A SIMPLE OPTICAL TECHNIQUE FOR FILTERING AND DISPLAYING RADAR DATA (U)

Report R-25

23 September 1952

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Contract DA-11-022-ORD-721
This report describes in detail some preliminary considerations pertaining to an optical method for formation of a "clear picture" from radar data. The equipment is intended for use in the short-term improvement program for a Tactical Air Control system described in C.S.L. Report R-23.
ABSTRACT

The efficiency of utilization of radar data is enhanced by the formation of a filtered situation plot of relevant information. Fairly complicated photographic methods have been developed to achieve this end. This report describes a considerably simpler system using direct optical techniques.
I INTRODUCTION

Vertical-Board Display

Radar data are usable for following and controlling a complicated air situation after a certain amount of filtering and correlation has been performed upon the raw data. In one common scheme, plots are followed in time and extended into tracks which show direction and position and which carry an arbitrary identifying track number. This information is normally displayed in map form on a constantly changing situation plot. Additional data which may be obtained — height, strength, speed, identification, etc. — for various track numbers is tabulated alongside on a "tote board". To decrease confusion under heavy traffic conditions it is highly desirable to provide means for selecting various classes of tracks appearing on this plot — for example a chief controller may want to see only suspected enemy tracks, an identification officer may wish
a display showing only new tracks, etc.

Such a display presented on a vertical board is more accessible for a sizable number of controllers with individual PPI's than is the horizontal board display with operators crowding around manipulating "Christmas tree" type markers. The simplest technique for achieving this type of display (without the selection facility) is the edge-lighted Lucite board showing grease-pencil tracks constructed by plot-tell teams.

Rapid-Photography Technique

Horizontal boards are sharply limited by the small number of persons who have access to them; even the edge-lighted vertical boards become saturated at certain level of traffic because of physical limitations of space for operators' bodies combined with the slowness of plot-tell operation. Because of this limitation the more recent trend has been toward the use of rapid photographic techniques which generate a large bright non-fading display upon which graphical tracking (either with pencil or chips) is performed directly without numerical transfer of information.
This display can be re-photographed to filter out the raw radar data. Furthermore, by use of colors and color filters, chosen classes of tracks can be selected for this photographing. The "clear picture" is then projected on a vertical translucent screen.

**Optical Technique**

During July and August of this year, means for achieving the over-all ends of this photographic tracking technique by purely optical means have been under investigation at this laboratory. These investigations and the working models which have been built appear so simple and promising that this preliminary report has been written without awaiting the completion of well-engineered equipment.
II BASIC METHOD

For superimposing the optical images of a fairly large PPI and a transparent plotting surface at the same scale, a plane partially reflecting beam-splitter is used. Track chips carried on the plotting surface are seen at a brightness level comparable with the brightness of weak blips on the PPI face so the chips will neither suppress the visibility of signals nor be themselves too dim to be seen. The track chips on this transparent plotting surface are brightly illuminated from below for projection by a long-focus lens onto a vertical screen at a suitable large scale. This strong illumination from below does not strike the PPI nor does it shine into the eyes of the operator. At the same time, whenever this light falls onto a portion of a track chip it is efficiently directed back down onto the projection lens. Scattered light from the operator's hands, etc., is not efficiently directed onto this lens so that images of such scattering objects do not appear on the screen.
III SPECIFIC TECHNIQUES

Projection Systems

Large plastic Fresnel lenses are now available which provide a convenient condenser for concentrating light from the chips upon the projection lens. By mounting a 15" dia. 1½" focal length lens obtained from Eastman Kodak in a plate glass sandwich, and using small mirrors with numbers and arrows painted on them for the track-chips, essentially the full lighting ability of any given projector source is realizable (Fig. 1(a)). The smooth side of the Fresnel lens faces the source and projection lens to minimize spherical aberration in the Fresnel condenser. These lenses are used under a flat glass plotting-surface. Therefore one must either: (1) use a flat-faced PPI, (2) use a plastic flattening-lens over a curved PPI face; or (3) simply accept small amounts of parallax between the images of a slightly curved tube face and the flat plotting surface.
Fig. 1a Projection System using Fresnel condenser Lens. Light is shown on center axis; a small portion of center of field is thereby obstructed.

Track Marker Chip
Mirror surfaced on bottom

Light source
Projection lens

Mirror

Fig. 1b Projection System using Spherical Glass plotting surface. Light is shown off-axis; therefore projection lens is not in position for optimum image quality.
An alternative method for directing the light from a small source back onto the projection lens makes use of the curvature of the usual PPI face and, thereby, avoids this parallax problem, but it introduces other minor disadvantages. This alternative, suggested by C. W. Sherwin, uses a spherical plotting surface of the same radius as the PPI face (in practice, a blank tube face obtained from the CRT manufacturers). This transparent surface carrying the mirror-surface chips acts as a spherical mirror, focusing an image of the source upon the projection lens (Fig. 1b).

Both of these methods have been tried out successfully. The choice of one or the other depends upon the weighting one assigns to their various distinguishing features for a given application.

Superposition Methods

Two superposition methods have been built and tried successfully. In the first method a reflectoscope used for map-superposition in the last war was adapted to the purpose; in this reflectoscope the operator looks directly at the scope.
through a dichroic beam splitter; sees the plotting surface and his hands after two reflections so they appear normally oriented (Fig. 2a). Only one operator per reflectoscope was feasible, so the final picture was to be a mosaic assembled from partial segment pictures obtained from several reflectoscopes.

The second method is much simpler and more flexible. It consists of a horizontal plotting surface observed directly from above through a horizontal beam-splitter of high reflectivity. The PPI face is placed horizontally (facing down) above this beam splitter and is observed by reflection as a virtual image superimposed upon the plotting surface (Fig. 2b). As many as six filter-plotters can work around this plotting surface simultaneously; in light traffic a single plotter can probably handle the entire job. Although a 15" diameter circle might seem too small for this purpose, on an actual working model one finds that the small scale is only a minor inconvenience.
Fig. 2a Reflectoscope technique first tried for superposing images of plotting surface on CRT face.

Fig. 2b Improved superposition technique which allows several operators to work around one plotting surface.
Figure 3 shows a complete equipment with the spherical-mirror condenser arrangement. Figure 4 is a photograph showing the first model of this arrangement (which used a Fresnel-condenser lens).

**Marker Chips**

A chip with two colors on opposite sides can be made from a rectangular slip of mirror surface-dyed with two chosen colors on its two sides. To give a direction and number to the marker it is partially painted over with colored opaque paint as shown in Fig. 5. If one side is dyed red, the opaque paint on the opposite side will be made red; likewise, if the other side is dyed, for example, blue, the opaque paint opposed to it will also be blue. Viewed from above with top lighting, mirror areas, however dyed, will appear dark while areas covered with opaque paint will be light. The converse will hold for the projected image. Therefore, when the operator sees a red marker, this marker is projecting red upon the screen. Turning the chip over, he sees a blue marker which simultaneously is projecting blue on the screen. The same scheme can be extended to four colors by...
Fig. 3 Diagram of entire equipment in its most recent form, using spherical plotting surface. Supports and light box omitted for clarity.

Fig. 5 Details of two-color track chip. When plotter sees red chips it appears red on screen, turning chip over changes both views to blue.
FIGURE 4
Full-scale model of an optical plotter
using square rod, mirror-polished on the sides, cut to lengths, and appropriately dyed and painted. Replacing the top lighting by ultra-violet light and the opaque paint by opaque fluorescent paint may be advisable since this eliminates any possible glare due to top-lighting that is reflected from the plotting surface. To avoid scratching the dyed mirror surfaces they are provided with .010" feet on three corners as shown. Sealing wax dots softened between warmed pieces of plate-glass and squeezed to proper thickness work well for these feet.

Combined Presentation From Several Radars; Cross-Communication

The weakness of present large radars for detection of jets can be diminished by tying together several smaller radars into our coordinated network. Various slowed-down video techniques are available or in development for transmitting radar data over normal communication links, but methods for filtering and assembling data from several radars at a central direction center are in a less advanced state. With the optical technique it is only necessary to provide an optical equipment for each remoted PPI and project the filtered pictures onto a common screen in
proper register. There is, however, one important refinement to be considered. Whenever two radars are seeing the same track in areas of overlap, the projected chip images will approximately coincide; the result will be confusion and difficulty in reading the track numbers. Furthermore, when two or more filter-plotters are carrying the same plane, effort is duplicated and efficiency per man is decreased. For these two reasons it is quite desirable that means for avoiding this duplication be worked out.

The reflectoscope form of the apparatus (shown in Fig. 2a) used the Fresnel condenser lens also as a field lens to form an image of the projection lens at the observer's eye. By this arrangement the observer looking at his plotting surface was able to see through it any chip images projected from other equipment. Furthermore, these images appeared at essentially the same brightness level as they appeared on the screen, and were automatically in register with his own plotting surface. Unfortunately however, they were visible to him only when he turned off his projection lamp, with the lamp on, unwanted light from several sources overpowered the desired images by an order
of magnitude; even when most of these sources were eliminated by various inconvenient optical techniques the residual scattering of light from the Fresnel lens was still about twice as bright as the desired images. Less elegant methods of meeting the problem were therefore required.

Preliminary experience at the Truro station of the Lincoln Laboratory indicates the probable desirability of segregating filter-plotters into two classes: (1) those who follow established tracks, and (2) those who search for new tracks. If this approach proves applicable to the optical technique, it will be sufficient for the searchers to see an image of their PPI superposed upon an image of the entire screen; they need not see the plotting surface of their own hands. This greatly simplifies the problem. One can view the screen directly through a beam splitter which superposes by reflection an image of the PPI (enlarged and pushed back by means of a lens to coincide with the screen). Alternatively, one can focus an image of the screen at PPI scale upon a Fresnel field lens and then superpose this image upon the PPI with a beam-splitter. Other variations are possible. It is also possible by increasing
the complication to devise an equipment in which even those who follow tracks will see the screen properly superposed. At the moment of writing this preliminary report, none of the latter possibilities for cross-communication has yet been tried; further discussion is reserved for a later and more complete report.

The optical filtering and presentation technique is scheduled for a system demonstration and evaluation at Pope Field in North Carolina within a few months. In this test it is planned that information from three radars - a large CPS-5 and two remoted gap fillers - will be combined into a single filtered display by using three of these optical equipments.