ARNOLD 63A.

A.M.E.S. TYPE 7000 - (Ground Gee)

PURPOSE

A.M.E.S. Type 7000 or Ground Gee, is a Radio Navigational Aid, by which an aircraft or ship (fitted with a Gee receiver) can find its position (i.e. obtain a fix) in the area served by the system.

It is NOT a radar equipment, as it does NOT employ the 'echo' principle.

PRINCIPLE

The system depends for its action upon:-

(i) Generation of pulses of E.M. waves, by ground transmitters, which are sent out at carefully controlled intervals, travelling at a constant speed.

(ii) Reception of these pulses by aircraft receiver, and measuring the time elapsing between arrival of the pulses from the various ground stations.

Position Lines from two ground stations

Master and one Slave

Consider two ground stations; one a Master station called A, and one a Slave called B. Station A transmits pulses at regular intervals and station B acts as a slave or repeater, transmitting a pulse as soon as it receives one from station A. Stations are 50 miles apart.

Display on Aircraft receiver.

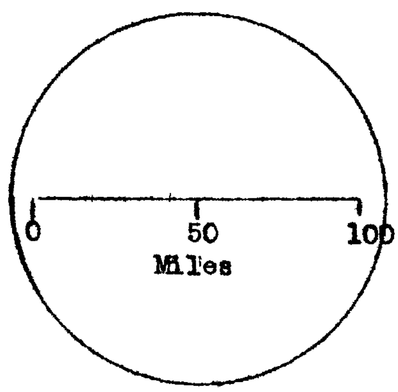
In an aircraft, assume there is a receiver with;

(i) Its output connected to Y1 of a CRT.

(ii) Time base connected to X1, and triggered by a pulse from A.

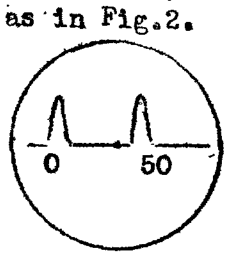
(iii) Time base sweep adjusted, so that spot travels across the tube in the Time taken for pulse to travel 100 miles, and CRT calibrated 0 - 100 miles as in Fig.1

Fig.1
Scale marking on Aircraft CRT.



If the aircraft is equidistant from A and B stations, navigator or operator will see pulses spaced 50 miles apart as in Fig.2.

Fig.2



The effect at the aircraft is the same as if two pulses were sent from A station, ONE DIRECT FROM A TO AC and the other from A to B to aircraft. (see Fig.3)

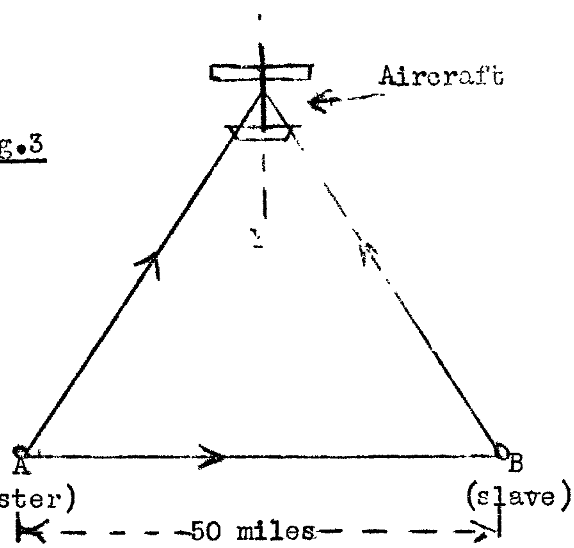
The second pulse on the tube has had to travel 50 miles further than first pulse.

N.B. Aircraft display measures time difference between pulses and not range from the stations.

Pulse spacing will remain the same, i.e. 50 miles, anywhere along XY, the perpendicular bisector of the line joining AB.

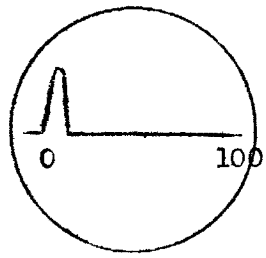
A particular reading on the aircraft CRT is therefore said to place the aircraft on a Position Line.

Fig.3



The appearance of the aircraft trace, with aircraft at extreme positions is shown in Fig.4

Fig.4
Two pulses superimposed (showing as one)



Pulses are superimposed when aircraft is anywhere on extension of line joining Master to Slave : because the direct distance of A to aircraft is same as from A to B to aircraft. (see also Fig.5

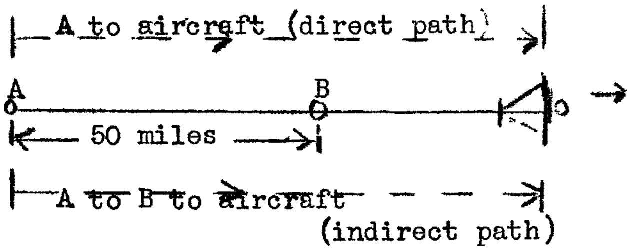


Fig.5

Now when the aircraft is flying anywhere on a line joining Slave to Master, pulses will be spaced twice AB = 100 miles, because the indirect path is greater than direct path by twice AB. (see figs.6 & 7)

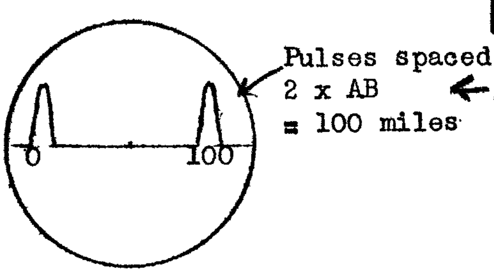


Fig.6

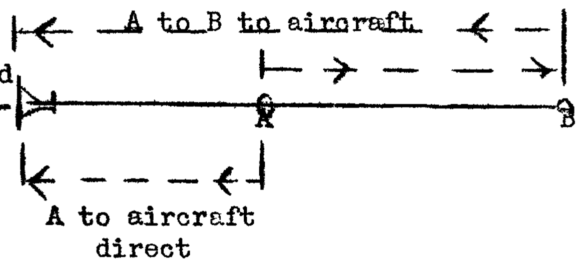


Fig 7.

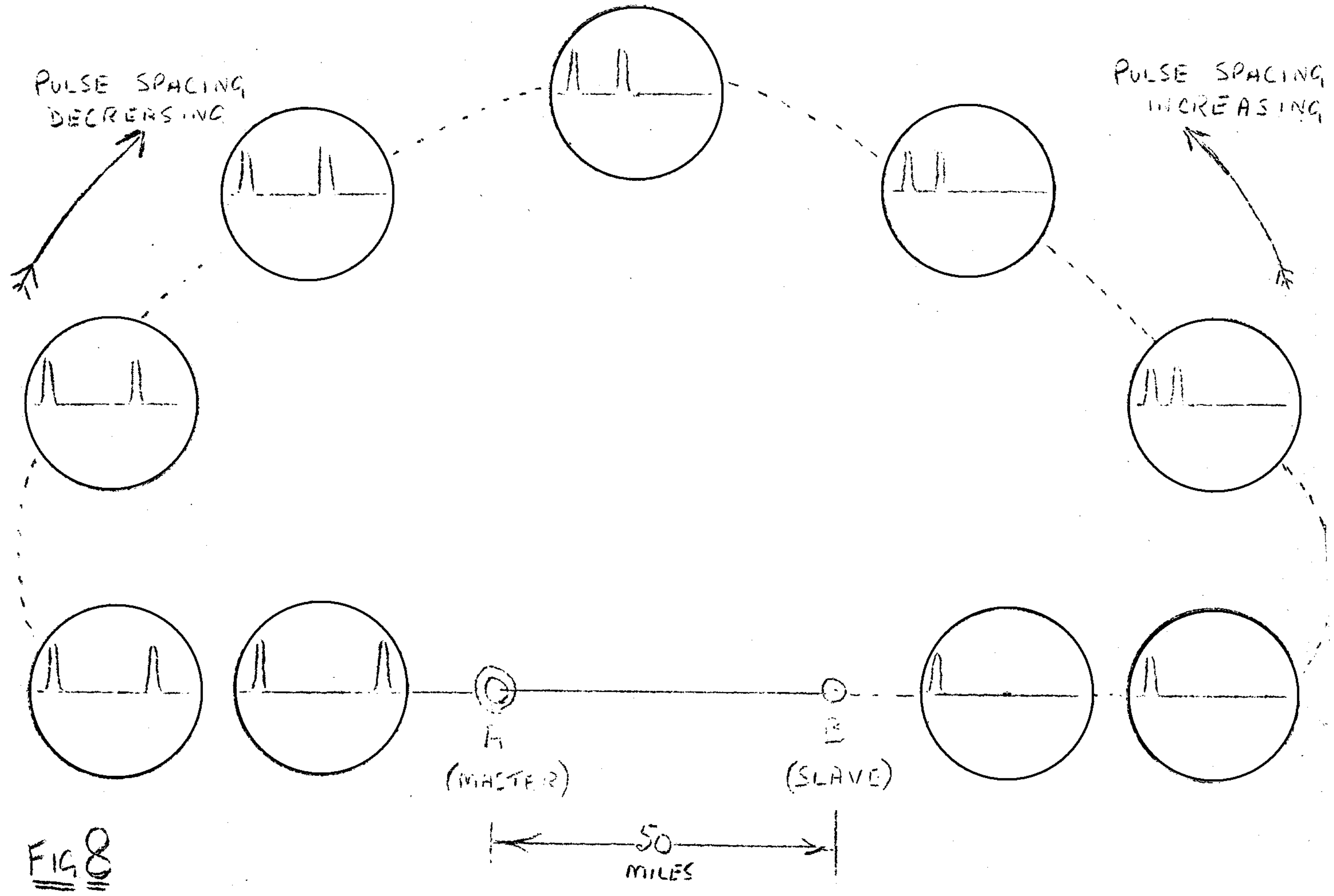
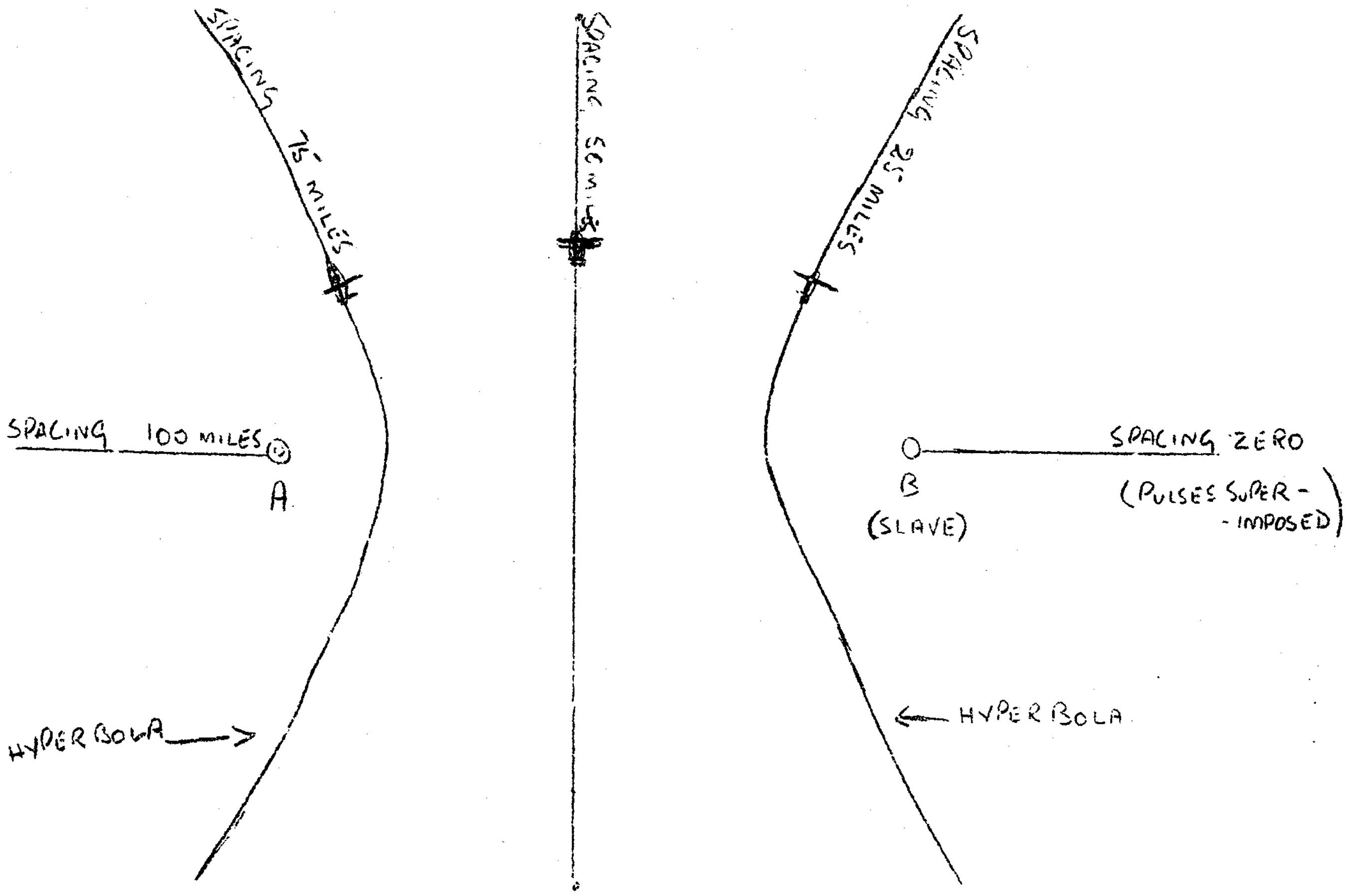

PULSE SPACING DECREASING
PULSE SPACING INCREASING
A
(MASTER)
B
(SLAVE)
50
MILES

FIG 8


SPACING 75 MILES
SPACING 50 MILES
SPACING 25 MILES
SPACING 100 MILES
A
B
(SLAVE)
SPACING ZERO
(PULSES SUPER-IMPOSED)
HYPERBOLA
HYPERBOLA

Movement of pulses on aircraft CRT

The two transmitting stations, Master 'A' and Slave 'B', comprise a simple GEE "CHAIN"

Now, if our aircraft flies through the coverage of the chain, making a D-shaped track, the navigator will see the pulse spacing vary as shown in Fig.8.

Notice that:-

(i) When the aircraft is flying near the two extreme positions on the line joining A and B, the rate at which the pulse spacing alters is extremely small, compared with the rate at which it changes at other points. This means that the accuracy of the system gradually decreases at these two positions.

(ii) For both pulses to be visible, the distance between Master and Slave must not exceed half the CRT trace length calibrated in miles.

Reference will be made to these two observations later

Position Lines giving constant Pulse-spacing.

It will be recalled that when the aircraft was flying on a line equidistant from A and B stations, a constant 50 mile pulse spacing was obtained, at any point on this line (within the coverage of the chain). Now this line was a straight line.

Similarly, at the two extreme positions, constant pulse-spacings were obtained. (see Figs. 2 to 7)

To obtain constant pulse-spacings on the CRT of, say 75 miles or 25 miles, the aircraft would have to fly on a curve, as shown in Fig.9. This curve is known as a HYPERBOLA

Definition

An HYPERBOLA is the locus of points whose difference in distance from two fixed points (e.g. A and B) is constant.

Hence when the aircraft is not equidistant from A and B stations, the line of constant pulse spacing is always a Hyperbola, because it is the line joining points having a constant difference in path length from A and B.

A straight line will only give constant spacing in the three instances mentinned previously, viz:- 50, 100, and 0 miles spacing on the CRT.

Fixes from Two Position Lines

Master and Two Slaves

In our simple system previously described (i.e. Master and one Slave), it was only possible to "place" our aircraft on a position line.

In order to obtain a fix, two sets of position lines, which will cross, are necessary. This entails having a Master and two Slaves.

GEE Chains

Such a system is called a GEE Chain. Referring to Fig.10, we have three transmitter stations, A - Master, and B and C - slaves; the position lines between A and B stations are called A - B position lines (or hyperbolae), and similarly those between A and C are known as A - C position lines (or hyperbolae)

Now in the aircraft, the operator will see three pulses on the CRT trace; one at the extreme left, looked to trace (Apulse), and two others (B and C pulses), which move along the trace, depending on where the aircraft is flying. See Fig.11.

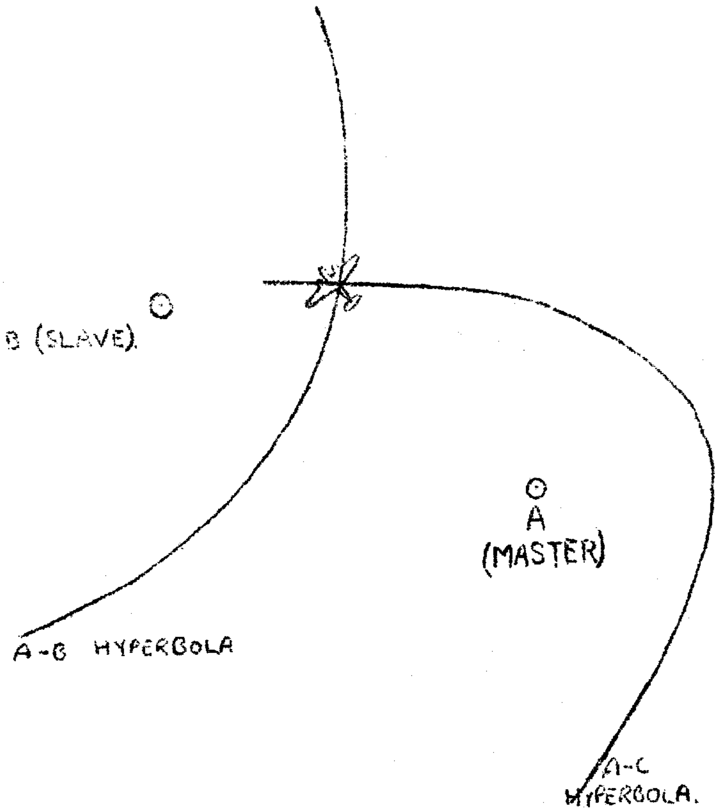


FIG 10

FIX FROM TWO POSITION LINES

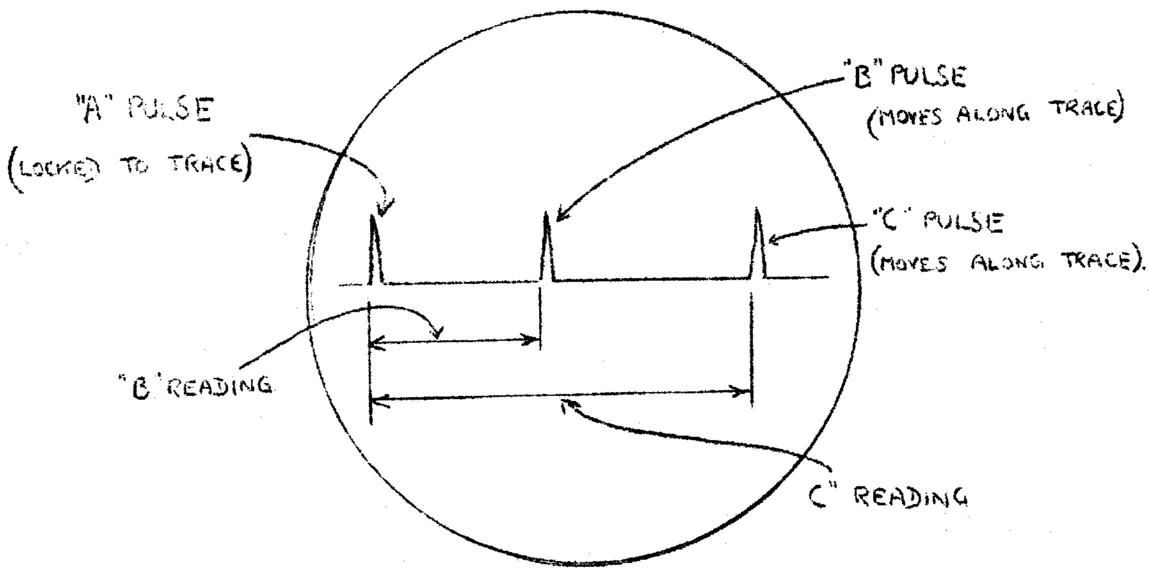


FIG 11.

APPEARANCE OF PULSES ON A/C C.R.T. USING SIMPLE CHAIN COMPRISING A MASTER AND TWO SLAVES.

Taking a FIX

It is now intended to give a simple explanation of how a navigator obtains a fix using GEE.

Referring again to Fig.11, the distance between A and B pulses on the CRT trace is called the 'B reading', and that between A and C pulses the 'C reading'.

Recalling also the fact that our hyperbolae are loci of points of constant time-difference, we can draw on a map, 'families' of hyperbolae between A and B stations, and A and C stations. Each hyperbola is numberedin a manner to be described later.

Now a given B reading will correspond to a particular A - B hyperbola, and a given C reading to a particular A - C hyperbola.

To take a fix, the navigator simply looks at his CRT, carefully noting time and the B and C readings, and looks for the corresponding A - B and A - C hyperbolae on his map. Where the two lines cross, will be the position of the aircraft, at the time the readings were taken

AMBIGUITY

Unfortunately, a simple chain using Master and two slaves may give two possible positions of the aircraft, i.e. ambiguity.

This is because A - B and A - C hyperbolae cross at two points, e.g. Fig.12, points F1 and F2.

NECESSITY FOR 'D' SLAVE

This necessitates the use of a third slave station, known as the 'D' slave

Thus 'D' slaves are employed:-

(i) To resolve all possible ambiguities
(ii) To increase coverof chain.

TYPE 7000 CHAINS - 'Star chains

From the foregoing it will be seen that a Type 7000 GEE Chain will comprise four stations, viz- Master A, and B, C and D slaves. These stations are normally arranged in a Star-shaped manner, with the Master station at the centre (Fig.13) and are knoen as STAR CHAINS.

MONITOR STATION

In addition, a Star chain has a monitor station, situated fairly centrally in the chain. This is a receiving station only, and its purpose is to :-

(i) Inspect pulses from all stations of the chain
(ii) Check frequencies.
(iii) Check phasings.

thus deriving maximum accuracy and reliability from the system.

PRINCIPAL LINE OF SHOOT.

Each type 7000 chain is designed to cover a certain geographical area, in which reliable Gee fixes may be obtained, e.g. Eastern Chain, eastern counties and North Sea area.

Hence radiation from stations is so arranged to have a "principal line of shoot".

PHASING FIGURES (Delays)

When discussing the simple Gee Chain using Master and one Slave, it was stated that the Slave transmitter was caused to emit a pulse immediately on reception of a pulse from the Master station.

In practice, this is not so, because when the aircraft flies over the slave station the two pulses will appear superimposed (Figs.4 & 5).

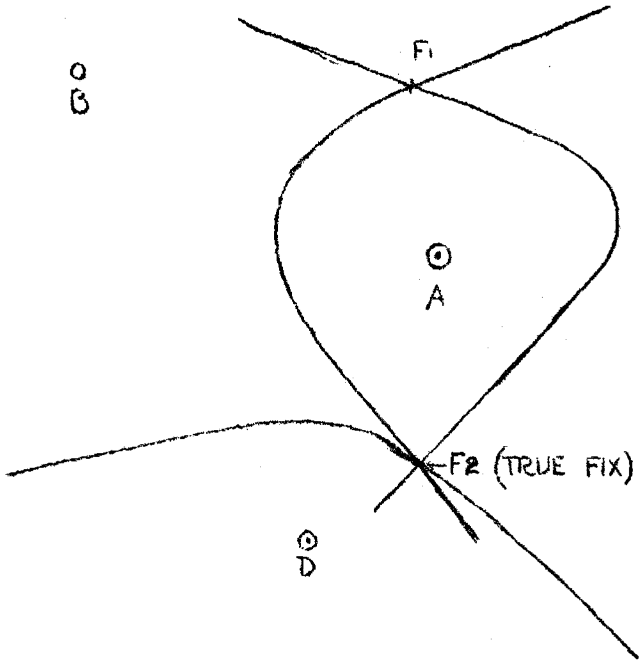
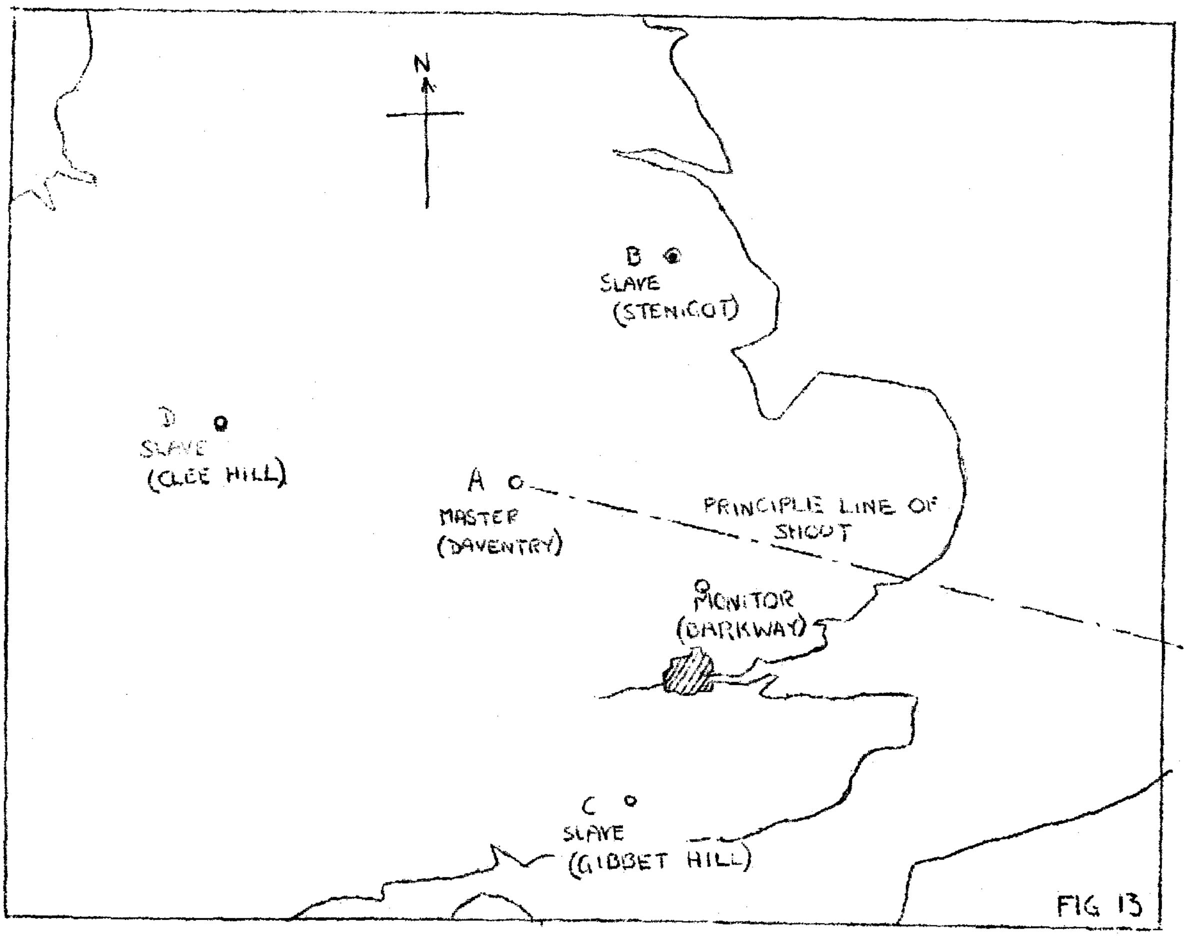


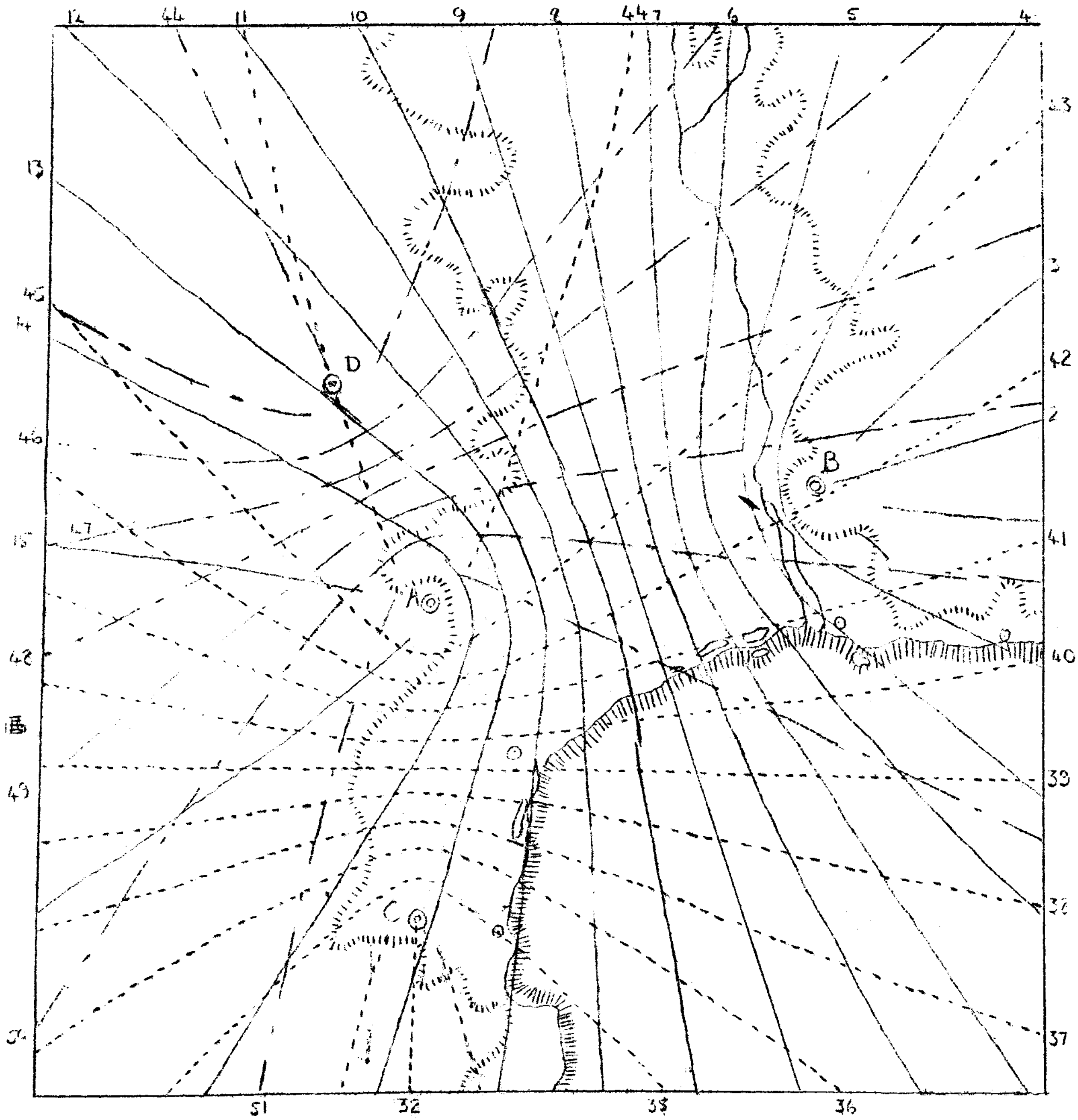
FIG 12

RESOLUTION OF AMBIGUITY BY USE OF A "D" SLAVE.



TYPICAL TYPE 7000 (GEE) CHAIN

– EASTERN CHAIN



LATTICE CHART FOR A TYPICAL TYPE 7000 4-STATION CHAIN.

LEGEND

A TO B LINES – RED.

A TO C LINES – GREEEN

A TO D LINES – PURPLE

Hence a time delay is introduced at the Slave station, so that the Slave transmitter fires at a pre-determined interval of time after the Slave has received the Master station pulse.

The "amount" of time delay (measured in Gee Units - to be defined later), introduced at the slave station, is known as the PHASING FIGURE of that slave station.

Standard phasing figures as used in Type 7000 chains, for B, C, and D slaves, are as follows:-

B Slave .... 2 Gee Units
C Slave ....32 " "
D Slave ....44 " "

THE GEE UNIT - Derivation.

The unit of time used in the Gee system is called the GEE UNIT, and is equal to 66 2/3 MICROSECONDS

This unit (often abbreviated to G.U.) is derived in the following manner:-

The basis of the whole Gee system, in both air and ground equipments, is the Timing Oscillator, which is of crystal type, and oscillates at 150 Kcs.

(i) 150 Kcs oscillator generates Calibration Pips
(ii) Oscillator maintained in oscillation by 'A' pulse every 1/500th secs (i.e. PRF of 'A' pulse = 500)
(iii) One G.U. is taken to be the spacing between 10 Cal. Pips. This is decided arbitrarily.
(iv) One G.U. therefore equals 1/15,000 secs. - Or 1 G.U. equals 66 2/3 microsecs.

NOTE 66 2/3 microsecs is the time taken for an E.M. pulse to travel 12.4 miles (20 Km) Speed of light = 186,240 miles per second.

FURTHER DATA ON TYPE 7000 CHAINS

Frequency Band used .. .. 20 - 80 Mcs.
P.R.F.'s of stations.

'A'	500 P.P.S.
'B'	250 "
'C'	250 "
'D'	166 2/3 P.P.S.

Distance between Master and Slaves.

A to B	70 - 140 Miles. Max
A to C	70 - 140 " Max
A to D	68 Miles Max.

Appearance of pulses on aircraft CRT when receiving type 7000 Chain

The manner in which pulses appear on the aircraft CRT, is shown in Fig.14.

Referring to Fig.14, notice the following important points:-

(i) Aircraft trace is split into two parts, as CRT not large enough to accomodate all pulses on one trace. Splitting effected by applying a square wave to Y 2. plate at 250 c/s. Trace sawtooth PRF = 500 c/s.
(ii) 'A' pulse appears on top and bottom traces, as its PRF = 500 c/s This pulse is placed at extreme left-hand end of traces, by navigator, so that it will remain locked there, when a fix is being taken.
(iii) A faint 'ident' or 'ghost' pulse known as 'A' ghost is radiated after every fourth 'A' pulse, so that it appears on bottom trace only. This is for chain identification

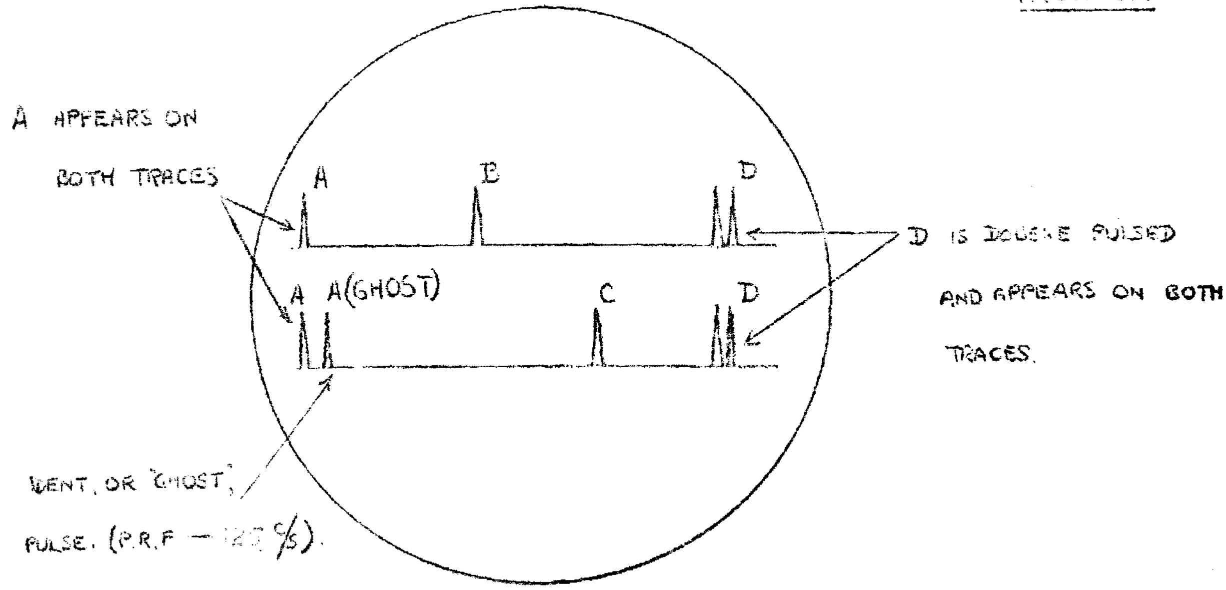


FIG 14.

TYPICAL AIRCRAFT TRACE, SHEWING ORDER IN WHICH PULSES APPEAR.

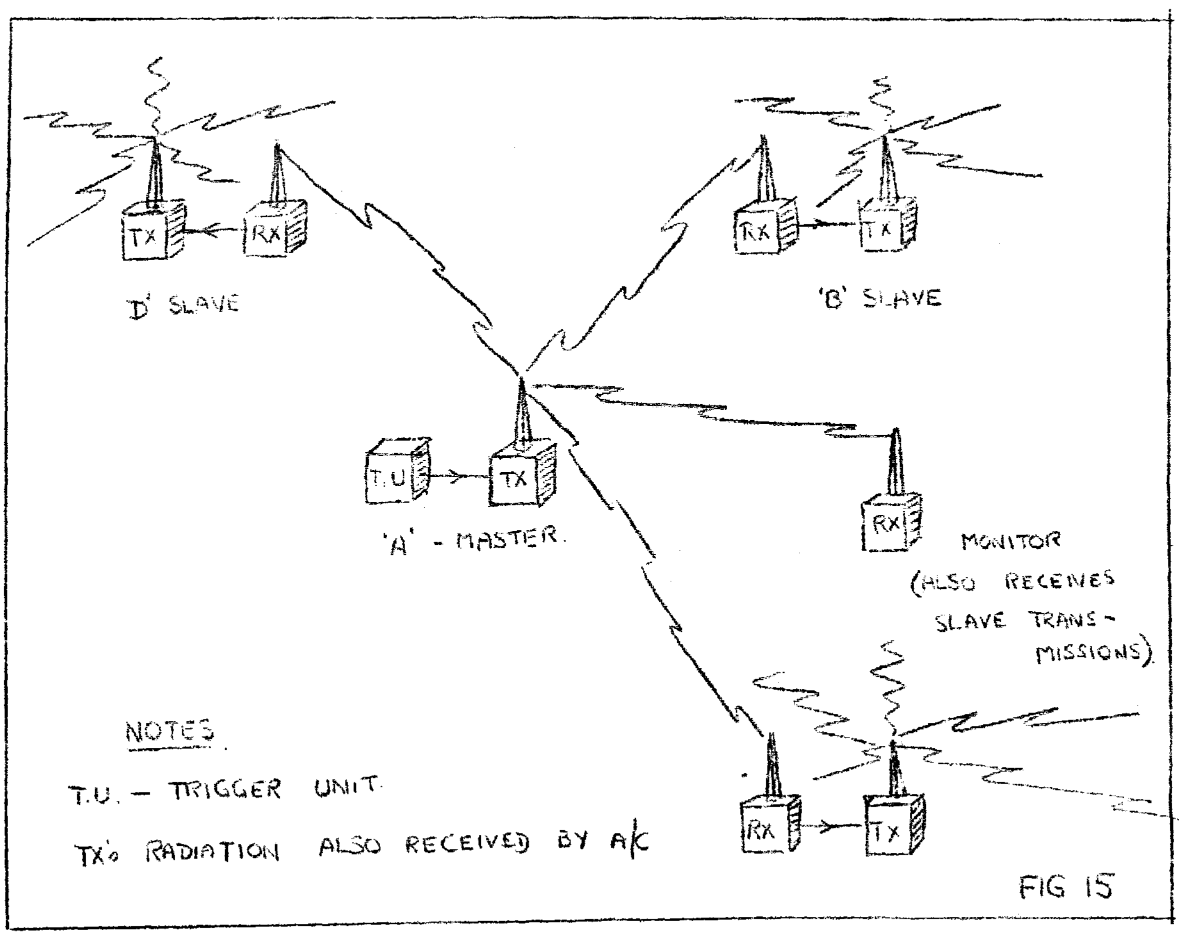


FIG 15

ARRANGEMENT OF EQUIPMENT ON T.7000 STATIONS.

(iv) The 'D' pulse appears on top and bottom traces, because its P.R.F. = 166 2/3 c/s, and hence will "Paint"on every THIRD trace. The 'D' pulse is also 'doubled-pulsed', in order to give positive station identification.

(v) Notice also that, A, B, and C pulses 'break' the trace; due to their P.R.F's, 500, 250, 250 respectively.
The 'A' ghost, and D pulses do not break the trace, their P.R.F's being 125 and 166 2/3 respectively, and the intervening traces cause the bottom of pulses to appear "closed"

(vi) The spacing between 'A' and 'A' ghost pulses is approx 1 G.U., and between the double 'D' pulses approx. 0.2 G.U.

IDENTIFYING A GEE CHAIN

The navigator in an aircraft identifies a particular Gee chain by observing the following:-

(i) Number of times 'A' ghost blinks in one minute. (The 'A' ghost is suppressed or 'blinked' from 1 to 6 times in one minute, according to a code laid down in C.C.O's)

(ii) All stations of a particular chain work on the same frequency.

IDENTIFYING STATIONS OF A GEE CHAIN

The stations are identified by positions taken up on traces, after navigator has set 'A' pulse at extreme left hand end of trace (See Fig.14)

(i) 'B' pulse always follows single 'A' pulse (on top trace which is known as 'B' trace)

(ii) 'C' pulse always follows A'A and 'A' ghost (on bottom trace, known as 'C' trace)

(iii) 'D' pulses appear on 'B' and 'C' traces, one following 'B' pulse, the other following 'C' pulse.

LATTICE CHARTS

As mentioned previously, lattice charts are families of hyperbolae, plotted between 'A' to 'B', 'A' to 'C', and 'A' to 'D' stations, on a topographical map.

The hyperbolae, which in Gee practice are called lattice lines, are coloured as follows:-

A to B - RED (Blood red)
A to C - Green (Sea green)
A to D - Purple (Deep purple)

NUMBERING OF LATTICE LINES

Lattice lines are numbered from Slave to Master, the first line being numbered 2 in the case of A - B lines, 32 for A - C lines, and 44 for A - D lines (i.e. these figures are the same as the phasing figures of the Slaves.)

General note on Type 7000 (Ground Gee) equipments.

From now onwards, no further mention will be made of Airborne Gee equipment. For further information, technicians are referred to AP.2556 Gee MkII - Manual of instruction.

Referring to Fig.15, it will be seen that equipment used at stations is as follows:-

Master 'A' - Trigger Unit which triggers Transmitter
Slave 'B' - Receiver " " "
Slave 'C' - Receiver " " "
Slave 'D' - Receiver " " "
Monitor station - Monitor Receiver(s) only.

(It must be realised of course, that, standby transmitters and receivers are also installed at stations).

The main purpose of receivers at Slave stations is to receive the Master 'A' pulse, and convert it into a suitable triggering pulse, for the Slave TX, and at the same time introduce the necessary time delay.

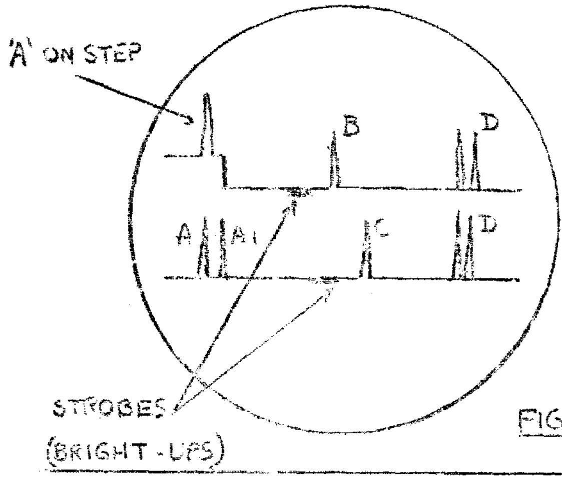
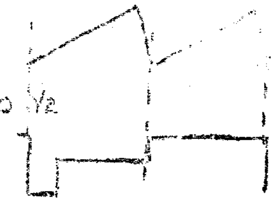


FIG 16

STEP BROUGHT ABOUT THUS :-

500 c/s S/T TO X + X1

250 c/s STEP W/F TO Y2



NORMAL 7K GROUND STATION TRACE

ARRANGEMENT OF TRACES, FLYBACKS AND MAJOR MARKERS

27-28 1ST FLYBACK.

57-58 2ND "

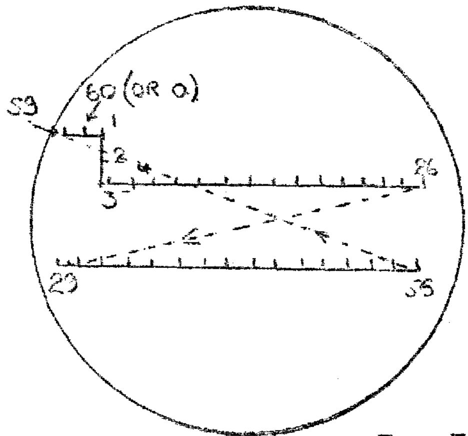


FIG 17.

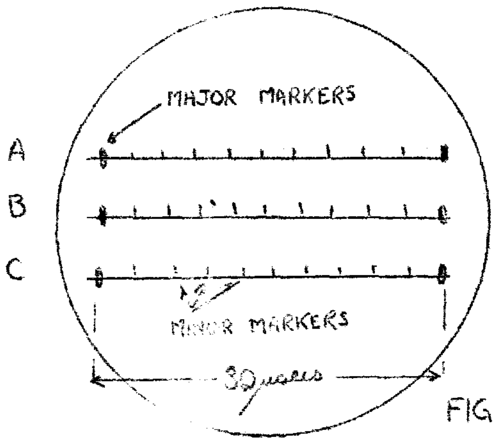


FIG 18.

STROBE TIME-BASES (3 TRACES).

MAJOR MARKERS = 1. G.U. = $66\frac{2}{3}$ μsecs.
(BRIGHT-UPS) = 15 Kc/s.

MINOR MARKERS = $\frac{1}{10}$ G.U = $6\frac{2}{3}$ μsecs
(BRIGHT-UPS) = 150 Kc/s.

HIGH SPEED TIME BASE

WITH 1·5 Mc/s SINE WAVES, USING PHASE SHIFTER V AND SINE WAVE. IT IS POSSIBLE TO GET ACCURACY OF ·001 G. U.

= 0·06 μsecs.

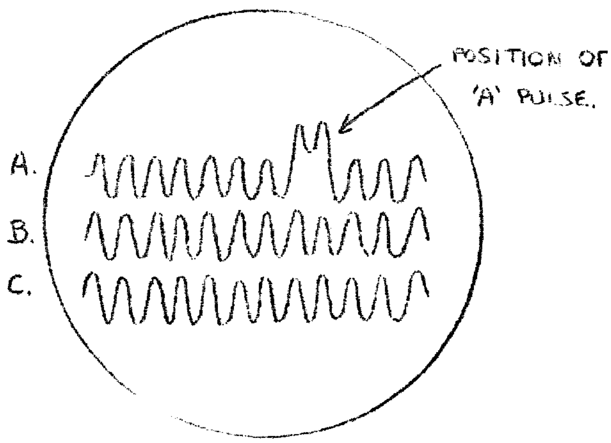


FIG 19.

TYPE 7000 GROUND RECEIVER DISPLAYS

The displays as seen on a slave or monitor Receiver, are depicted in Figs.16 - 19.

Again, a split trace is employed on Main timebase position, but the top trace is stepped, the top portion of the "step" being called the 'A' trace.

This is done, so that on 'strobe' and 'high-speed strobe' positions, three traces will be produced.

TRACE LENGTH AND FLYBACKS - Main Timebase.

On a ground Gee receiver CRT, the length of traces and flybacks are as follows:-

Whole Trace = 60 G.U. long (equal to 4000 microseconds)

Flybacks = 2 X 3 G.U.
= 6 .GU. (these are blacked out)

Top and Bottom Traces = $\frac{60 - 6}{2}$ G.U. each
= 27 G.U. each

CALIBRATION MARKERS

In fig.17, calibration markers known as 'Major' markers are shown. These have a frequency of 15Kc/s, and hence the space between two markers is 1 G.U.

It is important to notice the numbering of markers as shown in Fig.17.

'Minor' markers at 150 Kc/s representing 0.1 G.U., are provided for use on Strobe Timebase - Fig.18. On 'high-Speed' timebase, 1.5 Mc/s sine wave calibration is used, the 'troughs of the sine waves representing 0.01 G.U. Fig.19.

Using a calibrated Phase-shifter (P.S. V), in conjunction with these sine waves, an accuracy of 0.001 G.U. may be obtained when setting up pulses.

This concludes the section on 'Gee Principles'. For further information, technicians should consult the undermentioned Air Publications:-

A.P.2557V	The GEE System Manual
A.P.2556M	AMES Type 7000 Ground GEE equipment. Section 1 Chap.1
A.P.2557A	GEE Mkll Airborne Equipment A.R.I.5083
A.P.1234	Manual of Air Navigation

The remaining sections of these notes will deal with the following equipments:-

Receiver R1363B A basic type of Slave Receiver

Transmitter T1365 A basic type of Slave or Master Transmitter.

Rack 46 and Rack 29 Master Station Triggering Equipment.

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