

CHAPTER 4

AIRCRAFT NAVIGATIONAL AIDS

THE GEE - 7,000 SYSTEM

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Introduction

1. In the early part of the war, apart from the ordinary DF facilities, there were very few radio aids to navigation. Navigators had, in the main, to make use of dead-reckoning and astro-navigational methods. Both these methods are open to serious inaccuracies, and the main disadvantage of the DF system was that it could easily become saturated, i.e. there was a definite upper limit to the traffic which could be handled by a set of DF stations.

2. To overcome these difficulties, radar technique was summoned to the aid of navigation, and the Gee system was devised. Though Gee is classed as a radar equipment, since it uses pulse technique, it is in many ways completely different from all earlier equipments. The main difference lies in the fact that there is involved only transmission from ground stations to the aircraft. There is no transmission whatsoever back from the aircraft to the ground, either in the form of a repeated signal or as a re-radiated signal. Since the aircraft, therefore, is merely a receiver of radiation from the ground and does not retransmit, it follows that there is no limit to the number of aircraft that can use the system at any one time, just as there is no limit to the number of receivers which can tune in to an ordinary broadcast programme. Gee-7000 was first introduced into the service in the early part of 1941, and it was the aim to fit the equipment to as many aircraft as possible.

General principles of operation

3. The Gee-7000 system involves locked transmission from three or more ground stations ; and, in the air, the measurement of path differences from these stations. It is proposed, in the first place, to discuss the principle of path differences.

4. Suppose a ground station is set up at A (fig. 1), which is allowed to transmit a regular set of pulses, in the normal radar manner. An aircraft situated at P will receive these pulses a certain time after transmission.

5. In fact, if v be the velocity of electromagnetic waves, the time t_1 taken for a pulse to travel from A to P is

$$t_1 = \frac{AP}{v}$$

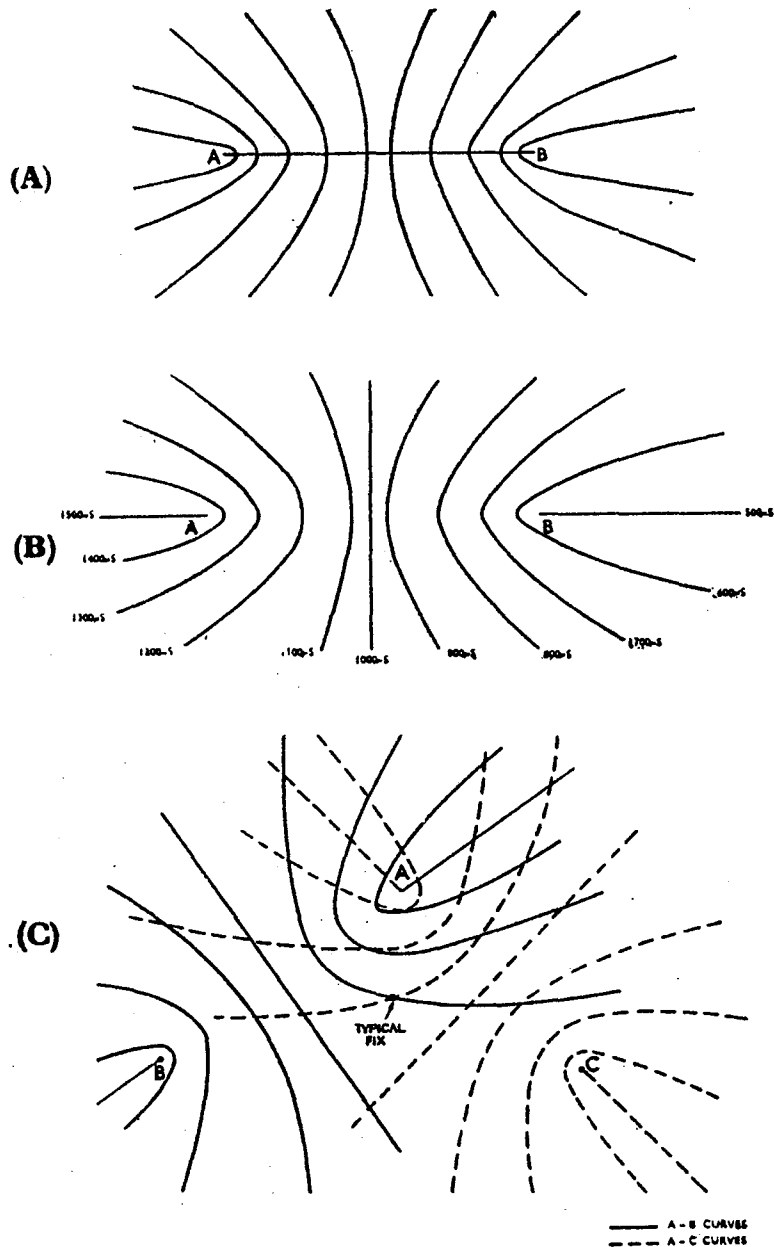


Fig. 1.—Gee hyperbolae

6. Suppose now that at the same time, the pulse from A is picked up at a second ground station situated at B, and that this second station itself transmits a pulse at definite time T after receiving the A pulse. Then, counting as an origin for time reference, the time at which A transmits, it follows that the aircraft will receive the pulse from B after a time

$$t_2 = \frac{AB}{v} + T + \frac{BP}{v}$$

(where T is the inevitable delay between reception of an A pulse at B and transmission from B).

7. It will be noticed that t_2 is made up of three parts:—

- (1) Time of travel from A to B.
- (2) Delay introduced at B.
- (3) Time of travel from B to P.

It will be seen that $t_2 > t_1$.

8. The equipment carried in the aircraft enables the navigator to measure rapidly the time difference between the arrival of the A and B pulses, that is, the quantity $t_2 - t_1$.

Now,

$$t_2 - t_1 = \frac{AB}{v} + T + \frac{PB}{v} - \frac{AP}{v}$$

The quantities AB, and v are known constants, and the equipment at a ground station enables T also to be kept constant. It follows, therefore, that if $t_1 - t_2$ is known, $(PB - AP)$ will also be known.

9. The best way to use this information is clearly to draw on a map containing A and B, a set of curves of constant path difference from those points. Along such a curve $BP - AP$ will remain constant, and so therefore will $t_2 - t_1$ remain constant. Each of the curves is labelled with the appropriate value of $t_2 - t_1$ which applies to it. All that has then to be done by the navigator is to measure $t_2 - t_1$ and this will immediately enable him to fix himself along one or other of the curves in the system.

10. It may be shown that these curves of constant path difference are hyperbolae about A and B as foci.

Example

11. Assuming the separation of the A and B stations to be 100 miles, a normal figure. Assume also that the delay introduced at the B station is 500 microseconds. As a further approximation, say the velocity of electromagnetic waves is such that it takes 5 microseconds for them to cover one mile. Then it can easily be seen that everywhere along AB produced (fig. 1(B)) a constant time difference of 500 μ s will be observed between reception of the A and B pulses,

$$(t_1 = \frac{AP}{v} = \frac{AB + BP}{v}$$

in this instance.)

12. Similarly, along BA produced, a constant time difference of 1500 μ s will be observed. Finally, the perpendicular bisector of AB will be the line of 1000 μ s time difference.

13. These three instances are those in which the hyperbolae mentioned previously degenerate into straight lines. All the other cases are, however, true hyperbolae as shown in fig. 1(B), and all have time-difference values lying between 500 and 1500 μ s. Hence one can deduce an important fact, namely, that there is a definite *upper limit* (1500 μ s) to the time-difference observed anywhere.

14. This fact is of importance in determining the length of timebase to be used in the display scheme, and means that (as compared with all other radar equipments) maximum range is not limited in any way by the length of timebase. For clearly, provided our timebases are of greater length than 1500 μ s, an A pulse displayed to the extreme left of a timebase will give rise to a B pulse always on that same timebase wherever the aircraft may be. In fact, a timebase length of 2 milliseconds (including blackout period) is used.

The hyperbolic mesh

15. To obtain a "fix," it is necessary to introduce a third ground station C (fig. 1(C)) which functions in the same manner as the B station, and a further set of hyperbolae can be drawn, this time with A and C as foci. By measuring the time difference between arrival of the A and C pulses the navigator can fix the aircraft along one of this family of curves.

16. It follows that the position of the aircraft can be fixed by measuring the (A-B) and the (A-C) time difference, and by finding where the corresponding curves in the two families of hyperbolae intersect.

17. The hyperbolic curves are very often called *lattice lines* and the whole system is said to provide a *hyperbolic mesh* over the map.

Ambiguity

18. It will be apparent that ambiguity may possibly arise because any two branch hyperbolae from the two systems have two points of intersection, (Fig. 2(a)). Difficulty may therefore be experienced in this respect, particularly in the vicinity of the A station. This may be overcome by introducing a fourth station D similar to the B and C stations. For though the A-B and A-C curves may intersect at two points P and Q, the navigator by measuring the A-D time difference can tell which is the correct point to take. A more important function of the D station is discussed later.

Accuracy

19. In the main the accuracy of the system is determined by two factors :—

- (1) Maintenance of constant value of T at a B, C or D station (this can be done to limits of less than 0.1 microsecond); and accuracy of reading of time difference in the aircraft (this can be done to limits of about 0.5 microsecond).
- (2) The number of lattice lines that can be drawn on a map without undue confusion, and the accuracy with which the navigator can determine their points of intersection (particularly when interpolating).

20. Provided pulses remain of sufficient strength, the errors introduced in (1) are appreciably independent of range. The errors introduced in (2), however, increase with range, for as the range from the ground stations increases the acute angle of cut of the hyperbolic curves will decrease. It is seen by reference to fig. 2(B) and 2(C) that as the angle of cut diminishes so does the decisive nature of that cut. The optimum case will be that of a right-angled cut.

21. If care is taken in the siting of the D station it can be arranged that in places where the angle of cut of the A-B and A-C curves begins to fall off then a better cut is obtained with either the A-B and A-D curves or the A-C and A-D curves, (fig. 2(D)).

22. In the vicinity of the stations, fixes can be obtained to an accuracy of a few hundred yards. Then, as range increases, the accuracy gradually falls until at extreme range of 500 miles the navigator could, in theory, place himself somewhere within a diamond figure (fig. 2(C)), with diagonals 5 and 3 miles long.

In practice the accuracy attained is somewhat inferior to this.

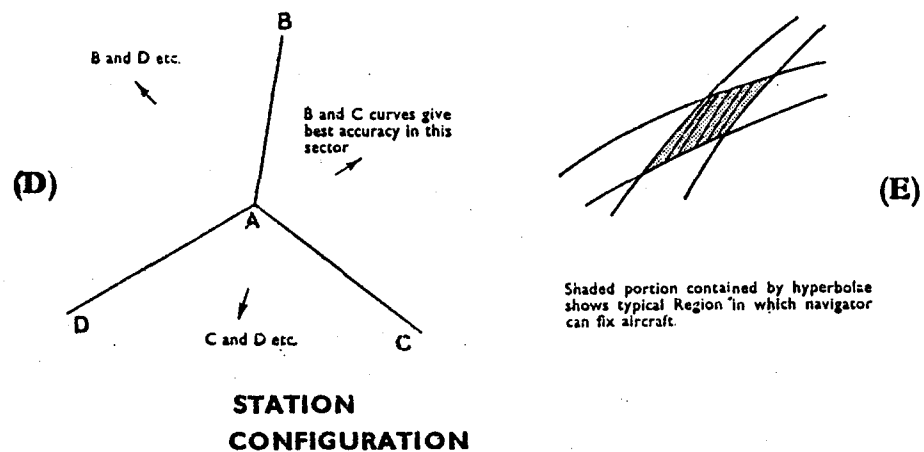
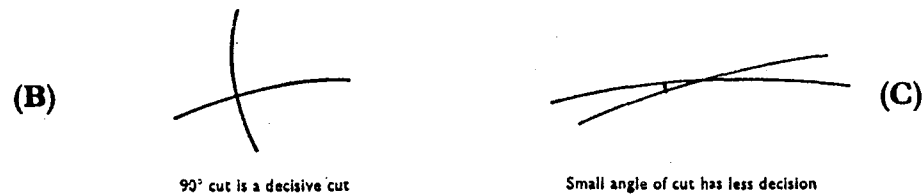
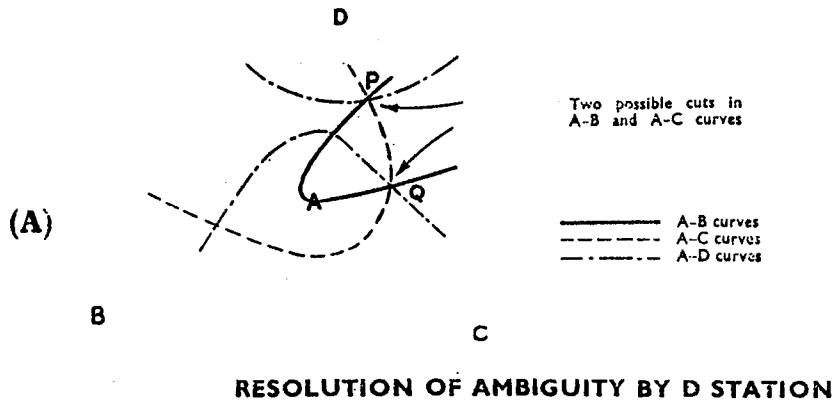


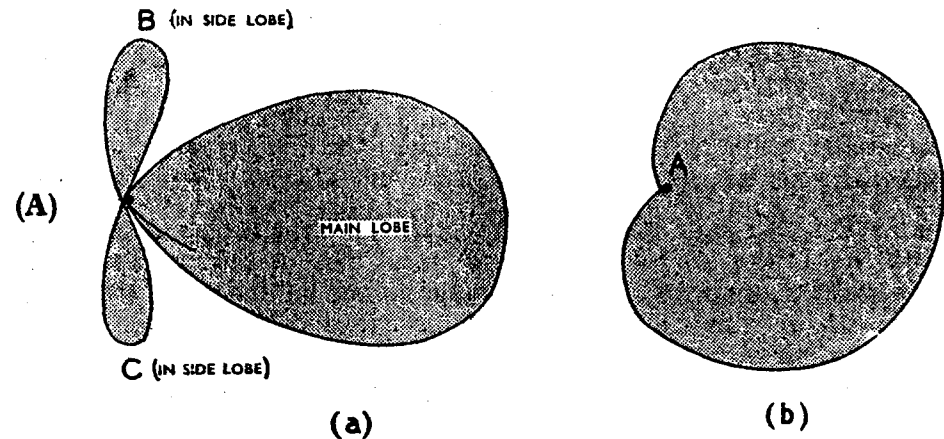
Fig. 2.—Ambiguity and accuracy

Range and coverage

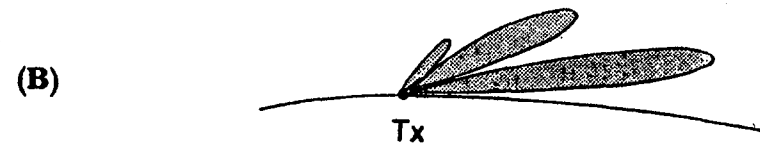
23. The range of Gee is limited by the power of the ground transmitters and by the height at which the aircraft can fly in order to remain within the radiation lobe in spite of earth curvature. At 15,000 feet a range of 450 miles is attainable with the present equipment, provided no jamming is present. At greater heights and under favourable atmospheric conditions greater ranges may be observed.

24. No special steps are taken to give intense beaming of the radiation from the ground, for a wide service area is desirable, compare the floodlight technique at CH stations. In general a simple reflector system on the ground station antennae serves to throw the bulk of the radiation forward, and to cut down back-radiation see fig. 3(A).

25. A stack of vertical dipoles is employed to provide vertically polarised radiation (= 6 metres).



(A) Typical horizontal polar diagrams



(B) Typical vertical polar diagram
(radiation may be beamed in a vertical plane as much as is convenient)

Fig. 3—Polar Diagrams

Monitoring of ground stations

26. It can be seen that though the precise value of T (the time delay introduced at B, C or D) is not particularly important; it is, however, of the utmost importance to keep it constant. It may be mentioned that its value need not be the same for all three stations.

27. In general an alteration in the value of T demands a corresponding change in the numbers affixed to the hyperbolic grids.

28. The B, C and D stations each have monitoring facilities in order to measure their individual T values, but in addition a cross-check is kept by introducing a final ground station into the scheme. This is the *monitor station*, and its function is to pick up pulses from the other ground stations, and to inform them if they are in error.

Ground station organisation

29. By examining the method by which the scheme has been developed it will be seen that the A station originates transmission, but that the other stations in the scheme follow it. For this reason the A station is commonly referred to as the *MASTER* station. At the same time, B, C and D are referred to as the *SLAVE* stations, the D in particular as the *STAR SLAVE*.

30. A complete Gee system, as described, comprises a master, monitor and three slave stations. It is known as a *Gee-7000 chain*.

31. Though the rôle of a monitor station is essentially passive, yet it serves as headquarters for its chain. It maintains constant telephonic communication with the other stations of the chain and through it are passed all operational messages from the Command using the system.

32. In general all chains transmit continuously, each chain having its own radio-frequency. At present there are five chains situated in Great Britain. They are, in order of erection:—

- (1) Eastern Chain, with stations in central England, directed towards Holland, Belgium and N.W. Germany.
- (2) Southern Chain, with stations in Southern England, directed towards France.
- (3) Northern Chain, with stations in the Northern part of Scotland, directed towards the North Sea and Norway.
- (4) South-Western chain, with stations in South Wales and Western England, directed towards the Bay of Biscay.
- (5) North-Eastern chain, with stations in North East England, directed towards Denmark.

Station identification and presentation in the aircraft

33. To enable the navigator to identify the ground stations of any one chain, a complex system of pulse recurrence frequencies is used, and, in consequence, a rather complex timebase system.

34. In the first place consider the master station transmission. The master sends out a steady set of pulses at a p.r.f. of 500 c/s. These pulses will occur at 2 millisecond intervals, and when they are put on a time scale, divided into two-millisecond sections, they appear as in fig. 4.

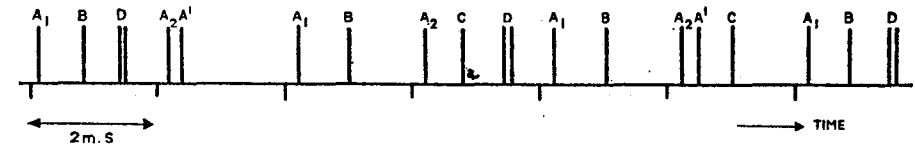


Fig. 4.—Pulse recurrence frequencies

35. The A pulses are now divided into two different sets; one set will be referred to as A_1 set and the other A_2 . The division into sets is done in such a manner that A_1 and A_2 are interleaved (again as seen in fig. 4).

36. The aircraft timebase is made to run also at 500 c/s, but alternate timebase traces are deflected downwards as in fig. 5(A). If follows that a complete timebase picture takes 4 milliseconds to complete (including flyback time). Moreover it will be seen that one A pulse will appear on each of these timebase traces, (an A_1 on one trace and an A_2 on the other).

37. Since the aircraft timebase is allowed to run freely, there is no means of estimating when the equipment is first switched on, where exactly the A pulses will be, relative to the timebase. However, the navigator can control the timebase phase, which controls the starting time of the timebase. By adjustment of this control, therefore, the navigator can set the equipment so that the A station pulses appear at the extreme left of the timebases.

38. It is impossible for the navigator so far to distinguish between A_1 and A_2 ; to help him do this, however, an auxiliary transmission A^1 is sent out from the master station. This is transmitted on a p.r.f. of 125 c/s, and will therefore occur once for every fourth main A pulse. It is phased so that it occurs at about $100 \mu\text{s}$ after every second A_2 pulse. The general appearance of the master transmission on the aircraft timebase is as in fig. 5(B).

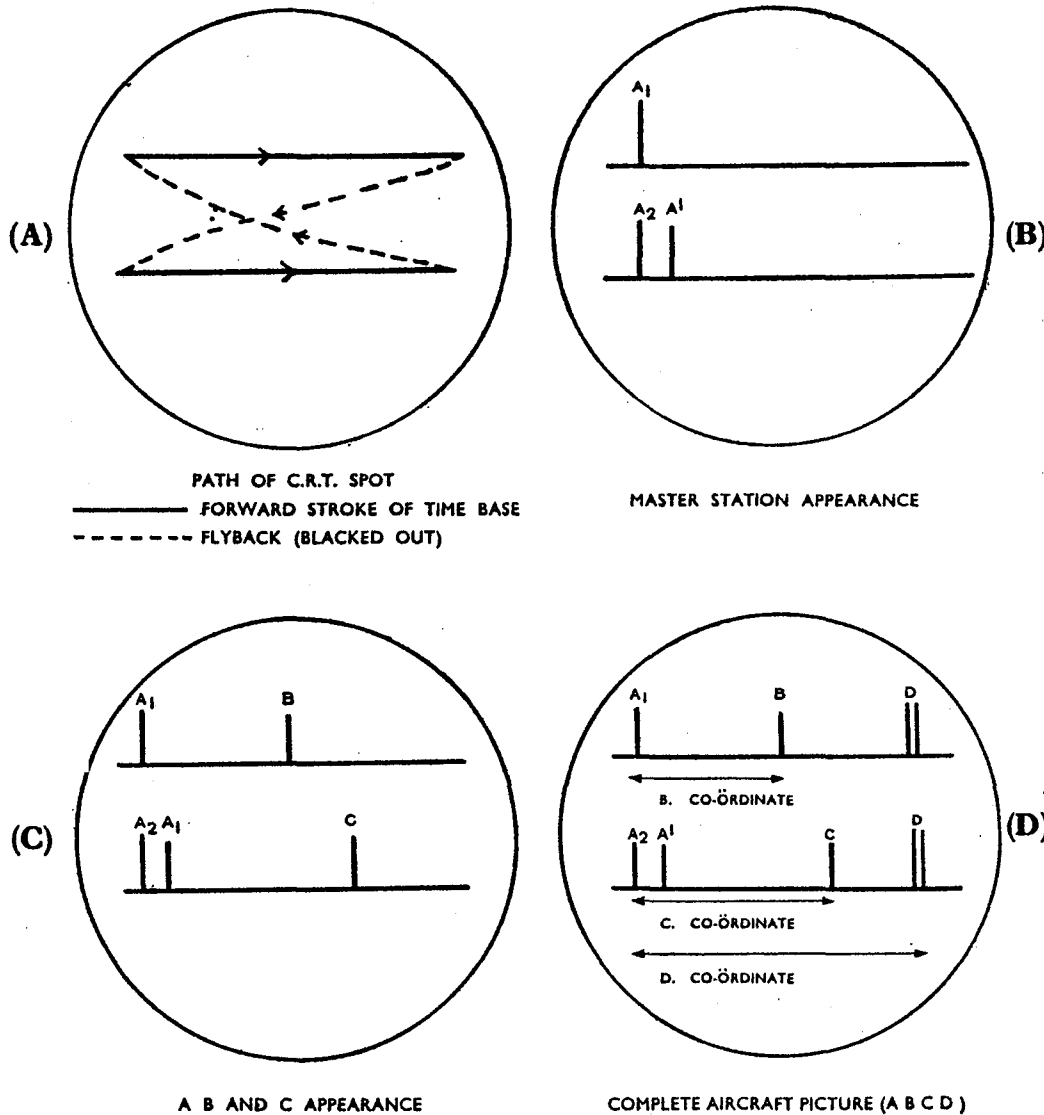


Fig. 5.—Development of display

39. Notice that even though an A^1 pulse appears after only every other A_2 , an impression of continuity will be obtained in the picture as in fig. 5(C). A^1 will, however, appear somewhat less brilliant than the other pulses, because the CRT spot only paints a pulse picture on every other trace, and for this reason A^1 is sometimes referred to as the *A ghost* or *A shadow* pulse rather than *A* identification pulse.

40. It is again stressed that the *A* pulses can occupy any position on the timebase initially, but that the timebase phasing control should always be adjusted so that the single *A* pulse (i.e. A_1) stands at the extreme left of the top trace. The sole purpose of the pulse A_1 is to enable the navigator to differentiate between A_1 and A_2 , for a reason which follows.

41. By employing a suitable filter, a *B* station is able to retransmit only the A_1 set of pulses, consequently the p.r.f. of the *B* station is 250 c/s; moreover, on reference to para. 11 it will be seen that the delay introduced at *B* is less than $500 \mu\text{s}$, so that wherever an aircraft may be it will always receive a *B* pulse not more than $1,500 \mu\text{s}$ after the A_1 pulse.

42. In a similar manner the *C*-slave retransmits only the A_2 pulses. Its p.r.f. is therefore 250 c/s also and again an aircraft will receive a *C* pulse always not more than about $1,500 \mu$ seconds after an A_2 pulse. The sequence of transmission can be seen on reference to fig. 4, and the appearance on the aircraft timebase as in fig. 5(C).

43. Thus, provided A_1 has been moved to its conventional position at the left of the top trace, then the *B* pulse will always appear some way out along the top trace and the *C* pulse out along the bottom trace. It follows that the existence of A^1 is necessary for distinguishing between the *B* and *C* pulses. The point to remember is that *C* is always associated with A^1 .

44. Finally the *D* station is made to retransmit every third *A* station pulse, i.e. first an A_1 and then an A^1 . Its p.r.f. is therefore $166\frac{2}{3}$ c/s and it will appear on every third timebase trace, (fig. 4 and fig. 5(D)). Moreover the *D* transmits a double pulse.

45. By virtue of its p.r.f. the *D* pulses will only occur on every other top trace and on every *other* bottom trace, but as far as the eye can perceive it will appear on each trace like A^1 . It should be noted, however, that if *D* and A^1 could be examined closely they would be found not to break the base-line of the trace.

46. Moreover fig. 5(D) indicates the time to be measured to give the *B*, *C* and *D* co-ordinates of the fix. For this measurement it is necessary to have some form of time calibration on the timebase traces, as explained later.

Strobing

47. On examination of the aircraft timebase it will be noticed that there are two small troughs, one on the top trace and one on the bottom (fig. 6(D)), and that signals occurring in these troughs are inverted. The timebase presentation that we have described so far is known as the Main Timebase or MTB.

48. In order to achieve greater accuracy in the measurement of time intervals, shown in fig. 5(D), a system of strobing is used. Strobing enables a small section of the trace to be selected and to be speeded up in the X direction. In the Gee indicator it is possible to select four small parts of the MTB for such magnification:—

- (1) The first 80μ seconds of the top main timebase (the A_1 strobe).
- (2) The first 80μ seconds of the bottom main timebase (the A_2 strobe).
- (3) Any 80μ seconds of the top main timebase (the B strobe).
- (4) Any 80μ seconds of the bottom main timebase (the C strobe).

49. The first two of these strobes are fixed in position. The B and C strobes can, however, be positioned at will along their respective traces (two position controls, coarse and fine, being provided for each strobe). It is therefore necessary to have the positions of the B and C strobes marked out on the MTB. For this reason the two troughs are provided. These troughs can therefore be moved in position along their traces by means of the B and C strobe position controls respectively.

50. The four 80μ second intervals mentioned above can be shown in an enlarged form by using the timebase change-over switch. Normally this switch enables the MTB to be displayed on the CRT, but another position is provided to give us the strobe timebase or STB picture. (figs. 6(B) and 6(C)). The timebase now has four traces, each lasting about 80μ seconds). Reading downwards these give a magnified version of the A_1 , B, A_2 and C strobe regions of the MTB.

51. It follows that any pulse occurring in any one strobe region of the MTB will appear in a magnified form on the corresponding STB trace. Signals during the B and C strobe intervals remain inverted, as on the MTB.

Calibration

52. Both types of timebase can be calibrated for time by X-deflection pips. A calibration switch enables signals to be removed from the trace and calibration applied instead.

53. On the MTB there is a set of pips with every fifth one of greater amplitude for ease in counting (fig. 6(D)). The pips on the top trace are numbered from 0 to 25 and those on the bottom from 30 to 55 (5 pips are lost in each flyback period, which of course is blacked out).

54. These pips are $66\frac{2}{3}\mu$ seconds apart, but for convenience $66\frac{2}{3}\mu$ s seconds is called *Gee unit* of time. It should be noted here that all maps are drawn and all operational instructions given in reference to Gee units of time. Pips on the MTB are therefore spaced at unit intervals.

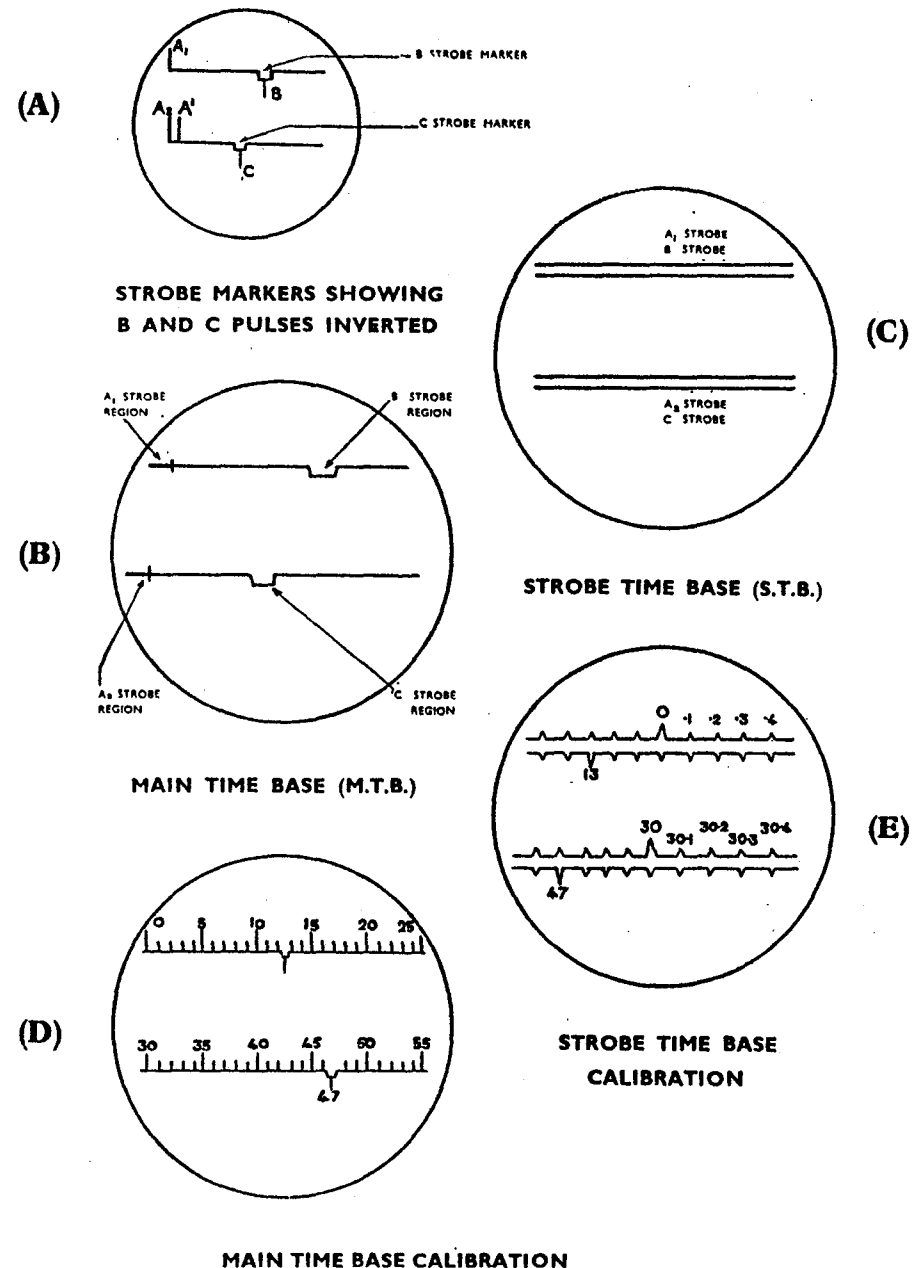


Fig. 6.—Range and strobe display

55. The STB is calibrated with pips occurring at 1/10 Gee unit intervals, with every tenth pip of greater amplitude (unit pips). The large pips on the A₁ and A₂ strobes are respectively the same as pips 0 and 30 in the A₁ and A₂ strobe regions of the MTB. As an example, if fig. 6(E) is the strobe picture of fig. 6(D), the unit pips on the B and C strobes there are 13 and 47 respectively. Note that calibration pips, as well as signals are inverted during the B and C strobe periods.

Taking a fix

56. Since there is a slight instability inherent in the frequency of the aircraft timebase, it is found impossible to keep received pulse exactly stationary on the trace for any length of time. It is thus impossible to set A₁ exactly at the zero pip and read off the calibration number under the B pulse. A differential method is needed (subtraction by sliding graduated scales against one another).

57. The procedure adopted for taking a fix is as follows (for B and C stations).

- (1) Pick out single A pulse on MTB (*see* fig. 7(A)).
- (2) Use TIMEBASE PHASE CONTROL to get A₁ to left of top trace into the A₁ strobe region. A₂ will then be in A₂ strobe region on the bottom trace (*see* fig. 7(B)).
- (3) Put B strobe marker over B pulse, and C strobe marker over C pulse, *see* fig. 7(C). B and C pulses will not be inverted.
- (4) Switch to STB when A₁, A₂ B and C should appear within their strobes, *see* fig. 7(D).
- (5) By fine adjustment of strobe position controls, place B with its leading edge under A₁ leading edge; and C under A₂ in the same way, *see* fig. 7(E).
Note the time of the operation.
- (6) Switch to calibration, *see* fig. 7(F).
- (7) The number of the calibration pip on the B strobe vertically beneath A₁ zero pip gives the B co-ordinate, and similarly that on the C strobe vertically beneath A₂ zero pip gives the C co-ordinate. The decimal part of the fix is read on the STB.

The whole number must be obtained by reference back to MTB, *see* fig. 7(G).

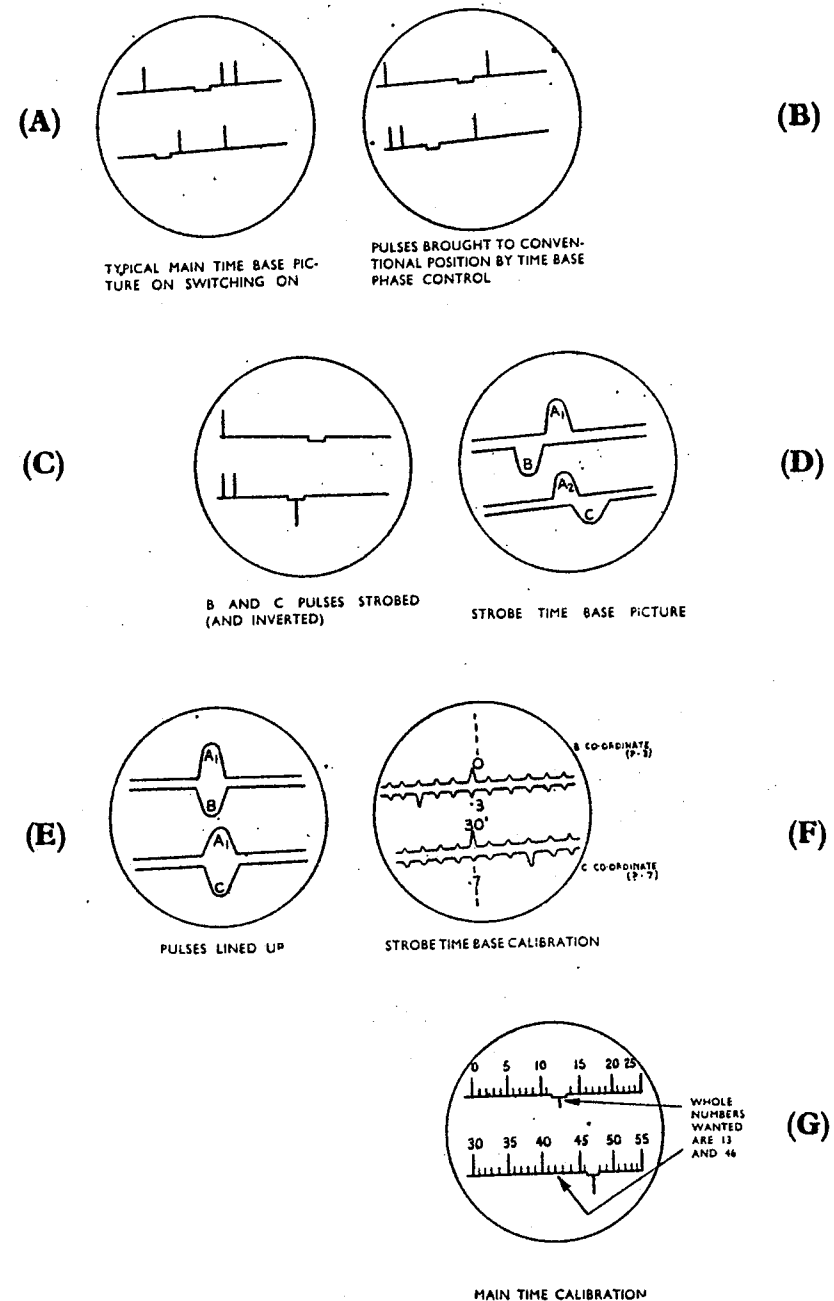


Fig. 7.—Taking a fix

58. Care must be exercised in determining the whole numbers in the fix. Sometimes the whole number wanted is the one within the strobe marker; sometimes the one to the left. The example shown gives both cases. The fix gives the position of the aircraft at the time of operation (5). It will be observed that the B co-ordinates always turn out to lie between 0 and 25, while the C co-ordinate lies between 30 and 55.

59. The maps are labelled accordingly. There is therefore no possibility of confusion of the numbers as they are transferred from tube face to the map.

60. If a fix is required from the D station, the latter can be strobed by either of the strobos. However, the numbering of the D lines on the map runs between 30 and 55. If D is strobed on the C trace, therefore, all is well. If it is strobed on the B trace, however, 30 must be added to the number obtained.

Unit details

61. Gee Mk. I (ARI 5033), comprises a receiver, type R.1324 and indicator unit, type 60. The equipment is now obsolete, being replaced by Mk. II. The general principles of the Mk. I and Mk. II aircraft equipment are the same, but Mk. II has an improved display.

62. Gee Mk. II (ARI 5083), comprises a receiver, type R.1355 and indicator unit, type 62.

Frequency. There are four frequency bands in use:—

20	—	30 Mc/s.
40	—	50 Mc/s.
50	—	65 Mc/s.
65	—	80 Mc/s.

Receivers are fitted with interchangeable RF units, one for each band; and the navigator can select one of five spot frequencies in each band.

These spot frequencies are preset on the ground.

RF units. RF stage.

Local oscillator.

Mixer.

Main receiver. 5 IF stages at 7.5 Mc/s.

Diode second detector.

VF amplifier.

Cathode follower output.

The gain control is on the indicator unit.

Supply. 80 volt, 1,600 c/s engine-driven generator.

Voltage control panel. Type 3.

Aerial. $\lambda/4$ whip aerial and matching unit into receiver.

Ground equipment

63. The master station possesses a transmitter and the associated drive equipment.

64. At a slave station it is necessary to have both a receiver, to receive locking pulses from the master, and also a transmitter to send on pulses to the aircraft. The receiver contains a monitoring section for measuring the time delay introduced at that station.

65. The display is as shown in fig. 8(A) and fig. 8(B). A main timebase with a step is used and this is calibrated with unit markers in the form of brilliance modulation. There are three strobos, their positions being indicated by brilliance markers. One of them can be positioned over the step, one along the rest of the top trace and one along the bottom trace.

66. The strobe timebase is calibrated by unit and 1/10 unit brilliance markers; there now being three strobe timebases, corresponding to the three strobe markers (this type of display was used in the airborne Mk. I equipment).

67. The slave station transmitter pulse is displayed on the tube as well as those coming from the other stations, and the equipment enables the local pulse to be sent out a fixed time after reception of the A pulses.

68. A monitor station does essentially the same thing as an aircraft observer, but since its position is known, errors at a slave station can be corrected.

Units

69. *Transmitters.* T.1348 (M.B.3 modified), or T.1356 or G.L. type transmitter.

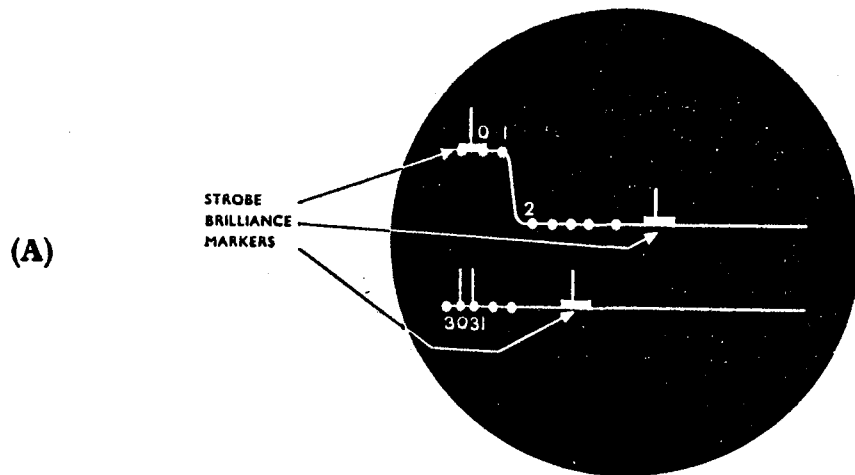
Output. 300 kW.

Oscillators. VT 58's in push-pull followed by push-pull power amplification in two VT114 A's.

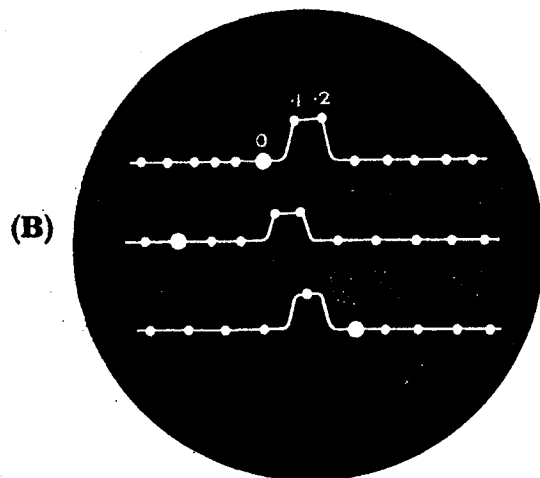
Frequency. As for aircraft equipment.

Aerials Floodlight technique. Vertically stacked dipoles with reflectors to throw main lobe forward.

(in general). Wide-band aerials now used frequently to avoid matching difficulties as frequencies are changed.



MAIN TIME BASE (SHOWING FIRST FEW CALIBRATION PIPS)



STROBE TIME BASE (WITH CALIBRATION)

Fig. 8.—Display

Receivers. R.1363 (Slave). R.1364 (Monitor).

- Aerials.*
1. Vertically stacked dipoles, beamed towards master station. (Slave normally in a side-lobe of the master) alternatively.
 2. Inverted V aerials, the plane of which contains the master station.

LORAN (LONG RANGE NAVIGATION) EQUIPMENT

General principle

70. This is the American counterpart of Gee and is based on the British equipment. The same principle of hyperbolae is used, but the ground station arrangement is somewhat different.

71. A number of ground stations are erected and they work in inter-laced pairs. Any one station acts as a slave for one of its neighbours and as a master for its other neighbour. Different master-slave pairs work on different pulse recurrence frequencies and the aircraft timebase can be run at any one of these p.r.f.'s. Thus, any one station-pair can be picked up at any one time. This will give one co-ordinate of the fix and the other must be obtained by switching to a different timebase speed. This means, of course, that only a running fix can be taken, one co-ordinate after another.

Other details

72. *Frequency.* Around 2 Mc/s.

P.R.F. Different for each pair but around 25 c/s.

Range. 600 miles using direct radiation : 1,200 miles under favourable atmospheric conditions by using waves reflected from the E-layer.

Accuracy. On the direct ray, comparable with Gee : on the reflected ray, errors approximately doubled.

The Loran aircraft equipment is made to conform in shape, size and cable connections with the Gee equipment to enable rapid interchanges to be made.

S.S. Loran

73. SS Loran is an adaptation of Loran, which is suitable for use by surface craft. For a summary of recent Marks of Gee-7000, Gee-H and Loran equipments refer to A.P.1093C, Chapter 4.

THE GEE-H SYSTEM

74. The Gee-H system implies (Gee airborne equipment with type 100 ground stations, employing the H-principle).

General principles

75. The Gee-H system applies the principle of the radar beacon to accurate blind bombing and precision navigation. Two ground beacons or transponders at the ends of a base line respond to interrogating pulses emitted by the aircraft desiring to fix its position. The beacons re-transmit pulses on another frequency, with negligible delay, to the aircraft, and these pulses are received by the Gee receiver of the aircraft and displayed on a linear timebase. The aircraft is thus able to find its range from the beacons whose positions are known and to find its own position from a range cut.

76. This system is more accurate than the Gee-7000 system and should not give an error greater than 300-400 yards at a range of 250 miles, but its aircraft handling capacity is lower, the maximum number that can be handled at one time being 50.

77. The beacons—or H-beacons (AMES, type 100) comprise a receiver R.1441 and a transmitter T.1488.

78. The aircraft equipment comprises a Gee set (slightly modified), a transmitter and modulator, and auxiliary devices. An aircraft carrying this equipment is able both to navigate by using the type 7000 ground stations (Gee-navigation) or by interrogating the AMES, type 100 ground beacons (Gee-H navigation).

79. The procedure for obtaining a Gee-H fix is very similar to that for finding a Gee fix, and again involves the lining up of pulses on the timebase of the display tube. The appearance of the Gee timebase is approximately preserved in Gee-H but the airborne transmitter is synchronised to pulse at the start of each timebase. The responses returned by the beacons appear on the timebase and the navigator notes their ranges from their positions relative to the aircraft transmitter pulse which appears at the beginning of the timebase. The technique of "lining up" and strobing is the same as that used in Gee.

80. To avoid saturating the ground beacons which would occur if the aircraft transmitted at 500 c/s, the normal recurrence rate of a Gee timebase, eight out of every 10 timebases and transmitter pulses are suppressed. The interrogating pulses are therefore emitted in pairs at the recurrence rate of 50 pairs per second.

81. To avoid mutual interference between aircraft using the same beacons, the recurrence rate is actually varied about 50 pairs per second as a mean value. Only the beacon response excited by its own transmitter then appears stationary on the timebase.

82. As it is necessary to associate the two beacon responses with their correct ground stations, one of the latter codes its responses by delaying its return periodically. The result is that the response from this ground station moves periodically a small distance to the right of its main position on the timebase of the aircraft receiver.

83. The normal Gee timebase runs for 1660 microseconds and is followed by a blackout interval of 340 microseconds before the next timebase.

84. Since a radar mile of range is equivalent to 10 microseconds of the timebase, the maximum range, if a normal Gee timebase were employed, would be 166 miles. Responses from beacons at ranges lying between 166 miles and 200 miles would fall in the blackout interval; and those from beacons at ranges greater than 200 miles, on the second timebase.

85. To permit the aircraft to receive all beacon responses up to the maximum operational range of about 360 miles, the normal Gee timebase is modified by introduction of an intricate system of switching; details will be found in the appropriate technical manuals.

86. Marks of Gee-H

Mk. I. (ARI.5525) is an interim airborne equipment.

Mk. II. (ARI.5597). Includes a high-power transmitter (type T1629) and a redesigned indicator unit (type 166) which affords Rebecca and BABS facilities.

ARI.5611 is a combination of Gee-H Mk. II and Rebecca Mk. II U.

87. Gee-H ground installations

AMES, type 100 is a heavy ground beacon equipment but mobile forms exist.

AMES, type 100—*Light transportable*, is a combination of types 100 and 7000 equipment which can provide both a Gee and a Gee-H service to aircraft. It is designed to be transportable by van or by air and is tropicalised.

Three ground stations form a normal Gee chain and any two of the three can function as a pair of Gee-H beacons.

A common transmitter is shared between the type 700 and type 100 equipment at a ground station.

The equipment provides close range support in army co-operation with Gee for navigation and Gee-H for blind bombing.

For special tasks the equipment may be resolved into separate type 7000 and type 100 stations.

SHORAN

88. *Shoran*—(Short Range Navigation), is an American blind-bombing equipment using the H principle.

AN/CPN-2 is the ground equipment.

AN/APN-3 is the airborne equipment. Radar information is automatically fed to computers which control the aircraft and release the bombs.

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