[redacted]

UNCLASSIFIED

A REPORT OF RESEARCH UNDER CONTRACT WITH

SPECIAL DEVICES CENTER, OFFICE OF NAVAL RESEARCH

MEMORANDUM REPORT

THE EFFECT OF CRT BIAS ON VISIBILITY OF TARGETS ON A REMOTE PPI

BY

S. B. WILLIAMS
AND
ELLWOOD KING

PSYCHOLOGICAL LABORATORY
AND
ELECTRICAL ENGINEERING LABORATORY
OF
THE JOHNS HOPKINS UNIVERSITY

A

10 DECEMBER 1946

166-I-6

SYSTEMS RESEARCH

operates under

Contract N5-ori-166, Task Order I

between

Special Devices Center
OFFICE OF NAVAL RESEARCH

and

THE JOHNS HOPKINS UNIVERSITY

Studies are conducted at

Systems Research Field Laboratory, Jamestown, Rhode Island
Electrical Engineering Laboratory, The Johns Hopkins University
Psychological Laboratory, The Johns Hopkins University

and under subcontract with

Industrial Engineering Laboratory, New York University
Motion-and-Time Study Laboratory, Purdue University
Applied Psychology Laboratory, Purdue University

concerning

Basic psychological, physical, and motion-and-time studies relevant to military information systems and devices

[redacted]

THE EFFECT OF CRT BIAS ON VISIBILITY OF TARGETS ON A REMOTE PPI

SUMMARY

The cathode ray tube of a VD remote PPI indicator has an optimal bias level with respect to target visibility. Every experiment in which CRT bias was varied yielded a curve of visibility with a maximum lying somewhere between the lowest and highest intensity (CRT bias) settings. In all cases maximum visibility was obtained with a moderately bright, light yellow background, that is, with a comparatively low bias, and not with the dark or high bias background frequently employed by trained operators. The exact specification of this optimal level in volts or in units of illumination is not yet possible with existing measuring instruments. However, it can be fairly well defined visually. The following experiments will illustrate the difficulties of measurement and the methods employed.

INTRODUCTION

Purpose

In a previous study conducted at the Systems Field Research Laboratory†, it was shown that there is an optimal setting of CRT bias for best target detectibility on the VG and VF remote PPI's. In setting up new target generating equipment in the Electrical Engineering Laboratory, it was considered desirable:

1. To repeat at least some of the previous study as a check on its results.

2. To add data on a modified VD remote indicator since this indicator was to be used for more basic and general studies of target detection.

3. To investigate briefly the effect of various amounts of video noise on the relation of CRT bias to detectibility. (Only one level of noise had been used in the earlier VG study.)

The results obtained in the investigation of these three problems are of sufficiently general interest in the design and operation of radar indicators to make the presentation of these data worthwhile.

---

† Garner, W.R., A Study of Factors Affecting Operation of the VG Remote PPI, Systems Research, The Johns Hopkins Univ., 1946. Report No. CRI-166-I-1. [redacted]

APPARATUS AND METHOD

A variety of procedures was used in these experiments. The general procedures and methods common to all experiments are described below; particular methods used in the individual experiments are described later.

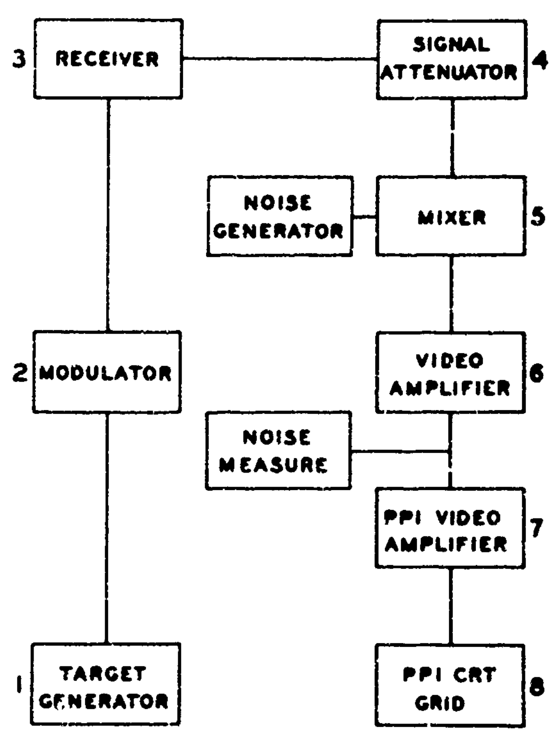
Remote PPI's Most of the data are based on a modified VD remote indicator which has a seven-inch tube (7BP7), though a few observations were made on the VF PPI (five-inch tube) and on the VG.

Observational Methods In some instances, the observers searched for several targets of unknown location. In other cases the observers knew the exact location of a single target and simply adjusted it to minimum visible intensity. Observations have been made with and without noise. Both experienced and relatively inexperienced observers were employed. A total of 12 observers was employed at one time or another.

Visibility Visibility is herein defined as the minimal signal voltage, in decibels attenuation of a reference voltage, required to make a single target visible with optimal viewing methods, that is, where the operator knows the target's location and is not required to search for it as well as to register its intensity.

Detectibility Detectibility is herein defined as the minimal signal voltage required to make a target visible under conditions of uncertainty of target location, thus requiring some amount of searching in addition to registering its intensity. Visibility and detectibility are expressed in identical units and are generally comparable save that, owing to the added search factor, detectibility scores tend to be poorer than visibility scores.

Equipment A block diagram of the signal generator and transmission system appears in Figure 1. In the first two experiments, a three-volt signal was sent through the regular video amplifier in the VD PPI. In later experiments with the modified VD, a stronger signal (five volts or more) was sent directly to the CRT grid circuit, by-passing the VD video amplifier.



BLOCK DIAGRAM OF GENERATOR AND TRANSMISSION SYSTEM

Figure 1

Noise When noise was used, it was fed into the mixer unit, and after amplification, measured directly on the video line to the remote indicator. Noise, however, was not systematically studied in these experiments.

Attenuation The Signal Attenuator could vary signal strength, without affecting noise level, in 1/2 decibel steps over a range of 0-99 db. Whenever more than one target was presented (five target generators were available), the attenuator affected all targets simultaneously. Both target generation and attenuation were accomplished outside the experimental room. Communication between observers and experimenter was by telephone.

EXPERIMENT I: DETECTIBILITY, NO NOISE

Methods Six subjects observed on the VD until each had observed 25 minimal strength targets at each of four bias settings. A modified method of limits was used. One threshold measure was obtained whenever the observer identified the range and bearing of a stationary target which was gradually increasing from subthreshold intensity. Viewing conditions were not rigidly controlled in all respects; observers selected their own viewing distances and adjusted the compass rose lights to suit themselves. No noise appeared on the scope. Range marks were absent. A 12-degree lobe width with a three-microsecond pulse and a pulse repetition rate of 600 pps were used. The antenna was rotated at 5 rpm. In all cases the 20-mile range scale was used. Target ranges and bearings were varied randomly from trial to trial. CRT bias was controlled by the intensity control knob on the panel of the VD; the bias voltage was measured by leads running from the grid and cathode of the CRT directly (without amplification) to the vertical plates of a calibrated oscilloscope (Dumont No. 208).

Results

The data are graphed in Figure 2. They show a definite peak of detectibility at 21 volts bias. Under these conditions, even full strength targets are not visible at more than about 36 volts bias. With decreasing bias, that is, with increasing background illumination, the targets become more easily detected until a point of maximum detectibility is reached, after which detectibility again falls off.

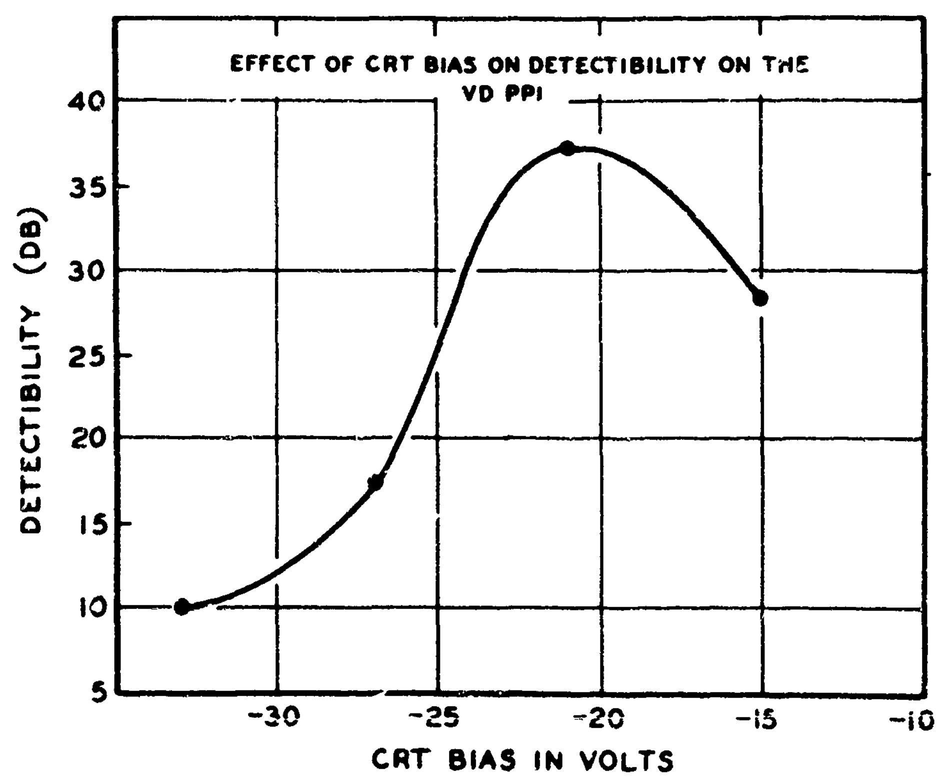


Figure 2

EXPERIMENT II: VISIBILITY, NO NOISE

Voltmeter vs. Oscilloscope as Measured

After Experiment I was completed, several changes were made in the equipment and in test procedures. To obtain greater consistency in day to day settings, a 0-50 voltmeter with 20,000 ohms per volt resistance was substituted for the oscilloscope as a measure of bias. The voltmeter does not give quite the same readings as the oscilloscope; for this and other reasons, it is not justifiable to compare results of different experiments with respect to absolute values. It is considered legitimate, however, to compare them with respect to the general shape of the function.

Psychophysical Method

Other differences instituted in Experiment II involve test procedures. Each of three observers (members of the research staff) adjusted the strength of a target until the pip was just barely visible.

Results

The results obtained by this method are in close agreement with those of the first experiment as to the general shape of the curve. Figure 3 presents data taken from observing the scope without noise. A peak of visibility definitely occurs at about 18 volts bias. Under these conditions maximum scope brightness obtainable was at about 12 or 13 volts bias. At peak visibility, the scope was still fairly bright and targets appeared as white traces on a yellow background. At 21 volts the scope was generally dark and the blue fluorescent sweep line was just barely visible. Targets appeared, when barely visible, as bluish-white traces on the sweep itself, rather than after the sweep line.

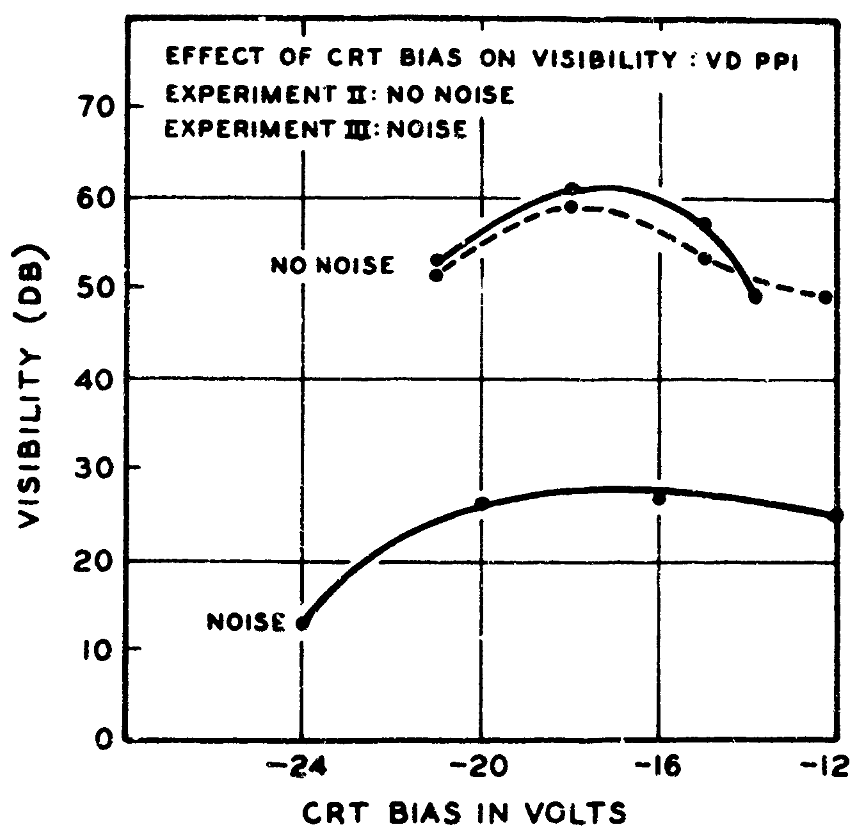


Figure 3

EXPERIMENT III: VISIBILITY WITH NOISE

Introduction of Noise Essentially the same method was used in this experiment as in the last one, with the addition of noise introduced into the video channel. The noise cannot be exactly defined in physical units, except that it is about 1.5 volts rms of noise which is nearly "white" (i.e., a random mixture of frequencies) up to approximately three megacycles. Visually, it appeared as a distribution of light spots of varying size with maximal size approximating target size. The noise used had at least two visual effects: it changed the discrimination of shapes and sizes; and it increased the over-all luminosity of the scope. For example, a sweep line which was just below threshold could easily be made visible by the addition of noise.

Results The lower curve in Figure 3 was obtained under noise conditions. The sharp drop in visibility with high bias voltage is still evident, but the drop with very low bias has largely disappeared. In addition, there is a suggestion that the cut-off point at which increased bias begins to reduce visibility, may have moved from about 18 volts to 20 volts.

EXPERIMENT IV: VISIBILITY WITH NOISE VARIED

Experimental Design

In this experiment the conditions were approximately the same, except for the systematic variation of noise. All observations were made in balanced order during a single morning. Although day to day comparisons of data are probably unwarranted, data from a balanced series within one day are comparable. Consequently, the data of Figure 4 are the only systematic and reasonably trustworthy observations we have on the interaction of noise and CRT bias.

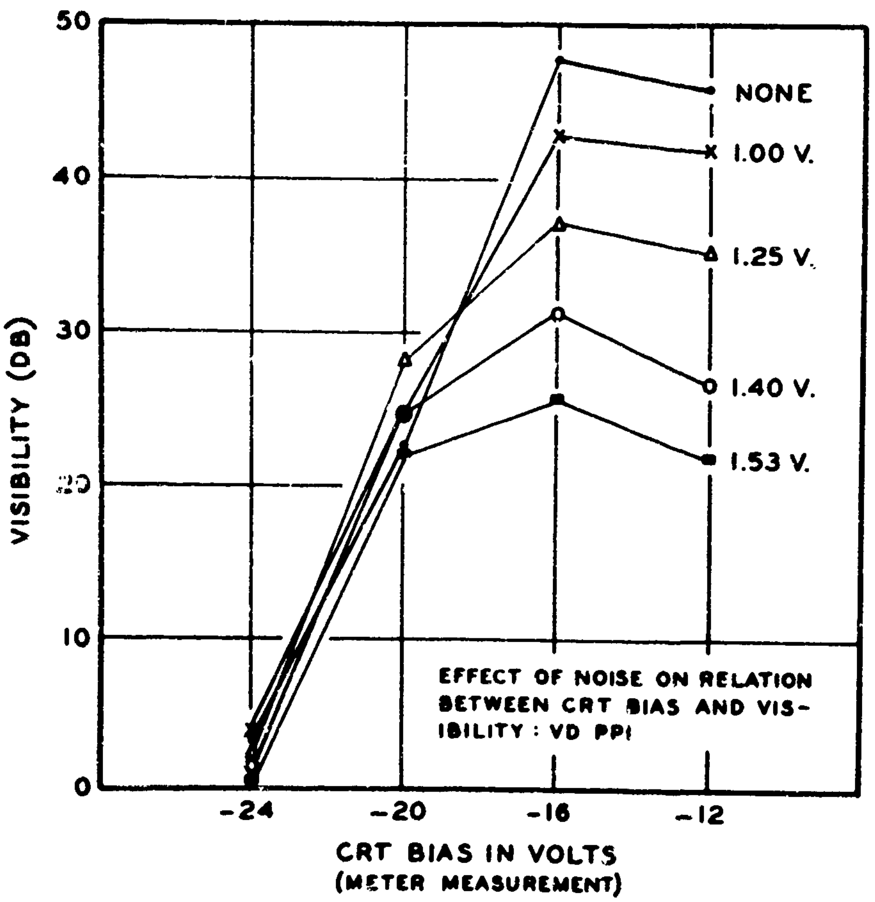


Figure 4

 [redacted]

Physical Definition of Noise

Although the noise generated was originally supposed to be nearly "white" up to three megacycles, it became quite apparent that the distribution of the frequencies was by no means random. The noise spectrum was tilted toward the lower frequencies and the relative predominance of low frequency components increased with rms voltage. Also, inasmuch as all measures of the rms values were taken with a meter calibrated only for sine waves, the error involved in the readings was unknown but probably considerable. For these reasons, the physical definition of noise is quite impracticable. A visual description of its appearance on the scope will be used instead.

Visual Appearance of Noise

There is no doubt that the five degrees of noise constitute subjectively a monotonic series, increasing gradually from "no noise" to "full noise". One volt rms was very near the threshold of detection of noise, whereas 1.25 volts rms of noise was definitely noticeable as a fine grain mosaic; 1.5 volts of noise appeared as numerous bright blobs on the scope with many of the blobs approximating target pips in area though not in shape. They were generally more circular, i.e., their "lobe width" was on the order of five or six degrees maximum rather than the 20 degrees of the target pip. The 1.4 volt noise condition was visually intermediate between 1.25 and 1.5 volts. The noise series represents a gradual change from contrast detection to a form discrimination.

Conclusions

Two conclusions regarding CRT bias can be drawn from the data of Figure 4.

1. With every value of noise tested, there is a bias level of the tube which is most favorable for detection of targets.

2. The optimal bias level is independent of noise. At every noise level, a medium bias representing a moderately bright scope background is more favorable than either a high or low level. This is true in spite of the obvious fact that visibility is a function of both bias and noise. At high bias levels (20 volts) the addition of some noise makes the target more visible. Very likely this means that the tube is operating at a point on the phosphor response curve where the phosphor is most sensitive to a change in excitation. The increment in scope illumination due to noise is a larger fraction of the total scope illumination when the scope is dark than when it is bright.

In regard to noise, it can be seen from Figure 4 that any detectible amount of noise on a PPI scope is detrimental to target detection with medium and low CRT bias levels. The impairment is quite marked; it can be as much as 24 db of signal strength. The differential effect of noise is much less at the higher bias level than at lower levels. Nonethess, the moderately low bias always favors visibility no matter what the noise conditions.

EXPERIMENT V: VISUAL REFERENCE FOR MEASURING BIAS

Method of Visual Reference This experiment was performed for the purpose of defining more closely the optimal operating bias level. In the foregoing experiments, lack of control of other CRT electrode voltages prevented the exact determination of the optimal bias level. Therefore, resort was made to a relative method. Taken as the reference point was that biasing voltage which allowed the sweep line to be just barely visible in foveal fixation after approximately 6-8 minutes of visual adaptation to the dark scope. A standard observer (a staff member) first determined the voltmeter reading corresponding to the sweep line threshold after 1, 3, 5, 7, 10, 15, 20, and 25 minutes of adaptation after exposure to a room illumination of approximately one foot candle. The results follow:

Minutes in Dark:	1	3	5	7	10	15	20	25
Voltmeter Reading:	20.1	20.4	20.9	20.9	20.9	20.9	20.9	20.9

Reliability of Visual Reference If the voltmeter reading is to be trusted--and it probably is quite reliable over short periods of time--these data mean that a visual threshold of sweep line intensity taken after five minutes is a reliably determined reference point. Other "repeat measures" indicate that an observer can repeat his intensity settings with very little error. This is to be expected on physiological grounds, of course, because the foveal intensity threshold is known to be fairly constant after a few minutes adaptation. The accuracy of setting this reference point is, therefore, primarily a visual matter and is not dependent on the voltmeter.

Differences in Brightness No such visual accuracy, however, can be obtained for intensity differences, that is, differences in scope brightnesses above the threshold for sweep line intensity. Recourse to the voltmeter was therefore necessary for the establishment of other brightness levels. (Direct photometry is impracticable with the constantly changing luminosities of a PPI scope). Having chosen the reference point (zero in Figure 5) the voltmeter was used to select scope brightnesses above and below it. Two-volt intervals were used. No noise was on the scope. The antenna was rotated at 10 rpm. Lobe width was 20 degrees and the pulse was three microseconds long. The target appeared at a little more than half range on the 20-mile scale. The method of average error was used in determining visibility thresholds.

<u>Results</u> The results for three newly trained observers (college students) appear in Figure 5. The visual reference point is indicated as zero on the abscissa, and higher voltages (greater negative values) are represented by minus signs in front of the number. The scope with maximum visibility is two volts more positive, i.e., two volts less biased, than the visual reference. Without noise, the decrease in visibility with very low bias is slight; in fact, it is absent for one of the observers. This result is in agreement with Experiment IV.

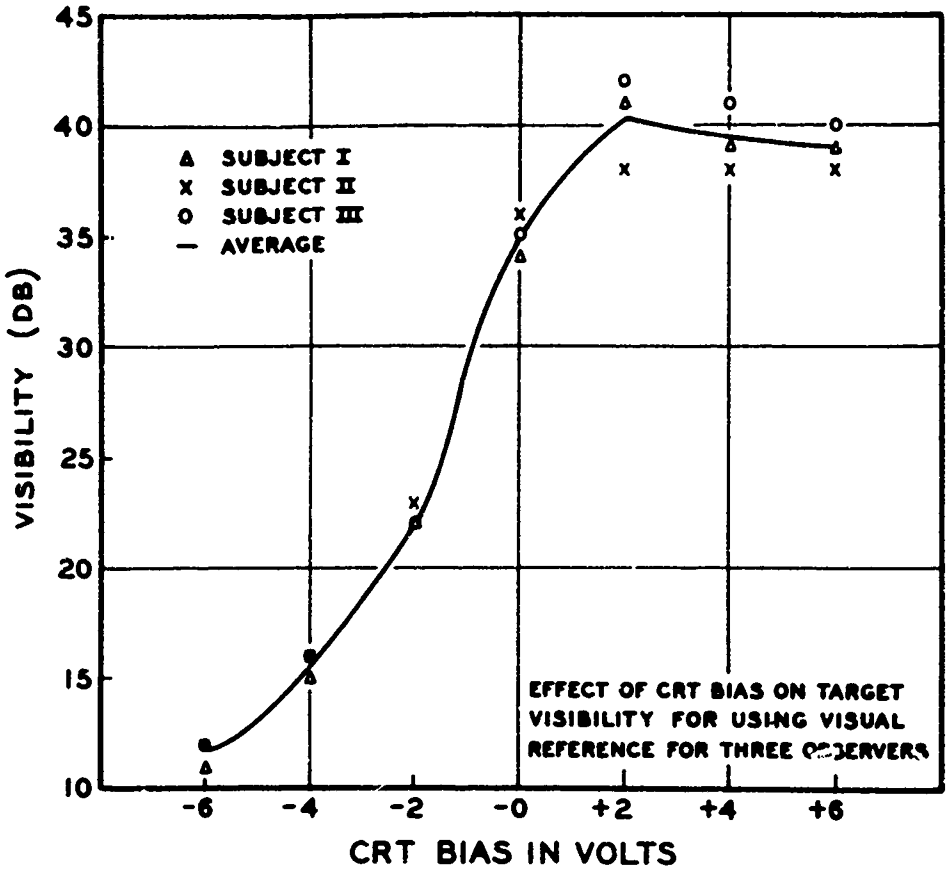


Figure 5

COMPARISON OF VD WITH VF AND VG REMOTE PPI'S

For comparative purposes, a few somewhat incomplete data from two other PPI's can be offered. Both sets of data were obtained by the method used in Experiment I, namely, five observers, using the method of limits, observing under relatively free viewing conditions, and without noise.

[redacted]

VF Remote PPI

The VF is a remote repeater with a PPI scope similar to that in the VD. It has a P7 Phosphor, but the scope was used with its amber-colored filter, which makes the blue fluorescence invisible. It is only 5 inches in diameter, instead of the 7 inch diameter of the VD scope. Figure 6 shows the function obtained. Each plotted point in Figure 6 is the mean of 150 observations. The reference point for CRT bias is here taken as the minimum bias obtainable with the intensity control knob. Target detectibility quite clearly is not as good with either maximum or minimum bias levels as with medium levels. This confirms the results of the VD experiments.

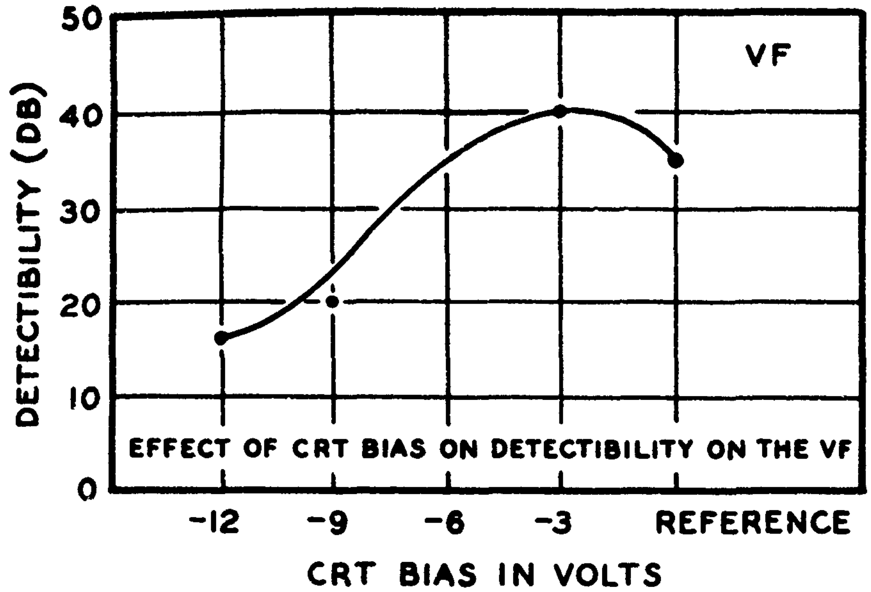


Figure 6

VG Remote PPI

The VG is a remote indicator which projects a greatly magnified reflection from a small cathode ray tube (4AP10) on to a diffusing surface 25 inches in diameter. Pips appear as purple traces against a white background. The points in Figure 7 are means of 150 observations each. The reference is again the minimum bias obtainable. The data show generally the same effect as those from the VD and the VF as regards optimal detectibility, though here the effect is much less marked. Still, a "middle region" is better than either the maximum or minimum bias levels.

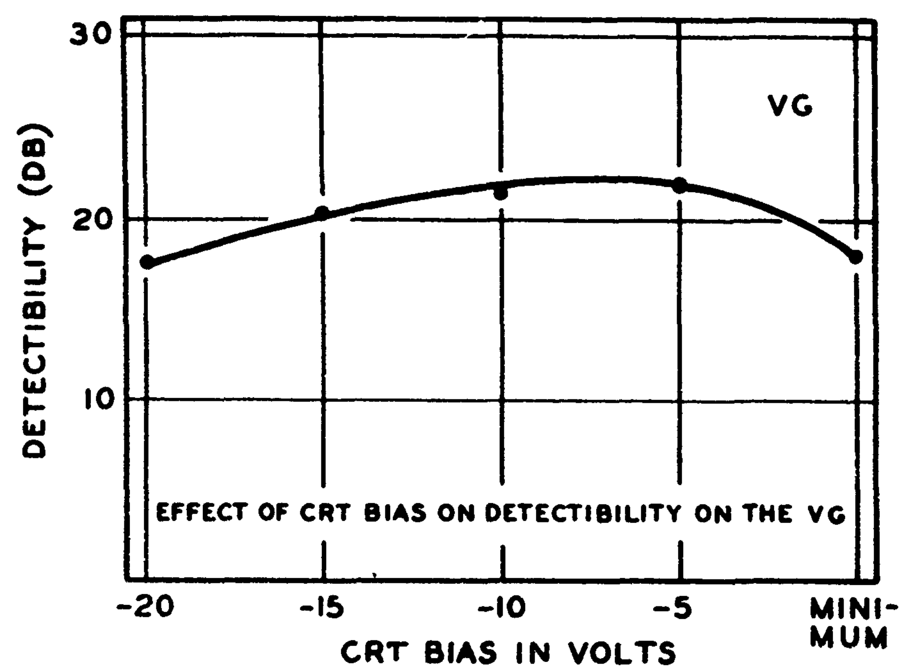


Figure 7

Comparison With Other Data Data from both the VF and VG can be compared, in a general way, with the results obtained by Garner on these remotes. Exact quantitative comparison, however, is not legitimate because Garner's observations were all made on scopes which were being fed a considerable amount of noise as well as signal. Garner's results do indicate that, for both the VG and VF, the optimal bias level is somewhere between maximum and minimum, though the precise value of this optimal region varies with other factors such as video gain and signal clipping. Garner's "low video gain" condition is most nearly like the "no noise" condition of the present experiment. Consequently, the present data yield a function most nearly resembling those obtained by Garner with conditions of low video gain.

INTERPRETATION OF RESULTS

Conclusions The conclusion to be drawn from these experiments is that visual detection of targets on a PPI is best accomplished with a medium-to-low bias on the tube, -- a bias such as to produce a moderately bright background. A tube which appears dark to the eye, even though it allows the sweep to be just visible, is inadequate.

Practical Applications It would be nice if one could compare this with the biasing voltages commonly used in radar practice. Incidental observations of scopes in operation as well as questioning of a few operators suggest that common practice is to use a much darker scope than is optimal for detection.

In order to test this observation, two of the laboratory personnel with fleet experience were asked to set the bias control to the most favorable operating level. They both set it to a point two to four volts more negative than had been found optimal by the experiments. In addition, two other persons (without radar experience) were asked to make repeated settings of the preferred bias control with various signal strengths (covering a range of 25 db). The two subjects behaved alike: for strong signals they increased the bias to the point where the scope was nearly black; for weak signals they reduced the bias until the scope was quite bright.

The conclusion appears to be, then, that operators prefer a darker scope when signal strength is high but are forced to a brighter scope when signals are weak. If this be true, it would be reasonable to predict that operators would set for a fairly dark scope during station-keeping but that maintenance of a dark scope would prevent them from detecting new targets of small intensity.

Other Advantages of a Lower CRT Bias

There are additional implications of the foregoing arguments. First, it is apparent that the brighter the PPI is, the less time it will take a light-adapted eye to adjust to it. Thus, if a person looks at a PPI scope after having been looking at the sky or sea or other bright surface than on the darker scope. Second, the brighter the PPI scope is, the more light can be tolerated as general illumination in the CIC. This is because of the same adaptive shift of the eye which characterizes any change in retinal illumination. In fact, with a very dark CIC and fairly bright scope, the operator's eyes may even require a few seconds to light adapt to the scope when he looks at it.

The optimal relation, of course, between scope illumination and general illumination is the condition of no difference. In this case, no light or dark adaptation is required when the operator shifts his eyes from one surface to another. In order to keep the scope-room difference at a minimum, a higher room illumination can be permitted with a higher scope intensity. Experimental evidence on these two points will be presented in separate reports. They are introduced here only because of their obvious pertinence to the problem of CRT bias.

(Unpublished Card) U ~~RESTRICTED~~

ATI 155 279 (Copies obtainable from ASTIA-DSC)

Johns Hopkins University, Psychological Lab., and Electrical Engineering Lab., Baltimore, Md. (166-I-6)

The Effect of CRT Bias on Visibility of Targets on a Remote PPI - Memorandum Report

Williams, S. B.; King, Ellwood 10 Dec'46 12pp. diagr, graphs

USN Contr. No. N5-ori-166, Task Order I

Displays - Psychological aspects
Display systems, Radar
Noise - Psychological effect
Vision - Effect of illumination

Psychology (63)
General (0)

Div 28

EO 1C501 dd 5 NOV 1953

~~RESTRICTED~~