

THE DECTRA SYSTEM for LONG-RANGE AIR NAVIGATION

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SUMMARY

DECTRA is a radio position-fixing system designed to cover specific air route segments and, in particular, long trans-ocean crossings. The system is based largely on existing Decca Navigator technique and a considerable proportion of the airborne installation is common to both systems. Similarly the DECTRA ground stations can be made integral with those of suitably-disposed conventional Decca Navigator chains. DECTRA comprises Master-Slave pairs of transmitting stations at each end of the route covered and a receiver in each aircraft. Each pair of stations provides a tracking facility while a combination of the transmissions from one station of each pair with a special oscillator in the aircraft receiver provides a ranging facility giving the aircraft's location along the track. A ranging accuracy of 10 miles or better by night and day is predicted for the full length of a North Atlantic route; the accuracy of tracking is estimated at 5 over most of the route length, rising to a very high order as the terminals are approached. The transmitted frequencies are in the Decca Navigator band (70/130 kc/s) and the DECTRA information can be presented pictorially on the Decca Flight Log.

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**THE DECTRA SYSTEM
FOR
LONG RANGE AIR NAVIGATION**

1. INTRODUCTION

With the growth of air transport over the years, and particularly since the end of the last war, the requirement for an effective long range navigational aid has steadily become more pressing. The introduction of jet-powered aircraft has emphasised this need and there can be little doubt that the provision of such an aid is essential if those aircraft are to operate at their maximum economic efficiency.

The long range aids which are currently in operation fall far short of meeting the overall requirement. This is because they suffer from one or more of the following handicaps:-

- (a) They are not sufficiently accurate,
- (b) Their accuracy is at its lowest in those areas where the need for high accuracy is greatest,
- (c) The method by which the information derived from them is presented in the aircraft is such that instantaneous position fixing is impossible,
- (d) In some cases, position fixing can only be accomplished by the separate derivation of information from two ground installations,
- (e) Manipulation of the airborne receiver must be done by a member of the crew other than the pilot.

2. THE OPERATIONAL REQUIREMENT

It follows therefore that the development of a new long range navigational aid should be made with the object of meeting the existing and likely-future operational needs as fully as possible. These may be broadly stated in the following terms:-

- (a) The system should have a range such that it affords accurate coverage over any route even if that route comprises long trans-oceanic crossings.
- (b) The system should have an intrinsic accuracy such that lateral track separation can safely be maintained by user aircraft.
- (c) The information derived from the system should be displayed, preferably pictorially, in the cockpit so that it is continually and immediately accessible to the pilot.
- (d) The accuracy of the system should not decrease in those areas where high traffic density can be expected.

The above factors form the basis of the operational requirement; from them may stem a number of subsidiary factors which are important in their own right and which have also to be borne in mind in the development of the new system.

3. THE DECTRA SYSTEM

The Decca Navigator Company Limited has proposed the DECTRA system to meet the overall operational requirement for a long range air navigational aid primarily for Trunk Route Operation, and a technical description of that system is given in the Appendix to this paper. The accompanying drawing shows the siting plan for a North Atlantic DECTRA chain.

3.1 ACCURACY

Complete fixing cover can be provided over a trans-oceanic route by positioning a Master and associated Slave station at either end of that route. Research indicates that the tracking error should not exceed 5 miles on a route length of 1600 miles, the error at greater ranges increasing directly with the increase in route length, and that the ranging error will not be greater than 5-10 miles, throughout the significant coverage. These predicted figures take into account the results of a detailed practical investigation into the reception of existing Decca Navigator transmissions at long ranges.

3.2 PRESENTATION

A Flight Log, mounted in the cockpit, may be used for presentation; on this the ranging information will be displayed on a suitably-scaled chart and tracking will be shown on a scale variable in steps from 2 miles to the inch, in terminal areas, to 40 miles to the inch at mid-route. Normally one chart will be sufficient for a particular route so that no in-flight re-setting will be required.

Alternatively, meter presentation only can be provided in those cases where it is desired to use the system primarily as tracking facility.

3.3 AIRBORNE EQUIPMENT

The weight of the airborne equipment will be dependent upon the precise function required of the system. If the requirement is for DECTRA alone, with meter presentation, the weight will be of the order of 70 lbs; the addition of the Flight Log will increase this by 55-60 lbs.

Further, it is possible to provide a combined airborne receiver capable of operation on both DECTRA and standard DECCA systems. Such a receiver would weigh approximately 20 lbs. more than the basic DECTRA airborne equipment.

3.4 ECONOMICS

In relation to the service it provides and the consequent increased operating efficiency of the aircraft using it, the DECTRA system is not expensive. The cost of the ground installation, for example, compares most favourably with existing long range navigational aids whose use is limited by one, or a combination, of the factors outlined in paragraph 2 of this paper.

Full details of DECTRA costings may be obtained from the Decca Navigator Company Limited.

4. CONCLUSION

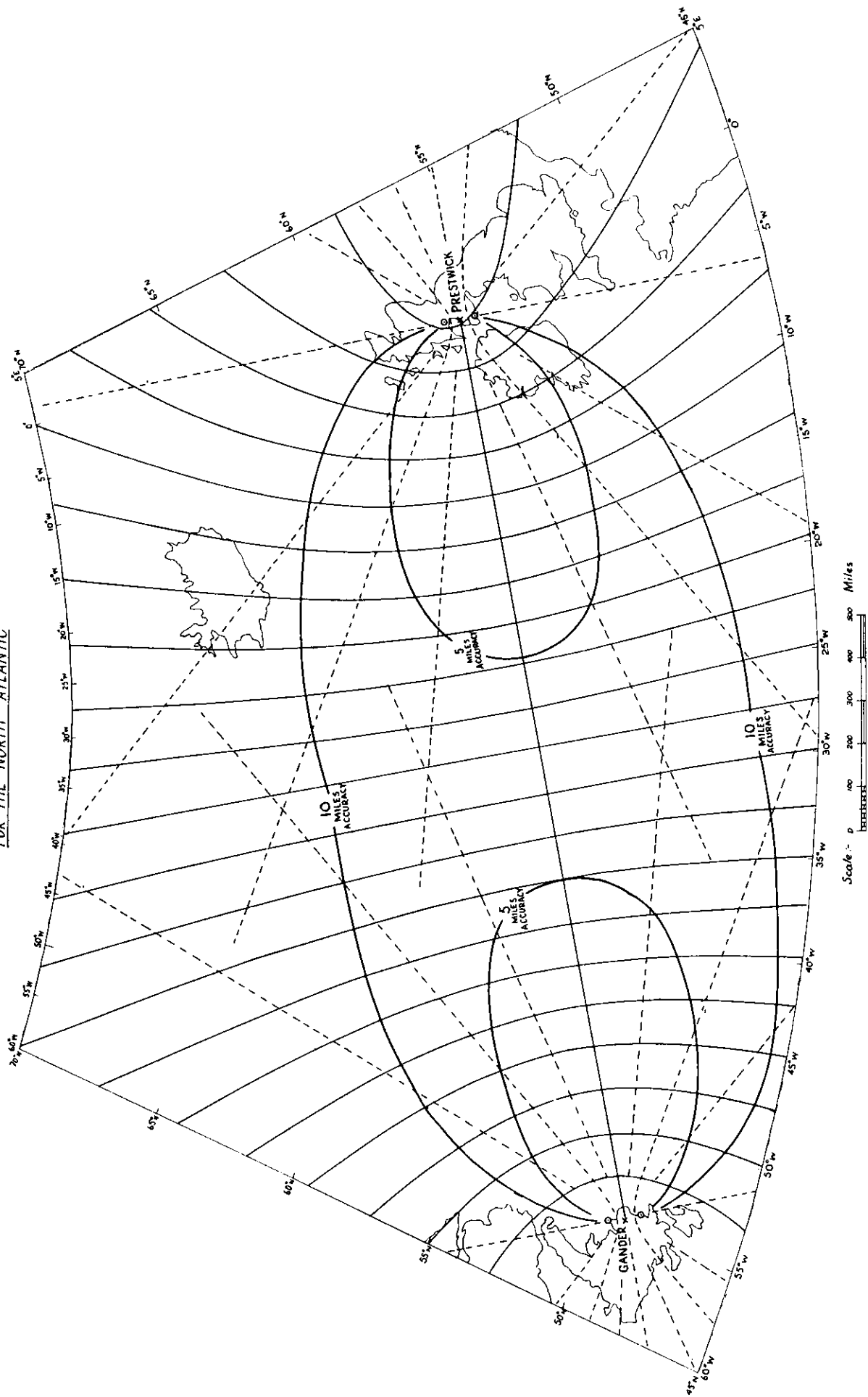
The DECTRA system fully meets the immediate operational requirements for a Long Range Air Navigational aid and, in so doing is considerably in advance of any system now under development.

DECTRA ground and air equipments can be available within nine months of ordering.

The Decca Navigator Company Limited,
1-3, Brixton Road,
London, S.W.9.

February, 1955.

DECTRA PLAN
FOR THE NORTH ATLANTIC



Scale: 0 100 200 300 400 Miles

Approximately every 10 lanes of Tracking Patterns are shown
and every 100 lanes of Ranging Pattern.

March 1954

Drq. No. M.247

APPENDIX

PRINCIPLES OF THE DECTRA SYSTEM

1. GROUND STATION LAYOUT

The diagram below shows the two pairs of DECTRA stations AB, CD at the route terminals, disposed so that the route forms the perpendicular bisector of the interstation baselines. The baselines are assumed to be about 80 miles long and the route between them 1500-2000 miles.

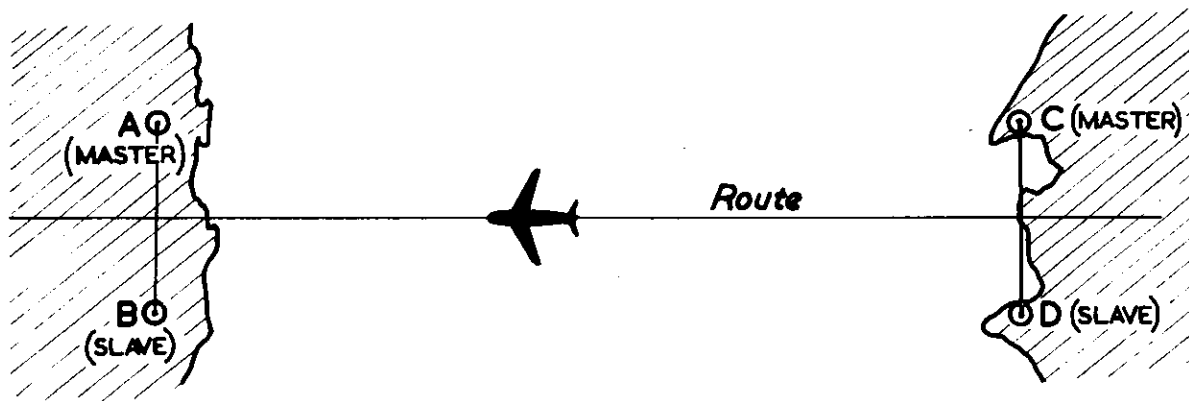


Fig. 1. DECTRA station layout.

2. TRANSMISSIONS AND TIME-SHARING SEQUENCE

2.1. TRACKING

Station A transmits a stable c.w. frequency F_1 in the same manner as a conventional Decca master. According to a suitable time schedule, its frequency is changed momentarily to $F_1 + \Delta$ as a signal to its slave station B and to the airborne receivers (as in normal Lane Identification signalling). After a delay of some fraction of a second, station A shuts down momentarily while the slave B radiates the same frequency F_1 before closing down in turn. As soon as B has closed down, station A resumes its c.w. signals as before and one cycle is completed. Thus the same frequency F_1 is radiated successively from A and B; assuming that the two signals are phase-synchronized, which is ensured by a stable oscillator at B which "remembers" the phase of the master signal during the interruptions of the transmission from A, a stable hyperbolic pattern will exist around the stations AB at the comparison frequency F_1 . As shown below, this is the tracking pattern for the AB terminal of the route; a similar process at stations C and D, using frequency F_2 , provides the tracking pattern from the other end of the route as in Fig. 2.

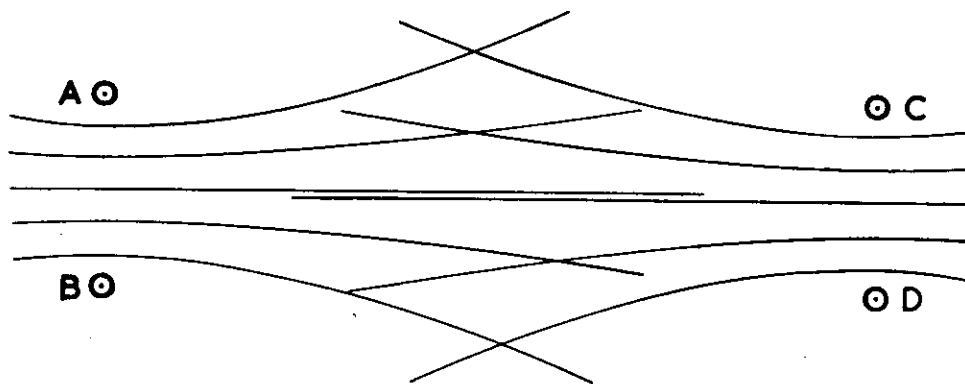


Fig. 2. Form of the TRACKING patterns produced by stations AB on frequency F_1 and CD on F_2 .

2.2. RANGING

The frequencies F_1 and F_2 are spaced by a difference frequency $F_1 - F_2 = f$ which is a sub-multiple of each. The phase of the F_2 transmission from station C is arranged at that station to have a fixed relationship to the F_1 signal received from A at the common comparison frequency f ; that is to say, the beat-note $F_1 - F_2$ as observed at C is in phase with the frequency f subharmonic of the received F_1 signal. As described below, there then exists a hyperbolic pattern about A and C whose lanewidth corresponds to frequency F_2 .

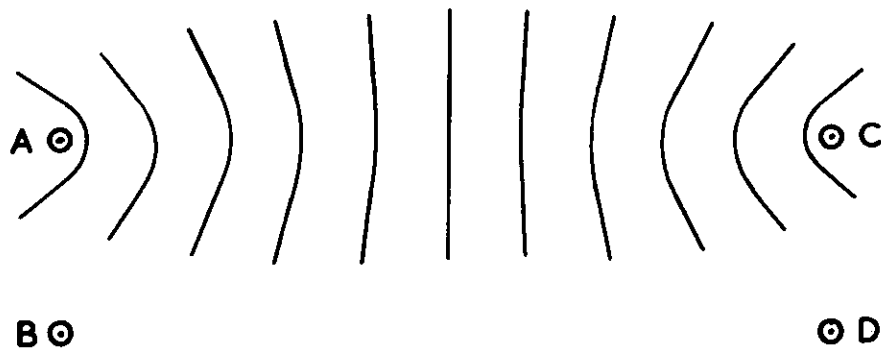


Fig.3. Form of the RANGING pattern about stations A and C (effective comparison frequency F_2).

2.3

A secondary ranging process known as the "single-signal" technique forms part of the DECTRA system, involving reception in the aircraft of either the F_1 signal from A or F_2 from C. One or other of these signals is compared with a highly stable oscillator in the aircraft as described in para. 4.6. below.

3. FREQUENCIES

3.1

It will be noted that stations A and C can form the master stations of normal Decca Navigator chains if desired, since their frequencies are standard and the mode of operation does not prohibit their use as such for normal Decca receivers. By radiating normal Decca slave transmissions, stations B and D could then each become one slave of each chain in addition to their function as DECTRA Tracking slave stations.

3.2

The following frequencies may be taken as typical for the DECTRA system.

$$F_1 = 85.100 \text{ kc/s (Decca frequency } 5\frac{1}{2}\text{)}$$

$$F_2 = 84.915 \text{ kc/s (Decca frequency } 4\frac{1}{2}\text{)}$$

$$f = 185 \text{ c.p.s.}$$

$$\Delta = \text{plus/minus } 60 \text{ c.p.s.}$$

4. THE DECTRA RECEIVER

4.1 TRACKING

The two pairs of stations AB, CD produce their respective tracking patterns independently and the user selects the one required by switching-in the appropriate RF channel. Essentially, the receiver is of the following form when switched for tracking from stations A and B, which it will be recalled generate their hyperbolic pattern at frequency F_1 :-

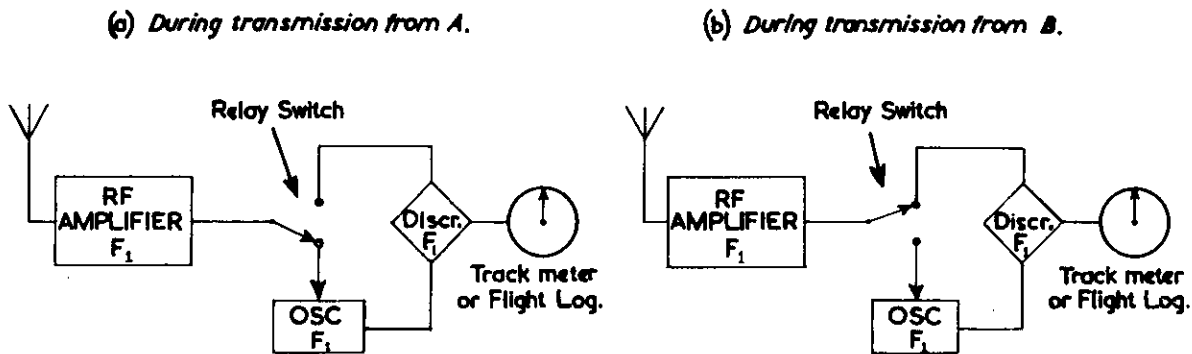


Fig.4. Elements of Tracking system.

4.2

The manual switch selecting the F_1 RF channel also selects a channel for the $F_1 + \Delta$ signal from the master; this signal operates a relay which switches the output of the F_1 channel from the oscillator, whose phase it has been controlling during the master transmission, directly to the discriminator so that the latter may then compare the phase of the F_1 signal from the slave with that of the oscillator. The tracking meter (or Flight Log) will then indicate the aircraft's position line in the tracking pattern. The process is repetitive at a rate sufficient to ensure, in conjunction with an appropriate value of time-constant for the meter, an apparently continuous indication.

4.3 RANGING

The ranging system is duplicated in the manner already outlined so as to minimize the effects of severe interference upon the reception of signals from long ranges. The two-signal ranging system is described first.

4.4 TWO-SIGNAL RANGING

Suppose that the user is close to the AB pair and has switched his receiver to that pair so that the oscillator is being phase-controlled by the master transmission as described above. The oscillator feeds a divider the output of which is at frequency f ; the divider output therefore represents the subharmonic f of the master signal, and is fed to one half of a discriminator phase-comparing at frequency f . The feed for the other side of the discriminator is derived from the beat note between the received signal from the near station A on frequency F_1 and the distant signal F_2 . Since the discriminator compares at frequency f a signal derived from both transmitting stations with that derived from only one (C_1 on F_2), the hyperbolic pattern between stations A and C to which the discriminator responds has a lanewidth, corresponding to one discriminator cycle of phase, based on the frequency F_2 of the un-divided signal.

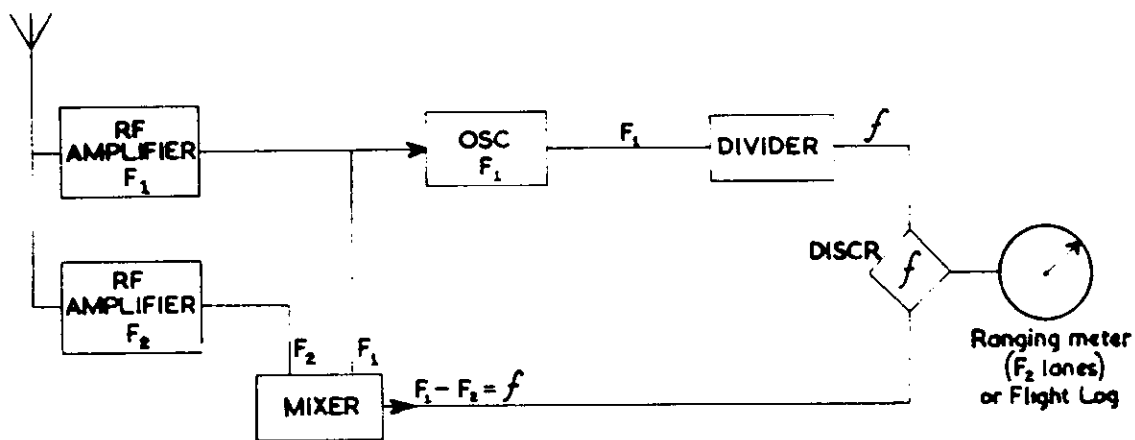


Fig. 5. Elements of Two-signal Ranging.

4.5

The output of the discriminator is taken to a servo feed unit, the main purpose of which is to impart a "flywheel" effect so that if the output fails due to loss of either received signal the velocity of rotation of the servo motor at the instant of failure is "stored" and retained to drive the ranging meter or Flight Log at a continuous rate until the interruption ceases.

4.6 SINGLE-SIGNAL RANGING

The DECTRA receiver includes a high-stability crystal oscillator whose phase is compared with that of station A or C to provide direct range indication to the appropriate station. Before take-off the frequency and phase of the oscillator can be adjusted and thereafter maintained, by means of an accurately controlled oven, to within one part in 100,000,000 for a period of about one hour. The actual crystal employed is cut for a relatively high frequency ($N_1 F_1$ or $N_2 F_2$ kc/s where N is a whole number and $F_1 F_2$ have the same meaning as above). Assuming that the crystal is of $N_1 F_1$ kc/s, the output of the oscillator is passed to a divider which produces F_1 which in turn feeds a discriminator working at this frequency.

4.7

Suppose that the aircraft starts from the AB end of the route and the receiver is switched to this pair. The other side of the discriminator would then be derived from the A signal F_1 via the local oscillator shown in Fig. 4 (labelled OSC. 1 in Fig. 6, which should be referred to henceforth); at the airfield, the $N_1 F_1$ high-stability oscillator (OSC.2) is adjusted so as to hold the output of the discriminator stationary, i.e. to be precisely in phase with the signal

from A. This adjustment would be carried out automatically in a calibration unit designed for the purpose, it being necessary only to remove the crystal oven from this unit, after checking that the reading is correct at the time of removal, and place it in the receiver. No other initial adjustment would be needed. If now the aircraft moves off, the discriminator will record the change of distance from A by comparison of the phase of the signal from that station with the $N_1 F_1$ oscillator output at F_1 . The output of the discriminator is passed to a "gear reduction and reversal unit", which has two functions: first, to convert the revolutions of the single-signal discriminator (labelled "Discr. 3" in Fig.6) to the same sense and scale as those of the two-signal discriminator (Discr.2) and secondly to allow the indication of range from the single-signal discriminator to be changed in sign if required. The single-signal output does not drive a separate range indicator but, as already implied by the function of the gear reduction and reversal unit, is integrated with the two-signal output to drive a common range meter or range component of a Flight Log display. The two outputs join in the servo feed unit and pass thence to the indicator via the "drive selector unit", the function of the latter being described below.

4.8 INTER-RELATION OF SINGLE AND TWO-SIGNAL RANGING

In practice the ranging facilities of DECTRA would be used as follows. Starting as above from the AB end of the route, the receiver would be switched to the AB pair and the AB tracking pattern used. The two-signal part of the receiver would be set up to divide the F_1 signal from A down to f , via the oscillator, and to feed one side of discriminator 2, but it might occur that the F_2 signal from the distant station C could not be received at the time of take-off owing, say, to a local thunderstorm. In this case the single-signal ranging would be used since frequency M, from the high-powered local station A would be received at adequate strength. The drive selector unit has the function of selecting automatically the single-signal output if the two-signal drive has failed, and would do so in this instance.

4.9

The single-signal drive will hold with adequate accuracy for about an hour but at any time that the two-signal system starts to work the velocities of meter rotation for both systems separately available in "storage" in the servo feed unit can be visually compared on a "velocity comparator" indicator driven from the drive selector unit. In the early stages of the flight this will show zero discrepancy, but as time goes on and the high-stability oscillator starts to slip, having outrun its time for holding the desired stability, this velocity comparator will show a discrepancy. When this occurs the oscillator is not adjusted, but a manual frequency control unit is used to feed in a small beat frequency of 8 NF to restore the reading of the velocity comparator to zero and so adjust the drive to the 1/N divider to the correct value.

4.10

To sum up, therefore, there are two ranging systems in the receiver. One uses a very accurate hyperbolic pattern but depends on the reception of the two signals from sources at the extremities of the route; the other depends on reception of a signal from one (generally the nearer) source only but also on the stability of the divided output of a crystal oscillator. The combination of these two, effected automatically, is expected to meet all demands and to provide adequate security against failure.

4.11

It should be emphasized that if at any time it is desired to change from F_1 control to the local crystal oscillator (OSC.1) to control by F_2 , i.e. to start single-signal range measurement to the other end of the route it is only necessary to move the manual switch and check the velocity comparator to effect the change. Only the Tracking meter or Flight Log tracking component will alter at the instant of changeover.

4.12

The assumption is made above that the alternation between single and two-signal ranging is geometrically valid, i.e. that along or near the route the two systems both give distance-along-track information. If, however, a sharp diversion is made from the route - consider for example the hypothetical case of an aircraft using the proposed North Atlantic Deetra coverage, travelling northwards towards Iceland after leaving Prestwick - the hyperbolae of the two-signal pattern would no longer coincide with the circular position lines of single-signal ranging and the two systems could no longer drive a common range indicator. In such a case the Flight Log's pictorial presentation would of course be unaffected by the diversion from route; with the tracking and two-signal ranging patterns forming the plotting co-ordinates, the Flight Log would indicate the diversion and would provide full position-fixing along the new route. If the constant-range circles (or distance-marks along a planned diversion track) were shown on the Flight Log chart the single-signal ranging information displayed on the range meter would remain operative and the facilities of cross-checking between the two systems would thus be preserved.

4.13 WARNING SIGNALS

These are denoted by Lp 1, 2 and 3 in Fig. 6. Lp 1 and Lp 2 would light up when the

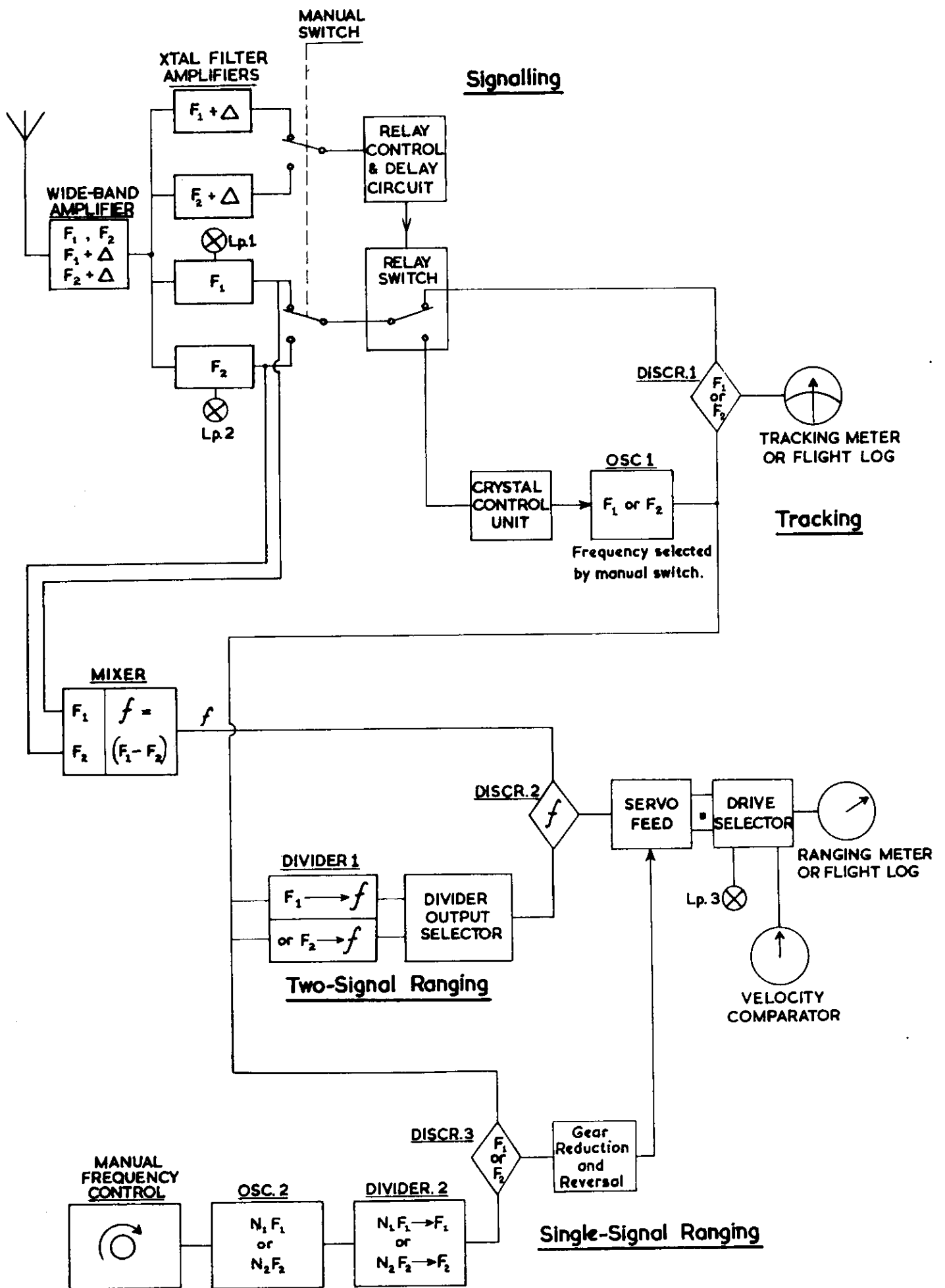


FIG. 6. PRINCIPAL ELEMENTS OF DECTRA RECEIVER.

F₁ or F₂ signals respectively were not being received at adequate strength; Lp 3, on the drive selector unit, would light when any one of the three types of range drive failed: two-signal, one-signal (i.e. when the signal not controlling OSC.1 failed), or servo feed "memory" (i.e. when the signal controlling OSC.1 or when both signals failed for more than, say, one minute). In the last case the user would reinstate single-signal control by turning the manual switch to give control of OSC.1 by the better signal available after or during the break.

4.14

If necessary the Flight Log could be arranged to indicate automatically which sections of its track were those over which the ranging drive was a "stored" velocity derived from the servo feed unit.