Radar Presentation Restitutor*

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ABSTRACT: *This paper describes the Radar Presentation Restitutor, an instrument designed and developed to correct positions on a 360 degree scan Plan Position Indicator radar scope photograph to their equivalent ground positions. Principles of operation of the instrument are optical-mechanical.*

The following corrections are performed automatically:

1. *Distortion due to slant-range*
2. *Distortion due to sweep-delay*
3. *Distortion due to aircraft motion during a single scan.*

Provision also has been made to introduce corrections for distortion due to:

4. *Non-uniform motion of the electronic sweep*
5. *The lens of the recording camera, and*
6. *Curvature of the cathode ray tube.*

The above corrections can be performed simultaneously in one operation.

The heart of the system is essentially a pair of rotating mirrors having a 90 degrees apex angle. The special properties of the system are discussed and some results using test patterns are shown.

THE Topographic Engineering Department of the Engineer Research and Development Laboratories was assigned a project several years ago—seven to be exact—to investigate the utilization of radar photography for mapping. As is generally known, the all-weather capability of radar is its most inviting factor, and as a result has created many investigations for its application to mapping and charting.

The subject of this paper—the Radar Presentation Restitutor—is an optical-mechanical instrument which corrects for various distortions contained in the radar PPI photograph. Photogrammetrically, this instrument can be considered as paralleling the rectifier for optical photography.

Figure 1 shows a radar *PPI* presentation. The center of the photograph represents the nadir point on the ground. The radar antenna, in transmitting, illuminates with energy a radial line on the ground, emanating from the nadir point. The antenna then receives the energy reflections and rotates through a small increment, continually transmitting and then receiving electromagnetic energy, repeating this until it has rotated through 360 degrees.

ROBERT P. MACCHIA

The distortions confronting the radar mapper are indicated on Figure 2.

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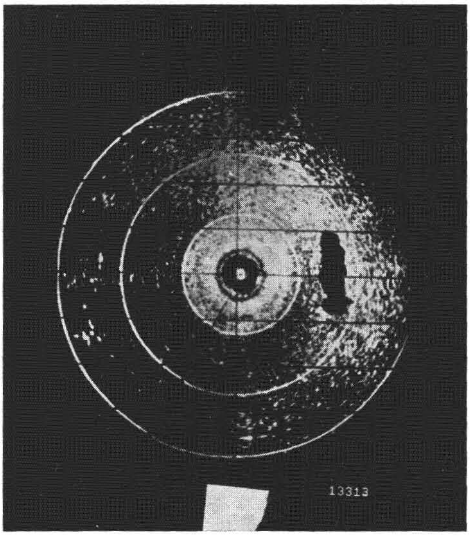

FIG. 1. Radar PPI presentation.

The first three distortions have the greatest effect on the radar accuracy, whereas the remaining distortions can be considered minor in the present state of the art of radar mapping.

The basis for slant-range distortion is evident from Figure 3. The radar measures the distance from the antenna to the target and is recorded as this distance rather than the true ground range.

The distortion due to sweep-delay is actually put into the system out of practical necessity. As shown on Figure 4, if the trace on the cathode ray tube is started at the same instant that the energy is radiated from the antenna, the first return cannot show until the energy has travelled to the ground and returned. A distance to scale, corresponding to the altitude, is therefore wasted on the cathode ray tube. The altitude hole—the area of no return at the *PPI* center—is marked evidence of this effect. For this reason the trace on the *CRT* is delayed for some interval of time, depending

FIG. 2. DISTORTIONS CORRECTED BY THE RADAR PRESENTATION RESTITUTOR.

1. Slant-range distortion
2. Sweep-delay distortion
3. Aircraft motion
4. Non-uniformity of the electronic sweep
5. Lens-distortion from the recording camera
6. Curvature of the cathode ray tube.

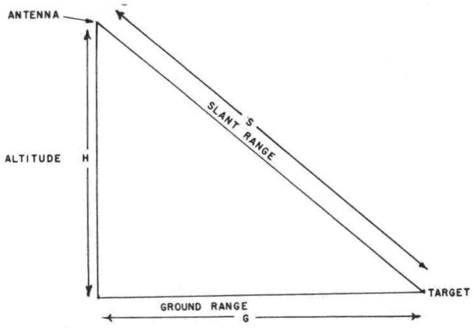

FIG. 3. The basis for slant range distortion.

on the altitude, in order to start the returns closer to the center of the *CRT*. Thus, for any given range set into the radar, a maximum area of the *CRT* face is available for the display and consequently the scale of the display is maximized.

The distortion due to aircraft motion during a single scan results from the fact that the narrow radial sweeps making up the scan all have a common origin on the *PPI* presentation. Each successive radial sector should emanate instead along a line representing the motion of the nadir of the aircraft during a single scan. Figure 5*A*, shows the *PPI* presentation as it is and *B* as it should be with each radius displaced in the direction of flight.

The distortions resulting from non-uniformity of the electronic sweep, and from the lens of the recording camera and the curvature of the scope face, are minor distortions affecting range which may be disregarded for now. There are radar systems which incorporate in-flight corrections for slant range and aircraft motion, but it is our experience for our purposes that at present these corrections can be performed more accurately on the ground.

Now, if one is to give any serious thought to mapping from radar, it is necessary to

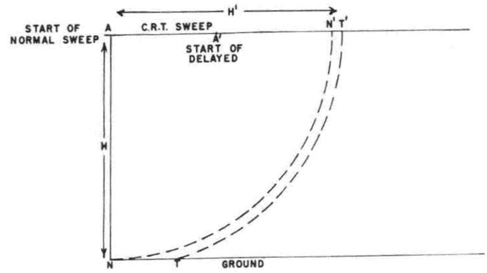

FIG. 4. Sweep delay distortion.

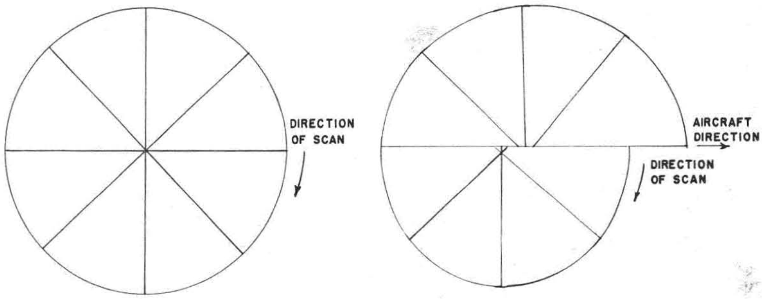

FIG. 5. Aircraft motion distortion.

compensate for these distortions in order to achieve some degree of accuracy. This may be done graphically for a finite number of points on each photo, but it is obviously more advantageous to rectify the photo as a unit. Hence, the development of the Radar Presentation Restitutor.

This instrument was developed by Freed Electronics and Controls Corporation, now named Fairchild Controls Corporation, under contract to the Map Compilation Branch, Topographic Engineering Department, of the Engineer Research and Development Laboratories.

Figure 6 is an over-all view of the instrument which utilizes principles of optics and mechanics in performing the desired rectifications. Rather than to give a running commentary on each sub-assembly of the instrument it seems more appropriate to explain the method by which each correction is applied. This in itself will help define the functions of the various sub-assemblies.

A radar *PPI* photograph is not an instantaneous view, but is, instead, made up of many individually recorded radial increments which scan a full 360 degrees in the rotation period of the antenna. Each radial increment is progressively recorded by the camera until a full circular scan is completed. The restitutor has consequently been designed to correct each sweep separately—but in such a manner as to retain continuity in the over-all picture.

On Figure 6, *C* indicates the uncorrected picture holder. The radar transparency is centered in this holder. A light source is contained in the instrument which is directed up and through the plane defined by the radar photograph. This light is completely masked from passing through the radar photograph except for a wedge-shaped slit which allows this sector of light to pass through a radius of the radar transparency. The dimensions of the slit are determined by the angular beamwidth of the antenna's transmitted energy. The light passing through the radar transparency is then reflected by a mirror at *D* to pass through an objective lens. The optical system is such that all the light passing through the radar transparency is received by the objective lens.

Upon emerging from the objective lens, the light is again reflected by a rather unique arrangement of mirrors which are the heart of the system. The light is reflected from one mirror to a second mirror, the angle between them being exactly 90 degrees. Now, by rotating these mirrors, all points on the radius of the uncorrected transparency which reach the rotating mirrors are thereby transformed into a circle of these points. In actuality we use two pairs of mirrors to perform this transformation. To indicate more clearly the optics involved, since this represents the heart of the system, I will elaborate somewhat on the gyrations, if I may call them that. If we rotate a pair of mirrors having an angle of 90 degrees between them, they can in effect be considered as representing a reflecting right circular hollow cone having a 90 degree apex angle. Such a reflecting cone is shown in Figure 7.

All the light rays representing the longitudinal surface of one-half of an imaginary cylinder with its axis coincident with the axis of symmetry of the cone will meet the reflecting surface on the inner side of the cone in a semi-circle, and will all be reflected so as to pass through a single point on the coincident axes. The cylinder is

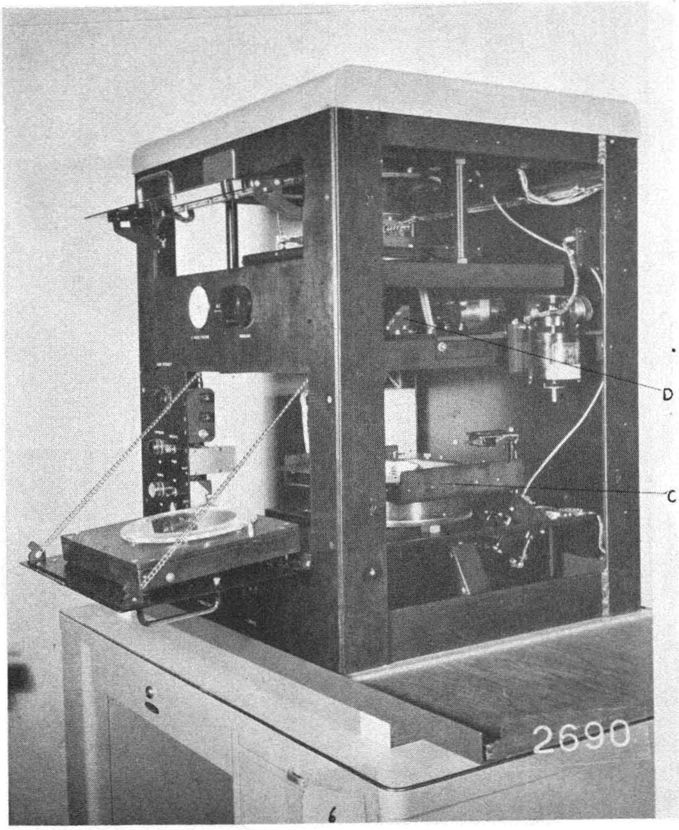

FIG. 6. Radar presentation restitutor.

merely a chosen configuration of rays and does not represent a solid object as does the cone. The rays passing through a single point on the axis will again meet the reflecting surface of the opposite half of the cone in a semi-circle, and will be reflected

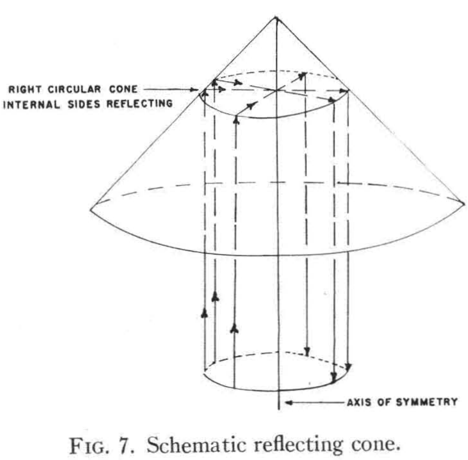

FIG. 7. Schematic reflecting cone.

down the surface of the other half of the cylinder. These rays intersect a plane perpendicular to the common axis of both cone and cylinder in a semi-circle.

Referring to our rotating mirrors once again, it can now be seen that any single point entering them is transformed into a circle whose locus is the radius of that point from the axis of symmetry.

For illustration purposes, if a radius on the uncorrected transparency contained five points spaced at equal intervals, this radius would, after passing through the optical train, be seen as five circles with radii spaced at proportionately equal intervals, as shown in Figure 8. At the image plane of these circles, there is photographic film which is masked except for a slit identical to the slit of the uncorrected film plane. Figure 9 shows the image plane with the circles of the points and the slit. Any radius on these circles represents the slant-range S, and if we displace the slit a distance in scale corresponding to the altitude

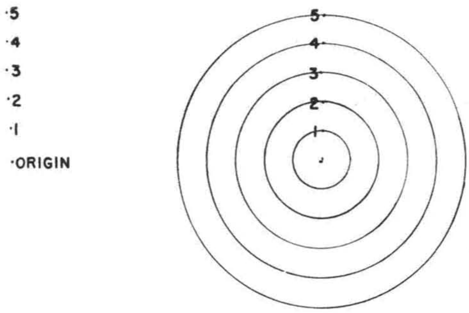

FIG. 8. Transformation of equally spaced points into equally spaced circles.

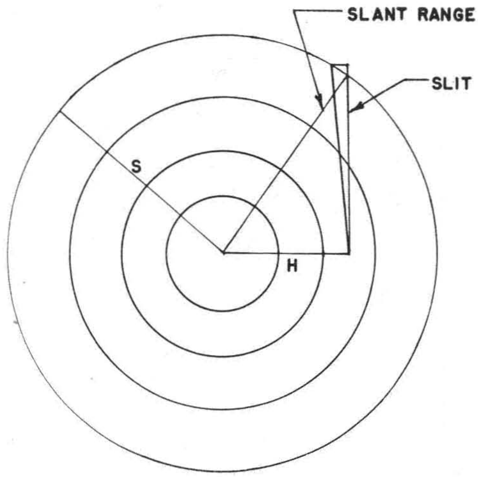

FIG. 9. Slant range correction at image plane.

H, the image produced on the film will represent the ground range G. This is simply the pythagorean theorem. To correct the entire radar presentation for slant-range merely requires that we rotate the uncorrected and corrected film planes simultaneously, through 360 degrees.

The correction for sweep-delay is applied simply by shifting the uncorrected radar transparency so that the uncorrected radius is increased in length in the image plane to present the true slant-range. The aircraft motion correction is performed at the same time by translating the photographic film in the direction of flight while it is rotating, so that each sweep-radius is displaced its proper distance from the origin of the start of the scan. This translation is performed by using a rack, a pinion and a cam which engages the corrected film holder. By adjusting the angle between the cam and the rack, and rotating the pinion which is controlled by rotation of the two film planes, the photographic film can be translated the proper distance corresponding to the aircraft displacement for each successive sweep. This translation is a uniform motion since we assume a constant speed for the aircraft in the scan period.

An example of each correction can be seen in illustrations 10 to 13. The photo on the left is the test pattern or the uncorrected transparency and the one on the right is corrected.

Figure 10 shows the original and the final

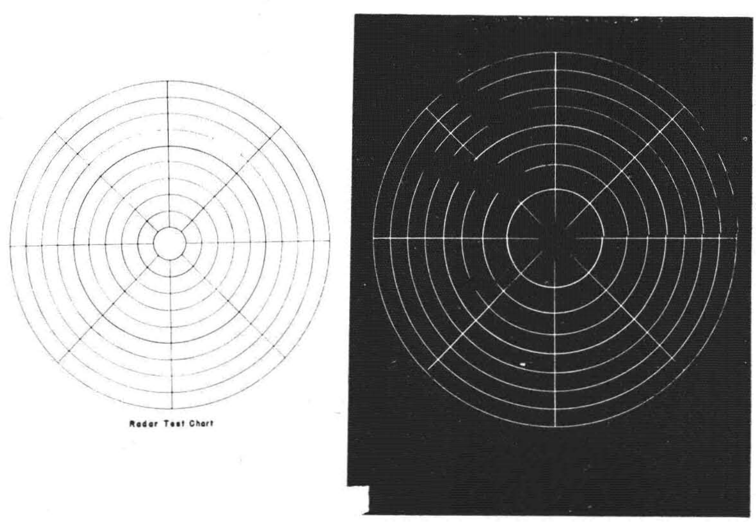

FIG. 10. Slant range correction, altitude/range ratio of .4. At left—Test pattern, At right—Corrected test pattern.

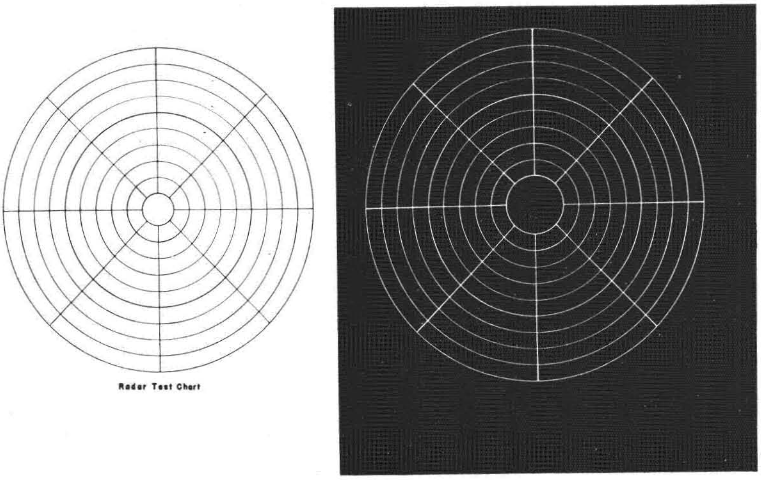

FIG. 11. Sweep delay correction, sweep delay .08 of range. At left—Test pattern. At right—Corrected test pattern.

product after correction for slant-range using an altitude/range ratio of .4. It will be noticed that the image has been compressed and that the four innermost circles on the original are no longer present.

Figure 11 represents the correction for sweep-delay and is shown as a linear expansion. Notice that the center circle is enlarged.

Figure 12 is an example of the aircraft motion correction. It was assumed that the motion equaled the distance between the successive radii and the result is a continuous spiral.

Figure 13 represents the simultaneous correction for altitude, sweep-delay and aircraft-motion.

The above corrections are set into the instrument simply by turning two dials and one micrometer screw. The instrument is set into operation by pressing a starter button, and three minutes later the corrected film is ready for development.

By empirical means the instrument can be made to compensate for nonuniformity of the electronic sweep, lens-distortion from the recording camera and curvature of the *CRT* face. These corrections are not automatic though they are simultaneously executed. Fortunately these are radial dis-

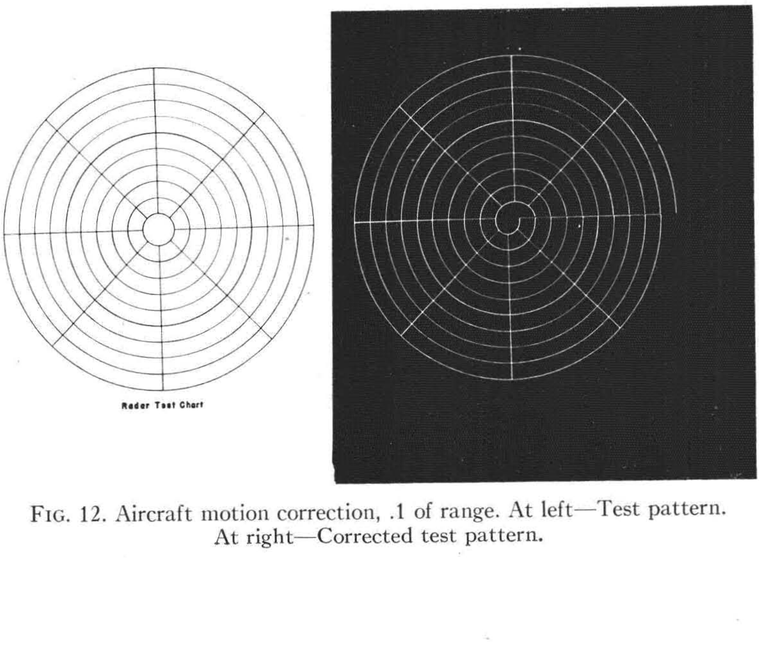

FIG. 12. Aircraft motion correction, .1 of range. At left—Test pattern. At right—Corrected test pattern.

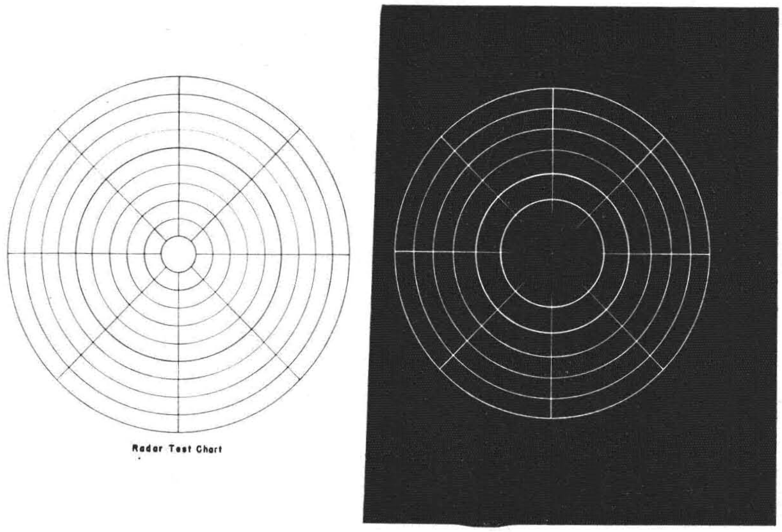

FIG. 13. Simultaneous correction for slant range, sweep delay and aircraft motion at .4, .2, and .01 of range respectively. At left—Test pattern. At right—Corrected Test pattern.

tortions and with the use of an adjustable curved mirror which is interchangeable with a plane mirror, and with the assumption that the distortions are known, the rectification can be made.

The restitutor is a promising instrument for correcting *PPI* presentations. It embodies novel and effective principles. However it should be considered as a future item of equipment until such time as suitable *PPI* radar photography for mapping is available.

*The Wild U-3 Printer**

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ABSTRACT: *The need for a photographic printer at Army Map Service, capable of processing heterogeneous photography from a variety of sources, is specified. A description of the basic approach to the problem resulting in the three printer categories, Types A, B, and C is given. The manufacturing tolerances are cited and the acceptance test procedure is outlined. Available test results and conclusions are presented.*

THE world-wide scope of the operations of an agency such as the Army Map Service necessitates the handling of photography from a variety of sources. This photography is distinguished by a wide diversity of focal lengths, format sizes and radial distortion characteristics. For satisfactory use in stereo-plotting equipment, this material often requires geometrical change and either introduction or removal of predetermined distortion.

Until recently, the printers available to Army Map Service either were designed to correct only for a fixed reduction ratio,

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