CENTRO DE INVESTIGACIÓN EN TECNOLOGÍAS DE AUDIO
PONTIFICIA UNIVERSIDAD CATÓLICA DE CHILE

RESOLUCIÓN DE FRECUENCIA

Rodrigo F. Cádiz
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Resolución de frecuencia y enmascaramiento

Resolución de frecuencia

“resolución”

La precisión a la cual un estímulo puede ser distinguido de estímulos que son similares en alguna dimensión

“resolución de frecuencia”

La habilidad de separar un componente en un sonido complejo

http://depts.washington.edu/sphsc461/freq_res/freq_res_files/freq_res.ppt

Audiogramas

Thresholds were measured at 10-cycle intervals over the range 400–3,000 c./s.

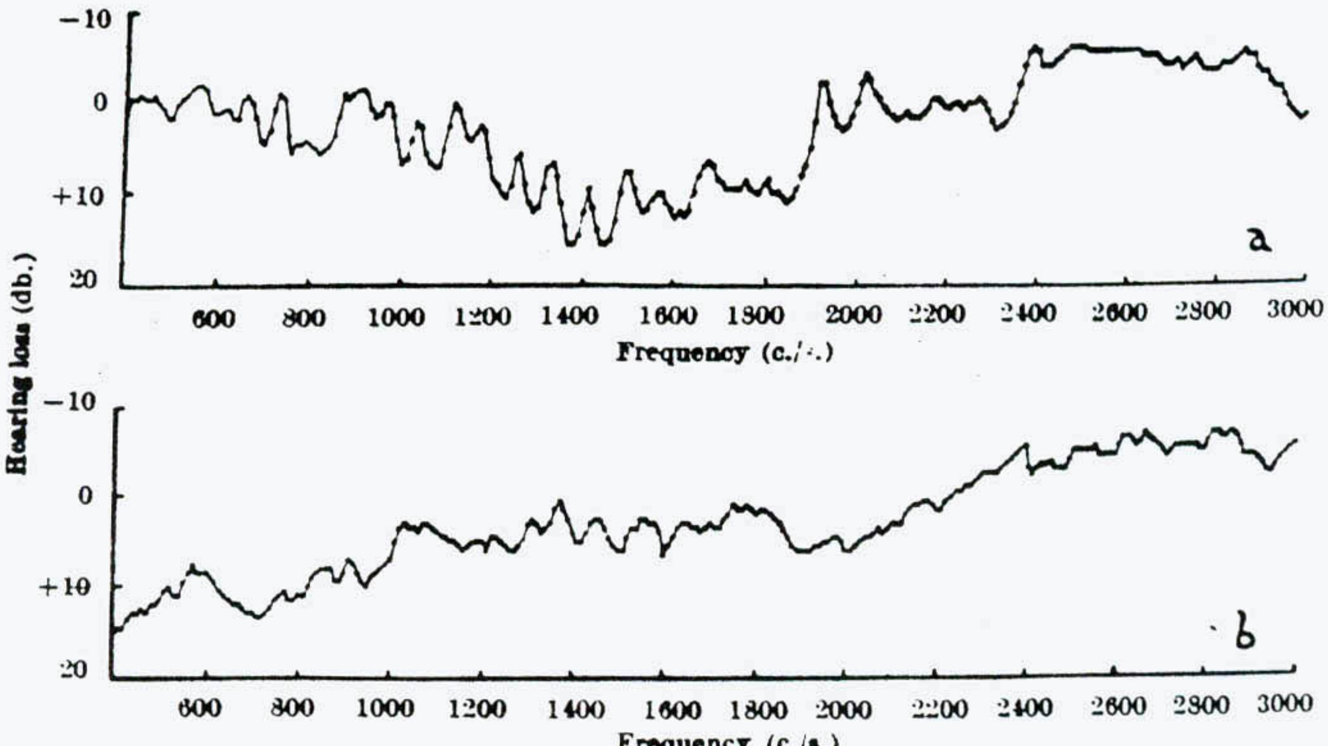
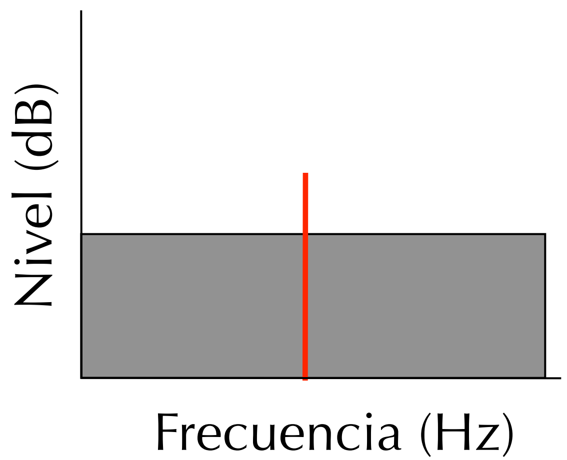


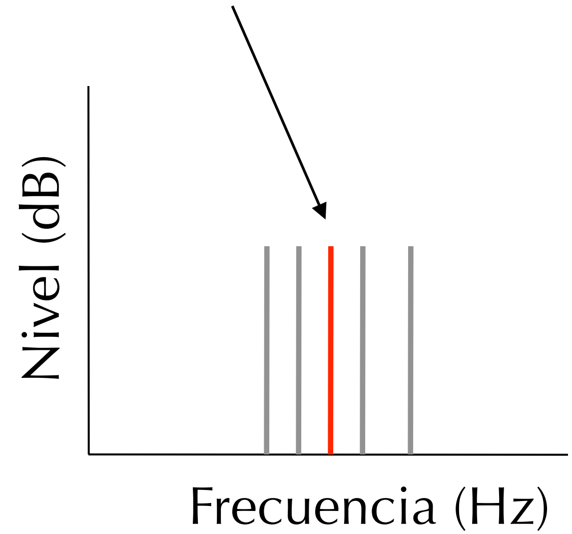
Fig. 1. Audiograms (*a*) for subject *A*, aged 21, and (*b*) for subject *B*, aged 28 years

Tareas que involucran resolución en frecuencia

Detectar un tono en ruido

Escuchar un componente en un complejo -- está 2100 Hz ahí?



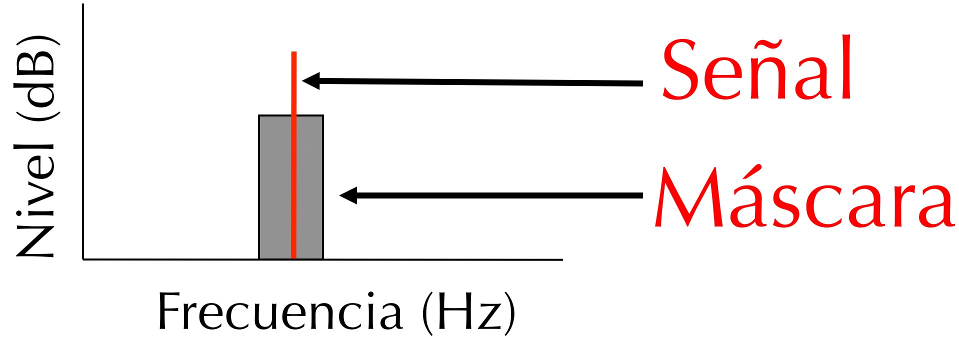


Demostración 1

http://depts.washington.edu/sphsc461/freq_res/freq_res_files/freq_res.ppt

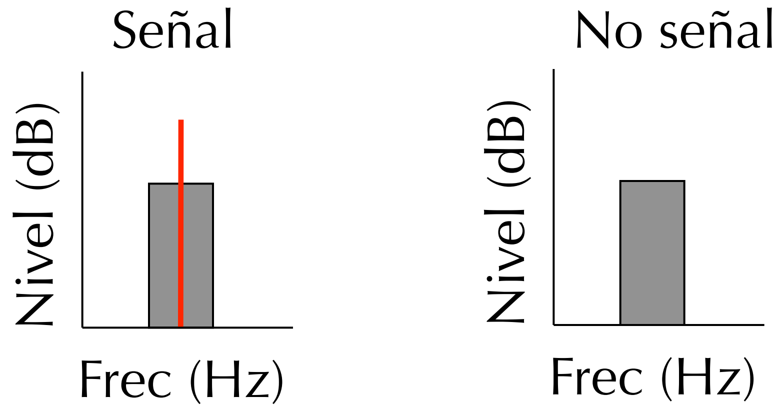
Midiendo la resolución en frecuencia: ancho de banda de enmascaramiento y las bandas críticas

Midiendo resolución en frecuencia



Nota: los términos 'resolución de frecuencia' y 'selectividad de frecuencia' son usualmente intercambiables

Opción forzada de dos alternativas



Señal

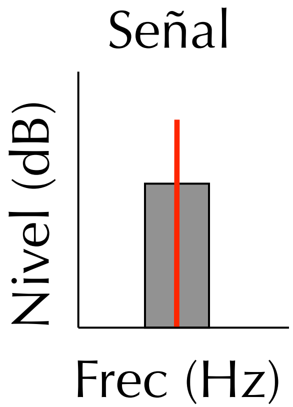
No Señal

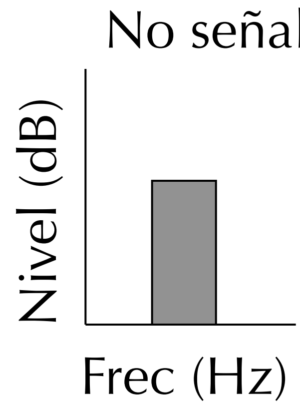
Tiempo →

					Feedback
Trial 1	Warning	Interval 1	Interval 2	Respond: 1 or 2?	1
Trial 2	Warning	Interval 1	Interval 2	Respond: 1 or 2?	2
Trial 3	Warning	Interval 1	Interval 2	Respond: 1 or 2?	2

http://depts.washington.edu/sphsc461/psychophysics/psychophysical%20methods_files/psychophysical%20methods.ppt

Opción forzada de dos alternativas





Ajustar el nivel de la señal para estimar el nivel necesario para tener ~75% de detecciones correctas, denominadas como 'umbral.'

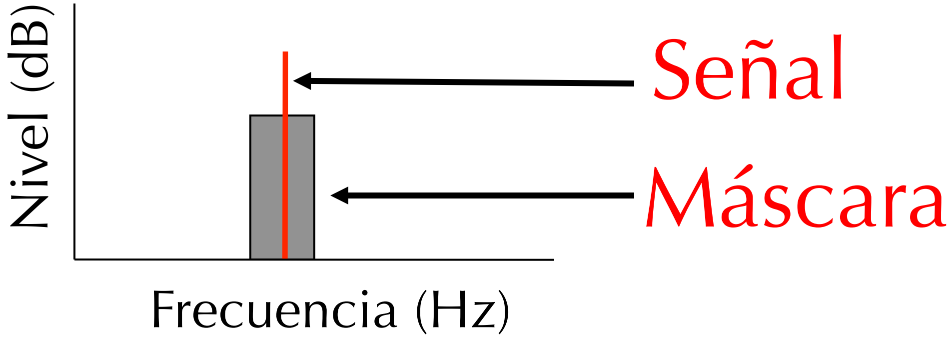
Señal (verde) | No Señal (rojo)

Tiempo →

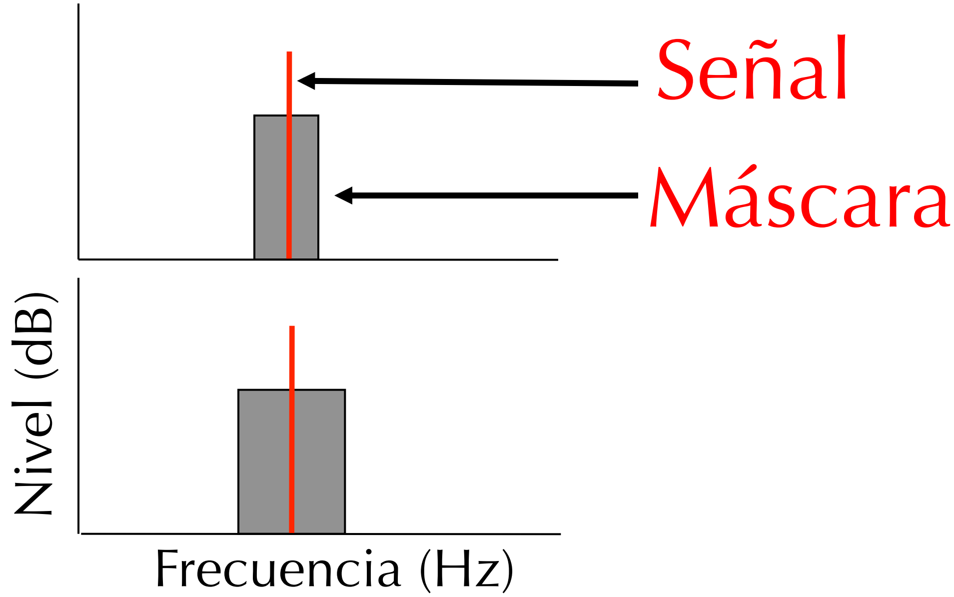
					Feedback
Trial 1	Warning	Interval 1	Interval 2	Respond: 1 or 2?	1
Trial 2	Warning	Interval 1	Interval 2	Respond: 1 or 2?	2
Trial 3	Warning	Interval 1	Interval 2	Respond: 1 or 2?	2

http://depts.washington.edu/sphsc461/psychophysics/psychophysical%20methods_files/psychophysical%20methods.ppt

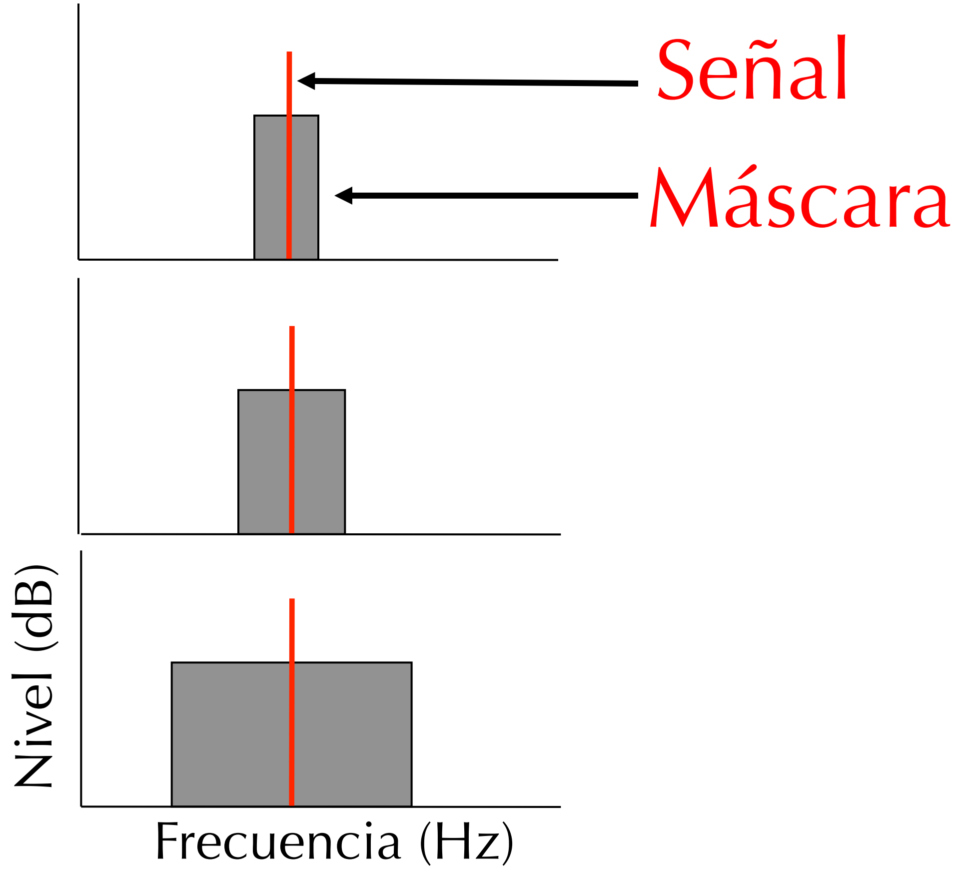
Midiendo la resolución de frecuencia



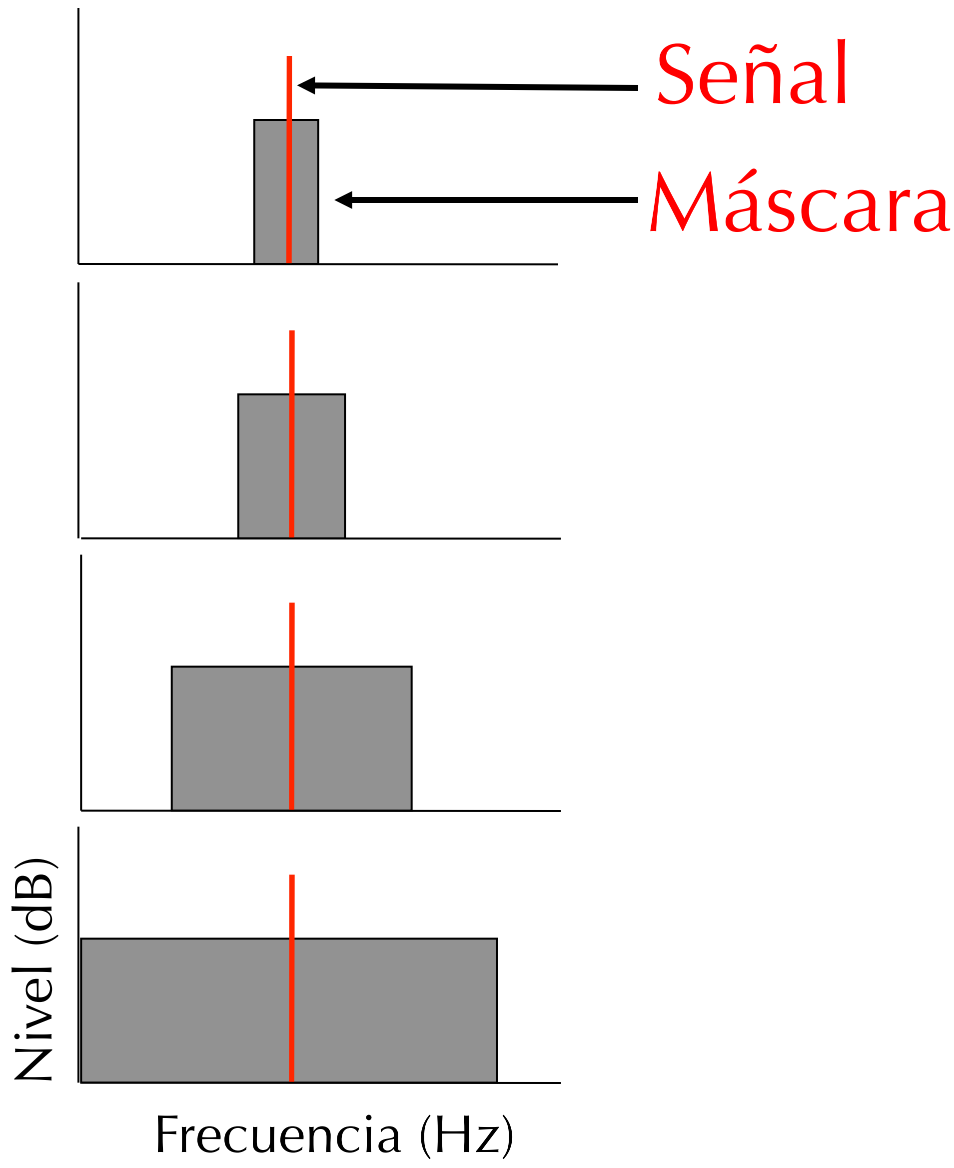
Midiendo la resolución de frecuencia



Midiendo la resolución de frecuencia

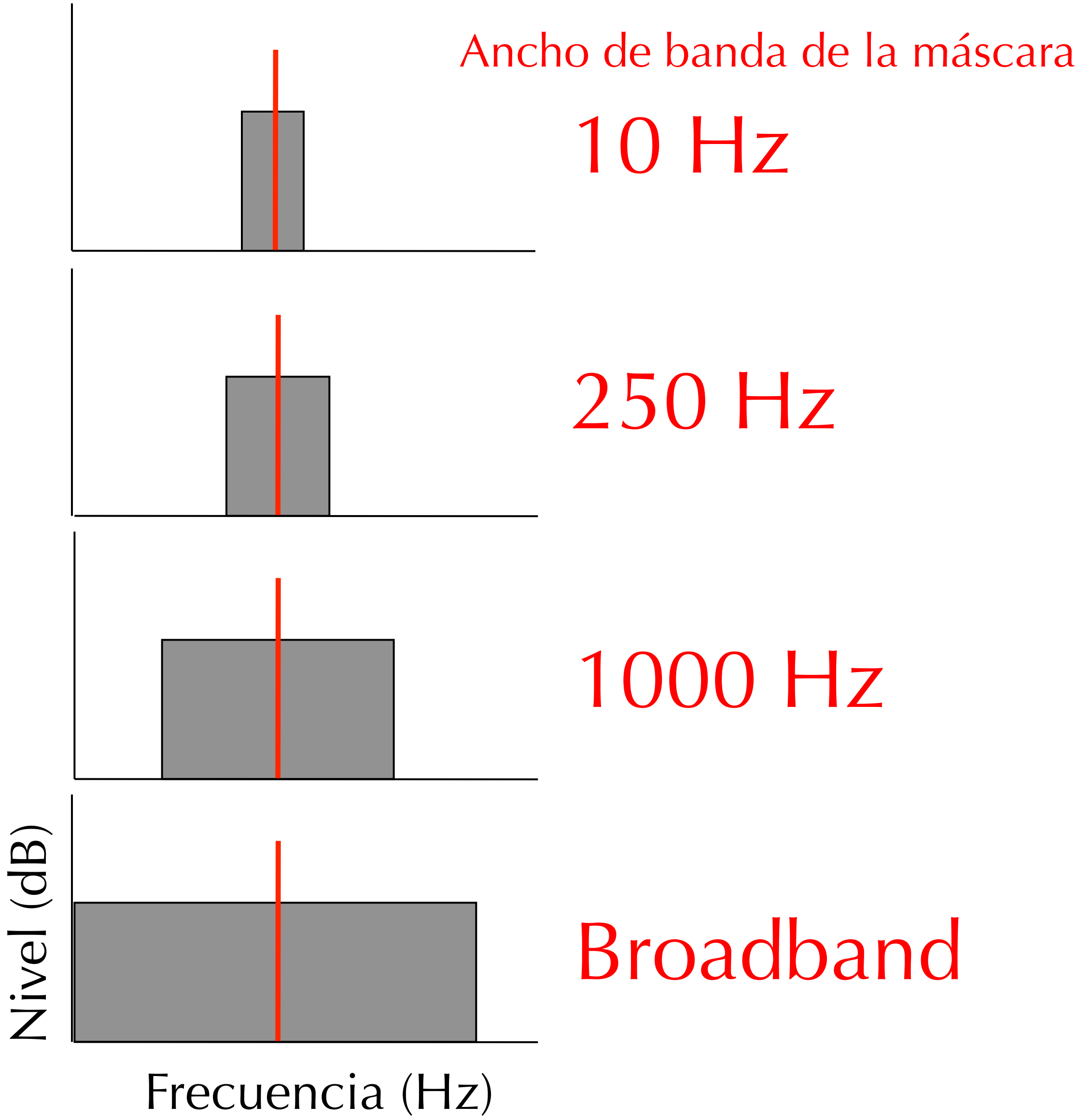


Midiendo la resolución de frecuencia



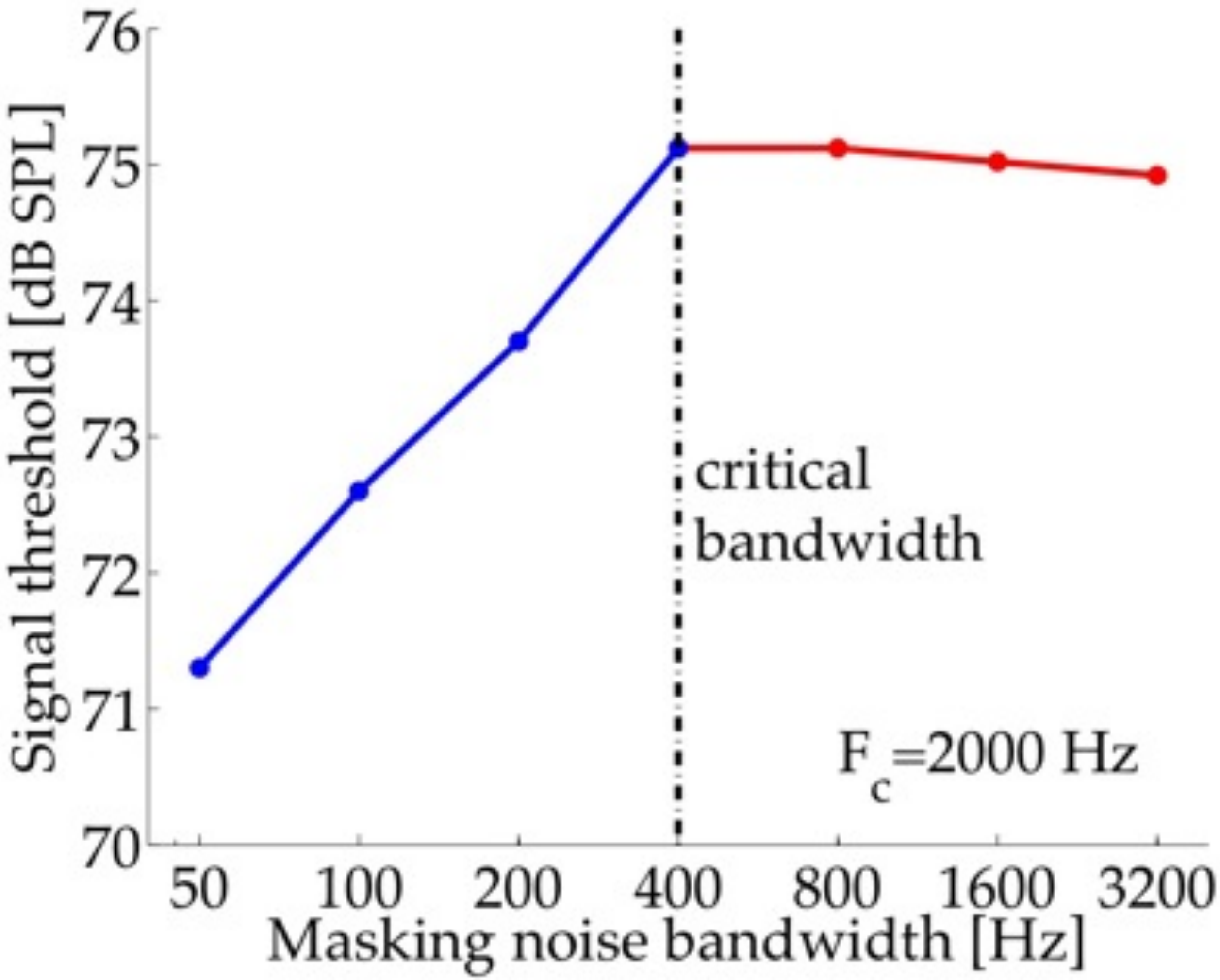
Midiendo la resolución de frecuencia

Señal



Demostración 2

Enmascaramiento y la banda crítica



http://www.cognition.tu-berlin.de/fileadmin/fg7/projekte/moore_copy.jpg

Banda crítica

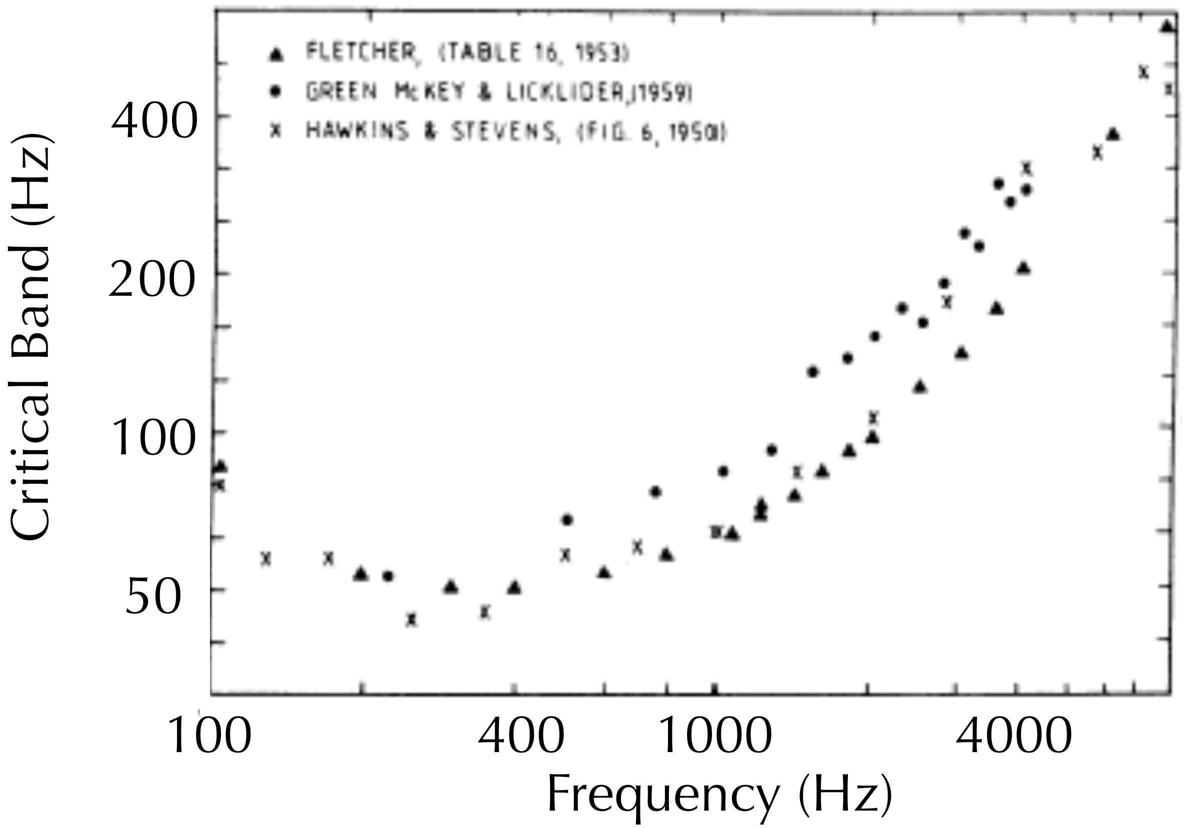
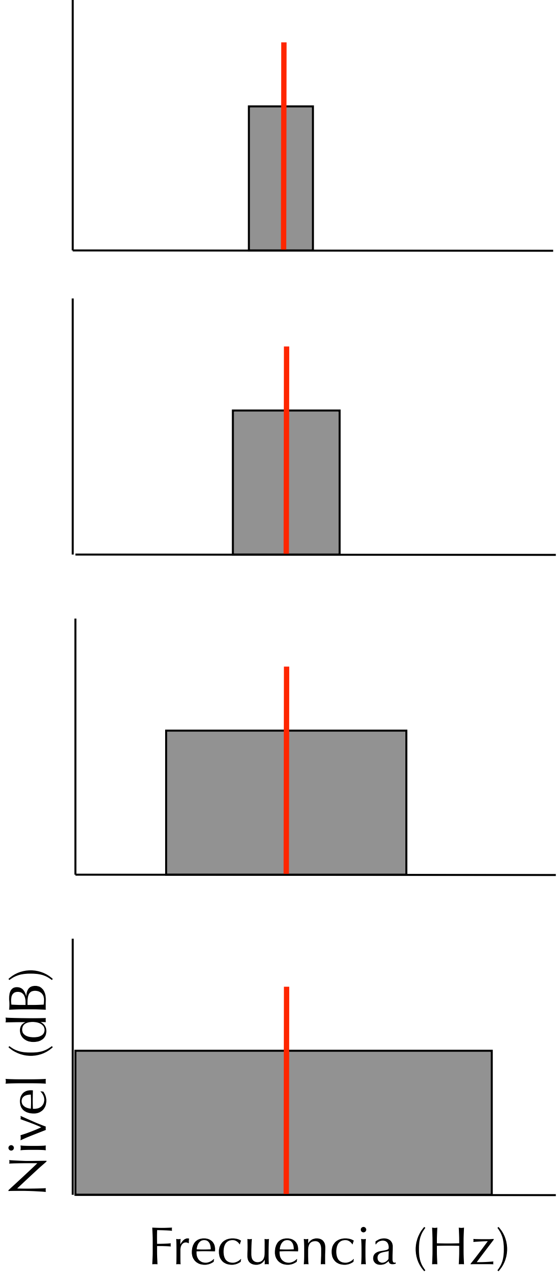


FIG. 3.2 Threshold signal-to-noise ratio plotted as a function of signal frequency. The masker is a broadband noise with a flat spectrum. Modified from Patterson and Green (1978).

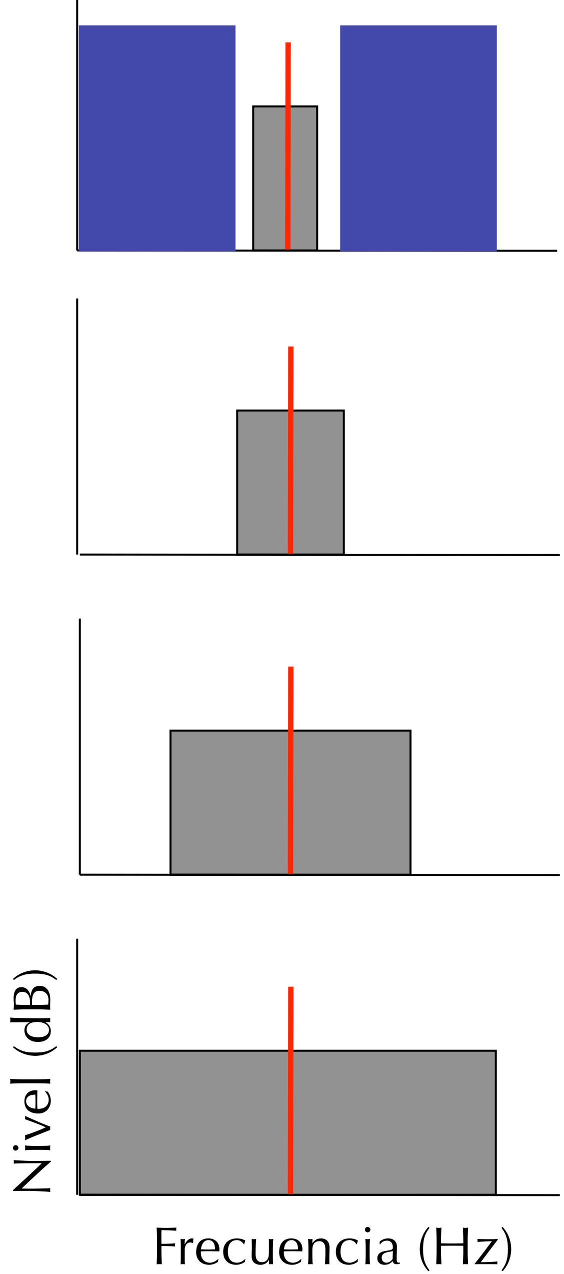
Patterson, R.D., and Green, D.M. (1978). Auditory Masking. In *Handbook of Perception* Vol. IV (eds. E.C. Carterette and M.P. Friedman) Academic Press, New York.

Enmascaramiento y los filtros auditivos

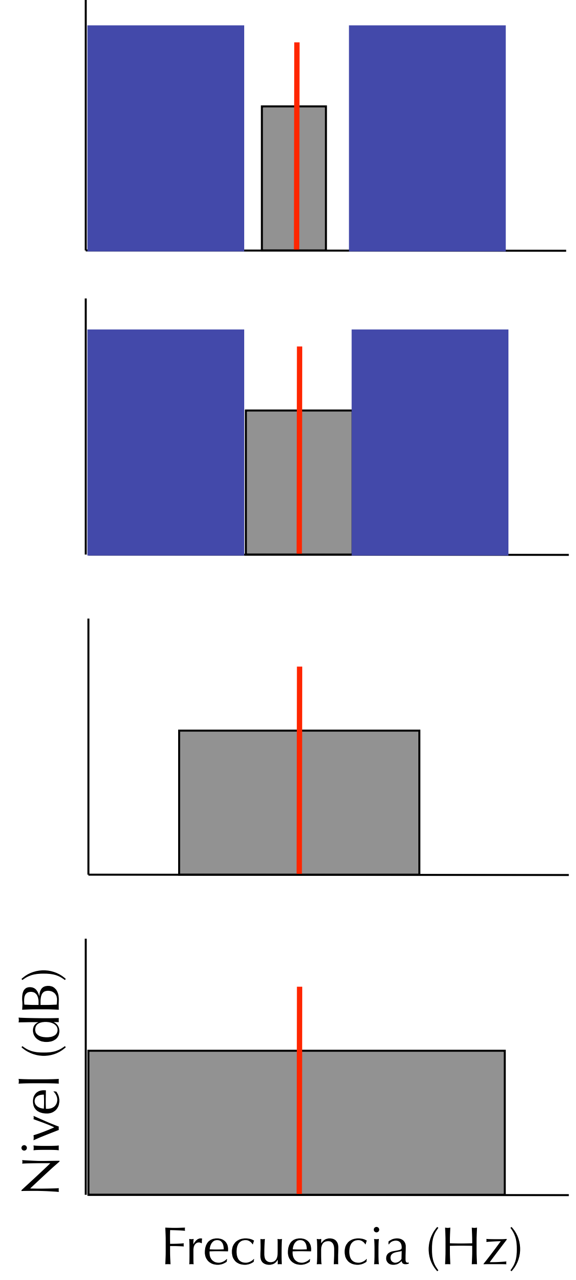
Enmascaramiento y el filtro auditivo



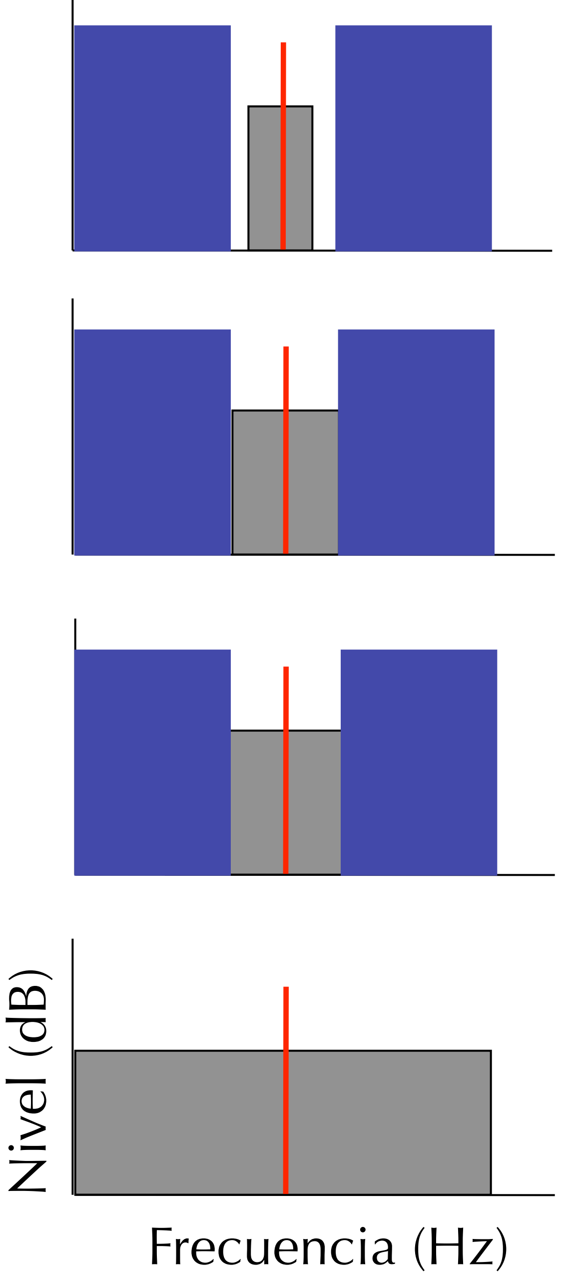
Enmascaramiento y el filtro auditivo



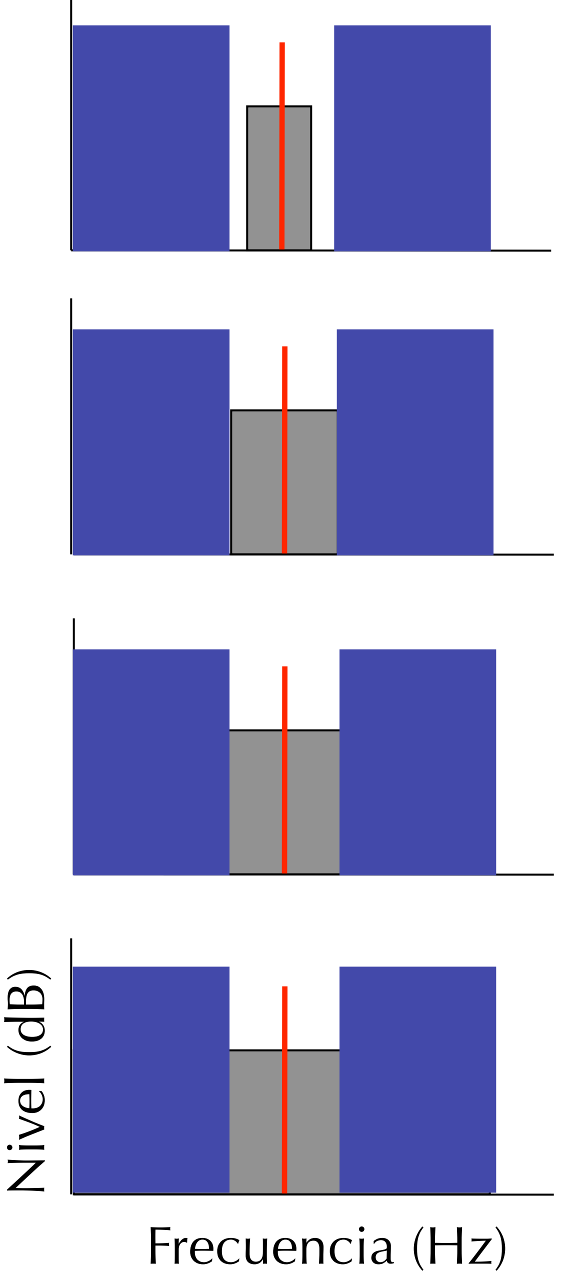
Enmascaramiento y el filtro auditivo



Enmascaramiento y el filtro auditivo



Enmascaramiento y el filtro auditivo



Enmascaramiento y el filtro auditivo

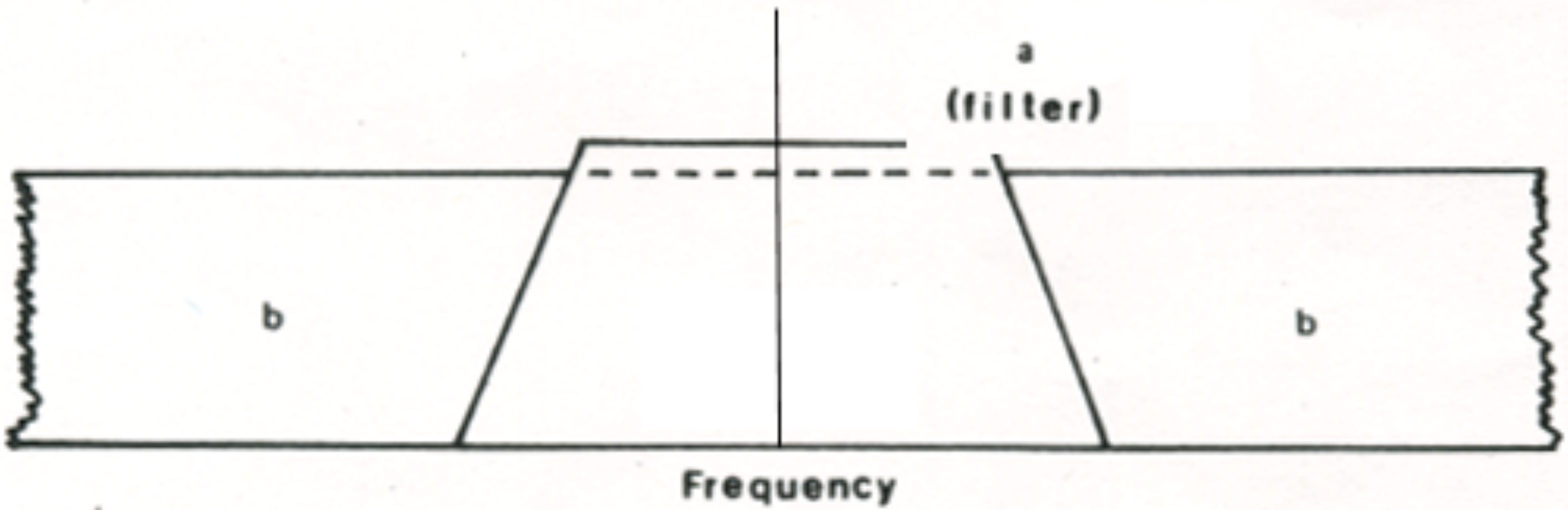
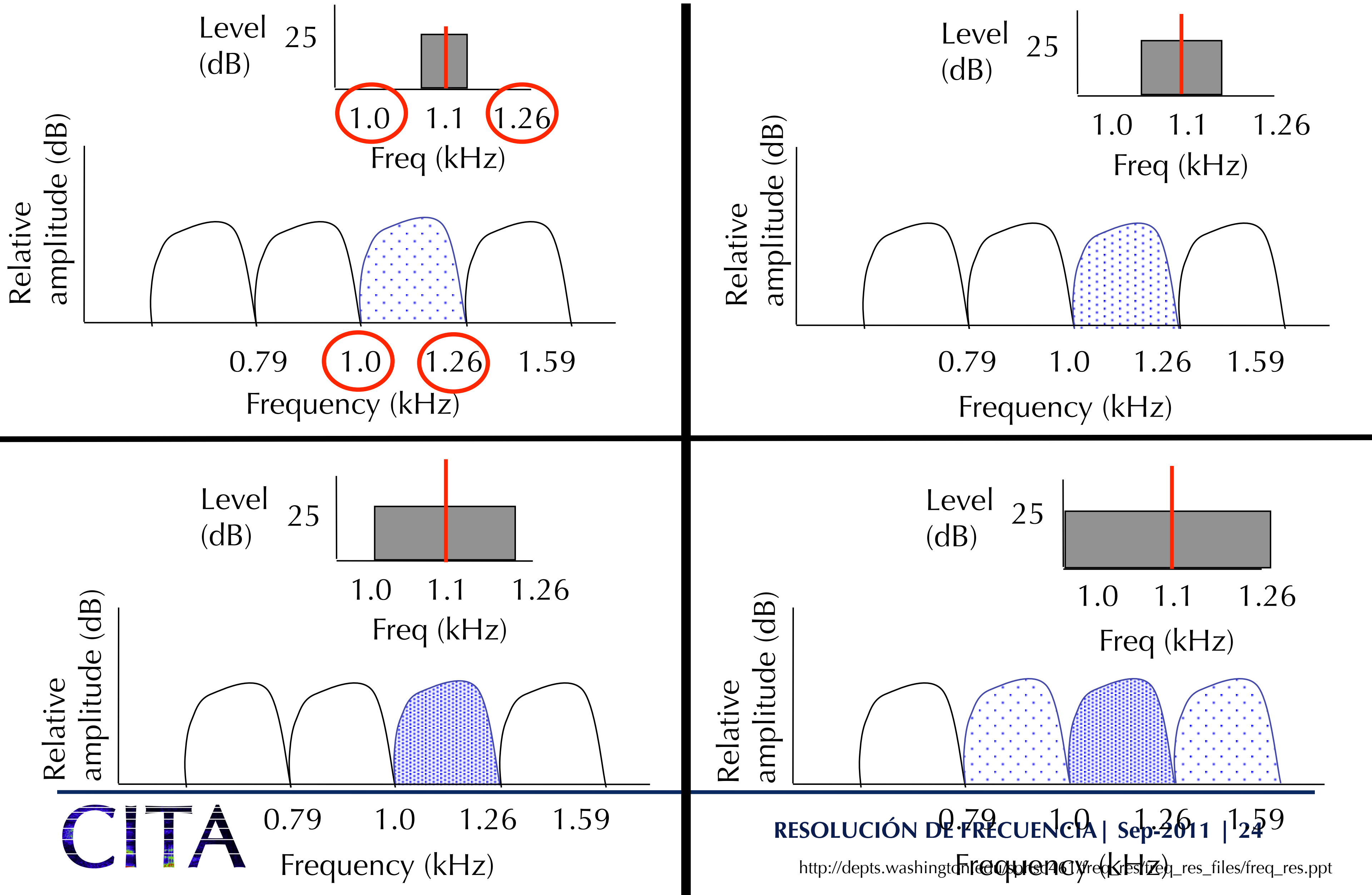


Figure 10.4 Energy within the filter (a) contributes to the masking of the tone at the center, whereas energy outside of the filter (b) does not contribute to the masking (see text).

Nota: ‘filtro auditivo’ y ‘banda crítica’ son usualmente intercambeables

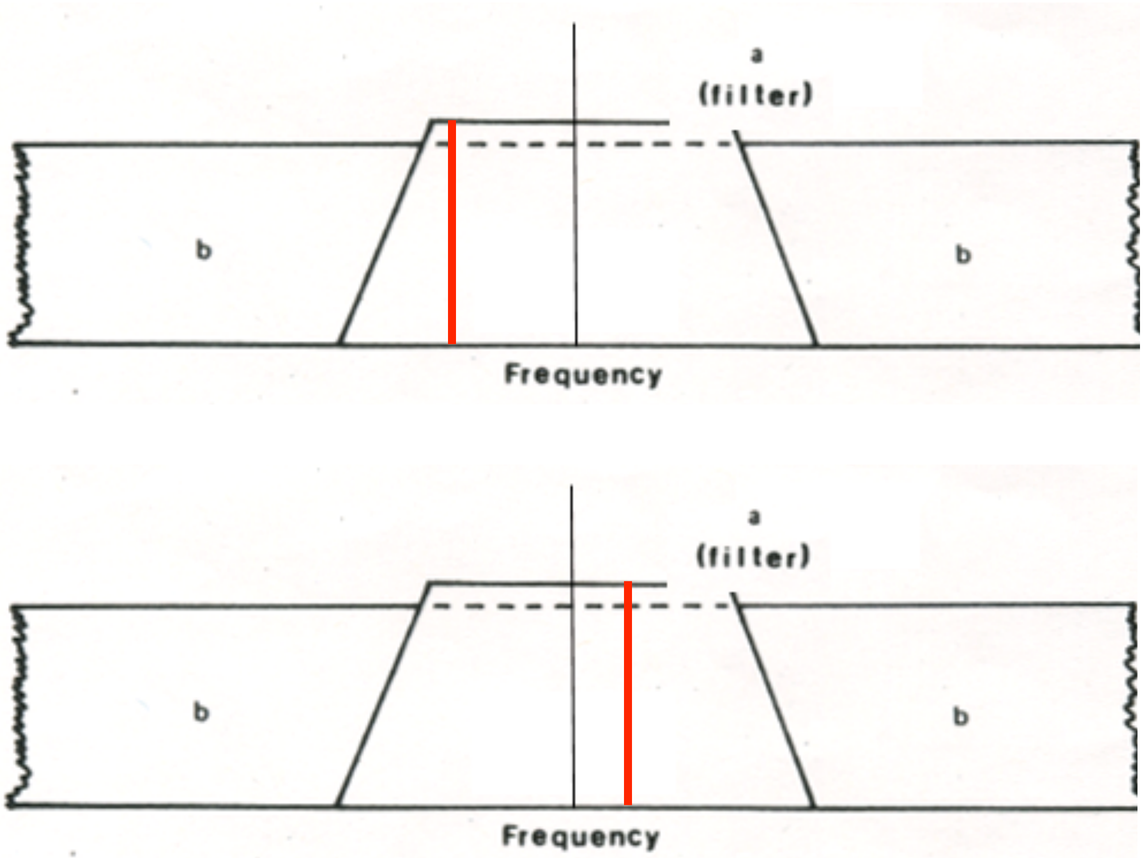
From Gelfand (1998)

Enmascaramiento y el filtro auditivo



http://depts.washington.edu/sphsc461/freq_res/freq_res_files/freq_res.ppt

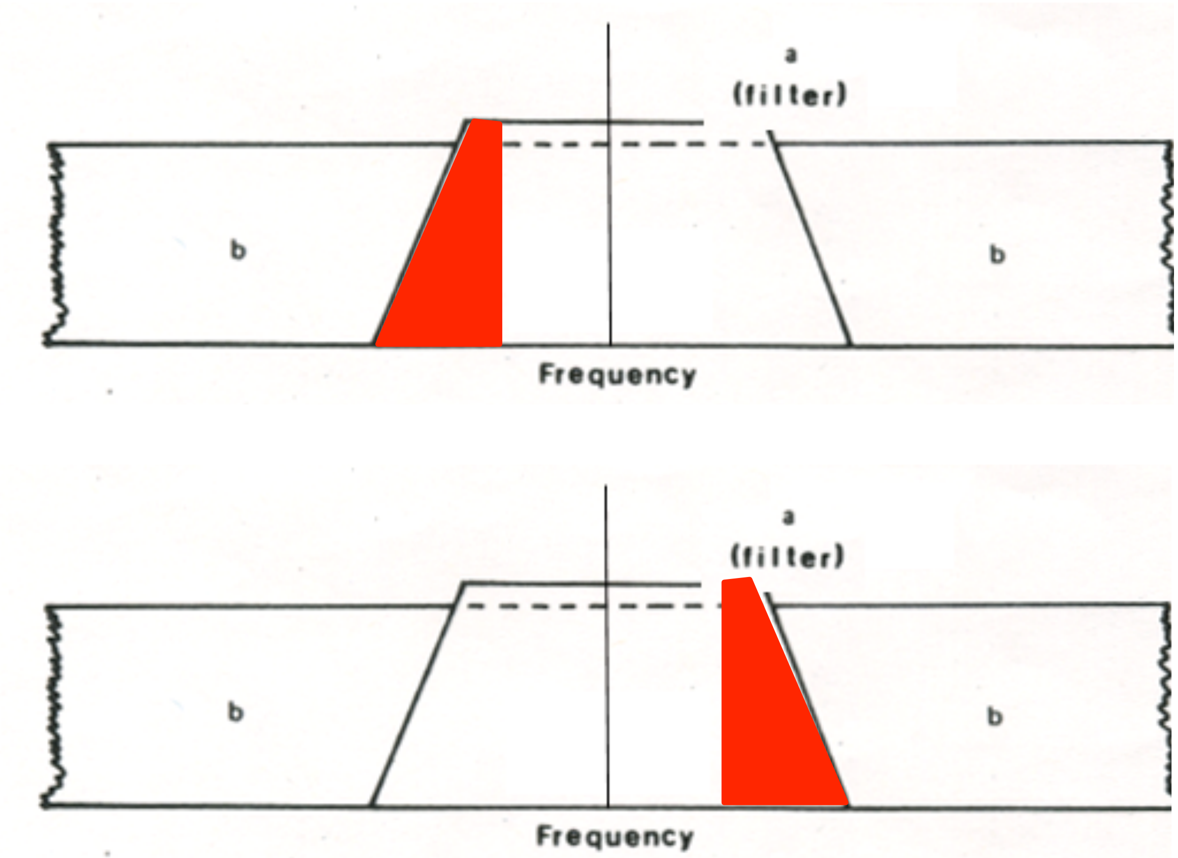
Filtros



A pesar de que las líneas rojas están a distintas frecuencias, la salida de este filtro individual será la misma en ambos casos, porque las líneas tienen la misma altura.

From Gelfand (1998)

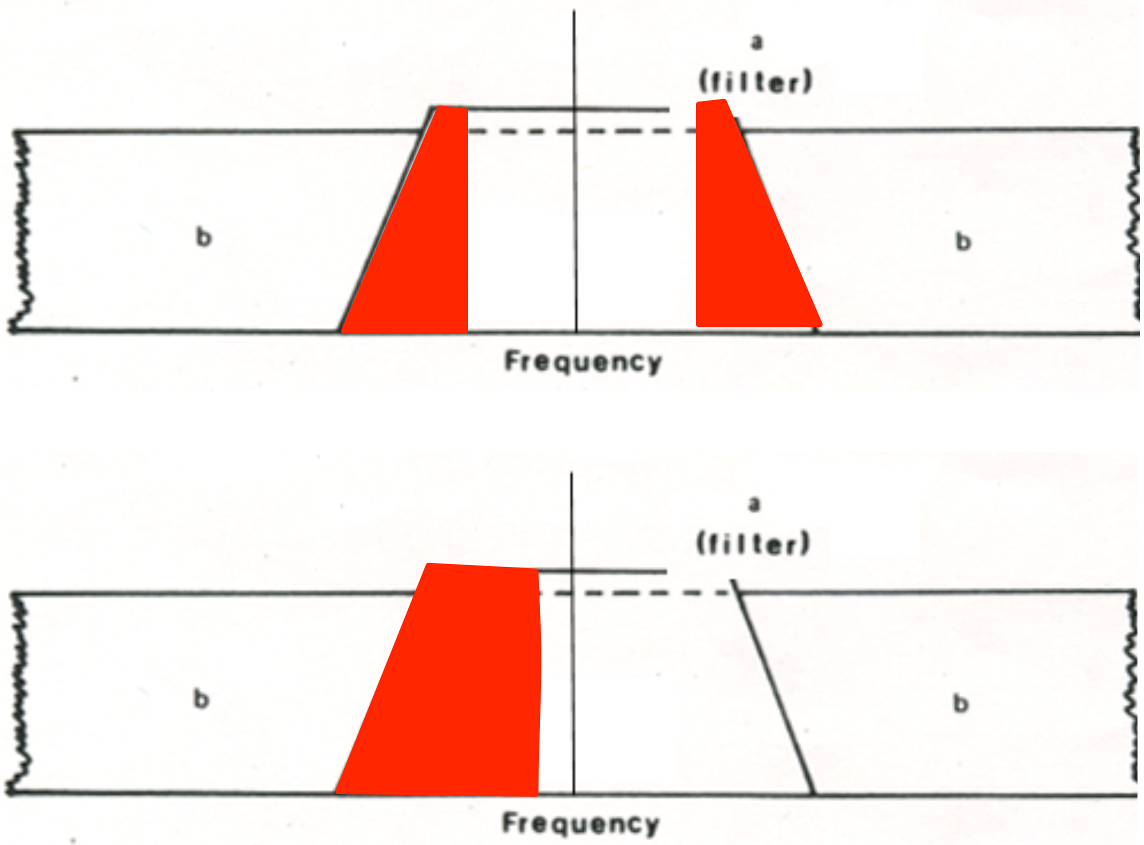
Filtros



¿Será la salida del filtro la misma en estos casos?

From Gelfand (1998)

Filtros



La salida será la misma en ambos casos, asumiendo que las áreas de ambas regiones son equivalentes.

From Gelfand (1998)

Midiendo resolución en frecuencia: Ruido mellado (notched noise)

Medición de filtros auditivos mediante ruido mellado (notch)

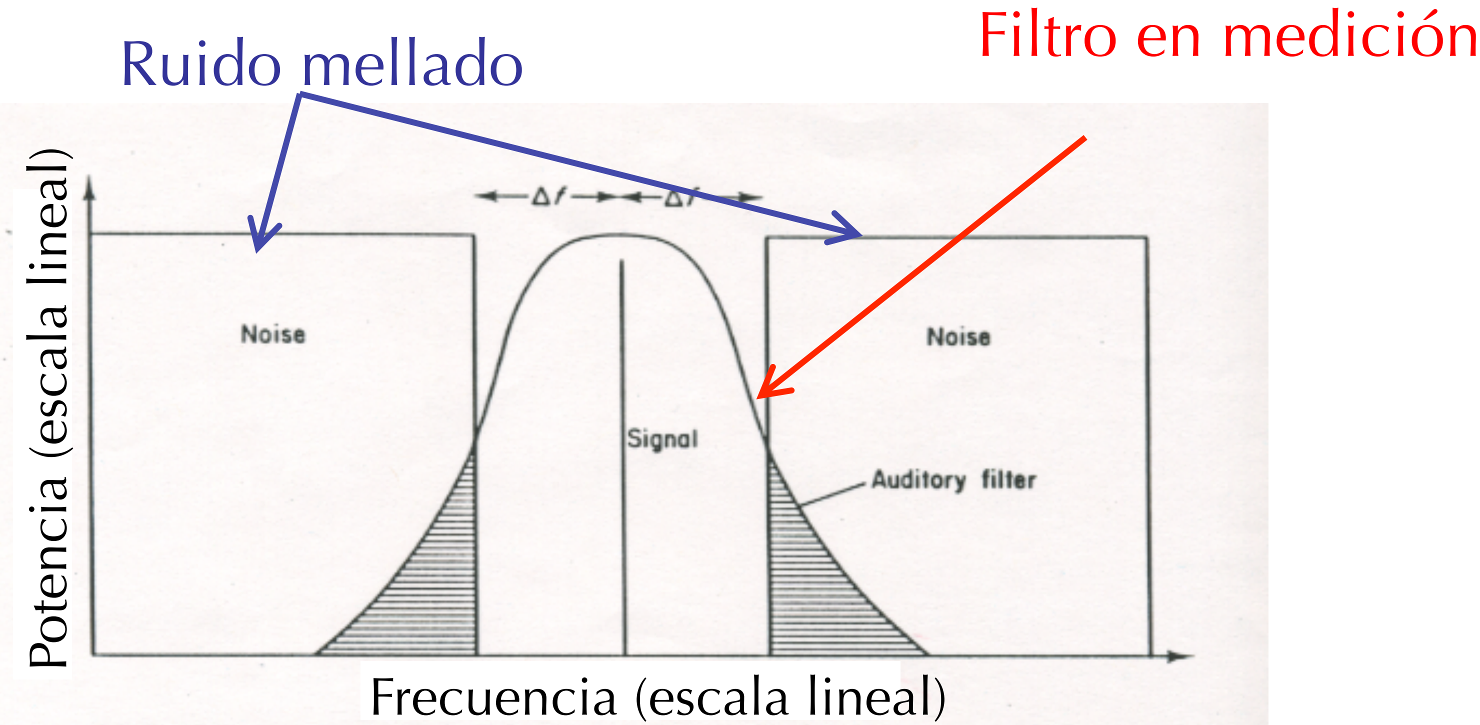
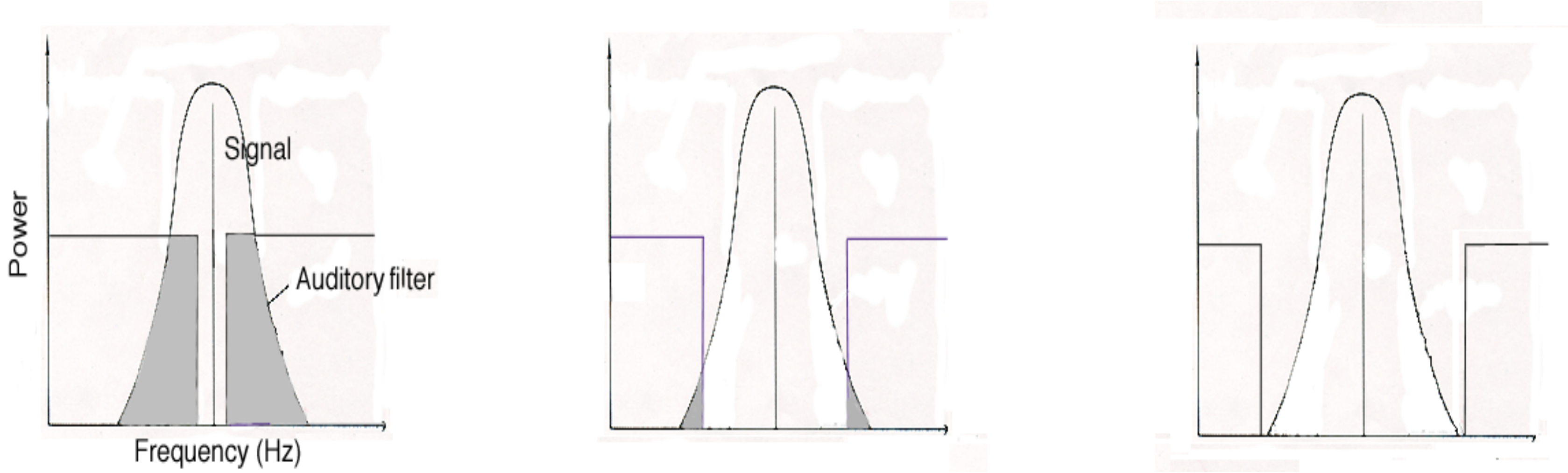


FIG. 3.6 Schematic illustration of the technique used by Patterson (1976) to determine the shape of the auditory filter. The threshold of the sinusoidal signal is measured as a function of the width of a spectral notch in the noise masker. The amount of noise passing through the auditory filter centred at the signal frequency is proportional to the shaded areas.

From Moore (1997)

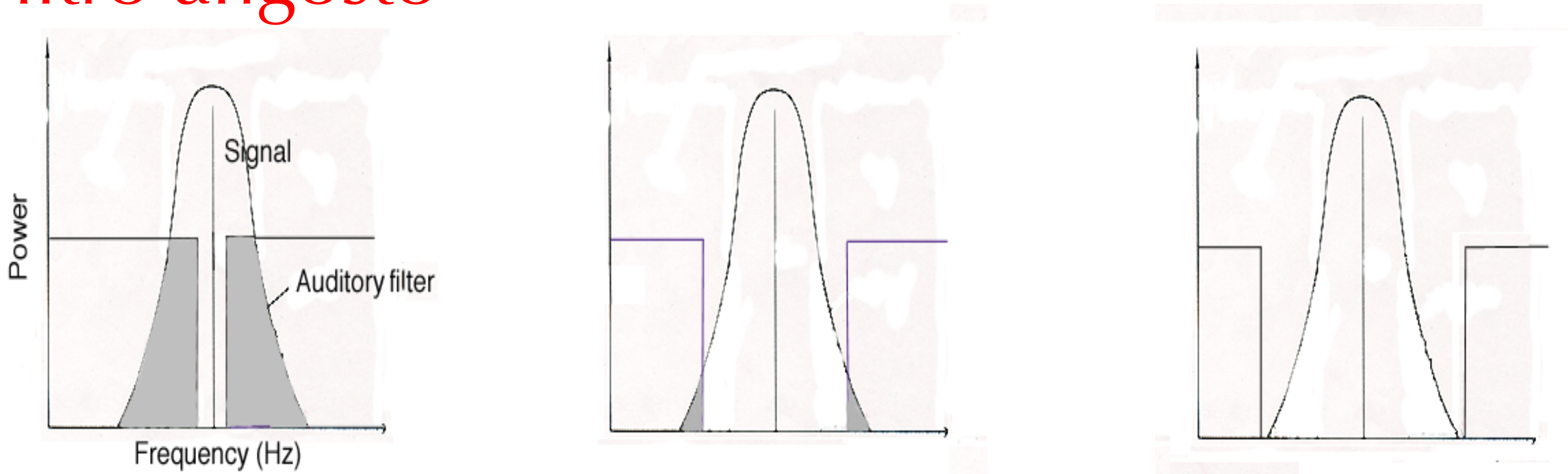
Ancho de filtro



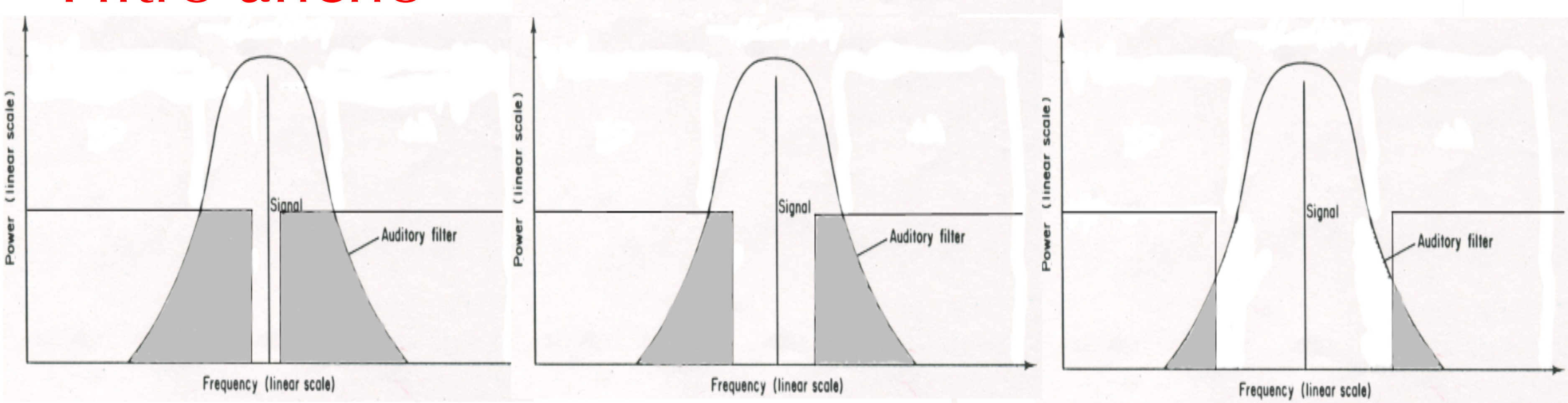
http://depts.washington.edu/sphsc461/freq_res/freq_res_files/freq_res.ppt

Ancho de filtro

Filtro angosto

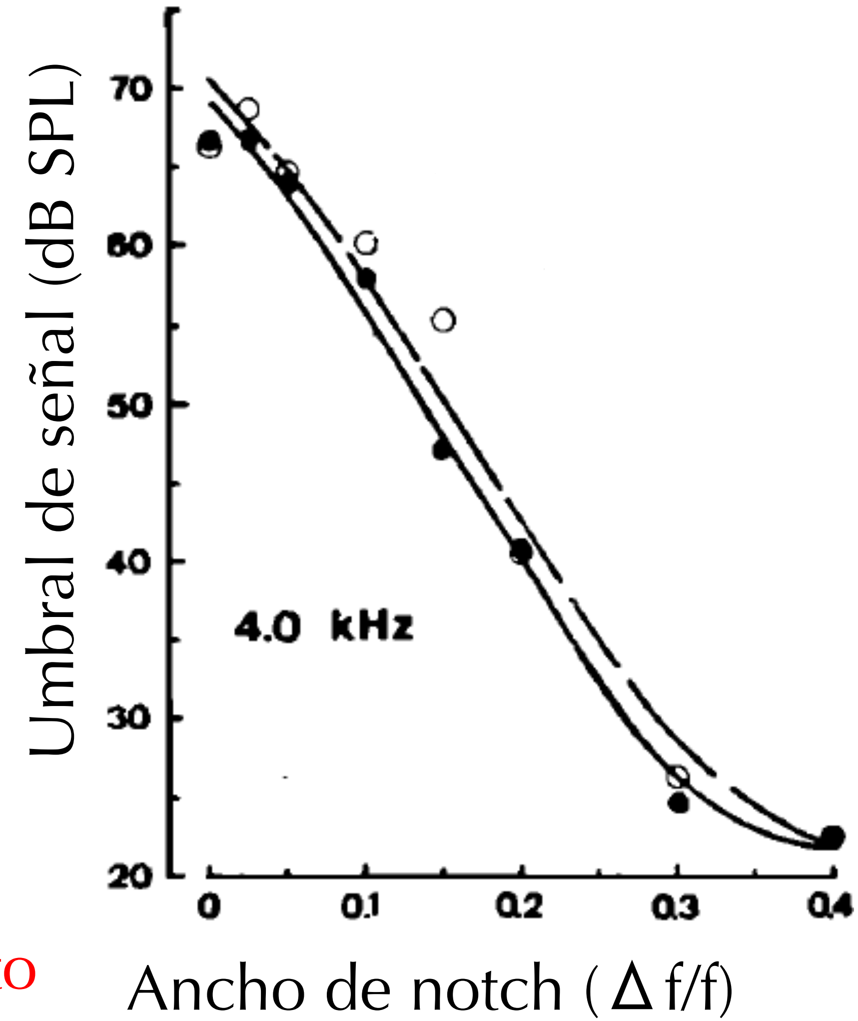


Filtro ancho



http://depts.washington.edu/sphsc461/freq_res/freq_res_files/freq_res.ppt

Umbrales a distintos niveles de mellado



Notch angosto

Notch ancho

From Patterson et al. (1982)

Medición de filtro mediante ruido mellado

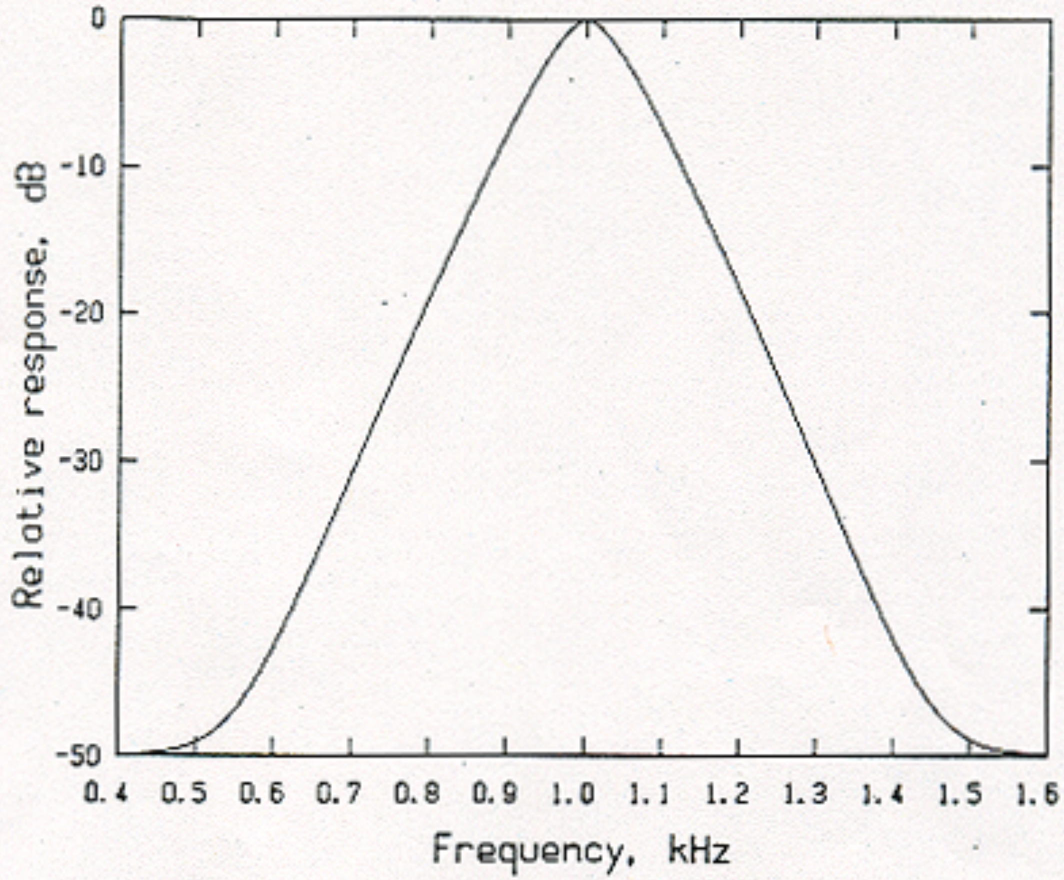


FIG. 3.7 A typical auditory filter shape determined using Patterson's method. The filter is centred at 1 kHz. The relative response of the filter (in dB) is plotted as a function of frequency.

CITA

From Moore (1997)

Filtrado y edad

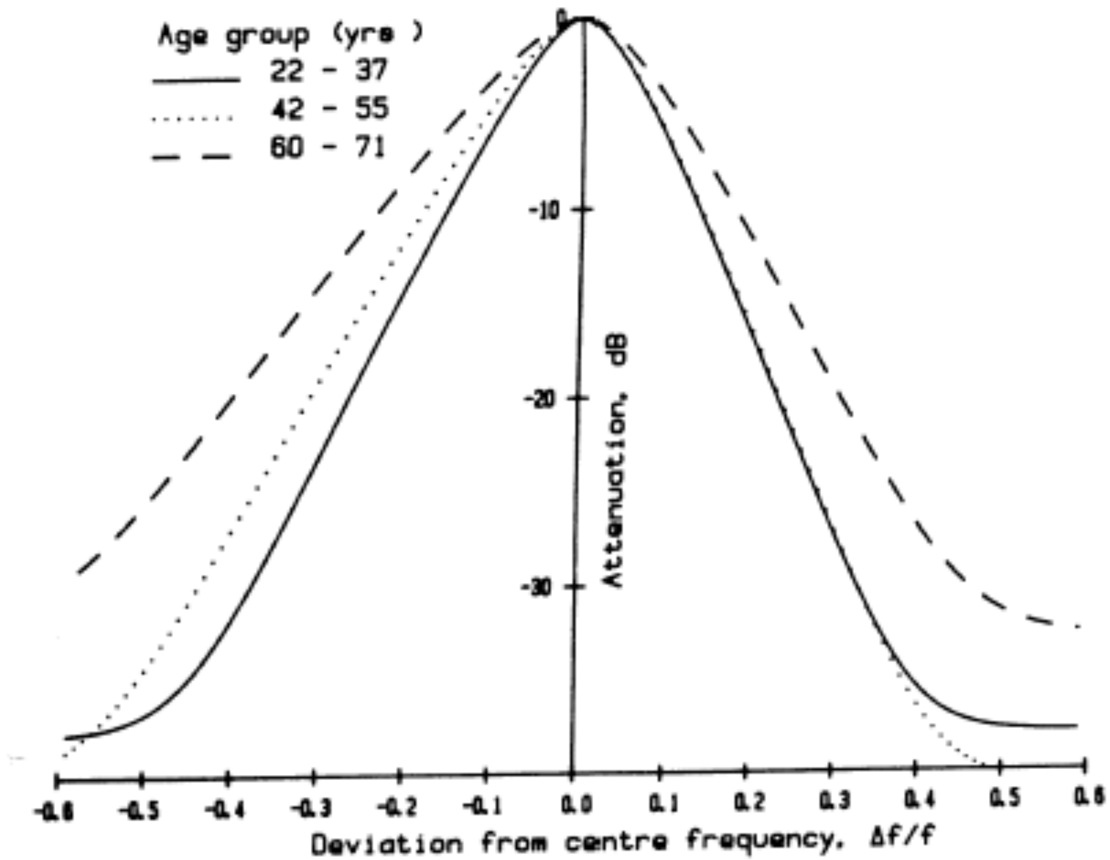
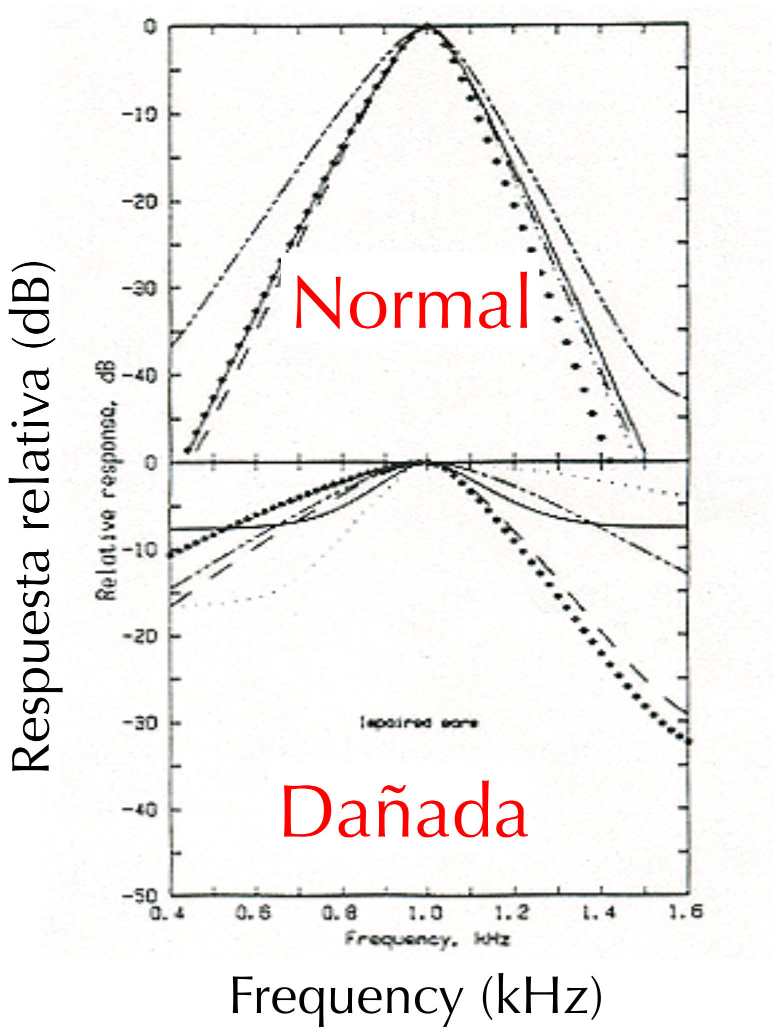


FIG. 3.12 Asymmetric auditory filter shapes derived from the mean data of three groups of listeners varying in average age.

Moore, B.C.J. (1997). *An Introduction to the Psychology of Hearing* Academic Press, London (Fourth Edition).

Filtrado y pérdida auditiva en la cóclea



From Glasberg & Moore (1985)

Eficiencia vs. forma de filtro

Eficiencia

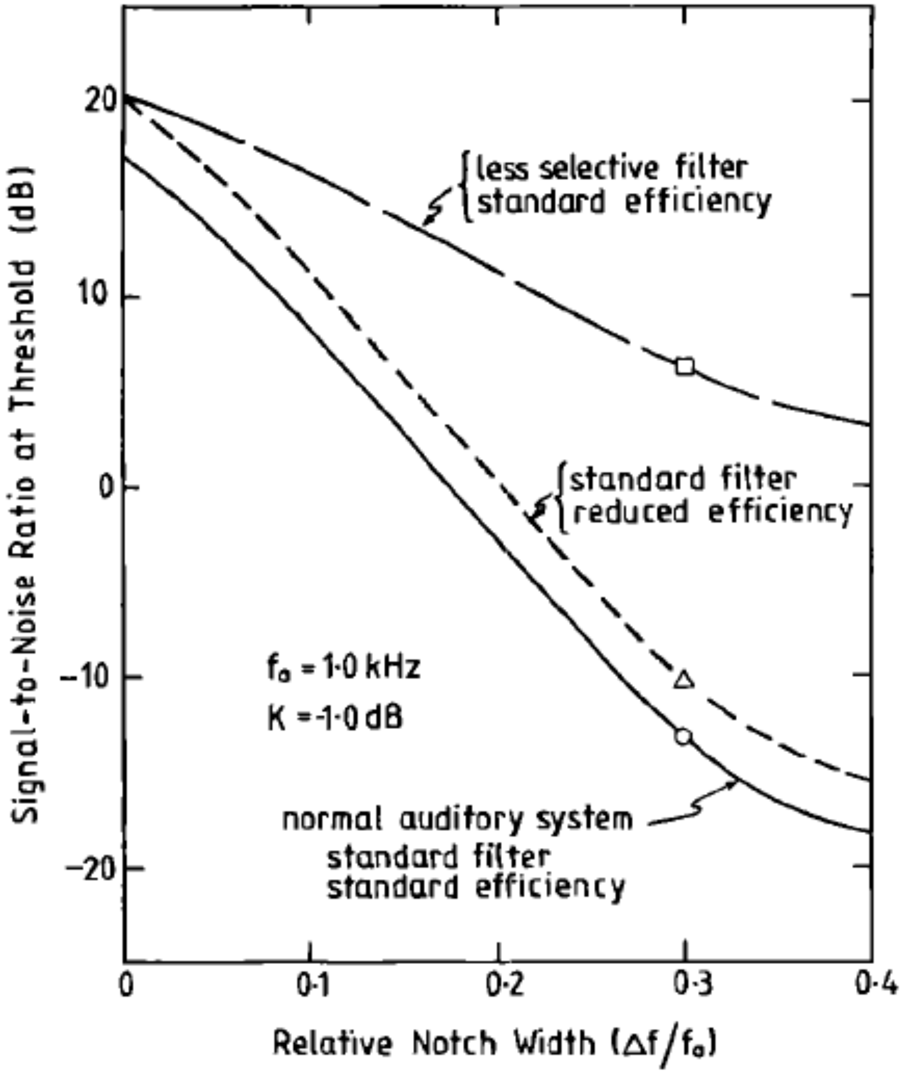
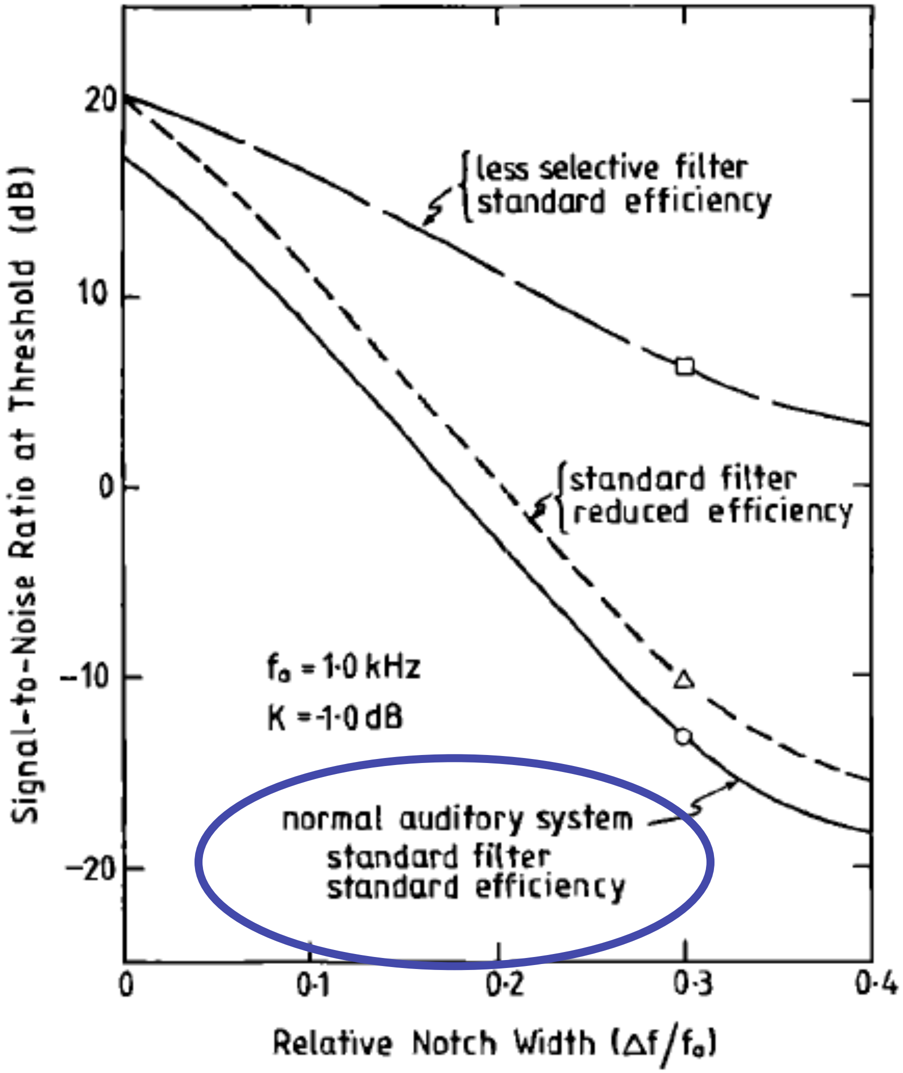


FIG. 1. Diagram of threshold curves produced when a tonal signal is masked by a notched noise. The notch is centered on the tone and its total width is $2\Delta f$ Hz. The solid curve shows how threshold drops as the notch is widened for a normal, young listener ($BW_{ER} = 0.13 f_0$, $K = -1.0$ dB). The broken and dashed curves show the thresholds for two hypothetical patients, one of whom has a broad filter but standard processing efficiency (broken line) ($BW_{ER} = 0.26 f_0$, $K = -1.0$ dB), and the other of whom has reduced processing efficiency but a standard filter (dashed line) ($BW_{ER} = 0.13 f_0$, $K = +2.0$ dB).

La eficiencia es cualquier cosa que afecte al filtro, sin cambiar su forma

From Patterson et al. (1982)

Eficiencia



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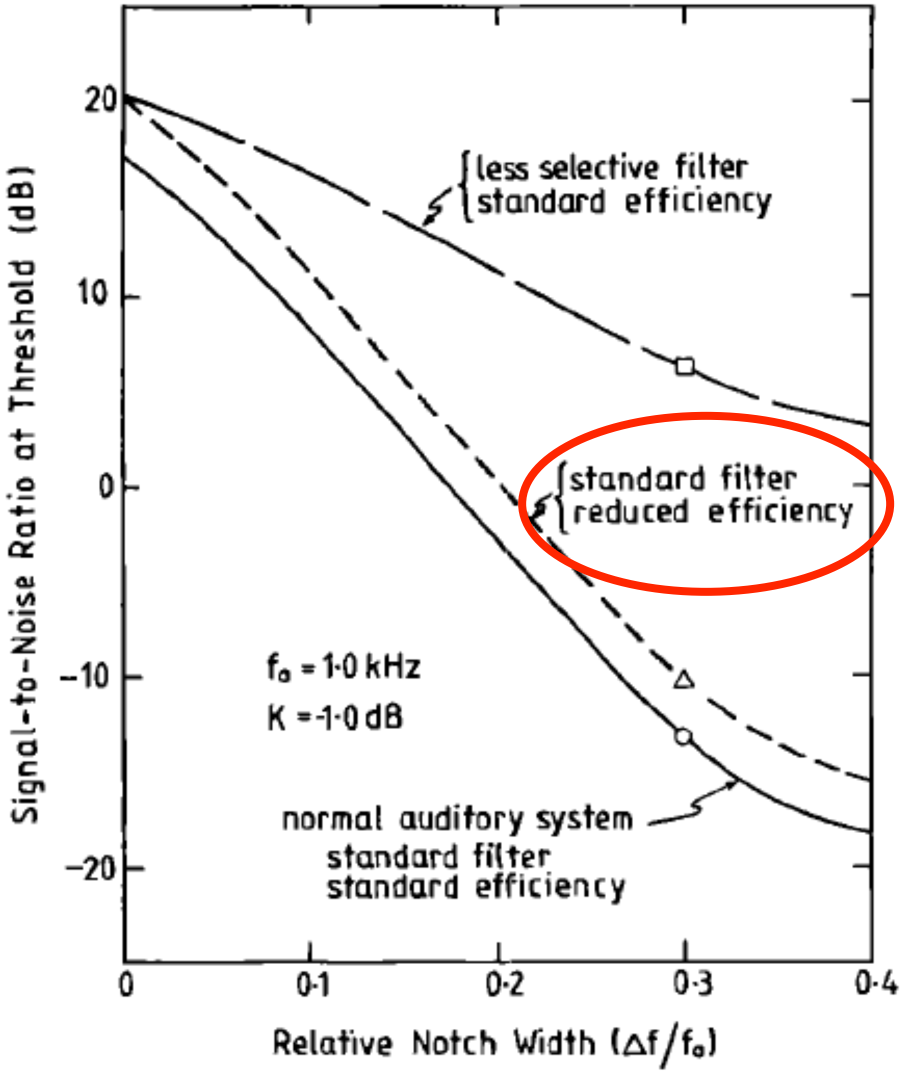
From Patterson et al. (1982)

Eficiencia



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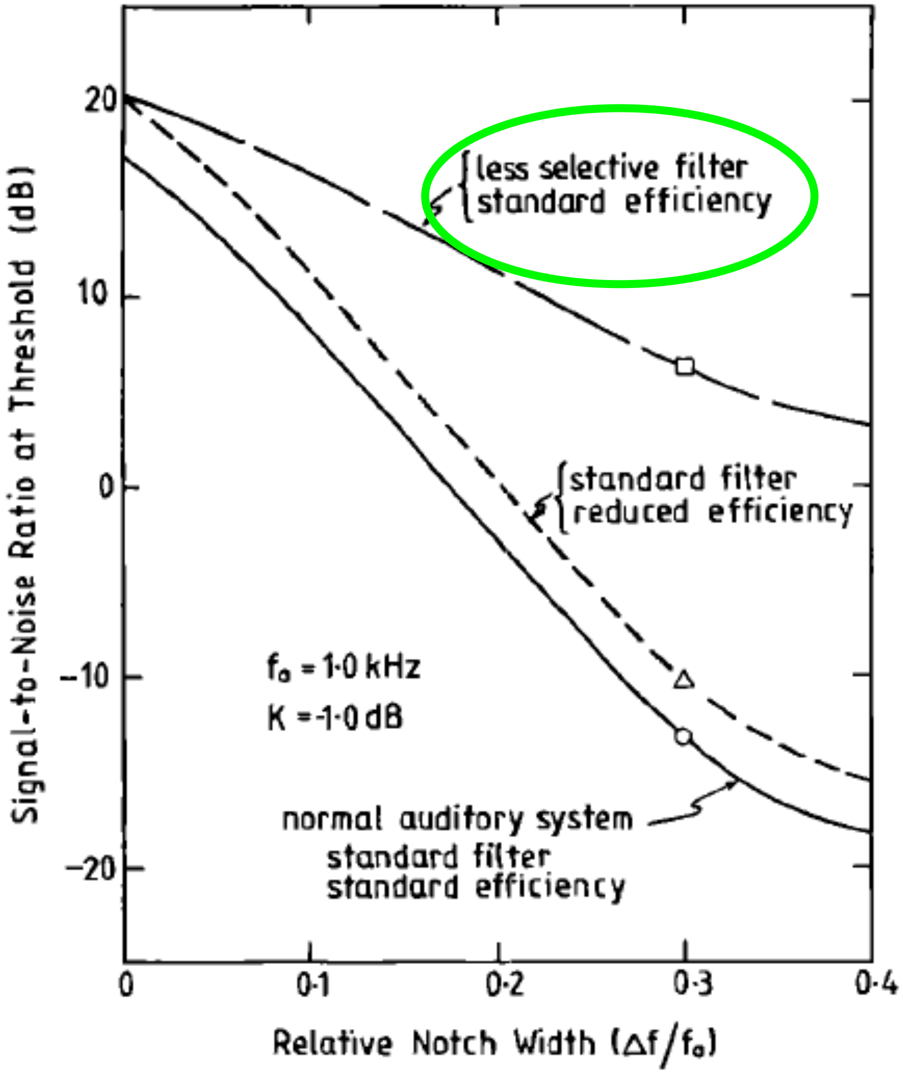
From Patterson et al. (1982)

Eficiencia



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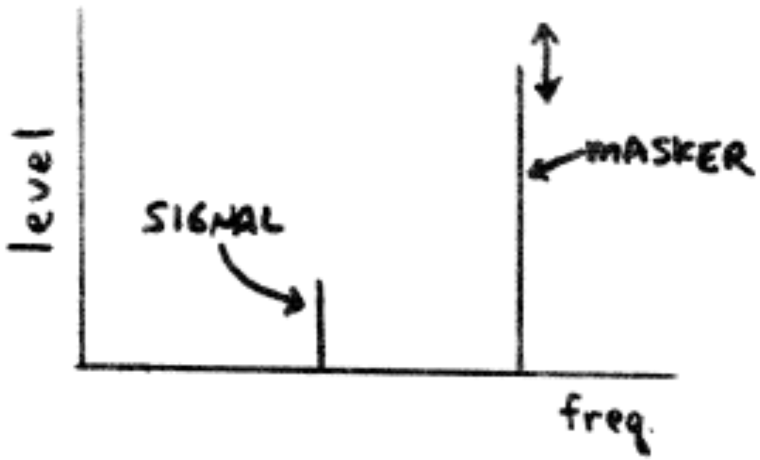
From Patterson et al. (1982)

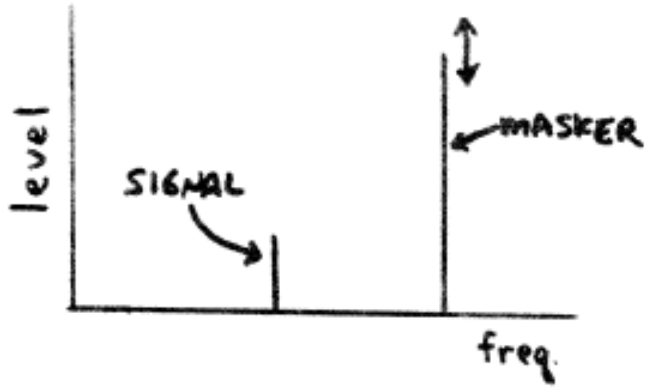
Midiendo resolución de frecuencia: Psychophysical tuning curve (PTC)

Psychophysical tuning curve



- Se fija la señal a una nivel bajo
- Se varía el nivel de la máscara para determinar el nivel al cual la señal apenas puede ser detectada en la presencia de la máscara
- La frecuencia de la máscara varía en los test para formar una curva en función de la frecuencia

Psychophysical tuning curve



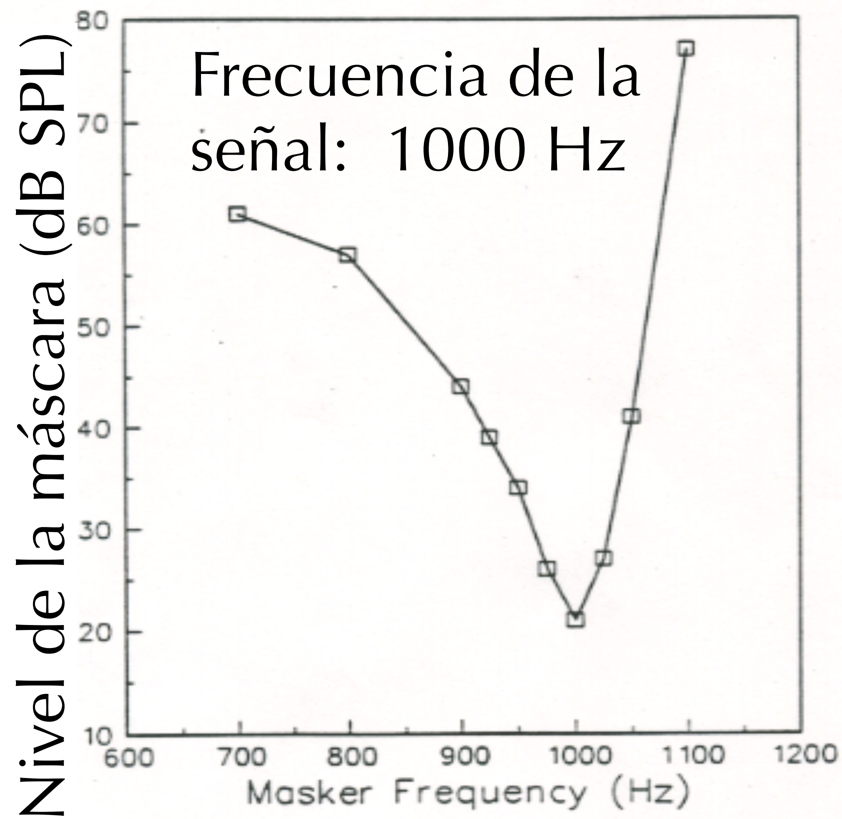


FIGURE 11.1 A psychophysical tuning curve for simultaneous tone-on-tone masking is shown. The signal was presented at 5 dB SL and the level and frequency of the masker were varied to obtain the function. For each masker frequency the level of the masker required to just mask the signal is displayed. Based on data from Moore (1978), with permission.

From Yost (1994)

Psychophysical tuning curve

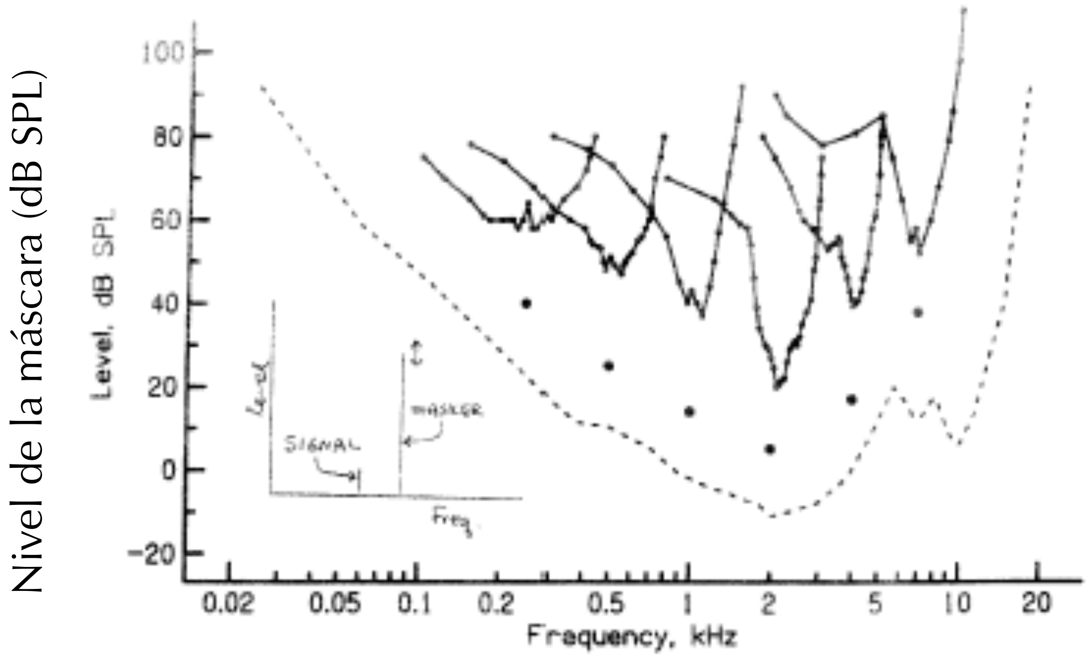
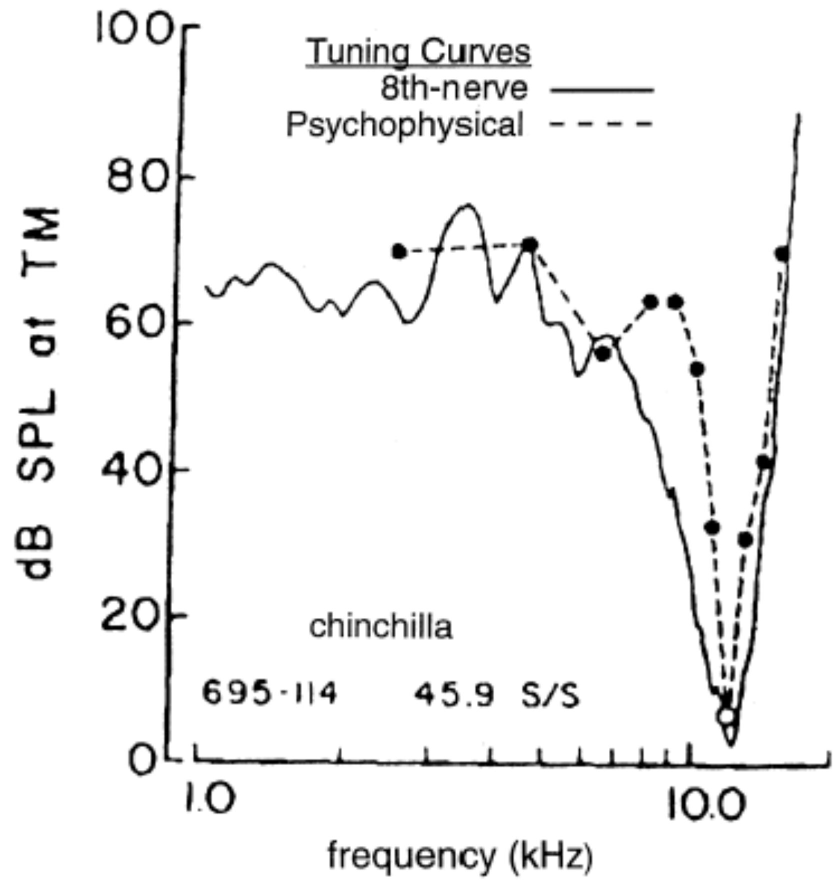


FIG. 3.7 Psychophysical tuning curves (PTCs) determined in simultaneous masking, using sinusoidal signals at 10 dB SPL. For each curve, the solid circle below it indicates the frequency and level of the signal. The masker was a sinusoid which had a fixed starting phase relationship to the 50-ms signal. The masker level required for threshold is plotted as a function of masker frequency on a logarithmic scale. The dashed line shows the absolute threshold for the signal. Data from Vogten (1974).

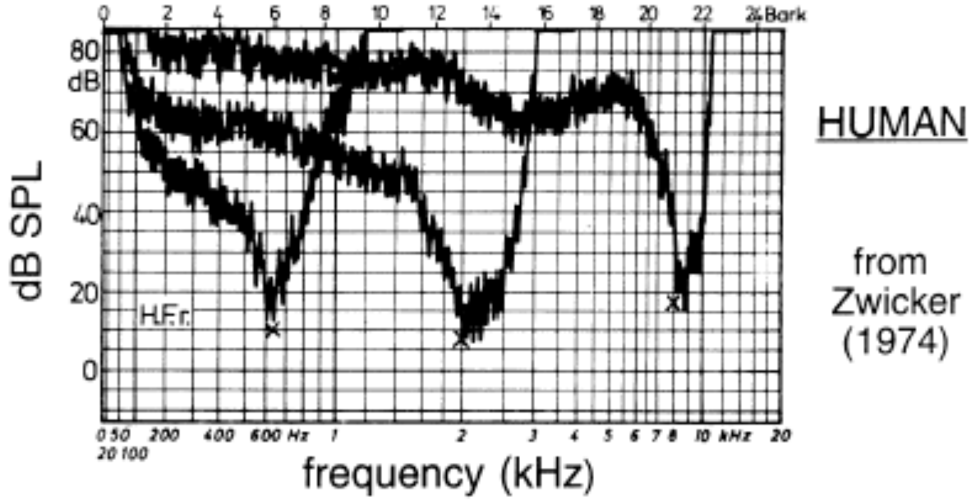
Vogten, L.L.M. (1974). "Pure-tone masking: A new result from a new method," in Facts and Models in Hearing, edited by E. Zwicker and E. Terhardt (Springer-Verlag, Berlin).

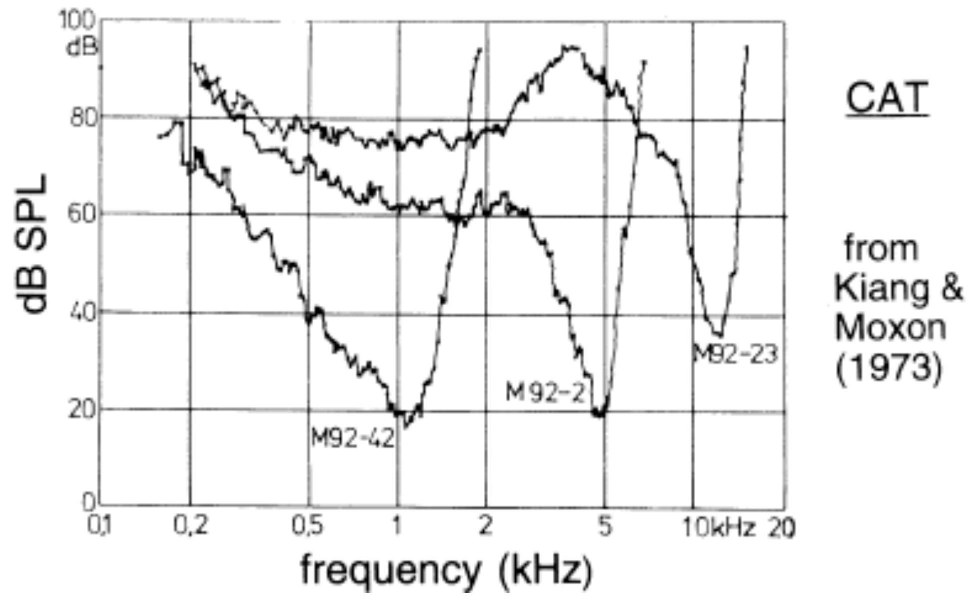
Psychophysical tuning curve



from Hamernik et al., (1982)

Psychophysical tuning curve





Psychophysical tuning curves y pérdidas auditivas

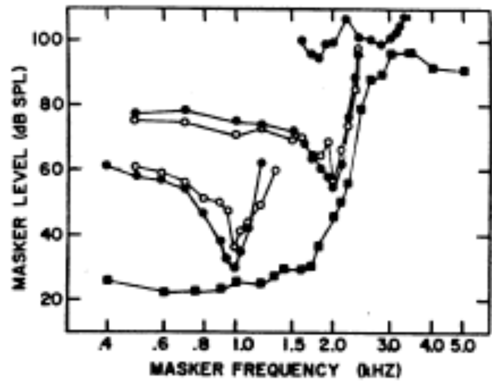


Fig. 4. Tuning curves obtained from hearing-impaired subject JA. The solid squares denote absolute threshold for the 20 msec probe (ordinate in this case gives probe level in dB SPL). A threshold of about 23 dB SPL is normal. The solid circles are data from forward-masking conditions; the open circles are data from simultaneous conditions. Probe frequencies used were 1.0 kHz (left curves), 2.0 kHz (middle curves), and 3.0 kHz (right curve). Because of the excessive masker levels required, no simultaneous-masked tuning curve was obtained with the 3.0 kHz probe.

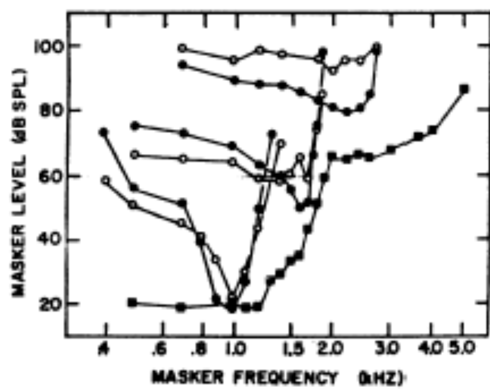
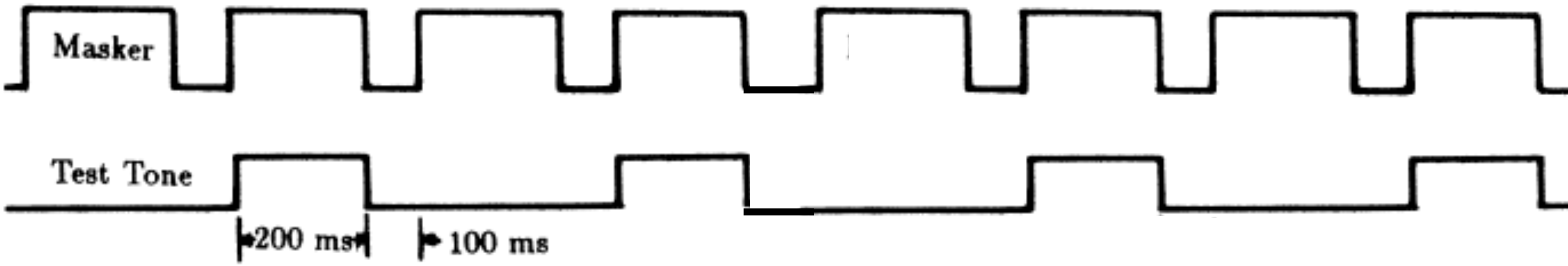


Fig. 5. Same as Fig. 4 but from hearing-impaired subject MM. In this case, the probe frequencies were 1.0 kHz (left curves), 1.7 kHz (middle curves), and 2.3 kHz (right curves).

Wightman, F., McGee, T., and Kramer, M. (1977). "Factors influencing frequency selectivity in normal and hearing-impaired listeners," in Psychophysics and Physiology of Hearing, eds. E.F. Evans and J.P. Wilson, Academic Press, New York, 295-310.

Asimetría de enmascaramiento

Demostración de asimetría de enmascaramiento



Nivel del tono de test decrece

Demostración 9

	Máscara	Tono de test
1st set:	1200 Hz	2000 Hz
2nd set:	2000 Hz	1200 Hz

Asimetría de enmascaramiento

Las bajas frecuencias enmascaran más a las altas que viceversa

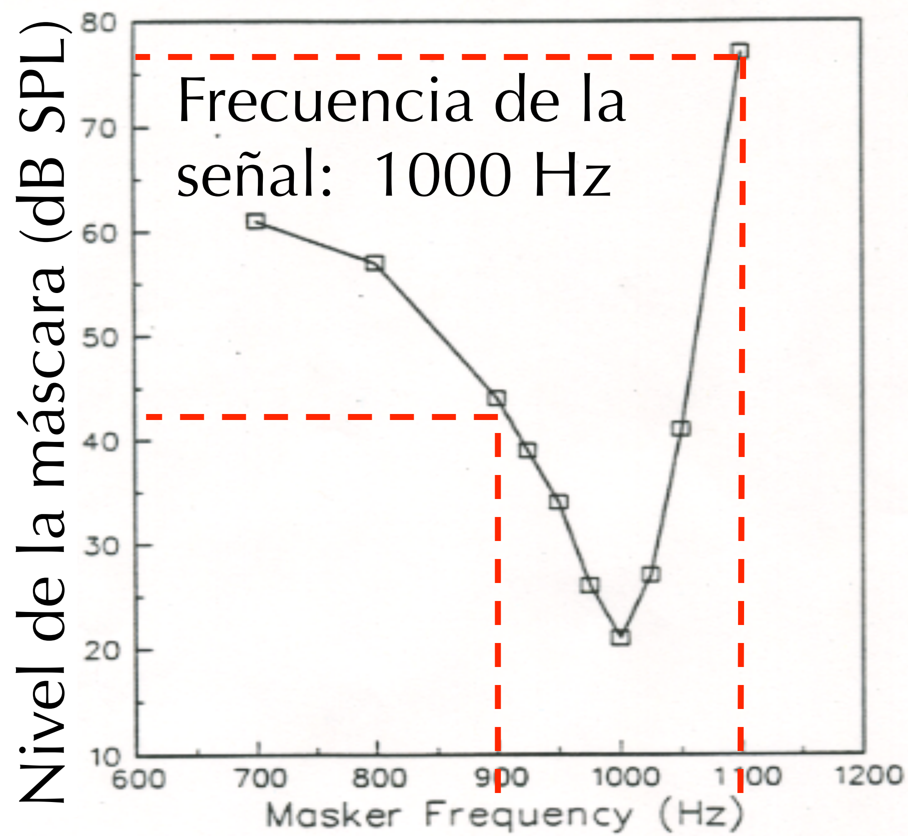


FIGURE 11.1 A psychophysical tuning curve for simultaneous tone-on-tone masking is shown. The signal was presented at 5 dB SL and the level and frequency of the masker were varied to obtain the function. For each masker frequency the level of the masker required to just mask the signal is displayed. Based on data from Moore (1978), with permission.

From Yost (1994)

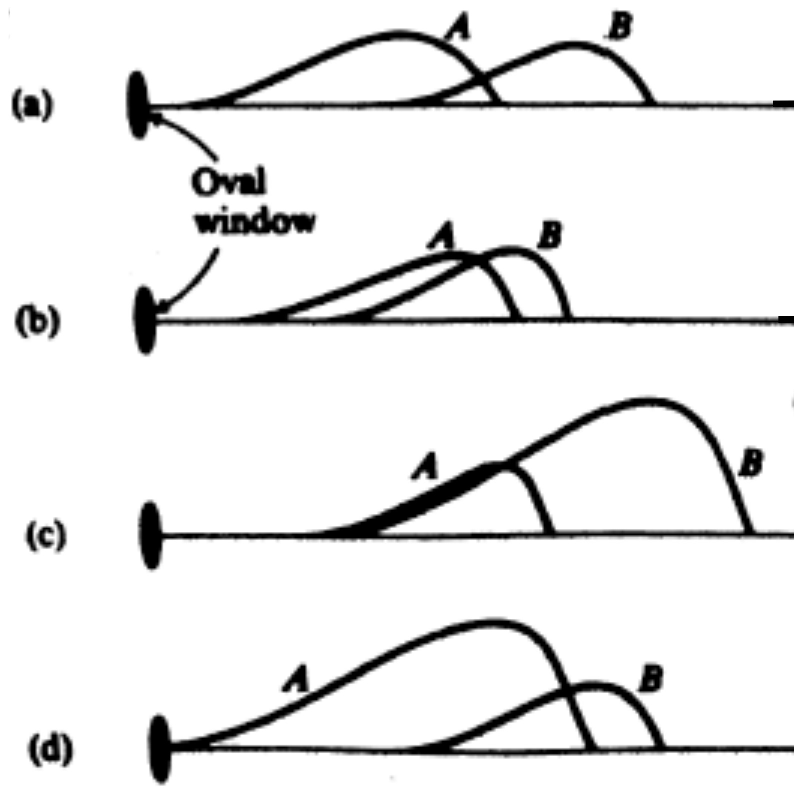
Razones para la asimetría

(A) La onda que se produce en la membrana basilar empieza en la base (en la zona de las altas frecuencias), y viaja hacia el lugar correspondiente a la frecuencia del estímulo.

(B) La onda una vez que alcanza el lugar correspondiente a la frecuencia del estímulo súbitamente muere (moviéndose hacia el apex, la zona de bajas frecuencias).

Adapted from: http://depts.washington.edu/sphsc461/freq_res/freq_res_files/freq_res.ppt

Asimetría de enmascaramiento



Poco enmascaramiento

B enmascara a A más de lo que A enmascara a B

B enmascara casi completamente a A

A no enmascara a B

Alta frecuencia

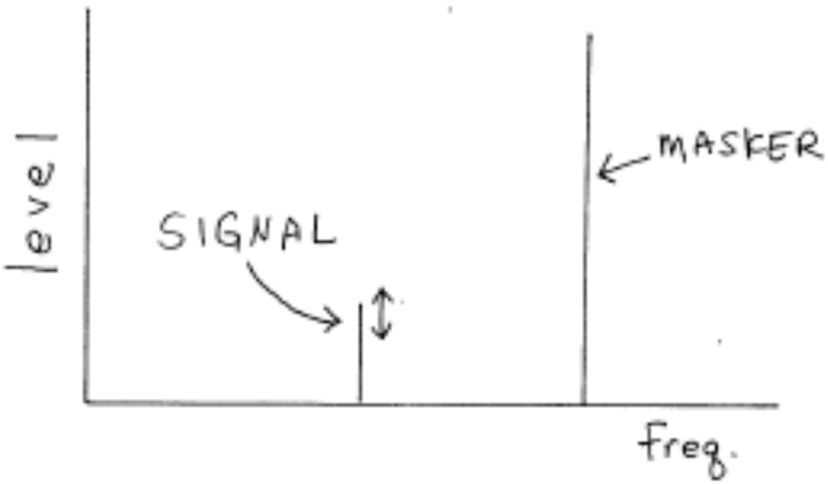
Baja frecuencia

Simplified response of the basilar membrane (from Rossing, 1982).

Rossing, T.D. (1982). The Science of Sound (Addison-Wesley, Reading, MA). Chap. 6

Midiendo resolución en frecuencia: patrón de enmascaramiento

Patrones de enmascaramiento



- Nivel de la máscara es fijo
- Se varía el nivel de la señal para determinar el nivel al cual la señal apenas puede ser detectada en la presencia de la máscara.
- La frecuencia de la señal se varía en distintos tests para construir una curva para cada nivel de máscara.

Patrones de enmascaramiento

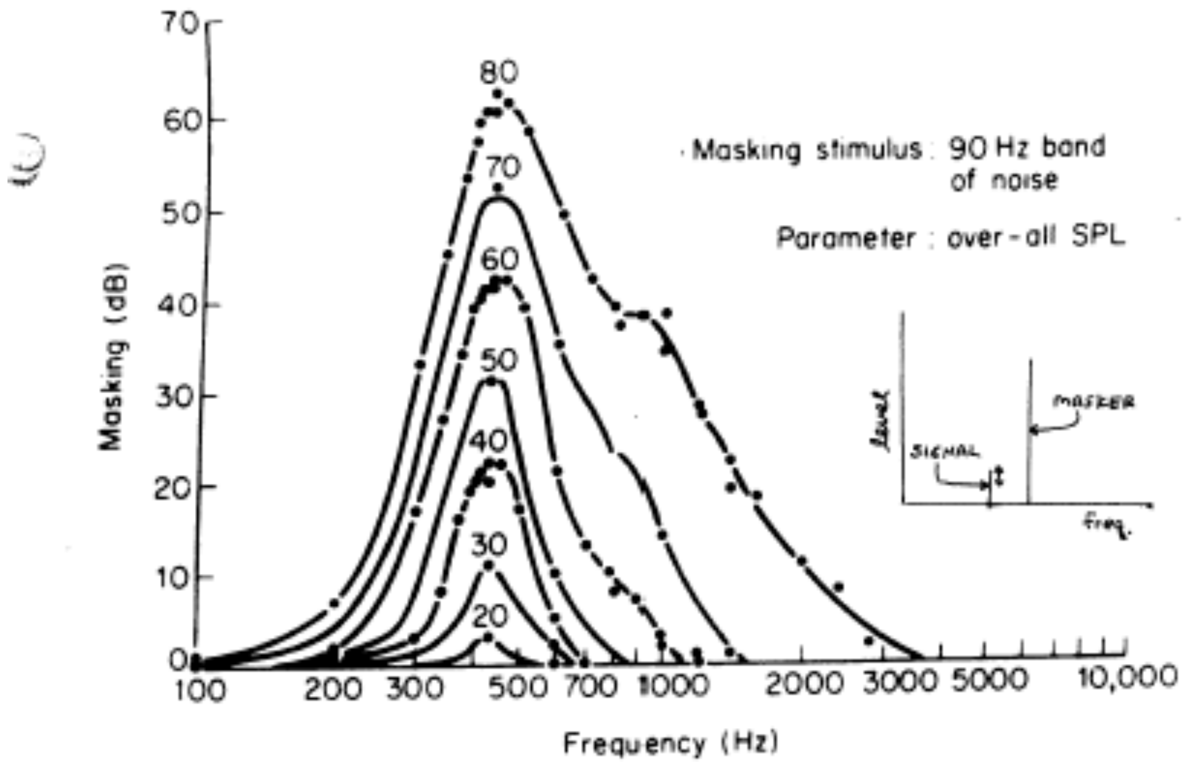


FIG. 3.12 Masking patterns (masked audiograms) for a narrow band of noise centred at 410 Hz. Each curve shows the elevation in threshold of a pure tone signal as a function of signal frequency. The overall noise level for each curve is indicated in the figure. Adapted from Egan and Hake (1950), by permission of the authors and *J. Acoust. Soc. Am.*

Egan, J.P., and Hake, H.W. (1950). "On the masking pattern of a simple auditory stimulus," J. Acoust. Soc. Am., 22, 622-630.

¿Cuál de las siguientes señales enmascarará de forma más efectiva a un tono de 1000 Hz?

(A) una banda de ruido centrada en 1000 Hz

(B) una banda de ruido centrada en 500 Hz

(C) un tono centrado en 500 Hz

¿Cuál de las siguientes señales enmascarará de forma más efectiva a un tono de 1000 Hz?

(A) un tono de 500-Hz

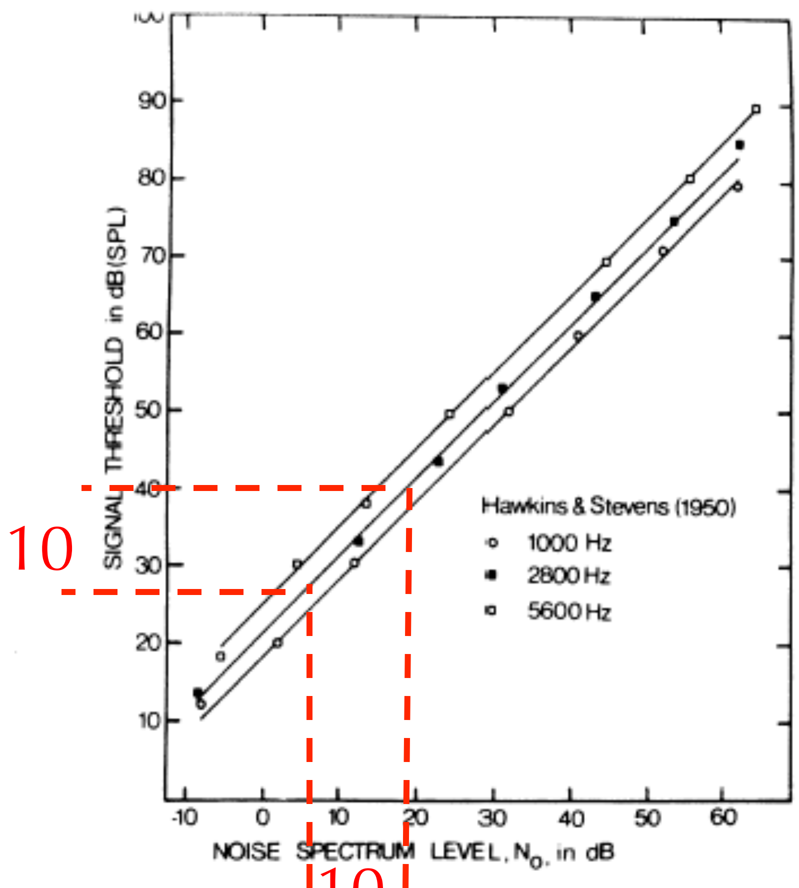
(B) un tono de 4000-Hz

(C) una banda de ruido a 4000 Hz

http://depts.washington.edu/sphsc461/freq_res/freq_res_files/freq_res.ppt

Crecimiento del enmascaramiento simultáneo

Crecimiento del enmascaramiento

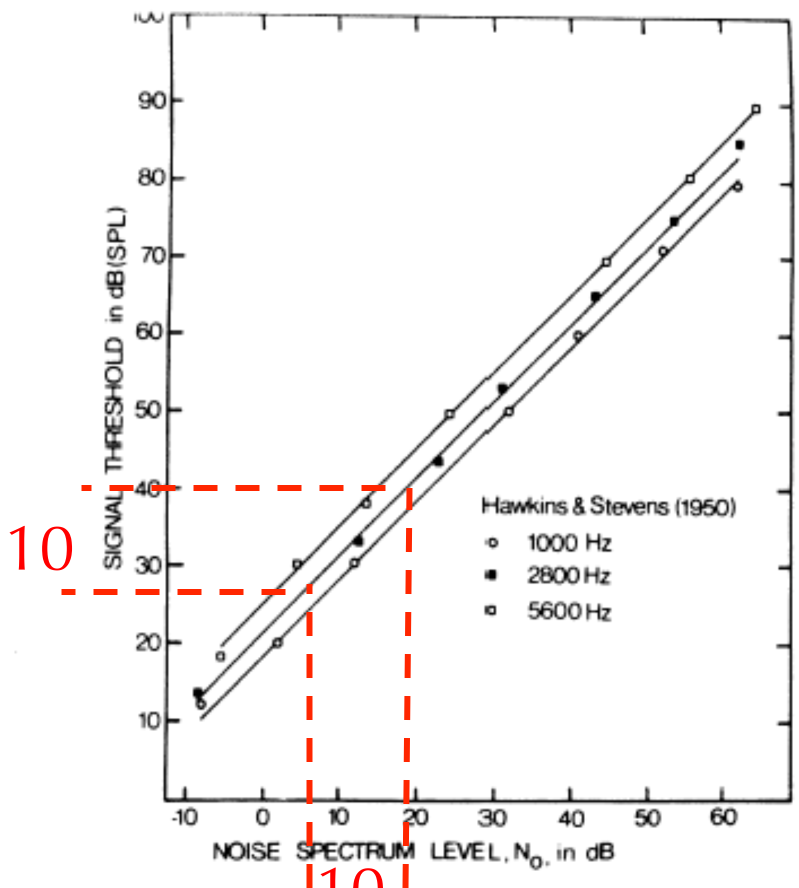


Threshold signal power plotted as a function of the spectrum level of a broadband masker with a flat spectrum. From Patterson and Green (1978).

Hawkins, J.E., and Stevens, S.S. (1950). "The masking of pure tones and of speech by white noise," J. Acoust. Soc. Am. 22, 6-13.

- En ruido de ancho de banda amplio, un incremento de 10 dB en el nivel de la máscara lleva a un incremento de 10 dB en el nivel del enmascaramiento

Crecimiento del enmascaramiento

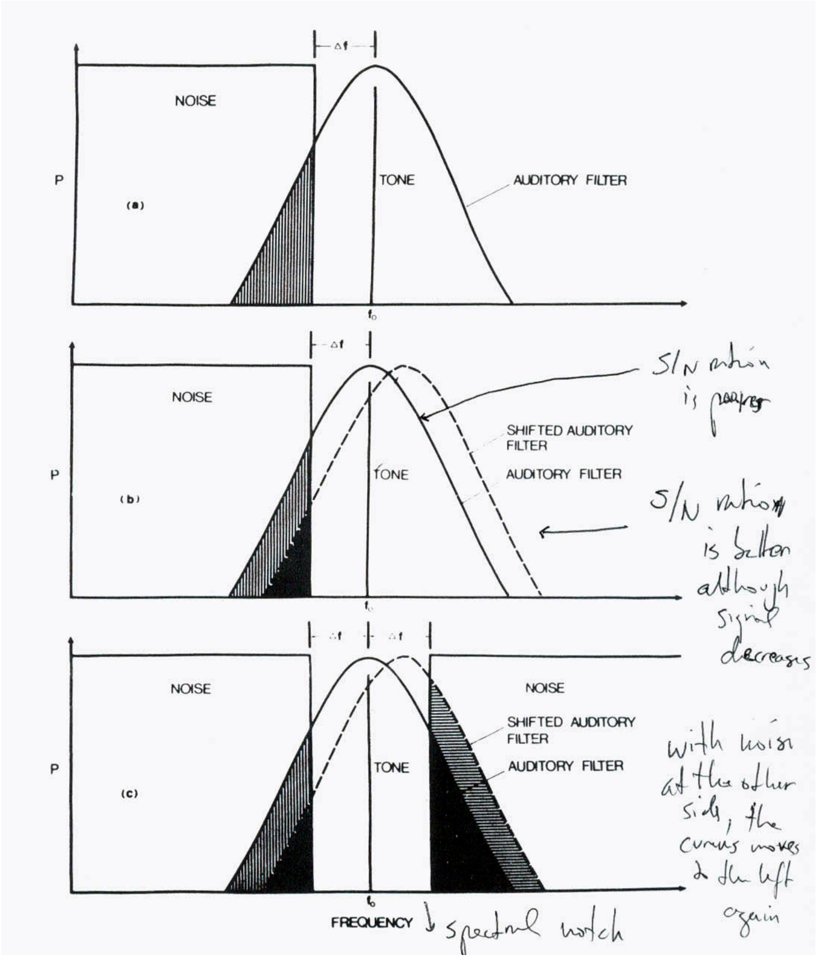


Threshold signal power plotted as a function of the spectrum level of a broadband masker with a flat spectrum. From Patterson and Green (1978).

Hawkins, J.E., and Stevens, S.S. (1950). "The masking of pure tones and of speech by white noise," J. Acoust. Soc. Am. 22, 6-13.

- En ruido de ancho de banda amplio, un incremento de 10 dB en el nivel de la máscara lleva a un incremento de 10 dB en el nivel del enmascaramiento
- ¿Se aplica esto para máscaras fuera de frecuencia?

Ajuste de la banda crítica



Patrón de exitación

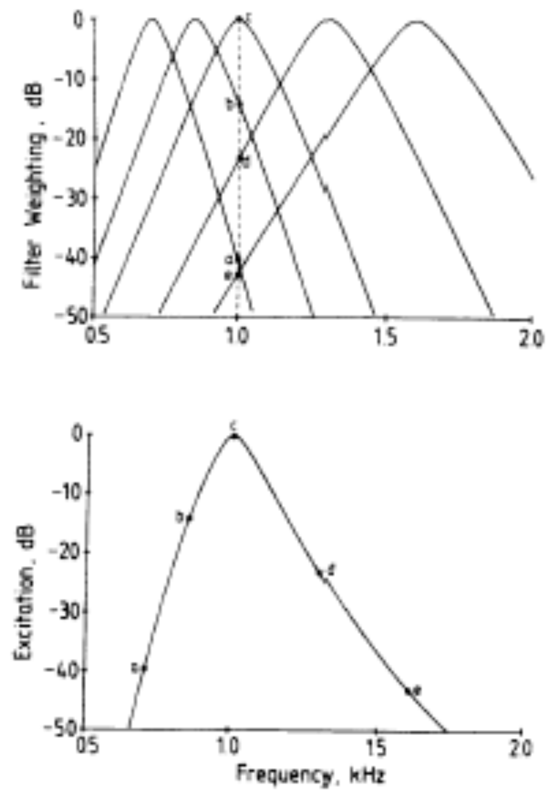


FIG. 3.13 An illustration of how the excitation pattern of a 1-kHz sinusoid can be derived by calculating the outputs of the auditory filters as a function of their centre frequency. The top half shows five auditory filters, centred at different frequencies, and the bottom half shows the calculated excitation pattern. See text for details. From Moore and Glasberg (1983b).

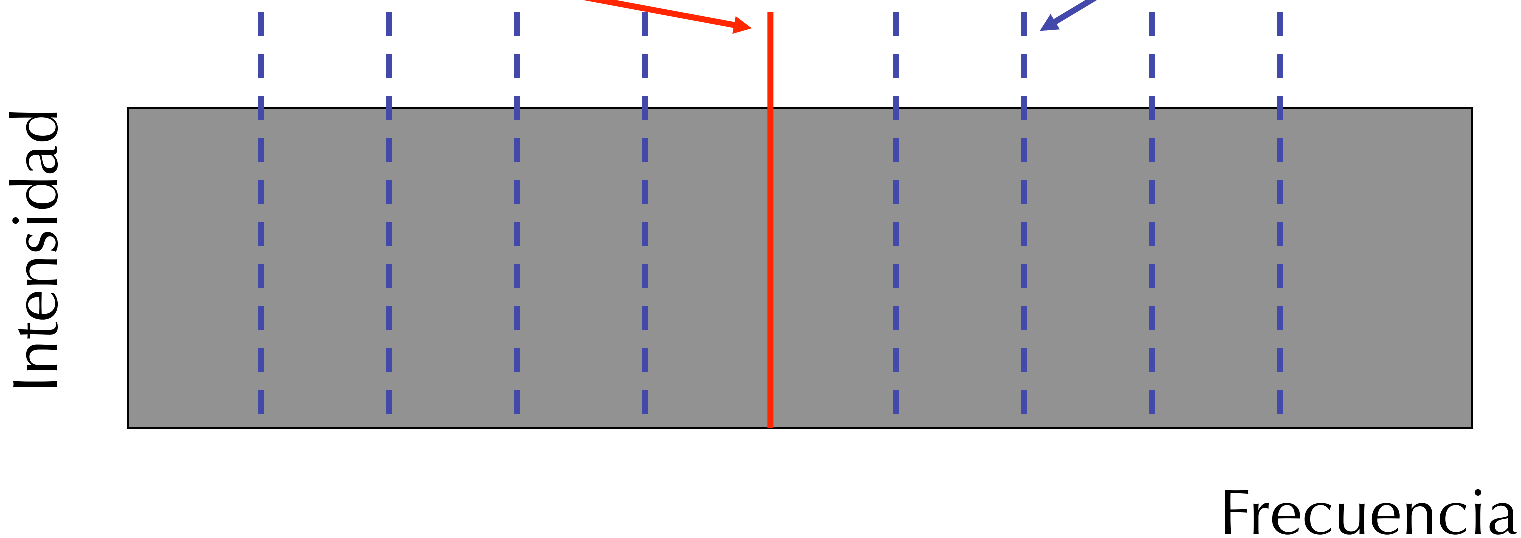
Moore, B.C.J., and Glasberg, B.R. (1983b) "Suggested formulae for calculating auditory-filter bandwidths and excitation patterns," J. Acoust. Soc. Am., 74, 750-753.

Expectación y detección de señales

Método de sonda-objetivo (probe-signal)

Señal objetivo (esperada) presente en muchos casos

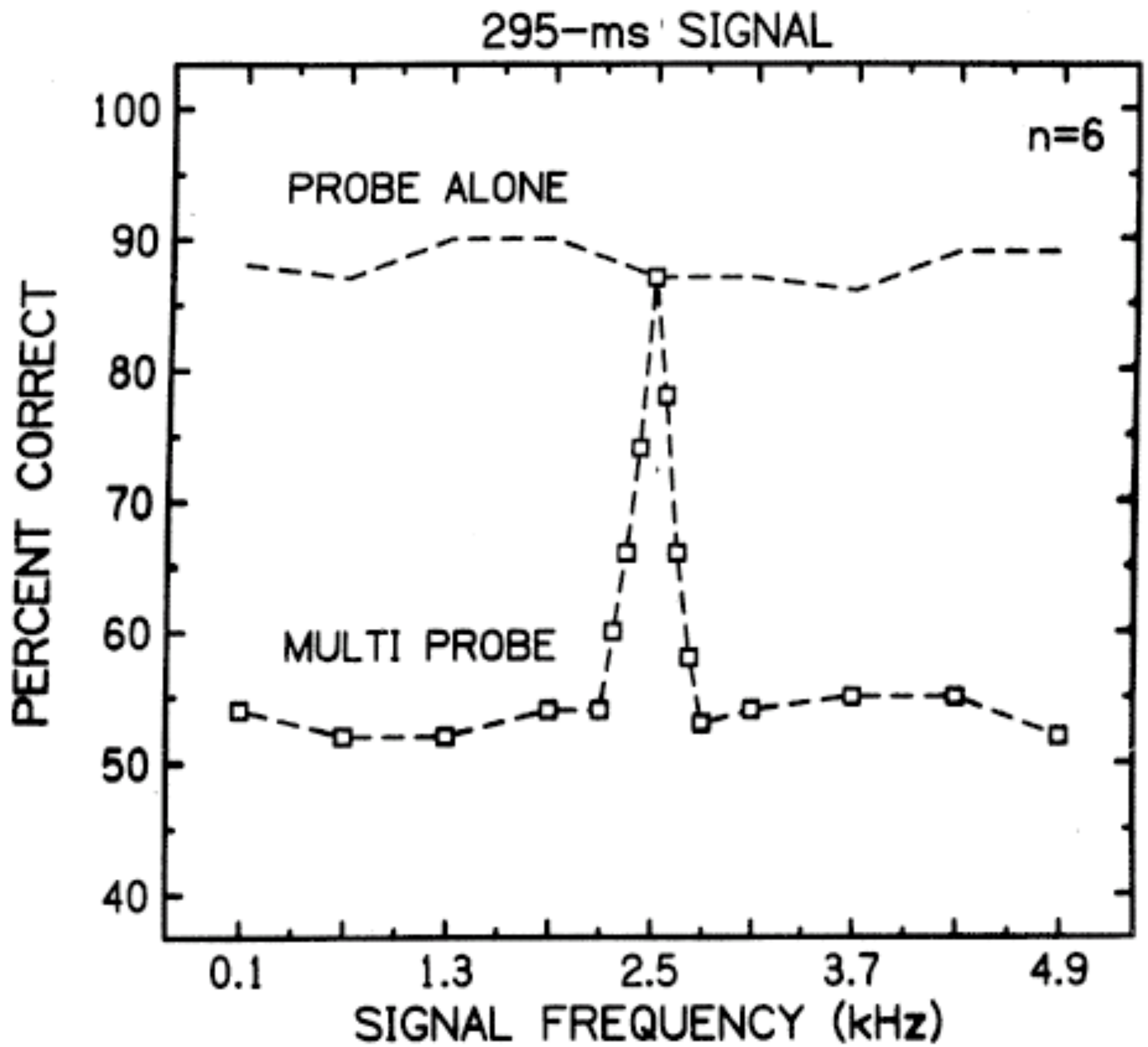
Señal sonda (inesperada) presenta en algunos casos



<u>Nivel de señal</u>: ajustar a cada señal de manera que el auditor pueda obtener un ~90% correcto solo con la señal presente

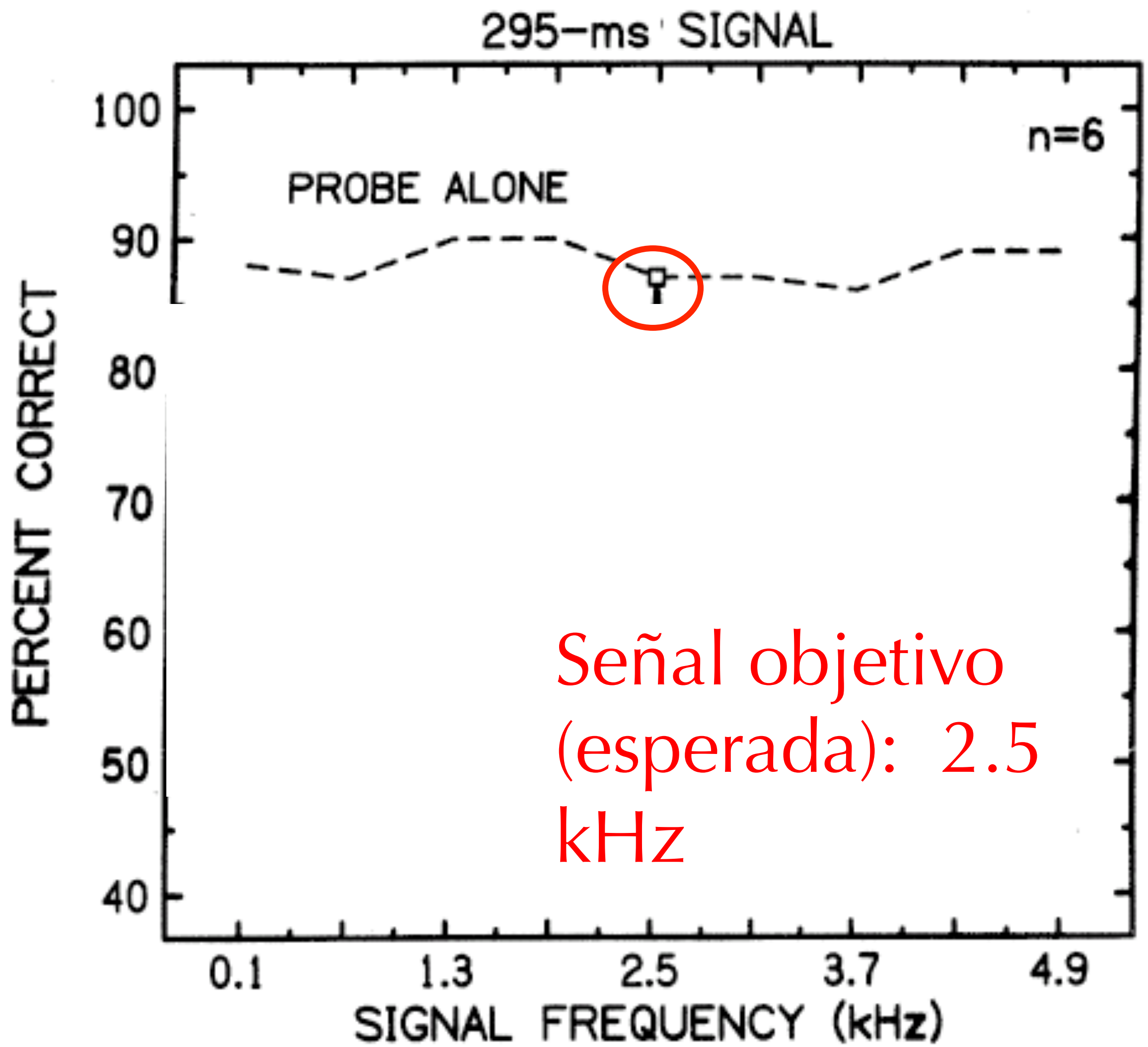
<u>Medir</u>: % detecciones correctas para cada señal

Expectación y detección de señales



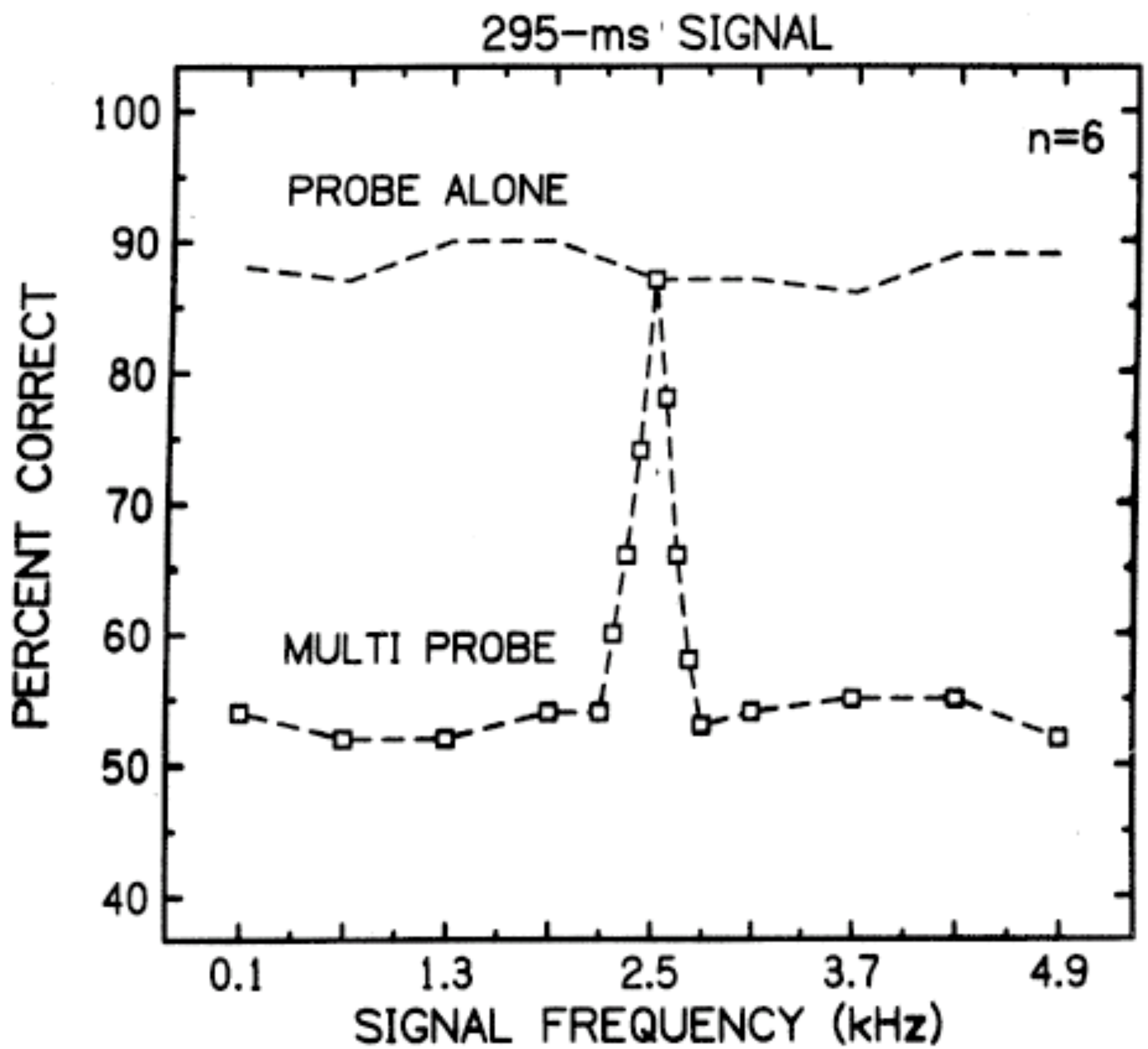
From Wright & Dai (1994)

Expectación y detección de señales



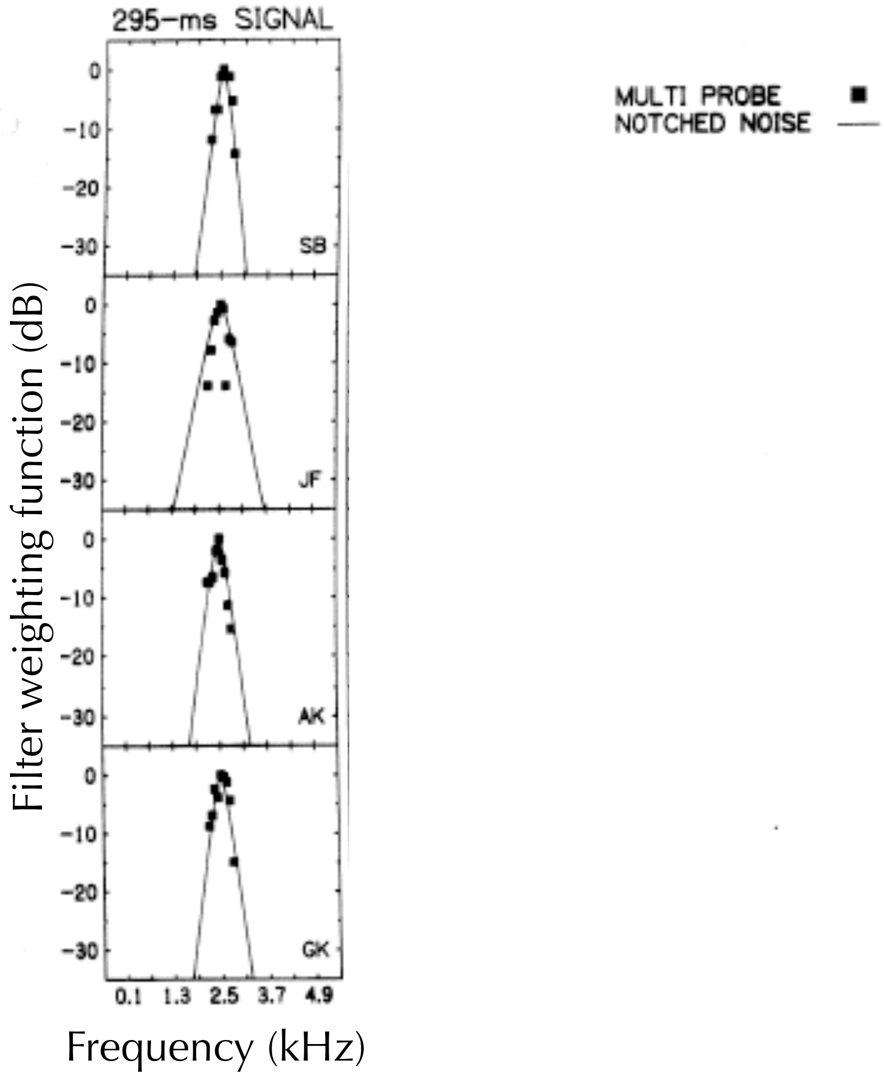
From Wright & Dai (1994)

Expectación y detección de señales



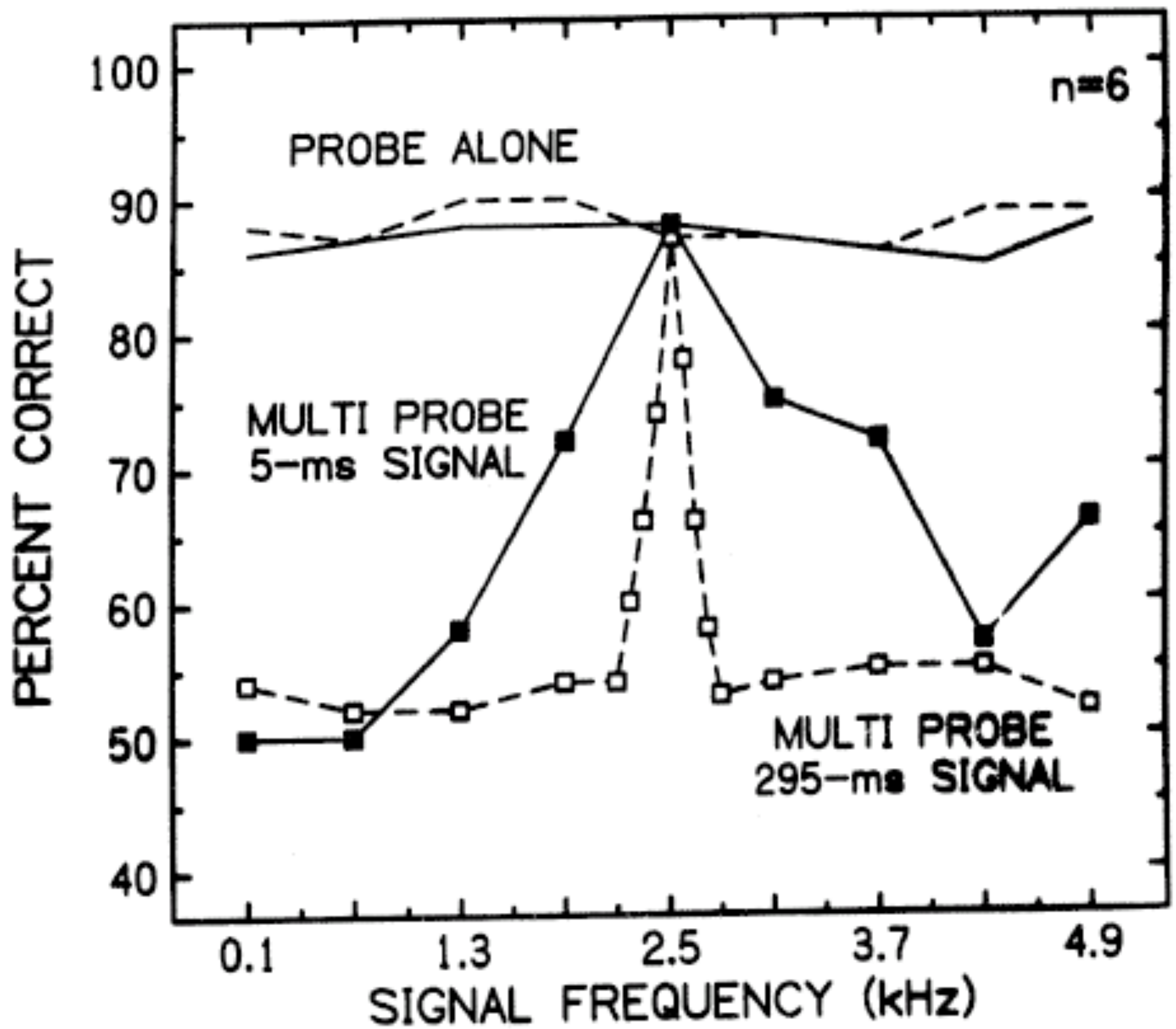
From Wright & Dai (1994)

Expectación y detección de señales



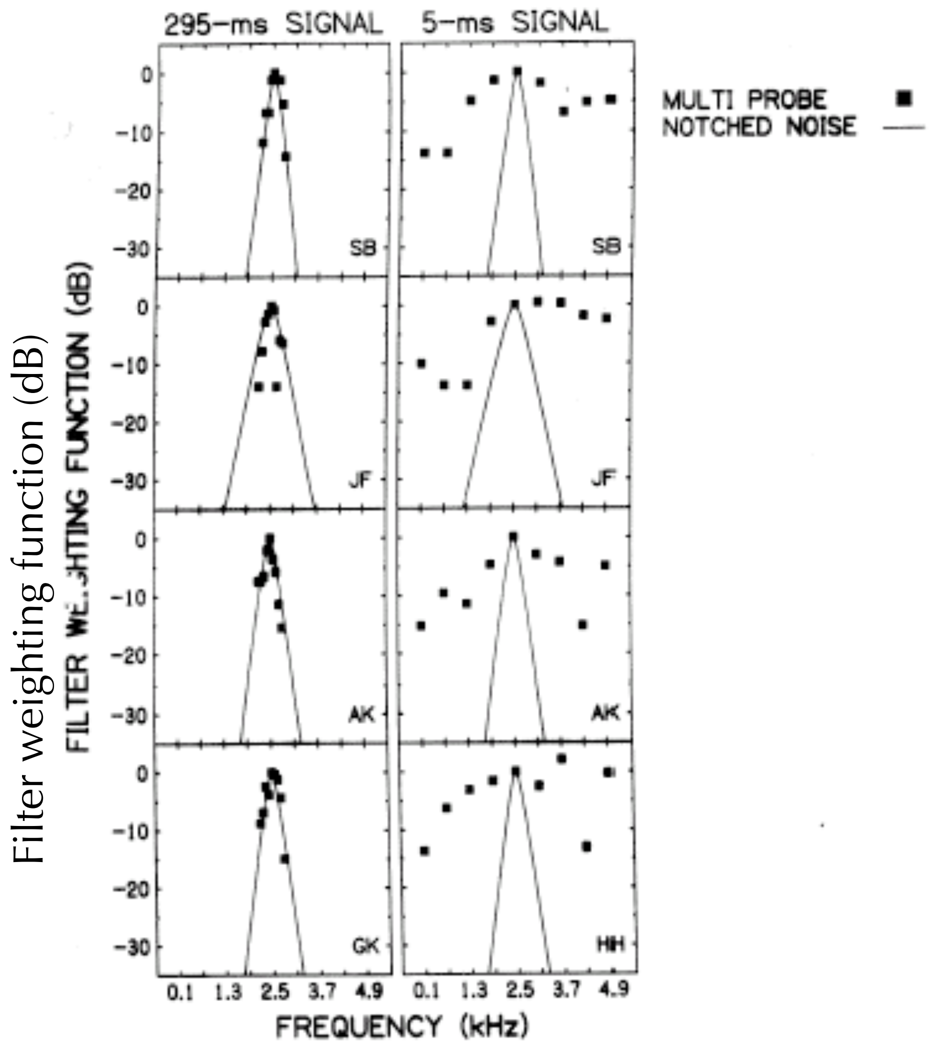
From Wright & Dai (1994)

Expectación y detección de señales



From Wright & Dai (1994)

Expectación y detección de señales



From Wright & Dai (1994)

Adultos vs Infantes

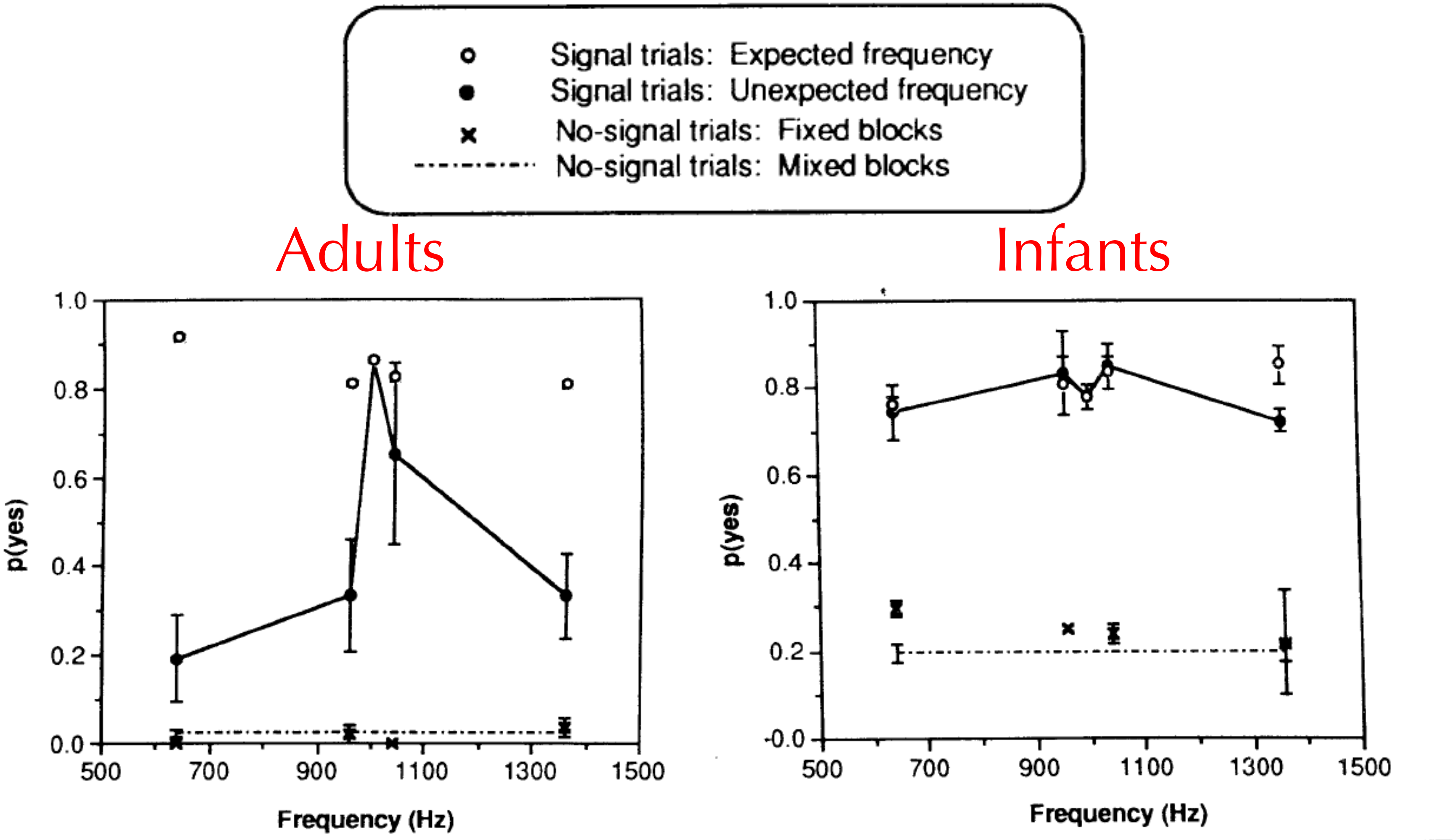


Fig. 1. Group listening bands for adults and infants. Average proportion of trials which the adult or the infant-observer team reported the presence of a signal trial plotted as a function of frequency. Error bars indicate ±1 *SE*.

From Bargones & Werner (1994)

¿Qué pasa si se corta el vínculo eferente (desde el cerebro) con la cóclea?

Antes

Después

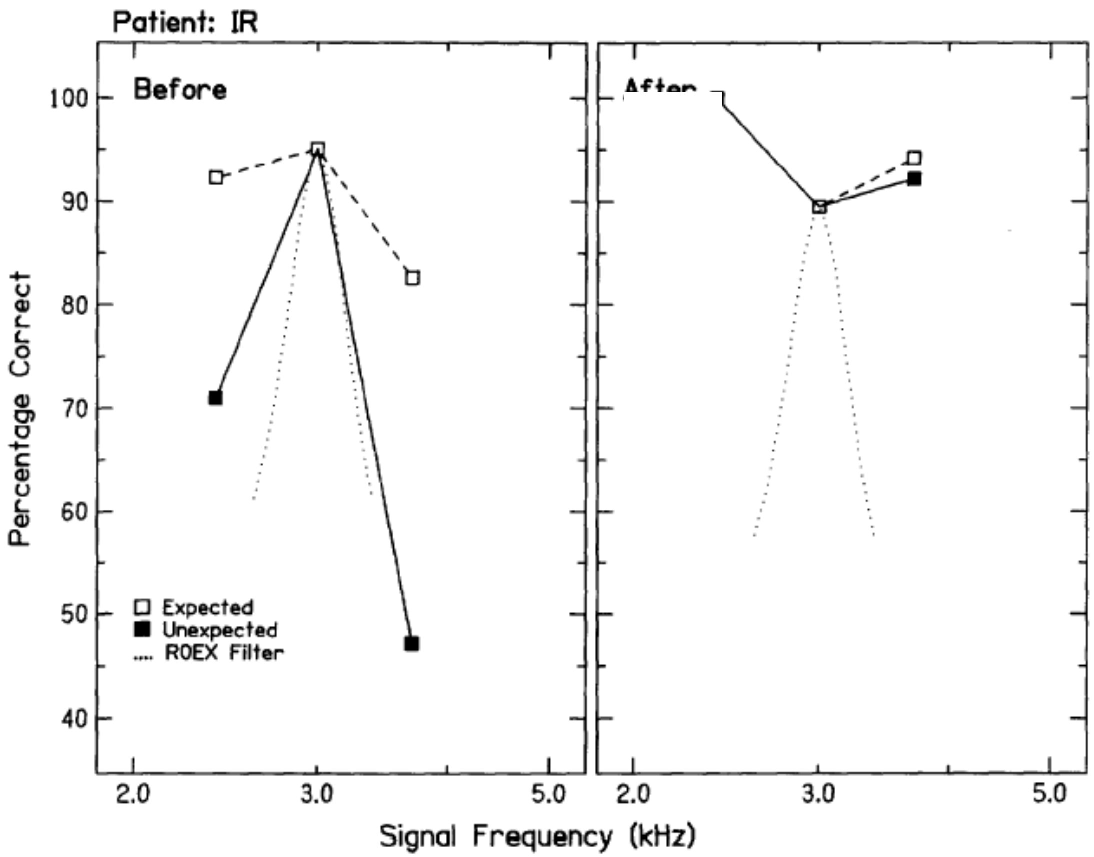
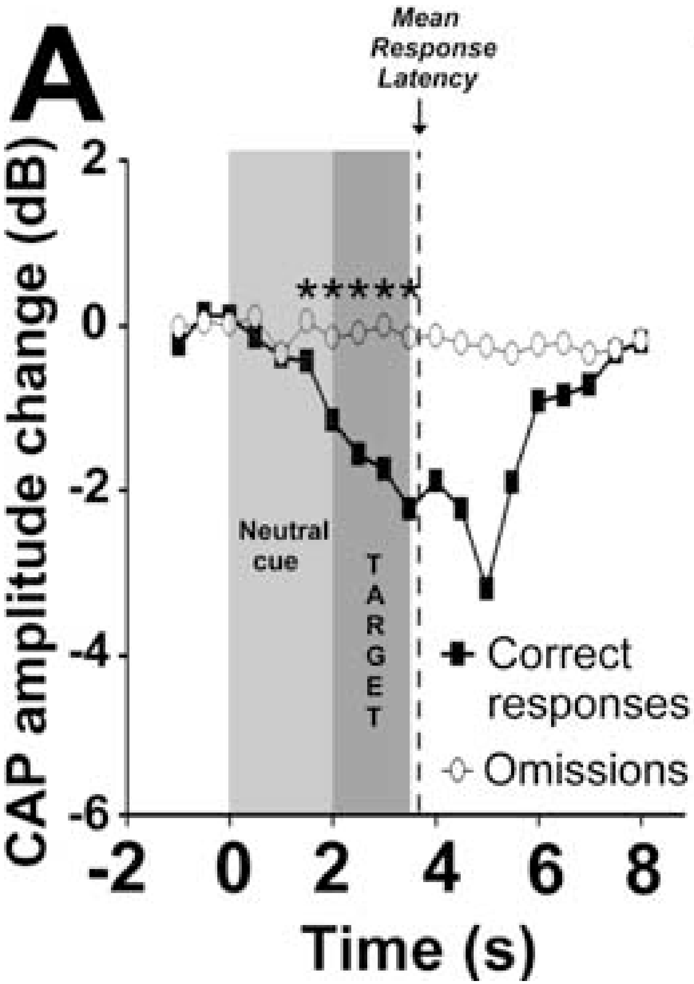


Fig. 4. The detection of expected and unexpected tones in a continuous noise before (left panel) and after (right panel) a vestibular neurotomy. Percentage correct in a 2IFC task is plotted as a function of signal frequency. Tones at unexpected frequencies (■) were detected much better by patient I.R. after the operation than before. The ROEX filter (· · ·) depicts normal performance on the task.

From Scharf et al (1997)

Atención selectiva a estímulos visuales reduce la sensitividad en la cóclea



Chinchilla

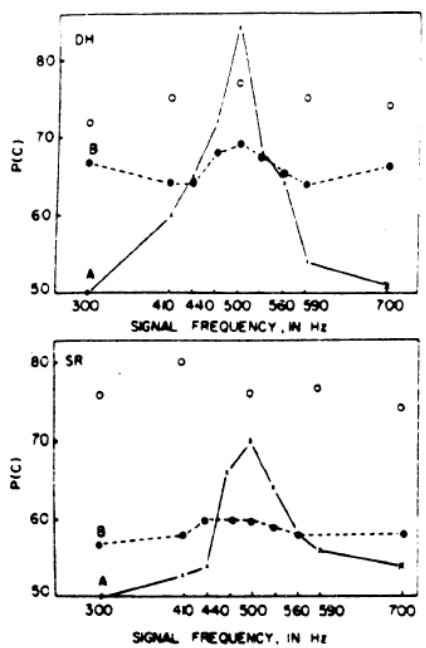
Figure 2. CAP results. ***A, Example of CAP reductions in correct-response trials (solid squares)*** compared with omission trials (open circles) during the period of visual attention (in this and the following figures; light gray, neutral-cue period; dark-gray, target-light period). Symbols on each trace represent CAP amplitude changes measured in decibels, referenced to the average amplitude of the potentials measured before the onset of the neutral cue. We show CAPs from a single recording session (100 trials) in response toa2Hz click train. Significant CAP reductions, calculated for pairs of values measured from the neutral-cue onset up to the mean response latency, are indicated by asterisks (unpaired *t test; p 0.05)*. Accuracy was 95% and mean response latency, ways measured from the target-light onset, was 1688 ms (vertical segmented line).

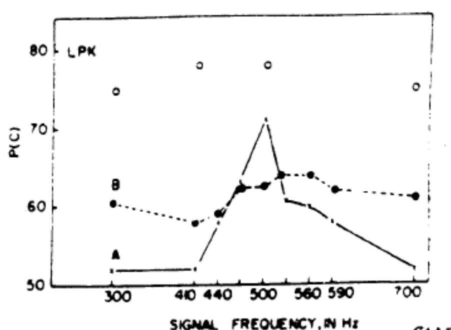
From Delano et al (2007)

Manipulación de las estrategias auditivas

Manipulación de estrategias auditivas

- ○ Sin incertidumbre de frecuencia
- X Condición A
- ● Condición B





CUE

Fig. 2. Graph of the probability of a correct response, P(C), as a function of signal frequency for the 500-Hz tone. The unfilled circles represent P(C) in a 2AFC paradigm with no frequency uncertainty. The xs represent P(C) for Condition A, and the filled circles represent P(C) for Condition B. For these data, $10 \log(E_s/N_0)$ is, in order of increasing frequency, 8.5, 8.6, 8.65, 8.70, 9.1, 9.13, 9.16, 9.25, 9.60, and for the cue tone, 9.4. For Conditions A and B, the average number of observations per point is 267. The noise power per cycle is 46 dB SPL.

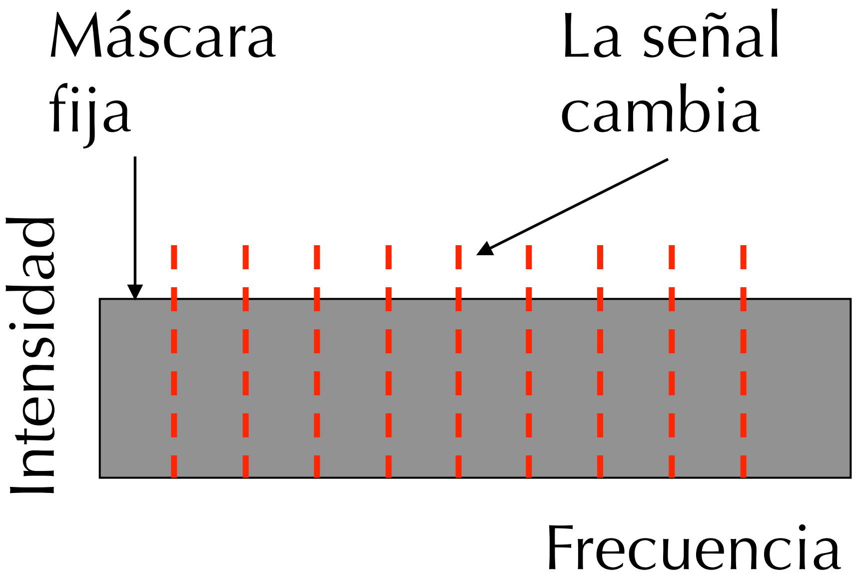
<u>Condición A</u>: Atención al tono de test con la misma frecuencia de la pista

<u>Condition B</u>: Atención a detectar todas las frecuencias.

From Penner (1972)

Incertidumbre de máscara y señal

Incertidumbre de la frecuencia de la señal



La frecuencia de la señal varía en forma aleatoria de presentación en presentación

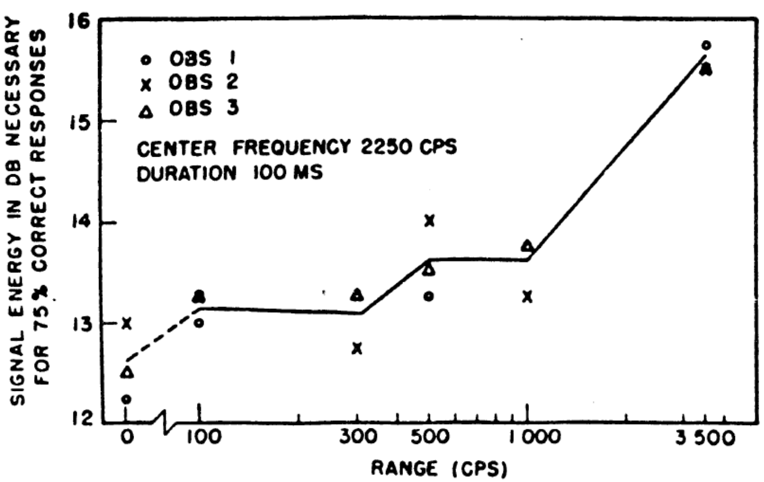
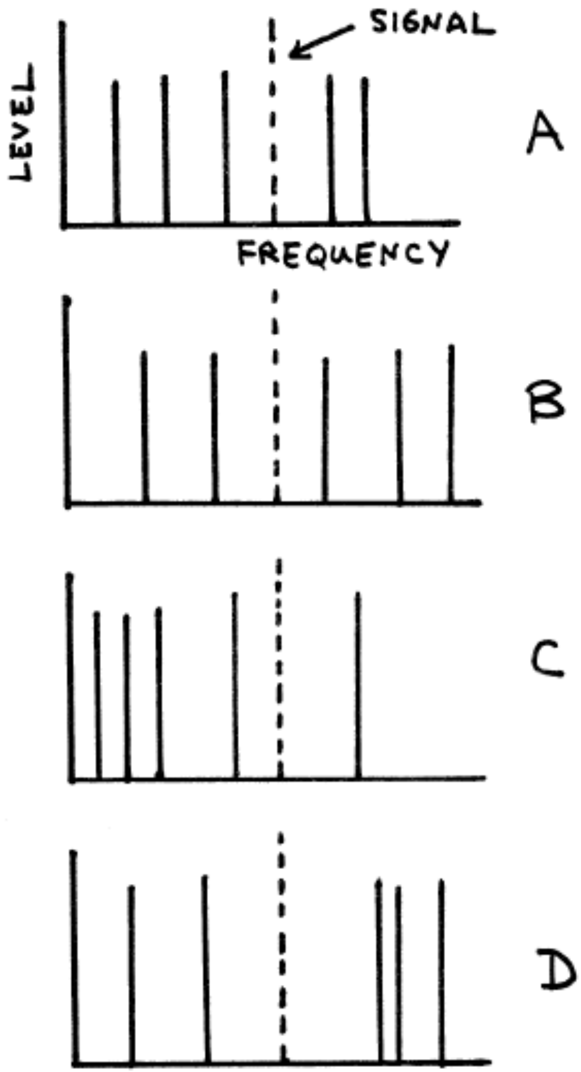


FIG. 3. This graph shows how the signal energy in db must be increased to maintain the same percentage of correct detections as the range of signal-frequency uncertainty is increased. For example, at the 3500-cps range, the signal might occur anywhere between 500 and 4000 cps. The signal energy was increased from about 12.5 db in the fixed-frequency condition, 0 range, to about 15.5 db at the 3500-cps range. The ordinate is in fact the quantity $\mathcal{E}\text{-}\mathfrak{N}_0$ for the zero-range condition.

From Green (1961)

Incertidumbre de la máscara



Is it harder to detect a known signal that is masked by a particular masker X (e.g., sample A) when that masker is randomly intermixed with other maskers (e.g., samples B, C, and D) than when only masker X is presented?

The answer can be be obtained by comparing two measurements:

(1) signal threshold in a fixed-masker condition in which only masker X is presented.

(2) signal threshold in a random-masker condition estimated from the responses only on those trials in which masker X is presented.

A higher threshold in the random than the fixed condition indicates that uncertainty about which masker is to be presented makes the signal more difficult to detect in masker X.

La frecuencia de la máscara cambia aleatoriamente entre presentaciones, mientras la frecuencia de la señal es fija.

From Wright & Saberi (1997)