ON MASKING EFFECTS OF NARROW BAND NOISE

by /264

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B. S., Kansas State University, 1968

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A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF ARTS

Department of Speech

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1970

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ACKNOWLEDGEMENTS

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CHAPTER I

INTRODUCTION

The existence of lateral sensory inhibition has been recognized in the area of vision for a number of years. Such inhibition results in a contrast effect between the areas of stimulation and no stimulation. This is easily demonstrated by the rapid rotation of black and white disks or drums. The eye averages out differences in stimulation and perceives the pattern on the disk or drum as a range from bright to dark. However, it has proved more difficult to observe such a contrast effect in hearing. A study of pitch perception of a band of noise with defined high and low frequency cut-offs would seem to be ideal for investigating the existence of such a contrast effect in hearing.

Traditionally, pitch has been defined in terms of the frequency of a sinusoid. However, there is some question as to how the auditory system functions in pitch perception. Two main theories are considered in explanation, the place theory and the periodicity theory. The place theory, according to Békésy (1963) is understood to mean that a sinusoid generates a point of maximum excitation on the basilar membrane and the locus of more central excitation is related directly with the point of basilar membrane excitation. Pitch perception is determined by the central locus of excitation.

According to Békésy (1960), each frequency of vibration produces a traveling wave along the basilar membrane with a characteristic maximum on the membrane. Since the distribution of excitation

along the basilar membrane is comparatively flat, it is difficult
to understand how very small changes, even changes such as five
percent in the frequency of a 1000 Hz tone, can consistently be
detected as pitch changes without considering the existence of in-
hibitory mechanisms which serve to sharpen the analysis.

Below about 50 Hz, according to Békésy (1963), the entire
basilar membrane tends to vibrate in phase. The distribution of
excitation in the cochlea does not change with decreasing frequency
of stimulation. Explanation of pitch perception at these low fre-
quencies is given by the periodicity theory which states that every
section of the basilar membrane is capable of performing a fre-
quency analysis independent of place or position and determines
pitch by means of a periodicity of vibrations at that particular
section of the membrane. Until recently, approximately 300 Hz was
considered to be the maximum rate of stimulation at which a periodi-
city analysis could be performed by the auditory system. However,
Kiang (1963) has observed periodicity in the firing rate of primary
auditory fibers up to approximately 5000 Hz.

Recently, interest has developed in certain pitch phenomenon
which are not readily explained by either a place theory or a peri-
odicity theory of pitch perception. Ekdahl and Boring (1934) had
listeners judge the pitch of tonal masses consisting of sinusoids
spaced at regular inharmonic intervals. Their subjects judged
the pitch of the mass to be equivalent to the midpoint of the mass.

Békésy (1963), on the other hand, found that an octave band
noise whose cut-offs were 300 Hz and 600 Hz elicited the perception
of two pitches corresponding to the 3 dB down points of the noise

band. According to the place theory, it is assumed that the noise band stimulates a certain section of the basilar membrane intensively with a drop in excitation at the two edges. Békésy contends that the two edges of the noise are emphasized by contrast phenomena. He stated that the sensory effect of a stimulus is greatest where it undergoes its greatest variation as shown in his model, Fig. 1. According to the place theory, a band of noise stimulates a section of the basilar membrane with a drop in excitation at both edges, producing a contrast effect which enhances the perception of those frequencies at the edges of the noise band. Békésy's study was the first time that the edge effect had been demonstrated in auditory psychophysics. It was generally believed that in the case of the auditory system, there must be laterally inhibitory nerve networks at some level of the nervous system which would explain our extraordinary capacity of frequency discrimination, but the existence of such inhibition had not been demonstrated prior to Békésy's work.

Rainbolt and Schubert (1968) attempted to study the pitch of bands of noise similar to that used by Békésy. Although no edge effect phenomenon was observed in their study, it was noted that small changes in frequency of a one-half octave band of noise were easily detected by the subjects. In their study, a reference band of noise was compared with a narrow band of noise having a fairly precise pitch rather than a pure tone. Their rationale being that a narrow band with a relatively precise pitch is more similar in character to a broad band of noise than is a pure tone. Subjects were asked to judge whether a band of noise called the reference
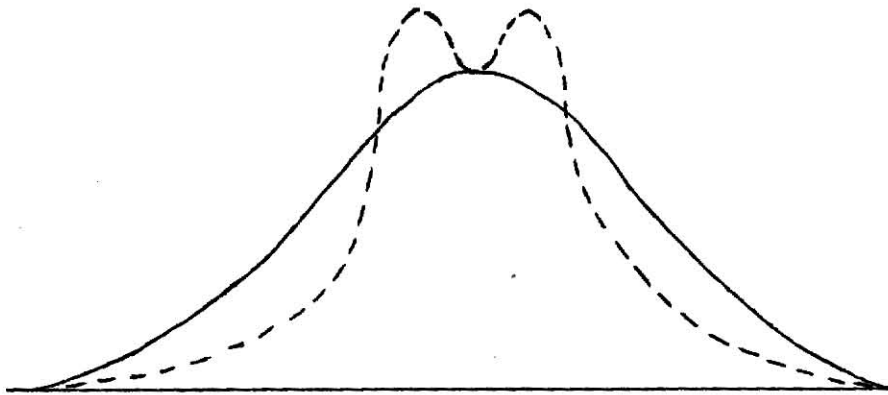
Fig. 1. A form of distribution of amplitude on the basilar membrane (solid line) and its expected sensory effect (broken line). Taken from Georg von Békésy, <u>Experiments in Hearing</u>, 1960, p. 417.

band, was higher or lower in pitch than the one-half octave comparison band. The center frequency of the comparison band was varied randomly over the range of the frequency spread of the reference band. They found that individual subjects were quite consistent in the pitch they assigned to a band-pass noise but subjects were not in agreement on which region of the noise band was judged to have the dominant pitch.

A study by Small and Daniloff (1967) was supportive of the work done by Békésy. Ten subjects were instructed to match high pass or low pass comparison noise bands so that they were one octave above a reference and one octave below the reference. The reference signals used were also bands of high pass and low pass noise extending over a range of 20 Hz to 20,000 Hz with a 35 dB per octave skirt slope. Octave judgments were used to rule out the possibility of some perceptual aspect, other than pitch, influencing the judgments. Results indicated that the subjects placed the cut-off of the comparison signal either one octave above or one octave below the cut-off of the reference signal. They found that, "...'octave below' judgments are systematically low, whereas the 'octave above' judgments are, with one exception, slightly high.[p. 508]." For low pass noise, they found a relatively linear relationship between pitch and cut-off frequency from 80 Hz to 10,000 Hz. The percept of pitch was absent above 10,000 Hz due to the earphone response and a less sensitive threshold for the frequencies above 10,000 Hz. A linear relationship existed for high pass noise only in the range of 600 Hz to 10,000 Hz. Subjects reported a vagueness in pitch "...at and below 610 Hz

(high pass) cut-off. $\boxed{\text{p. 509}}$." The ability to make good pitch judgments was found to be less accurate as bandwidth increased.

If edge effects are observed in the pitch perception of bands of noise, it follows that these edge effects ought to be observable as well in direct masking. The first paper with the explicit intent of exploring edge effects in direct masking was that of Carterette, Friedman and Lovell (1969). The majority of their data were obtained using a computer generated synthetic noise composed of 56 randomly spaced sinusoids centered at 530 Hz with a width of 100 Hz. This gave a rectangular band of masking noise with extremely steep skirt slopes of almost 90°. Such a noise band seems ideal for studying edge effects due to a sudden drop in excitation at the two edges of the band of noise. Masking data was obtained using a modified tracking procedure. These investigators indicated their data showed edge effects in the neighborhood of the nominal cut-off frequencies. The lower edge tended to be more pronounced than the upper edge at Sensation Levels above 30 dB so that the tonal center of gravity is shifted below the midfrequency of the noise band. It is of interest to point out that in some individual data, it was difficult to reject the possibility that a peak in the masking occured at the nominal center of the band.

Particular interest is generated in these masking data since they are not consistent at any masking level with traditional data obtained in support of the critical band hypothesis originated by Fletcher (1940). Licklider (1951) stated that the only important frequencies for masking are those that lie within a small band

centering around the tone being masked. This implies that the masked threshold of a tone at the center of the band will not increase as the bandwidth grows beyond critical width. Proponents of the critical band theory believe that a critical band corresponds to a certain distance along the basilar membrane and the stimuli in this region summate so as to generate maximum masking at the center frequency. The frequencies at the cut-offs of a band of noise are not surrounded by a critical band so according to the critical band theory, less masking should be generated at these points. This is contrary to the edge effect hypothesis.

In a study by Zwicker, Flottorp and Stevens (1957), the loudness of a band of noise of constant sound pressure level was found to be related to the width of the band. If the noise band was extended to become supracritical, subjects reported that the loudness of the noise increased. This would indicate that center frequencies of a masking band which are surrounded by a critical band sound louder, and therefore have the greatest masking effect.

The most recent and complete study concerning the critical band was that of Greenwood (1961). He studied masked audiograms as a function of bandwidth, level and frequency of a masking noise. At low masking Sensation Levels, his data were consistent with the hypothesis that masking should increase linearly with the level of the masking sound. He did find a transition level at which his data departed from this hypothesis. However, he did not observe any asymmetries or edge effects in the threshold shifts.

The contrast hypothesis indicates the points of sudden acceleration or deceleration of stimulation are enhanced while the

critical band theory states that the stimuli summate to produce the most effective masking at the center of a band of noise. This study was based on the contention that an effective way to investigate the edge effect hypothesis was to assume that the steeper the slope of a band of noise, the steeper its gradient of physical excitation and therefore, the edges of such a noise band will be more enhanced than those of a noise band with less steep skirt slopes. The shift in the threshold of pure tones caused by each segment of the noise band was the criteria used to determine the strengthening or enhancing of frequencies within the band of noise. The larger the threshold shift, the more effectively that frequency of the masking noise was masking out the corresponding pure tone.

The specific questions studied in this investigation were as follows:

1) Is there an increase in masking produced at the cut-off frequencies of a narrow band masking noise?

2) Does steepening the skirt slope of a band of masking noise alter the shift of masking produced at the cut-off frequencies of that band of noise?

CHAPTER II

METHOD

Subjects

Subjects used were four young adults whose pure tone thresholds were within 10 dB of audiometric zero at each of the standard test frequencies. Each subject practiced the task until his pure tone threshold tracings on a fixed frequency Békésy audiometer were consistent both in quiet and in the presence of a masking noise. Testing lasted approximately six weeks. The length of each session was from one to one and a half hours. None of the subjects had more than three non-test days in a row during this time. All tests were conducted in an IAC double walled test room.

Signal Generation

Masking signals were generated in a manner described by Greenwood (1961). The output of a Grason-Stadler model E10588-A noise generator was low-pass filtered by an Allison model 2BR filter. This low-pass noise was led to the modulator input of a Grason-Stadler model E3382C modulating switch. The carrier signal was generated by a Hewlett-Packard 3300A Function Generator. The output of the modulating switch was led to a locally constructed mixer.

Test signals were generated by a Hewlett-Packard 200 CDR oscillator. Test signals were gated by a Grason-Stadler 829S electronic switch, set to give signal bursts of 250 miliseconds with a 25 milisecond rise-decay time at a 50% duty cycle. The output of the electronic switch was led to a Grason-Stadler E3262A

recording attenuator with a nominal attenuation rate of 2.5 dB per second. The output of the attenuator was, in turn, led to the mixer. Masker and test signal voltages were monitored at appropriate points with a Bruel-Kjaen type 2409 electronic voltmeter. Figure 2 gives a block diagram of the instrumentation.

The frequency of the test signal was set by a Hewlett-Packard model 5244L electronic counter. These measurements were made at a single session when a temporary dial was affixed to the dial with spacings of 15 Hz in the range of 1850 Hz to 2150 Hz. It was estimated that a particular point value could be set with an accuracy of ±3 Hz. The carrier frequency was set to the center of the range of interest by leading the outputs of the carrier oscillator and the test signal oscillator to the vertical and horizontal plates of a Hewlett-Packard model 132A oscilloscope, and adjusting the frequency of the carrier oscillator to give the desired lissajous figure.

Spectral analysis of the masker electrical waveform at the input to the earphone was determined by a Hewlett -Packard 302A waveform analyzer. This analysis indicated that distortion at the second harmonic, 4000 Hz, of the carrier signal was at least 35 dB down. Figures 3 and 4 give the analyses of the two noise bands.

The nominal slope of the Allison filter is 30 dB per octave. The modulator effectively steepens this slope because it looks at the modulator input in terms of its slope per Hz, rather than its slope per octave. For example, if the modulator input is set at a cut-off of 75 Hz, it will be down 30 dB at 150 Hz. However, the output of the modulating switch will be down 30 dB in 75 Hz. If
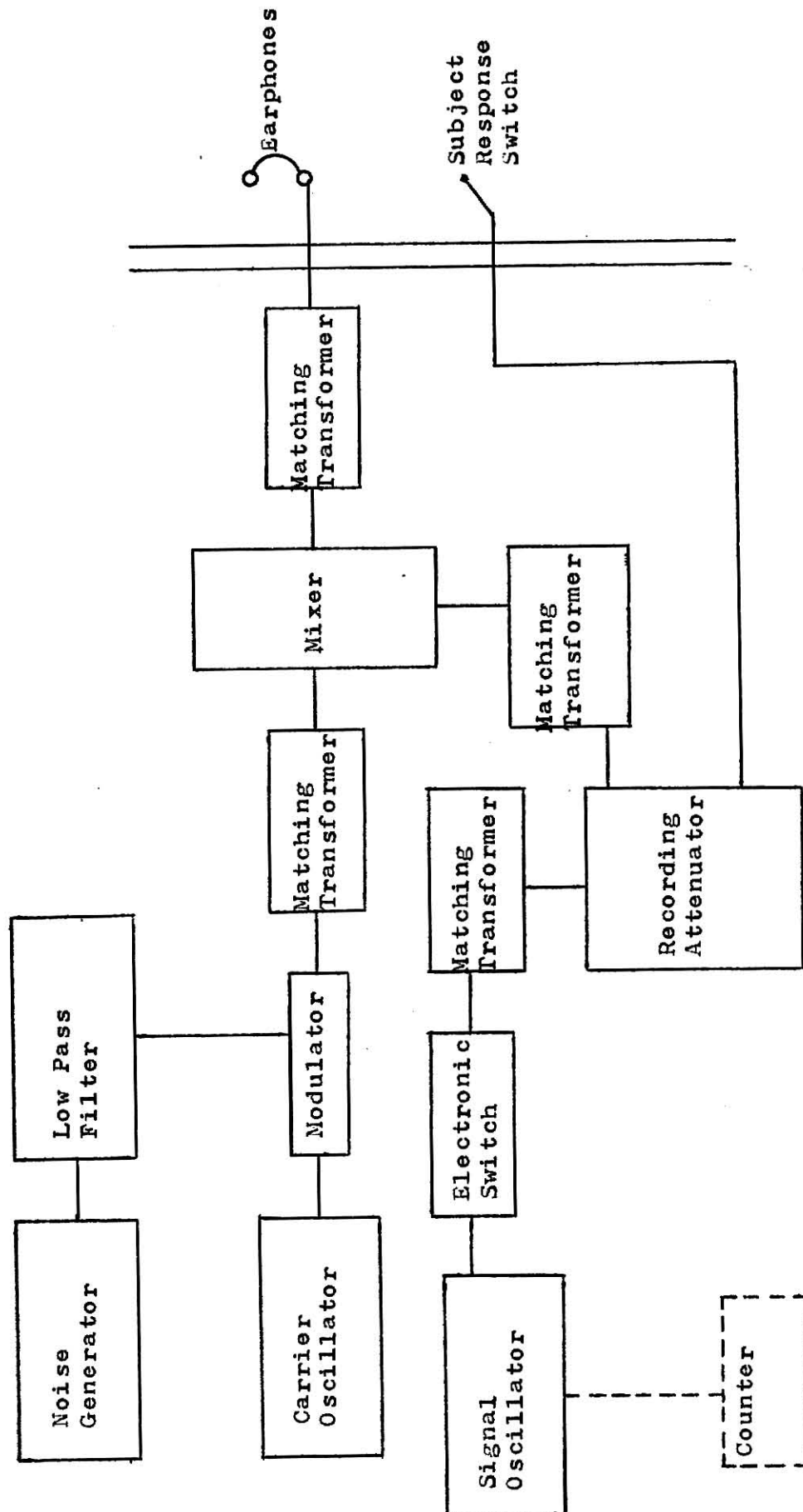
Fig. 2. Block Diagram of Apparatus.

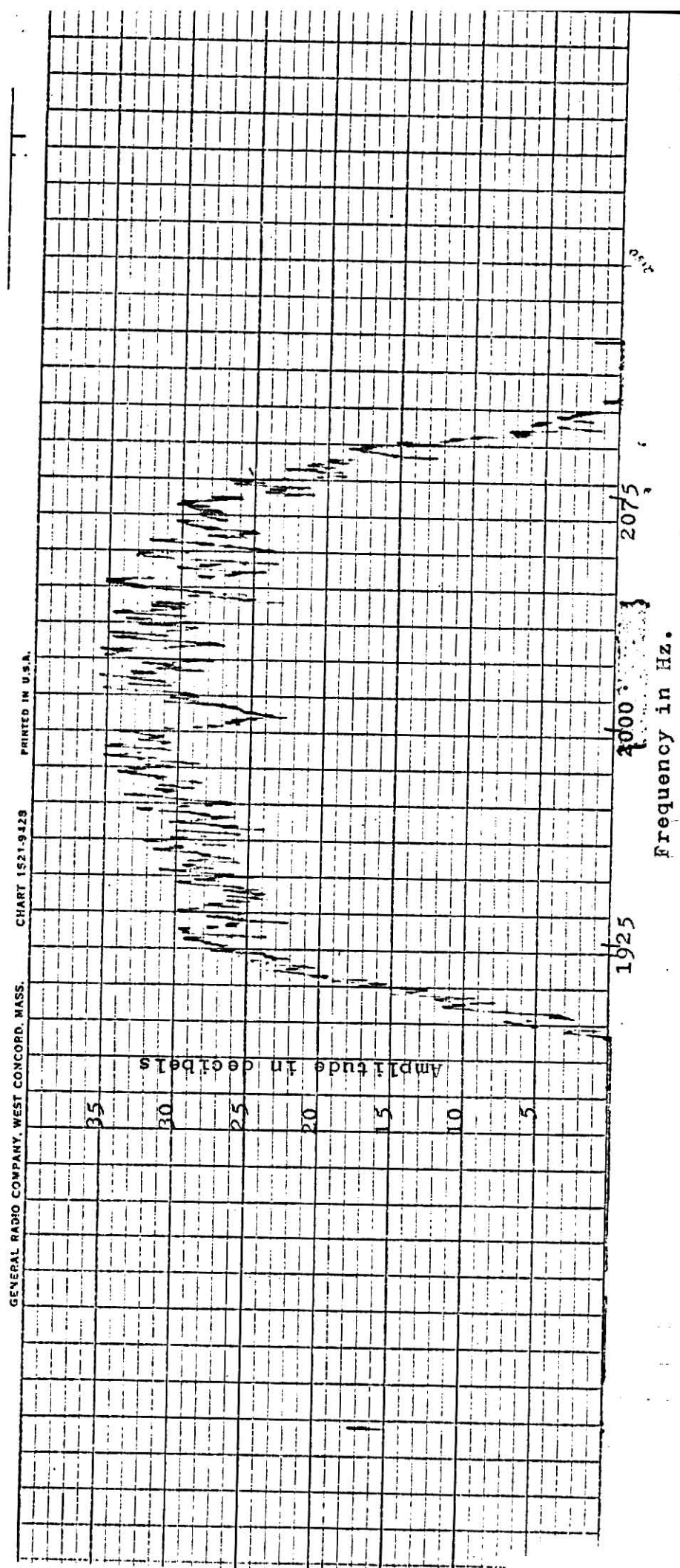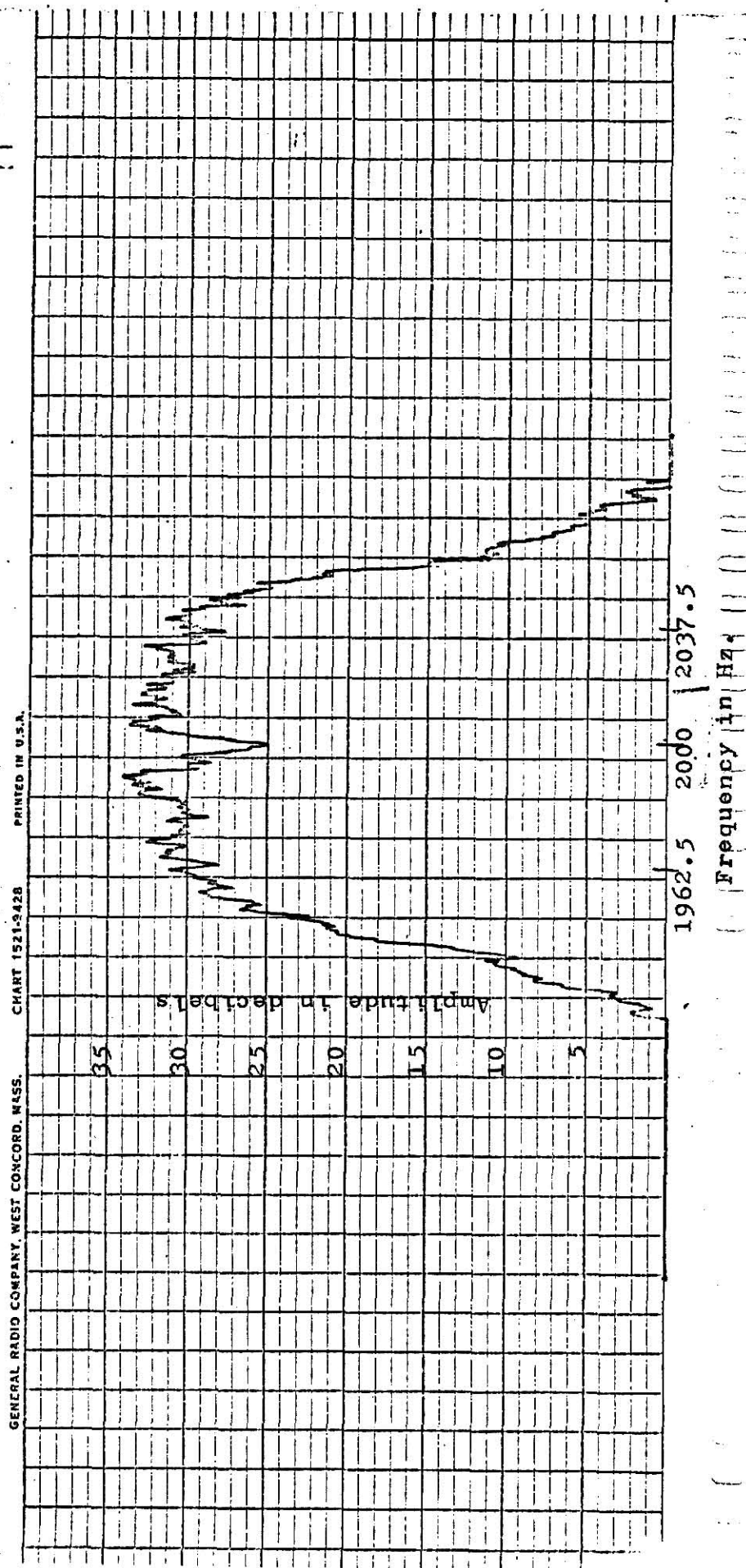Fig. 3. 150 Hz wide noise band masker.

Fig. 4. 75 Hz wide noise band masker.

the carrier is set at 2000 Hz, the noise generated will drop 30 dB between the points of 2075 Hz and 2150 Hz on the high side. This slope will be identical on the low side (30 dB drop in 75 Hz). The ratio of 2150 Hz to 2175 Hz is $\cong 1.03$ which is less than one semitone. Therefore, the drop is 30 dB in less than one semitone.

Procedure

Subjects were instructed to attend to the pure tone and to depress the subject switch when they could hear the pure tone and to release the subject switch when they could no logner hear the pure tone. The frequency of the pure tone was set by the experimenter but the intensity of the signal was controled by the subject switch. Signal intensity decreased by $2\frac{1}{2}$ dB steps while the subject switch was depressed and increased by $2\frac{1}{2}$ dB steps when the subject switch was released. Thirty-two pure tone audiograms, consisting of tracing each frequency in alternating periods of quiet and noise, were obtained from each subject. The method of obtaining threshold values consisted of drawing a line through the midpoints of the stable tracing at each frequency. This midpoint was read as the value for a tracing.

A masking noise band with a width of 75 Hz was used for half of the runs. The second noise band was 150 Hz wide. Both noise bands had a carrier frequency of 2000 Hz. This frequency was chosen for the carrier because it is within the flattest region on the sensitivity curve (1000 Hz - 3000 Hz). The intensity of the masker was held constant at 40 dB Sensation Level re: the experimenter's threshold for half of the tests and 60 dB Sensation Level for the other half. The pure tone frequencies tested ran

from 1850 Hz to 2150 Hz, with tracings being run at each 15 Hz interval. In all, 21 frequencies were tested. The presentation of the pure tones was alternated each time between low-to-high and high-to-low so that learning and fatigue factors could be minimized.

CHAPTER III

RESULTS

In order to facilitate the presentation of the results, the
questions chosen for investigation in this study will be presented
here for reference. They are as follows:

1) Is there an increase in masking produced at the cut-off
frequencies of a narrow band masking noise?

2) Does steepening the skirt slope of a band of masking noise
alter the shift of masking produced at the cut-off frequen-
cies of that band of noise?

In order to test these questions, an experiment was designed
using four subjects with normal hearing sensitivity. The data were
collected utilizing Békésy tracings under the following conditions:
1) thresholds in quiet using 41 pure tones, spaced every 15 Hz
from 1850 Hz to 2150 Hz, and 2) masked thresholds of these pure
tones were obtained using narrow band noise maskers. Two band
widths with nominal cut-offs at 1925 Hz - 2075 Hz and 1962.5 Hz -
2037.5 Hz were used at 40 dB and 60 dB Sensation Levels. Figure
5 is a sample of one of the tracings performed by subject TS.
This tracing was made using the 1925 Hz - 2075 Hz band of noise
at 40 dB Sensation Level. The sequence was from low-to- high. The
threshold shift in the presence of the noise is given by the dif-
ference in attenuation between the tracing in quiet and the tracing
in the noise. In order to assist the reader, the tracing in the
quiet is always the one showing the greater amount of attenaution.

The mean threshold shift for each subject at the cut-offs and

Fig. 5. Sample Békésy tracing by subject TS.
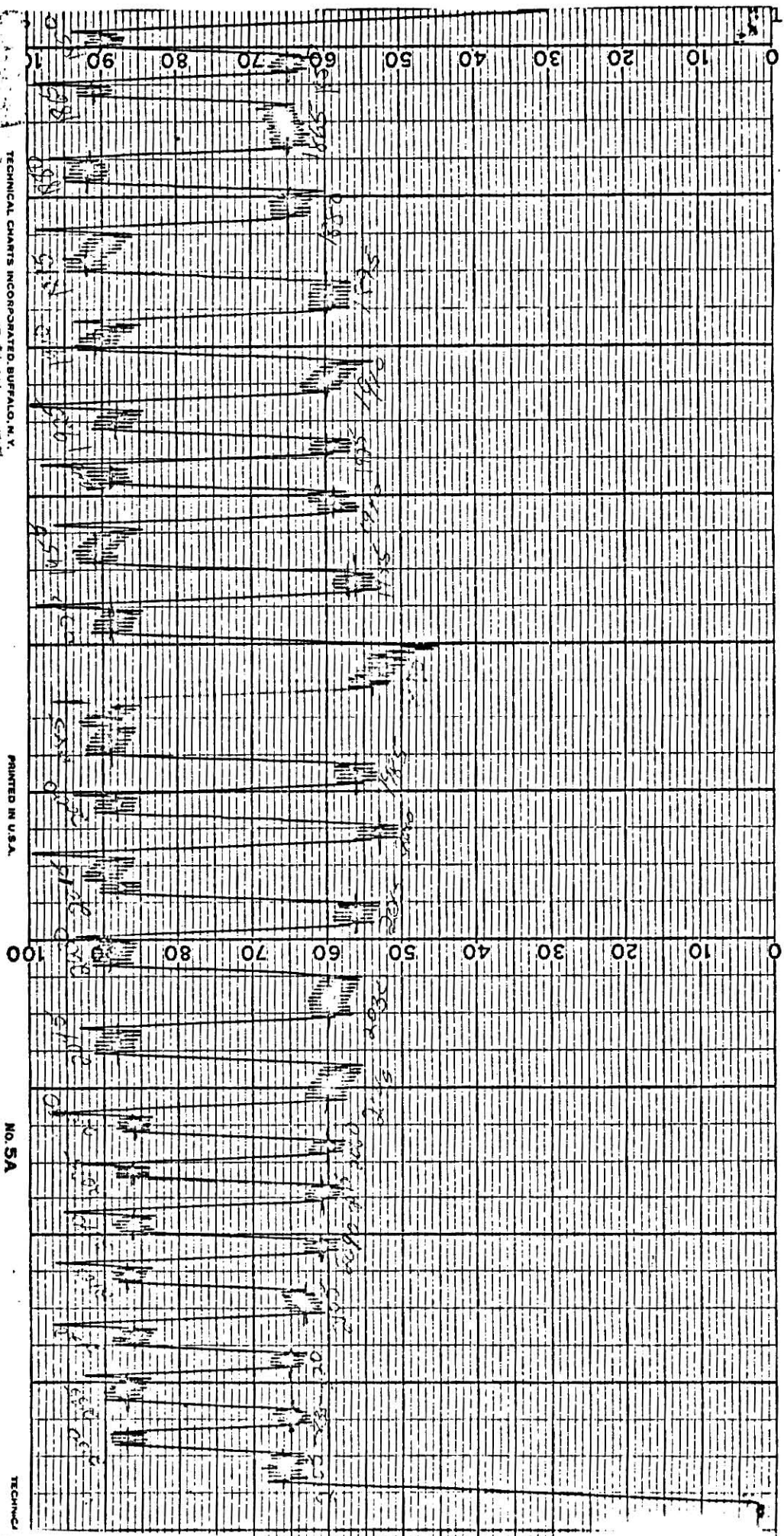
the center frequency of the 1925 Hz - 2075 Hz band are plotted
in Fig. 6. Horizontal lines indicate the standard deviation at
these points. Similar data are plotted in Fig. 7 for the 1962.5
Hz - 2037.5 Hz band. The average threshold shifts produced by the
1925 Hz- 2075 Hz band at 40 dB and 60 dB Sensation Levels and by
the 1962.5 Hz - 2037.5 Hz band at 40 dB and 60 dB Sensation Levels
are plotted for all subjects as a function of frequency in Fig. 8
and Fig. 9 respectively. Half of the runs were presented from low
frequency to high frequency and the other half were from high fre-
quency to low frequency. There was essentially no difference in
the masking observed relative to the direction of the runs, there-
fore, the data for the two were combined. This is in agreement
with the findings of Carterette, Friedman and Lovell (1969) that
the direction of the runs was not of significance.

The basic guide for the statistical procedures used in this
experiment was Winer (1962). The level of significance used through-
out this study was selected to be the 1% level. A two-by-eleven
repeated measures analysis of variance was performed on the data
obtained for the 1925 Hz - 2075 Hz noise band. Results of this
analysis of variance are summarized in Table 1. Frequency is sig-
nificant at the 1% level, indicating that masking was not constant
at all measured points within the noise band. The noise levels
were also significant at the 1% level. One would expect this re-
sult since the two levels used differed by 20 dB. The interaction
of frequency by noise level was not significant. This result would
indicate that the masking curves were essentially the same shape
for the two levels of noise.
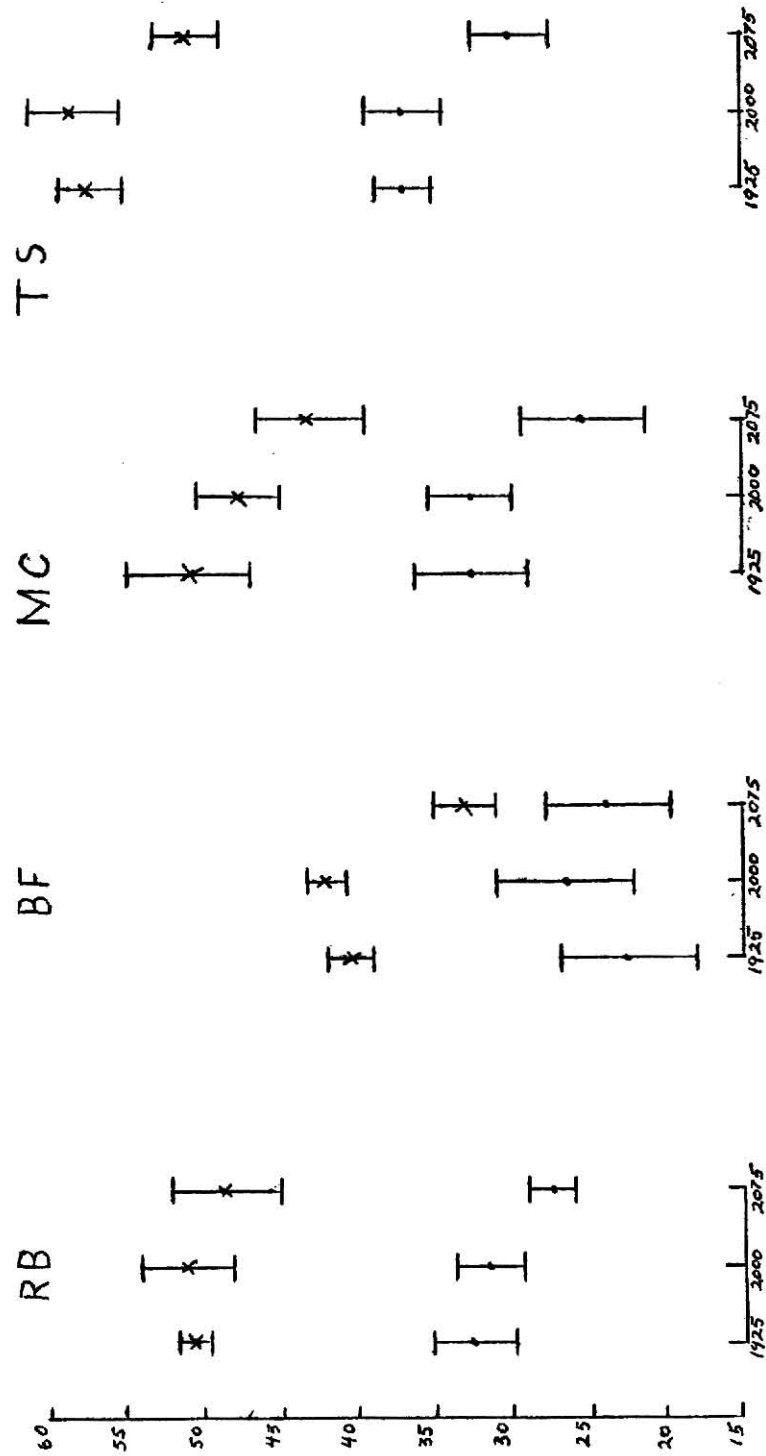
Fig. 6. Mean threshold shift for each subject at cut-off and center frequencies of the 1925 Hz - 2075 Hz band. Horizontal lines indicate one standard deviation above and below the mean.
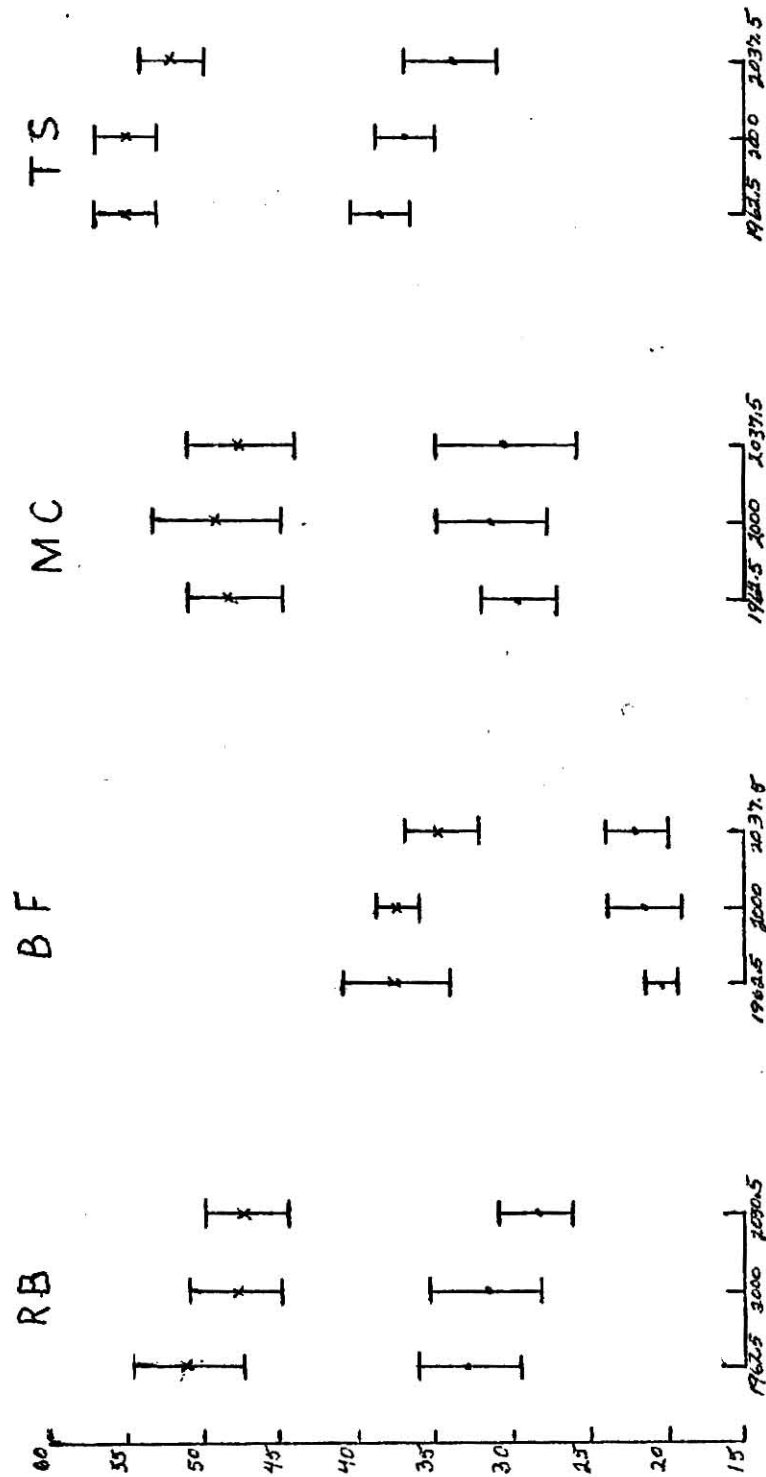
Fig. 7. Mean threshold shift for each subject at cut-off and center frequencies of the 1962.5 Hz - 2037.5 Hz band. Horizontal lines indicate one standard deviation above and below the mean.
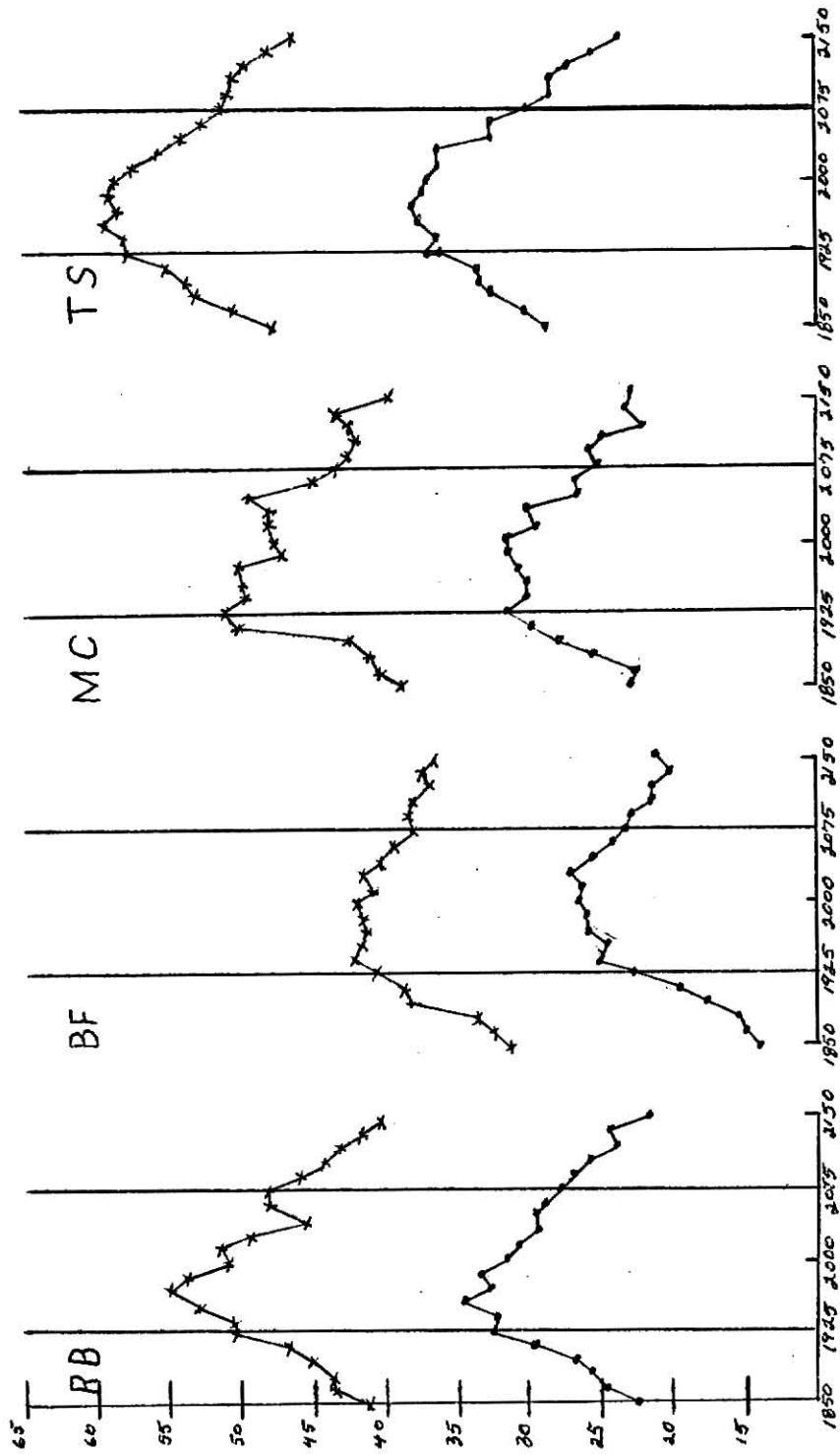
Fig. 8. Average threshold shift for each subject plotted as a function of frequency in the presence of the 1925 Hz - 2075 Hz masker.

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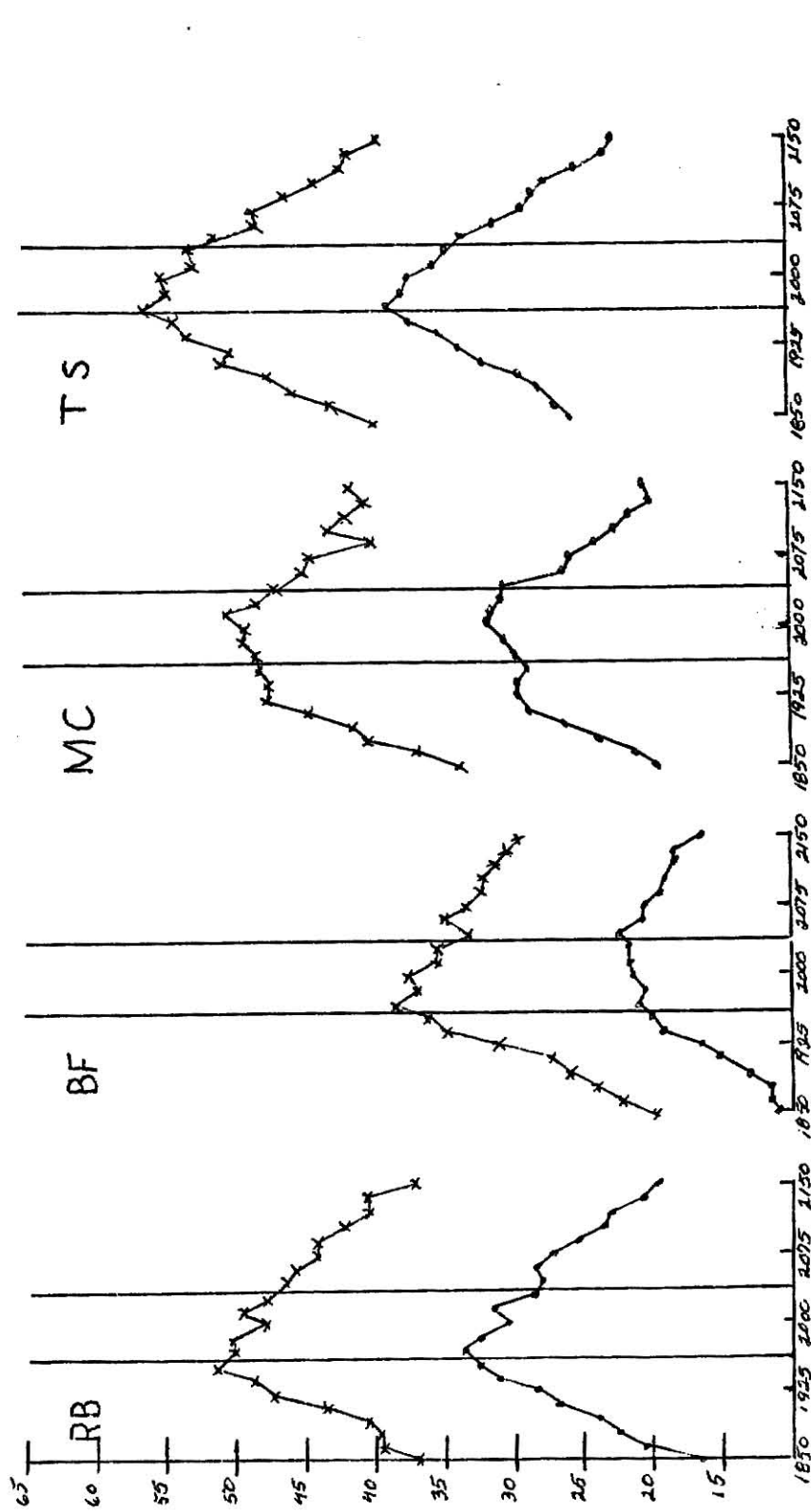
Fig. 9. Average threshold shift for each subject plotted as a function of frequency in the presence of the 1962.5 Hz - 2037.5 Hz masker.

Table 1. Summary of Analysis of Variance comparing differences between frequency, noise level, and frequency with noise level for the 1925 Hz - 2075 Hz noise band.

Source of Variation	df	ss	ms	f	
Subjects	3	1917.48			
Frequency	10	271.38	27.138	90.474	++
Noise Level	1	7566.59	7566.594	305.477	++
F x N	10	3.43	0.343	0.079	
S x F	30	9.04	0.301		
S x N	3	74.31	24.771		
S x F x N	30	128.71	4.290		
Total	87				

++ Statistically significant at the .01 level

In order to study the specific frequencies at which threshold shifts were significantly different, t-tests were run on the average threshold shift at each frequency within and including the edges of the 1925 Hz - 2075 Hz band. The results of this are shown in Table 2. Taken together with the graphs on Fig. 8, it is seen that 1985 Hz was the only frequency to show a significant upward shift from the cut-off frequencies. However, this frequency did not show a shift significant from the frequencies of 1955 Hz and 1970 Hz, but was significantly higher than those frequencies above 1985 Hz.

A similar analysis of variance was performed on the data obtained from the 1962.5 Hz - 2037.5 Hz band also. A summary of these results are shown in Table 3. For this band of noise, frequency was not found to be significant which means, in effect, that for data pooled across subjects, the threshold shifts were the same at all frequencies inside and including the edges of the 1962.5 Hz - 2037.5 Hz band of noise. For this band also, there was a significant difference between the 40 dB and 60 dB Sensation Levels. The interaction of frequency and noise level was not significant in this analysis either.

Discussion

In regards to Question 1 mentioned at the beginning of this chapter, the shift produced at the cut-off frequencies of the masking noise is not significantly increased over the shifts occurring at frequencies lying between the two edges. The frequency showing the greatest shift is 1985 Hz in the presence of the 1925 Hz - 2075 Hz masking noise. However, this frequency was not significantly greater than the threshold shifts at 1955 Hz and 1970 Hz.

Table 2.   Results of t-test by frequencies for the 1925 Hz – 2075 Hz noise band.

	1940	1955	1970	1985	2000	2015	2030	2045	2060	2075
1925		*		*				*	*	*
1940		*	*	*				*	*	*
1955						*	*	*	*	*
1970						*	*	*	*	*
1985					*	*	*	*	*	*
2000								*	*	*
2015								*	*	*
2030								*	*	*
2045									*	*
2060										*

* p. .05

Table 3. Summary of Analysis of Variance comparing differences between frequency, noise level, and frequency with noise level for the 1962.5 Hz - 2037.5 Hz noise band.

Source of Variation	df	ss	ms	f	
Subjects	3	1909.76			
Frequency	6	39.73	6.623	2.481	
Noise	1	4131.45	4131.450	98.296	++
F x N	6	2.06	0.341	0.404	
S x F	18	48.00	2.677		
S x N	3	12.61	4.208		
S x F x N	18	15.38	0.849		
Total	55				

++ Statistically significant at the .01 level

With reference to Question 2, the band of noise exhibiting the steeper skirt slope, 1962.5 Hz - 2037.5 Hz, showed that no frequency had a significantly different threshold shift. However, data were pooled across subjects for this analysis. It is perhaps more meaningful to look at data of individual subjects. It appears that, without question, the subjects performed consistently on the 1962.5 Hz - 2037.5 Hz band of noise. That is, a sharp peak was evident in the masking curves of individual listeners. However, the location of this peak varies in frequency position.

CHAPTER IV

DISCUSSION AND CONCLUSIONS

The data from this investigation indicated that there was
a significant difference in masking at certain frequencies lying
within the 1925 Hz - 2075 Hz band. This would indicate that all
of the subjects tended to perform in the same manner. In general,
the frequencies which demonstrated the most masking were slightly
below the center frequency. This result is in agreement with the
data of Carterette, Friedman and Lovell (1969), in that they note
"...that the tonal center of gravity is shifted below the midfre-
quency of the noise band. [p. 992]." If one looks at the data of
individual listeners, it is obvious that irregularities exist.
Therefore, in order to decide if, in fact, these irregularities
are actually valid, it would seem that more data would be required
so that the data on each individual listener could be evaluated,
separately. This is perhaps a more reserved view of the data than
that of Carterette, Friedman and Lovell. In general, it was the
conclusion of this experimenter that maximum masking occurs between
the limits of the noise band and in no instance does it appear that
maximum masking is at the low frequency or the high frequency end.

A statistical analysis of the data pooled across listeners
showed there was no difference in the masking produced at the fre-
quencies falling inside the 1962.5 Hz - 2037.5 Hz band of noise.
When data of individual subjects is viewed, it can be seen that
subjects RB and TS show the greatest amount of masking at the low
frequency edge of the noise band. However, subject MC showed

more masking on the high frequency side of the noise band. These
data are consistent for the three listeners mentioned for the two
Sensation Levels. On the other hand, the data of BF are not con-
sistent for the two Sensation Levels. He showed greater masking
toward the low frequency end for the lower intensity noise band
but, for the higher intensity band, he showed greater masking to-
ward the high frequency side. Although the skirt slope of this
noise band was steeper than that of the 1925 Hz - 2075 Hz band,
it is also true that this noise band was narrower than the band
previously discussed.

Since differences are apparent in the point at which maximum
masking occurs for the subjects, one can not comment with much
certainty on the effects which result from steepening the skirt
slope. Figures 6 and 7 which give the standard deviations at each
frequency measured for the individual listeners does not seem to
indicate that judgements were more difficult to make for the nar-
rower noise band. It would seem that the only point one could
make is that subjects appear to show greater individual differences
for the narrower band masker. It is not readily apparent why data
for the narrow band of noise are not as consistent since the vari-
ability of the individual data points appears to be the same.

It is of interest to point out that, for an individual graph,
twice as many data points were obtained in this study as in the
study by Carterette, Friedman, and Lovell (1969). It is this ex-
perimenter's conclusion that more subjects and a much larger num-
ber of data points are required to see if these are valid differences
between listeners. While 11 points could be used for the analysis

of the wider band of noise, only seven points fell within the cut-offs of the narrower band of noise. This could have some effect on the analysis of these bands statistically. Further, it is the experimenter's conclusion that the Békésy technique of gathering data may not provide the precision required for this type of study. It proved extremely difficult for the listeners to maintain a constant judgmental criteria. The experimenter arbitrarily chose to accept only the stable part of a subject's tracing as a reliable data point. It may well be that one should accept only a given duration of tracing without regard to its stability. That is, perhaps the mean of all excursions for a given tracing duration would provide the data for that particular trial, rather than accepting only the data from a given period of stable tracing.

In summary, the data for the wide band supports Carterette, Friedman, and Lovell's (1969) data that the center of masking would seem to be shifted below the center frequency of the band of noise, but certainly not as low as the edge. The narrower band, when viewed graphically, does show instances of edge effects which would also indicate a greater number of runs are needed in order to obtain the precision required to determine if these small differences in masking between adjacent points are real or just a result of variability in listener criterion. Additional research, obtaining more data per subject and perhaps a set duration of tracing should be undertaken before the edge effect hypothesis can be substantiated or refuted by masking techniques.

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AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF ARTS

Department of Speech

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1970

The purpose of this investigation was to study the performance of the auditory system in the presence of a masking stimulus and to relate the data obtained to the edge effect hypothesis of pitch perception. At present there are several theories of hearing, which are, in fact, theories of how the auditory mechanism perceives the pitch of a sound stimulus. These theories deal with the distribution, along the basilar membrane, of the vibrations produced by a sound stimulus. None of these theories adequately explains the pitch perception of different stimuli such as pure tones, tonal masses and noise. Most listeners agree on the pitch they assign to a pure tone or a tonal mass, but there is a lack of such intersubject agreement on the pitch of a band of noise.

One theory concerning the perception of pitch of a band of noise is by Békésy (1960) and is based on the role of lateral sensory inhibition. Such inhibition has been recognized in vision for many years. According to this theory, the sensory effect of a stimulus is greatest where it undergoes its greatest variation. This would indicate that a band of noise would stimulate a section on the basilar membrane with a drop in excitation at both edges, producing a contrast or edge effect which should enhance the perception of those frequencies at the edges or cut-offs of the band of noise.

If the edge effect hypothesis is true, then the cut-off frequencies would be the pitches of a band of noise and subsequently, pure tones at those frequencies would be more effectively masked than other pure tones. Also, it would follow that the more pronounced the contrast, the more enhanced the pitch of a cut-off

frequency. Steepening the skirt slope of a band of noise should steepen the gradient of physical excitation and increase the amount of contrast corresponding to the cut-off frequency. An opposing theory is that of the critical band. According to this theory, the center frequency of a band of masking noise is louder than other frequencies due to summation. This would indicate that the center frequency should cause the most masking and be perceived as the pitch of a band of noise.

For the purposes of this study, four subjects, using a Bekesy audiometer, traced their pure tone thresholds in the quiet and then in the presence of a narrow band masking noise. Two bands of masking noise were used. Both of these bands of noise had steep skirt slopes, but one was slightly steeper than the other. The carrier for both bands of noise was 2000 Hz. Each band of noise could be presented at 40 dB Sensation Level and at 60 dB Sensation Level. Pure tone thresholds were traced at 41 frequencies which were spaced every 15 Hz from 1850 Hz to 2150 Hz.

The results of this study did not show enhancement at the cut-off frequencies of either band of masking noise. A statistical analysis revealed that there was no significant upward shift in threshold at edge frequencies or at the middle frequency. For the two bands of noise run at both Sensation Levels, all subjects showed more masking at the low frequency end of the noise band with a marked decrease in masking shift at the higher frequencies. It should be noted that the masking curves obtained were similar in shape for all subjects under all conditions. Also a study of the range and standard deviations at the cut-off frequencies and

midpoint for both bands of noise at both Sensation Levels indicated that subjects did not experience more difficulty with the task at any particular frequency or under any one condition.

When individual data is looked at separately instead of pooled together, slight differences can be seen between adjacent data points. However, there was not enough data on each subject to evaluate the subjects separately. In light of these findings, further research, utilizing a much larger number of runs per subject, is indicated.