volts across $R_4$. The manual volume control $R_{8(1)}$ is connected across $R_3$ and any voltage between $-3{\cdot}6$ and $-30$ can be applied to $V_5$ and $V_4$ for grid bias. This voltage is broken down by means of the potential divider $R_{10}$, $R_{11}$, and $R_{12}$ for connection to $V_6$ and $V_3$.

## Automatic volume control

22. Automatic control of the gain of the valves $V_3$, $V_4$, $V_5$, and $V_6$, is effected by the strength of the received signals when the master switch MS is in the A.V.C. position. Manual control of the A.F. from the detector diode of $V_8$ to the output valve, that is, the triode of $V_8$, is also provided from the potentiometer $R_{8(2)}$. The controls of $R_{8(1)}$ and $R_{8(2)}$ are ganged for operation and the panel knob is labelled VOLUME CONTROL. The position of the master switch MS determines which of the potentiometers is operative:—OMNI for $R_{8(1)}$, A.V.C. for $R_{8(2)}$. The received signal applied to the grid of the R.F. amplifier valve $V_3$ is amplified by the I.F. amplifier valves $V_5$ and $V_6$. The amplified I.F. voltage appears across the primary winding of the third I.F. transformer $L_{21}$. This primary winding is tapped, and a proportion of the R.F. voltage is led to the strapped diodes of the double-diode-triode valve $V_7$. Rectification takes place and the rectified current flows through a series R.F. choke $L_{25}$, and a resistance-capacitance filter and decoupling circuit composed of $R_{68}$ and the condensers $C_{108}$ and $C_{103}$.

23. At the A.V.C., BALANCE, and VISUAL positions, the switch section $MS_{af}$ disconnects the slider of $R_{8(1)}$ and connects the fixed potentiometer $R_{10}$, $R_{11}$, and $R_{12}$ across the A.V.C. diode load resistor $R_9$. This diode has a delay of 3·6 volts due to the drop across $R_4$ in series with $R_3$. On ranges 1 and 2 this delay is reduced to 2·4 volts by switching $R_{64}$ (and $R_{69}$, if fitted) across $R_4$. The rectified current flows through $R_{10}$, $R_{11}$, and $R_{12}$, with $R_9$ in parallel, back to the cathode *via* $R_4$. The voltage developed across $R_9$ and the network $R_{10}$, $R_{11}$, and $R_{12}$, is divided to suit $V_3$ and $V_6$. On BALANCE and VISUAL, $C_{94}$ is shunted across $R_9$ to give a longer time constant and reduce the flicker of the tuning indicator $V_{10}$.

24. Approximately one-half the full value of the biasing voltage is applied to the R.F. amplifier valve $V_3$ through the line A.V.C.2, tapping the junction of $R_{10}$ and $R_{11}$. The grid-return circuit includes the resistance-capacitance circuit of $R_{45}$ and $C_{40}$ to prevent back-coupling between $V_3$, and $V_4$, $V_5$, and $V_6$, and has a time-constant which is much longer than the lowest incoming signal frequency. The frequency-changer $V_4$ and the first I.F. amplifier $V_5$ receive full A.V.C. bias voltage from the top end of the resistor $R_{10}$ through the line A.V.C.3 and decoupling combinations $R_{38}$–$C_{37}$ and $R_{33}$–$C_{33}$ respectively. The second I.F. valve $V_6$ receives approximately one-tenth of the bias voltage through the circuit $R_{29}$–$C_{30}$.

25. The A.V.C. is subjected to a voltage delay of approximately 13 volts, that is, it does not come into operation until the received carrier reaches the predetermined level of strength represented by 13 volts. This delay is partly accomplished by running the cathode of $V_7$ positive with respect to its diode anodes by means of resistors $R_{14}$ and $R_{15}$ which are connected between H.T. positive and earth. An additional resistor $R_{16}$ is introduced for C.W. reception (i.e. when the switch $S_4$ is ON) to reduce this delay voltage. The full delay voltage is a composition of the voltage produced here and the standing bias on the R.F. valves (see para. 26). The voltage delay assists in giving an A.V.C. characteristic which, for a change in input signal of 80 db. results in a change in output of approximately 8 db.

26. None of the A.V.C. controlled valves is automatically biased by cathode resistors. To preserve a standing bias during no-signal periods, therefore, the resistance network of $R_{12}$, $R_{11}$, and $R_{10}$ is returned to a point which is 3·6 volts negative with respect to the cathodes. On ranges 1 and 2 (H.F.) this standing bias is reduced by approximately 2·4 volts in order to preserve reasonably constant amplification over all ranges. This is done by introducing the resistors $R_{64}$, (and $R_{69}$, if fitted) into the circuit by means of switch section $FS_{WT}$.

## Beat frequency oscillator

27. In addition to providing A.V.C. the valve $V_7$ also acts as a beat frequency oscillator, the triode section of the valve being used for this purpose. The oscillatory circuit is of the series-fed Colpitts type, and consists of a coil $L_{22}$ and the condensers $C_{14}$ and $C_{15}$. The frequency of this oscillator can be varied over a range of approximately 3 kc/s by means of a pre-set trimming condenser $C_{13}$. This condenser can be adjusted by inserting a screwdriver through a small port in the front panel. Automatic bias is developed across the grid leak resistor $R_{19}$. The grid coupling condenser is $C_{17}$. The oscillatory circuit is tuned to approximately half the I.F., that is, to 280 kc/s, and the second harmonic of this is used to heterodyne the I.F. signal. The use of the second harmonic prevents the oscillator from being locked by incoming I.F. signal. The output from the oscillator is coupled through the condenser $C_{11}$ to the signal diode of the valve $V_8$. The I.F. signal is also applied to this diode and the A.F. beat frequency voltage appears across the load resistor $R_{21}$.

**Tuning indicator**

28. Correct tuning of the receiver is indicated by a minimum angle of shadow in the tuning indicator valve $V_{10}$. This indicator gives a varying angle of shadow on a fluorescent "target" anode, the angle being dependent upon the voltage developed across the resistor $R_9$, which is the A.V.C. diode load.

29. The tuning indicator valve operates as follows:—Connected to the triode anode is a "deflector" wire which protrudes into the path of the electron stream between the cathode and the target anode. In the absence of a signal the voltage across the resistor $R_9$ is small, and therefore the negative voltage applied to the grid of the indicator valve is small, resulting in a high current through the valve. This current produces a large voltage drop across $R_{13}$, in consequence of which the potential of the triode anode is considerably less than that of the target anode. The deflector wire therefore has a repelling action on the electrons approaching the target anode, and a V-shaped shadow is produced. When the receiver is correctly tuned, the voltage across $R_9$ reaches a maximum, the grid bias increases and the anode current falls. The reduced current results in a smaller volts drop across $R_{13}$ and the potential of the triode anode rises to a voltage comparable with that of the target anode. In this condition, therefore, the deflector wire has a much smaller influence on the electron stream, and the V-shaped shadow on the target anode narrows to a minimum.

## COMMUNICATIONS CIRCUITS, OTHER VERSIONS

**R.1155A, R.1155E, and R.1155M**

30. These types differ from the R.1155 and R.1155D in the R.F. amplifier stage, where filters have been introduced to prevent interference from certain M.F. broadcasting stations having a carrier frequency near to the I.F. of the receiver (560 kc/s). Receivers bearing the suffix letter M are identical with the R.1155A except that a corrosive flux was used in error during production. Receivers type R.1155M are to be used at ground schools only.

31. The three filters are the grid rejector circuit, $L_{33}$ and $C_{113}$, the anode rejector circuit, $L_{32}$ and $C_{114}$, and the anode acceptor circuit $L_{31}$ and $C_{111}$. In addition, an assembly consisting of the resistor $R_{71}$ in parallel with condenser $C_{112}$ is inserted to minimise the effects of the added capacitance introduced by the grid rejector circuit. The circuit changes will be seen by reference to fig. 3, where the modifications are shown as an inset on the full circuit diagram of the R.1155.

**R.1155B and R.1155F**

32. The circuit of these types incorporates the filter circuits of the R.1155A and, in addition, the six R.F. chokes annotated $HFC_1$ to $HFC_6$ in fig. 3A. These chokes are introduced to filter unwanted frequencies due to certain radar transmitters. As will be seen by reference to the circuit, fig. 3A, $HFC_1$ to $HFC_4$ are in series with the aerial leads, $HFC_5$ is in the common grid circuit of the L.F. switching valves $V_1$ and $V_2$, and $HFC_6$ in the grid lead to the R.F. amplifier valve $V_3$. A further slight alteration to the circuit is involved by the fitting of the condenser $C_{115}$ in parallel with the resistor $R_{72}$ between contact 3 of switch section $FS_{xf}$ and the primary of $L_3$.

**R.1155C**

33. The R.1155C was a modified version of the R.1155A and was produced for use in Coastal Command aircraft engaged on certain duties necessitating D.F. facilities on Range 1. As this special requirement no longer exists the receivers have been declared obsolete, but some may still be found in service for normal communications purposes. The R.1155C required a special loop aerial in addition to that normally used, and the receiver embodied a new dummy loop circuit for ranges 1 and 2 in addition to the $L_1$ and $C_{99}$ combinations used on the other ranges. These changes involved alterations also to the switching circuits. In view of the small number of receivers affected and the fact that they are obsolete, no circuit diagram is given.

**R.1155L and R.1155N**

34. The R.1155L and R.1155N are developments from the R.1155B and R.1155F to meet requirements for reception on the 1·5 to 3·0 Mc/s band. The frequency coverage therefore differs from that of the rest of the R.1155 series, range 5 (200 kc/s to 75 kc/s) having been omitted and range 2A (3·0 Mc/s to 1·5 Mc/s) inserted. Thus these types have a continuous frequency coverage from 18·5 Mc/s to 200 kc/s with the exception of the band between 600 kc/s and 500 kc/s. The changes have necessitated considerable alterations in the R.F. amplifier, frequency-changer, and R.F. oscillator stages, and a circuit diagram is given in fig. 4. Apart from the changes in these stages the circuit remains basically that of the R.1155B.

35. It will be seen that the coils $L_6$, $L_{11}$, and $L_{17}$ (range 5) have been removed from the circuit of the R.1155B. Range 3 and 4 coils have been repositioned in the circuit diagram and alterations

have been made in the wiring of the switch sections $FS_{wf}$, $FS_{xf}$, $FS_{xr}$, $FS_{yf}$, $FS_{yr}$, and $FS_{zf}$. Three new coils $L_{40}$, $L_{41}$, and $L_{42}$ have been introduced for the new range 2A. Other components re-positioned are the resistors $R_{40}$, $R_{41}$, $R_{60}$, and $R_{61}$, and the condensers $C_{74}$, $C_{75}$, $C_{80}$, and $C_{91}$. New resistors, $R_{73}$ and $R_{74}$, and a condenser $C_{116}$ have been added, and $R_{59}$ and $C_{73}$ have been removed.

## THE DIRECTION-FINDING CIRCUITS

36. The change from the communications circuit to the direction-finding circuit is made by the master switch MS, of whose five positions the three labelled BALANÇE, VISUAL, and ∞ (figure-of-eight) are for this purpose. Simplified diagrams of the D.F. circuits are given in figs. 10 to 13. The receiver may be used for direction finding on ranges 2, 3, 4, and 5. The D.F. ranges of the L and N versions are ranges 2, 3, and 4. On the R.1155C (now obsolete) D.F. was possible on ranges 1, 2, 3, 4, and 5. With a suitable loop aerial used in conjunction with the H.F. aerials the following facilities are available:—

(i) Determination of bearing of a given transmitter, with sense discrimination by visual or aural means.

(ii) Homing on to a transmitter by fixing the loop aerial in relation to the aircraft and maintaining course so that the two needles of the visual indicator type 1 intersect on a line marked centrally on the face of the instrument.

37. The loop aerial normally used is the type 3, which has a nominal inductance of 100 $\mu$H, and self-capacitance when installed of 20 $\mu\mu$F. In order to effect a match between this aerial and the receiver a small pre-set condenser $C_{104}$ is built into the loop lead terminating plug. When the total loop and lead capacitance is too small to enable tuning to be effected by $C_{104}$ alone, the fixed condenser $C_{106}$ may be inserted in parallel with $C_{104}$. The procedure to be adopted for matching is described in para. 72. When a loop aerial other than type 3 is employed a suitable impedance matching unit, such as the type 12, 13, or 15 should be used to enable the input tuned circuits to gang correctly with the other tuned circuits. These units are dealt with in Appendix 1.

### General principles

38. Direction finding is accomplished either by visual or aural means. The aural method used follows the well-known practice of swinging the loop for a minimum, and then sensing by superimposing fixed aerial voltages on the loop voltages. (The theory of this system of direction finding is covered in Chapter XVI of A.P.1093.) The method used for direction-finding by visual means employs a principle known as the "switched heart". Before the circuit is dealt with in detail this principle should be understood; its features are briefly as follows.

39. A push-pull oscillator operating at either 30 c/s or 80 c/s is used to switch the fixed aerial in such a manner that its voltages are applied alternately in phase and in anti-phase with the instantaneous voltage due to the loop. The same oscillator simultaneously switches the rectified output from the detector stage alternately to the two pairs of moving coils which operate the indicator needles of a visual indicator. Thus one needle is moved to an extent proportional to the fixed aerial voltage plus the loop voltage, and movement of the other is proportional to the fixed aerial voltage minus the loop aerial voltage. Therefore, when the loop aerial is swung until the voltage induced in it is nil, both the needles will rise to the same extent. This will be when the loop is at right-angles to the bearing of the transmitter. This state of affairs is indicated by the point at which the crossed needles intersect falling on a vertical white line painted on the face of the instrument. For homing, the loop is set in relation to the aircraft—usually athwartships—(see para. 103 with regard to other settings) and the pilot swings the aircraft until the two needles cross on the vertical line, thereafter maintaining course by keeping the point of intersection of the needles on this line. Since the voltage actuating each needle is represented by a cardioid curve (see diagram C of fig. 14) it will be clear that any deviations from course will cause one needle to fall and the other to rise, as a result of which the point of intersection will move off the vertical line. The significance and use of such movements for sense determination is explained in paras. 52 and 99.

### L.F. oscillator for D.F. switching

40. The triode portions of the triode-hexode valves $V_1$ and $V_2$ are connected as a push-pull oscillator. The frequency of this oscillator is determined by the constants of the tuned circuit consisting of the primary winding of the L.F. transformer $L_{23}$ and the two fixed condensers $C_{54}$ and $C_{55}$. When the switch $S_1$ is open the oscillatory frequency is 80 c/s. Closing the switch $S_1$ throws the condenser $C_{55}$ into circuit and thereby lowers the frequency to 30 c/s. The higher frequency is used when D.F. is being carried out on a W.T. signal, and the lower frequency when R.T. signals are being used. The lower frequency causes negligible interference with R.T. intelligibility but is too low a switching frequency for W.T. signals.

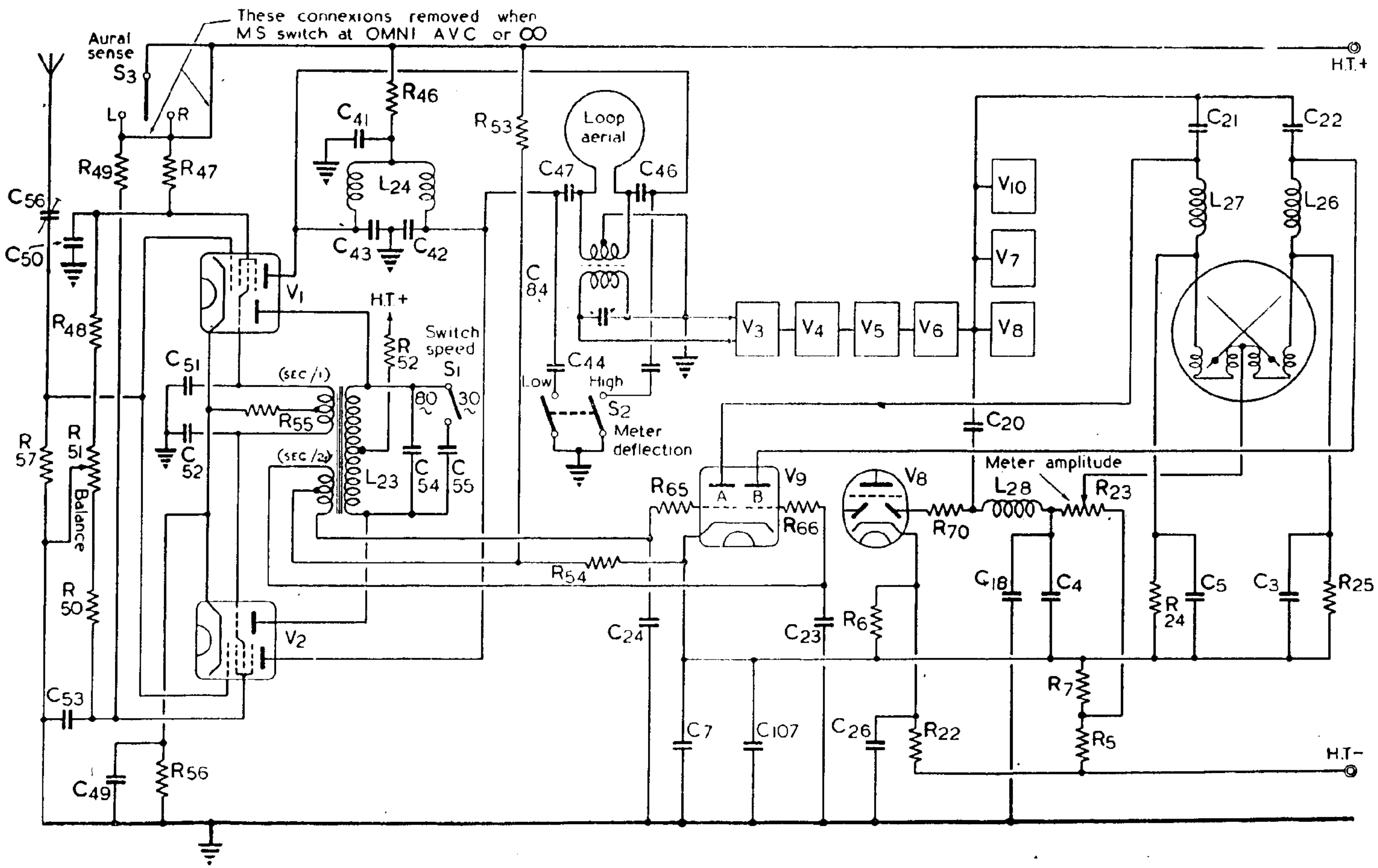


Fig. 10.—Simplified visual D.F. circuit

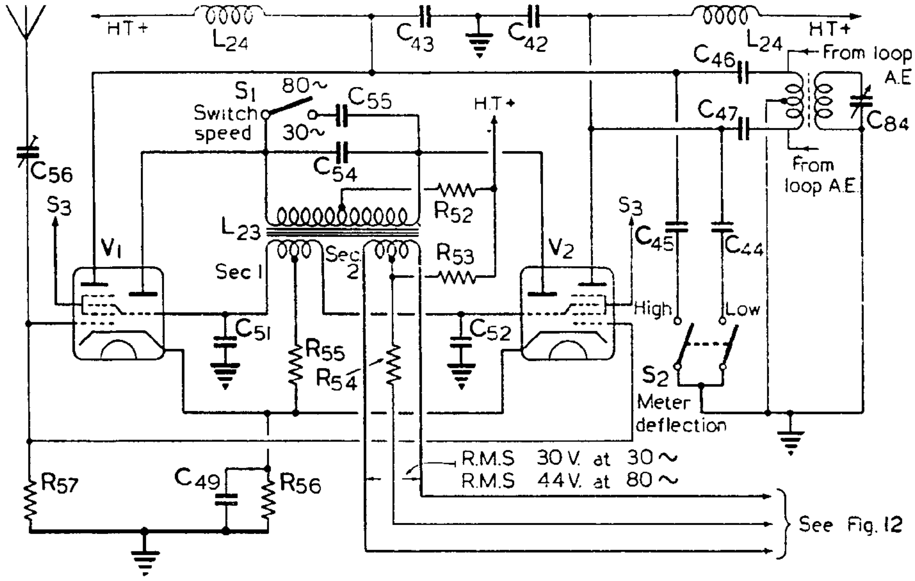


FIG. 11.—L.F. OSCILLATOR SWITCHING CIRCUIT

*Aerial switching*

41. The use of the centre-tapped secondary winding SEC 1 of $L_{23}$ has the effect of simultaneously applying equal, but anti-phase, voltages to the oscillator grids of $V_1$ and $V_2$. During a positive half-cycle the grid is held only slightly positive due to grid current developing a biasing voltage across the resistor $R_{55}$. In the negative half-cycle the full secondary voltage is applied to the oscillator grids. Since these grids are connected to the injector grids ($G_3$) of the respective hexode portions, the effect is to bias the hexodes to cut-off during alternate half-cycles at the oscillator frequency. The fixed-aerial voltage is therefore applied through $V_1$ to $C_{46}$ during one half-cycle, and during the next half-cycle, when the valve $V_1$ cuts off, the aerial voltage is applied through $V_2$ to $C_{47}$. As the two condensers $C_{46}$ and $C_{47}$ are at opposite ends of the loop aerial (and of the coil across it, which forms the primary of an R.F. transformer) the oscillator serves to switch the fixed aerial voltages at the oscillator frequency alternately into phase and anti-phase with the loop aerial input. The resultant voltages are applied to the grid of $V_3$ by inductive coupling to the grid circuit of the range in use.

42. The H.T. positive feed to the anodes of the triode sections is via a voltage dropping resistor $R_{52}$ and the centre tap of the primary winding of $L_{23}$. The hexode anodes are fed through the R.F. choke assembly $L_{24}$ and the dropping resistor $R_{46}$. The associated by-pass condensers are $C_{41}$, $C_{42}$, and $C_{43}$. A suitable screen voltage is provided by the two potentiometers $R_{47}$, $R_{48}$, and $R_{51}$, or $R_{49}$, $R_{50}$, and $R_{51}$, the by-pass condensers being $C_{50}$ and $C_{53}$. The cathode bias is provided by the resistor $R_{56}$ by-passed by $C_{49}$. $R_{57}$ provides a grid return for the hexodes.

*Visual indicator switching*

43. The basic principles of operation of the visual indicator have been explained in paras. 38 and 39, and the switching circuit employed to operate the visual indicator, type 1, will now be dealt with in detail. Simplified circuits are given in figs. 12 and 13.

44. The amplified signal voltages are applied to the anodes of the double-triode valve $V_9$. It is convenient to regard the two sections A and B of $V_9$ as diodes which are switched into and out of operation by the grids $G_1$ and $G_2$. The grids are connected to a secondary winding SEC 2 of the L.F. transformer $L_{23}$ and, by a similar arrangement to that used in the oscillator stage, equal but anti-phase voltages are applied to the two grids of $V_9$ in synchronism with the aerial switching. The voltage applied to the grids of $V_9$ is approximately 30 volts (R.M.S.) at 30 c/s or 44 volts at 80 c/s. The resistors $R_{53}$ and $R_{54}$ constitute a potentiometer connected between H.T. positive and the cathode of $V_9$. The grid returns of $V_9$ are connected to the junction of these two resistors and consequently the grids are at a potential positive with respect to the cathode, reducing the valve impedance and increasing sensitivity.

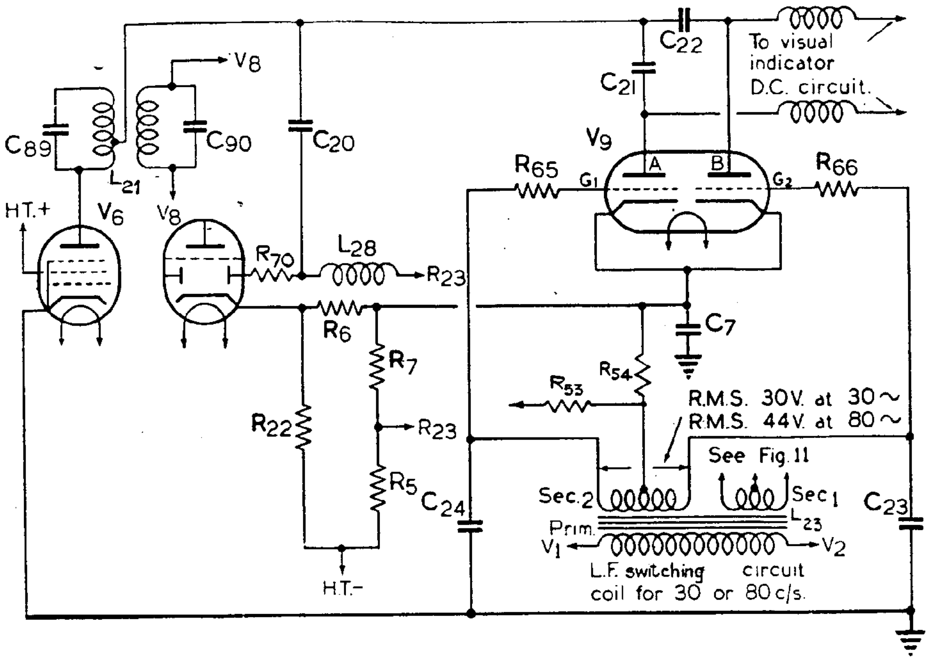


FIG. 12.—VISUAL INDICATOR SWITCHING CIRCUIT

45. It will be seen from fig. 13 that the diodes A and B rectify the signal impulses, but owing to the switching voltage applied to the grids of $V_9$ from the L.F. transformer $L_{23}$ they are alternately conducting and non-conducting according to the condition of the grid. Since this switching is synchronised with the aerial switching the output of one diode will be proportional to the fixed aerial voltage plus the loop voltage, and the output of the other diode will be proportional to the fixed aerial voltage minus the loop voltage as stated in para. 39. The pulsating D.C. output produced through diode A will tend to charge the fixed condenser $C_5$ which is across the anode load resistor $R_{24}$ and will at the same time flow through the two left-hand coils of the visual indicator and the variable resistor $R_{23}$. The effect will be to actuate the needle which points to the right, causing it to rise. Collapse of the needle during the alternate (negative) half-cycle of the switching voltage is prevented by the charge on $C_5$, which tends to discharge through the circuit VPZW. In a similar manner the needle which points to the left is operated by diode B and its associated load $R_{25}$ and condenser $C_3$, with the common resistor $R_{23}$. When the charges on the condensers $C_5$ and $C_3$ are equal the needles will rise by equal amounts and will therefore intersect on the central line marked on the instrument, but when the charges are unequal the needles will rise to different heights giving an intersection to left or right of the centre line according to which section is passing the greater current. In addition, when the charges on $C_5$ and $C_3$ are unequal there is a tendency for current to flow between V and X via P (see fig. 13), a circumstance which assists the differential action of the needles.

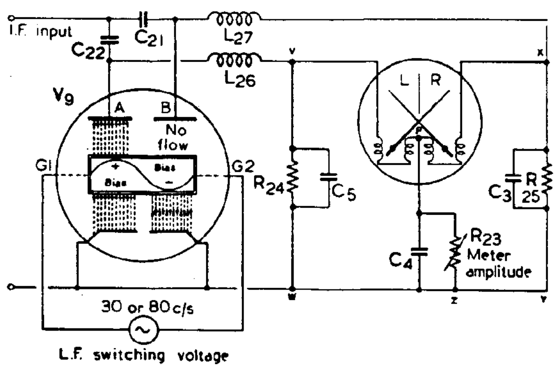


FIG. 13.—SIMPLIFIED VISUAL INDICATOR SWITCHING CIRCUIT

**Meter amplitude**

46. The sharpness of a bearing is determined by the relative amplitudes of the fixed and loop aerial voltages. When these are equal the sharp minimum shown in curve C of fig. 14 is obtained.

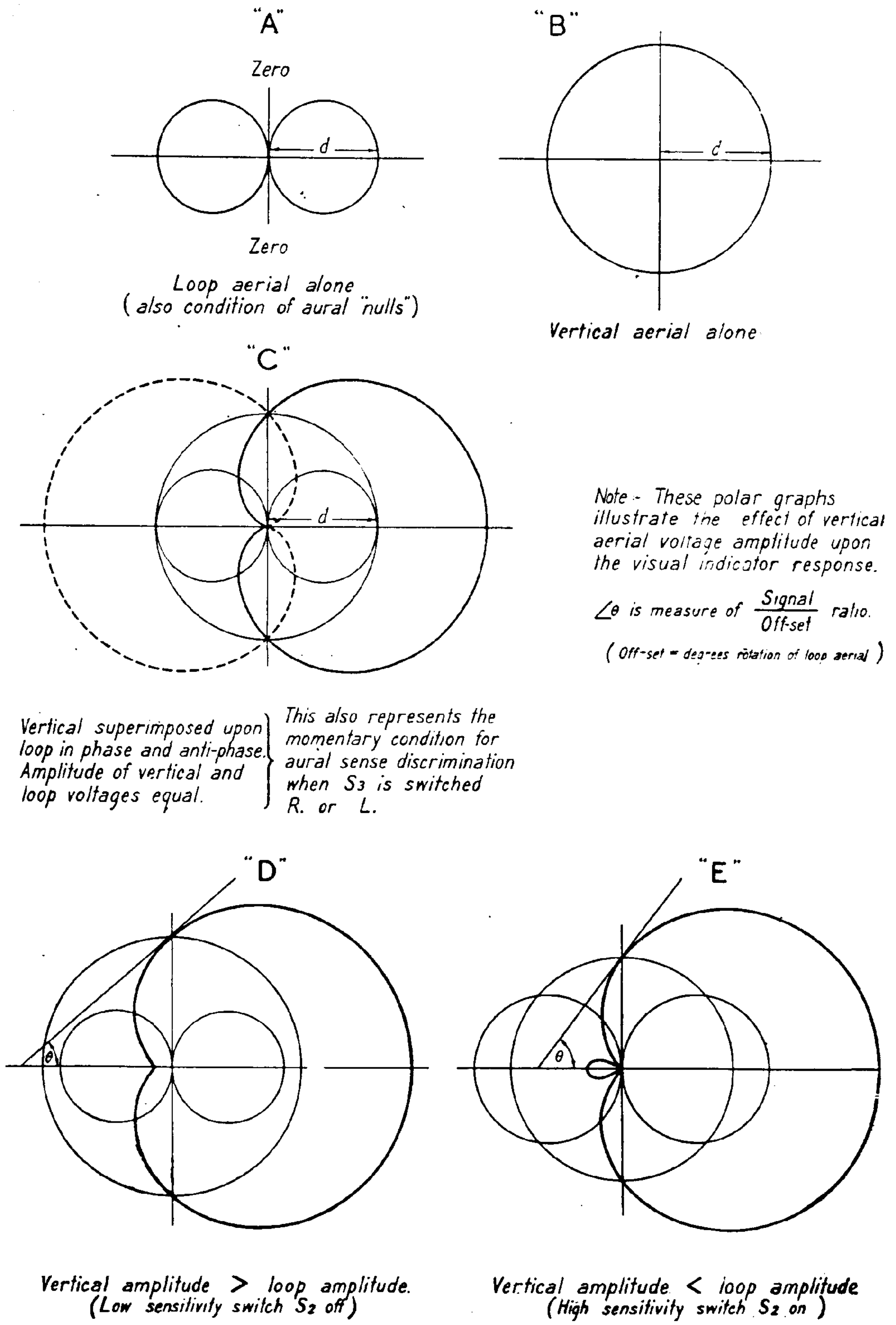


FIG. 14.—POLAR DIAGRAMS

When the fixed aerial voltage is greater than the loop aerial voltage the minimum is less sharp, as will be seen by the flattening of the cardioid curve D of fig. 14. When the loop voltage is the greater an additional lobe is introduced into the polar diagram, and two minima are obtainable (curve E of fig. 14). The two condensers $C_{42}$ and $C_{43}$ are provided to reduce the amplitude of the fixed aerial voltages to the correct value for a sharp minimum.

47. When using the visual indicator for homing this sharp minimum is a disadvantage, as a very small deviation off course causes a considerable movement of the needles, with consequent strain upon the pilot in maintaining course. To eliminate this difficulty a meter sensitivity switch is provided. This switch has two positions HIGH and LOW, indicating high and low sensitivity respectively. In the LOW position the switch introduces the further condensers $C_{44}$ and $C_{45}$ in parallel with $C_{42}$ and $C_{43}$ respectively, reducing the fixed aerial voltage relative to the loop voltage. This results in a less sharp minimum and homing is therefore simplified.

### The diode limiter valve

48. It has already been explained that the pulsating D.C. output from $V_9$ is fed through the R.F. chokes $L_{26}$ and $L_{27}$ to the actuating coils of the visual indicator. In order to prevent the needles rising due to noise output in the absence of a signal, a delay bias is provided between cathode and anode. One diode of the double-diode-triode valve $V_8$ is fed through a condenser $C_{20}$ from a tapping on the primary winding of the I.F. transformer $L_{21}$. The rectified output from $V_8$ flows via a swamp resistor $R_{70}$, and the R.F. choke $L_{28}$ to the meter amplitude control, which is the variable resistor $R_{23}$. The cathode of $V_8$ is biased by the resistor $R_{22}$. Any current injected at $R_{23}$ tends to drive both needles downwards without interfering with the differential action of the circuit. The action of the normal A.V.C. alone is insufficient to keep the intersection point of the needles on the scale for the possible range of signal variation.

49. The limiter delay voltage is supplied across the resistors $R_6$ and $R_7$ and is about 4 volts. It does not come into action until the peak voltage applied to the common point of $C_{20}$, $C_{21}$, and $C_{22}$ exceeds the delay voltage. This limiter device is effective for changes up to 80 db and, given a correct setting of $R_{23}$, the point of intersection will not move beyond the limits of the scale.

### Visual indicator balancing circuit

50. Accuracy of indication depends on the balancing of the two input switching valves $V_1$ and $V_2$ and their associated circuits. Balance is achieved by the potentiometer $R_{51}$. When the master switch MS is in the BALANCE position the loop aerial is disconnected and earthed by $MS_{ef}$, and a dummy loop consisting of a coil $L_1$ and condenser $C_{69}$ is connected in its place (see fig. 3). As the dummy loop does not pick up signals any deflection of the point of intersection of the visual indicator needles is due to lack of symmetry in the circuit. To correct this the potentiometer $R_{51}$ is adjusted until the intersection point coincides with the central indicating line of the instrument.

51. After renewal of one of the valves $V_1$ or $V_2$ it may be found to be impossible in some receivers to effect balance within the limits of the balance control knob. In such a case it will be necessary to replace one of the valves with another whose characteristics are such that they will permit a balance. The unmatched valve displaced is not to be discarded but is to be matched with another V.R.99A for future use.

### Visual sense determination

52. The direction of movement of the visual indicator needles reflects the angle of the plane of the loop aerial relative to the path of the incident wave. Orientation of the loop is such that, having obtained a bearing by turning it so that the needles cross on the white line, a reduction in loop reading by a few degrees will cause the needles to fall to the ***right*** if the sense is ***correct***. If the needles fall to the left when the loop reading is reduced the bearing is 180° out, i.e. it is a reciprocal. For homing the sense test is to swing off course to the left. If the needles move to the ***right*** the sense is *correct*.

### Aural D.F.

53. For aural D.F. the fixed aerial is disconnected by the master switch $MS_{bf}$, and the loop aerial gives a figure-of-eight polar diagram as shown in curve A of fig. 14. The switch section $MS_{cr}$ breaks the H.T. supply to the L.F. oscillator, rendering the switching circuits inoperative. The volume control is switched, changed from automatic to manual by $MS_{af}$ and $MS_{cf}$. To overcome the 180° ambiguity which results from the use of a loop aerial alone, the three-position switch $S_3$ is operated. This switch applies H.T. to the screens of one or other of the hexode portions of $V_1$ or $V_2$ thus coupling the fixed aerial through to the loop circuit, and producing a cardioid polar diagram. Sense determination by aural means is described in paras. 104 to 106.