EFFECT OF THE REFLECTION PLOTTER ON THE VISIBILITY OF SIGNALS ON PPI SCREENS

The Johns Hopkins University
Psychological Laboratory (ICR)
10 December 1950

SDC Human Engineering Project 20-F-I
Contract N5-ori-166, T. O. I
Project Designation NR 784-001

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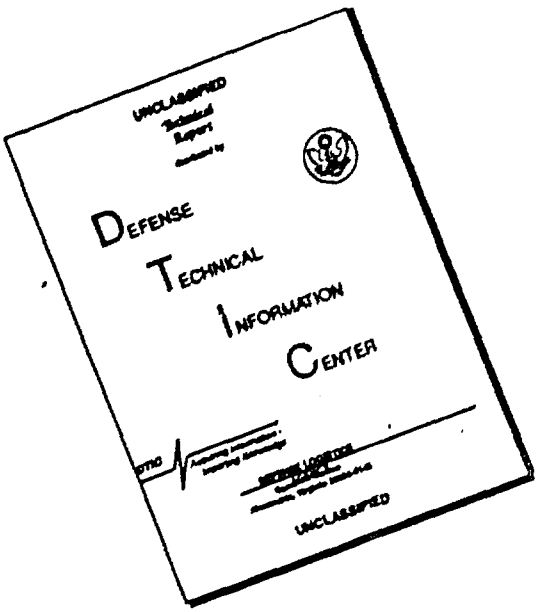

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SUMMARY

Measurements were made to determine the effect of the Reflection Plotter on the visibility of simulated radar signals on PPI screens. Three sizes of target were viewed at 12 inches on a CRT with a P-7 phosphor. These were: small (1 μsec X 1°), medium (3 μsec X 10°) and large (10 μsec X 30°). The data were obtained by the method of attenuating an eight volt signal until a just visible signal was discerned. This measure was expressed in decibels attenuation and was found at screen luminances corresponding to 2, 5.5, 8 and 10 volts of CRT bias beyond visual cut-off for the tube. No noise was used in the tests.

Four conditions of visibility were investigated:

1. No Reflection Plotter.
2. Clean Reflection Plotter without edge lighting.
3. Clean Reflection Plotter with faint edge lighting.
4. Dirty Reflection Plotter with bright edge lighting.

The results show that the clean Reflection Plotter (condition 2) produced about three db of loss in signal visibility over the condition where no Plotter was used. A brightly lighted Plotter whose surface has been used and wiped to smear the residue of old grease pencil marks (condition 4) produced a seven db loss over the condition where no Plotter was used.

It is recommended that the Reflection Plotter should not be used on equipment whose primary purpose is the detection of weak radar signals.

INTRODUCTION

Problem. During discussions with design engineers on repeater PPI equipment currently under development for the Navy Department (6), a question was raised as to the effect of Reflection Plotters on the visibility of weak radar signals. This report presents the findings of an appraisal of the Reflection Plotter used with the VJ radar equipment (5). The problem was to measure the visibility losses due to the use of the Reflection Plotter over P-7 cathode-ray tube screens.

The Reflection Plotter. The Reflection Plotter is a plotting device fitted over the tube screen of a PPI. Fig. 1. Its purpose is to permit the plotting of targets from a PPI screen on a polar coordinate surface directly above the tube with a minimum of error due to parallax. This is achieved by placing two transparent surfaces above the tube face. The top surface is non-reflecting and is the plane on which the plotting is done.

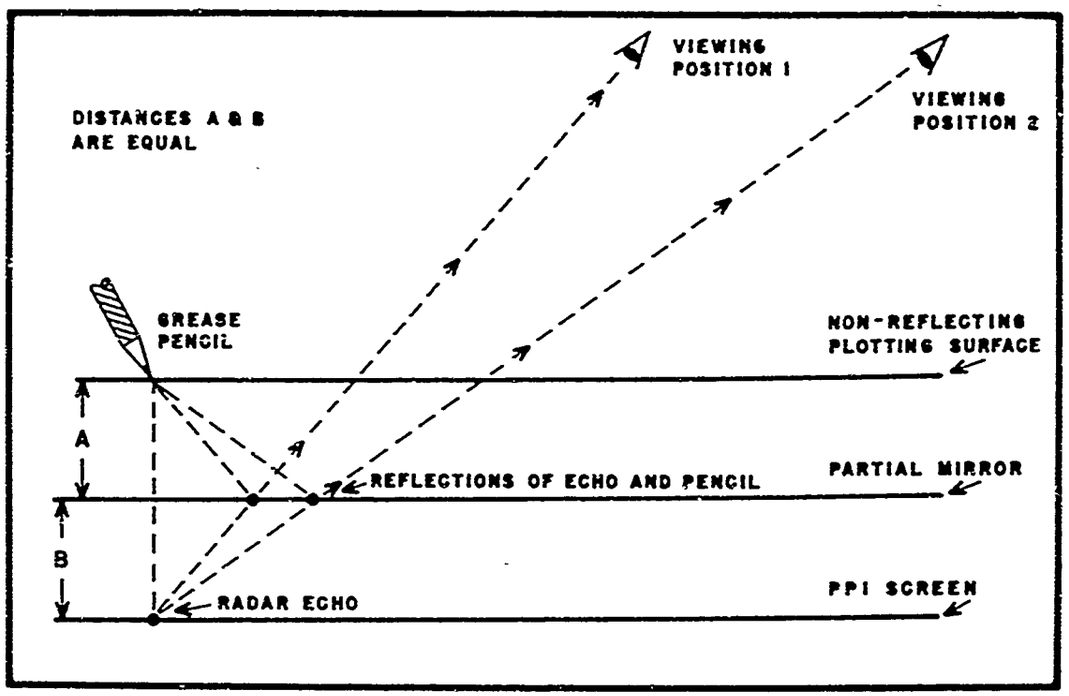

Fig. 1. Cross section sketch of the Reflection Plotter showing the principle of operation. (After BuShips Electronic Field Change Bulletin: VJ Plotting Accessories, 5)

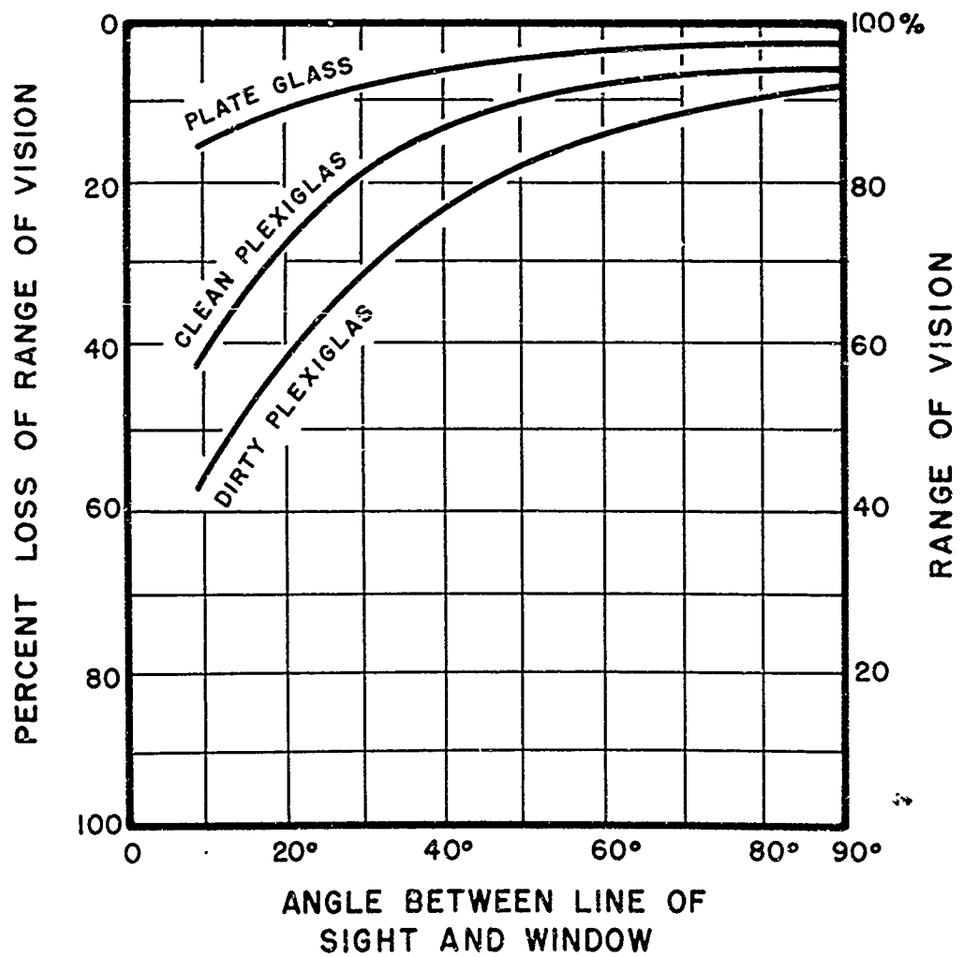

Fig. 2. Loss of luminance contrast due to the combined effects of dirty plastic and angle of view. (After Olenski and Gooden, 2)

The second surface is partly reflecting and is equidistant from the tube face and the plotting surface. When a mark on the plotting surface is directly over a target on the tube face, both will be reflected from the same place on the intermediate surface and will appear superimposed whatever the position of the eye.

In addition to the two essential surfaces described above, the model tested had a third non-reflecting surface immediately below the top one on which was engraved a bearing dial.

The two non-reflecting surfaces interposed between the tube screen and the eye do not greatly decrease the amount of light coming from the tube screen. The reflecting surface, however, is a partial minor which in the VJ model reflects 30% of the light and transmits the rest (5). The transmission of all three surfaces together, in the VJ unit used in this appraisal, was measured and found to be 0.597 or approximately 60%. Whether this loss can be compensated for by an increase in screen luminance when the top surface is perfectly clean is one aspect of the problem. When the top surface becomes smeared with the residue of grease pencils, however, it will appear bright, especially when edge lighted. This has the effect of decreasing the contrast. Whether this can likewise be compensated for by adjusting screen luminance is the other, and more important, consideration.

General Considerations. Williams and his associates (3, 4) have shown that from the standpoint of the eye, the most critical factor in the visibility of radar signals is the screen luminance as controlled by the bias voltage on the tube. There is an optimum screen luminance level at which the tube should be operated to achieve best visibility. If the screen is too bright or too dim, signal visibility falls off. This effect is shown in Figs. 3-5. The relationship that background screen luminance bears to signal visibility is that of determining contrast. The eye does not detect as small a contrast difference when the surrounding luminance is low as it does when the background is bright. The smallest discernable contrasts are not seen until the background luminance is over 100 foot lamberts. But when one attempts to get a P-7 screen up to such luminances the phosphor begins to saturate. It is impossible, therefore, to take advantage of the region where the eye is most efficient in detecting contrast because of the phosphor's lack of responsiveness to new excitation. It is clear, therefore, that if a filter of sufficient density were placed between the tube screen and the eye it would become impossible to achieve either sufficient signal or background luminance before saturation of the phosphor occurred. The filtering action of the Reflection Plotter is not especially severe but it can be expected that some effect on visibility will take place. More important than the filtering action, however, is that of the scattering of light from the top surface of the Plotter. When this surface becomes dirty, as it no doubt will, it will appear very bright when edge lighted. The decrease in visual efficiency brought about by dirty plastic has been studied for aircraft windows by Olenski and Gooden (2). Their data in Fig. 2 clearly show how visual efficiency is decreased. Especially notable is the effect of viewing angle. Dirt and grease on the surface of clear materials transforms them, to some extent, into diffusing screens. Diffusers interfere with image formation and reduce contrast by scattering light. This effect is directional and becomes worse as the angle between the line of sight and the diffuser decreases. It may be expected that this state of affairs will apply to the scope situation and that an increase

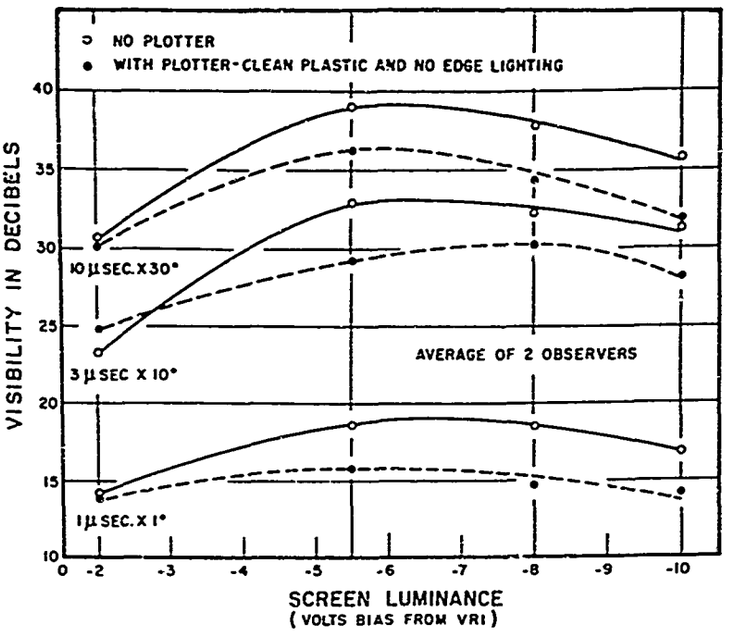

Fig. 3. Visibility with no plotter compared with a perfectly clean plotter without edge lighting. The deflection Plotter produces three decibels of loss for small and large targets.

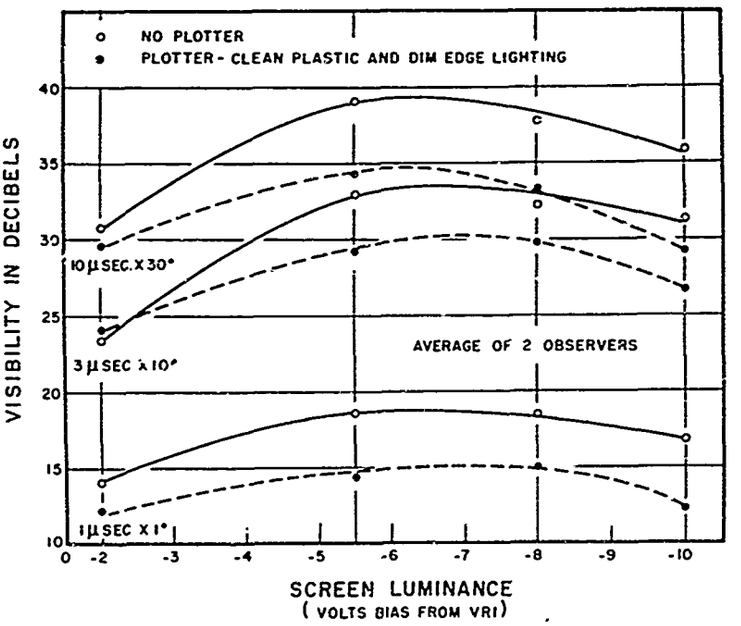

Fig. 4. Visibility with no plotter compared with a perfectly clean plotter with dim edge lighting. The deflection Plotter produces about four decibels of loss for small and large targets.

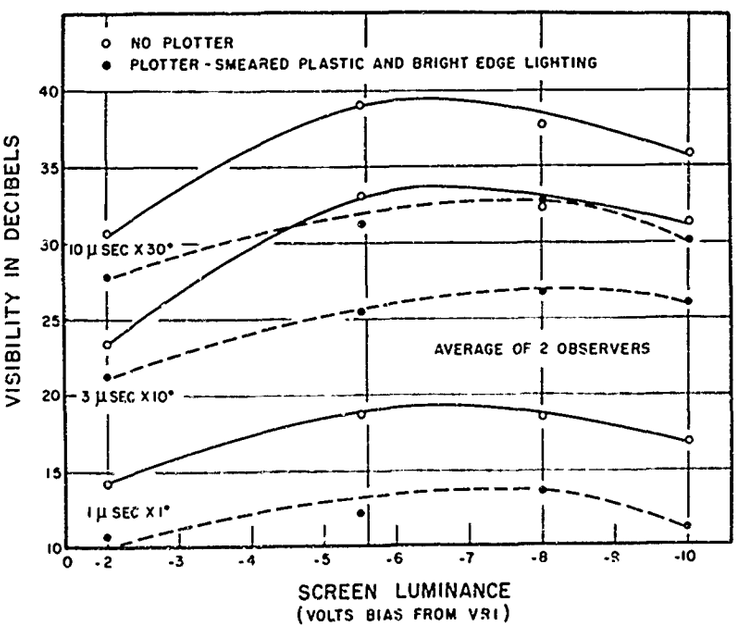

Fig. 5. Visibility with no plotter compared with a dirty plotter and bright edge lighting. The deflection Plotter produces about seven decibels of loss for small and large targets.

in signal strength will be necessary before a pip can be seen.

METHOD

A complete description of the radar simulating apparatus used in this experiment appears in a report by Arnold and Hamburger (1). The radar parameters for the appraisal were as follows: sweep rotation rate, 15 rpm; pulse repetition frequency, 667 pulses per second. No video noise added to the system. Three sizes of target were tested. These were termed small, medium and large and are defined: small -- one microsecond pulse and one degree beam width ($1\,\mu$sec X 1^{0}); medium -- three μsec pulse and 10 degree beam width ($3\,\mu$sec X 10^{0}); and large -- ten μsec pulse and 30^{0} beam width ($10\,\mu$sec X 30^{0}). The angular subtense of these targets was 3'31" X 7'31", 10'36" X 1^{0}14'52" and 35'10' X 3^{0}44'56" respectively, when viewed at a distance of 12 inches.

Data were obtained by a method in which an eight volt signal was attenuated in one volt steps. The observer at the scope in a darkened room telephoned instructions as to whether or not he saw the target to the experimenter in a control room. The former's task was to request adjustment of signal in intensity until it was just visible to him. The strength of the just visible signal in decibels of attenuation below the starting level of eight volts was the value recorded for each trial.

Screen luminance was set by obtaining a visual reference intensity (VRI) for each day's measures and decreasing the bias voltage by fixed amounts from this reference level. The VRI is defined as the point at which the sweep is just visible to the dark adapted eye. It is a very stable measure as represented by CRT bias voltage and is, in effect, the visual cut-off point of the tube. The screen luminance levels at which signal visibility was measured corresponded to bias settings of 2, 5.5, 8 and 10 volts less than the VRI (shown in Figs. 3-5 as zero volts).

Four conditions of visibility were tested.

1. No Reflection Plotter. Signals were seen directly on the CRT screen.

2. Reflection Plotter over tube screen. The plotting surface of a unit that had never been used was made as clean as possible. Neither edge lighted surface was illuminated.

3. Reflection Plotter over tube screen. The plotting surface was clean as before but the dial lights were adjusted until the compass markings could just be read.

4. Reflection Plotter over tube screen. The plotting surface was smeared with grease pencil and then wiped off. This left a residue of grease that scattered the light. In addition, the dial lights were turned up until the markings were clear and bright. The resulting condition may be considered severe but entirely within the range of what can be expected during shipboard use.

Measurements were obtained for two practiced operators each tested under the above conditions. Observations were always made with the line of

sight making a 90° angle with the surfaces of the Plotter.

RESULTS

The effect of using the Reflection Plotter on visibility is shown in Figs. 3-5. In each of the figures the condition of "no Plotter" is paired with "Plotter" for all three target sizes tested. It is clear that the Plotter produced a loss in visibility for all conditions and that this could not be compensated for by changing screen luminance. All curves show that CRT bias voltage controlling screen luminance passed through an optimum point for signal visibility. This point occurred at about six to seven volts before cut-off. The loss for the clean Plotter without edge lighting, Fig. 3, was about three decibels of signal attenuation. This is not large but it represents a loss, nevertheless, under a condition where the Plotter is useless; i.e., without dial lights and no grease pencil. Turning on the dial lights so that the bearing scale was just visible added another decibel of loss. Fig. 2. This condition still does not permit plotting. If plotting was done so that the top surface of the Plotter became greasy and the dial lights were turned up to see the scale readily, the loss in visibility rose to about seven decibels in the range where visibility is best. Fig. 3. It is clearly evident from these results that the Reflection Plotter, under any circumstance, decreases the visibility of radar signals.

DISCUSSION

The unfavorable effect of a reflection plotting device on the visibility of radar signals has been demonstrated in this appraisal study. It is clear that the early detection of marginally visible echos must be done using unencumbered tube screens. The consequence of this is that early detection and plotting cannot be combined in this particular way. Current radar PPI design calls for the installation of Reflection Plotters. These units are bolted to the repeater consoles and cannot be removed at will. This procedure makes unavoidable the acceptance of a three to seven decibel loss in visibility even when the screen luminance controlled by the CRT bias level is set correctly and the operator's line of sight is at right angles to the display. An obvious solution immediately presents itself. It is to set up the function of early detection on a separate display without a Reflection Plotter. This is in line with the opinion that it is impossible to devise equipment that serves all possible purposes with equal efficiency.

RECOMMENDATION

It is recommended that plotting aids of the Reflection Plotter type should not be used over cathode-ray tube screens whose primary function is the detection of radar echos at the earliest possible moment. Detection and reflection plotting functions should be done on separate displays. Where it may be desirable to equip all radar repeater PPI console with Reflection Plotters, the Plotters should be easily removable. It is suggested that the design of a plotting unit capable of being swung away from the tube screen be investigated. Such a unit might be hinged to the console in a manner that would permit unhindered viewing of the tube screen when desired as well as storage behind the console during long search watches.

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