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WHAT IS MASKING?

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Electronic Defense Group
Department of Electrical Engineering

W. P. Tanner, Jr.

Approved by: A. B. Macnee

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ABSTRACT

Three experiments are presented and analyzed in terms of a conventional definition of masking and a masking index conforming to this definition. It is demonstrated that, even though all of these experiments yield data permitting calculation of the masking index, that at least three distinct processes lead to this data: signal masking, distortion of the sound wave form, and listener distraction. Either masking theories should take these three processes into account, or masking should be redefined.

WHAT IS MASKING?

I. INTRODUCTION

According to Licklider (Reference 1), "masking is thus the opposite of analysis; it represents the inability of the auditory mechanisms to separate the tonal stimulation into components and to discriminate between the presence and absence of one of them." He continues by pointing out that the "degree to which one component of a sound is masked by another is determined by the measuring of two thresholds": that of the masked tone with the masking agent present and without the masking agent present.

In view of a result first reported by Tanner and Norman (Reference 2), it appears to be worthwhile to re-examine the masking concept. In that experiment the detectability of a tone appears to be changed when the observer is uncertain of the frequency of that tone. Is this uncertainty a masking agent in the same sense that one usually conceives of a masking agent which actually introduces physical energy into the ear at the same time that detection occurs? Certainly the result is the same.

However, if one is not willing to accept the similarity of result as an indication that the same type of phenomenon is occurring in the two cases, then one might extend his doubts to the question concerning the similarity between masking by white noise and masking by pure tones. This paper is intended to treat the differences between these three types of experiments: (1) the change in the detectability of a tone through the introduction of an additional white noise, (2) the change in detectability of a tone in the presence of an additional pure tone, and (3) the change in the detectability of a tone when the observer knows that it might have been a different tone.

The measurements employed in the experiments reported below depend on the definitions of η and d' presented by the author (Reference 3). η is the ratio of the energy required of the ideal observer (Reference 4) to the energy employed in an experiment, leading to equal performances for the ideal observer and the observer in the experiment. For purposes of comparison over the three types of experiment the masking index M is defined as

$$M = \frac{\eta_1 - \eta_2}{\eta_1}$$

where η_1 is the efficiency of performance without the masking signal and η_2 is the efficiency of performance with the masking signal present.

II. THREE MASKING EXPERIMENTS

All of the experiments reported below are of the class referred to as "temporal forced choice" (Reference 5). A signal is known to occur in one of n positions in time. It is the observer's task to state in which of the n positions in time the signal occurred. Since in all of the experiments each of the positions was equally likely to be that of the signals, and each had associated an equal risk function, d' could be obtained from the percentage of correct responses and the approximations of Peterson and Birdsall (Reference 6) for the probability of a correct choice among one of n alternatives.

2.1 Masking by White Noise

The first problem treated is that of masking by white noise. In this problem, the data of Green, Birdsall, and Tanner (Reference 7) is employed. In the experiments reported in that paper, involving weak signals, d' is found to vary approximately linearly with signal energy for every case in which signal duration is held constant. Since d' ideally should vary linearly with the square root of signal energy, this means that η is a small number when d' is small, and increases as d' increases. Actually, η has been observed to be as large as 0.3 in some of these experiments. This result, along with the result that d' varies in nearly the same manner with the ratio $2E/N_0$ when the ratio is varied by varying the noise level rather than the signal level (Reference 8), suggests that only the higher values of η should be used in computing the masking index if one is interested in signal masking as such. The reason for the low values of η appears to exist in some effect other than masking of the signal itself.

2.2 Alternate-Frequency Masking

Next, consider the decrement in performance which results from the fact that the signal might have been at another frequency. In this experiment the signal appears in one of n positions in time. The observer knows that the signal will be randomly selected from one of two possible frequencies. He is graded as being correct if he states the correct interval in time; he need not state the frequencies. The masking index, calculated from the data of Tanner and Norman is zero when the two frequencies are the same, and increases as the two possible frequencies become farther separated. The effect of a 1000 ~ tone on 1000 ~ , 900 ~ , 800 ~ , and 700 ~ , is shown in Figure 1. Surely, this tone which might have been the signal is not masking in the usual sense. It appears rather that it is serving to distract the attention of the observer from the signal. Of course, in these experiments involving two tones either signal can be considered to be the masking tone.

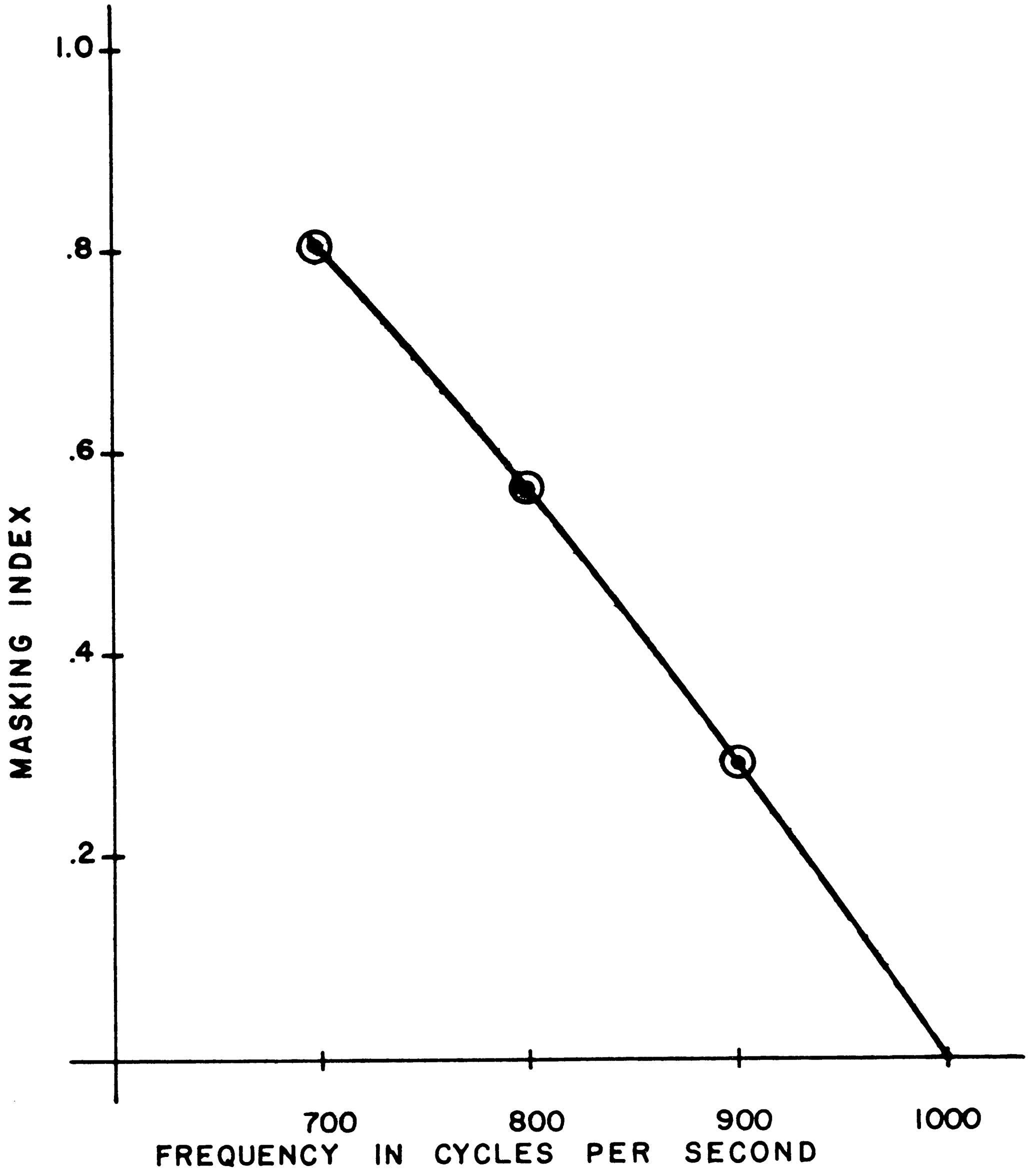

FIG 1 MASKING BY A 1000∼ TONE WHICH MIGHT HAVE BEEN THE SIGNAL

2.3 Masking by Pure Tone

The third type of masking experiment is like that performed by Wegel and Lane (Reference 9). In this experiment, a pure tone is employed as the masking signal. It is added to a noise background present to permit the calculation of η. The effect of the presence of this tone on the performance in two types of experiment, each employing the same information-carrying component, is studied. One of these experiments is a detection experiment, the other a recognition or discrimination experiment.

The two experiments are illustrated in Figure 2. The first experiment has presented in two positions in time the signals illustrated in lines 1 and 2, the order randomized. The observer states whether the larger, that in line 2, came first or second. The difference signal, that which carries the information, is shown in line 3. The second experiment presents in the same way the signals shown in lines 4 and 5. Again the observer is asked to state whether the larger came first or second. The difference signal, carrying the information, is illustrated in line 6. It is to be noted that the signals in line 6 and line 3 are the same.

Perhaps a little discussion will help the reader see that, ideally, the two experiments lead to the same results. In the second experiment, the smaller of the two signals (line 4) appears in both positions in time. In one of the time positions the information carrying signal (line 6) is added to the smaller. The ideal observer subtracts the smaller signal from the observation in each of the two positions in time. This leaves in one position the signal in line 1, plus noise of course, and in the other the signal of line 2 plus noise. Ideally, he now tests to determine whether the signal in line 2 is more likely to be in position 1 or position 2. This is, of course, the identical task required of the observer in the first experiment.

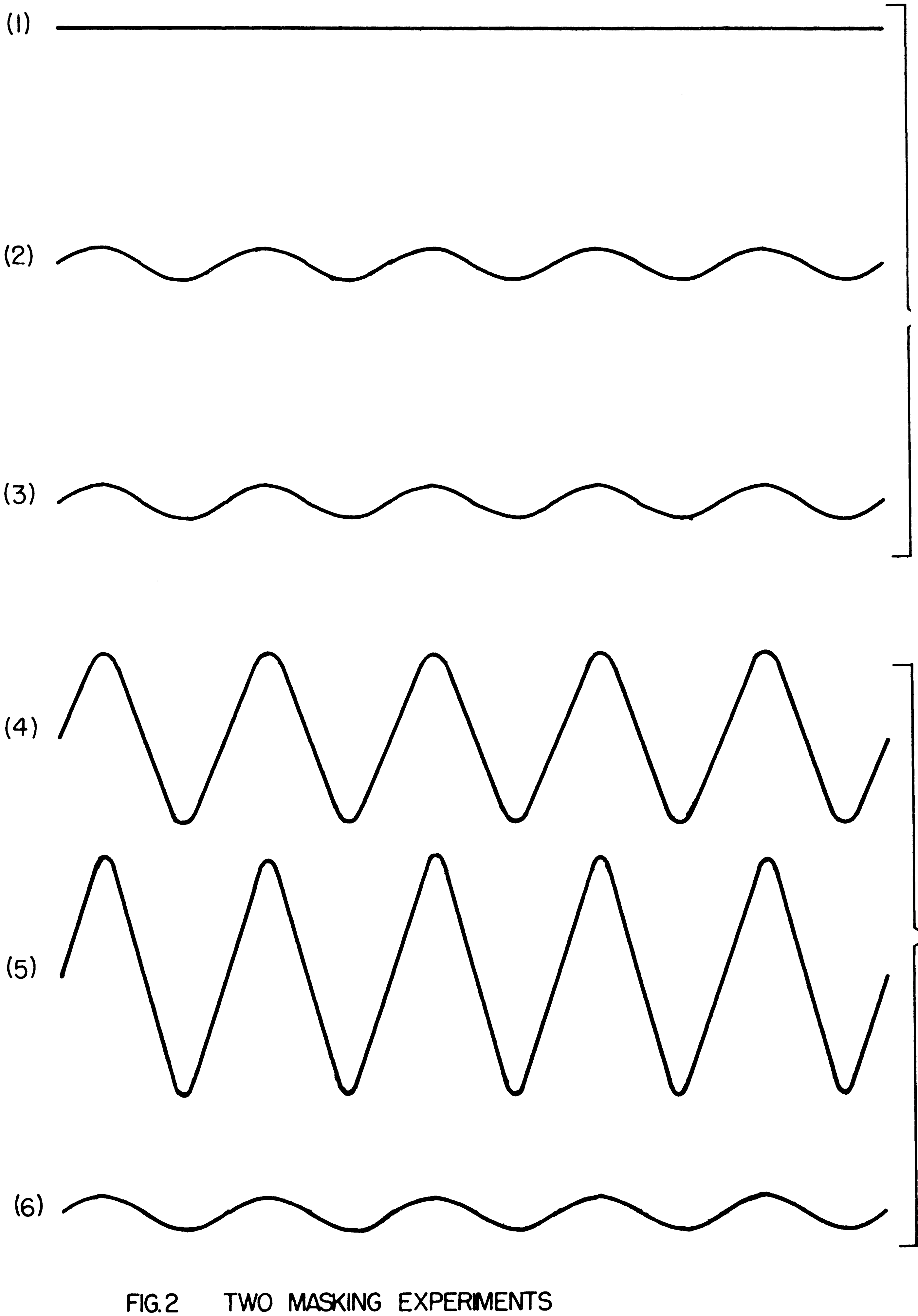

FIG. 2 TWO MASKING EXPERIMENTS

Experiment 1 involved two signals: zero volts and .05 volts. The other experiment employs signals of .20 volts and .25 volts. The difference in each case is .05 volts. Each experiment was performed with masking tones at 1200 cycles, first with the masking tone at .10 volts, and then at .40 volts. The sound pressure level of these two tones at the output of the earphones is approximately 65 and 77 db re .0002 dynes/cm^2. The masking tone was continuously present in the noise, while the signals were .1 second in duration. The determination of each η involved 200 observations for the unmasked condition and 200 observations for the masked condition.

III. DISCUSSION OF RESULTS

The results of these experiments are shown in Figures 3 and 4. It is obvious at a glance that the "masking" tone does not appear to be affecting the signal equally in the two cases. When the weak signal is presented at the same frequency and in phase with the weaker of the two masking tones, the masking index is less than -1. In other words, performance is enchanced rather than decreased. However, when the two signals are separated by 100 cps, the masking index is nearly 1.00, and with the larger masking tone is 1.00. As the separation becomes greater, the effect decreases faster for the lower masking tone than for the larger tone.

For the second experiment, the "masking" effect is much less except for that case in which the large signals are at the same frequency and in phase with the masking tone. The sum of the two is sufficient to place the two in the range in which distortion might be expected, more than 80 db above .0002 dynes/cm^2. Other than this case, there appears to be relatively little effect, particularly for the smaller masking tone.

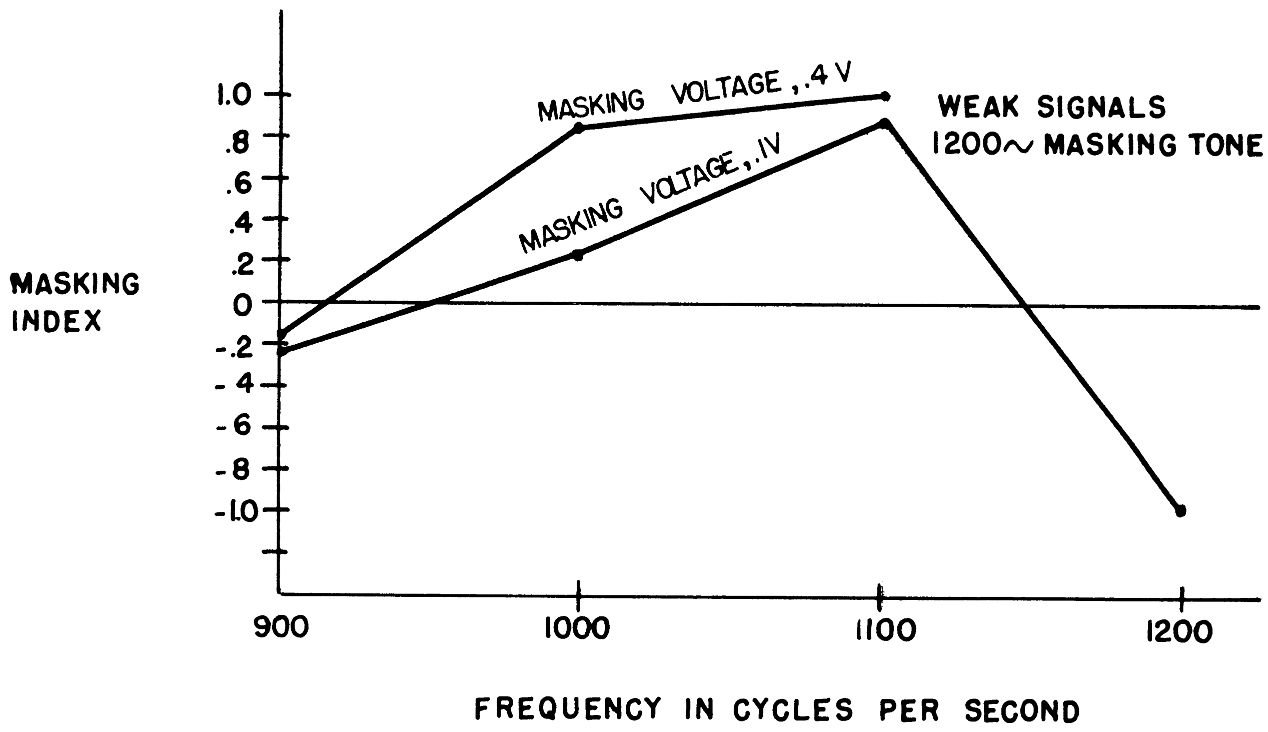

FIG. 3 RESULT OF FIRST EXPERIMENT OF FIG. 2

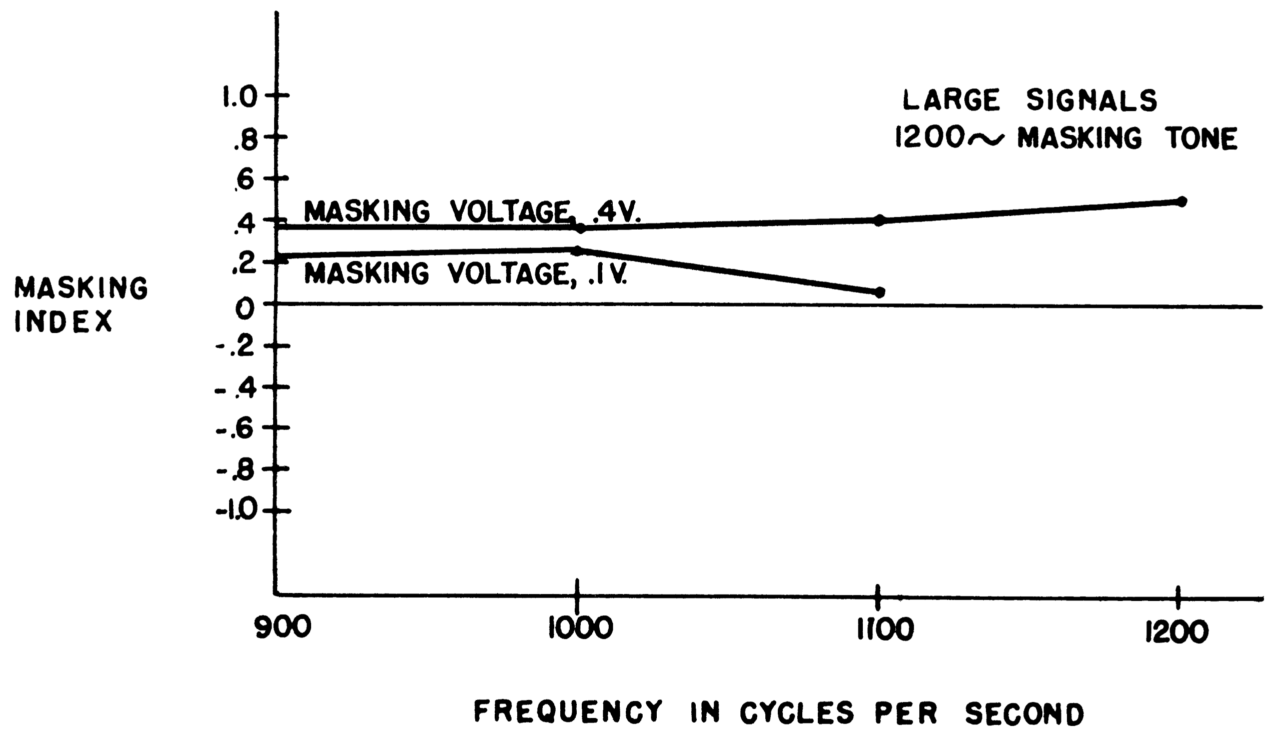

FIG. 4 RESULT OF SECOND EXPERIMENT OF FIG. 2

Reviewing all three types of experiments, there appear to be at least three types of effects involved. One of these is the signal masking (Reference 10) accomplished by white noise. The size of this effect probably is not much greater than one would predict based on the theory of signal detectability (Reference 4).

The second is the distraction of the observer from the signal he is trying to detect. Some of this effect may exist when only noise is used to mask, since the noise may tend to disturb the observer's memory for the signal frequency. In the case where the signal frequency is uncertain, it seems fairly clear that this type of effect may exist. The notion is further supported in the third type of experiment. When the signal is weak, the masking tone interferes except in that case where it serves as the memory of the signal frequency. When the signal has the carrier, as in experiment 2 of the third type, the carrier is strong enough to resist the distraction.

The third effect is that illustrated when the large signals are added to the larger masking tone, a distortion effect. This leads to a spreading of energy which could cause a decrease in performance.

The masking by white noise appears to be at least as much physical as it is physiological. When noise is introduced, the signal is masked even for the ideal observer. The difference between the physical effect and the measured effect can be in part attributed to internal noise. When noise is the masking signal, both distraction and distortion may also exist. If the noise is large enough, it can lead to distortion. This would be the same type of effect as that occurring when the large signal is added to the larger of the masking tones. This effect can be considered either as physical or physiological, probably being a function of the structure of the ear. Distraction appears to be largely a central process. It involves the control of attention by the observer.

IV. SUMMARY

In the three experiments reported, masking appears to take place in all three. Still, careful analysis suggests that there are three different processes involved. Should all three be accepted as masking? If so, then masking theories should take into account the fact that they must account for these processes. If not, then masking should be redefined.

It seems to the author that the difficulty lies not so much in the definition as it does in the acceptance of an operational definition based on the method of measure. Does masking occur merely because conditions are established leading to a change in performance?

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