COURSE OF TECHNICAL INSTRUCTION BOOK

LONG LINE EQUIPMENT 11

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LONG LINE EQUIPMENT 11.

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The subject of Long Line Equipment is presented in three books -

LONG LINE EQUIPMENT I includes the elementary theory of transmission, principles of carrier telephony and telegraphy, details of the apparatus used and information about crosstalk and power plant.

LONG LINE EQUIPMENT II includes voice frequency repeaters, signalling on trunk circuits, description of carrier telephone and telegraph systems and radio programme transmission over trunk lines.

LONG LINE EQUIPMENT III includes long line installation, maintenance and testing notes, line considerations, and transmission measurements.

LONG LINE EQUIPMENT II.

NOTES.

INDEX.

INDEX TO PHOTOGRAPHS.

COMMONWEALTH OF AUSTRALIA.

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COURSE OF TECHNICAL INSTRUCTION.

LONG LINE EQUIPMENT II.

VOICE FREQUENCY REPEATERS.

CONTENTS.

1. INTRODUCTION.

1.1 Prior to the invention of the thermionic valve and the consequent development of the voice frequency(V.F.) repeater, the most serious hindrance to the extension of trunk line communication was the excessive attenuation introduced by the long trunk lines. This could be partially overcome only by the costly expedients of "loading" or by using heavy gauge copper conductors, and a number of 600 lb. aerial trunk lines were installed for this reason. With the introduction of the V.F. repeater, this limitation was removed and it is now possible, by installing repeaters at regular intervals along the route, to extend trunk line communication over very long distances without departing from the requirements of modern transmission standards.

1.2 As previously referred to in Long Line Equipment I, the Overall Transmission Performance Standard requires that when any two subscribers connected to two different telephone exchanges within the Commonwealth network are interconnected via junction and trunk lines, the maximum permissible attenuation between those two terminal exchanges (at a frequency of 1 kc/s) is limited to 15 db. To ensure that this figure is not exceeded, it is necessary, in practice, to limit the attenuation of certain types of trunk lines to 6 db; and, furthermore, to ensure that trunk lines between Main, Primary, and Secondary Trunk Centres are zero loss equivalent.

1.3 Because of line attenuation, however, the distance over which V.F. transmission of the required overall equivalent may be obtained, is restricted. For example, the attenuation of a 200 lb. H.D.C. aerial trunk line at a frequency of 1 kc/s is approximately 0.06 db/mile, resulting in a limiting length of about 100 miles for a permissible transmission loss of 6 db. In order to obtain transmission within the required standards and over greater distances, it is necessary to use either heavier gauge line conductors or thermionic valve amplifier units, known as V.F. repeaters. For economic reasons the latter method is preferred.

1.4 Thermionic valve amplifiers are unidirectional in operation in that, whilst a signal voltage applied to the input terminals (that is, between grid and cathode) is amplified in the output circuit (that is, between anode and cathode), a signal voltage applied to the output terminals is not of amplified form in the input circuit. When operating as a V.F. repeater, however, the thermionic valve must be capable of amplifying the powers transmitted in each direction over the trunk line and this necessity, together with other considerations referred to later, has led to the development of three general types of V.F. repeaters, namely -

(i) type 21 (2-wire - one element),
(ii) type 22 (2-wire - two element) and
(iii) the 4-wire type.

Two-wire repeaters are commonly used in aerial trunk line circuits, and 4-wire repeaters in trunk cable circuits.

1.5 This Paper deals with the operation and provision of V.F. repeaters on aerial and cable trunk line circuits.

2. TYPE 21 V.F. REPEATER.

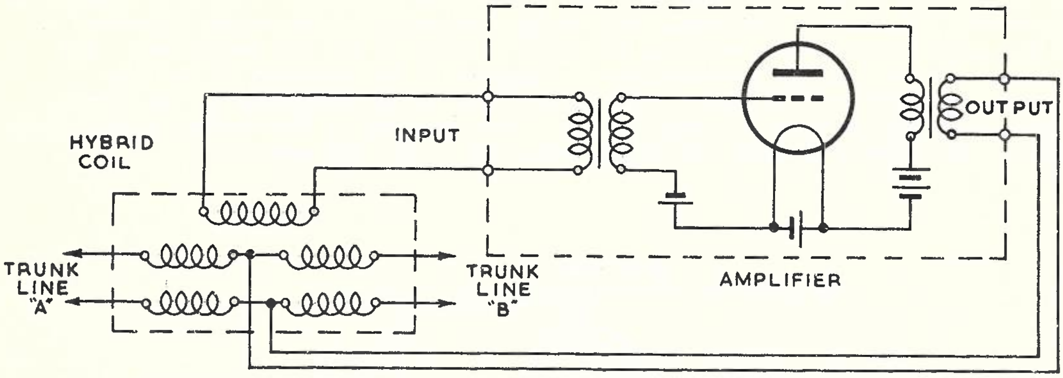
2.1 The type 21 V.F. repeater, although now obsolete, is briefly mentioned here, as it represents a stage in the development of the type 22 V.F. repeater in general use.

2.2 The repeater (see Fig. 1) consists essentially of a single thermionic valve amplifier stage with input and output connected to a special three winding transformer known as a hybrid coil or differential transformer. V.F. signals arriving from either line are applied via the hybrid coil to the input and output circuits of the amplifier. The portion entering the input circuit is amplified by the valve and applied to the midpoint of the line windings of the hybrid coil. Here it divides, half returning back along the trunk line from which the original signal was received and serving no useful purpose, the other half being applied to the distant trunk line section.

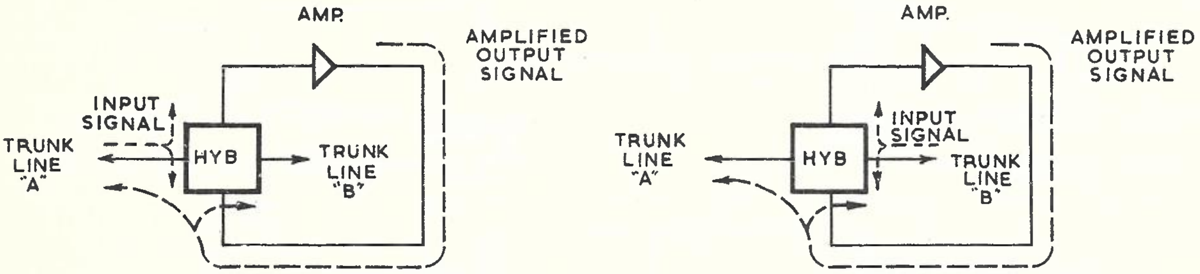
2.3 An essential condition for the satisfactory operation of the repeater is that the impedances of the trunk line sections on either side of the hybrid coil must be identical over the range of voice frequencies transmitted over the circuit. When the impedances of the lines are unequal, portion of the amplified signal voltage applied to the midpoint of the line windings of the hybrid coil is reapplied back to the input of the amplifier and further amplified. This process continues in a cumulative manner until the amplifier commences to oscillate or "sing."

2.4 Although this form of repeater has the economic advantage of using only one thermionic valve for amplifying both directions of transmission, its application is limited because of the practical difficulty of maintaining a close balance between the trunk line impedances. This disadvantage led to the development of the type 22 V.F. repeater for use on 2-wire trunk line circuits.

/ Fig. 1.



(a) Schematic Circuit.



(b) Equivalent Block Schematic Circuit.

V.F. REPEATER - TYPE 21.

FIG. 1.

3. TYPE 22 V.F. REPEATER.

3.1 In the type 22 V.F. repeater two amplifier units are provided, one for each direction of transmission. The basic arrangement is shown in Fig. 2.

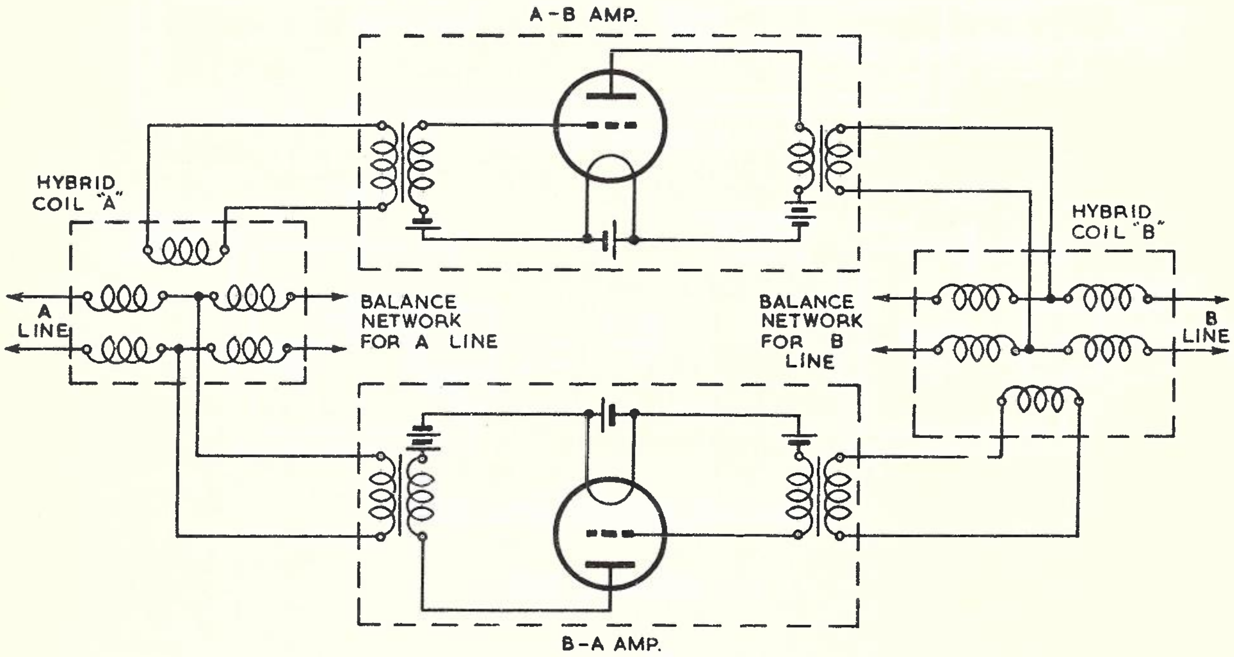
3.2 To prevent the possibility of "singing" with this arrangement, it is necessary to ensure that the amplified signals in the output of either amplifier are not applied to the input of the other amplifier. This necessitates the separation of the opposite directions of transmission, which can be done in a V.F. repeater only by the use of hybrid coils - filters are not satisfactory - because the same frequency range is transmitted in opposite directions.

To ensure that the hybrid coils isolate the input of each amplifier from the output of the other, the impedance of each balance network must simulate the impedance of the trunk line with which it is associated, over the range of voice frequencies transmitted over the circuit.

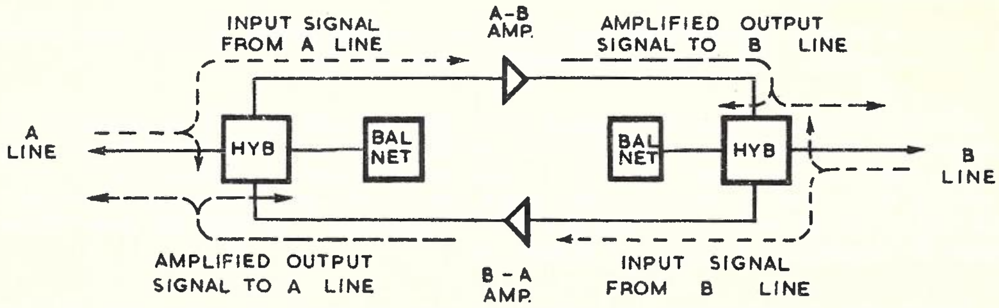
Fig. 2a shows a typical arrangement of the hybrid coil connections. In some repeaters the input and output connections of the amplifier to the hybrid coil are reversed.

/ 3.3

3.3 With either type of hybrid connection, the V.F. signal from trunk line A is applied to hybrid coil "A", where it divides, half being dissipated in the output impedance of the B-A amplifier and half entering the input circuit of the A-B amplifier. The amplified output from the A-B amplifier is applied to the midpoint of the line windings of hybrid coil "B" where it divides, half being dissipated in the balance network, and half passing to trunk line B. Transmission in the reverse direction is similar, the signals in this case being amplified by the B-A amplifier.



(a) Schematic Circuit.



(b) Equivalent Block Schematic Circuit.

V.F. REPEATER - TYPE 22.

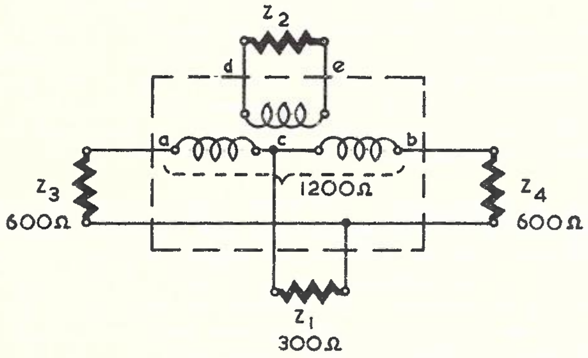
FIG. 2.

4. HYBRID COIL - THEORY OF OPERATION.

4.1 In this section, the operation of the hybrid coil is considered in more detail for signals passing through it in the various directions of transmission.

4.2 The hybrid coil may be of the unbalanced or balanced type. In the unbalanced type, which is the simpler arrangement, there are windings in one side of the line only. This type is used in such cases as submarine cable operation. In the balanced type, which is the type more commonly used in practice, these windings are divided into two halves, one half of the winding being in each side of the line to preserve balanced impedance conditions for crosstalk considerations. The theory of operation is similar for both types, but for simplicity of explanation, the description is given here for the unbalanced type.

4.3 Impedance Relations of Hybrid Coil. Fig. 3 shows a simplified circuit for an unbalanced hybrid coil in which the amplifier connections, trunk line and balance network have been represented by appropriate impedances. For the satisfactory operation of the circuit, certain impedance conditions must exist. The relative values of these are shown for a trunk line impedance of 600 ohms.



IMPEDANCE RELATIONS OF HYBRID COIL.

FIG. 3.

Notes on Fig. 3 -

Winding a-b is centre tapped at c.

Z1 and Z2 = Input and Output Impedances of Amplifiers.

Z3 = Trunk Line Impedance.

Z4 = Balance Network Impedance.

The impedance of 1,200 ohms shown across the a-b winding represents the impedance (Zr) "reflected" from Z2 when current flows through the a-b winding, and is determined by the formula -

$$Zr = T^2(Z2).$$

$$\text{where } T = \text{turns ratio of } \frac{a-b}{d-e} \text{ windings.}$$

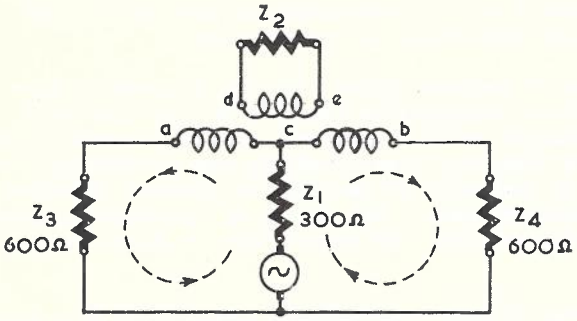
In connection with the effective impedance of the hybrid coil windings however, it is important to note the following -

(i) When the currents flowing in the a-c and b-c windings are equal and in opposite directions, no resultant flux is produced and the windings do not possess impedance, but present only their low ohmic resistance to the flow of an A.C. through them.

(ii) When a current flows in Z2 due to an e.m.f. induced in the d-e winding from the a-c (or b-c) winding only, then the impedance which Z2 "reflects" into the a-c (or b-c) winding is 300 ohms, because halving the effective turns on a transformer winding reduces the "reflected" impedance to one quarter.

/ 4.4

4.4 Transmission from Amplifier Output (Z1) to Trunk Line. Assume an alternating signal voltage applied to the hybrid coil from the output of the amplifier represented by Z1 in Fig. 4. Because Z3 = Z4 and the winding a-b is centre tapped, the resulting signal current divides equally between the trunk line and balance network. The directions of the currents flowing in the hybrid coil windings are those existing at some instant. No resultant flux is produced by the currents flowing through the a-c and b-c windings, and, therefore, no resultant voltage is induced in the d-e winding or applied to the input of the amplifier represented by Z2. The power from the output of the amplifier therefore divides equally between the trunk line and the balance network, no power being applied to the input of the amplifier serving the opposite direction of transmission.

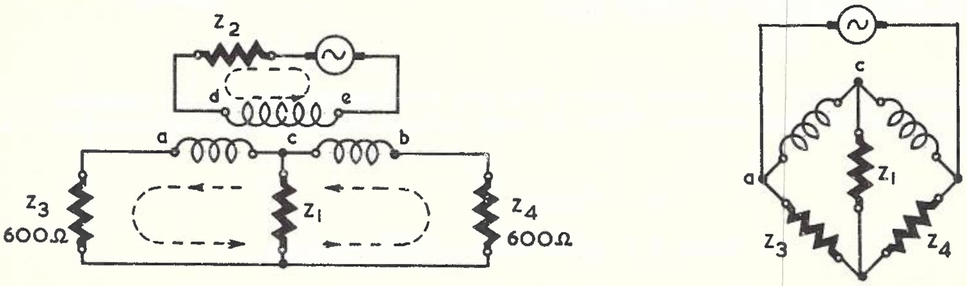


TRANSMISSION FROM Z1 TO TRUNK LINE.

FIG. 4.

Only half the power supplied from the output of the amplifier is applied to the trunk line. A power loss of one half is equivalent to a loss of 3 db, and so the hybrid coil at the output of the amplifier produces an equivalent loss of 3 db in the desired direction of transmission. To ensure conditions of maximum power transfer, the impedance of the supply source Z1 (300 ohms) is correctly "matched" to its load comprising Z3 (600 ohms) and Z4 (600 ohms) in parallel.

4.5 Transmission from Amplifier Output (Z2) to Trunk Line. In some applications of the hybrid coil, the input and output connections of the amplifiers are reversed and Z2 represents the output of the amplifier applying an alternating signal voltage to the d-e winding of the hybrid coil (Fig. 5a). The induced e.m.f. in the a-b winding produces a current flow through Z3 and Z4 in series. No voltage is applied to the input of the amplifier represented by Z1 as it is connected across points of equal potential. This is shown in the equivalent bridge circuit (Fig. 5b).



(a) (b)

Z3 = Z4.

Winding a-b is centre tapped at c.

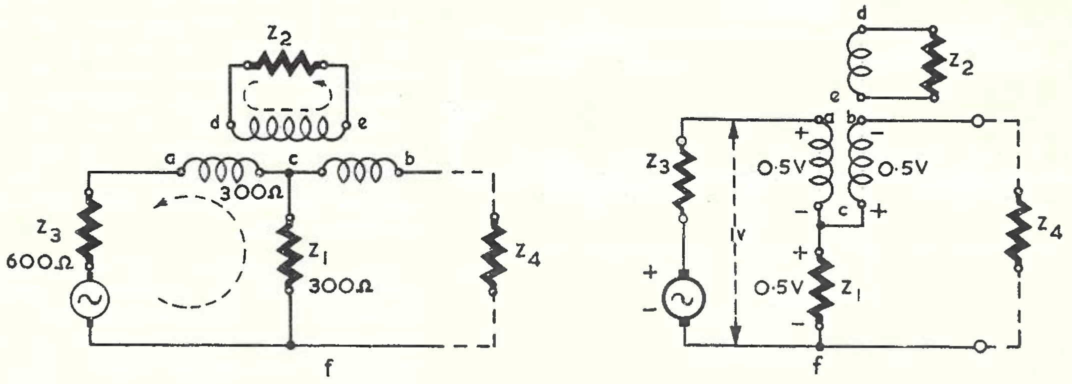
TRANSMISSION FROM Z2 TO TRUNK LINE.

FIG. 5.

As in the previous case, therefore, the power from the output of the amplifier divides equally between the trunk line and the balance network, no power being applied to the input of the amplifier serving the opposite direction; and the hybrid coil again produces an equivalent loss of 3 db in the desired direction of transmission. By suitable selection of the turns ratio of the coil windings, the impedance of the supply source (Z2) "reflects" an impedance of 1,200 ohms across the a-b winding and, therefore, is correctly "matched" to its load comprising Z3 (600 ohms) and Z4 (600 ohms) in series.

/ 4.6

4.6 Transmission from Trunk Line (Z3) to Amplifier Input. Assume now, an alternating signal voltage applied from the trunk line (Z3) to the hybrid coil with the balance network (Z4) initially disconnected as shown in Fig. 6a.



(a) (b)

TRANSMISSION FROM TRUNK LINE TO AMPLIFIER INPUT.

FIG. 6.

Under these conditions the resulting signal current flows through Z1 and the a-c winding of the hybrid coil in series. The flux produced by this winding induces a signal voltage across the d-e winding which is applied to Z2. The power from the trunk line, therefore, divides between Z1 and Z2. For maximum power transfer, the turns ratio of the hybrid coil windings must be such that Z2 "reflects" an impedance of 300 ohms into the a-c winding. This, in series with the 300 ohms impedance of Z1 provides the required termination of 600 ohms for the trunk line.

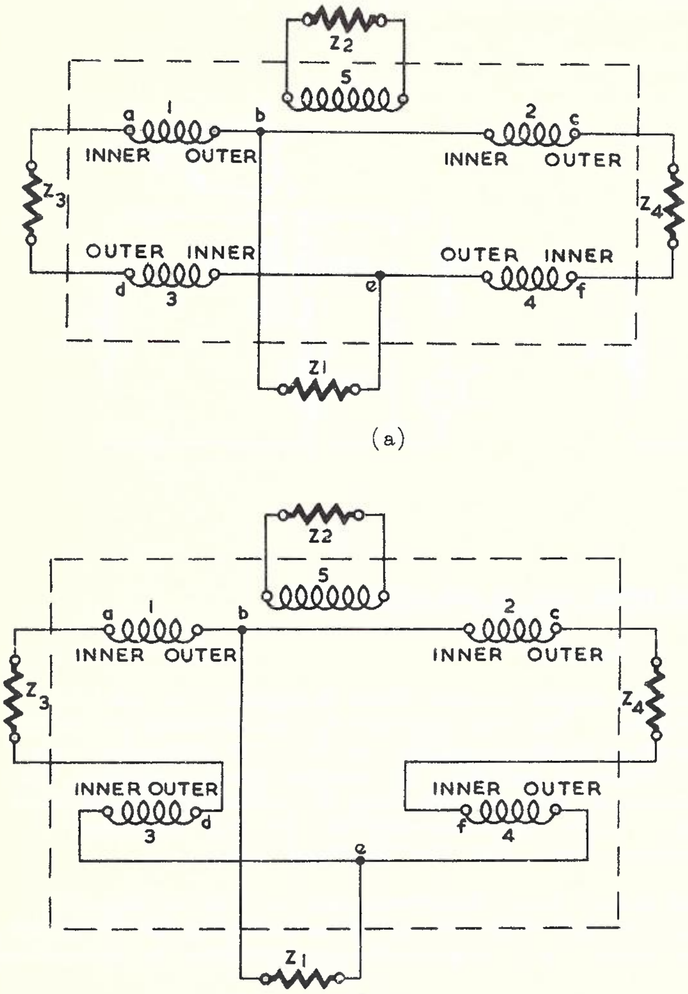
When a voltage is applied to the hybrid coil, therefore, half of that voltage is dropped across Z1, the other half being dropped across the a-c winding of the hybrid coil. This condition is shown in Fig. 6b at some particular instant, for an applied signal of 1 volt.

The voltage across the a-c winding is a voltage of self-induction, this being produced by the current flowing through the a-c winding via Z1. Voltages of mutual induction are induced across the d-e winding and the b-c winding, that across the former being responsible for the loss of half the input power. The direction of the voltage across the b-c winding is indicated and is in the same direction as that across the a-c winding, because the same flux produces both voltages and the two windings are wound in series. The voltage across the b-c winding equals that across the a-c winding, as the two windings have an equal number of turns. Points b and f therefore, are at the same potential, and if the balance network is connected across these points, as it is in practice, no current flows through that network as the necessary condition for a current flow is a difference of potential.

Thus, when power from a trunk line is applied to a V.F. repeater, one half of that power is applied to the input of the appropriate amplifier, the other half being dissipated in the output of the other amplifier. The hybrid coil again produces an equivalent loss of 3 db in the desired direction of transmission. None of the power from the line, however, appears in the balance network, resulting effectively in an infinite loss in this direction of transmission.

/ 4

4.7 Balanced Hybrid Coil. In the balanced hybrid coil, a schematic circuit of which is shown in Fig. 7a, the various windings are wound on the same core. The coils 1, 2, 3 and 4 are connected series-aiding and are equal in all respects, having the same number of turns, resistance, self-capacitance, etc. Coil 5 need not have the same number of turns, etc. as coils 1-4, and may provide a step-up or step-down action by suitably choosing the turns ratio. For correct impedance matching, assuming a trunk line impedance (Z3) of 600 ohms, the turns ratio is adjusted so that Z2 "reflects" an impedance of 1,200 ohms across the coils 1-4 when connected series-aiding.



(a)

(b)

FIG. 7. BALANCED HYBRID COIL.

Fig. 7a is purely a schematic representation of the hybrid coil and is not intended to indicate that the points b and e are the centre points of single windings a-c and d-f respectively. Usually the coils 1, 2, 3 and 4 are wound simultaneously, four spools of wire being used. There are, therefore, four "inner" and four "outer" connections, and care must be taken to interconnect these leads in correct phase relationship. A number of different arrangements are used to connect these coils, a typical arrangement being shown in Fig. 7b. In Fig. 7b, the points have been marked to correspond with the previous figure.

The operation of the balanced hybrid coil is similar to the unbalanced type discussed previously, and may be followed from Fig. 7b for the various directions of transmission.

4.8 Power Loss in Hybrid. Irrespective of the connection to which the input power is applied, the hybrid produces a minimum loss of 3 db in the desired direction of transmission. This condition is summarised in Fig. 8 in which the hybrid coil is replaced by a square in which are indicated the transmission paths existing under perfectly balanced conditions. Between each two adjacent impedances, the equivalent loss of the transmission path is 3 db, whilst between opposite impedances the transmission loss is infinite.

Because of the 3 db loss in each hybrid the gain introduced by a type 22 V.F. repeater in either direction of transmission is 6 db less than the gain of the amplifier appropriate to that direction.

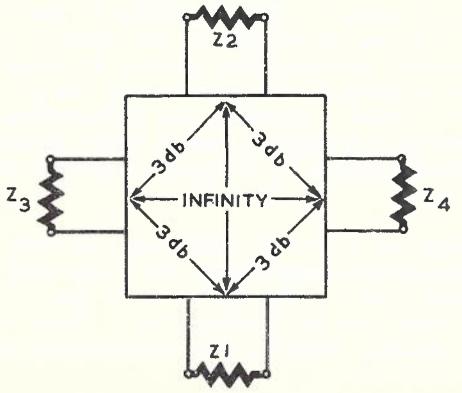
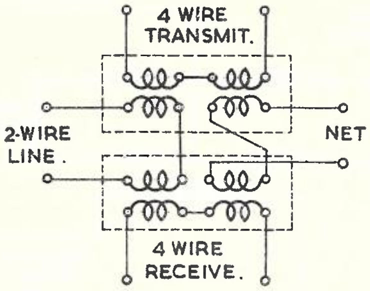


FIG. 8. TRANSMISSION PATHS IN HYBRID COIL.

/ 5.

5. TYPICAL APPLICATIONS OF THE HYBRID COIL.

5.1 One of the most common applications of the hybrid coil in telephony is to convert from a 2-wire to a 4-wire circuit, or vice versa. This is the reason for its use in the 2-wire V.F., repeater. Another method of providing a 2-wire/4-wire connection is by the use of a 4-wire terminating set as shown in Fig. 9. This is a combination of two transformers which is used in the same way as a hybrid coil, but has the advantage that the 2-wire/4-wire and balancing network impedances may be equal. The operation is essentially similar to that of the hybrid coil arrangement shown in Fig. 7.

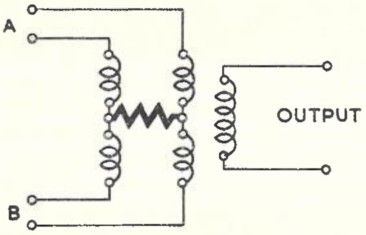


4-WIRE TERMINATING SET.

FIG. 9.

5.2 The hybrid coil may be used to combine two sources of signal power as shown in Fig. 10. This arrangement is used to apply the signals from two circuits A and B to a common output of different impedance, without interaction between the circuits. When the hybrid coil is perfectly balanced, no transmission occurs between A and B. In practice, the coil is not perfectly balanced and there is some transmission between A and B, but it is possible by careful design to reduce this to negligible proportions.

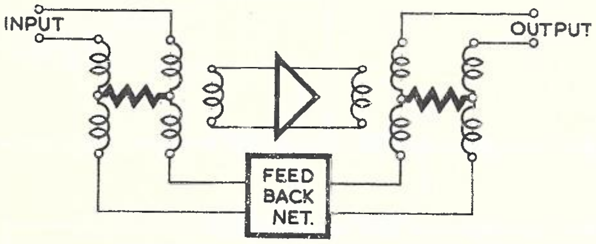
A similar arrangement may be used in reverse for splitting the output of a circuit.



HYBRID COIL COMBINING CIRCUIT.

FIG. 10.

5.3 Negative feedback amplifiers may be designed in which the feedback circuit is provided via the hybrid coils as shown in Fig. 11. The advantages of this arrangement are that the characteristics of the input and output transformers as well as the amplifier proper, are stabilised by feedback action and certain economics in design are effected. Equalisation to compensate for the slope of the line or cable characteristic may be included in the feedback network.



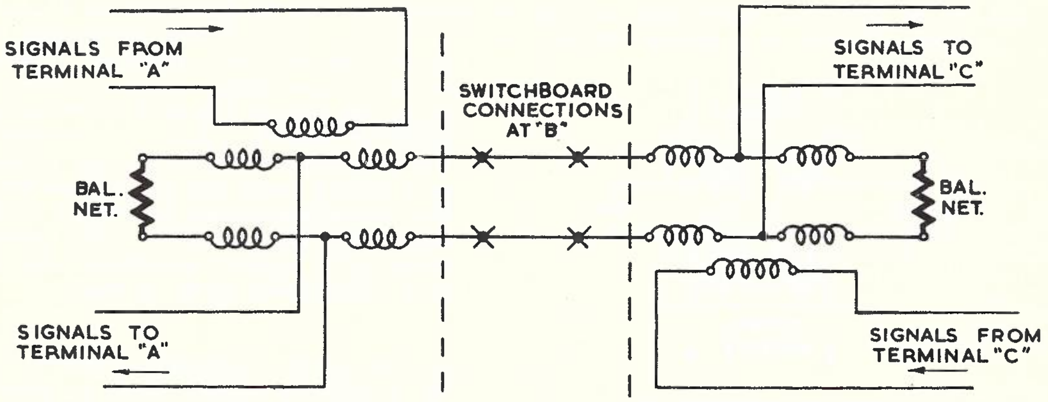
FEEDBACK AMPLIFIER WITH HYBRID COIL.

FIG. 11.

5.4 "Tail-Chasing" or "Tail-Eating" connection. When circuits equipped with hybrid coils are interconnected, the 3 db losses produced by each hybrid coil are additive. In some circuit connections, it is necessary to reduce the overall loss of the circuit by reducing the losses produced by the hybrid coils at the interconnecting stations. To achieve this, an arrangement known as a "tail-chasing" or "tail-eating" connection is used. Although this type of connection can be made to give an increase in gain at the point of connection, this is seldom necessary in practice as most 4-wire circuits are adjusted to zero loss between hybrid line terminals. In switchboards using the "tail-eating" connection, the additional gain is usually cancelled by the inclusion of pads in the connection circuit, and tail-eating serves rather to reduce echo and "singing" effects in the circuit, and to enable the telephonist to monitor the circuit using a 2-wire telephone set. This type of connection is described, therefore, principally because it provides an interesting example of the hybrid coil operation.

/ Assume

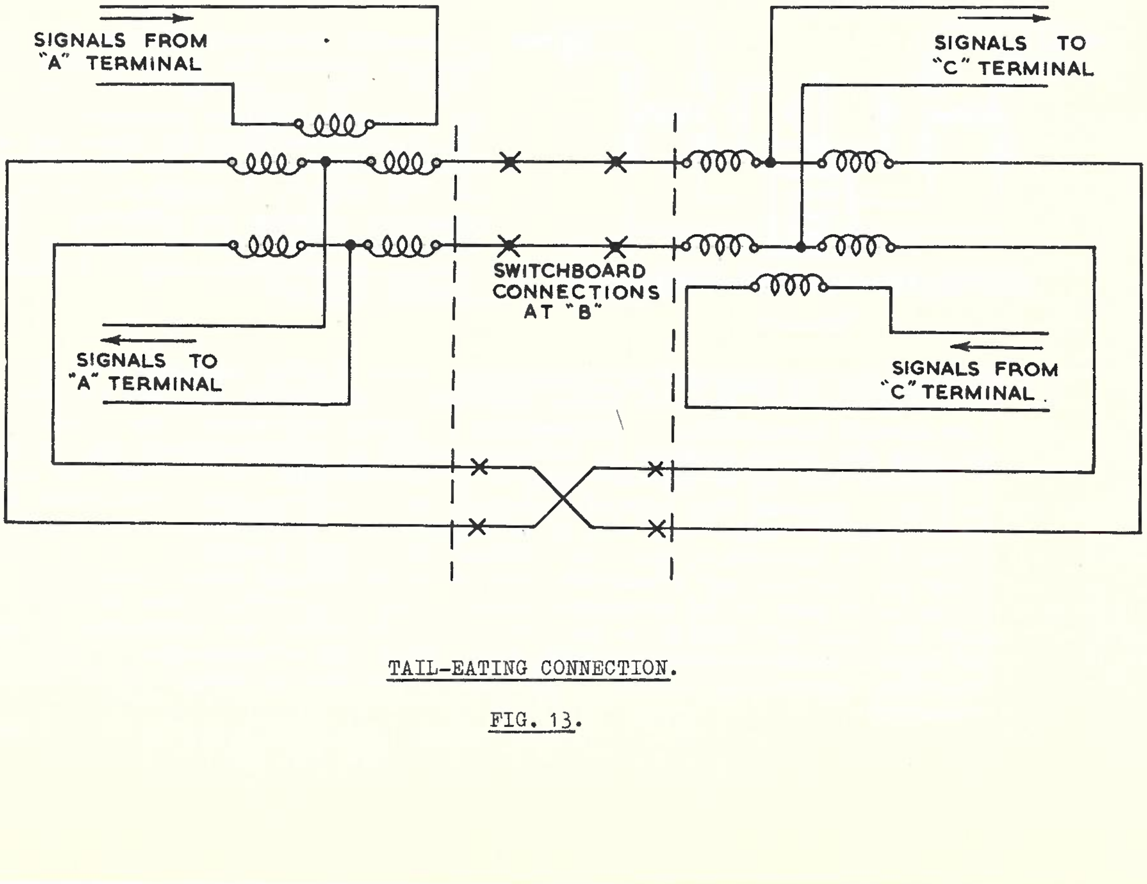
Assume firstly, an A-B channel connected at B to, say, a B-C channel as shown in Fig. 12.



2-WIRE CONNECTION OF 4-WIRE CIRCUITS.

FIG. 12.

Assuming that the A-B and B-C circuits each have a 6 db loss from switchboard to switchboard then, when the two circuits are connected together at B, the overall loss will be 12 db. To provide the same loss over the A-C connection as over the A-B or B-C connection, it is necessary to reduce the overall loss in the A-C circuit by 6 db. This is done by eliminating the 3 db loss produced by each hybrid coil at the switching point, using a "tail-chasing" or "tail-eating" connection at the switching point, as shown in Fig. 13.

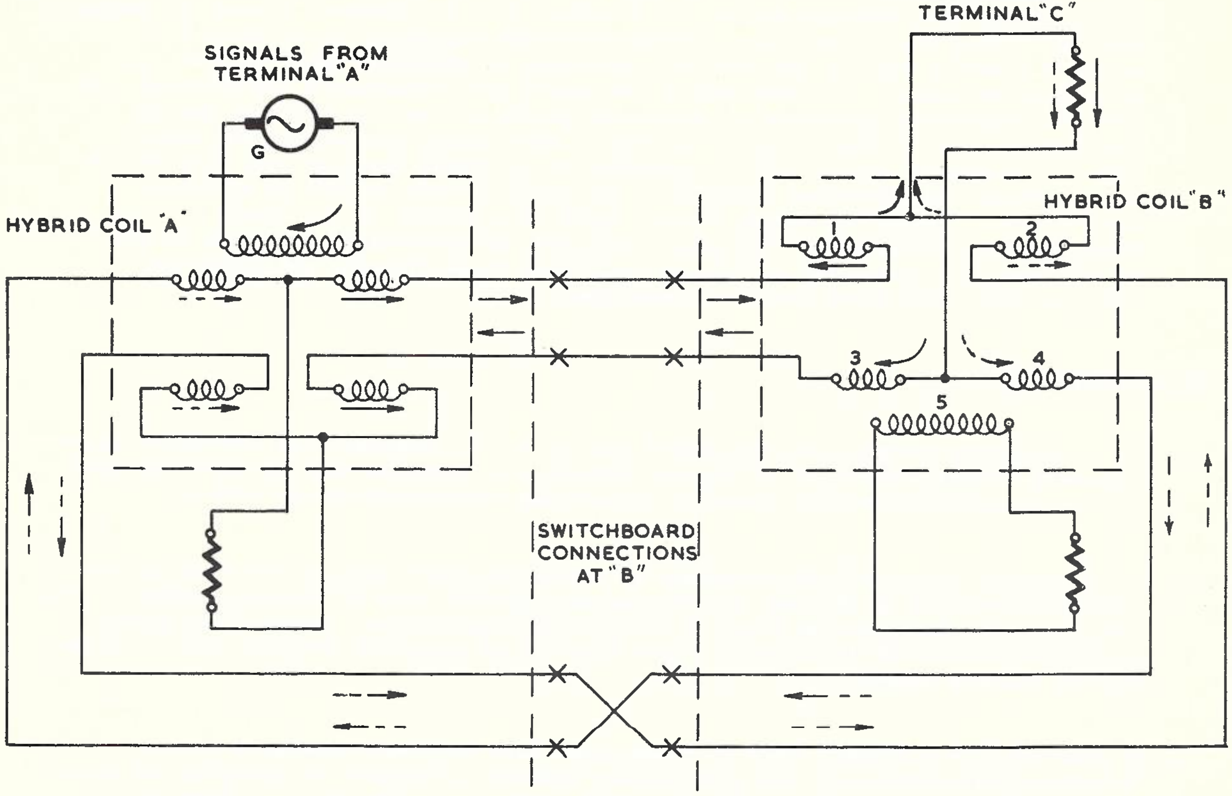


TAIL-EATING CONNECTION.

FIG. 13.

The switching operation of connecting the A-B line to the B-C line at B automatically connects the switchboard side of the two hybrid coils together. The switchboard balance networks are disconnected and the balance sides of the two hybrid coils are connected together with a cross-over in the connection as in Fig. 13.

An explanatory circuit of the tail-eating connection is shown in Fig. 14, using the hybrid coil arrangement as shown previously in Fig. 7b.



⟶ Signal current flowing in "line" sides of hybrid coils.
- - -➝ Signal current flowing in "network" sides of hybrid coils.

FIG. 14. EXPLANATORY CIRCUIT OF TAIL EATING CONNECTION.

To explain the operation of the circuit, transmission in the direction A-C is considered. The generator G represents the signal voltages applied to the hybrid coil from the A terminal. The direction of the currents flowing in the hybrid coil windings are those existing at some instant. These currents are in series because the four windings of the hybrid coil are connected series aiding.

One half of the power applied to the hybrid coil from A, is applied to the circuit to C via the straight-through connections at the switchboard jacks. The remaining half, normally lost in the network, also is applied to the circuit to C via the connection between the network sides of the hybrid coils. No resultant flux is produced by the currents flowing through the individual windings of hybrid coil B and therefore the currents encounter only the non-inductive resistance of these windings. In addition, no signals are induced in coil No. 5 and no power is dissipated in the terminating impedance connected to this winding. All the power arriving from the A terminal, therefore, is applied to the circuit to C. (It is interesting to note that the current flowing in the impedance connected across the centre points of the line windings of hybrid coil B, is doubled due to the tail-eating connection. Doubling the current is equivalent to a 6 db gain in the power sent to terminal C.)

/When

When, therefore, two circuits are switched together by a tail-eating connection, the 3 db losses normally produced by each hybrid coil at the connecting point are eliminated and the overall loss is reduced by 6 db.

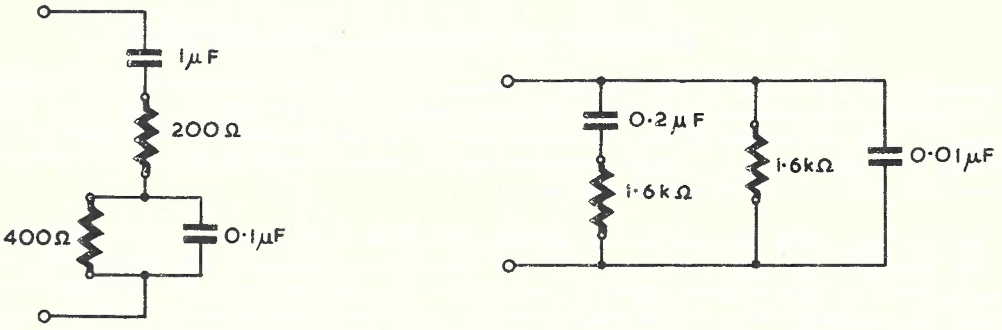
A common method of connecting a hybrid coil to a 4-wire circuit is that shown in Fig. 14, in which the transmitting side at any station is connected across the centre points of the line windings whilst the receiving side is connected across the secondary winding. When two of these circuits are connected together, one cross-over is required (usually made in the network connection) to eliminate the 6 db loss, as previously explained. In some cases, the hybrid coil connections are reversed, the receiving side being connected to the centre points of the line windings and the transmitting side to the secondary winding. Here again, one cross-over (usually made in the network connection) is necessary to eliminate the 6 db loss when two of these circuits are connected together. The proof of this is left as an exercise to the student. Again, one 4-wire circuit could be connected to the hybrid coil as first outlined above, whilst the other could use the connections mentioned in the second case. A cross-over is not necessary when these circuits are connected together, this also being left as an exercise.

6. BALANCE NETWORKS.

6.1 For satisfactory operation of the hybrid coil in a V.F. repeater, the impedance versus frequency characteristic of the balance network must simulate that of the trunk line as far as possible, over the range of frequencies transmitted by the circuit.

6.2 As the nominal characteristic impedance of telephone trunk lines is 600 ohms, a non-inductive resistor of 600 ohms may be used as a general type of balance network. The characteristic impedance of lines is predominantly capacitive, however, and a non-inductive resistor of 600 ohms in series with a 2 μF capacitor provides a more satisfactory balance network.

6.3 In practice, the different types of trunk lines have different impedance versus frequency characteristics, and each balance network is designed to simulate the particular characteristics of the trunk line with which it is associated. Some typical forms of balance networks are shown in Fig. 15.



(a) Open-Wire Line.

(b) Cable Pair.

TYPICAL BALANCE NETWORKS.

FIG. 15.

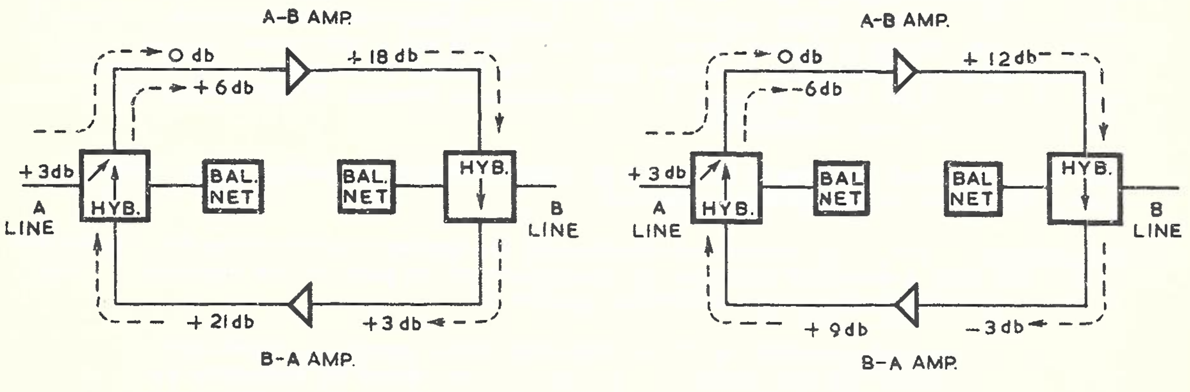
7. "SINGING" IN V.F. REPEATERS.

7.1 In the theory of the hybrid coil discussed in Section 4, the network was assumed to be perfectly balanced against its line. While it is possible to design networks which simulate the line which they have to balance, at the time the measurements for such networks are made, it is not possible to maintain this balance over a period of time due to changing weather conditions which affect the line impedance. In 2-wire circuits, the total gain which can be obtained in practice, is limited by the degree of balance which can be maintained between each line and its balance network.

7.2 When a line is unbalanced against its network, some of the power applied to the hybrid coil is dissipated in the opposite impedance, and the loss across the opposite impedances of the hybrid coil becomes a finite value. The greater the degree of unbalance, the greater the power transferred. This means that when power is applied from the trunk line, some is dissipated in the balance network; and when power is applied from the output of one amplifier, some is fed to the input of the other amplifier.

7.3 This unbalance reduces the gain which the whole system can provide, because some of the output of each amplifier in the system is lost due to the unbalance, which loss has to be added to the 3 db loss at each hybrid coil described previously.

7.4 In addition, the total gain is further reduced by the unbalances limiting the gains of the individual repeater amplifiers. When both lines into a 2-wire repeater are unbalanced against their networks, a "singing" path is available and the repeater will "sing" if the added gain of the two amplifiers were greater than the added losses across the two hybrid coils. As an example, let the amplifiers of Fig. 16a have a gain of 18 db each and let the loss across each hybrid coil between the output of one amplifier and the input of the other be 15 db each. A signal is now applied from the A line to the hybrid coil having a level of +3 db (all levels referred to 1 mW). The input to the A-B amplifier is 0 db, because of the 3 db loss in the hybrid coil. The output of the A-B amplifier is +18 db and the input to the B-A amplifier is 15 db below this, that is, +3 db. The output of the B-A amplifier is +21 db, of which +6 db appears at the input to the A-B amplifier again. This action continues with the levels increasing until they reach a steady value fixed by the cut-off and saturation features of the amplifier valves. Once initiated, the action continues after the signal is withdrawn, because the system provides its own input. When the gains of the amplifiers are reduced to 12 db each, then, with the same signal input, the input and output levels of the amplifiers are as shown in Fig. 16b. In this case, the level of -6 db returned to the input of the A-B amplifier is less than the original level of 0 db, and the returned signal does not proceed to build up as in the previous case.



(a) (b)

FIG. 16. SINGING PATH IN V.F. REPEATER.

7.5 This example is illustrative only. In practice, it is not necessary to apply an input signal to the repeater to produce "singing". Usually sufficient inherent noise exists in the circuit components to produce oscillation immediately D.C. power is applied to the amplifier circuit. This means that, when the gain around the singing path exceeds the loss, the repeater acts as an amplifier providing its own input, and "sings". When the gain of the amplifiers is reduced until the loss around the singing path exceeds the gain, the circulating energy is attenuated to a greater degree than it is amplified, and the repeater is stable.

7.6 The gain of each repeater amplifier, therefore, is limited by the tendency of the repeater to sing. The "singing point" is an expression for the lowest gain in the circuit at which a repeater will sing. The safe working point for stability in the repeater is the "singing point" less 5 db. To prevent the repeaters from singing under all circumstances on a 2-wire circuit, the gains of the repeater amplifiers have to be kept fairly low, because in each repeater there are two possible sources of unbalance - the lines on each side of the repeater against their respective networks. Thus, the effectiveness of 2-wire repeaters is limited by the number of balances which must be provided, particularly on long circuits where a number of repeater stations is necessary.

8. TYPICAL 2-WIRE V.F. REPEATER.

8.1 A typical 2-wire V.F. repeater is the type manufactured by the Telephone Manufacturing Co. (T.M.C.). This repeater is designed for use with open-wire lines having a nominal characteristic impedance of 600 ohms and has a maximum gain of 19 db in each direction of transmission over the frequency range 300-2,600 c/s. It consists essentially of a single stage amplifier for each direction of transmission with input and output transformers, gain control units, filter units and hybrid coils for connection to the 2-wire lines. A schematic circuit of a typical 22 repeater is shown in Fig. 17a, and an equivalent simplified circuit is shown in Fig. 17b.

8.2 Circuit Description. Speech power from the Up Line is applied to the hybrid coil. Half this power is dissipated in the output circuit of the Down-Up amplifier, which is bridged across the centre of the hybrid circuit. The voltage induced across the secondary of the hybrid, however, causes a current to flow through a potentiometer and a resistor to the primary of the input transformer. A capacitor and parallel resistor in the primary winding of the input transformer act as an equaliser for low frequencies. The voltage induced across the secondary winding of the input transformer is applied between the grid and cathode of the triode valve, through a capacitor and parallel resistors. After amplification, the amplified speech voltages are induced across the secondary winding of the output transformer, and these are applied to a low-pass filter unit. From this filter unit, the output power is applied to the centre points of the hybrid coil. (The x marks indicate that a Ringing Relay-Set, as described in Paper 2 of this book, may be connected here.) At the hybrid coil, this power divides equally between the Down Network and the Down Line. The hybrid coil connections ensure that none of this output power is applied to the secondary winding of the hybrid, which forms the input to the return amplifier.

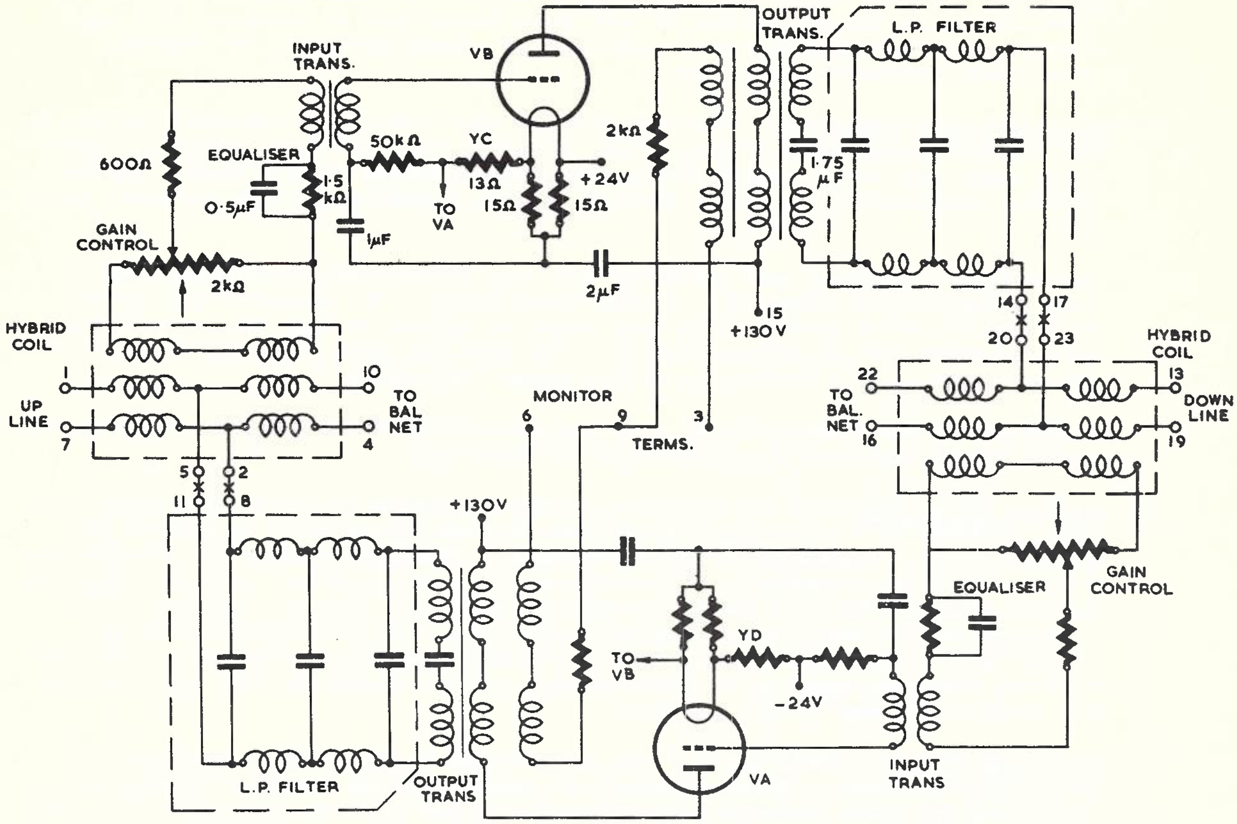
The operation from the Down Line to the Up Line terminals is similar to the above description, but in the reverse direction.

8.3 Gain Control. The input potentiometers provide the correct terminations for the hybrid coils, and also a means of limiting the amplification or gain of the repeater. These controls are necessary for the following reasons -

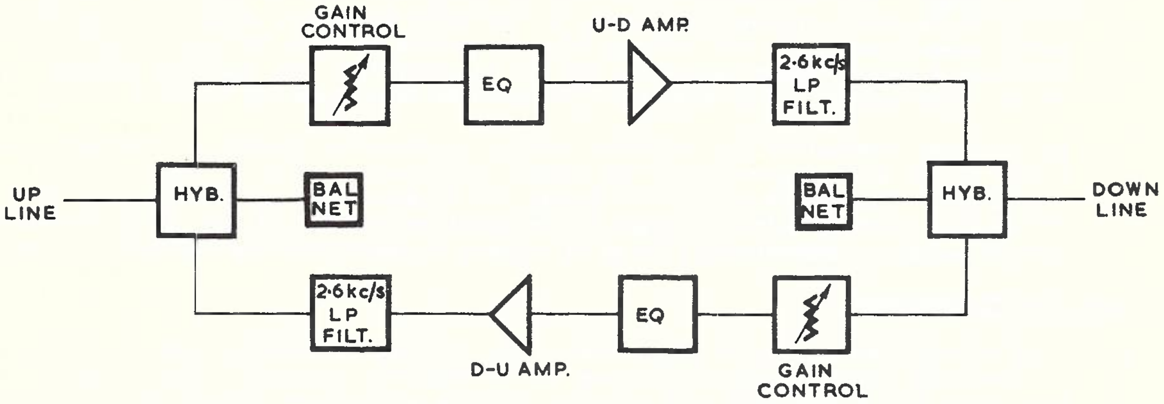
(i) to prevent instability of the repeater which appears as "howling" or "singing" on the circuit. Instability is caused by excessive gain, as described in Section 7, the balance network not being sufficiently accurate in practice to prevent some energy circulating around the repeater.

(ii) to prevent overloading the thermionic valve amplifier. This results in amplitude distortion of the transmitted speech.

/ Fig. 17.



(a) Schematic Circuit.



(b) Equivalent Simplified Circuit.

V.F. REPEATER (TYPE 22).

FIG. 17.

8.4 Equaliser. A simple equaliser comprising a resistor and capacitor in parallel, is connected in the primary winding of each input transformer to ensure uniform amplification of the various frequency components of speech applied to the repeater. This reduces frequency distortion.

8.5 Thermionic Valve Amplifier. The circumstances under which V.F. repeaters operate do not require a large power output. V.F. repeaters are, therefore, generally single stage amplifiers using a valve with a medium amplification factor, which, together with the impedance of the output circuit, acts as a combined voltage and power amplifier.

In the T.M.C. repeater, each amplifier unit is a conventional transformer coupled stage using a triode type T.M.C. 14 thermionic valve. The potential drop across resistors YC and YD provides grid bias, which is applied through resistors to the grids of valves VB and VA respectively. The grid and anode leads are returned to the centre point of a resistor connected across the cathode.

Investigation has recently established the suitability of using 6V6GT tetrode valves in the T.M.C. repeaters with minor circuit modification.

8.6 Low-Pass Filter Unit. A 2.6 kc/s low-pass filter network is connected in each amplifier, between the anode circuit of the valve and the hybrid coil, to prevent the passage of high frequencies in the voice range. Frequencies above 2.6 kc/s are not essential for the transmission of satisfactory commercial speech, and are eliminated because it is difficult to design a balance network that exactly simulates a long telephone circuit over a wide range of frequencies. The inclusion of low-pass filters within the repeater means that the balance network need now balance the line over the frequency range up to 2.6 kc/s only, and any unbalance above 2.6 kc/s does not produce "singing" in the repeater.

8.7 Monitoring Circuit. Auxiliary windings are provided on the output transformers for supervision purposes. These windings are connected to the "monitor" terminals. A monitoring telephone connected across terminals 3 and 6 allows a technician to listen and speak in both directions of transmission. With the telephone connected between terminals 3 and 9, speech from the Up Line is heard and speech is transmitted to the Down Line. With the telephone connected between terminals 6 and 9, speech from the Down Line is heard and speech is transmitted to the Up Line.

8.8 Power Supply. The valve cathode circuits are completed from the positive terminal of the 24 volts supply through the cathode of the valve VB (across which is connected a centre tapped resistor), the resistor YC, the cathode of valve VA (across which is connected a centre tapped resistor), and the resistor YD to the negative terminal of the 24 volts supply. Approximately 0.3 ampere is taken from the 24 volts battery.

The positive terminal of the 130 volts battery is connected directly or through alarm relays to the primary windings of the output transformers and so to the anodes of the valves. The return circuit is through the filament circuit, the negative terminal of the anode battery being connected to the positive terminal of the 24 volts battery (and to earth). Approximately 20 mA of current is taken from the 130 volts battery.

9. CORD CIRCUIT REPEATERS.

9.1 A cord circuit repeater is an adaptation of the 22 type, so arranged that it may be switched into circuit between two lines in the form of a connection cord circuit. Twin plugs on the answering cord comprise the line and network circuit of one side of the repeater. Similar plugs on the calling cord form the connections to the other side of the repeater. This form of repeater is used for improving cross-country traffic in country centres. A range of balance networks is provided to suit lines between which the repeater is required to operate. The balance to suit any particular line is switched in when a connection is set up. The switchboard operator regulates the gain of the repeater by means of keys located on the operating position.

/ 10.

10. TWO-WIRE REPEATERED CIRCUITS.

10.1 On long 2-wire circuits producing a high loss, a number of low gain repeaters spaced at equal intervals, rather than one high gain repeater at either end or in the centre, is used. The arrangement of such a circuit is shown in Fig. 18, indicating the symbol commonly used in trunk line diagrams for V.F. repeaters.

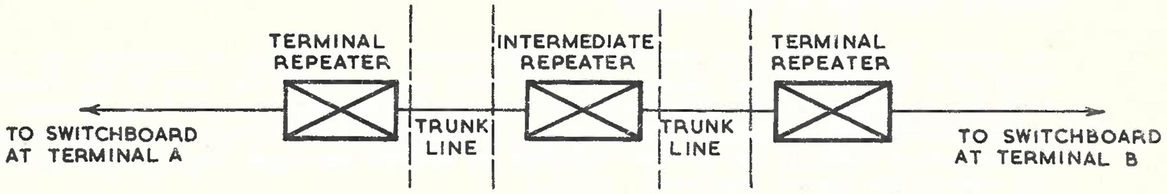


FIG. 18. ARRANGEMENT OF LONG 2-WIRE CIRCUIT.

There are a number of reasons for doing this, the main ones being -

(i) On very long circuits, the high gain required from the repeater amplifiers would make them costly to manufacture and maintain.

(ii) On a line with high attenuation, the signal level could fall so low before amplification by a single repeater that the signal level could become comparable with the line noise due to interference from other circuits. The amplifier would, therefore, amplify both signal and line noise, so that the latter, normally inaudible, would be heard at a level which would interfere with the signal. By spacing the repeaters as in Fig. 18, the signal level is amplified before it falls to a level comparable with that of the line noise.

(iii) Crosstalk would be severe with a single high gain amplifier. Fig. 19 shows two circuits connecting the same terminals and equipped with single repeaters.

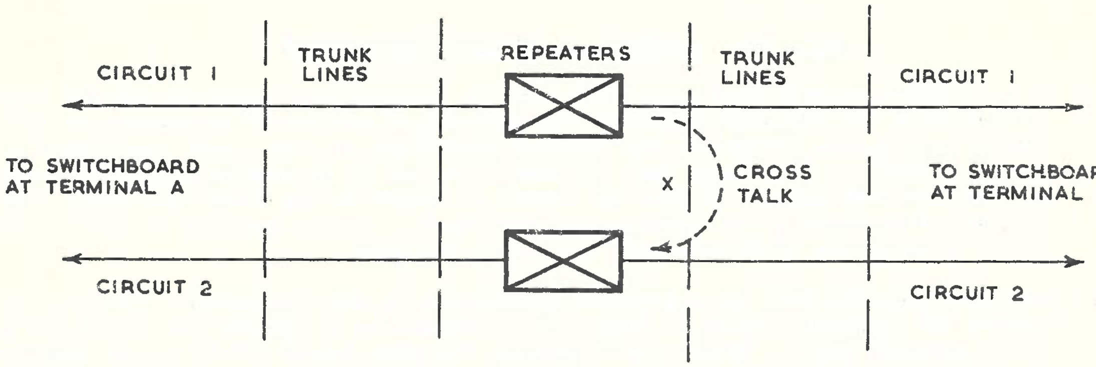


FIG. 19. CROSSTALK IN LINES WITH ONE REPEATER.

When transmitting in the direction A-B over circuit 1, point x would be a point of high level on that circuit but a point of low level for transmission in the direction B-A over circuit 2. Due to the high level of the output from the repeater, the crosstalk from point x on circuit 1 into point x on circuit 2 would be severe and of a level comparable with the low signal level there. Both signal and crosstalk would be amplified, and both circuits would crosstalk into one another fairly severely.

/ 11.

11. FOUR-WIRE REPEATERED CIRCUITS.

11.1 In 4-wire V.F. repeatered circuits, four wires are used for each speech channel. Two of these wires are used in the "go" direction, and the other two wires are used in the "return" direction. Thus, considering a subscriber speaking over a 4-wire circuit, his own speech passes over one pair of wires and the incoming speech from the distant subscriber is confined to the other pair of the 4-wire channel. When repeaters are applied to 4-wire circuits, therefore, they need amplify the speech in only one direction of transmission.

The 4-wire trunk circuit is connected to the 2-wire subscriber's or junction line by means of a hybrid coil and balance network which serve, as in the case of the 2-wire repeater, to separate the opposite directions of transmission, or as 4-wire/2-wire conversion devices. Balance networks are required, therefore, only at the terminals of the 4-wire circuit, and are not required to balance the trunk line impedances as in the case of the 2-wire repeatered circuit.

The block schematic circuit of a typical 4-wire V.F. repeater installation is shown in Fig. 20. In some cases, it is possible to obtain sufficient amplification by the use of terminal amplifiers only, without the need for repeater stations.

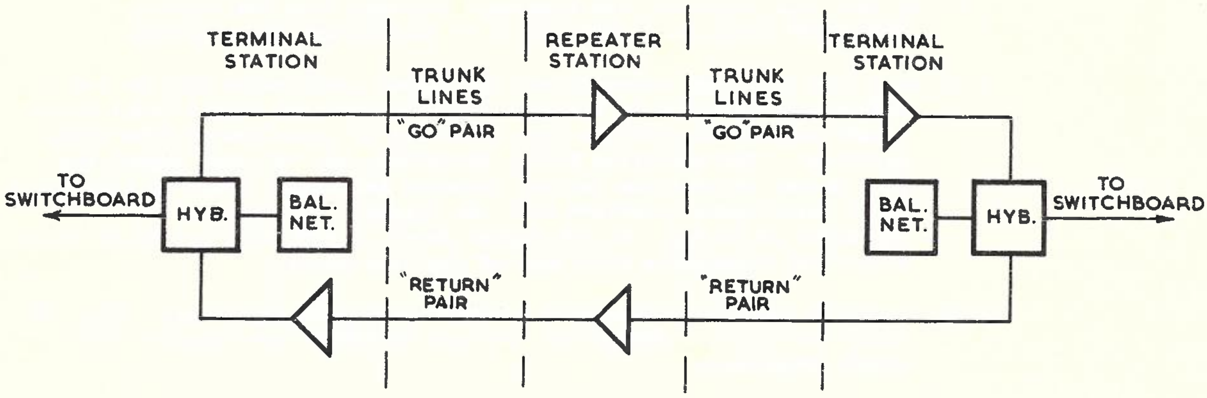


FIG. 20. 4-WIRE V.F. REPEATER INSTALLATION.

11.2 As the balance networks are eliminated from the intermediate repeaters and the trunk line side of the terminal repeaters, the majority of sources of unbalance are removed, and it is possible to operate the repeater amplifiers at much higher gains than in the 2-wire circuit. This means that the conductors can be of smaller gauge, so that, whilst 4-wires are used instead of two, the amount of copper in the 4-wire is usually less than in the 2-wire circuit, so effecting economy there. In the majority of 4-wire trunk cable circuits the conductors used are 20 lb. per mile.

11.3 Four-wire circuits find their greatest application in cable circuits. In order to secure the greatest economy in copper, it is desirable to operate the amplifiers at their greatest gain. Under this condition, the high output levels of the amplifiers would cause crosstalk into adjacent low-level circuits, as described previously in section 10. It is necessary, therefore, to "shield" the pairs used for transmission in one direction from those used for transmission in the opposite direction. This is done by using metallic screens between the two groups of pairs when only one cable is used between two stations. The most usual method adopted in present day 4-wire working is to lay separate cables, the pairs in one cable being used for transmission in one direction and the pairs in the other cable for transmission in the opposite direction. One cable is known as the "go" cable and the other as the "return" cable.

/ 12.

12. TYPICAL PENTODE REPEATER FOR 4-WIRE CIRCUITS.

12.1 Fig. 21 shows the circuit of an amplifier used for 4-wire working on some cable installations.

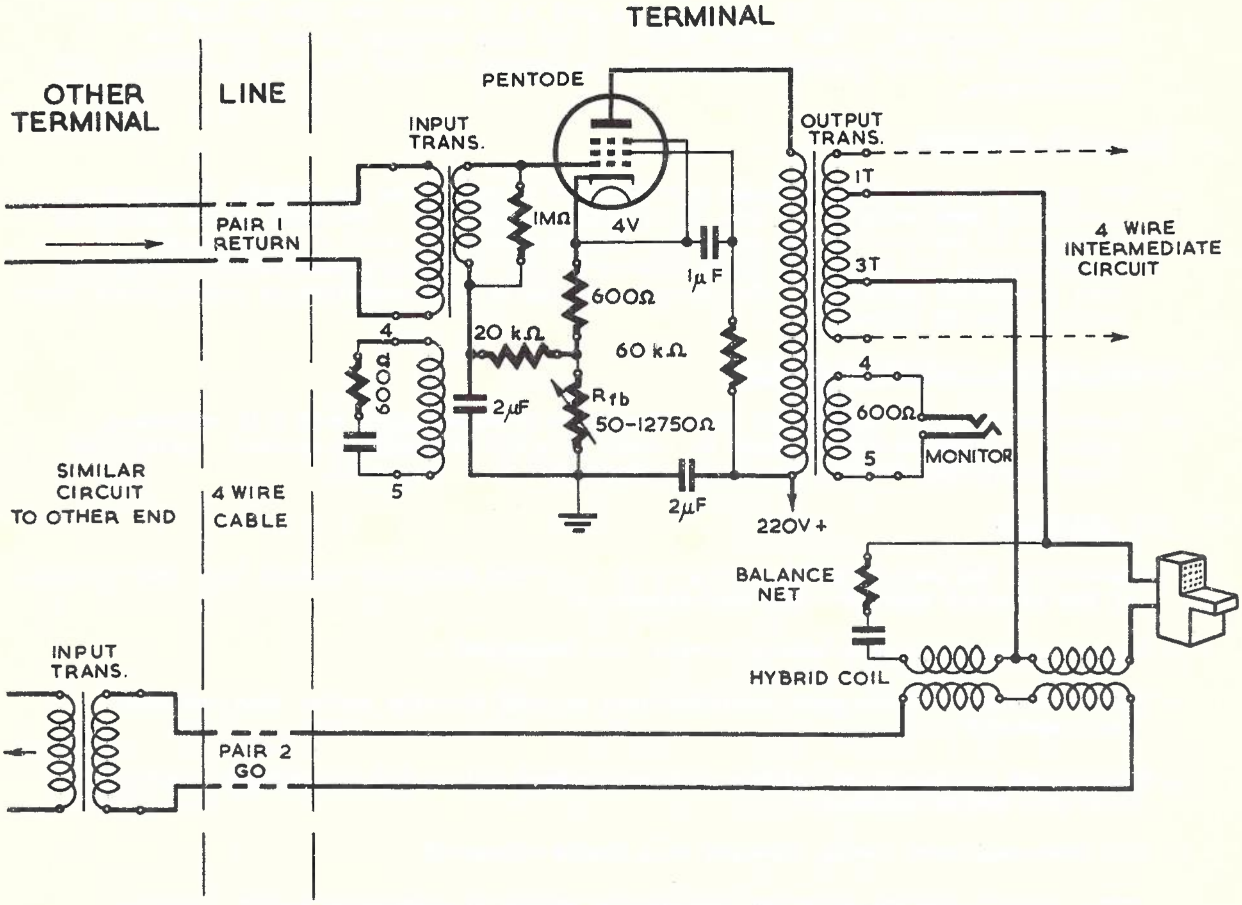


FIG. 21. TYPICAL 4-WIRE PENTODE REPEATER.

12.2 A type 4046 pentode valve with negative "current" feedback is used. Bias is obtained from the voltage drop produced across the 600 ohms cathode resistor by the anode current flowing through it. The feedback resistor Rfb is in series with the cathode resistor and is capable of being varied in steps giving values between 50 ohms and 12,750 ohms. The value of the feedback resistor determines the gain of the amplifier and is set at the time of installation. The maximum and minimum gains provided by the repeater are 34 and 18.5 db respectively. The 20,000 ohms resistor applies the bias to the grid without short-circuiting the feedback resistor, whilst the 2 μF capacitor allows the input voltage developed across the secondary of the input transformer to be applied across the grid and cathode in series with Rfb without affecting the bias voltage. Absence of this capacitor means that the bias is the voltage dropped across the 600 ohms resistor in series with that dropped across Rfb and the 20,000 ohms resistor in parallel.

12.3 The input and output transformers are identical. The input transformer connects the cable to the input of the pentode, and terminates the cable by means of the terminating or balancing winding 4-5 across which a balance network is connected. In the output transformer, this winding is used for monitoring purposes. When the repeater is used at an intermediate point in a conventional 4-wire circuit, the connections from the output transformer to the hybrid coil are omitted, and the output is shown by the dotted connections.

/ When

When used with the hybrid coil and balance network, the repeater functions as a terminal amplifier and provides a 4-wire/2-wire connection as shown in Fig. 21. In this case, tappings 1T and 3T (shown in full lines in the output transformer) are used to provide a 300 ohms output impedance. When looking into the output of the line winding of the hybrid coil, the impedance is such as to match the line to which it is directly connected. The centre points of the line windings of the coils are accessible, so that phantom circuits may be derived without the use of external line transformers.

13. SPACING OF REPEATERS.

13.1 The spacing of repeaters is largely a question of economics, as several factors must be considered when selecting a site for a repeater station. The cost of the cables in relation to the cost of the repeaters, together with the cost of the repeater accommodation and provision for maintenance, must be closely examined to produce the most economical solution. The general spacing of V.F. repeaters on aerial trunk lines is from 100-150 miles.

14. SIGNALLING OVER REPEATERED CIRCUITS.

14.1 Several methods are in use for signalling over lines equipped with V.F. repeaters, namely, the use of a Ring Round Relay-Set or a V.F. signalling System. Details of these signalling methods are given in Paper No. 2 of this book.

15. TEST QUESTIONS.

1. Explain why the gain of a V.F. repeater in a certain direction is 6 db less than the gain of the repeater amplifier for that direction.

2. Why are low-pass filters used in 2-wire V.F. repeaters?

3. Why are a number of low gain repeaters used on long circuits rather than one high gain repeater?

4. Explain how the degree of balance obtained between a line and its network limits the gain of a 2-wire repeater.

5. What advantage have 4-wire circuits over 2-wire circuits?

6. Draw a circuit showing a typical tail-eating method of connecting 4-wire circuits together. Explain how this method of connection is used to eliminate the 3 db losses normally produced by each hybrid coil at the connecting point.

16. REFERENCES.

Maintenance Circular No. 13 "Voice Frequency Repeaters".

Transmission Engineering Instructions.

Long Line Equipment R4100 - "Modification of T.M.C. Two-wire V.F. Repeater".

END OF PAPER.

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COURSE OF TECHNICAL INSTRUCTION.

LONG LINE EQUIPMENT II.

SIGNALLING ON TRUNK CIRCUITS.

CONTENTS:

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1. INTRODUCTION.

1.1 Modern transmission technique has provided a high standard of speech transmission over long circuits, but, until recently, the methods of signalling were not entirely satisfactory. By signalling is meant not only the signals sent over long trunk lines by one operator to attract the attention of an operator at a remote station, but also the signals sent over long trunk lines to enable operators to dial into an automatic network without the aid of an operator in that network. This Paper describes the various types of signalling systems in use.

2. DIRECT-CURRENT DIALLING.

2.1 Although direct-current dialling facilities are readily provided over long circuits and were used extensively in the past, certain factors limit their use.

The main methods of direct-current signalling are -

(i) Loop dialling.

(ii) Phantom dialling.

(iii) Composite dialling.

2.2 Fig. 1. shows the essentials of a loop dialling circuit, the automatic exchange end only being drawn. The operation of plugging up the line at the distant manual exchange establishes a loop to operate relay A, whose operated contacts A1 establish the pre-dialling loop to the automatic exchange. The operation of a dialling key at the manual exchange connects a dial across the line there and disconnects all other equipment. Relay A impulses, under the control of the dial, contact A1 repeating the impulses into the automatic exchange equipment.

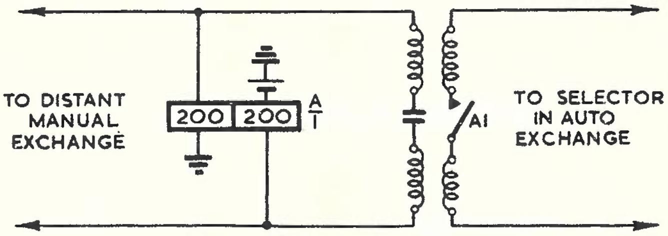


FIG. 1. LOOP DIALLING CIRCUIT.

2.3 When a similar arrangement is used on a phantom circuit, the pair of wires to the distant manual exchange in Fig. 1 is connected to the centre points of the phantom transformers at the automatic exchange end of the circuit instead of to a physical circuit, as in Fig. 1. Similarly, at the distant manual exchange end, the switchboard equipment for this dialling line is connected to the centre points of the phantom transformers.

2.4 Composite dialling circuits use a C.X. leg over which to dial, with a physical circuit for speech transmission. Fig. 2 shows a typical circuit.

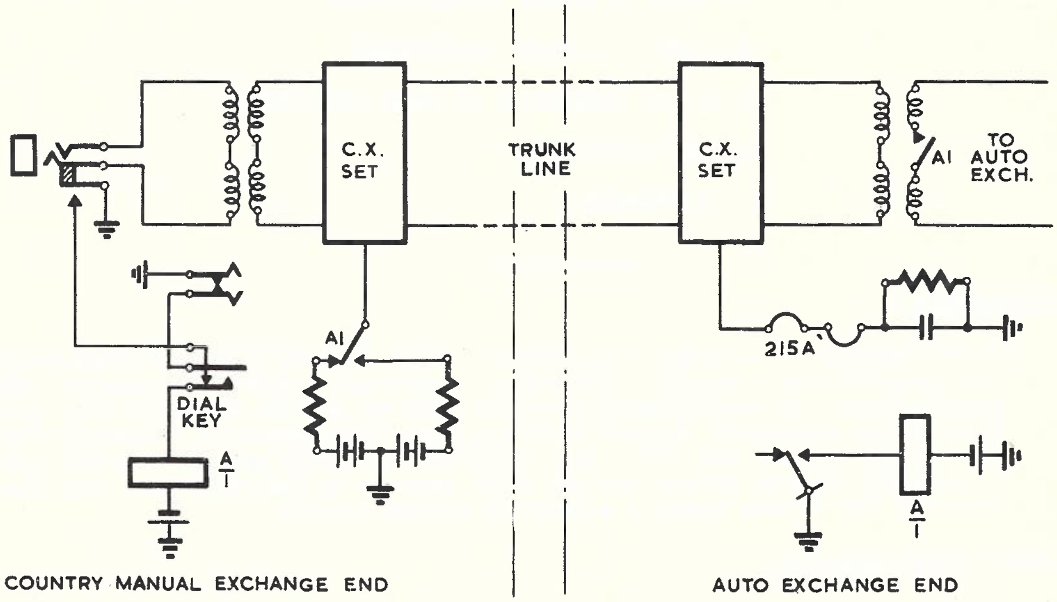


FIG. 2. MAIN ELEMENTS OF COMPOSITE DIALLING CIRCUIT.

In this circuit, double-current signalling is used, a polarised telegraph relay, type 215A, being used to repeat the impulses into the automatic exchange equipment. The advantages of double-current working are dealt with in Telegraphy I, Paper No. 4, and the same advantages which its use provides in Telegraphy also apply to Automatic Telephony.

/ 2.5

2.5 D.C. dialling over physical or phantom circuits is unsatisfactory for the following reasons -

(i) The mutual capacity of long trunk circuits introduces severe impulse distortion.

(ii) The insulation resistance of open wire circuits also produces impulse distortion, which renders the circuits unworkable during wet weather.

(iii) On extremely long circuits, it is necessary to regenerate the signals at intermediate points.

Composite dialling circuits are satisfactory over cable or aerial wires, but it is often difficult to secure a composite circuit because of the demand for such circuits for telegraph use. The use of D.C. dialling circuits is also limited to circuits without V.F. repeaters, unless special arrangements are provided to "dial around" the repeaters. Thus, the D.C. dialling circuits have only a limited use over trunk circuits.

3. 17 c/s SIGNALLING.

3.1 In general, 17 c/s signalling is used only on relatively short physical or phantom circuits. Where V.F. repeaters are installed on circuits over which 17 c/s signalling is used, it is necessary to provide a "Ring Round" relay device at each repeater. Such a device usually consists of a group of relays associated with each repeater in such a manner that incoming 17 c/s signalling current operates a high impedance relay bridged across the line incoming to the repeater and, via a chain of relays, applies 17 c/s signalling current to the line on the far side of the repeater. The use of these relay-sets is necessary because the V.F. repeaters do not pass frequencies below 200 c/s very satisfactorily, so prohibiting ringing through the repeater with 17 c/s ringing current.

3.2 A typical Ring Round Relay-Set is shown in Fig. 3.

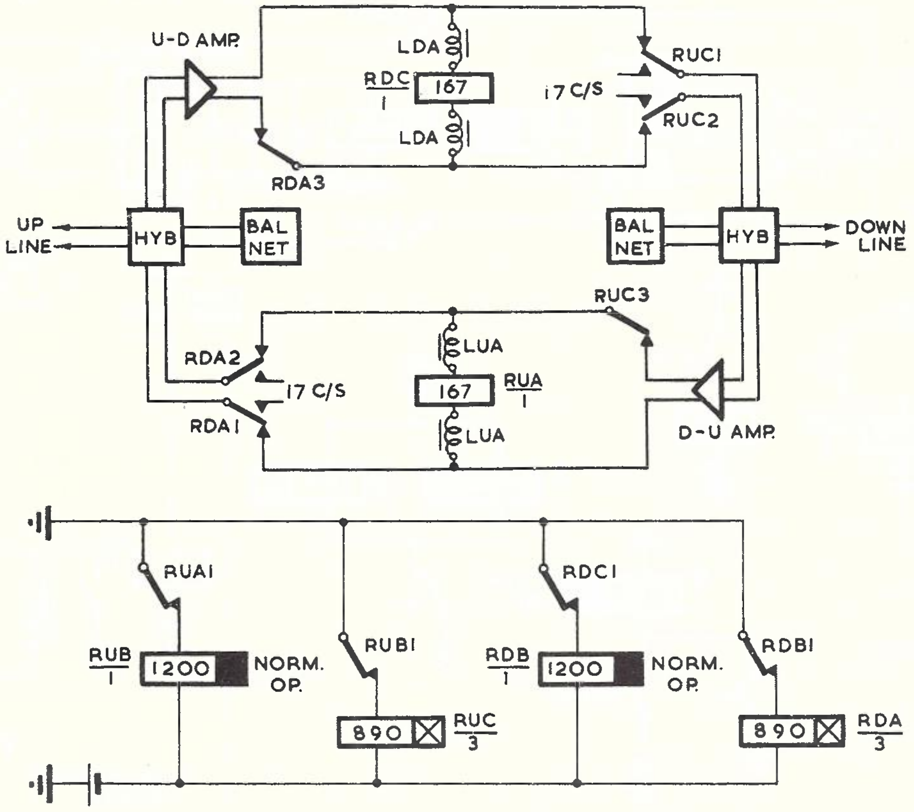


FIG. 3. RING ROUND RELAY-SET.

The 17 c/s ringing power from the Up line enters the hybrid coil where it divides, half being dissipated in the input circuit of the U-D amplifier where it serves no useful purpose. The other half enters the output circuit of the D-U amplifier, and operates the A.C. relay RUA. Operated contacts RUA1 release the normally operated relay RUB (slow to release), whose normal contacts operate relay RUC (slow to operate). Contacts RUC1 and RUC2 apply 17 c/s ringing current to the Down line via a hybrid coil. Contact RUC3 opens one side of the D-U amplifier connection to prevent the possibility of ringing current passing through the D-U amplifier and holding relay RUA operated.

The operation is similar in the Down to Up direction, and may be traced from Fig. 3.

Retard coils are connected in series with the A.C. relays RUA and RDC, so that the bridging loss which they produce on speech is small.

3.3 This method of signalling is unsuitable for use on circuits provided with more than one V.F. repeater, because of the excessive time delay which is introduced by the additional relay sets.

4. 135 c/s SIGNALLING.

4.1 The low and high-pass filter groups in composite sets have a cut-off frequency of 80 c/s, making it necessary to use a signalling frequency higher than 80 c/s over a telephone channel provided with a C.X. set. A frequency of 135 c/s was chosen as being sufficiently low to lie outside the range produced by the average speaking voice. However, guard features are provided in the circuit to prevent operation of the circuit by 135 c/s components of speech should they exist.

4.2 Fig. 4 shows the details of a 135 c/s ringing relay-set in the telephone circuit of a composited line.

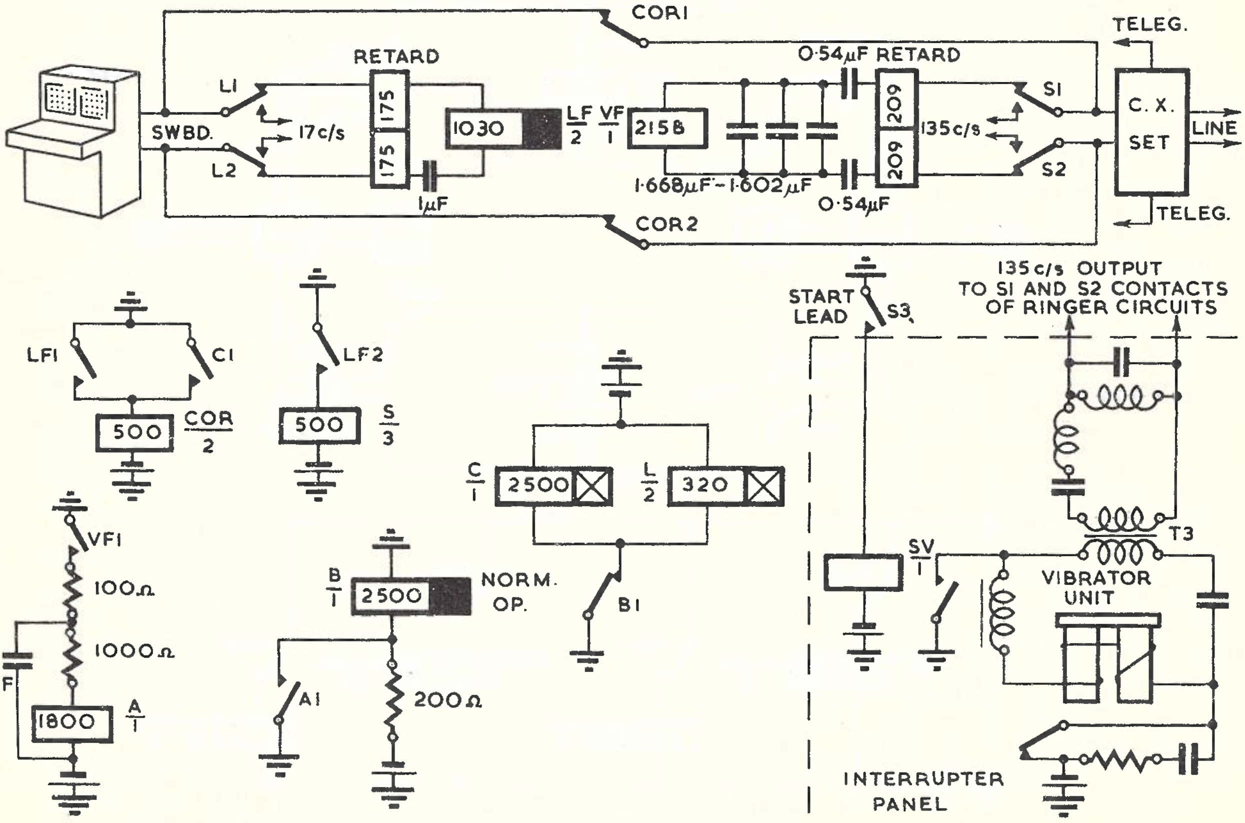


FIG. 4. 135 c/s RINGER CIRCUIT AND INTERRUPTER PANEL.

The operation of the ringer is as follows -

Outgoing Ring. Upon operation of the ringing key at the switchboard, 17 c/s ringing current is applied to the relay-set. This 17 c/s current operates relay LF which forms part of a circuit tuned to 17 c/s. Operated contacts of relay LF operate relays S and COR. The operated contacts S1 and S2 apply 135 c/s current to the line via the C.X. set, whilst the operated contacts of relay COR keep the 17 c/s and 135 c/s circuits separated during ringing.

Incoming Ring. The 135 c/s current from the line operates relay VF, which forms part of a circuit tuned to 135 c/s. Contact VF1 operates relay A, and A1 in turn, short-circuits the normally operated relay B which releases. B1 normal, operates relays L and C in parallel. L1 and L2 apply 17 c/s ringing current to the switchboard, whilst C1 operates relay COR, which functions as described previously.

4.2 Immunity from operation by 135 c/s components of speech is secured by making relay A slow to operate by means of the shunt capacitor and series resistors, relay B slow to release, and relay L slow to operate. The frequency content of speech changes continually, no frequency being present for more than a very short time as a general rule. By introducing a time delay between the application of 135 c/s current to the ringer and the application of 17 c/s to the switchboard, which is longer than the interval during speech when 135 c/s might be present, operation of the ringer by 135 c/s speech currents is prevented. The tuning of the two relay circuits also prevents operation of the ringer by currents of other than 17 c/s and 135 c/s.

4.3 Power Supplies. A 24 volt D.C. supply and 17 c/s and 135 c/s alternating current supplies are needed for the operation of this ringer.

4.4 The 135 c/s ringing current is usually supplied from an "Interrupter Panel". This panel supplies 135 c/s signal current to a maximum of 20 ringer circuits. A simplified circuit of this equipment is shown in Fig. 4. Earth via the start lead operates relay SV, whose operated contacts connect earth via a retard coil and the windings of the vibrator unit to battery. The vibrator is tuned to vibrate at 135 c/s, and its operation causes pulses of D.C. at 135 c/s to flow in the primary of transformer T3. The secondary of this transformer is connected to the output terminals through a 135 c/s tuned circuit which eliminates unwanted harmonics.

4.5 In Fig. 4, relay B in the ringer circuit is normally operated and causes a constant drain on the supply. At small installations of one or two ringers, where a mains supply panel is not used and 24 volt batteries are not installed in connection with other equipment, dry cells are used. The ringer operates satisfactorily when the circuit is amended so that relay B is normally unoperated and performs its functions by operating instead of releasing. This is done by connecting battery instead of earth to contact A1, disconnecting the normal battery to B relay, and reversing the operation of B1 contact.

The standard operation of this ringer requires a 17 c/s supply to be permanently connected to the panel. This means that the 17 c/s machine must run continuously and has obvious disadvantages, particularly at small offices with one machine. A normal trunk line indicator on a country switchboard, however, operates with a pulse of D.C., and, to avoid continuous running of the ringer, an earthed 24 volt battery is connected in place of the 17 c/s supply.

The use of the Subcycle Convertor, which statically converts the normal 50 c/s commercial supply to 17 c/s ringing current (see Telephony V), has offered another solution and, where these convertors are installed, ringer circuits are left normal.

/ 5.

5. VOICE FREQUENCY SIGNALLING.

5.1 The introduction of V.F. repeaters and carrier telephone systems to trunk line networks led to the development of a ringer which generated a ringing frequency within the pass-band of the channel frequencies of the associated repeater or carrier equipment, that is, approximately 200 to 2,600 c/s. Of recent years, the increased demand for direct dialling facilities between trunk exchanges is another important problem and this, as discussed previously, is unsatisfactory when its solution is attempted by D.C. dialling methods. The most satisfactory method of dialling over long trunk circuits is that in which the actual channel used for transmission is also the medium by which the dialling impulses are conveyed. The use of frequencies within the V.F. range for ringing and/or dialling purposes is referred to as V.F. Signalling, and is the modern system of trunk line signalling.

Trunk communication channels are inherently designed for V.F. transmission, and whether such a channel is part of a carrier system, whether it has V.F. amplifiers, or whether it is the physical trunk line itself, if it effectively transmits speech, then it must also be suited for V.F. signalling. With this method, it is possible to extend almost indefinitely the range for direct dialling and signalling on trunk lines and to cater for a wide range of signalling requirements. A V.F. signalling system, therefore, provides a universal means of signalling whether for ringing, dialling or supervisory purposes.

5.2 V.F. Ringer. The first efforts at V.F. signalling used 1,000 c/s as the signalling frequency. A number of 1,000 c/s V.F. ringer circuits have been developed, the main differences in design being the various methods adopted to obtain immunity from operation by normal speech currents.

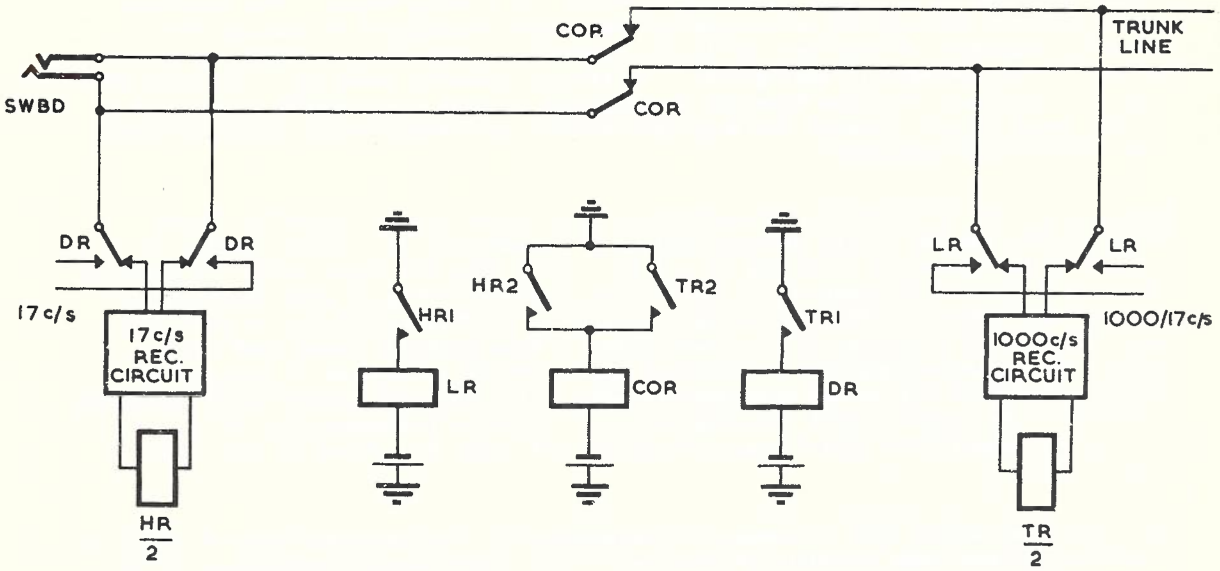
Early types of ringers were designed on the assumption that a single frequency is not maintained in speech for any length of time. Tuned signal receivers were used and slow acting relays, which delayed the ringer response, were incorporated in the circuit design. Since the delay required was of the order of several hundred milliseconds, more complicated signal frequencies were introduced with the object of increasing the delay period, thus leading to the development of the 1,000/17 c/s ringer. The complex signal thus used reduced the chance operation by speech components, but further circuit refinements were still necessary before wholly satisfactory voice immunity was obtained.

In this system, operation of the ringing key by the operator sends a 1,000 c/s current, interrupted at a 17 c/s rate, over the line. At the distant end, this current is received and operates a series of relays which connect a local 17 c/s current to the switchboard circuit. The ringer circuits used at each end of the line are similar, being arranged for two-way operation. No intermediate voice frequency ringers are needed, because the telephone repeaters used for amplifying the voice currents also amplify the interrupted 1,000 c/s signalling current, since the latter frequency is in the middle of the V.F. range.

Fig. 5 shows how a 1,000 c/s ringer is connected between the trunk line and switchboard. When the telephonist operates a ringing key, relay HR is operated through the 17 c/s tuned circuit bridged across the line jack. Contact HR1 operates the line relay LR, which applies interrupted 1,000 c/s current to the line. Contact HR2 operates the cut-off relay, COR, and the switchboard is thus disconnected from

/ the

the trunk line by the cut-off relay contacts. The distant terminal ringer receives this current in the 1,000 c/s receiving circuit operating relay TR, which, in turn, operates the cut-off relay COR and drop relay DR. The operated contacts of DR apply 17 c/s ringing current to the switchboard. As far as the operator is concerned, the procedure is similar to ordinary ringing, except that code ringing is not possible.



SCHEMATIC OF 1,000 c/s TERMINAL RINGER.

FIG. 5.

5.3 2 V.F. Signalling. Recent developments with V.F. circuits include features designed to make receivers immune from operation by V.F. currents. These systems use bursts of tone of varying duration for signalling. This tone is transmitted via V.F. repeaters or carrier systems just as the V.F. currents are transmitted. In one system, two tones of 600 c/s and 750 c/s are used. In providing a code of signals to give the required calling and supervisory functions, pulses of tone of different length are used. The measurement of signal lengths is accomplished by placing the application of tone to the line under the control of relays with release lags of the required order. The 750 c/s or X tone is used for calling, dialling and recall signals. The 600 c/s or Y tone is used for supervisory tones in both directions during the progress of the call. This method of signalling on trunk line circuits is known as 2 V.F. signalling and is described in Section 9 of this Paper.

/ 6.

6. TYPICAL 1,000 c/s RINGER.

6.1 The S.T.C. Type 122, LU.5 Ringer, a schematic circuit of which is shown in Fig. 6, has been taken as a typical example of a 1,000 c/s ringer.

6.2 Ringing Out. The 17 c/s signalling currents from the exchange switchboard operate the A.C. relay S bridged across the line. Also bridged across the line is the high input impedance 1,000 c/s branch of the ringer, consisting of two stages of amplification followed by two tuned rectifier circuits and a relay train. The insertion of a capacitor between the two halves of the primary winding of T1 ensures that the shunting impedance of this path to 17 c/s currents is very high, so that its effect on the 17 c/s currents is negligible. Contact S1 operates relay SR. Contacts SR1 and SR2 disconnect the line from the exchange and connect the 1,000/17 c/s supply to the trunk line. Contact SR3 supplies an earth to a start relay associated with the 1,000/17 c/s equipment.

6.3 Ringing In. The 1,000/17 c/s frequency from line passes via the normally closed contacts SR1 and SR2 to the primary winding of transformer T1, thence through two stages of amplification in valves V1 and V2. Grid bias for these valves is obtained from the voltage drop produced by the cathode current flowing through resistors in the cathode circuit. When the incoming signal is sufficiently large to drive the grid of valve V2 positive, grid current flows. This produces "grid leak" bias across the resistor-capacitor combination R6, C6, which is applied to the grid of V2 in series with the normal grid bias voltage. As the input signal level increases, therefore, the negative grid bias applied to V2 likewise increases, and so maintains a constant output from this valve, irrespective of large variations in the input signal level.

The amplified output from V2 passes to transformer T3, the secondary side of which is connected to two tuned circuits in parallel. The first circuit consists of C1 in series with L1 and is resonant at 1,000 c/s. The second circuit consists of capacitors C2, C3, C4, C5 and the inductors L2 and L3, which combination is anti-resonant at 1,000 c/s. Two dry-plate rectifier circuits W1 and W2 are tapped across portions of the resonant and anti-resonant circuits respectively. Relays I and G are also connected across the bridge points of the same rectifiers.

When a pure 1,000/17 c/s signal is received, relay I operates and I1 opens the circuit of the normally operated D relay which releases, after a period of approximately 300 milliseconds. Contact D1, in falling back, closes the circuit of relay R which operates. Change-over spring-sets R1 and R2 disconnect the exchange from the line and connect the 17 c/s supply to the exchange to operate the switchboard signalling equipment. In the process, a 600 ohms termination is connected across the line for the period of the ring.

The 1,000 c/s branch of the ringer is bridged across the transmission path. Because of its sensitivity, speech frequencies of sufficient intensity and duration could cause faulty operation of the ringer, unless special precautions are taken to render it immune from operation due to this cause. The guard relay G provides this particular function. All frequencies other than 1,000 c/s are accepted by the anti-resonant circuit, causing G to operate. The change-over spring-set G1 opens the circuit of relay I and maintains the operating circuit of relay D, thus preventing the operation of relay R and the consequent transmission of 17 c/s signal to the exchange equipment.

The guard circuit, together with the automatic gain control feature incorporated in the grid circuit of valve V2 and the delay period of approximately 300 milliseconds in the release of relay D, ensure a high degree of immunity from voice operation.

/ Fig. 6.

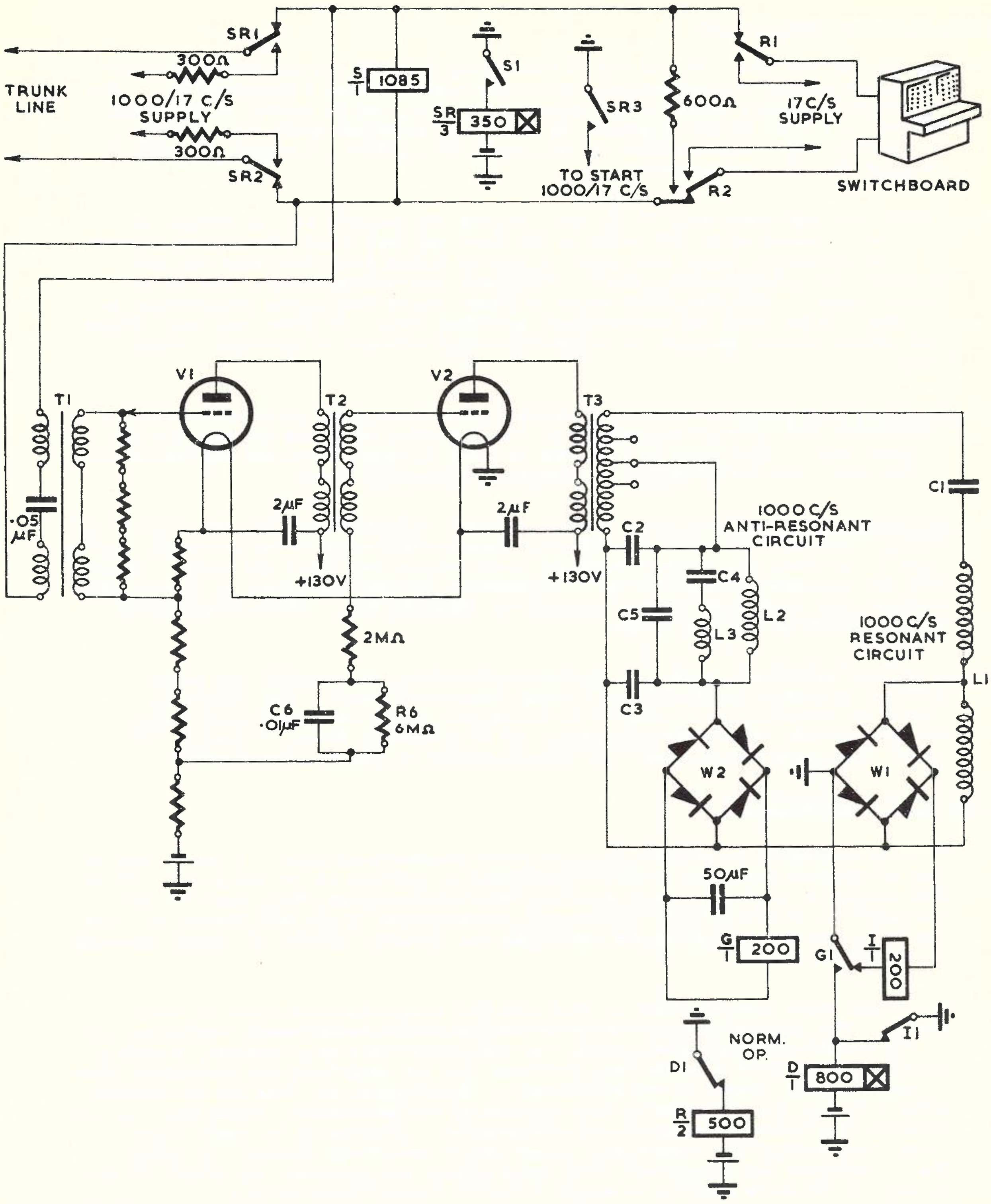


FIG. 6. 1,000/17 c/s RINGER (S.T.C. TYPE 122, LU.5).

7. NOTES ON RINGER INSTALLATIONS.

7.1 In large centres, the 1,000 c/s and 17 c/s ringing currents are supplied from motor generators mounted with associated controlling apparatus upon a Generator Bay. The generator is usually rated at 35 milliamperes 6 volts, and is capable of supplying current to a total of 400 ringers. By the use of solid and split rings used in conjunction with collector brushes, two sources of 1,000/17 c/s supply are readily obtained from the one generator.

7.2 A fully equipped ringer bay, of the type required for use with machine derived A.C. supplies, consists of a 10'6" rack, on the front and rear sides of which are mounted 11 ringer panels, a ringer test panel, a jack or U-link field for patch and test purposes, and a distribution panel. Thus, each rack accommodates a total of 22 ringer panels. When the installation is large, ringer test panels are provided on the basis of one front and one rear side per three bays. On those bays where ringer test panels are not equipped, it is usual practice to mount an additional ringer panel.

7.3 The ringer test panel permits the operation of the ringer panel to be tested when it is supplied with 1,000/17 c/s current on the line side, or 17 c/s current from the exchange side. This panel is also used to check the sensitivity and the timing delay of the panel, and its immunity from operation by speech currents.

7.4 The distribution panel provides a convenient means of distributing the two 1,000/17 c/s sources from one of a number of different transmission levels to two groups of ringers, usually the front side units forming one group and the rear units the other. Ringer Bays are purchased initially wired to accommodate the full complement of ringers and equipped with only those ringers required for immediate use. Extra ringer panels are then added as the need arises.

7.5 In offices requiring no more than 44 ringers ultimately, the 1,000/17 c/s supply is provided by a valve oscillator and a relay interrupter panel. The initial bay mounts two oscillators (one spare), an interrupter panel, two ringer test panels, two jack fields, two distribution panels and 20 ringers (9 front, 11 rear). The second bay, requiring no ringer test panels, mounts 24 ringers (12 each side).

8. 1,000 c/s RINGER OSCILLATOR.

8.1 It is not economical to provide 1,000 c/s motor generators or 1,000 c/s master oscillators at stations which use 1,000 c/s signalling on only one or two circuits. To meet this demand, a 1,000 c/s ringer oscillator has been developed, which uses the same equipment for providing 1,000 c/s current interrupted at 17 c/s when ringing out from the office and for amplifying and rectifying the incoming 1,000/17 c/s signal incoming to the office.

8.2 The circuit to be described here is that of a W.E. ringer oscillator and is shown in Fig. 7. The circuit contains two valves and associated transformers, resistors, etc. In the normal condition, shown in Fig. 7a, the circuit acts as a receiver, accepting incoming 1,000/17 c/s currents from the trunk line and amplifying and rectifying these to provide a D.C. signal to the switchboard. When ringing out from the switchboard, relay E in Fig. 7 is operated by D.C. supplied by the switchboard ringing key, operated contacts of E operating relays A and B in parallel. Various of the leads interconnecting parts of the circuit are brought out to some forty contacts (not shown in Fig. 7) on these two relays, and, when these relays are operated, the circuit is rearranged as shown in Fig. 7b, to supply 1,000 c/s current interrupted at 17 c/s to the trunk line.

/ Fig. 7

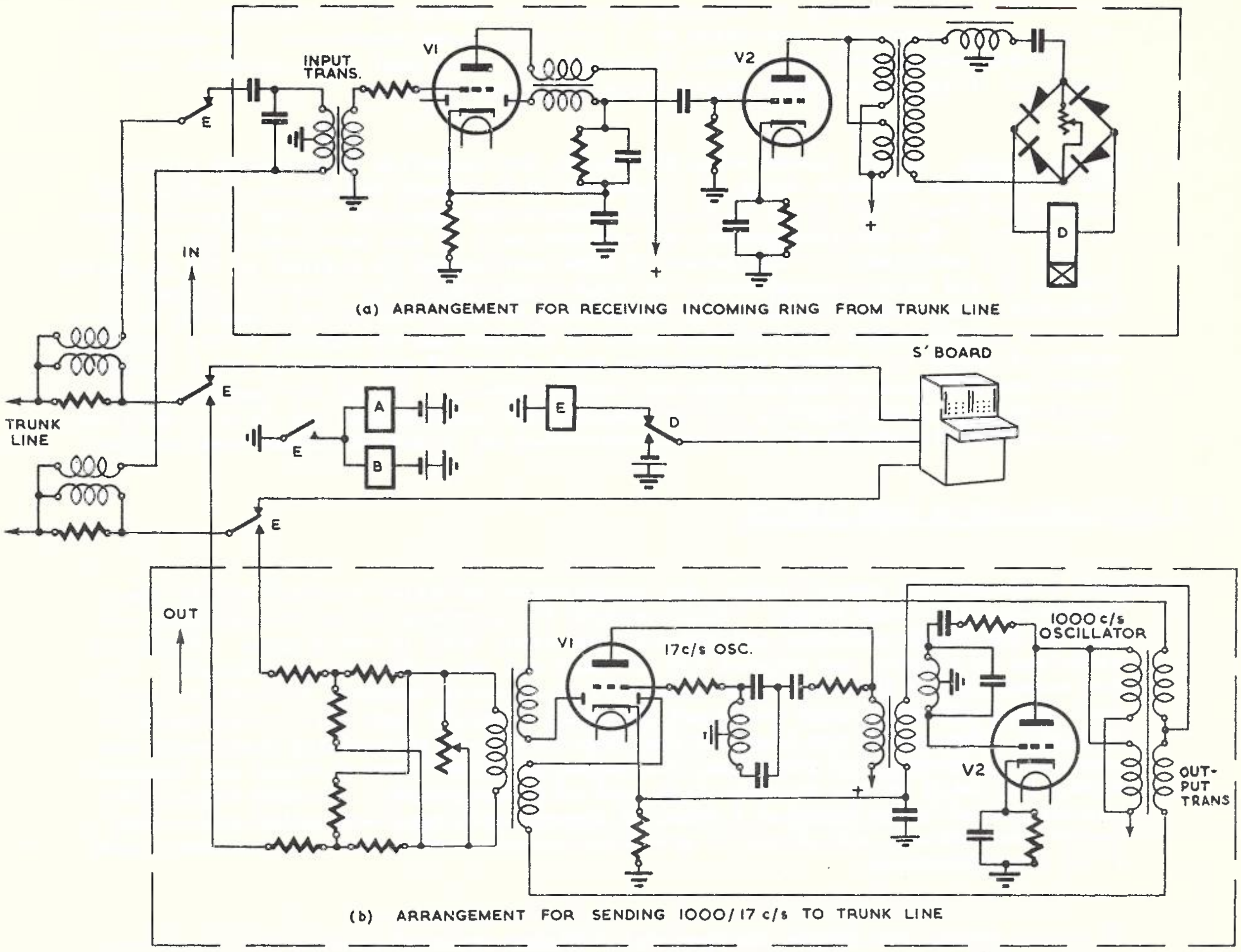


FIG. 7. 1,000 c/s RINGER OSCILLATOR.

8.3 When switchboards associated with this ringer oscillator require 17 c/s signalling, a 17 c/s circuit has been developed which acts as an intermediary for sending and receiving 17 c/s current to and from the switchboard.

8.4 Incoming Ring. The circuit is normally in the receiving condition as shown in Fig. 7a, that is, with contacts of the relays A and B in the normal position the circuit functions as an incoming ring receiver. The 1,000/17 c/s ringing current from the trunk line is applied initially to an input transformer tuned to 1,000 c/s. It is then applied on the amplifying section of V1 (which is a two function valve) and impressed on a diode anode of the rectifying section of V1. The diode rectifies the output, which is transformed to a pulsating current containing 17 c/s interruptions of the signal. This pulsating current is applied to the grid of valve V2, which acts as a 17 c/s amplifier. The output of V2 is fed to a 17 c/s tuned circuit. The amplified 17 c/s current is rectified in this circuit and operates D relay.

/ Contacts

Contacts of D relay signal the switchboard by the application of D.C. It will be noted that voice immunity is obtained by a double tuning of the receiving circuit, so that only 1,000 c/s interrupted at 17 c/s will cause operation. In addition, the ringing relay has slow operate characteristics, so that short duration combinations of speech currents cannot cause false operation.

8.5 Outgoing Ring. In the transmitting direction, the operation of a ringing key at the switchboard operates relay E. Contacts of E operate two relays A and B, the contacts of which (not shown in Fig. 7) convert the apparatus to the circuit shown in Fig. 7b. In this arrangement, V1 operates as a 17 c/s oscillator, and V2 as a 1,000 c/s oscillator. The output of both oscillators is applied to the secondary winding of the output transformer. At this transformer, the 1,000 c/s current is modulated with 17 c/s. The 17 c/s connection is such that it is connected to the midpoint of the output transformer, where it divides and is applied to the 2 diode anodes of valve 1. During the positive half of the 17 c/s current, the 2 diode anodes are positive to the cathode and current flows. During the negative half, the diode anodes are negative to the cathode, and current does not flow. As a result, an output current of 1,000 c/s interrupted at 17 c/s is transmitted to line.

9. 2 V.F. SIGNALLING ON TRUNK CIRCUITS.

9.1 Until comparatively recent times, the system known as "delay working" was in use on practically all trunk lines. This required the services of two telephonists per call at the trunk exchange, and the call was dealt with in two stages. The first stage was to receive the request for the call and enter details on a docket. In the second stage, the docket was passed to an operator reserved to provide service over that particular trunk route and who would complete each call in its order of booking. The system was based on the idea that delay in handling most calls was inevitable, because, at that time, the number of trunk lines provided was comparatively few owing to the relative high cost of construction. On many routes, the restriction of lines produced a state of almost continuous congestion with normal traffic conditions, and delays in providing service during the busy periods could be of hours duration.

Of recent years, the public has demanded a higher grade of service for trunk line calls with less waiting time. Further, the cost of providing trunk line channels has decreased, mainly due to the introduction of carrier systems. These two factors caused the introduction of the "Demand" service, in which only one telephonist is required to complete a call and with so little delay that the subscriber, having called the trunk exchange, is not required to leave the telephone and await recall.

A satisfactory system of supervisory signalling becomes almost a necessity when trunk lines are to be efficiently handled by the demand method of working. To provide good service, a trunk exchange demand telephonist needs to have every facility to aid her in operating, and, hence, should have instantaneous advice of all action pertaining to connections established under her direction at a country exchange. For example, she should receive immediate notification of the insertion of a plug at the manual country exchange in response to her call, and correspondingly advice when the plug is withdrawn. Similarly, the country telephonist requires a signal which indicates positively the result of a call set up by her to a metropolitan subscriber, and when the call is to a C.B. or automatic subscriber, switch-hook control of this signal is desirable. From an operating viewpoint, it is, in fact, generally accepted that a comprehensive system of supervisory signalling over trunk lines tends to keep the pay time of demand trunks at a maximum without the need for continuous monitoring by telephonists.

/ 9.2

9.2 Signalling Frequencies. The Siemens' system of V.F. signalling to be described here uses two tones, which are individually impressed on a circuit to form signals. Under this V.F. system, the tones are not combined as a composite note under any circumstances. The two frequencies are conventionally known as X and Y tones, X being 750 c/s and Y 600 c/s. These frequencies have been adopted by the C.C.I. International authority as standard for V.F. systems employing two tones (2 V.F.).

9.3 Nature of Signals. Since, with the V.F. system, all signals concerned with the establishment, supervision and release of the trunk connection fall within the voice range, they must consist of pulses, at least during conversation periods. This is contrary to D.C. signalling practice, where certain signalling conditions consist of the steady flow of current for the duration of the conditions.

Generally speaking, the X tone (750 c/s) is used for signals concerned with the establishment of a connection. Such signals as the calling or "pick up" signal, dialling signals, ringing signals, etc., are at this frequency. Y tone (600 c/s) deals mainly with supervisory and release functions.

Other than difference in frequency, the signals are further distinguished by varying duration. Some signals are quite short, a pulse of 600 milliseconds being possible for the pick-up signal, whilst other signals associated with the release function may extend to six seconds. In some cases, the signals are repeated at fixed intervals until an acknowledge signal is received during a silent period. In most cases, the duration of a distinctive signal or pulse is controlled between marginal limits, but one, the recall signal, is variable in length at the discretion of the operator. The individual signals are detailed in Fig. 12 and paragraph 9.8.

9.4 Terminal Equipment. The equipment involved in a complete V.F. signalling connection, as apart from the normal trunk circuit or channel apparatus, falls into two sections -

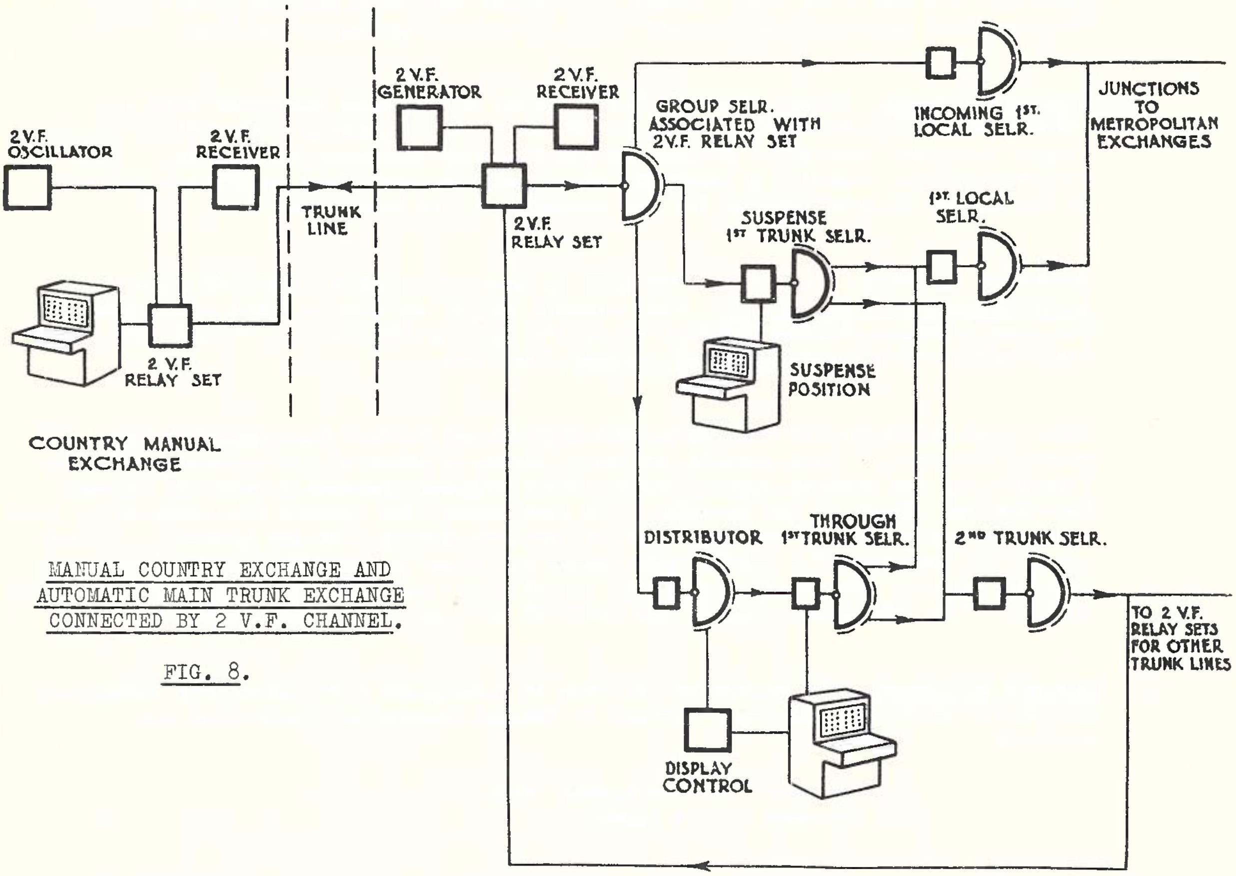
(i) Production of the signal, and,
(ii) Response to the signal.

Each of these may be further sectionalised, since the production of the signal involves, first, the use of some form of continuous tone generator, and, second, the application of pulse producing mechanism to the generated tone. Similarly, the receiving apparatus consists of a so-called V.F. "receiver", which converts the received V.F. signals into D.C. equivalents. This receiver is then followed by relay equipment which responds to the D.C. signals so as to produce the appropriate supervisory indication at the manual board, or, alternatively, to repeat the pulses, if of dialling type, to switches which respond to dialling impulses. At the main trunk exchange, tones are produced by a tone generating machine, but, at smaller country exchanges, oscillators produce the necessary frequencies.

Received V.F. signals are converted by valve operation into D.C. pulses, the equipment associated with this action being mounted in an orthodox relay-set. However, only three relays are included in this assembly which otherwise comprises static equipment, such as valves, transformers, etc. This set is the V.F. receiver referred to previously, and it is provided on the basis of one at each end of a both way trunk line circuit, that is, one at each main and country exchange per line or channel.

/ Fig. 8

Fig. 8 shows how 2 V.F. signalling equipment can be used between a manual country exchange and an automatic main trunk exchange situated in a metropolitan network containing automatic and, perhaps, manual exchanges. Uniselectors, rather than bi-motional switches, are used in the automatic trunk exchanges, and provide the same facilities using a different set-up.



MANUAL COUNTRY EXCHANGE AND AUTOMATIC MAIN TRUNK EXCHANGE CONNECTED BY 2 V.F. CHANNEL.

FIG. 8.

Associated with each 2 V.F. relay-set at the main trunk exchange is a uniselector which acts as a group selector. This switch is actuated by the first digit dialled by the country operator and, depending on the number of impulses in that first digit, directs the call as follows -

Digit 1 - To Incoming First Local Selectors through which access is obtained to the metropolitan exchanges, both automatic and manual, local to the main trunk exchange.

Digit 2 - To Suspense Positions at the Main Trunk Exchange which deal with calls that are not completed when originated either at country exchanges or at exchanges local to the main trunk exchange, for such reasons as particular person not in attendance, and so on.

Digit 3 - To "Through" Positions at the Main Trunk Exchange, these dealing with those calls from one country exchange to another which have to be routed via the Main Trunk Exchange.

Note: The above dialling code may not be representative of any particular Main Trunk Exchange system - it is used only for illustrative purposes.

/ Access

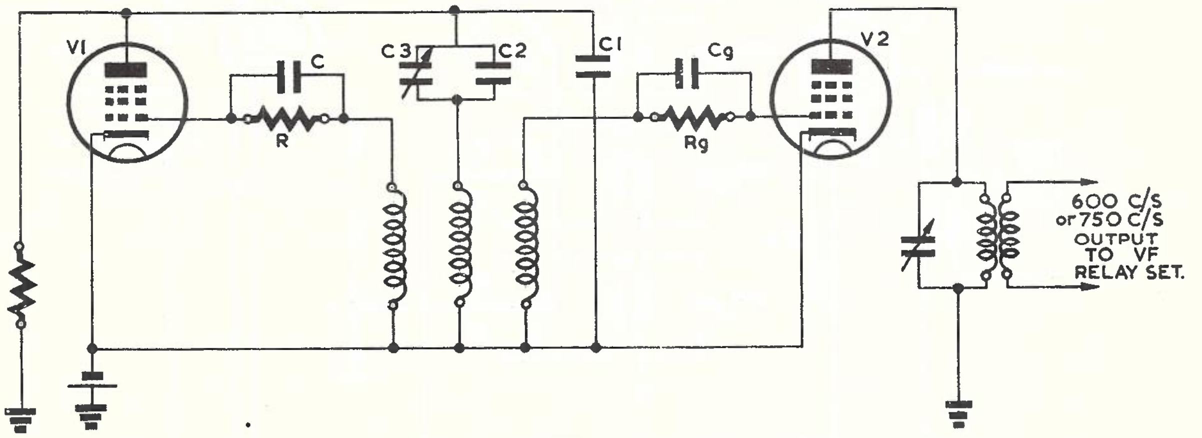
Access to individual trunk lines from the "Through" or "Suspense" positions is gained via trunk selectors, and, for this purpose, a number is allotted to each group of trunks. To gain access to a particular group of trunks, the "Through" or "Suspense" position operators dial the appropriate digits which actuate the appropriate 1st and 2nd Trunk Selectors. These operators gain access to the local network via 1st local selectors.

The purposes of the Distributor and Display Control features of Fig. 8 are, firstly, to signal on the first vacant display circuit on the "through" positions, and, secondly, to associate with the calling trunk line the particular operator's circuit which is used to answer the call.

9.5 Frequency Generating Equipment. The choice of apparatus for generating the tones for use with the 2 V.F. signalling system is a matter which depends upon the amount of signalling tone required.

When this is considerable, as in the case of an exchange with a large number of connected trunk lines, it is usual to use a motor-generator set. These sets are operated from the exchange 50 volt supply and, besides generating the 600 c/s and 750 c/s tones for 2 V.F. signalling, also generate 900 c/s "pip-pip" tone for indicating the approach of a three-minute period and also a 500 c/s tone not used in Australia at present.

Where the number of trunks to be supplied is small, the provision of a machine, with a standby and control equipment, becomes uneconomical and, in such cases, a form of thermionic valve generator, which can serve a limited number of trunks, is used. These are oscillators operating from a 50 volt supply from a transrector, a typical circuit being shown in Fig. 9.



NOTE: 50 volt supply with positive terminal earthed is used.

SIMPLIFIED CIRCUIT OF 2 V.F. OSCILLATOR.

FIG. 9.

The oscillator, V1 and its associated circuit, is a tuned anode oscillator. C1 and C2 broadly determine the frequency of the resonant circuit, fixing that frequency higher than that required, that is, above 750 c/s, the highest frequency to be developed. C3 provides a fine adjustment to reduce the frequency as required. Grid leak bias is provided for V1 by the resistor-capacitor combination RC.

The oscillator output is coupled to the output valve V2 by means of the third winding of the tuned transformer in the anode circuit of V1. The voltage applied to V2 from V1 normally drives V2 to grid current, and the low grid impedance of V2, under this condition, lowers the selectivity of the tuned anode circuit of V1. This dampening

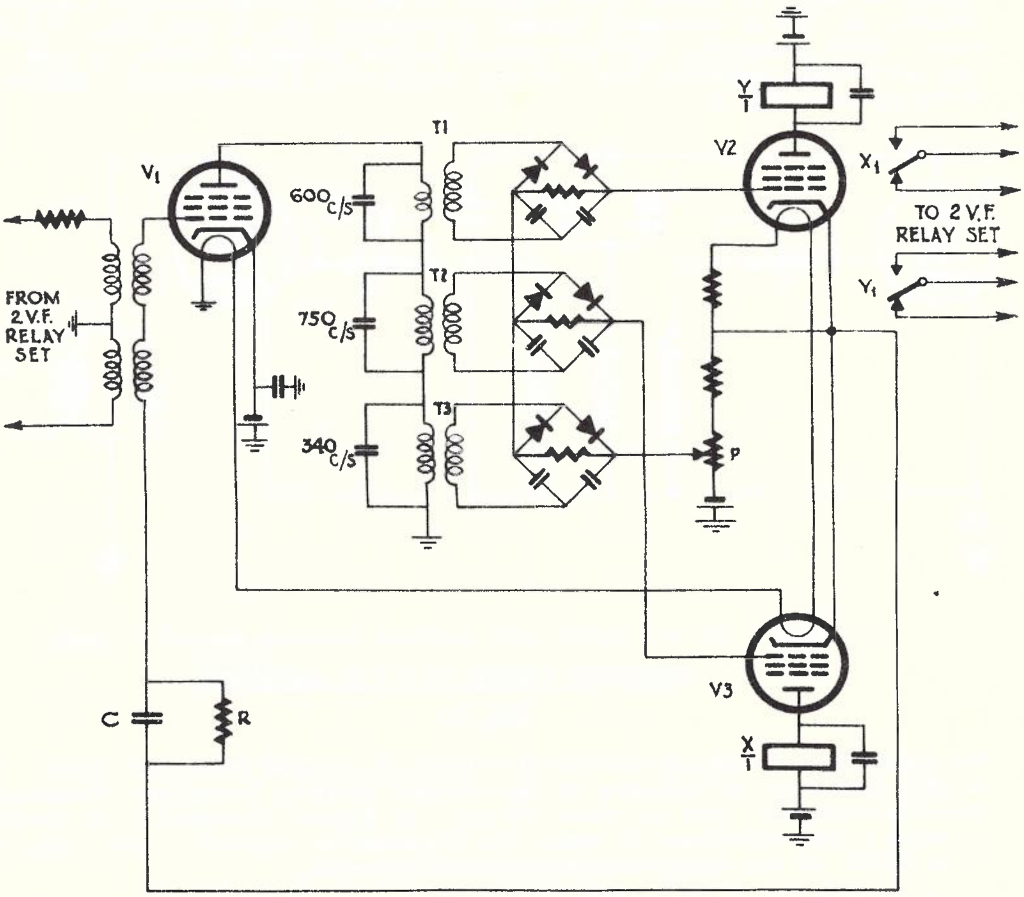
/ of

of the tuned circuit is prevented by the presence of the grid leak combination RgCg. This grid leak also ensures a constant output from V2 by being responsible for the bias on that valve. With no signal, V2 is biased negatively by the voltage drop produced across RgCg by the small grid current which flows through it. When signal is applied, the grid is driven positive, increasing the grid current and producing a greater voltage drop across RgCg and, therefore, a larger bias - actually to beyond anode current cut-off. This limits the amplitude of the anode current pulses (for any large value of grid input) to between zero and the value it reaches when grid current starts to flow, so that small changes in grid excitation produce no changes in the output.

The output of V2 is rich in harmonics of the fundamental frequency applied to V2 from V1. The tuned transformer in the output of V2 selects the 600 c/s or 750 c/s fundamental and rejects the harmonics.

9.6 2 V.F. Receiver. The main essentials of the receiver are shown in Fig. 10.

Each receiver contains three valves, the first (V1) acting as an amplifier-limiter and the second and third (V2 and V3) as D.C. amplifiers for operating the signal relays Y and X particular to each frequency. Metal type rectifiers arranged as voltage doublers rectify the voice frequency signals.



NOTE: 130 volts on anodes of V2 and V3. 50 volt supply with positive terminal earthed used for heaters and anode voltage of V1.

FIG. 10. MAIN ELEMENTS OF 2 V.F. RECEIVER.

When an incoming signal drives the grid of valve V1 positive, grid current flows. This produces a "grid leak" bias voltage across the resistor-capacitor combination RC, in the grid circuit, which is applied as negative bias to the grid of V1. The larger the input signal level, the greater is the bias voltage produced across RC by the increased grid current flowing through it. By this process, the amplified output signal of valve V1 is "limited" to a reasonably constant value over a large range of input voltages.

The D.C. voltage applied to the anode of V1 is comparatively small and, consequently, only a small amount of A.C. power appears in the output. When pure signal tone is applied to the input, the output power from V1 is mainly signal power with some harmonics, and the circuit is so arranged that this power operates the receiver. When speech is received, several frequencies are present simultaneously, one of which may be the signal frequency. The limiting action ensures that the total power in the anode circuit of V1 is the same with speech as with a pure signal applied. As power at the signalling frequency component represents only a small percentage of the total anode power during speech, the limiting action keeps this signalling frequency power down to a level which does not falsely operate the receiver during speech.

The anode circuit of V1 contains two resonant transformers, T1 and T2, with primaries sharply tuned to the signalling frequencies, that is, 600 c/s and 750 c/s. The secondaries are connected to metal type rectifiers and associated capacitors to form voltage doubler circuits, so that the received signals are then converted to D.C. potentials which are applied to the grid of either V2 or V3, depending on the frequency of the received signals. The bias applied to V2 and V3 is normally about anode current cut-off and is adjusted by means of potentiometer P, the adjustment being such as to give the best operation for relay X, the dialling relay.

Thus, pulses of 600 c/s and 750 c/s received by the receiver are amplified by the limiter valve V1, selected by the appropriate tuned circuit T1 or T2, rectified, and appear as a voltage on the grid of V2 or V3, This voltage changing the voltage on the grid of the particular valve from almost anode current cut-off to some positive value for the duration of the pulse. Thus, the anode current of the particular valve rises from almost zero to a value high enough to operate the particular signal relay Y or X, remaining at that value for the duration of the signal. When the signal ceases, the voltage on the grid of the signal valve falls to the cut-off value and the signal relay releases. These signal relays are of the high speed type and this, together with their low inductance, ensures that the signals repeated by them into the 2 V.F. relay-set are not distorted.

The amplification obtained from V1 is not distortionless as, in most cases, it operates almost at anode current cut-off. Thus, harmonics of the signal input to V1 appear in the anode circuit, these increasing in amplitude as the level of the applied signal is raised. When a frequency of about one-half of either signal frequency, that is, 300 c/s or 375 c/s, appears at the input, the second harmonic of this frequency in the anode circuit, if strong enough, would cause false operation of the appropriate signal relay. An example of this is when busy tone at 400 c/s is received. The busy tone could be slightly lower than 400 c/s, say 380 c/s, due to the busy tone generator running slow. The second harmonic of this frequency is 760 c/s, and this falls within the band-width passed by the 750 c/s signal circuit. (The 600 c/s and 750 c/s tuned circuits in the receiver are arranged to pass a band of frequencies 20 c/s on either side of their resonant frequency in order to pass dialling signals, and to allow for slight frequency changes in the 2 V.F. oscillators, etc.) To overcome such false operation, a bias circuit, consisting of the tuned transformer T3 and its associated rectifiers and capacitors, is included in the anode circuit of V1. This circuit is tuned to a frequency midway between the half values of the signalling frequencies, in this case to 340 c/s. This circuit produces a negative voltage, in opposition to the positive voltages produced by the signal rectifier circuits, of such a value that neutralisation is obtained over a band extending from about 280 c/s to about 400 c/s, thus covering the band of both signalling frequencies. This bias rectifier circuit is in series with both signal rectifier circuits and is operative on both grids together, so that operation of the receiver is paralysed when signals containing any frequency between 280 c/s and 400 c/s are present.

9.7 2 V.F. Relay-Sets. In order to appreciate the significance of the signals sent over a line during the progress of a call carried on over a 2 V.F. channel, it is necessary to study the operation of the 2 V.F. relay-sets which terminate each end of such channels. Unfortunately, both relay-sets are fairly complex, this being brought about by the fact that they provide facilities not only for establishing calls in either direction, but also for positive supervision at each end of the channel at all stages of the call. Further complications are introduced by the necessity for guarding the relay-sets from false operation by signal frequencies present during speech. The relay-set at the main trunk exchange is still further complicated by the facts that impulse repetition circuits are necessary to repeat the received dialled impulses on to the automatic equipment, a group selector forms part of the relay-set, and so on. The necessity for these circuit features is obvious from an examination of Fig. 8.

These complications mean that a full and detailed description of the operation of the relay-sets shown in Fig. 8 is beyond the scope of a course of this nature. However, advantage can be taken of the fact that the signal sequence over a 2 V.F. channel between two manual exchanges is, with the exception that dialling is eliminated, much the same as between a manual exchange and an automatic exchange, and that the relay-sets at each end of the channel are identical and simpler than that at the main trunk exchange of Fig. 8. Fig. 11 (at rear of Paper) is, therefore, included, and the following description covers only the setting up of a call between the two manual exchanges, stopping at the point at which the called operator answers. The description stops at this point, because the object is to give the student some knowledge of how the equipment at one end of a line can produce a V.F. signal appropriate to a certain call condition existing there, and how that V.F. signal can be translated into the appropriate visual or other signal at the other end. With this knowledge, the student should be better able to appreciate the significance of the full signal sequence listed later.

Before proceeding with the description, it is pointed out that Fig. 11 contains only that part of a country manual exchange 2 V.F. relay-set necessary for the purpose mentioned, certain elements, such as four-wire switching arrangements and pad control being omitted.

(i) Calling Operator Plugs Up Call Jack. Relay SC operates on its a-b winding via the springs of the "call" jack.

The "engaged and supervisory" lamp displays in series with the a-b winding of relay SC, and a holding circuit for SC and a circuit to maintain the lamp display independent of relay BA are established at SC2 operated.

The termination provided by QC and YE is disconnected at SC7 operated, its place being taken by the secondary of the operator's telephone circuit.

A circuit is completed to operate relay H at SC3 operated. This relay, however, operates very slowly due to its high resistance and an armature end slug.

Relay BA operates to earth at SC4 operated.

/ Relay

Relay SP operates on its d-e winding to earth at BA5 operated. The main function of relay SP is to split the line and its termination at SP1 and SP2 operated before tone is applied to the line, so that little of that tone is heard in the operator's receiver.

Relay TN operates from earth via the normal contacts of the 2 V.F. receiver, X and Y contacts, normal contacts HS2, HR7, and BR2, operated contacts BA6, normal contacts BR3 and G7 to earthed battery via the d-e winding of relay TN.

The operation of relay TN applies X tone (750 c/s) to the trunk line via operated contacts SC1 and SC5, TN1 and TN2, and SP1 and SP2. This tone signals the distant operator in the case of a manual exchange, or establishes pre-dialling conditions in the case of an automatic exchange. To prevent false operation on the outgoing signal, the local 2 V.F. receiver is disconnected at operated contacts TN4 and TN5.

Relay H operates after a delay period long enough to allow X tone to be sent to line for a period of from 50 to 100 milliseconds.

Relay HR operates via H3 operated.

Relay A operates from earth on the dialling key, in the case of manual to automatic 2 V.F. channels, via HR4 operated.

Relay TN releases, its operating circuit being opened at HR7 operated.

The operation of relay A and the release of relay TN cause the X tone to be disconnected from the trunk line and the local 2 V.F. receiver to be reconnected at the appropriate normal contacts of relays A and TN.

Thus, on the operator plugging up to make a call, a pulse of X tone is applied to the line for a period of from 50 to 100 milliseconds. This is the "pick-up" signal and, as mentioned previously, it signals the distant operator in the case of a manual exchange, or establishes pre-dialling conditions of the distant exchange to automatic.

At this stage, relays SC, H, HR, BA, A and SP are operated in the 2 V.F. relay-set at the originating end.

At the distant exchange, this pulse of X tone operates the X relay in the 2 V.F. receiver there, as described in paragraph 9.6, irrespective of whether that exchange is manual or automatic.

When the distant exchange is manual, the following operation takes place there -

Relay B operates from earth via the normal Y contact and operated X contact. Relay B operates on its d-e winding and locks on its a-b winding.

Relay BA operates from earth at B1 operated.

/ Relay

Relay BR operates from earth at B3 operated.

At the end of the pulse of X tone, relay X releases.

Relay Z operates from earth via the X and Y relay contacts normal and BR2 operated.

The operation of relay Z completes a circuit to display the "call" lamp from earth at Z4 operated via BR4 operated.

In the case of an automatic exchange, the operation of the X relay on the "pick-up" signal and its release at the end of that signal establishes a loop into the automatic equipment to prepare that equipment for the dialling impulses which now follow.

Although the case being dealt with is a manual to manual connection, the dialling sequence is dealt with here to give the student some idea of how the dialling circuit at the country end functions.

(ii) Calling Operator Operates Dial Key. On the dial key being operated, the d-e winding of relay N and the a-b winding of relay TN are connected in series with the 1,200 ohms resistor YJ and the 5,000 ohms resistor in the dial circuit, neither relay operating under these conditions. Also, the circuit for relay A is changed over from the outer to the inner springs of the dial key, relay A holding to the earth via the impulsing contacts of the dial.

Operator Dials. On the dial being pulled off-normal, the off-normal springs short-circuit the 5,000 ohms resistor in the dial circuit.

Relay N operates due to the reduction of the resistance in the circuit of its d-e winding.

Relay TN operates on its a-b winding due to operated contacts N6, removing the 1,200 ohms resistor YJ from the operating circuits of relays N and TN.

On the dial contacts opening during the "break" period of the impulses, relay A releases, reoperating during the "make" periods. The release of relay A during the "break" periods of the impulses means that X tone is applied to the trunk line during such periods at A1 normal, whilst the reoperation of relay A during the "make" periods, means that no tone is transmitted during such periods. By this means, contacts A1 send X tone to line for the "break" period of the dial contacts and no tone for the "make" period.

At the end of each impulse train, the 5,000 ohms resistor in the dial circuit is introduced into the circuits of relay N and TN. Relay TN releases for the duration of each interdigital pause, but relay N holds. Relay TN reoperates at the beginning of the next impulse train and remains released after dialling has finished.

/ These

These impulses of X tone are converted into D.C. impulses by the X tone rectifier at the distant end, so causing the X relay to repeat impulses of the prescribed ratio into the 2 V.F. relay-set there, from which they are repeated into the automatic equipment.

(iii) Operator Restores Dial Key. On the dial key being restored to normal after dialling has finished, relay HS operates from earth at BA5 operated, HS6 normal, a-b winding of relay HS, N2 operated, normal contacts of dial key, and so to earthed battery via the a-b winding of relay TN and the d-e winding of relay N. Relay TN does not operate over this circuit but relay N holds.

Relay HS locks itself viá HS6 operated, and opens its operating circuit. As this operating circuit is also the holding circuit for relay N, relay N releases.

Relay Z operates via HS2 operated to the earth at Y relay contact normal.

The operation of relay Z and the release of relay N cause relay SP to release, and the trunk line is now switched through to the switchboard.

In the case of a manual to manual relay-set, the connection shown dotted in Fig.11 (bridging out contacts H3) is provided. This means that relay HS operates on its d-e winding immediately HR operates, as described in paragraph (i). Relays HS and Z operate and relay SP releases on the "pick-up" signal being sent, and the circuit conditions are precisely the same as when dialling finishes.

(iv) Distant Operator or Subscriber Answers. The distant operator plugging up to answer will operate relay D (in the 2 V.F. relay-set at the called exchange) on its d-e winding via the springs of the "answer" jack, HR3 normal, BA4 operated, N6 normal, BR5 operated and L1 normal.

In the case of an automatic exchange, relay D is in the calling loop into the automatic exchange equipment, and operates to the battery reversal supplied on the called subscriber answering.

Relay D locks on its a-b winding in series with the a-b winding of relay SP.

Relay SP operates over this circuit and splits the connection at the called exchange preparatory to sending an "answer" signal back to the originating exchange.

The operation of relay D also connects relay TN to interrupted earth pulses, on for 0.375 second and off for 0.375 second, at D5 operated. Relay TN, therefore, operates and releases in synchronism with these earth pulses, and sends back to the originating exchange corresponding pulses of Y tone via TN1 and TN2 pulsing and SP1 and SP2 operated. The local 2 V.F. receiver is disconnected at the appropriate TN contacts whilst the tone is being sent, that is, whilst relay TN is operated, to prevent false operation of the sent signal.

At the originating exchange, the first pulse of the "answer" signal sent back on the called operator or subscriber answering operates the Y relay in the 2 V.F.

/ receiver

receiver there. The operation of relay Y at the originating exchange opens the circuit of relay Z, which releases slowly. During this release time, relay ZR and relay G operate in parallel to the earth at the operated Y contact.

On the release of relay Z, relay SP operates to split the connection, and the circuit to relay ZR is opened. Relay ZR releases after its slow release period and operates relay AT from earth at the operated Y contact. (The first answer pulse is still being received, which means that relay Y is still operated, relay Z released and relay G operated.) Relay AT locks itself to earth at AT3 operated and operates relay AR on its d-e winding from earth at AT1 operated.

Contacts AR6 operated place the 2,000 ohms winding of relay SC in series with the 1,000 ohms winding, and, as these two windings are now in series with the "engaged and supervisory" lamp, that lamp is extinguished because of the high resistance in its circuit. The "answer" signal thus gives the calling operator a positive visual signal on the called operator or subscriber answering.

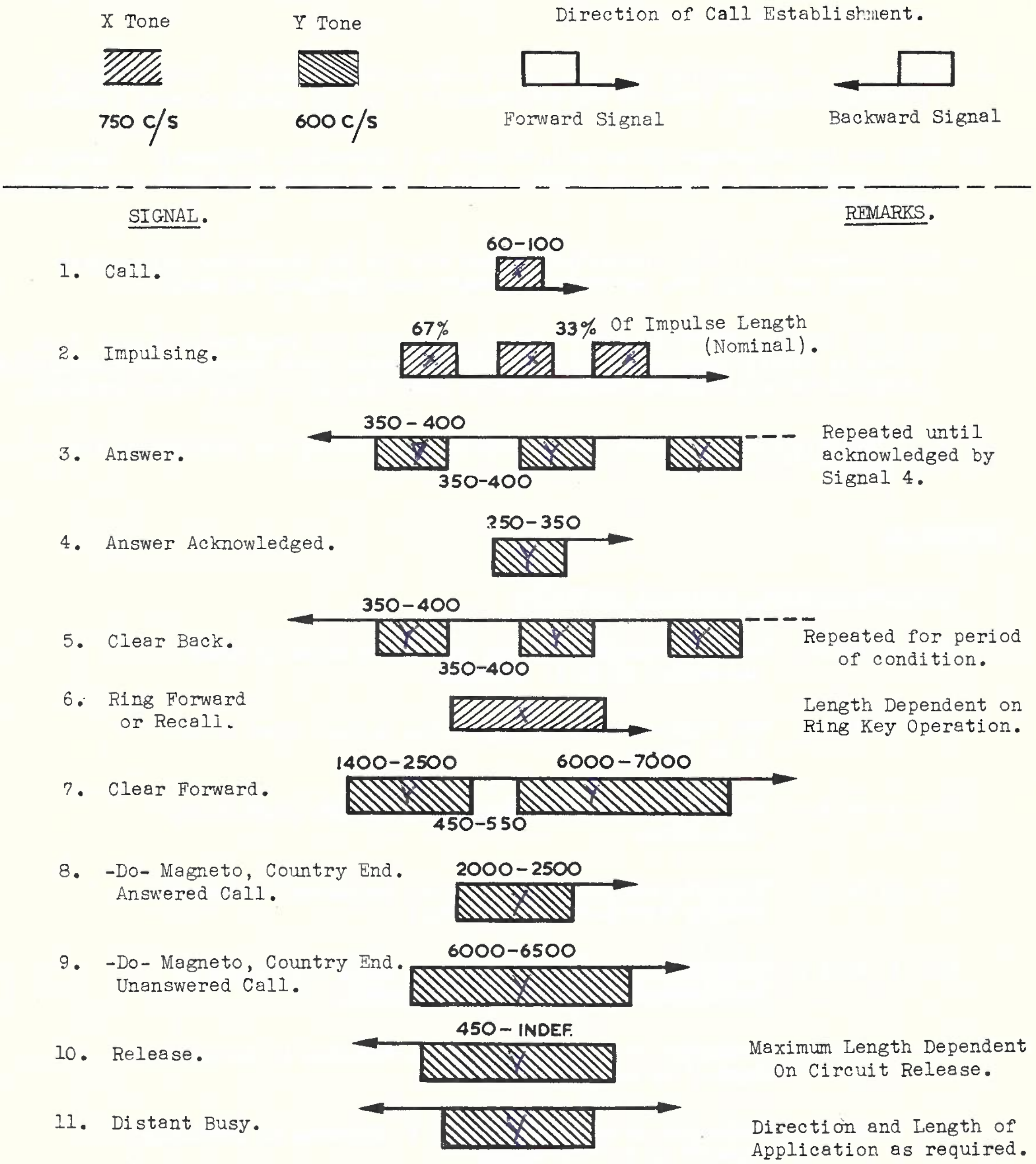
After the first "answer" signal causes the above operation to take place at the originating end, it becomes necessary to stop further "answer" signals being sent. This is done by means of the "answer acknowledge" signal as follows -

On the cessation of the first answer signal, relay Y releases to reoperate relay Z and release relay G. The release of relay G opens the locking circuit of relay AT. This relay has a release time of about 350 milliseconds, so that, for this time, the circuits to the c-e winding of relay SP and the d-e winding of relay TN are completed from earth at AT3 operated, and G2 and BR3 normal. Relay SP, therefore, holds, and relay TN operates to transmit a pulse of Y tone (the "answer acknowledge" signal) to the called exchange. The length of this pulse is controlled by the release time of relay AT, because, when relay AT releases, relays SP and TN release to terminate the "answer acknowledge" signal. The length of this signal is from 250 to 350 milliseconds. At the distant exchange, the "answer acknowledge" pulse of Y tone operates the Y relay there, because this signal is sent in the silent period of the "answer" signal, that is, when relay TN at the called exchange is released and the 2 V.F. receiver there is connected across the trunk line again. The operation of the Y relay will operate relays G and ZR, release relay Z and operate relay SP, as described previously. Also, relay TN is disconnected from the earth pulse lead at G7 operated.

On the "answer acknowledge" signal finishing, relay Y releases to reoperate relay Z which releases relay SP. Eventually, relays G and ZR release, and, as the SP relays in both relay-sets are released, conversation can now take place.

9.8 Signal Sequence. From the previous description, the student may gain some idea of the way a particular call condition at either end of the line is translated into V.F. signals for transmission to the other end. Fig. 12 shows typical signal sequences used on some calls using 2 V.F. channels.

/ Fig. 12.



SIGNAL CODE.

FIG. 12.

10. TEST QUESTIONS.

1. Why is a "Ring Round" relay-set necessary when 17 c/s signalling is used on repeatered circuits? Describe, with the aid of a circuit, the operation of such a relay-set.

2. Why is 17 c/s signalling not possible on composited circuits? Using a block schematic diagram, describe the operation of a 135 c/s ringer on such a circuit.

3. What are the advantages of using 1,000 c/s as a signalling frequency? Describe the operation of a 1,000 c/s ringer, using a block schematic diagram to illustrate your answer.

4. What is meant by 2 V.F. signalling? What are the two signalling frequencies employed, and state the functions for which each frequency is used?

5. With the aid of a block schematic circuit, describe the progress of a call from a country manual exchange, through a main automatic trunk exchange to a subscriber connected to an automatic exchange in the same area as the main trunk exchange.

6. List the nature and functions of the signals used during the progress of the call in Question 5.

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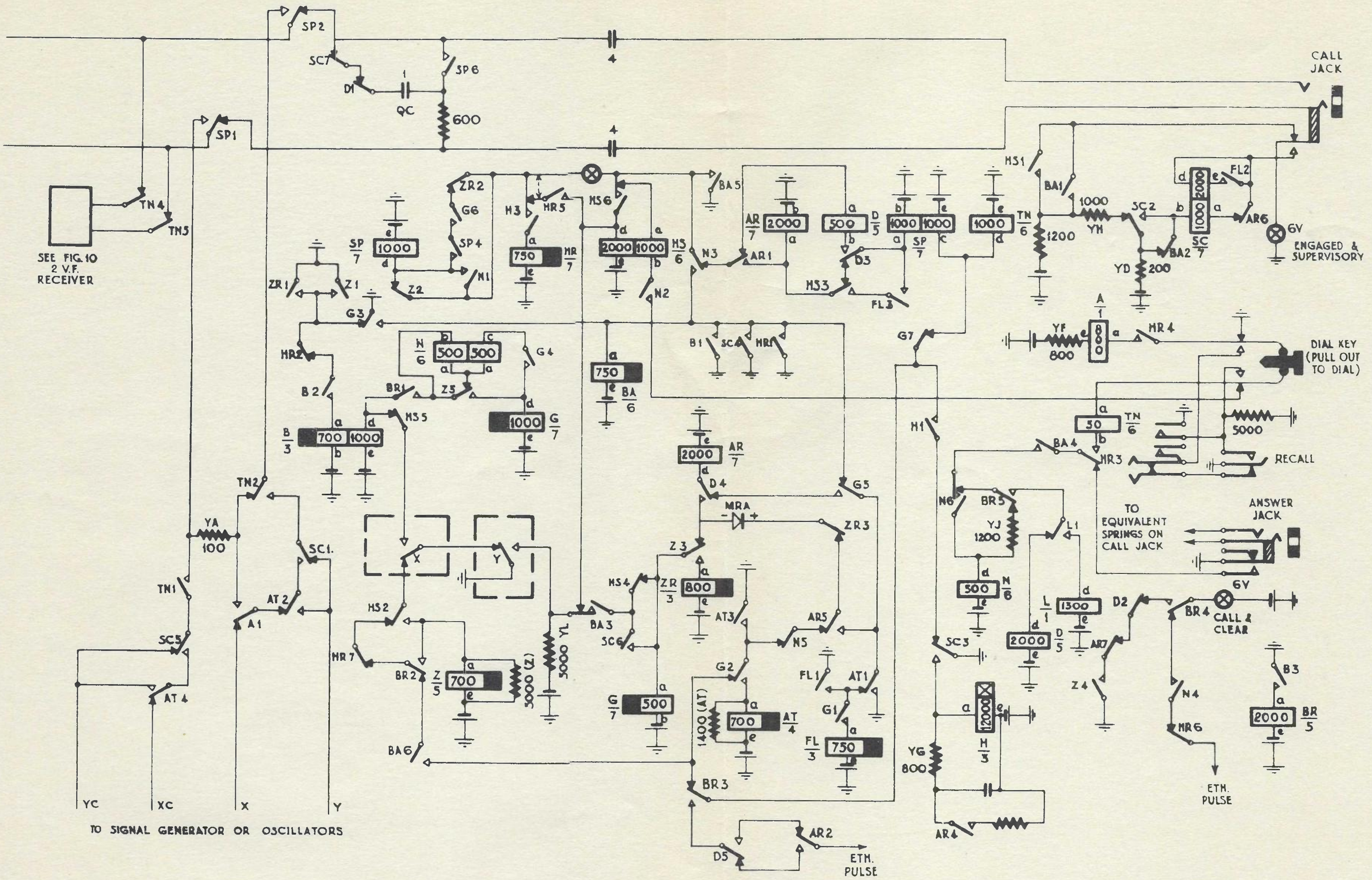
END OF PAPER.



MAIN ELEMENTS OF SIEMENS 2 V.F. RELAY-SET (MANUAL EXCHANGE END).

FIG. 11.

Engineering Branch,
Postmaster-General's Department,
Treasury Gardens,
Melbourne. C.2.

COURSE OF TECHNICAL INSTRUCTION.

SINGLE CHANNEL CARRIER TELEPHONE SYSTEMS.

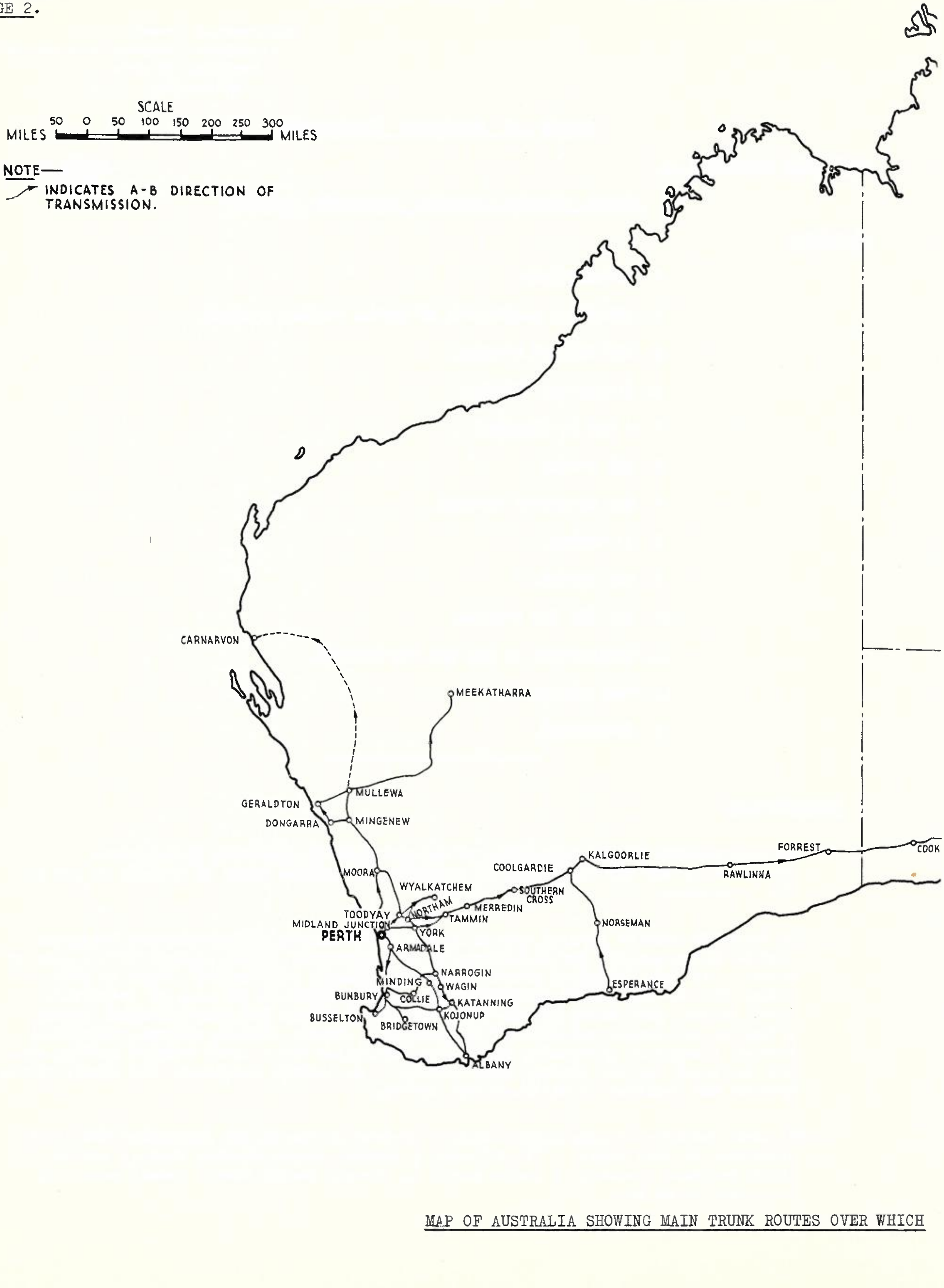
CONTENTS:

1. INTRODUCTION.

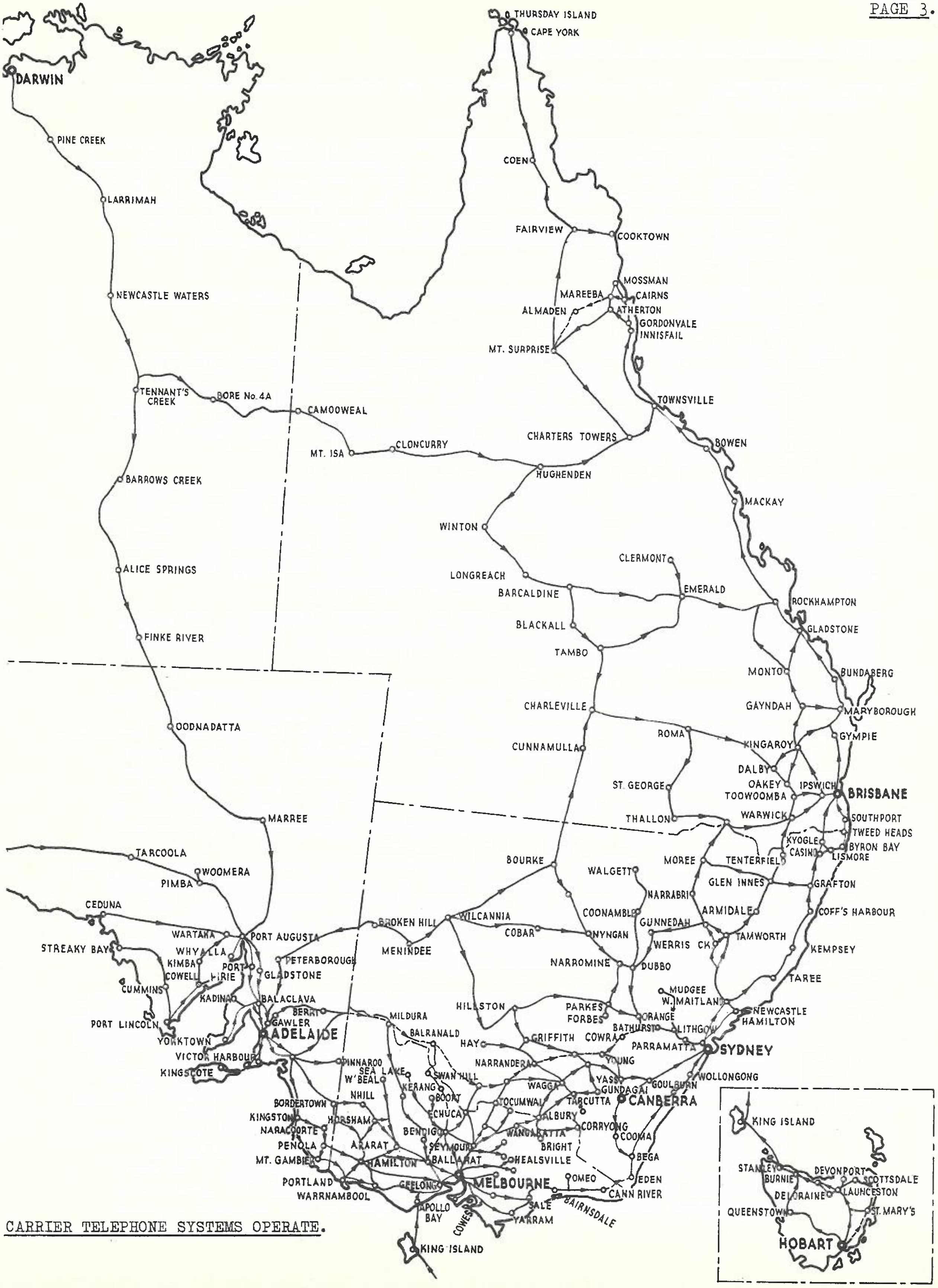
1.1 The applications of the principles of carrier working discussed in Long Line Equipment I, are now considered by studying the various types of systems in use in the Department.

1.2 The simplest type of carrier system in use is the Single Channel Carrier Telephone System, which permits the derivation of one additional speech channel from a pair of wires. In many instances where the traffic demands are limited, there is often a demand for one additional speech circuit, particularly in the case of intrastate trunk routes, and, where the distance exceeds 50 miles, the single channel system offers an economical solution of the problem. Single channel systems, therefore, provide a means of increasing trunk line facilities where three channel systems are not justified for the present requirements. As traffic increases, the single channel systems are replaced by multi-channel systems.

1.3 The main features of some single channel systems in use in the Department are briefly described in this Paper. In addition, a typical single channel carrier system which includes a number of improvements in circuit design during recent years, is described in detail.



MAP OF AUSTRALIA SHOWING MAIN TRUNK ROUTES OVER WHICH



CARRIER TELEPHONE SYSTEMS OPERATE.

2. FREQUENCY ALLOCATION OF SINGLE CHANNEL SYSTEMS.

2.1 Basic Requirements. The basic requirements of the equipment comprising a single channel system, are -

(i) A band of audio frequencies sufficiently broad to ensure adequate intelligibility and quality must be shifted to a desired position in the frequency spectrum. This is done by causing the audio frequency signals to amplitude modulate a "carrier" frequency, resulting in the production of upper and lower sidebands. Satisfactory quality and intelligibility of speech are obtained in a normal telephone channel when the audio frequency range covers 0.3-2.6 kc/s.

(ii) The modulated band must be transmitted without undue attenuation or distortion.

(iii) At the receiving end, the audio component of the modulated band must be reproduced in its original form, that is, demodulated. The original audio intelligence can be reproduced at the receiving terminal by a combination of the carrier frequency and a single sideband. The upper or lower sideband required for the transmission of intelligence over the carrier system is selected by filters.

2.2 Single Sideband Transmission. In modern carrier telephone systems, it is usual to filter out both the unwanted sideband and the carrier frequency, thus transmitting one sideband only to line. In this case, it is necessary to supply the carrier frequency at the receiving terminal. The frequency of the injected carrier must equal the frequency of the carrier at the transmitting end, as a discrepancy of more than a few cycles spoils the quality of the received speech.

The suppression of the carrier frequency and the unwanted sideband at the transmitting terminal, and the transmission of the intelligence by a single sideband only, have the following advantages -

(i) The best possible use is made of the available frequency spectrum. When the carrier and one sideband are suppressed, the transmitted sideband occupies a band of frequencies equal to that of the original voice frequency. Thus, when a frequency range 0.3-2.6 kc/s modulates a 10 kc/s carrier frequency, and the upper sideband only is transmitted, the frequencies range from 10.3-12.6 kc/s and the band-width is 2.3 kc/s, which is the same band-width as the original speech. When the carrier and both sidebands are transmitted to line the band-width extends from 7.4-12.6 kc/s.

(ii) The effect of crosstalk increases as the frequency increases, and, therefore, is greater at carrier frequencies than at voice frequencies. Crosstalk can be reduced by increasing the number of line transpositions, but the suppression of the carrier frequency reduces the power transmitted to line, and this assists in reducing crosstalk and also simplifies the design of amplifiers and other equipment in the carrier system.

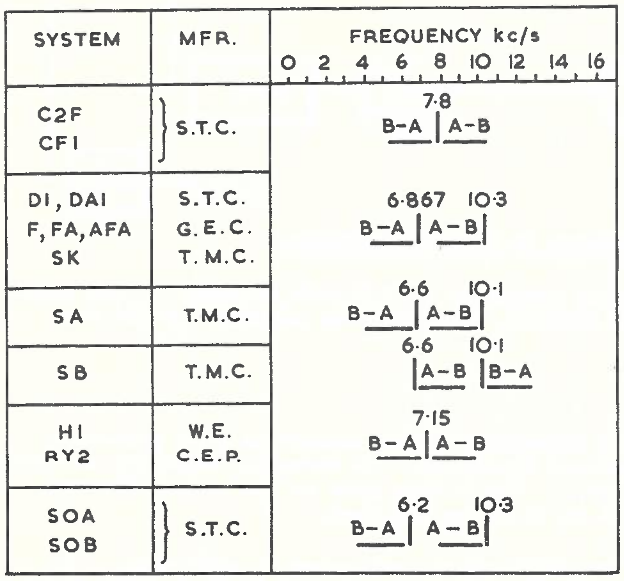
(iii) When the carrier frequency is transmitted over the line, the original audio frequency currents are reproduced at the receiving terminal by the operation of the demodulator circuit, which reproduces the desired audio intelligence from the combination of the incoming carrier and sideband currents. The volume of the reproduced audio current depends on the amplitudes of the incoming carrier and sideband currents. Now, both these currents traverse the line and, in consequence, suffer all the disadvantages due to variations in line attenuation caused by varying line conditions. Thus, the demodulated audio signal depends on the combined effect of two currents, both of which are subject to changes in amplitude. If the variations due to these causes were eliminated, it would be possible to obtain more stable operation. The variations in the sideband currents

/ cannot

cannot be avoided, but by eliminating the necessity for transmitting the carrier, an improvement is obtained because the amplitude of the injected carrier at the receiving terminal may be as high as required, and it is not subject to line variations.

2.3 Single channel systems are designed for operation over a 2-wire aerial circuit connecting the terminal stations. Most of the systems in present use operate on the "grouped" arrangement, transmitting a separate group of sideband frequencies in each direction of transmission. Discrimination between the two groups is obtained by high and low-pass directional filters at each terminal.

2.4 A number of different single channel carrier systems are used in the Department, and their designations and frequency allocations are shown in Fig. 1. The carrier frequency is shown by a vertical line, and the transmitted sidebands, whether upper or lower, for each direction of transmission are shown by the horizontal lines at right angles to the appropriate carrier frequency.



SYSTEM	MFR.	FREQUENCY kc/s 0 2 4 6 8 10 12 14 16
C2F CF1	S.T.C.	7·8 B-A | A-B
D1, DA1 F, FA, AFA SK	S.T.C. G.E.C. T.M.C.	6·867 10·3 B-A | A-B |
SA	T.M.C.	6·6 10·1 B-A | A-B |
SB	T.M.C.	6·6 10·1 | A-B | B-A
H1 RY2	W.E. C.E.P.	7·15 B-A | A-B
SOA SOB	S.T.C.	6·2 10·3 B-A | A-B |

FREQUENCY ALLOCATION FOR SINGLE CHANNEL SYSTEMS.

FIG. 1.

It is noted in Fig. 1 that a number of the single channel systems have different frequency allocations. These frequency differences are for various reasons. For example, the staggering of the transmitted frequencies is of assistance in reducing crosstalk between single channel systems which are operated on adjacent circuits on the same trunk route. This aspect is not of major importance for single channel systems as the maximum frequency transmitted is approximately 10 kc/s. As the tendency to crosstalk increases with frequency, this problem is more serious in operating parallel 3-channel and 12-channel carrier systems, and, therefore, is dealt with in Paper No. 4 on 3-channel systems.

Another reason for the frequency differences in single channel systems is to permit co-ordination with 3-channel systems, which may be operated on other pairs on the same pole route. With the rapid growth in carrier working, the tendency is for single channel systems to be restricted to minor trunk routes, and hence it is not necessary to have a wide range of single channel systems with different frequency allocations.

2.5 In the SB system, the frequencies are chosen so that 5.6 kc/s line filters can be used to separate the V.F. and the carrier telephone channels. Frequencies up to approximately 5 kc/s can then be transmitted over the V.F. channel and it is suitable for broadcast programme relays. This is not possible in the case of the other single channel systems.

2.6 In general, for crosstalk considerations, carrier telephone systems in use in the Commonwealth are installed so that the A-B direction of transmission is counter-clockwise around Australia, taking Perth as a starting point. Thus Adelaide is a B station for Perth to Adelaide circuits, but an A station for Adelaide to Melbourne circuits. There are many exceptions to this rule, however, such exceptions being dictated by crosstalk considerations.

In the Western Electric (America) systems, the terminals are designated East and West. Under Australian conditions, these terminals correspond to A and B terminals respectively.

/ 3.

3. C2F AND CF1 SYSTEMS.

3.1 These systems are made by Standard Telephones and Cables Ltd., London. The systems are similar, the CF1 being the later model of the original C2F system. A block schematic circuit of a typical CF1 carrier terminal is shown in Fig. 2.

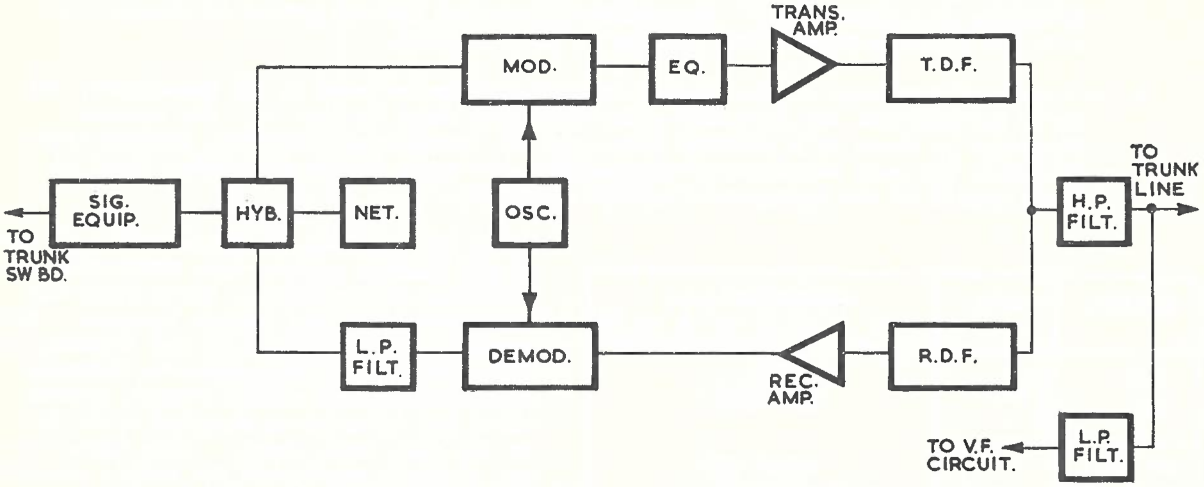


FIG. 2. BLOCK SCHEMATIC OF TYPE CF1 TERMINAL.

3.2 Frequency Allocation. A single carrier frequency of 7.8 kc/s is used. The upper sideband is transmitted in the A-B direction, and the lower sideband in the B-A direction.

3.3 Modulator and Demodulator.

(i) The modulator uses two 4101D thermionic valves connected in a push-pull circuit to suppress the carrier frequency. A variable capacitor is provided for carrier leak adjustments. Two L type pads in the output circuit provide attenuation of 4, 8 or 12 db as required.

(ii) The demodulator also uses two 4101D valves connected in push-pull. An input potentiometer provides control over a range of 22 db in steps of 2 db.

(iii) A common oscillator unit using a single 4101D valve supplies the carrier frequency to both modulator and demodulator units. This oscillator is mounted on the modulator panel and includes a variable capacitor for oscillator tuning adjustments.

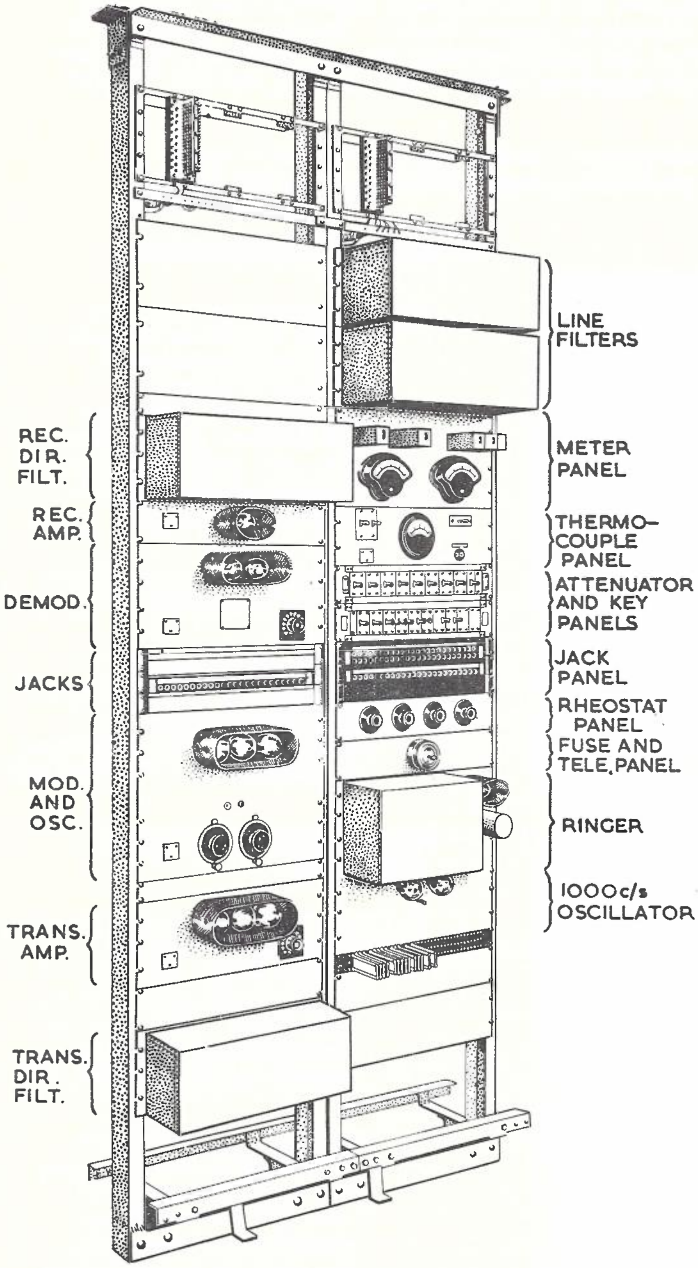
3.4 Transmitting and Receiving Amplifiers.

(i) The transmitting amplifier is a two stage amplifier having a maximum gain of 36 db. An input potentiometer provides gain adjustment in steps of 2 db over the entire amplification range. The first stage is equipped with one 4101D valve, and the second stage with two 4104D valves in push-pull connection.

(ii) The receiving amplifier uses a single 4101D valve, and has a maximum gain of 20 db. The gain is controlled by three attenuator pads of 4, 8 and 16 db connected in the input circuit.

3.5 Signalling Arrangements. V.F. ringing facilities are incorporated in the design of the system. The signalling frequency is derived from a 1,000 c/s oscillator, the output of which is modulated at the rate of 16-20 c/s. The operation of this equipment is similar to the 1,000/17 c/s ringer unit described in Paper No. 2 of this Book.

/ 3.6



TYPE CF1 CARRIER TERMINAL.

3.6 Test Equipment.

(i) Meter Panel includes an ammeter with a single reading of 2 amperes maximum and a milliammeter with two scales. One scale is calibrated up to 1.5 mA and the other to 75 mA. These meters measure filament and anode currents respectively.

(ii) Oscillator Panel. A balanced oscillator, using two 4101D valves is mounted on this panel. The oscillator provides uninterrupted 1,000 c/s testing current for transmission loss and gain measurements on the terminal equipment and also supplies the signalling frequency referred to in paragraph 3.5.

(iii) Thermo-couple Panel includes a thermo-couple operated microammeter with three scales calibrated in milliamperes, namely, 0-4, 0-16 and 0-40. An additional scale calibrated in db enables the meter to be used for transmission measurements.

(iv) Attenuator Panel comprises a number of key controlled pads providing maximum attenuation of 59 db.

(v) Monitoring. A telephone set is provided for monitoring purposes.

3.7 Power Supply. The system operates from 24 volts filament and 130 volts anode battery supplies. A grid bias battery of 33 volts (which is tapped for various voltages) is also required.

3.8 These systems were originally mounted on two racks, with an inter-connecting cable between them. Many of the systems have since been rebuilt to mount all the equipment on one 10'6" rack provided with fuse and lamp panels. This results in a saving in floor space, and the inter-connecting cable is dispensed with.

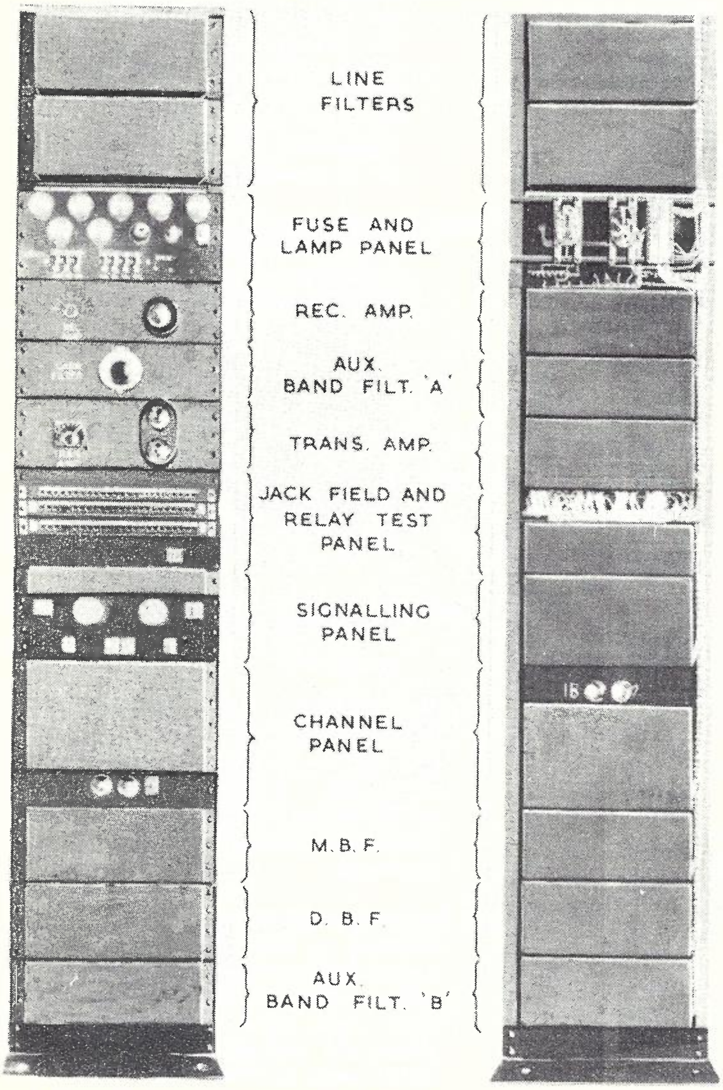
/ 4.

4. D1 AND DA1 SYSTEMS.

4.1 The systems are made by Standard Telephones and Cables Ltd., London. The type D1 system is designed for use on short trunk lines. The type DA1 system is identical with the type D1 system with the addition of a transmitting amplifier and auxiliary band-pass filters, and is designed for use on longer lines. The type DA1 system is also provided with a receive amplifier and auxiliary band filters which are connected in circuit when required. The block schematic circuit of a type D1 and DA1 carrier terminal is shown in Fig. 3.

4.2 Frequency Allocation.

A-B direction - lower side-band of 10.3 kc/s.
B-A direction - lower side-band of 6.867 kc/s.



Front.

Rear.

TYPE DA1 CARRIER TERMINAL.

4.3 Modulator and Demodulator.

(i) The modulator uses two 4101D valves in a self-oscillating balanced push-pull circuit. Although the sidebands are present in the output, the push-pull connection suppresses the carrier frequency.

(ii) The demodulator is similar to the modulator.

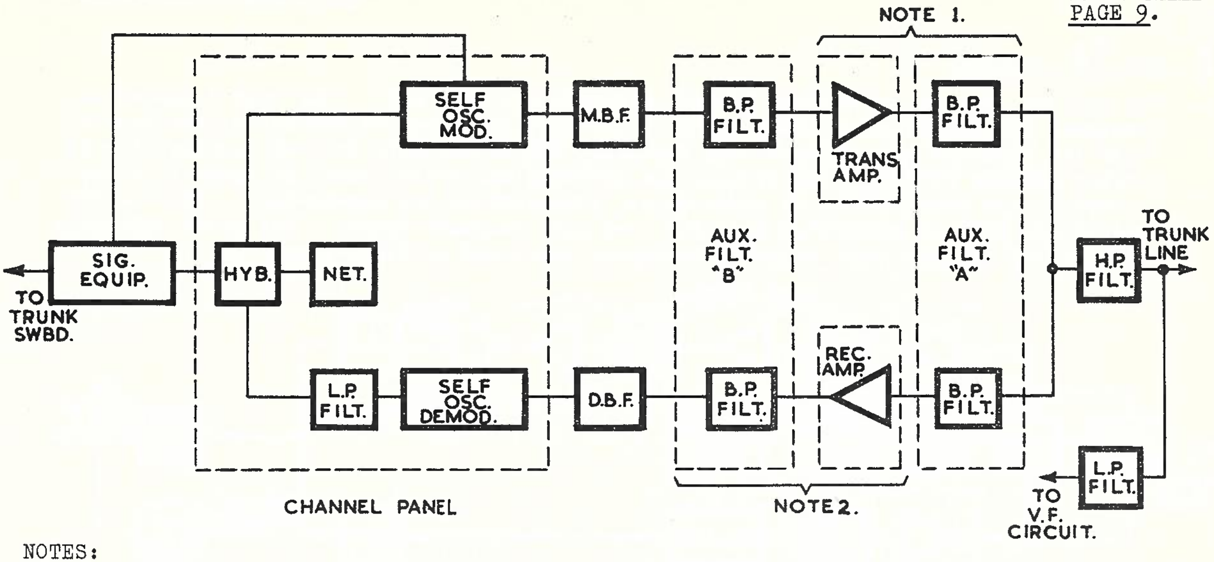
(iii) As the modulator and demodulator circuits are self-oscillating, no separate carrier frequency oscillator unit is required.

4.4 Transmitting and Receiving Amplifiers.

(i) The transmitting amplifier (provided on the DA1 system only) uses two 4104D valves connected in push-pull. The gain is approximately 19 db, and maximum output 250 mW.

(ii) The receiving amplifier (provided on the DA1 system only when required) uses two 4101D valves connected in push-pull. The gain is approximately 22.5 db, and maximum output 200 mW.

/ Fig. 3



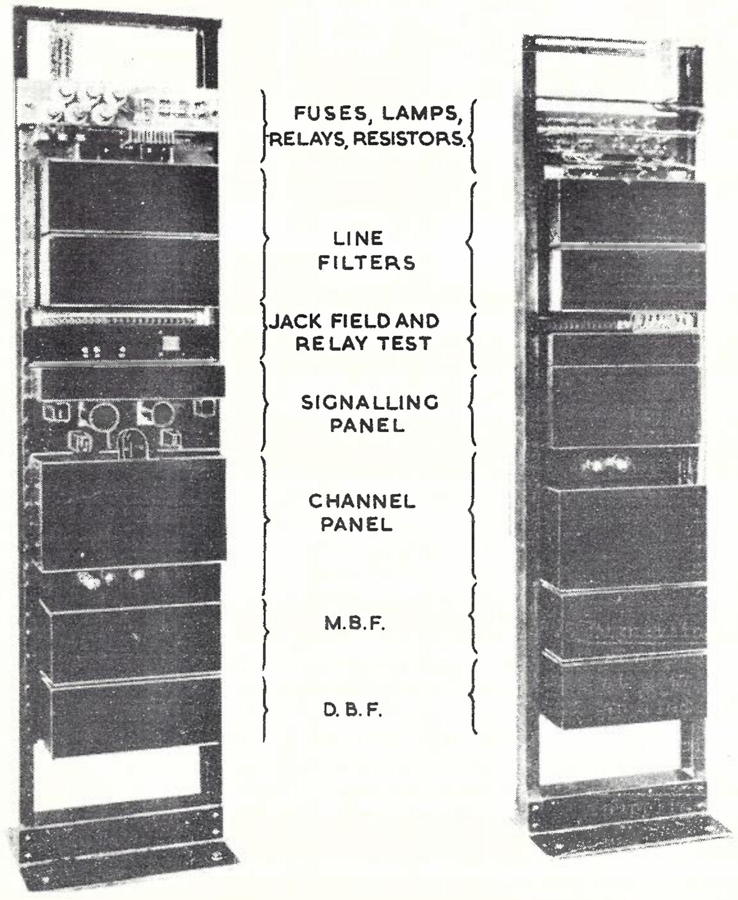
NOTES:
(1) Trans. Amp. and Auxiliary Band Filters "A" provided at DA1 Terminal only.
(2) Rec. Amp. and Auxiliary Band Filters "B" provided at DA1 Terminal only if required.

FIG. 3. BLOCK SCHEMATIC OF TYPES D1 AND DA1 TERMINALS.

4.5 Signalling Arrangements. A relay circuit tuned to 17 c/s causes the carrier to be shifted 1,000 c/s, and the output is interrupted at a 17 c/s rate. The modulator is unbalanced during signalling to permit the carrier to pass to line. The altered carrier frequency, when demodulated, produces a 1,000 c/s tone interrupted at 17 c/s, which operates the usual type of ringer receiver circuit with resultant application of 17 c/s to the trunk switchboard.

4.6 Testing Equipment. No transmission measuring equipment is provided. An adjustment panel for adjustment of the 215 FA ringer relay is included. Test jacks provide access to various parts of the circuit for test purposes.

4.7 Power Supply. The systems operate from 24 volts and 130 volts battery supplies. A grid bias battery of 27 volts is also required for the transmitting amplifier of the DA1 terminal.



Front. Rear.

TYPE D1 CARRIER TERMINAL.

/ 5.

5. F AND FA SYSTEMS.

5.1 The systems are made by British General Electric Co. Pty. Ltd. The type F system is designed for use on short trunk lines. The type FA system is similar to the type F with the addition of a transmitting amplifier and is suitable for the transmission of higher sending levels. The systems are of three varieties, known as Issue 1, 2 and 3 models, and these differ in performance, construction and appearance. The various models are further subdivided into D.C. and A.C. operated types. The block schematic circuits of typical type F and FA terminals are shown in Figs. 4 and 5.

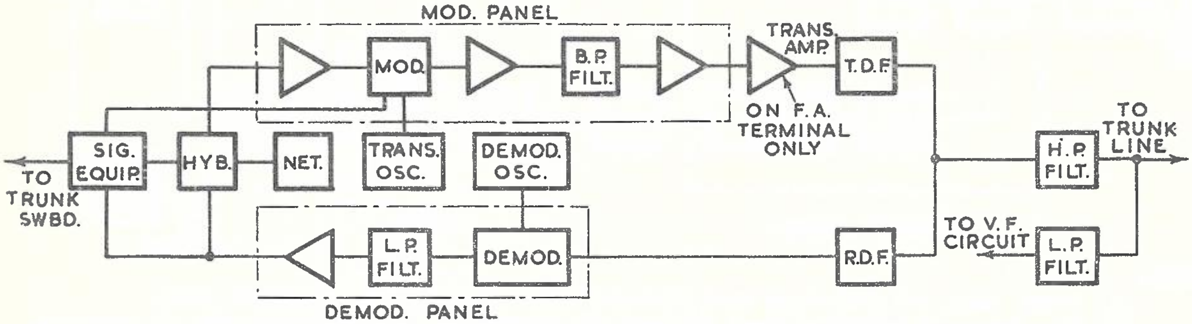


FIG. 4. BLOCK SCHEMATIC OF TYPES F AND FA TERMINAL (ISSUES 1 AND 2.)

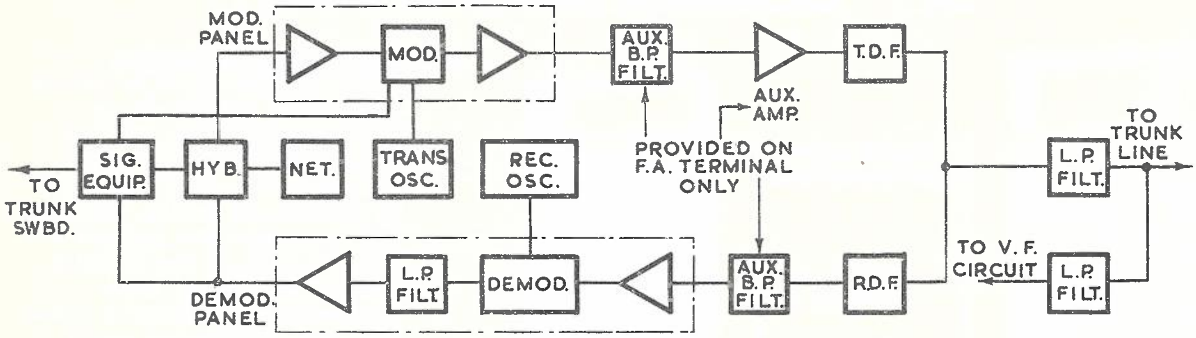


FIG. 5. BLOCK SCHEMATIC OF TYPES F AND FA TERMINAL (ISSUE 3).

5.2 Frequency Allocation.

A-B direction - lower sideband of 10.3 kc/s.
B-A direction - lower sideband of 6.867 kc/s.

5.3 Modulator and Demodulator.

(i) The modulator panel incorporates a copper oxide rectifier balanced modulator, and V.F. and sideband amplifier stages. On Issues 1 and 2, three amplifier stages are provided using VT82 valves. On Issue 3, two amplifier stages are provided, consisting of a V.F. amplifier using a VT82 valve and a sideband amplifier using a VT108 valve. The gain of the complete modulator unit is about 38 db.

(ii) The demodulator panel incorporates a copper oxide rectifier type demodulator, a low-pass filter and amplifier. On Issues 1 and 2, the single stage amplifier uses a VT82 valve. On Issue 3, two amplifier stages are provided consisting of a sideband amplifier using a VT82 valve and a V.F. amplifier using a VT108 valve. The gain of the complete demodulator unit is about 28 db. The level of the sideband input to the demodulator is adjusted by an attenuator to compensate for variations in the loss of the line caused by climatic changes.

(iii) Separate single valve (VT82) oscillators supply the carrier frequencies to the respective modulator and demodulator units.

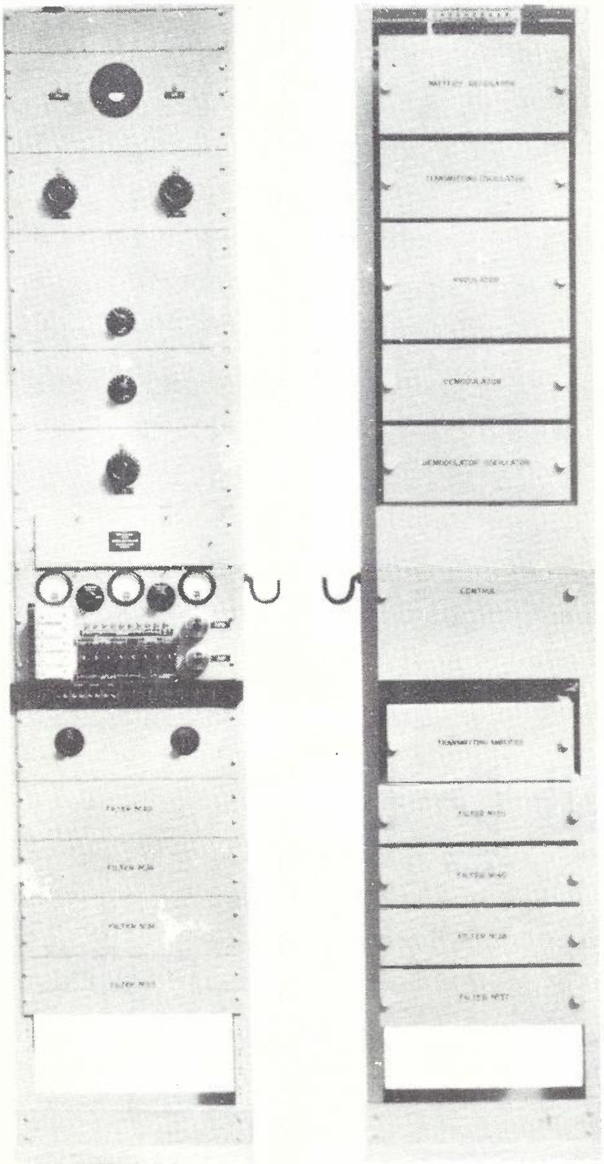
/ 5.4

5.4 Transmitting and Receiving Amplifiers.

(i) Separate transmitting and receiving amplifier panels are not provided in the type F terminal, as sufficient gain exists in the complete modulator and demodulator units for this system to be used on short trunk lines.

(ii) The transmitting amplifier of Issues 1 and 2 of the FA system is a single stage amplifier using two VT108 valves in push-pull. Output power is about 500 mW and the maximum gain is 12 db. The gain adjustment consists of an input potentiometer, designated "Input Adjust.", which is variable in steps of 1 db.

(iii) The transmitting amplifier of Issue 3 of the FA terminal uses four VT108 valves in parallel push-pull. In this model, two auxiliary band-pass filters are provided. The filter in the transmit path attenuates the unwanted (upper) sideband to prevent overloading the amplifier. The filter in the receive path increases the attenuation to unwanted sideband components reaching the demodulator from the modulator, and is necessary in the FA terminal owing to the higher levels produced by the transmitting amplifier.



Front. Rear.

TYPES F AND FA CARRIER TERMINAL (ISSUE 1).

5.5 Signalling Arrangements. The 17 c/s ringing current from the trunk switchboard operates a relay which reduces the carrier frequency by 500 c/s and the reduced frequency is interrupted at a 17 c/s rate. The modulator is unbalanced during signalling to permit this carrier to pass to line. At the distant end, the altered carrier frequency, when demodulated, produces 500 c/s. This demodulated frequency is applied to a signalling receiver using a VT108 valve and tuned to 500 c/s, with resultant application of 17 c/s to the trunk switchboard.

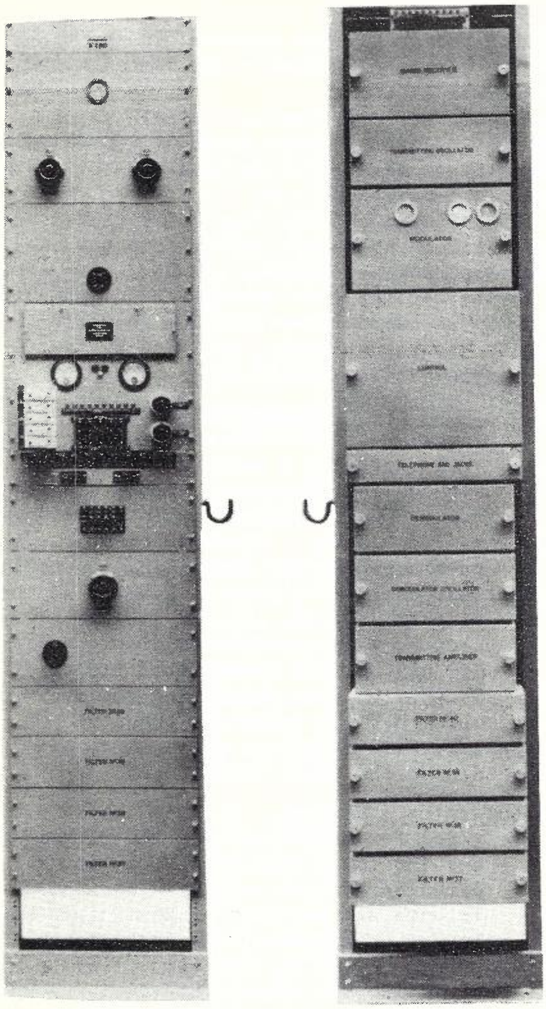
5.6 Testing Equipment. A voltmeter is provided for measurement of the 24 volts and 130 volts supplies. The anode circuits of each valve are connected through the contacts of individual keys to a milliammeter, which indicates the anode current in each circuit by operating the appropriate key. A meter and keys are provided in a similar manner for the measurement of the filament current in each valve circuit. The anode current milliammeter can be used also to check the transmission equivalent of the system for approximate level adjustments.

5.7 Power Supply. The power supply consists of -

(i) a 24 volts (smoothed) supply for filament circuits,
(ii) a 24 volts (noisy) supply for relay and miscellaneous circuits, and
(iii) a 130 volts anode supply.

In the battery operated systems, a voltage regulator maintains the filament voltage between 20 and 21 volts. The A.C. operated systems include 3 bridge rectifier power units with associated smoothing circuits for the 130 volts and 24 volts filament circuits. The 24 volts relay and miscellaneous supply does not include a smoothing filter.

/ Type



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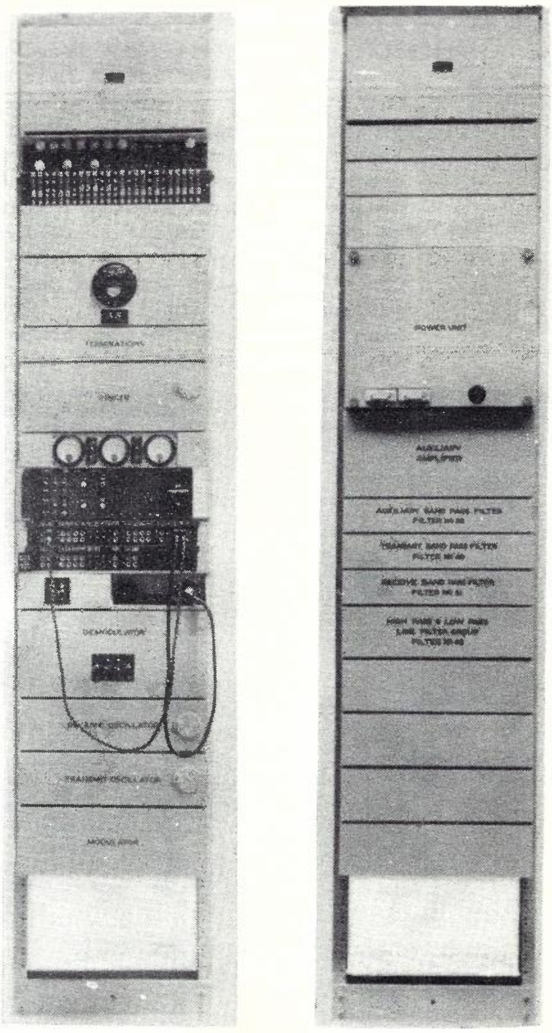
TYPES F AND FA CARRIER TERMINAL.
(ISSUE 2).



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TYPES F AND FA CARRIER TERMINAL.
(ISSUE 3).

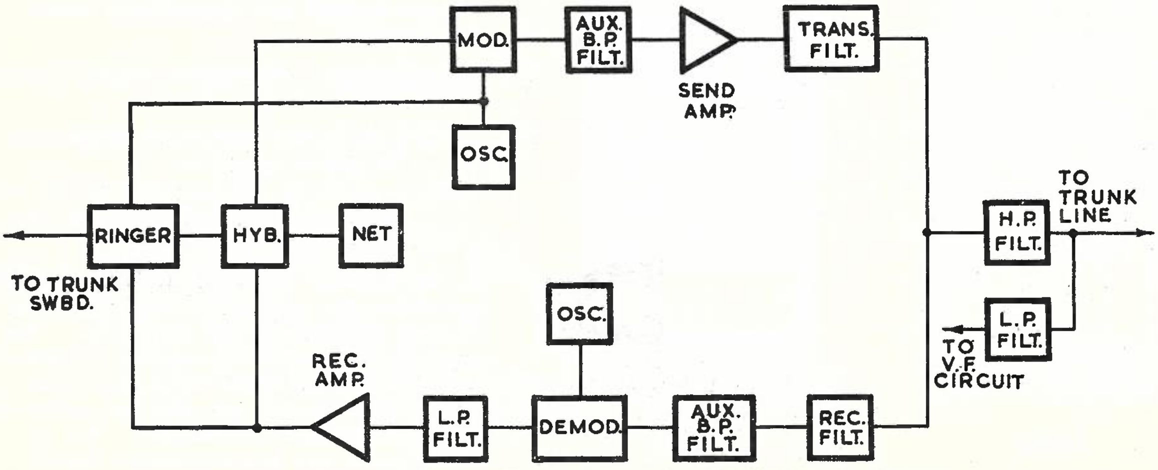
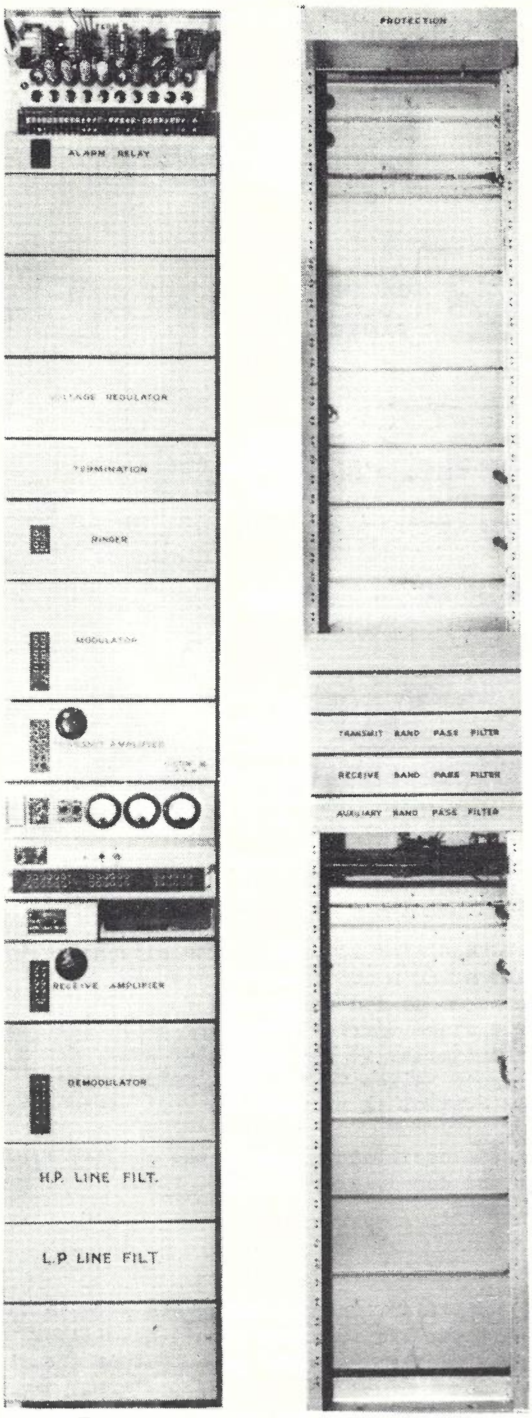


FIG. 6. BLOCK SCHEMATIC OF TYPE AFA TERMINAL.

6. AFA SYSTEMS.

6.1 The systems are made by British General Electric Co., Pty. Ltd., Melbourne. The block schematic circuit of a typical carrier terminal is shown in Fig. 6.



Front. Rear.

TYPE AFA CARRIER TERMINAL.

6.2 Frequency Allocation.

A-B direction - lower sideband of 10.3 kc/s.
B-A direction - lower sideband of 6.867 kc/s.

6.3 Modulator and Demodulator.

(i) Copper oxide rectifier modulator and demodulator units are used.

(ii) Separate single valve (6V6G) oscillators supply the carrier frequencies to the respective modulator and demodulator units. These are mounted on the modulator and demodulator panels respectively.

6.4 Transmitting and Receiving Amplifiers. These amplifiers are identical in design, having a maximum gain of 45 db. The gain is controlled by a variable attenuator over a range of 33 db in steps of 3 db. The amplifiers are two stage negative feedback types using 6V6G valves.

6.5 Signalling Arrangements. The carrier shift method of signalling is used. The incoming ring from the trunk switchboard causes a reduction of approximately 1, 000 c/s in the carrier frequency which is transmitted to line. A delay of 500 milliseconds in the ringing relays guards the ringer against false operation during speech.

6.6 Testing Equipment. The following test equipment is provided on each terminal -

(i) a D.C. voltmeter for the measurement of power supply voltages,

(ii) a milliammeter for the measurement of anode currents,

(iii) a moving-iron ammeter for the measurement of heater currents, and

(iv) a telephone set for monitoring purposes.

6.7 Power Supply. The systems are individually designed to operate from either 24 and 130 volt D.C. supplies or 200/240 volt A.C. supply.

In the D.C. operated system, a voltage regulator of the carbon disc type is provided to control the filament voltage between 20 and 21 volts.

/ 7.

7. SA, SB AND SK SYSTEMS.

7.1 These systems are made by the Telephone Manufacturing Company, Ltd. England. With the exception of the frequency allocations, the systems are identical. As mentioned in paragraph 2:5 the frequency allocation of the SB system permits the physical circuit to be used for musical programme transmission if desired. The block schematic of a typical carrier terminal is shown in Fig. 7.

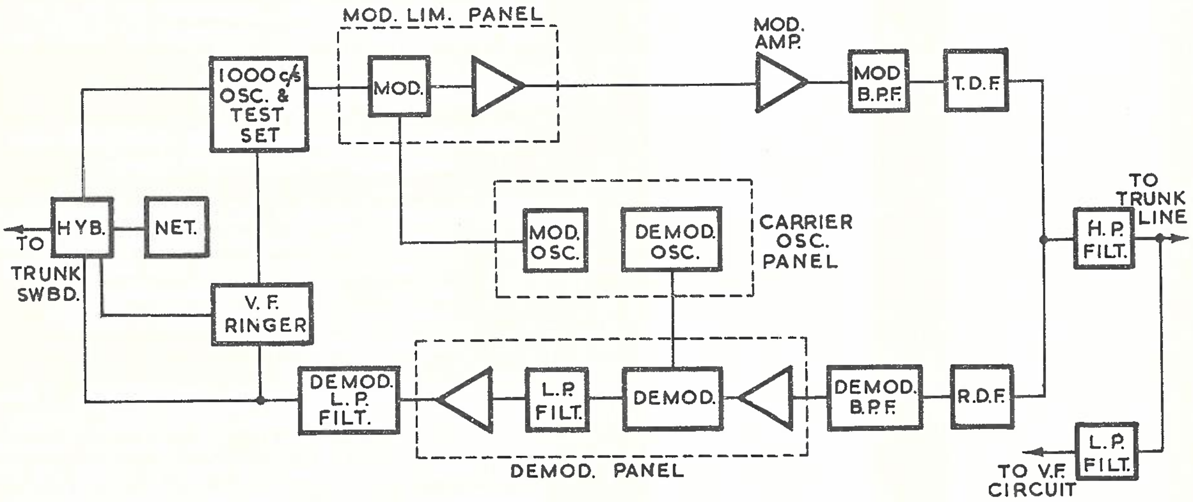


FIG 7. BLOCK SCHEMATIC OF TYPES SA, SB AND SK TERMINALS.

7.2 Frequency Allocation.

System	A-B Direction.	B-A Direction.
SA	Lower sideband of 10.1 kc/s.	Lower sideband of 6.6 kc/s.
SB	Upper sideband of 6.6 kc/s.	Upper sideband of 10.1 kc/s.
SK	Lower sideband of 10.3 kc/s.	Lower sideband of 6.867 kc/s.

7.3 Modulator and Demodulator.

(i) A double balanced metal rectifier type modulator is used. The sideband output is applied to a single stage amplifier using a TMC16 valve, with an input gain control adjustable over a range of 30 db and designated Voice Input.

(ii) The demodulator panel includes a single stage carrier frequency amplifier using a type TMC19 valve, a demodulator unit similar to the modulator unit, and a single stage V.F. amplifier using a TMC16 valve. The total gain of the equipment is 33.5 db. An input gain control is provided in 2 db steps over a range of 30 db.

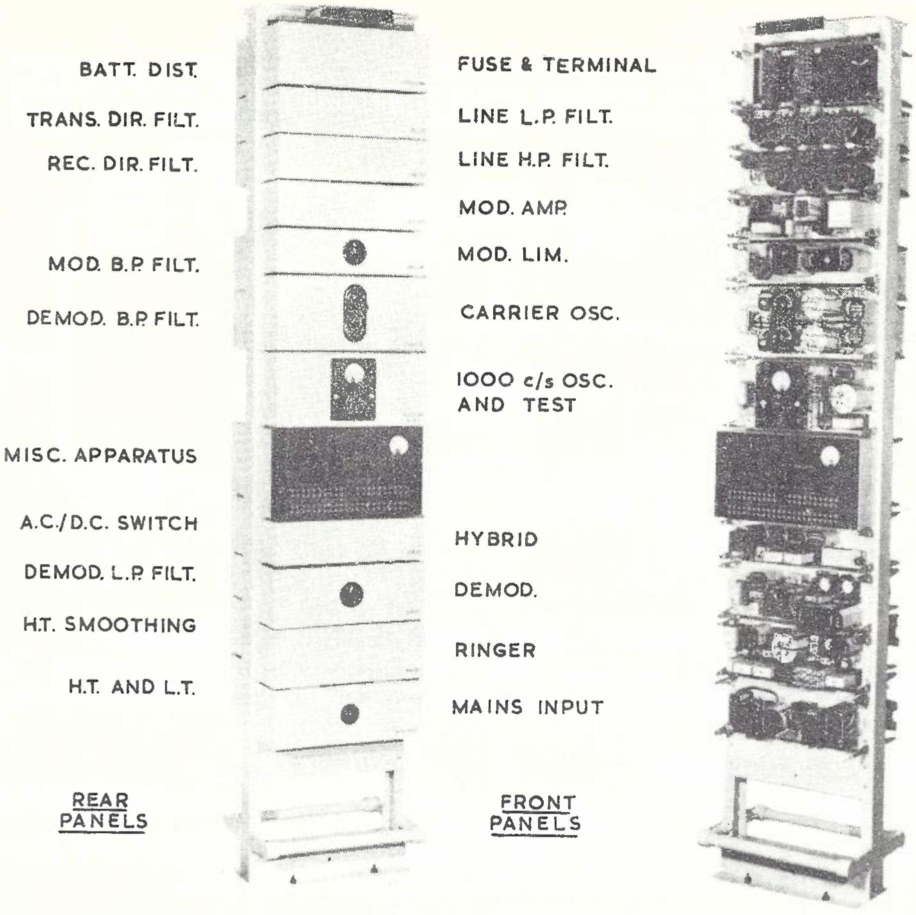
(iii) Separate single valve (TMC15) tuned anode oscillators supply the carrier frequencies to the respective modulator and demodulator units. These oscillators are mounted on the same panel.

7.4 Transmitting and Receiving Amplifiers.

(i) A negative feedback 2-stage modulator amplifier, using a TMC19 and a TMC18 valve, follows the sideband amplifier and performs the function of a transmitting amplifier. The maximum gain is approximately 30 db and power output about 400 mW (+26 dbm).

(ii) The single stage amplifier which precedes the demodulator unit and is mounted on the demodulator panel performs the function of a receiving amplifier.

/ Types



Covers On. Covers Off.

TYPES SA, SB AND SK CARRIER TERMINAL.

7.5 Signalling Arrangements. V.F. signalling is incorporated in the design of each system. The apparatus includes a 1,000/17 c/s ringer and a tuned anode 1,000 c/s oscillator. The 17 c/s ringing current from the switchboard operates a relay which applies 1,000 c/s to the modulator. Before passing to line, the sideband output is interrupted by a 17 c/s vibrating relay at the input to the modulator amplifier. At the distant end, the 1,000/17 c/s output from the demodulator is applied to a ringer receiver (using a TMC16 and a TMC19 valve) which applies local 17 c/s to the switchboard.

7.6 Test Equipment. The following test equipment is mounted on each terminal -

(i) A milliammeter for the measurement of cathode currents.
(ii) A level indicator having a range of -20 db to +10 db, with terminations of 50,000 ohms, 300 ohms or 600 ohms. The frequency range is from 50 to 50,000 c/s.
(iii) A 600 ohm balanced attenuator variable over a range of 40 db in four settings (0, 10, 20 and 40 db).
(iv) A 1,000 c/s oscillator which, although primarily intended for signalling, is used to provide a test current supply. Normal output is 0.125 volt into 600 ohms but, for testing, may be increased to 2.0 volts into 600 ohms. It must be reset to 0.125 volt for channel signalling.
(v) A handset, keys and jacks provide the monitoring facilities.
(vi) The SK terminal provides 800 c/s for test purposes, if desired, whilst still retaining 1,000 c/s for signalling.

7.7 Power Supply. The systems normally operate from 24 and 130 volts D.C. supplies.

/ 8.

8. H1 SYSTEM.

8.1 This system is made by Western Electric Co., U.S.A. The terminal equipment is compact and designed for mounting either on a standard rack or in a portable steel cabinet. The block schematic of a typical carrier terminal is shown in Fig. 8.

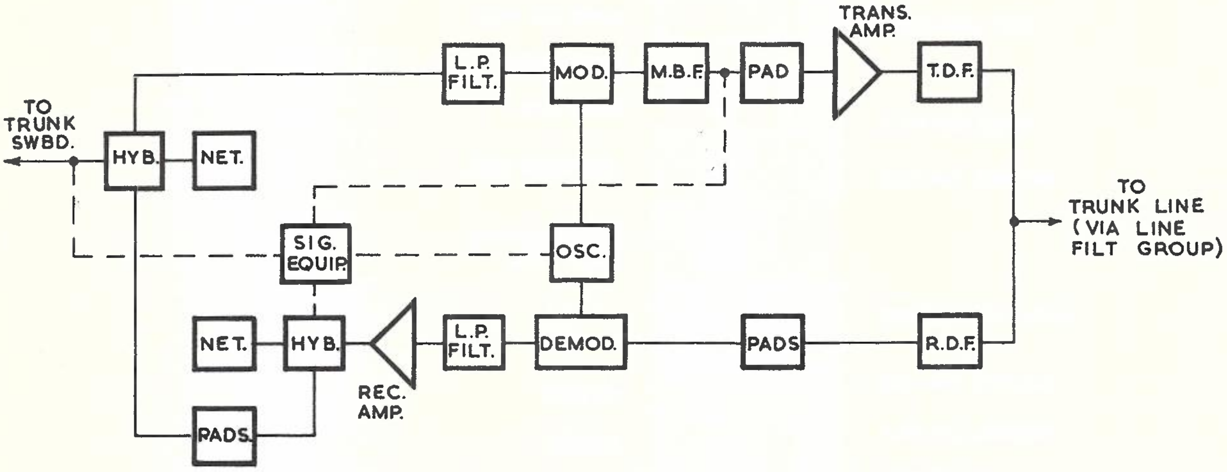


FIG. 8. BLOCK SCHEMATIC OF TYPE H1 TERMINAL.

8.2 Frequency Allocation. A single carrier frequency of 7.15 kc/s is used. The upper sideband is transmitted in the A-B direction, and the lower sideband in the B-A direction.

8.3 Modulator and Demodulator.

(i) Copper oxide rectifier units - bridge connected - are used, without provision for adjustment of carrier leakage.

(ii) A single valve oscillator using a type 328A valve, supplies the carrier frequency to both modulator and demodulator circuits.

8.4 Transmitting and Receiving Amplifiers.

(i) The transmitting amplifier is a single stage negative feedback pentode type using a 328A valve. The maximum gain is 32 db, adjustable by soldered straps on the Transmitting Gain Pad in steps of 0.5 db. The amplifier follows the modulator and amplifies the sideband range of frequencies.

(ii) The receiving amplifier is similar to the transmitting amplifier, but, as it follows the demodulator, it amplifies the V.F. range. The amplifier incorporates a hybrid type output transformer, which separates the incoming signalling (1,000 c/s) currents from the V.F. currents. The level of the incoming sideband is controlled by the Receiving Gain Pad and the audio level to the switchboard by the Receiving Level Pad. Each control is adjustable in steps of 0.5 db. Rapid adjustment of level is provided by key-controlled 2 db and 4 db pads preceding the receiving gain pad.

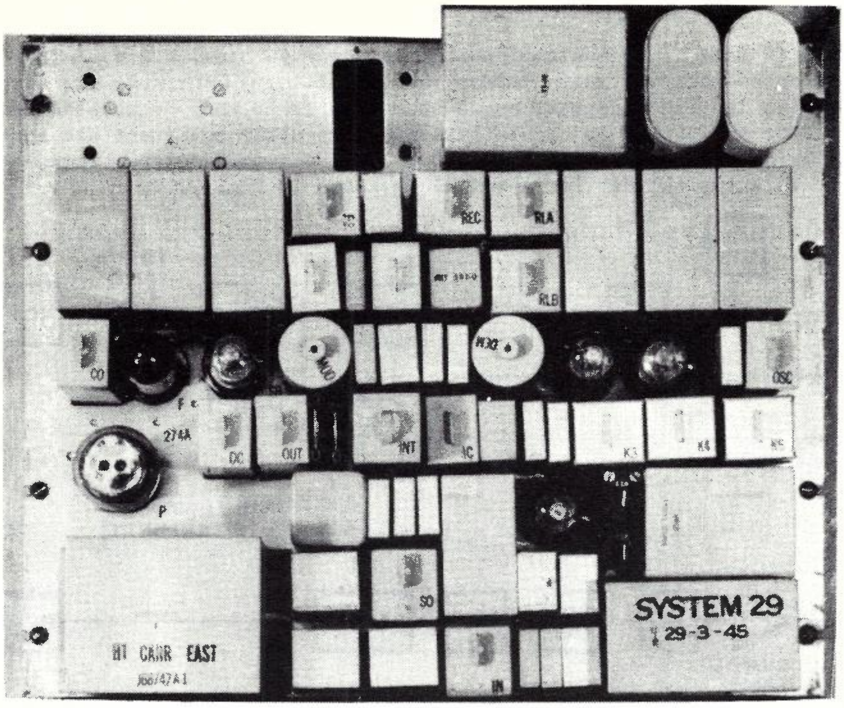
8.5 Signalling Arrangements. The carrier shift method of signalling is used. Incoming ring from the switchboard shifts the carrier 1,000 c/s, and the output is interrupted at a 17 c/s rate and applied to line. The demodulator 1,000/17 c/s current is applied to a ringer receiver which applies local 17 c/s to the trunk switchboard.

8.6 Test Equipment. No test equipment is included with the system.

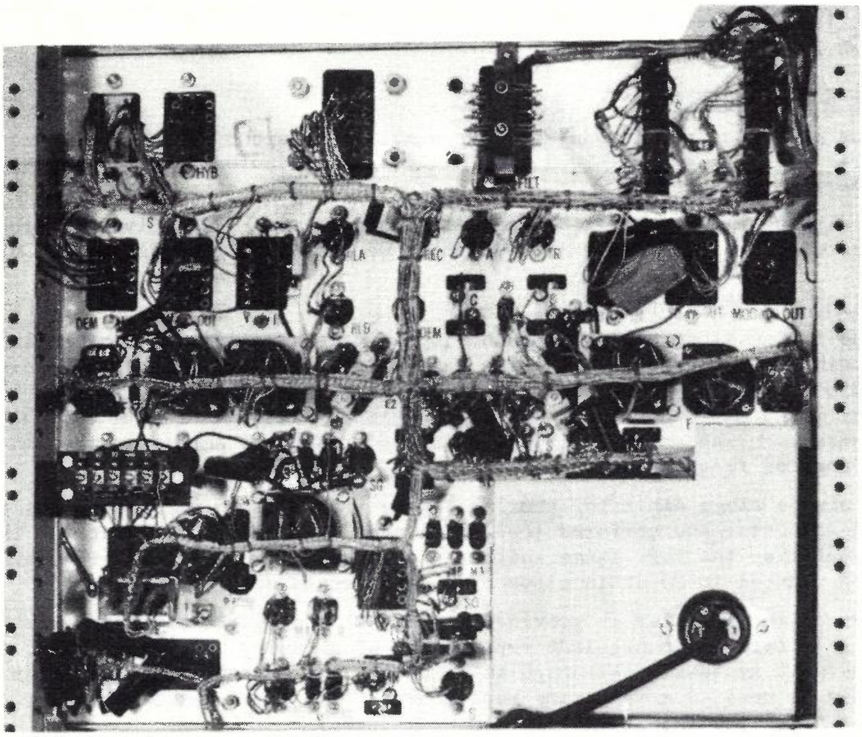
8.7 Power Supply. The system normally operates from 24 volts and 130 volts D.C. supplies.

For A.C. operation, a power supply unit is included. This unit supplies A.C. to the indirectly heated valves for filament operation. A valve rectifier type 274A supplies 160 volts for the anode supply and a bridge metal rectifier unit supplies 24 volts for relays and miscellaneous apparatus.

/ Type



Front.



Rear.

TYPE H1 CARRIER TERMINAL.

9. RY2 SYSTEM.

9.1 This system is made by Communication Engineering Pty. Ltd., N.S.W. The terminal equipment is compact and suitable for rack mounting. Four complete terminals together with testing equipment and a spare amplifier, may be mounted on a 10'6" rack. After the "first in" installation, the testing equipment and spare amplifier are usually omitted and five complete terminals accommodated per rack. The block schematic of a typical carrier terminal is shown in Fig. 9.

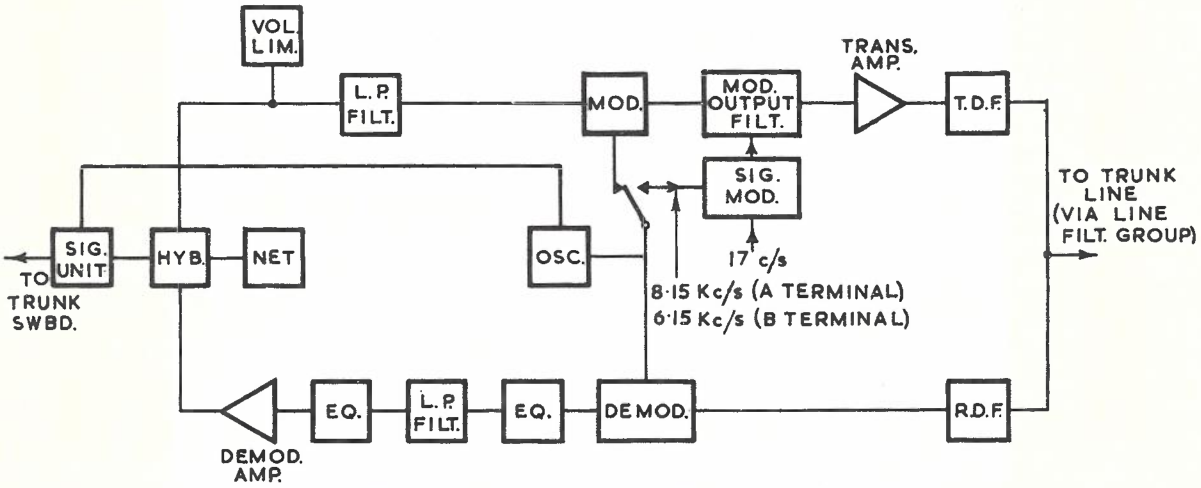


FIG. 9. BLOCK SCHEMATIC OF TYPE RY2 TERMINAL.

9.2 Frequency Allocation. A single carrier frequency of 7.15 kc/s is used. The upper sideband is transmitted in the A-B direction, and the lower sideband in the B-A direction.

9.3 Modulator and Demodulator.

(i) The modulator and demodulator are similar and are of the copper oxide rectifier type - balanced ring circuit - with potentiometer control of carrier leakage.

(ii) A single valve tuned grid oscillator using a type 6V6G valve supplies the carrier frequency to both modulator and demodulator circuits.

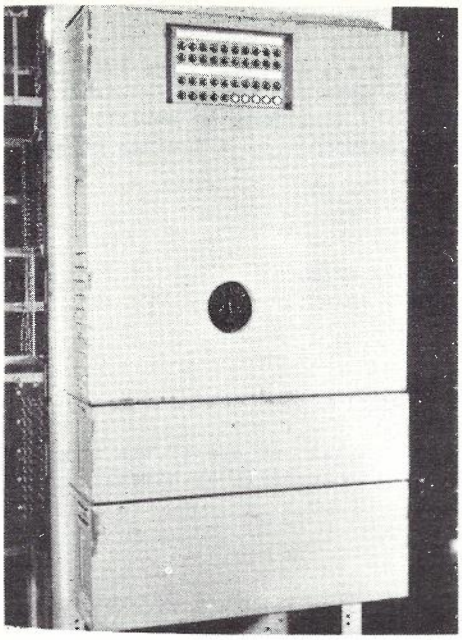
9.4 Transmitting and Receiving Amplifiers.

(i) The transmitting amplifier is a single stage negative feedback amplifier using a type 6V6G valve. The maximum power output without appreciable distortion is 500 mW and the maximum gain is 33 db. The gain is reducible by 30 db in 2 db steps by means of an input attenuator with variable straps. The amplifier follows the modulator and amplifies the sideband range of frequencies.

(ii) A single stage amplifier similar to the transmitting amplifier, follows the demodulator and performs the function of a receiving amplifier. This amplifies the V.F. range and has a maximum gain of 29 db. The gain may be reduced to 20 db in steps of 1 db by means of a switch.

(iii) The spare amplifier is provided with input and output jacks in the central jack field for convenient replacement of a faulty amplifier in one of several systems. Although it is actually a transmitting amplifier, it may be used as a temporary replacement for a demodulator amplifier, provided the receive levels are readjusted.

/ Type



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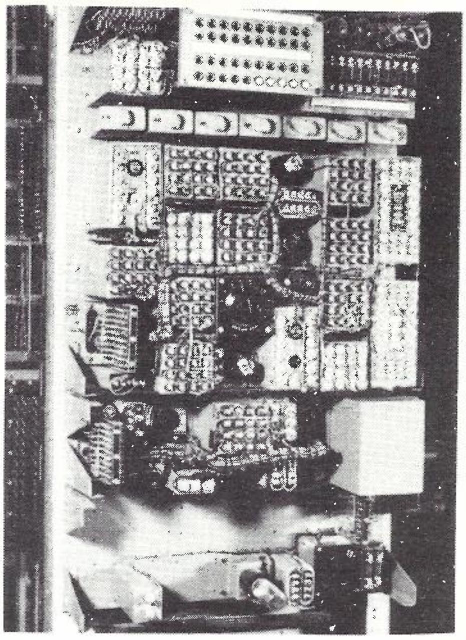


Covers Off.

TYPE RY2 CARRIER TERMINAL.

9.5 Signalling Arrangements. Signalling over the system is by the carrier-shift method, the ringing signal corresponding to a modulator input of 1,000 c/s interrupted at the frequency of the exchange ringing supply. The method by which the signal to line is produced is somewhat unusual in that the carrier supply, apart from being increased or decreased in frequency by 1,000 c/s depending whether at an A or B terminal, is removed from the modulator circuit and applied to a special signalling modulator where it is modulated with the exchange ringing supply before passing via pads to the modulator output filter.

The ringer panel incorporates a ringing receiver, using two 6V6G valves, which operates only with interrupted 1,000 c/s inputs.

9.6 Test Equipment.

(i) Test Oscillator. The Test Oscillator may be a 1,000/20 c/s oscillator, providing 1,000 c/s and 1,000/20 c/s supplies for use with the Test Panel; or alternatively, a 10-Frequency Oscillator may be equipped, enabling transmission measurements to be made at nine different frequencies in the V.F. range and providing a 7.15 kc/s source as an emergency carrier supply. A modulator unit is used with the 10-frequency oscillator to produce 1,000/20 c/s.

(ii) Test Panel. The test panel facilities are as follows -

(a) monitoring at various parts of the circuit, in conjunction with the bay jack field,
(b) testing of transmission by application of steady tone and measurement of levels (measurement range -8 dbm to +22 dbm),
(c) testing of signalling circuits, and
(d) measurement of anode and filament currents of all valves and A.C. and D.C. supply voltages.

9.7 Power Supply. The system is designed for operation from 130 volts and 24 volts D.C. supplies, or may be equipped with a power supply panel, using a 5V3G rectifier valve, for operation from 210/260 volts A.C. supply.

/ 10.

10. SOA AND SOB SYSTEMS.

10.1 The systems are made by Standard Telephones and Cables Ltd., London. The type SOA system is designed for use on short trunk lines. The type SOB system is similar to the type SOA system with the addition of an auxiliary transmitting amplifier, and is designed for use on longer lines. The block schematic of a typical carrier terminal is shown in Fig. 10.

10.2 Frequency Allocation.

A-B direction - lower sideband of 10.3 kc/s.
B-A direction - lower sideband of 6.2 kc/s.

10.3 Modulator and Demodulator.

(i) Copper oxide rectifier types are used with potentiometer control for adjustment of carrier leakage.
(ii) The modulator and demodulator oscillators are similar and are of the tuned anode type. A single 4328A valve is used in each oscillator circuit. The oscillators are mounted on a common panel.

10.4 Transmitting and Receiving Amplifiers.

(i) The transmitting amplifier is a single stage negative feedback type using a 4328A valve. Maximum gain is 30 db, controlled by input pads variable over a range of 15 db in 1 db steps. Output power is approximately 300 mW.
(ii) The auxiliary transmitting amplifier, provided on SOB systems only, is a single stage negative feedback type using a type VLS452 valve. Maximum gain is 20 db, controlled by variable pads over a range of 16 db in 1 db steps. Both transmitting amplifiers are designed to operate over the frequency range 3-10 kc/s.
(iii) The receiving amplifier is a single stage negative feedback type using a 4328A valve. Maximum gain is 35 db adjustable by strapping of input pads. A tapped input transformer provides a further 7 db variation of gain in 1 db steps. This gain control compensates for variation in the transmission equivalent of the aerial trunk line with changing weather conditions. The receiving amplifier is designed to operate over the frequency range 0.2-4 kc/s.

10.5 Signalling Arrangements. The carrier shift method of signalling is used. Incoming ring from the switchboard reduces the carrier frequency by 1,000 c/s (or 500 c/s), and the output is interrupted at a 17 c/s rate and applied to line. At the receiving end, the demodulated output is applied to a signalling receiver, which, in turn, applies local 17 c/s to the trunk switchboard.

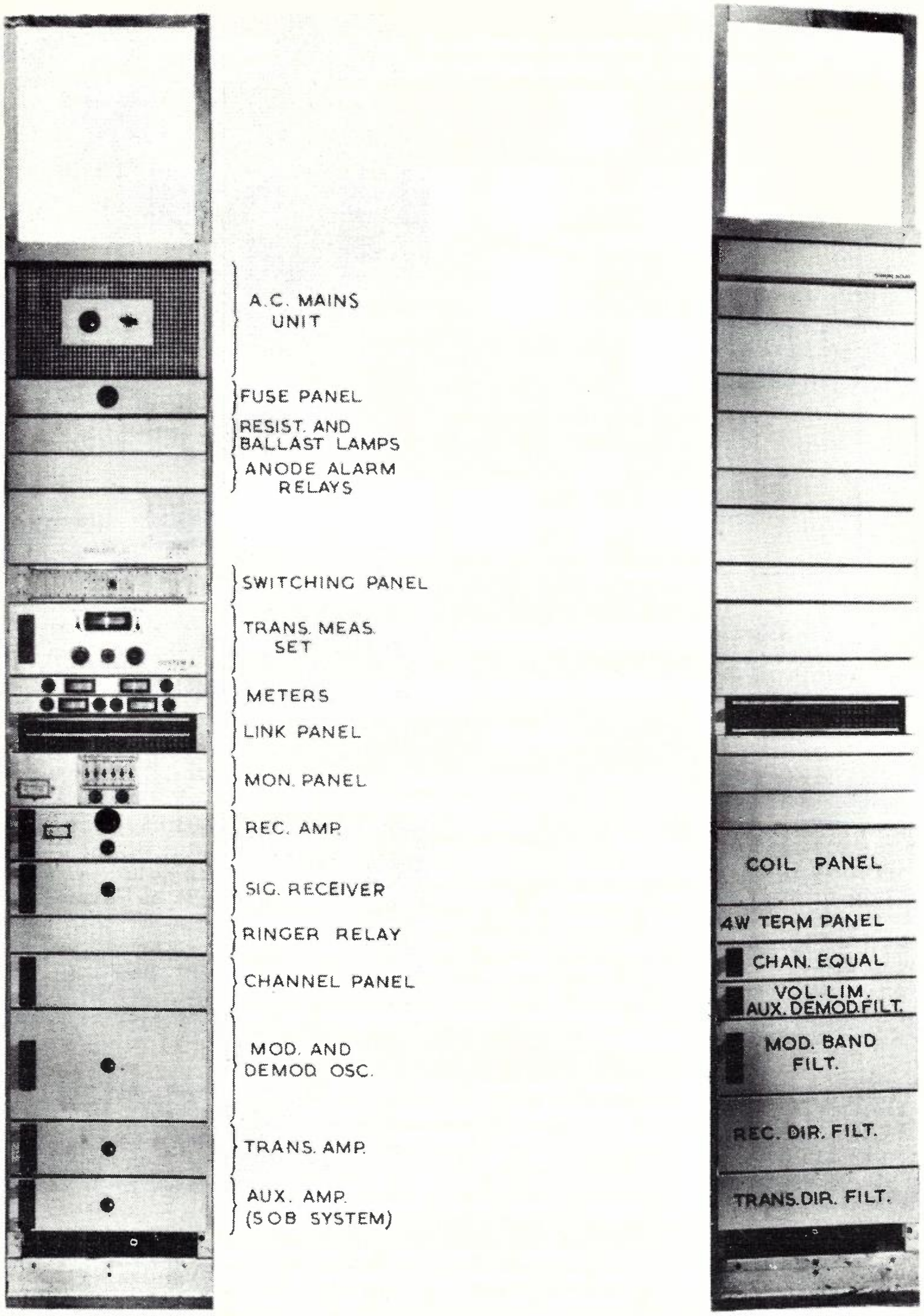
The signalling equipment is provided and mounted on the following panels -

(i) Signalling receiver panel, which amplifies and detects incoming ringing current.
(ii) Ringer relay panel, which mounts all relays associated with the ringing equipment.

10.6 Testing Equipment. The following is provided -

(i) a transmission measuring set, comprising a receiving unit for the measurement of levels from -15 dbm to +20 dbm, and a sending unit, which uses an 800 c/s oscillator to send a fixed level of either 1 mW or -4 db referred to 1 mW,
(ii) a meter panel equipped with all meters, U-link sockets, jacks and keys necessary for filament, anode and general battery supply measurements, and
(iii) a monitoring panel, complete with talking and ringing facilities.

10.7 Power Supply. The systems normally operate from 24 volts and 130 volts D.C. supplies, but, if required, a power unit is provided for operation from the A.C. mains supply.

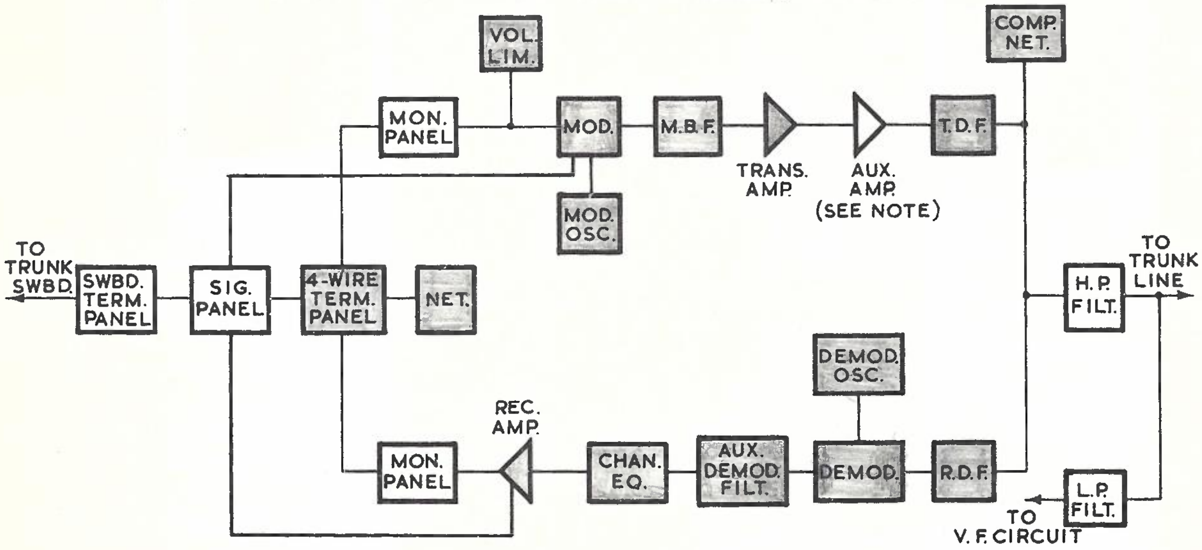


Front. Rear.

TYPE SOA AND SOB CARRIER TERMINAL.

11. DESCRIPTION OF SOA AND SOB SYSTEMS.

11.1 Circuit Operation. A block schematic diagram of the systems is shown in Fig. 10 and the front and rear views of the panel mounted equipment on page 21.



NOTE - Auxiliary Amplifier provided on SOB Terminal only.

BLOCK SCHEMATIC OF SINGLE CHANNEL CARRIER TERMINAL - SOA AND SOB SYSTEMS.

FIG. 10.

Transmitting Direction. Incoming speech currents from the trunk switchboard pass via the switchboard termination and signalling panels to the line side of the 2-wire/4-wire terminating panel. This unit connects the 2-wire speech circuit to the 4-wire carrier circuit, and is a hybrid coil arrangement. The transmit side of the 2-wire/4-wire terminating unit is connected via the monitoring panel to the modulator input. The monitoring panel permits listening, ringing and speaking tests to be carried out over the channel. A voltage limiter unit across the modulator input prevents high peak levels of speech from over-loading the transmitting and repeater amplifiers and other equipment in the circuit, and causing distortion. The carrier supply to the modulator is provided from a single valve modulator oscillator unit. The main products of modulation are the upper and lower sidebands, as the modulator is arranged to suppress the carrier frequency.

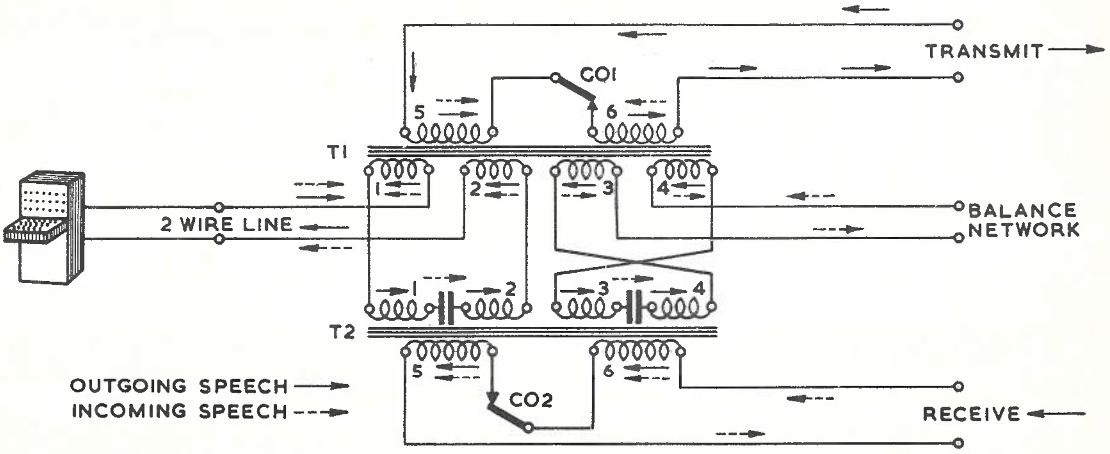
These sidebands are applied to the modulator band filter, which passes only the lower sideband and effectively suppresses the upper sideband. The lower sideband then passes to the transmitting amplifier, which raises the sideband power to a suitable level for application to line. In the SOB terminal, the output is then applied to another single stage amplifier which is of similar type but has greater power handling capacity and permits a still higher level to be transmitted to line.

After amplification, the sideband energy is applied to the transmitting directional filter, which in conjunction with the receiving directional filter, separates the transmitted sideband from the sideband received from the distant terminal. The transmitted sideband then passes via the high-pass line filter to the trunk line. The high and low-pass line filters separate the carrier frequencies from the normal voice frequencies transmitted over the same line.

/ Receiving

Receiving Direction. The incoming sideband from the line passes through the high-pass line filter to the receiving directional filter and to the demodulator. The carrier supply for the demodulator is provided by a single valve oscillator of similar design to the modulator oscillator. Included in the products of demodulation is the original speech intelligence. All the products of demodulation are applied to a low-pass filter included in the demodulator unit. This filter accepts only the V.F. product of demodulation and attenuates all other unwanted products. An auxiliary demodulator filter further suppresses the unwanted products of demodulation, and the V.F. output from this filter is passed via a channel equaliser to the receiving amplifier. This amplifier is necessary, because the speech frequencies after demodulation are at a low level and the receiving amplifier supplies the gain to raise the level to a suitable value for application to the trunk switchboard. The output of the receiving amplifier is then applied via the monitoring panel to the 2-wire/4-wire terminating panel, where the speech currents divide equally between the line and network. The speech currents on the line side pass via the switchboard termination panel to the trunk switchboard.

11.2 Four-Wire Terminating Unit. This unit performs the functions of the usual hybrid transformer. It connects the 4-wire circuit from the carrier terminal to the 2-wire switchboard termination, and is used with a balance network which simulates the impedance of the 2-wire termination. The unit comprises two separate transformers T1 and T2 as shown in Fig. 11.



NOTE - CO1 and CO2 contacts in ringer circuit. (See Fig. 19.)

FOUR-WIRE TERMINATING UNIT.

FIG. 11.

Outgoing Speech. (——►) V.F. currents from the switchboard flow in windings 1 and 2 of transformers T1 and T2. These currents produce secondary currents in windings 5 and 6 of T1 and T2. Secondary currents are also produced in windings 3 and 4 of T1 and T2, but these currents are in opposite directions and, when the coils are balanced, current does not flow in the balance network. Thus, assuming perfect balance, the energy received from the 2-wire line divides equally between the transmit and the receive circuits, the portion in the transmit side proceeding to the modulator. The energy in the receive side is dissipated in the output circuit of the receiving amplifier. The loss from the line side to transmit side, theoretically, is 3 db.

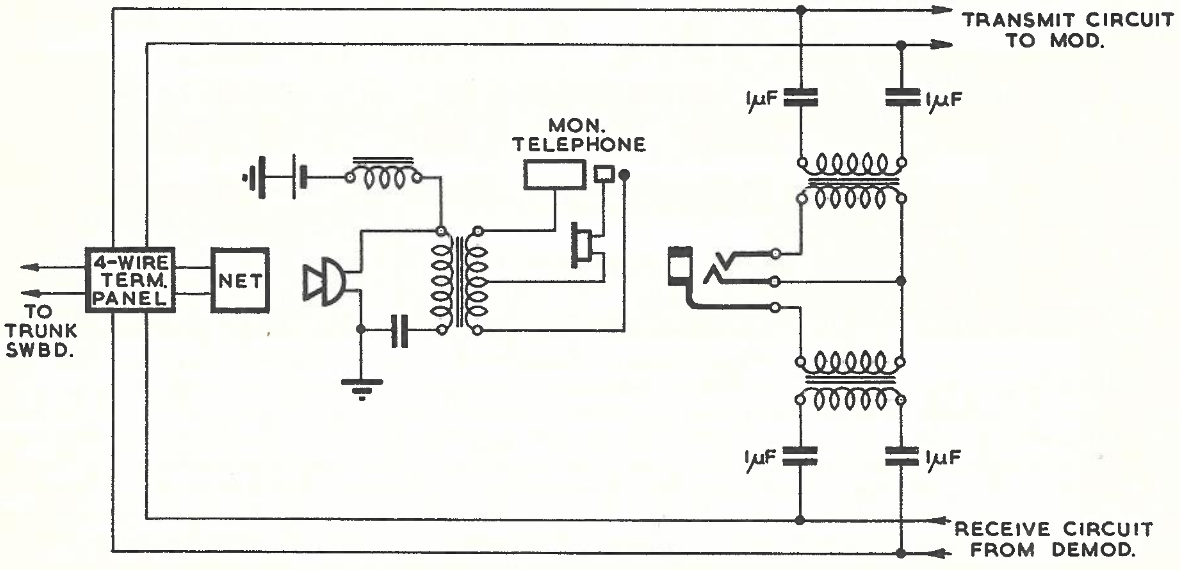
/ Incoming

Incoming Speech. (--►) Currents from the receive circuit are applied to windings 5 and 6 of T2. These currents produce equal secondary currents in windings 1 and 2, 3 and 4 of T2, which flow respectively through windings 1 and 2, 3 and 4 of T1. When the coils are balanced and the line and balance network impedances are equal, the currents in the line and balance network sides are equal. Therefore, as the currents in windings 1 and 2, 3 and 4 of T1 are in opposite directions, current does not flow in windings 5 and 6 of T1. Thus, half the energy from the receive circuit passes into the 2-wire line and half is dissipated in the balance network. The loss from receive side to line side, theoretically, is 3 db. This action produces a result identical with that of the normal hybrid transformer.

As in the case of all practical applications of the hybrid coil, it is not possible to obtain ideal coils or perfect balancing, with the result that, even when the 2-wire and network terminals are terminated in carefully matched resistors, the loss from receive to transmit terminals is not infinite, but about 60 db. Similarly, the loss from 2-wire to transmit and from receive to 2-wire is not the theoretical 3 db but is about 3.4 db. The factors which, in practice, limit the degree of balance and, therefore, the loss from receive to transmit are the terminations which are applied to the 2-wire and network sides. Since the 2-wire terminals are connected in practice to lines of various lengths and types, the impedance across these terminals varies, and the highest loss obtained in service from receive to transmit is about 40 db or less.

The connections between windings 5 and 6 of T1 and T2 and, therefore, the transmitting and receiving sides of the 4-wire terminating circuit, are opened during outgoing and incoming ringing periods by contacts of the CO relay in the ringer circuit. During outgoing ringing, these contacts prevent the passage of 17 c/s current to the modulator and, during incoming ringing prevent the transmission of 1,000 c/s ringing current to the switchboard.

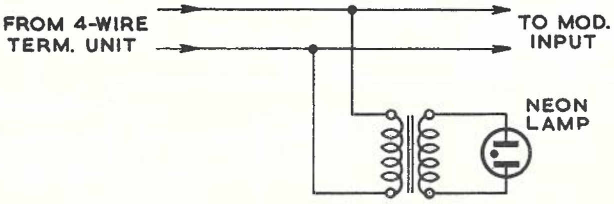
11.3 Monitoring Circuit. This circuit enables monitoring, ringing and speaking facilities to be obtained over the channel. These facilities are obtained by plugging the monitoring telephone set into the appropriate jacks on the monitoring panel. The basic arrangement of the circuit for monitoring and speaking is shown in Fig. 12.



MONITORING CIRCUIT.

FIG. 12.

11.4 Voltage Limiter. This device prevents overloading of the channel equipment, particularly the transmitting and repeater amplifiers, irrespective of the level received from the subscriber. This overloading would produce distortion. It comprises a transformer and a neon lamp as shown in Fig. 13. The primary of the transformer is connected across the 4-wire transmit circuit and the neon lamp is connected across the secondary. The transformer has a high step-up ratio.



VOLTAGE LIMITER CIRCUIT.

FIG. 13.

When the voltage during either a positive or negative half-cycle of the incoming speech level exceeds a certain predetermined value, the neon lamp flashes over, and "reflects" a low impedance into the primary winding and, therefore, a large shunt loss across the transmit circuit. At amplitudes below that at which limiting occurs, there is negligible shunt loss due to the transformer and the capacitance between the lamp electrodes. The operation of the limiter has negligible effect on intelligibility, and its action cannot be detected by the subscribers.

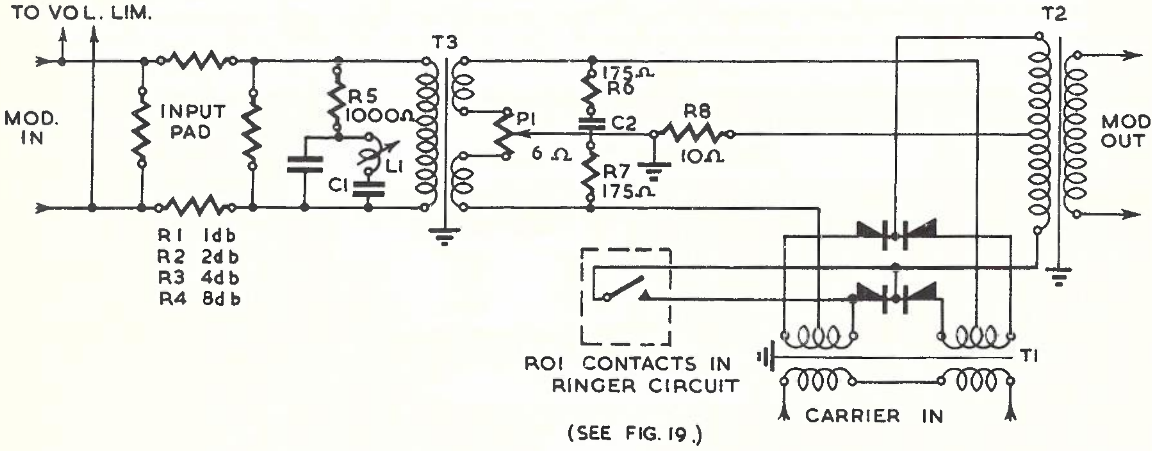
Normally, the limiter is adjusted to its maximum sensitivity and operates with a voltage on the primary winding corresponding to a power level of +3 dbm into 600 ohms. For operation on carrier telephone channels, the limiter is normally connected in circuit at a point where the level is 4 db below zero reference level. Thus, operation of the limiter occurs when a level of +7 dbm exists at the point of zero reference level in the circuit.

Since the striking of the neon depends on the instantaneous applied voltage, the neon is struck and then extinguished at each positive and negative half-cycle of a large input, with the result that the peaks are reduced, and maintained at a constant value and an excessive sinusoidal input becomes approximately a square wave. The cutting of the peaks prevents overloading of the transmitting and repeater amplifiers, whose power handling capacities depend on the maximum potentials involved. Overloading could possibly occur if the component frequencies of the square wave suffered considerable phase distortion after the limiter, but this is unlikely since such distortion occurs only at the extreme upper and lower frequencies of the range and these components are sufficiently attenuated by the band filter to prevent any appreciable increase of the amplitude of the composite wave.

Whilst the peak power is kept constant by the limiter, the R.M.S. value of the power which it allows to pass increases from that of a sine wave of given amplitude just below the limiting point, to that of a square wave of the same amplitude after limiting. This is a ratio increase in the effective R.M.S. power of two to one, that is, an increase of 3 db for the extreme condition of a square wave.

/ 11.5

11.5 Modulator. A simplified schematic circuit of the modulator is shown in Fig. 14.



MODULATOR CIRCUIT (SOA AND SOB SYSTEM).

FIG. 14.

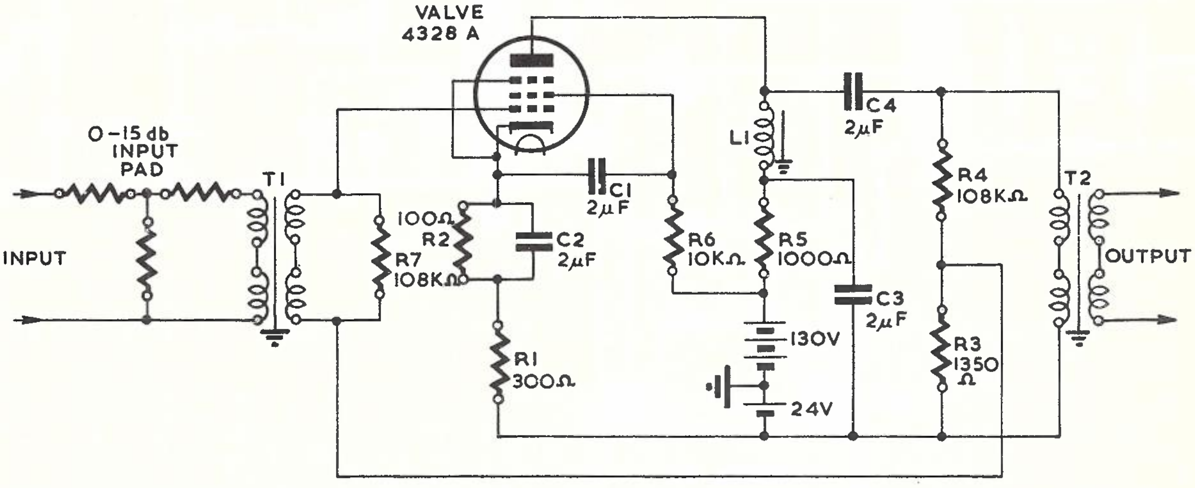
The modulator comprises input pads, an equaliser, and the modulator proper. The input pads provide losses of 1, 2, 4 and 8 db respectively, and are 600 ohms balanced resistor networks. The pads are connected in or out of circuit as required, and adjust the incoming speech level to a value that does not overload the modulator. Following the pads an equaliser consisting of R5, L1 and C1 is connected across the circuit. This equaliser compensates for the frequency distortion over the sideband, caused by the modulator band filter. In conjunction with a similar equaliser in the demodulator circuit, it ensures that the overall quality characteristic is substantially flat over the range of frequencies transmitted by the channel. The equalisers are set during manufacture and do not require subsequent adjustment.

The modulator proper consists of the V.F. input transformer T3, the carrier input transformer T1, four metal rectifiers, resistor R8, the carrier leak potentiometer P1 and the sideband output transformer T2. A resistor capacitor combination, R6, C2, R7 connected across the secondary winding of transformer T3, absorbs high frequency products of modulation which may be reflected back into the modulator from the modulator band filter or beyond. This suppressor circuit has negligible loss at voice frequencies.

The carrier frequency supply to the modulator is obtained from a valve oscillator (see paragraph 11.15) having a high degree of stability with battery and temperature variation. The modulator produces an output similar to the double balanced type described in Long Line Equipment I. Normally the carrier frequency is suppressed in the modulator. Relay contacts RO1 in the ringer circuit unbalance the modulator during signalling conditions and allow the modulator oscillator frequency to be transmitted, as described in paragraph 11.16.

11.6 Modulator Band Filter. The two sidebands produced in the modulator pass to the modulator band filter, where the upper sideband is suppressed and only the lower sideband is transmitted. Owing to the additional gain in the SOB system, it is necessary that the modulator band filter in the latter system should have a greater loss to unwanted frequencies than in the case of the SOA system. Therefore, in the SOB system, an auxiliary unit is added to the modulator band filter for this purpose. The filters consist of assemblies of dust-cored coils and mica capacitors. /11.7

11.7 Transmitting Amplifier. The lower sideband from the modulator band filter is applied to the transmitting amplifier, which is a single valve negative voltage feedback amplifier. A simplified schematic circuit of this amplifier is shown in Fig. 15.



TRANSMITTING AMPLIFIER (SOA AND SOB SYSTEMS).

FIG. 15.

The value of the input pad is set at the time of installation to give the desired output level to line. The secondary winding of T1 is terminated by resistor R7 and the high potential end connects to the control grid of the valve, which is an indirectly-heated pentode, type 4328A. The opposite end of the winding connects to the cathode via resistors R3, R1 and R2. Grid bias for the valve is derived from the D.C. voltage drop across R1 and R2 in the cathode circuit. The A.C. output voltage is applied across R4 and R3 in series and the voltage developed across the feedback resistor R3 is applied as a negative feedback voltage to the grid of the valve. R5 and C3 provide an anode decoupling circuit. R6 is a screen-grid voltage dropping resistor and C1 is the screen by-pass capacitor. The output of the valve is choke-capacity coupled by inductor L1 and capacitor C4 to the primary winding of the output transformer T2.

11.8 Auxiliary Transmitting Amplifier. In the SOB system, the output of the transmitting amplifier is applied to a auxiliary transmitting amplifier with a single pentode valve type VLS 452 using negative feedback and capable of producing a larger output. A input pad which is preset at the time of installation is provided also for this amplifier.

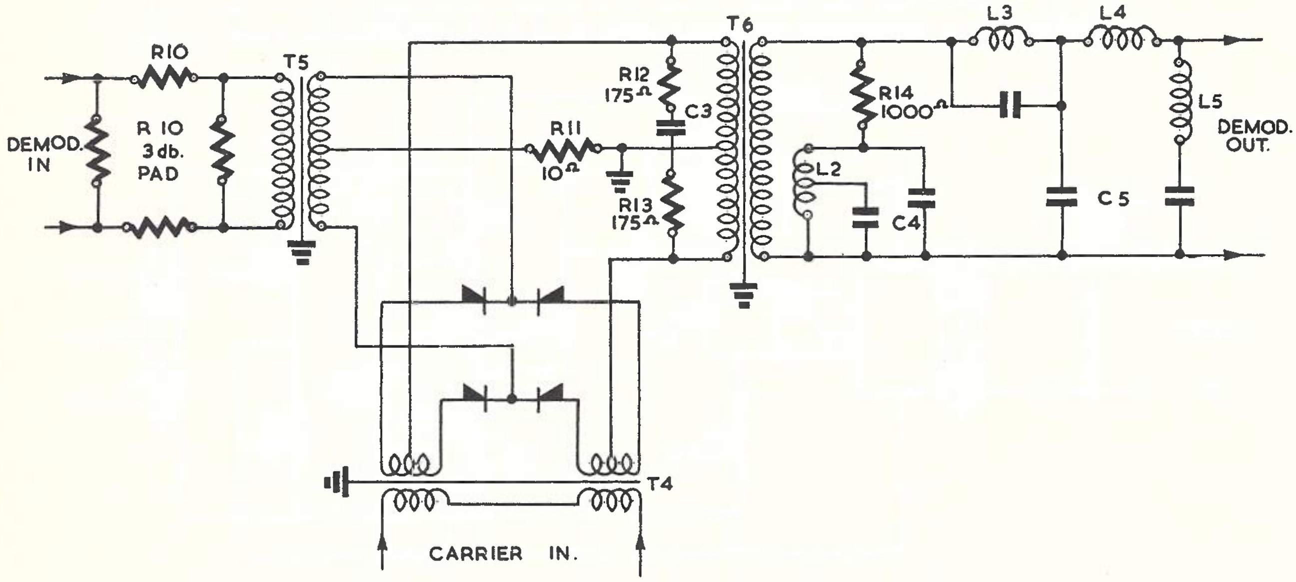
11.9 Transmitting Directional Filter. The output from the transmitting amplifier(s) is applied to the transmitting directional filter, which separates the transmitted sideband from the sideband received from the distant terminal. In the SOB system, the transmitting directional filter at the B terminal has an auxiliary unit added, giving it a greater attenuation in the block range. The transmitted sideband then passes through the high-pass line filter and so to line.

11.10 Receiving Directional Filter. Sideband currents from the line pass through the high-pass line filter and are selected by the receiving directional filter. In the SOB system, the receiving directional filter at the A terminal has an auxiliary unit added, giving it a greater attenuation in the block range. The carrier sideband then passes to the demodulator.

11.11 Compensating Network. This unit is connected across the line side of the directional filters to make the terminal impedance equal to that of the line over the frequency ranges corresponding to the two directions of transmission.

/ 11.12

11.12 Demodulator. A simplified schematic circuit of the demodulator is shown in Fig. 16.



DEMODULATOR CIRCUIT. (SOA AND SOB SYSTEMS).

FIG. 16.

The circuit is similar to the modulator but differs in that -

(i) a potentiometer is not provided for adjustment of the carrier leak (P1 of modulator),
(ii) the equalising network is connected across the secondary of the output transformer instead of the primary of the input transformer,
(iii) a low-pass filter is connected across the V.F. output from the demodulator, and
(iv) the demodulator is not unbalanced during signalling conditions.

The demodulator consists of the demodulator proper, the demodulator equaliser, and the demodulator low-pass filter.

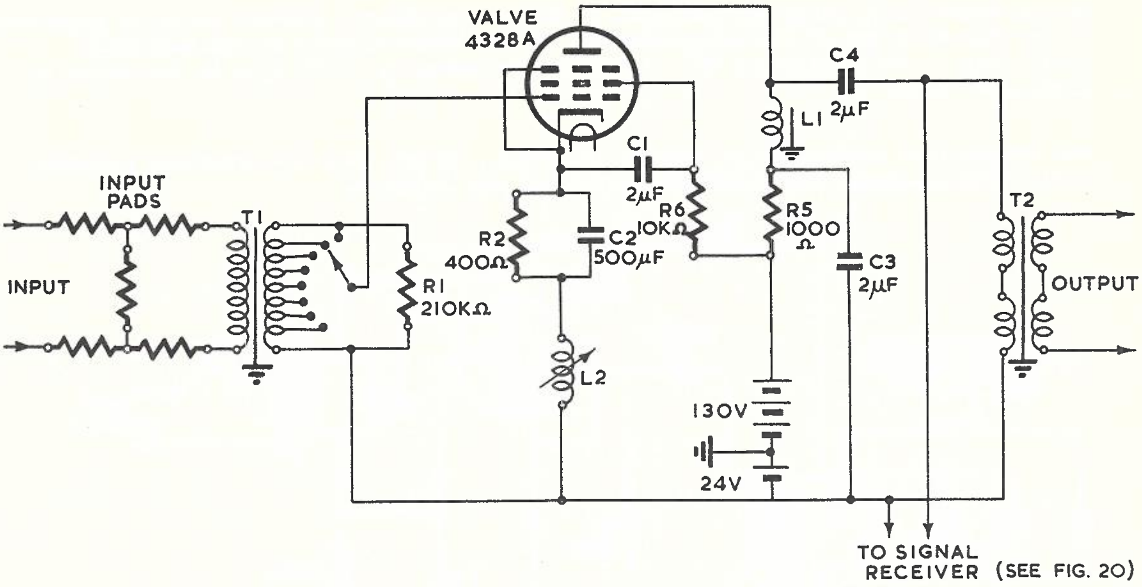
The demodulator proper consists of a carrier input transformer T4, the sideband input transformer T5, four rectifier elements, the V.F. output transformer T6, and resistor R11. A resistor-capacitor combination R12, C3 and R13 connected across the primary winding of transformer T6, absorbs high frequency products of demodulation, and prevents reflection from the demodulator output low-pass filter. An equaliser consisting of R14, L2 and C4 is connected across the secondary winding of transformer T6. This equaliser serves a similar function to the modulator input equaliser. A 3.1 kc/s low-pass filter consisting of inductors L3, L4 and L5 and capacitors C5 is connected across the V.F. output of the demodulator. This filter prevents carrier leak and high-frequency products of demodulation from passing into the V.F. circuit.

The demodulator produces an output similar to the "double balanced" type described in Long Line Equipment I.

11.13 Auxiliary Low-pass Filter. The V.F. output from the demodulator passes through this filter, which, in conjunction with the filter in the demodulator circuit, prevents the unwanted products of demodulation from entering the receiving amplifier.

/ 11.14

11.14 Receiving Demodulator Amplifier. This amplifier raises the low level V.F. output from the demodulator to the desired level for application to the switchboard. A simplified schematic circuit is shown in Fig. 17.



RECEIVING AMPLIFIER (SOA AND SOB SYSTEMS).

FIG. 17.

The receiving demodulator amplifier is a single stage amplifier with negative feedback and circuit equalisation. The gain is set by the preset input pads. A further pad of 6 db (R4 not shown in Fig. 17) may be switched in or out of the circuit by U-link connections. The tappings of the secondary of the input transformer T1 are connected to U-link sockets arranged around a centre socket. A U-link is connected from the centre socket to the tapping giving the required overall equivalent for the channel. This U-link, in conjunction with the 6 db pad, provides for day-to-day adjustment of gain. The amount of feedback and the degree of equalisation is controlled by the inductor L2. The working tapping for this inductor is chosen at the time of installation of the system. Grid bias for the valve is derived from the D.C. voltage drop across the resistor R2 in the cathode circuit. C2 is a by-pass capacitor across R2. Capacitor C3 and resistor R5 provide an anode decoupling circuit. The output from the receiving amplifier passes via the monitoring coil panel to the 4-wire terminating unit (hybrid) and thence to the switchboard. The signalling receiver described in paragraph 11.17 is connected across the amplifier output.

11.15 Modulator and Demodulator Oscillator. A schematic circuit of this unit is shown in Fig. 18.

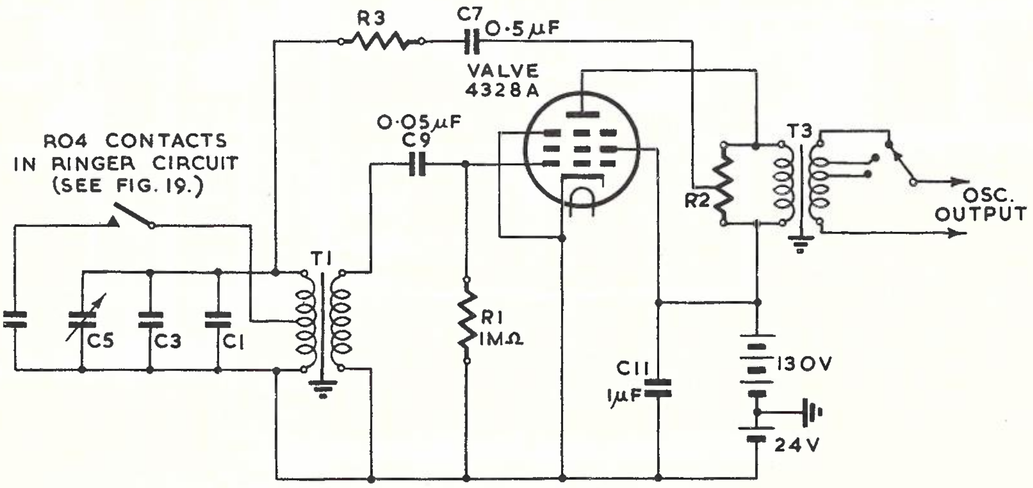
The oscillator is a tuned anode type. The amount of energy injected into the oscillatory circuit via C7 and R3 is adjusted by the setting of the resistor network R2. The capacitor C7 blocks the path for D.C. from the anode battery. One winding of the transformer T1 is tuned by capacitors C1, C3 and C5 to the carrier frequency to be generated, and the oscillations of this frequency are applied to the grid circuit of the valve through the transformer T1. C1 is fixed and is the main tuning capacitor. C3 gives the approximate frequency required, and the final adjustment is made with the variable air capacitor C5, which is provided with a locking device, so that it cannot be accidentally altered when set. Grid leak bias for the

/ valve

valve is obtained from the grid current flowing through resistor R1 in conjunction with the grid capacitor C9. The output may be varied by means of tappings on the output winding of the transformer T3.

During signalling, relay contacts RO4 in the ringer circuit connect an extra capacitance across the windings of the transformer T1 in the tuned circuit of the modulator oscillator. This decreases the oscillator frequency by 1,000 c/s, as described in paragraph 11.16.

The demodulator oscillator is similar in design, except that the frequency changing capacitors necessary for outgoing ringing are not required.



MODULATOR AND DEMODULATOR OSCILLATOR (SOA AND SOB SYSTEMS).

FIG. 18.

11.16 The Ringing Circuit. The ringing equipment consists of two panels - a Signalling Receiver Panel, which amplifies and rectifies incoming ringing current, and a Relay Panel, which mounts all the relays associated with the ringing equipment. Fig. 19 shows a simplified circuit of the general arrangement of the ringing circuit. In the normal working condition with no incoming or outgoing ringing, only relay D is held operated, relay B being energised over one winding only.

Outgoing Ringing. The 17 c/s ringing current from the switchboard operates relay F via contacts RI3 and RI4. Contact F1 operates relays RO and CO. (When D.C. signalling from the switchboard is used for outgoing ringing, an earth is applied to these relays when a ringing key is operated.) Contacts CO1 and CO2 open-circuit both the transmitting and receiving sides of the 4-wire terminating set and prevent the passage of 17 c/s current to the modulator.

The operation of RO contacts performs the following functions -

RO1 unbalances the modulator circuit and allows the modulator oscillator frequency to be transmitted. (See Fig. 14) Normally the carrier frequency is suppressed in the modulator.

RO2 operates relay I which vibrates at 17 c/s.

RO3 connects the vibrating contacts of relay I across the modulator output, thus interrupting the transmitted carrier at 17 times per second. The resistance in parallel with contacts I1 is adjusted to give the desired output of ringing level.

/ Fig. 19

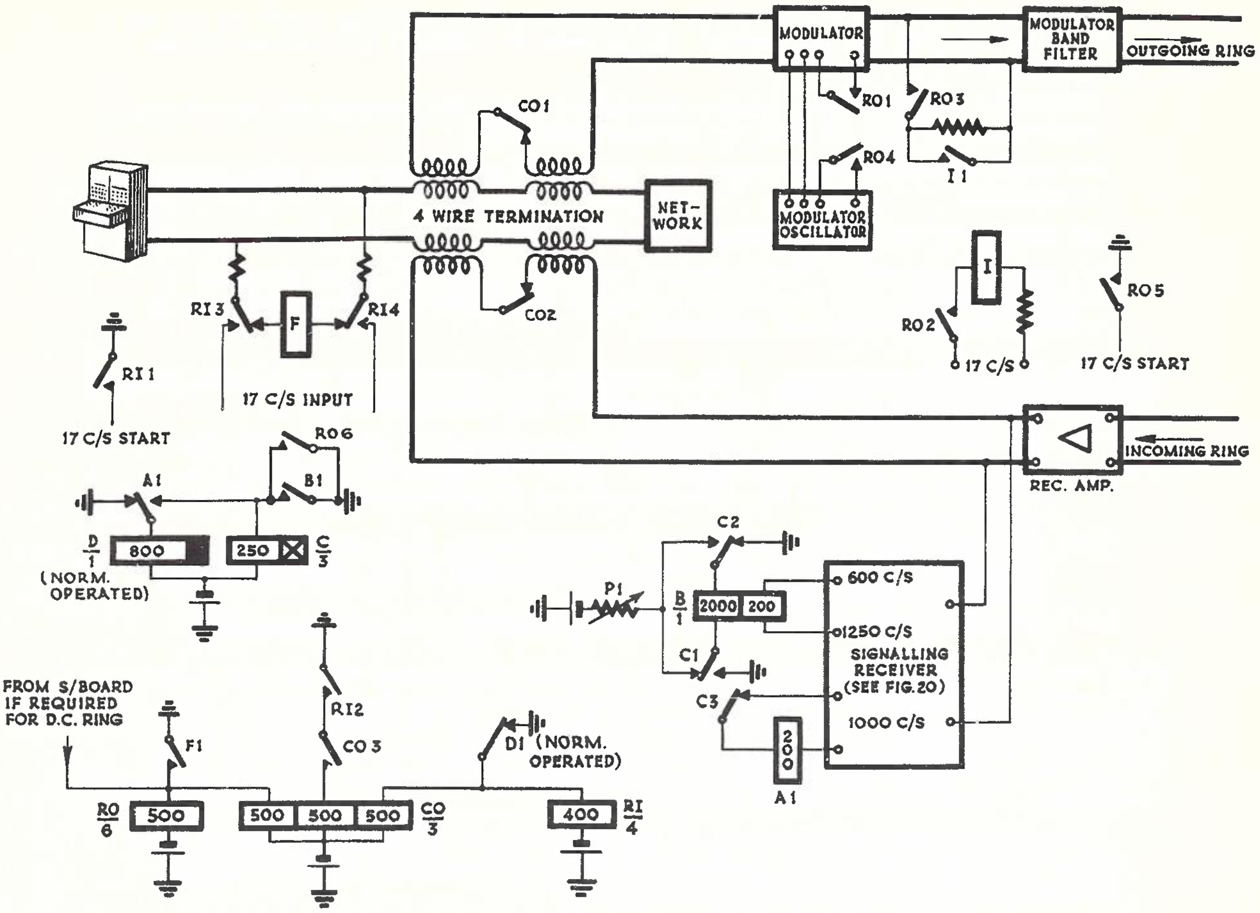


FIG. 19. RINGING CIRCUIT (SOA AND SOB SYSTEMS).

RO4 increases the capacitance of the tuned circuit in the modulator oscillator (see Fig. 18), and lowers the carrier frequency by 1,000 c/s. This change moves the carrier frequency to a point within the normally transmitted sideband 1,000 c/s from the nominal carrier frequency of the channel.

RO5 connects earth to the start wire of the 17 c/s ringer when this facility is required.

RO6 operates relay C, and C3 opens relay A, so that any incoming ringing current is made ineffective.

Thus, in outgoing ringing when 17 c/s is sent into the system from the switchboard, relays F, CO, RO and I are operated and these cause a specified level of carrier current, reduced in frequency by 1,000 c/s and interrupted at 17 c/s, to be transmitted to the distant terminal. In effect, this corresponds to the application at the switchboard of a 1,000 c/s tone interrupted at 17 c/s, and is consequently demodulated as such at the receiving terminal.

Incoming Ringing. At the distant terminal, the incoming ringing signal is demodulated to produce a 1,000 c/s current interrupted at 17 c/s, which is amplified by the receiving amplifier and further amplified and rectified by the signalling receiver. The rectified 1,000/17 c/s current operates a relay train which applies the local 17 c/s supply to the switchboard.

The rectified 1,000/17 c/s current operates relay A via contact C3. Contact A1 opens the normally operated relay D which releases after a time delay period of about 200 milliseconds. Contact D1 restores and operates relays CO and RI. Contacts of these relays perform the following functions -

/ CO1

CO1 and CO2 open-circuit both the transmitting and receiving sides of the 4-wire terminating set and prevent the passage of 1,000/17 c/s current to the switchboard.

CO3 closes a circuit for another winding of relay CO, locking the latter via contact RI2 so that CO will not release before RI.

RI1 connects earth to the start wire of the 17 c/s ringer when this facility is required.

RI2 completes the locking circuit for relay CO.

RI3 and RI4 disconnect the winding of the 17 c/s relay F which responds to outgoing ringing, and connect the local 17 c/s supply to the switchboard to operate the normal calling equipment.

Immunity from False Operation. The conditions for operation of the 1,000 c/s relay train and application of local 17 c/s supply to the switchboard are -

(i) The input power to the signalling receiver must be mainly 1,000 c/s current for relay A to operate. When the proportion of 1,000 c/s current to current of other frequencies is unfavourable, the relay fails to operate.
(ii) The signalling frequency must be maintained for more than 200 milliseconds. A slow release relay D is included in the 1,000 c/s relay train for this purpose.
(iii) Certain frequencies commonly present in speech must not be present.

When the input to the signalling receiver contains frequencies of 600 and 1,250 c/s at a level comparable with the normal ringing signal, relay B operates. The sensitivity of relay B to these currents is increased by the provision of an additional coil carrying an aiding bias current supplied from the 24 volt relay battery via contacts C1 and C2 and the potentiometer P1 which is adjusted for correct operation. Contact B1 operates relay C.

C1 and C2 reverse the direction of the bias current through the winding of relay B, so that the relay quickly releases when the level of the spurious signals falls below a pre-determined level.

C3 opens the circuit to relay A to prevent its operation. Should relay A have been instantaneously operated; relay D is prevented from releasing because of the earth supplied via operated contacts B1.

Thus, the effect of any speech at signalling frequency is nullified before false signalling is produced, and relay B chatters or holds up so long as 600 or 1,250 c/s components are present at an appreciable level.

11.17 Signalling Receiver. The signalling receiver used in conjunction with the ringing circuit is shown in Fig. 20.

The circuit comprises a single stage of amplification followed by three output circuits tuned to 1,000, 600 and 1,250 c/s respectively. The 1,000 c/s output is applied to a full-wave bridge rectifier circuit. The 600 and 1,250 c/s outputs are combined and applied to another full-wave bridge rectifier circuit.

Circuit Description. The signalling receiver is connected across the output of the receiving amplifier as shown in Fig. 19 and is of high impedance input so that it does not produce a shunt loss across the normal V.F. circuit. The input impedance is about 40,000 ohms. The preset potentiometer adjusts the level of the demodulated incoming 1,000/17 c/s ringing signal. A 6 db pad in the input (R3 and R4 not shown in Fig. 20) is normally plugged out but is used for testing purposes. When the applied signal peak voltage on the valve exceeds the D.C. bias due to the voltage drop across the grid bias resistor R2, grid current flows and the grid-cathode impedance is reduced. R5 prevents this low impedance from reducing the high input impedance of the receiver. This grid current flows in pulses only during part of the positive half-cycle of the input signal, and develops a grid leak bias voltage across R1C1 which is added in series with the normal bias voltage. The effect of this is -

/ (i)

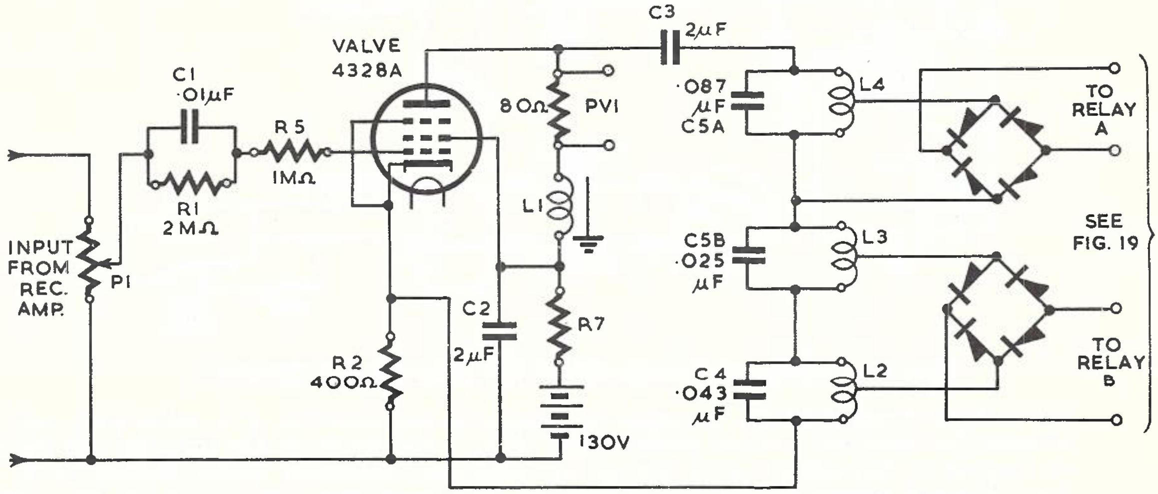
(i) to reduce the gain of the amplifier by moving the working point further down the anode current/grid volts curve, and

(ii) to minimise the harmonic distortion due to grid circuit rectification of the input wave.

The output from the valve is choke-capacity coupled by L1 and C3 to the three tuned circuits.

The first circuit is sharply tuned to 1,000 c/s and accepts the incoming ringing signals. The output from the 1,000 c/s circuit is rectified and applied to relay A on the ringer relay panel. This operates the relay train which applies 17 c/s to the switchboard as described for incoming ringing in paragraph 11.16.

The circuits tuned to 600 and 1,250 c/s act as guard circuits to prevent operation of the ringer during conversation on the channel. When frequencies of this order are present in the demodulated signal at a level comparable with the normal ringing signal, the rectified output from the second rectifier circuit operates the guard relay B on the ringer relay panel. This prevents application of ringing current to the switchboard as described in paragraph 11.16



NOTE:- C5A AND L4 TUNED TO 1000 c/s
C5B AND L3 TUNED TO 600 c/s
C4 AND L2 TUNED TO 1250 c/s

FIG. 20. SIGNALLING RECEIVER (SOA AND SOB SYSTEMS).

11.18 Testing Facilities. Meters are provided in the equipment for reading supply voltages, anode voltages, and anode and filament currents. A suitable resistor is provided in each anode circuit so that, with normal anode current flowing, a drop of 0.5 volt occurs across the resistor. The meter for checking the anode currents is an 0-1 volt range voltmeter calibrated as an anode current indicator. The centre of the scale is marked with a red line indicating normal current - to the left is marked 20 per cent. and 50 per cent. low, and to the right is marked 20 per cent. and 50 per cent. high. A typical connection for this purpose is shown at PV1 in Fig. 20.

11.19 Transmission Measuring Set. Transmission tests at the terminal station are made with a Transmission Measuring Set provided as part of the equipment. This unit includes two distinct circuits -

(i) an 800 c/s oscillator and associated pads, and

(ii) a rectifier type Loss and Level Meter with attenuation pads.

/ The

The sending unit can send a fixed level of 1 mW (or -4 db referred to 1 mW) from the 800 c/s oscillator. The measuring unit is of high impedance when switched for measuring levels, or it may be switched to present a 600 ohm termination to the circuit being measured. Losses and levels from -15 db to +20 db (referred to 1 mW into 600 ohms) may be measured.

The general method of testing is to send a fixed level at a suitable point in the transmission path of the carrier channel, and to measure the level at successive points in the transmission path by bridging the high impedance Transmission Measuring Set receiving unit across these points. The simplified circuit of the set is given in Fig. 21.

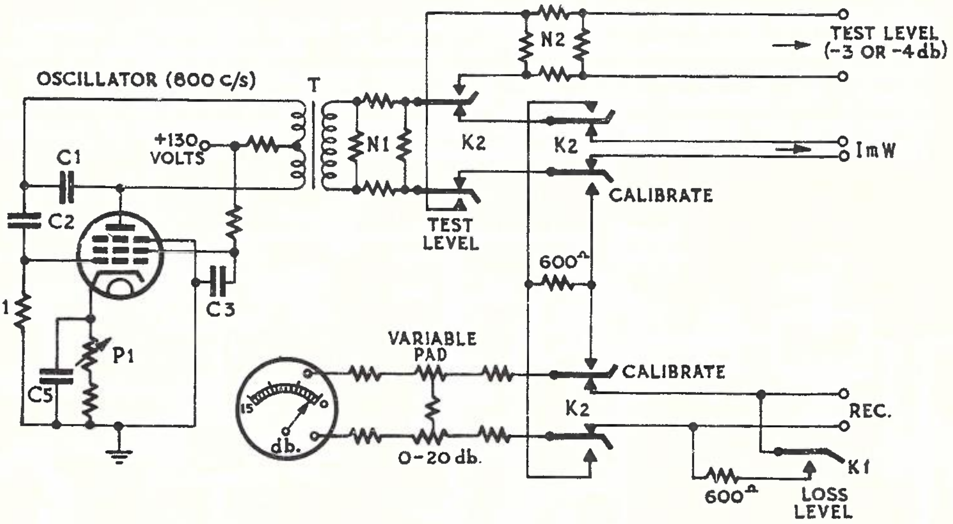


FIG. 21. TRANSMISSION MEASURING SET (SOA AND SOB SYSTEMS).

The sending circuit of the transmission measuring set consists of a valve oscillator, attenuation pads and a three position key (K2). The anode of the pentode 328A valve is coupled to the control grid through two windings (connected series aiding) of a three winding transformer T, and through the grid-leak bias combination C2, R1. The two windings providing the feedback are tuned by the capacitor C1 to a frequency of 800 c/s ±2 per cent. The anode supply passes through the mid-point of these two windings from which an A.C. path to the cathode is provided by the capacitors C3 and C5, the latter by-passing the grid bias resistance inserted between the cathode and control grid terminals. (The grid bias resistance is made up of a continuously variable potentiometer, used to adjust the oscillator output to its standard value, and three resistors. The total value of the three resistors can be adjusted by strapping to allow for difference between valves. Thus, all possible variations in output due to their differences are brought within the range adjustable by P1 (± 1 db) with further allowance for the permissible variation of anode voltage.) A step-down action is provided from the oscillating circuit to the output winding of the transformer to an attenuation pad N1 from which the oscillator, when its output is calibrated, sends zero level (1 mW into 600 ohms).

The three positions of the key K2 provide the following connections -

(i) normal position, when 1 mW is sent to line,
(ii) operated to test level position when a pad with either 3 or 4 db loss is connected across the oscillator output. The choice of 3 or 4 db pads is made on installation,
(iii) operated to the Calibrate position (2 spring-sets operate). In this position, the output of N1 is connected directly to the receive circuit, and the Receive sockets are disconnected from the receive circuit. A 600 ohm termination is also connected across the receive circuit. / The

The receiving circuit of the transmission measuring set is a simple level measuring set consisting of a direct reading rectifier meter (having shaped poles to give a more even scale), and graduated in steps of 0.5 db from 0 to -10 db and in steps of 1 db from -10 to -15 db. Between this meter and the receive sockets is a variable pad controlled by a switch, which introduces losses in steps equivalent to 5 db. This extends the range of measurements to +20 db. When the key K2 is operated to the calibrate position, measurements cannot be made on external circuits, but with K2 in either the 1 mW or the test level position, the attenuation pad is connected to the receive terminals. The key K1 (designated loss level) enables a 600 ohm resistance to be bridged across the receive terminals when it is in the loss position. This key is provided in case it is desired to terminate a 600 ohm line with the set.

Calibration Circuit. This section of the circuit provides a means of checking the output of the oscillator by operating key K2 to the calibrate position. In this position, the output of N1 is switched across the input to the variable pad, and the send and receive sockets are disconnected from the rest of the circuit. This enables the 1 mW output to be measured directly and corrected by means of the variable potentiometer in the oscillator circuit.

11.20 Testing Points. Testing points in the form of U-links and sockets are provided at the input and output of the various panels. In the normal condition of the circuit the U-link is inserted in the socket. For breaking the connection or for point-to-point testing, the U-links are removed. Level measurements across a pair of U-links are made without removing them by means of sockets contained in the U-links. Diagrams of U-links and a socket are shown in Fig. 22.

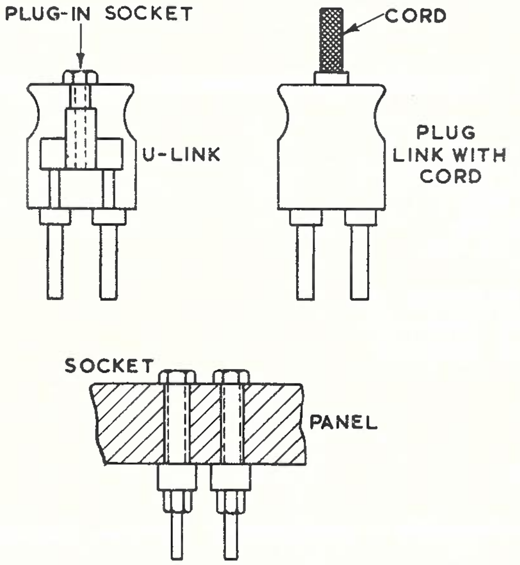


FIG. 22. U-LINKS AND SOCKET.

11.21 Alarms. The usual power failure alarms are provided. A relay in the anode voltage lead of each valve circuit is held operated by the current flowing through it. When the anode current fails, the release of the relay operates an alarm buzzer calling attention to the failure.

11.22 Mains Unit. When the terminal operates from the A.C. mains, a unit is provided which gives the following -

(i) a rectifier with well smoothed 150 volt output for the anode supply,

(ii) a rectifier with partially smoothed 24 volt output for relay operation,

(iii) an A.C. 24 volt output for the valve heaters.

Selenium dry plate rectifiers are used in the bridge connection. Alarm fuses in each of the supply circuits, on operation, cause alarm lamps to light. Alarm bells are not provided in these circuits but anode filament supply failures operate the anode current fail alarms in the system, and the failure of the relay supply operates a no volt alarm in the relay panel of the system.

/ 12.

12. TEST QUESTIONS.

1. Assuming a V.F. band of 300-2,600 c/s, tabulate the sideband frequencies transmitted for each of the systems described in this Paper.

2. A single channel carrier telephone system operates between terminals A and B. It is found that speech can be transmitted over the physical circuit but is not possible in the A-B direction over the carrier channel. Draw a block schematic circuit of the system, and, assuming the fault is at terminal B, list the units of equipment shown in your circuit which might be faulty.

3. Draw a block schematic circuit of the SOA or SOB single channel carrier telephone terminal. State the function of each item of equipment.

4. Explain the operation of a typical 4-wire terminating unit.

5. State the function and explain the operation of a typical voltage limiter.

6. Describe the "carrier shift" method of signalling used in a typical single channel carrier telephone system.

13. REFERENCES.

Transmission Engineering Instructions. The following Instructions refer to Single Channel Carrier Telephone Terminals -

Long Line Equipment C01121 - Type CF1.
Long Line Equipment C01125 - Types D1, DA1.
Long Line Equipment C01131 - Types SOA, SOB.
Long Line Equipment C01141 - Types SA, SB, SK.
Long Line Equipment C01151 - Type AFA.
Long Line Equipment C01161 - Types F, FA (Issue 1).
Long Line Equipment C01162 - Types F, FA (Issue 2).
Long Line Equipment C01163 - Types F, FA (Issue 3).
Long Line Equipment C01171 - Type H1.
Long Line Equipment C01181 - Type RY2.

Telecommunication Journal of Australia.

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Drawing No. CN670 - Frequency Allocations - Carrier Systems in Australia.

END OF PAPER.

COMMONWEALTH OF AUSTRALIA.

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Postmaster-General's Department,
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COURSE OF TECHNICAL INSTRUCTION.

LONG LINE EQUIPMENT II.

THREE CHANNEL CARRIER TELEPHONE SYSTEMS.

CONTENTS.

1. INTRODUCTION.

1.1 The 3-channel open wire carrier telephone system is at present widely used in the Commonwealth for the provision of long distance telephone circuits over aerial trunk lines. In the case of the main interstate trunk routes, however, development is being catered for by the application of the type J open wire 12-channel carrier telephone system. The frequency allocation of the type J system was influenced by the existence of large numbers of 3-channel systems, and is such that it can be placed in operation without affecting the operation of a 3-channel system over the same pair of wires. The introduction of the type J 12-channel system does not mean that 3-channel systems are to be superseded. Three-channel systems will continue to play a major part in trunk line development for many years. Three-channel systems may, in time, be superseded by multi-channel cable carrier systems on the more important main routes, but, at that stage, will be utilised on important intrastate routes.

2. FREQUENCY ALLOCATION OF 3-CHANNEL SYSTEMS.

2.1 Many different types of 3-channel systems are at present in use, and these are classified into groups which differ in their frequency allocation, as shown in Fig. 1. The carrier frequencies for each channel are shown by the vertical lines, and the transmitted sidebands are indicated by the horizontal lines at right angles to the appropriate carrier frequency.

Three channel systems operate over 2-wire circuits, and transmit a separate group of frequencies in each direction of transmission. The group of sideband frequencies from about 6-16 kc/s is transmitted in the A-B direction, and the group from 18-30 kc/s in the B-A direction. Even though the actual channel frequencies vary with different types of systems, the order of channels is the same. On all modern 3-channel systems the order of channels (in ascending frequency) is -

A-B direction : 3-2-1
B-A direction : 2-1-3

Thus channel 2 is the mid-frequency channel in the A-B direction, but the low-frequency channel from B-A.

The differences in the frequency allocations are very important from the point of view of crosstalk minimisation, particularly in the higher frequency (B-A) direction of transmission. Where several carrier systems are operated simultaneously over the same pole route, crosstalk between systems becomes an important consideration. In general, crosstalk increases as the transmitted power increases and as the frequency increases. Thus, lines which are suitable as regards crosstalk at voice frequencies are not satisfactory for the higher frequency range of 3-channel systems. Crosstalk is reduced by transposing the pairs of a trunk route, but without making major alterations to an existing route the effects of transpositions are satisfactory up to about 17 kc/s only.

To further reduce the effects of crosstalk, systems designed by the one manufacturer are usually supplied in a number of types, identical in physical and electrical characteristics, but differing in the carrier and sideband frequencies used. This enables the sideband frequencies to be "staggered" and/or "inverted" with respect to one another, and, as a result, the effects of crosstalk are greatly reduced.

2.2 "Staggering" of Sideband Frequencies. When the sideband ranges of two parallel 3-channel systems on a route are staggered in the frequency spectrum with respect to one another, the maximum speech energy of each channel of one system, which occurs about the midpoint of the transmitted sideband, lies largely outside the sideband range of the other system, and vice versa. As a result, any crosstalk between two such systems on the same pole route is considerably reduced below that which would occur between two systems of identical frequency allocation.

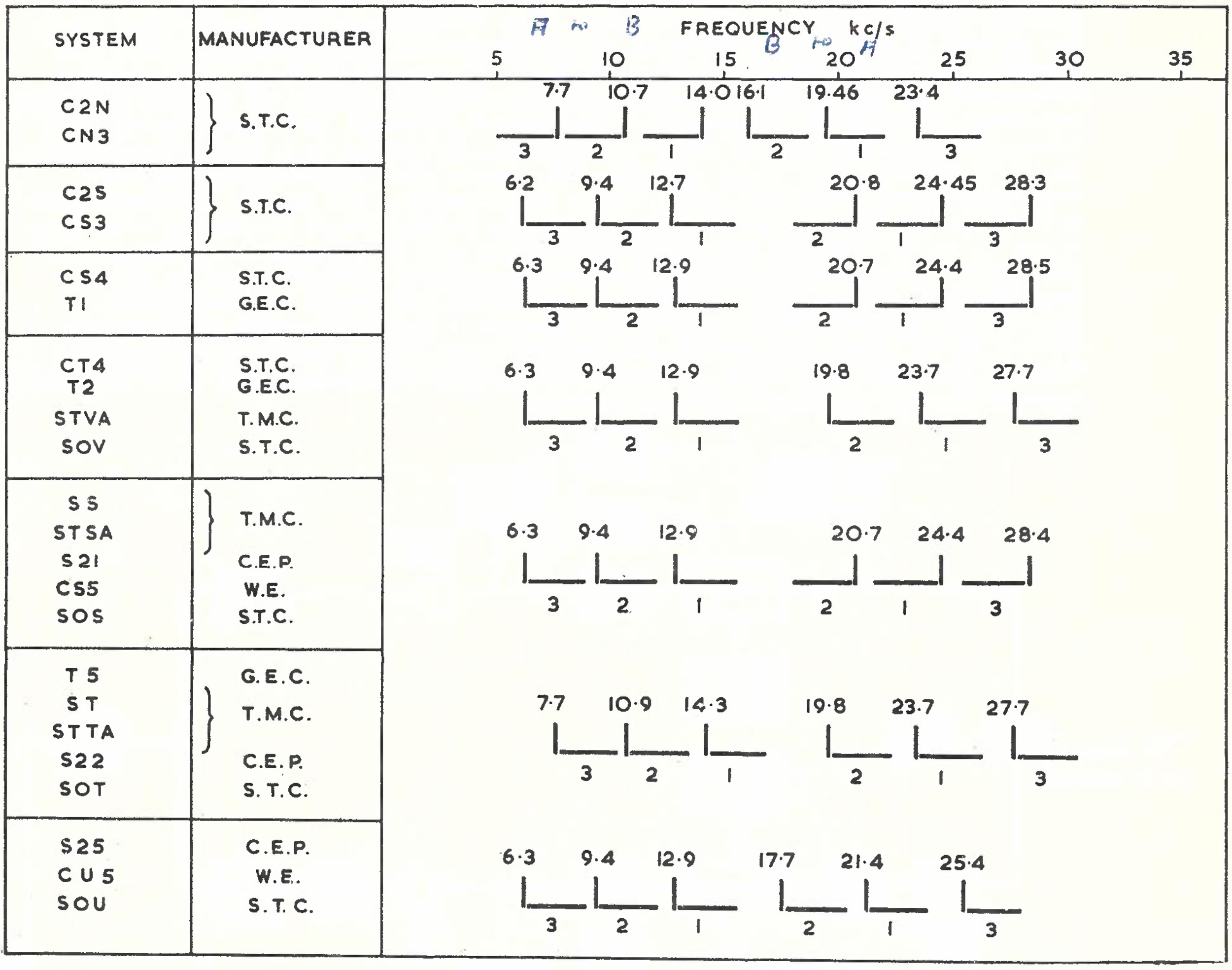
This feature is shown in the frequency allocations of the SOS and SOT systems for both directions of transmission. As an example, consider the B-A direction. Channel 3 of the SOS system has a carrier frequency of 28.4 kc/s and the maximum power of this channel occurs about 27.1 kc/s. This frequency falls between the sideband ranges of channels 1 and 3 of the SOT systems which are 24.0-26.3 kc/s and 28-30.3 kc/s respectively. Similarly, in channel 3 of the SOT system, the maximum power occurs about 29 kc/s which is outside the sideband range of channel 3 of the SOS system.

2.3 "Inversion" of Sideband Frequencies. This feature is shown in the frequency allocations of the CS5 and CU5 systems for the B-A direction of transmission. In this case, the same sideband range of frequencies is transmitted to line for both systems, but in the CS5 system, the frequencies are the lower sidebands of the carrier frequencies, and in the CU5 system, they are the upper sidebands of the carrier frequencies. Any crosstalk which occurs from a channel in one system to the corresponding channel in the other system, is inverted and, after demodulation, the crosstalk is unintelligible. This is of benefit as compared with intelligible crosstalk of the same level and is equivalent to a 6 db crosstalk advantage. As an example, consider a 400 c/s signal applied to, say, channel 3 of a CS5 system. This signal appears in the sideband range as 28 kc/s. Appearing as crosstalk in the adjacent CU5 system, it would be accepted by the band-pass filter of channel 3, but on demodulation with the applied frequency of 25.4 kc/s, the V.F. product is 2.6 kc/s. In the same manner, a 2.6 kc/s applied signal would demodulate in the adjacent system as 400 c/s, and so on.

/ 2.4

2.4 From an inspection of Fig. 1, it is noted that the majority of systems use the same frequencies in the low-frequency (A-B) direction of transmission. This is because usually the line transpositions satisfactorily reduce crosstalk up to about 17 kc/s, but at higher frequencies, the staggering and inversion of the sideband frequencies is of definite crosstalk reduction value. It should be noted that it is possible to provide line transposition arrangements which are entirely satisfactory for the operation of a number of similar type systems on the one route, but the use of "staggering" and "inversion" of the sideband frequencies is of economic advantage and, in many instances, permits the provision of additional trunk line facilities considerably in advance of the major task involved in retransposition of a route.

2.5 This Paper summarises the main features of various 3-channel systems in use in the Department, and the SOS and SOT systems, which are of comparatively recent introduction, are treated in detail. The advantage of staggering and inversion of the sideband frequencies are obtained by the frequency allocation of these systems.



NOTES: (1) Carrier frequencies are not transmitted to line.
(2) Figures under sidebands indicate channel numbers.
(3) Nominal Pilot Frequencies for 3-channel systems are as follows -

(i) In A-B direction, 9.45 kc/s or 10.95 kc/s.
(ii) In B-A direction, 21.45 kc/s, 23.75 kc/s or 24.35 kc/s.

The actual pilot frequency used depends on the system and is 50 c/s removed from the carrier frequency in the middle of the frequency range transmitted.

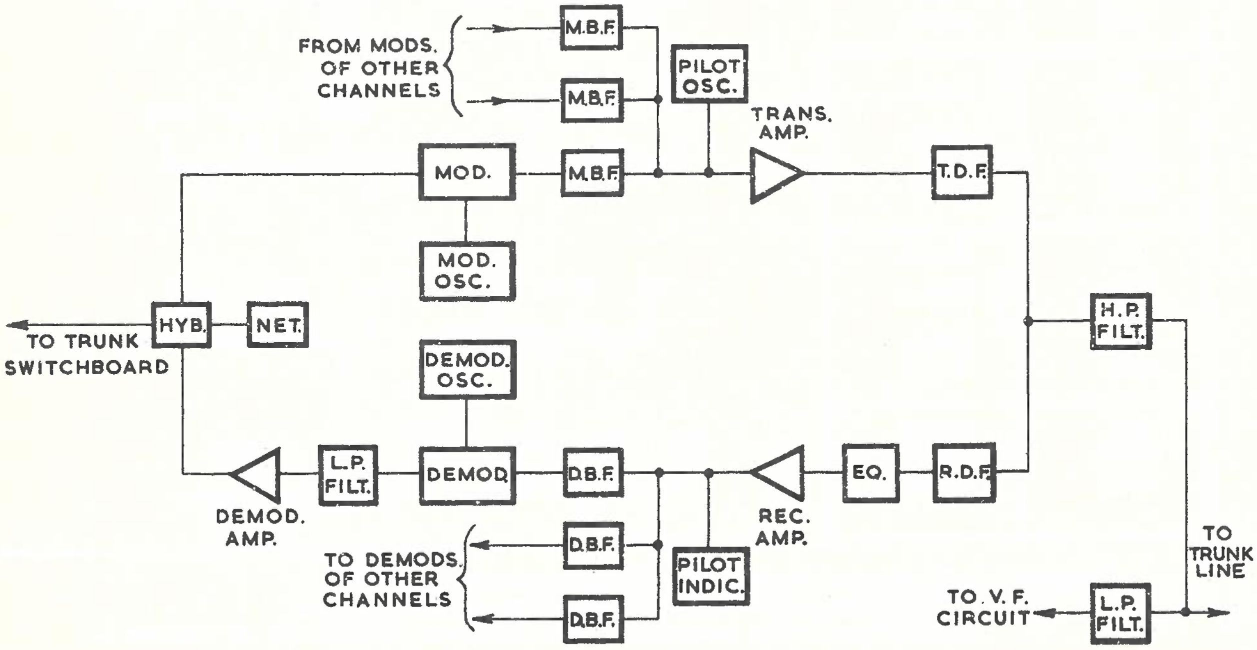
FIG. 1. FREQUENCY ALLOCATION. 3-CHANNEL CARRIER TELEPHONE SYSTEMS.

3. BASIC OPERATION OF 3-CHANNEL SYSTEM.

3.1 A 3-channel carrier telephone system consists basically of three single channel systems connected in parallel. A simplified block schematic diagram of one terminal of a basic 3-channel system is shown in Fig. 2.

3.2 It should be noted that the channel circuits are individual from the audio termination up to and including the channel band-pass filters. Between the band filters and the trunk line, common transmitting and receiving circuits are used for all three channels. The apparatus for one channel only is shown in Fig. 2, that required for the other two channels being connected to the modulator and demodulator band-pass filters in a similar manner.

3.3 Transmitting Direction. Referring to Fig. 2, audio-frequency signals from any one channel are applied via the Hybrid Coil to the Modulator (Mod.), to which also is supplied a high-frequency carrier current from the Modulator Oscillator (Mod. Osc.). The process of modulation results in the production of sideband frequencies. The frequency allocation requires the transmission of only the upper or lower sideband frequencies and the Modulator Band-Pass Filter (M.B.F.) selects the desired sideband, rejecting all unwanted frequencies. The desired sideband, in conjunction with the transmitted sidebands of the other two channels, is applied to a common Transmitting Amplifier (Trans. Amp.) which amplifies the signals to a satisfactory level for transmission over the trunk line. After amplification, the carrier frequencies are accepted by the Transmitting Directional Filter (T.D.F.) which is usually a low-pass filter at an "A" terminal and a high-pass filter at a "B" terminal. The output of the T.D.F. is connected to the carrier line in parallel with the input to the Receiving Directional Filter (R.D.F.). The T.D.F. and R.D.F. are designed to separate the opposite directions of transmission. Outgoing carrier currents are applied to the trunk line through the High-Pass Line Filter which, in conjunction with the Low-Pass Line Filter, separates the carrier frequencies from voice frequencies transmitted over the normal physical circuit.



3-CHANNEL CARRIER TELEPHONE SYSTEM.

FIG. 2.

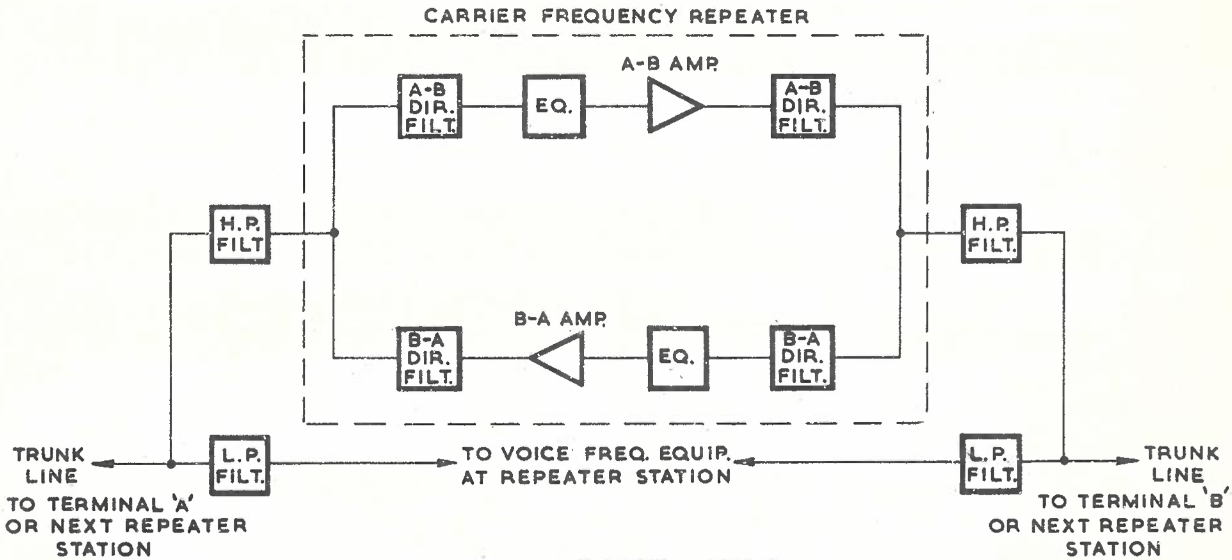
3.4 Receiving Direction. Incoming high-frequency currents from the line pass through the High-Pass Line Filter and are selected by the Receiving Directional Filter. The Equaliser (Eq.) maintains the level of all channels substantially equal at the input of the receiving amplifier, and compensates for the frequency distortion caused by the attenuation frequency characteristics of the preceding equipment and trunk line section. The sidebands are then amplified by a common Receiving Amplifier (Rec. Amp.) to compensate for trunk line attenuation. The different frequency bands associated with each individual channel are selected from one another by the Demodulator Band-Pass Filters (D.B.F.) and then pass to the appropriate Demodulator (Demod.). In the demodulator, the voice frequencies are derived by the modulation of the sideband currents with a carrier frequency supplied by a Demodulator Oscillator (Demod. Osc.), the frequency of which is synchronised with that of the corresponding channel modulator oscillator at the opposite terminal. The output of the demodulator circuit includes a low-pass filter for suppressing the unwanted components of demodulation. The V.F. signals, amplified to the desired level, then pass via the hybrid coils to their respective terminations.

4. CARRIER REPEATER FOR 3-CHANNEL SYSTEM.

4.1 Carrier telephone repeaters are used when the distance between the carrier terminals exceeds that for which the terminal transmitting apparatus is effective in maintaining the transmission level well above the line noise. The function of the repeater is to amplify the carrier frequency currents so that they pass on to the succeeding line sections at a level comparable to that sent from the terminals.

4.2 The carrier frequency repeaters for the 3-channel systems are installed along the aerial trunk line route at the same spacing as the V.F. repeaters on the same wires. This means a spacing of from 100-150 miles. The installation of both V.F. and carrier repeaters in the same repeater station reduces the equipment, simplifies the maintenance problem and enables the same sources of power supply to be used for the repeaters.

4.3 The block schematic of a typical repeater for a 3-channel carrier telephone system is shown in Fig. 3.



CARRIER FREQUENCY REPEATER.

FIG. 3.

4.4 The high-pass line filter in conjunction with the low-pass line filter separates the carrier sideband frequencies from the voice frequencies, and directs them to the carrier repeater. These filters are similar to the corresponding filters at the carrier terminals. After passing through these filters, the carrier sidebands are applied to two directional filters connected in parallel. The directional filters separate the groups of sidebands transmitted in the two directions. Since the A-B direction of transmission uses the lower groups of frequencies (see Fig. 1), the A-B directional filters are low-pass filters, whilst the B-A directional filters are high-pass filters, passing the upper groups of sidebands. The equalisers compensate for the attenuation-frequency characteristics of the preceding trunk line sections, so that the levels of the sidebands corresponding to each of the three carrier channels are substantially the same at the input of the amplifiers. The amplifiers are similar to the terminal transmitting amplifiers. The gain and power output are determined by the repeater spacing, the gain being controlled by the attenuation loss between the repeaters, and the power output by the output level desired because of noise and crosstalk considerations.

4.5 The higher attenuation of the trunk line in the carrier range of frequencies means that the carrier repeaters must have a higher maximum gain than that of the V.F. repeaters operated on the same wires. In a 3-channel system, for instance, the gain for the highest frequency transmitted is required to be approximately four times that of the V.F. repeater. Whereas gains of the order of 8-15 db. may be readily obtained from V.F. repeaters using hybrid coils and balance networks, the 30-45 db. gain required by the carrier repeaters necessitates the use of 4-wire operation or its equivalent, by using different frequencies in opposite directions of transmission, and directional filters for the prevention of "singing".

5. PILOT REGULATING EQUIPMENT.

5.1 The variation in attenuation of open wire lines caused by changing weather conditions is considerably greater at carrier frequencies than at voice frequencies. For this reason, it is necessary to adjust the levels of a carrier system periodically at the receiving terminal to ensure that the overall transmission loss between switch-boards does not vary by more than a tolerable amount from the value at which it has been lined up for operation in the trunk network. Further, where repeaters are involved, it is necessary to ensure that the input level to each repeater is not too low, causing excess noise, or too high, causing the repeater valves to be overloaded and produce distortion and interchannel crosstalk.

For short systems without repeaters, or where only one repeater is involved, a daily adjustment of levels is probably sufficient to ensure satisfactory service, but, where long systems are required to operate in a high grade trunk network, it is desirable that the pilot channel equipment should be supplied, since its continuous indication of the level conditions in the system avoids the necessity for taking channels out of service for level lining up purposes.

5.2 In multi-channel carrier telephone systems, two forms of Pilot Channel Equipment are available - Manual and Automatic.

(i) The Manual Pilot Channel gives in db a direct reading of the average level of the three sidebands at the output of each repeater and receiving terminal. This channel also gives an alarm at the receiving terminal when this average level varies by more than a predetermined amount from that at which it was set when lined up.

(ii) The Automatic Pilot Channel, in addition to these facilities, automatically varies the amplification of each repeater in turn and of the receiving terminal, so that the levels are maintained at the values at which they should normally be set.

/ 5.3

5.3 Manual Pilot Regulation. In a system equipped with Manual Pilot Regulation, the output of a pilot oscillator is applied to the input of the transmitting amplifier at each terminal, as shown in Fig. 2. This is a valve oscillator of high-frequency stability and usually includes a limiter to maintain the output at a constant level and a meter showing continuously the exact level of the oscillator output. The pilot oscillator frequency is set at a frequency lying between the ranges of the transmitted channel sidebands, and the pilot current output level is set at the time of installation to a value which is low compared with the sideband levels.

On the receiving side of each terminal, a pilot indicator is bridged across the output of the receiving amplifier. This indicator incorporates an input filter of very narrow band-width which is tuned to the pilot frequency, a feedback type amplifier, and a rectifier circuit. A feedback amplifier is used for this purpose, since the gain of such a circuit is practically independent of valve changes and, within limits, of supply voltage variations. The rectified pilot current is applied to an indicating meter calibrated in db, which shows the level of the incoming pilot frequency. The pilot indicator is followed by a pilot alarm, which gives a visual and audible alarm when the level of the pilot frequency departs by more than a predetermined amount from its normal value.

5.4 Automatic Pilot Regulation. In the case of Automatic Pilot Regulation the pilot indicator is followed by a relay circuit driving a step-by-stepswitch which operates a variable attenuator. This variable attenuator is connected in the receiving circuit between the basic equaliser and the input of the receiving amplifier. In this case, when the level of the incoming pilot frequency departs by more than a predetermined amount (usually 0.5 db) from its normal value, the relay circuit is operated, which causes the switch to step in a suitable direction to adjust the loss in the variable attenuator to restore the pilot level to its normal value.

Thus, when the incoming level of the pilot frequency is too low, the loss in the variable attenuator is reduced, but, when the pilot level is high, the loss in the attenuator is increased. In addition, when there is a sudden and very large change in the level of the incoming pilot frequency such as could only be caused by a fault condition the relay circuit is ineffective, and, instead of attempting to correct the incoming level, an alarm is given so that the attention of the maintenance staff may be attracted to the fact that an abnormal condition exists on the circuit.

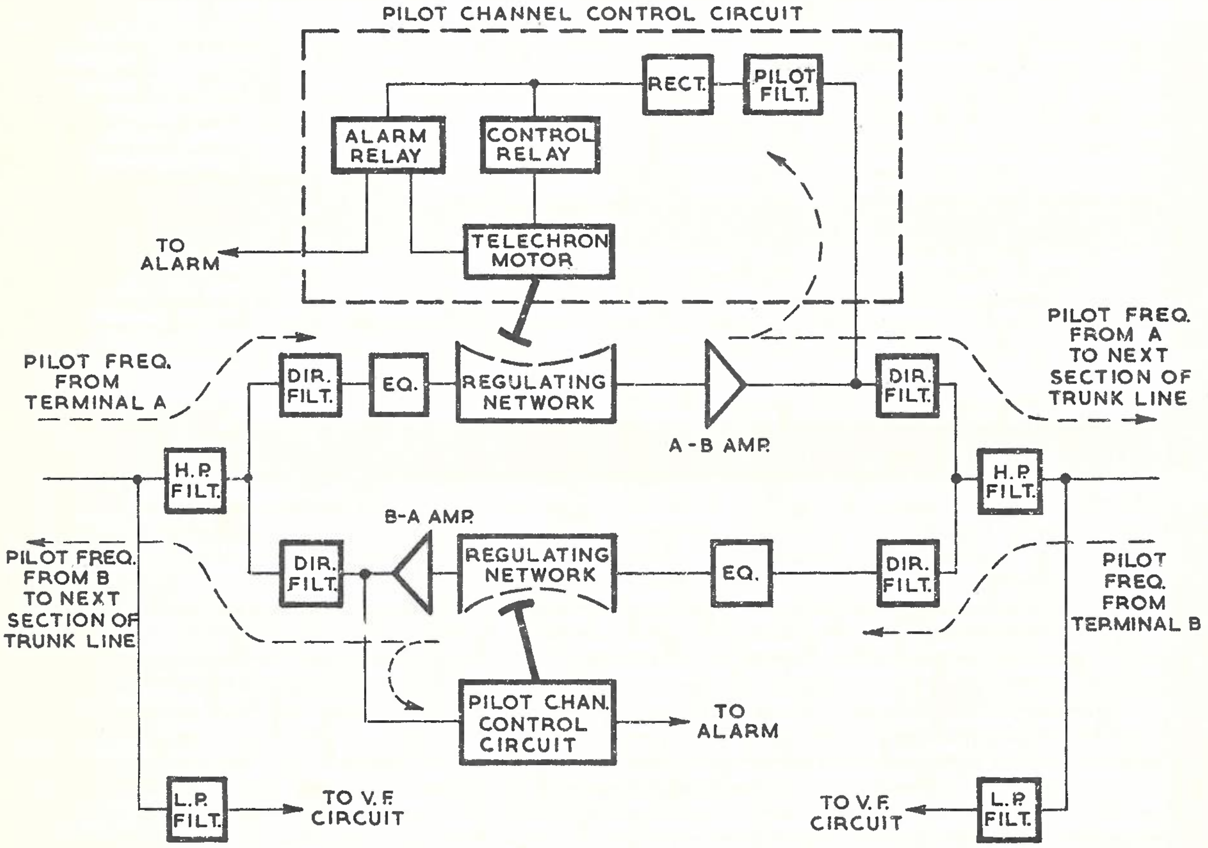
5.5 At the repeater stations, pilot indicators are connected across the outputs of the amplifiers in each direction of transmission. These indicators are exactly the same as those at the receiving sides of the terminals. When manual pilot control is provided, the terminal alarm panel is omitted, since, under these conditions, all level regulation at the repeaters should be carried out under instructions from the terminal stations. When automatic pilot control is provided, the pilot indicators are usually followed by the same relay circuits as at the terminals, and automatic switch controlled attenuators are connected at the input of each amplifier in a similar manner. To ensure that the repeater immediately following a line section (the transmission loss of which has varied) is the first to apply the necessary correction of levels, instead of repeaters at later stages in the transmission path, a delay feature is incorporated in the automatic pilot relay circuit, which is adjusted in such a way on installation that the first repeater in each transmission direction corrects level variations after the minimum delay, whilst the second, third, etc., repeaters and finally the receiving terminal correct after progressively increasing delays. In this way, hunting between different repeaters attempting to correct for level variations is avoided.

/ 6.

6. AUTOMATIC GAIN REGULATION.

6.1 In modern multi-channel carrier telephone systems, automatic gain regulation of terminal and repeater station equipment is effected by means of pilot channels. One or more pilot frequencies, occupying positions between the carrier channel bands, are applied to the line at each end. These frequencies are then picked off from the outputs of the repeater amplifiers and terminal receiving amplifiers and used to control a regulating circuit connected in the line at the amplifier input. Since the pilot frequencies are transmitted along with the regular channel frequencies, they suffer the same attenuation losses in passing over the line and are affected by any change in the line characteristics in the same way, and to the same extent as, the sideband currents of the several channels. By establishing normal values for the pilot frequency currents at each amplifier point, therefore, any change due to changing line conditions may be caused to register in such a way as to produce automatically a correcting adjustment of each amplifier gain.

6.2 A typical automatic regulating circuit is shown in simplified form in Fig. 4. This is similar to the method used in the types CS5 and CU5 three channel systems and the type J1 twelve channel system, manufactured by the Western Electric Co., U.S.A., and is known as the type 2B Pilot Regulator.



BLOCK SCHEMATIC OF AUTOMATIC PILOT REGULATOR.

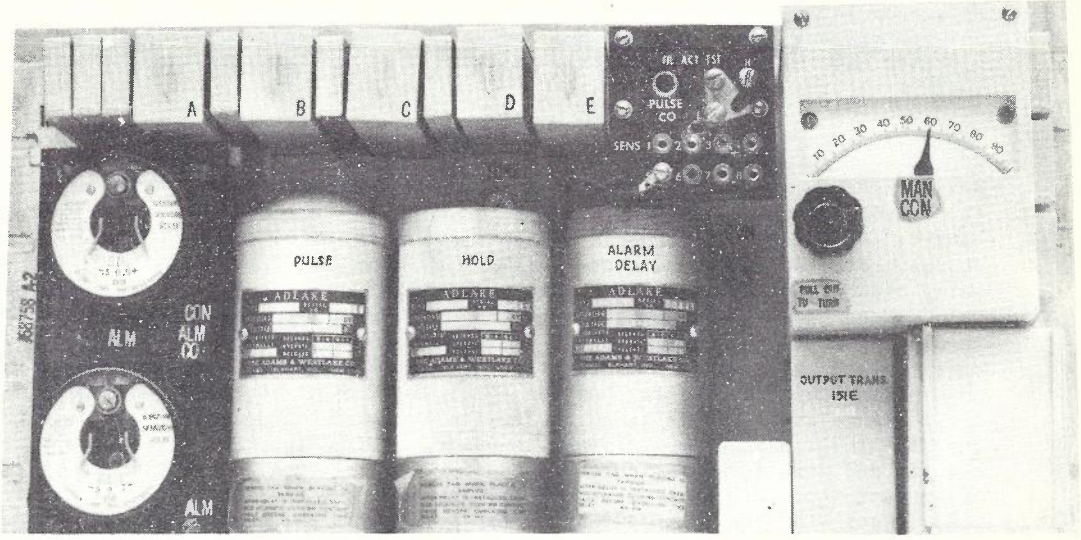
FIG. 4.

As shown schematically in Fig. 2, the pilot channel current is applied to the line at the input of the transmitting amplifier. At repeater points, this single-frequency current is tapped off at the output of the line amplifier and led back through an amplifier and rectifier circuit to a pilot channel control circuit which controls the net loss or gain of a regulating amplifier connected in the main transmission path in front of the line amplifier. The same general plan applies at the receiving terminal, except that here the pilot channel current is taken off at the output of the receiving amplifier.

6.3 Fig. 5 shows the circuit of the pilot channel control equipment which controls the gain of the regulating amplifier.

6.4 Regulating Amplifier. The regulating amplifier circuit consists essentially of a variable attenuator in series with a valve amplifier. The attenuator, known as the regulating network, is designed to have the same loss-frequency characteristic as the line and is divided into three units of equal loss. Its net loss to through transmission is varied by means of a capacitor the movable plate of which rotates under the control of the pilot channel current. The moving plate of the capacitor is connected to the input of the amplifier and the voltage applied to the input depends upon the position of this plate. When the moving plate is at its extreme left position, the regulating network is effectively out of the transmission path. At its extreme right position, the entire network is in the transmission path; and at any other position, the loss inserted is some definite fraction of the total loss of the regulating network. This arrangement provides a smooth control of the net loss or gain of the regulating circuit and avoids the use of sliding contacts or relays in the transmission path.

It should be noted that the regulating amplifier circuit is not ordinarily intended to introduce a net gain. This function is taken care of by the fixed-gain line amplifier. In practice, the regulating amplifier circuit usually introduces a net loss, but it varies this loss in such a way as to counteract any changes in the loss of the preceding line section.



PORTION OF WESTERN ELECTRIC 2B AUTOMATIC PILOT CHANNEL

REGULATOR EQUIPMENT (FRONT VIEW).

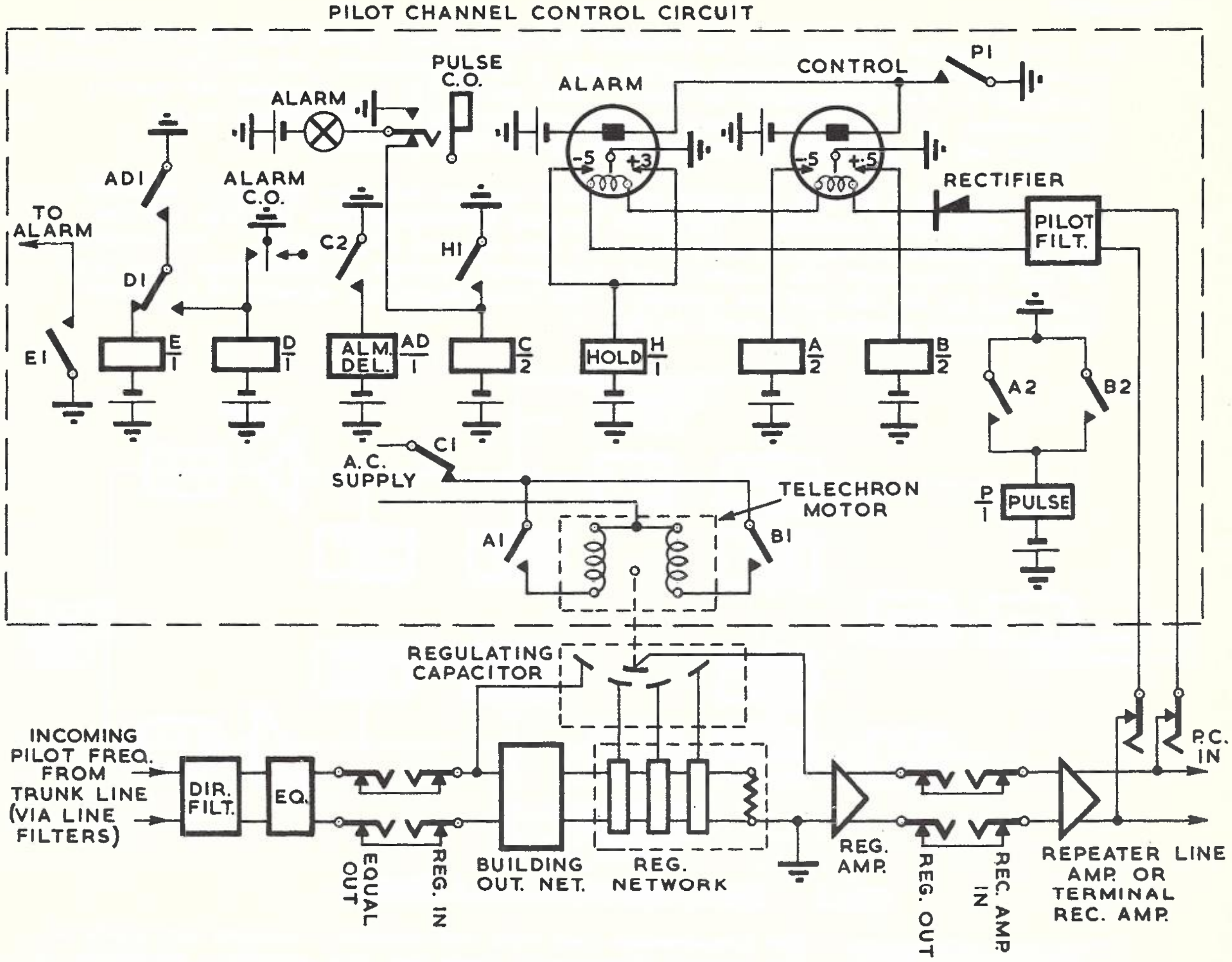
6.5 Pilot Channel Control Equipment. The upper part of Fig. 5 shows how the pilot channel current controls the position of the regulating capacitor in the regulating amplifier circuit. The incoming pilot channel current is selected by a highly selective band filter termed the pilot filter and then rectified. The resulting D.C. passes through the operating windings of the control and alarm relays termed Sensitrol relays. These relays are in fact, microammeters with high and low contacts to which the pointer (or armature) is attracted. The relays are given a mechanical bias so that the armatures are centered between the contacts when the rectified pilot current is at the normal level. A change of about 0.5 db in this current causes the armature of the control relay to move sharply to one or the other of the contacts, where it stays until released by the action of the second winding of the relay. As the contacts are magnetised and the armature is of magnetic material, good contact is ensured. Large level changes of plus or minus several db cause both control and alarm relays to operate.

The direction of movement of the armature depends upon whether the pilot level is increased or decreased. Thus, when the level increases by 0.5 db or more, the armature of the control relay moves towards and is held by the magnetic contact on the right. This causes the operation of relay B which connects current to the right winding of the "telechron" motor, causing it to rotate in such a direction as to increase the loss of the regulating network. This network is in effect a variable attenuator. The telechron motor continues to operate until the control relay is released. This release is effected by the "pulse" relay P, the winding of which is connected to a second contact of relay B. The pulse relay is slow-operating and does not operate until about four seconds after its circuit is closed. When it operates, a circuit is closed through the second winding of the control relay. This restores its armature to normal thus releasing relay B and the pulse relay, and disconnecting the A.C. supply from the motor which stops. When high level conditions still persist, the armature is attracted to and held by the magnetic contact, again completing the circuit to the motor, and the above operation is repeated.

To summarise, when the pilot channel current deviates from normal, the telechron motor operates for about four seconds to counteract the effects of this deviation, and then stops. If sufficient correction has not been obtained in this time, the operation is repeated intermittently at the rate of 1 db per minute until the level of the pilot frequency is restored to plus or minus 0.5 db of its normal value. When the pilot channel current decreases the same series of operations occur except that relay A now operates and the telechron motor rotates in the opposite direction to decrease the loss of the regulating network.

The remaining relays shown in Fig. 5, are provided to take care of sudden large changes in the pilot channel level. Such changes either require manual attention or are of such short duration that a correction is undesirable. The alarm relay, the winding of which is in series with that of the control relay, is adjusted to operate for large level changes of the order of -5 db or +3 db. When such a change occurs, both the alarm and control relays operate, and the operation of the alarm relay closes a circuit to the "hold" relay H. The latter, in turn, operates the C relay which opens the circuit to the motor and thus prevents any change in the regulating amplifier circuit. At the end of about four seconds, the pulse relay P operates and restores both the control and alarm relays to normal. The hold relay H does not release immediately but has a release time of about four seconds and when the level change still persists, no correction is made because relay C is held operated. When the level change is temporary, however, relay C releases after about four seconds and normal regulation is resumed. When a level change of sufficient magnitude to operate the alarm relay persists for any considerable time, the second contact on relay C operates the "alarm delay" relay AD after a period of about 25 seconds. The AD relay, in turn, operates relay E to give visible and audible alarms that the circuit needs manual attenuation. An "alarm cut-off" push-button is provided to disconnect the alarms, when required.

/ Fig. 5.



SCHEMATIC CIRCUIT OF AUTOMATIC PILOT REGULATOR.

FIG. 5.

6.6 The P, H and AD relays shown in Fig. 5 are "Adlake" relays, which are mercury operated time delay relays. They may be made either slow operating or slow releasing, delays of the order of 1 second to 1 minute being easily obtainable. Their main application in the Department is in the regulating and alarm circuits of carrier equipment. The operate and release times of the above relays are -

P relay : operate 3-5 seconds, release 0.18-0.5 second.

H relay : operate 0.5 second, release 5 seconds (max).

AD relay : operate 20-28 seconds, release 0.5 second (max).

/ 7.

7. C SYSTEMS.

7.1 The type B system manufactured by Standard Telephones and Cables Ltd., was the first multi-channel carrier telephone system used by the Department, and the first system was installed in the Commonwealth in 1925. This system did not suppress the carrier frequencies, but transmitted them to line continuously. This system is now obsolete and no types are at present used in the Commonwealth.

The S.T.C. type C systems followed the type B systems and were the first 3-channel carrier suppressed systems. The first systems introduced were the type C2N and C2S, and these were later succeeded by the type CN3 and CS3 systems. The letters "N" and "S" represent the "normal" and "staggered" systems. Both types were later superseded by the CT4 and CS4 systems. The block schematic circuit of a typical type C carrier terminal is shown in Fig. 6.

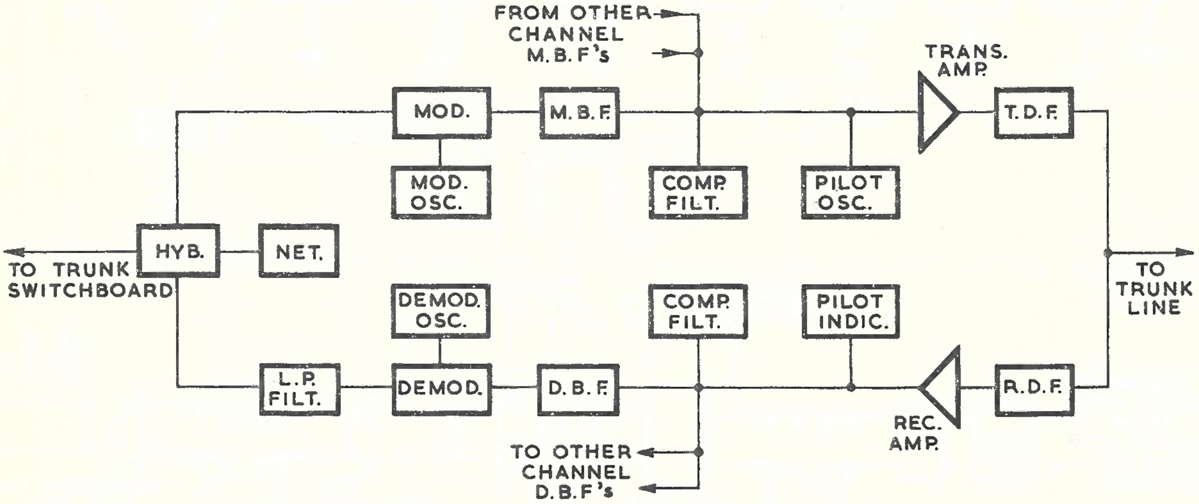
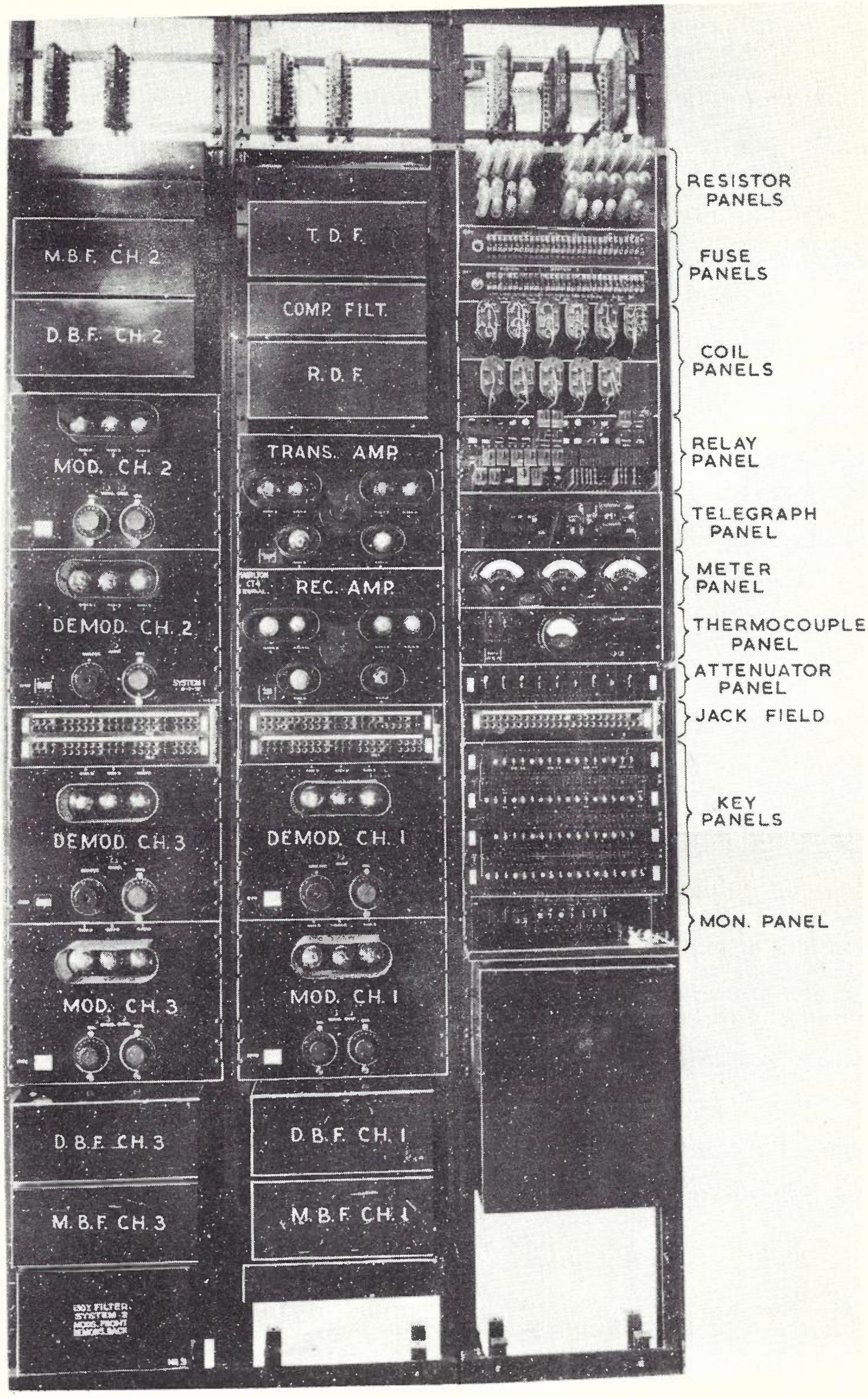


FIG. 6. BLOCK SCHEMATIC OF TYPE C TERMINAL.

7.2 Frequency Allocation. The frequencies used with the various C systems are shown in the following table. The carrier frequencies shown may vary slightly, depending on the particular system model used, for example, the early CS4 systems used a carrier frequency of 28.5 kc/s for channel 3 in the B-A direction.

System	Channel	A-B Direction		B-A Direction	
		Carrier Frequency	Sideband	Carrier Frequency	Sideband
C2N and CN3	1	14.0 kc/s	Lower	19.46 kc/s	Upper
	2	10.7 kc/s	Lower	16.1 kc/s	Upper
	3	7.7 kc/s	Lower	23.4 kc/s	Upper
CT4	1	12.9 kc/s	Upper	23.7 kc/s	Upper
	2	9.4 kc/s	Upper	19.8 kc/s	Upper
	3	6.3 kc/s	Upper	27.7 kc/s	Upper
C2S, CS3 and CS4	1	12.7 kc/s	Upper	24.45 kc/s	Lower
	2	9.4 kc/s	Upper	20.8 kc/s	Lower
	3	6.2 kc/s	Upper	28.3 kc/s	Lower



TYPICAL TYPE C CARRIER TERMINAL.

7.3 Modulator and Demodulator.

(i) Each modulator uses two 4101D valves connected in a push-pull circuit to suppress the carrier frequency. A variable capacitor is provided for carrier leak adjustments. Volume limiters are not provided.

(ii) Each demodulator uses two 4101D valves connected in a push-pull circuit. An input potentiometer is provided for level adjustments.

(iii) The individual modulator oscillators and demodulator oscillators are mounted on the modulator and demodulator panels respectively. Each oscillator is of the tuned anode type using a type 4101D valve, and includes a variable capacitor for oscillator tuning adjustments.

7.4 Transmitting and Receiving Amplifiers. While the power output required at the receiving amplifier is usually small compared with that required at the transmitting amplifier, the two amplifiers are identical mainly for economy in production. They are of two stage balanced push-pull design with a maximum output of 1 watt. The first stage uses two 4101D valves connected in push-pull and is choke-capacity coupled to the output stage which has four 4101D valves connected in parallel push-pull. The maximum amplifier gain is approximately 30 db controlled by a variable attenuator over a range of 20 db in 2 db steps.

7.5 Signalling Equipment. Signalling equipment is not incorporated in the design of the system, and, when required, it is necessary to provide separate signalling equipment, for example, a 1,000/17 c/s ringer unit.

7.6 Test Equipment.

(i) Meter Panel. Three meters for measuring filament currents, anode currents, and battery supply voltages, are mounted on this panel.

(ii) Thermo-couple Panel includes a thermo-coupled operated Weston microammeter with a range of 0-40 mA calibrated to read either mA or db.

(iii) Attenuator Panel comprises a number of key controlled pads providing a maximum attenuation of 59 db.

(iv) Monitoring. Telephone and telegraph sets are provided for monitoring and observation purposes.

7.7 Power Supply. The systems are designed to operate from 24 volts filament and 130 volts anode battery supplies.

7.8 During recent years, the 4101D and 4104D valves in many type C systems have been replaced by 6V6GT valves.

8. T SYSTEMS.

8.1 The T1, T2 and T5 systems made by General Electric Company, England, are similar, differing in their frequency allocations to enable several systems to be operated on the same pole route. The block schematic circuit of a typical type T carrier terminal is shown in Fig. 7.

8.2 Frequency Allocations.

System	Channel	A-B Direction		B-A Direction	
		Carrier Frequency	Sideband	Carrier Frequency	Sideband
T1	1	12.9 kc/s	Upper	24.4 kc/s	Lower
	2	9.4 kc/s	Upper	20.7 kc/s	Lower
	3	6.3 kc/s	Upper	28.5 kc/s	Lower
T2	1	12.9 kc/s	Upper	23.7 kc/s	Upper
	2	9.4 kc/s	Upper	19.8 kc/s	Upper
	3	6.3 kc/s	Upper	27.7 kc/s	Upper
T5	1	14.3 kc/s	Upper	23.7 kc/s	Upper
	2	10.9 kc/s	Upper	19.8 kc/s	Upper
	3	7.7 kc/s	Upper	27.7 kc/s	Upper

8.3 Modulator and Demodulator.

(i) The modulators are of the copper oxide rectifier type. A balanced arrangement is used resulting in the suppression of the carrier frequency and only the input voice frequencies and sidebands appear in the output of the modulator. A potentiometer in the modulator circuit is provided for carrier leak adjustment. A rectifier type volume limiter is provided in the input circuit of each channel modulator.

(ii) The demodulators are of the copper oxide rectifier type. A key controlled attenuator is provided in the output circuit for level adjustment.

(iii) The modulator and demodulator oscillator circuits are identical. Each oscillator uses two VT82 valves, one in the oscillator stage and the second in an amplifier stage. The oscillator is a shunt-fed Hartley type. The arrangement of the oscillator followed by an amplifier gives a high degree of frequency stability as the amplifier acts as a "buffer" between the oscillator and any variation of load. A variable capacitor is provided for oscillator tuning adjustments.

8.4 Voice Frequency Amplifiers.

(i) A single stage amplifier using a VT82 valve precedes the modulator on a few of the early type T systems delivered to the Department. On later models, this amplifier is not provided. The maximum gain of the amplifier is 26 db adjustable by means of variable pads over a range of 22 db. This amplifier is mounted on the "V.F. amplifier" panel, together with the demodulator amplifier.

(ii) A single stage amplifier using a type VT82 valve, follows the demodulator. The maximum gain is 26 db with an attenuator adjustment of 9 db.

8.5 Transmitting and Receiving Amplifiers.

(i) On those systems in which a V.F. amplifier precedes the modulator, the transmitting amplifier is a two stage negative feedback type using four valves. The first stage uses two MSP4 valves in push-pull, choke-capacity coupled to the output stage using two PX4 valves in push-pull. The maximum gain is 40 db and the maximum output 500 mW. The working gain for each particular system is fixed at the time of installation by the input attenuator. No facilities for day to day adjustment of output level are provided.

(ii) The receiving amplifier is a two stage type using a single valve in the first stage, choke coupled to two valves in push-pull in the second stage. The valves in both stages are type VT82. The amplifier has a fixed gain of 31 db.

(iii) On those systems not equipped with a V.F. amplifier before the modulator, the transmitting and receiving amplifiers are identical and are of three stage resistance coupled negative feedback type. The first two stages use MSP4 valves and the output stage uses a type PX4. Maximum gain is 46 db and power output 500 mW. A spare amplifier is provided at each terminal.

8.6 Signalling Equipment. The systems do not include any signalling equipment, and when required, it is necessary to provide separate signalling equipment, for example, 1000/17 c/s ringer.

/ 8.7

8.7 Test Equipment. The following test equipment is provided at each terminal -

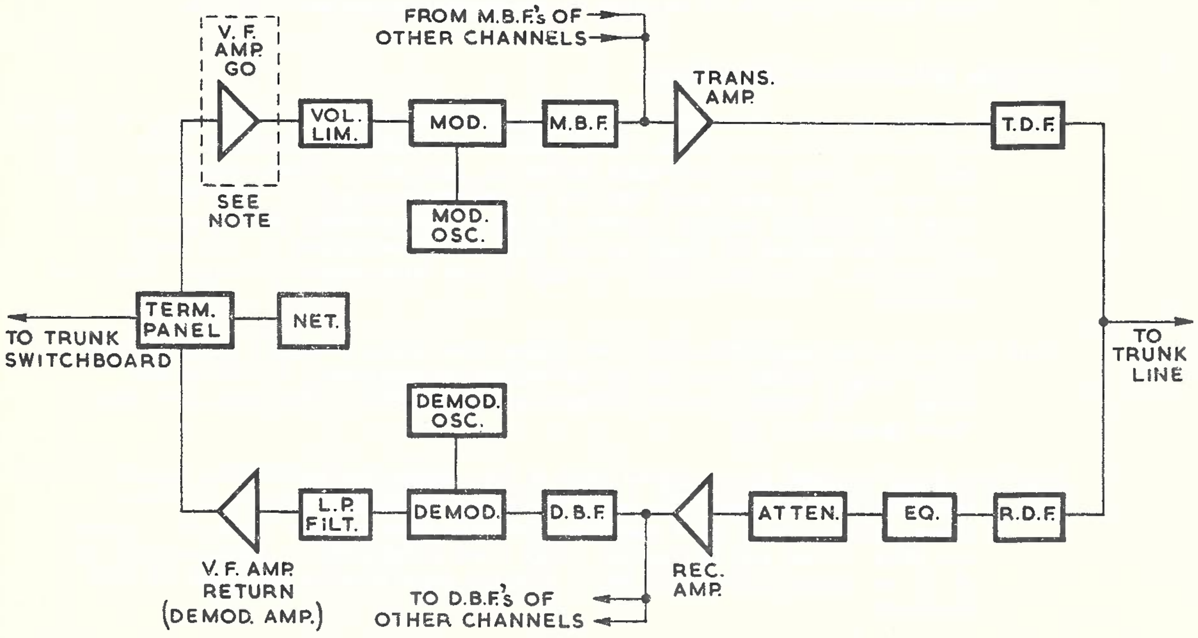
(i) A level measuring indicator. This set enables the power at various points of the carrier equipment to be measured by connecting the jacks at which the measurement is to be made to the Level Indicator jacks with a double ended cord. The scale is calibrated in db with respect to 1 mW, and measurements can be made at frequencies from 0.3 kc/s to 31 kc/s.

(ii) A test oscillator with a fixed frequency of 800 c/s. The oscillator unit includes one VT82 valve connected to supply a testing frequency of 800 c/s to four sets of jacks. Output levels of 1 mW (0 db), -10 db, -20 db, -30 db, can be obtained directly from the respective jacks.

(iii) Meters for measuring anode currents, battery supply voltages, and filament currents.

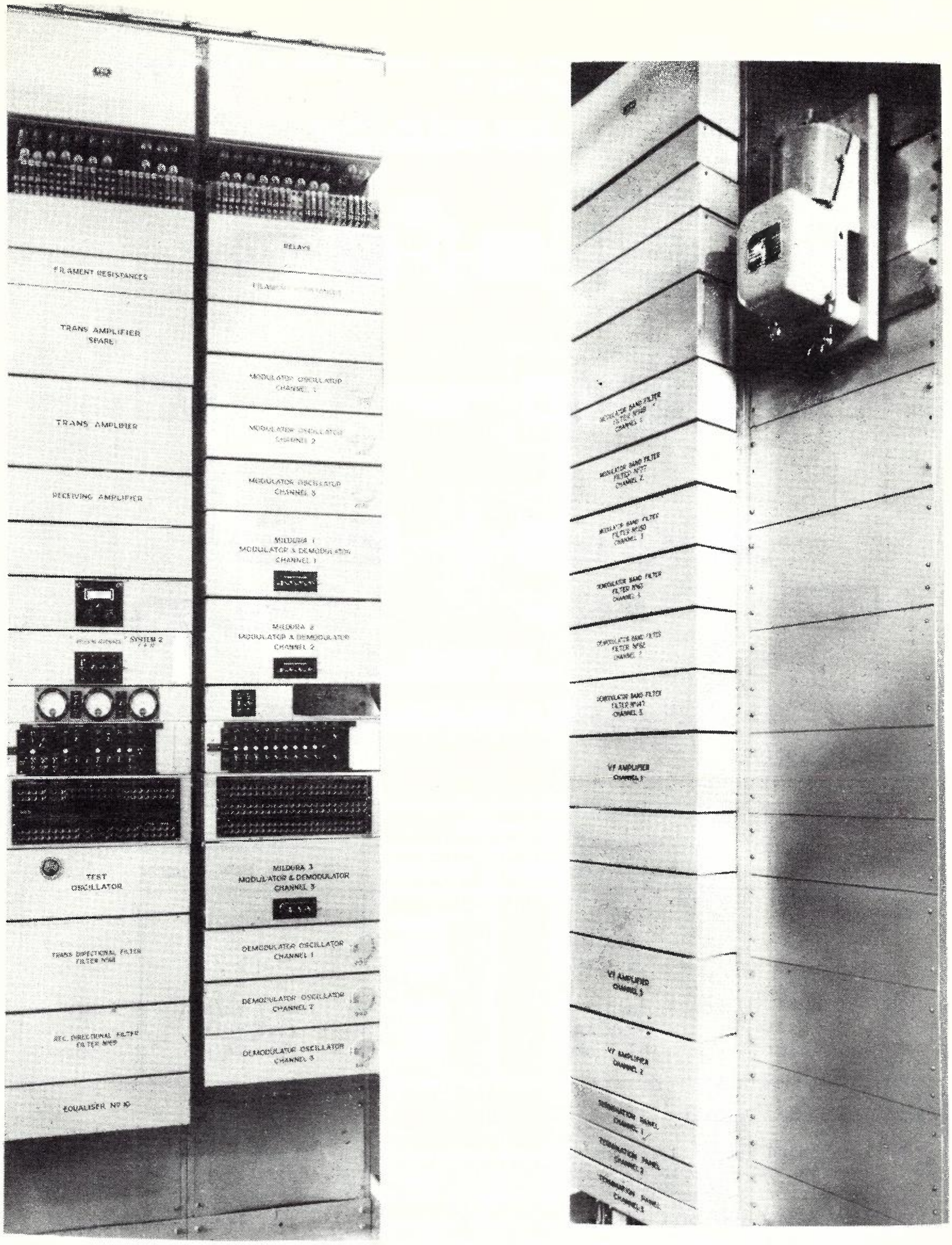
(iv) A telephone set for observation and monitoring purposes.

8.8 Power Supply. The systems are designed to operate from 130 volts and 24 volts D.C. supplies. Usually the 130 volts anode supply can be kept within suitable limits without the use of automatic regulation, but the filament supply is required to be kept within very close limits. An automatic carbon pile regulator is connected in the 24 volts filament circuit to regulate the cathode voltage for the valves to 20.5 volts. The unregulated 24 volts supply is connected to the relay and lamp circuits. Relays are connected in the various anode circuits, which on failure of anode current, release and provide an audible and visible alarm.



Note. "V.F. Amp. Go" provided on some models only.

FIG. 7. BLOCK SCHEMATIC OF TYPE T TERMINAL.



Front View.

Rear View.

TYPICAL TYPE T CARRIER TERMINAL.

9. SS AND ST SYSTEMS.

9.1 The block schematic circuit of a typical carrier terminal made by the Telephone Manufacturing Co., England, is shown in Fig. 8.

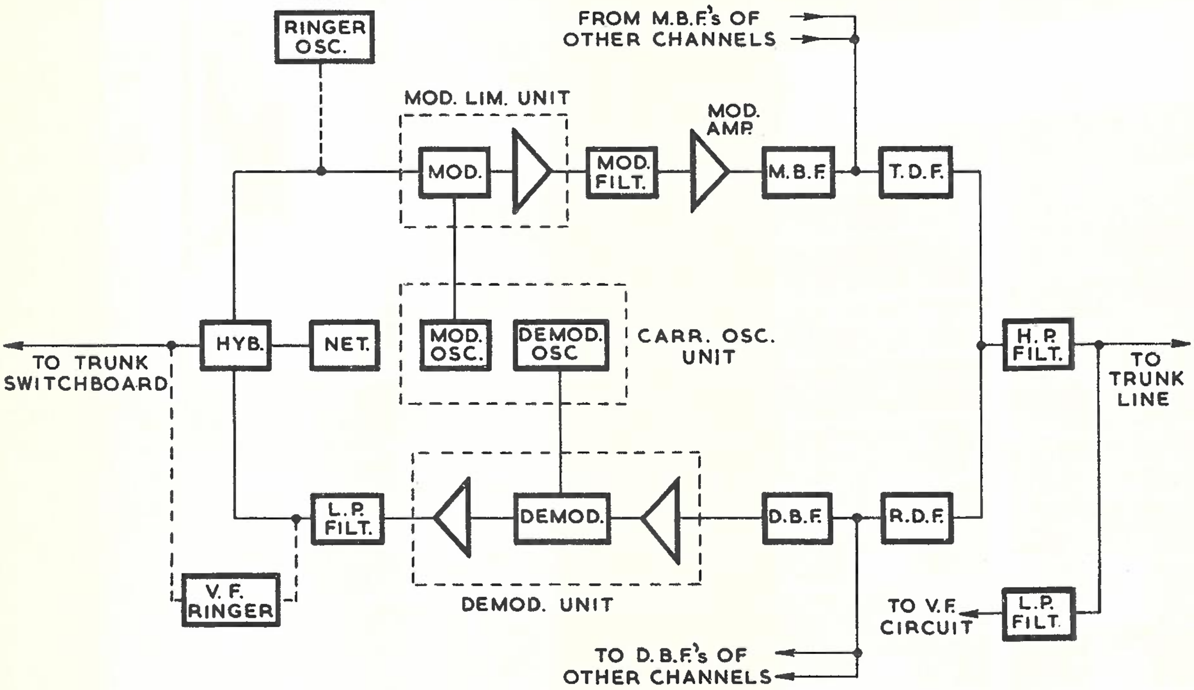


FIG. 8. BLOCK SCHEMATIC OF TYPE SS AND ST TERMINAL.

9.2 Frequency Allocation.

System	Channel	A-B Direction		B-A Direction	
		Carrier Frequency	Sideband	Carrier Frequency	Sideband
SS	1	12.9 kc/s	Upper	24.4 kc/s	Lower
	2	9.4 kc/s	Upper	20.7 kc/s	Lower
	3	6.3 kc/s	Upper	28.4 kc/s	Lower
ST	1	14.3 kc/s	Upper	23.7 kc/s	Upper
	2	10.9 kc/s	Upper	19.8 kc/s	Upper
	3	7.7 kc/s	Upper	27.7 kc/s	Upper

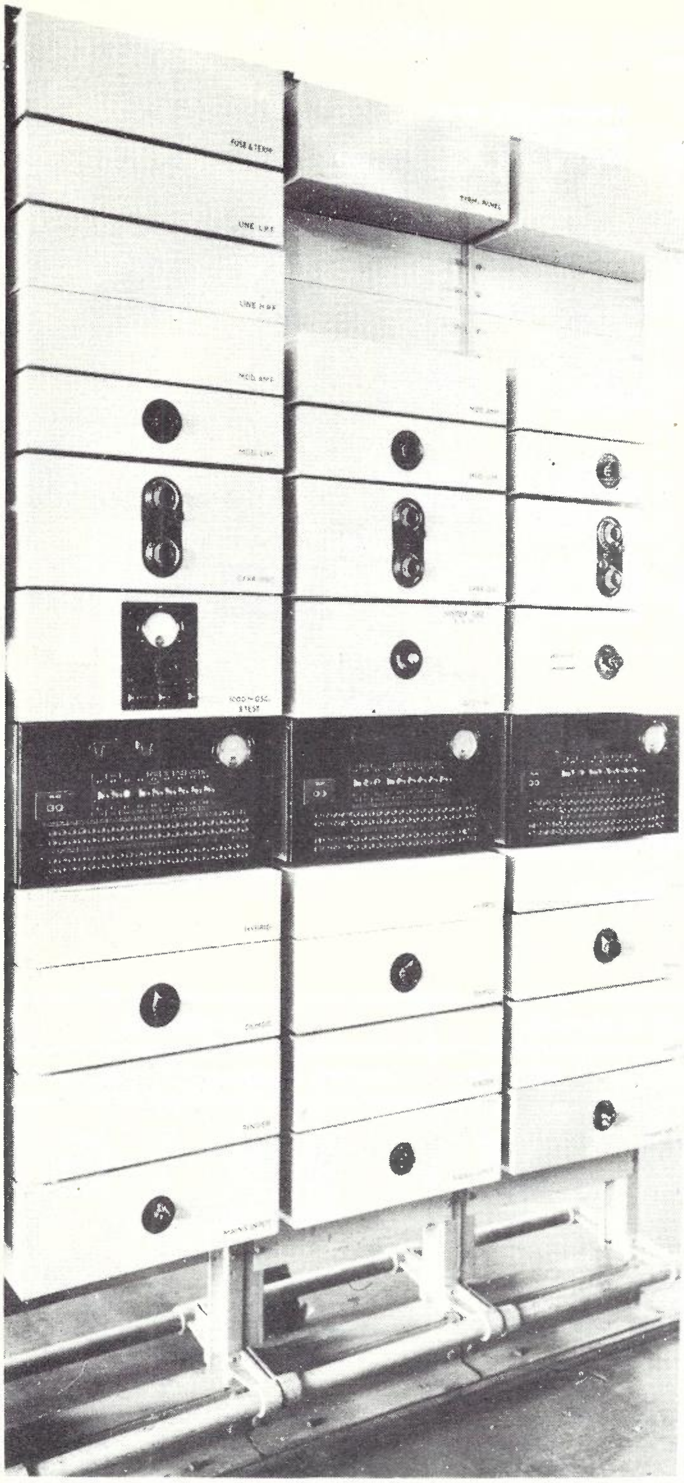
9.3 Modulator and Demodulator.

(i) A balanced metal rectifier type modulator is used. A single stage amplifier using a TMC16 valve, adjustable over a range of 30 db, follows the modulator. These units are mounted on the modulator limiter panel.

(ii) The Demodulator Unit includes a single stage sideband amplifier using a TMC19 valve, a balanced metal rectifier demodulator, and a single stage V.F. amplifier using a TMC16 valve. The maximum gain of the unit is 33.5 db, with potentiometer control of 30 db.

(iii) A single stage valve oscillator using a type TMC15 valve, is associated with each modulator and demodulator unit.

/ 9.4



TYPICAL TYPE SS AND ST CARRIER TERMINAL.

9.4 Transmitting and Receiving Amplifiers.

(i) A common transmitting amplifier is not provided. Each individual channel is provided with a two stage negative feed-back modulator amplifier, using TMC19 and TMC18 valves, which serves the purpose of a transmitting amplifier. Power output is 400 mW and maximum gain is 33 db, adjustable in 3 db steps over a range of 12 db.

(ii) A common receiving amplifier is not provided. In each demodulator unit, the sideband amplifier preceding the demodulator, serves the purpose of a receiving amplifier.

9.5 Signalling Arrangements. A 1,000/17 c/s ringer circuit for each channel is included as an integral part of each terminal.

9.6 Test Equipment. The following test equipment is provided -

(i) The 1,000 c/s oscillator and test panel includes a variable attenuator (range 0 to 40 db), level indicator (-20 db to +10 db) and a V.F. oscillator. This oscillator is primarily intended as a ringer oscillator, but may be used to supply test current and is associated with the level indicator for measuring gains and levels throughout the system.

(ii) A meter for the measurement of filament currents.

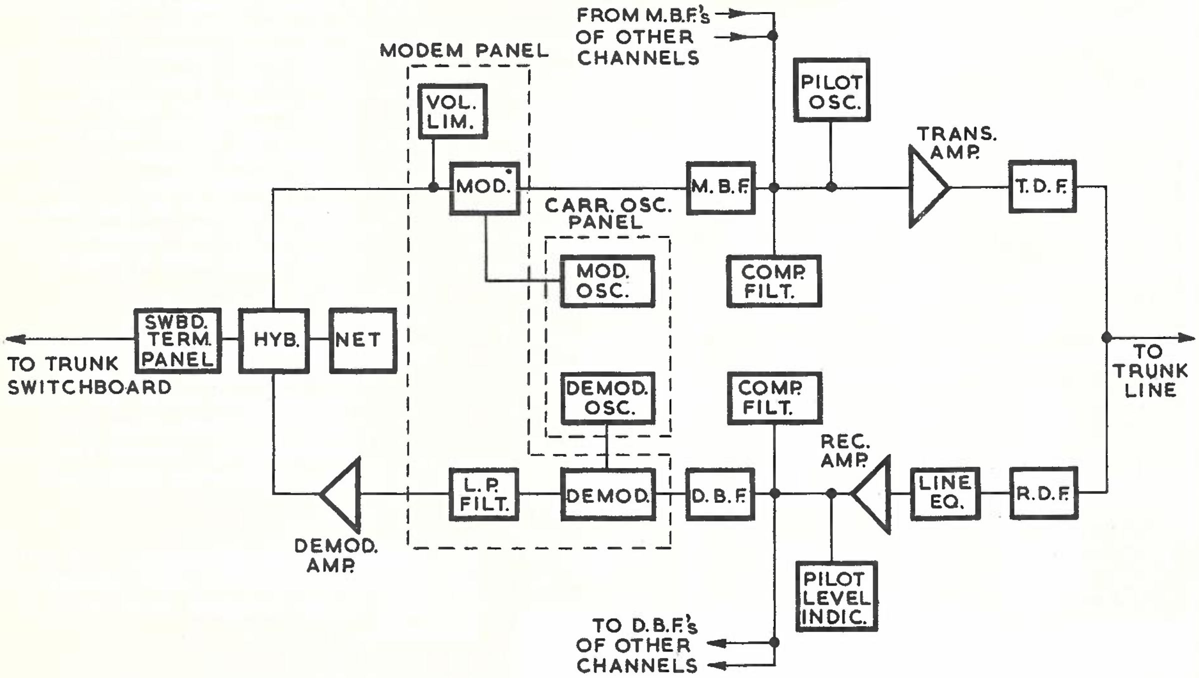
(iii) A telephone set is provided for monitoring purposes.

9.7 Power Supply. The systems are designed to operate normally from 24 volts and 130 volts D.C. supplies.

/ 10.

10. STSA, STTA AND STVA SYSTEMS.

10.1 The block schematic circuit of a typical carrier terminal made by the Telephone Manufacturing Co., England, is shown in Fig. 9.

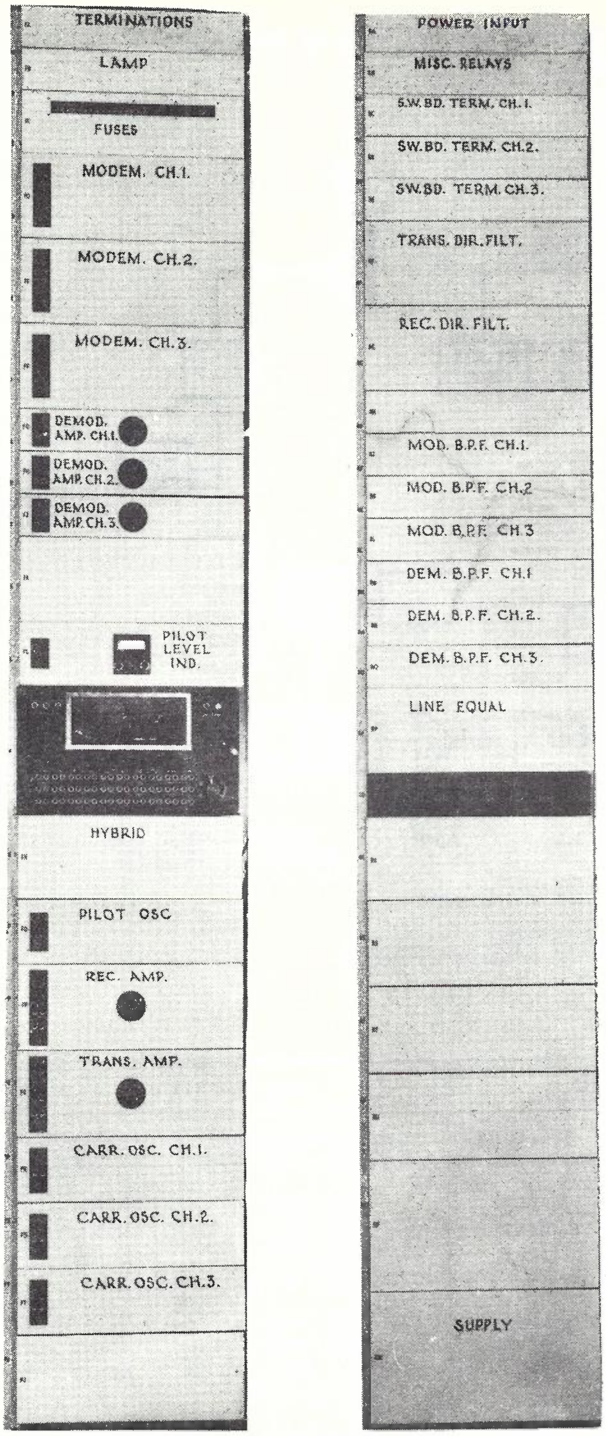


BLOCK SCHEMATIC OF TYPE STSA, STTA AND STVA TERMINAL.

FIG. 9.

10.2 Frequency Allocation.

System	Channel	A-B Direction		B-A Direction	
		Carrier Frequency	Sideband	Carrier Frequency	Sideband
STSA	1	12.9 kc/s	Upper	24.4 kc/s	Lower
	2	9.4 kc/s	Upper	20.7 kc/s	Lower
	3	6.3 kc/s	Upper	28.4 kc/s	Lower
	Pilot	9.45 kc/s	-	24.35 kc/s	-
STTA	1	14.3 kc/s	Upper	23.7 kc/s	Upper
	2	10.9 kc/s	Upper	19.8 kc/s	Upper
	3	7.7 kc/s	Upper	27.7 kc/s	Upper
	Pilot	10.95 kc/s	-	23.75 kc/s	-
STVA	1	12.9 kc/s	Upper	23.7 kc/s	Upper
	2	9.4 kc/s	Upper	19.8 kc/s	Upper
	3	6.3 kc/s	Upper	27.7 kc/s	Upper
	Pilot	9.45 kc/s	-	23.75 kc/s	-



Front View. Rear View.

TYPICAL TYPE STSA, STTA AND STVA CARRIER TERMINAL.

10.3 Modulator and Demodulator.

(i) Modulators and demodulators are of the "ring" type with copper oxide rectifiers, and a potentiometer adjustment of the carrier leak. The modulator and demodulator of each channel together with V.F. input limiter, channel equalisers, low-pass filter and attenuation pads, are mounted on a single panel termed a Modem Panel. A single stage negative feedback amplifier using a 6V6GT valve, follows the demodulator. The maximum gain of the amplifier is 31 db over the V.F. range and the gain is adjustable from 20 db to 31 db.

(ii) The modulator oscillator and demodulator oscillator of each channel use 6SJ7GT valves and are mounted on a single panel.

10.4 Transmitting and Receiving Amplifiers. These amplifiers are identical, and are three stage amplifiers with negative feedback from the output stage to the input circuit of the first stage. The first two stages use 6SJ7GT valves, with two 6V6GT's in parallel in the output stage. The maximum gain is 51 db, adjustable from 5 db to 51 db.

10.5 Signalling Equipment. Signalling equipment is not incorporated in the design of the system, and, when required, it is necessary to provide separate signalling equipment, for example, a 1,000/17 c/s ringer unit.

10.6 Test Equipment. No test equipment is supplied with the system. The cathode current of any valve can be measured by plugging a 1,000 ohm D.C. voltmeter (1 volt full scale deflection) into the relevant jack on the panel concerned. A monitoring panel is provided to give ringing, speaking, and/or listening facilities by patching to any part of the V.F. circuits.

10.7 Power Supply. The systems are designed to operate from 24 volts and 130 volts D.C. supplies.

/ 11.

11. S21, S22 AND S25 SYSTEMS.

11.1 The block schematic circuit of a typical carrier terminal made by Communication Engineering, Pty. Ltd., Australia, is shown in Fig. 10.

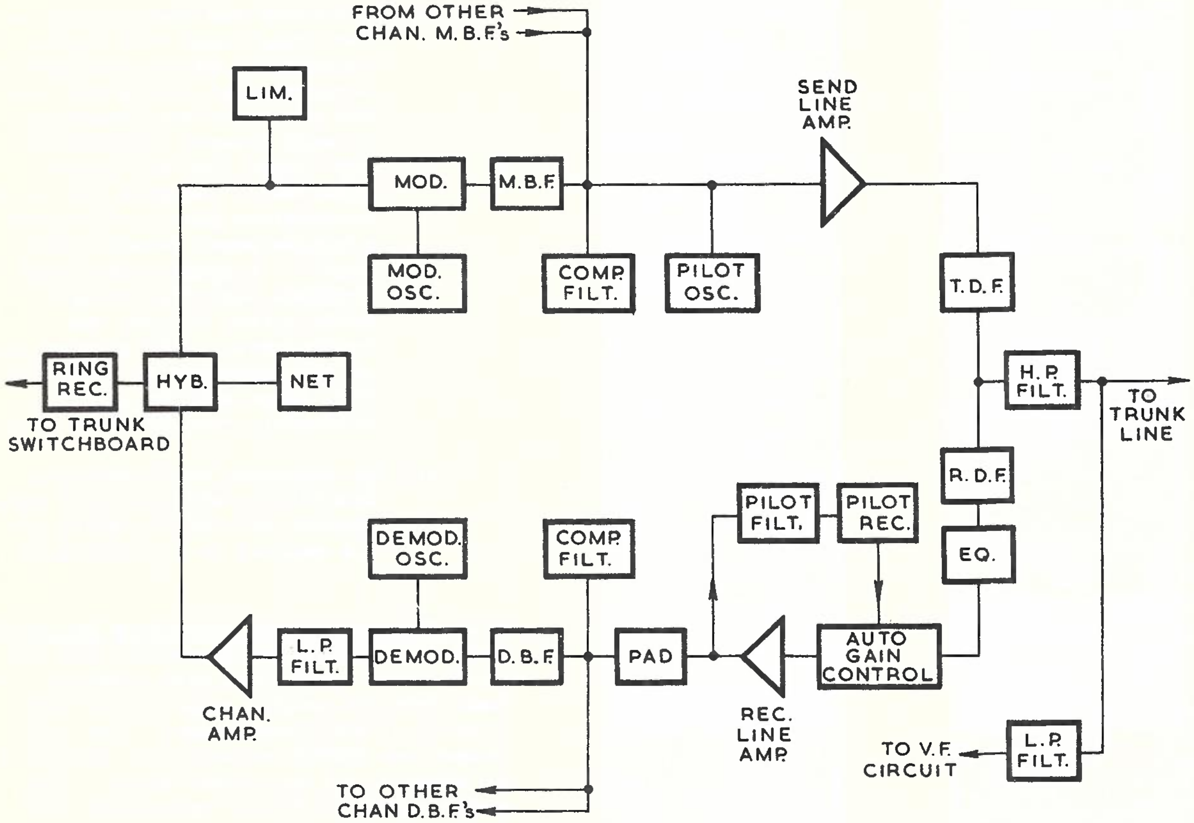
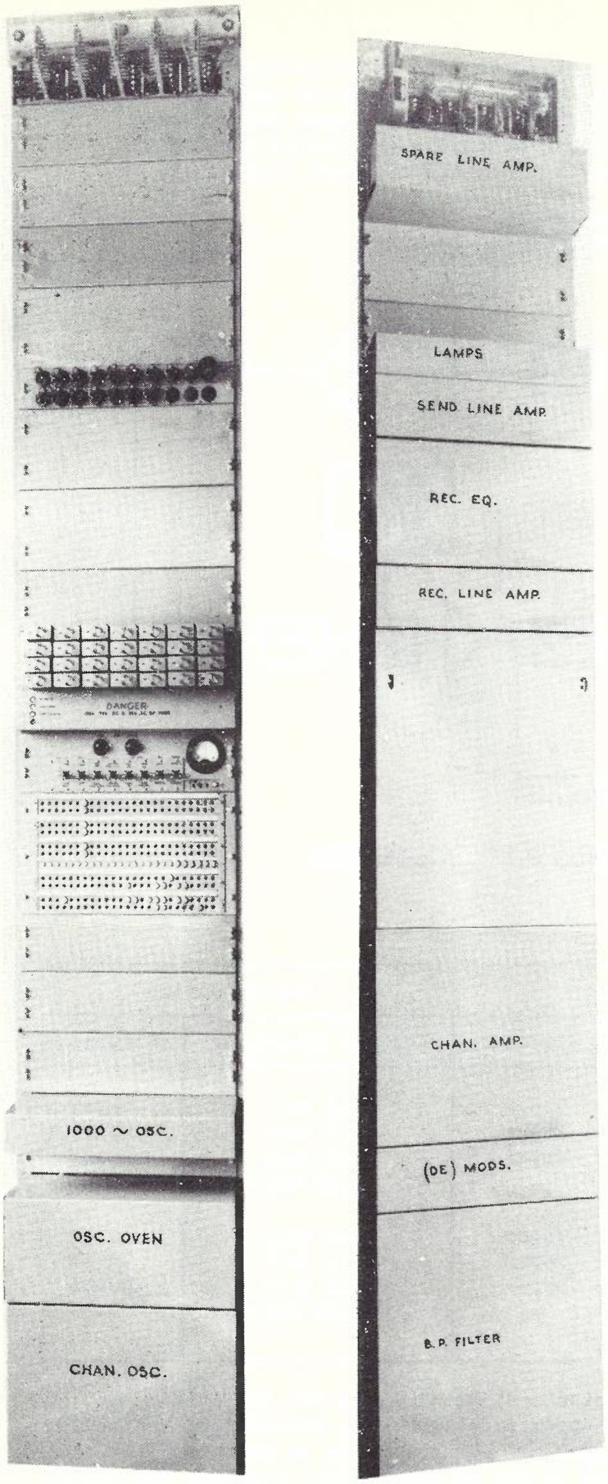


FIG. 10. BLOCK SCHEMATIC OF TYPE S TERMINAL.

11.2 Frequency Allocation.

System	Channel	A-B Direction		B-A Direction	
		Channel Frequency	Sideband	Channel Frequency	Sideband
S.21	1	12.9 kc/s	Upper	24.4 kc/s	Lower
	2	9.4 kc/s	Upper	20.7 kc/s	Lower
	3	6.3 kc/s	Upper	28.4 kc/s	Lower
	Pilot	9.45 kc/s	-	24.35 kc/s	-
S.22	1	14.3 kc/s	Upper	23.7 kc/s	Upper
	2	10.9 kc/s	Upper	19.8 kc/s	Upper
	3	7.7 kc/s	Upper	27.7 kc/s	Upper
	Pilot	10.95 kc/s	-	23.75 kc/s	-
S.25	1	12.9 kc/s	Upper	21.4 kc/s	Upper
	2	9·4 kc/s	Upper	17.7 kc/s	Upper
	3	6.3 kc/s	Upper	25.4 kc/s	Upper
	Pilot	9.45 kc/s	-	21.45 kc/s	-



Front View. Rear View.

TYPICAL TYPE S CARRIER TERMINAL.

11.3 Modulator and Demodulator.

(i) Balanced copper oxide rectifier types are used. A copper oxide rectifier type volume limiter precedes each modulator. A single stage feedback amplifier using a 6V6GT valve follows each demodulator. The maximum gain of this amplifier is 32 db adjustable by means of a potentiometer over a range of 9 db in steps of 1 db. Output power is approximately 60 mW.

(ii) The resonant circuits associated with the modulator and demodulator oscillators are mounted in a thermostat controlled oven, with the relative oscillator valves (6J7G's) mounted immediately below.

11.4 Transmitting and Receiving Amplifiers. These are identical and are of the negative feedback type. Each consists of two stages using 6J7G and 6V6GT valves. Maximum gain is 52 db variable over a range of 9 db in steps of 1 db. Power output is approximately 1 watt.

11.5 Signalling Equipment. A 1,000/17 c/s ringer circuit for each channel is included as an integral part of each terminal.

11.6 Test Equipment. The following test equipment is provided -

(i) A test oscillator providing frequencies of 1,000 c/s and 1,000/17 c/s.

(ii) A rectifier type meter for use as-

(a) A level meter with range -10 to +32 db (reference 1 mW) in 600 ohms.

(b) An ammeter for measurement of filament and anode currents.

11.7 Power Supply. The systems are designed to operate from 24 volts (regulated) and 130 volts D.C. supplies.

/ 12.

12. CU5 AND CS5 SYSTEMS.

12.1 The CU5 and CS5 are the latest American Type C systems made by the Western Electric Company, U.S.A., and replace the CT4 and CS4 systems. They are of recent introduction and include all the advances in circuit design that have taken place during recent years. The C5 systems are equipped with automatic gain pilot regulation. The block schematic circuit of a typical carrier terminal is shown in Fig. 11.

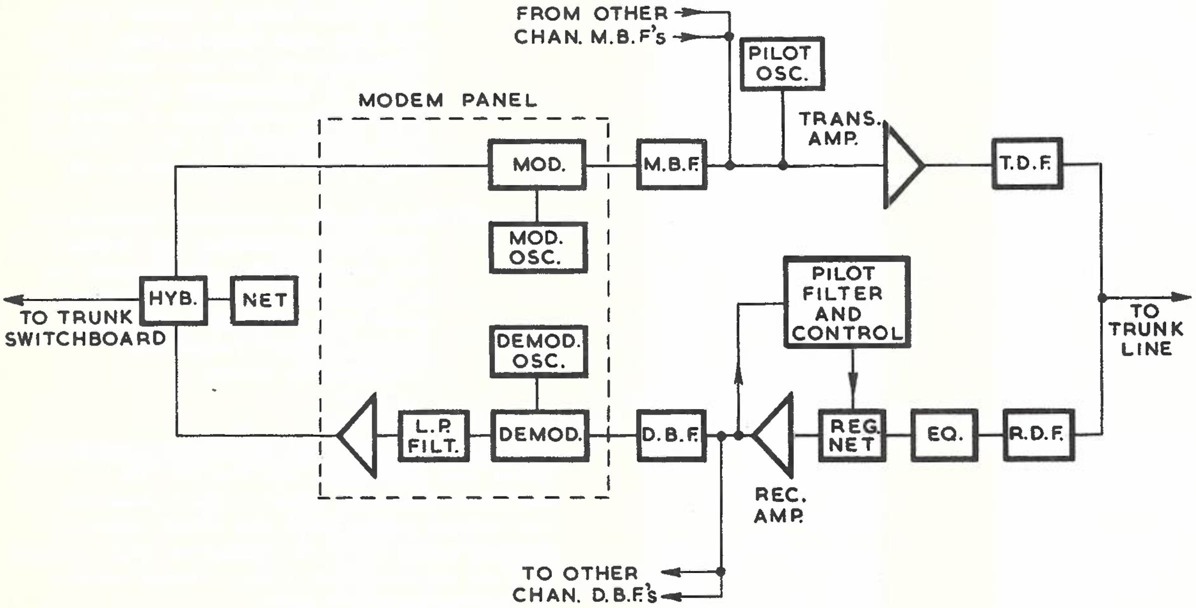


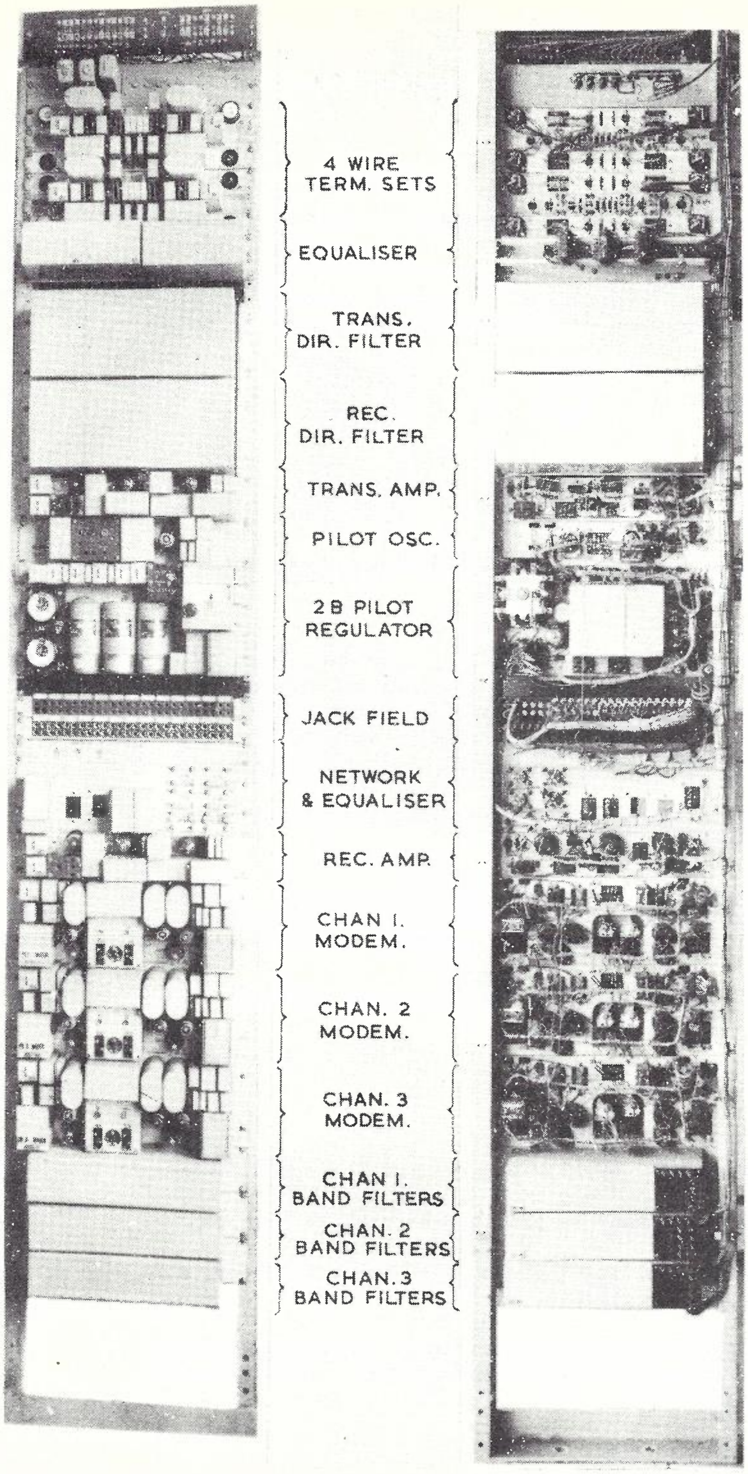
FIG. 11. BLOCK SCHEMATIC OF TYPE CU5 AND CS5 TERMINAL.

12.2 Frequency Allocation.

System	Channel	A-B Direction		B-A Direction	
		Carrier Frequency	Sideband	Carrier Frequency	Sideband
CU5	1 2 3 Pilot	12.9 kc/s 9.4 kc/s 6.3 kc/s 9.45 kc/s	Upper Upper Upper -	21.4 kc/s 17.7 kc/s 25.4 kc/s 21.45 kc/s	Upper Upper Upper -
CS5	1 2 3 Pilot	12.9 kc/s 9.4 kc/s 6.3 kc/s 9. 45 kc/s	Upper Upper Upper -	24.4 kc/s 20.7 kc/s 28.4 kc/s 24.35 kc/s	Lower Lower Lower -

In the B-A direction, the sideband frequencies are identical in the two systems but the carrier frequencies are different, the upper sideband being transmitted in the CU5 system, and the lower sideband in the CS5 system. This results in any crosstalk which occurs between adjacent systems of the CU and CS type being inverted, and therefore, unintelligible.

/ 12.3



Front View.

Rear View.

TYPICAL TYPE CU5 AND CS5 CARRIER TERMINAL.

12.3 Modulator and Demodulator.

(i) Copper oxide modulator and demodulator units with suppressed carrier circuit arrangement, are used. No provision is made for adjustment of carrier leak. The modulator and demodulator units for each channel are mounted on a single panel termed a Modem panel.

(ii) Voltage limiters are not used, but the modulators themselves are designed to have limiting characteristics which prevent the overloading of common amplifiers during loud speech passages. The demodulator is followed by a single stage amplifier using a 328A (or 310A) valve and a low-pass filter. The maximum gain of the demodulator amplifier is 36.5 db and adjustment of gain over a range of 10 db is provided by a variable potentiometer.

(iii) Separate single valve (328A or 310A) oscillators are associated with each modulator and demodulator unit.

12.4 Transmitting and Receiving Amplifiers. These are identical and are of the negative feedback type, having fixed gains of approximately 50 db. Each consists of two stages using a 328A (or 310A) and a 329A (or 311A) valve. Power output is approximately 1.5 watts.

12.5 Signalling Equipment. Signalling equipment is not incorporated in the design of the system, and, when required, it is necessary to provide separate signalling equipment, for example, a 1,000/17 c/s ringing unit.

12.6 Test Equipment. No test equipment is supplied with the system.

12.7 Power Supply. The systems normally operate from 24 volts cathode and 130 volts anode D.C. supplies.

/ 13.

13. SOS AND SOT SYSTEMS.

13.1 Typical SOS and SOT, 3B and 3F carrier terminals made by Standard Telephones and Cables Ltd., England, are shown on Pages 27, 28 and 29.

13.2 Frequency Allocation.

System	Channel	A-B Direction		B-A Direction	
		Carrier Frequency	Sideband	Carrier Frequency	Sideband
SOS	1	12.9 kc/s	Upper	24.4 kc/s	Lower
	2	9.4 kc/s	Upper	20.7 kc/s	Lower
	3	6.3 kc/s	Upper	28.4 kc/s	Lower
SOT	1	14.3 kc/s	Upper	23.7 kc/s	Upper
	2	10.9 kc/s	Upper	19.8 kc/s	Upper
	3	7.7 kc/s	Upper	27.7 kc/s	Upper

13.3 Modulator and Demodulator.

(i) Balanced copper oxide rectifier types are used. A volume limiter normally consisting of a transformer and a neon lamp is connected across the input to each channel modulator. A single stage amplifier using a 4019A valve follows the demodulator. The maximum gain of this amplifier is 27.5 db and it may be adjusted over a small range in 0.5 db steps by a U-link control.

(ii) Separate single valve (4019A) oscillators supply the carrier frequencies to each modulator and demodulator.

13.4 Transmitting and Receiving Amplifiers. These are identical and are of the negative feedback type, having a maximum gain of 50 db. Each consists of three stages using two 4046A valves and a 4045A valve. Power output is approximately 1 watt.

13.5 Signalling Equipment. V.F. ringing equipment is provided at each terminal. The ringing equipment comprises -

(i) A 500 c/s or 1,000 c/s ringer oscillator.

(ii) A ringer test panel.

(iii) Four ringer panels - one for each carrier channel and one spare.

13.6 Test Equipment. The following test equipment is provided at each terminal -

(i) A Transmission Measuring Set comprising an 800 c/s test oscillator, a sending circuit and a receiving circuit.

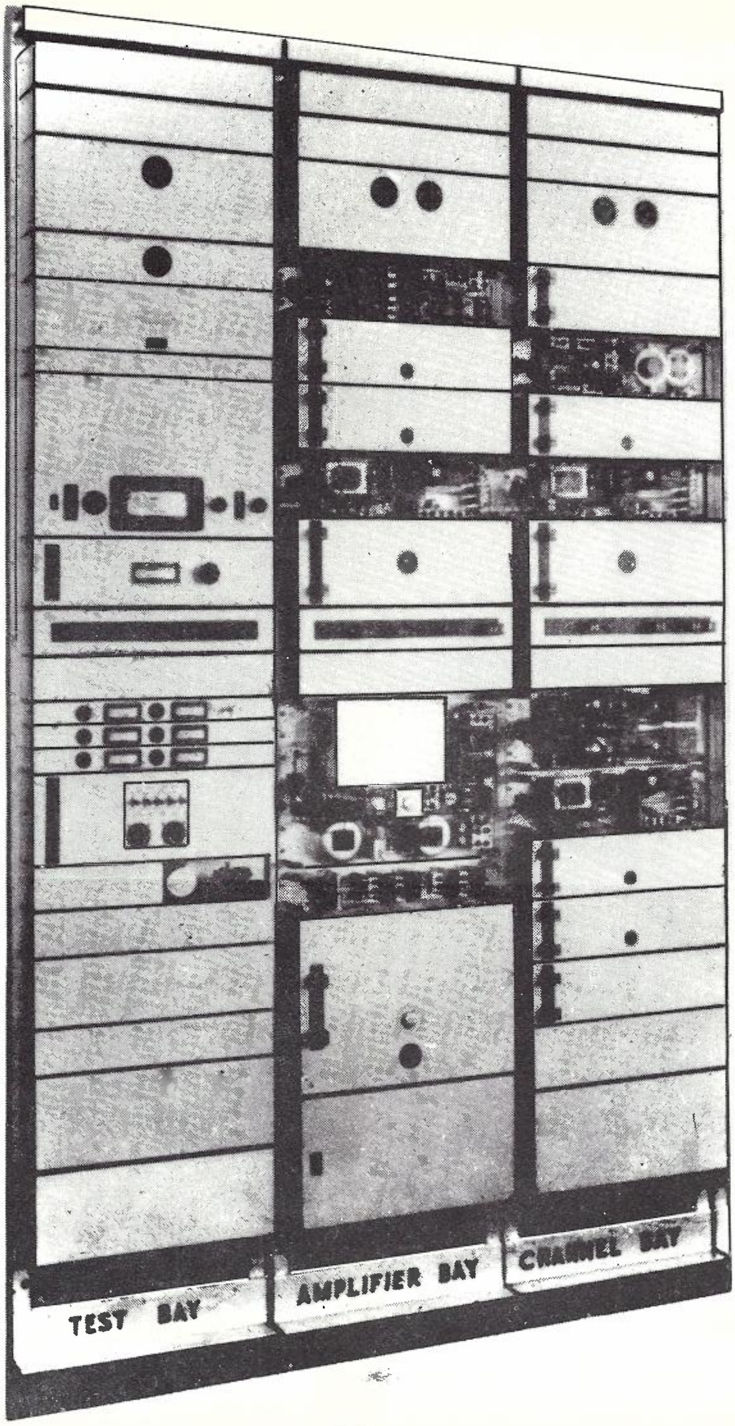
(ii) A meter panel equipped with voltmeters for measuring the various supply voltages, an ammeter for filament current measurements, and a voltmeter arranged to indicate anode currents.

(iii) A telephone for monitoring purposes.

(iv) U-links are provided and mounted on individual panels at all points in transmission circuits to which access may be required for testing purpose.

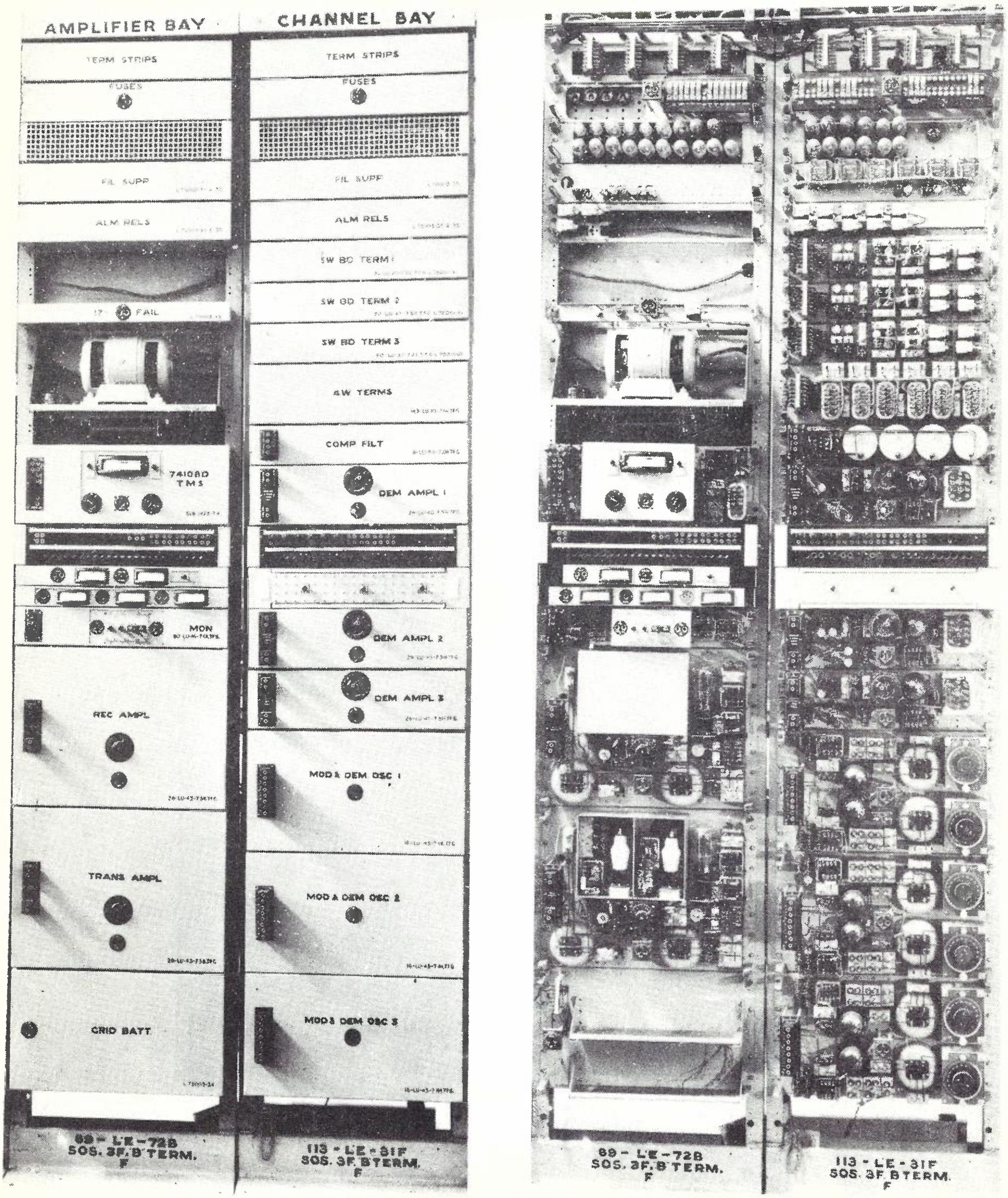
13.7 Power Supply. The systems are designed to operate from 24 volts and 130 volts D.C. supplies.

/ Front

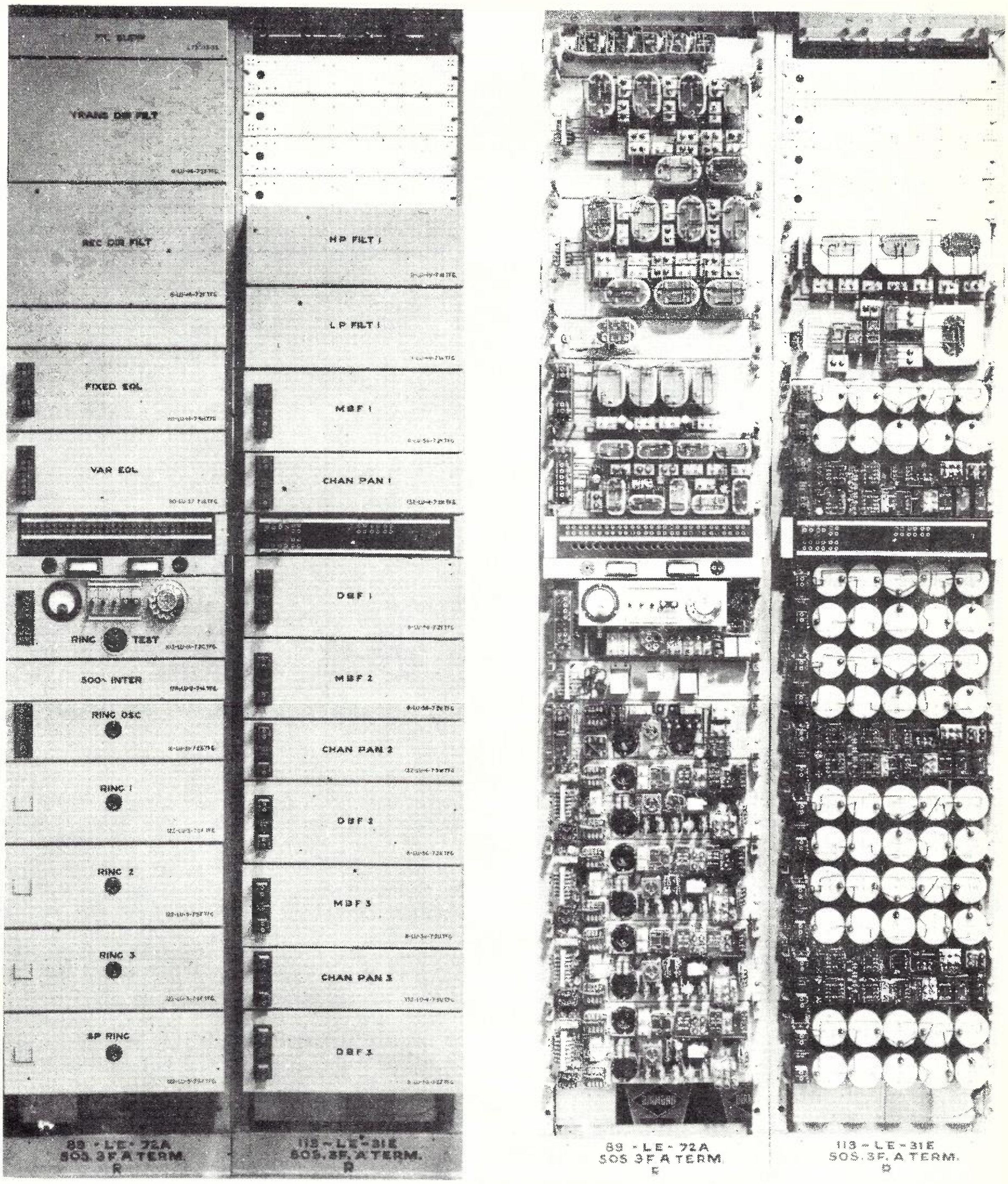


Front View.

TYPE SOS AND SOT 3B CARRIER TERMINAL.



TYPE SOS AND SOT 3F CARRIER TERMINAL. (FRONT VIEW.)



Covers On.

Covers Off.

TYPE SOS AND SOT 3F CARRIER TERMINAL. (REAR VIEW.)

14. SOS, SOT, SOU AND SOV SYSTEMS.

14.1 These systems are made by Standard Telephones and Cables, Ltd., Australia. A number of models of these systems have been installed. These models differ in minor circuit details, but are basically similar.

14.2 Frequency Allocation.

System	Channel	A-B Direction		B-A Direction	
		Carrier Frequency	Sideband	Carrier Frequency	Sideband
SOS	1	12.9 kc/s	Upper	24.4 kc/s	Lower
	2	9.4 kc/s	Upper	20.7 kc/s	Lower
	3	6.3 kc/s	Upper	28.4 kc/s	Lower
	Pilot	9.45 kc/s	-	24.35 kc/s	-
SOT	1	14.3 kc/s	Upper	23.7 kc/s	Upper
	2	10.9 kc/s	Upper	19.8 kc/s	Upper
	3	7.7 kc/s	Upper	27.7 kc/s	Upper
	Pilot	10.95 kc/s	-	23.75 kc/s	-
SOU	1	12.9 kc/s	Upper	21.4 kc/s	Upper
	2	9.4 kc/s	Upper	17.7 kc/s	Upper
	3	6.3 kc/s	Upper	25.4 kc/s	Upper
	Pilot	9.45 kc/s	-	21.45 kc/s	-
SOV	1	12.9 kc/s	Upper	23.7 kc/s	Upper
	2	9.4 kc/s	Upper	19.8 kc/s	Upper
	3	6.3 kc/s	Upper	27.7 kc/s	Upper
	Pilot	9.45 kc/s	-	23.75 kc/s	-

14.3 Modulator and Demodulator.

(i) Balanced copper oxide rectifier types are used. A single stage negative feedback amplifier using a 6SJ7GT (or 328A) valve follows the demodulator.

(ii) Separate single valve (6SJ7GT or 328A) oscillators supply the carrier frequencies to each modulator and demodulator. In later models, quartz crystal oscillators are used to ensure stability of the carrier frequencies.

14.4 Transmitting and Receiving Amplifiers. These are identical and are of the negative feedback type, having a gain of approximately 50 db. Type 6SJ7GT (or 328A) and 6V6GT (or 329A) valves are used. Power output is approximately 1 watt.

14.5 Signalling Equipment. Signalling equipment is not incorporated in the design of the system, and, when required, it is necessary to provide separate signalling equipment, for example, a 1,000/17 c/s ringer unit.

14.6 Test Equipment. No test equipment is supplied with the system.

14.7 Power Supply. The systems are normally designed to operate from 24 volts and 130 volts D.C. supplies.

/ Front

Front View.

Rear View.

Side View.

TYPICAL TYPE SOS, SOT, SOU AND SOV CARRIER TERMINALS.

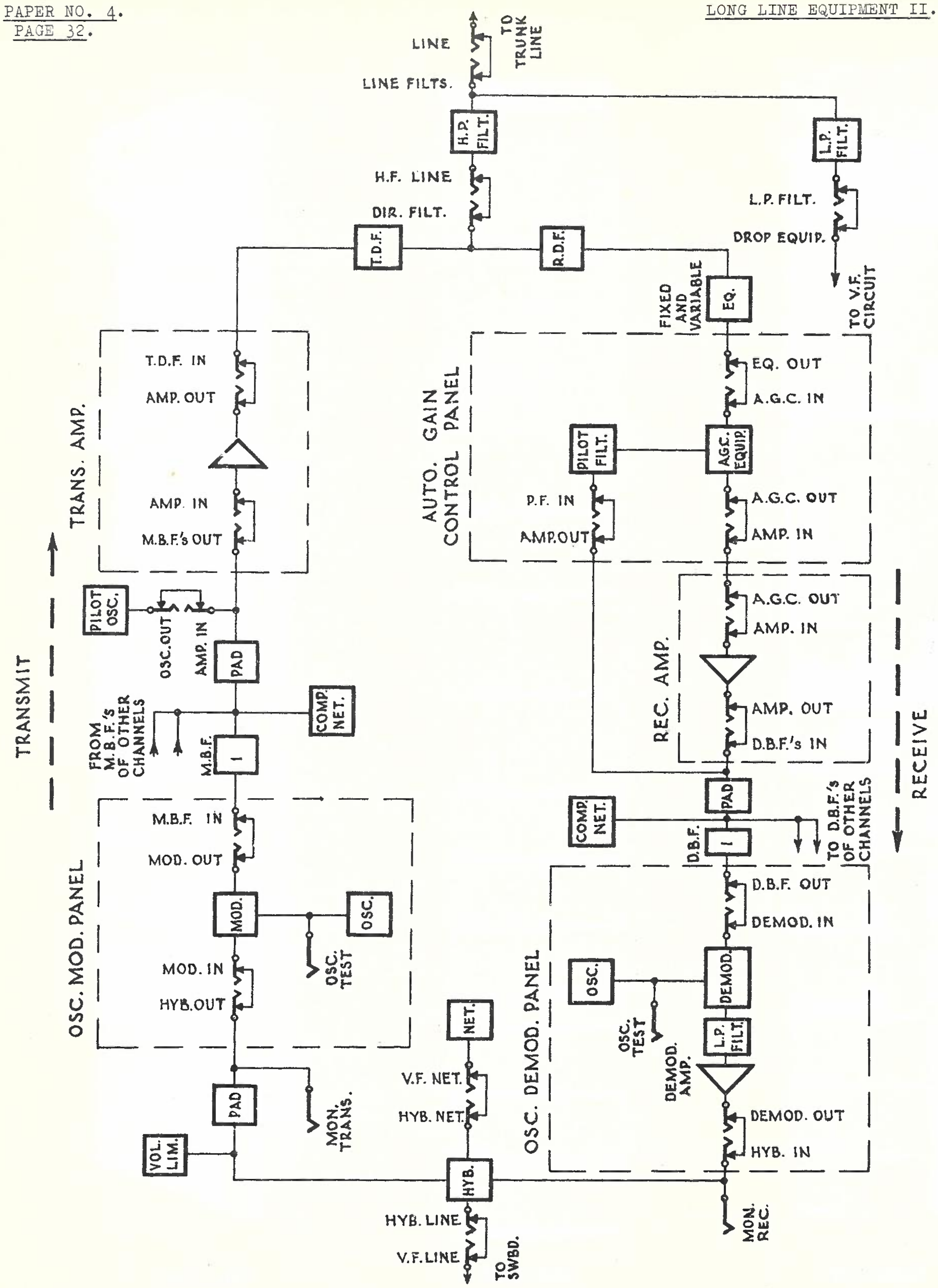


FIG. 12. BLOCK SCHEMATIC OF 3-CHANNEL CARRIER TERMINAL - SOS, SOT AND SOV SYSTEMS.

15. DESCRIPTION OF TYPICAL SOS, SOT AND SOV SYSTEMS.

15.1 A block schematic diagram of the terminal equipment of a typical SOS, SOT and SOV system is shown in Fig. 12.

15.2 Transmitting Direction. Speech currents from the switchboard pass to the line side of the 4-wire terminating set, which divides the current equally between the transmit branch and the receive branch. The current flowing in the receive branch is dissipated in the output transformer of the demodulator amplifier. The current in the transmit branch passes to the input of the modulator. A voltage limiter unit is connected across the modulator input to prevent high peak levels of speech from overloading the modulator and causing distortion. The modulator is the balanced copper-oxide metal rectifier type, and, owing to the nature of circuits of this type, it is necessary to ensure that the incoming speech levels at the rectifiers do not exceed a certain maximum value. For this reason, pads which are suitably adjusted at the time of installation are included at the input to the modulator. The carrier frequency supply to the modulator is obtained from the modulator oscillator, which is a single valve oscillator of high stability. The modulation of the carrier frequency by the speech frequencies takes place in the modulator. The carrier frequency is suppressed in the modulator itself, and the two sidebands produced by the process of modulation are passed from the modulator to the modulator band filter. This filter is designed to pass only one of these two sidebands, either the lower sideband or the upper sideband according to the particular channel. The output of the modulator band filter is connected in parallel with the outputs of the modulator band filters of the other two channels, and also in parallel with a compensating filter. The compensating filter maintains the required impedance conditions at the top and bottom of the frequency range covered by the three modulator band filters. The three sidebands, one corresponding to each of the three channels then pass to a 3 db pad which maintains the desired impedance conditions for the pilot oscillator, which, when required, is connected in the circuit at this point.

The sidebands of the three channels are then amplified by the transmitting amplifier, which is of the feedback type. The gain of this amplifier is adjusted by means of input pads in conjunction with a potentiometer. The gain is set at the time of installation and does not normally require readjustment. The three sidebands thus amplified then pass to the transmitting directional filter, the function of which is to separate the transmitting circuit from the receiving circuit. In the case of the A terminal, the transmitting directional filter is a low-pass filter passing the lower group of sidebands, and the receiving directional filter is a high-pass filter passing the upper group of sidebands. At the B terminal, these filters are interchanged. From the transmitting directional filter, the sidebands pass to the high-pass line filter, passing all frequencies above the voice range, and so to line. Connected in parallel with this high-pass line filter on the line side is the low-pass line filter passing only frequencies in the voice range. These two filters separate the carrier frequencies from the normal speech frequencies on the open-wire line, and are designed to prevent any appreciable interference between the carrier channels and the audio-frequency circuit. The directional filters and line filters, which are connected directly in the open-wire line circuit, are balanced with respect to earth.

Receiving Direction. On arrival at the distant terminal (see receiving section of Fig. 12), the carrier sidebands pass through the high-pass line filter to the receiving directional filter, which is the same as the transmitting directional filter at the distant terminal. From the receiving directional filter, the carrier sidebands pass to fixed and variable equalisers. These equalisers compensate for any distortion introduced by the frequency characteristics of the receiving directional filter and the transmitting directional filter of the other terminal, and also compensate for the attenuation-frequency characteristic of about 100 miles of open-wire line over the band of frequencies covered by the receiving terminal in question. Depending on the length and characteristics of the open-wire line section preceding any terminal, the setting of these equalisers is adjusted at the time of installation, and, subsequently, at such times as seasonal changes occur, to maintain the level of all channels substantially equal at the input to the receiving amplifier.

/ When

When automatic pilot control is not equipped, the output of the equalisers is connected to the receiving amplifier. This amplifier is similar to the transmitting amplifier. After amplification, the three sidebands are taken through a 6 db pad to the three demodulator band filters, the inputs of which are connected in parallel. The receiving pilot indicator or filter circuit, when equipped, is connected across the output of the receiving amplifier in front of the 6 db pad, this pad being provided to maintain the necessary impedance conditions for the pilot circuit. Connected in parallel with the inputs of the three demodulator band filters is a compensating network, which fulfils a similar function to the compensating network in parallel with the modulator band filters.

Each demodulator band filter selects the sideband associated with its particular channel, and the sideband so selected passes to the copper oxide demodulator which is similar to the modulator. The carrier frequency, which is in synchronism with the frequency of the modulator oscillator of the corresponding channel at the distant terminal, is supplied to the demodulator from the demodulator oscillator which is similar to the modulator oscillator. The demodulator reproduces, among other products of demodulation, the original speech frequencies. A low-pass filter in the output of the demodulator allows only the reproduced speech frequencies to pass on to the demodulator amplifier. This amplifier is a single stage V.F. amplifier, and is required since, by the nature of copper-oxide demodulator circuits which must operate at low levels, the level of the speech frequencies at the output of the demodulator is low. The output of the demodulator amplifier is applied to the receive side of the 4-wire terminating set, where the current divides equally between the line and network sides. The energy transferred to the line side of the terminating set is passed to the trunk switchboard.

Two variable gain controls for normal maintenance purposes are provided in the receiving circuit to compensate for variation of transmission equivalent of the open wire line with varying weather conditions. The gain control on the receiving amplifier covers a range of 20 db, in steps of 2 db, and adjusts the level on all channels simultaneously. A control individual to each channel is provided on the demodulator amplifier covering a range of 10 db in steps of 1 db, which adjusts for the difference in attenuation variations of the open-wire line at the different sideband frequencies.

15.3 Four-Wire Terminating Unit. The function of this unit is to connect the 4-wire carrier channel to the 2-wire line from the trunk switchboard. The equipment and circuit arrangement is similar to the 4-wire terminating unit in the SOA and SOB single channel system described in Paper No. 3.

15.4 The Monitoring Circuit comprises two monitoring coils, one connected across the transmitting branch and the other across the receiving branch of the carrier channel. These monitoring circuits are connected to a jack, and, by connecting the jack to the monitoring circuit provided on the test bay, it is possible to monitor, speak and ring on the carrier channel.

15.5 The Voltage Limiter, consisting of a transformer and neon lamp is connected across the modulator input. The function of the limiter is to keep the input to the modulator from exceeding a certain value, irrespective of the level received from the switchboard. The action of the limiter is similar to that described in Paper No. 3 for the SOA and SOB single channel systems.

15.6 Oscillator-Modulator. In early models of the SOS and SOT systems, the modulator, demodulator and demodulator low-pass filter for a particular carrier channel, were mounted on a single panel. In later models, the modulators and demodulators are mounted on separate panels together with their respective oscillators. A schematic circuit of an oscillator-modulator panel, which mounts the modulator and associated oscillator for a particular channel is shown in Fig. 13.

The modulator unit comprises an input pad, an equaliser, the modulator proper, and an output pad, with jack access to both input and output. The operation of the modulator circuit is similar to that described in Paper No. 3 for the SOA and SOB systems. The output of the modulator includes an unbalanced 600 ohms pad to provide a loss which compensates for the varied losses of the different equalisers' settings for each channel, thus allowing all channels to be lined up to the same transmitting gain.

The oscillator is of the tuned anode type and the unit is designed to have high frequency stability with variation of temperature, battery supplies and valve changes.

/ Fig. 13

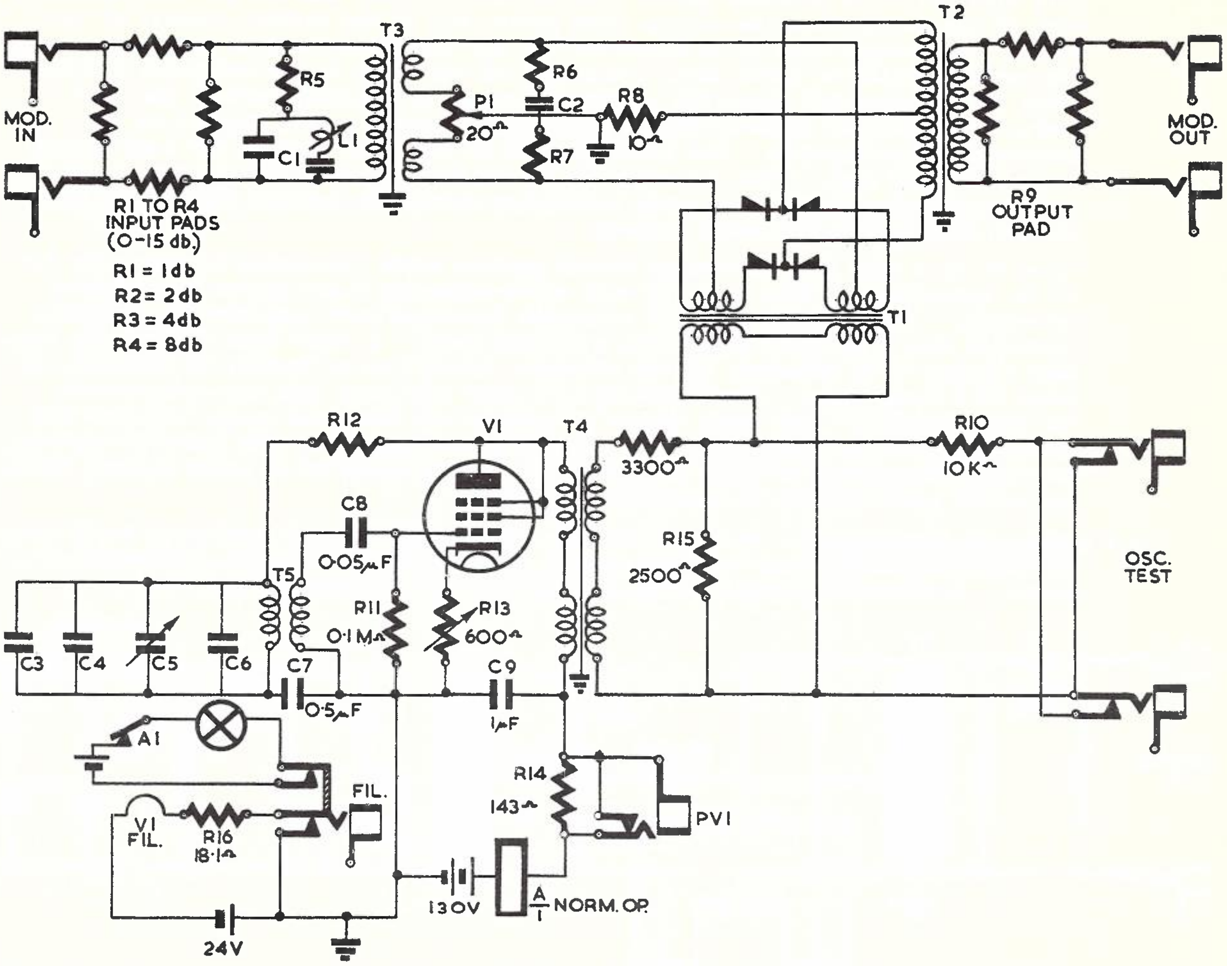


FIG. 13. OSCILLATOR-MODULATOR CIRCUIT. (SOS, SOT AND SOV SYSTEMS).

The oscillations generated by valve V1 and associated apparatus are applied to -

(i) The modulator via the output transformer T4, and
(ii) The oscillator coil T5 via the feedback resistor R12. The return path for the oscillatory currents to the cathode is via C7. This capacitor prevents the flow of D.C. from the anode battery via T5.

Capacitors C3, C4, C5 and C6 and a winding of transformer T5 form the tuned circuit, which is set to the required frequency by adjustment of the capacitor values. The oscillations are applied to the grid of V1 via transformer T5. The amount of energy fed back is adjusted by resistor R12 to a value necessary to maintain oscillation without overloading the valve. The tuning capacitors consist of -

(i) C6, a fixed mica type, which has a different capacitance for differing carrier frequencies.
(ii) C3 and C4, multi-unit mica types, which are strapped to adjust for correct frequency.
(iii) C5, a variable air type for fine tuning adjustment. This capacitor is provided with a locking device, so that it cannot be accidentally altered when set.

/ Grid

Grid bias for V1 is obtained partly from the grid current through R11 in conjunction with C8 and partly from the voltage drop across R13 in the cathode circuit of the valve. The output from T4 is connected via the resistance network R15 to the load, the impedance of which is 5,000 ohms, consisting of the input to the modulator (10,000 ohms) and resistor R10 connected across the output in conjunction with the test jacks. The cathode resistor R13 is variable to provide a fine control on the intensity of oscillation. The normal output is 5 mW into each of the load impedances of 10,000 ohms. The capacitor C9, in conjunction with the inductance of the anode alarm relay provides an anode decoupling circuit to prevent the passage of carrier frequency to the anode battery.

Valve V1 is a type 328A indirectly heated pentode valve (connected in this case for triode operation). This is a 7.5 volt valve requiring 0.425 ampere for filament operation. The filament of V1 is connected in series with resistor R16 to enable operation from a 24 volts supply via a ballast lamp. A "FIL" jack enables the filament current to be measured, or the filament circuit to be opened, if required, by means of a dummy plug. The insertion of a plug into this jack also disconnects the alarm circuit. The anode supply is applied via the alarm relay, resistor R14 associated with the jack PV1, and the output transformer T4. The jack PV1 enables percentage deviations of anode current to be read by means of an anode current meter. The normal anode current is approximately 4 mA.

15.7 Oscillator-Demodulator. On later systems, the demodulator and associated oscillator, and demodulator amplifier for each channel are mounted on an oscillator-demodulator panel. A schematic circuit of the demodulator unit is shown in Fig. 14.

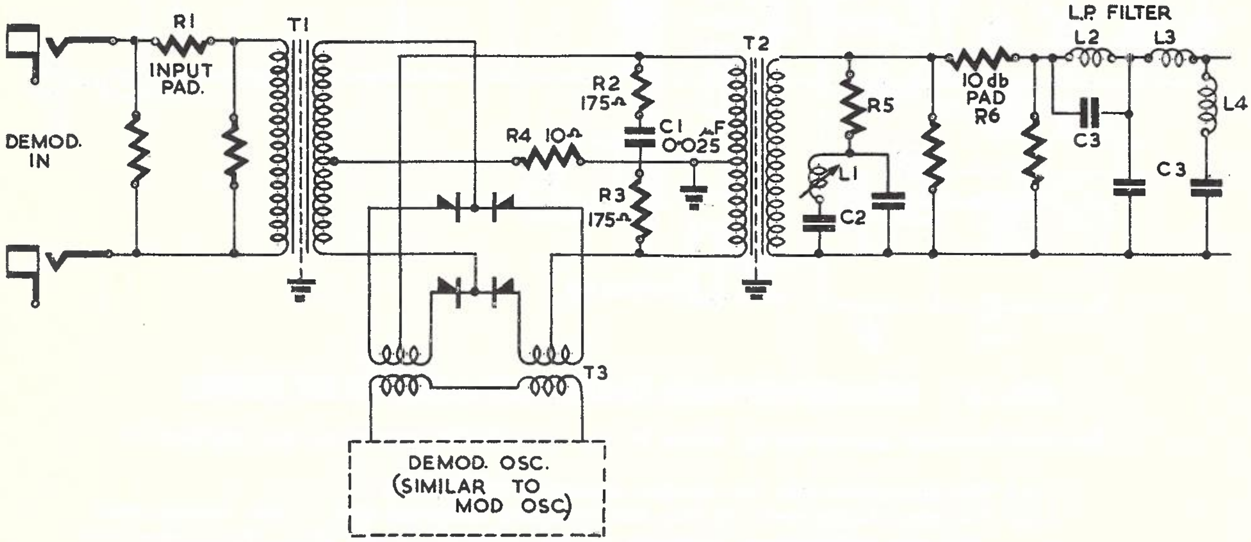


FIG. 14. OSCILLATOR-DEMODULATOR CIRCUIT (SOS, SOT AND SOV SYSTEMS.).

The demodulator unit comprises an input pad, the demodulator proper, the demodulator equaliser and output pad, and the demodulator low-pass filter, with jack access at the input. The operation of the demodulator circuit is similar to that described in Paper No. 3 for the SOA and SOB systems. The input of the demodulator includes an unbalanced 600 ohm pad, the value of which varies for each channel and adjusts the various channel levels to the correct input value.

The demodulator oscillator is identical with the modulator oscillator, subject to different designation of components due to the frequency difference between the two circuits, and the description previously given applies also in this case. The only circuit difference is that the filament of the oscillator valve V1 is connected in series with the filament of the amplifier valve V2 and not in series with a resistor as before.

/ 15.8

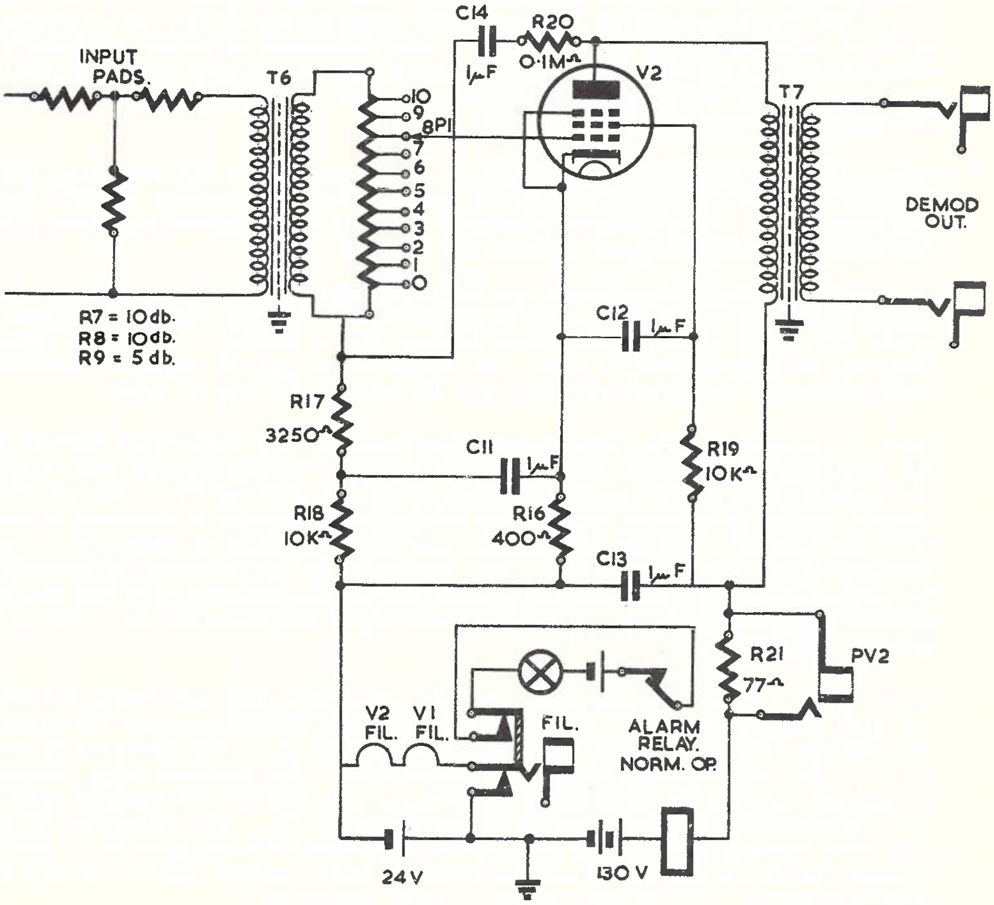
15.8 Demodulator Amplifier. The demodulator amplifier, which follows the demodulator low-pass filter, is mounted on the oscillator-demodulator panel, and consists of a single stage of amplification using a 328A valve and incorporating negative feedback. The input and output impedances of the amplifier are 600 ohms and the maximum gain is approximately 38 db. A schematic circuit of the amplifier is shown in Fig. 15.

The input is applied to the primary of transformer T6 via pads R7, R8 and R9 which may be adjusted by strapping, between 0 db and 25 db in steps of 5 db. The pads adjust the output level of the channel to the correct level during installation.

A gain control P1, adjustable in 10 steps of 1 db, is connected across the secondary of T6. This control enables the gain of the individual channel to be adjusted during line-up conditions. The moving arm of P1 is connected to the grid of valve V2, and the amplified signals pass via the output transformer T7 to the output jacks.

The feedback voltage is fed from the anode via R20 and C14, to R17 in the grid circuit. The grid bias voltage is obtained as a voltage drop across R16 and is supplied to the grid through the resistor-capacitor combination R18 and C11.

Jacks are provided to enable measurement of the filament and anode currents. The current drain of the panel is 0.45 ampere at 24 volts and approximately 10 mA at 154 volts.



DEMODULATOR AMPLIFIER CIRCUIT (SOS, SOT AND SOV SYSTEMS).

FIG. 15.

15.9 Modulator and Demodulator Band Filter. These filters are required to separate the sideband required for transmission from the other unwanted products of modulation, and to direct the different sidebands into their appropriate demodulators at the receiving end. They are three section band-pass filters of the unbalanced type, and consist of a number of series and shunt resonant units. The modulator band filter of each channel at one terminal is identical with the demodulator band filter of the same channel at the other terminal.

Each resonant unit consists of a toroidal coil and mica capacitor mounted together in a copper case. In order to compensate for manufacturing variations, a trimmer capacitor is connected across the main capacitor. After they have been resonated, the units are sealed. The copper case serves as one terminal of the resonant unit, and these units are, therefore, mounted on insulated bushes. It is important not to earth the units by loose screws, solder spots, etc.

The filters offer a loss of 2-4 db at the middle of the wanted sideband, and at the carrier frequency of the channel the loss increases to 15-20 db.

15.10 Compensating Filter. When two filters with cut-off frequencies adjacent are connected in parallel, the effect of each filter on the other is to sharpen the cut-off and improve the characteristics of each filter. When the band filters of three channels are connected in parallel, both upper and lower cut-off points of the middle filter are sharpened, but only the lower cut-off of the highest frequency band filter and the upper cut-off of the lowest frequency band filter are sharpened by the middle filter. To correct for this lack of symmetry, the compensating filter is connected in parallel with the three band filters. The compensating filter consists of two resonant units, one of which resonates at a frequency above the range of the three band filters and the other at a frequency below the range, with resultant correction of the upper and lower filter characteristics.

15.11 Transmitting and Receiving Amplifiers. The transmitting and receiving amplifiers are identical and are designed to amplify the sideband frequencies of all three channels simultaneously. A simplified schematic circuit of a typical amplifier, which is of the negative feedback type, is shown in Fig. 16.

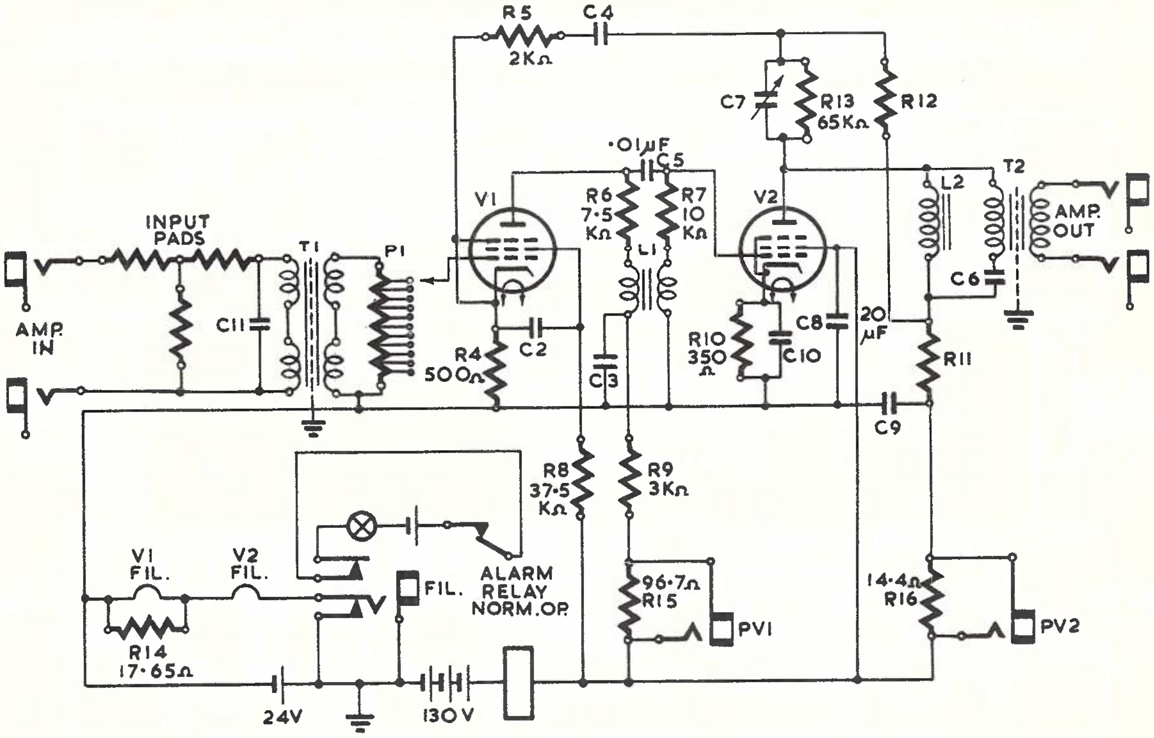
The input and output impedances are both 600 ohms, the input being unbalanced and the output balanced. The frequency range is from 6-35 kc/s, the maximum gain approximately 50 db and substantially flat between these limits. The power handling capacity is approximately 1 watt, and owing to the use of negative feedback, the intermodulation products are small and the gain stability is good.

Valve V1 is a type 328A voltage-amplifier pentode with indirectly heated cathode. The grid bias is obtained from the anode current flowing through the resistor R4 in the cathode lead and is applied through P1 to the grid of V1. The positive high tension supply is applied through the winding of a relay, a resistor R15 associated with the jack PV1, the decoupling resistor R9, a winding of inductor L1, and the resistor R6 to the anode of V1. The capacitor C3 and resistor R9 provide an anode decoupling circuit. The screen voltage for V1 is obtained from the positive high tension supply through the relay mentioned above and resistor R8. C2 is the screen by-pass capacitor.

Valve V2 is a type 329A low-power pentode amplifier with indirectly heated cathode. The grid bias is obtained from the anode current flowing through the resistor R10 in the cathode lead and is applied through a winding of L1 and resistor R7 to the grid of V2. C10 is a by-pass capacitor across R10. The positive high tension supply is applied through the winding of a relay, a resistor R16 associated with the jack PV2, resistor R11 and inductor L2 to the anode of V2. The capacitor C6 prevents D.C. from flowing through the winding of the output transformer T2. The screen voltage for V2 is obtained from the positive high tension supply through the relay mentioned above. C8 is the screen by-pass capacitor.

/ The

The incoming signals, after passing through the input pads, enter the shielded input transformer T1, the secondary of which is terminated in the potentiometer P1. The input pads and potentiometer P1 enable the gain of the amplifier to be varied. P1 is variable in 10 steps of 2 db. After being stepped up in voltage by T1, the signals are applied to the grid of valve V1. The incoming signals are amplified in the valve V1, and passed to the grid of valve V2 through the coupling circuit consisting of the two-winding coil L1, the resistors R6 and R7 and the capacitor C5. This capacitor prevents the D.C. anode voltages on V1 from being applied to the grid of V2 and allows the signal frequencies to pass freely. For the purpose of obtaining the feedback voltage, an output bridge is used, the four arms consisting of the cathode-anode path of V2, R13 and C7 in parallel, R12, and R11 and C9 in series. C7 is made adjustable for the purpose of setting the output impedance accurately during manufacture. This capacitor is set in the factory and is not altered after installation. The output transformer T2 (in series with C6) is connected across one pair of diagonals of the bridge formed by these four impedances, while the feedback voltage is taken across the opposite pair of diagonals. Thus, the feedback voltage is taken across the two points consisting of the junction of R12 and R13, and the L.T. negative, which is the common point of the amplifier and is connected directly to the bottom end of R4. The point of junction between R12 and R13 is connected through the feedback capacitor C4 and resistor R5 to the junction of R4 and the cathode of V1. The feedback voltage set up across the diagonals of the output is, therefore, applied across the resistor R4.



TRANSMITTING AND RECEIVING AMPLIFIER CIRCUIT (SOS SOT AND SOV SYSTEMS).

FIG. 16.

The positive terminal of the 24 volts battery and the negative terminal of the 130 volts battery are earthed. A total voltage of 154 volts is, therefore, available between the positive 130 volts and negative 24 volts terminals for anode voltage supply. The filaments of the two valves are connected in series, but owing to the difference in the filament currents, it is necessary to shunt the filament of V1 with a resistor R14. The total current drain of the amplifier is 0.85 ampere at 24 volts and about 50 mA at 154 volts.

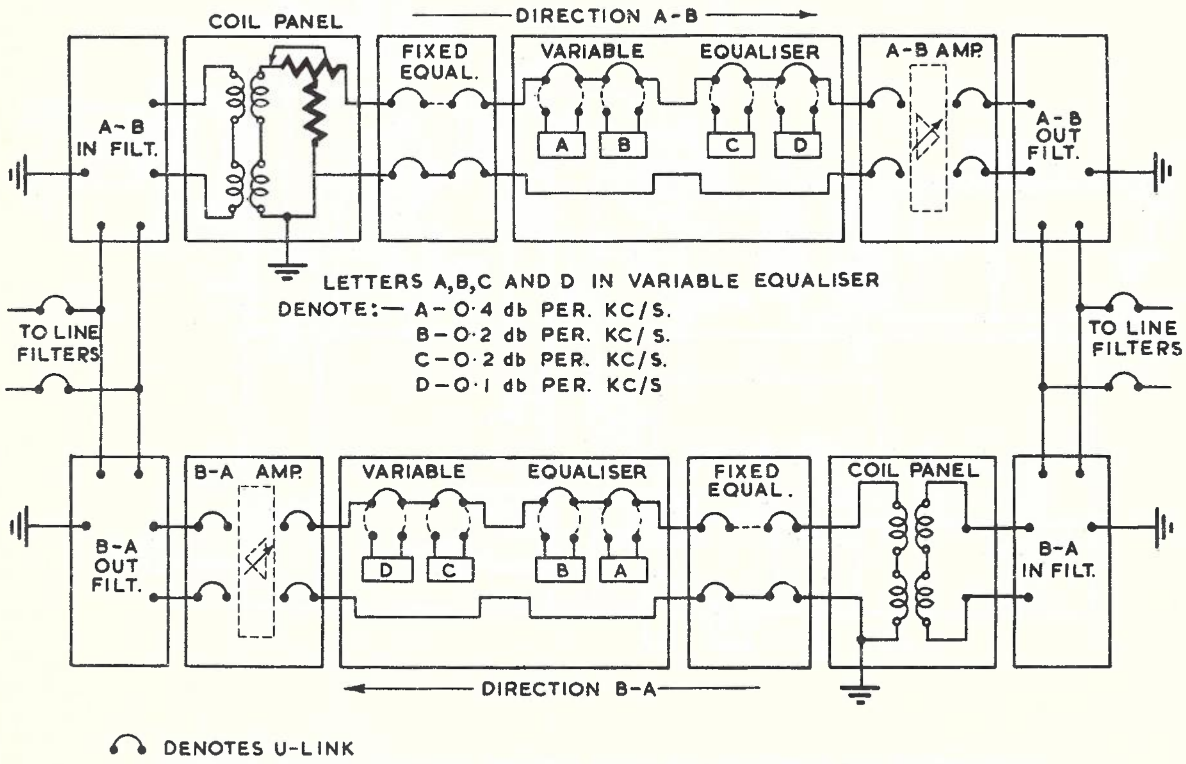
The resistors R15 and R16 associated with the jacks PV1 and PV2 enable percentage deviations of anode current to be read by means of cord connection to an anode current indicator, which is a 1,000 ohm voltmeter, range 0-1 volt. The resistors are designed so that with normal anode current flowing, a voltage drop of half a volt occurs across the resistor, and this provides a mid-scale deflection on the meter. Current deviations, high and low, cause corresponding changes in the voltage drop, and consequently in the deflection.

The anode currents of V1 and V2 flow through the alarm relay in the H.T. circuit. This relay indicates failure of heater or anode supplies or of valves, as well as providing decoupling for the H.T. supply in conjunction with capacitor C8. Under normal conditions, the relay is operated. When the relay releases due to valve or supply failure, a circuit is completed to the alarm circuit.

15.12 Directional Filters and Line Equalisers. The functions of these items are similar for both terminal and repeater equipment, and are discussed in Section 16.

16. REPEATER CIRCUIT DESCRIPTION.

16.1 A typical block schematic of the repeater equipment for the SOS and SOT systems is shown in Fig. 17, and photographs of typical repeater station equipment on Page 42.



BLOCK SCHEMATIC OF TYPICAL SOS AND SOT CARRIER TELEPHONE REPEATER.

FIG. 17.

Considering the A-B direction of transmission at the repeater, the carrier sidebands transmitted over the line from the A terminal reach the A side line filter set (not shown in Fig. 17). These filters are similar to the corresponding high and low-pass line filters at the terminals, and direct the carrier sidebands to the carrier repeater, whilst separating the audio physical circuit. The carrier sidebands are then applied to the two directional filters connected in parallel. These directional filters separate the groups of sidebands transmitted in the two directions and are similar to the directional filters at the carrier terminals. Since the A-B direction of transmission uses the lower groups of frequuencies, the A-B IN directional filter is a low-pass filter, whilst the B-A OUT directional filter is a high-pass directional filter.

The A-B frequencies pass via the A-B IN filter to fixed and variable equalisers. These equalisers are similar to those equipped on the receiving side of the carrier terminal. The equalisers compensate for the attenuation-frequency characteristic of the preceding open-wire trunk line section, so that the level of the sideband corresponding to each of the three carrier channels is substantially the same at the input of the amplifier which follows the last equaliser. When automatic pilot channel equipment is supplied, a variable attenuator is introduced between the last equaliser and the input of the amplifier. The amplifier is of the same type as the terminal transmitting or receiving amplifiers and has the same arrangement for gain adjustment. When a Pilot Indicator is installed, it is bridged across the output of the amplifier. The amplified carrier sidebands are then applied to the A-B OUT directional filter, which has a similar frequency characteristic to the A-B IN directional filter, and so to the B side high-pass line filter and to line.

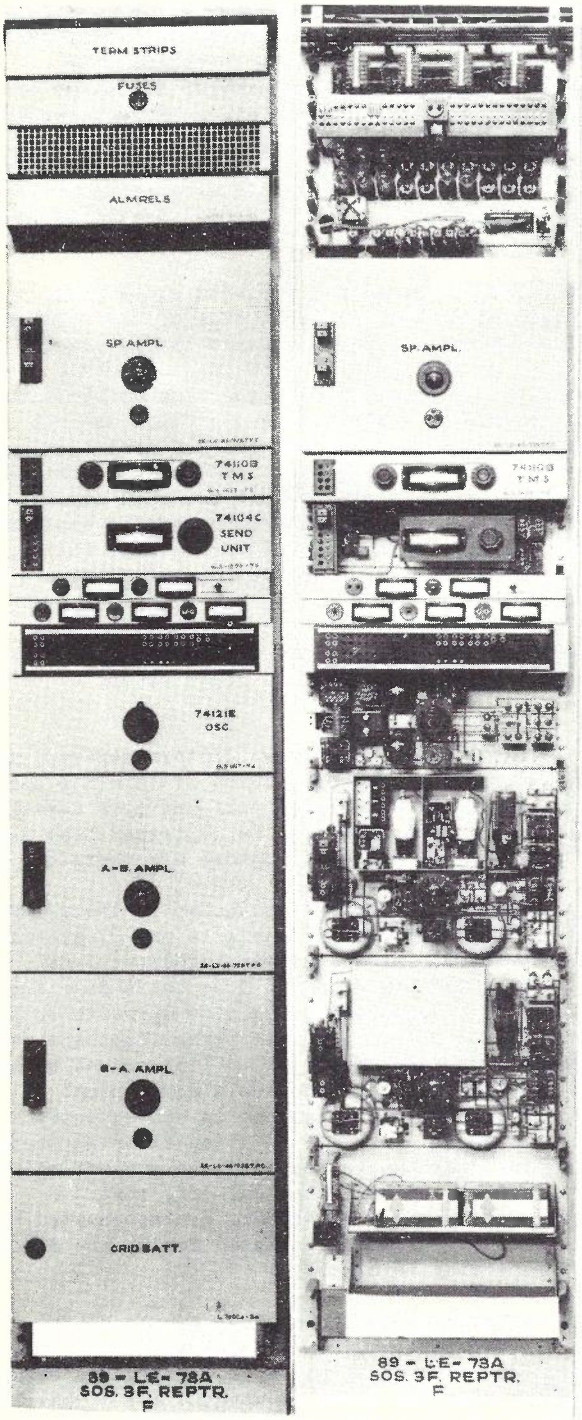
The transmission path in the B-A direction is exactly similar, except that, in this case, the directional filters are high-pass filters passing the upper groups of sidebands to the B-A direction.

16.2 Transmitting, Receiving and Repeater Directional Filters. These filters separate the high and low groups of sidebands for each direction of transmission at terminal and repeater stations, and consist of assemblies of air-cored inductors and mica capacitors. Since the filters each pass three sidebands simultaneously, it is important that intermodulation between the sidebands is avoided, and air-cored inductors are therefore used.

The filters are designed to have a very low attenuation to frequencies in their respective pass ranges, in order not to reduce the level of the sidebands to any great extent. This aspect is particularly important in the case of the transmitting directional filters and the repeater output filters, since the power output from the amplifiers preceding them is limited and it is desirable to transmit the carrier currents to line at approximately the maximum output, in order to obtain the best signal-to-noise ratio for a given line attenuation. Any serious reduction of output to line caused by the directional filters must be compensated by extra gain at the receiving terminal in order to obtain the same overall equivalent, and any interference is consequently amplified to a greater extent if the filters do not possess low attenuation in the pass range. Owing to the curvature of the filter characteristics near the cut-off points, frequencies in the sideband immediately adjacent to the filter cut-off, that is, channel 1 in the A-B direction and channel 2 in the B-A direction, are attenuated more than those of the other two sidebands. This effect is compensated for by the fixed equaliser at the succeeding repeater or receiving terminal.

16.3 Fixed Line Equalisers. The equalisers are connected on the equipment side of the receiving directional filter at the carrier terminal, and on the equipment side of the input directional filter in each direction at the carrier repeater. They are designed to compensate for the attenuation distortion over the lower or upper group of carrier sidebands, introduced by directional filters and line filters of the system, together with 100 miles of average open wire aerial line.

/ Type



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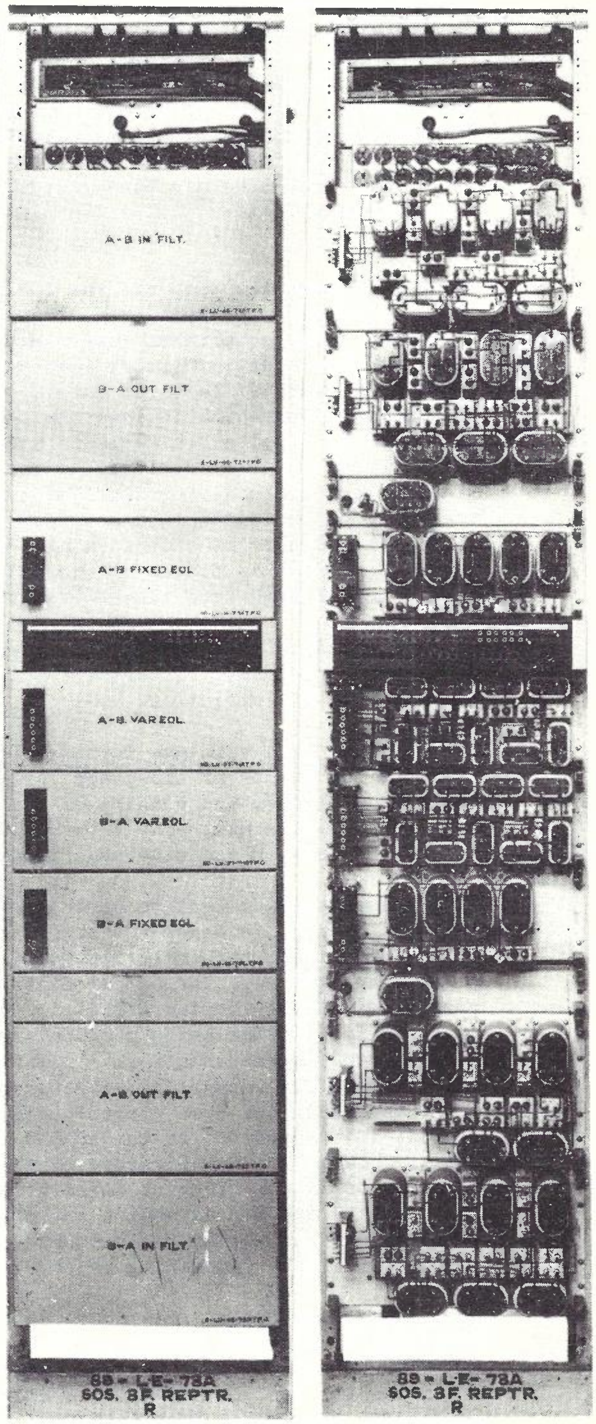
TYPE SOS 3F CARRIER REPEATER.

(FRONT VIEW.)



Covers On. Covers Off.

TYPE SOS 3F CARRIER REPEATER.

(REAR VIEW.)

Considering the transmission of sidebands through the carrier system at each terminal, the channel levels at the output of the transmitting amplifier are substantially equal for all three channels. After this point, a certain amount of attenuation distortion is introduced by the transmitting directional filter over the sideband nearest to its cut-off point. A similar distortion is introduced at the input of the first repeater by the input directional filter. The effect of this distortion is annulled by the fixed equaliser following the input directional filter at the first repeater. Similarly, the fixed equaliser at the second repeater compensates for the distortion of the output filters of the preceding repeater and its own input filters. At the distant terminal, the fixed equaliser compensates for the output filters of the last repeater and its own receiving filters. The attenuation distortion introduced by 100 miles of line (considered the minimum repeater section occurring in practice) is also annulled by these equalisers. Variable equalisers follow the fixed equaliser at each terminal and repeater to compensate for the attenuation distortion of the remainder of the repeater section. By this means, the input and output levels on all channels at each terminal and repeater amplifier are made substantially equal.

The fixed equalisers consist of assemblies of inductance, resistance and capacitance networks and, for reasons discussed above, differ for each type of system. These equalisers also differ in the A-B direction dependent on whether 3 kc/s or 5.6 kc/s line filters are used. Since the equalisers are unbalanced networks with respect to earth, it is necessary to insert a screened repeating coil between these equalisers and the directional filters which are balanced to earth. This coil is included on the equaliser panel.

16.4 Variable Line Equalisers. These equalisers are provided between the fixed line equalisers and the input of the receiving amplifier at the terminals, and between the fixed line equalisers and amplifiers in each direction at the repeaters. In conjunction with the fixed line equaliser, they compensate for the attenuation distortion introduced by the line section immediately preceding the terminal or repeater. These equalisers, which have substantially straight line characteristics, are adjustable in steps of 0.1 db per kc/s. Four equaliser sections consisting of inductance, resistance, and capacitance networks are provided on each panel. The variable equalisers are unbalanced networks with respect to earth.

17. TEST QUESTIONS.

1. What is the reason for the difference in frequency allocations in the B-A direction of certain 3-channel carrier telephone systems?

2. Why is it generally unnecessary to "stagger" the frequencies in the A-B direction of 3-channel carrier telephone systems?

3. Describe with the aid of a block schematic diagram, the operation of a typical 3-channel carrier telephone terminal.

4. Draw a block schematic diagram of a typical carrier telephone repeater and explain the function of each item of equipment.

5. What are the advantages gained from the use of a pilot channel in a carrier telephone system?

6. Describe a method used in practice to provide automatic gain regulation of a 3-channel carrier telephone system.

/ 18.

18. REFERENCES.

Transmission Engineering Instructions. The following instructions refer to 3-channel Carrier Telephone Terminals -

Long Line Equipment C01301 - Types CU5, CS5.

Long Line Equipment C01311 - Types SOS, SOT 3B.

Long Line Equipment C01321 - Types SOS, SOT 3F.

Long Line Equipment C01331 - Types SOS, SOT (Aust. Issue 1).

Long Line Equipment C01332 - Types SOS, SOT, SOV (Aust. Issue 2).

Long Line Equipment C01333 - Types SOS, SOT, SOV (Aust. Issue 3).

Long Line Equipment C01336 - Types SOS, SOU.

Long Line Equipment C01341 - Types S21, S22, S25.

Long Line Equipment C01351 - Types C2N, C2S.

Long Line Equipment C01352 - Types CN3, CS3.

Long Line Equipment C01353 - Types CS4, CT4.

Long Line Equipment C01361 - Types T1, T2, T5 (Issue 1).

Long Line Equipment C01362 - Types T1, T2, T5 (Issue 2).

Long Line Equipment C01363 - Types STSA, STTA, STVA.

Long Line Equipment C01371 - Types SS, ST.

Telecommunication Journal of Australia.

Vol. 4, No. 4 "Pilot Regulator System for a 3-channel Carrier System" by F. P. O'Grady.
Vol. 8, No. 5 "Notes on the Adlake Relay" by J. G. Bartlett.

Drawing No. CN670. Carrier Systems in Australia - Frequency Allocations.

END OF PAPER.

COMMONWEALTH OF AUSTRALIA.

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COURSE OF TECHNICAL INSTRUCTION.

LONG LINE EQUIPMENT II.

WIDE-BAND CARRIER SYSTEMS FOR AERIAL LINES.

CONTENTS:

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1. INTRODUCTION.

1.1 Wide-band carrier telephone systems operate over a wider range of frequencies, and, therefore, provide more speech channels per system than single and three channel carrier systems. The frequency band transmitted over each channel is wider being from about 300-3,400 c/s, as compared with 300-2,600 c/s in the systems previously described. A number of wide-band systems are at present in use in Australia and these operate over both open-wire aerial trunk lines and underground trunk cables. The wide-band systems used on open-wire aerial lines are known as type J systems, and provide 12 speech channels over a 2-wire aerial circuit, using a frequency range from 36-84 kc/s in the B-A direction of transmission and from 92-140 kc/s (approximately) in the A-B direction.

1.2 The first type J 12-channel system in Australia was installed between Melbourne and Sydney in 1939. This system manufactured by the Western Electric Company of America, was known as the type J1. Modifications were made to the type J1 system and later systems installed in Australia were known as the type J2.

1.3 The type J2 system is similar to, and has the same application as, the J1 system in that it provides twelve 2-way telephone channels on an open-wire pair. The channel frequencies, line equipment and a large proportion of the terminal equipment are similar to that used in the J1 system. The more important improvements included in the J2 system are -

(i) Four frequency allocations instead of one, which permit more liberal cross-talk coupling arrangements on open-wire lines. The four frequency allocations provided for the J2 system are designated NA, NB, SA and SB, respectively.

(ii) Regulation by means of two pilot frequencies in each direction of transmission. This automatically corrects changes in attenuation which are the same over the frequency range involved, and also changes in attenuation greater at one end of the range than at the other. A single pilot frequency only is used in the J1 system.

(iii) A maximum repeater and normal terminal gain of 77 db at 140 kc/s as compared with 45 db in the J1 systems.

1.4 Details of these features together with the main principles of operation and application of type J systems, are given in this Paper.

2. FREQUENCY ALLOCATION FOR TYPE J SYSTEMS.

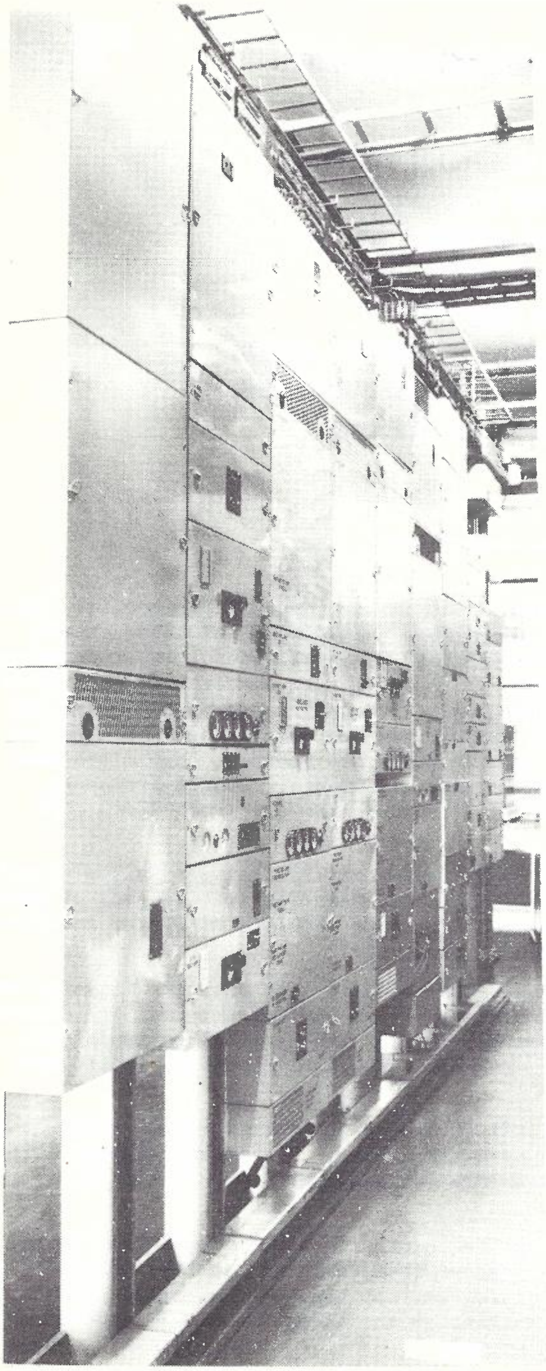
2.1 The carrier frequencies used for the type J systems are above 30 kc/s to permit simultaneous operation of the normal V.F. speech circuit and a 3-channel carrier system over the same trunk line. Under these conditions, it is possible to derive 16 speech circuits from one trunk line, as shown in the block schematic diagram of Fig. 1.

2.2 The frequency allocations for the types J1 and J2 systems are shown in Fig. 2. As in the case of 3-channel systems, "normal" and "staggered" type J2 systems, arbitrarily designated NA, NB and SA, SB, respectively, have been developed to minimise interference between systems when more than one are installed on the same pole route.

In the low-frequency (B-A) direction of transmission, the line frequencies for the normal and staggered systems are the same, but are inverted, and any crosstalk between the systems is unintelligible. The inversion means that, in the NA system, for example, the channels number 1 to 12 from 36 to 84 kc/s, whilst, in the SA system, the channels number 1 to 12 from 84 to 36 kc/s. Channel 1 of the NA system could crosstalk into channel 12 of the SA system, but, because the two channels are inverted with respect to one another, the crosstalk is inverted and, therefore, unintelligible. This also applies to channels 2 and 11, 3 and 10, and so on, and also to the NB and SB systems.

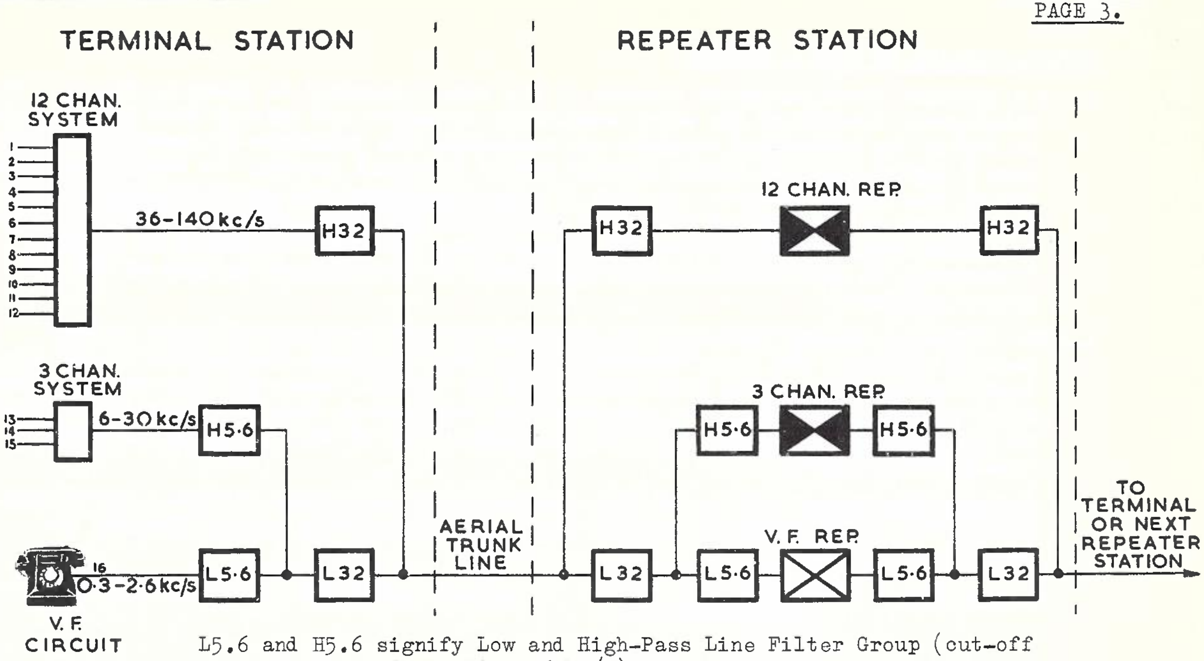
Staggering of frequencies is not provided in the B-A direction (as it is in the A-B direction), because the line practices used to reduce the crosstalk in the A-B direction, coupled with the lower frequency, lower attenuation and lower levels in the B-A direction means that the crosstalk level is sufficiently low without resorting to staggering.

In the high-frequency (A-B) direction, however, "staggering" as well as "inversion" is used to reduce the crosstalk to a minimum.



GROUP EQUIPMENT AND CARRIER SUPPLY FOR FOUR TYPE J 12-CHANNEL CARRIER TELEPHONE TERMINALS.

/ Fig. 1.



L5.6 and H5.6 signify Low and High-Pass Line Filter Group (cut-off frequency 5.6 kc/s).

L32 and H32 signify Low and High-Pass Line Filter Group (cut-off frequency 32 kc/s).

FIG. 1. DERIVATION OF 16 SPEECH CIRCUITS FROM ONE TRUNK LINE.

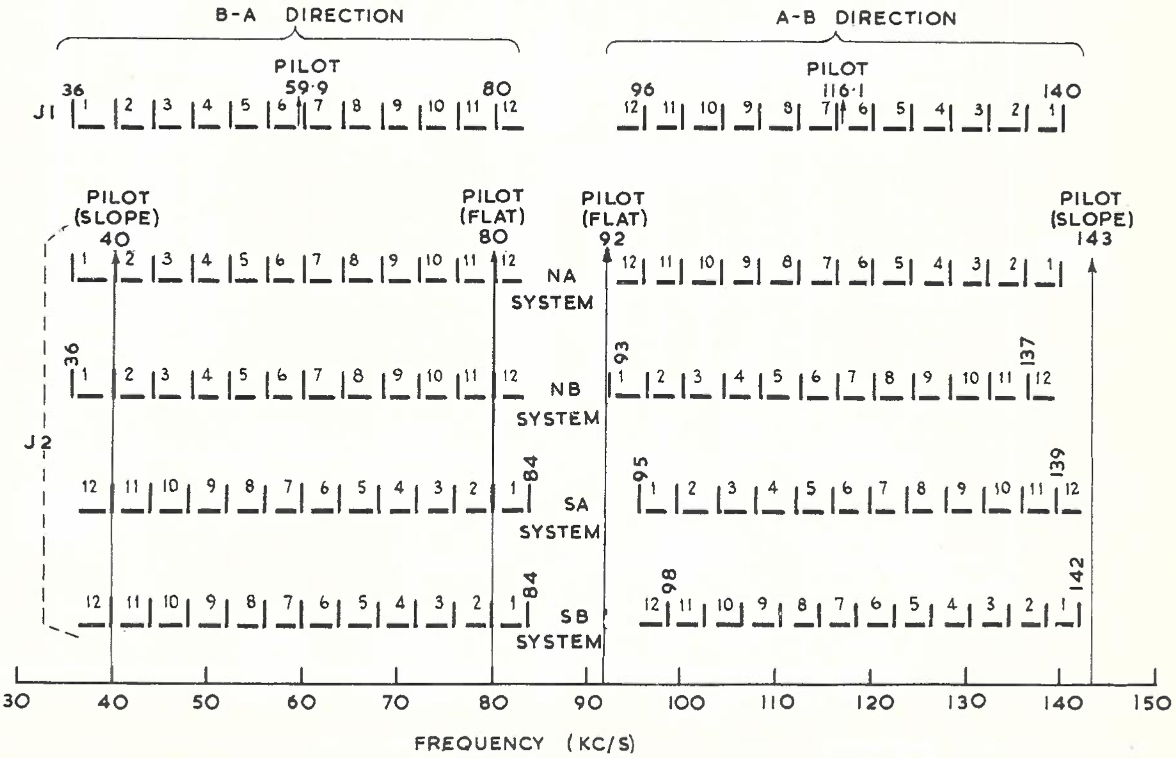


FIG. 2. FREQUENCY ALLOCATIONS FOR TYPE J CARRIER SYSTEMS.

3. GENERAL OUTLINE OF TYPE J SYSTEMS.

3.1 A simplified block schematic diagram of the type J terminal is shown in Fig. 3. For simplicity, details of the pilot regulation equipment are omitted from the circuit. As far as the individual channels are concerned, the principle of operation of the type J system does not differ greatly from a 3-channel system. An additional feature of the system, however, is that of group modulation and group demodulation for, in addition to the initial stages of modulation and demodulation per channel, there are other stages of modulation and demodulation, in which the groups of channel frequencies in each direction are transferred to the required portion of the frequency spectrum.

3.2 The following summary indicates the frequencies used in different parts of the various systems. The term "inverted" means that the lower frequencies of the sidebands correspond with the high frequencies of the V.F. band, and vice versa. Where, after further modulation, the sidebands are restored so that the lower frequencies of the sideband correspond with the low frequencies of the V.F. band, the term "restored" is used.

Channel Modulators. 64 to 108 kc/s carriers in 4 kc/s steps at both A and B terminals. The lower sidebands produce a 60-108 kc/s inverted output from the 12-channel modulators.

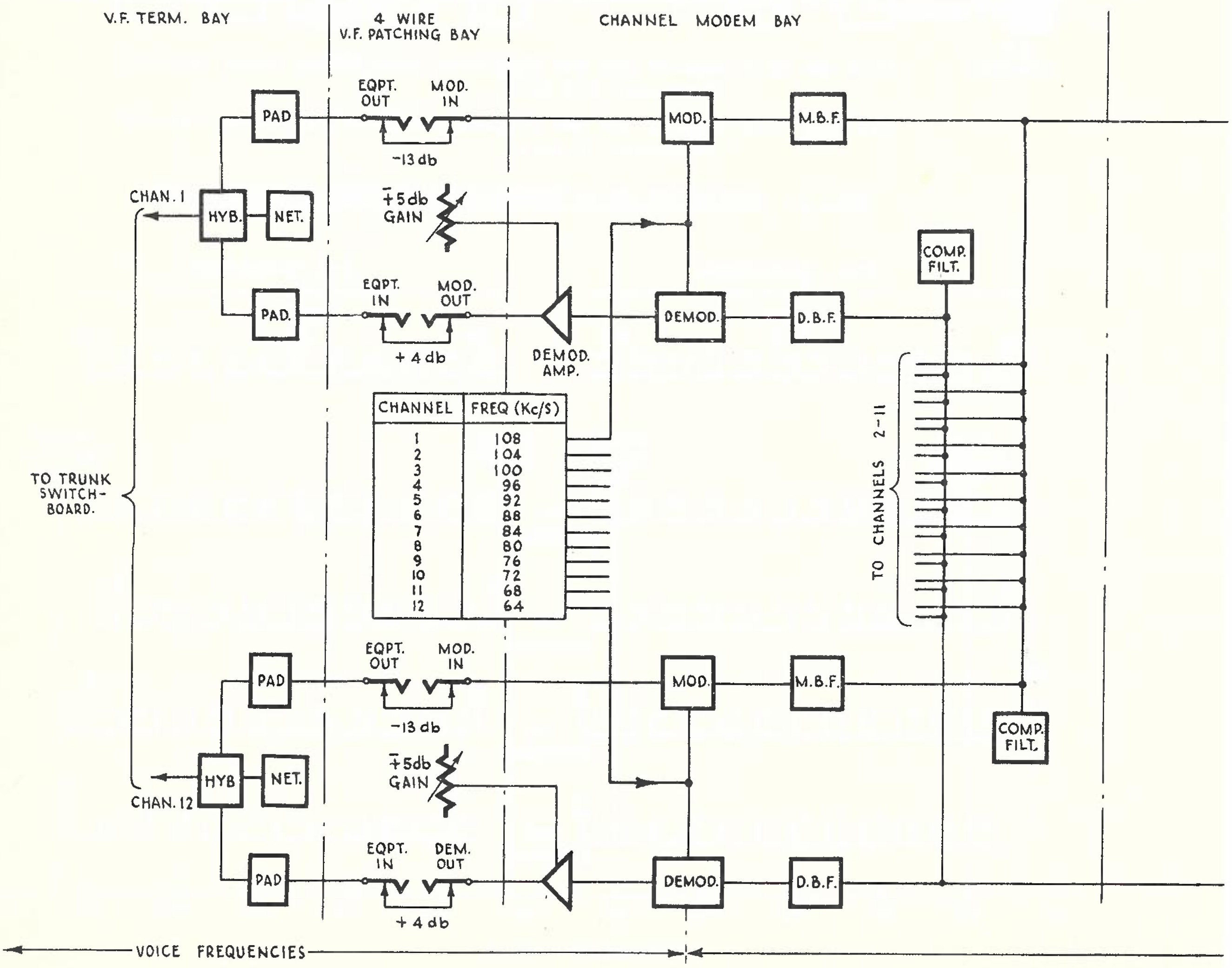


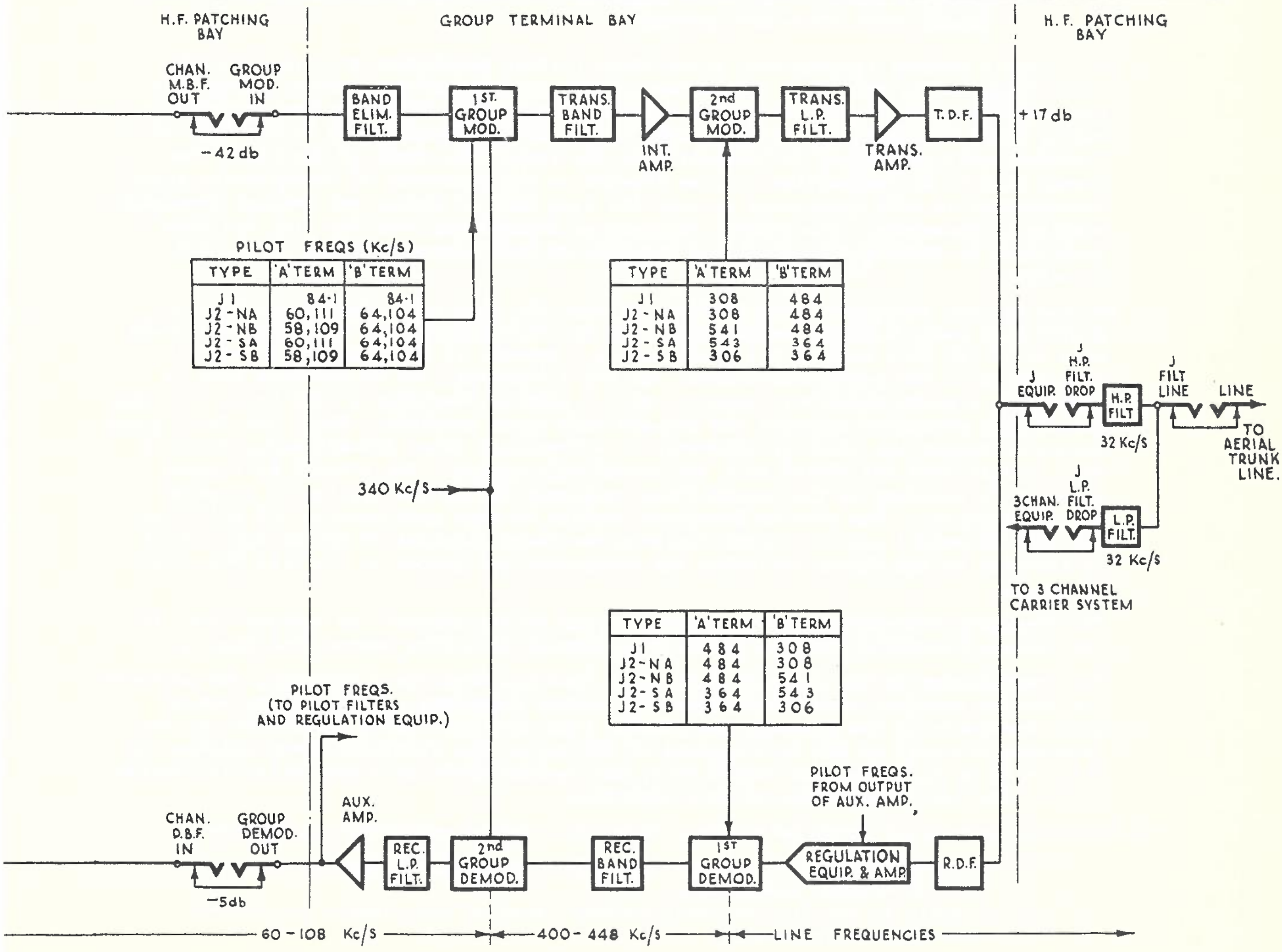
FIG. 3. SIMPLIFIED BLOCK SCHEMATIC

A TERMINAL.

System	1st Group Modulator	2nd Group Modulator	Line Frequencies
J1	340 kc/s U.S.B. inverted	308 kc/s L.S.B. inverted	92-140 kc/s inverted
J2 (NA	340 kc/s U.S.B. inverted	308 kc/s L.S.B. inverted	92-140 kc/s inverted
(NB	340 kc/s U.S.B. inverted	541 kc/s L.S.B. restored	93-141 kc/s restored
(SA	340 kc/s U.S.B. inverted	543 kc/s L.S.B. restored	95-143 kc/s restored
(SB	340 kc/s U.S.B. inverted	306 kc/s L.S.B. inverted	94-142 kc/s inverted

B TERMINAL.

System	1st Group Modulator	2nd Group Modulator	Line Frequencies
J1	340 kc/s U.S.B. inverted	484 kc/s L.S.B. restored	36-84 kc/s restored
J2 (NA	340 kc/s U.S.B. inverted	484 kc/s L.S.B. restored	36-84 kc/s restored
(NB	340 kc/s U.S.B. inverted	484 kc/s L.S.B. restored	36-84 kc/s restored
(SA	340 kc/s U.S.B. inverted	364 kc/s L.S.B. inverted	36-84 kc/s inverted
(SB	340 kc/s U.S.B. inverted	364 kc/s L.S.B. inverted	36-84 kc/s inverted



PILOT FREQS (Kc/s)

TYPE	'A' TERM	'B' TERM
J1	84·1	84·1
J2-NA	60,111	64,104
J2-NB	58,109	64,104
J2-SA	60,111	64,104
J2-SB	58,109	64,104

TYPE	'A' TERM	'B' TERM
J1	308	484
J2-NA	308	484
J2-NB	541	484
J2-SA	543	364
J2-SB	306	364

TYPE	'A' TERM	'B' TERM
J1	484	308
J2-NA	484	308
J2-NB	484	541
J2-SA	364	543
J2-SB	364	306

DIAGRAM OF TYPE J CARRIER TERMINAL.

3.3 The 12 carrier channel frequencies (that is, the basic frequencies applied to modulators and demodulators) are 64, 68, 72, 76 and so on up to 108 kc/s. The modulators and demodulators of similar channels at each terminal are supplied with the same carrier frequency, for example, a frequency of 64 kc/s is fed to both modulator and demodulator of channel 12, 68 kc/s to modulator and demodulator of channel 11, etc., and 108 kc/s to modulator and demodulator of channel 1, giving a channel separation of 4 kc/s. The main reasons for selecting the above basic frequencies are -

- (i) High grade crystal filters are economically designed for operation in this part of the frequency spectrum. This type of filter permits a wider transmitted band for a given channel spacing, a more uniform attenuation in the pass band, a steep cut-off in the stop band, together with more compact assembly than is obtained from the coil and capacitor type of filter.
- (ii) The range is such that the lowest harmonic of the lowest frequency is above the highest frequency of the band. Thus, the second harmonic of 60 kc/s, which is the lowest frequency in the lower sideband of the 64 kc/s carrier, is 120 kc/s, and this is well above the highest frequency of 108 kc/s. This prevents the possibility of any harmonics that may be generated in the channel modulators, interfering with other channels.
- (iii) A general design and manufacturing economy is obtained by using this same group of channel carrier frequencies for both open-wire aerial and underground cable wide-band systems.

3.4 The 12 basic channel frequencies, after their initial modulation with the applied voice frequencies, and after elimination of all products of modulation, except the lower sideband, by channel band-pass filters, represent a frequency band 48 kc/s in width, which is translated by additional stages of group modulation to the band of frequencies it is desired to transmit over the line. The range of the final frequency band to be transmitted to line depends on the direction of transmission since transmission in both directions is over the same pair of wires, and grouped frequency working is necessary. The channel frequencies transmitted over the line are from 36-84 kc/s in the B-A direction, and from 92-140 kc/s (approximately) in the A-B direction.

3.5 Because the two frequency bands transmitted over the line both overlap the initial 60-108 kc/s band, a direct translation from the 60-108 kc/s band to either the 36-84 kc/s or 92-140 kc/s band is not practicable. Instead, it is necessary to make the translation in two modulation stages. At the A terminal, the 60-108 kc/s band is applied to a group modulator, together with a carrier frequency of 340 kc/s. The output of this modulator includes the 400-448 kc/s upper sideband. Thus, the first group modulator raises the block of sidebands to a frequency range 400-448 kc/s, which is well outside both the 60-108 kc/s and 92-140 kc/s ranges. The 400-448 kc/s upper sideband is selected by the transmitting band-pass filter and applied to a second group modulator. The carrier frequency applied to this modulator is 308 kc/s (for the type NA model) and its output includes the lower sideband of 92-140 kc/s, which is selected by the filter following the modulator, and passed to the line via other equipment.

The frequency translations at the receiving end of the circuit are similar, but, in the reverse direction, and may be followed through in a like manner from Fig. 3.

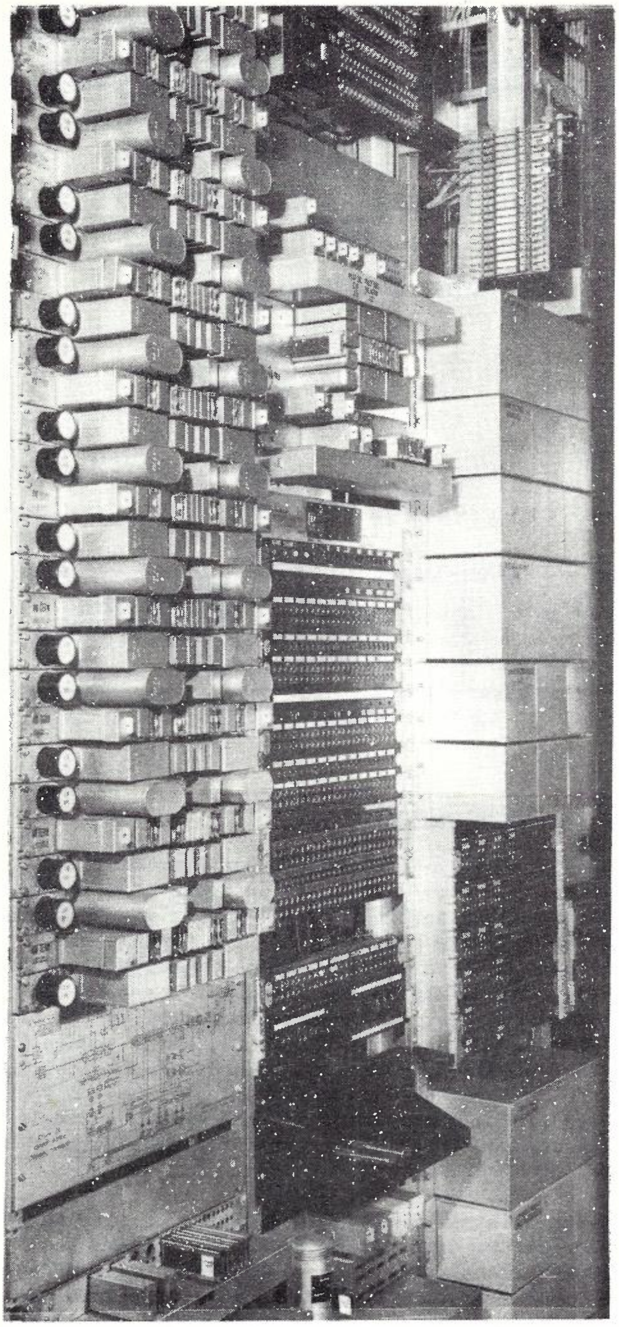
For transmission in the opposite direction, that is, from the B terminal, the processes are exactly similar, except that here the carrier frequency applied to the second group modulator in the transmitting circuit (and the first group demodulator in the receiving circuit) is 484 kc/s instead of 308 kc/s. The resultant lower sideband of this is 84-36 kc/s or, when turned over, the desired 36-84 kc/s band which is applied to the line for transmission in this direction.

3.6 The basic purpose of group modulation, therefore, may be summarised as follows -

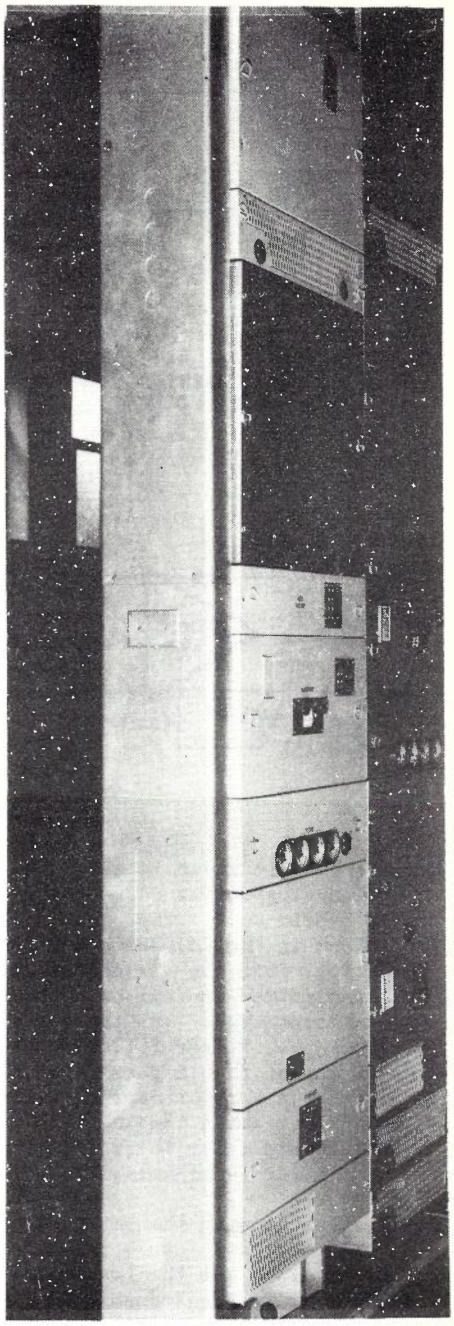
- (i) to permit the use of the most desirable group of frequencies for the initial channel modulation;
- (ii) to apply to the line the most suitable band of frequencies for optimum transmission efficiency.

/ 3.7

3.7 The previous description applies to the type NA model, and is similar for the types NB, SA and SB models except that different carrier frequencies are applied to the second group modulator in the transmitting circuit and the first group demodulator in the receiving circuit. By the simple process of altering these carrier frequencies as shown in Fig. 3, "staggering" and "inversion" of the various channel frequencies are readily obtained.



V.F. TERMINAL RACKS AND LINE PATCHING RACKS.



GROUP TERMINAL RACK.

TYPE J CARRIER TELEPHONE TERMINAL.

4. CHANNEL MODULATORS AND DEMODULATORS.

4.1 Fig. 4 shows the circuit of a channel modem, as a channel modulator and its associated demodulator are called. Also indicated are the connections for the eleven other channels which make up the fundamental 12-channel group.

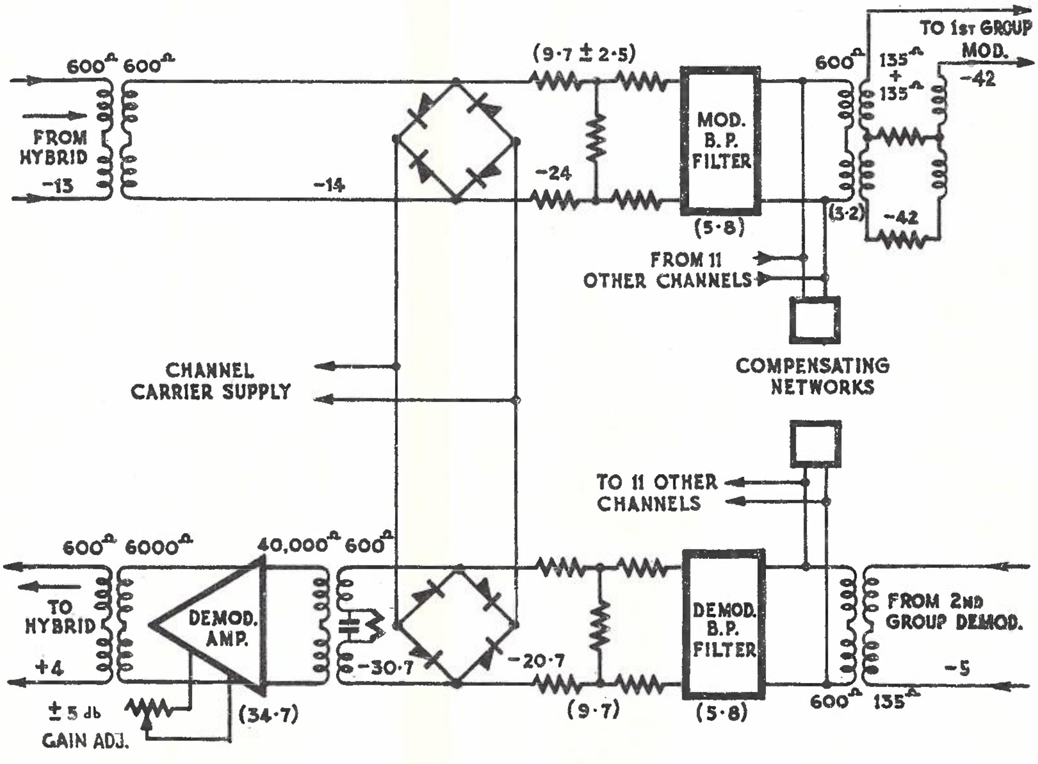


FIG. 4. CHANNEL MODEM.

4.2 The circuit shown is that used in the type J2 system. The output from the 12-channel group is connected to the first group modulator via one pair of windings of a hybrid coil. The other pair of windings is terminated in 135 ohms via jacks (not shown in Fig. 4) which can be used for patching purposes. In the type J1 system, the output from the 12-channel group is connected to the first group modulator via a transformer instead of a hybrid coil. The modulator and demodulator are of the balanced type. Of the two resultant sidebands, the lower is selected by the crystal band-pass filter following the modulator. On the receiving side, after separation by one of the 12 parallel filters, the sideband is applied to a demodulator supplied with the correct carrier frequency to restore the V.F. message. Because of the low level at which demodulation takes place, the demodulator is followed by a single stage amplifier to produce the level desired in the V.F. circuit. The gain of this amplifier is adjustable over a range of 10 db.

4.3 Besides showing the impedance relations existing in the circuit, Fig. 4 also shows the gains and losses produced by the circuit components (these being shown in brackets), and the levels existing at various points when a test tone of 1 mW is applied to the transmitting switchboard. Pads, not shown in Fig. 4, reduce the level input to the channel modulator to -13 db (all levels relative to the transmitting switchboard power). The carrier is applied to the channel modems at a level of -3db (0.5 mW). After losses sustained in the 9.7 db pad which is provided for improving the impedance relations between the channel modulator and the channel

/ modulator

modulator band-pass filter as well as adjusting the level, the modulator band-pass filter and the hybrid coil, the level input to the group equipment is -42 db. This level refers to only one channel. The actual level increases as more channels are taken into consideration, reaching a maximum when the 12 channels are considered.

4.4 In the receiving direction, a single channel provides a level of -5 db output from the group demodulating equipment. After channel demodulation and amplification by the channel demodulator amplifier, a level of +4 db is delivered by the channel equipment. This power is padded back in the 4-wire terminating set (not shown in Fig. 4) to give a 6 db overall circuit.

5. GROUP MODULATORS AND DEMODULATORS.

5.1 The function of the group modulators and demodulators is to shift the combined 12-channel frequency group to the desired part of the frequency spectrum. The group modulators and demodulators are of the double balanced "ring" type. These modulators produce twice as much sideband output as the balanced bridge type, and, further, the modulating frequencies as well as the carrier frequencies are suppressed. These characteristics are particularly desirable in a group modulator, where the wide band transmitted makes maximum sideband output and the reduction of the number of unwanted products very important.

5.2 Group Transmitting Circuit. The top section of Fig. 5 shows the essential circuit arrangements of a group transmitting circuit.

Band Elimination Filter. The output from the 12-channel group is applied to the 1st group modulator via a band elimination filter. At an A terminal, this is a "comb" filter which eliminates all of the 12-channel carrier leaks whilst passing the sidebands, and, at a B terminal, this is a filter having suppression peaks at 64 and 104 kc/s, thus suppressing the carrier leaks of channels 12 and 2 respectively.

The band elimination filter at the B terminal is necessary, because the pilot frequencies on the line in the B-A direction are 40 and 80 kc/s. The pilot frequencies are produced by injecting 64 and 104 kc/s pilot frequencies into the 1st group modulator, as shown in Fig. 5. Any carrier leak from channels 12 and 2, which have 64 and 104 kc/s carriers respectively, would interfere with the pilots. Such interference is prevented by ensuring, by means of the band elimination filter, that any carrier leak from these two channels is highly attenuated before reaching the 1st group modulator.

In the A-B direction, the line pilots are 92 and 143 kc/s. The line pilots are produced by applying frequencies of 60 and 111 kc/s for the NA and SA systems, and 58 and 109 kc/s for the NB and SB systems, to the 1st group modulators at the respective A terminals. As none of these frequencies coincide with the channel carrier frequencies, no interference with the pilot operation by channel carrier leaks takes place. However, any channel carrier leaks reaching the line after group modulation and amplification would appear on the line as steady tones, and could be introduced into neighbouring circuits carrying J2 systems having other frequency allocations. As the line frequencies of the channel carriers of normal systems fall within the line frequencies of the channel bands of staggered systems in the A-B direction, the crosstalk produced by the channel carrier leaks would appear as fixed tones of sufficient magnitude to be disturbing. The "comb" filter for attenuating the channel carrier leaks prevents this occurring.

The hybrid coil input to the 1st group modulator keeps the output of the pilot supply and the output of the 12-channel group separated.

The First Group Modulator is supplied with a carrier frequency of 340 kc/s. The carrier input to the 1st group modulator is about +14 db, the signal level being about -43 db from each channel.

/ The

The transmitting band-pass filter following the 1st group modulator is of the coil and capacitor type and passes the upper sideband of 400-448 kc/s to the intermediate amplifier.

The intermediate amplifier keeps the level of the group transmission above the noise level. This amplifier has two stages of transformer coupled pentodes to which overall negative feedback is applied. The gain is adjustable between 25 and 38 db by means of the feedback circuit. Coil C between the output of the intermediate amplifier and the input to the 2nd group modulator adjusts the impedance relations between those circuits.

The 2nd group modulator is supplied with a carrier whose frequency is appropriate to the particular system. These frequencies are shown in Fig. 3.

The transmitting low-pass filter following the 2nd group modulator passes all frequencies below 150 kc/s, and passes the 36-84 kc/s or 92-143 kc/s transmitted over the line in either direction. Besides attenuating the unwanted products of modulation from the 2nd group modulator, this filter suppresses any group carrier leaks which together might overload the transmitting amplifier.

The transmitting deviation equaliser compensates for variations over the various pass ranges produced by the characteristics of the various filters in the transmitting terminal.

A supplementary high-pass filter with a cut-off frequency of 92 kc/s is included at A terminals. This, with the transmitting low-pass filter, constitutes a band-pass filter passing a range extending from 92-143 kc/s. Some of the difference products of the 2nd group modulation stage at the A terminal fall in the B-A line frequency range (36-84 kc/s), and, if not suppressed, would cause interference. This supplementary high-pass filter ensures their suppression.

Transmitting Amplifier. The line frequency range at either terminal is now passed through a transmitting amplifier. This amplifier has a gain of 51.7 db and has three stages. The first two stages are voltage stages, and the third stage (the power stage) has four valves in parallel. All valves are pentodes. Negative feedback is applied over two paths - an inner and an outer path. The inner path couples the anode circuit of the output stage to the grid circuit of the input stage, and controls the singing margin of the amplifier at frequencies above the transmitted band. The outer feedback path connects conjugate windings of the input and output transformers, which are arranged as hybrid coils. By this means, the feedback circuit covers the characteristics of the input and output transformers as well as the amplifier itself. Included in this outer feedback circuit is an equaliser, which controls the amount of feedback at each frequency and, therefore, the gain at each frequency.

The transmitting directional filter which follows the transmitting amplifier, is a high-pass filter with a cut-off frequency of 92 kc/s at an A terminal, and a low-pass filter with a cut-off frequency of 84 kc/s at a B terminal. All filters in the group transmitting circuit are of the coil and capacitor type.

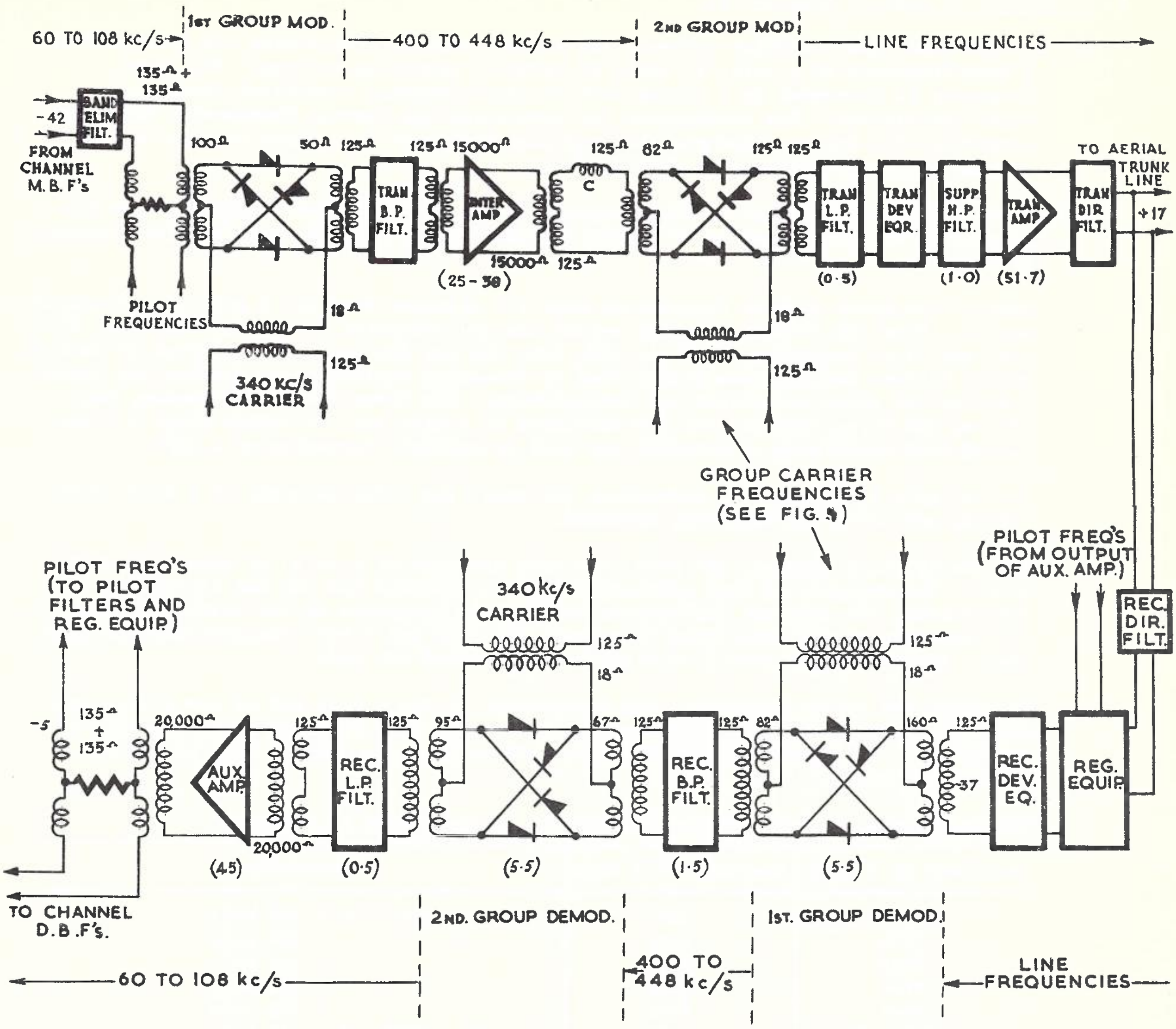
As the input to the group transmitting circuit is -42 db per channel and the output to line is +17 db, the gain of the circuit is about 60 db per channel.

5.3 Group Receiving Circuit. The lower section of Fig. 5 shows the main elements of the group receiving circuit following the regulating circuit, which is described in Sections 7 and 8.

The receiving deviation equaliser compensates for variations over the various pass ranges produced by the characteristics of the various filters in the receiving terminal.

Following the receiving deviation equaliser is the 1st group demodulator, which is supplied with the same group carrier as the 2nd group modulator at the transmitting terminal. The frequency band required from this 1st group demodulation is 400-448 kc/s for all allocations, and this is selected by the receiving band-pass filter which is identical with the transmitting band-pass filter following the 1st group modulator.

/ Fig. 5.



GROUP TRANSMITTING AND RECEIVING CIRCUIT.

FIG. 5.

The band of frequencies 400-448 kc/s is then applied to the 2nd group demodulator, which is supplied with a 340 kc/s carrier. The lower sideband produced by this 2nd group demodulation is the channel band 60-108 kc/s. This band is passed by the receiving low-pass filter, which is identical with the transmitting low-pass filter and passes all frequencies below 150 kc/s.

The 60-108 kc/s group is then amplified by the auxiliary amplifier. This is a two-stage negative feedback amplifier having a gain of 45 db. The function of the amplifier is to raise the level of the 60-108 kc/s band to the -5 db level required at the input to the channel demodulator. The output transformer is arranged as a hybrid coil to isolate the input of the pilot circuit from the channel equipment.

6. GENERATION OF CARRIER FREQUENCIES.

6.1 In wide-band type J carrier systems, the various carrier frequencies are derived from a base-frequency of 4 kc/s, by means of harmonic producing devices. The base-frequency is generated by a tuning fork or quartz crystal controlled thermionic valve oscillator. The arrangement for generating the carrier frequencies which are harmonics of 4 kc/s is discussed in Long Line Equipment I. Other details of the carrier supply are covered in this Section.

6.2 In the type J systems, the carrier frequencies for the 12-channel modulators and demodulators are all harmonics of 4 kc/s and are derived from the 4 kc/s base-frequency generator.

Some of the group carrier frequencies also are obtained from the 4 kc/s base-frequency supply. From the circuit in which appear the odd harmonics of 4 kc/s, the 77th, 85th, 91st and 121st harmonics, that is, 308, 340, 364 and 484 kc/s, are selected by carrier supply filters and separately amplified by two-stage amplifiers to produce the powers required for group modulation and demodulation. The three other frequencies, 543, 541 and 306 kc/s, however, are not harmonics of 4 kc/s and, to secure them, a 5 kc/s tuning fork oscillator is provided and used to modulate harmonics of 4 kc/s.

The 543 kc/s is obtained by modulating 548 kc/s (the 137th harmonic of 4 kc/s) with 5 kc/s, and selecting the lower sideband.

For the 541 kc/s carrier, 268 kc/s (the 67th harmonic of 4 kc/s) is modulated with 5 kc/s. The products of such modulation include, besides the sum and difference frequencies, the sums and differences between the harmonics of the carrier and the odd harmonics of the modulating frequency, 268 kc/s and 5 kc/s respectively, in this case. Twice 268 kc/s plus 5 kc/s gives the required 541 kc/s.

To secure the 306 kc/s carrier, the connections of the 5 kc/s and of the 4 kc/s harmonic to the modulator are interchanged, so that an even harmonic of 5 kc/s will be available. The 79th harmonic of 4 kc/s (316 kc/s) minus twice 5 kc/s yields the desired 306 kc/s.

The derivation of these carrier frequencies is summarised in Table 1.

Harmonic of 4 kc/s	Harmonic of 5 kc/s	Derivation
79th	2nd	316 - 10 = 306 kc/s
77th	None	= 308 kc/s
85th	None	= 340 kc/s
91st	None	= 364 kc/s
121st	None	= 484 kc/s
67th × 2	1st	(2 × 268) + 5 = 541 kc/s
137th	1st	548 - 5 = 543 kc/s

TABLE 1. GROUP CARRIER FREQUENCY SOURCES.

Fig. 6 shows a circuit of the 5 kc/s oscillator used to modulate odd harmonics of 4 kc/s to obtain the 306, 541 and 543 kc/s group carrier frequencies. The grid and anode coils are shunted by capacitors to tune these to 5 kc/s, the grid capacitor being made adjustable to give control of frequency over a small range.

The modulating circuits with which this oscillator is used are shown in Fig. 7. Metal type rectifiers are used, the circuit connections being the same for both the 541 and 543 kc/s carriers, but the filters are different. For the 306 kc/s carrier, the arrangement is similar, but the connections of the 5 kc/s oscillator and 4 kc/s harmonic are interchanged for the reasons discussed previously. In all cases, amplifiers follow the filters to raise the level of the carrier to that required for satisfactory modulation. The carrier level applied to the group modulators and demodulators is about +14 dbm, and the level of the carrier applied to the channel modulators and demodulators is about -3 dbm.

/ Fig. 6.

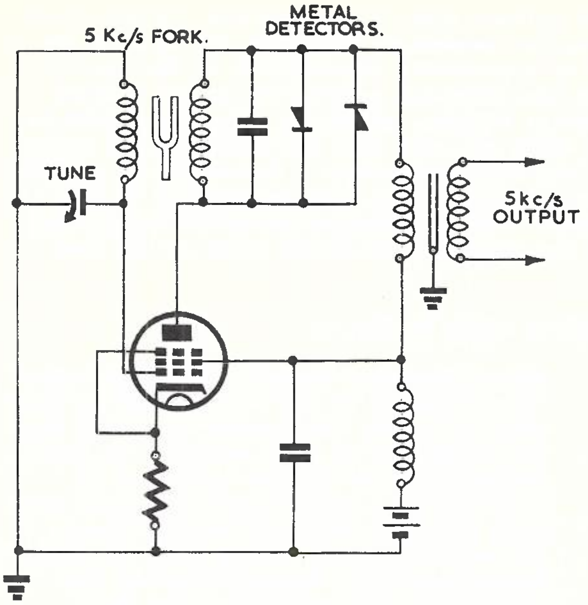


FIG. 6. 5 kc/s OSCILLATOR USED TO OBTAIN GROUP CARRIER FREQUENCIES.

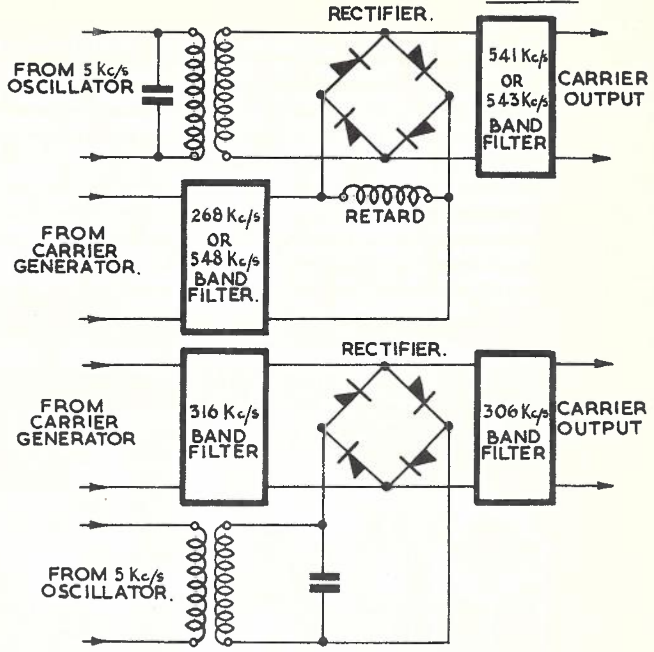
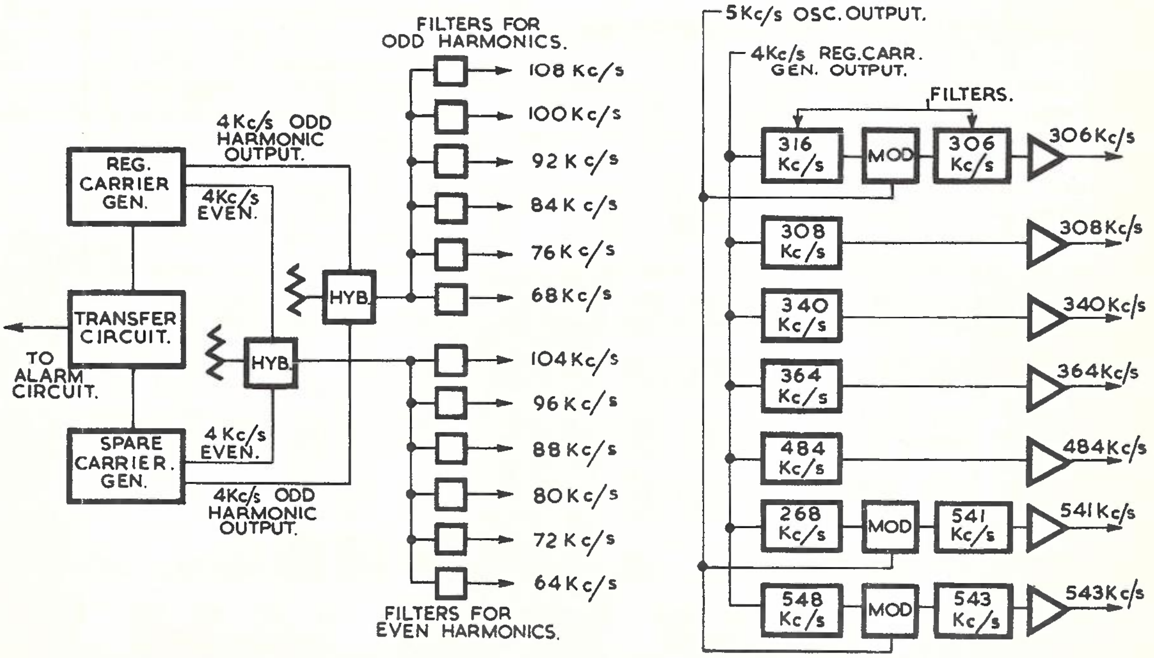


FIG. 7. MODULATING CIRCUITS USED TO OBTAIN GROUP CARRIER FREQUENCIES.

6.3 Transfer Circuit. Dependability of the 4 kc/s base-frequency carrier supply is secured by providing two complete carrier generators, one of which normally carries the load and the other of which automatically picks up the load on the failure of the regular carrier supply. A simplified block schematic circuit of the channel and group modem carrier supply arrangements is shown in Fig. 8. The equipment shown in Fig. 8 (b) is duplicated for emergency supply.



(a) Channel Carrier Supply. (b) Group Carrier Supply.

FIG. 8. SIMPLIFIED CIRCUITS OF CHANNEL AND GROUP MODEM CARRIER SUPPLIES.

The two carrier generators are identical, and between them is the transfer circuit which, in case of failure of the carrier from the regular generator, transfers the load to the emergency generator so rapidly that there is no appreciable interruption of the service. Both the regular and the emergency generators are connected permanently to the filters through hybrid coils, so that, in case of carrier failure, switching through contacts is not required. The connections to the hybrid coils are such that the carriers from either generator will flow to the load but not into the other generator. Normally, the regular generator supplies the carrier, the emergency generator being made inoperative by a negative bias on the grid of its control valve. When the regular generator fails, this negative bias is at once reduced to zero and the emergency generator picks up the load with practically no interruption.

A simplified schematic of the transfer circuit is shown in Fig. 9.

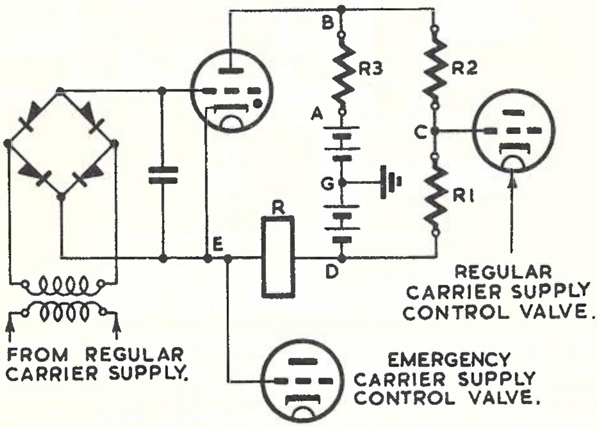
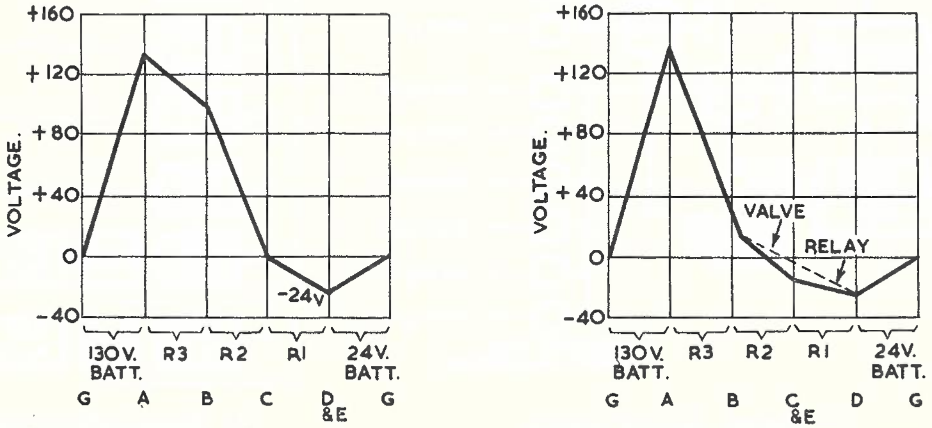


FIG. 9. ELEMENTS OF TRANSFER CIRCUIT.

Either generator becomes inoperative when the potential on its control grid is below about -9 volts, and becomes operative when the voltage is at zero potential or above. Carrier from the regular generator is rectified by a copper oxide rectifier network, and this rectified voltage biases the grid of the gas-filled valve to anode current cut-off. Current from the 130 volt and 24 volt batteries, therefore, flows through R3, R2 and R1 in series. The voltage drop over R3 + R2 is 130 volts, so that point C is at zero potential and, as the grid of the control valve in the regular carrier generator is connected to this point, the control valve in this generator is operative.

Point E, to which the grid of the control valve in the emergency generator is connected, is at a potential of -24 volts, so that the control valve in that generator is inoperative. When the regular generator fails, the carrier disappears, and the bias on the gas-filled valve likewise disappears. This valve instantly becomes conducting, and, therefore, shunts R2 and R1. The circuit currents alter and the potentials alter correspondingly, point E taking up a potential of zero and making the control valve in the emergency generator operative, and point C taking up a potential of about -12 volts and holding the control valve in the regular generator inoperative. The relay R operates on the anode current of the gas-filled valve to give an alarm. Fig. 10 shows graphically the voltages produced at various points in the transfer circuit as an aid to the preceding description.



(a) Regular Generator Operating.

(b) Regular Generator Fails.

FIG. 10. VOLTAGES ACROSS TRANSFER CIRCUIT.

7. AUTOMATIC GAIN REGULATION FOR TYPE J1 SYSTEM.

7.1 The purpose of automatic gain regulation is to correct automatically the effects of varying line attenuation produced by weather changes. This is done by adjusting the amplification at each repeater station and in the receiving terminal circuits under the control of a pilot frequency.

7.2 In the J1 system a single pilot frequency of 84.1 kc/s is applied to the transmitting side of the terminal circuit between the 12-channel modem group and the first group modulator (see Fig. 3), where the message band lies between 60 and 108 kc/s. A sharply selective crystal band elimination filter is inserted between the output of the 12-channel group and the point where the pilot frequency is applied, and eliminates any frequencies near the pilot frequency which would interfere with the small pilot current sent out to control the system. The two group modulation processes alter this pilot frequency of 84.1 kc/s, so that it appears on the line as 116.1 kc/s in the A-B direction and 59.9 kc/s in the B-A direction.

7.3 The pilot frequency 84.1 kc/s, is obtained by modulation of 88 kc/s from one of the output taps of the channel supply of that frequency, with 3.9 kc/s derived from a tuning fork oscillator. The modulation is performed in a copper oxide bridge similar to the channel modulators, and the lower sideband is selected by a carrier supply filter. The pilot frequency of 84.1 kc/s is applied to the 1st group modulator to which is also supplied a carrier frequency of 340 kc/s. The upper sideband of 424.1 kc/s is applied to the 2nd group modulator. At an A terminal, a carrier frequency of 308 kc/s is also applied to the 2nd group modulator and the lower sideband of 116.1 kc/s is selected and applied to the line for pilot regulation purposes. At a B terminal, a carrier frequency of 484 kc/s is applied to the 2nd group modulator, and the lower sideband of 59.9 kc/s is selected and applied to the line.

7.4 At repeater stations and at the receiving terminal, the pilot current is picked off at the output of the line amplifier, being separated from the message transmissions by a quartz filter which has about a 30 c/s band-pass. The pilot current is rectified and applied to a regulating circuit, the gain of which is determined in accordance with the amount of pilot current flowing in the direction concerned. The method of automatic gain regulation used in the J1 system is similar to that described earlier in Paper No. 4. The output of the regulating amplifier is applied to the line amplifier at repeater stations, and to the first group demodulator at terminal stations.

8. AUTOMATIC GAIN REGULATION FOR TYPE J2 SYSTEM.

8.1 In the J1 system, single pilot frequencies located near the centre of each of the transmitted frequency bands are used in each direction to regulate the transmission gain. A single pilot frequency is satisfactory under ordinary weather conditions, because, in the entire range of wet and dry attenuation over the normal temperature range, the slope of the attenuation curve does not change much. For example, if a normal change in weather conditions increases the attenuation by 2 db at 36 kc/s in the B-A direction of transmission, then the attenuation at 84 kc/s generally increases by a similar amount. Under extreme weather conditions, however, a single pilot frequency for each band is inadequate. Conditions giving the same loss at the mid-frequency of a band may give losses over a single repeater section differing by more than 5 db at the edges of the band. To compensate for this variation in the slope of the attenuation versus frequency characteristic of the line sections under extreme weather conditions, it is necessary to measure the loss at two frequencies - preferably near the edges of the frequency bands involved - and then to provide a complementary repeater or receiving terminal amplifier gain characteristic. To do this, two pilot frequencies are used in each direction in the J2 systems, one at each end of the two bands. The precise way this complementary gain is provided depends on the direction of transmission, being different for the A-B and B-A directions.

/ 8.2

8.2 Pilot Frequency Allocations. It is desirable to have the pilots for one direction of transmission all at the same frequency on the line, so that the same pilot filters used with the regulators can be used for all frequency allocations. This is accomplished for B-A transmission by selecting two of the carrier positions for the pilots, because these remain carrier positions for all four allocations. With A-B transmission, however, the carrier positions for the different allocations are staggered, so that, if the same pilot frequencies are to be used for all allocations, they must fall outside the transmitted sideband frequency range.

In the B-A or low-frequency direction, the line pilots are 40 and 80 kc/s for all allocations. The line pilots are produced by applying frequencies of 64 and 104 kc/s to the 1st group modulator at a B terminal. After the group modulation processes at the B terminal, the line pilots appear as 40 and 80 kc/s on the line.

In the A-B or high-frequency direction, the line pilots are 92 and 143 kc/s for all allocations. The line pilots are produced by applying to the 1st group modulator at an A terminal frequencies of 60 and 111 kc/s for the NA and SA systems and 58 and 109 kc/s for the NB and SB systems, together with the 60-108 kc/s output from the 12-channel group. After the group modulation processes at the A terminal, the line pilots appear as 92 and 143 kc/s on the line.

The effects of the two group modulations in bringing the pilots to their line positions are summarised in Table 2.

Allocation.		Pilot Frequencies		
		To 1st Group Modulator.	To 2nd Group Modulator.	To Line.
A Terminal	NA	60 and 111 kc/s	400 and 451 kc/s	92 and 143 kc/s
	NB	58 and 109 kc/s	398 and 449 kc/s	143 and 92 kc/s
	SA	60 and 111 kc/s	400 and 451 kc/s	143 and 92 kc/s
	SB	58 and 109 kc/s	398 and 449 kc/s	92 and 143 kc/s
B Terminal	NA NB	64 and 104 kc/s	404 and 444 kc/s	80 and 40 kc/s
	SA SB	64 and 104 kc/s	404 and 444 kc/s	40 and 80 kc/s

GROUP MODULATION OF PILOT FREQUENCIES.

TABLE 2.

8.3 Generation of Pilot Frequencies. For the B-A transmission, the pilots are at 40 and 80 kc/s on the line for all allocations. These frequencies are the positions that would be occupied by the channel carriers of 64 and 104 kc/s if they were transmitted. All carriers are suppressed in the channel modulating circuits, however, and these two frequencies must be resupplied as pilots.

Although the carriers are suppressed in the channel modulators, there is always a small amount of carrier leak. Should the pilot and carrier frequencies differ, beat frequencies would result and would be objectionable. Such beating is avoided by using the same 4 kc/s as the source for both channel carrier and pilot frequencies. It is necessary, however, that the level of the pilot be accurately constant, while slight variations in the level of the carrier are unobjectionable.

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This constant level of the pilot is secured by using a second oscillator, whose frequency is locked by the 4 kc/s harmonic and whose output is stabilised by a lamp-resistance bridge in the feedback path. The circuit in simplified form is shown in Fig. 11.

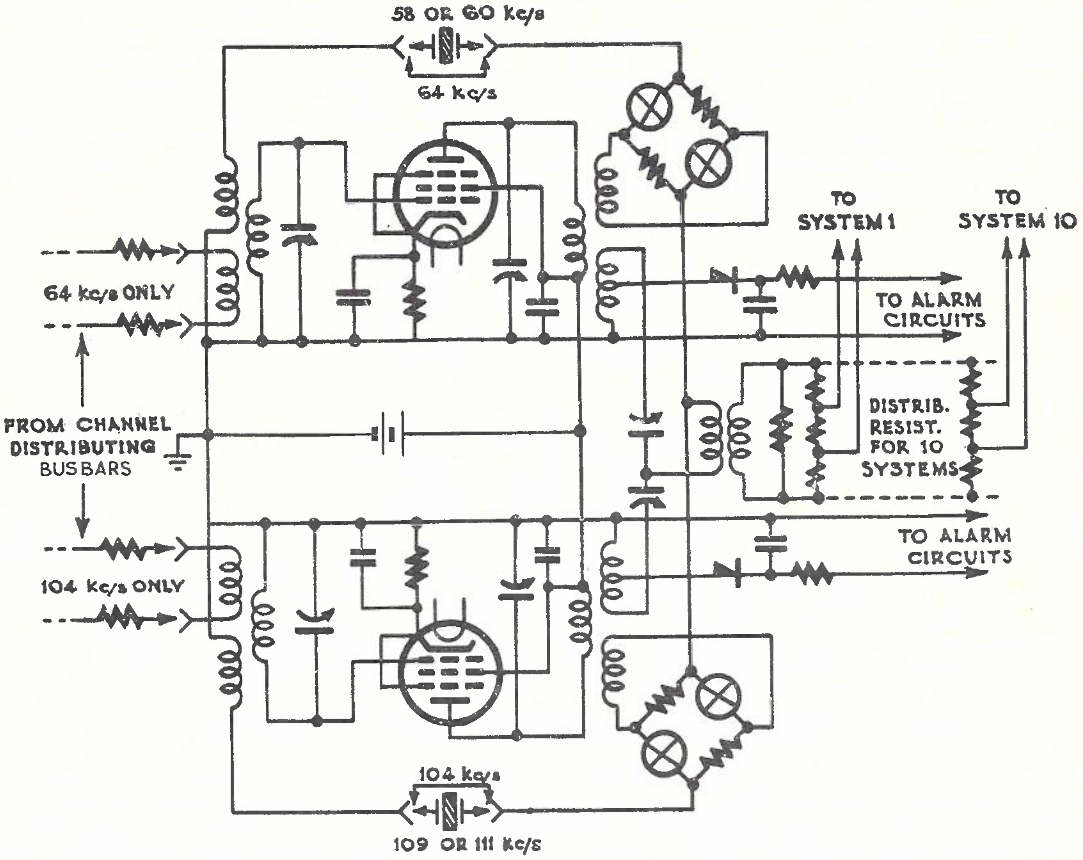

FIG. 11. SUPPLY CIRCUIT FOR THE PRODUCTION OF PILOT FREQUENCIES.

As the output increases, the lamps heat up and the bridge approaches the balanced condition, decreasing the positive feedback. Equilibrium is reached when the loss in the lamp-resistance bridge equals the gain in the amplifier. In the vicinity of the balanced condition, the circuit is very sensitive and maintains a constant output with considerable accuracy. Variation in the level of the locking frequency or in the gain of the amplifier produces very little change in the output, since a small change in the resistance of the lamps in the nearly balanced bridge produces a relatively large change in the loss. A 5 db change in the input or in the gain of the amplifier, for example, results in less than a 0.1 db change in output. One locked oscillator is used for the 64 kc/s pilot and one for the 104 kc/s pilot, and their outputs are connected to a single busbar that supplies the two pilots for as many as 10 systems.

For the A-B transmission, the pilots are at 92 and 143 kc/s for all allocations. By selecting pilot frequencies of 92 and 143 kc/s on the line, only two pairs of pilot frequencies before modulation are required. These frequencies are 60 and 111 kc/s for the NA and SA allocations, and 58 and 109 kc/s for the NB and SB allocations. Since these frequencies are not normally provided by the carrier supply, separate oscillators are used. The oscillators for these pilots are identical with those of Fig. 11, except that there is no locking circuit, and instead, a crystal is placed in the feedback circuit to control the frequency, as indicated in the diagram.

One such pair of oscillators supplies the pilot frequencies for the NA and SA allocations, and the other pair the NB and SB allocations.

8.4 Regulation in the A-B Direction. At B terminals, and in the A-B side of repeaters, the 92 kc/s pilot is used to control the gain of a regulating amplifier by means of a regulating capacitor. Changes of 0.5 db or more in the level of the 92 kc/s pilot cause the regulating capacitor to either increase or decrease the gain of the amplifier by the same amount over the 92-143 kc/s band. This is the "flat gain" amplifier and the "flat regulating" capacitor. The 143 kc/s pilot is used to control the gain of another regulating amplifier by means of the regulating network. The gain of this amplifier varies from zero at 92 kc/s to 35 db at 143 kc/s, the precise gain at 143 kc/s being determined by the pilot level. This is the "slope gain" amplifier and "slope regulating" network. Fig. 12 is a block schematic of the pilot control circuit at a B terminal, this circuit preceding the receiving deviation equaliser shown in Fig. 5.

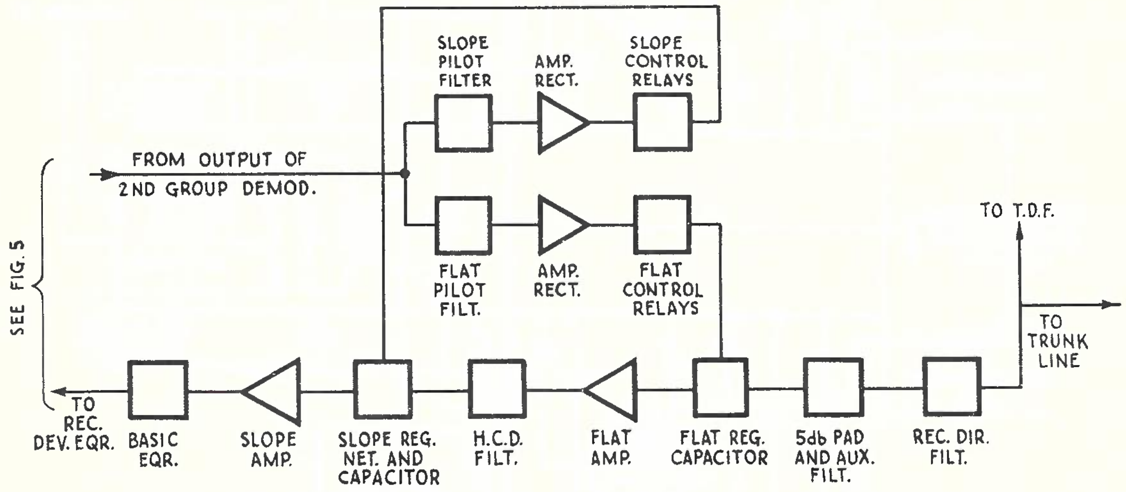

FIG. 12. BLOCK SCHEMATIC OF REGULATOR CIRCUIT - B TERMINAL.

At the B terminal, the line pilots of 92 and 143 kc/s appear at the input to the pilot control circuit after the two stages of group demodulation. Sharply tuned crystal filters direct each pilot to its appropriate amplifier-rectifier. Here, each pilot is amplified by a single stage amplifier before being applied to a single metal type rectifier, which half-wave rectifies the output of the amplifier. This rectified output passes through alarm and control relay circuits, which function in the same manner as that described for the J1 system in Paper No. 4 of this book.

A simplified schematic of the actual regulating arrangements for a B terminal is shown in Fig. 13.

An increase in line loss causes the pilot level to drop, operating the "control" relays in both flat and slope control circuits. In the case of the flat regulation circuit, the operation of the flat control relay completes a circuit to a small reversible motor which rotates the rotors of a double stator capacitor. In the case of the increased loss mentioned, the movement is in the direction towards 100 in Fig. 13. This movement increases the series capacitance between the secondary of the input transformer and the grid of the first stage of the flat amplifier, and reduces the shunt capacitance across the secondary of the input transformer. This operation increases the input to the flat amplifier by the same amount at all frequencies, thus increasing the gain of that amplifier.

Both the flat and slope regulators operate ahead of two-stage feedback amplifiers, each amplifier having a gain that is flat with frequency.

The maximum gain of the flat amplifier is 45 db so that, with the slope and flat amplifiers at their maximum gain, the gain provided by the two of these in tandem varies from 45 db at 92 kc/s to 80 db at 143 kc/s. When both amplifiers are at their minimum gain, the gain provided by the pair is zero. In the curves of Fig. 14, the lower set shows some possible slope characteristics of the regulating circuit when the flat regulator produces no gain. The upper set shows some possible characteristics with the flat regulator

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producing its maximum gain, that is, 45 db. Curves for intermediate settings of the flat regulator will lie between the two sets of curves shown. The numerals refer to dial readings displayed as the motor turning the regulating capacitors revolves.

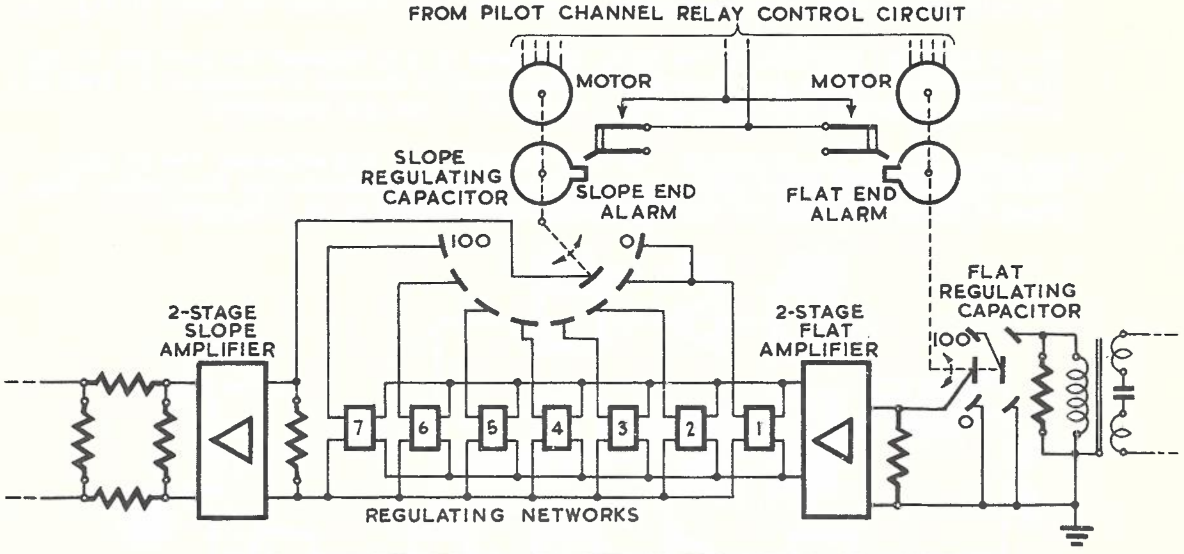
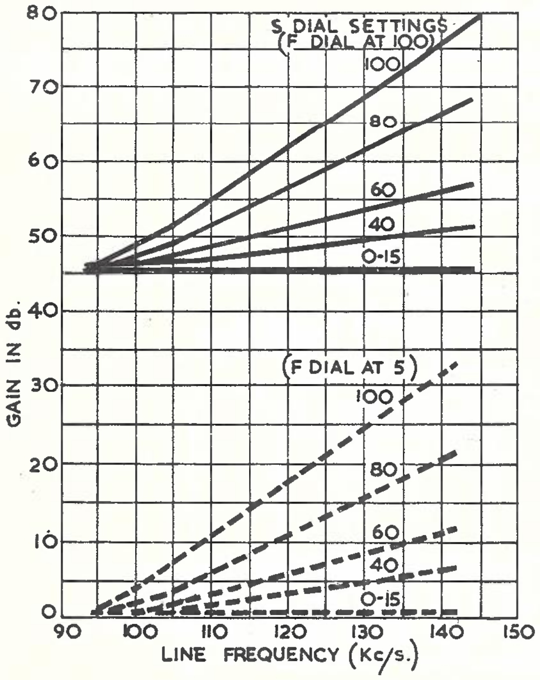


FIG. 13. SIMPLIFIED SCHEMATIC CIRCUIT FOR A-B REGULATION.

The slope regulating capacitor at a B terminal substitutes one regulating network for another as it revolves. This capacitor has eight stator plates, to which seven regulating networks are connected. At the B terminal, a basic equaliser (see Fig. 12) provides losses varying from about 13 db at 92 kc/s to about 3 db at 143 kc/s, the resultant 10 db slope being about complementary to that of a long repeater section in wet weather. The first three regulating networks in Fig. 13 have slopes opposite to the 10 db slope, the first providing about 10 db greater loss at 143 kc/s than at 92 kc/s, the next about 6 db greater loss, and the third about 3 db greater loss, the losses at 92 kc/s being nearly the same for each section. The fourth network consists of resistors and introduces a flat loss equivalent to the 92 kc/s loss of the preceding sections. Thus, the slope provided by the basic equaliser is counteracted when the first regulating network is involved, as shown for the slope dial setting of 0 in Fig. 14. As the slope dial is rotated towards 100, more and more of the slope of the basic equaliser becomes effective until the rotor is fully meshed with the fifth stator introducing the fourth (flat loss) regulating network, the gain-frequency characteristic assumes the slope dictated by the basic equaliser alone. This occurs at a slope dial setting of about 57. The fifth, sixth and seventh sections of the regulating network introduce slopes of the same nature as the basic equaliser, and are therefore additive thereto. The fifth section has about 6 db less loss at 143 kc/s than at 92 kc/s, the sixth section



REGULATION AVAILABLE FOR A-B TRANSMISSION MINIMUM AND MAXIMUM FLAT GAIN AND SEVERAL VALUES OF SLOPE GAIN.

FIG. 14.

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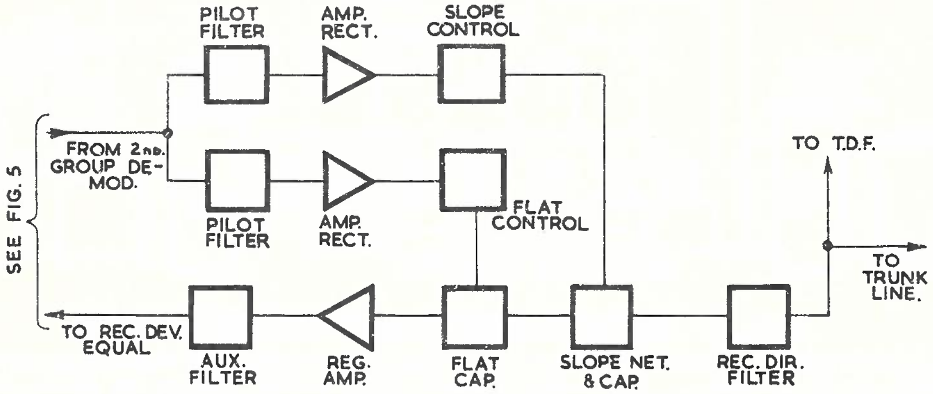
about 14 db less loss, and the seventh about 24 db less loss, the losses at 92 kc/s being the same in each case as those of preceding sections. As the dial traverses the range 57 to 100, gain-frequency characteristics of progressively steeper slopes, but with practically unchanged gains at 92 kc/s, are obtained, as shown in Fig. 14.

The 10 db slope produced by the basic equaliser at a B terminal is provided in the line amplifier in the A-B direction of transmission through a repeater, so that the preceding operation also applied to a repeater in the A-B direction.

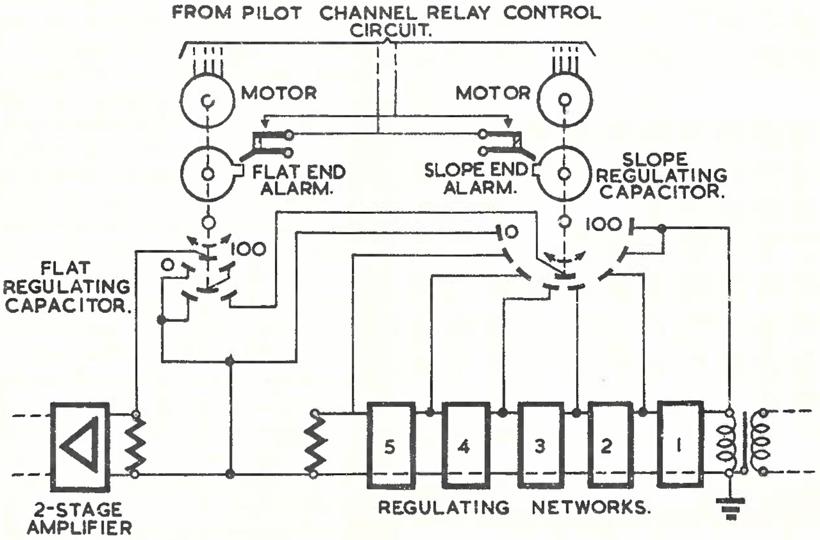
8.5 Regulation in the B-A Direction. In this direction of transmission, the 40 kc/s pilot controls the slope gain, and the 80 kc/s pilot controls the flat gain. Fig. 15 shows a block schematic of the regulating arrangements at an A terminal.



BLOCK SCHEMATIC OF "A" TERMINAL REGULATION.

FIG. 15.

A simplified schematic of the regulation arrangements is shown in Fig. 16. The flat regulating capacitor operates as described in the case of the A-B direction, but the action of the slope regulation differs.



SIMPLIFIED SCHEMATIC CIRCUIT FOR B-A REGULATION.

FIG. 16.

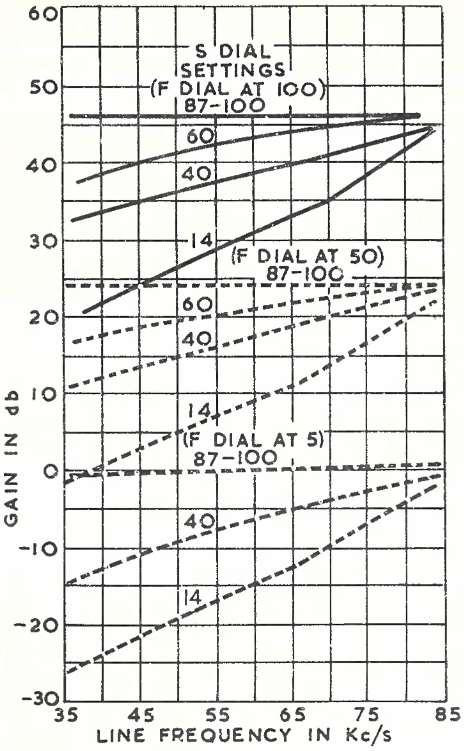


FIG. 17. REGULATION AVAILABLE FOR B-A TRANSMISSION: MINIMUM, INTERMEDIATE, AND MAXIMUM VALUES OF FLAT GAIN.

With the slope dial at 100, the full input voltage is applied to the rotor of the slope regulating capacitor. As the capacitor rotates towards 0, additional sections are "cut-in" in tandem, these sections having slopes which produce the curves of Fig. 17.

Only one regulating amplifier is provided, this being controlled by both the flat and slope regulating circuits. The maximum gain of this amplifier is 45 db, and the flat regulating capacitor carries this gain from 0 to 45 db by the same amount over the range 36-84 kc/s. The slope regulating capacitor and network produce zero loss at 84 kc/s, but are capable of varying the gain at 36 kc/s by a maximum of 35 db. This action produces curves of which Fig. 17 contains some examples. The lower curves show some possible slopes with the flat regulator producing zero gain, and the upper curves show some possible slopes with the flat regulator producing maximum gain, whilst the centre set of curves apply when the flat regulator is producing about half of its maximum gain.

9. CARRIER REPEATERS FOR TYPE J SYSTEMS.

9.1 At each repeater station, line filters and directional filters are provided on both sides of the amplifying equipment. The line filters separate the type J frequency range 36-140 kc/s from the lower frequencies for the V.F. circuit and the 3-channel system. The directional filters separate oppositely directed groups of frequencies for amplification in the one-way line amplifiers. These filters separate a 12-channel band of frequencies lying below 84 kc/s for one direction of transmission from the 12-channel group lying above 92 kc/s for the opposite direction.

Regulating equipment for each direction of transmission, properly controlled to compensate for variations in the attenuation of the preceding line section, is provided at each repeater station and is similar to that provided in the receiving side of the terminal equipment.

Equalisation is necessary in each direction of transmission at repeater stations and in the receiving direction at the terminals, to compensate for frequency distortion produced by the preceding section of line. The slope of the attenuation/frequency curve over the 36-84 kc/s range is nearly the same as that over the 92-140 kc/s range for the usual type of aerial trunk lines, so that the various circuits can be equalised alike.

/ 9.2

9.2 Repeaters for the J1 System. Fig. 18 shows the circuit elements of a type J1 repeater, and indicates the location of the directional filters and certain supplementary filters for suppressing frequencies outside the transmitted range. The regulating amplifier circuit and the pick-off of the pilot channel which controls the gain are also shown.

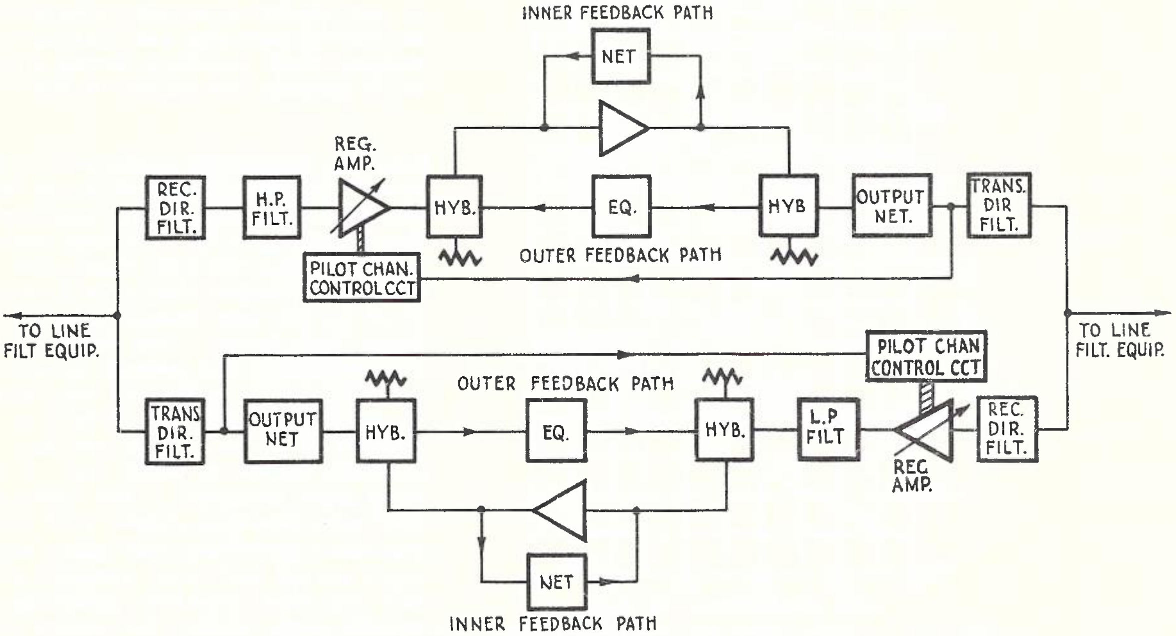


FIG. 18. BLOCK SCHEMATIC OF TYPE J1 REPEATER.

The line amplifier has three stages. The first two stages use single pentode valves of high-voltage amplification and low-power capacity, whilst the third stage has four power pentodes in parallel to increase the output power. Negative feedback is supplied over two paths to improve the operation of the amplifier. The inner feedback path reduces the gain at frequencies outside the required band, and so prevents singing at those frequencies. This feedback path has little effect on frequencies within the Type J range. The outer feedback circuit includes the input and output transformers which are made as hybrid coils. In each of these transformers, one pair of opposite windings is connected to the input or output circuit of the amplifier, whilst the other pair is used for the feedback connection. By feeding back through the transformers in this way, the overall characteristic of the amplifier is made practically independent of the transformer characteristics.

The frequency response of a feedback amplifier is the inverse of the frequency response curve of the feedback circuit itself, that is, if the output voltage from the amplifier decreases as the frequency rises, then the feedback circuit supplies a voltage to the input which increases as the frequency rises. In other words, the feedback circuit equalises the amplifier. The preceding line section is responsible for an attenuation which increases as the frequency rises. If the feedback circuit contained a network which behaved in the same manner, then the feedback voltage would decrease as the frequency rises, so that the feedback circuit would equalise both the amplifier and preceding line section. An equaliser is included in the outer feedback circuit of the repeater. This equaliser has a characteristic that varies with frequency in exactly the same way as the longest line section does in wet weather. Thus, there is provided at the repeater a basic equalisation for this longest wet weather line. At a receiving terminal, a basic equaliser is provided which performs this same compensation, but as it is not included in the feedback circuit of the amplifier there, the slope of the characteristic curve must necessarily be opposite to that of the line attenuation and of the equaliser in the feedback circuit of the repeater. Line sections, however, vary in length and, in order that they may be properly corrected by this basic equalisation, they must be built up to equal this longest wet weather section. For this purpose, there are provided flat loss-pads and building-out networks, whose losses have the same frequency response as short lengths of open-wire line. These pads and networks can be inserted or omitted by simple strapping changes, and suffice to build up the shortest line section likely to be encountered.

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9.3 Repeaters for the J2 System. Fig. 19 shows a block schematic of the Type J2 repeater.

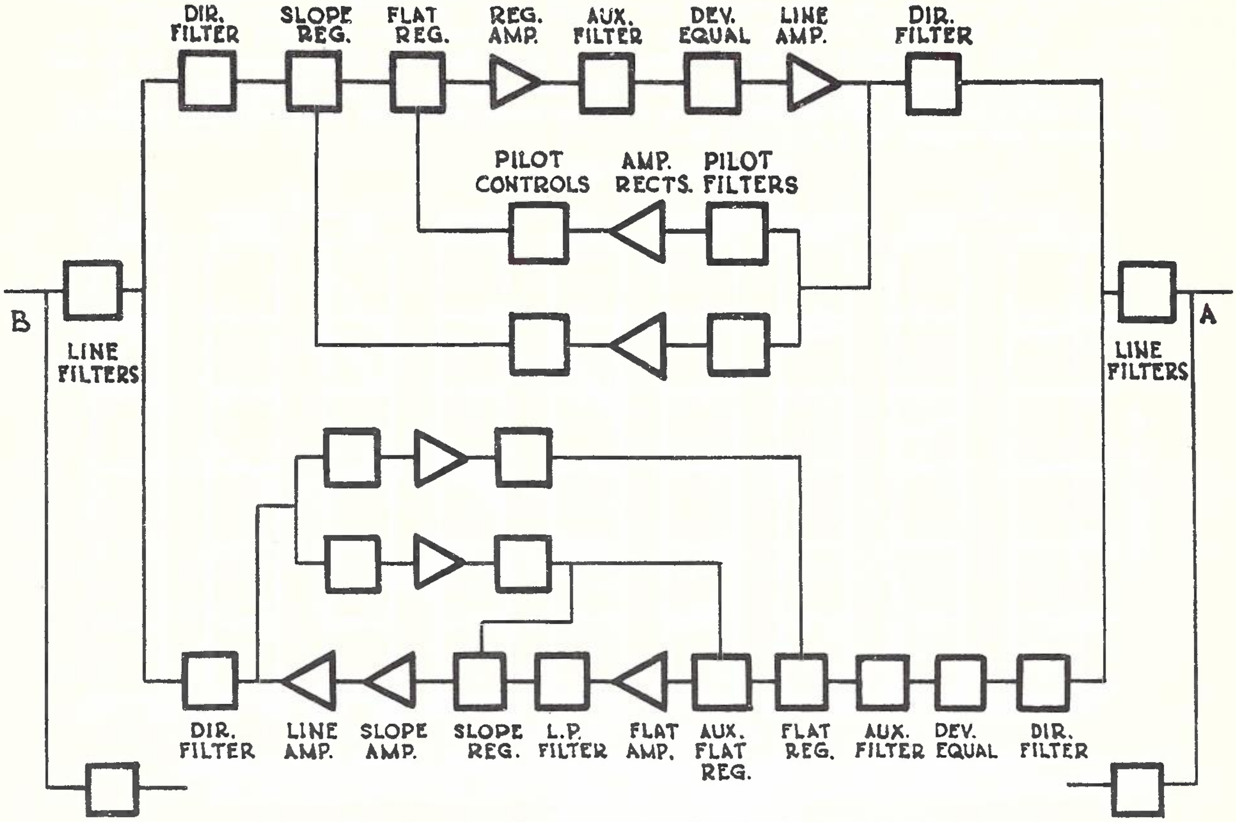

FIG. 19. BLOCK SCHEMATIC OF TYPE J2 REPEATER.

The maximum gain is 77 db at 140 kc/s as compared with 45 db in the Type J1 system. Regulation is under the control of the two pilot frequencies in each direction of transmission and operates in much the same way as at the terminals, the A-B regulation being equivalent to the B terminal regulation and the B-A regulation to the A terminal regulation. In the flat-gain regulating circuit there is an auxiliary capacitor driven by the slope control. This capacitor comes into operation only for low-slope conditions, that is, when little or no gain is required from the slope control.

An example of the action of the regulator under adverse weather conditions requiring the use of the auxiliary capacitor is shown in Fig. 20.

This figure consists of nine graphs side by side plotting signal level against frequency at the beginnings and ends of a series of repeater sections. In normal operation, the output of each repeater would be flat with frequency, and at a level not greater than +17 db. Such an input to section 1 is shown, and the loss over section 1 results in a level at the end of the section that decreases with increasing frequency. The total loss is moderate and the combination of flat and slope regulators restores the signal to a flat +17 db at the input to section 2. Over sections 2, 3 and 4, it is assumed that the weather conditions cause a very large attenuation with only moderate slope. The loss at 92 kc/s is so great that the 45 db flat gain of the next three repeaters can raise the level at the low frequencies to only -7 db at the input to section 5.

However, the total of 80 db available at the high frequencies of each repeater, made up of 45 db flat regulation and 35 db slope regulation, is ample to bring the level of the high frequencies up to the desired +17 db. As a result, the signal leaves the repeater at the beginning of section 5 with a level that increases with increasing frequency - a reversed slope as compared with the preceding sections. This next section (6), it is assumed, is a comparatively short one, operating under ordinary dry or wet weather conditions. The reversed slope is, therefore, decreased, but the total attenuation is small. The flat regulator at the end of this section inserts its full 45 db in an

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effort to bring the level at 92 kc/s up to +17 db, but, in doing so, it raises the level at 143 kc/s to +32 db, as indicated by the dotted line, even without any slope gain added. This would put too high a level on the line, and it is for this reason that the auxiliary flat capacitor is added. Coming into play when the slope regulator is at its low end, this capacitor introduces a flat loss that results in the solid line. The next section (7) takes out enough of the reverse slope to enable the following repeater to restore the signal to a flat +17 db.

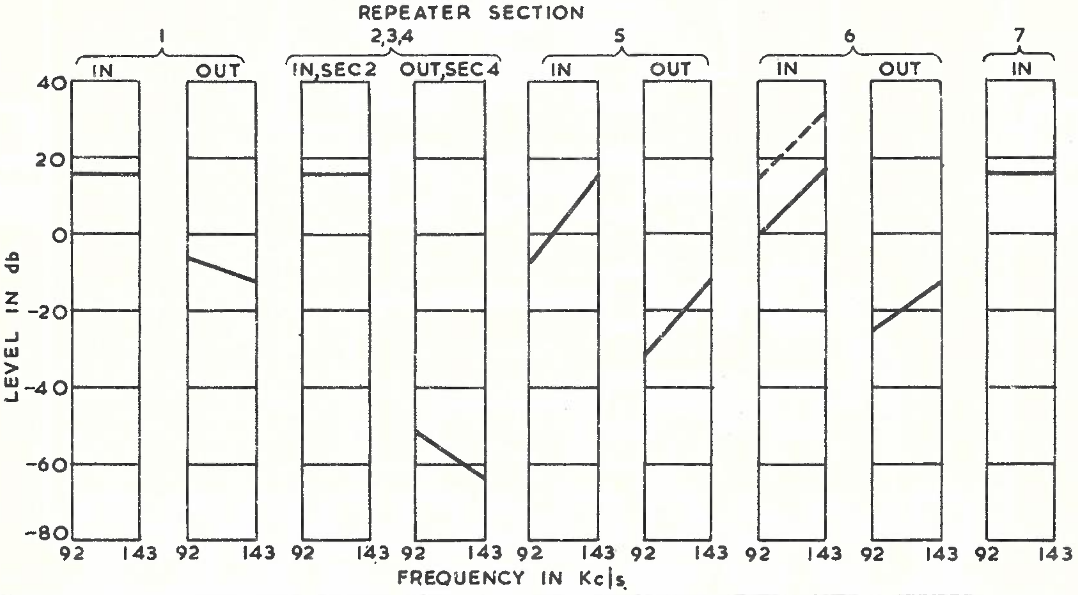

FIG. 20. LEVEL FREQUENCY GRAPHS FOR THE INPUT AND OUTPUT LEVELS OVER A NUMBER OF SECTIONS IN SERIES UNDER ADVERSE WEATHER CONDITIONS REQUIRING THE USE OF AUXILIARY CAPACITOR.

10. TEST QUESTIONS.

1. What are the main points of difference between the Type J 12-channel Carrier Telephone system and the 3-channel Carrier Telephone system?
2. What are the reasons for employing basic frequencies of 64, 68 - and so on up to 108 kc/s (4 kc/s separation) for use in Type J Carrier Telephone systems?
3. What do you understand by the term "Group Modulation" as applied to wide-band carrier systems?
4. Explain briefly the principles of generation of carrier frequencies in wide-band carrier systems. What are the advantages of this method as compared with methods used in 3-channel systems?

11. REFERENCES.

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Long Line Equipment T5615, "Twelve-Channel Carrier Telephone System (Type J2). Routine Test and Adjustment Methods."

Telecommunication Journal of Australia.

Vol. 2, No. 2, "The J12 Open-Wire Carrier System" by C.J. Griffiths.
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Vol. 6, No. 2, "The Type J2 Twelve Channel Carrier Telephone System" by J.E. Freeman.

END OF PAPER.

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COURSE OF TECHNICAL INSTRUCTION.

LONG LINE EQUIPMENT II.

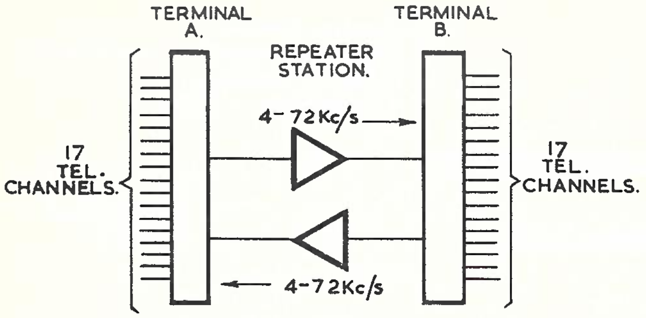
CABLE CARRIER SYSTEMS.

CONTENTS:

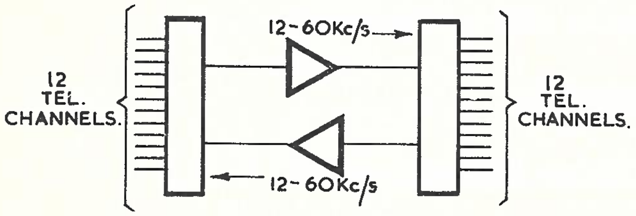
1. INTRODUCTION.

1.1 This Paper describes a number of carrier telephone systems which are suitable for application to trunk and junction cable routes.

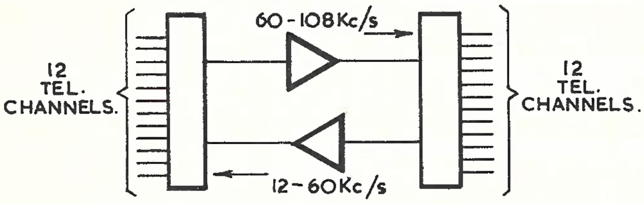
1.2 Although the multi-channel carrier systems designed for use over open-wire aerial lines may be operated satisfactorily over cable circuits, it is more economical to use 4-wire operation for cable carrier systems, transmitting the frequency ranges over separate cable pairs for each direction of transmission. The use of separate pairs eliminates the necessity for directional filters at terminal and repeater stations. As a certain frequency band is allowed in the region of the cut-off frequencies of the directional filters to make the filter design practicable, the elimination of these filters enables additional channels to be operated in this region. In addition, repeater equipment is reduced to a very simple form.



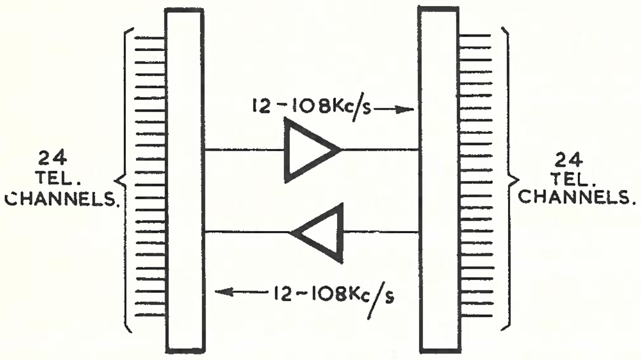
(a) 17-channel System Using Pairs in Separate Cables.



(b) 12-channel System Using Pairs in Separate Cables.



(c) 12-channel System Using Separate Pairs in Single Cable.



(d) 24-channel System Using Pairs in Separate Cables.

APPLICATIONS OF CABLE CARRIER SYSTEMS
TO 4-WIRE CABLE CIRCUITS.

FIG. 1.

2. FREQUENCY ALLOCATIONS OF CABLE CARRIER SYSTEMS.

2.1 The development of cable carrier systems in Australia is summarised briefly as follows -

(i) The first cable carrier systems were installed in 1943 between Sydney and Maitland. These were 17-channel systems manufactured by Communication Engineering Pty. Ltd. of Sydney. These systems transmit a frequency range 4-72 kc/s over pairs in separate cables for each direction of transmission.

(ii) Subsequently, a number of type K2 12-channel systems manufactured by the Western Electric Company of America were installed between Melbourne and Seymour in 1948. These systems transmit a frequency range 12-60 kc/s over pairs in separate cables for each direction of transmission.

(iii) From 1949 onwards, additional 12-channel systems manufactured by Standard Telephones and Cables, Pty. Ltd., Australia, have been installed over trunk cable routes. These systems are of similar design to the W.E. system, and have the following applications -

(a) 12-channel system, which transmits a frequency range 12-60 kc/s over pairs in separate cables for each direction of transmission.

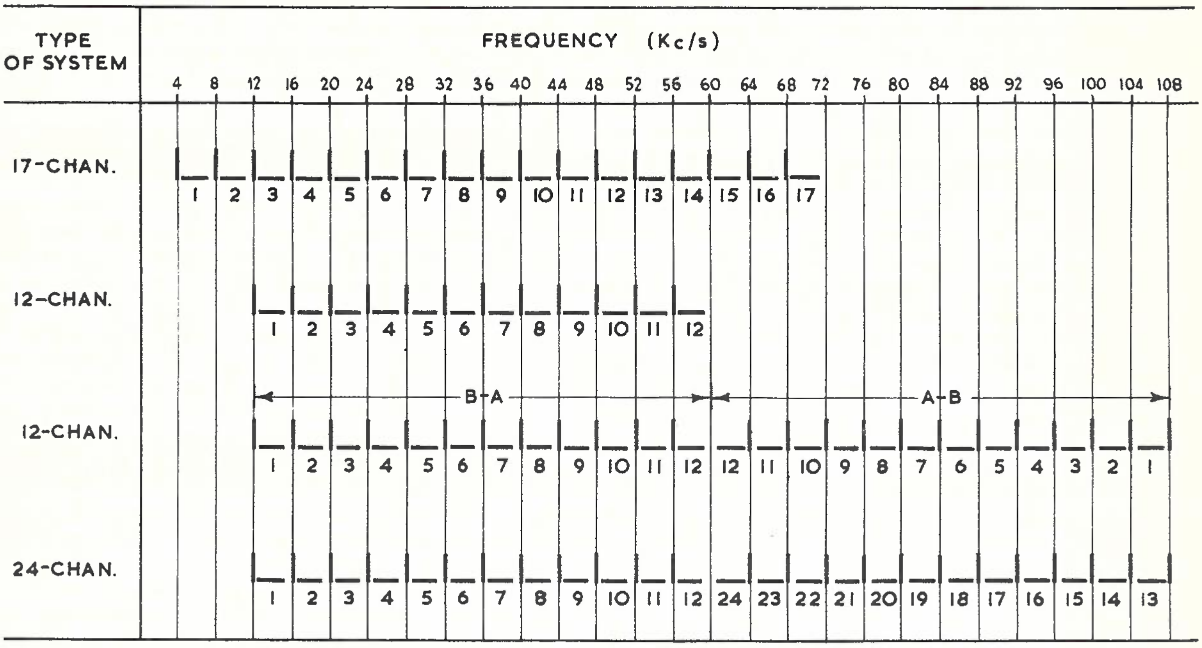
(b) 12-channel system, using separate pairs in a single cable for each direction of transmission. A frequency range 12-60 kc/s is transmitted in the B-A direction, and 60-108 kc/s in the A-B direction.

(c) 24-channel system, which transmits a frequency range 12-108 kc/s over pairs in separate cables for each direction of transmission.

The above systems are designed for 4-wire operation on unloaded cable pairs or radio link bearer circuits. The various applications are shown in Fig. 1.

/ 2.2

2.2 The channel frequency allocations are shown in Fig. 2.



CHANNEL FREQUENCY ALLOCATIONS FOR WIDE-BAND CABLE CARRIER SYSTEMS.

FIG. 2.

When a number of these channels are interconnected on long distance calls, each additional link reduces the channel band-width. To prevent serious reduction in intelligibility in this case, an effective band-width of 0.3-3.4 kc/s is provided on each channel. To obtain the necessary band-width and allow filter margins for the design of channel band filters, carrier frequencies are spaced at 4 kc/s intervals. To simplify the carrier supply equipment and reduce its cost, all carrier frequencies are multiples of 4 kc/s.

No provision is made in the frequency allocation of cable carrier systems for crosstalk reduction by staggering and inversion of the channel frequencies of different systems, as in the case of open-wire carrier telephone systems designed for operation over 2-wire aerial circuits. Crosstalk between cable carrier systems is reduced by the following methods -

(i) using pairs in separate cables for each direction of transmission,

(ii) using different frequencies for each direction of transmission over separate pairs, when a single cable only is available on a route, and

(iii) using crosstalk neutralising networks.

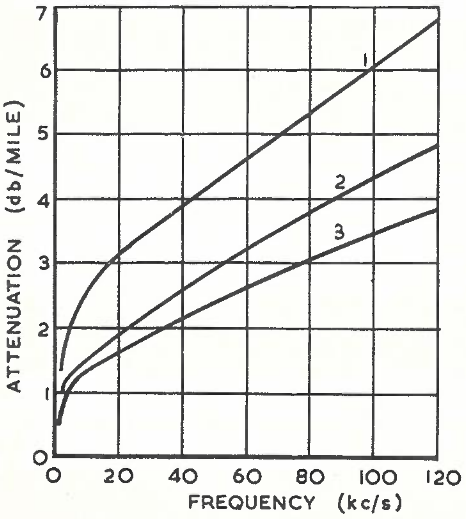
/ 3.

3. TRUNK CABLE CHARACTERISTICS.

3.1 In Australia the chief application of cable carrier systems has been to routes where there are no existing cables, and special carrier type cables have been provided for 12-, 17- and 24-channel operation. The first cables of this type were laid on the Sydney-Newcastle-Maitland route. Similar carrier type cables consisting of two 24-pair 40 lb./mile star quad cables forming a "go" and "return" 4-wire system have since been installed on different routes. These are similar to trunk type star quad cables. The essential differences are lower mutual capacity, mutual capacity deviation and capacity unbalance limits.

Recently, cable carrier equipment has also been applied to obtain additional channels from existing V.F. type trunk cables which have reached the limit of their traffic carrying capacity. Where two existing V.F. type cables are available on a route, the method of operation of carrier systems is similar to that on the special carrier type cables. Where single cables only are available on a route, different frequencies are used for each direction of transmission to reduce crosstalk. As existing V.F. type cables are not designed for multi-channel carrier operation, the crosstalk characteristics are inferior to those of the carrier type cables, and it is necessary to select cable pairs suitable for carrier working. Where V.F. or 30 kc/s carrier loading is provided on the V.F. type cables, it is necessary to deload the cable pairs required for multi-channel operation.

3.2 The attenuation of cable circuits is much higher than that of aerial lines and this necessitates a closer spacing of repeater stations on trunk cable routes. The maximum repeater spacing is about 20 miles and depends on the attenuation per mile of the cable used, since the maximum and minimum level, and therefore, the total attenuation, are limited by amplifier and noise considerations. Typical attenuation versus frequency characteristics of cables used for carrier operation are shown in Fig. 3.



Notes:

(1) 20 lb. Local Type Star Quad.

(2) 40 lb. Trunk " " "

(3) 40 lb. Carrier " " "

CABLE ATTENUATION VERSUS FREQUENCY.

FIG. 3.

The maximum spacing allowable between repeater stations based on a maximum permissible attenuation of 57 db is shown in Table I, for the types of systems in use in Australia.

/ Table I.

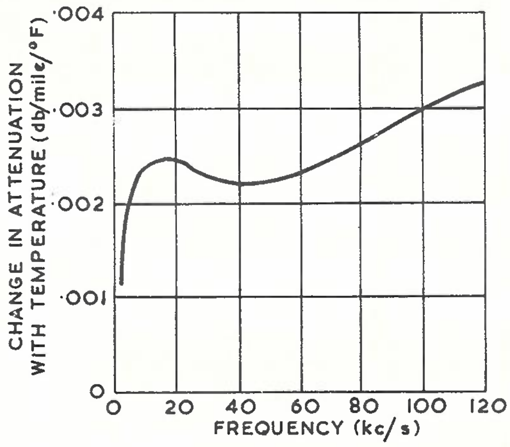
No. of channels.	Frequency Range (kc/s)	Maximum repeater spacing (miles)	
		40-lb Carrier Star Quad.	20-lb Local Type Star Quad.
12	12-60	21.8	12.25
17	4-72	20.0	11.2
12 and 24	12-108	15.8	8.9

MAXIMUM REPEATER STATION SPACING FOR CABLE CARRIER SYSTEMS.

TABLE I.

3.3 The cable attenuation at any frequency depends on the temperature of the cable, due chiefly to the variation in resistance of the conductors with temperature. Fig. 4 shows the variation in attenuation per degree Fahrenheit change of temperature for 1 mile of a typical 40 lb. carrier type star quad cable.

It is noted in Fig. 4, that, in the range 8-70 kc/s, the change in attenuation with temperature is approximately independent of frequency. This is important in the design of equipment which compensates for the variation of cable attenuation. The necessity for some form of automatic regulating equipment in certain cases is seen from the fact that a 2° change in temperature on a 1,000 mile circuit causes an over-all attenuation variation of approximately 5 db. However for underground cables buried over 18 inches deep, the temperature variation is seasonal rather than daily or weekly, and on the shorter cable routes at present provided in Australia, attenuation variations can usually be compensated for by a seasonal adjustment of amplifier settings. Special automatic gain control equipment is therefore, necessary at only a few stations on the longer cable routes in Australia.



40 lb. CARRIER TYPE STAR QUAD CABLE.
VARIATION IN ATTENUATION
WITH TEMPERATURE.

FIG. 4.

3.4 Future Developments. A number of carrier type cables have been laid on several routes in Australia, and a large programme for the future provision of cables of this type has been planned. However, subsequent development for new routes must be limited by the introduction of coaxial cable carrier systems, which are at present used extensively in Great Britain and U.S.A. These systems can provide more channels than are provided by two 24-pair carrier type cables carrying 24-channel carrier systems, and the cost per channel is generally less than that of the cable carrier systems. A typical coaxial cable system is the type L1 which provides up to 600 channels, using the frequency range up to 3 Mc/s, but this system is not used in Australia at present. After the introduction of coaxial systems in Australia it is probable that further installations of cable carrier type equipment will be confined largely to existing carrier cable routes, and to trunk line relief on existing V.F. type cables.

/ 4.

4. BASIC OPERATION OF 12- AND 24-CHANNEL SYSTEMS.

4.1 In 12- and 24-channel carrier-on-cable systems, the basic principle of operation is similar to the type J 12-channel open wire systems described in Paper No. 5. The procedure is to translate each telephone channel from the normal V.F. band to such a position in the frequency spectrum that each channel is placed side by side to form one broad continuous band for transmission over the cable pair. At the distant terminal a reverse procedure is used to separate each of the channels.

In the more common 12-channel systems, a frequency band 12-60 kc/s is transmitted over the cable and two stages of frequency translation are required to shift the twelve channels to the desired frequency range. In the less common 12-channel systems a frequency band 60-108 kc/s is transmitted over the cable and only one stage of modulation is required.

In the 24-channel system, which is a combination of the above two types of 12-channel system, a frequency band 12-108 kc/s is transmitted over the cable and twelve of the channels are subjected to one modulation process and twelve to two modulation processes. The first stage of modulation is known as channel modulation, and the second as group modulation.

4.2 12-Channel System (Transmitted Over Pairs in "Go" and "Return" Cables.) Fig. 5 shows a simplified block schematic diagram of a 12-channel cable carrier terminal. The channel equipment up to the 60-108 kc/s point is similar to that used in the type J 12-channel open-wire system described in Paper No. 5.

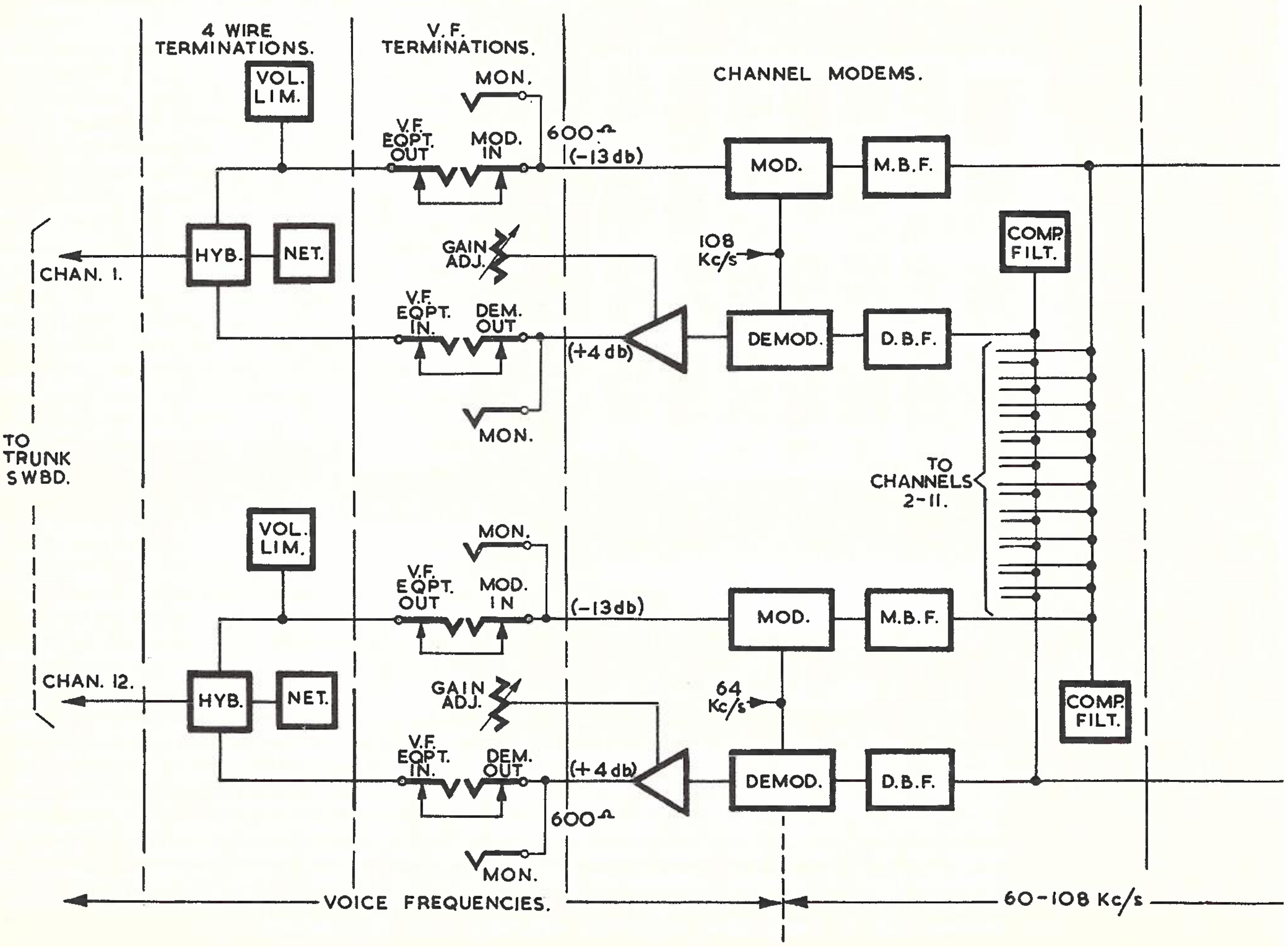
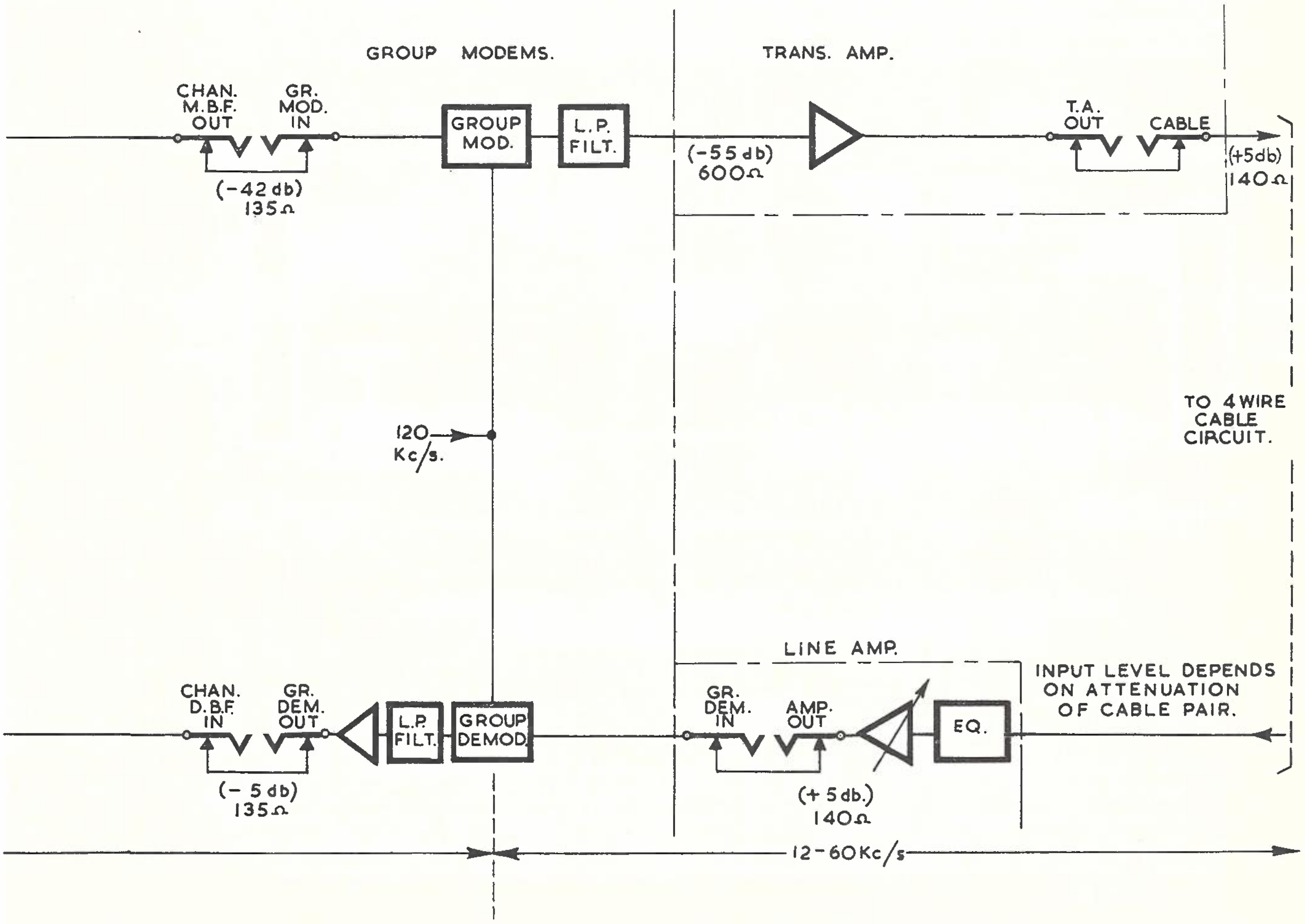


FIG. 5. BLOCK SCHEMATIC CIRCUIT

The V.F. circuits of each channel pass to and from the local switchboard via the 4-wire terminations bay. The hybrid coil equipment that interconnects the 4-wire carrier terminal circuits with the local 2-wire circuits is mounted on this bay. The 4-wire speech circuits are connected via jack fields on the V.F. terminating bay where monitoring and testing procedures are carried out.

In the transmitting direction, each of the 12 V.F. channels lying in the range 0.3-3.4 kc/s passes from its terminating panel to its associated channel modulation stage mounted on the channel bay where it modulates one of the 12 carrier supplies. These carrier frequencies range from 64-108 kc/s and are spaced at intervals of 4 kc/s. From the products of these modulation processes, the lower sideband is selected by a crystal band-pass filter and the original signals, carrier frequencies and upper sidebands are suppressed. The outputs of all 12 band-pass filters are paralleled together resulting in a signal lying in the frequency range 60-108 kc/s. This block of frequencies represents the lower sidebands of the 12 channel modulators. This signal passes to the group modem bay which mounts the group modulator and demodulator panels. In the group modulation stage, the 60-108 kc/s band from the channel modulation stages, is modulated with the group carrier frequency of 120 kc/s. As in the channel modulation stage, the lower sideband of this modulation process is selected by a filter. The resulting signal band of 12-60 kc/s is taken to the transmitting amplifier bay and raised in level by the transmitting amplifier to a value suitable for transmission over the cable. The channel frequency ranges are listed in paragraph 4.5.

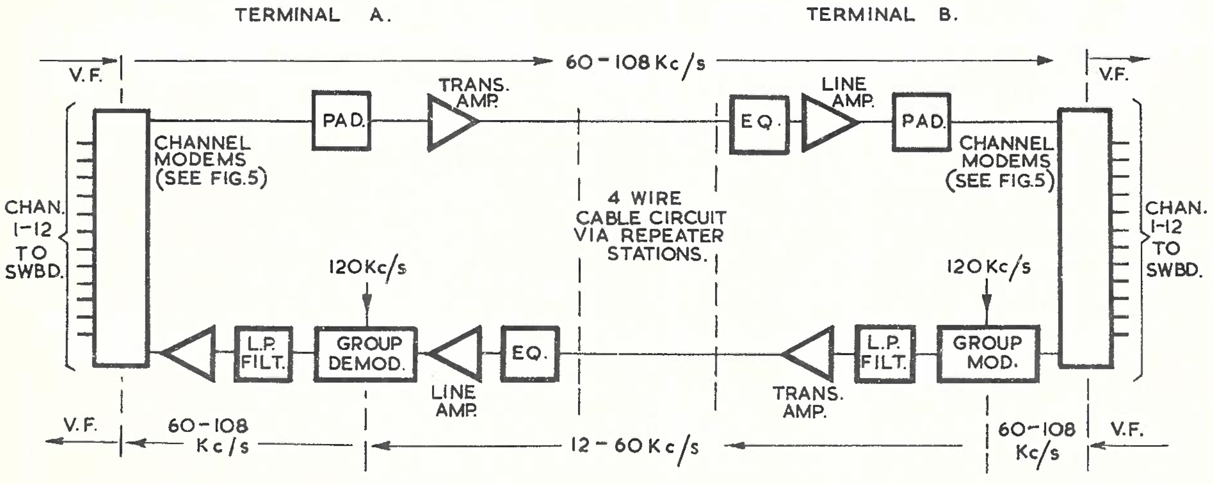


OF 12-CHANNEL CABLE CARRIER SYSTEM.

The chief reason for this method of generation of the cable frequencies is to permit the use of crystal type band filters in the channel modem stages. Crystal band filters are most economical for frequencies above 50 kc/s, and enable a very good channel frequency response to be obtained.

In the receiving direction the 12-60 kc/s frequency band transmitted over the cable passes to the line amplifier bay where an equaliser corrects the frequency distortion introduced by the cable, and an amplifier raises the signal level to a suitable value. It then passes to the group modem bay and is applied to the group demodulator to which is also applied a carrier frequency of 120 kc/s. The lower sideband of the group demodulation process is the channel band 60-108 kc/s, and this band is selected and passes to the channel bay. Here each circuit is selected by the appropriate channel band-pass filter and applied to its channel demodulator to which is also applied one of the 12-channel carrier supplies. The resulting V.F. band in each channel is amplified by the channel demodulator-amplifier and the output is applied to the local switchboard via the associated terminating panel.

4.3 12-Channel System (Transmitted over Pairs in Single Cable). When separate pairs in a single cable are used for each direction of transmission, a frequency range 12-60 kc/s is transmitted in the B-A direction and 60-108 kc/s in the A-B direction. The terminal equipment in this case is similar to that described in paragraph 4.2, except that group modulation and demodulation processes are not applied in the 60-108 kc/s direction of transmission. A simplified block schematic diagram is shown in Fig. 6.



BLOCK SCHEMATIC CIRCUIT OF 12-CHANNEL CABLE CARRIER SYSTEM,
USING SEPARATE FREQUENCIES FOR EACH DIRECTION.

FIG. 6.

In the transmitting direction, the 60-108 kc/s output from the modulator band-pass filters is applied via a pad to the transmitting amplifier input. In the receiving direction at the opposite terminal, the line amplifier output is applied via a pad to the inputs of the channel demodulator band-pass filters. The pads adjust the correct levels at the inputs to the transmitting amplifier and the channel bay respectively.

/ 4.4

4.4 24-Channel System. In 24-channel systems, the 12-60 kc/s frequencies of a 12-channel system are combined with a second 12-channel group in the range 60-108 kc/s at each terminal to form a 12-108 kc/s band for transmission over the cable. The terminal equipment is similar to that provided in the case of the 12-channel systems previously described. An additional bay is necessary to mount the equipment that combines the two individual groups into one group for transmission over the cable, and divides them again into their respective groups at the distant receiving terminal. A simplified block schematic diagram of a 24-channel cable carrier terminal is shown in Fig. 7.

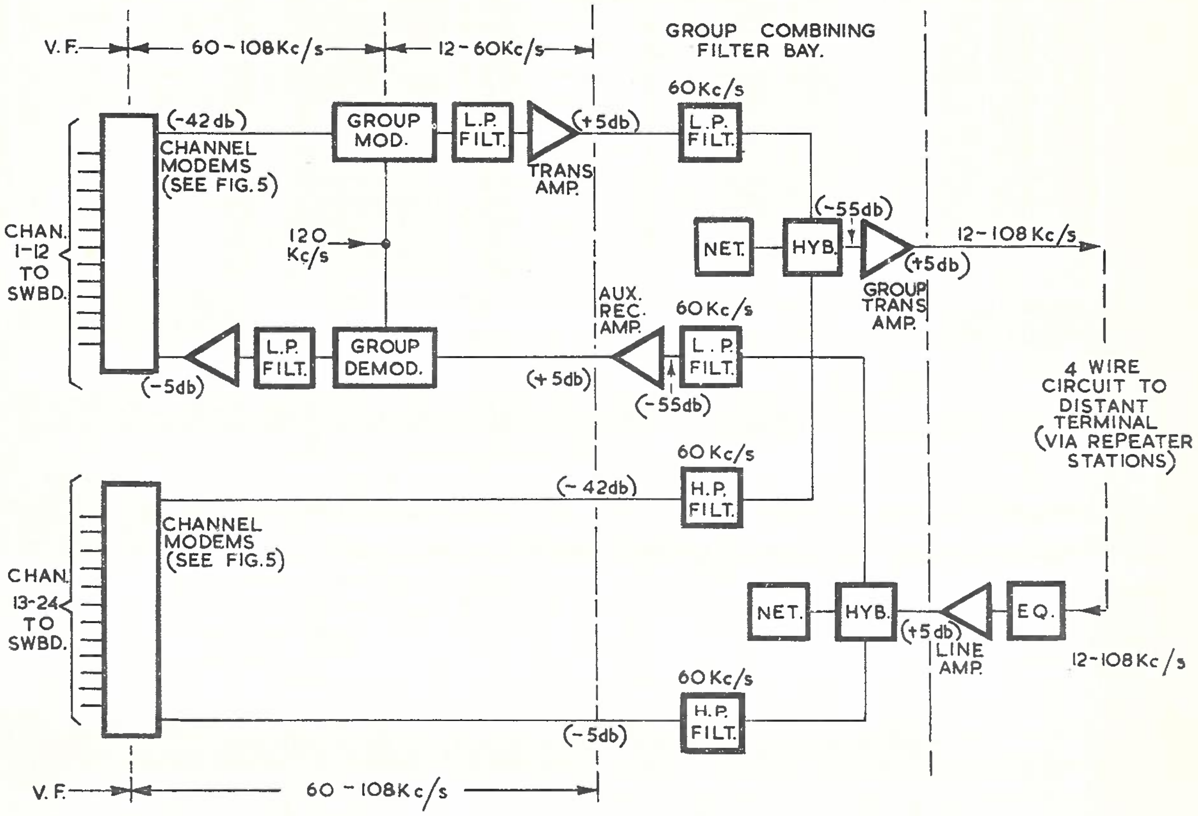


FIG. 7. BLOCK SCHEMATIC DIAGRAM OF 24-CHANNEL CABLE CARRIER TERMINAL.

In the transmitting direction, the 12-channels comprising the 12-60 kc/s group are treated in the manner outlined in paragraph 4.2 until they reach the output of the transmitting amplifier. From here they are applied to a group combining filter bay where they pass through a 60 kc/s low-pass crystal filter to a hybrid coil. The twelve channels comprising the 60-108 kc/s group are taken, however, directly from the paralleled outputs of the channel modulator band-pass crystal filters via a 60 kc/s high-pass crystal filter to the other pair of input terminals of the hybrid coil. The two groups are thus combined and the signal is amplified to a suitable level for transmission over the cable by the group transmitting amplifier.

In the receiving direction, the reverse of the procedure described above occurs. At the distant terminal, the signal passes from the cable terminating equipment to the line amplifier bay and to the group combining filter bay. The 12-60 kc/s group passes via a hybrid coil to a 60 kc/s low-pass crystal filter and then to the auxiliary receiving amplifier where it is amplified before passing to the group demodulating equipment. The 60-108 kc/s group passes via the hybrid coil and a 60 kc/s high-pass crystal filter to the parallel inputs of the channel demodulator band-pass crystal filters. Each channel equipment is identical, an advantage from both the manufacturing and maintenance aspects. As in the case of the 12-channel system, the channel equipment comprises the major portion of the terminal equipment.

/ 4.5

4.5 Channel Frequency Bands. Table II shows the carrier and sideband frequencies at various stages in the 12-channel system shown in Fig. 5, assuming a V.F. band of 0.3-3.4 kc/s.

Channel (1)	Channel Modem Carrier Freq. (2)	Group Mod. Input and Group Demod. Output (3)	Group Modem Carrier Freq. (4)	Line Frequencies (5)
1	108 kc/s.	107.7-104.6 kc/s.	120 kc/s.	12.3-15.4 kc/s.
2	104 kc/s.	103.7-100.6 kc/s.		16.3-19.4 kc/s.
3	100 kc/s.	99.7- 96.6 kc/s.		20.3-23.4 kc/s.
4	96 kc/s.	95.7- 92.6 kc/s.		24.3-27.4 kc/s.
5	92 kc/s.	91.7- 88.6 kc/s.		28.3-31.4 kc/s.
6	88 kc/s.	87.7- 84.6 kc/s.		32.3-35.4 kc/s.
7	84 kc/s.	83.7- 80.6 kc/s.		36.3-39.4 kc/s.
8	80 kc/s.	79.7- 76.6 kc/s.		40.3-43.4 kc/s.
9	76 kc/s.	75.7- 72.6 kc/s.		44.3-47.4 kc/s.
10	72 kc/s.	71.7- 68.6 kc/s.		48.3-51.4 kc/s.
11	68 kc/s.	67.7- 64.6 kc/s.		52.3-55.4 kc/s.
12	64 kc/s.	63.7- 60.6 kc/s.		56.3-59.4 kc/s.

TABLE II. CHANNEL FREQUENCIES FOR 12-CHANNEL SYSTEM.

For the 12-channel system shown in Fig. 6, the table applies to the B-A direction of transmission. For the A-B direction, the frequencies shown in Column 3 are applied directly to line.

For the 24-channel system shown in Fig. 7, the table applies to channels 1-12 for both directions of transmission. For channels 13-24, the frequencies shown in Column 3 are applied directly to line for both directions of transmission.

Reference should also be made to Fig. 2 for channel frequency allocations.

4.6 Relative Transmission Levels. The systems are designed so that a wide range of levels can be accepted by the 4-wire terminating set in which each channel terminates, and at the same time levels of -13 db at the input to the channel modulator and +4 db at the output of the channel demodulator, may be established. The modulator band-pass filter output from each channel is -42 db, and the demodulator band-pass filter input is -5 db. The level of each channel at the output of the transmitting amplifier and transmitted to line is +5 db. All levels are referred to the level at the trunk switchboard.

The receiving equipment has sufficient gain to enable overall circuits with zero equivalent to be obtained over 40 lb. carrier quad cable, with repeater spacings of up to about 22 miles for 12-channel systems which transmit up to 60 kc/s, and 16 miles for systems which transmit up to 108 kc/s. The repeater and line amplifiers are operated at an output level for each channel of +5 db referred to switchboard zero and have a maximum gain of 65 db.

5. TYPICAL 12- AND 24-CHANNEL TERMINAL EQUIPMENT.

5.1 A picture of the equipment bays used in a typical 12-channel cable carrier terminal installation is shown on page 13. The equipment is manufactured by Standard Telephones and Cables Pty. Ltd., Australia. The bays are self-contained in respect of power supply circuits. Each bay is equipped with all necessary fuses, resistance lamps and alarm relays. Power is distributed by busbars attached to the top of the bays. The equipment normally operates from 24 volt and 130 volt power supplies. Normal fuse and failure alarms are provided to give warning of equipment failures.

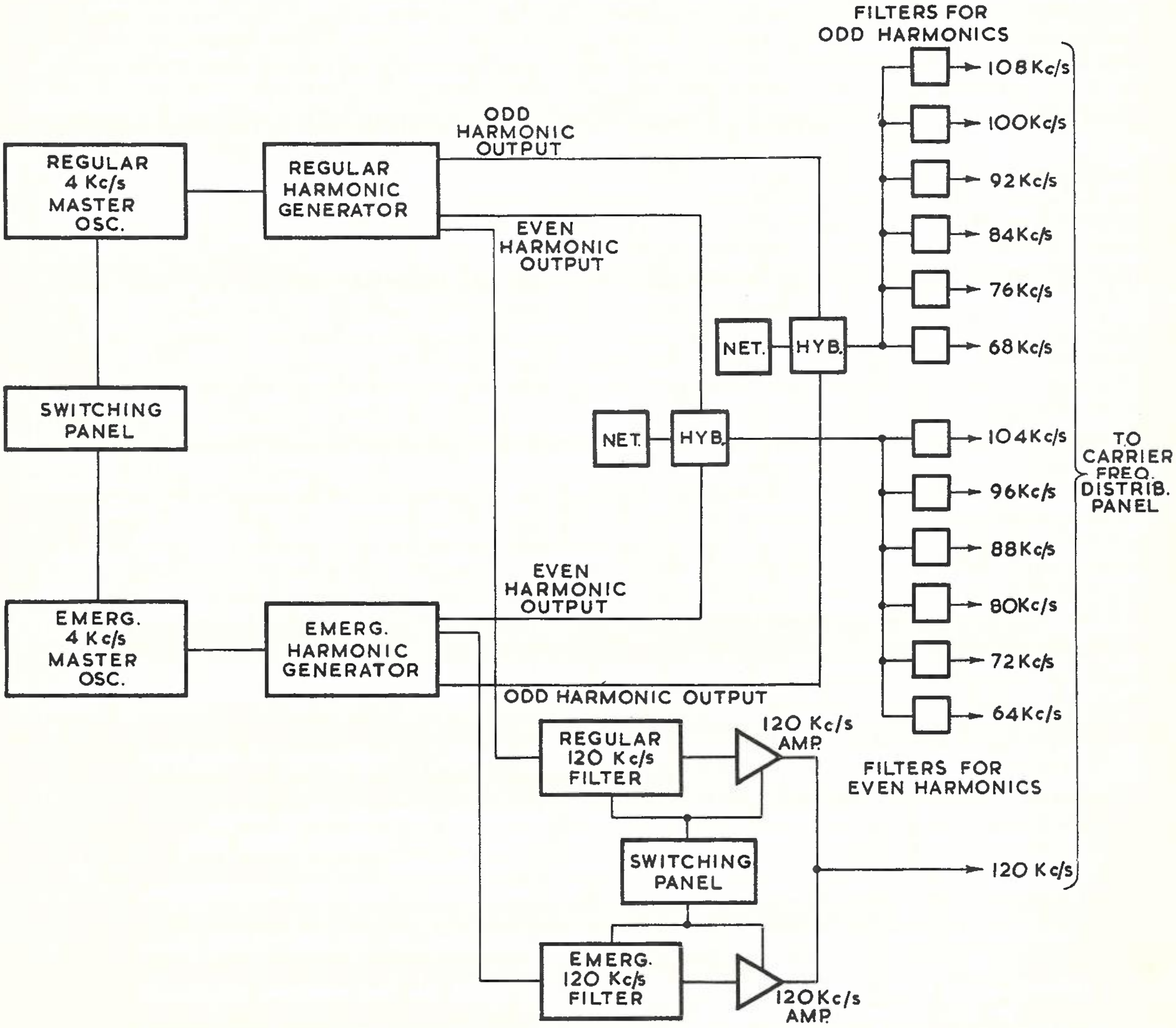
5.2 Carrier Supply Bay. The carrier supply bay equipment generates all the channel carrier and group carrier frequencies for the various modulation and demodulation processes. All these frequencies are derived from a single basic generator as harmonics of a 4 kc/s fundamental frequency. One bay supplies up to twelve 12-channel systems. Duplicate equipment is provided to avoid interruption to the large numbers of communication channels which depend on these supplies. In the event of a failure or interruption of the regular supplies, the load is transferred from the regular circuit to the emergency or standby circuit.

/ The

The bay is equipped with -

(i) Regular and emergency 4 kc/s master oscillator panels.
(ii) Regular and emergency harmonic generator panels.
(iii) Regular and emergency 120 kc/s amplifier panels.
(iv) Change-over switching panel.
(v) Hybrid coil panel.
(vi) Even harmonic carrier filter panel.
(vii) Odd harmonic carrier filter panel.

A block schematic circuit showing the interconnection between these items is given in Fig. 8.



CHANNEL AND GROUP MODEM CARRIER SUPPLY ARRANGEMENTS.

FIG. 8.

A valve oscillator controlled by a tuning fork generates the basic frequency of 4 kc/s. For stability of oscillation, the tuning fork is mounted in a temperature controlled oven. The output of the oscillator is amplified, filtered and applied to a harmonic generating circuit. This circuit consists essentially of an easily saturated coil with non-linear characteristics and associated capacitors which produce an output wave form rich in the odd harmonics of the carrier frequency. The even harmonics are obtained by using the frequency doubling characteristics of a full-wave rectifier. The principle of operation of this arrangement is described in Long Line Equipment I.

The required carrier frequencies are selected from the odd and even harmonic outputs by narrow band-pass crystal filters. The channel carrier frequencies are applied directly to a distribution panel from which the required frequencies for the systems are obtained. The 120 kc/s group carrier frequency supply is first amplified by a stable negative-feedback amplifier before appearing on the distribution panel.

Because failure of the channel carrier and 120 kc/s group carrier supplies interrupts communication on a large number of channels, provision is made to avoid such a breakdown. Each of the three panels concerned in the generation of the supplies - the master oscillator, the harmonic generator and the 120 kc/s amplifier - is duplicated. Two completely independent generating circuits are thus provided. The change-over from the regular circuit to the emergency or standby circuit may be made either manually, by means of a key, or automatically when the 120 kc/s supply fails, is interrupted, or its level drops to a predetermined value. The switching panel provides these facilities.

5.3 4-Wire Terminations. The 4-wire terminations bay provides facilities for connecting 4-wire circuits to 2-wire terminations. A fully equipped bay mounts 20 terminating panels and 6 terminal strip panels. These provide terminations for a maximum of 60 circuits, as each panel is equipped with three 4-wire terminating sets. In addition to the three hybrid coil arrangements, which constitute the terminating circuits proper, each panel mounts three limiter circuits, and six level adjusting pad circuits.

5.4 V.F. Terminations. The V.F. terminations bay provides access by jack fields to points in the 4-wire V.F. circuits of the carrier systems. Facilities for monitoring these points by an amplifier and associated switching panel are sometimes provided. The demodulator-amplifier gain control potentiometers are mounted on one of the two jack fields associated with each system. A fully equipped bay provides jack fields for five 12-channel systems and all the equipment is mounted on the front of the bay.

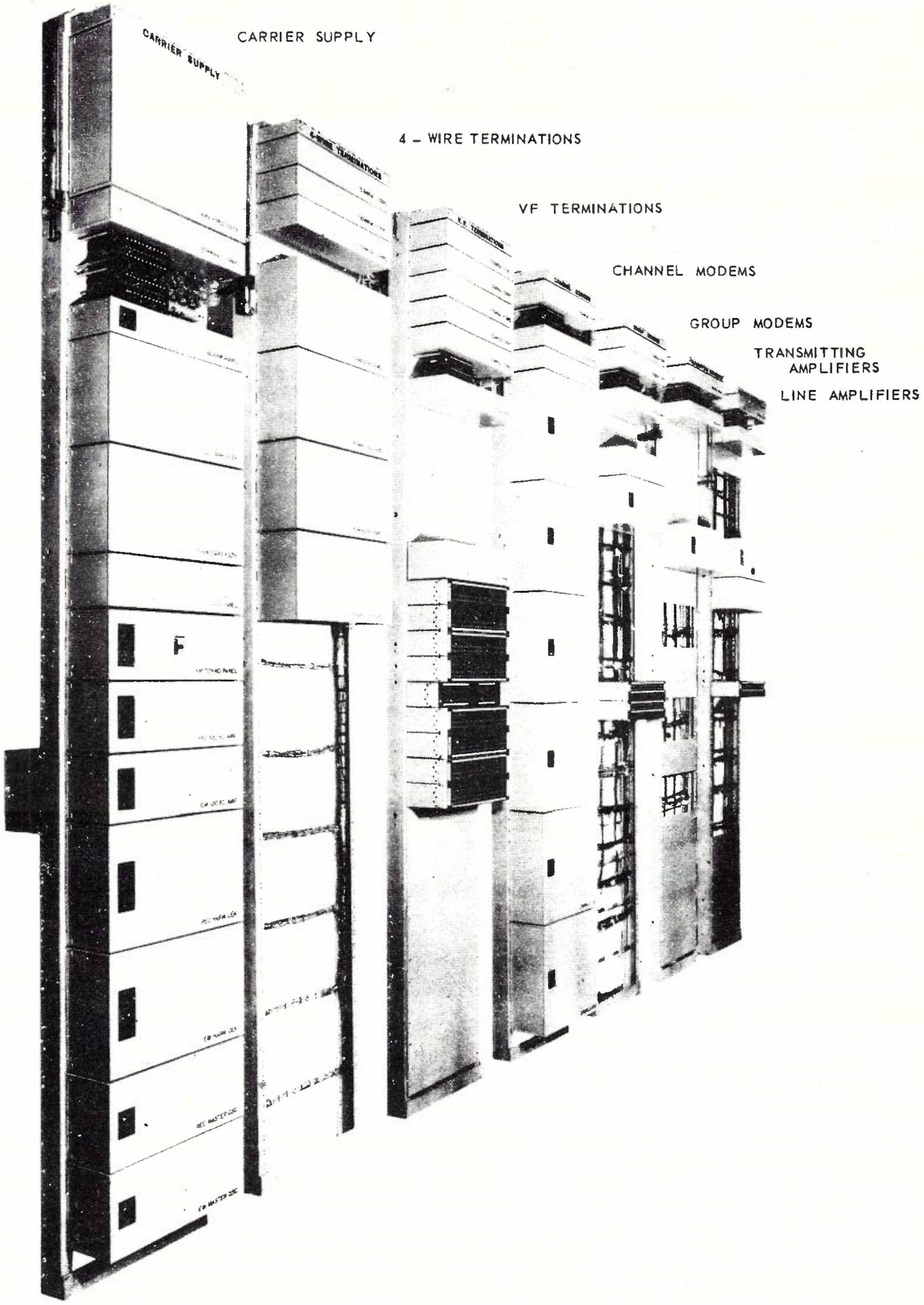
A jack field consisting of two sections is provided for each 12-channel system. The 4-wire circuits of the 2-wire/4-wire terminating panels and the V.F. inputs and outputs of the channel panels are terminated on this jack field. By patching into these jacks, access to the appropriate point in the circuit is obtained and testing procedures carried out. In addition, by use of the monitoring panel and its associated switching panel in conjunction with the jack field, facilities are provided for monitoring, talking or ringing over the 4-wire circuits of the carrier channels and over physical trunk circuits.

The monitoring panel contains a single stage amplifier using a 6SJ7GT valve (or 4328A valve) with a hybrid coil arrangement in the input circuit, and an anti-sidetone coil for use with a physical 2-wire circuit.

The switching panel mounts 4 keys and a small jack field. Operation of the keys provides the following facilities. -

(i) Listening at the input to the channel modulator circuit. (Mon. -13.)
(ii) Listening at the output of the channel demodulator circuit. (Mon. +4.)
(iii) Listening at both points simultaneously. (Key Normal.)
(iv) Talking over the carrier channel to the near and/or distant switchboard. (Talk 4-W.)
(v) Talking over a 2-wire physical circuit terminated on the switching panel jack field. (Talk 2-W.)
(vi) Ringing over the carrier channel from the input to the channel modulator to the distant switchboard. (Ring -13.)
(vii) Ringing the local switchboard from the output of the channel demodulator amplifier. (Ring +4.)
(viii) Ringing over a 2-wire physical circuit terminated on the switching panel jack field. (Ring 2-W.)

/ Bays



BAYS USED IN 12-CHANNEL CARRIER-ON-CABLE SYSTEM.

5.5 Channel Modems. The equipment installed on this bay operates on a 4-wire basis. In the transmitting direction, it modulates the V.F. circuits, translating groups of 12 V.F. channels into the frequency band 60-108 kc/s. In the receiving direction, it selects each of the channels from a group in the 60-108 kc/s band and restores them to the V.F. range.

When fully equipped each bay provides channel equipment for two groups of twelve channels - the equipment for one group being mounted on one side of the bay and that for the other group on the other side.

Each channel panel provides equipment for two transmitting and two receiving channels and mounts 2 modulators, 2 demodulators, 2 demodulator amplifiers, 4 crystal band-pass filters and 4 level adjusting networks. Valves used are 6SJ7 or 4328A.

In addition to the channel panels, the bays are equipped with terminal strip panels, fuse and lamp panels and compensating network panels.

5.6 Group Modems. The equipment on this bay operates on a 4-wire basis. In the transmitting direction, a group of 12 channels in the frequency range 60-108 kc/s as a result of the initial channel modulation process, modulates the group carrier frequency of 120 kc/s, and is translated to a frequency band 12-60 kc/s for transmission over the cable. In the receiving direction, the signal from the distant terminal, occupying the line frequency band of 12-60 kc/s, is demodulated by the same group carrier frequency, and is translated to the group frequency band 60-108 kc/s.

When fully equipped each bay provides group modulation and demodulation equipment for twelve 12-channel systems, 6 systems on each side. The group modulator panel consists of a modulator circuit and a low-pass filter. The group demodulator panel includes a two stage negative feedback amplifier, using 6SJ7GT (or 4328A) valves, a low-pass filter and a demodulator circuit.

Two jack panels mounted on each bay provide patching facilities for both directions of transmission. Fuse and lamp, and relay panels are also provided.

5.7 Transmitting Amplifiers. This bay mounts the transmitting amplifiers and associated fuse and lamp, and relay panels. The amplifiers are designed to transmit to the line a frequency band 12-108 kc/s.

When fully equipped each bay accomodates equipment for twelve 12-channel systems. The transmitting amplifier is a 4-stage amplifier using three 6SJ7GT (or 4328A) resistance-coupled stages and a 6V6GT (or 4329A) power output stage. Negative feedback is applied over all four stages from a bridge network in the output circuit of the output valve to the cathode circuit of the input valve. The gain with feedback is fixed at a nominal value of 60 db and the gain without feedback is about 90 db. The frequency response is essentially flat over the range 12-108 kc/s.

5.8 Line Amplifiers. The line amplifier bay is used either as a receiving amplifier bay at a terminal or as a repeater amplifier bay at a repeater station. A jack field is included in the equipment to provide patching facilities. In addition to the amplifiers, line equalisers are also mounted on the bay together with fuse and lamp, and relay panels. A fully equipped bay provides amplifying and equalising equipment for twelve 12-channel systems.

The line amplifier which is used as a receiving amplifier at a terminal, or a repeater amplifier at a repeater station, is similar to the transmitting amplifier except that a gain control is provided. This can reduce the amplifier gain from its maximum value by up to 10 db in 1 db steps.

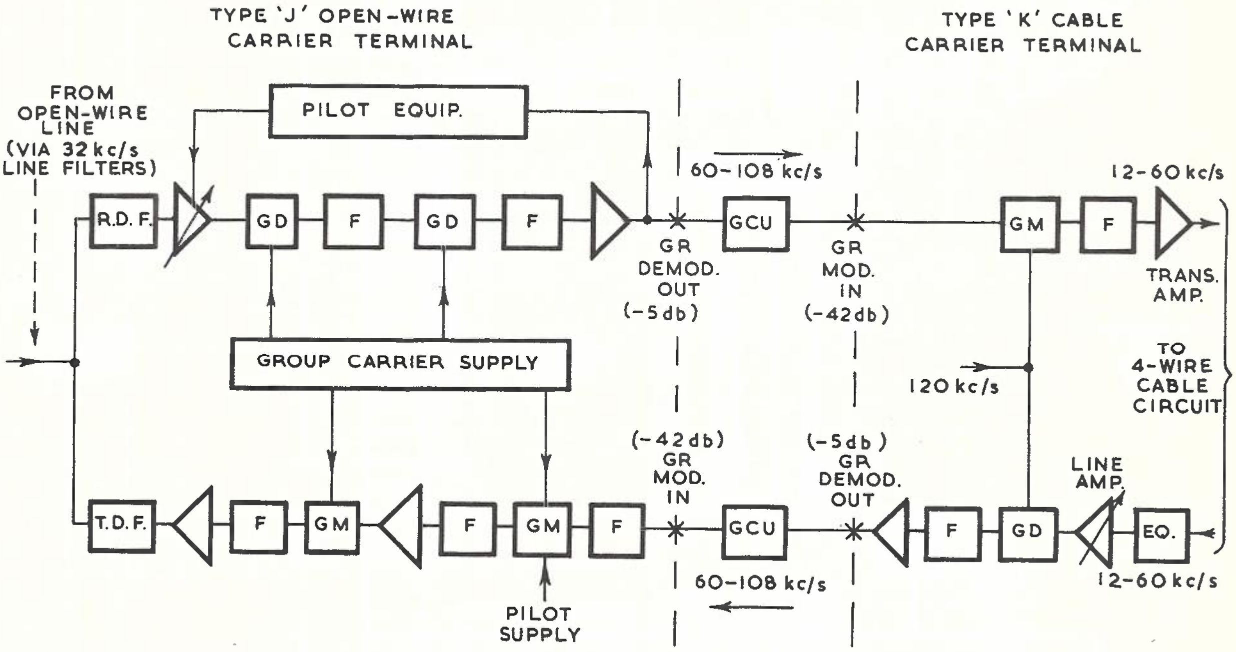
5.9 Group Combining Filters. The group combining filter bay is used in 24-channel carrier-on-cable systems to combine in the transmitting direction and separate in the receiving direction the two groups of twelve channels comprising the 24-channel system.

/ The

The group transmitting amplifier, the auxiliary receiving amplifier, and the transmitting and receiving group filters are mounted on the bay. Two jack panels, a terminal panel, a fuse panel and a relay panel are also supplied. A fully equipped bay mounts equipment for four 24-channel systems.

6. GROUP CONNECTION OF CARRIER SYSTEMS.

6.1 The standardisation of channel equipment in 12- and 24-channel cable, 12-channel open wire and coaxial cable carrier systems permits a very simple means of interconnecting systems of different types without the necessity of demodulating all channels of the first system to voice frequencies and then modulating again to the line frequencies of the second system. This provides a considerable saving in terminal equipment costs as the channel equipment in both connected terminals is unnecessary. The overall frequency response of each channel is also improved, due to the reduction in the number of band filters in the channel. Fig. 9 shows the means of interconnecting open wire and cable carrier systems without demodulating the channels to voice frequencies. The systems are connected at the 60-108 kc/s points by group connecting units. These consist chiefly of level adjustment pads and filters to prevent the transfer between systems of unwanted group modulation products, and pilot frequencies used for the control of automatic gain regulating equipment.



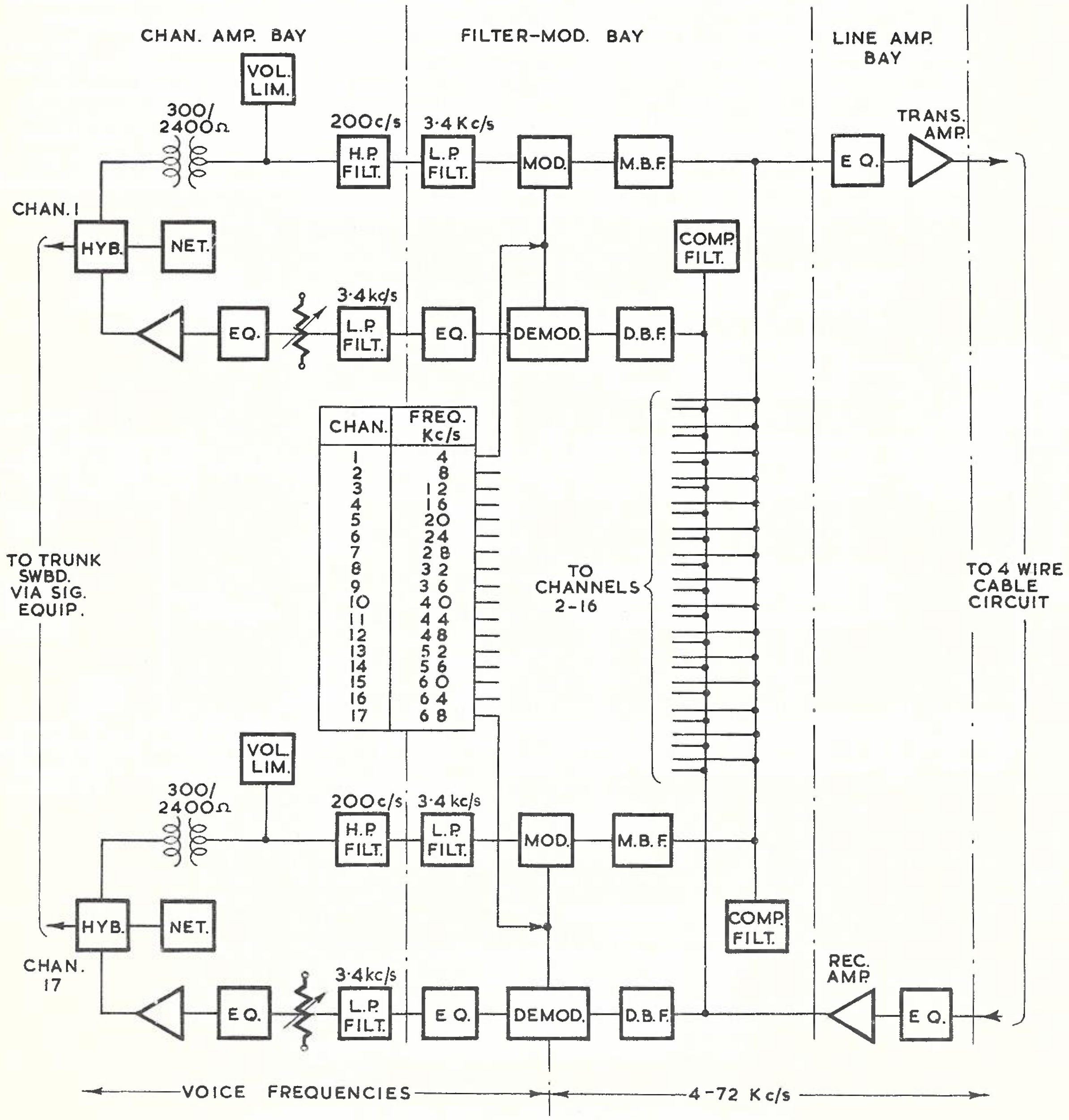
EQ = Equaliser.
F = Filter.
GCU = Group Connecting Unit.
GD = Group Demodulator.
GM = Group Modulator.
RDF = Receiving Directional Filter.
TDF = Transmitting Directional Filter.

GROUP CONNECTION OF TYPE J AND TYPE K TERMINALS.

FIG. 9.

7. 17-CHANNEL CABLE CARRIER SYSTEMS.

7.1 General Outline. The 17-channel cable carrier systems provide 17 speech channels in the frequency range 4-72 kc/s and are designed for 4-wire operation over unloaded cable pairs in separate cables for each direction of transmission. A block schematic diagram of the terminal equipment is shown in Fig. 10. Unlike the 12- and 24-channel cable carrier systems, the 17-channel systems do not use group modulation, but follow generally the method used in 3-channel open-wire carrier systems, relying on the channel modulator alone to translate each V.F. band to the band of frequencies which it occupies on the line.



CHAN.	FREQ. Kc/s
1	4
2	8
3	12
4	16
5	20
6	24
7	28
8	32
9	36
10	40
11	44
12	48
13	52
14	56
15	60
16	64
17	68

BLOCK SCHEMATIC CIRCUIT OF 17-CHANNEL CABLE CARRIER TERMINAL.

FIG. 10.

Transmitting Direction. V.F. signals from the switchboard enter the transmitting side of the channel equipment at a terminal via a carrier signalling circuit and a hybrid coil, the latter separating the opposite directions of transmission. From the hybrid coil, the V.F. signals pass through a matching transformer, limiter, high-pass filter and low-pass filter to the modulator.

A 300-2,400 ohms transformer is provided between the hybrid coil and the limiter for impedance matching purposes. The impedance viewed from the centre points of the hybrid coil, that is, the switchboard termination in parallel with its balance network, is 300 ohms. The equipment between the voltage limiter and the input to the modulator is designed with an impedance of 2,400 ohms.

The voltage limiter suppresses peaks in the V.F. signals above a certain limit and thereby prevents overloading of the transmitting and repeater amplifiers, which would produce distortion.

The high-pass filter suppresses all V.F. signals up to about 200 c/s, in order to prevent false operation of the carrier signalling equipment, and is supplied only on systems which use carrier signalling.

The low-pass filter suppresses all frequencies above 3.4.kc/s, and so allows greater tolerances in the modulator band-pass filters.

The modulator is of the double balanced copper-oxide rectifier type and uses a separate circuit for each half-cycle of carrier to facilitate fault localisation. It is supplied with a carrier frequency appropriate to the channel concerned. All carrier frequencies are multiples of 4 kc/s as shown in Fig. 10.

The modulator band-pass filter selects from the products of modulation the upper sideband required for transmission. Seventeen of these band-pass filters are paralleled on the trunk cable side of the modulators with a correction filter to compensate for the characteristics of the outside filters of the paralleled group. The filters are of the coil and capacitor type, and, as the carrier frequencies to the 17-channel modulators are only 4 kc/s apart, the design of the filters is fairly critical.

The 17 sidebands covering a range 4-72 kc/s then pass through a transmitting line amplifier and are applied to the trunk cable pair for transmission to the distant station.

Receiving Direction. In the receiving direction, the block of 17 sidebands incoming to a terminal from a trunk cable pair passes through a common equaliser and a receiving line amplifier. This equaliser, in conjunction with the equaliser of the transmitting terminal, corrects the frequency distortion introduced by the cable and the amplifier raises the signal level to a suitable value. The output of this amplifier is applied to the 17 demodulator band-pass filters in parallel. These filters direct each sideband to its appropriate channel equipment on the receiving side of the terminal. Each sideband passes through a demodulator supplied with the same carrier frequency as the corresponding modulator. The demodulators are similar in design to the modulators. The products of demodulation include the original V.F. signals which, together with other products of demodulation, pass through an equaliser to a low-pass filter. This filter rejects the unwanted products of modulation and passes the V.F. alone through a level control and an equaliser to a channel amplifier. The output of this channel amplifier passes to the switchboard via the hybrid coil and carrier signalling equipment.

Line Amplifiers. The transmitting, receiving and repeater line amplifiers, are designed to operate over the frequency range 4-72 kc/s. The amplifier is of the negative feedback type and comprises three resistance coupled voltage stages using 6J7G valves and a 6V6G power stage. Minimum gain is 60 db and maximum gain is 70 db, with a continuous adjustment of gain within the range. This is provided by a capacitor potentiometer between the second and third stages. The gain control can be manually or automatically operated. At repeater stations and receiving terminals using automatic gain control, the manually adjusted capacitor is replaced by a capacitor carried on the stepping mechanism of a reversible step-by-step switch. This varies the amplifier gain in accordance with the indications received as to the cable temperature. The switch is energised by impulses obtained from the temperature control equipment.

7.2 Generation of Carrier Frequencies. As in the case of 12-channel systems, the carrier frequencies for 17-channel systems are provided by distorting the output from a 4 kc/s oscillator. This produces harmonics of 4 kc/s, many of which are used as carriers.

/ The

The base frequency of 4 kc/s is generated by a tuned grid oscillator. To preserve frequency stability, the tuned grid circuit is maintained at a constant temperature in a temperature-controlled oven. A sharply peaked wave form, rich in harmonics, is produced by passing the 4 kc/s output from the base frequency oscillator through a unit termed a Multivibrator. This consists of a number of resistance-capacitance coupled thermionic valve stages which, with suitable adjustment of electrode and input voltages, produce the peaked wave form desired. The multivibrator output is applied to the carrier supply filters which select the 17 separate carrier frequencies, and then to carrier amplifiers which provide sufficient power to feed all the modulators and demodulators of the same frequency for a complete station. A simplified basic circuit of the arrangement is shown in Fig. 11.

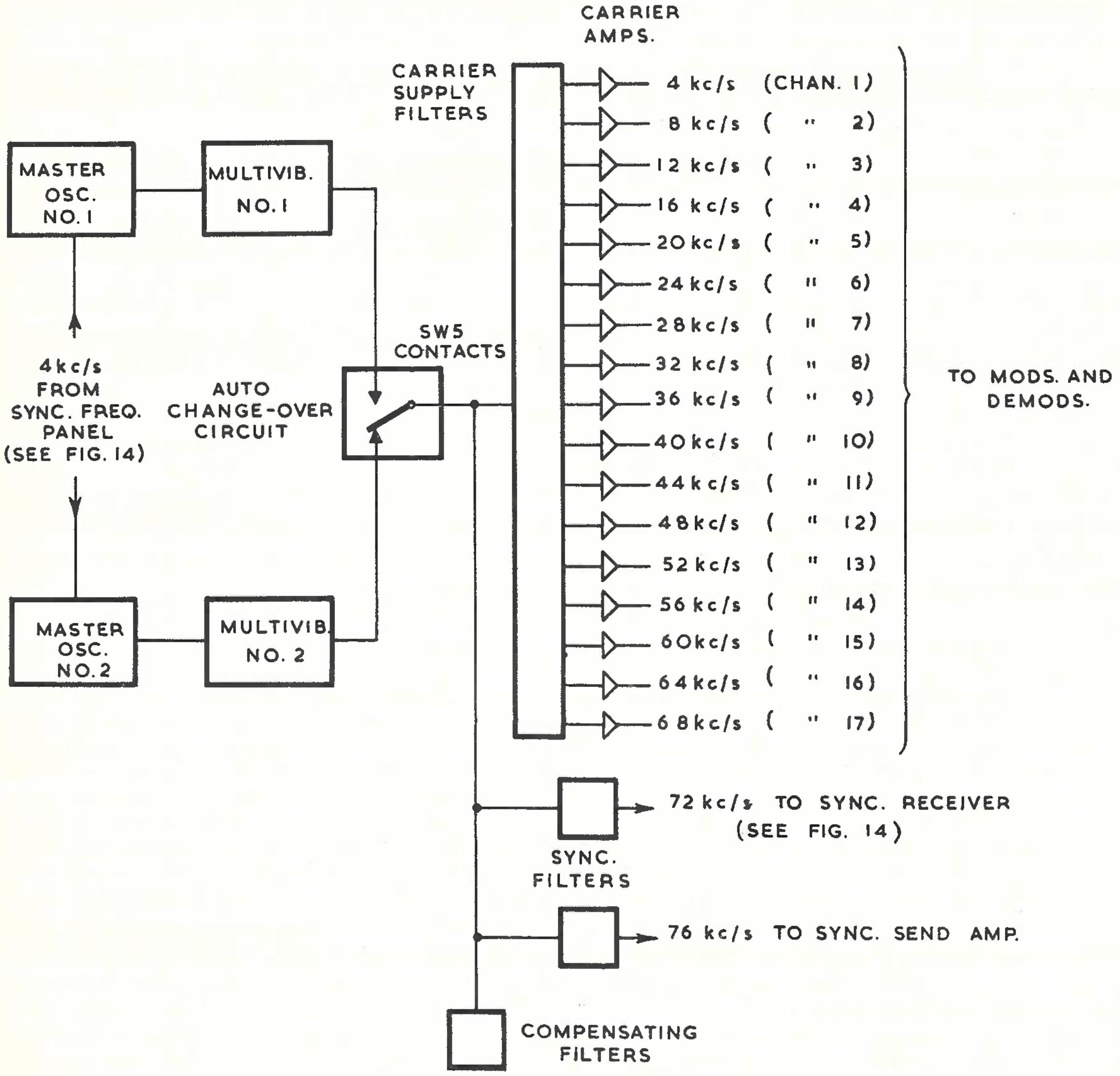


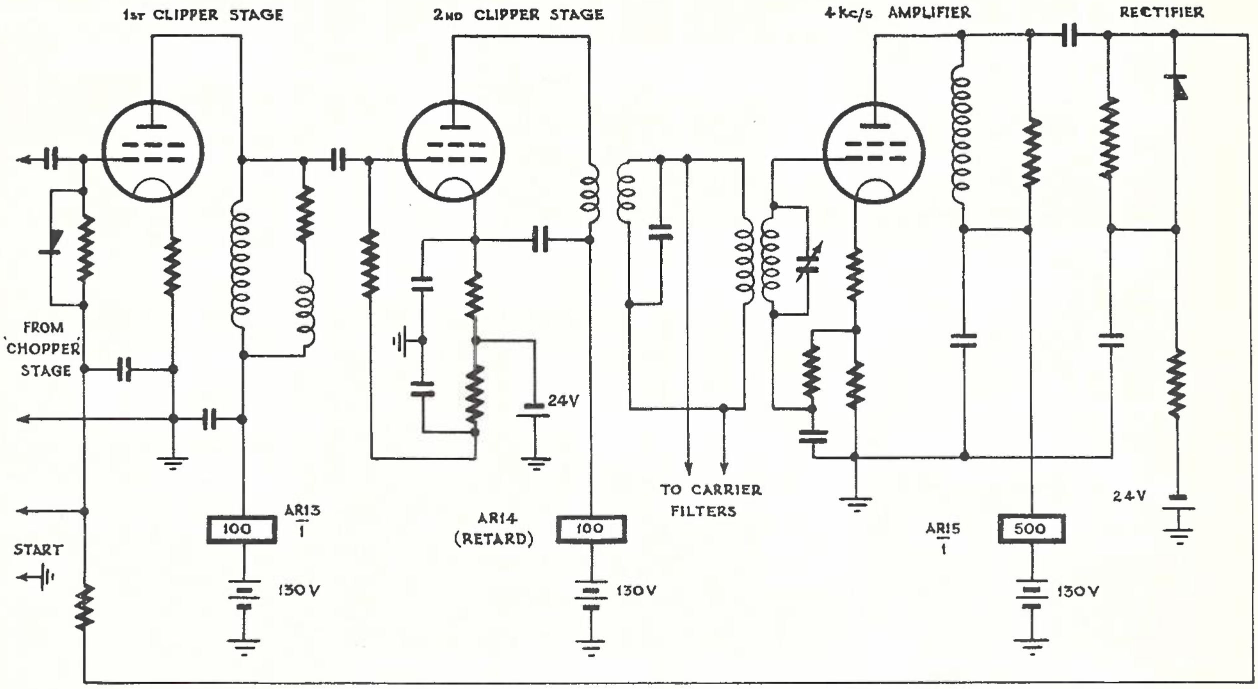
FIG. 11. CARRIER SUPPLY ARRANGEMENTS FOR 17-CHANNEL SYSTEMS.

Duplicate master oscillators and multivibrators are supplied, together with an automatic change-over and alarm circuit in the event of an oscillator or multivibrator failing. As in the 12-channel systems, this duplication is necessary because of the number of channels involved in the system and also because one carrier supply unit provides the frequencies for a number of systems at each terminal station. The change-over occurs when the carrier supply fails, and also when it diminishes or changes frequency beyond predetermined limits. By operation of a key, either set is selected for normal operation, the automatic change-over taking place in all cases to the other set. Both sets of master oscillators and multivibrators, all

/ switching

switching equipment and nine carrier filters and amplifiers are mounted on one carrier supply bay. The remaining eight filters and amplifiers are provided on another carrier supply bay.

The principle of operation of the multivibrator used to generate the carrier frequencies for 17-channel systems is described in Long Line Equipment I. Further details of this equipment are given in these notes. A schematic of the multivibrator circuit is shown in Fig. 12.



NOTE: Alarm Relay Designations refer to Multivibrator No. 1.

MULTIVIBRATOR CIRCUIT SHOWING BIAS AND START ARRANGEMENTS.

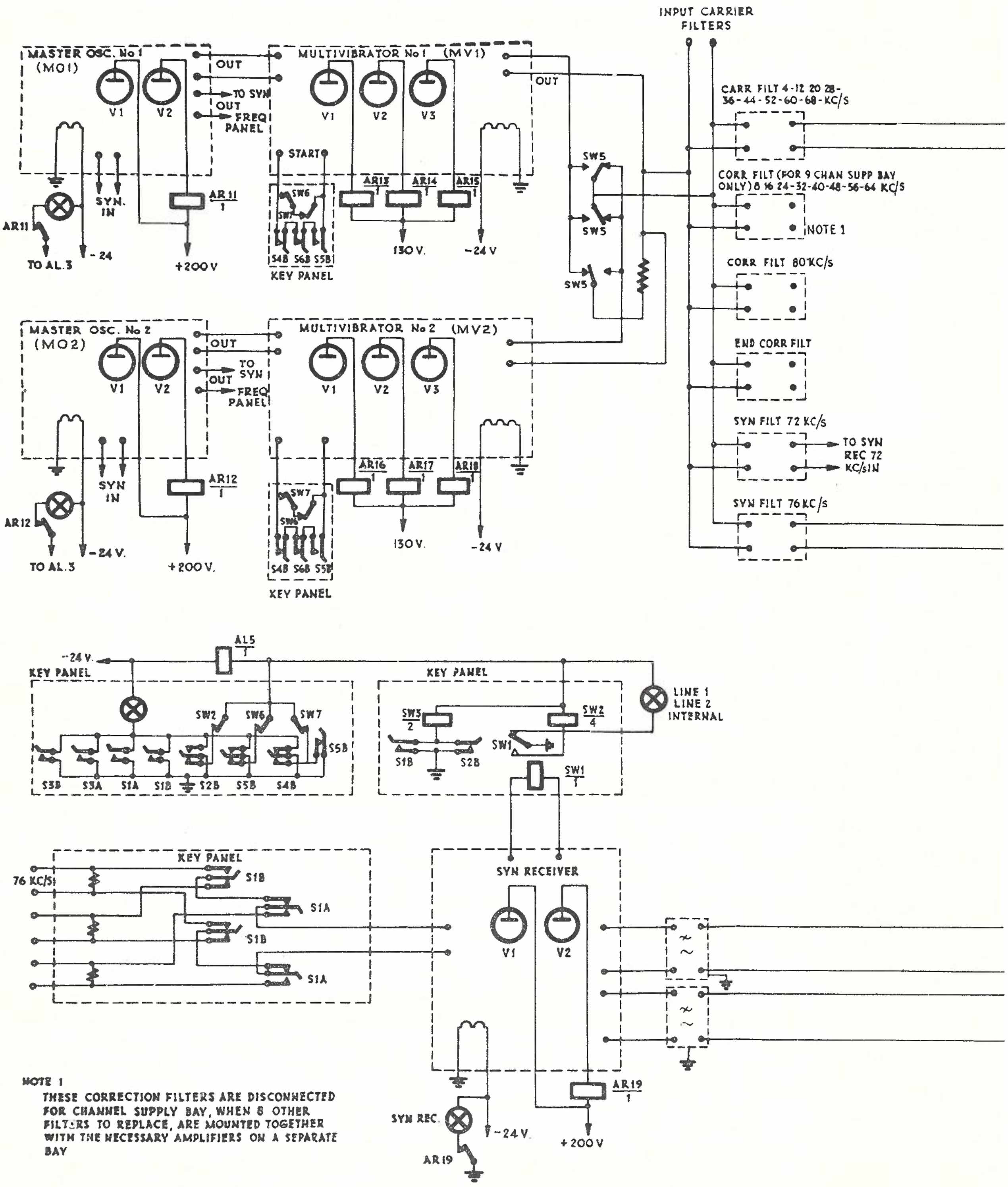
FIG. 12.

The first clipper stage has a bias of -24 volts applied via a rectifier in the output circuit of a 4 kc/s amplifier, which follows the second clipper stage. This second clipper stage likewise has -24 volts bias, the 4 kc/s amplifier using cathode bias. The signal applied to the first clipper stage from the chopper stage is not sufficient to produce any anode current in the first clipper stage when the bias on that stage is -24 volts. Thus, the unit is not self-starting.

The unit is started by short-circuiting (either electrically by relay contacts or manually by key contacts) the "start" leads of Fig. 12. This places an earth potential on the grid of the first clipper stage and the unit functions as described in Long Line Equipment I.

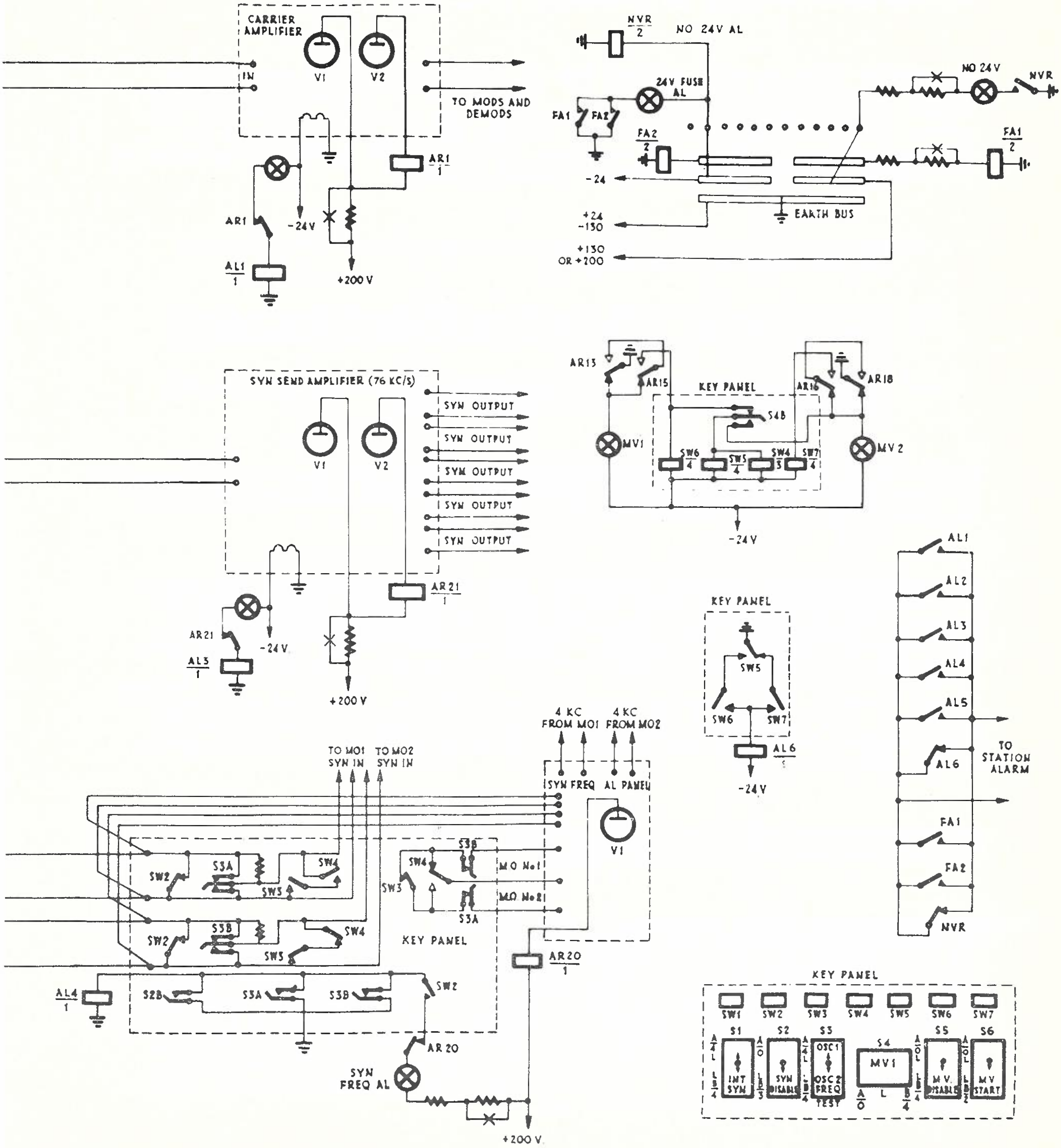
Thus, when the start leads are short-circuited, 4 kc/s and harmonics of that frequency are applied to the carrier filters and to a 4 kc/s tuned circuit connected across the output of the second clipper stage. The voltage developed across this tuned circuit is amplified by the valve and rectified by the rectifier in the output circuit. The rectified 4 kc/s voltage opposes the -24 volts applied to the grid of the first clipper stage via the rectifier, and reduces the negative bias on the grid of that stage to a value well below -24 volts. Thus, when the "start" leads to a multivibrator are short-circuited, the bias on the first clipper stage is reduced from a blocking to an operating value. The unit continues to function when the short circuit is removed from the "start" leads.

/ Fig. 13



NOTE 1
THESE CORRECTION FILTERS ARE DISCONNECTED FOR CHANNEL SUPPLY BAY, WHEN 8 OTHER FILTERS TO REPLACE, ARE MOUNTED TOGETHER WITH THE NECESSARY AMPLIFIERS ON A SEPARATE BAY

FIG. 13. SCHEMATIC CIRCUIT OF CARRIER SUPPLY BAY FOR 17-CHANNEL SYSTEM



SHOWING AUTOMATIC CHANGE-OVER, ALARM AND SYNCHRONISING ARRANGEMENTS.

Two alarm relays, AR13 and AR15, and a retard AR14 are included in the anode circuits of the valves in Fig. 12. The alarm relays cause an automatic change-over to the auxiliary master oscillator and multivibrator in the event of failure.

The complete alarm system is shown in Fig. 13, which also shows the synchronising arrangements discussed in paragraph 7.3. From Fig. 13 it is seen that both master oscillators and multivibrators are equipped with alarm relays, the contacts of which control the circuits of four relays, SW4, SW5, SW6 and SW7. To illustrate how the change-over circuit functions, it is assumed that MO1 and MV1 in Fig. 13 are supplying the load and that the following circuit conditions apply -

(i) Key S4 is in the MV1 position, which means that all contacts designated S4B are normal as shown in Fig. 13.

(ii) The anode currents of V1 and V3 in MV1 are sufficiently large to operate relays AR13 and AR15 when MO1 and MV1 are functioning satisfactorily.

(iii) MO2 is operating but MV2 is not functioning because of the excessive bias (-24 volts) on the first clipper valve V1 of MV2.

Thus, when MO1 and MV1 are operating satisfactorily, relays AR13 and AR15 are operated, and their contacts operate relays SW4, SW5 and SW6. Operated contacts of SW5 apply the output of MV1 to the carrier filters.

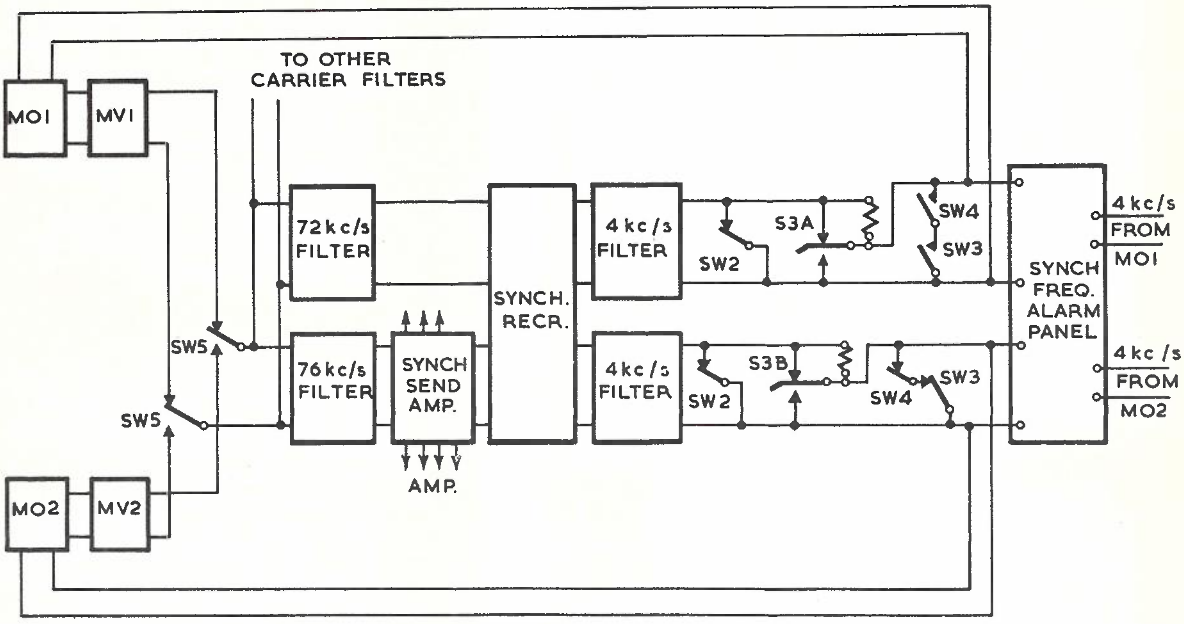
When either MO1 or MV1 fails for any reason, there is no output from MV1 and, therefore, no rectified 4 kc/s to reduce the -24 volts applied to the grid of V1 in MV1. The anode currents of V1 and V3, therefore, fall and relays AR13 and AR15 release, thus releasing relays SW4, SW5 and SW6. Normal contacts of relay SW6 operate relay AL5 to give an alarm and, in conjunction with normal contacts of relay SW7, short-circuit the "start" leads to MV2 which starts to function. The rise of anode current through V1 and V3 of MV2 operates relays AR16 and AR18, the contacts of which operate relay SW7. The operation of relay SW7 opens the start circuit for MV2, which functions normally, its output being directed to the carrier filters via normal contacts of relay SW5.

Whilst one or other multivibrator is operating, relay AL6 is held operated. When both multivibrators fail, relay AL6 releases to provide an alarm via its normal contacts.

7.3 Synchronisation of Carrier Frequencies. The modulator and demodulator frequencies of any one channel must be the same at both terminals. This is achieved by synchronising the 4 kc/s oscillators at each terminal. One terminal is selected as the master station and the other terminal is synchronised to it. For this purpose, a multiple of the synchronising oscillator frequency (76 kc/s) is sent out over the line. At the receiving end, the 76 kc/s frequency is modulated with a frequency of 72 kc/s which is a multiple of the local oscillator output, and the resulting 4 kc/s synchronises the local oscillator. Provision is made for any terminal to act as master and for any terminal to be synchronised. All synchronising units, together with an indicator panel, are mounted on the carrier supply bay.

/ Fig.

Fig. 14 shows in simplified schematic form the synchronising arrangements at a master station assuming that MO1 and MV1 are supplying the load at the master station. Fig. 14 is obtained from Fig. 13. The conditions shown in Fig. 14 apply when key S1 in Fig. 13 is in the position designated "Int. Syn", that is, the key contacts designated S1B are operated.



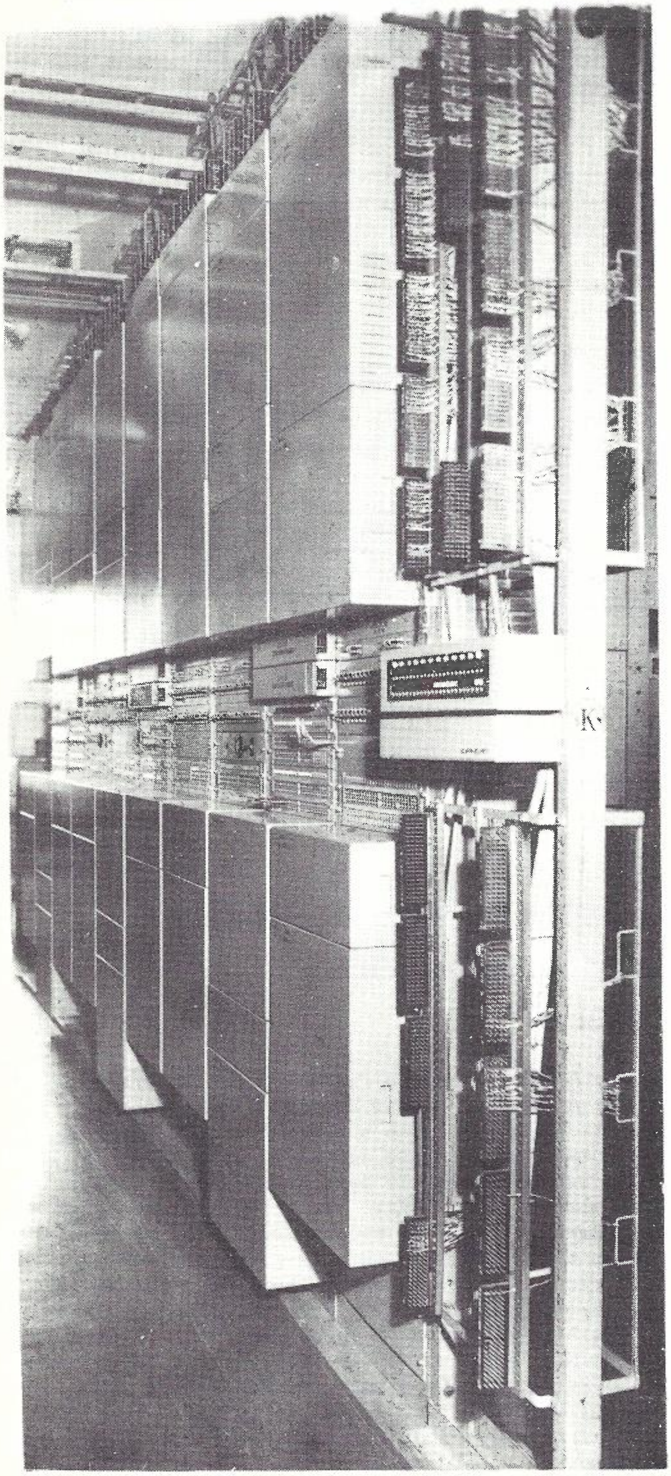
NOTE: SW5 contacts shown in simplified form and in operated position.

SYNCHRONISING ARRANGEMENTS AT MASTER STATION.

FIG. 14.

For synchronising purposes, the master station sends a frequency of 76 kc/s to all stations. The "Syn. Send" amplifier provides a number of outputs at the correct level for this purpose. This amplifier also provides a reduced output at 76 kc/s for local or "internal" synchronising purposes. This output is used to synchronise MO2 with MO1. As shown in Fig. 14, frequencies of 72 kc/s and 76 kc/s are applied to the synchronisation receiver from the output of MV1. This receiver contains a modulating stage and an amplifying stage. The lower sideband produced by modulating 76 kc/s and 72 kc/s is 4 kc/s. There are two 4 kc/s outputs from the receiver, one for MO1 and the other for MO2. Reference to Fig. 13 shows that, when MO1 and MV1 are operating with all keys normal except S1, which is in the "Int. Syn" position, relays SW3 and SW4 are operated. Operated contacts of these relays short-circuit the 4 kc/s output from the receiver to MO1, and permit the other 4 kc/s output from the receiver to be applied to MO2. Injecting this 4 kc/s frequency into MO2 synchronises the frequency generated by MO2 with that generated by MO1. Thus, at the master station, the synchronising frequency of 76 kc/s obtained from the working oscillator and multivibrator is sent to all other stations, and is used at the master station to synchronise the emergency oscillator with the working oscillator.

/ At



EQUIPMENT FOR SIX 17-CHANNEL CARRIER TELEPHONE TERMINALS.

At the distant stations, the synchronising frequency of 76 kc/s is received with the block of sideband frequencies and is directed to the synchronising circuit by a 76 kc/s filter. This incoming 76 kc/s is applied to the receiver at the distant stations via key S1 (see Fig. 13) in the Line 1 or Line 2 position. There, it is modulated with a locally generated 72 kc/s current to produce two 4 kc/s outputs, which are applied to the oscillators to synchronise them with the oscillator at the master station.

As well as applying 4 kc/s to the emergency oscillator at the master station and 4 kc/s to the two oscillators at each other station, the synchronisation receivers also apply two 4 kc/s inputs to a synchronisation frequency alarm panel at each station. In the case of the master station the input corresponding to the working oscillator is short-circuited as described above. The two master oscillators at each station also supply two 4 kc/s inputs to the alarm panel, these inputs being adjusted to equal levels at a common point in the grid circuit of V1 in the alarm panel (see Fig. 13). Frequency difference, due to the divergency of any master oscillator at a synchronised station, results in a periodic addition of the voltages and a high negative bias to V1, thus decreasing the anode current of that valve. This releases relay AR20 (see Fig. 13) and the synchronising alarm lamp lights. The lamp goes out when the voltages cancel sufficiently and the bias is reduced. Consequently, the lamp flashing indicates a difference between the frequencies.

/ 7.4

7.4 Signalling. For dialling and other signalling methods, the systems use the channel carrier frequency as a signalling frequency. When an operator dials on a channel, the carrier frequency appropriate to the particular channel is transmitted in pulses corresponding to the dial impulses. The power is sufficiently low to prevent overloading the line amplifiers. The channel carrier frequency, however, is balanced out in the channel modulator and is therefore applied to the input of the modulator band-pass filter during dialling conditions. Signalling relay groups to work in conjunction with carrier dialling are used on the channels.

The carrier pulses traverse the equipment and the cable as described for the channel sideband frequencies.

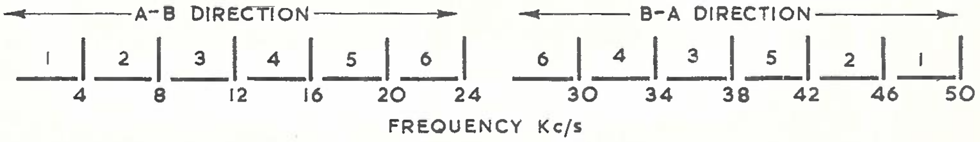
At the distant receiving end, the carrier pulses are directed to a signalling receiver, mounted on the carrier signalling bay, which converts them to D.C. pulses again. This receiver contains three stages - a modulator, an amplifier and a rectifier. The modulator is of the double-balanced metal rectifier type and is supplied with a carrier 4 kc/s above or below the channel carrier. This carrier is available from the carrier supply bay, so no additional carrier supply apparatus is necessary. One of the products of modulation will, therefore, be a 4 kc/s sideband in pulses corresponding to the dialling train. All products of modulation are amplified by the amplifier, which is followed by a 4 kc/s sharply tuned filter circuit. The selected 4 kc/s passed by this filter is then applied to the rectifier valve, the rectified output of which operates a "receive" relay. Contacts of this relay apply the dialling impulses to the automatic exchange equipment.

An advantage of this method of signalling is that it is independent of speech, and in addition the narrow band-pass filter and a high-pass filter in the send circuit eliminate interference from signalling tones.

8. 6-CHANNEL JUNCTION CARRIER SYSTEMS.

8.1 During recent years, delays have occurred in the provision of additional junctions between automatic telephone exchanges in a unit fee area as a result of lack of cable pairs. The main reasons for this were the shortages of labour and materials. To provide temporary relief in these cases, an investigation was made of the junction position generally, with the object of applying carrier methods to the problem. Generally, the use of carrier systems over relatively short distances was not justified economically, but the seriousness of the position was such that, within reason, the important consideration was time and not cost. Subsequently a number of 6-channel carrier systems, each designed for operation over a junction pair using the frequency band up to 50 kc/s, were manufactured by Communication Engineering Pty. Ltd. The first of these systems was installed in the Sydney Metropolitan Area in 1947. 17-Channel cable carrier systems and 1 + 4 carrier systems are also used to provide additional channels over junction cables.

8.2 Frequency Allocation. The frequency allocation of the junction carrier system is shown in Fig. 15.



CHANNEL FREQUENCY ALLOCATION FOR JUNCTION CARRIER SYSTEM.

FIG. 15.

Different frequency groups are used in the two directions of transmission so that the equivalent of 4-wire operation is obtained over each cable pair. The channel carrier frequencies in each direction are spaced at intervals of 4 kc/s.

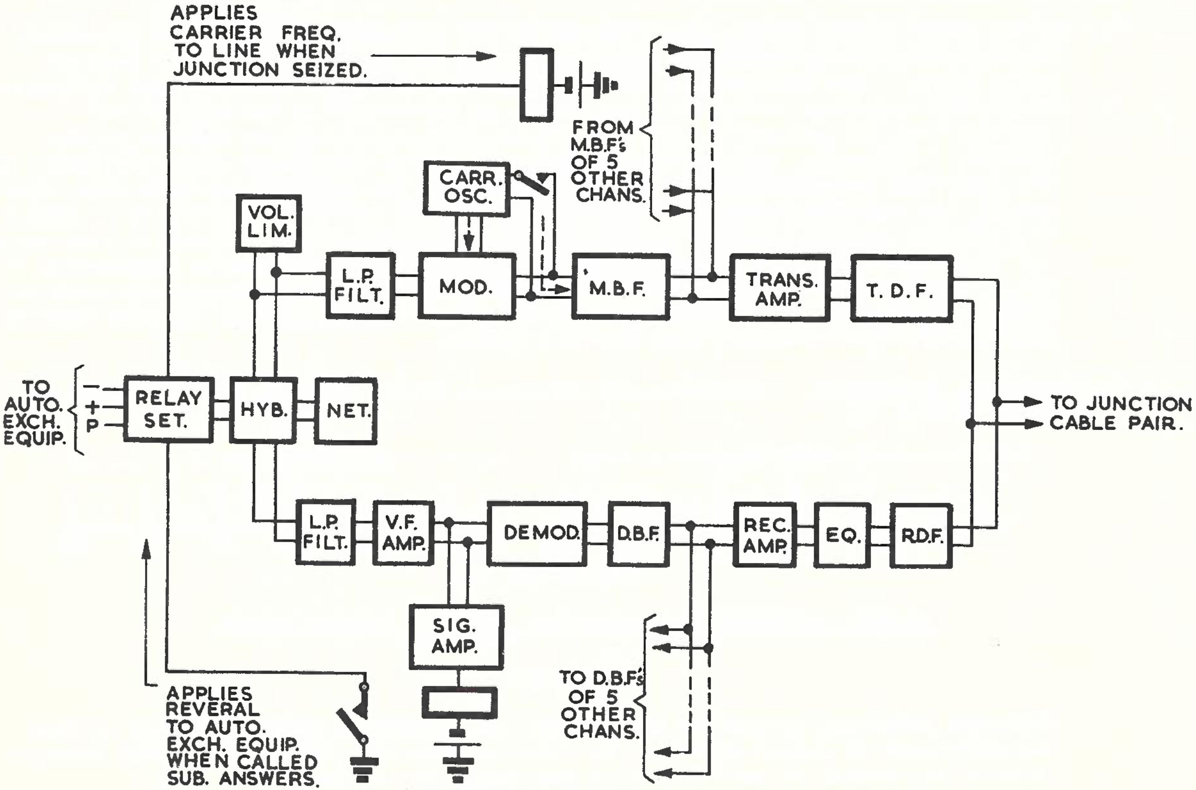
/ The

The channel numbering in the B-A direction is arranged so that, as far as possible, the major portion of the near-end interference caused by transmitting on any particular channel in the A-B direction, is received on the same channel in the B-A direction, and is therefore, substantially ineffective. Some of the factors which affect the near-end inter-channel interference of a carrier terminal are the characteristics of the directional and band filters and harmonics of frequencies transmitted from the terminal.

8.3 Description of System. A simplified block schematic circuit of the system is shown in Fig. 16. The system is of the single sideband, transmitted carrier type. This has advantages over the usual suppressed carrier type system as far as simplification of signalling equipment is concerned. The use of transmitted carrier frequency current permits demodulation to be effected by rectification and eliminates the possibility of faulty synchronisation. Also, as demodulator oscillators are not necessary, the carrier supply equipment is simplified, and comprises six carrier oscillators only for each terminal station. The main disadvantages of transmitted carrier operation are overloading of common amplifiers and crosstalk from the transmitted carrier current. In this case, however, these disadvantages are not very important as there are no intermediate carrier repeaters, and as all systems have the same frequency allocation, crosstalk from transmitted channel carrier frequency current does not fall inside the pass range of the channel band filters.

The system is operated over one cable pair, and directional filters are used at each carrier terminal to separate the "go" and "return" carrier frequency currents and to obtain the equivalent of 4-wire operation over a 2-wire line. The cut-off frequency of the directional filters is about 26 kc/s.

The circuits of the carrier channels are identical, but, when connected between automatic exchanges, the channels become either outgoing or incoming junctions, as far as an automatic exchange is concerned. The carrier terminal equipment includes a relay-set for each channel, and this is connected between the carrier channel and the automatic exchange equipment.

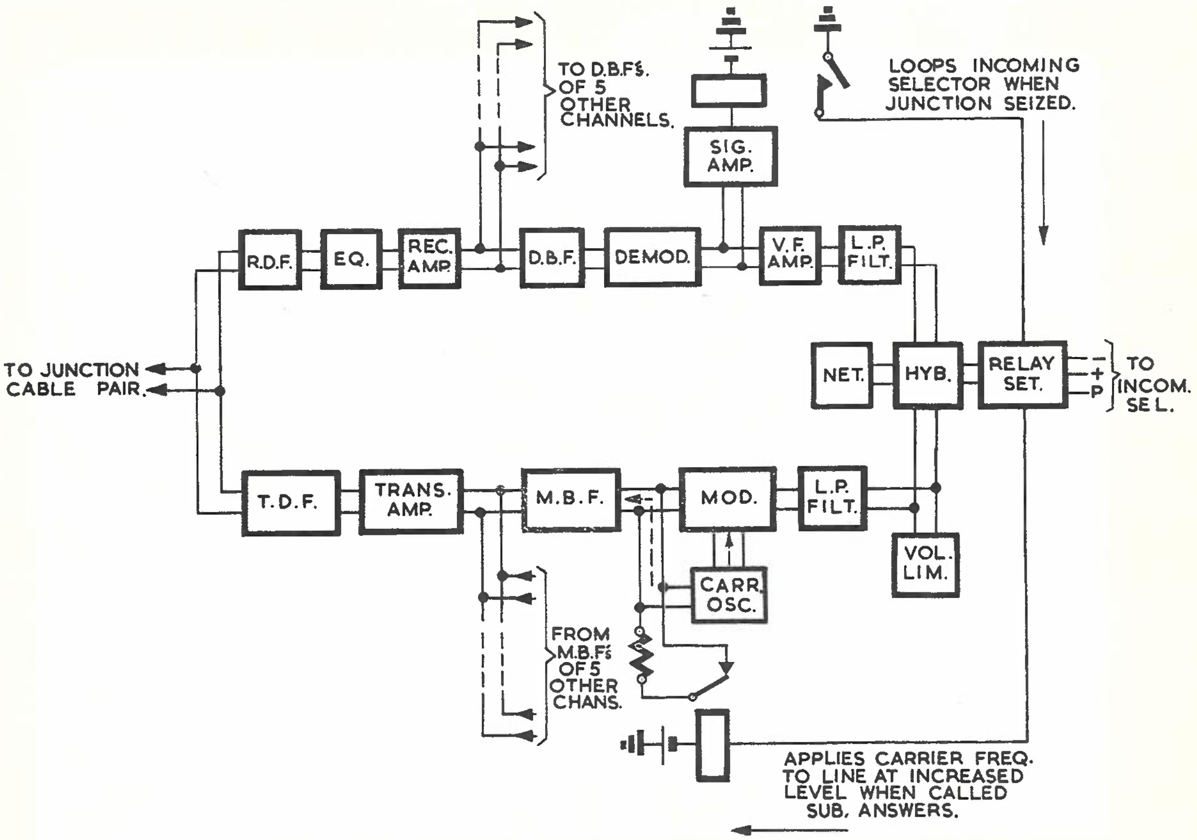


(a) Outgoing Junction.

FIG. 16. SCHEMATIC CIRCUIT OF

The relay-sets are of two types for the outgoing and incoming ends of a channel respectively, and, as they are interchangeable, the channels of a system are arranged as either outgoing or incoming junctions at a particular exchange. In a typical installation, a carrier system could provide three outgoing and three incoming junctions.

The method of signalling is very similar to that of the physical junction, so that when the carrier junction is seized, carrier current is transmitted and causes a relay to operate at the receive end of the channel, and so loops the incoming automatic switch. During impulsing over the channel, the transmitted carrier current is interrupted so that the make-to-break ratio of the impulses are similar to those of the dial and these impulses are repeated into the incoming automatic switch. Release is effected by stopping transmission of the carrier current. In the reverse direction, it is necessary to arrange for one signal only, and that is the reversal which follows the answer of a call. In this direction, carrier current is transmitted continuously since it is often necessary for speech to be transmitted back over the channel prior to reversal occurring, as happens when a manual exchange telephonist answers an incoming junction. Also, prior to reversal, it is often necessary to transmit busy tone or ring tone, and in some circumstances, dial tone. Signalling in the reverse direction is therefore arranged by changing the level of the transmitted carrier current and using this change in level to operate a marginal relay so that the reversal is passed back towards the calling subscriber.

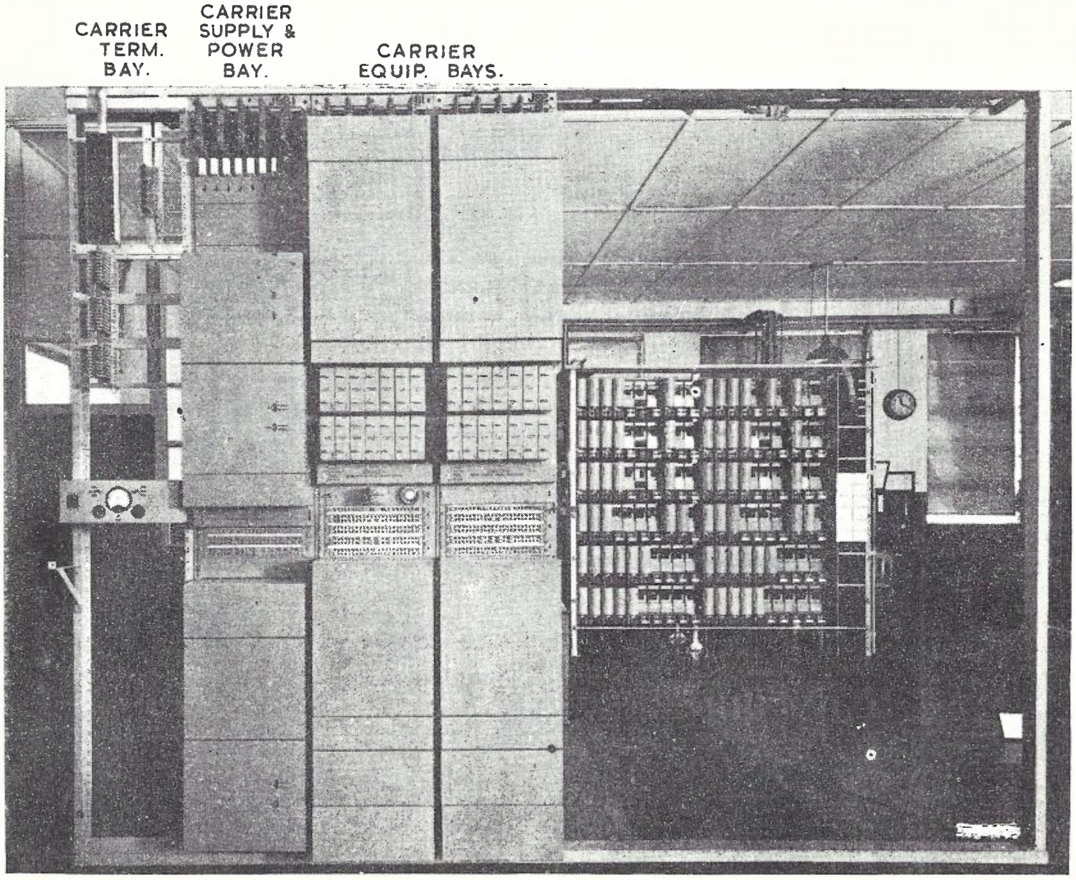


(b) Incoming Junction.

CHANNEL JUNCTION CARRIER SYSTEM.

8.4 A photograph of a typical junction carrier installation of four systems is shown below. The cable terminating bay is at the left, situated next to the combined carrier supply and power bay. Included on the carrier supply and power bay are six carrier frequency oscillators and associated carrier supply equipment. These are capable of supplying up to twelve carrier terminals. When the bay is fully equipped, it accomodates seven power panels in addition to the carrier supply equipment. One of these panels is required for the operation of the carrier supply equipment, and the others are fitted, as required, on the basis of one for each carrier terminal. When more than six carrier terminals are installed, a second power bay is provided for mounting the additional power panels. This second power bay is not fitted with carrier supply equipment.

The two bays at the right each accommodate the terminal equipment for two systems, On the carrier terminal bays, the panels are arranged so that the equipment for one carrier system is at the front of the bay and that for the other system is at the rear. The jack field is flush-mounted at the front of the bay and is common to both systems. The channel relay-sets for both systems are also mounted at the front of the bay. In some installations, the relay-sets are mounted on separate relay-set racks as part of the automatic exchange equipment. A talking and monitoring panel is provided adjacent to the jack field on the terminal bay and incorporates dialling facilities.

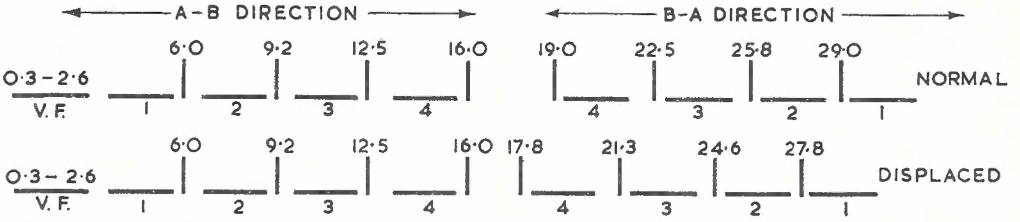


TYPICAL JUNCTION CARRIER INSTALLATION.

9. 1 + 4 CARRIER SYSTEMS.

9.1 In addition to the 17-channel and 6-channel systems described previously, carrier junction circuits are also provided using type 1 + 4 carrier telephone systems. This equipment is portable and compact and was designed for Army use during the war. It normally provides one V.F. channel and four carrier channels between terminal stations. The systems are used also over radio link circuits (4-wire operation), 4-wire trunk cable circuits using separate pairs in a single cable for each direction of transmission, and 2-wire aerial trunk circuits.

For 4-wire operation over radio link circuits, and over pairs in separate cables for each direction of transmission, a frequency band 0.3-15.7 kc/s is transmitted in each direction. For 4-wire operation over separate pairs in a single cable and for 2-wire operation, separate frequency bands are transmitted in each direction for the carrier channels. To reduce crosstalk in the higher frequency (B-A) direction of transmission between systems operating over the same route, "normal" and displaced" systems have been developed in which the sideband frequencies are staggered. The frequency allocations for these systems are shown in Fig. 17.



NOTE: Frequencies shown in kc/s.

FIG. 17. CHANNEL FREQUENCY ALLOCATIONS FOR 1 + 4 CARRIER SYSTEMS.

9.2 4-Wire Operation. The block schematic circuit of the terminal equipment for 4-wire operation sending the same frequency band in each direction of transmission is shown Fig. 18.

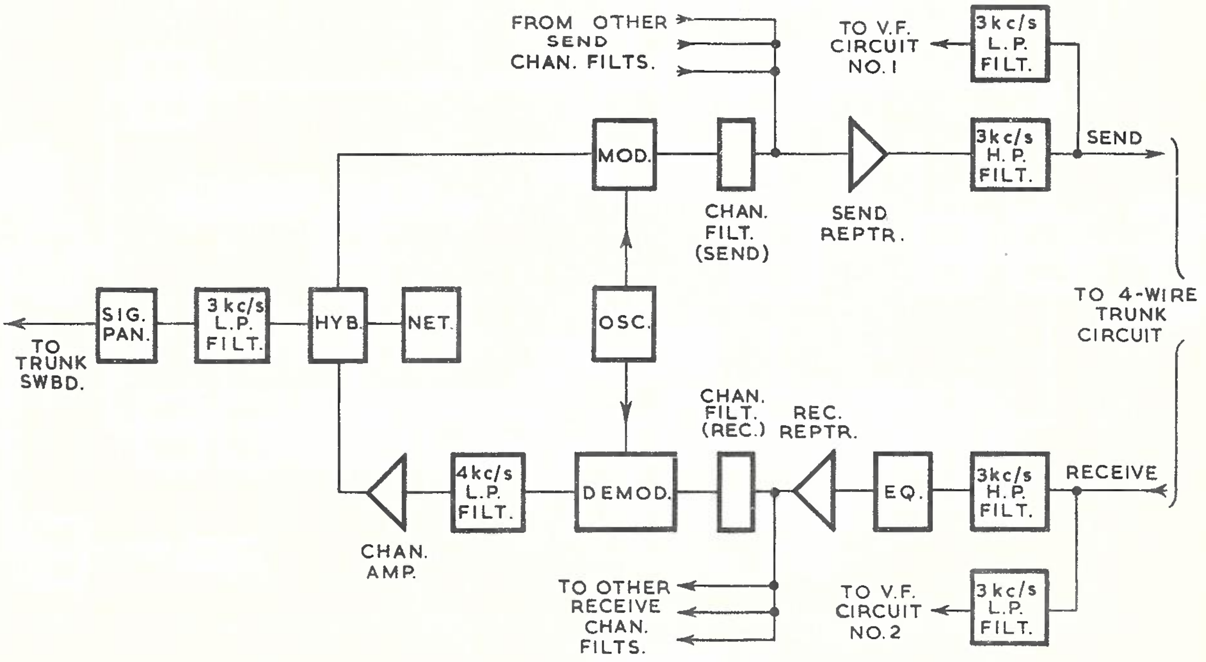
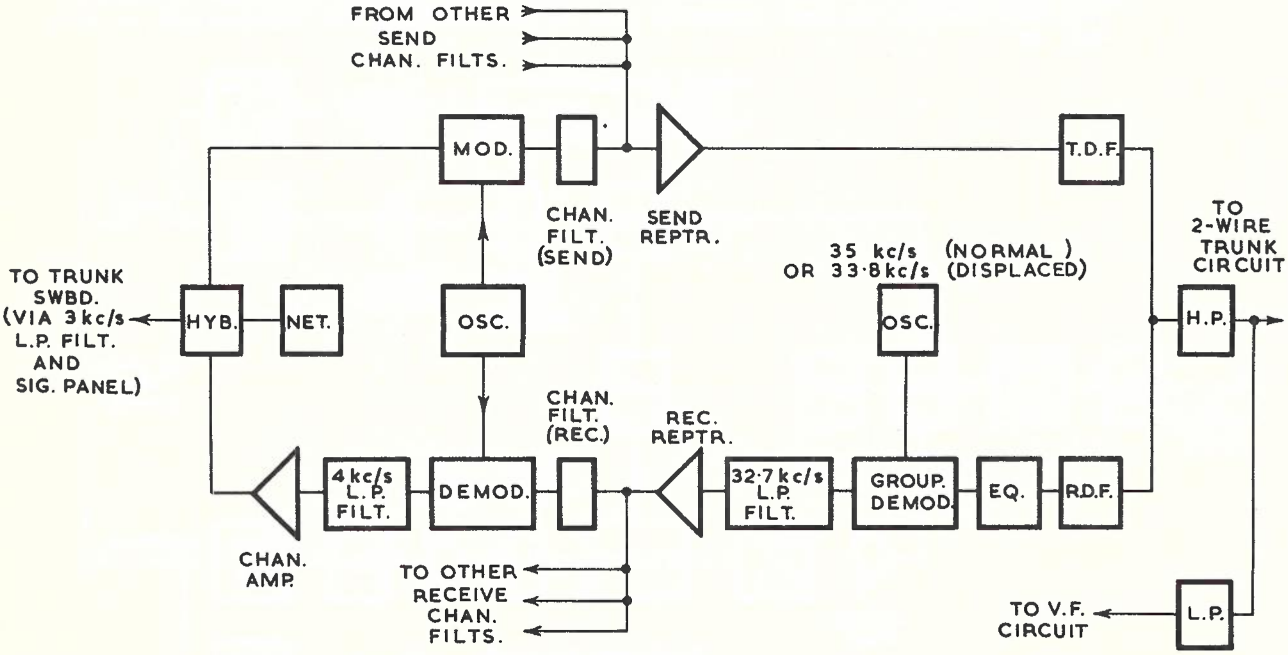


FIG. 18. BLOCK SCHEMATIC OF 1 + 4 CARRIER TERMINAL ARRANGED FOR 4-WIRE OPERATION.

V.F. signals from the switchboard pass via the signalling panel and 3 kc/s low-pass filter to the hybrid coil, where they divide. Half the power is dissipated in the output circuit of the channel amplifier and half is applied to the channel modulator. The output from the modulator comprises upper and lower sidebands formed by the modulation of the carrier by the speech currents, and also any residual carrier leak which arises from imperfect balance of the rectifiers and modulator transformers. The sidebands pass to the sending band filter which eliminates the upper sideband and further attenuates any carrier leak which is present. The output terminals of the four send channel band-pass filters are connected in parallel. The four channel sidebands covering the range 3.4-15.7 kc/s are applied to a common amplifier, where they are amplified to the correct sending level. The transmitted sideband group then passes via the high-pass line filter to the send pair of the 4-wire circuit.

In the receive direction, the four lower sideband channel frequencies in the range 3.4-15.7 kc/s from the distant terminal are selected by the high-pass filter in the receive side of the 4-wire circuit, and applied to the equaliser. During transmission, different frequencies are attenuated in varying degrees and the equaliser compensates for these variations and reduces all incoming frequencies to approximately the same level. The equaliser also contains attenuation pads which are inserted as required to reduce the sideband signals to the level required by the receive repeater input circuit. From the equaliser, the sideband frequencies are amplified by the receive repeater amplifier and pass to the receive channel band-pass filters, where they are separated into their respective channels. In each channel, the lower sideband is applied to the demodulator, which is supplied with the same carrier frequency as the modulator of the corresponding channel. The lower sideband of the demodulator output corresponds to the original V.F. signals and is selected by the low-pass filter and amplified by the channel amplifier. The V.F. output is applied via the hybrid coil and the 3 kc/s low-pass filter to the trunk switchboard.



(a) Terminal A.

FIG. 19. BLOCK SCHEMATIC CIRCUIT OF 1 + 4 CARRIER

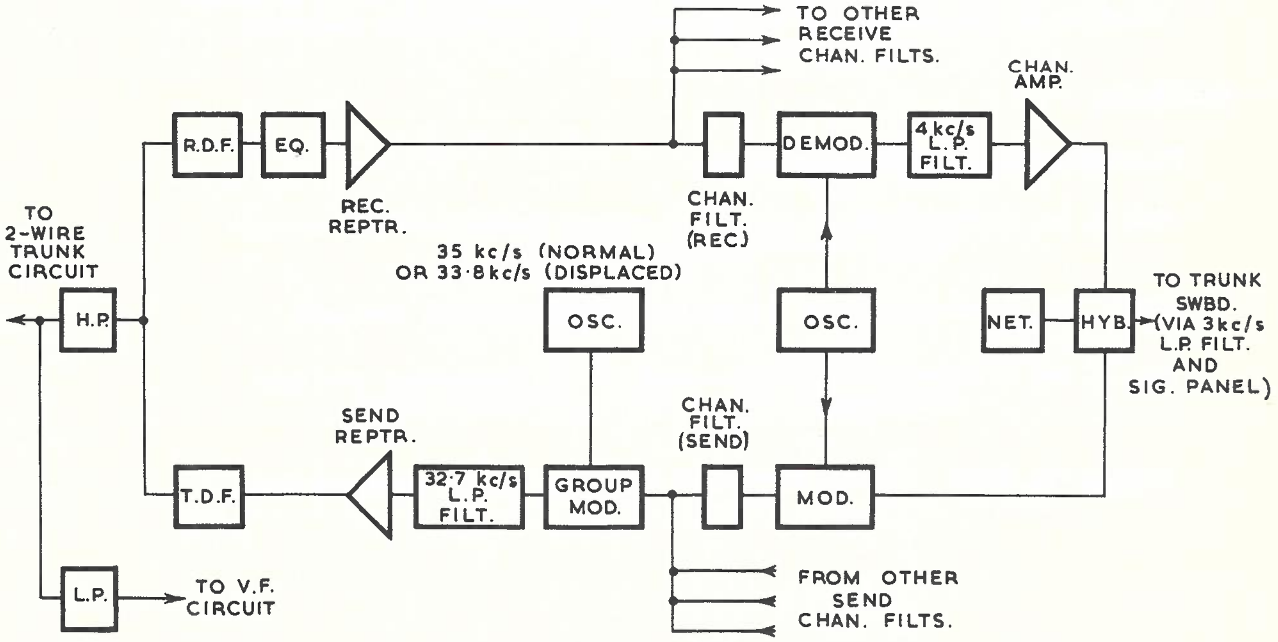
Signalling current from the switchboard is applied to the signalling panel and converted into 500 c/s interrupted tone. This tone modulates the channel oscillator frequency in the modulator and the lower sideband is transmitted over the channel for signalling purposes. At the distant end, the demodulated 500 c/s tone is applied to the signalling panel and converted to signalling current for application to the switchboard.

9.3 2-Wire Operation. The block schematic circuits of the A and B terminal equipment for 2-wire operation are shown in Fig. 19.

The circuit arrangements and operation for the A-B direction of transmission are similar to those described for 4-wire operation. A frequency range 3.4-15.7 kc/s is transmitted in this direction.

In the B-A direction, the sending circuit arrangement at terminal B is similar to that described for 4-wire operation until the point where the outputs from the send channel filters are connected together. At this point, the lower sidebands in the range 3.4-15.7 kc/s are applied to a group modulator where they modulate a group carrier frequency of 35 kc/s for a "normal" system, and 33.8 kc/s for a "displaced" system.

The lower sideband is amplified and applied to line via the directional filter and high-pass line filter. A frequency band 19.3-31.6 kc/s is transmitted for a "normal" system, and 18.1-30.4 kc/s for a "displaced" system. At the receiving terminal A, the transmitted sideband is applied via the line and directional filters, and an equaliser to the group demodulator. This is supplied with a carrier frequency similar to that supplied to the group modulator at the distant end. The lower sideband output 3.4-15.7 kc/s corresponding to the four lower sidebands of the four channels, is selected, amplified and applied to the receive channel filters. The channel demodulators restore each sideband to the original V.F. signals which are amplified and applied to the switchboard.



(b) Terminal B.

TERMINAL ARRANGED FOR 2-WIRE OPERATION.

10. TEST QUESTIONS.

1. Draw a block schematic diagram of a typical 12-channel cable carrier system, and explain its operation.

2. Draw a simplified block schematic diagram of a typical 24-channel cable carrier system, and explain its operation.

3. On the block schematic circuits for typical 12-channel and 24-channel cable carrier systems, indicate the frequency ranges and relative transmission levels at various stages of the circuit.

4. Explain briefly the method of generating the channel and group carrier frequencies in a typical cable carrier system.

5. Draw a simple block diagram showing the method of interconnecting open wire and cable carrier systems without demodulating the channels to voice frequencies. What are the advantages of this arrangement?

6. Draw a block schematic circuit of a 17-channel cable carrier system, and describe its operation.

7. What is the basic difference in operating principles between 12- and 17-channel carrier systems?

8. Describe the method of signalling over a typical junction carrier system.

9. Draw the block schematic diagrams of the A and B terminals of a 1 + 4 carrier telephone system arranged for 2-wire working, and describe its operation.

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Vol. 8, No. 2, "Junction Carrier Equipment and its Integration into Unit Fee Automatic Networks in N.S.W." by G.R. Lewis.

Drawing No. CN670. Carrier Systems in Australia - Frequency Allocations.

END OF PAPER.

COMMONWEALTH OF AUSTRALIA.

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Postmaster-General's Department,
Treasury Gardens,
Melbourne. C.2.

COURSE OF TECHNICAL INSTRUCTION.

CARRIER TELEGRAPH SYSTEMS.

CONTENTS:

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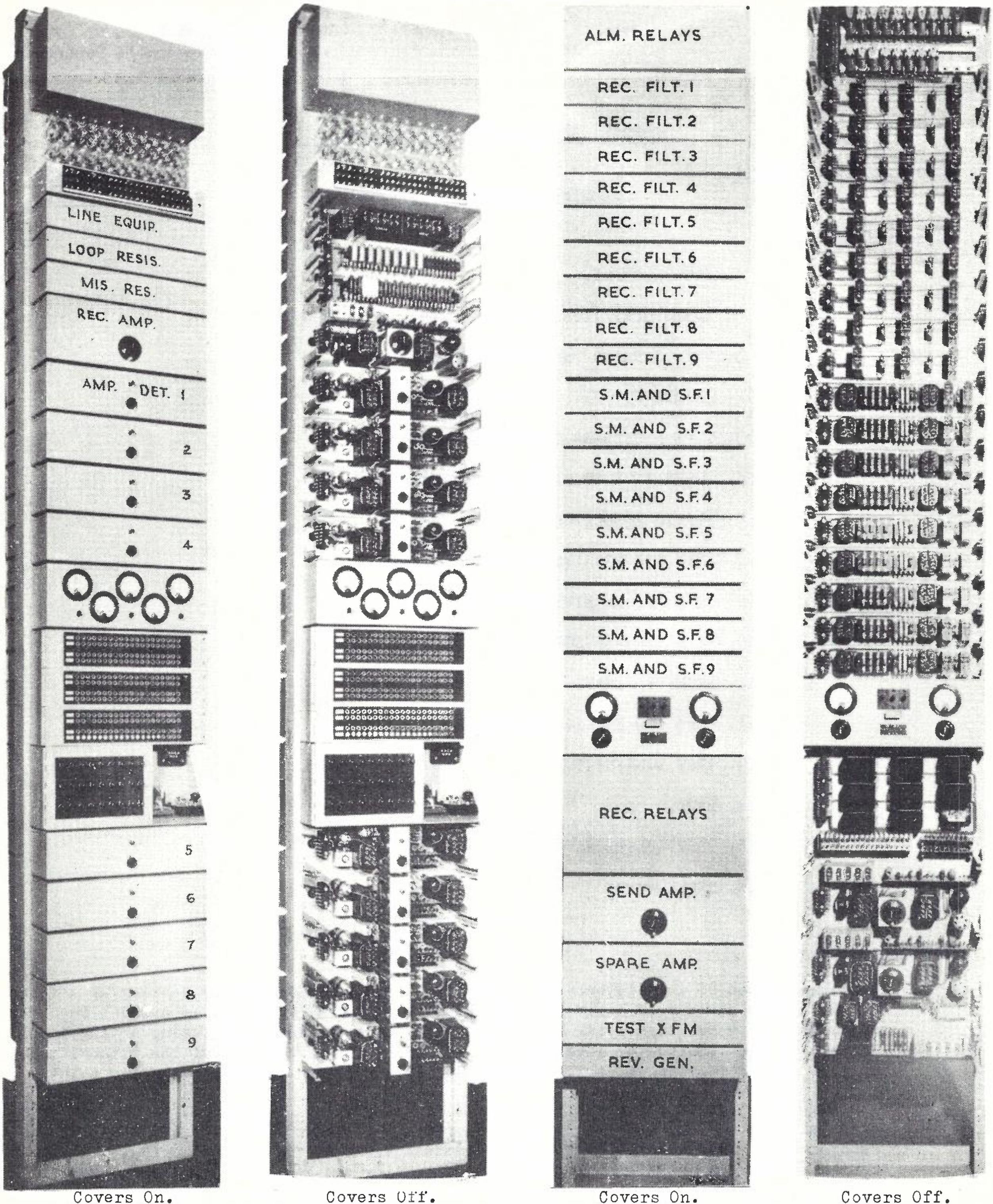
1. INTRODUCTION.

1.1 The transmission of intelligence by a Telegraph System is secured by setting up a flow of electrical current in a circuit and interrupting or reversing this current in accordance with the signalling code used, the receiving instrument being arranged to respond to the impulses or reversals of current. Thus, the form of the transmitted message can be reproduced at the distant end of a circuit connecting the two points.

The simplest type of telegraph circuit, as explained in Telegraphy I, is one composed of a relay or sounder at one end of a line with a battery in circuit and a key at the sending end. The closing of the key permits current to flow in the circuit for the length of time the key is depressed, thus operating the relay or sounder to the Operated or Marking position. Opening the key breaks the current flow, and the relay or sounder moves to the Open or Spacing position. These terms marking and spacing still survive from the time when telegraph signals, in the form of dots and dashes with separating spaces, were recorded on a tape.



Covers On. Covers Off. Covers On. Covers Off.

Front View. Rear View.

TYPICAL 9-CHANNEL V.F. CARRIER TELEGRAPH TERMINAL.

1.2 Since the commencement of telegraph working, numerous improvements in telegraph sending and receiving equipment have been introduced. These improvements have permitted substantial advances to be made in the methods of telegraph working, and circuits enabling messages to be transmitted in both directions simultaneously over the line have been developed. Sensitive relays have been designed capable of responding to very weak currents received over long land line and submarine cable circuits, whilst high speed relays suitable for the transmission of intelligence via High Speed Telegraph Systems and Multiplex Systems have also been introduced (see Telegraphy II.)

1.3 High Speed Telegraph Systems obtained increased output by using automatic telegraph transmitters, which were fed with perforated tape prepared in advance by a number of operators. Multiplex Systems, such as the Murray Multiplex, operate on the principle of assigning the line in turn to a number of operators working at normal speed, thus obtaining high channel carrying capacity.

1.4 The purpose of this Paper is not, however, to describe the telegraph equipment, but to detail the changes and improvements whereby telegraph messages are transmitted over long distances, and by which the operation of a large number of telegraph channels can be secured over one trunk line.

1.5 With the introduction of the telephone and the development of apparatus for use on long distance circuits, the demand for additional lines for telephone purposes led to the absorption of all available space on aerial line poles. To meet this demand in some instances telegraph lines were used for telephone purposes. The use of these telegraph lines led to the introduction of systems of combined telegraphy and telephony, such as the Cailho system and the Composite system. As shown in Long Line Equipment I, the Cailho system provides a telegraph circuit as an additional facility over the two wires of the telephone circuit, whilst the Composite system provides a telegraph circuit over each wire of the pair of wires forming the telephone circuit.

1.6 The introduction of carrier working has revolutionised telegraph transmission over long distances, and a large percentage of long distance telegraph circuits are now provided by carrier telegraph systems. With the advent of carrier telegraph systems capable of subdividing a line (or, alternatively, a speech channel) into a large number of telegraph channels offering greater flexibility and obviating the need to retain complicated mechanical apparatus, it became economical to assign one channel per operator on the basis of machine operating using teleprinter or teletype machines. The earliest carrier telegraph system was known as the Type B and the first of these systems was installed in 1927 between Melbourne and Sydney. This type is now obsolete and has been superseded by the Voice Frequency (V.F.) Carrier Telegraph System.
The restricted band-width suitable for Teleprinter-Teletype-transmission was introduced with the V.F. Carrier Telegraph System. The first system of this type was installed in 1935.

1.7 The V.F. Carrier Telegraph System is adaptable for economical operating over telephone circuits by making use of the whole frequency band usually allocated for speech purposes, and thus requires transmission characteristics similar to those of the telephone speech channels. It may be said, therefore, that every improvement in quality and performance of telephone circuits, such as improved band-width, better equalisation and regulation of circuits, and reduction of interference and crosstalk, contributes towards improved telegraph transmission and enhances the usefulness of telegraphy not as a competitive but rather as a complementary service to telephony. Thus, wherever telephone circuits are established, high speed reliable V.F. telegraph channels can follow.

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2. BASIC OPERATION OF CARRIER TELEGRAPH SYSTEM.

2.1 Basic Requirements. In carrier telegraph systems, an A.C. is interrupted to form the signalling characters, just as a D.C. is interrupted in a simple telegraph circuit. In a telegraph system using A.C. signalling, the following components are necessary -

(i) a source of A.C., for example, valve oscillator or machine generator,

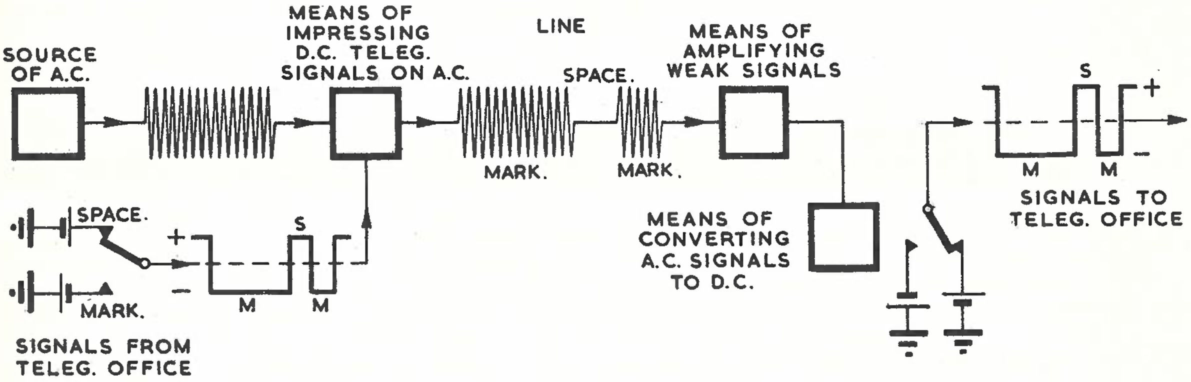
(ii) a means of impressing the D.C. telegraph signals on the A.C., for example, a copper oxide modulator unit called a static modulator or static relay,

(iii) a connecting circuit between the two terminals, either open-wire or cable lines, or a radio link circuit,

(iv) a means of amplifying the weak received signals and then converting the A.C. signals to D.C. signals, for example, detector and receiving relay.

These requirements have their counterpart in a simple D.C. telegraph circuit. The source of A.C. is comparable to the battery supply. The means of modulating it are equivalent to the key, the connecting circuit is basically the same, and the means of amplifying the weak signals and converting them into D.C. signals from a local battery supply are comparable to the relay.

Fig. 1 shows the basic requirements of an A.C. telegraph circuit, with the various currents indicated in each part of the circuit. As this type of circuit is capable of signalling in one direction only, it is necessary to duplicate the apparatus for transmission in the reverse direction.



BASIC REQUIREMENTS OF CARRIER TELEGRAPH SYSTEM.

FIG. 1.

At the sending end, marking and spacing signals from the telegraph office control the flow of A.C. to the line. A.C. is transmitted to line when a marking element is received, and suppressed during a spacing element. At the receiving end, the A.C. signals are amplified and converted to D.C. signals similar to those originating at the sending end.

In order to provide many telegraph channels over the connecting link between two stations, a number of these basic A.C. telegraph circuits are connected in parallel, each channel having a source of A.C. of different frequency. To separate one channel from the others, band-pass filters, which accept the channel frequency but reject all the other channel frequencies, are connected in series with each channel at both terminals. A band-pass filter is an electrical network of capacitance and inductance which permits the selected band of frequencies to pass but rejects all others.

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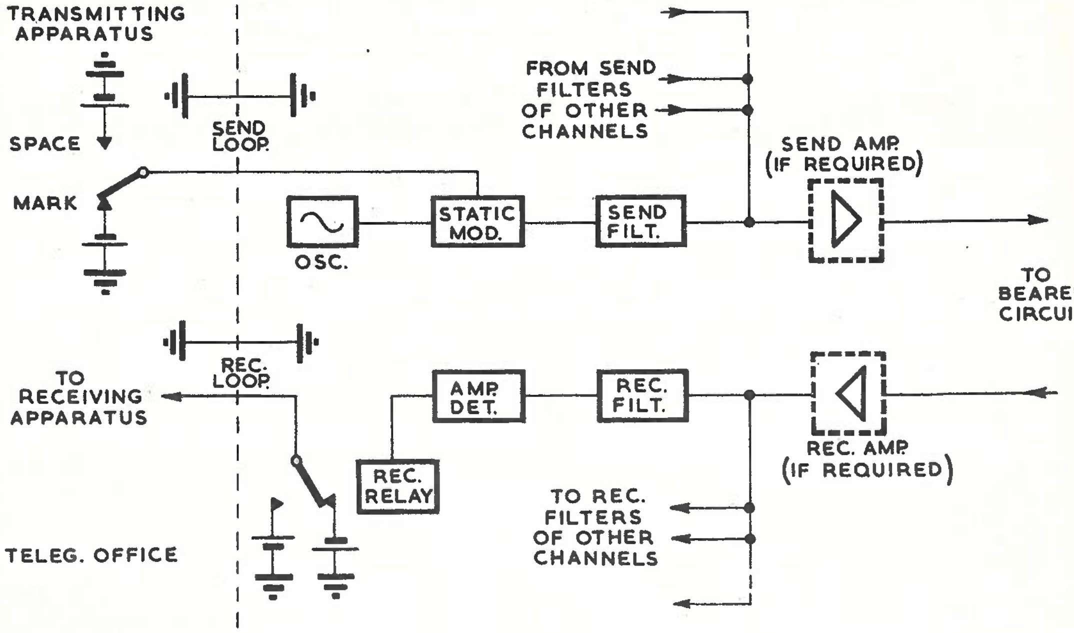
2.2 A block schematic of a typical carrier terminal is shown in Fig. 2.



TYPICAL CARRIER TELEGRAPH TERMINAL.

FIG. 2.

Carrier telegraph systems are similar to carrier telephone systems in that they use alternating currents of different frequencies to provide for the transmission of several messages simultaneously over the same pair of wires without interfering with each other or with the normal telephone and telegraph circuits on these wires.

Double-current signals from the telegraph office consisting of positive and negative impulses (positive for a space condition, negative for a mark condition) are applied to the static modulator which is also supplied with the appropriate channel frequency from the channel oscillator.

In the static modulator the polarity of the applied telegraph signals controls the flow of channel frequency in such a way as to produce impulses of the frequency in a code corresponding to the transmitted telegraph intelligence. Thus, when a marking signal is applied to the static modulator the carrier current generated by the channel oscillator is passed by the static modulator and send filter, and applied to line together with the carrier currents of other channels. When a spacing signal is applied, the carrier current is suppressed.

The filter at the sending end of the circuit prevents all unwanted frequencies produced by the process of modulation, passing to line and interfering with the signals on any other channel at the receiving terminal. These filters also present a high impedance to the carrier frequencies of other channels, thus ensuring that the carrier of any one channel is not dissipated in all the parallel send filters at the commoning point or modulated by the send equipment of other channels.

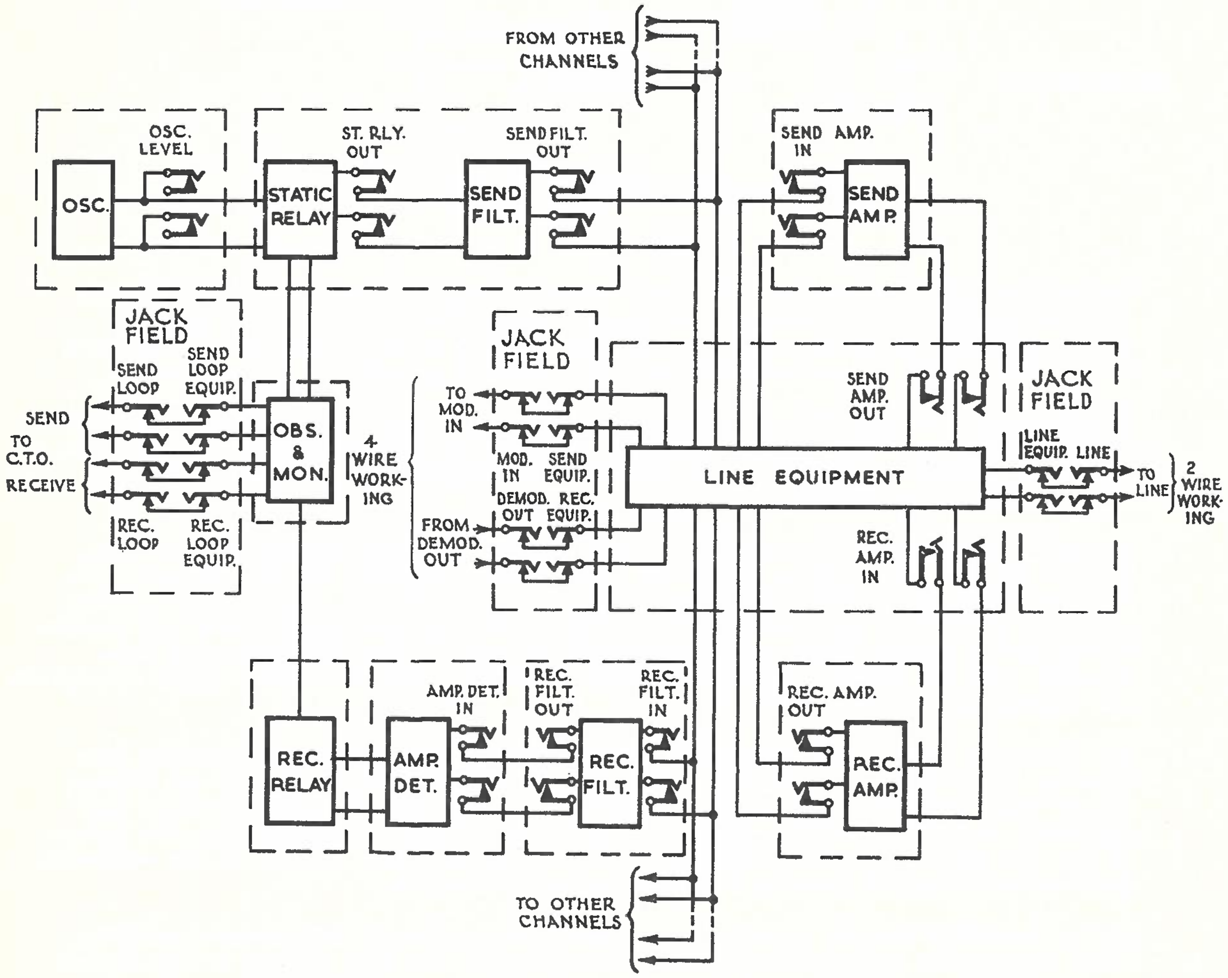
At the receiving end the incoming A.C. signals are applied to the receive amplifier which compensates for line attenuation (if required), and then applied to the channel receive filters. Each receive filter accepts only the signals for its particular channel, and rejects signals of all other channels. In each channel the signals are then applied to an amplifier-detector where they are further amplified and converted

/ to

to D.C. impulses which operate the carrier receive relay, the line winding of which forms part of the anode circuit of the detector or rectifier valve. The contacts of the receiving relay are connected to the positive and negative telegraph battery supplies, and the tongue of the relay supplies positive and negative signals to the receive telegraph loop, corresponding to the signals originating at the transmitting end.

To summarise, when a negative marking signal is applied at the sending end, a pulse of carrier current corresponding to this marking signal is transmitted to line. At the receiving end, pulses of carrier current are rectified to D.C. impulses, which operate the carrier receive relay to the marking contact, resulting in the application of negative signals from the tongue of this relay to the receiving telegraph apparatus. When a positive spacing signal is applied at the sending end, the carrier current in the channel concerned is suppressed, and the carrier receive relay at the receiving end is held on the spacing contact until the control of its bias winding. This results in the application of positive signals to the receiving telegraph apparatus.

The general principles described above, apply to the various types of carrier telegraph systems used in the Department.



BLOCK SCHEMATIC OF V.F. CARRIER TELEGRAPH TERMINAL (A.P.O. TYPE.).

FIG. 3.

3. V.F. CARRIER TELEGRAPH SYSTEMS.

3.1 The successful adaptation of A.C. methods to telegraph working was first introduced by the type B 10-channel carrier telegraph system, and the first system was installed between Sydney and Melbourne in 1927. These systems provided ten simplex telegraph channels in each direction between the two terminal stations. The frequency range 3.3-10 kc/s was used, the lower portion providing transmission in one direction, and the higher portion being used for transmission in the other direction. These frequencies were chosen so that the type B system could be superimposed on a telephone circuit, without interfering with the normal use of the line for V.F. telephone and C.X. telegraph working. The type B system is no longer in service, as it is extravagant in its use of the frequency spectrum as compared with V.F. telegraph equipment, and its use prevents a single or 3-channel carrier telephone circuit or a broadcast programme channel operating over the same line. This is because the carrier frequencies overlap the frequencies normally used by these circuits.

3.2 Carrier Frequencies and the Number of Channels. The next development in carrier telegraph working was the V.F. telegraph carrier system, so named because the carrier frequencies of the telegraph channels are within the V.F. range (200-3,200 c/s). The systems in use are mainly 9, 18 and 24-channel systems.

9-channel systems use 240 c/s spacing of channel frequencies in the range 540-2,460 c/s.
18-channel systems use 120 c/s spacing of channel frequencies in the range 420-2,460 c/s.
24-channel systems use 120 c/s spacing of channel frequencies in the range 420-3,180 c/s.

The block schematic circuit of a typical V.F. carrier telegraph terminal is shown in Fig. 3, and a detailed wiring schematic circuit is shown in Fig. 4. This is the circuit of the terminal equipment shown on Page 36. The basic operation of this equipment is similar to that described in Section 2.

The channel frequency allocations are shown in Table 1. In all cases, the channel frequencies are odd multiples of 60 c/s.

Frequency c/s	9-Channel System.	18-Channel System.	24-Channel System.
420	-	1	1
540	1	2	2
660	-	3	3
780	2	4	4
900	-	5	5
1020	3	6	6
1140	-	7	7
1260	4	8	8
1380	-	9	9
1500	5	10	10
1620	-	11	11
1740	6	12	12
1860	-	13	13
1980	7	14	14
2100	-	15	15
2220	8	16	16
2340	-	17	17
2460	9	18	18
2580	-	-	19
2700	-	-	20
2820	-	-	21
2940	-	-	22
3060	-	-	23
3180	-	-	24

TABLE 1. CHANNEL FREQUENCY ALLOCATION FOR V.F.CARRIER TELEGRAPH SYSTEMS.

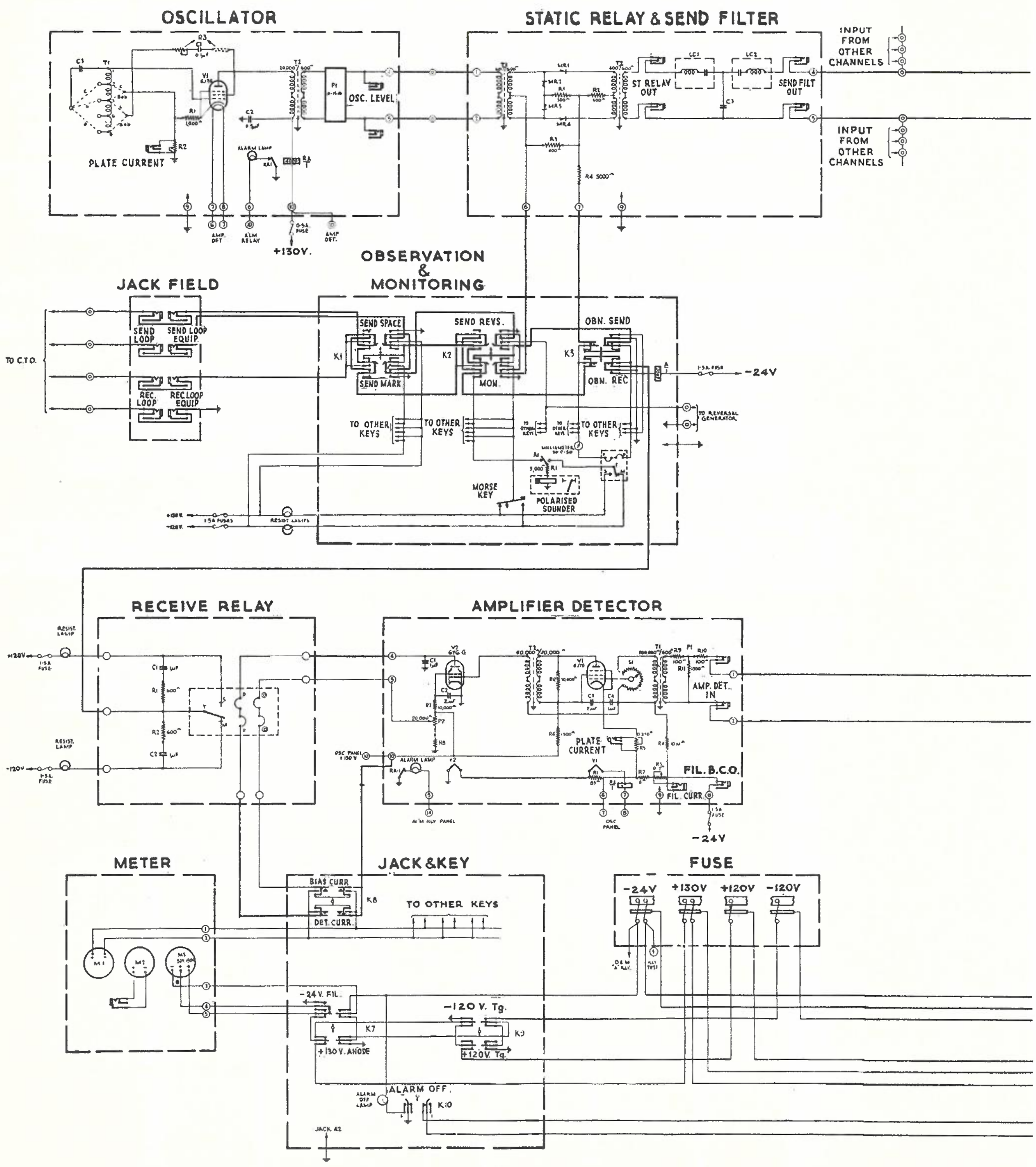
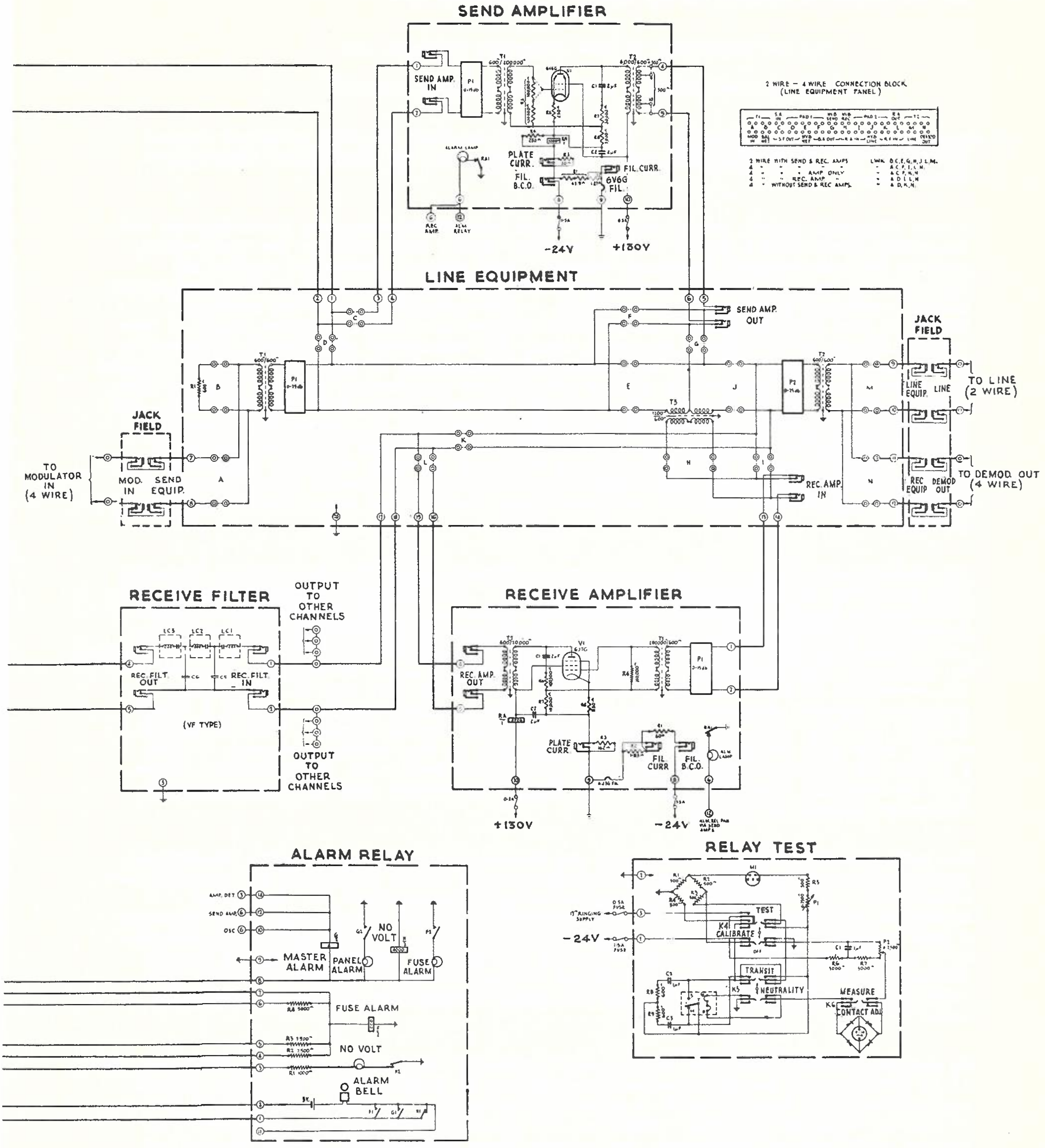


FIG. 4. WIRING SCHEMATIC CIRCUIT OF V.F.



CARRIER TELEGRAPH TERMINAL (A.P.O. TYPE).

The number of channels on a route is determined by the amount of traffic to be handled and the number of channels in any system is determined by -

(i) the band-width of each telegraph channel, and

(ii) the band-width of the bearer telephone circuit.

3.3 Band-width of Telegraph Channel. The band-width required for each telegraph channel depends on the signalling speed, the filter design, and the permissible interchannel interference.

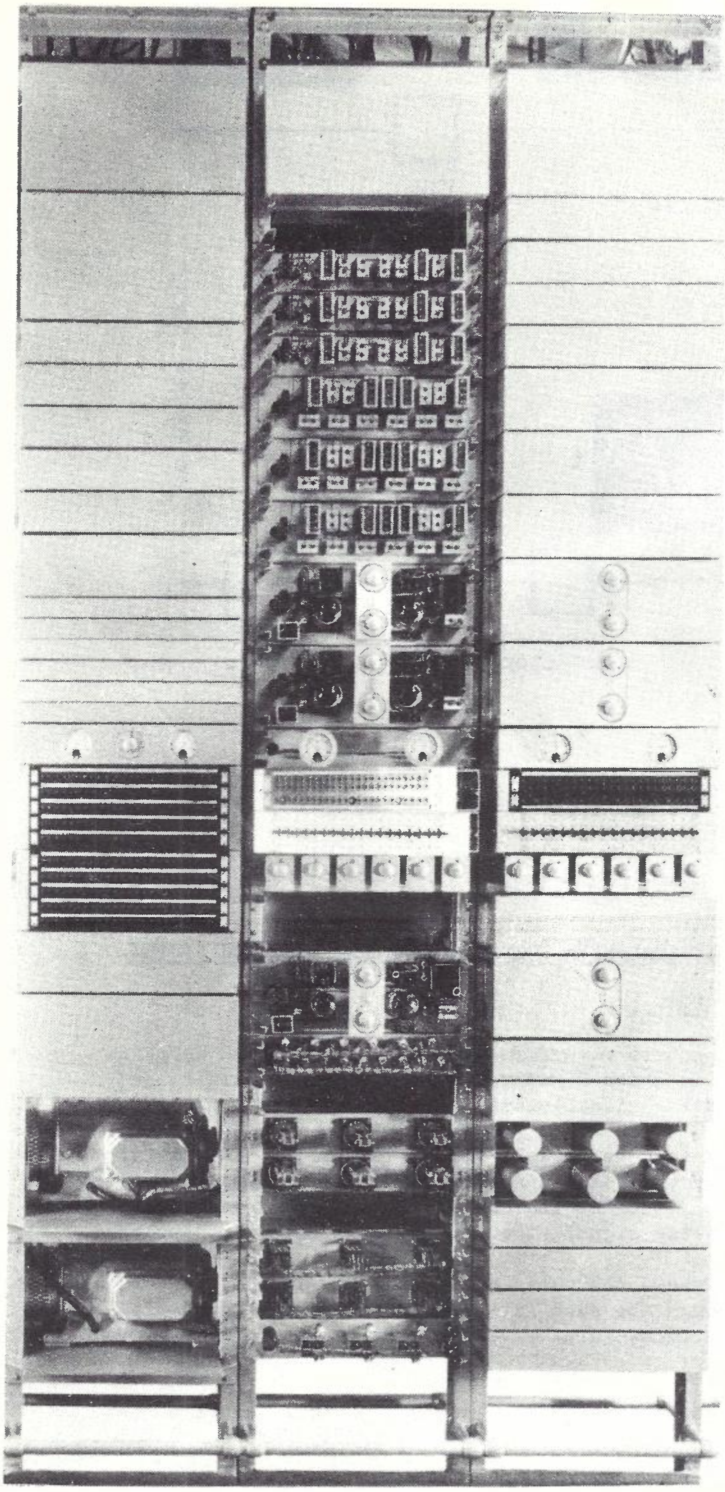
A D.C. telegraph signal can be resolved into a fundamental frequency determined by the signalling speed plus a number of odd harmonics which, when added to the fundamental, produce the square-topped telegraph signal. When the D.C. telegraph signals are impressed on the A.C. carrier frequency in the static modulator circuit of a particular channel, sideband frequencies are produced. The upper sideband is the carrier frequency plus the fundamental and harmonic frequencies of the telegraph signal. The lower sideband is the carrier frequency minus the fundamental and harmonic frequencies of the telegraph signal. For distortionless transmission of the A.C. telegraph signals, it is necessary to transmit the carrier and sideband frequencies over the carrier telegraph channel. It is not necessary, however, to transmit the full sideband range, and it is usual in practice to restrict the channel band-width to a value which ensures that the distortion introduced by each channel does not exceed a certain allowable margin, keeping in mind that these carrier telegraph channels should be capable of satisfactorily transmitting start-stop machine signals when used as links in a long telegraph circuit comprising two or three links, provided the other links are of equal quality.

The channel band-width is limited to a value slightly wider than the carrier frequency plus and minus the maximum modulating frequency. The modulating frequency for start-stop machine signals, in which the signalling speed is 50 bauds (see Section 14 for definition of baud), is 25 c/s. As the channel carrier frequency and both sidebands are transmitted, an effective band-width of about 33 c/s each side of the carrier frequency is required. This provides a margin over the required speed of 50 bauds and permits the connection of 2 or 3 channels in tandem. Allowance must also be made in the separation between channels for the filter characteristics which do not have a sharp cut-off (see Fig. 15). In practice, therefore, the nominal channel width is approximately twice this value, that is, 60 c/s each side of the carrier frequency, to give a margin for filter design and allow the filter pass band to be approximately linear over the required frequency band. This channel band-width sets the minimum carrier frequency spacing at 120 c/s.

The actual channel carrier frequencies are chosen with a view to reducing interchannel interference which may occur due to non-linearity of coils, amplifiers and other circuit components. The interference frequencies of greatest magnitude are the second harmonics and simple sum and difference frequencies of any two carriers. By choosing a base frequency and then taking the odd multiples of it, the interference frequencies will be even multiples of the base frequency and will lie midway between the carrier frequencies which is the point of maximum attenuation of the channel filters. The base frequency chosen is 60 c/s, and the channel frequencies are the odd multiples of this.

In carrier telegraph systems, it is usual to transmit the carrier and both sidebands, as it is difficult in the small band-width available to design channel band-pass filters with sufficiently sharp cut-off to eliminate the carrier and one sideband as in the case of carrier telephone systems. Moreover, in telegraph transmission, wave-front distortion is of primary importance, and correct phase relationship between carrier and sideband is essential. With the carrier in the centre of the transmission band, the phase compensation is automatic. If the carrier were suppressed, it would involve

/ reintroduction



TYPICAL V.F. CARRIER TELEGRAPH TERMINAL.

(REAR VIEW OF EQUIPMENT SHOWN ON PAGE 18.)

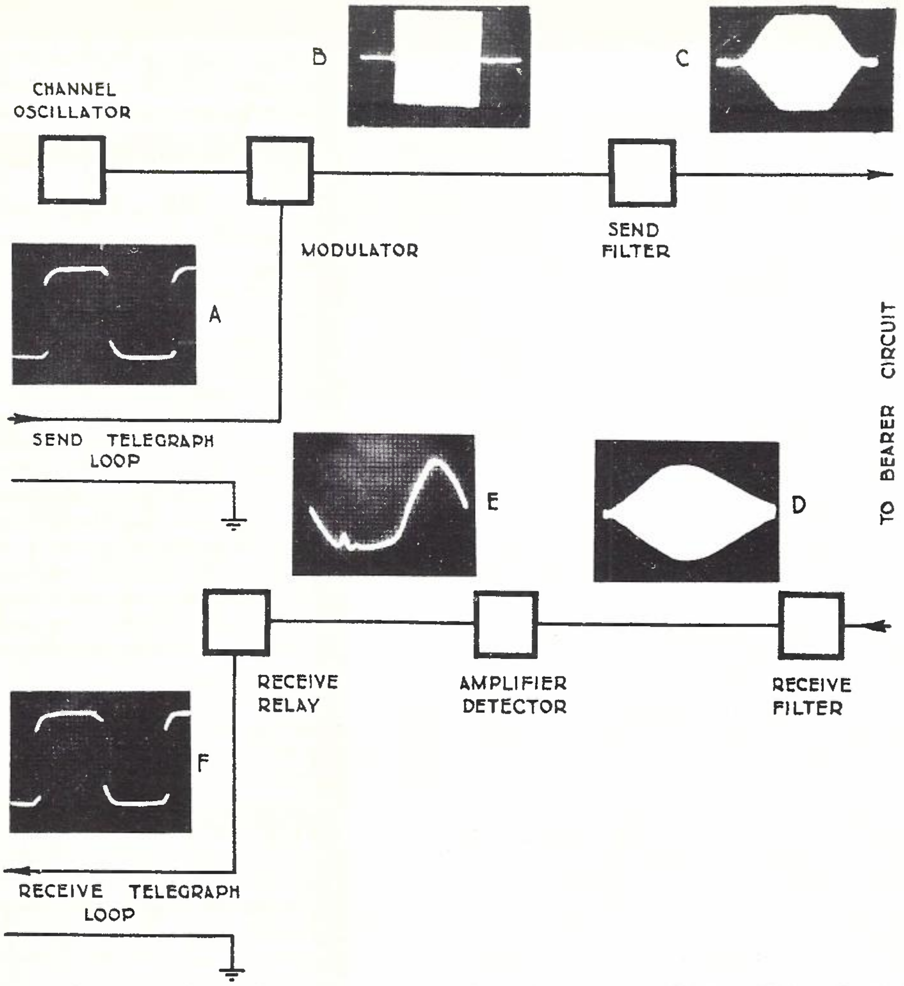
reintroduction at correct frequency and phase at the distant terminal, with consequent synchronisation and phase correction adjustments.

3.4 Band-width of Bearer Telephone Circuits. The average telephone circuit is capable of transmitting frequencies in the range 300-2,600 c/s, and this consideration sets the lower and upper limits to the choice of telegraph carrier frequencies for V.F. systems which must be capable of operating over a normal telephone circuit. The maximum number of telegraph channels with 120 c/s spacing which can be accommodated by the average telephone channel is standardised at 18. Carrier telephone channels complying with the revised C.C.I.F. specification for increased band-width from 300-3,400 c/s are now in operation in the case of wide-band carrier telephone systems. V.F. telegraph systems operated over channels of this band-width are extended to an upper limit of 3,180 c/s, permitting the derivation of 24 telegraph channels with 120 c/s spacing from one telephone circuit.

3.5 Where less than 18 channels are required for traffic reasons, a 9-channel system can be used. In this system, because of the lower number of channels, the spacing between the channel frequencies is increased to 240 c/s. The filter design is, therefore, less stringent and the transmitted band-width of each channel is wider. These channels transmit higher speed telegraph signals than the closer spaced systems. The 9-channel system is used when, for some reason, it is necessary to transmit high speed telegraph of at least 100 bauds, or normal 50 baud signals with a minimum amount of distortion.

3.6 Typical Wave forms. A simplified block schematic of the essential elements of a carrier telegraph system is shown in Fig. 5. The superimposed oscillograms in this figure show the character of a marking element of modulation at the various stages of the circuit. The photographs were taken at a transmission speed of 50 bauds in a system having a spacing of 120 c/s between adjacent channels, the carrier frequency of the particular channel being 1,860 c/s.

/ Fig. 5.



SIMPLIFIED BLOCK SCHEMATIC SHOWING TYPICAL WAVE FORMS IN CARRIER TELEGRAPH SYSTEM.

FIG. 5.

Oscillogram A. The reversals of square wave form in the send telegraph loop, as shown, are double-current signals in which negative and positive potentials are applied during the marking and spacing signal elements respectively.

Oscillogram B. The signal in the send telegraph loop is applied to the modulator, which is also supplied with the appropriate channel frequency. The product of modulation consists of a rectangular envelope at the carrier frequency corresponding to a marking signal. During the spacing signal, the carrier frequency is suppressed.

Oscillogram C. This oscillogram shows the pulse of carrier corresponding to the marking element after passing through the send filter. The envelope shows the characteristic rounding off of the rectangular wave form due to the restricted bandwidth of the send filter.

Oscillogram D. The envelope at the output of the receive filter is shown in oscillogram D. The increased rounding of the envelope is caused by the further restriction of the frequency band by the receive filter.

Oscillogram E. The output from the receive filter is applied to the amplifier-detector, and the detected current, as shown in oscillogram E, is passed through one winding of the carrier receive relay. The pulse of rectified current, corresponding

/ to

to the marking signal, operates the relay armature to the marking contact against the spacing bias provided by the bias winding. During the interval of no current, which corresponds to the spacing element, the bias winding operates the relay armature to the spacing contact. An interesting feature of this oscillogram is that, at the instant of operation of the relay, a current oscillation of small amplitude is generated in the windings of the relay due to the movement of the armature in the magnetic field. This small fluctuation is seen in the oscillogram.

Oscillogram F. As negative and positive potentials are connected to the marking and spacing contacts respectively of the carrier receive relay, the output from the relay tongue is of the square wave double-current form shown in oscillogram F.

4. BEARER CIRCUITS FOR CARRIER TELEGRAPH SYSTEMS.

4.1 The V.F. telegraph system transmits telegraph signals as impulses of A.C., the frequencies of which are within the normal V.F. range. As each telegraph channel operates on a narrow frequency band, a number of circuits can be obtained within the limits of normal speech frequencies. The system can, therefore, be applied to any physical or carrier telephone channel which is suitable for the transmission of V.F. intelligence. Except in special circumstances the systems are operated over a 4-wire or equivalent 4-wire circuit, because they use the same frequencies for each direction of transmission. When operating over a 4-wire circuit or equivalent, an 18-channel system provides a maximum of 18 duo-directional simplex telegraph channels. V.F. telegraph systems are not usually operated over a 2-wire circuit, because, in this case, the number of derived channels is halved. This is because different carrier frequencies are used for transmission in each direction, to prevent interference between the signals passing in either direction. Thus, in an 18-channel system nine different frequencies must be used in each direction. Moreover, it is usual to delete the mid-channel for hybrid or directional filter discrimination purposes, so that only 8 duo-directional simplex channels are obtained.

The main types of bearer circuits over which V.F. telegraph systems can be operated are -

(i) 4-wire operation over separate pairs of wires for either direction of transmission, as would exist in a short distance trunk cable operated at voice frequencies only.

(ii) 4-wire operation over separate channels derived by carrier methods over separate pairs of wires in long distance trunk cables operating at carrier frequencies.

(iii) Equivalent 4-wire operation over a pair of wires operating at carrier frequencies. This is the type of channel provided by a carrier telephone system operating over an open wire aerial trunk line.

4.2 Use of Carrier Telephone Channel for Bearer Circuit. V.F. telegraph systems are generally operated over the transmit and receive paths of a carrier telephone channel. This is due mainly to the fact that carrier telephone circuits generally exist between the centres where telegraph facilities are required, and, in addition, are more stable, and have a lower overall equivalent than the corresponding physical circuit. Under these conditions, the transmitting medium is effectively a 4-wire circuit, and the same telegraph frequencies are used for transmission in each direction.

When the carrier telephone channel is used as a bearer for a telegraph carrier system, the connections are made straight to the telephone system modulator from the send side of the carrier telegraph circuit, and straight from the demodulator low-pass filter to the receive side of the carrier telegraph circuit. Thus, the telegraph circuits have separate send and receive channels. This is indicated in Fig. 6 as well as the connections to other telegraph channels separated from one another by their band-pass filters.

/ Because

Because a virtually separate channel is used in each direction, full duplex telegraph operation between the two terminals is possible and actually consists of two complete simplex channels, one operating in each direction, that is, duo-directional simplex operation.

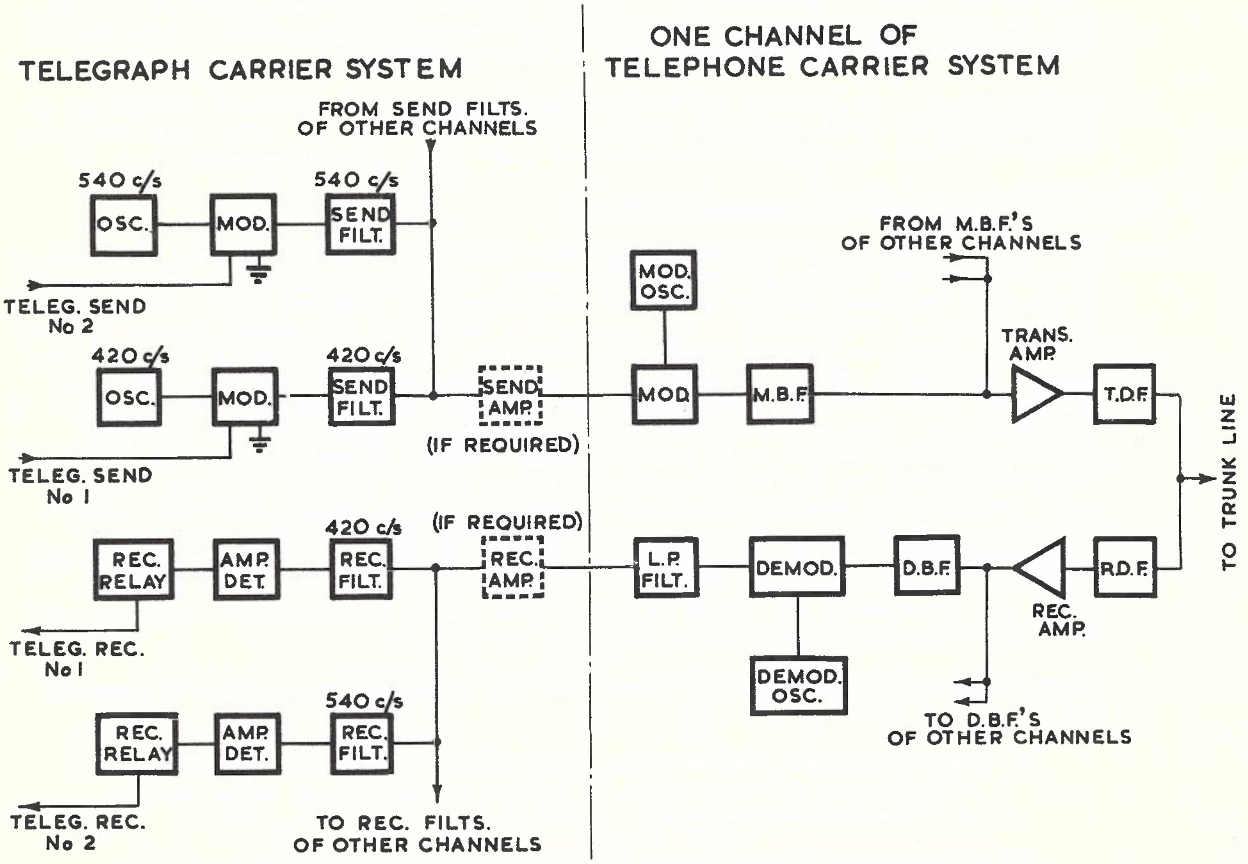


FIG. 6. USE OF CARRIER TELEPHONE CHANNEL AS BEARER CIRCUIT.

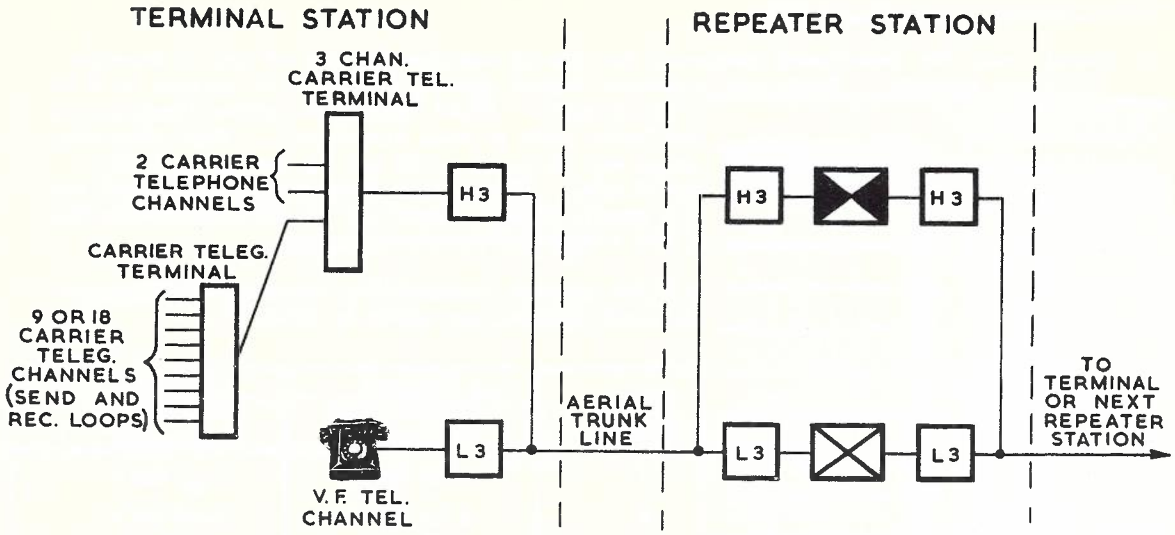
A maximum of 18 duo-directional telegraph channels is obtained from a carrier channel of a single or 3-channel telephone system, and a maximum of 24 duo-directional telegraph channels is obtained from a carrier channel of a wide-band telephone system.

Typical trunk line circuit diagrams showing the application of V.F. carrier telegraph systems to carrier telephone channels is given in Figs.7 and 8. V.F. telegraph systems could be connected simultaneously to the other carrier telephone channels, if desired.

4.3 Requirements of Bearer Circuit. Before installing a V.F. telegraph system on a bearer circuit, it must be ascertained whether the bearer circuit can transmit the frequencies involved without excessive distortion and attenuation. The frequency response should be linear within ± 1 db from 60 c/s below the lowest carrier telegraph channel frequency used, to 60 c/s above the highest channel frequency used. The attenuation should not exceed 25 db and should not vary more than ± 5 db. The crosstalk should not be greater than -45 dbm at a point of zero level.

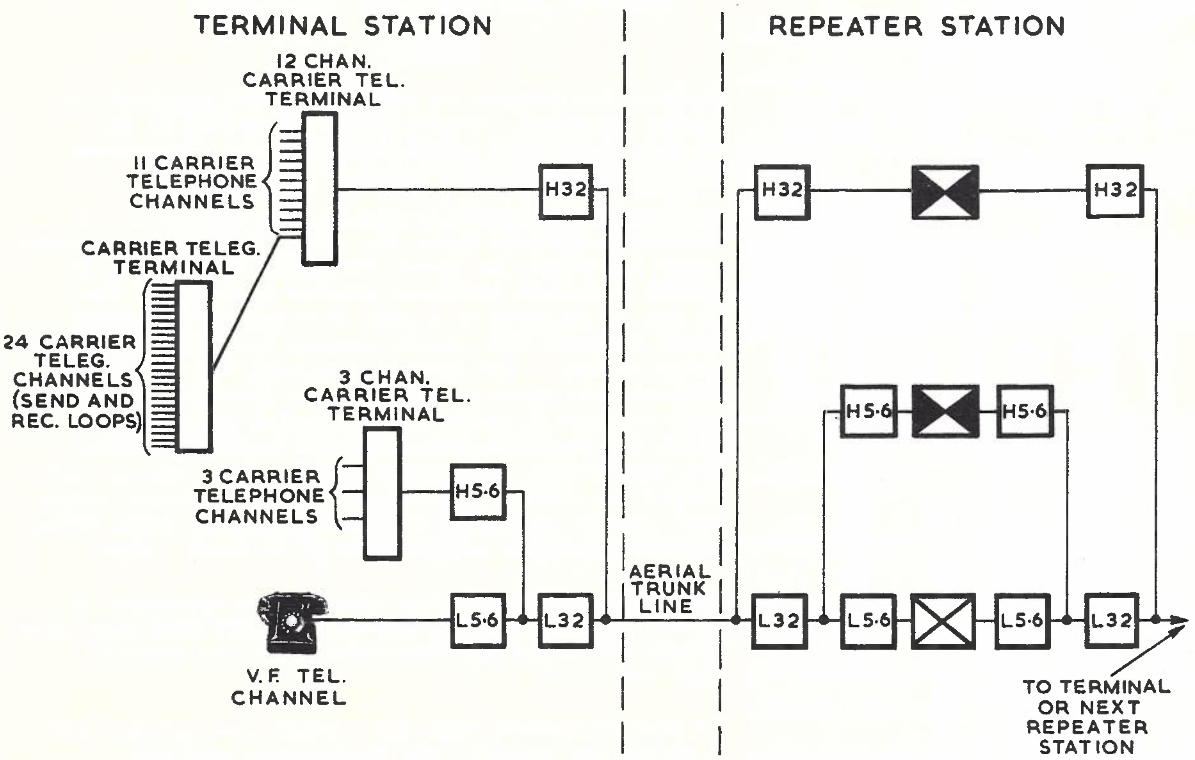
When operated over a 4-wire telephone circuit derived from a carrier telephone system, the distance over which a V.F. telegraph system can be operated is limited by the spacing of the carrier telephone repeaters. Some V.F. systems in use are operating over distances exceeding 1,000 miles.

/ Fig. 7



TYPICAL LINE CIRCUIT ARRANGEMENT FOR V.F. CARRIER TELEGRAPH SYSTEM.

FIG. 7.

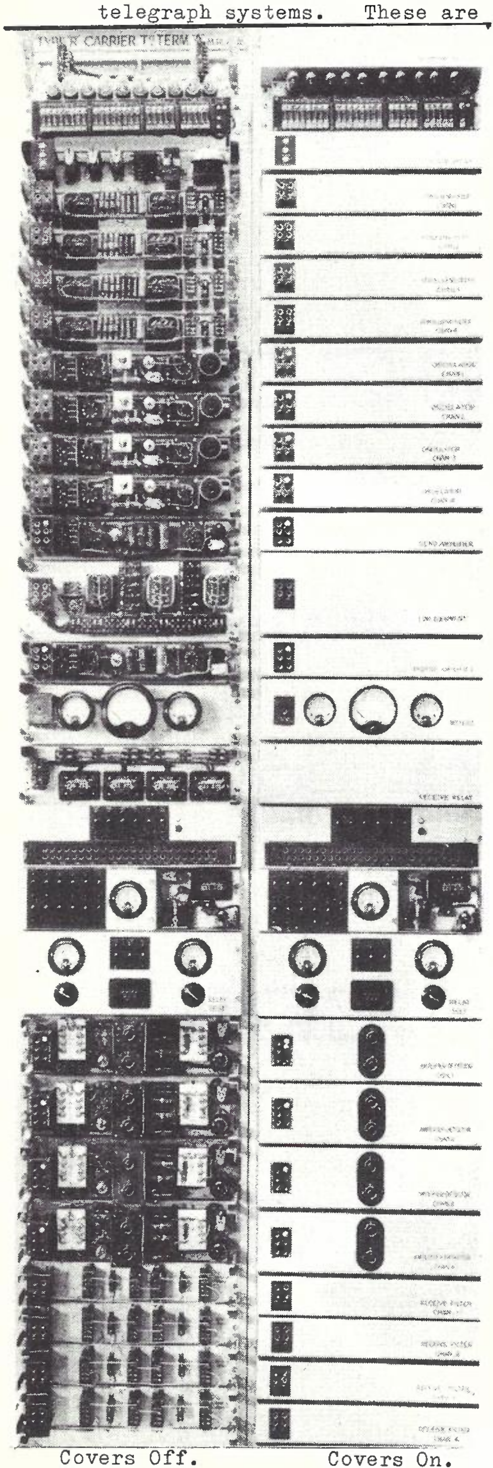


USE OF WIDE-BAND CARRIER TELEPHONE CHANNEL AS BEARER CIRCUIT
FOR 24-CHANNEL V.F. CARRIER TELEGRAPH SYSTEM.

FIG. 8.

5. TYPE R CARRIER TELEGRAPH SYSTEMS.

5.1 During 1941, the Department commenced the design and manufacture of type R carrier telegraph systems. These are 4-channel duplex systems designed to operate on a 2-wire circuit. Eight different carrier frequencies are used, four in each direction . Each frequency is an odd multiple of 60 c/s in the range 3,300-5,220 c/s. The carrier frequencies are spaced 240 c/s apart, with a separation of 480 c/s between the A and B terminal frequency groups.


Covers Off. Covers On.

TYPE R CARRIER TELEGRAPH TERMINAL.

5.2 The channel transmitting frequency allocations for each channel are shown in Table 2 -

Channel Number	A Terminal	B Terminal
	Transmitting Frequency	Transmitting Frequency
1	4.50 kc/s	3.30 kc/s
2	4.74 kc/s	3.54 kc/s
3	4.98 kc/s	3.78 kc/s
4	5.22 kc/s	4.02 kc/s

FREQUENCY ALLOCATION FOR TYPE R SYSTEM.

TABLE 2.

Because the frequencies are above those required for normal telephone conversations, the system is said to be a super V.F. system, although the frequencies are within the audible range of the human ear.

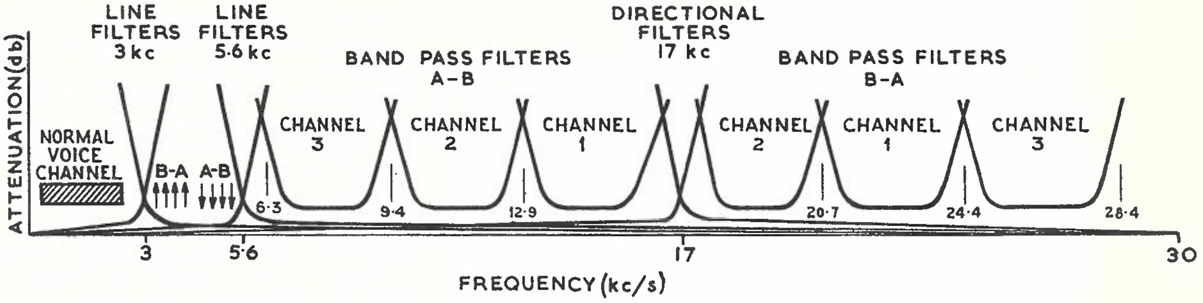
5.3 The type R system is designed to operate in the frequency spectrum above the normal V.F. speech channel range and below the lowest frequency transmitted by modern 3-channel telephone carrier systems, so that it may be operated on a pair of wires which already carry a normal V.F. speech channel and a carrier telephone system. The frequency allocations for these channels are shown in Fig. 9. It follows, of course, that the type R system can be applied to a pair of wires not equipped with a carrier telephone system. The application of the type R system to a circuit precludes the simultaneous operation of a physical broadcast channel employing a wide transmission band, which normally requires a band-width of at least 5 kc/s.

The system is principally intended for operation on open-wire lines working between a 3 kc/s high-pass line filter and a 5.6 kc/s low-pass filter, as shown in Fig. 10.

It must be ensured that the circuit used for the type R system can transmit the frequencies involved (3.30-5.22 kc/s) without too high an attenuation. A line equivalent exceeding 15 db at 5 kc/s is not recommended. This is equivalent to a distance of 175 miles on a 200 lb. copper circuit.

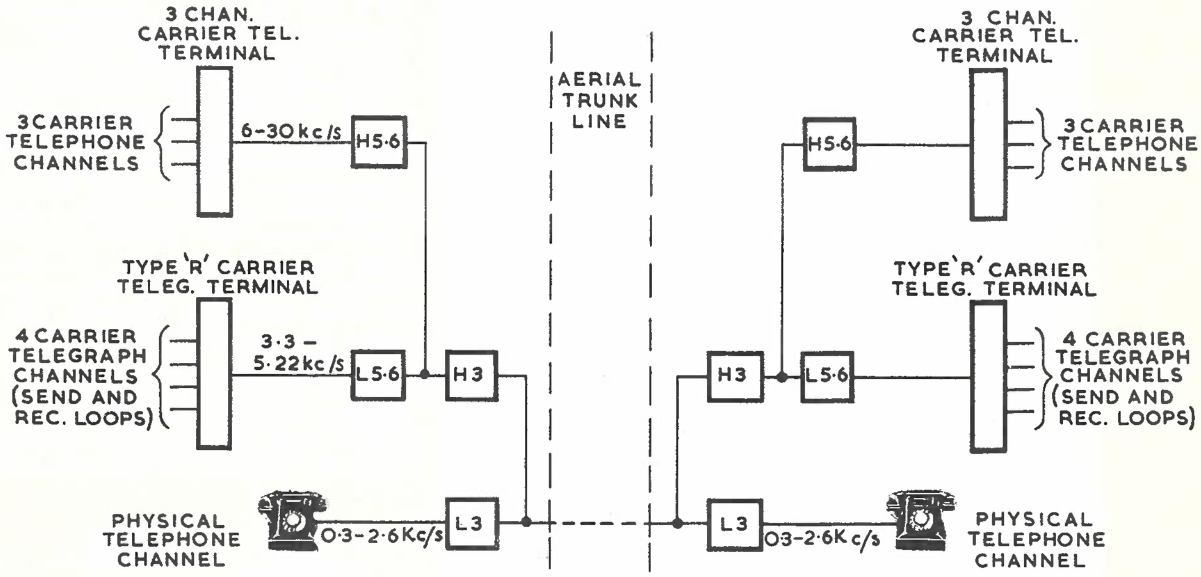
/ The

The type R system can also be operated over a lightly loaded cable circuit having a cut-off frequency of not less than 5.4 kc/s, and an attenuation not exceeding 15 db. The system is designed for channel working speeds of 50 bauds, and provides stable telegraph channels over a relatively short distance where only limited development is anticipated.



FREQUENCY ALLOCATION FOR V.F., TYPE R CARRIER TELEGRAPH AND TYPICAL 3-CHANNEL CARRIER TELEPHONE SYSTEM.

FIG. 9.



LINE CIRCUIT ARRANGEMENT FOR TYPE R TELEGRAPH CARRIER SYSTEM.

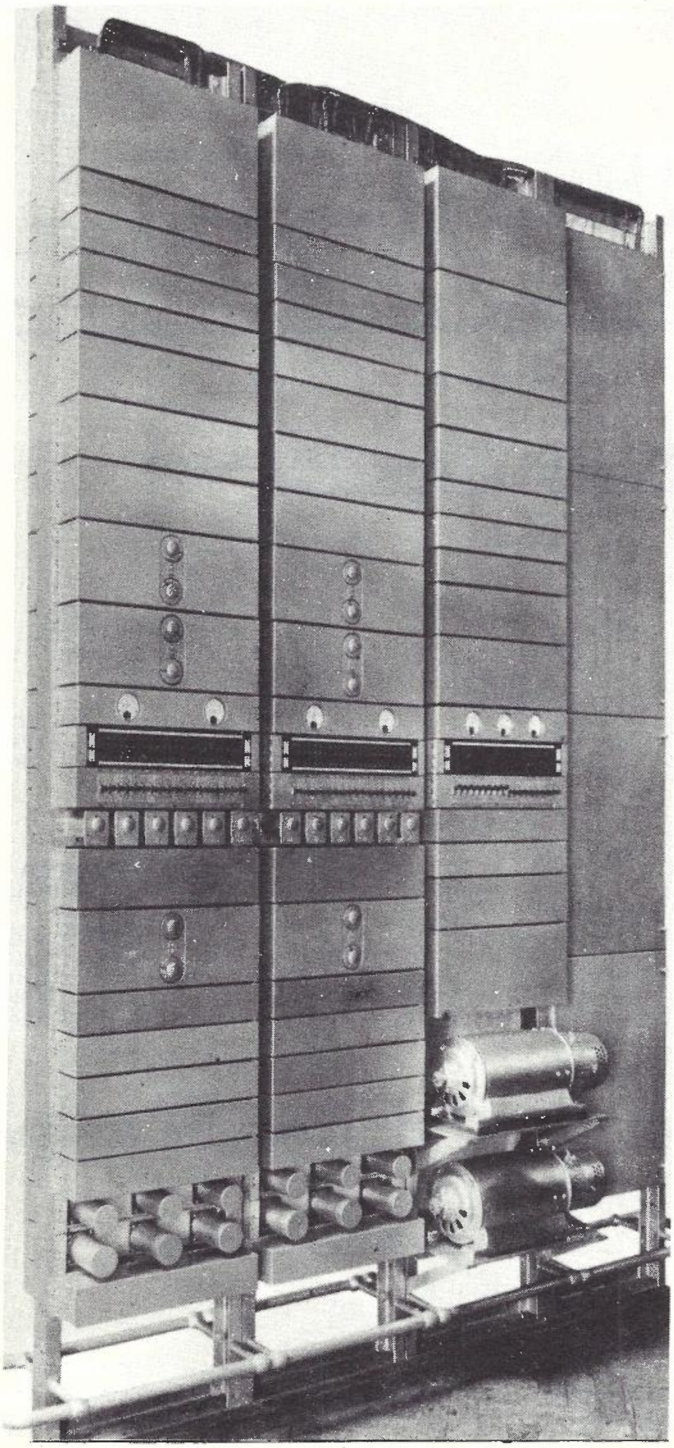
FIG. 10.

5.4 The circuit components of the type R system are similar to those used in the V.F. telegraph system, the main difference being in the frequencies transmitted. The send and receive sides of the telegraph terminal are connected to the 2-wire bearer circuit by means of a hybrid coil.

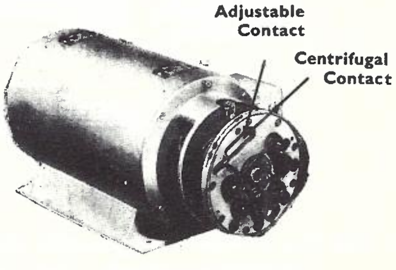
/ 6.

6. GENERATION OF CARRIER FREQUENCIES.

Multi-frequency Generators. At large offices where a number of V.F. carrier telegraph systems operate, the various frequencies are produced by a special multi-frequency generator mounted on one of the supply bays associated with the equipment. This is an inductor alternator direct coupled to a 24-volt motor operating from the 24-volt battery, and having 18 sets of rotors and stators, one for each frequency. The alternator field exciting windings are all connected in series and are energised by D.C. from the 24-volt battery. A rheostat is included in the field circuit to control the exciting current, and this, in turn, regulates the A.C. output voltages of the 18 alternator sections. Further individual adjustments are made by varying shunt resistors across the alternator outputs. The output voltage of each section is 1 ± 0.05 volt. The speed of the machine is 3,600 r.p.m. governor controlled to within close limits of ± 0.1 per cent., the governor contacts intermittently short circuiting a series field resistor. Associated with the generator is a 1,020 c/s fixed frequency oscillator used to check the generator speed and, consequently, the channel frequencies. The output of the oscillator is connected to a neon lamp mounted over a stroboscopic disc which is fitted to the end of the generator shaft. The number of black and white segments (34 each) is proportioned to the shaft speed (60 r.p.s.) so that at the correct speed a black or white segment arrives at a fixed point 2,040 times per second in synchronism with the flashes of the neon lamp.



TYPICAL V.F. CARRIER TELEGRAPH TERMINAL
SHOWING MULTI-FREQUENCY GENERATORS.

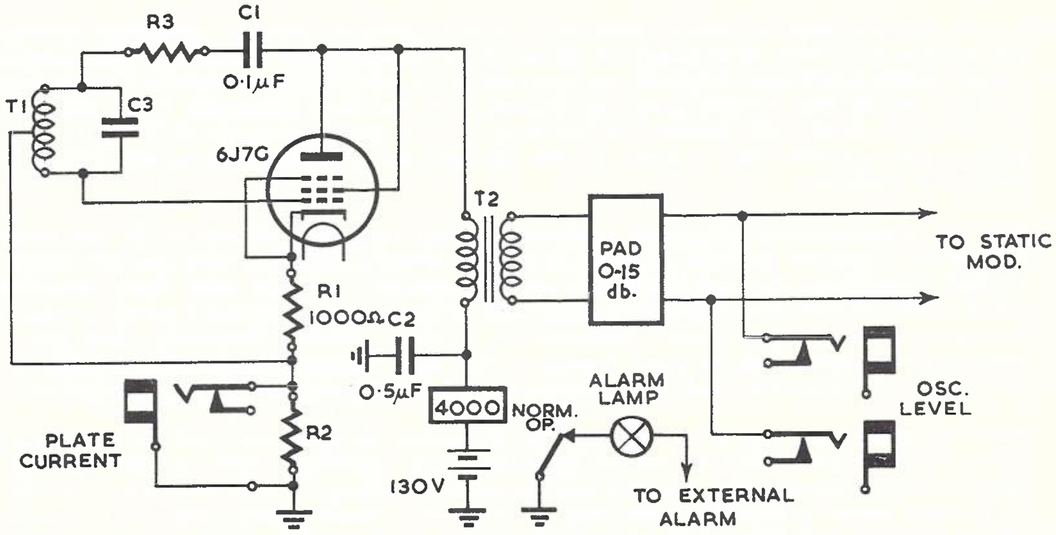


MULTI-FREQUENCY GENERATOR,
END COVER REMOVED.

When this actually happens, the disc appears to be stationary. When the speed is slightly out, then the disc appears to be rotating, backward if the speed is slow and forward if the speed is fast. A further check of speed is obtained by patching the outputs of the 1,020 c/s channel and the 1,020 c/s test oscillator together and listening for the beat note or, alternatively, patching both supplies into a detector and watching the beats on the rectified current meter. Multi-frequency generators, as described above, are designed to supply up to ten separate systems.

6.2 Thermionic Valve Oscillators. On smaller installations where development beyond one or two systems is not anticipated, the channel frequencies are produced by individual thermionic valve oscillators. The oscillators are set at the correct frequencies by reference to a standard oscillator and, being designed for stability of output and frequency, require very little further attention.

An adjustable pad is connected between the output of the oscillator and the modulator to adjust the level to 1 volt and to mask impedance variations in the modulator which could affect the frequency of the oscillator during signalling. A typical Hartley oscillator circuit is shown in Fig. 11. The theory of oscillation is described in Long Line Equipment I.



TYPICAL OSCILLATOR FOR A TELEGRAPH CARRIER SYSTEM.

FIG. 11.

In some large installations, valve oscillators are installed which are capable of supplying a number of systems in the same way as the machine generators. In these cases, a highly stable base frequency oscillator is used, the output of which is fed into a network of capacitors and inductors to produce the odd harmonics of the base frequency. These harmonics are then selected by filters and used to stabilise the individual channel oscillators. By this means, it is possible to maintain the phase relationship of each individual frequency.

By suitably reversing the output of some oscillators, it is possible to limit the peak current that occurs when the outputs from a number of oscillators reach a maximum simultaneously. This peak current, if it reaches a high enough value, can momentarily overload common amplifiers in either the telegraph or telephone carrier systems and would result in distortion and interference between channels of the telegraph carrier system.

7. STATIC MODULATOR.

7.1 The function of the static modulator is to control the flow of the carrier frequency current to line, in accordance with the polarity of the telegraph signals applied from the telegraph office, resulting in pulses of carrier current to line corresponding to a marking signal with practically no carrier current to line during a spacing signal.

7.2 The use of a non-linear conductor (for example, metal rectifiers) as a variable impedance under the control of the polarity of the applied voltage has been used extensively in recent years for many telecommunication circuit purposes, and one of the main applications has resulted in the replacement of telegraph sending relays in modern carrier telegraph systems by static modulators. The static modulator was first introduced with V.F. carrier telegraph systems in 1935. This device allows the D.C. telegraph signals to impress or modulate the A.C. carrier. It has no moving parts and requires a minimum of maintenance attention. The elimination of apparatus which contains moving parts and requires regular maintenance attention to ensure operation free from contact and bias troubles, is a definite advantage, and the discrimination of the latest static modulator circuits is such as to establish their superiority over mechanical send relays.

7.3 Fig. 12 shows a typical static modulator circuit used in carrier telegraph working. The static modulator unit consists of an input transformer, modulator unit comprising copper oxide rectifier units MR1-4, resistors R1 and R2 and an output transformer. Resistor R4 is the current limiting resistor in the send telegraph loop, and its value is chosen to limit the current in the loop to the standard value of 25 mA. The shunt resistor R3 ensures that current of the correct value is applied to the copper oxide rectifier network.

When the transmitting telegraph apparatus at the telegraph office is in the marking condition, negative battery is applied to the static modulator and current flows through rectifiers MR1 and MR4 which are conducting. At the same time, rectifiers MR2 and MR3 become non-conducting, and thus offer a high impedance shunt across the secondary winding of the input transformer. Thus, carrier frequency from the oscillator is permitted to pass freely to the send filter through MR1 and MR4 which act as low resistances, and the attenuation of the modulator is low, being about 4 db.

When the potential applied to the static modulator is reversed, due to the application of a spacing signal, the rectifier impedances are reversed, that is, MR2 and MR3 become conducting and MR1 and MR4 become non-conducting. This results in a low resistance shunt across the secondary of the input transformer, and a high resistance series path to the passage of carrier frequency from the channel oscillator. The attenuation of the modulator is now greater than 44 db.

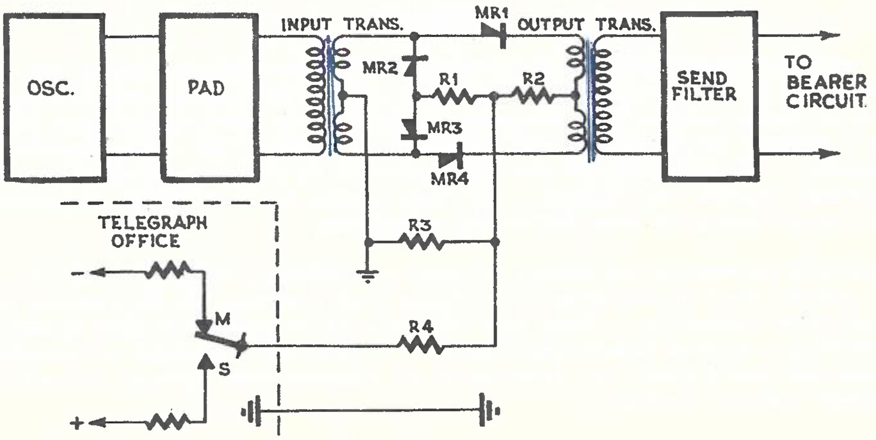
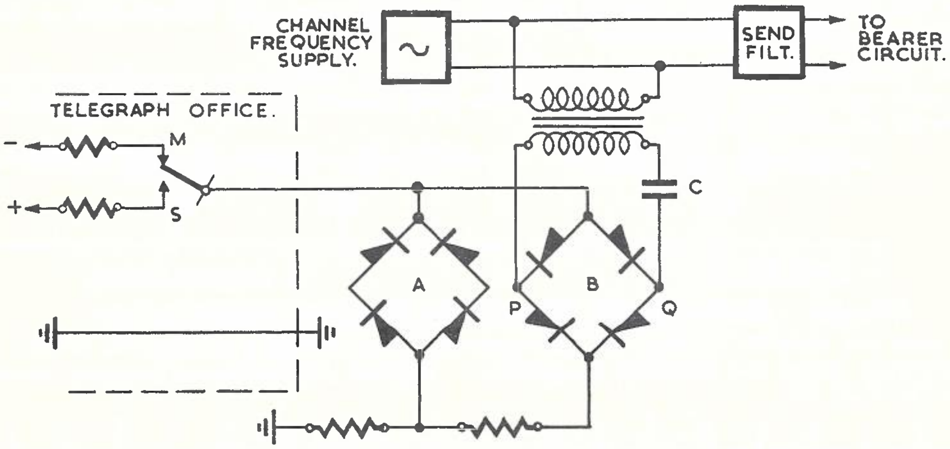


FIG. 12. TYPICAL STATIC MODULATOR FOR TELEGRAPH CARRIER SYSTEM.

7.4 Another type of static modulator is shown in Fig. 13. The two bridge circuits A and B are identical and are made up of copper oxide metal rectifier elements. The transformer has a 10:1 ratio step up, and the primary is connected across the output of the channel frequency source, whilst bridge B is connected across the secondary. The impedance of bridge B between points P and Q, is, therefore, effectively in shunt across the carrier frequency source, and modulation is effected by varying the value of this reflected impedance from a low value during spacing signals to a high value during marking signals. The variation is controlled by the magnitude and direction of current in the send telegraph loop. When a marking signal is applied, bridge A presents a low forward resistance, and the send loop current flowing through it and the series resistance biases the rectifier elements in bridge B in the backward direction, so that these present a high impedance and carrier frequency is transmitted to line. When the polarity of the applied D.C. is reversed on a spacing signal, bridge A becomes high resistance and bridge B low resistance, so that the shunting loss is high and practically no carrier passes to line. Typical values of the A.C. impedance across points P and Q are 300,000 ohms and 100 ohms during marking and spacing elements respectively, the corresponding reflected impedances through the transformer being 3,000 ohms and 1 ohm. Bridge A and its series resistance produce the correct value of negative bias across bridge B in the marking condition, and equalise the D.C. loop current in the marking and spacing intervals. The capacitor C prevents the flow of D.C. through the secondary winding of the transformer.



STATIC MODULATOR CIRCUIT.

FIG. 13.

7.5 The static modulator may be regarded as an attenuator switching device, so that, with an applied D.C. polarity of negative potential, the attenuation offered to the A.C. channel frequency is approximately 4 db, whereas, upon reversal of the D.C. polarity to a positive potential, the attenuation increases to about 44 db. In other words, the discrimination of the static modulator is, on the above quoted values, 40 db. Thus, whilst in the blocking condition carrier is still passed to line, the level is so low that it is below the threshold of operation of the receiving equipment. In early static modulators, discrimination values of about 30 db were obtained, but, in circuits used in recent years, the discrimination has been increased to values of 40 and 50 db, due mainly to steeper voltage-resistance characteristics of the rectifier elements.

/ 8.

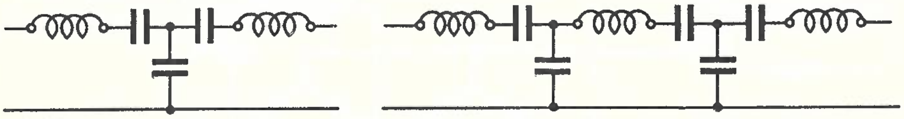
8. SEND AND RECEIVE FILTERS.

8.1 The send and receive filters of a carrier telegraph system provide separation between the various channels. The filters are designed to pass a sufficiently wide band of frequencies above and below the carrier frequency to prevent undue distortion of signals. The stop band attenuation is sufficient to exclude interfering currents of other frequencies, whether caused by crosstalk, direct transmission from other channels, or interchannel modulation. The filters are of the conventional coil-capacitor type.

8.2 Send Filters. The send filters associated with each channel of a V.F. system restrict the frequency band-width transmitted to line for each channel. This restriction of band-width is necessary because the modulation of the carrier frequency of each channel with the applied D.C. telegraph signals in the static modulator results in the generation of a wide spectrum of sideband frequencies on either side of the carrier. Suppression of the unwanted harmonics reduces the power to line and decreases the possibility of interchannel interference. The restricted band-width also prevents harmonics of the channel carrier frequencies from passing to line and perhaps causing interchannel interference in a similar manner. The send filters also present a high reactive impedance to the carrier frequencies of other channels at the commoning point of the filters. This ensures that the carrier output of any one channel is not dissipated in, or modulated by, the sending equipment of other channels which are connected in parallel with it.

8.3 Receive Filters. The receive filters separate the various channel frequency bands from the multi-frequency signals received from the line, and direct them to the appropriate amplifier-detectors.

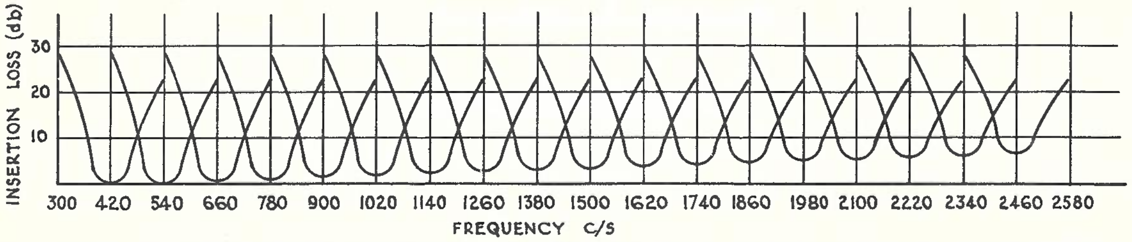
8.4 In the 18-channel V.F. systems, to fulfil the above functions, a single section suffices for each send filter and two sections for each receive filter. Typical filter networks are shown in Fig. 14.



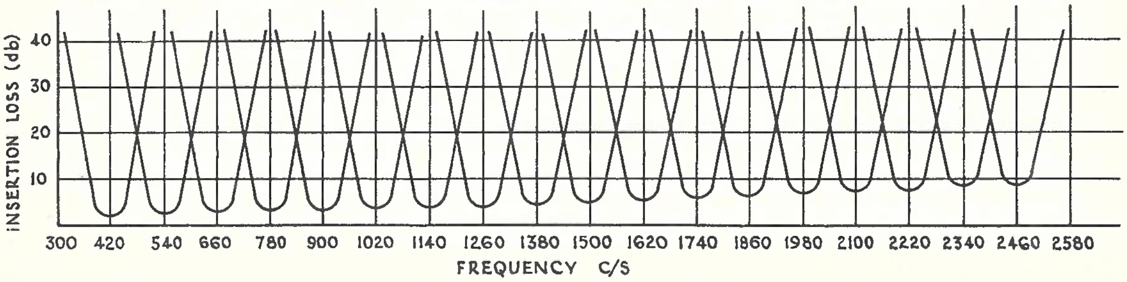
(a) Send Filter. (b) Receive Filter.

FIG. 14. TYPICAL FILTER NETWORKS FOR TELEGRAPH CARRIER SYSTEM.

The send and receive filters are band-pass filters having a band-width of 120 c/s symmetrical about the mid-band frequency. Typical attenuation-frequency curves are shown in Fig. 15.

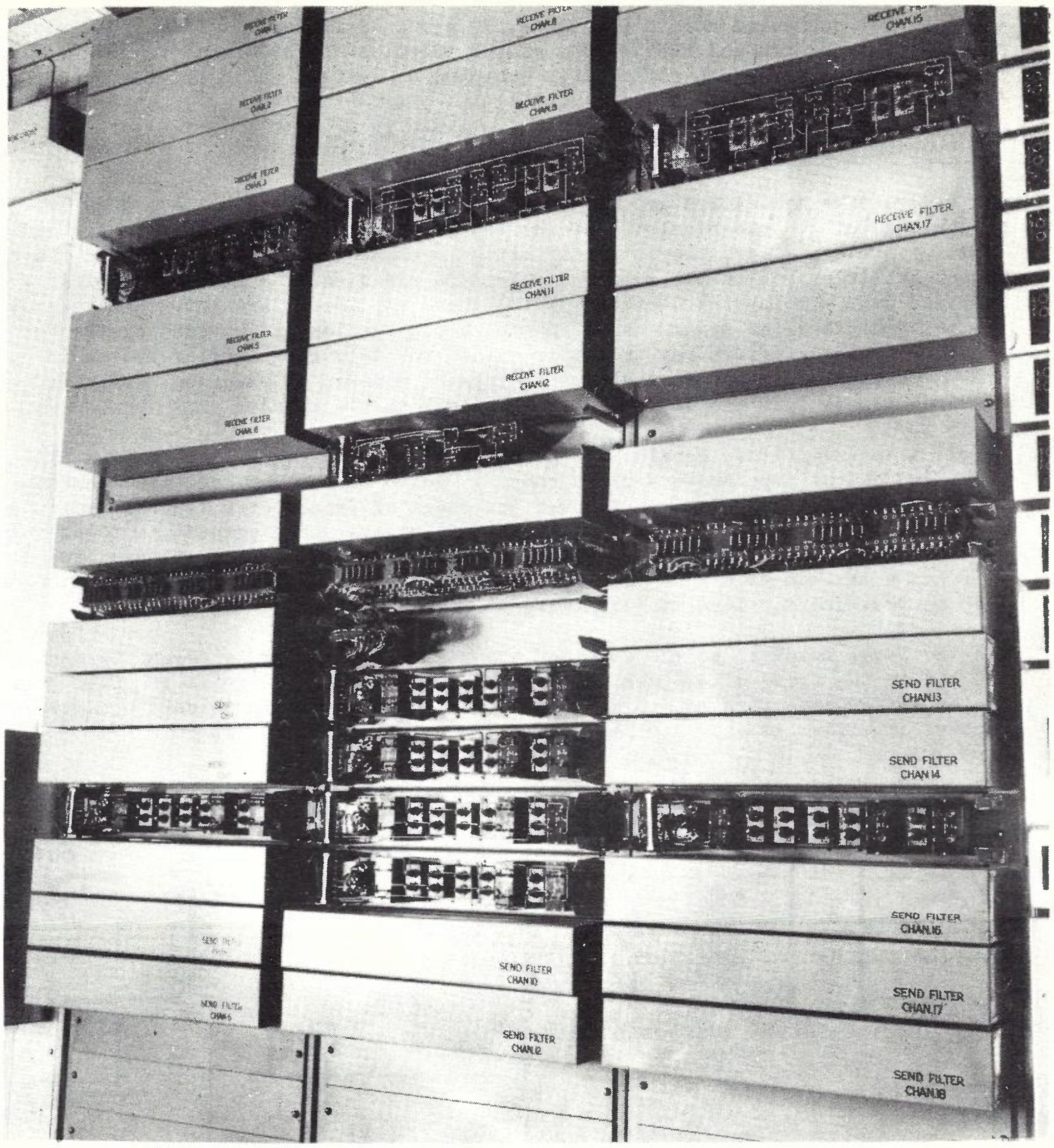


(a) Send Filters.



(b) Receive Filters.

FIG. 15. ATTENUATION CHARACTERISTICS FOR SEND AND RECEIVE FILTERS.



SEND AND RECEIVE FILTER PANELS ON V.F. TELEGRAPH TERMINAL.

8.5 Filter Design. The transmission requirements of the filters are -

(i) The attenuation characteristic should be approximately symmetrical about the mid-band frequency.

(ii) The phase characteristic should be approximately linear and of equal and opposite symmetry about the mid-band frequency.

(iii) The attenuation of each receive filter ± 35 c/s from its mid-band frequency should not be more than 2.5 db above the attenuation at the mid-band frequency.

(iv) The attenuation of each receive filter ± 120 c/s from its mid-band frequency (that is, at the mid-band frequencies of the directly adjacent filters) should not be less than 30 db above the attenuation at the mid-band frequency.

8.6 Compensating Network. The outputs of the send filters and the receive filters in an 18-channel system are connected in parallel, and, at the common point, compensating

/ networks

networks are connected across each parallel group of filters. These networks provide a flanking impedance and improve the characteristics of the higher frequency filters. Compensating networks are not usually equipped on systems which provide less than 18 channels.

9. SEND AND RECEIVE AMPLIFIERS.

9.1 Send and receive amplifiers are used, when required, to increase the signal level prior and subsequent to transmission over the line. The low level signal is applied to the input of the amplifier, the output of which is connected either to line in the case of a send amplifier, or to the receive filters in the case of a receive amplifier. When operated over a telephone carrier system, these amplifiers are not usually required in the telegraph carrier system as sufficient amplification is provided by the telephone system. The amplifiers may be required when the telegraph carrier system is operated over a physical line (as in the case of type R systems) or when the terminals are situated remote from the telephone carrier terminal equipment.

9.2 A typical send amplifier consists of a single stage power amplifier using a 6V6G valve. Input and output impedances are 600 ohms. Due to the use of negative feedback, the frequency response is within 1 db over the range of frequencies transmitted. By applying 154 volts (130 and 24 volts combined) to the anode circuit, a power output of +26 dbm (400 mW) can be obtained with less than 2 per cent. distortion. The amplifier has a maximum gain of 25 db and a 15 db input attenuator variable in steps of 1 db is provided for level adjustments.

9.3 When the level received at the input of the receiving carrier telegraph terminal is reduced to the order of -25 dbm to -30 dbm, a receive amplifier is required to allow the amplifier-detectors to operate effectively. A schematic circuit of a typical receive amplifier is shown in Fig. 16.

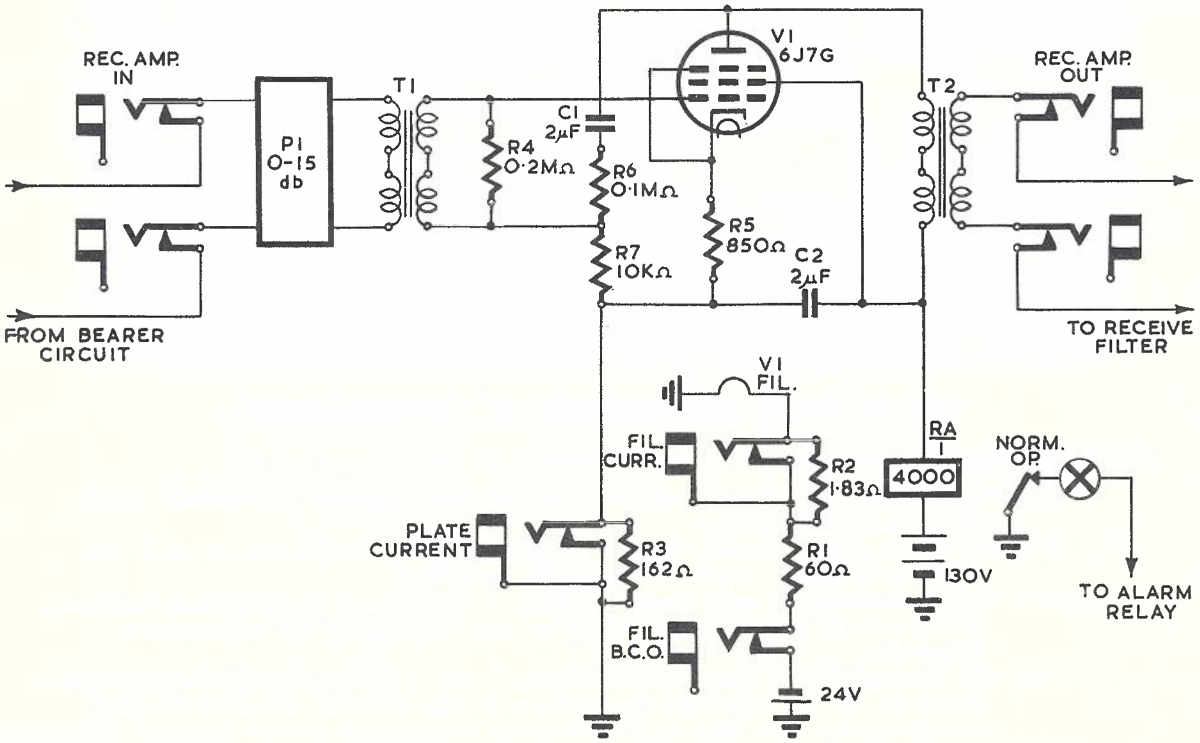
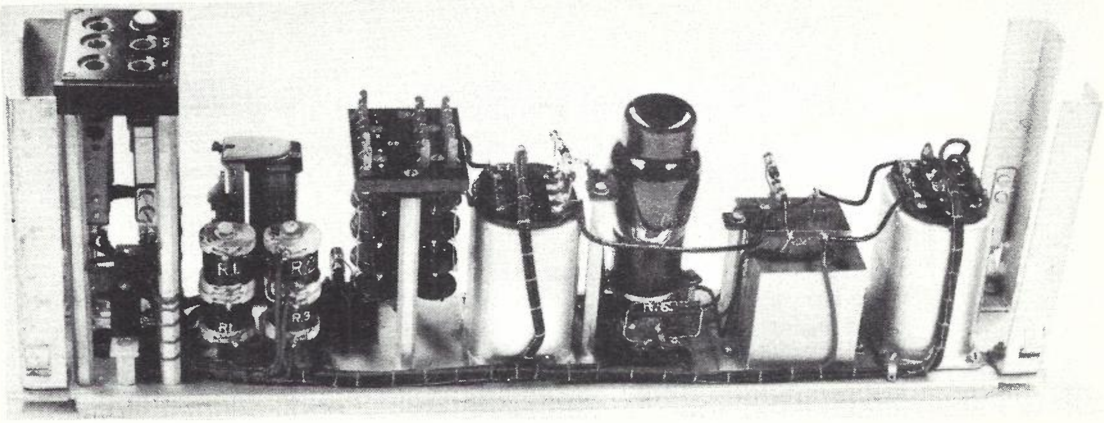


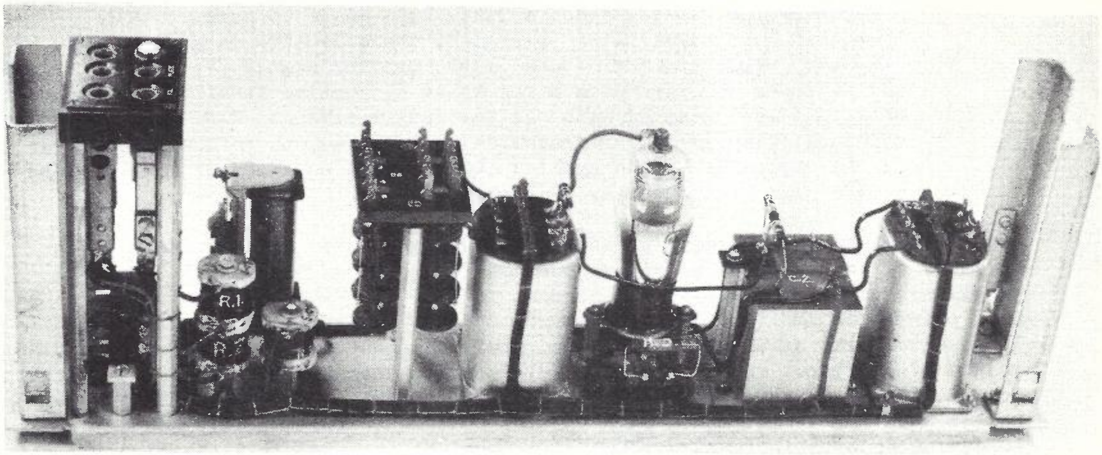
FIG. 16. TYPICAL RECEIVE AMPLIFIER FOR TELEGRAPH CARRIER SYSTEM.

This amplifier is of similar design to the send amplifier but uses a 6J7G valve. Input and output impedances are 600 ohms. Frequency response is within 1 db over the range of frequencies transmitted. At a power output of +10 dbm (10 mW), the distortion is less than 2 per cent. The amplifier has a maximum gain of 22 db, and a 15 db attenuator variable in steps of 1 db adjusts the overall gain of the amplifier to the required value.

Both current and voltage negative feedback are applied to the amplifier stage. Current feedback is obtained by omitting the by-pass capacitor across the cathode bias resistor R5. Voltage feedback is provided by connecting resistors R6 and R7 across the output circuit. The voltage developed across R7 is fed back to the input circuit in series with, and in opposition to, the normal input signal developed across the secondary of transformer T1. C1 is a D.C. blocking capacitor. The inductance of the alarm relay and the capacitor C2 provide an anode decoupling circuit. Facilities are provided for the measurement of anode and filament currents, and for opening the filament circuit by plugging an open-circuit plug into the "Fil. B.C.O." jacks.



TYPICAL SEND AMPLIFIER FOR CARRIER TELEGRAPH SYSTEM.



TYPICAL RECEIVE AMPLIFIER FOR CARRIER TELEGRAPH SYSTEM.

10. AMPLIFIER-DETECTOR.

10.1 The function of the amplifier-detector is to convert the received pulses of carrier frequency into D.C. signals suitable for operating the receive relay and thus reproducing with a minimum of distortion, at the tongue of the relay, D.C. signals of the same character as those applied at the input of the channel. To perform this function satisfactorily, the amplifier-detector is designed to take account of the rounding off of the carrier envelope caused by the channel filters and the variations in received level due to circuit attenuation changes. The effect of filter distortion and line level variations is shown in Fig. 17.

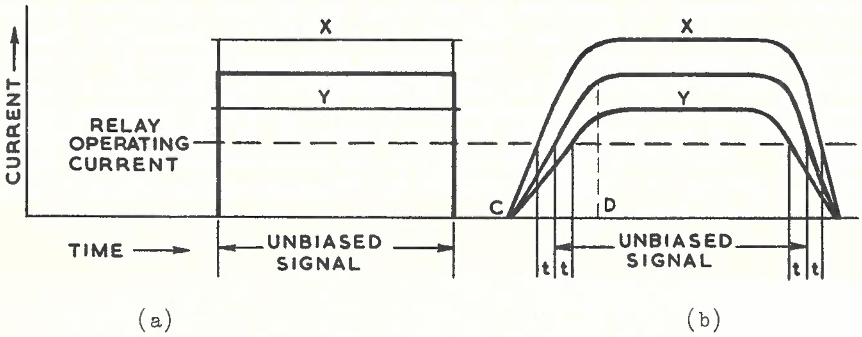


FIG. 17. EFFECT OF FILTER DISTORTION AND LINE LEVEL VARIATIONS.

(i) Filter Distortion. The pulses of carrier applied to the amplifier-detector input have passed through send and receive band-pass filters, with the result that the carrier envelope is no longer square topped as shown in Fig. 17a.

The carrier signal applied to the channel band-pass filters takes a definite time to build up to a steady state value. The extent of the building-up time is largely a function of the filter characteristics and increases with a reduction in filter band-width. The building-up time causes the applied signal to be tapered at both ends as shown in Fig. 17b.

(ii) Line Level Variations. The effect of line level variations on the rectified current is shown also in Fig. 17 by the X and Y values. The horizontal dotted line represents the steady bias condition and indicates the point where the incoming signal strength is sufficient to operate the carrier receive relay from space to mark. With respect to the normal line up signal, the effective mark signal (X) commences earlier and finishes later, but the signal (Y) commences later and finishes earlier, with a resultant distortion in either case equal to 2t. (Fig. 17b is concerned with one particular fixed band-width having a constant building-up time represented by C-D, and, therefore, any change in the amplitude of the applied signal produces a change in the slope of the signal envelope as indicated.)

10.2 In carrier telegraph working, therefore, the necessity for maintaining constant amplitude of the received signal depends on the shape of the signal envelope. If the signal were of square wave form, as shown in Fig. 17a, the bias distortion caused by small changes in amplitude would be zero. When, however, the signal is not of square wave form, as shown in Fig. 17b, small changes in amplitude are sufficient to produce distortion. Some form of regulation is necessary to ensure that signals of constant amplitude are applied to the carrier receive relay. This is achieved by the inclusion of an automatic gain control feature in the amplifier-detector circuit. The inclusion of this feature results in a slight increase in distortion but this is negligible, particularly when the large improvement in distortion during input level variations of the order of ±5 db is taken into account.

/ Many

Many telephone carrier systems, which are used as bearer channels for V.F. telegraph systems, are provided with an automatic gain regulation feature, but this is often relatively slow in its action. The telegraph carrier system usually requires its own quick response automatic gain control which is also more sensitive on smaller level variations.

10.3 The usual method of compensation for the effects of changes in amplitude of the applied signals depends for its operation on the change of grid-cathode impedance of a valve, when the potential on the grid reaches a point where grid current commences to flow, and also on the rectifying property of the grid-cathode circuit. The elements of a limiter of this type are shown in Fig. 18, the value of grid bias depending on whether the valve is used as an amplifier or rectifier.

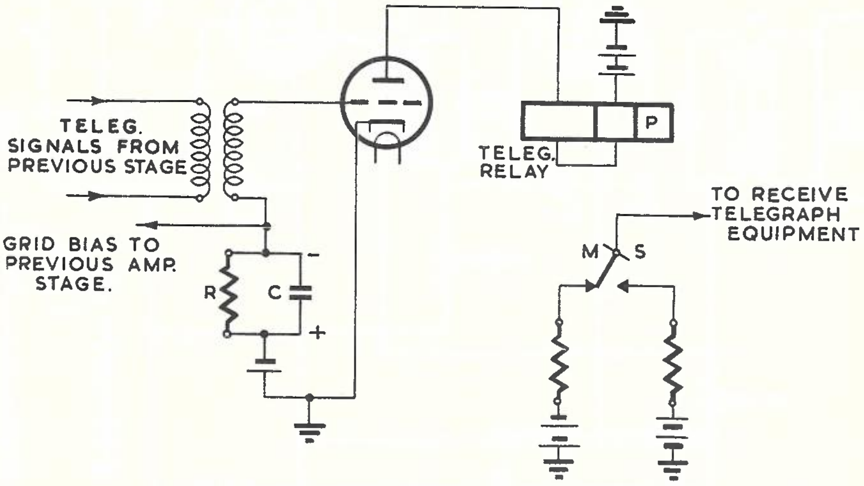


FIG. 18. SIMPLE GRID LIMITER.

When a signal of large amplitude is applied between grid and cathode, the carrier receive relay operates just after the commencement of the building-up period of the signal envelope. When the peak amplitude exceeds the normal grid bias, the grid becomes positive with respect to the cathode, grid current flows and the voltage developed across R charges the capacitor C. The voltage developed across the CR combination increases the negative bias applied to the grid. Any variation in amplitude of the input signal causes a variation in grid current, with a resultant change of bias on the grid. When the peak amplitude increases due to line level variations, it tends to increase the anode current through the relay. However, an increase in peak amplitude produces greater grid current and this further increases the negative grid bias. This effect opposes the increase in anode current, and the anode current remains practically unchanged. When the peak amplitude decreases, the anode current tends to decrease. However, less grid bias is now produced and the anode current again remains unchanged. By a suitable choice of circuit constants, the anode current is held substantially independent of input level variations over a range of ±7.5 db. The additional bias developed across the limiting circuit may be applied to other stages to give greater control, and is usually applied to the amplifier stage preceding the detector in amplifier-detector units.

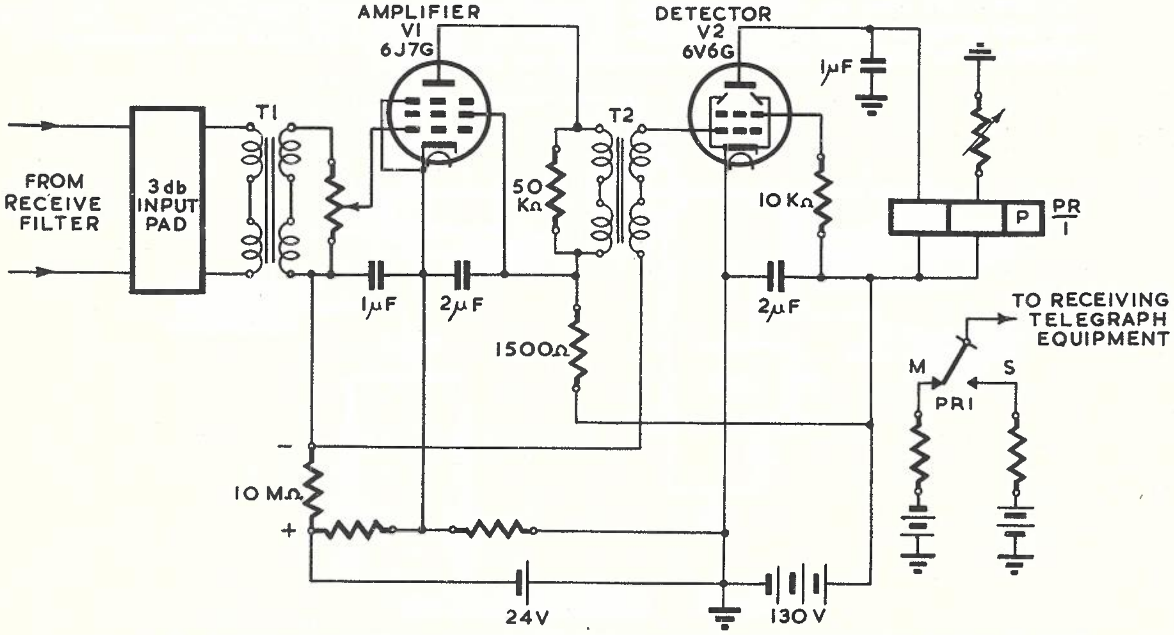
The time constant of the CR combination is large in comparison with the time between successive half-waves, and is chosen to be greater than the longest interval between marking elements in the telegraph 5 unit code. The new bias value determined by the peak amplitude of the marking element is therefore maintained on the grid during the spacing elements in the telegraph code.

10.4 A typical amplifier-detector circuit is shown in Fig. 19. The amplifier portion of this circuit, comprising V1 and its associated components, amplifies the individual channel signals to the correct value for the satisfactory operation of the detector

/ V2

V2 which, in conjunction with the receive relay, converts the A.C. signals to direct double-current signals for operating the telegraph equipment.

When an A.C. signal is received by the amplifier-detector, corresponding to a marking signal, anode current flows in valve V2 and the receiving relay PR/1 operates to mark, applying negative battery to the telegraph equipment. When the A.C. signal ceases, corresponding to a spacing signal, the receiving relay is operated to space by current in the bias winding, applying positive battery to the telegraph equipment.



TYPICAL AMPLIFIER-DETECTOR FOR TELEGRAPH CARRIER SYSTEM.

FIG. 19.

To maintain the signal level constant, irrespective of line attenuation variations of up to ±7.5 db from the nominal, an automatic gain control feature is incorporated in the circuit. This consists of the 10 megohm resistor and 1 μF capacitor in the grid circuit of V1 in Fig. 19, and the action is as follows -

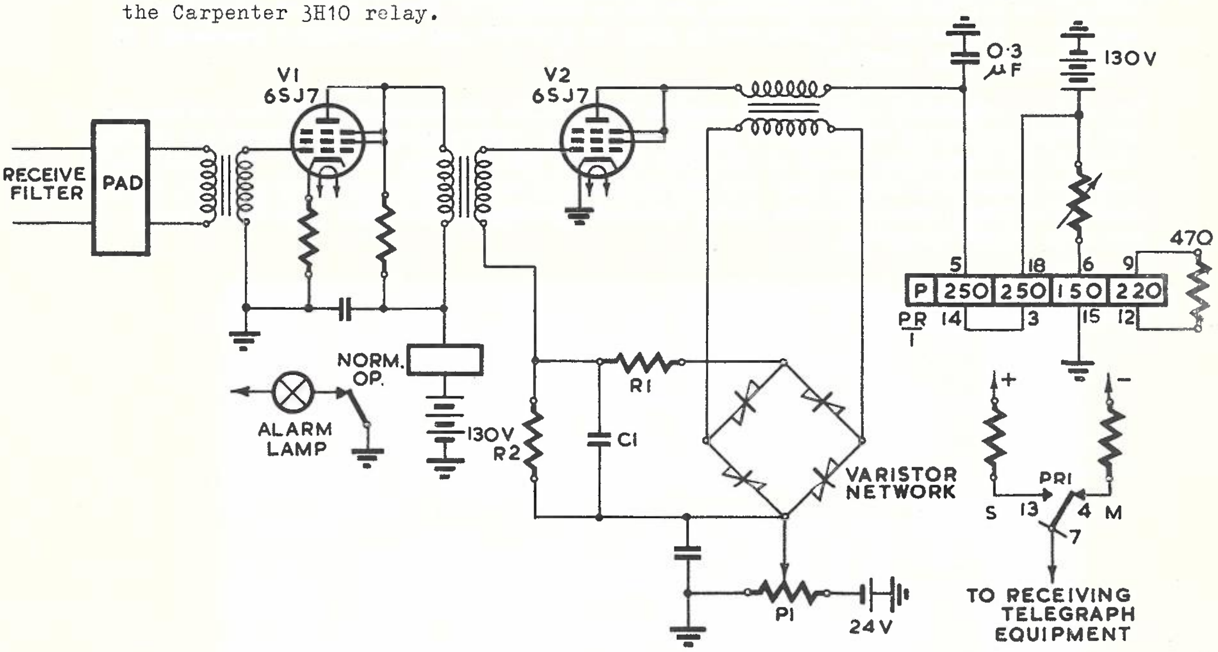
A marking signal, amplified by the amplifier valve V1 makes the grid of the detector valve V2 slightly positive, with the result that grid current flows in the detector valve via the 10 megohm resistor. The flow of current through this resistor increases the negative bias of the amplifier valve, and reduces its amplification. This extra negative bias tends to fall to a lower value during spacing signal interruptions to the incoming carrier, due to the discharge of the 1 μF capacitor, which stores the extra bias potential, through the 10 megohm resistor. The value of the capacitor is such that it holds its charge for a time at least equal to the length of the maximum spacing signal in the start-stop machine telegraph code. The flow of detector grid current through the 10 megohm resistor also affects the grid bias voltage of the detector valve slightly, but the change from its normal value is not sufficient to appreciably move its operating point, hence the effect on the signals delivered is negligible. When the attenuation of the line circuit decreases, the input level to the amplifier-detector increases, the detector grid current increases, and the grid bias of the amplifier valve is further increased so that the gain is reduced accordingly. When the attenuation of the circuit increases, the grid current through the 10 megohm resistor is reduced and the capacitor discharges slightly, so that the grid bias is reduced and the gain of the amplifier is increased. By this means a constant output is obtained from the detector valve over a wide working range.

/ If

If this feature were not provided, any variations in the overall attenuation of the circuit would cause variations in the current operating the receiving relay to mark. This would cause the relay response to be biased and manual adjustment of the bias current would be necessary to restore the circuit to its normal condition. However, the automatic gain control network maintains the relay operating current constant over the range of line variations likely to be encountered under most normal working conditions, and eliminates the necessity of manual attention apart from the initial line-up of the channel.

The 1 µF capacitor connected to earth from the anode of V2 acts in conjunction with the inductance of the receiving relay winding as a low-pass filter which removes the A.C. components from the detected current. The A.C. components could cause the relay to vibrate against the marking contact especially on the lower frequency channels.

10.5 Fig. 20 shows an alternative type of amplifier-detector. The main points of interest are the use of silicon carbide varistors in the automatic gain control circuit and the Carpenter 3H10 relay.



ANOTHER TYPICAL AMPLIFIER-DETECTOR FOR TELEGRAPH CARRIER SYSTEM.

FIG. 20.

The silicon carbide varistor is a component with non-linear conductivity, that is, its resistance depends on the voltage applied to it. With a low voltage its resistance is high, but with a high voltage its resistance is low. In this respect, it is somewhat similar to the metal rectifier. Unlike the rectifier, however, its resistance is independent of the applied polarity.

Valve V1 is an amplifier with constant gain, unlike the corresponding component in Fig. 19. Valve V2 is a detector whose grid is given a negative bias of suitable value via the potentiometer P1.

On incoming marking signals A.C. components of the detected current are applied, through the transformer in the anode circuit of V2, across one pair of the diagonals of the varistor network, and this causes the resistance between the other pair of

/ diagonals

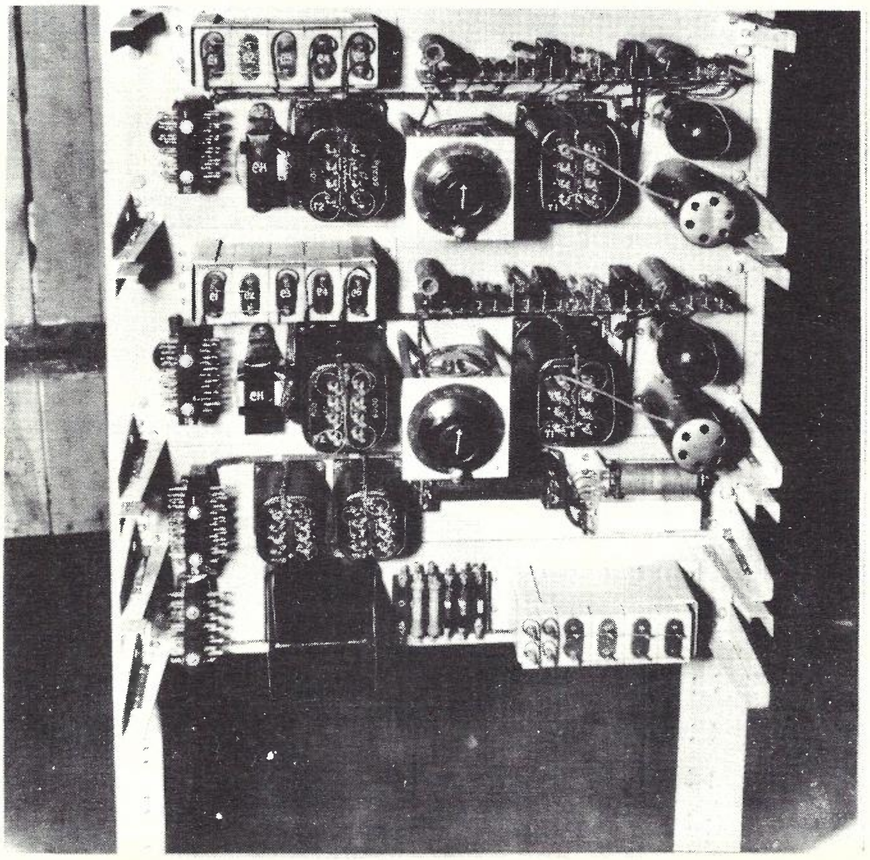
diagonals to fall to a relatively low value. Positive peaks of the incoming signal are greater than the negative bias via P1, and cause grid current to flow via R1. The negative bias on the grid of V2 is increased, thus limiting the anode current. The potential of the capacitor C1 quickly becomes equal to that across R1 via the low resistance varistor network.

When the signal level increases the grid current increases, increasing the negative grid bias, so that the anode current is limited to a constant value.

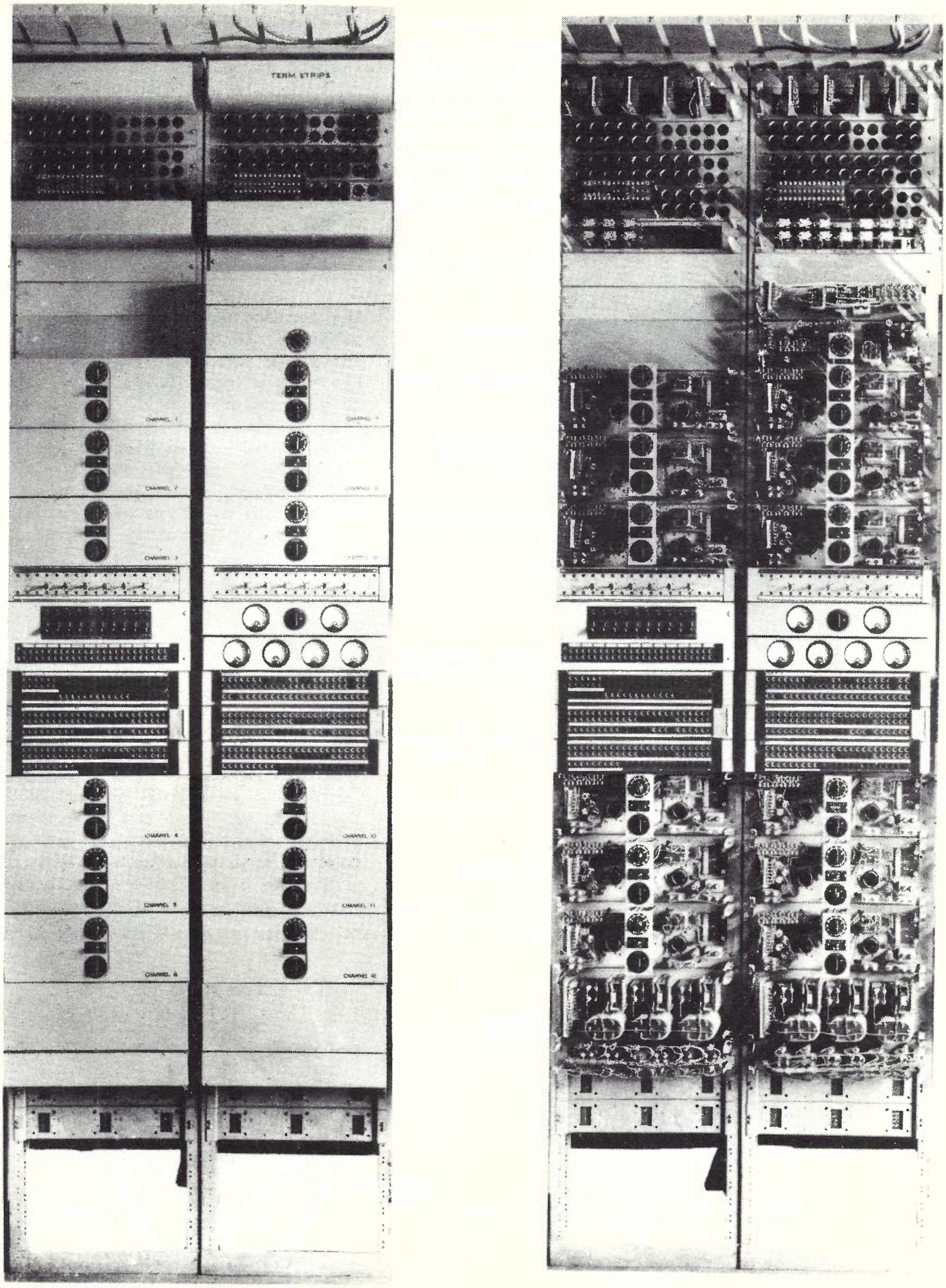
When the signal level decreases, the capacitor discharges quickly its excess potential and takes up the new potential across R1 which is at a lower value, in order to maintain the anode current constant.

During a spacing signal there is practically no potential applied to the varistor network, and its resistance becomes high and prevents the discharge of C1 so that V2 remains biased to the correct value for distortionless reception of the next marking signal. The resistor R2 maintains a permanent connection between the grid and cathode of the valve, irrespective of the condition of the automatic gain control network. Its value is sufficiently high to prevent any appreciable discharge of C1 during spacing signals.

The 0.3 µF capacitor acts as a low-pass filter, in conjunction with the inductance of the receiving relay winding, to prevent the A.C. components of the detected current causing the receiving relay to vibrate against the marking contact. The 470 ohm resistor connected across the 220 ohm winding of the receiving relay reduces the induced voltage caused by the relay armature movement, and this results in more reliable relay operation.



TYPICAL AMPLIFIER-DETECTOR PANELS.



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AMPLIFIER-DETECTOR PANELS ON V.F. TELEGRAPH TERMINAL.

11. RECEIVE RELAYS.

11.1 The function of the receive relay is to convert the variation of D.C. produced in the anode circuit of the amplifier-detector by the incoming carrier telegraph signals to corresponding double-current marking or spacing telegraph signals of the required voltage with a minimum of distortion. The double-current signals are then applied to the receiving telegraph equipment. The line winding of the relay is connected to the amplifier-detector output. On receipt of a marking signal, the detector anode current in the line winding operates the relay against the force produced by current in the bias winding, which normally holds the relay tongue on the spacing contact. Two main types of polarised telegraph relays are used for this purpose - the W.E. type 209FA and the Carpenter type 3H10.

11.2 Type 209FA. This relay is enclosed in a dustproof cover and is provided with plug-in terminals so that it can be removed from the relay panel.

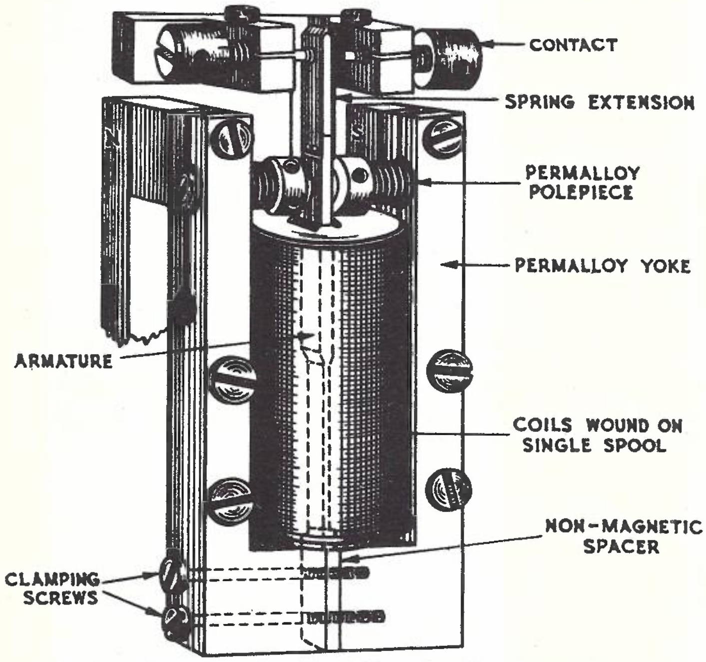
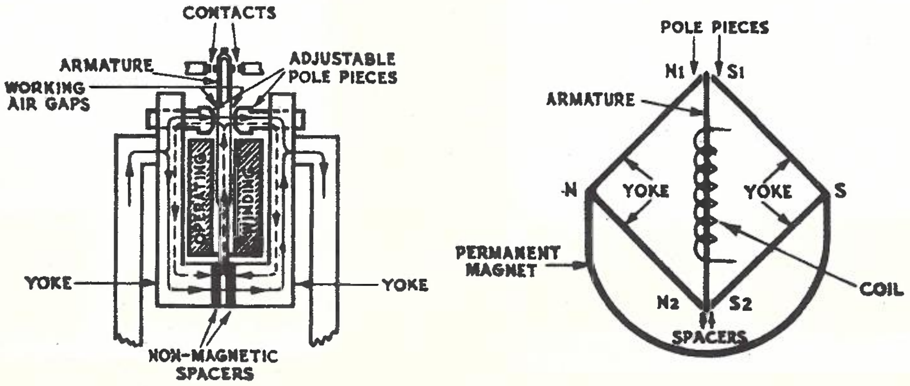


FIG. 21. WESTERN ELECTRIC POLARISED RELAY.

The general construction of this polarised relay is shown in Fig. 21. The yoke, armature and pole pieces are made of permalloy. (Permalloy is a nickel-iron alloy with a very low coercivity and a high permeability.) The yoke is in two pieces; these are clamped together over the end of the armature, the magnetic circuit between the armature and the pole pieces being broken by two spacers of non-magnetic material. The movement of the armature is due to the flexing of its lower end. The contacts are mounted on two springs which are riveted to the end of the armature. The ends of the springs are bent to touch each other with a definite pressure. When the armature strikes one of the contacts, its energy is partly dissipated by the friction between the two springs, thus tending to eliminate contact bounce. The relay is polarised by a permanent magnet, the poles of which are in contact with the yoke at the point where the pole pieces pass through it. The coils are wound on a bobbin which is slipped over the armature, but does not touch it. Fig. 22a shows the magnetic circuit and Fig. 22b the circuit of the W.E. relay in a diagrammatic form.



(a) Relay Elements. (b) Diagrammatic Magnetic Circuit.

FIG. 22. W.E. POLARISED TELEGRAPH RELAY.

It will be seen that it is the magnetic equivalent of the Wheatstone Bridge. The permanent magnet produces two poles in each half of the yoke, namely, at the pole pieces and at the spacers. When the armature is midway, the force, due to the permanent magnet, is nil since flux does not pass through it longitudinally. When, however, the armature moves towards, say, N1, the reluctance of the air-gap between the pole and armature on this side is decreased, while that on the other side is increased.

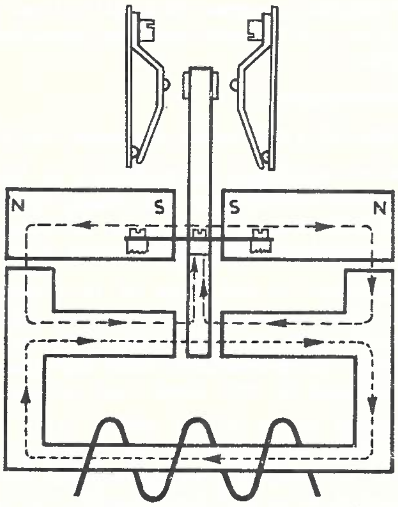
The flux now tends to flow from N1 through the armature to S2 and causes the armature to be attracted to N.1. Similarly, when the armature moves slightly towards S1, it is attracted to this pole. The relay coil magnetises the armature, the flux dividing at the lower end and returning via the poles. When the flux in the armature produces a north pole at the top end of the armature, it is repelled by N1 and attracted by S1, so that the armature extension makes contact with the spacing contact. Similarly, when the flux produces a south pole at the top, the armature is repelled by S1, and attracted by N1, so that the extension makes contact with the marking contact.

11.3 Carpenter Relay 3H10. This relay is a lightly side stable relay, that is, the armature hinge exerts a restoring mechanical force on the armature but this force is insufficient to make the relay centre stable. The effect of this is to make the relay very sensitive. It is capable of operating at speeds up to 100 c/s and is equipped with four windings. General features of the relay are shown on page 35, and described below.

(i) Magnetic Circuit. It is seen from Fig. 23 that the fluxes of two permanent magnets unite in the armature and flow through it longitudinally. The electro-magnetic circuit is reduced to a simple form, having only a single air-gap in which the armature is situated. Thus, the longitudinal reluctance of the armature is in circuit only with the permanent magnets, and the signal winding has only to overcome the lower transverse reluctance.

The core carrying the electro-magnet winding connects points on the structure which are at the same mean magnetic potential; therefore, when the armature is central, the core is not traversed by the polarising flux. Hence the cross-section of this core is only large enough to carry the electro-magnetic flux so that the diameter of the signal winding can be kept small and the resistance of this winding correspondingly reduced.

Those portions of the iron circuit which are traversed both by the polarising flux and the signal flux can be made of ample cross-section so that their reluctance can be kept negligible.



MAGNETIC CIRCUIT CARPENTER RELAY.

FIG. 23.

The reluctance of the upper pair of air-gaps between the inner poles of the magnets has to be overcome only by those magnets, hence these air-gaps can be made wide and only the lower or working-gaps need to be kept small.

(ii) Contact Mounting. Contact chatter is eliminated by the use of damped compliant mountings for the side contacts. When compliance is used for this purpose, damping must also be introduced, or the armature will continue to vibrate for an appreciable period of time after the closure of the contacts, and such vibration can cause considerable irregularity in the accuracy of repetition of pulses of short duration. Thus, should a reversal of current in the operating winding occur when the armature is moving towards its central position, the response to such a reversal would be much more rapid than that which would occur should the reversal coincide with the instant at which the armature is still moving outwards away from the central position.

/ In

In order, therefore, to introduce the correct degree of damping, each side contact is mounted on a bowed spring, one end of which is fixed and the other arranged to slide on a mounting. The pressure between the spring and the friction screw is so adjusted that the armature is brought to rest as quickly as possible after the closure of the contacts. The damping, however, is deliberately made slightly less than critical in order to avoid the danger of introducing mechanical hysteresis.

Apart from the question of accuracy of pulse repetition, the rapid damping of the armature enables the relay to work at high speeds and to prevent contact bounce. The compliance of the contact mounting is so chosen in relation to the moment of the armature as to make the frequency of oscillation high as well as heavily damped, and the armature is brought substantially to rest in about 2 milliseconds.

A further advantage of using quite separate compliant mountings, for one of each pair of co-operating contacts, is that the transit time can be made very short, whilst still obtaining adequate opening of the contacts. This follows from the fact that the free travel of the armature between break and make can be made quite short, but after the free travel is completed the armature will, under the influence of the operating forces and its own momentum, continue to move forward. This provides additional separation between the opening contacts, ensures a clean break, and ruptures the microscopic metallic bridges which often form current-carrying contacts at the moment of separation.

(iii) Contact Adjustment is effected by knurled screws with divisions corresponding approximately to contact movement of 0.001 inch and the adjustment is locked by screws acting through fibre pads.

(iv) Contacts are made of 60:40 palladium-copper.

(v) The Armature is hinged at its centre of gravity on springs, no pivots being used.

(vi) The number of turns and resistance of windings is recorded on the bobbin label. The bobbin tags on which windings are terminated are shown by the numbers outside the brackets, odd numbers indicating inner ends of windings. Numbers inside the brackets identify corresponding plug and socket tags.

(vii) Bias Adjustment. The coarse adjustment of the bias of the relay for neutrality is obtained by the setting of the side contacts. For fine adjustment a movable bar magnet is provided which gives a smooth and precise adjustment of bias. The bias adjusting magnet is accessible when the cover is in position so that any slight bias introduced by the cover can be corrected.

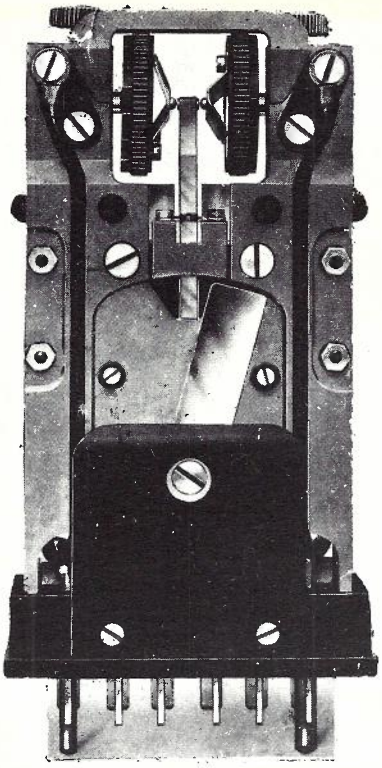
(viii) Magnetic Screen Cover. The screening cover of the relay is of magnetic material so that relays may be mounted adjacent to one another on the same panel. A spring clip arrangement is used for retaining the relay and cover in position when the relay is mounted on a vertical panel, or is liable to be subjected to such vibration as may tend to dislodge it from its socket.

11.4 Receive Relay Adjustment. Readjustment of the relay is necessary at times owing to the variations of the original adjustments by vibration due to constant operation and also from wear and pitting of contacts.

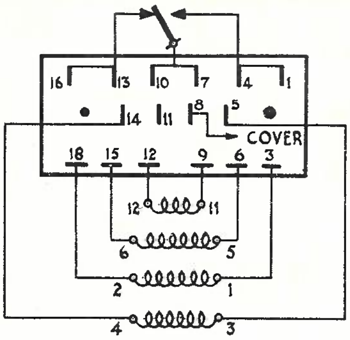
The adjustments made while the relay is in service are to the bias control on the channel. This is a potentiometer which regulates the current flowing through the bias winding of the relay. The adjustment to the bias is made by sending reversals at the correct speed from the sending terminal and adjusting the bias control until the meter in the telegraph receive loop reads zero. No mechanical alteration should be made to the relay whilst in service.

With the relay removed from the terminal and placed on a relay test table, the relay and armature contacts should be cleaned, burnished, and checked for the correct adjustment by means of the facilities provided by a relay test circuit. (See paragraph 13.4.)

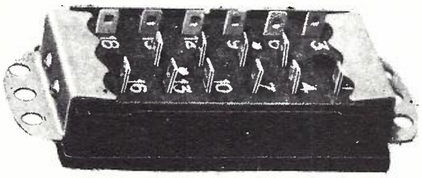
/ General



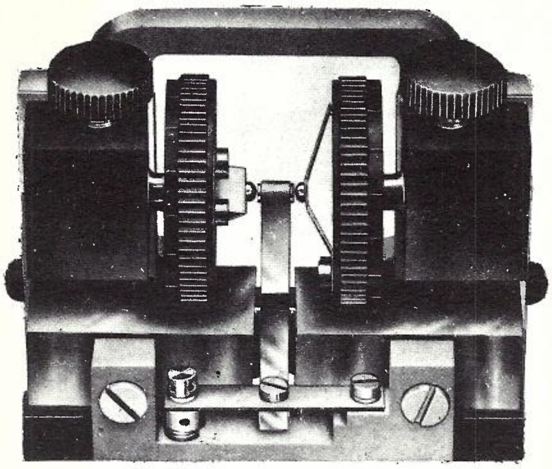
The movable bar magnet provided for the fine adjustment of bias is shown swung nearly full right.



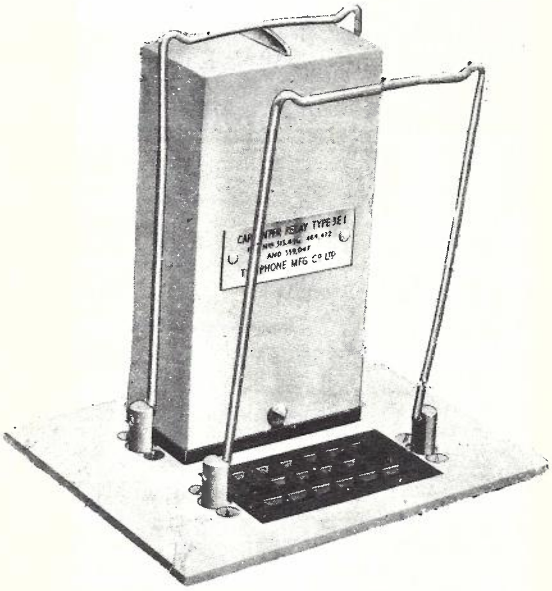
Winding and Terminal Connections.



View of wiring side of standard socket showing the numbering of the tags.

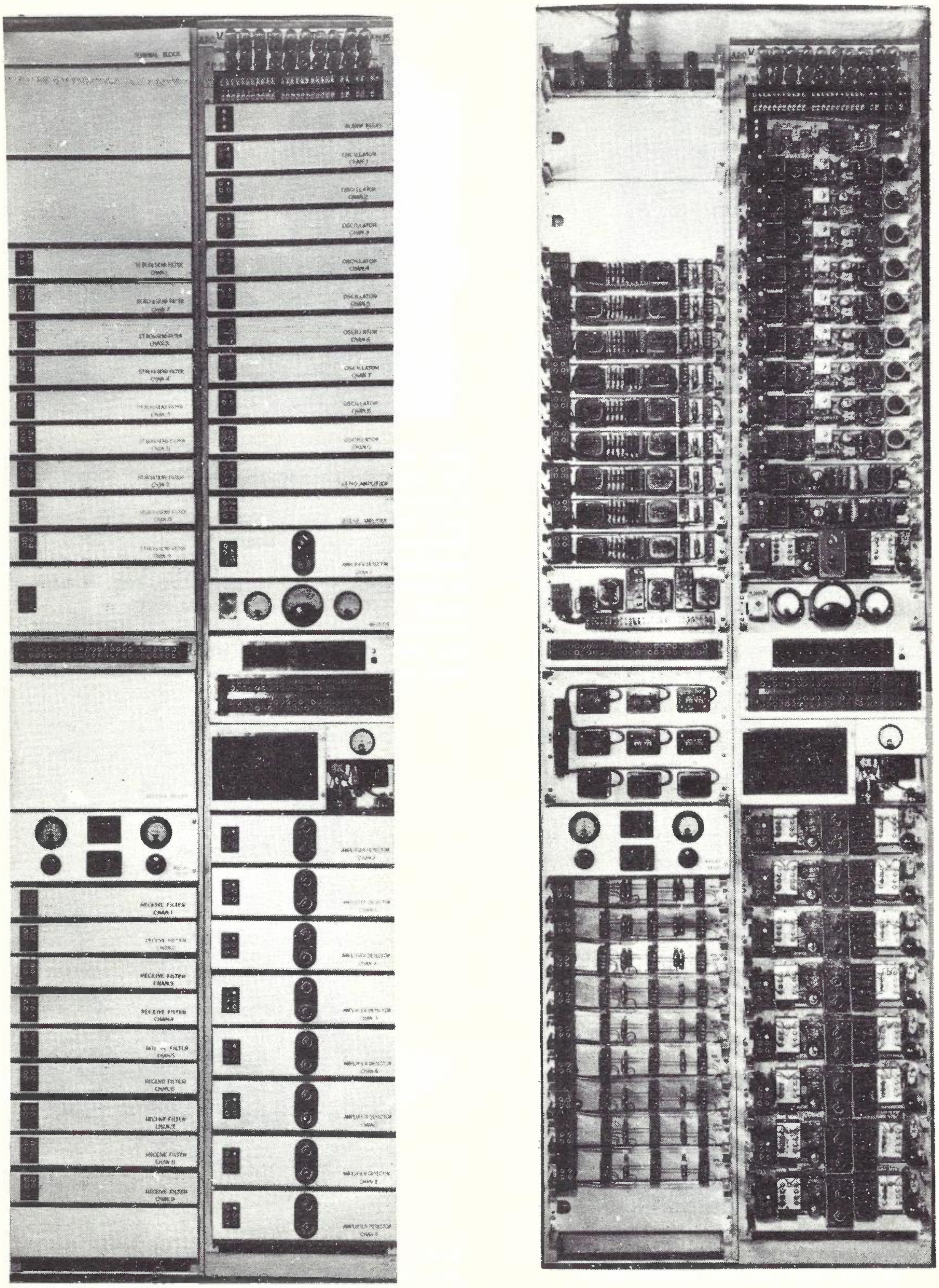


Note the springs carrying the side contacts. The tip of the damping screw, on which the right-hand side contact spring rubs, can just be seen projecting through the knurled contact adjusting head. The stiffer armature hinge spring necessary to give high sensitivity in the type 3H relays is also shown. The capstan-headed screws clamping the left end of this spring are for the purpose of eliminating mechanical bias and are locked during manufacture.



Relay mounted in socket, with cover in position, and the retaining clip used when the relay is installed on vertical panels, or subjected to severe vibration.

GENERAL FEATURES OF CARPENTER RELAY 3H10.



Rear View. Front View.

Covers On.

Rear View. Front View.

Covers Off.

9-CHANNEL V.F. CARRIER TELEGRAPH TERMINAL (A.P.O. TYPE).

12. SEND AND RECEIVE TELEGRAPH LOOPS.

12.1 The D.C. telegraph signals, transmitted from the telegraph equipment to the carrier equipment, and received by the telegraph equipment from the carrier equipment, have been standardised in the Department as double-current signals. Signals of negative polarity are sent for the marking signal, and of positive polarity for the spacing signal.

12.2 The marking and spacing currents in both send and receive loops are adjusted to 25 mA for the following reasons -

(i) To provide ample margin for the adjustment of current required for various types of static modulators.
(ii) To permit the direct operation of polarised telegraph receiving instruments in the receive carrier loop.
(iii) To permit the easy detection of bias in received reversals during the lining-up of the channel by observing the signals on the commonly used 50-0-50 milliammeter.

The current is limited at the terminal which receives the signals. The limiting resistor in the send telegraph loop is located in the static modulator at the carrier telegraph terminal. The limiting resistor in the receive telegraph loop is located at the telegraph receiving equipment.

12.3 It is usual to use one wire of a cable pair for each leg of the circuit from the telegraph equipment to the carrier equipment, and to earth the mate wire at both ends. This acts as a screen to reduce cross-fire between the various circuits in the cable.

Cross-fire is the interference which occurs between telegraph circuits (at the instant of current change in one circuit) because of the coupling which exists between them. It results in a current surge which either momentarily aids or opposes the current in the circuit suffering the interference, depending upon the polarity of the current already flowing in that circuit and the direction of the current change. Cross-fire corresponds to crosstalk between telephone circuits.

13. TEST EQUIPMENT.

13.1 The operating margins on carrier telegraph channels are more critical than on carrier telephone speech channels, and it is essential that the testing facilities provide a ready means of checking the performance of the various channels, and the adjustment of the carrier receive relays.

The transmission of intelligence over each channel involves a collection of signals of marking and spacing conditions accurately timed, one to the other. When this time relationship is upset, distortion is said to exist. When the circuit condition or instrument adjustment causes the time relationship between the two conditions to be upset consistently and by a uniform amount in the one direction, Bias Distortion is said to exist. When the marking signals are lengthened and the spacing signals shortened, the bias is said to be marking. When the spacing signals are lengthened and the marking signals are shortened, the bias is spacing. Means are provided for transmitting reversals for lining-up the channel to be free of bias distortion. This is achieved by adjusting the receive relay spacing bias current. Telegraph reversals are continuous double-current signals of equal mark and space time duration.

It is possible to send permanent marking and permanent spacing signals on any or all channels simultaneously for interchannel interference tests, and also to test each channel by an exchange of Morse signals from the terminals. On some systems, it is possible to transmit signals approximating various start-stop machine signals and measure the distortion introduced by transmission over the system on either a time-current bridge type of distortion measuring set or a stroboscopic display type of equipment.

13.2 On a typical A.P.O. type telegraph system (see page 36), the following test panels are provided. (Wiring schematic diagrams of these panels are shown on pages 8 and 9.)

(i) Observation and Monitoring Panel.
(ii) Relay Test Panel.
(iii) Meter Panel.

/ 13.3

13.3 Observation and Monitoring Panel. Observation facilities are provided to enable the carrier attendant to observe the signals passing on either the send or receive telegraph loop, when any channel is extended to the telegraph office or a channel of another system. The observation circuit does not interrupt the message passing over the channel. A 2-position make-before-break key is connected in each send and receive loop and, in either the Observe Send or Observe Receive position, connects a 50-0-50 milliammeter and monitoring relay in series in the loop. A polarised sounder is connected to the tongue of the monitoring relay so that both audible and visual observation of the signals is possible.

Monitoring facilities are provided to allow communication with the distant terminal. A 2-position key is connected in each send and receive loop and in the Monitor position connects a double-current key to the respective channel static modulator and a polarised sounder to the tongue of the channel carrier receive relay, thus permitting communication between terminals. The other position of the monitoring key is used to transmit on any channel double-current reversals to the distant terminal for lining-up purposes.

A third 2-position key connected in each send and receive loop transmits a continuous mark or a continuous space signal to the distant terminal. This is used during line-up of a system and is also of assistance in fault attention.

The key wiring is arranged so that the send loop from the telegraph office is looped back to its corresponding receive loop in the Monitor, Send Revs, Send Mark and Send Space positions. This feature enables the telegraph testing officer to determine whether the keys have been restored on completion of tests.

13.4 Relay Test Panel. This panel enables testing and adjustment of the carrier receive relays. Spare relays are provided at each terminal, but it is necessary to attend to the relays at regular intervals to ensure the satisfactory operation of the system. The relay test set provides for accurate contact adjustment, measurement of transit time and a check of the neutrality of the relay.

(i) Contact Adjustment. This test ensures that the armature of the relay makes reliable contact on the mark and space contact screws.

(ii) Transit Time. The purpose of this test is to determine the percentage time of one complete cycle during which the armature is travelling from one contact to the other, and a circuit is arranged so that a meter deflection, proportional to the time that the contacts are open, is obtained. The transit time from contact to contact is half the meter reading and, if outside the limits laid down, the relay must be readjusted.

(iii) Neutrality. To ensure that the marking and spacing signals are of equal length, the relay armature must rest on the two contacts for equal periods of time. A circuit is arranged so that a meter reads centre scale when reversals are applied to the relay winding. Any bias in the mark or space direction is indicated by the deflection of the meter to left or right, and must be corrected by readjustment of the relay.

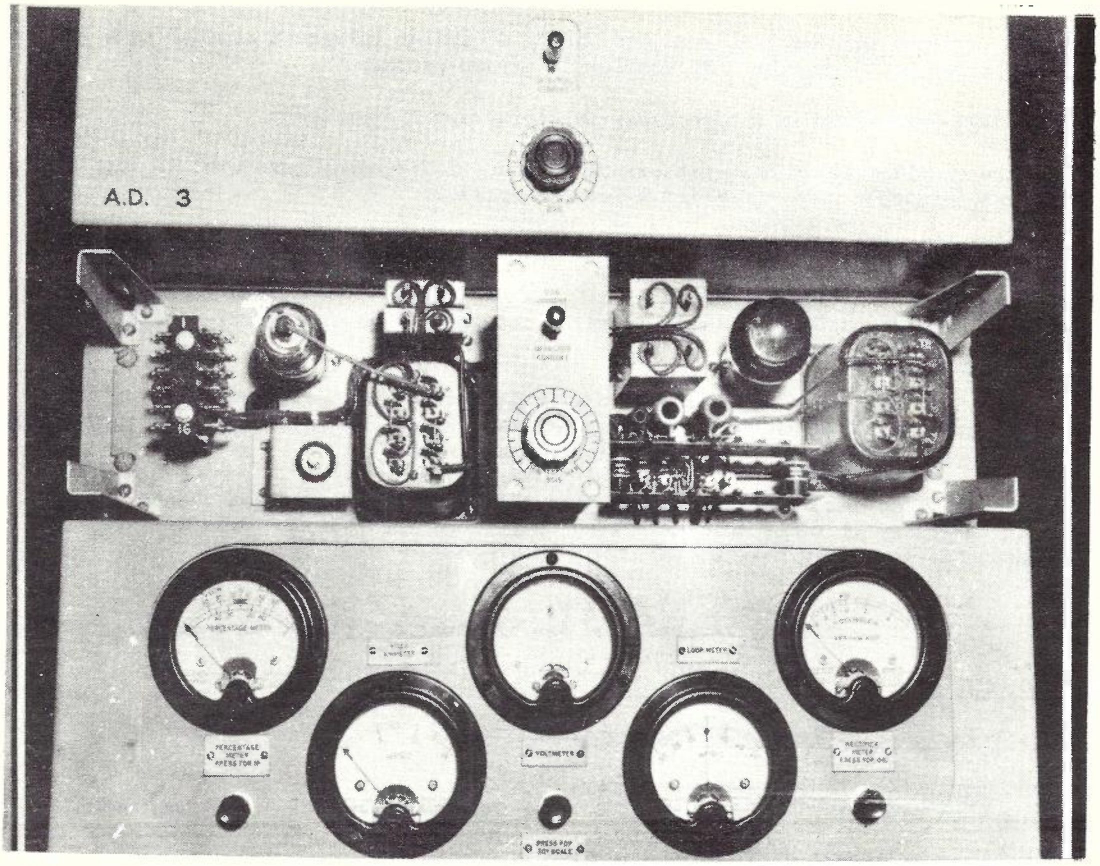
13.5 Meter Panel. The following meters are provided on this panel. (See page 36).

(i) An 0-15 mA meter to measure the detected current and the bias current in the windings of the carrier receive relays associated with each amplifier-detector. Operation of a non-locking key in the channel concerned to either "Det. Curr." or "Bias Curr." connects the meter in circuit. The channels keys are located on the main jack and key field.

(ii) An 0-1 mA meter calibrated as a percentage meter for checking anode and filament currents. The meter resistance is built out to 1,000 ohms and the shunt resistors in the anode and filament circuits are so adjusted that when the normal filament current flows through the shunt, a current of 0.5 mA flows through the meter. Mid-scale on the meter is marked 0 to correspond with the 0.5 mA meter current representing normal conditions. Any deviation from the mid-position is read as a high or low percentage.

/(iii)

(iii) A combined 0-50 and 0-150 voltmeter enables measurement of the 24 volt filament and 130 volt anode supplies, and the positive and negative 120 volt telegraph battery supplies. The connections to this meter are made via keys on the main jack and key field.



AMPLIFIER-DETECTOR AND METER PANELS ON TYPICAL CARRIER TELEGRAPH SYSTEM.
(RACK LAYOUT SHOWN ON PAGE 2.)

14. BAUD.

14.1 Reference has been made in this Paper to the baud which is the unit of telegraphic speed used in the Department. The telegraphic speed in bauds expresses the number of shortest elements of signals which may occur in one second. Thus, for a speed of 1 baud, the shortest element of signal is 1 second.

Expressed generally,

$$\text{Speed in bauds} = \frac{1000}{\text{duration (in milliseconds) of the shortest signal element.}}$$

When a period of 20 milliseconds is required to transmit the shortest signal element, the speed is said to be $\frac{1000}{20} = 50$ bauds.

When reversals are sent over a telegraph channel for testing purposes, the speed of transmission (in bauds) may be divided by two to give a result equal to the frequency of the current on the line. The most commonly used speed is 50 bauds, that is, 25 c/s or 20 milliseconds impulses of each polarity.

/ 15.

15. TEST QUESTIONS.

1. Describe the basic operation of a V.F. Carrier Telegraph System using simplified block schematic diagrams.

2. Show by a block schematic diagram the use of a carrier telephone channel as a bearer circuit for an 18-channel V.F. carrier telegraph system.

3. Under what conditions is a type R carrier telegraph system used?

4. When are oscillators used in preference to a multi-frequency generator to supply carrier frequencies to a carrier telegraph system?

5. What is the advantage in making all frequencies of a carrier telegraph system multiples of a fundamental frequency?

6. Describe the operation of a typical static modulator used in a carrier telegraph system.

7. In a V.F. carrier telegraph channel, why is it necessary to control, within fairly close limits, the received carrier signal level at the input to the detector? Describe the operation of a circuit which achieves this feature.

8. What is the function of a receive relay in a V.F. carrier telegraph channel? Why is it necessary at times to make a readjustment of the relay? Briefly list the adjustments you would make -

    (i) while the relay is in service,
    (ii) with the relay removed from the terminal and placed on a relay test table.

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Volume 5, No. 3, "Developments in Carrier Telegraph Transmission in Australia - Part 3", by J.L. Skerrett and S.T. Webster.

END OF PAPER.

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COURSE OF TECHNICAL INSTRUCTION.

LONG LINE EQUIPMENT II.

PAPER NO. 8.

RADIO PROGRAMME TRANSMISSION OVER TRUNK LINES.

CONTENTS:

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1. INTRODUCTION.

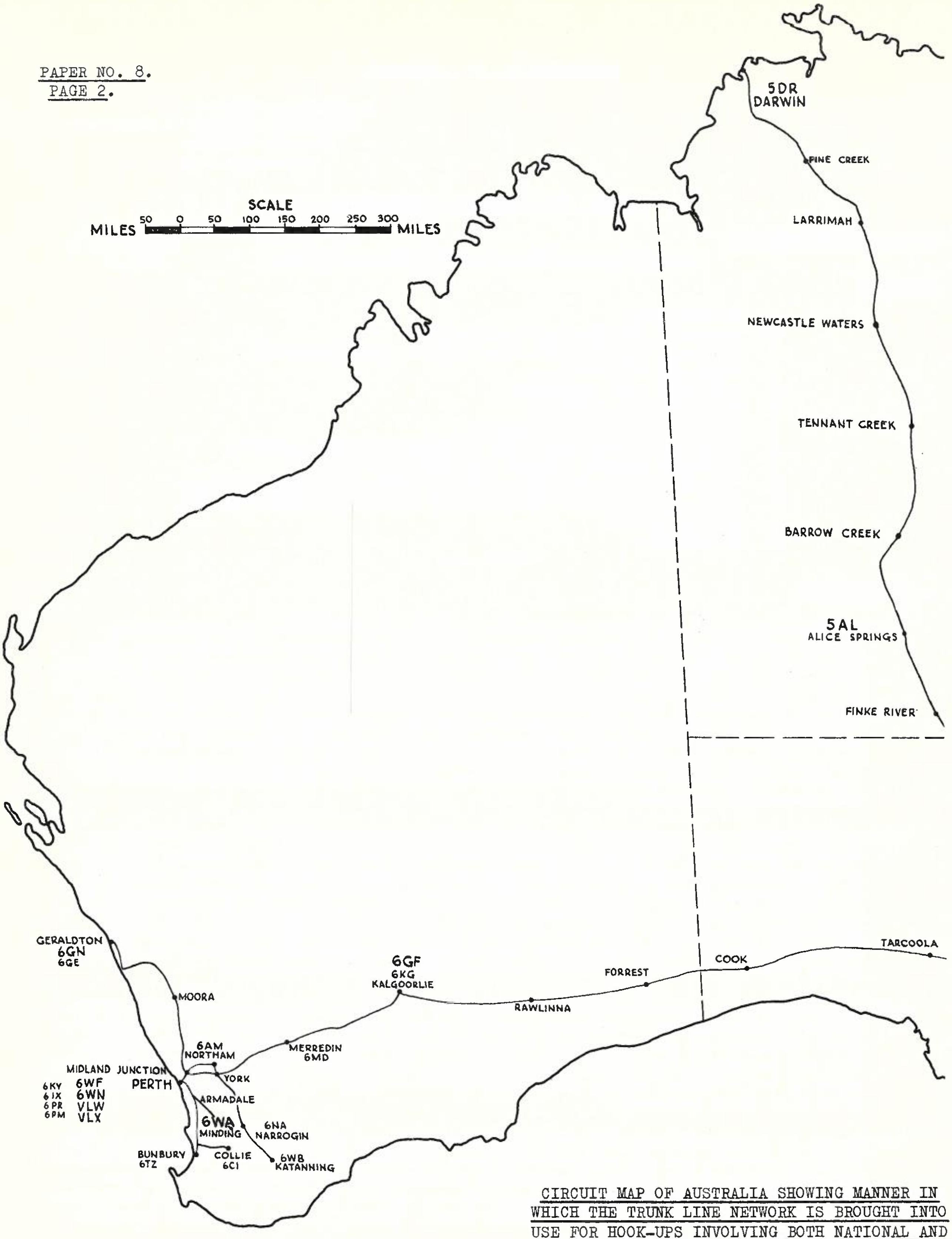
1.1 An important use of the trunk line network is the interconnection of broadcasting studios and stations for the transmission of radio programmes. In this field, the Department provides service for the Australian National Broadcasting Stations and also caters for over 100 Commercial Radio Stations. These stations are linked regularly in various combinations to form the many Commonwealth-wide networks for the relaying of programmes. To meet the needs of the broadcasting companies for relay facilities, an extensive network of programme channels has been provided throughout the country by the Department. Programme channels are provided for special relays and, in addition, a number of permanent programme circuits are provided for the National Stations and some Commercial Stations.

1.2 The development and maintenance of an adequate broadcasting service in a country as large as Australia, in which a comparatively small population is so widely scattered, is almost entirely dependent on the trunk line telephone network and the ability of the Engineering Branch to provide facilities for the linking together of studios and broadcasting stations. The efficient use of the trunk line system for the relaying of programmes from pick-up points to studios, and the interconnection of studios and radio stations for the simultaneous transmission of programmes, provides the listening public with an almost unrestricted selection of broadcast programmes.

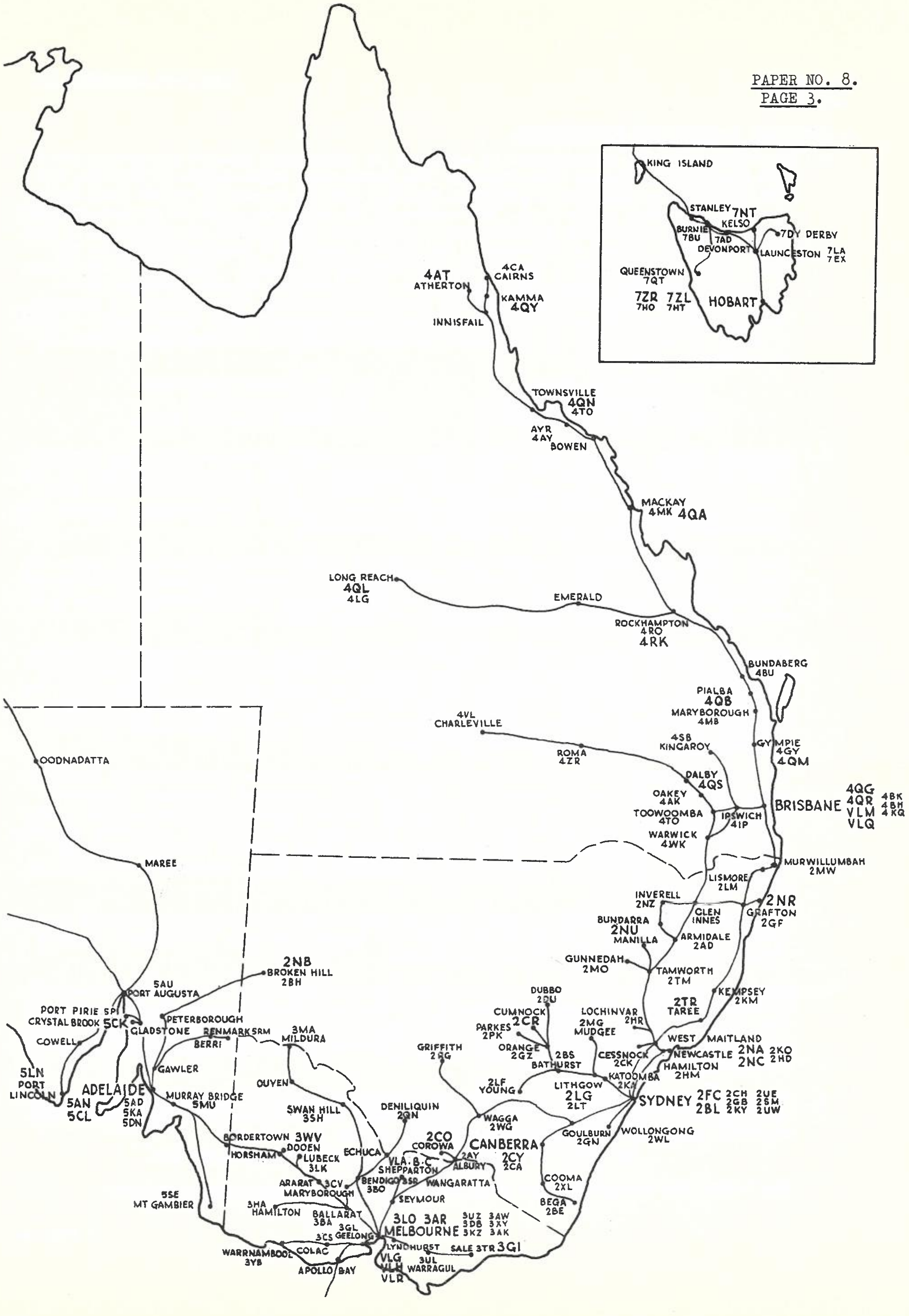
1.3 The installation, maintenance and setting up of facilities for programme relays of the diverse types required in practice requires a high grade of skill, so that the performance standards can be satisfied. Owing to the necessity for freedom from interruption and the demand for a high quality service, the set-up of these channels is in the hands of the technical staff, and is carried out usually at trunk test panels associated with trunk exchanges.

1.4 The use of intrastate and interstate programme channels is controlled primarily by the Telephone Branch, and all applications, when approved, are covered by Telephone Orders. The allocation of the intrastate channels is determined by the Superintending Engineer's Branch in the State concerned. In the case of interstate channels, the allocations are determined by the Engineering Branch, Central Office, to ensure co-ordination of the work.

1.5 Both physical and carrier telephone channels are used for programme transmission. The transmission requirements of these programme circuits and details of the equipment used in their provision are described in this Paper.



CIRCUIT MAP OF AUSTRALIA SHOWING MANNER IN WHICH THE TRUNK LINE NETWORK IS BROUGHT INTO USE FOR HOOK-UPS INVOLVING BOTH NATIONAL AND COMMERCIAL BROADCASTING STATIONS.


KING ISLAND
STANLEY 7NT
KELSO
BURNIE 7BU
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HOBART
4AT ATHERTON
4CA CAIRNS
KAMMA 4QY
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MACKAY 4MK 4QA
LONG REACH 4QL 4LG
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MARYBOROUGH 4MB
4VL CHARLEVILLE
ROMA 4ZR
4SB KINGAROY
GYMPIE 4GY 4QM
DALBY 4QS
OAKEY 4AK
TOOWOOMBA 4TO
IPSWICH 4IP
BRISBANE 4QG 4QR VLM VLQ 4BK 4BH 4KQ
WARWICK 4WK
MURWILLUMBAH 2MW
LISMORE 2LM
INVERELL 2NZ
GLEN INNES
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BUNDARRA 2NU
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ARMIDALE 2AD
GUNNEDAH 2MO
TAMWORTH 2TM
KEMPSEY 2KM
2TR TAREE
DUBBO 2DU
CUMNOCK 2CR
PARKES 2PK
LOCHINVAR 2HR
2MG MUDGEE
WEST MAITLAND
ORANGE 2GZ
2BS BATHURST
CESSNOCK 2CK
NEWCASTLE 2NA 2NC 2KO 2HD
HAMILTON 2HM
GRIFFITH 2RG
2LF YOUNG
LITHGOW 2LG 2LT
KATOOMBA 2KA
SYDNEY 2FC 2BL 2CH 2GB 2KY 2UE 2SM 2UW
DENILIQUIN 2QN
WAGGA 2WG
GOULBURN 2GN
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2NB BROKEN HILL 2BH
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RENMARK 5RM
BERRI
3MA MILDURA
5LN PORT LINCOLN
GAWLER
OUYEN
ADELAIDE 5AN 5CL 5AD 5KA 5DN
MURRAY BRIDGE 5MU
SWAN HILL 3SH
BORDERTOWN 3WV
DOOEN
HORSHAM
LUBECK 3LK
ECHUCA
VLA. B. C.
SHEPPARTON
ARARAT 3CV
MARYBOROUGH
BENDIGO 3BO
3SR
WANGARATTA
SEYMOUR
5SE MT GAMBIER
3HA HAMILTON
BALLARAT 3BA
3GL GEELONG
3CS
3LO 3AR MELBOURNE 3UZ 3DB 3KZ 3AW 3XY 3AK
LYNDHURST
SALE 3TR 3GI
WARRNAMBOOL 3YB
COLAC
APOLLO BAY
VLG VLH VLR
3UL WARRAGUL

2. PROGRAMME TRANSMISSION REQUIREMENTS.

2.1 The ideal programme transmission is one which is transmitted without distortion and is not degraded by external interference. The fundamental requirements of circuits for the satisfactory handling of programme material are not greatly different from those for good telephone connections. The nature of the programme material is such, however, that a higher standard of transmission is essential. Generally, the object is to provide a channel so that a listener at the far end receives a programme which is the same as that received by a listener in the originating studio. This is more difficult to achieve than the fundamental necessities of an ordinary telephone channel where good volume and intelligibility are the prime factors, with "naturalness" of reproduction an important but nevertheless secondary consideration. With these points in mind, a number of factors must be considered to enable a satisfactory programme channel to be obtained. These are -

(i) Frequency Range.
(ii) Frequency Response.
(iii) Frequency Distortion.
(iv) Non-linear Distortion.
(v) Delay Distortion.
(vi) Volume Range and Noise.

2.2 Frequency Range. The average normal human ear can detect sounds in the range approximately 30-15,000 c/s which fall within the boundaries of the curve shown in Fig. 1, and the ideal circuit for programme transmission should be capable of transmitting this range. This is not an economical proposition under present circumstances, however, and in practice the upper limit is considerably restricted.

Fig. 2 shows the frequency range required for the realistic transmission of speech and music. From Fig. 2, it is seen that little is lost by cutting off frequencies outside the limits of, say, 35-10,000 c/s. This is the frequency range transmitted over permanent physical programme lines operating over cable pairs.

When the upper limit is further restricted to 7 or 8 kc/s, certain sounds of a percussion nature, the jingling of keys, etc., may not be accurately reproduced, but it is unlikely that a listener, without direct comparison, would detect any difference. The upper frequency limit can be reduced from 15 to about 7.5 kc/s, therefore, without seriously affecting the programme. A further reduction of the upper limit to 5 kc/s produces about the same noticeable difference.

In early programme carrier systems for use on open wire lines, the programme frequency range transmitted over the channel is 35-7,500 c/s. Programme equipment associated with 3-channel and wide-band carrier telephone systems uses varying band-widths ranging in upper limit from about 5.6-10 kc/s. At present, the physical programme channels used for music transmission over open-wire aerial lines transmit a frequency range 35-5,000 c/s to permit the operation of a 3-channel telephone carrier system over the same pair of wires.

When the programme includes speech only, the upper limit may be further reduced to about 3 kc/s, and a frequency range of 200-2,800 c/s transmitted over the circuit. Such a channel is unsuitable for music transmission.

2.3 Frequency Response. All frequencies in the required range must be transmitted over the programme channel with equal efficiency, so that the balance between instruments and the relative levels of the components of a chord or sequence of notes remains unchanged at the receiving terminal, that is, the attenuation of the channel must be substantially independent of frequency.

The attenuation-frequency characteristic (frequency response) is measured by sending constant level tone into the channel and changing the frequency in steps to cover the required range. The frequencies usually chosen are -

35, 50, 100, 1,000, 3,000, 5,000, 7,000, and 7,500 c/s.

The latter two frequencies are used in the case of programme carrier systems.

/ Fig. 1.

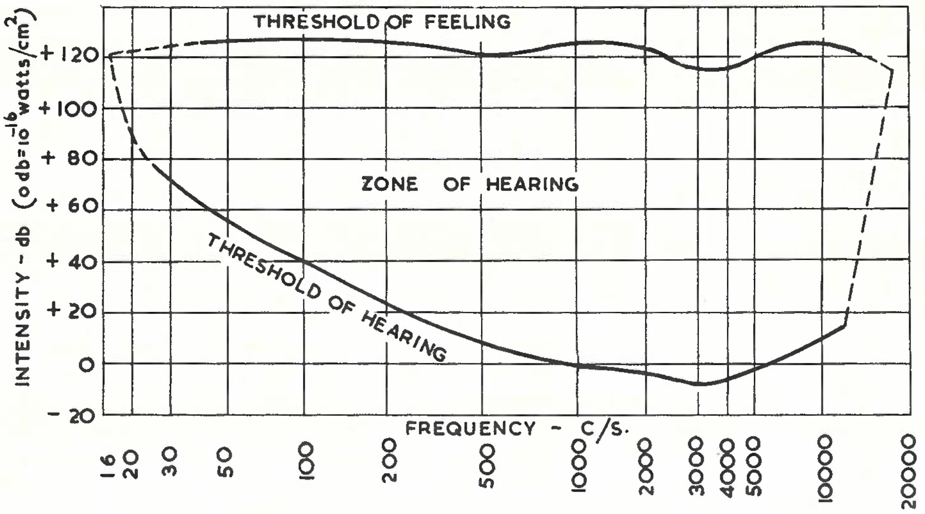


FIG. 1. LIMITS OF AUDIBILITY.

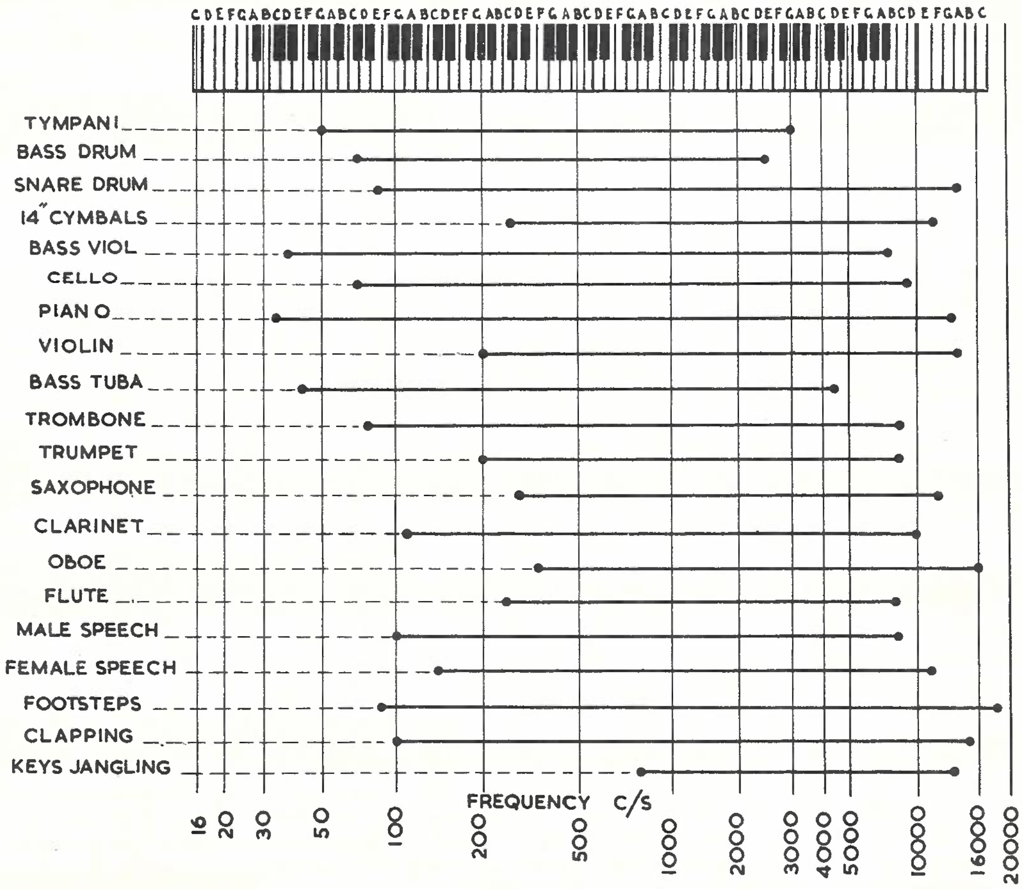


FIG. 2. FREQUENCY RANGE FOR SPEECH AND MUSIC.

The received level is measured at the far end. The variation in this received level must be as little as possible within the limits of the frequency band transmitted and must not vary by more than ±1 db from the level at 1 kc/s.

2.4 Frequency Distortion. When the frequency response curve of a circuit is not flat as specified, some frequencies are received at higher levels than others. Due to the complex character of sound waves, any variation in the frequency response of a programme circuit alters the character of the programme material during transmission. This effect is known as frequency distortion. Most programme circuits exhibit this effect to a greater or lesser degree.

It is the aim, in practice, to limit this variation to ±1 db of the value at 1 kc/s within the limits of the frequency band transmitted. It is generally possible to design equipment in which the frequency distortion is negligible. However, the programme line itself introduces a considerable amount of frequency distortion, which is reduced to suitable limits by the provision of equalisers at the receiving terminals and at intermediate stations.

2.5 Non-linear Distortion. To ensure that the complex programme wave form remains unchanged during transmission, the channel must not generate extraneous frequencies. When the application of a signal to the channel input produces an output signal which contains frequencies additional to those present at the input, non-linear distortion exists.

Non-linear distortion is caused by overloaded amplifiers, transformers, inductors, etc., and causes two undesirable effects -

(i) Harmonics of the various frequencies present in the transmission are produced.

(ii) Intermodulation occurs between the different frequencies being transmitted, thus producing new frequencies, which are not necessarily harmonically related to the original frequencies.

As described in Long Line Equipment I, when a pure single frequency tone (sine wave) is applied to the input of a thermionic valve amplifier and the valve operates over the straight part of the negative portion of the dynamic characteristic curve, the harmonic distortion is low. When, however, the valve operates over the non-linear part, the percentage of harmonics rises rapidly. When two pure tones are applied simultaneously to the input there may be produced, as well as harmonics of each, intermodulation tones having frequencies equal to the sum and difference of the two fundamentals. Further, more complex tones are often produced, made up from sums or differences of various multiples of the two fundamentals. Other components such as transformers and inductors, similarly cause distortion when overloaded. Of the two effects the tones resulting from intermodulation products are more annoying that the production of harmonic frequencies, which, although they may alter slightly the character of a sound, are not unpleasant to the ear.

In operating programme equipment, therefore, care must be taken to ensure that the programme level, particularly during loud passages, is kept well below the overload point of the equipment in the transmission circuit.

Another effect of overloading is to reduce the gain of the amplifier, and hence the ratio between soft and loud passages of programme is not maintained. This provides a ready means of checking the performance of a channel or amplifier by graphing the input level versus output level over a range of increasing inputs. Within the limits of operation, this graph should be a straight line.

Since the intermodulation products are caused by the same trouble as the harmonics (that is, non-linear input-output characteristic of the channel), it is usual in specifying equipment and making distortion measurements, to deal with harmonics of a single sine wave input frequency. The distortion is expressed as a percentage ratio of the R.M.S. values of the harmonics to the R.M.S. value of the fundamental.

Programme line amplifiers are designed so that the total harmonic distortion does not exceed 4 per cent. when the amplifier is delivering its rated output (see paragraph 2.11).

/ 2.6

2.6 Delay Distortion. The velocity of propagation of an electromagnetic wave through most trunk circuits and equipment varies with frequency. Consequently, during the transmission of programme material some frequencies are delayed more than others, and this delay, when sufficiently long, is noticeable in the reproduced sound. The deterioration in quality caused by the differing transmission times of various frequencies is known as delay distortion. Generally, the transmission time over a circuit is greater at the upper and lower limits of the transmission band than at the mid-band frequencies.

Delay distortion is noticeable when the delay at 100 c/s is more than 20 milliseconds greater than that at 1 kc/s, and when the transmission time at 10 kc/s (or at the highest frequency transmitted over the circuit) is more than 8 milliseconds greater than that at 1 kc/s.

Delay distortion in programme equipment is generally controlled during manufacture by careful attention to the design of filters, amplifiers and other circuit elements. In cases where it is impossible to reduce the delay distortion of circuits and equipment to reasonable values in the design stage, it is reduced in service by the insertion of delay equalisers at appropriate points in the circuits. Delay equalisers are provided in the carrier programme equipment used with 12-channel carrier telephone systems (see Section 11).

2.7 Volume Range and Noise. To ensure exact reproduction of a musical programme, it is desirable to handle a wide range of volumes. The volume or dynamic range is the difference between the maximum and minimum power levels to be transmitted. It is expressed in db.

Reference to Fig. 1 shows that the ear can detect sounds which differ in intensity over a range of about 100 db. The range of sound from a symphony orchestra, however, is about 70 db and the range of sound intensities from most other programme material is much less than this. For example, the dynamic range of most musical programmes is about 40-50 db and for speech, about 15 db.

The maximum programme level transmitted is limited -

(i) by the power handling capacities of the amplifiers in the circuit, and

(ii) because too high a power level causes crosstalk into neighbouring circuits.

In practice, the programme level is adjusted on average peaks to a reference level of 6 mW, that is, +8 dbm. This allows for occasional peak levels of about 10 db above this without overloading amplifiers (see paragraph 2.11).

The minimum programme level depends on the circuit noise level. As the volume range of a circuit is determined largely by the circuit noise, these two factors are considered together.

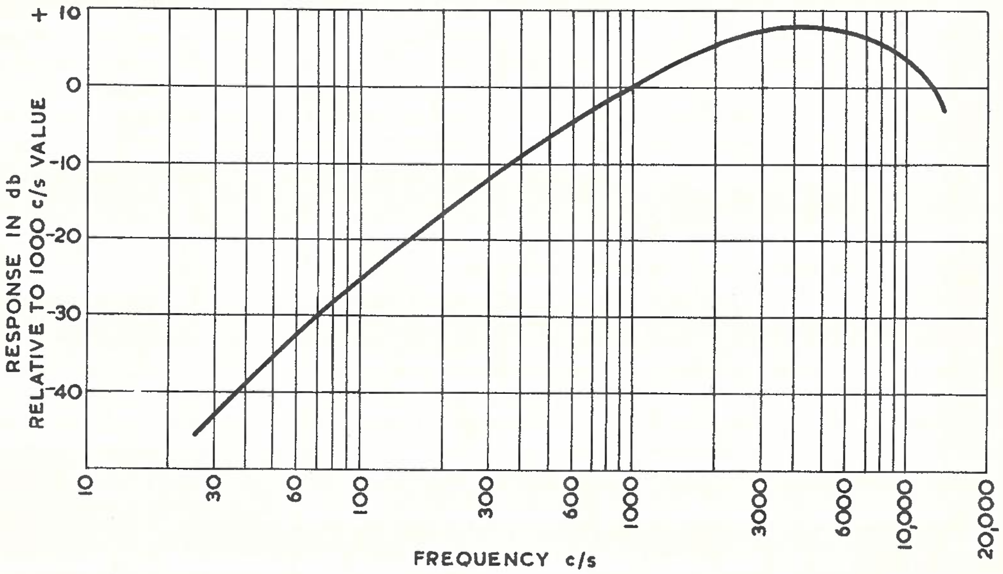
The weighted noise level (see paragraph 2.8) on programme circuits must not exceed -50 dbm measured at a point of zero reference level (6 mW or +8 dbm). This is equivalent to a signal-to-noise ratio of 58 db. To maintain a reasonable signal-to-noise margin during low programme level conditions, it is necessary to restrict the minimum programme level transmitted to a value 10 db above the weighted noise level. For a noise level of -50 dbm, therefore, the minimum programme level transmitted must not be less than -40 dbm. The volume range of the circuit in this case is from +8 dbm to -40 dbm, that is, 48 db. Any reduction in noise level below -50 dbm correspondingly increases the volume range of the circuit.

By adopting 6 mW as a reference level instead of 1 mW, a wider dynamic range is obtained by keeping the majority of the programme matter an extra 8 db above the noise level.

/ 2.8

2.8 Weighting Network. The human ear is not equally sensitive to all frequencies in the programme range, being particularly sensitive to frequencies of the order of 2-4 kc/s. Even though the power levels read on a level indicator are similar, a noise frequency within this range is more objectionable to the ear than a noise frequency of, say, 50 c/s. Thus a direct measurement of the actual noise voltage or level on a measuring instrument is not entirely satisfactory as a means of determining the interference level as it affects the ear.

To compensate for this effect, noise measurements are made with a "weighting" network connected before the measuring instrument. This is a reactive network having approximately the same response characteristic as the human ear. A curve giving the response characteristic of a network used for programme transmission channels is shown in Fig. 3.



RESPONSE CURVE OF WEIGHTING NETWORK.

FIG. 3.

The attenuation of the network is higher at the less objectionable frequencies than for frequencies to which the ear is more sensitive. Thus, the level indicator reads lower for the less objectionable frequencies and gives a better indication of the interference caused. The weighted value of noise so measured is an indication of the amount of noise heard by the listener and it is this value which is taken into consideration when measuring the noise level of a programme circuit.

2.9 Compandors. It is apparent from paragraph 2.7 that it is necessary at times to compress certain programme material which normally has a volume range of 70 db. Obviously, this is undesirable as the delicate shades of tone in say, a symphony orchestra performance, are lost. A satisfactory arrangement, and one which is likely to be used to a large extent in the future, is the installation of compandors on all major programme circuits.

Compandor is the name applied to a system comprising two complementary pieces of apparatus, the compressor and the expander. The purpose of its use is to increase the signal-to-noise ratio in the transmission medium, and thus enable a greater volume range to be transmitted on the programme circuit. This is achieved by compressing the volume range to the transmitting terminal and expanding it again at the receiving terminal.

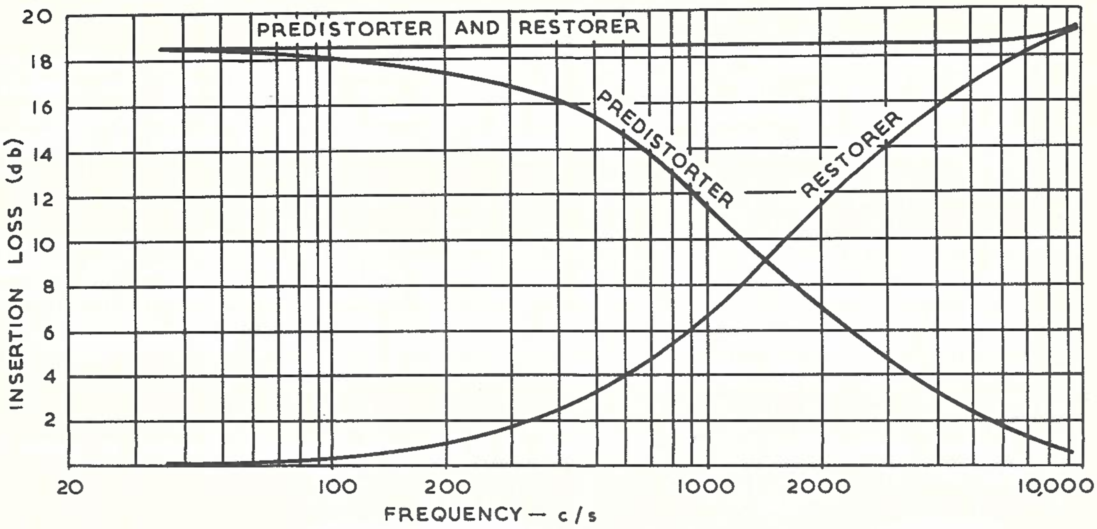
A compandor is used with any type of programme circuit, either carrier or physical.

/ Through

Through the use of compandors, an improvement in the signal-to-noise (including crosstalk) ratio of up to 25 db is readily obtained. This improvement allows compandors to be used on programme circuits to obtain one of two results -

(i) they may be used on existing circuits which are otherwise unsatisfactory for programme working because of high noise or crosstalk levels existing, or
(ii) they may be used on existing circuits to enable a greater volume range to be transmitted, thus permitting the effective transmission of higher class programme material.

2.10 Pre-distorter and Restorer. The power contained in speech and music is present mainly at frequencies from about 100-1,000 c/s. The energy from noise is distributed uniformly throughout the frequency spectrum. This means that the signal-to-noise ratio is poorer at low and high frequencies than it is at mid-band frequencies.



PRE-DISTORTER AND RESTORER CHARACTERISTICS.

FIG. 4.

The pre-distorter and restorer are included in the programme terminals to increase the signal-to-noise ratio at the higher frequencies. The pre-distorter network in the send equipment has a greater insertion loss at lower frequencies than at higher frequencies. The higher frequencies are therefore transmitted to line at a level higher than they would be normally. A restorer network in the receive equipment has an inverse characteristic to the pre-distorter. This restores the levels of the various frequencies to their original relationship. These operations are shown by the curves in Fig. 4. A pre-distorter and restorer are provided in the carrier programme equipment used with 12-channel carrier telephone systems (see Section 11).

2.11 Rated Output of Amplifiers. Although, on average peaks, the programme amplifier supplies a power of 6 mW to line, it must be capable of supplying, without serious distortion, powers greater than this to allow for occasional peaks of programme material which exceed the average peak voltage. The maximum peaks may be up to 10 db greater than 6 mW. In addition, a certain margin must be allowed above the maximum peak level for aging of amplifier valves and components. For these reasons, programme line amplifiers are designed to supply a power level of 120 mW without serious distortion. This is known as the Rated Output or Power Capability of the amplifier. When delivering its rated output, the total harmonic distortion of the amplifier must not exceed 4 per cent.

In some amplifiers, a 3 db pad is connected between the amplifier output and the programme line (see paragraph 4.5). In this case the rated output is increased to 240 mW.

/ 3.

3. PROGRAMME TRANSMISSION OVER PHYSICAL TRUNK CIRCUITS.

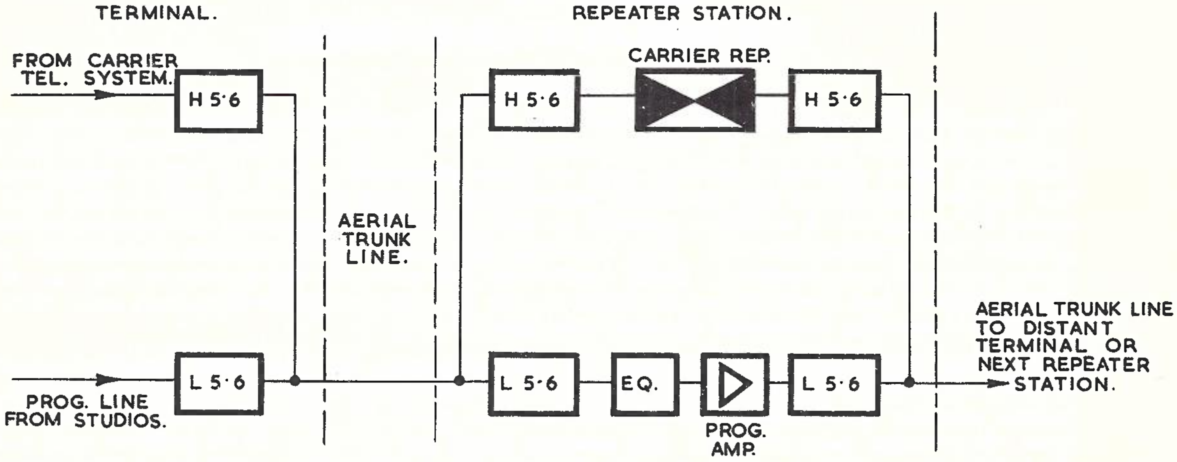
3.1 Although programme circuits over 3-channel and wide-band carrier systems are now coming into prominence, the physical programme circuit will still be the major long distance programme link for many years.

The physical trunk circuits used for programme relay purposes are mainly open-wire pairs, with some underground cable circuits and combinations of both. Some circuits are used permanently for programme, and others are normally used for trunk telephone calls and adapted for programme transmission when necessary.

The programme channels are set up on a unidirectional basis, and this eliminates the danger of singing. The channels are lined-up to zero equivalent and this simplifies the problem of interconnecting a number of programme channels to form a complex network as several channels may be connected in tandem without change in programme level.

3.2 Most programmes are transmitted over a physical trunk line at audio frequencies, allowing carrier telephone systems to be superimposed in the usual manner. The normal trunk line channels used for speech purposes are not suitable, however, for the transmission of the very low and high audio frequencies essential to the provision of high fidelity reproduction of musical programmes. This has led to the development of special circuits and apparatus suitable for such a purpose.

3.3 A typical arrangement for the provision of a physical programme circuit is shown in Fig. 5.



USE OF PHYSICAL CIRCUIT FOR PROGRAMME TRANSMISSION.

FIG. 5.

The use of 5.6 kc/s line filters, instead of normal 3 kc/s line filters, extends the frequency range transmitted over the physical programme circuit without interfering with the operation of the carrier telephone systems. Both 3- and 12-channel systems may be applied to the aerial circuit.

/ On

On any trunk route, due to the attenuation caused by the copper wires, it is necessary to provide an amplifier at about every 120 miles to restore the radio programme level to normal. These amplifiers are known as programme line amplifiers and are provided at repeater stations on the trunk line route. The line amplifier is used for the amplification of the radio programme and separate amplifying equipment is provided for the carrier telephone systems. The line amplifier at the repeater station is uni-directional, but is often made reversible to enable programme transmission in the opposite direction. The reversal is controlled manually by patch cords or keys at each station or remotely by D.C. signals sent over a cailho circuit.

Transmission at audio frequencies has the advantage that it is the cheapest method of providing programme channels, and, in addition, the equipment used is of simple design. The main disadvantage as far as music transmission is concerned is that the highest frequency of transmission on open-wire lines is limited to 5.6 kc/s by the line filters used to separate the carrier and audio-frequency transmission circuits.

4. PROGRAMME SPLITTING.

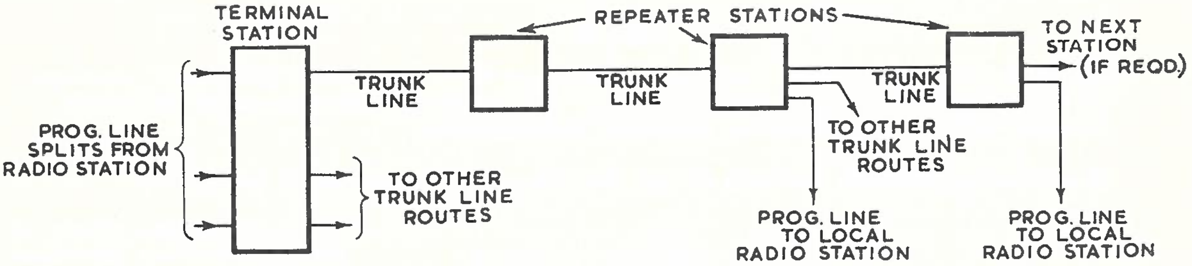
4.1 A network for the specific distribution of a given programme frequently involves the interconnection of distributing points at various stations along a trunk line route. At these points, equipment is provided consisting of equalisers, amplifiers, volume indicators, switching facilities, etc., so arranged that the programme is -

(i) amplified and sent on to the next station,

(ii) split and sent to other routes, or

(iii) branched off to a local station.

Fig. 6 shows these arrangements in block schematic form.



PROGRAMME SPLITTING ARRANGEMENTS.

FIG. 6.

4.2 When a programme is relayed to more than one radio transmitting station, it is often necessary, therefore, to divide one programme feed into two or more outputs at a terminal or intermediate trunk station. These are connected either to local broadcasting stations over short junction lines or to distant broadcasting stations over trunk lines.

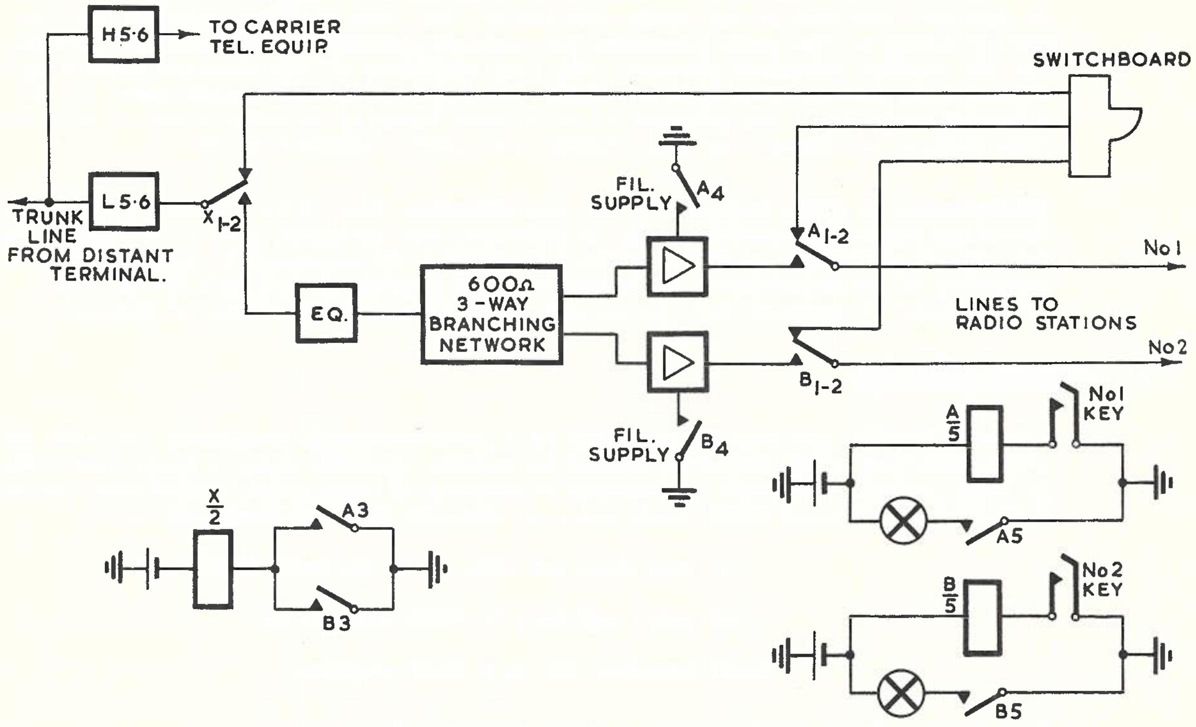
There are two methods in general use to achieve this -

(i) a branching unit, and

(ii) branching or splitting amplifiers.

The method adopted depends on local circumstances and economic considerations./ 4.3

4.3 When only two splits are required, they are often provided by a 3-way branching network as shown in Fig. 7.

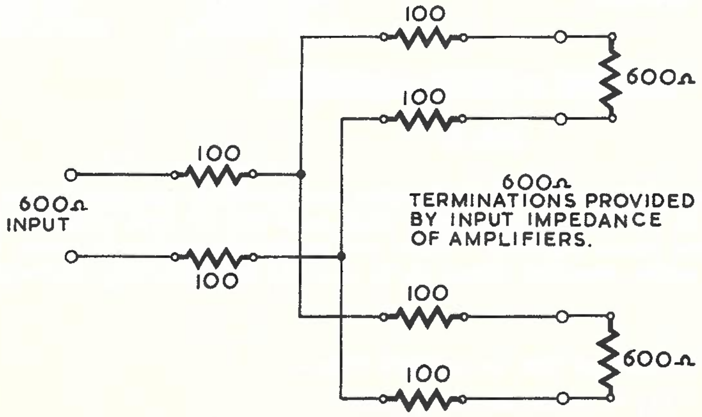


SPLITTING OF PROGRAMME BY 3-WAY BRANCHING NETWORK.

FIG. 7.

Programme from the distant terminal is switched to either one or both radio stations by the operation of the appropriate keys. The lines are used for normal telephone purposes when not required for programme transmission.

The branching network consists of six 100 ohm resistors, as shown in Fig. 8.



These values are chosen to maintain correct impedance conditions when the network is terminated in impedances of 600 ohms. Under these conditions, the input impedance of the network is also 600 ohms and the input circuit is, therefore, correctly terminated. The insertion loss of the network between the input terminals and either output is 6 db. The amplifiers in the output of each split compensate for this loss.

3-WAY BRANCHING NETWORK.

FIG. 8.

/ 4.4

4.4 Branching Unit Installation. When more than two programme splits are required, a branching unit is often provided, as shown in Fig. 9.

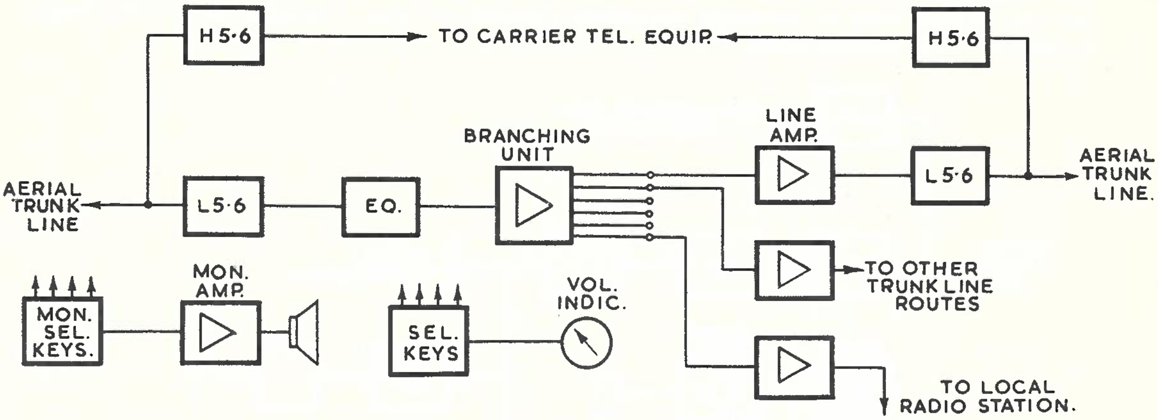


FIG. 9. BRANCHING UNIT AT REPEATER STATION.

The unit operates from a low level, and has six outputs. A line amplifier is patched in each output, as required, to raise the output level to 6 mW, and the programme is then at a satisfactory level to the next repeater station and also to the local broadcasting stations. The equaliser compensates for the frequency distortion of the preceding line section. A monitoring amplifier and volume indicator are wired through appropriate switching keys so that any point in the programme circuit may be monitored as desired. A circuit of a typical branching unit is shown in Fig. 10.

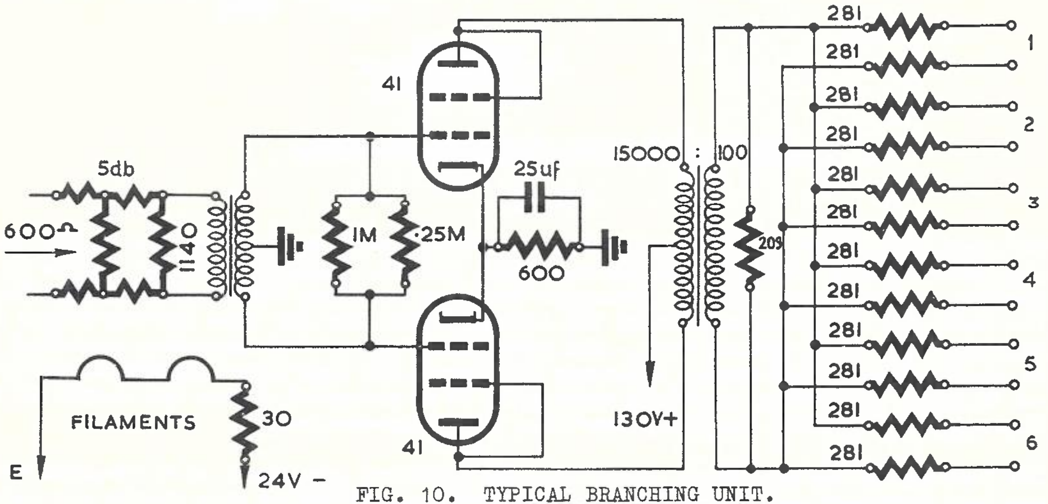


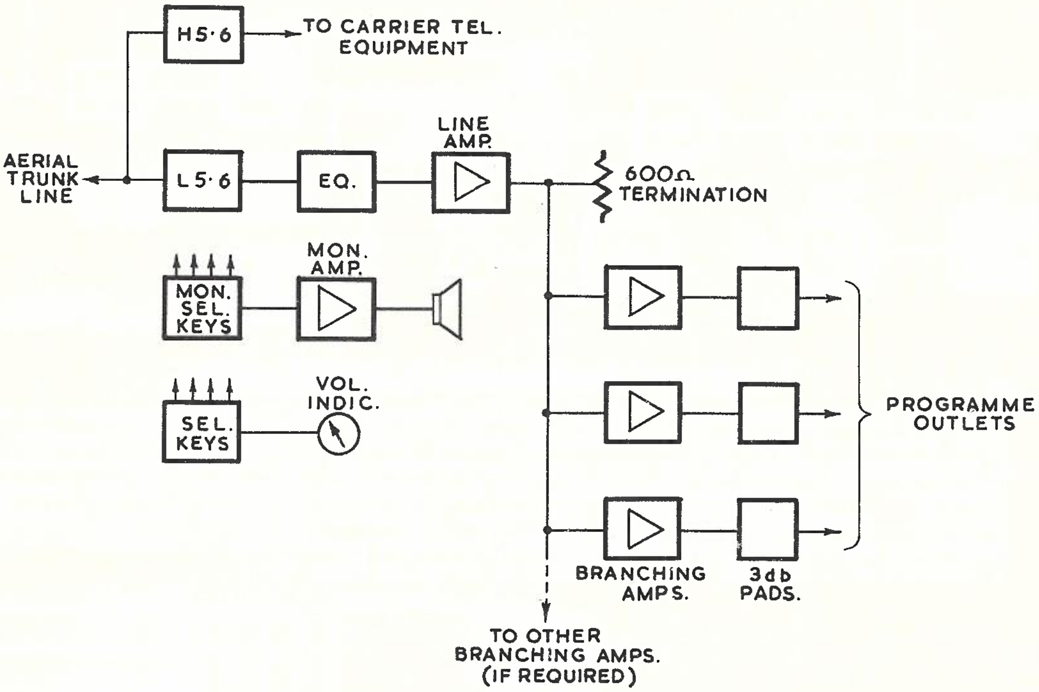
FIG. 10. TYPICAL BRANCHING UNIT.

The unit consists of an input transformer, two valves connected in push-pull, and an output transformer providing six outputs. The input impedance is 600 ohms. The outputs are designed for connection to lines or equipment of 600 ohm impedance. Resistors of 281 ohms in each side of each output reduce the effect of impedance variations in the load attached to any one output upon the transmission through the other outputs. When each output is terminated in 600 ohms, the output circuits and the 209 ohm resistor provide a total impedance of 100 ohms across the secondary of the output transformer. The output transformer has an impedance matching ratio of 15,000 : 100. This gives an exact impedance match when all outputs are in use, and only a slight mismatch when one is in use. Under this condition, the impedance of the output is 177 ohms.

The unit has zero db equivalent between the input and any one of the six outputs and handles a power level of 1 mW without distortion. Each output is connected to line via a line amplifier to give the required level at the output of the branch and to prevent fault conditions in one branch interfering with all other branches in use.

/ 4.5

4.5 Branching Amplifier Installation. Branching amplifiers are used to amplify and supply the programme matter at the correct level to a number of outlets. The programme is derived either from an incoming programme circuit or from a local source. The basic arrangement is shown in Fig. 11.



INSTALLATION USING BRANCHING AMPLIFIERS.

FIG. 11.

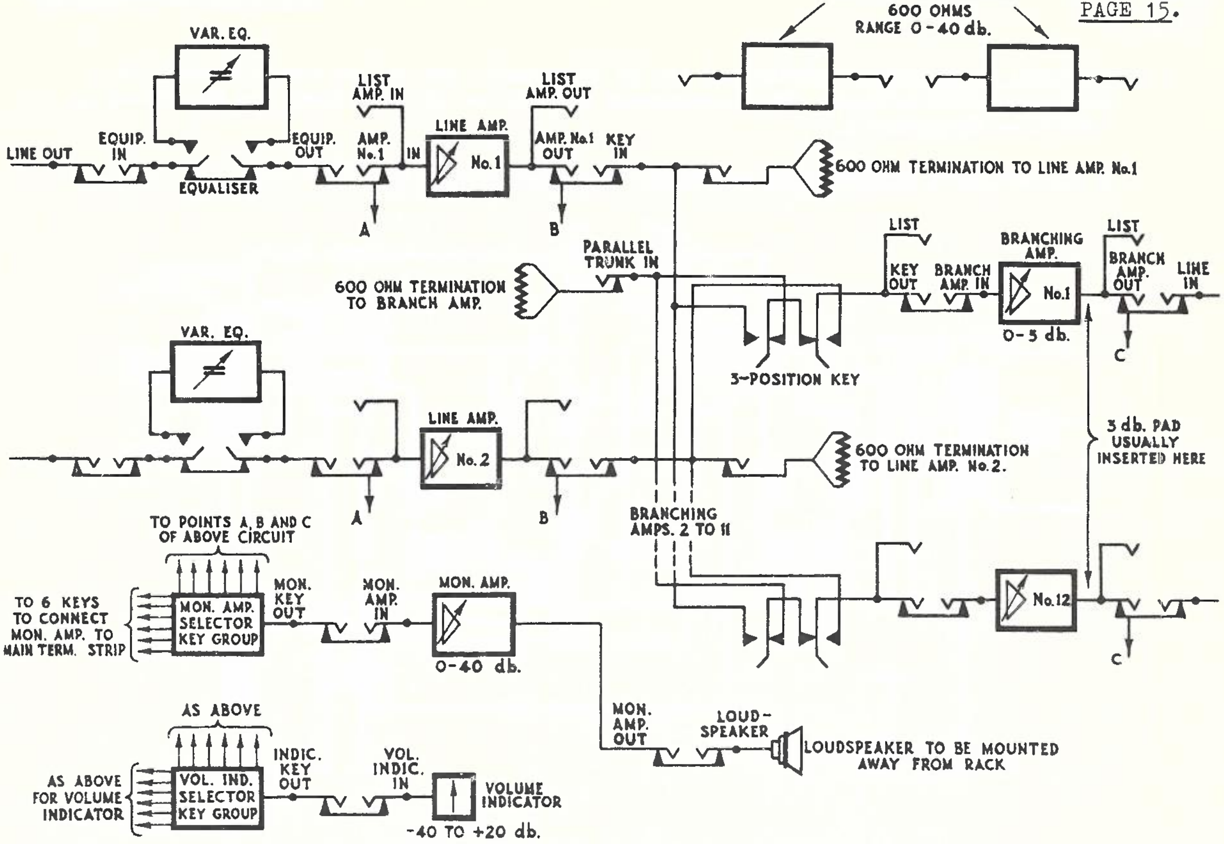
The branching amplifiers are designed to permit a number to be connected across the programme circuit, and thus provide programme from an incoming line to a number of channels. To maintain correct impedance matching under any condition of connection, the input and output impedances of the line amplifier are 600 ohms and the output is terminated in a 600 ohm resistor. The input impedance of each branching amplifier is 10,000 ohms and the output impedance 600 ohms. The high input impedance permits one or more, up to ten, branching amplifiers to be connected across the output of the line amplifier without seriously upsetting the impedance match.

The 3 db pad in the output of each branching amplifier provides a more constant 600 ohm load impedance on the amplifier, and makes its performance more stable and independent of varying line impedances.

A block schematic circuit of a typical terminal installation using branching amplifiers is shown in Fig. 12. It consists of two line amplifiers and equalisers, ten branching amplifiers which provide ten separate outputs, and monitoring facilities.

A 3-position key is associated with each branching amplifier. The first position connects the amplifier to No. 1 line amplifier, the second position to No. 2 line amplifier, and the middle position to a jack terminated parallel trunk, which enables all branching amplifiers to be joined together to a common input and correctly terminated. The facilities enable connection to be made from either or both line amplifiers to any number of branching amplifiers, or from one line amplifier to all branching amplifiers. Two different programmes, therefore, are dealt with simultaneously.

/ Fig. 12.



BLOCK SCHEMATIC OF TYPICAL TERMINAL INSTALLATION USING BRANCHING AMPLIFIERS.

FIG. 12.

A group of keys is associated with the system. These enable the input and output of each line amplifier and also the outputs of the branching amplifiers to be monitored on the loud-speaker and observed on the level indicator.

The branching amplifier installation has the following advantages over a branching unit -

(i) greater number of outputs,

(ii) greater flexibility of connection and switching as the outputs may be connected to the inputs in any combination, and switched instantaneously from one to the other.

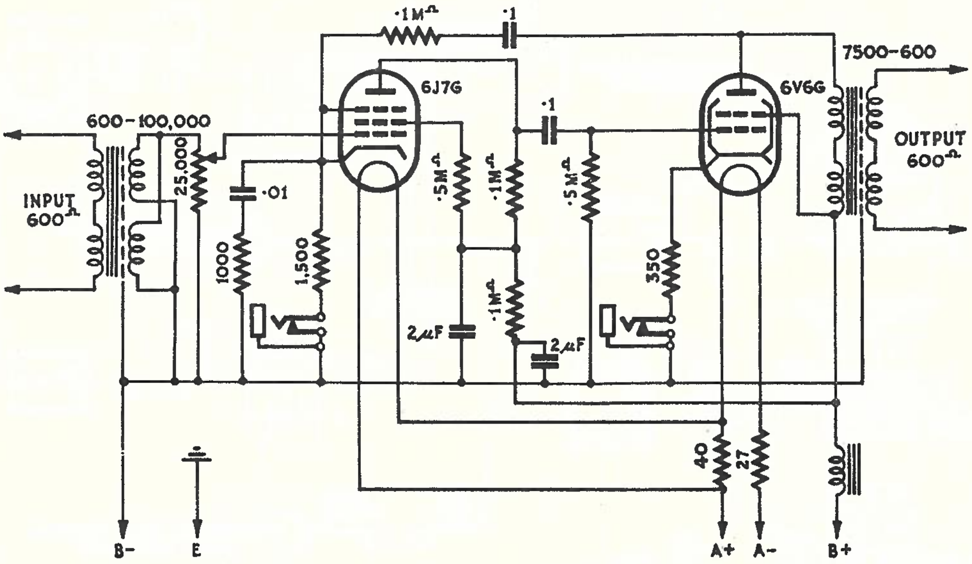
4.6 It is common practice to send a programme direct to a number of country stations which are on different trunk line routes (see Fig. 6). In this case, the sending radio station may split its programme locally and feed programme direct to the Programme Test Room over the required number of lines. These lines terminate on jacks in the test room. The reason for this is purely economical. If only one line were provided from the radio station, splits would have to be provided at the programme room by splitting amplifiers, etc., for which a charge is made. It is cheaper for the station concerned to pay rental on a number of lines, without the necessity for providing amplifiers at the programme room.

It is important that the correct level reaches the point where the patching is made to the trunk lines. Weekly tests are carried out by sending tone through the station splitting amplifiers, thereby enabling the control operator to adjust the gain stops until the correct level of 6 mW reaches the programme room.

/ 4.7

4.7 Programme Amplifiers. Amplifiers are an important item in the establishment of a programme line network. The fundamental principles of amplifiers are described in Long Line Equipment I.

A circuit of a typical line amplifier is shown in Fig. 13.



TYPICAL LINE AMPLIFIER FOR PROGRAMME TRANSMISSION.

FIG. 13.

Typical performance details of line and branching amplifiers are as follows -

(i) Line Amplifier.

(a) The input and output impedances are 600 ohms.

(b) Maximum gain is about 35 db.

(c) A typical response curve is within ±0.5 db (compared with the value at 1 kc/s) over the frequency range 35-10,000 c/s.

(d) The normal sending level to line is 6 mW. This is measured on average peaks. The power capability is 120 mW. This provides a margin for programme peaks and allows for aging of the valves in the amplifier.

(e) The harmonic content is less than 4 per cent. for 120 mW output.

(f) The noise content is 75 db down on 120 mW.

(ii) Branching Amplifier.

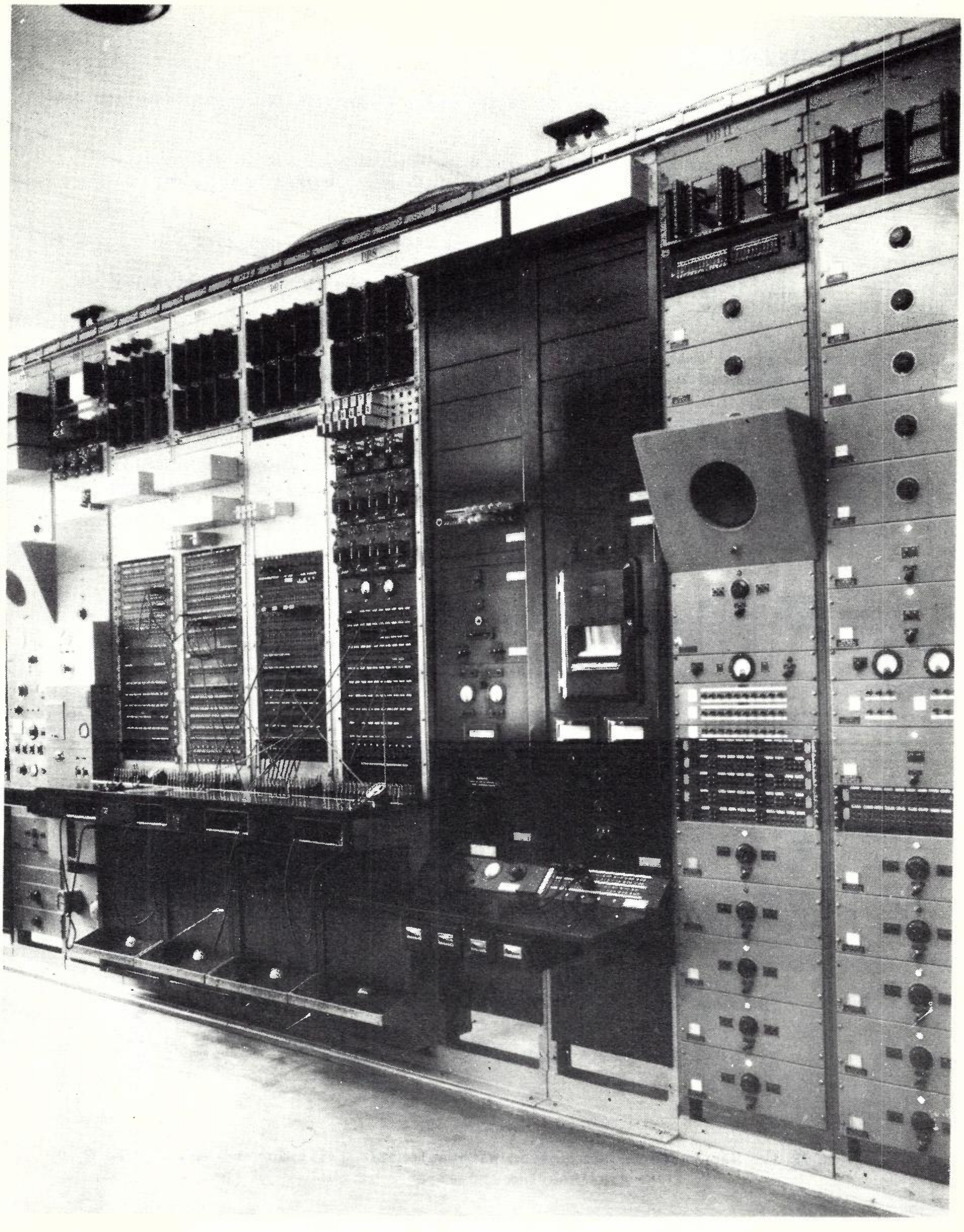
(a) The input impedance is 10,000 ohms to permit connection across a 600 ohm circuit without introducing a serious shunt loss. The output impedance is designed for connection to a 600 ohm circuit.

(b) Maximum gain is 5 db.

(c) A typical response curve is within ±0.3 db (compared with the value at 1 kc/s) over the frequency range 30-10,000 c/s.

(d) The power capability is 240 mW.

/ Typical



TYPICAL PROGRAMME ROOM TERMINAL EQUIPMENT AND PATCH PANEL.

5. PROGRAMME LINE SWITCHING.

5.1 In a programme switching scheme, it is necessary to provide for interconnection between the following circuits -

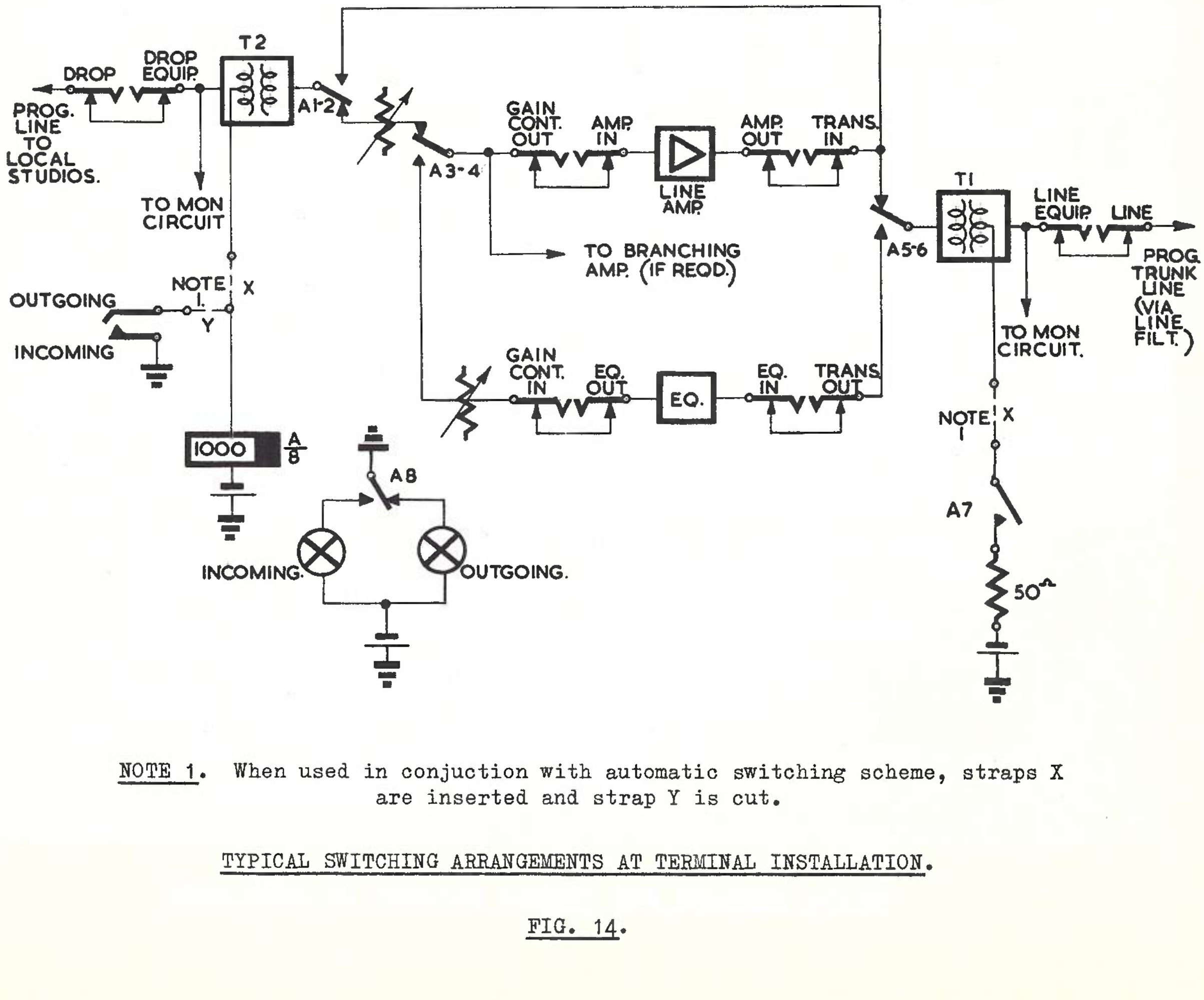
(i) Direct lines from the programme switching centre to the studios of the various broadcasting stations, permanently used for programme relaying.

(ii) Permanent interstate and intrastate programme channels.

(iii) Trunk lines frequently used for programme relaying but normally used for trunk line service.

5.2 Programme circuits are set up either manually by patch cord connection or automatically by relays or uniselectors operating under the control of set-up keys. In the latter case, the switching is completely automatic and no patching is required as the programme lines are permanently wired to switching equipment.

5.3 Relay Switching. The circuits of typical terminal and intermediate installations using relay switching for setting up and reversal of the programme equipment are shown in Figs. 14 and 15, respectively.



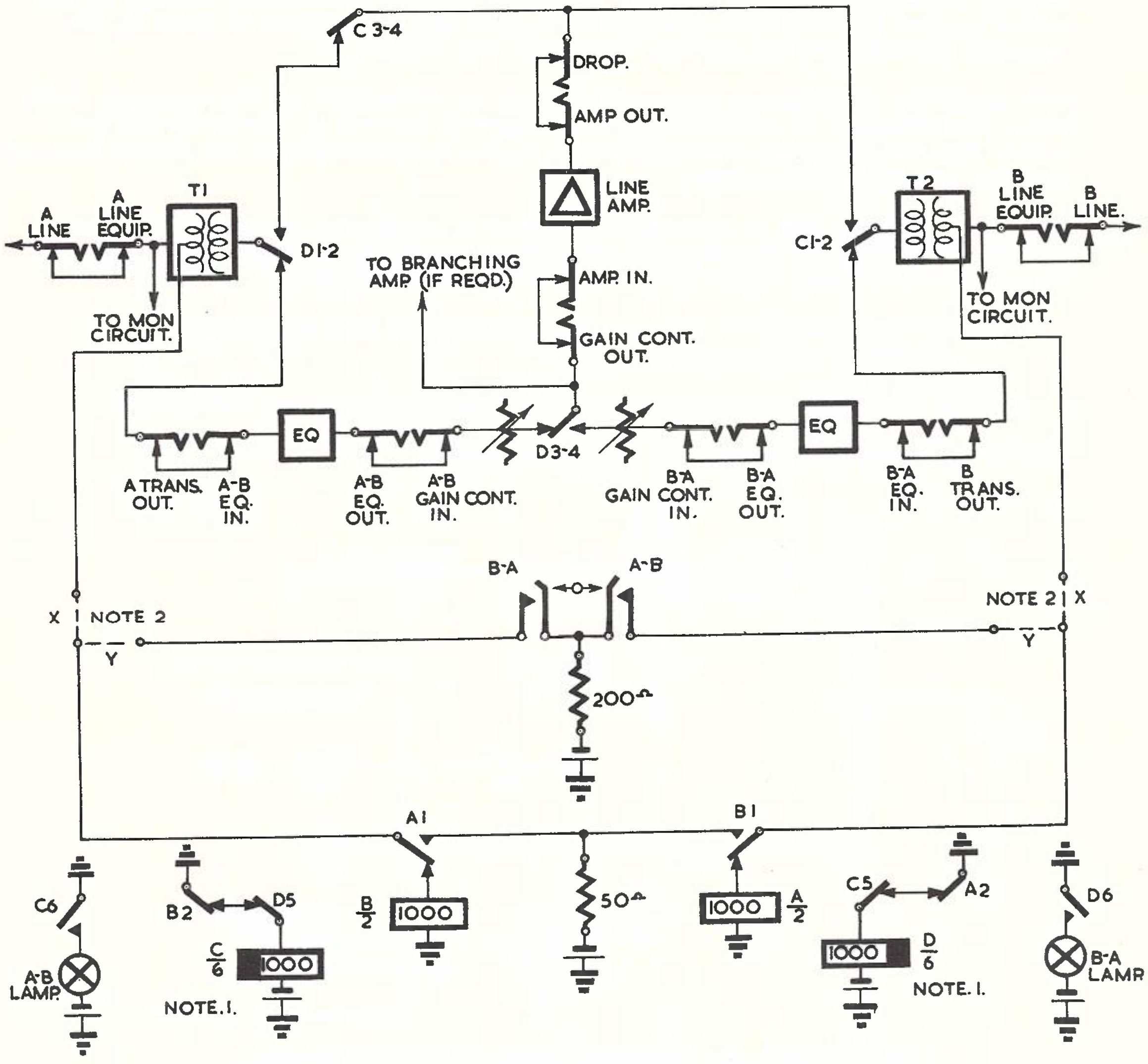
NOTE 1. When used in conjuction with automatic switching scheme, straps X are inserted and strap Y is cut.

TYPICAL SWITCHING ARRANGEMENTS AT TERMINAL INSTALLATION.

FIG. 14.

In the normal condition of Fig. 14, the circuit is arranged so that the programme is sent from the terminal to the programme trunk line. When programme is to be received from the trunk line, relay A is operated by earth, fed over the cailho of the drop circuit or from the reversing key. This depends upon whether automatic or manual reversing is used. At a terminal station, key reversing is used unless the equipment is associated with an automatic programme switching scheme. Contacts of relay A reverse the connections to the line circuit, light the appropriate direction indicating lamp and feed battery over the cailho to the next station when automatic reversing is used.

At the intermediate installation, the reversal is controlled either by the operation of a key or by reversing signals received over a cailho circuit from either direction. The switching arrangement is shown in Fig. 15.



NOTES 1. Either relay C or D is normally operated, but the contacts of both relays are shown unoperated.

2. For remote control of switching, straps X are inserted, and straps Y are cut.

FIG. 15. TYPICAL SWITCHING ARRANGEMENTS AT INTERMEDIATE INSTALLATION.

For an A-B transmission, relay A is operated by battery from the cailho on the B line or the reversing key. Relay A prevents relays B and D from operating, and feeds battery via the centre tap of transformer T1 to the next station when automatic reversal is required. As relays B and D are normal, relay C operates, thus arranging the line equipment in the A-B direction and lighting the A-B indicating lamp.

When transmission in the B-A direction is required, battery is removed from relay A which releases, removes battery from the cailho on the A line, and prepares a circuit for relay D. Relay D does not operate, however, until relay C releases, and relay C is locked until relay B operates. When battery is applied on the A line, relay B operates, releasing relay C, operating relay D, and feeding battery to the cailho on line B. With the operation of relay D and the release of relay C, the reversal is completed and the B-A indicating lamp lights.

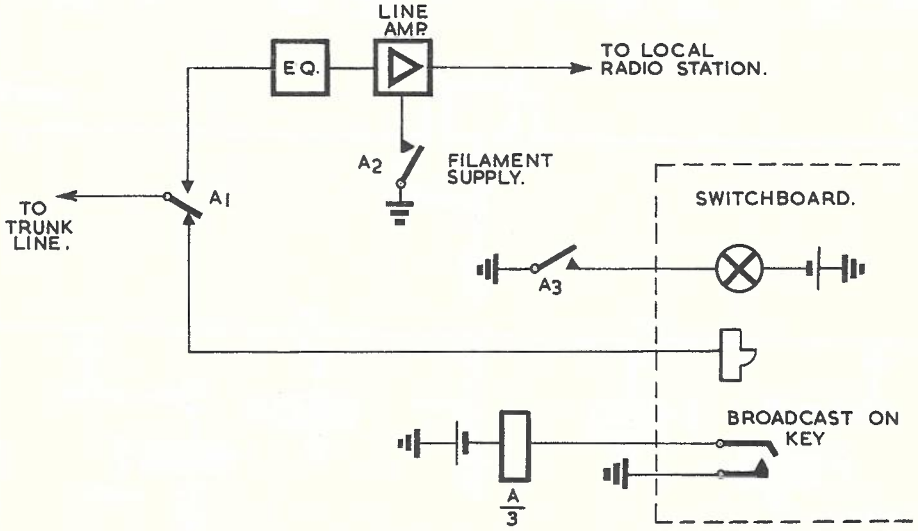
When automatic reversing is used, the reversal is controlled by the receiving terminal. The reversal is effected only when negative battery is received over the cailho from the receiving terminal and no signal is received over the cailho from the terminal sending the programme.

5.4 When a technician is not in constant attendance at a repeater or country terminal station, the necessary switching of programme circuits is generally done by relays. The operation of these relays is controlled by one of two ways -

(i) by the operation of a key at a remote station by a technician, as described previously, or

(ii) by the local telephonist operating a key mounted on the switchboard.

Fig. 16 is a practical example of the latter method.



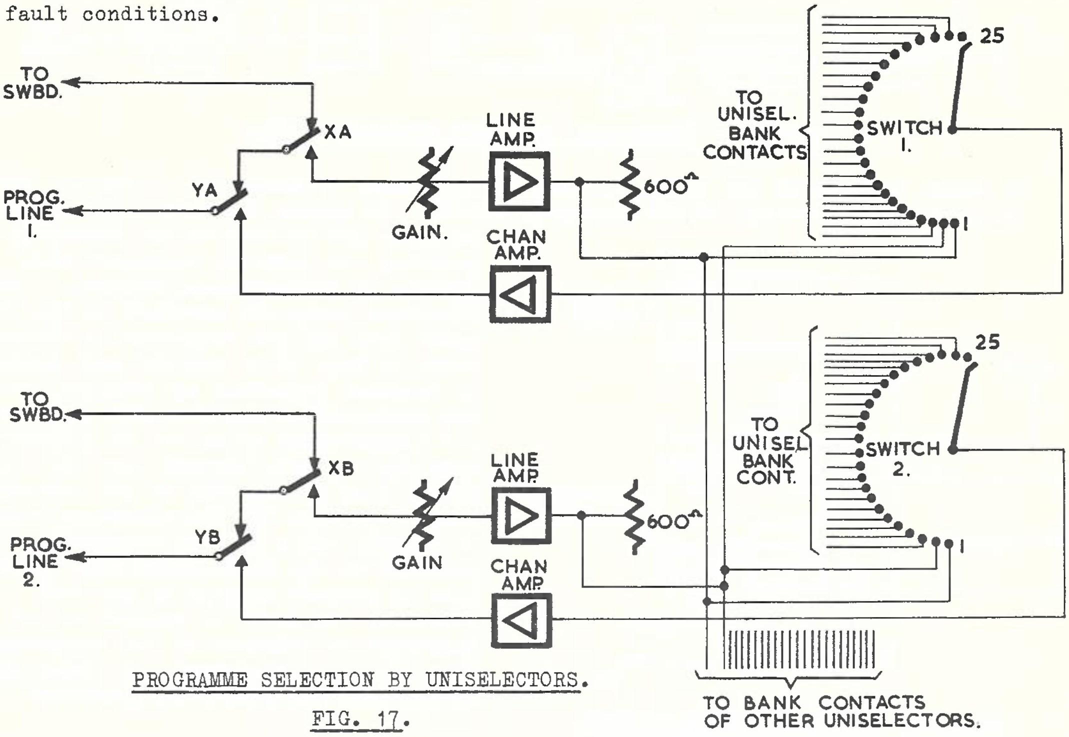
LINE SWITCHING FOR BROADCAST RELAYS AT COUNTRY CENTRES.

FIG. 16.

In Fig. 16, the local telephonist, when instructed, operates a key which, in turn, operates a relay to connect the programme through from the trunk line to the local radio station. A guard lamp lights above the key on the switchboard and remains alight during the broadcast. At the end of the broadcast, the key is restored and the trunk line is used for trunk telephone calls.

/ 5.5

5.5 Uniselector Switching. The basic circuit of a programme switching scheme using uniselectors is shown in Fig. 17. For simplicity, details of the complete switching and supervisory arrangements have been omitted from the circuit. The lines, and inputs and outputs of amplifiers are connected via jacks to permit testing and patching during fault conditions.



PROGRAMME SELECTION BY UNISELECTORS.

FIG. 17.

The switching circuits are designed to arrange any desired combination of the programme channels in the group. Each of the channels may be selected for use as a programme channel from which a number of splits may be taken, or, alternatively, as a channel taking a split from another channel in the group.

The programme circuits may be normally connected via the X and Y relay contacts to the trunk switchboard, or, in the case of V.F. dialling circuits, to the automatic exchange. When required for broadcasting, the line is disconnected from the switchboard and connected either to the input of its line amplifier via the X contacts when receiving an incoming programme, or the output of the channel amplifier via the Y contacts when transmitting a programme. The choice of connection is effected by the operation of non-locking set-up keys not shown in Fig. 17.

When an incoming programme on line 1 is to be connected to line 2, relay XA in circuit 1 is operated to connect the programme to the No. 1 bank multiple of the uniselectors. Uniselector 2 then steps to No. 1 bank contacts and relay YB in circuit 2 operates to connect the programme to line 2. Similarly by stepping other uniselectors to the No. 1 bank contact, the programme may be simultaneously fed to other programme lines. Homing type uniselectors are used and the wipers rest in the homing position when not in use. The channel amplifiers are high impedance to permit a number to be connected across the output of the line amplifier without affecting the impedance conditions in the circuit.

5.6 Intercept Line Jacks. (See Fig. 18.) In the case of physical trunk lines which are adapted for programme transmission, all items of equipment which affect the quality of the programme must be removed from the circuit for the duration of the broadcast. This includes composite sets, V.F. repeaters, 3 kc/s line filters (which should be replaced by 5.6 kc/s line filters) and sections of V.F. loaded cables which have a cut-off frequency of about 3 kc/s. Any 1,000 c/s ringers in the circuit are also removed because a 1,000 c/s component in the programme may operate the ringer and cause interference to the programme transmission.

/ Fig. 18.

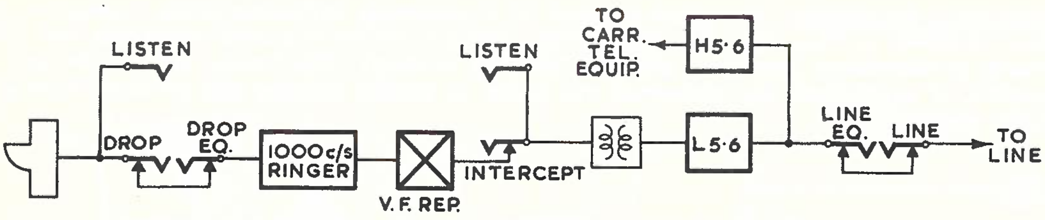


FIG. 18. PROGRAMME LINE WITH INTERCEPT JACKS.

On trunk lines which are regularly used for programme transmission, intercept jacks are frequently provided at the appropriate point, to reduce the number of cord connections and to obviate the necessity for patching out terminal equipment when setting up the programme channel. The intercept jacks are provided on the line patch rack and are connected in circuit as shown in Fig. 18 to exclude such equipment as terminal repeaters and ringers, but are connected on the drop side of filters and transformers so as not to interfere with any circuits derived over the line. When a plug is inserted in the intercept jacks (see Fig. 19) the telephone circuit is opened, and a 600 ohm termination is provided on the switchboard side of the line to prevent singing of any V.F. repeater. An earth is applied to the busy wire to indicate to the telephonist that the line is engaged. A listen jack is provided for monitoring purposes.

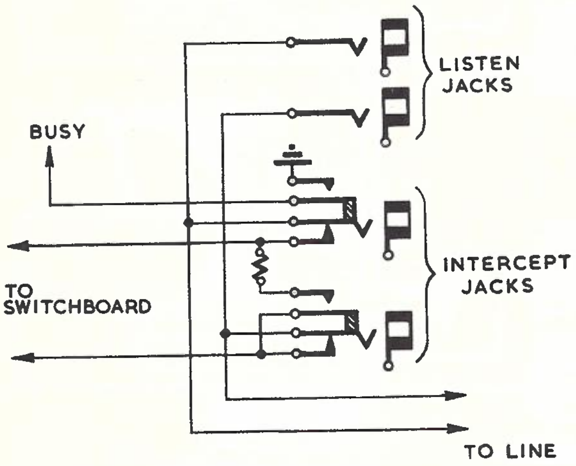


FIG. 19. INTERCEPT TRUNK CIRCUIT.

6. MONITORING EQUIPMENT.

6.1 For setting up and observation of programmes, monitoring facilities are provided to enable an incoming or outgoing programme to be monitored on head-phones or loud-speakers. A check of programme level is also made at the same points.

The equipment comprises -

(i) Monitoring amplifier and loud-speaker.
(ii) Level indicator.

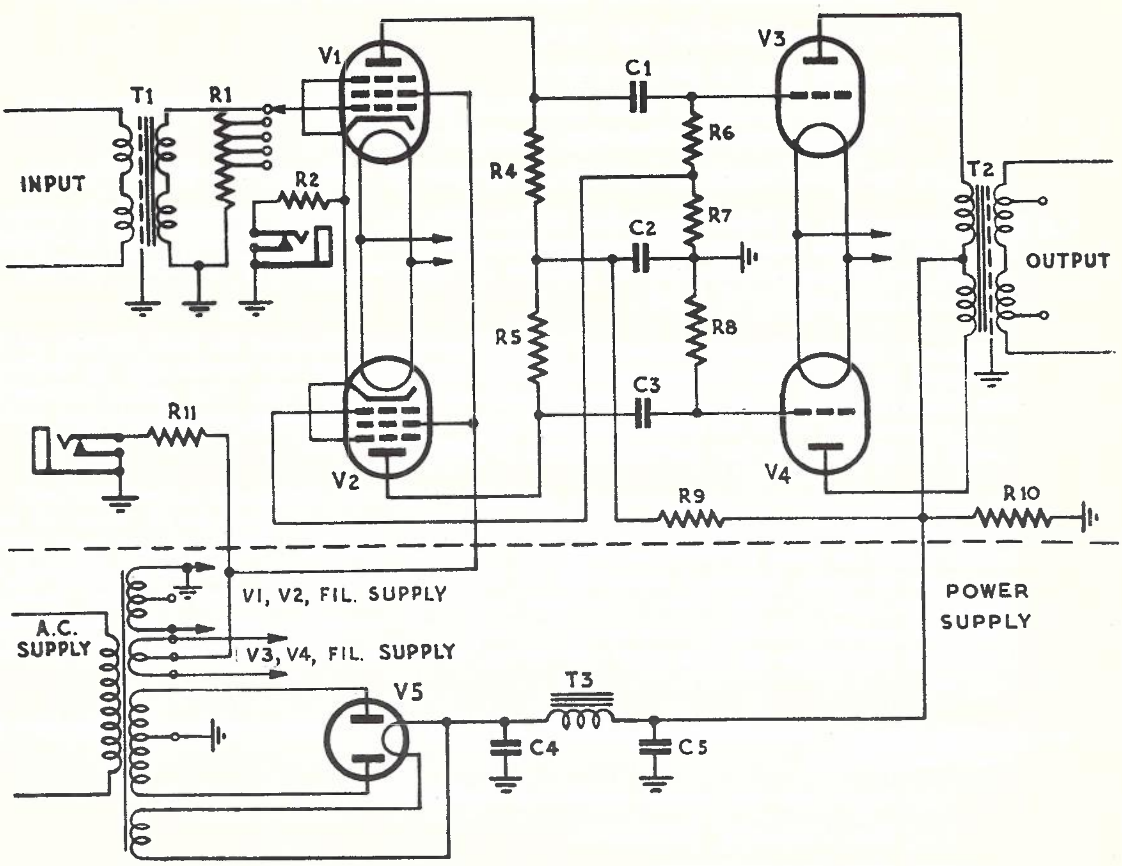
The amplifier and level indicator have a high impedance input to permit connection across the programme channel without producing an impedance mismatch and appreciably affecting the programme level.

6.2 In the larger terminal installations, the monitoring equipment is connected to any desired channel by rotary uniselectors operating under the control of selecting keys. By operating any one of the selecting keys, the uniselector moves to the contact corresponding to the key depressed. A typical operation is as follows -

When the monitoring key is operated, every bank contact of the uniselector is earthed with the exception of the one associated with the line selected. These earths complete the circuit through the motor magnet coil of the uniselector, and the wipers step until the contact without the earth is reached. A relay is also energised, and this removes the monitoring amplifier, level indicator and lamp from the wiper contacts while the switch is in action. The relay is slow releasing so that it holds during break periods in rotation, but, when the uniselector stops, the relay releases and the circuit is monitored on a loud-speaker or head-phones. The channel under observation is indicated by a lamp.

/ 6.3

6.3 Monitoring Amplifier. The monitoring amplifier is used with a good quality loud-speaker which handles the full range of frequencies. A circuit of a typical monitoring amplifier is shown in Fig. 20.



MONITORING AMPLIFIER AND POWER SUPPLY CIRCUIT.

FIG. 20.

The input signal is applied via the input transformer T1 and gain control R1 to the grid of V1. The output of V1 is resistance-capacitance coupled to the grid of V3. Portion of the output signal voltage of V1 is tapped off across R7 and applied to the grid of V2. This signal voltage appears in the output of V2 and is 180° out of phase with the input voltage. The output of V2 is resistance-capacitance coupled to the grid of V4. By a suitable choice of R6 and R7, the output signals of V1 and V2 are made equal. Signals of equal voltages but 180° out of phase, therefore, are applied to the grids of the push-pull output stage and these are amplified and applied to the monitoring loud-speaker via the output transformer T2.

Grid bias for V1 and V2 is obtained from the D.C. voltage drop across the cathode resistor R2. Grid bias for V3 and V4 is obtained from the D.C. voltage drop across R11. As the A.C. signals through these resistors from each valve are equal and 180° out of phase, it is not necessary to by-pass the resistors with a capacitor. The screen voltages for V1 and V2 are also obtained from the D.C. voltage drop across R11. An anode decoupling circuit for V1 and V2 is provided by R9 and C2. A separate filament transformer winding is necessary for V3 and V4 which have directly heated cathodes.

/ Performance

Performance details are as follows -

(i) High input impedance of about 15,000 ohms to prevent impedance mismatch and alteration of level when connected across a 600 ohm circuit.

(ii) Output impedance of 600 ohms.

(iii) Maximum gain of about 45 db.

(iv) A typical response curve is within ±1 db (compared with the value at 1 kc/s) over the frequency range 30-10,000 c/s.

(v) The power handling capacity is 3 watts at 1 per cent total distortion.

6.4 Level Indicator. A level indicator is provided for visually monitoring the programme level at offices containing programme equipment. As the level indicator is connected across the programme circuit, it must be of high impedance to prevent impedance mismatch and alteration of level.

A typical level indicator consists of a voltmeter calibrated to read levels in db referred to 6 mW, and incorporates an amplifier so that low levels may be indicated. The range extends from -40 to +20 db with reference to 6 mW. The meter movement is of a high speed type so that programme peaks may be observed to ensure that such peaks do not exceed the overload point of the equipment.

In the past, several types of level indicators having different electrical and dynamic characteristics have been used for this purpose. Because of this, no correlation could be made between readings on different meters. To overcome this difficulty one type of meter has been standardised during recent years for the monitoring of programme levels. This type of volume indicator is known as the vu meter (see Long Line Equipment III) and is in use at a number of installations. A two stage negative feedback amplifier is used with the meter to extend the level range from -40 vu to +33 vu.

6.5 Test Equipment. The testing equipment at a typical office containing programme equipment comprises -

(i) Noise and distortion measuring equipment.

(ii) Beat frequency oscillator.

(iii) 400 c/s oscillator.

(iv) Transmission measuring set.

Details of this equipment are given in Long Line Equipment III.

7. LINE-UP OF PROGRAMME CIRCUITS.

7.1 When a programme line is to be used for the transmission of music, it is prepared as follows -

(i) When it is necessary to withdraw a telephone channel from traffic for programme transmission, it is generally necessary to make alterations to the circuit. All apparatus which restricts the frequency range of the programme is removed from the circuit by patching out for the duration of the broadcast. (See paragraph 5.6.) Broadcast amplifiers are patched into the line, as required, at repeater stations and the receiving terminal. An equaliser designed for the particular length of line concerned, precedes each amplifier. The necessary measuring instruments, such as level indicators or db meters, are also provided.

(ii) The programme circuit is adjusted to zero equivalent. A frequency of 1,000 c/s at a level of 6 mW is applied to line at the transmitting terminal. Starting at the station nearest the transmitting terminal, each repeater station in turn and, finally, the receiving terminal adjusts the programme amplifier output to 6 mW.

/ (iii)

(iii) Frequency Response. Frequencies of 35, 50, 100, 3,000 and 5,000 c/s at a level of 6 mW are applied to line at the transmitting terminal. At each frequency, each station reads the amplifier output levels in terms of db above or below the reading at 1,000 c/s, namely 6 mW. All readings are recorded at both terminals.

(iv) Harmonic Distortion. A frequency of 400 c/s at a level 6 db greater than 6 mW is applied to line at the transmitting terminal and the percentage distortion is measured at the receiving terminal on a noise and distortion set. The amplifiers and equipment are tested under high peak conditions to take care of instantaneous high programme peaks which are approximately 6 db higher than average programme peaks.

(v) Noise. The line is terminated at the sending terminal and the noise level in db below 6 mW, both unweighted and weighted, is measured at the receiving terminal.

(vi) Finally, a programme is sent from the originating station at zero level for observation purposes. The channel is then patched to the studios ready to receive the programme which is switched to the various networks as required.

Typical figures for such a line-up are shown in Table 1.

Channel.	Repeater Station.	Equivalent in db.						Percentage Distortion and Noise Level below Programme in db.
		35	50	100	1000	3000	5000	
P1 (Melb-Sydney)	Wangaratta	+1	0	+1	0	0	-1	Distortion 1.5% Noise -58 db (weighted).
	Wagga	+1	-1	0	0	-1	-1	
	Goulburn	+1	0	+1	0	0	-1	
	Sydney	+1	0	+1	0	0	0	

TYPICAL LINE-UP FIGURES FOR PROGRAMME CHANNEL.

TABLE 1.

8. PROGRAMME TRANSMISSION OVER CARRIER TELEPHONE CHANNELS.

8.1 When a channel of a carrier telephone system is used for the programme transmission of speech, the channel is made unidirectional by connecting the programme to the modulator input jacks at the transmitting terminal and from the demodulator output jacks at the receiving terminal. This prevents the possibility of the channel "howling" and also excludes any channel ringing equipment. Connection to the modulator is made via a suitable pad, generally 25 db, to ensure that the programme peak level does not overload the channel equipment. At the receiving terminal, connection from the demodulator output is made via a 10 db pad to prevent overload of the control amplifier which raises the programme level to 6 mW. Carrier channels are often operated on a full 4-wire basis, that is, a programme is sent into the Mod. In jacks of a channel and a different programme received at the Demod. Out jacks of the same channel at each terminal.

8.2 When a channel of a type J system is used, the programme fed to the Mod. In is padded back to a level not exceeding -13 dbm and the programme from the Demod. Out, which rises to +4 dbm, is attenuated by a 10 db pad to prevent overload of the control amplifier which raises the level again to 6 mW.

8.3 Carrier channels are suitable for the transmission of speech such as sporting broadcasts, but, owing to their restricted frequency band-width, they are not suitable for the transmission of musical programmes.

/ 9.

9. PROGRAMME CARRIER SYSTEMS FOR OPEN-WIRE LINES.

9.1 In addition to the up-grading of normal physical lines by the inclusion of special programme amplifiers and attenuation equalisers, high quality programme carrier systems manufactured by Standard Telephones and Cables were introduced during 1936. These systems use a band of frequencies above the range occupied by the normal 3-channel carrier telephone systems, and, therefore, do not interfere with the provision of a 3-channel system over the same trunk line.

However, the application of Type J 12-channel carrier telephone systems on open-wire routes prevents the simultaneous operation of programme carrier systems due to crosstalk problems. For example, the installation of Type J carrier systems between Sydney and Melbourne and between Melbourne and Adelaide necessitated the closing down of the programme carrier system on these routes.

The requirements of a carrier system for the transmission of broadcast programmes are more stringent than those of the usual carrier telephone system, as a much higher standard of quality is required. This means that the transmitted audio frequency band must be wider, distortion due to non-linearity must be reduced as low as possible, and extraneous noises eliminated.

The carrier programme systems in use in the Commonwealth are unidirectional systems, thereby eliminating singing problems. The systems are, however, arranged so that the direction of transmission can be reversed as and when required. Unidirectional operation permits the system to be lined up to a low equivalent (usually 6 db over-all). To provide for rapid reversal, a large proportion of the equipment used in the transmitting and receiving terminals is common, and the change in direction is accomplished by key switching.

9.2 General Description. The system is designed to transmit an audio-frequency band from 35-7,500 c/s over line sections not exceeding 40 db loss (wet-weather attenuation). This permits repeater spacings to be coincident with those adopted for normal 3-channel carrier telephone systems. The system is suppressed carrier, single sideband, using a carrier frequency of 42.5 kc/s and transmitting the lower sideband. Transmitted frequencies, therefore, are 35-42.5 kc/s.

To permit the system to operate over the same pair as a 3-channel system, special high and low-pass line filters (programme line filters) are used. Cut-off frequencies are 32.4 kc/s (H.P.) and 31.9 kc/s (L.P.). This line filter group is connected between the normal 3 kc/s or 5.6 kc/s line filter group and the programme equipment. A typical trunk line arrangement is shown in Fig. 21.

The equipment is mounted on standard 10'6" racks, a combined transmitting and receiving terminal (reversible) requiring two racks.

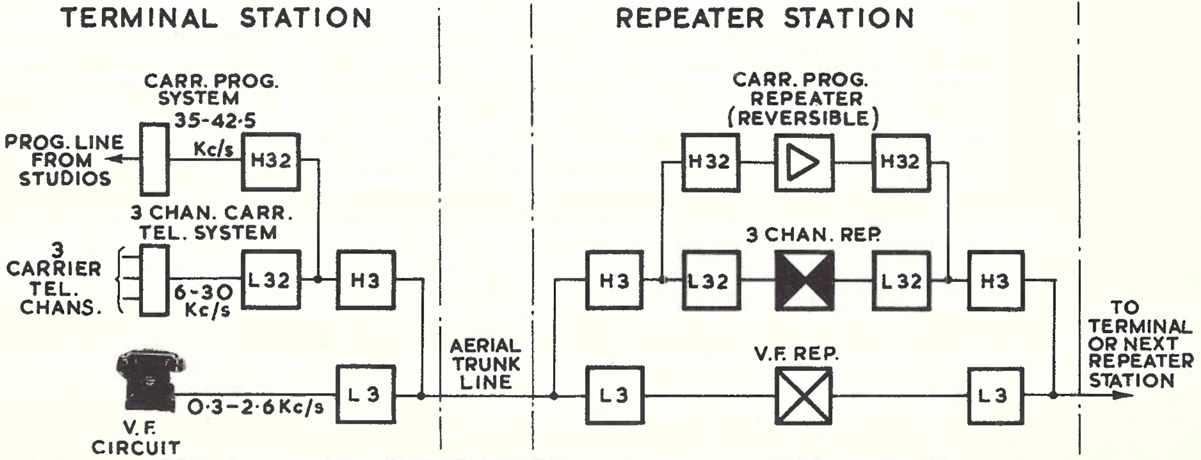
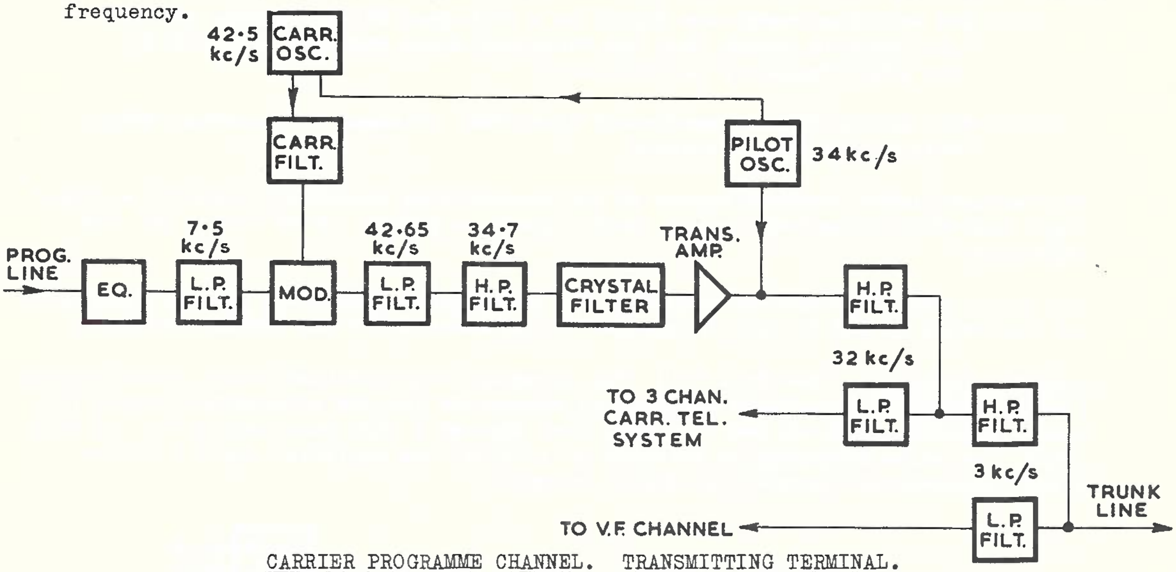


FIG. 21. APPLICATION OF CARRIER PROGRAMME SYSTEM TO TRUNK LINE.

9.3 Synchronism. Usually, in normal carrier systems using suppressed carrier, single sideband transmission, it is the practice to use separate carrier oscillators at the transmit and receive terminals and synchronise these oscillators at regular intervals. Where it is necessary to transmit very low audio frequencies down to 35 c/s, a small difference between the carrier frequencies at each terminal causes distortion. In carrier programme systems, therefore, special arrangements are provided to ensure close synchronism.

Each terminal, as shown in Figs. 22 and 23, is provided with a carrier oscillator tuned to 42.5 kc/s but capable of operation over a range ±100 c/s from this nominal frequency. At the transmitting terminal, a pilot oscillator, which is very stable and is tuned to 34 kc/s, is also provided. A ratio of 4 : 5 exists between the pilot and carrier frequencies. The pilot frequency is injected into the grid circuit of the carrier oscillator and holds it in synchronism, thus ensuring stability of the 42.5 kc/s carrier frequency.



CARRIER PROGRAMME CHANNEL. TRANSMITTING TERMINAL.

FIG. 22.

To synchronise the distant terminal, the pilot frequency is transmitted over the line and injected into the grid circuit of the receiving terminal carrier oscillator. By this means, both carrier oscillators are held in synchronism by using a common stable pilot frequency.

The pilot frequency also has a secondary function as a level indicator. It is tapped off at each repeater station (see Fig. 24) through a circuit tuned to 34 kc/s and operates a pilot indicator, thus providing an indication of attenuation variations in the preceding line section. If the line attenuation varies, the pilot level changes and the pilot indicator at the receiving terminal operates an alarm circuit. Adjustment of repeater gains is then made to restore the over-all equivalent to normal.

9.4 Elimination of the Unwanted Sideband. As the transmitted audio frequency band extends from 35-7,500 c/s, the two carrier sidebands are only 70 c/s apart, and their separation presents considerable difficulty and cannot readily be effected by the normal coil and capacitor type filters. As the presence of the upper sideband introduces distortion, special crystal filters are used to provide a sharp cut-off.

The crystal filter circuit is actually a 2-stage amplifier with a quartz crystal element inserted between the stages. The characteristic curve of this combination shows a gain of approximately 24 db at frequencies below 42.5 kc/s, and then an extremely sharp cut-off for frequencies just above the carrier. When used in conjunction with a conventional filter, the upper sideband is effectively eliminated.

/ 9.5

9.5 Transmitting Terminal. (See Fig. 22.) The audio frequencies pass through an equaliser which compensates for irregularities in the terminal equipment, through a filter which limits the audio-frequency band to 7.5 kc/s, and then to the modulator. The limitation of the audio-frequency band to an upper value of 7.5 kc/s is important, as a frequency of 8.5 kc/s, when modulated, becomes 34 kc/s, and such a frequency corresponding to the pilot frequency might interfere with the stability of the carrier oscillators.

Grid current modulation is used, the carrier being balanced out. The resulting products of modulation pass to three filters in tandem.

(i) The modulator filter is a low-pass filter cutting off at 42.65 kc/s, thus eliminating the major portion of the unwanted upper sideband.

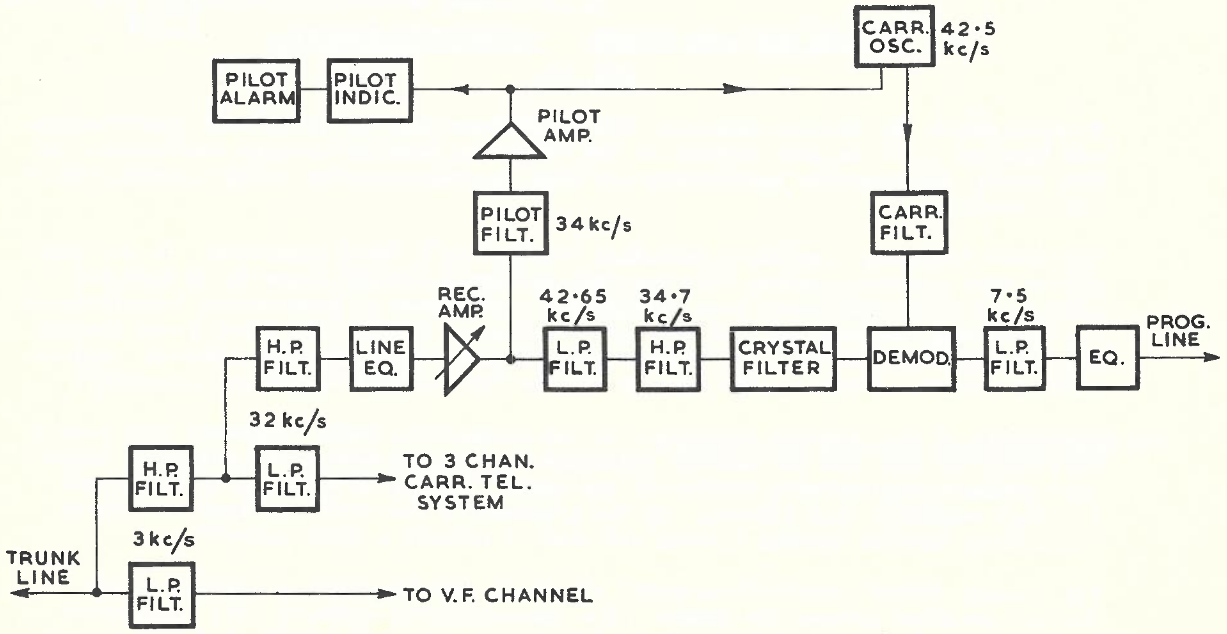
(ii) The auxiliary modulator filter is a high-pass filter cutting off at 34.7 kc/s to ensure that any frequency which might interfere with the pilot frequency is eliminated.

(iii) The crystal filter, previously described, eliminates remaining components of the upper sideband.

The required lower sideband passes to the transmitting amplifier, which is a single stage amplifier using four valves, with a power output of 190 mW into a 600 ohm impedance.

The pilot oscillator has two outputs. One synchronises the local carrier oscillator and the other is fed to line to provide for synchronism of the distant terminal.

9.6 Receiving Terminal. (See Fig. 23.) The incoming lower sideband first passes through carrier frequency equalisers designed to compensate for the attenuation versus frequency characteristic of the line, and then through a high gain amplifier. At this point, the pilot frequency is selected by a filter and amplifier and fed to the pilot indicator and carrier oscillator circuits.



CARRIER PROGRAMME CHANNEL. RECEIVING TERMINAL.

FIG. 23.

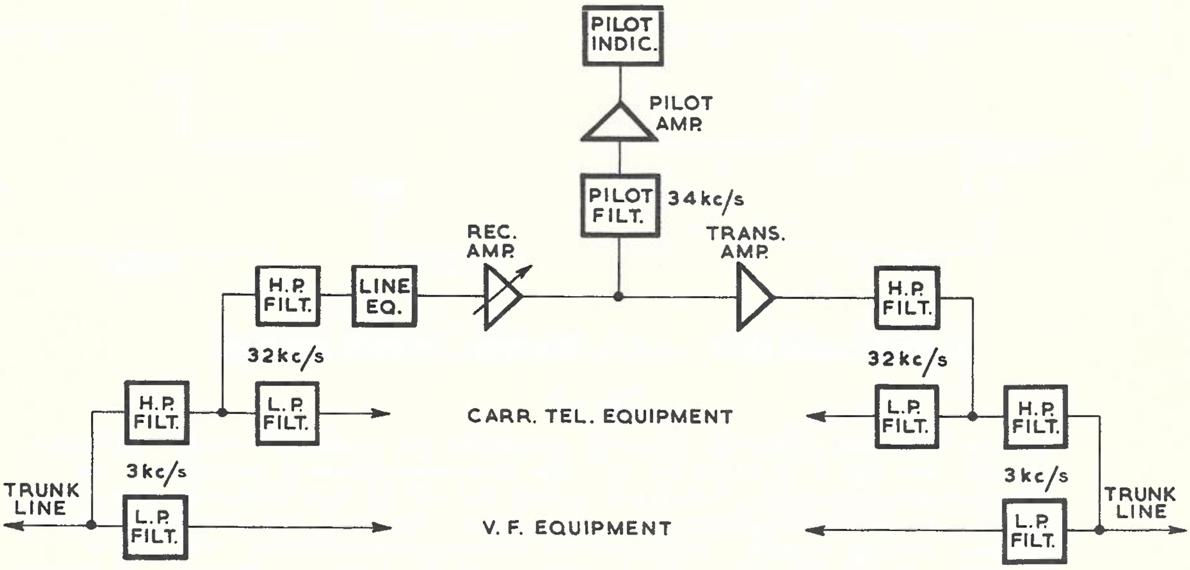
The pilot amplifier and the receiving amplifier are identical and use three reactance coupled stages, giving a total gain of about 56 db. The actual gain depends on the attenuation of the preceding repeater section and is set at initial line-up to a suitable value. An input potentiometer then provides a working margin of 20 db in steps of 1 db.

The required sideband (35-42.5 kc/s) passes from the receiving amplifier to a filter group identical with those described for the transmitting terminal. These filters ensure that only the required sideband frequencies are applied to the demodulator, which is similar to the modulator circuit in the transmitting terminal.

The products of demodulation pass via a filter and equaliser, which select the required audio-frequency band (35-7,500 c/s) and equalise terminal irregularities.

The pilot indicator consists of a valve rectifier with a milliammeter in the anode circuit. A slow operate relay is in series with the meter, so that the alarm does not operate for momentary variations in pilot level.

9.7 Repeater. Fig. 24 shows a straight through repeater for programme transmission. This consists of line filters for separating programme carrier, 3-channel carrier and voice frequencies, equalisers to compensate for attenuation versus frequency characteristics of the line, and two amplifiers in tandem. The amplifiers are as described for the terminals. The pilot circuit is bridged across the receiving amplifier output.



CARRIER PROGRAMME CHANNEL REPEATER.

FIG. 24.

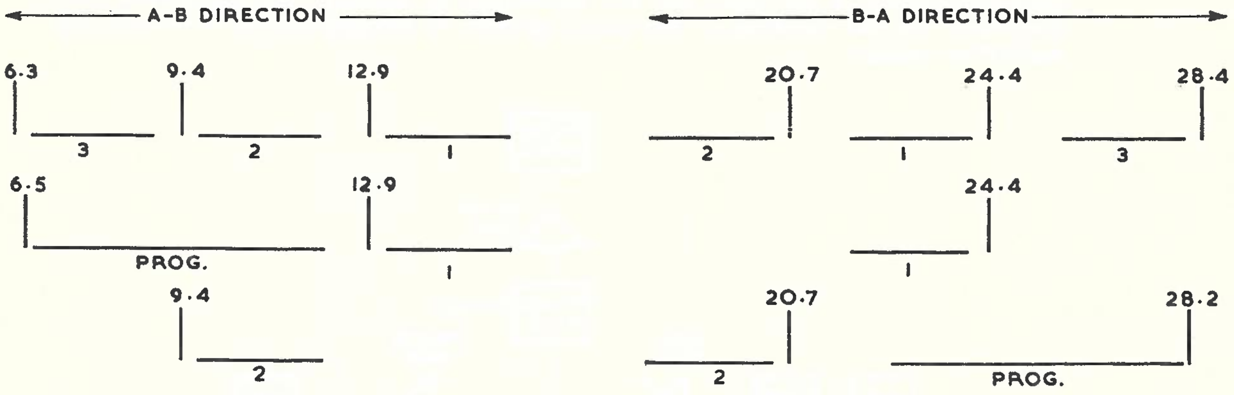
9.8 Demodulating Repeater. This type of repeater is actually a combination of the ordinary repeater and the receiving terminal. After the receiving amplifier, a demodulating circuit corresponding to the receiving terminal is bridged across the channel, the pilot circuit being used to synchronise the carrier oscillator. A repeater of this type enables a programme to be tapped off at an intermediate point.

/ 10.

10. PROGRAMME EQUIPMENT FOR 3-CHANNEL CARRIER TELEPHONE SYSTEMS.

10.1 Programme carrier equipment has been developed recently to meet special requirements on open-wire routes, and to avoid the crosstalk problems of the 34-42.5 kc/s system described in Section 9. The chief application of this equipment is to routes where it is not possible to obtain a 5 kc/s physical channel due to the intermediate office facilities required. The crosstalk problem is avoided by locating the programme channels in the same position in the frequency spectrum as those of a 3-channel carrier telephone system, namely, 6-16 kc/s in the A-B direction, and 18-30 kc/s in the B-A direction. Minor advantages of open-wire carrier programme channels over physical channels are that power hum is generally less, and automatic gain regulating equipment can be provided with the carrier equipment, making the channel loss independent of line attenuation changes.

10.2 Typical programme equipment of this type is that manufactured by General Electric Co. (G.E.C.), England. This equipment is designed to work in conjunction with a 3-channel carrier telephone system and uses a frequency band normally allotted to two speech channels of the latter. It provides a programme channel band-width of 100-5,600 c/s. A typical frequency allocation is shown in Fig. 25.



FREQUENCY ALLOCATION. G.E.C. BROADCAST PROGRAMME EQUIPMENT.

FIG. 25.

The top row shows a typical frequency allocation for 3-channel carrier telephone systems (see Fig. 1 of Paper No. 4). The programme equipment operates in one direction only, that is, either A-B or B-A, but not in both directions simultaneously. In the A-B direction, speech channels 2 and 3 are used for the programme channel, leaving channel 1 available for ordinary communication. In the B-A direction, speech channels 1 and 3 are used for the programme channel, and channel 2 is available for normal use. These allocations are shown in the middle and bottom rows respectively.

10.3 Transmitting Terminal. A simplified block schematic diagram of the transmitting terminal is shown in Fig. 26.

Programme frequencies (0.1-5.6 kc/s) are applied via an attenuator, equaliser and 6 kc/s low-pass filter to the modulator, to which a carrier frequency of 6.5 kc/s is also applied. The upper sideband of 6.6-12.1 kc/s is selected by the band-pass filter.

/ Fig. 26.

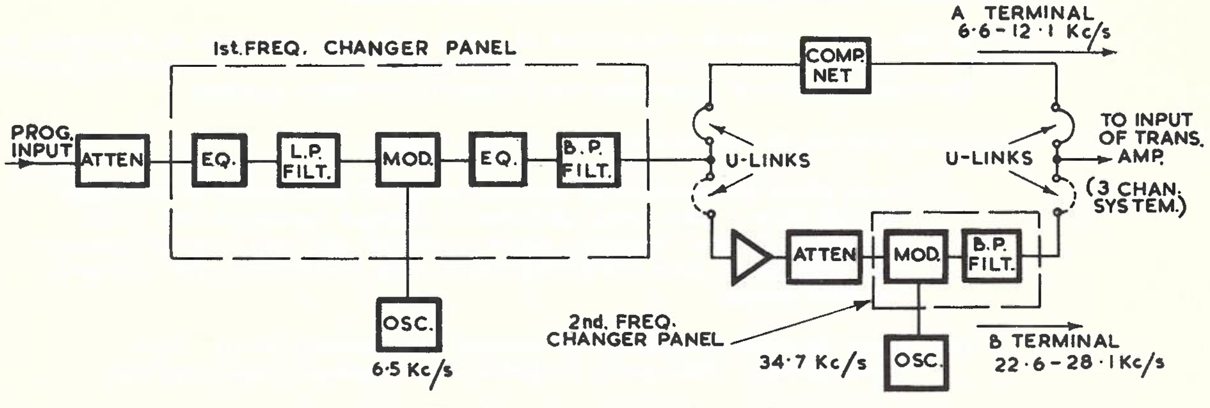


FIG. 26. TRANSMITTING TERMINAL.

When transmitting from an A terminal, the sideband passes via a compensating network to the 3-channel system. It is applied to the input of the transmitting amplifier together with the transmitted sideband of the speech channel.

When transmitting from a B terminal, the 6.6-12.1 kc/s sideband passes through the U-links, amplifier and attenuator to a second modulator stage, to which a carrier frequency of 34.7 kc/s is also applied. The lower sideband of 22.6-28.1 kc/s is selected by the band-pass filter and passes to the input of the transmitting amplifier of the 3-channel system.

10.4 Receiving Terminal. When used at a receiving terminal the equipment is rearranged by U-link switching (not shown in Fig. 26). A simplified block schematic of the receiving terminal is shown in Fig. 27.

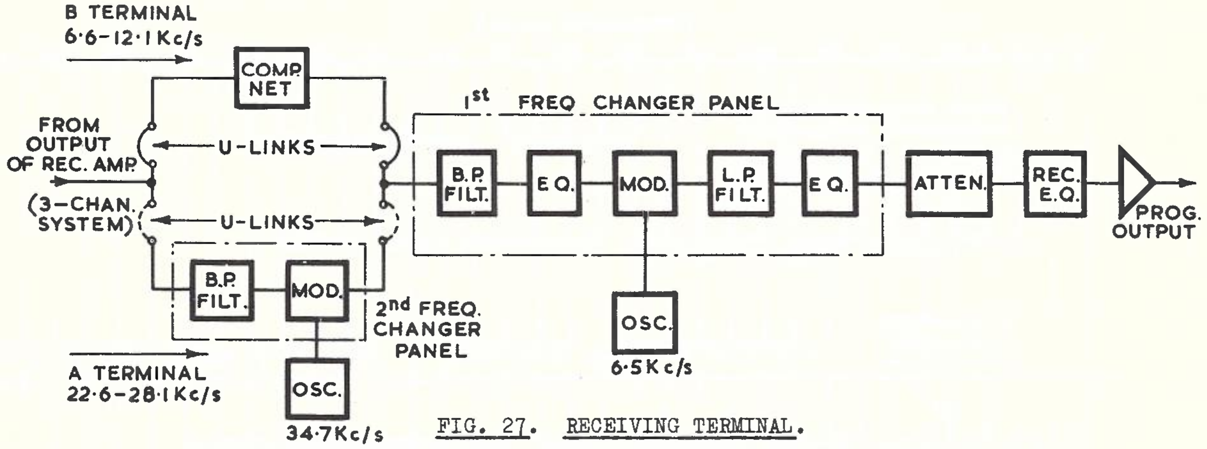


FIG. 27. RECEIVING TERMINAL.

When receiving at a B terminal, the programme channel sideband of 6.6-12.1 kc/s passes from the output of the receiving amplifier in the 3-channel system via the compensating network to the first frequency changer panel. The output from this panel is the programme frequency range (0.1-5.6 kc/s). This is amplified and applied to the programme line.

When receiving at an A terminal, the programme channel sideband of 22.6-28.1 kc/s passes from the 3-channel system to the second frequency changer panel. The output of 6.6-12.1 kc/s is applied to the first frequency changer panel and restored to the programme frequency range (0.1-5.6 kc/s) as in the case of a B terminal.

/ 11.

11. PROGRAMME EQUIPMENT FOR WIDE-BAND CARRIER TELEPHONE SYSTEMS.

11.1 A large and ever-increasing proportion of trunk telephone channels in Australia is provided by wide-band carrier systems, and equipment has been developed to provide for the transmission of programmes over channels of these systems.

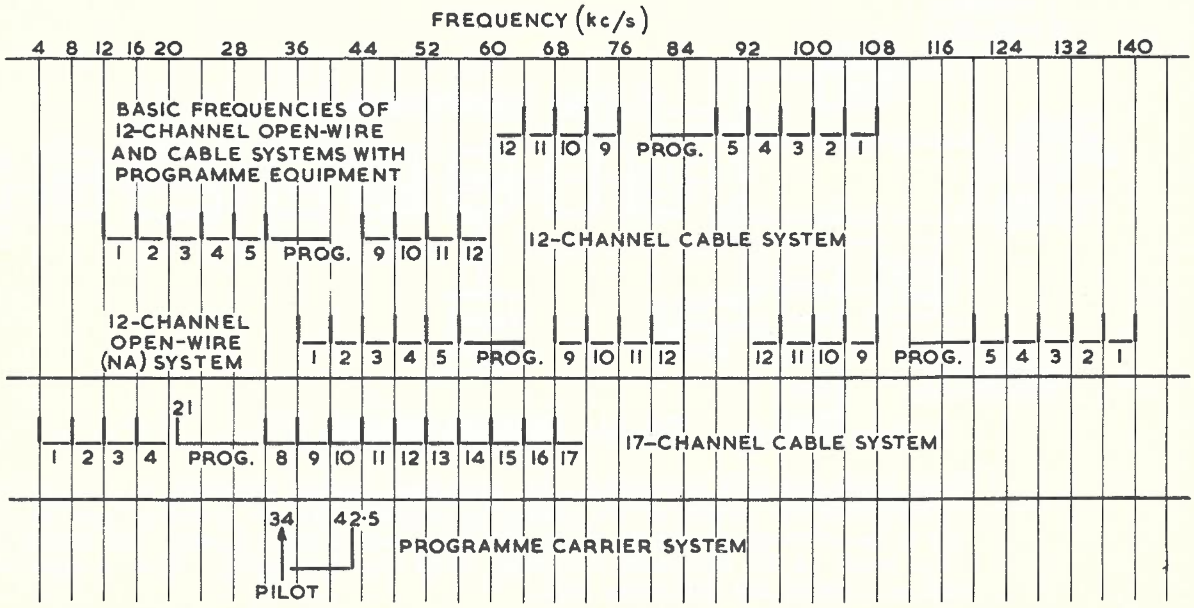
Wide-band systems in this country are of two types -

(i) Those which incorporate an initial stage of modulation in the range 60-108 kc/s. This group includes 12-channel open-wire and cable systems. Coaxial systems, which, although not used here at present, are certain to have a wide application in the future, are included in this group.

(ii) Those in which modulation is carried out directly at the line frequencies. This group includes the 17-channel cable systems.

Programme equipment for use with 12-channel carrier systems has been developed by the Western Electric Co., America, and by Standard Telephones and Cables Pty. Ltd., Australia. The equipment was designed originally for use with type K cable carrier systems, but can be used with type J open-wire systems. Programme equipment for use with 17-channel systems has been developed by Communication Engineering Pty. Ltd.

Fig. 28 shows the essential frequencies used in the above wide-band systems, and the position in the frequency spectrum of the programme equipment associated with these systems. For comparison, the allocation of the programme carrier system described in Section 9 is also shown.

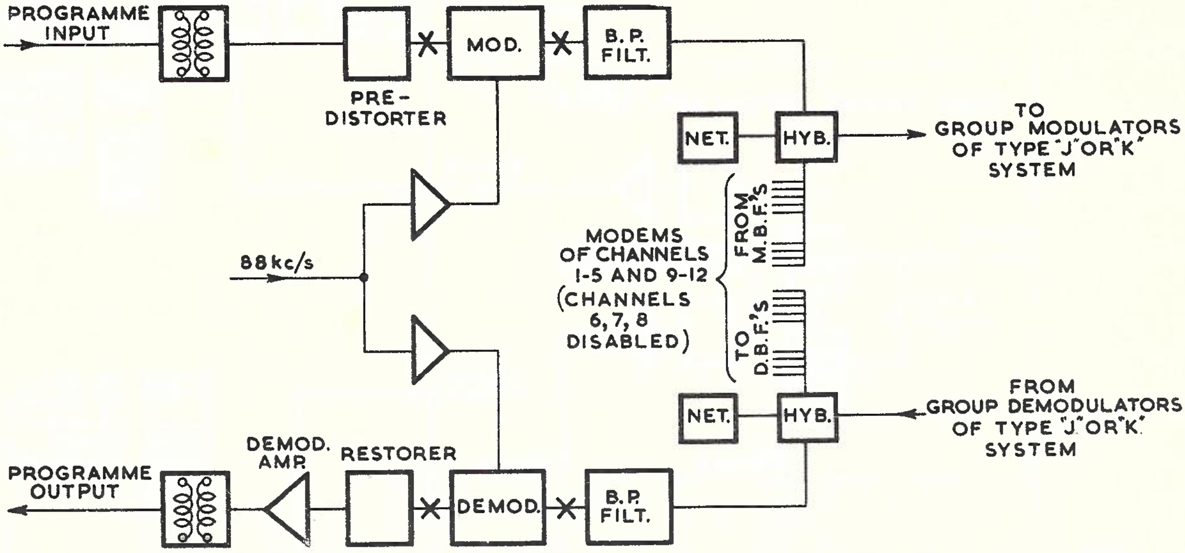


FREQUENCY ALLOCATION OF CARRIER PROGRAMME CHANNELS.

FIG. 28.

11.2 It is usual to operate programme equipment on a duplex basis, that is, two unidirectional channels, thus providing a programme circuit in each direction of transmission simultaneously over the 4-wire bearer.

A block schematic circuit of the programme terminal used with the 12-channel systems to provide duplex facilities is shown in Fig. 29.



NOTE. Delay equalisers inserted at point X.

BLOCK SCHEMATIC OF PROGRAMME TERMINAL USED WITH 12-CHANNEL SYSTEMS.

FIG. 29.

The terminal provides a single sideband programme circuit in each direction, which replaces channels 6, 7 and 8 on a type J or K system.

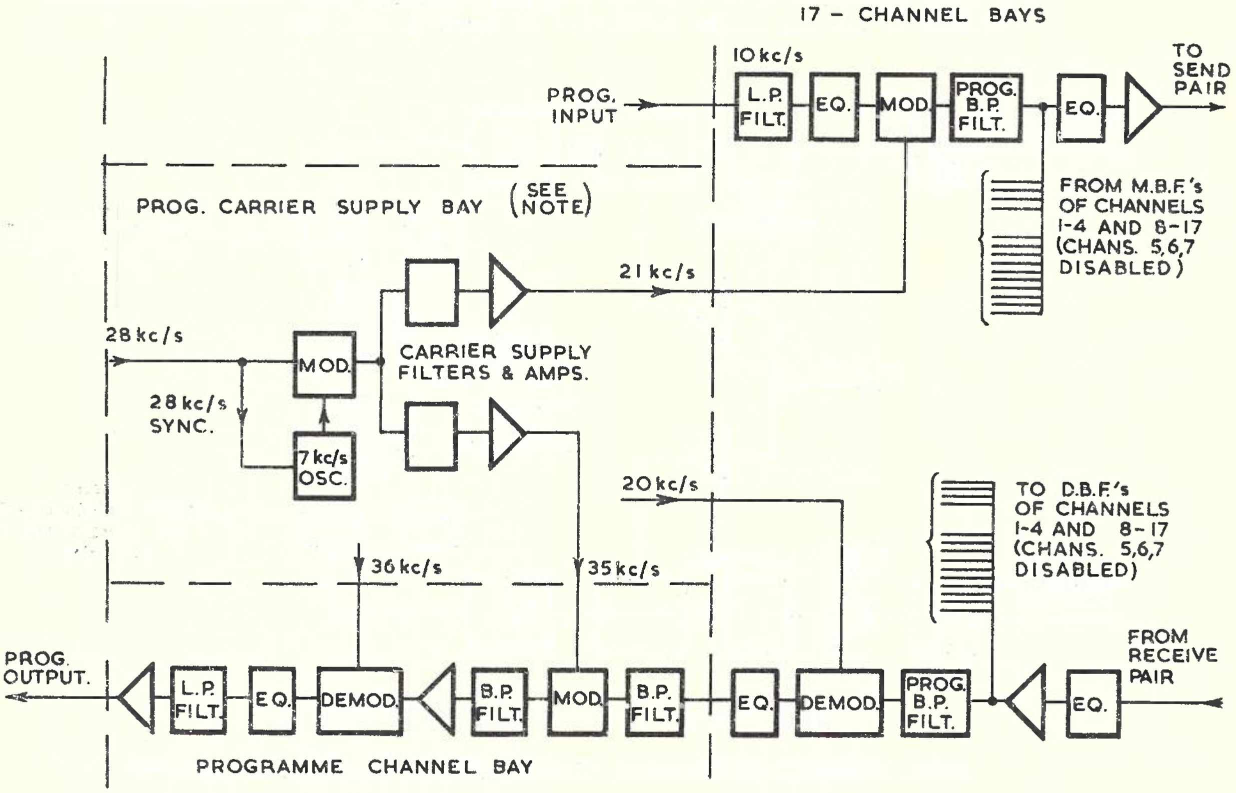
The programme at audio frequencies 35-8,000 c/s is modulated with an 88 kc/s carrier, obtained from the normal carrier distribution system of the associated J or K system. The lower sideband is selected by the band-pass filter for transmission over the system. The programme sideband is fed through a hybrid into the group modulator of the system where it is translated to the line transmission frequencies. The same operation in reverse occurs at the receiving terminal, the programme sideband being selected by the band-pass filter and demodulated to audio frequencies.

The pre-distorter permits the higher frequencies to be transmitted to line at a level greater than that normally transmitted. This results in an increase in the signal-to-noise ratio at the higher frequencies (see paragraph 2.10). The restorer at the receiving terminal restores the levels of the various frequencies to their original relationships and this prevents frequency distortion.

Two delay equalisers are used at each terminal for a particular direction. One operates at audio frequencies and the other at carrier frequencies. These reduce the delay distortion (see paragraph 2.6) to satisfactory limits to permit operation of a number of links in tandem.

/ 11.3

11.3 Programme equipment for use with 17-channel carrier telephone systems has been developed by Communication Engineering Pty. Ltd. A block schematic circuit of the transmitting and receiving terminal equipment is shown in Fig. 30.



NOTE. 20, 28 and 36 kc/s supplies obtained from 17-channel carrier supply bay.

BLOCK SCHEMATIC OF PROGRAMME EQUIPMENT USED WITH 17-CHANNEL SYSTEMS.

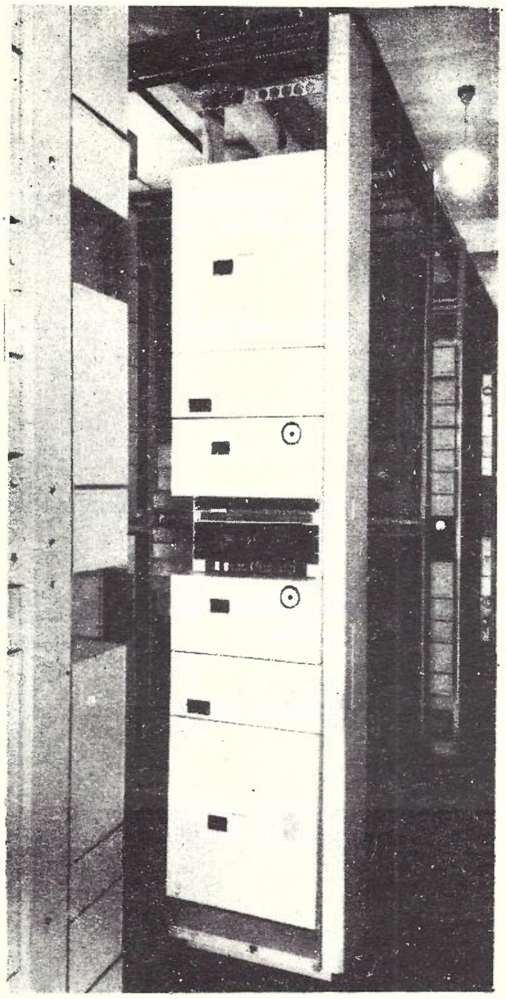
FIG. 30.

As in the case of the 8 kc/s programme carrier described previously, three channels of the associated carrier telephone systems are displaced by this programme system. Duplex operation is possible by providing the necessary transmitting and receiving equipment at each terminal.

At the transmitting terminal, the programme is fed through a 10 kc/s low-pass filter to eliminate all higher frequencies, which, in general, are mainly produced by noise. It is then modulated by a 21 kc/s carrier. The upper sideband is selected by the programme band-pass filter for transmission over the 17-channel system to line. The programme sideband range transmitted to line is 21.035-31 kc/s, that is, in place of telephone channels 5, 6 and 7. The unwanted sideband is not completely suppressed in the programme band-pass filter and frequencies in the lower sideband adjacent to the carrier frequency are transmitted at a reduced level. Complete suppression is obtained in the receiving terminal.

/ At

At the receiving terminal, the programme sideband frequencies are selected by the programme band-pass filter and modulated with a 20 kc/s carrier. The lower sideband range 1.035-11 kc/s is selected by a band-pass filter. Complete suppression of the original unwanted sideband is achieved in this filter. The frequency translation to the 1.035-11 kc/s range enables a sharp cut-off filter to be constructed to obtain the required sideband suppression. To translate the 1.035-11 kc/s sideband to audio frequencies, two further stages of modulation are used. This is done so that spurious products of modulation fall outside the programme band. A 35 kc/s carrier is used in the first modulator. The upper sideband 36.035-46 kc/s is selected, amplified, and fed to the second modulator, which has a 36 kc/s carrier supply. The lower sideband, which is at the original audio frequencies 0.035-10 kc/s, is selected, amplified and applied to the programme circuit. Equaliers are provided in the circuit to correct for losses introduced by the filters.



TYPICAL PROGRAMME EQUIPMENT
FOR USE WITH 12-CHANNEL
WIDE-BAND CARRIER SYSTEMS.

The equipment is mounted on standard 10'6" racks. Portion of the equipment is mounted on the 17-channel system bay in place of the equipment for the three telephone channels which are displaced by the programme system. The remainder of the equipment, apart from that for the carrier supply, is mounted on a separate rack. A carrier supply bay which supplies carrier for up to 20 systems is also provided.

The various carrier frequencies are derived from the master 4 kc/s oscillator associated with 17-channel systems. (See Paper No. 6.) This master oscillator uses inductors and capacitors in the tuned circuit, and is mounted in a controlled temperature oven for better stability. The master oscillators at opposite terminals are synchronised by a 76 kc/s tone transmitted over a cable pair.

The normal 17-channel carrier frequencies, which are harmonics of 4 kc/s, are obtained by placing narrow band-pass filters tuned to the required frequency across the output of a multivibrator driven by the master oscillator. These are then amplified and distributed to the various systems. In the programme system, two frequencies, 21 and 35 kc/s, which are not multiples of 4 kc/s, are used. These are derived as shown in Fig. 30 by modulating 28 kc/s with 7 kc/s. which produces the required frequencies as lower and upper sidebands, respectively. The 7 kc/s oscillator is synchronised by the 28 kc/s supply, which is in turn controlled by the master oscillator, thus ensuring stability of all carrier frequencies.

/ 12.

12. TEST QUESTIONS.

1. Why is a wider band of audio frequencies required for the transmission of a music programme as compared with that required for telephone conversation?

2. What is the effect of overloading an amplifier of the type normally used on programme channels?

3. In specifying amplifiers for use on programme channels, consideration is given, among other things, to the frequency response, gain and power capability. Give figures showing typical values.

4. What is meant by the volume range of a programme circuit and what factors limit this range?

5. Why are equalisers used on programme channels?

6. Draw a block schematic circuit showing equipment which would be used for splitting a single programme to five outgoing channels.

7. Describe the operation of a typical circuit using relay switching for setting up and reversal of the programme equipment at a repeater station.

8. Outline the line-up procedure to be adopted when a physical programme line is to be used for the transmission of musical programmes.

9. Draw a block schematic diagram of the terminal equipment to provide for the transmission of musical programmes over channels of a wide-band carrier telephone system. Describe the operation of the circuit.

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END OF PAPER.