

## CHAPTER 3.

## TYPES OF DISPLAY

## LIST OF CONTENTS

	<i>Para.</i>
Introduction .....	1
Range-amplitude or type A .....	2
Split display .....	3
Strobe marker .....	4
Plan position indicator .....	5
Skiatron .....	6
Range-azimuth or type B .....	7
Range-elevation or type E .....	9
Elevation-azimuth or type C .....	10
Spot indicator and pilot's indicator .....	11
Use of standard co-ordinate system .....	12

## LIST OF ILLUSTRATIONS

	<i>Fig.</i>
Type A display.....	1
Side-by-side split display .....	2
Up-and-down split display .....	3
Strobe marker .....	4
PPI display .....	5
Range-azimuth display.....	6
Range-elevation display .....	7A
Height calibration flight .....	7B
Elevation-azimuth display .....	8
Spot indicator display .....	9
Use of standard co-ordinate system .....	10

## CHAPTER 3

### TYPES OF DISPLAY

#### Introduction

1. The echo from the distant object, having been picked up on the aerial and then amplified and rectified in the receiver, must be displayed to the operator in such a way that the co-ordinates ( $r, \theta, \alpha$ ) of the echoing object may be deduced as desired. A visual display is almost invariably used, involving a cathode ray tube (c.r.t.). The c.r.t. employs a narrow pencil of cathode rays to produce a bright spot on a fluorescent screen formed on the end of the tube. By means of deflecting plates or by coils, this spot can be moved electrically as desired over the screen at a very fast rate. Owing to the persistence of vision, and afterglow in the fluorescent material, a steady display is formed on the screen. The various types of display are briefly described in the following paragraphs.

#### Range-amplitude or type A

2. This is historically the oldest type of display, and has already been mentioned briefly in Chapter 1. The tracing spot appears near one edge of the fluorescent screen at the same time as the transmitted pulse is emitted (or a little before) and moves across the screen with uniform speed, tracing out a line. It is then suppressed and appears again in its initial position when the next transmitter pulse is emitted and the process is repeated. This motion of the spot is produced by a sawtooth wave of voltage, synchronised with the pulse recurrence rate and applied to one pair of deflecting plates. The echo signal is applied to the other deflecting plates (at right angles to the first pair). Thus during the very short period when an echo is being received the trace on the screen is deflected by an amount proportional to the amplitude of the echo signal. Since noise is

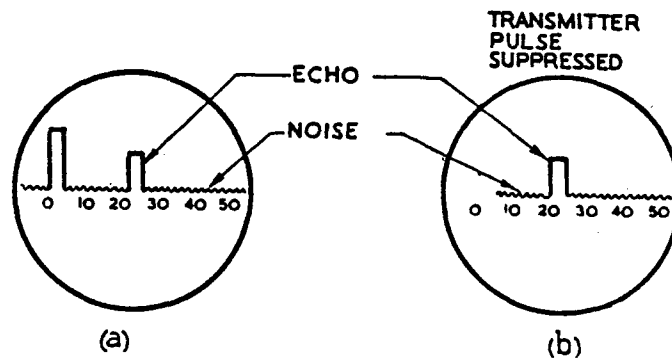


Fig. 1—Type A display

being generated in the receiver and aerial circuits, the trace also shows small irregular deflections of a random nature. The result is shown in fig. 1(a) and fig. 1(b). In fig. 1(b) the receiver has been rendered insensitive during the time when the transmitter is sending out its pulse. This is a common procedure in radar equipment. It should be noted that the deflections of the trace may be arranged to be up or down according to the taste of the designer. The whole display may also be turned through a right angle from the position shown in fig. 1, so as to give a vertical trace with deflections to the right or left. The range,  $r$ , of the echoing object is determined by the distance on the trace from the leading edge of the transmitter pulse to the leading edge of the echo. A scale, or indicating marks, may be provided. If it is desired to display echoes up to a range of  $r$  miles, the corresponding echo delay will be  $10.75r$  microseconds. Thus the tracing spot must move across the screen in  $10.75r$  microseconds which figure determines the slope of the deflecting sawtooth voltage. It is often desirable to have a choice of traces which can be switched on as desired, including a very "fast" trace or time base, corresponding to a small range and giving an open and more accurate reading for nearby echoes. The maximum range that can be indicated (or the "slowest" trace that can be used) is decided by the time between successive pulses. Thus if the pulse recurrence frequency is  $p$  pulses/second, then the greatest range,  $r_{\max}$  which can be indicated is given by

$$r_{\max} = 93,000/p \text{ miles.}$$

This formula applies to all displays with a range co-ordinate. It is clear that, with type A display alone the co-ordinates  $\theta$  and  $\alpha$  must be found from dials or scales unconnected with the actual display tube, the operator studies the amplitude of the echo in relation either to physical movements of the aerial system or to electrical changes in the connections and couplings from the parts of the aerial system in the receiver.

### Split display

3. The co-ordinates  $\theta$  or  $\alpha$  are sometimes determined by comparing echo signals received on two aerials with different polar diagrams or on the same aerial shooting in two different directions, as explained in Chapter 2. A switching motor may be employed, synchronised with the recurrence frequency so that the two different conditions of reception are obtained in turn. At the same time, alternate traces on the screen are displaced a little by having one start nearer to the edge of the screen than the other. The signals under the two different conditions are thus displayed side by side (fig. 2). The same effect can be obtained without displacing the traces but by arranging that the deflection is upwards (or to the right) under one condition and downwards (or to the left) under the other (fig. 3).

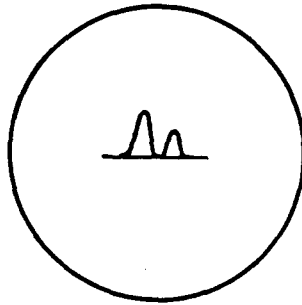


Fig. 2—Side-by-side split display

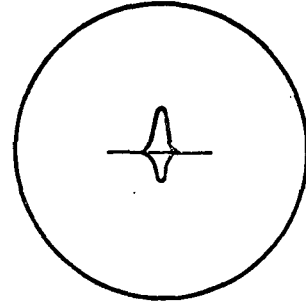


Fig. 3—Up-and-down split display

### Strobe marker

4. The strobe is a "gate" circuit which is only open during each recurrence for a few microseconds. The signals occurring in that time are allowed through and may be displayed separately on another c.r.t. In order to strobe an echo a type A display may be used (or any display with a range co-ordinate). A small part of the trace is brightened up or otherwise made noticeable during the time that the "gate" is open. This is called the strobe marker (fig. 4). A control is provided to alter the position of the gate in the recurrence interval and this strobe control is moved until the bright mark coincides with the echo which it is desired to pass through the gate. The strobe control can also be used to provide a range indication, the operator merely keeping the echo covered by the strobe marker.

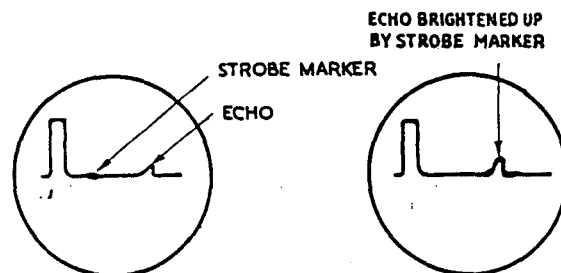


Fig. 4—Strobe marker

### Plan position indicator (PPI)

5. The tracing spot of the c.r.t. starts, when the transmitter pulse is emitted, from the centre of the screen and moves out along a radius until the edge of the screen is reached. The spot is then suppressed but appears again at the centre with the beginning of the next transmitter pulse and the sequence is repeated. The particular radius along which the spot travels is controlled (either electrostatically or magnetically) so as to be related to the azimuthal direction in which the aerial system is shooting at that moment. If the aerial turns round at uniform angular speed, there is traced out in succession on the screen a series of spokes. Let the aerial scan  $360^\circ$  in azimuth at  $N$  revolutions/minute and let the pulse recurrence frequency be  $p$  pulses per second. Then the angle between the spokes or radial traces is  $6N/p$  degrees. The traces not being superimposed as in type A display, one here relies entirely on the long afterglow of the specially designed fluorescent

screen in order to obtain a display which can be seen easily by the operator. The echo signal in the case of PPI display is applied to the grid of the c.r.t. so as to brighten up the tracing spot on the

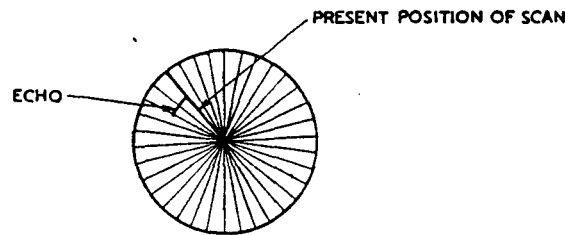


Fig. 5—PPI display

screen (intensity modulation). Depending on the size of the echoing object, the sharpness of the aerial beam and the length of the transmitter pulse, the echo appears on the long afterglow screen as a bright spot or smudge (see fig. 5). It is usual to adjust the controls so that the traces are only just visible unless there is an echo present. By correlating the positions of the radial traces relative to the directions of the aerial beam this display gives directly the coordinates  $r, \theta$  of the echoing object, and, indeed, a transparent outline map can be superimposed in the case of a fixed ground station. The PPI, in its simple form, does not give the co-ordinate  $\alpha$

### Skiatron

6. This is a special type of PPI in which the picture on the c.r.t. screen is transferred by strong reflected light to a large translucent glass plate. A larger display can thus be obtained than is possible with a c.r.t. alone. The tube employed has a screen which turns dark purple under the influence of a strong electron beam but soon returns to its original grey colour when subject to the heat produced by the associated high-density light source.

### Range-azimuth or type B

7. This display is used in aircraft sets with centimetre equipment. The tracing spot starts near the bottom edge of the screen when the transmitter pulse is emitted and traces out a vertical line. It reaches the top of the screen in a time determined by the maximum range which it is desired to indicate. The spot is then suppressed and appears at the bottom of the screen as the next transmitter pulse goes out, when the sequence is repeated. These successive vertical sweeps are spaced out across the screen so as to correspond with the azimuthal direction in which the aerial is shooting. When the aerial shoots straight forward along the axis of the aircraft the vertical sweep is along the centre line of the screen; when shooting at an angle to the left of the forward direction, the vertical sweep is a proportionate distance to the left of the centre line. As in PPI,

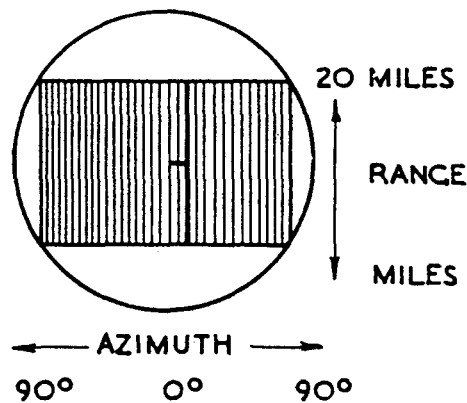


Fig. 6—Range-azimuth display

the echo signal is used to intensity-modulate the c.r.t. beam so that the tracing spot is brightened up when an echo is received. An afterglow screen is used and thus the echoes are displayed as spots or short lines or extended smudges (depending on the beam width and the size of the echoing object). The final result is a kind of distorted map of the region scanned by the aerial (fig. 6). Type B display does not show the co-ordinate  $\alpha$

8. If  $N$  is the number of aerial scans per minute and  $p$  the number of pulses per second then the number of vertical lines comprising the complete picture is  $60p/N$ . Note that type B display is superior to the PPI in that it gives much greater angular resolution at short ranges; type B has the disadvantage that the picture is distorted, and does not correspond to a map, so that practice is required in interpreting the display. Type B is only suitable for scans up to the limits of  $+90^\circ$  and  $-90^\circ$ .

**Range-elevation or type E**

9. The tracing spot starts near the left-hand edge of the screen, at the moment when the transmitter pulse begins, and moves horizontally with uniform speed to the right-hand edge. As usual, this speed is determined by the maximum range it is desired to indicate. Successive horizontal sweeps are spaced up and down the screen so as to correspond with the zenithal or elevation angle at which the aerial is shooting at the moment in question. Intensity modulation is used to show the echo as in PPI and type B. The co-ordinates  $r, \alpha$  can be read off. In the case of a ground station the alternative co-ordinates  $r, h$  may be obtained where  $h$  is the height of the echoing aircraft. For this purpose a series of lines may be drawn on the screen giving contours of equal heights and corresponding to solutions of the equation  $h = r \times \sin \alpha$  with allowance for earth curvature (fig. 7 (a))

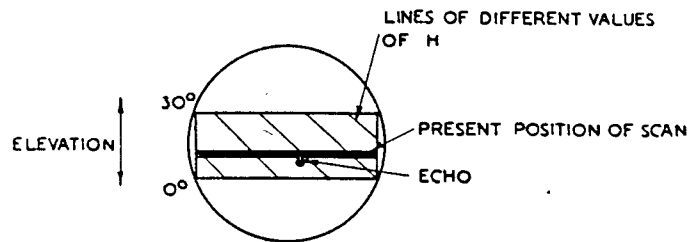
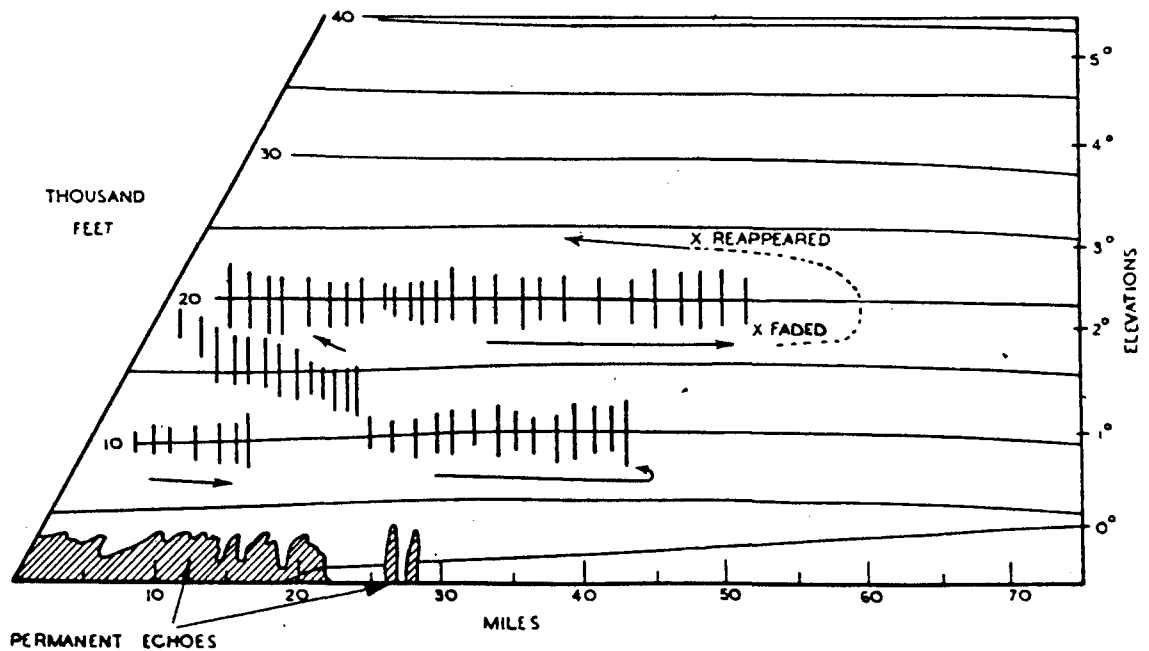


Fig. 7A—Range-elevation display

The curvature of the lines at constant  $h$  make this an unsatisfactory type of display and it is now obsolete. In the latest CMH (Centimetre Height) equipments the display assumes the following form. It is a Cartesian plot of  $kr \sin \alpha$  as ordinate, against  $r$ , where,  $k$  is a constant,  $r$  the range and  $\alpha$  the elevation. This is achieved by imposing a portion of the sawtooth time base X-scan on the Y



HEIGHT CALIBRATION FLIGHT-2 SPITFIRES-AMES TYPE 13.

Fig. 7B—Height calibration flight

plates, to an amount proportional to the elevation of the beam. The constant height lines are now almost straight and by tilting the line of zero elevation to correct for earth curvature they also can be set horizontal. A further advantage of this tilt is that the trace sweeps below the position of zero elevation of the aerial with the result that permanent echoes can be distinguished from low flying aircraft. Responses appear as vertical straight lines. A maximum range of 75 miles and height of 45,000 feet can be displayed in a space of 18 cm.  $\times$  10 cm. Fig. 7(b) shows the plots on a test flight with two Spitfires.

### Elevation-azimuth or type C

10. The tracing spot moves up or down, left or right, in sympathy with the movements of the aerial system. Fig. 8 shows the traces for an aerial doing a helical scan. The receiver is made insensitive during the transmitting period and signals received at other times are used to intensity-modulate the brightness of the spot. The co-ordinates  $\theta, \alpha$  can be read off. It is clear, however, that the tracing spot is effectively stationary during a period between transmitter pulses. Consequently all extraneous signals including noise are accumulated together in the spot. The contrast between

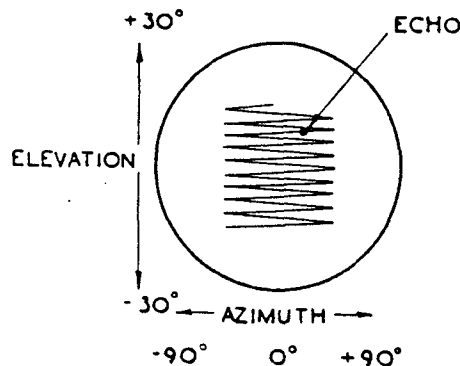


Fig. 8—Elevation-azimuth display

echo and noise is thus poor. This disadvantage can be eliminated by using in addition a display with a range co-ordinate (such as Type A or B), "strobing out" the desired echo in range and then displaying the selected echo alone on the type C indicator. The strobing may be done manually or automatically. Type C display does not give the coordinate  $r$ .

### Spot indicator and pilot's indicator

11. These are type C indicators which must be preceded by a strobe or gate, as described in para. 10. The range of the echo (or strobe position) is shown in the pilot's indicator by adding horizontal "wings," of varying length, to the spot (fig. 9).

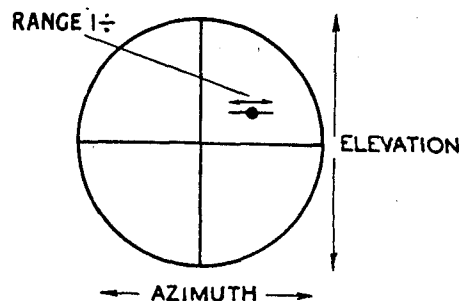


Fig. 9—Spot indicator display

**Use of standard co-ordinate system**

12. The co-ordinates  $(r, \theta, \alpha)$  of an echoing aircraft or ship, as determined by a radar equipment are measured with that radar station as origin. In airborne sets this is all that is desired in order to carry out attacks. But, in cases where there is a network or chain of ground radar stations, it is normal practice to report or "tell" to a central control operations-room; the relative co-ordinates  $(r, \theta, \alpha)$  are then inconvenient. Before reporting the position of an echoing aircraft the "teller" might convert  $(r, \theta, \alpha)$  to latitude, longitude and height above sea level. This being an absolute co-ordinate system, the central operations-room plotter could easily show the result, with those of neighbouring radar stations, on a large scale map. Although latitude and longitude are used by the Navy, they have not found favour with the R.A.F. owing to the subdivisions of sixty which are required in latitude and longitude notation. Instead a decimal system has been introduced:—A straight line is drawn on the ordnance survey map through a point in the Isle of Wight and running

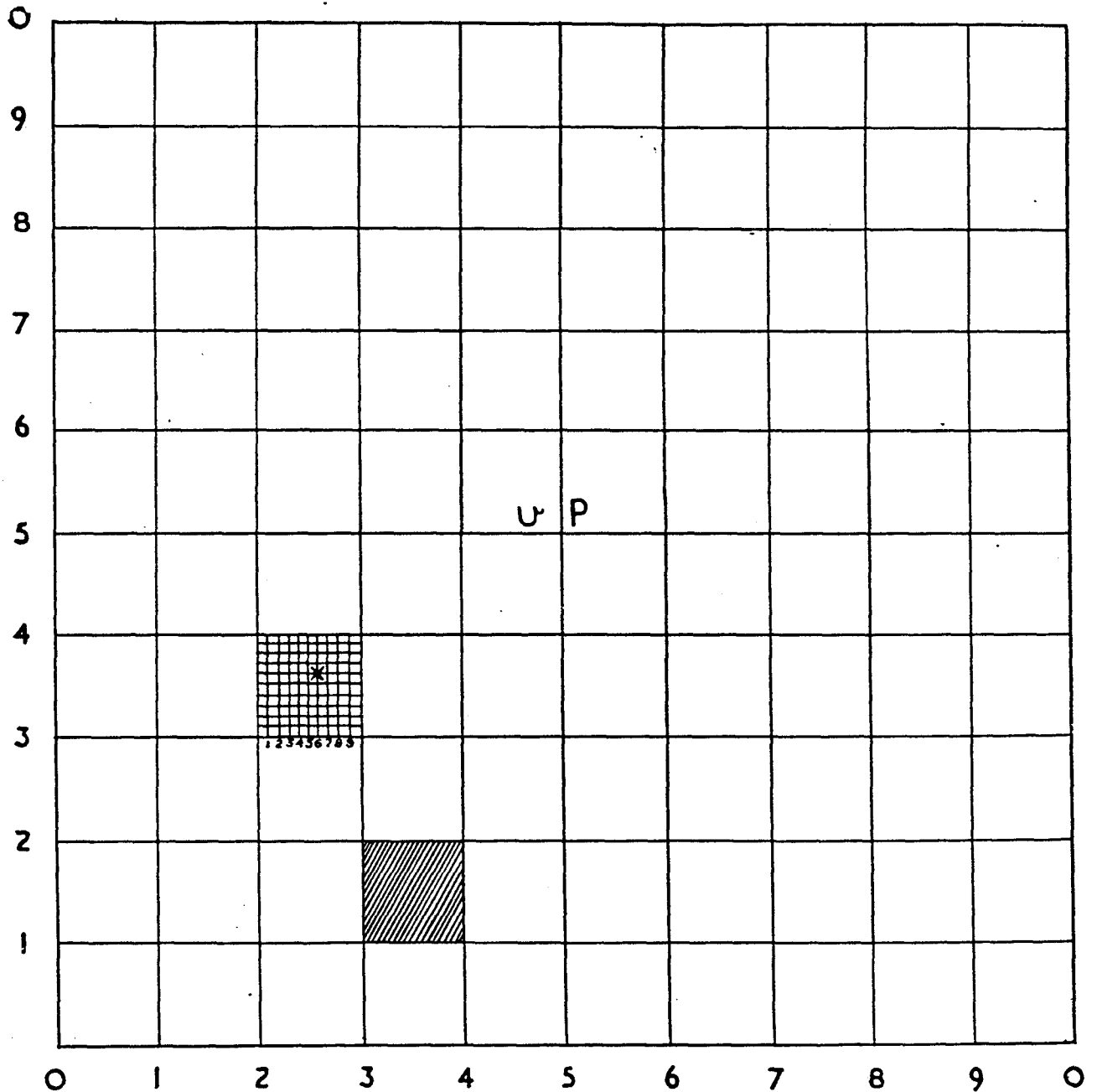
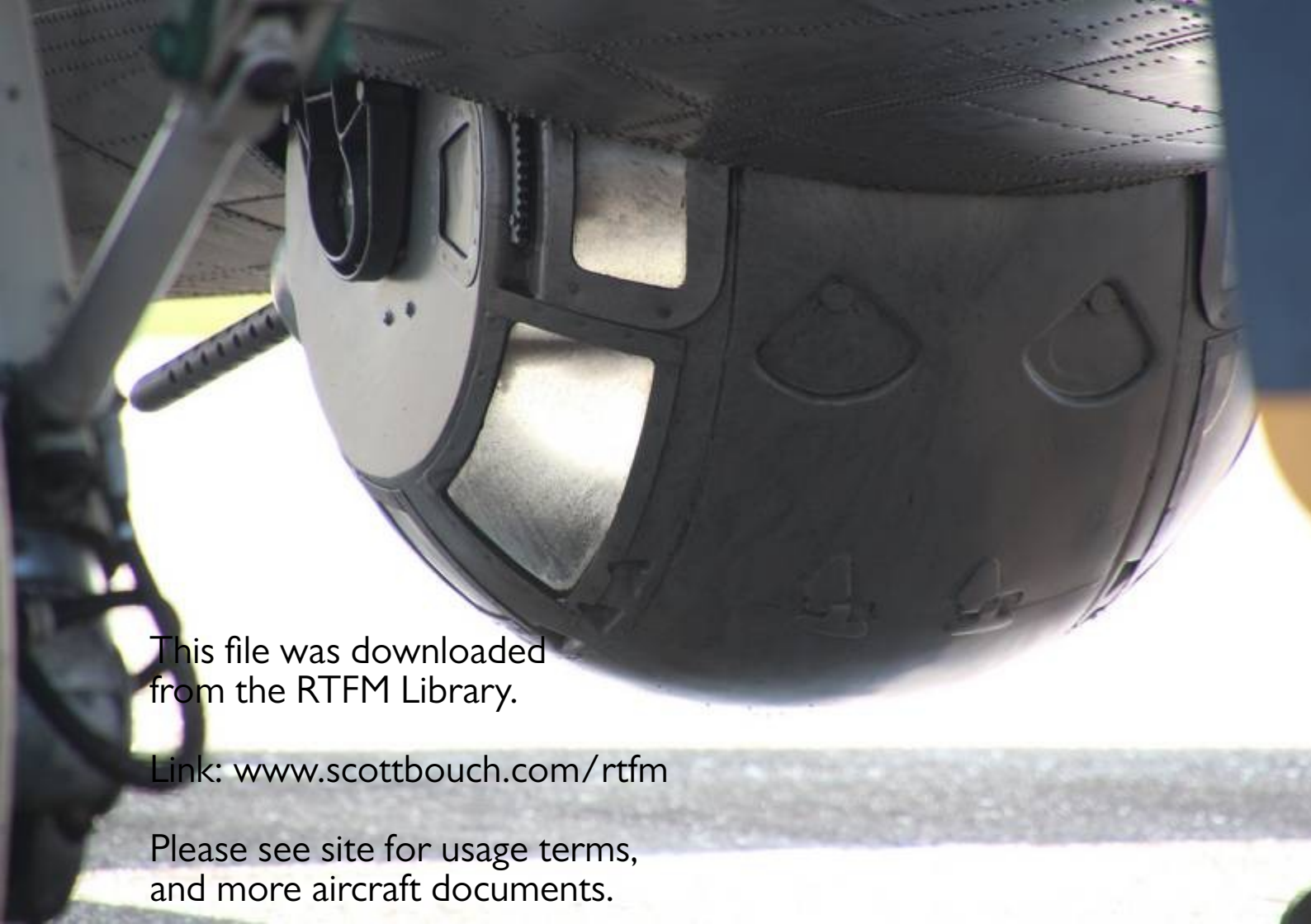


Fig. 10—Use of standard co-ordinate system

true North and South. A straight line is drawn East and West through the same point. A series of horizontal and vertical straight lines is then drawn parallel to the first pair and spaced out 100 kilometres apart. This divides the area of England, Scotland and Wales, with the surrounding coast, into 100 kilometre squares which are given letter references such as aA, aB and so on. Each square is further subdivided into squares of ten kilometre side by drawing parallel lines as shown in fig. 10. The lines are numbered from left to right and from bottom to top. Any square is referred to by the numbers of the vertical and horizontal lines crossing at its bottom left hand corner. Thus the shaded square in fig. 10 would be referred to as vP.31. A further subdivision of the kilometre squares into squares of 1 kilometre side yields a four figure reference ; thus the point marked with a cross in fig. 10 lies in the square vP.2636. The first two figures refer to vertical lines (or x — co-ordinate) and the second two to horizontal lines (or y — co-ordinate). Six figure references are occasionally used. It should be noted that as one moves East or West of the vertical line through the Isle of Wight the sides of the squares no longer lie North and South. The whole network is referred to as the Air Force Grid and the co-ordinates are called “grid-references.” The Ordnance Survey maps issued by the Air Ministry have this grid drawn on them. Each radar station of a network is required to convert the co-ordinates ( $r, \theta$ ) to a grid reference—either by ruler and protractor on a map or by a mechanical calculator—before reporting to the Central Operations room. The labour of converting is eliminated when a PPI display is available since the grid can be superimposed on the PPI screen and the reference read off. The calculation of height,  $h$ , above sea level from  $r$  and  $\alpha$  must be done using charts or calculators, unless a type E display is provided.



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