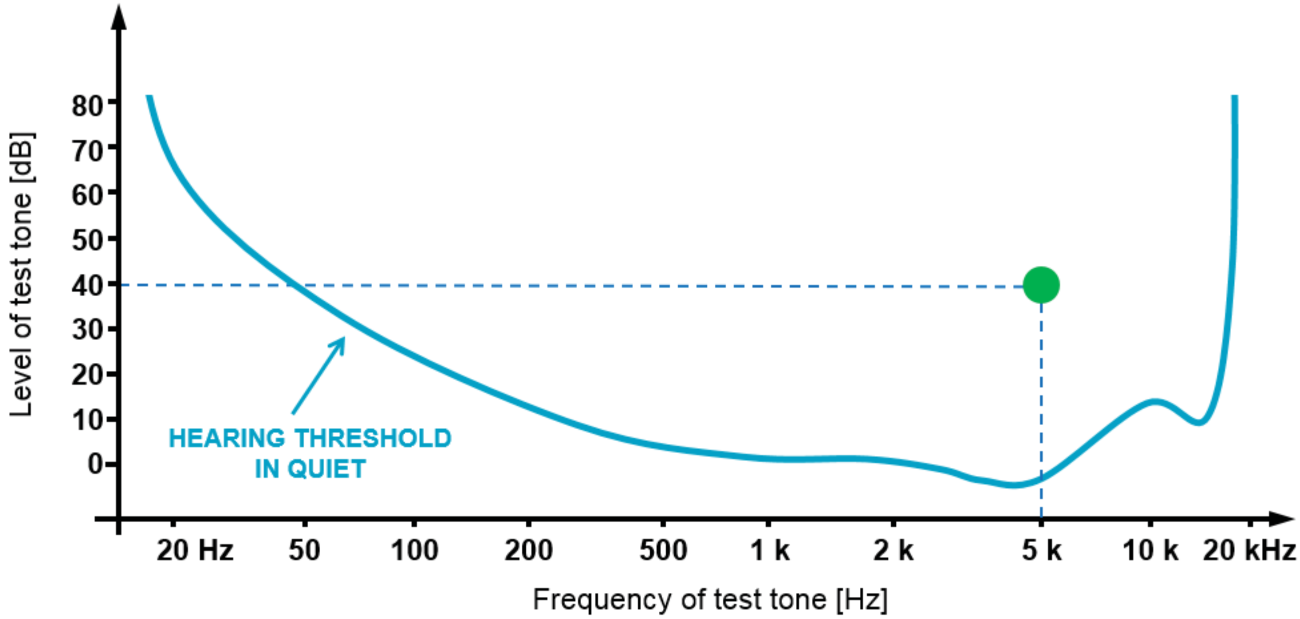


Figure 3: A tone at 5000Hz and 40dB is above the threshold in quiet and should be audible assuming no other noise is present.

If white noise with an overall level of 63dB is played, the hearing threshold will rise and the sine tone at 5000Hz should be masked.

The pink dashed line represents the new hearing threshold. Anything under this line is considered masked and is thus inaudible, including the 5000Hz tone at 40dB.

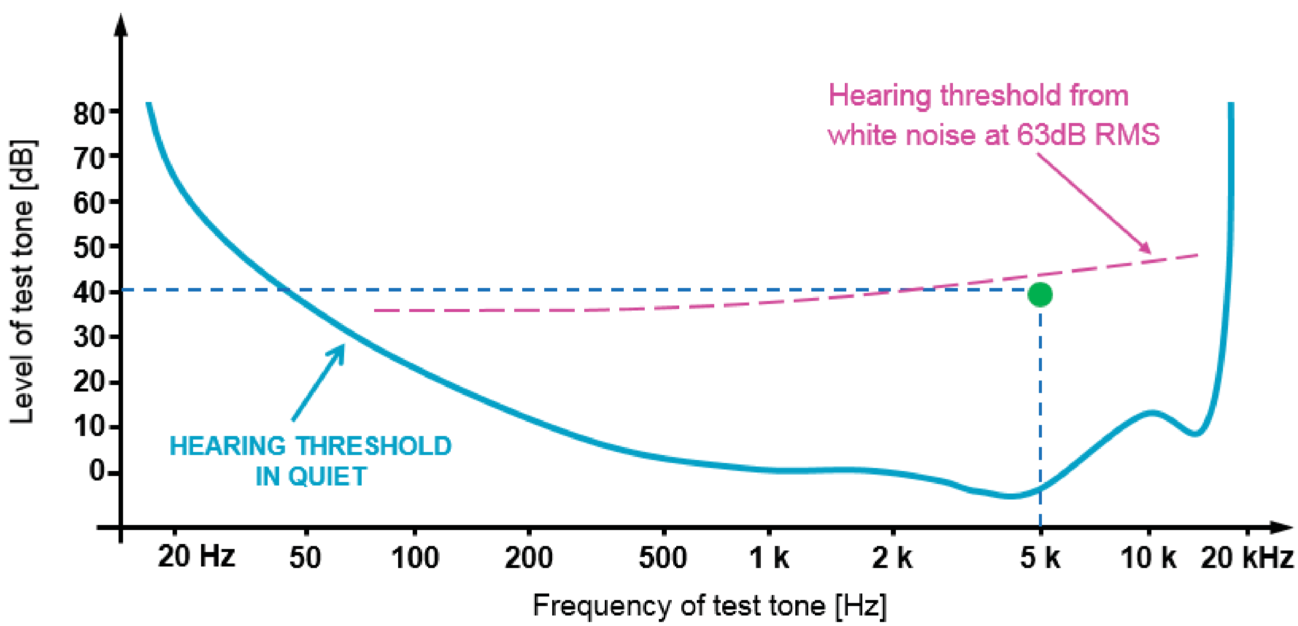


Figure 4: Anything under the new threshold of human hearing is considered inaudible: including tones that would normally be audible assuming all else was quiet.

To make the 5000Hz tone audible above the background noise, the tone would need to be raised to a level above the masking threshold.

For example, if the tone were raised to a level of 50dB, it would become audible.

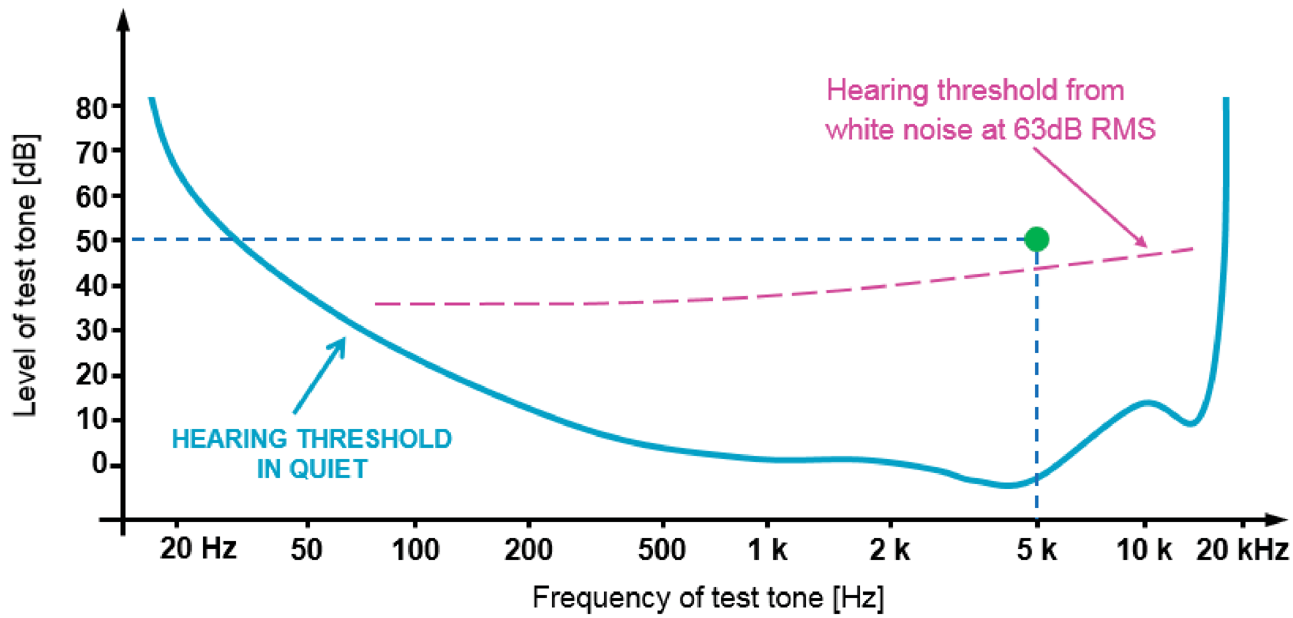
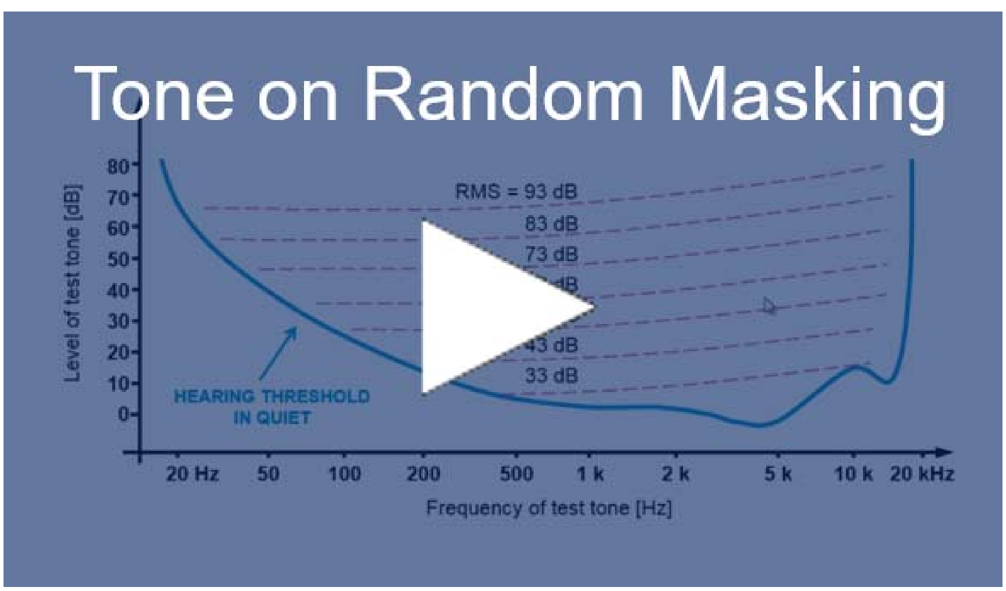


Figure 5: A 50dB tone at 5000Hz is audible over white noise at 63dB RMS.

The video below contains the sounds from this example. Listen to the video and see if your perception matches the graphs above. It is recommended to use high quality headphones while listening to this video.



[(https://videos.mentor-cdn.com/mgc/videos/5400/57ce3627-d7ac-41b0-a153-856c879c7032-en-US-video.mp4)](https://videos.mentor-cdn.com/mgc/videos/5400/57ce3627-d7ac-41b0-a153-856c879c7032-en-US-video.mp4)

Video: Tone masked by Broadband (https://videos.mentor-cdn.com/mgc/videos/5400/57ce3627-d7ac-41b0-a153-856c879c7032-en-US-video.mp4)

Check out the Tone to Noise ratio and Prominence Ratio (/s/article/tone-to-noise-ratio-and-prominence-ratio) article for more information about perceiving tones above background noise. Note that these metrics consider narrow band noise as the masker.

Tones Masked by Tones

When two tones (a test tone and a masker tone) are played at the same time, several phenomenon can occur:

- The test tone can be completely masked by the masker tone
- The test tone and masker tone can modulate (/s/article/sound-modulation-metrics-fluctuation-strength-and-roughness)with one another
- The test tone and the masker tone can both be distinctly heard

NOTE: This article will discuss masking and distinct tones. Check out the Sound Modulation Metrics (/s/article/sound-modulation-metrics-fluctuation-strength-and-roughness) article for more information about how tones modulate.

To determine if the test tone will be masked or heard separate from the masking tone, the masking curves below can be used (Figure 6).

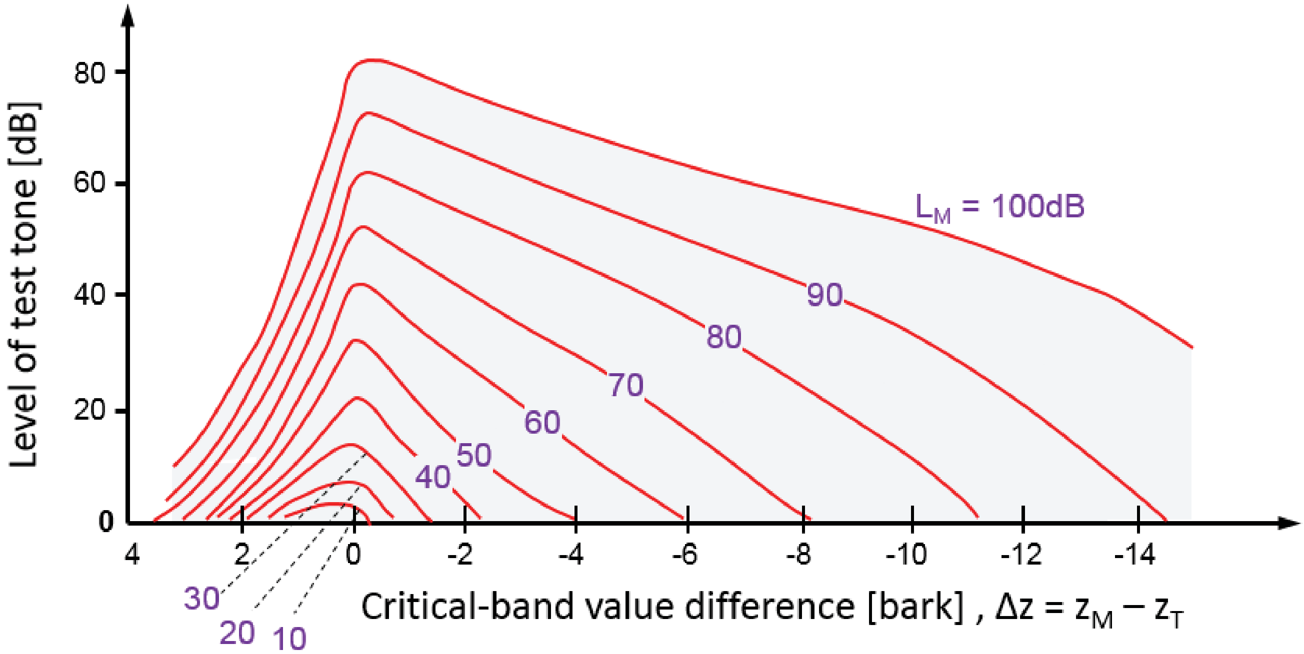


Figure 6: Masking curves.

The y-axis is the level of the test tone. The curves represent different levels of masking tone. The x-axis represents the difference in frequency between the test and masker tones.**

Looking at Figure 6 a few conclusions can be drawn:

- The higher the level of the masking tone (L_M), the greater the range of frequencies it will mask.
- Tones close in frequency mask one another more than tone widely separated in frequency.
- A tone is better at masking tones of higher frequency that tones of lower frequency.

Given the frequencies and levels of the test and masking tones, the masking curve will help determine if masking takes place or not.

The level of the test tone is indicated by the y-axis in Figure 6. The level of the masking tone (L_M) is indicated by the curves: as the level of the masking tone increases, the area under the curve increases.

The frequency of the test tone and the frequency of the masking tone must be considered together. This is because the closer the frequencies are, the more likely that masking will take place. The *critical band rate difference* is the metric which compares the frequencies of the masking tone to the test tone (x-axis of Figure 6).

The critical band value is the bark value that corresponds to a specific frequency.

Below is a table of critical bands (/s/article/critical-bands-in-human-hearing) (barks) and their corresponding frequency. A frequency of 1000 has a critical band rate of 8.5.

Critical band (bark)	Center frequency	Bandwidth
0.5	50	100
1.5	150	100
2.5	250	100
3.5	350	100
4.5	450	110
5.5	570	120
6.5	700	140
7.5	840	150
8.5	1000	160
9.5	1170	190
10.5	1370	210
11.5	1600	240
12.5	1850	280
13.5	2150	320
14.5	2500	380
15.5	2900	450
16.5	3400	550
17.5	4000	700
18.5	4800	900
19.5	5800	1100
20.5	7000	1300
21.5	8500	1800
22.5	10500	2500
23.5	13500	3500

Figure 7: Critical bands and the bark scale.

Below, the critical bands are graphed vs. frequency. This makes it easier to determine a critical band value (bark) for a given frequency.

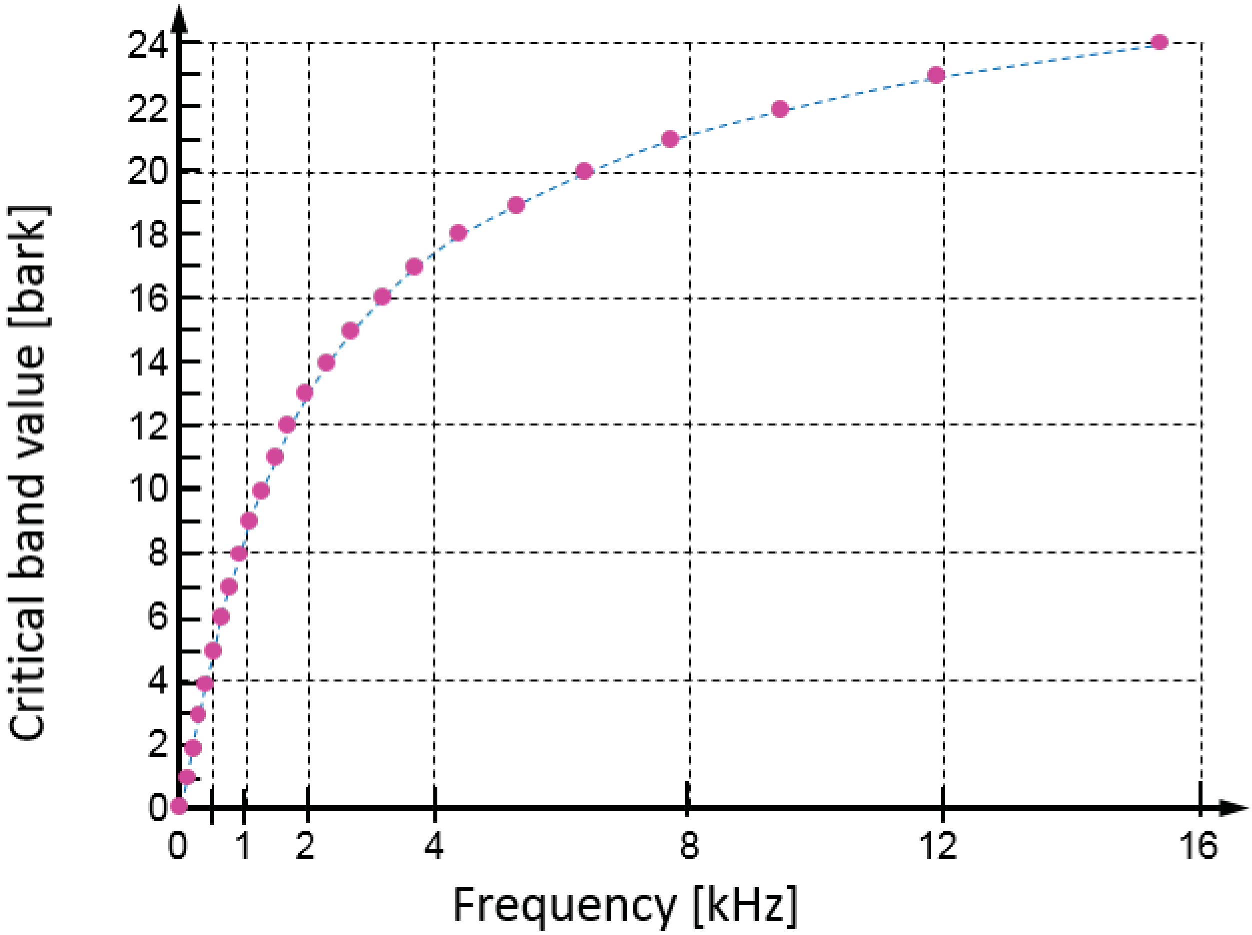


Figure 8: Critical band value (bark) plotted as a function of frequency.

This graph can be approximated using Equation 1 below. This allows for even easier determination of the critical band value of a given frequency.

$$Bark\ (z) = 13 \arctan\left(\frac{0.00076}{f}\right) + 3.5 \arctan\left(\left(\frac{f}{7500}\right)^2\right)$$

Equation 1: Determine the bark value (z) of a frequency.

Critical bands are important to masking as the closer the frequencies are, the more likely masking is to take place. The x-axis in Figure 6 is the difference in critical band values for the masker and test tone.

Determining the critical band difference is key in determining whether masking takes place.

Example of masking a tone with a tone:

Example 1:

Considering the two tones below, will the masking tone mask the test tone?

- Masking tone: 1000Hz, 70dB
- Test tone: 1370 Hz, 35dB

First we need to determine the critical band value difference between the masking and test tone.

We simply plug the masking tone frequency and the test tone frequency into Equation 1 and take the difference.

$$z_M = 13\arctan\left(\frac{0.00076}{1000}\right) + 3.5\arctan\left(\left(\frac{1000}{7500}\right)^2\right) = 8.51$$

$$z_T = 13\arctan\left(\frac{0.00076}{1370}\right) + 3.5\arctan\left(\left(\frac{1370}{7500}\right)^2\right) = 10.58$$

$$\Delta z = z_M - z_T = -2.07$$

Now, we can plot the critical band difference and test tone level on our masking graph.

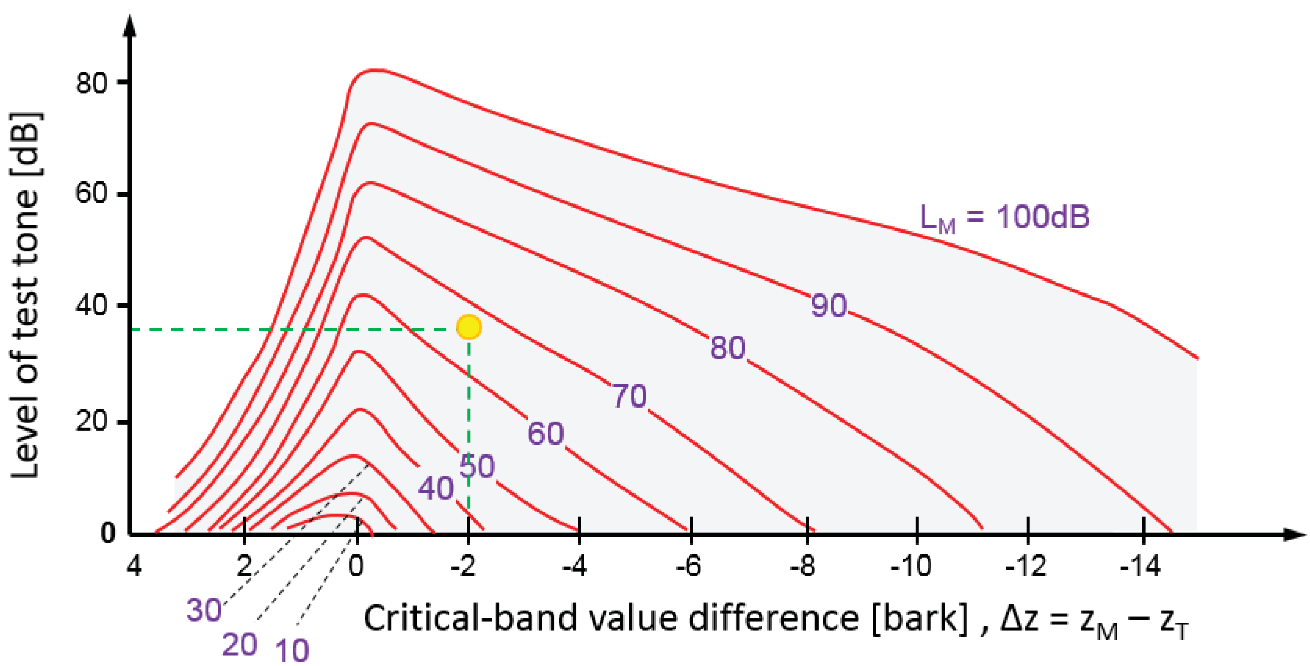
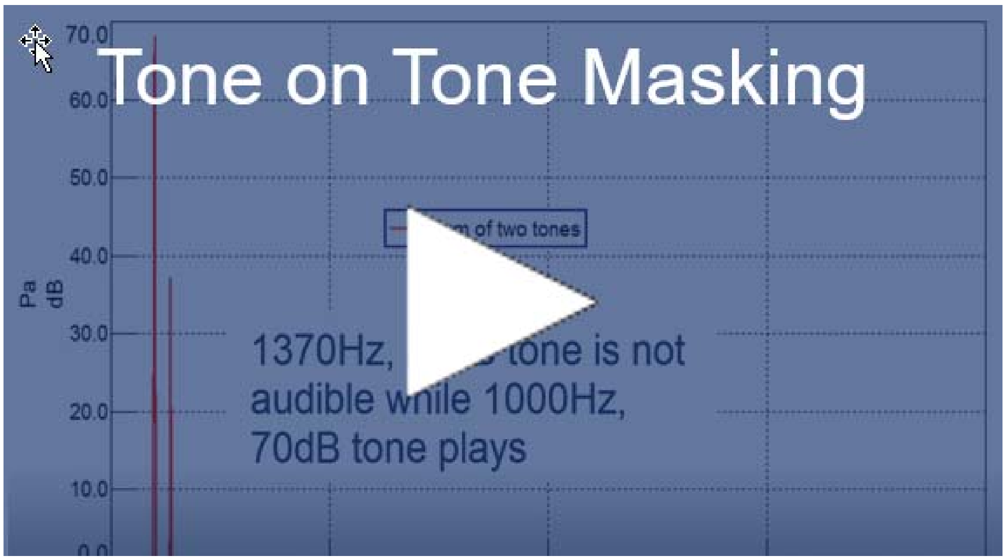


Figure 9: The masking tone will mask the test tone.

The x-axis value is 2.07 bark, the y-axis value is 35dB. The intersection (yellow dot) falls under the 70dB masking curve. This means that the 70dB masking tone will mask the test tone.

Therefore, the 1370Hz tone at 35dB would be completely masked by the 1000Hz tone at 70dB.

Listen to the tones below to see if your perception matches the graph. It is recommended to use high quality headphones while listening to this video.



(https://videos.mentor-cdn.com/mgc/videos/5400/a3da120c-8469-418e-ba90-d14396e566b0-en-US-video.mp4)

Video: Tone on Tone Masking (https://videos.mentor-cdn.com/mgc/videos/5400/a3da120c-8469-418e-ba90-d14396e566b0-en-US-video.mp4)

Example 2:

Considering the two tones below, will the masking tone mask the test tone?

- Masking tone: 770Hz, 45dB
- Test tone: 2000Hz, 40dB

First we need to determine the critical band value difference between the masking and test tone.

Simply plug the masking tone frequency and the test tone frequency into Equation 1 and take the difference.

$$z_M = 13 \arctan\left(\frac{0.00076}{770}\right) + 3.5 \arctan\left(\left(\frac{770}{7500}\right)^2\right) = 6.91$$

$$z_T = 13 \arctan\left(\frac{0.00076}{2000}\right) + 3.5 \arctan\left(\left(\frac{2000}{7500}\right)^2\right) = 13.01$$

$$\Delta z = z_M - z_T = -6.10$$

Now, we can plot the critical band difference and test tone level on our masking graph.

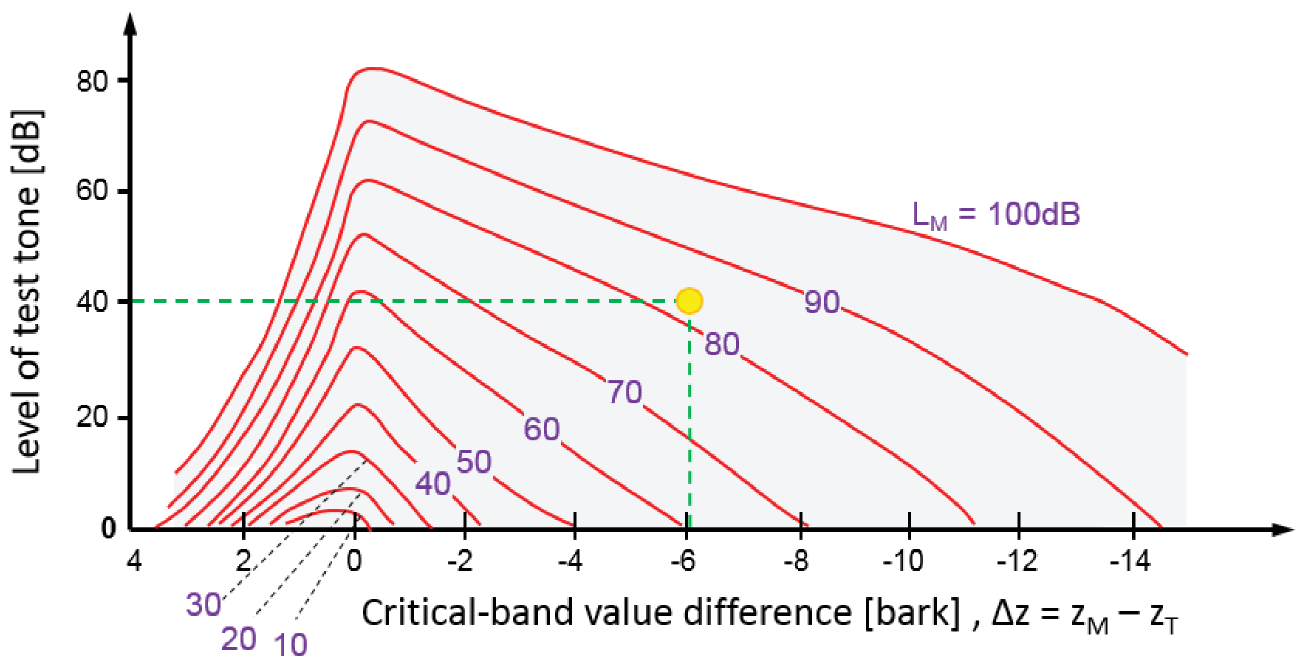


Figure 10: The test tone is not masked by the masking tone.

In this case, the masking tone would need to be above 80dB to mask the test tone. Because the masking tone is only 45dB, the test tone is not masked.

Listen to the tones below to see if your perception matches the graph. It is recommended to use high quality headphones while listening to this video.

(https://videos.mentor-cdn.com/mgc/videos/5400/07ec7248-64dc-463f-8eaf-48d65fd42fe6-en-US-video.mp4)

Video: Tones not Masking (https://videos.mentor-cdn.com/mgc/videos/5400/07ec7248-64dc-463f-8eaf-48d65fd42fe6-en-US-video.mp4)

Spectral masking causes tones that can be heard in quiet to be inaudible over other spectral content.

Temporal Masking

Temporal masking is a time-domain phenomenon in which the duration of a sound and the length between sounds can cause sounds to be inaudible.

Temporal masking acts in three main ways:

- Pre-masking: A phenomenon in which a test sound is masked *before* the masker sound is turned on. Of course, humans cannot hear into the future. Rather, the build-up time for our ears to perceive the sound results in sounds occurring after the test sound to mask the test sound. Pre-masking can only occur about 20 milliseconds before the masking sound starts. This phenomenon is usually ignored as it is very brief and very difficult to quantify.
- Simultaneous masking: A phenomenon in which a test sound is masked while the masker sound is playing. During simultaneous temporal masking, the

duration of the test sound is very important. The shorter duration of the sound, the quieter the sound is perceived.

- Post-masking: A phenomenon in which a test sound is masked *after* the masker sound is turned *off*. Post-masking is dependent on the duration of the masker sound. The shorter the masker sound is on for, the quicker the post-masking effect decays. Post-masking occurs within 200 milliseconds of the masking sound turning off. After about 200 milliseconds, hearing returns to typical "threshold in quiet" behavior.

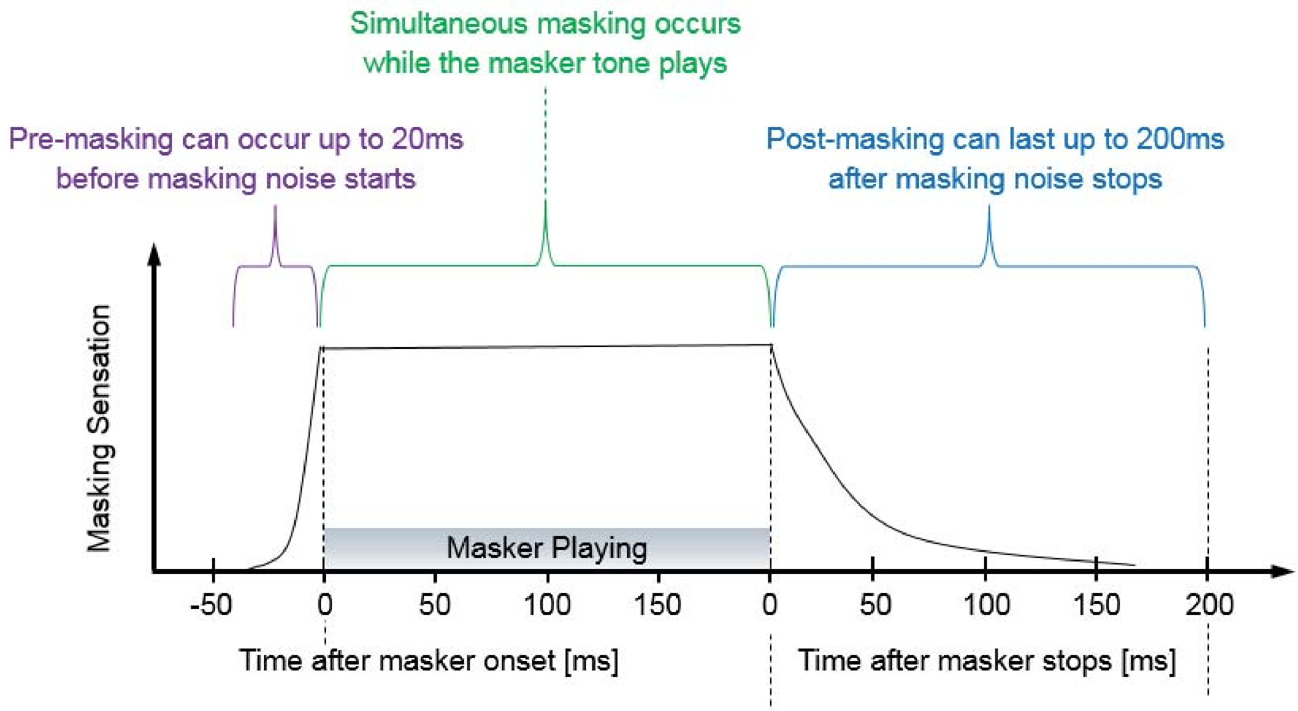


Figure 11: Temporal masking in three regions.

"Masking sensation" represents how impactful the sensation is relative to the masker turning on and off. Pre-masking is more effective the nearer to the masker turning on. Post masking is more effective the nearer to the masker turning off. **

Psychoacoustics: Facts and Models by Hugo Fastl and Eberhard Zwicker is a good source for more information regarding temporal masking (including audio examples).**

Conclusion:

Masking can occur both in a steady-state condition (spectral masking) and in a temporal condition.

It is important to understand how masking effects the perception of sound, how sounds interact with one another and how the human ear processes signals of different intensity levels that occur very closely.

Keep in mind that there is variability in the perception of masking. Some people are able to distinguish between tones more easily than others. Both training and the condition of one's ears contribute to this variability.

** For more information about masking please reference:

Zwicker, Eberhard, and Hugo Fastl. *Psychoacoustics: facts and models*. Berlin, Springer, 2010.

Related Links:

- History of Acoustics (/s/article/history-of-acoustics)
- Sound Pressure (/s/article/sound-pressure)
- What is a decibel? (/s/article/basics-what-is-a-decibel-db-anyway-why-is-it-used)
- What is A-weighting? (/s/article/what-is-a-weighting)
- Octaves and Human Hearing (/s/article/octaves-in-human-hearing)
- What is Sound Power? (/s/article/what-is-sound-power)
- Decibel Math (/s/article/the-wacky-world-of-acoustics-decibel-funny-math-and-human-hearing)
- Sound Quality Metrics: Loudness and Sones (/s/article/tone-to-noise-ratio-and-prominence-ratio)
- Speech Interference Level (SIL) (https://community.sw.siemens.com/s/article/sound-metrics-speech-interference-level)
- Articulation Index (https://community.sw.siemens.com/s/article/articulation-index)
- Tone-to-Noise Ratio and Prominence Ratio (/s/article/tone-to-noise-ratio-and-prominence-ratio)