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SECOND REPORT ON PANORAMIC RECEIVER CW THRESHOLDS

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SECOND REPORT ON PANORAMIC RECEIVER CW THRESHOLDS

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June 21, 1949

Approved by:

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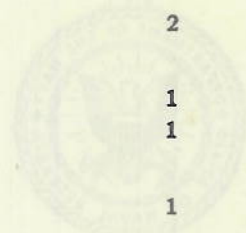
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ABSTRACT

The problem of perception by an observer of signals in the presence of receiver noise, as presented on the cathode-ray tube indicator of a panoramic system, is further considered. Additional data are given on the effect of variation of video bandwidth on minimum perceptible signal. A tentative form of an expression for minimum perceptible signal is derived as a function of the system's parameters, and it is found that, with respect to sweep rate, a minimum occurs in the expression at about 14 c/s. The range limits of the various parameters, presented graphically, may be useful as a guide in design procedures.

PROBLEM STATUS

This report completes one phase of this problem. Work is continuing on other phases.

AUTHORIZATION

NRL Problem No. R06-17R (BuShips Problem S-1255.3)

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SECOND REPORT ON PANORAMIC
RECEIVER CW THRESHOLDS

INTRODUCTION

The problem of intercept of signals in the presence of noise is especially pertinent to the early-warning problem of search for a signal of unknown frequency, or for search for a known signal activated for an unknown period of time at an unknown instant. Because these signals might be of the order of magnitude of the mean noise itself, the characteristics of the intercept receiver should be such as to provide the optimum possibilities for discrimination. A continuing study has been underway of these so-called threshold signals in the presence of noise, as viewed on a panoramic indicator, with the aim of improving the chances of intercept by a favorable adjustment of the parameters of a panoramic system.

This is the second of a series intended further to interpret data recorded in the previous report on this problem¹ and to include additional new information. It now appears that the derivation of an expression for the minimum perceptible signal power is a possibility, and the results of an attempt at the tentative form of this expression are given. Use is made of a procedure similar to one given by Haeff² to determine, in this case, a logarithmic relationship between two parametric functions of the system. The resulting expression appears reasonable with respect to variation of the several parameters, at least within the investigated region.

EXPERIMENTAL RESULTS

A special video amplifier with d-c response and adjustable bandwidth was built to check further the relative importance of the video in a panoramic system. The bandwidths were capable of being varied in steps, the lowest bandwidth being 250 c/s, and decade steps were available from one kilocycle to one megacycle. This switching was done without changing the over-all gain of the entire system, and without affecting the characteristics of the second detector, the bandwidth discrimination having been accomplished following the first video tube by switching condensers in three separate stages. The effective video bandwidth, b , was taken as

$$b = \int_0^{\infty} \left[\frac{G(f)}{G(dc)} \right]^2 df,$$

¹ Beck, H. M., Faust, W. R., and Weidemann, H. K., "Panoramic receiver thresholds." NRL Report R-3336 (Restricted), 17 August 1949.

² Haeff, A.V., "Minimum detectable radar signal and its dependence upon parameters of radar systems." Proc. I.R.E., 34: 857-861, November 1946.

where $G(dc)$ is the gain at zero frequency, and the integration was done by planimeter from a linear plot.

With the intermediate-frequency bandwidth, B , held constant at 25 Kc, a run was made for each of the five video bandwidths now available, utilizing a minimum of five observers per run. The data was evaluated in the same manner as indicated in the previous report on this problem.³ No significant dependence of $(S/N)_{50}$ on video bandwidth was found except for the very narrowest bandwidth used, that is, 250 c/s, where $(S/N)_{50}$ increased about 4.5 db, as shown in Figure 1.

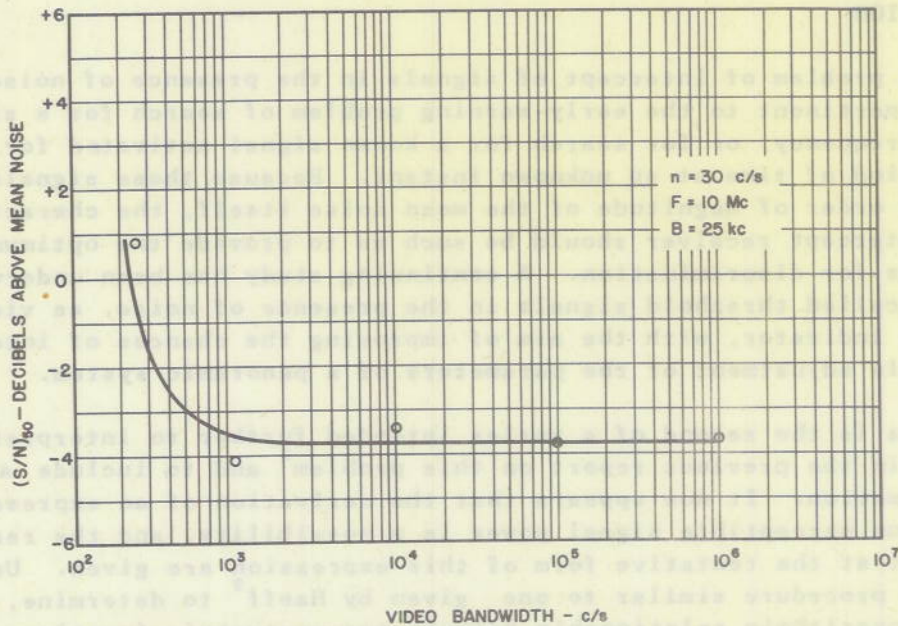


Figure 1- Minimum perceptible signal-to-noise ratio for video bandwidth, b .

It should be noted that 250 c/s was almost the narrowest video bandwidth possible while still maintaining six distinct positions on the indicator screen. The "pulse" stretching due to the very large rise and decay times in the video prevented the use of still narrower bandwidths. Other parametric limitations of a panoramic system for CW reception are given in Appendix I.

MINIMUM PERCEPTIBLE SIGNAL

A tentative form of the expression for minimum perceptible signal, on the basis of the fit indicated in Figure 4 (Appendix II), is:

$$S_{min.p.} = (\frac{1}{2} \overline{NF} KTR)^{\frac{1}{2}} \left((10/B + 1/b) nF \right)^{0.20} \left(\frac{5.3}{n^{1.20}} B \right)^{0.30}, \quad (1)$$

where \overline{NF} = "mean noise factor" of system (the mean of several noise factors taken at sufficiently close intervals throughout F under nonsweeping conditions)

³ Beck, Faust, and Weidemann, *op. cit.*

K = Boltzmann's Constant;
T = temperature, degrees Kelvin;
R = input resistance of system, ohms;
n = sweep rate, c/s;
F = frequency band swept, c/s;
B = second i-f bandwidth, c/s; and
b = video bandwidth, c/s.

With respect to the parameter, n, a minimum occurs in this expression at about 14 c/s, apparently due to psychological complications involving the fact that the flicker is becoming prominent with further decreasing n, and perhaps also due to the characteristics of the type of phosphor and similar factors.

IMPLICATIONS

For a system designed primarily for minimum perceptible signal, equation (1) would seem to indicate a choice of B as small as possible, video bandwidth b as large as possible, neither bandwidth being exceptionally critical. Video bandwidth can be made considerably smaller than the bandwidth B for the same sacrifice in minimum perceptible signal.

The sweep rate would probably be chosen just large enough so that flicker would not be a disturbing factor for the type of screen chosen. But intercept probability may actually increase with larger sweep rate, n, up to a rate determined by the rise times of the i.f. and video, without too great loss in visibility. The sweep-frequency width, F, should for this purpose be made as small as possible, but it can be made as large as convenient without much sacrifice in visibility.

It should be noted carefully that minimum perceptible signal is not always the only design criterion. The usual design rule for "optimum" resolving power, $B = K \sqrt{nF}$, would seem still to be a valid design factor.

ACKNOWLEDGMENT

Thanks are extended to Dr. W. R. Faust for his active participation in this study. Acknowledgment is also due Mr. H. K. Weidemann for his many worthwhile criticisms and suggestions.

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With regard to the parameter, a minimum occurs in this expression at about 1/2 of the frequency due to psychological conditions involving the fact that the flicker is increasing somewhat with frequency decreasing and perhaps also due to the characteristics of the type of response and related factors.

IMPLICATIONS

For a system designed primarily for minimum perceptible signal, Equation (1) would seem to indicate a choice of 5 as small as possible. However, it is possible that larger bandwidths being experimentally obtained. When bandwidths are made considerably smaller than the bandwidth A, the same results in minimum perceptible signal.

The above case would probably be chosen, just large enough so that it would not be a degrading factor for the type of system chosen. For instance, bandwidths are actually measured with larger noise than for a case determined by the size of the 1/2 and video, without the noise being in frequency. The response frequency which T should be chosen to be made as small as possible, but it can be made as large as desired without affecting such capability in stability.

It should be noted especially that minimum perceptible signal is not always the only design criterion. The usual design rule for "constant" bandwidth would seem still to be a valid design factor.

ACKNOWLEDGMENT

Thanks are extended to Dr. W. E. Post for his active participation in this study. Acknowledgment is also due Dr. E. E. Reichmann for his many constructive criticisms and suggestions.



APPENDIX I

Parametric Limitations of Panoramic Systems for CW Reception

The practical and more fundamental limits of the four parameters of a panoramic system so far investigated for the CW case appear to be, at least qualitatively, as in Figure 2.

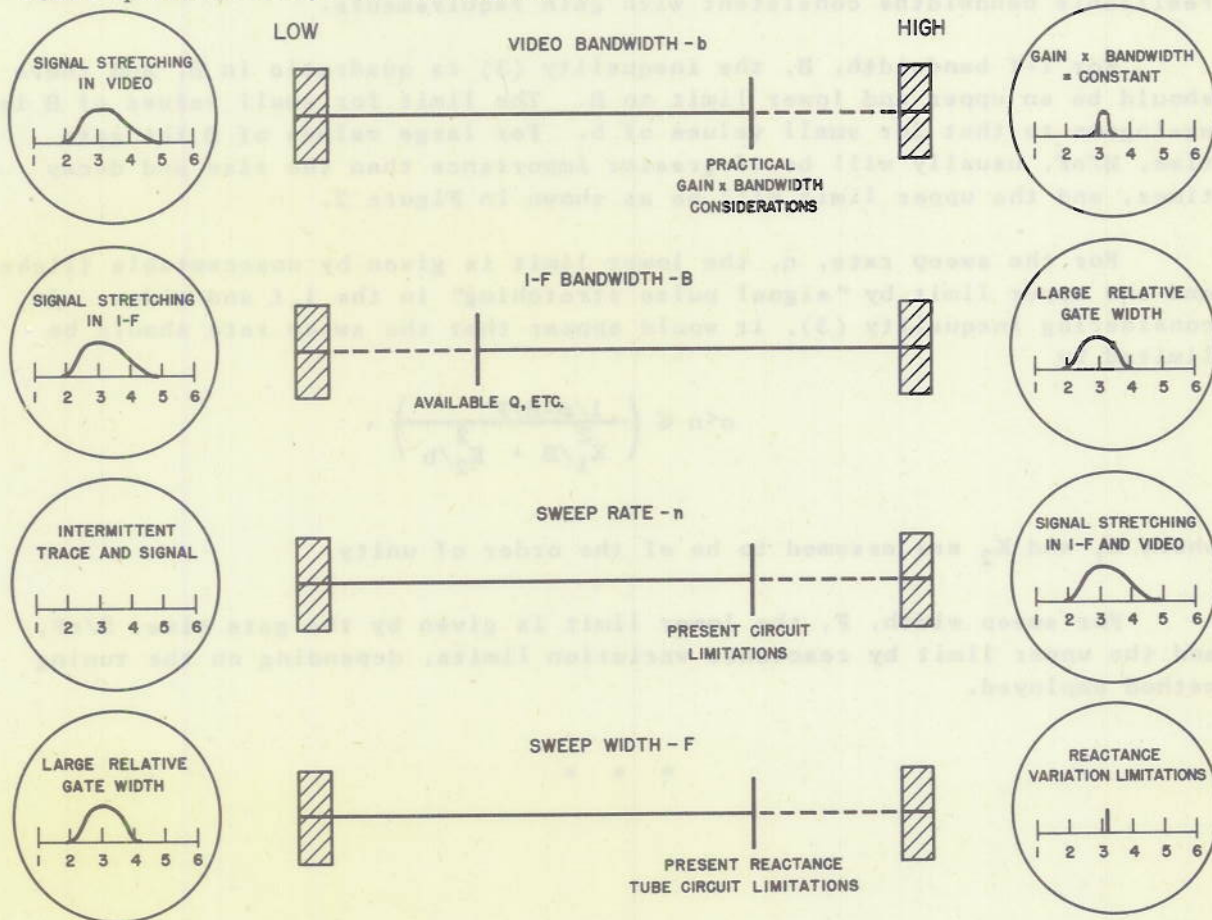


Figure 2- Some of the more fundamental as well as practical limitations of some important parameters of a panoramic system.

Using as a criterion some desirable, arbitrary minimum number of non-overlapping (that is, resolved) signals, say m , it will be seen that the several parameters considered each exhibit at least one limit which the design cannot pass without lowering the value of m . It will be seen that this is a very definite limitation in panoramic systems design. For example, if m is chosen as unity, one can no longer say he has a panoramic system, if a panoramic system is defined as a system displaying simultaneously several discrete signals.

In Appendix I of the previous report on this problem, the proportion of the total trace occupied by the effective pip length, α , was given as

$$\alpha = B/F + n(K_1^2/B + K_2^2/b). \quad (2)$$

If a value m , as given above, is chosen, then it must follow that

$$\alpha \leq 1/m. \quad (3)$$

In Figure 2, for video bandwidth, with m taken arbitrarily as six, $\alpha = 1/6$ is shown as a limit determined by "stretching" in the video amplifier. There is no corresponding upper limit to video bandwidth except physically realizable bandwidths consistent with gain requirements.

For i-f bandwidth, B , the inequality (3) is quadratic in B , and there should be an upper and lower limit to B . The limit for small values of B is analogous to that for small values of b . For large values of B the gate time, B/nF , usually will be of greater importance than the rise and decay times, and the upper limit will be as shown in Figure 2.

For the sweep rate, n , the lower limit is given by unacceptable flicker and the upper limit by "signal pulse stretching" in the i. f. and video. In considering inequality (3), it would appear that the sweep rate should be limited by

$$0 < n \leq \left(\frac{1/m - B/F}{K_1^2/B + K_2^2/b} \right),$$

where K_1 and K_2 are assumed to be of the order of unity.

For sweep width, F , the lower limit is given by the gate time, B/nF , and the upper limit by reactance variation limits, depending on the tuning method employed.

* * *

APPENDIX II

Derivation of Expression for Minimum Perceptible Signal

In Figure 3 the circled points correspond to experimental data on the parameter n , the sweep rate, plotted as $(S/N)_{50}$ against the sweep rate.⁴ An expression that fits this data reasonably well (X points) is:

$$(S/N)_{50} = 0.262 \left(\frac{5.3}{n} + n^{0.19} \right) \quad (4)$$

This expression may be used in arriving at an expression for minimum perceptible signal.

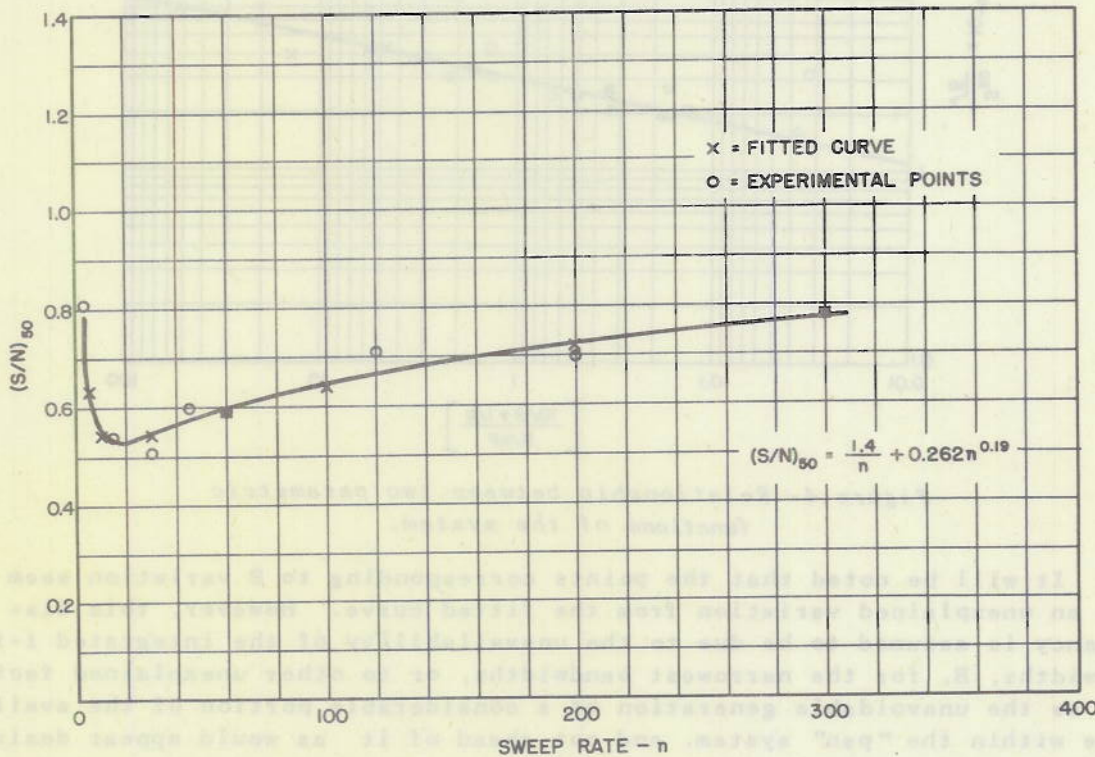


Figure 3- Minimum perceptible signal-to-noise ratio for variable sweep rate, n .

Assuming that the minimum perceptible signal-to-noise ratio, defined as $(S/N)_{50}$, is a function of some parameter, β , of the present system, several attempts were made to find the form of this function. Here β was initially taken as the over-all "noise bandwidth" of the system,

$$\beta = 1/t_n = 1/(1/B + 1/b), \quad (5)$$

⁴ Beck, Faust, and Weidemann, op. cit.

and τ was taken as the gate time, B/nF . Then,

$$\beta = \frac{B/nF}{(1/B + 1/b)} \quad (6)$$

A modified form of the reciprocal of this expression is plotted as abscissa in Figure 4. The noise voltage at the second detector was assumed to vary as the square root of B , the narrow i-f bandwidth, and S/\sqrt{B} is plotted as ordinate. The form of the "abscissa function" will be seen to de-emphasize the importance of the video bandwidth for visual purposes.

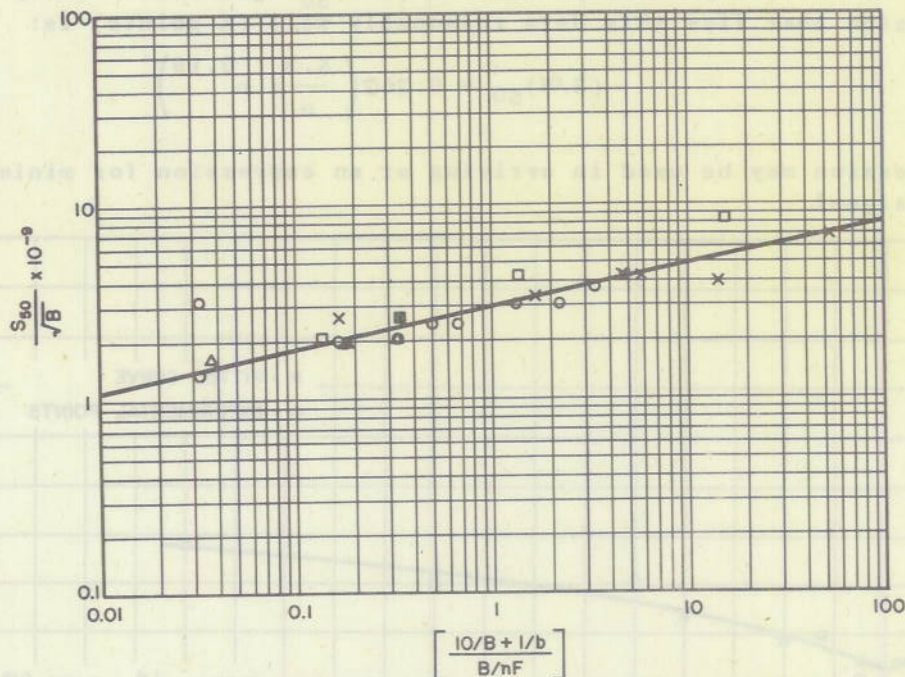


Figure 4- Relationship between two parametric functions of the system.

It will be noted that the points corresponding to B variation seem to have an unexplained variation from the fitted curve. However, this discrepancy is assumed to be due to the unavailability of the integrated i-f bandwidths, B , for the narrowest bandwidths, or to other unexplained factors, such as the unavoidable generation of a considerable portion of the available noise within the "pan" system, and not ahead of it as would appear desirable for this type of check.

Assuming that Figure 4 is a reasonably straight line fit to all the data, and remembering that we are dealing with a log-log plot, it follows that

$$Y = mX + C$$

$$\text{Log} \frac{S_{50}}{\sqrt{B}} = 0.204 \text{ log} \left[\frac{10/B + 1/b}{B/nF} \right] + \text{log } 2.90$$

$$\frac{S_{50}}{\sqrt{B}} = 2.90 \times 10^{-9} \left[\frac{10/B + 1/b}{B/nF} \right]^{0.204}$$

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$$S_{50} = 2.90 \times 10^{-9} \left[\left((10/B + 1/b)nF \right) \right]^{0.20} B^{0.30} \quad (7)$$

The factor $(1 + 5.3/n^{1.2})$ appearing in equation (1) will be seen to correspond to equation (4). Essentially, this factor affects in a relative manner only the point on Figure 4 corresponding to the smallest value of n.

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$$2.2 \times 10^{-10} = 2.2 \times 10^{-10} \left[(10^{-10} + 1.6 \times 10^{-10}) \right] \quad (7)$$

The factor $(1 + 1.6 \times 10^{-10})$ appearing in equation (7) will be seen to correspond to equation (6). Essentially, this factor affects in a relative manner only the point on Figure 2 corresponding to the smallest value of n .

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