August, 1939

TECHNICAL DESCRIPTION
MARCONI-E.M.I. SYSTEM OF TELEVISION

PART 11 BALANCED VISION CABLE TERMINATION APPARATUS

CONTENTS

BALANCED VISION CABLE TERMINATION APPARATUS

Function of the Apparatus

In carrying out a television O.B., the vision signals generated by the scanning van must be communicated to the radio transmitter either by a link embodying a radio transmitter and receiver, or by some form of line. Unfortunately, ordinary telephone lines, such as are commonly used for programme transmission in sound broadcasting, have an attenuation characteristic as regards the wide band of frequencies necessary for the transmission of high-definition vision signals which presents a severe technical problem when the distances involved are considerable. However, a special vision frequency cable having considerably less attenuation has been developed, which when associated with suitable amplifier-equaliser circuits is capable of faithfully transmitting the required vision frequency band width from an O.B. originating in London to the London Television Station. This cable has been installed at important centres in London, and communicates via Broadcasting House with the London Television Station. The signals from the O.B. point are passed to Broadcasting House, where the attenuation which they have suffered is corrected by means of equalisers and amplifiers. Since the length of vision frequency cable between Broadcasting House and the O.B. point may be variable, the amount of equalisation and amplification can be correspondingly controlled. The signals are then applied to the Broadcasting House—London Television Station section of the vision frequency line, and at the London Television Station are further equalised and amplified in the Vision Cable Termination Apparatus.

The cable operates under balanced conditions in order to reduce interference due to induction from neighbouring power cables and other sources, and the D.C. component of the signals is not transmitted since this can easily be restored. In addition therefore to correcting for the attenuation of the cable, the termination apparatus must restore the D.C. component, and deliver the signal finally at the standard levels which are required by the transmitter. It will be remembered that these levels are as follows :

White level	..	+16.5V
Black level	..	+10V
Sync level	..	+3.5V

The termination apparatus, further, provides a number of standard monitor outputs, having the usual monitor or preview levels, which are as follows :

White level	..	+10V
Black level	..	+3.5V
Sync level	..	0V

The Vision Cable

Since the cable has to transmit frequencies which may be as high as $2\frac{1}{2}$ Mc/s, it is essential, in order to keep losses to the minimum, that a minimum amount of dialectric should be used. The cable has, therefore, been designed as shown in Fig. 1.

There are two conductors, each of 100 lb. copper, and each contained in a paper tube, the diameter of which is much greater than that of the conductor. The conductors are crinkled at intervals so as to provide support

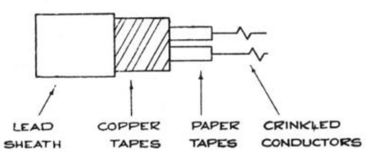

Figure 1. Construction of Vision Cable

against the insides of the paper tubes, but it will be seen that the conductor is largely air-insulated. This construction is successful in producing a low loss cable, as will be seen from the attenuation frequency characteristic, which is given in Fig. 2. The two conductors in their individual paper tubes are twisted together and surrounded by paper worming, which in turn is covered with a layer of copper tapes. The whole is then enclosed in a lead sheath. The characteristic impedance is 186 ohms.

For the higher frequencies the propagation constant of the cable is given by

$$P = \alpha + \mathrm{j}\beta = \frac{R}{2}\sqrt{\frac{C}{L}} + \frac{G}{2}\sqrt{\frac{L}{C}} + \mathrm{j}\omega\sqrt{LC}$$

where α is the attenuation constant and specifies the frequency characteristic of the cable ; β is the phase constant, and specifies the phase characteristic of the cable ; R is the resistance per unit length ; L is the inductance per unit length ; C is the capacity per unit length ; and G is the leakance per unit length.

Equating the real and imaginary sides of the above equation, we have

$$\alpha = \frac{R}{2}\sqrt{\frac{C}{L}} + \frac{G}{2}\sqrt{\frac{L}{C}}$$

and

$$\beta = \omega\sqrt{LC}$$

The Vision Cable *(Contd)*

It will be seen that if R, L, G and C do not vary with frequency, then the attenuation constant is independent of frequency, and there is no frequency discrimination. Also the phase constant is directly proportional to ω, and therefore to the frequency, that is to say, every individual frequency will be rotated through an angle proportional to the numerical value of the frequency, in which case all frequencies are delayed by a definite amount, but no frequency is delayed with respect to any other frequency. There is therefore no phase distortion. Unfortunately, R, L, G and C do not remain constant at the upper frequencies, so that both frequency discrimination and phase distortion are produced. In particular, R rises with frequency, while L falls, both these changes being due to skin effect in the conductors. This distortion must be corrected by the process of equalisation.

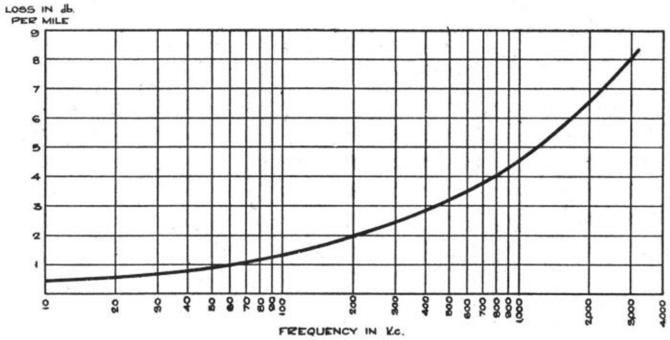

Figure 2. Attenuation-Frequency Characteristic

Principles of Equalisation

Any small element of the cable may be represented by the equivalent circuit of Fig. 3, in which the elements $R_1 L_1$, $R_2 L_2$, etc., are imitating the effect due to the change of inductance and resistance of the cable with frequency. In Fig. 3, $R_1 L_1$, $R_2 L_2$, etc., can be so chosen that the impedance of L_1 and L_2 at low frequencies is much less than R_1 and R_2, and therefore R_1 and R_2 may be neglected, leaving only L_1 and L_2 in circuit. At very high frequencies the impedance of L_1 and L_2 is much greater than R_1 and R_2, and therefore at such frequencies L_1 and L_2 may be neglected, leaving R_1 and R_2 in circuit. The constant component of inductance of the cable is represented by L_0, and the constant component of resistance by R_0. At low frequencies, therefore, the inductance of the cable is $L_0 + L_1 + L_2$, etc., but at high frequencies it is only L_0. The resistance of the cable at low frequencies is R_0, but at high frequencies it is clearly $R_0 + R_1 + R_2$, etc. Thus, the circuit of Fig. 3 indicates an increase of resistance and a reduction of inductance as the frequency rises, which corresponds to the effect in the cable, so that the circuit of Fig. 3 is equivalent to that of the cable. It is the elements $R_1 L_1$, $R_2 L_2$, etc., of Fig. 3 which produce the frequency

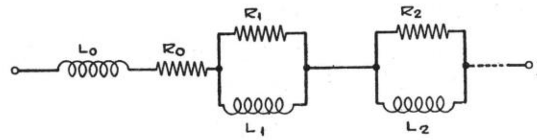

Figure 3

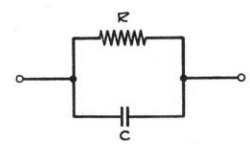

Figure 4

discrimination and phase distortion, and it would seem that to correct for this effect we must apply the remedy, so well known in television technique, of building these elements out to constant impedance. This may be done by inserting in the cable at intervals the small circuit of Fig. 4, and choosing the value of C and R of Fig. 4, as usual, so that it is related to a typical pair of elements, L_1 and R_1, of Fig. 3, by the well known constant impedance formula $\frac{L_1}{C} = RR_1$. It would, however, be inconvenient to insert such elements at intervals in the cable ; we desire to do all the equalisation at the end of the cable. We cannot collect together the total number of circuits of the type shown in Fig. 4, which would be needed completely to correct the frequency characteristic of the cable, and arrange them in series at one end of the cable, because the result would not be the same as if they were evenly distributed along it. If they were inserted at intervals along the cable, each would see on either side of it an approximately constant impedance, the characteristic impedance of the cable, but if they were all connected in series at the end of the cable, each circuit would see the impedance of the cable modified by all the circuits between it and the cable, and equalisation would not be effected. This difficulty is avoided by adopting, instead of the circuit of Fig. 4, the correction network of Fig. 5, from which it will be seen that every series pair of correction elements, such as

$C_1 R_1$, is associated with a pair of shunt elements of the type shown as $L_1 R_2$, etc. The characteristics of any shunt pair, $L_1 R_2$, are inverse to the characteristics of its associated pair, $C_1 R_1$, and the impedance of such a section comprising $C_1 R_1$, $L_1 R_2$ is constant with frequency, or approximately so. A number of such sections may therefore be joined together, each section having a constant impedance but a different attenuation characteristic, so

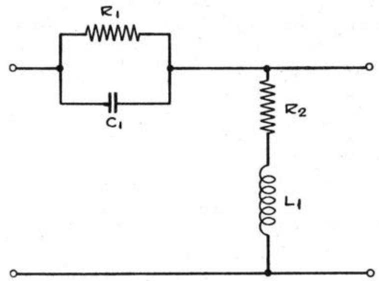

Figure 5

that by the use of a sufficient number of them, a given frequency characteristic, such as that of the vision cable, may be corrected to be straight. It will be seen that the arrangement simulates the effect which would be obtained were a number of circuits of the type shown in Fig. 4 to be inserted at intervals along the cable, since in an equaliser made up of the sections shown in Fig. 5 each of the correction circuits corresponding to Fig. 4 will see on either side of it a constant impedance, as they would do if inserted at intervals in the cable.

In theory, an infinite number of little equalising sections, of the type shown in Fig. 5, will be required to equalise a given physical length of the cable. In practice, however, it has been found possible to use a comparatively small number, which, if properly proportioned, will, to a close approximation, simulate the effect of a very large number of small sections. The term *equalisation* is used here to include correction both for frequency discrimination and phase distortion, both of which effects are simultaneously corrected by the circuits of Fig. 4 or 5. In theory, such simultaneous equalisation of both effects is completely achieved by an infinite number of small sections, but the equalisation will depart from this ideal if, for convenience, we endeavour to lump it into too few a number of sections. The actual number chosen in practice is the minimum which will simultaneously equalise the frequency discrimination and the phase distortion to a sufficiently close approximation.

The practical design of equaliser arising from the above considerations, therefore, consists of a number of sections of the type shown in Fig. 5, and known as the *L*-type, through which the signals pass in turn. The values of the section elements change progressively from section to section, and the successive sections each act upon a portion of the frequency characteristic, commencing with the low-frequency end and ending with the upper frequencies. Each section attenuates the frequencies below the lower end of the small portion of the spectrum upon which it is designed to operate by a certain amount, but passes without attenuation all frequencies above the upper end. For convenience in design and manufacture it has been arranged that, with one or two exceptions, the attenuation produced by each section on the frequencies below its operating region is the same standard figure of 3 db. For example, supposing a certain section is designed to operate upon the frequency band extending between .5 and .6 Mc/s, then the attenuation to frequencies below .5 Mc/s will be 3 db, and that for frequencies above .6 Mc/s will be zero, the attenuation changing smoothly from 3 db to zero over the range between .5 and .6 Mc/s. If the following section is designed to act upon the next small part of the spectrum, say between .6 and .7 Mc/s, it will attenuate all frequencies below .6 Mc/s by 3 db, but will not attenuate the frequencies above .7 Mc/s. Thus, due to the action of the two sections in our example, the attenuation acting on all frequencies below .5 Mc/s will be 6 db. Over the range from .5 to .6 Mc/s the attenuation will smoothly fall to 3 db, and over the range from .6 to .7 Mc/s it will fall to zero. It can be seen, therefore, that by assembling a number of properly graduated sections in cascade, a very considerable attenuation can be built up at the lowest frequencies, such as 50 c/s, and thus can be made to fall to zero at, say, 2 or $2\frac{1}{2}$ Mc/s. Such a group of equalisers will produce precisely the reverse effect on the signals as was exercised by the cable, and the resulting overall characteristic will be flat.

By properly graduating the law controlling the change of the section element values, the facility of simultaneous equalisation of frequency discrimination and phase distortion is retained, even though the actual number of sections is a small finite number, instead of the infinite number theoretically required.

Another advantage attaches to this method of equalisation, in that, if an equaliser is designed to correct for a given length of cable, an equaliser correcting half the length of cable may be formed by utilising every alternate section of the original equaliser. One design will thus cover a number of practical cases.

It has been stated above that the impedance of each equaliser section can be made constant, or approximately constant. For various reasons,

Principles of Equalisation *(Contd)*

it was not convenient to make the impedance constant, and it rises at low frequencies. The manner in which it rises will be different for each equalising section. It therefore becomes impossible to connect a complete series of equalising sections in series, because we are once more departing from the necessity that each section must see a constant impedance on either side of it. It is found, however, that a number of sections may be joined together without any serious error, but between one such group of sections and another group, circuits must be inserted to correct for the change of impedance. The number of circuits in a group will be small in the case of those equalisers which are dealing with the lower part of the frequency spectrum, but a group may include a comparatively large number of sections in the case of those dealing with the upper part of the spectrum. The correction of the error takes the following form. A given group of equalising sections is terminated in a network which is divided into two parts. The second part builds out the impedance of the following equalisers to a constant impedance, and the first part modifies this impedance so that it simulates the impedance of the preceding sections. By this means reflections of energy, with their consequent ill effects upon the picture, are avoided, and any number of groups of equalising sections may be connected together. This problem will be dealt with in more detail in consideration of the individual equaliser circuits.

As usual, the process of equalisation must be accompanied by considerable amplification, since the effect of equalising is, of course, to reduce the level of those frequencies which have suffered little attenuation from the cable to the level of those which have suffered great attenuation. The necessary amplification is accordingly provided.

It might be thought that the whole of the equalisation could be done in one stage, the total attenuation of a cable and equaliser being then made up by appropriate amplification either preceding or following the equaliser, but certain practical difficulties stand in the way of such an arrangement. Owing to the fact that the attenuation of the cable is small at low frequencies and large at the upper frequencies, the low frequency components of the vision signals arrive at the receiving end at a comparatively high level, while the upper frequency components are at a low level. If we connect an amplifier directly to the cable in order to raise the general level of the signals before equalisation, it will deal satisfactorily with the low level upper-frequency components, but it will be overloaded by the high level low-frequency components. We must clearly commence by connecting the cable to the equalising apparatus, and follow the latter with an amplifier. If, however, we connect the whole of the equalising apparatus to the cable, the signals will be so much attenuated that they will fall below the mush level of the subsequent amplifier. It follows that only a portion of equalisation can be connected directly to the cable, after which the emergent signals must be amplified before being equalised further. If we endeavour to effect all the amplification in one stage following the first equaliser, it will be necessary to raise the signals to a much higher level than we finally desire in order to allow for the attenuation of the subsequent equalisation. It follows therefore that the amplifier would necessarily contain many stages, and the latter stages would have to incorporate very large valves. Only a part therefore of the amplification can be performed immediately after the first stage of equalisation, and it will be seen that the amplification, like the equalisation, must be divided up.

It has been found necessary in the practical interpretation of these considerations to divide up both the amplification and equalisation into a number of parts, the signals being alternately equalised and amplified, and in practice the amplifier-equaliser section of the apparatus consists of the following series of stages in cascade :—

(1) Equaliser No. 1.
(2) Equaliser No. 2.
(3) Amplifier No. 1.
(4) Equaliser No. 3.
(5) Amplifier No. 2.
(6) Equaliser No. 4.
(7) Amplifier No. 3.
(8) Equaliser No. 5.
(9) Amplifier No. 4.
(10) Amplifier No. 5.

As a result of dividing the amplification into a number of parts, a further advantage appears in that amplifiers Nos. 1, 2, 3 and 4 of the above list may be all of the same type, and they are known as Cable 'A' Amplifiers ('CA' Amplifiers). Amplifier No. 5, however, must possess rather different characteristics, and is known as a Cable 'B' Amplifier ('CB' Amplifier).

Restoration of Signal to Standard Characteristics

The above series of equalisers and amplifiers comprise all the apparatus necessary to correct for the attenuation of the vision cable and develop a peak to peak amplitude of vision and synchronising signals of some 10 V, and it is now necessary to provide apparatus which will deliver vision and synchronising signals at the standard transmission and preview levels. These levels can clearly be conveniently obtained from a standard Distribution Amplifier. The input to the latter must consist of signals having the following characteristics :—

White level	..	+49.5V
Black level	..	+33V
Sync level	..	+16.5V

Apparatus must therefore be inserted between the output of the CB Amplifier and the input of the Distribution Amplifier, which will deliver to the latter a signal having the required characteristics. This unit is known as the Receiving Amplifier. In addition, some means must be provided of measuring separately the amplitudes of the picture and synchronising signals at the input of the Distribution Amplifier, and for this purpose a unit known as the Peak Level Indicator is provided, a suitable input for which is also generated by the Receiving Amplifier. An A.C., L.T. supply, various stabilised H.T. supplies, and a negative H.T. supply are required to operate this apparatus, and for general examination of waveforms a Waveform Monitor is provided.

The Complete Equipment

The complete equipment required to receive signals from the vision cable and deliver them in the form of transmission and preview outputs at the standard levels, comprises the following :—

(1) Equaliser No. 1.
(2) Equaliser No. 2.
(3) CA Amplifier.
(4) Equaliser No. 3.
(5) CA Amplifier
(6) Equaliser No. 4.
(7) CA Amplifier.
(8) Equaliser No. 5.
(9) CA Amplifier
(10) CB Amplifier
(11) Receiving Amplifier.
(12) Distribution Amplifier.
(13) Peak Level Indicator.
(14) Waveform Monitor.
(15) L.T. Unit.
(16) Two H.T. Units.
(17) Two Stabilisers, Type 5c.
(18) Stabiliser, Type 4c.
(19) Negative Rectifier.
(20) Battery Panel.

Of these various pieces of apparatus, the Distribution Amplifier has been described in Item 5.7 : the Receiving Amplifier and the Peak Level Indicator in Item 9.1 : the Waveform Monitor in Item 6.1 : and the Stabilisers and Battery Panel in Item 6.2. The H.T. and L.T. power units and the Negative Rectifier are of straightforward design and do not warrant detailed treatment. It remains, therefore, to describe the following, namely, the Equalisers, the CA Amplifier and the CB Amplifier, which is done in Items 11.1, 11.2, and 11.3, respectively. The operation and maintenance of the equipment as a whole is dealt with in Item 11.4.

VISION CABLE EQUALISERS

The group of equalisers described in this section form part of the apparatus at the London Television Station for terminating the balanced vision cable incoming there from Broadcasting House. The equalisers provide equalisation for both the frequency discrimination and the phase distortion occurring in the cable, and are five in number.

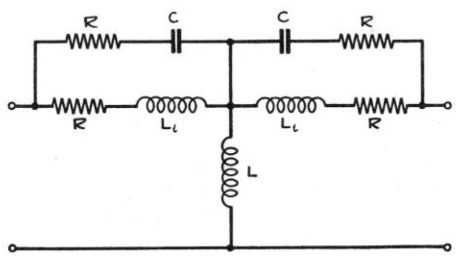

Figure 1

Equaliser No. 1

The circuit of this equaliser is shown in Fig. 3.

Since the cable is balanced, either the equaliser which is connected to it must be balanced, or the cable must be connected to a transformer or other device for rendering the signals unbalanced, after which an unbalanced equaliser can be used. An unbalanced equaliser is more convenient since it contains fewer components.

It is necessary, however, for one or two other functions apart from equalisation to be carried out by the first equaliser, and such functions require it to be balanced. In the first place there is a liability that surges in power cables running near to the vision cable may from time to time induce high voltages into the latter. Such voltages must obviously be prevented from influencing the equaliser/amplifier apparatus, and so it is desirable to insert at an early stage a transformer which will not pass such surges. It is accordingly inserted in the first equaliser, and is shown in Fig. 3 as TR_1. This transformer is insulated for 1,000V A.C. The core of this transformer would be overloaded by the high level low-frequency components from the cable, so that it is not placed at the beginning of the equaliser, but the signals first pass through two stages of equaliser of the type shown in Item 11.0, Fig. 5, in order that the low-frequency components may be somewhat
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attenuated. These two sections of equalisation must clearly be balanced.

Referring to Fig. 3, the vision cable is connected to the terminals T_1 T_2, and ignoring for the moment the function of the elements L_1 R_1, L_2 R_2, and R_3, the signals pass in turn through the first stage of equalisation involving the elements C_1, R_4, L_3 and R_5 on the one side, and C_2, R_6, L_4 and R_7 on the other side. They then pass through the second stage of equalisation,

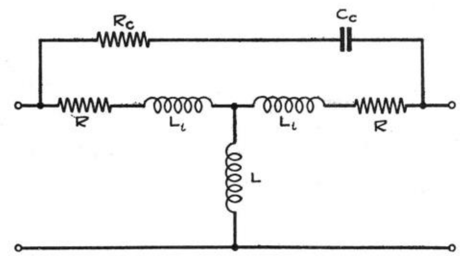

Figure 2

involving the elements C_3, R_8, L_5 and R_9 on the one side, and C_4, R_{10}, L_6 and R_{11} on the other. They then enter the transformer TR_1.

It was not practicable to design the transformer TR_1 to operate satisfactorily over the whole range of frequencies, from nearly zero up to some 2 Mc/s, and it was therefore arranged that the transformer would pass the lower frequencies only, and that with it would be associated a network to carry the upper frequencies. The transformer TR_1 can be represented at the upper frequencies by the equivalent circuit shown in Fig. 1, where L is a very high inductance, L_l L_l are the leakage inductances, and R R are the resistances of the windings. Employing once again the principle of constant resistance, if the condensers C in series with the further resistances R are connected between the two windings of the transformer, and are so chosen that $\frac{L_l}{C} = R^2$, the whole device will behave at all frequencies as though it were a constant resistance equal to R. The low frequencies of the vision signal pass through the transformer, which, however, holds back any surges induced from neighbouring cables, as such surges would not be balanced, i.e. they will arrive in parallel along both of the cable connectors. The upper frequencies of the vision signals will pass through the shunt condensers and resistances. Clearly the two pairs of shunt condensers and resistances of Fig. 1 may be replaced by one pair, as in Fig. 2. As a further refinement,

Equaliser No. 1 *(Contd)*

the whole of the network of Fig. 2, which is equivalent to a pure resistance, may be used as a series resistance for the next equaliser section.

Referring to Fig. 3, we can now see how this technique is interpreted in the practical equaliser. After having passed through the first two stages of balanced equalisation, the signals have arrived at the point AA'. They now pass through the resistances R_{12} and R_{13}, and then through the primary winding 1, 2 of the transformer TR_1, which completes the circuit. It is still desired to retain the balanced circuit, so the transformer TR_1 has a secondary, 3, 4, 5, 6, with the centre point earthed, and the signals emerging from this pass through the resistance R_{14} on the one side and R_{15} on the other. The function of the resistances R_{12}, R_{13}, R_{14} and R_{15} are to build out symmetrically the primary and secondary resistances to a convenient total value (R of Fig. 1), so that the practical value of the leakage inductance L_1 can be accommodated. The signals have now arrived at the point BB'. The constant resistance network of Fig. 2 is now formed by the addition on the one side of the elements C_5 R_{16}, and on the other side by the corresponding elements C_6 and R_{17}. Each of these pairs of elements corresponds to the elements R_c and C_c of Fig. 2.

We can now commence the next section of equalisation. As has been explained, the network involving the transformer TR_1 and its associated elements is equivalent to a pure resistance. Before entering the network the signals had arrived at the point A on the one side, and A' on the other, and after leaving the network they have arrived at the point B on the one side and B' on the other. Between the points A and B there is therefore a pure series resistance, and also a similar series resistance between the points A' and B'. These resistances can be the series resistances of the next stage of balanced equalisation, of the type shown in Item 11.0, Fig. 5, and they must therefore be shunted by condensers. The condenser on the one side is C_7, and that on the other C_8. This stage of equalisation is completed by the addition of the usual shunt elements L_7 and R_{18} on the one side, and L_8 and R_{19} on the other. The fourth stage of equalisation follows, involving on the one side the elements C_9, R_{20}, L_9 and R_{21}, and on the other side C_{10} R_{22}, L_{10}, and R_{23}. The signals now pass to the fifth stage of equalisation, involving on the one side the elements C_{11}, R_{24}, L_{11} and R_{25}, and on the other side C_{12}, R_{26}, L_{12} and R_{27}. The signals have now arrived at the point DD'.

It is now necessary to guard against what are known as *phantom currents*. In a balanced circuit all the desired currents should be absolutely balanced, that is to say, the two sides of the circuit should be operating in push-pull. It is, however, difficult to keep the vision cable carefully balanced at the very high frequencies, and there is a possibility that a part of the signals, due to loss of balance, may tend to be transmitted along the two inner conductors in parallel, using the outer as a return. Such an unbalanced circuit, in which currents flow in phase along the two conductors of an existing circuit, which is intended to be operating in the balanced state, is known as a *phantom circuit.* (The balanced circuit is often referred to as the *side circuit.*) There is the liability that the unbalanced signals transmitted along the phantom circuit would, at the receiving end, interfere with the balanced signals transmitted along the side circuit, and the phantom signals must therefore be eliminated. This is the function of the transformer TR_2 in Fig. 3.

It will be seen that this transformer has two windings, one of which is connected in series with each side of the balanced circuit. By connecting the windings in the appropriate direction it can be arranged that the transformer is effectively non-inductive to the balanced currents of the side circuit, but that the phantom currents will cancel out. This transformer has, as is always the case, some residual leakage inductance, which appears as a small resultant inductance in the side circuit, and if this is not cancelled out it might cause distortion at the very high frequencies. It is, however, avoided by designing the windings of the transformer so that the leakage inductance and distributed capacity between the two windings together form a short section of line whose characteristic impedance is the same as that of the equaliser.

The signals have now arrived at the point EE', and all the operations upon the signal which necessitate the circuits being retained in the balanced state have been completed. One side of the equaliser is therefore terminated to earth in its own impedance, and the voltage in it is ignored, while the other side provides an unbalanced output, which is passed to the next equaliser.

The equaliser (No. 1) is not of the constant resistance type, so that the termination for that side which is now to be terminated will not be a pure resistance. Referring to Fig. 3, the upper half of the equaliser is shown terminated, the termination consisting of the elements C_{13}, R_{28} and R_{29}. The lower half of the equaliser provides, between the point E' and earth, the desired unbalanced output, and is terminated by the subsequent circuit, which is actually equaliser No. 2. This, together with all subsequent equalisers, will be unbalanced.

It has been stated that the equaliser is not of the constant impedance type; clearly, therefore, it can not terminate the vision cable in its own impedance of 186 ohms. The elements L_1 R_1 and L_2 R_2 are therefore connected between the equaliser as a whole and the vision cable, in order to build the equaliser out to a constant resistance, which, when combined with the further resistance R_3 in Fig. 3, terminates the vision cable exactly.

The impedance of each side of the equaliser is 93 ohms, so that the impedance of the complete equaliser, as shown in Fig. 3, is 186 ohms, which matches the characteristic impedance of the cable.

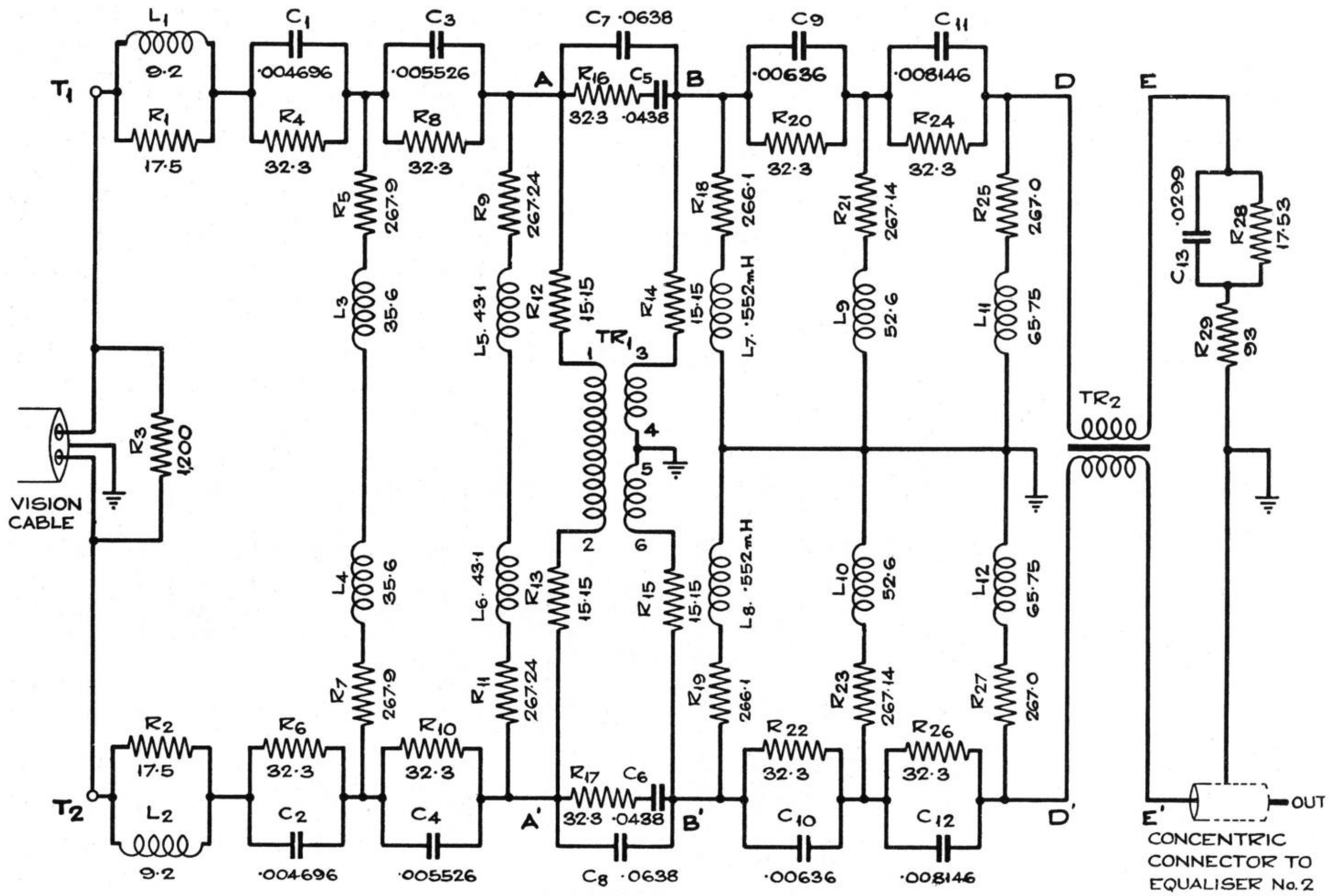

Figure 3. Equaliser No. 1

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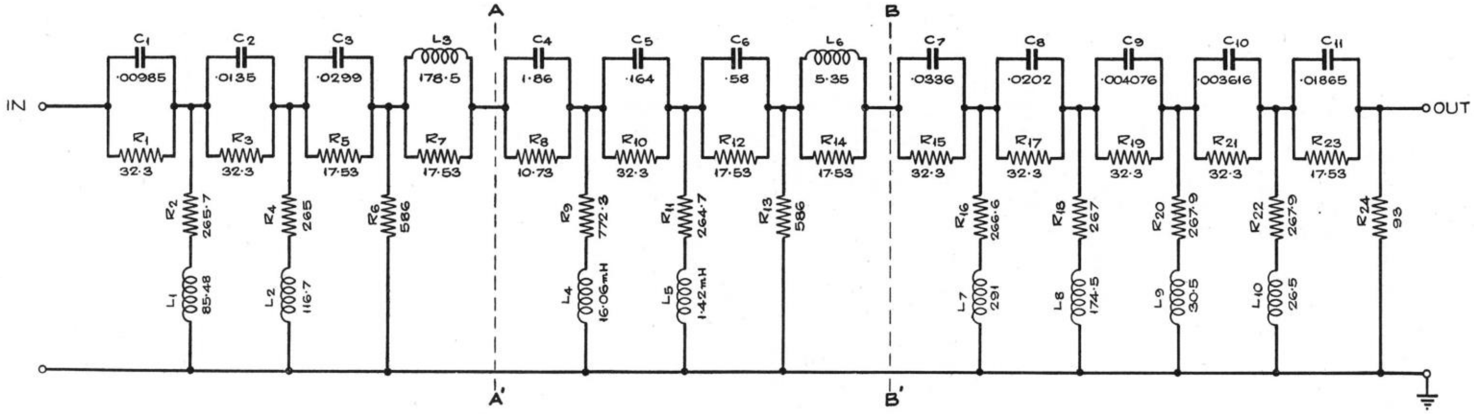

Figure 4. Equaliser No. 2

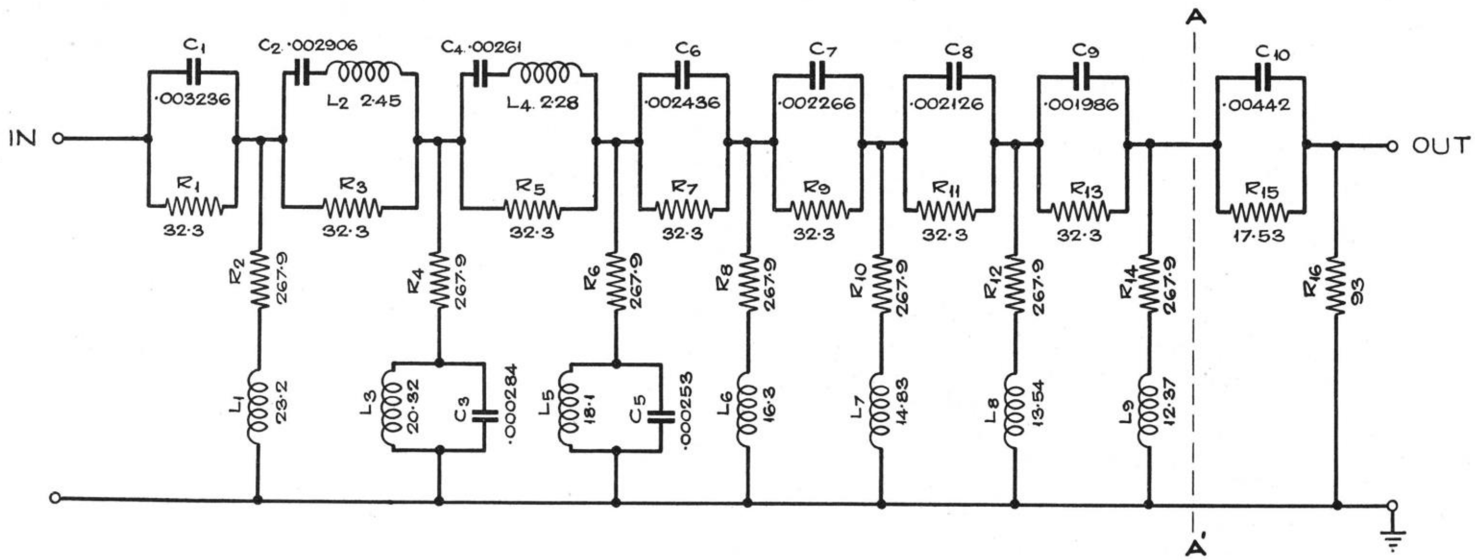

Figure 5. Equaliser No. 3

Equaliser No. 2

The circuit of this equaliser is shown in Fig. 4.

It has, as we expect, an iterative impedance of 93 ohms. The signals from Equaliser No. 1 are applied to the input and passed through the first section involving C_1, R_1, L_1 and R_2, and then to the second section comprising C_2, R_3, L_2 and R_4. At this stage it becomes necessary to insert one of the terminating sections, the principle of which has been described above in Item 11.0 under "Principles of Equalisation."

In the first place the impedance of the whole of the subsequent equaliser, that is to say of the apparatus to the right of the line AA' in Fig. 4, must be built out to appear to have a constant value. This is done by the inclusion of the elements L_3 and R_7. The elements C_3, R_5 and R_6 are now inserted to modify this constant impedance, so that the first two sections comprising $C_1 R_1 L_1 R_2 C_2 R_3 L_2 R_4$ are terminated in their own impedance. The signal is then supplied from the points AA' to two further stages of equalisation involving respectively the elements $C_4 R_8 L_4 R_9$ and $C_5 R_{10} L_5 R_{11}$, by which time the impedance has once more deviated from a constant value to an extent which requires a further termination. The elements C_6, R_{12}, R_{13}, L_6 and R_{14} are therefore included, and perform respectively the same functions as the elements C_3, R_5, R_6, L_3 and R_7, which we met earlier on. We have now arrived at the points BB', and can continue with further equalisation.

It will be seen from Fig. 4 that four stages of equalisation now follow, after which there is a termination section involving the elements C_{11}, R_{23} and R_{24}. It will be noticed that this termination differs from the two previous terminating sections situated at AA' and BB'. This is because we have now arrived at the end of the equaliser, and it will deliver its output to an amplifier instead of a further equaliser. The amplifier will have a constant input impedance of high value, so that in the first place it will be unnecessary to include any elements similar to L_3 and R_7, and secondly the value of R_{24} will obviously differ from one of the previous equivalent resistances such as R_6, since the input impedance of the amplifier is much higher than that of the group of equalisers between AA' and BB'. It is given, in fact, the value of the iterative impedance of the equaliser, 93 ohms, and this, the final terminating impedance, is modified by the inclusion of the elements C_{11} and R_{23} so as to match the impedance of the group of equalisers between BB' and the output.

Equaliser No. 3

The circuit of this is shown in Fig. 5. It contains seven individual stages of equalisation, followed by one terminating section, the iterative impedance being 93 ohms.

The output from 'CA' Amplifier No. 1 is applied to the input terminals, and passes through a normal equalising section comprising C_1, R_1, L_1 and R_2. The signals then pass through two equalising sections of rather different character, but operating on the same principle.

This equaliser is operating on the upper middle frequencies, where the attenuation is changing with frequency rather more quickly than over the remainder of the frequency band. It is consequently necessary for the reactance of certain of the equalising sections in this equaliser to change with frequency rather more quickly than at the remaining sections in this and the other equalisers in order that the correction may correspond precisely to the inverse of the cable attenuation. The second and third equalising sections in Fig. 5, therefore, have series circuits in the series arms involving $C_2 L_2$ and $C_4 L_4$, the addition of the inductances L_2 and L_4 causing the reactance of the complete arms $C_2 L_2$ and $C_4 L_4$ to change more rapidly than if they were to be formed with condensers only. Since the impedance characteristic of the shunt arms must be the inverse of that in the series arms, it becomes necessary for the shunt arms of these two equalising sections to contain parallel combinations of inductance and capacitance, instead of the more usual inductances. These are shown as $L_3 C_3$ and $L_5 C_5$ in Fig. 5. By this means the two sections still retain their approximately constant impedance characteristic.

The signal then passes through four sections of normal equalisation, and arrives at the point AA'. The impedance of the equaliser as a whole has now deviated from a constant value to an extent which renders a termination necessary according to the technique already described. The equaliser is accordingly terminated in a pure resistance R_{16}, and this is built out to match the impedance of the equaliser by the inclusion of the elements C_{10} and R_{15}. The output is applied to 'CA' Amplifier No. 2.

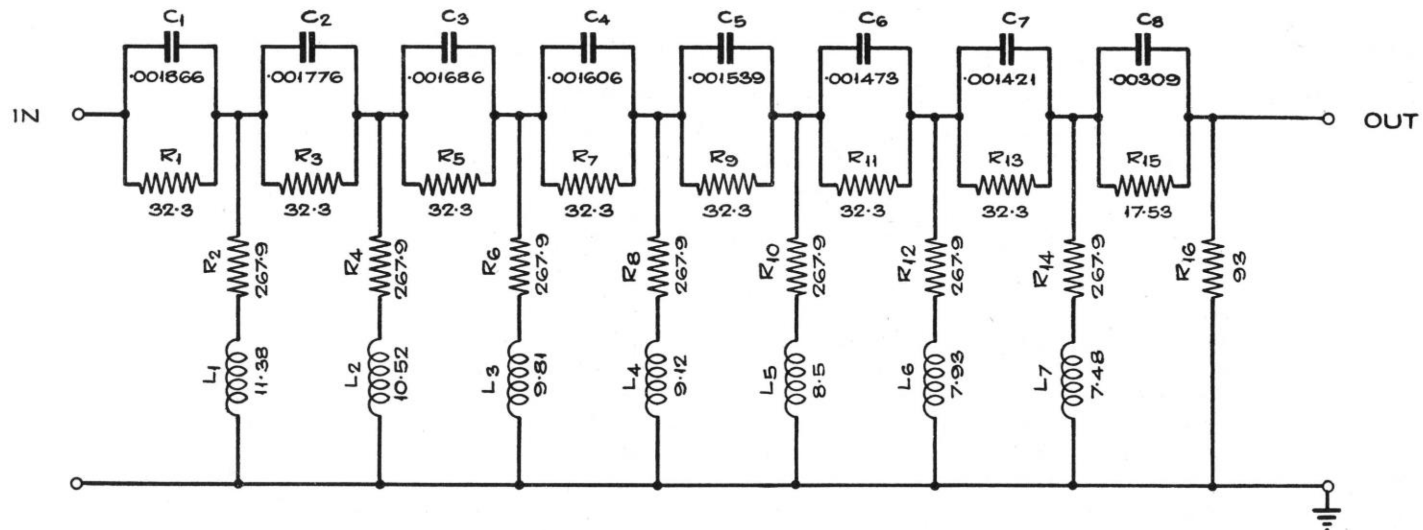

Figure 6. Equaliser No. 4

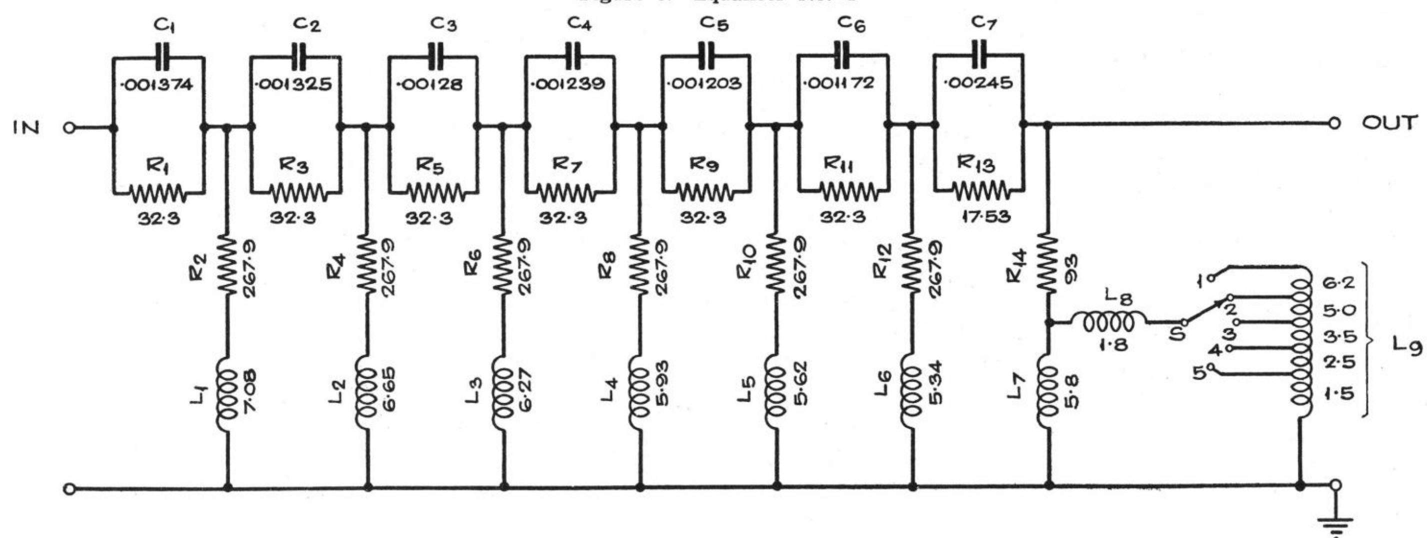

Figure 7. Equaliser No. 5

Equaliser No. 4

The circuit of this is shown in Fig. 6. It contains seven individual stages of equalisation, followed by one terminating section, the iterative impedance being 93 ohms.

The output from ' CA ' Amplifier No. 2 is applied to the input terminals, and no special description of this equaliser is necessary, as it will be seen that it consists of seven straightforward sections, after which the now familiar impedance deviation is corrected by the usual termination, shown as R_{16}, together with the correction elements C_8 and R_{15}. The output of this equaliser is applied to ' CA ' Amplifier No. 3.

Equaliser No. 5

The circuit of this is shown in Fig. 7. It contains six individual stages of equalisation, followed by one terminating section, the iterative impedance being 93 ohms.

The output from ' CA ' Amplifier No. 3 is applied to the input terminals, and passes through the six stages of equalisation. The impedance deviation is, as before, corrected by the termination resistance R_{14}, which has the value of the iterative impedance, together with the correction elements C_7 and R_{13}.

In the case of this final equaliser one further correction was found to be desirable. The attenuation of the cable at the uppermost frequencies varies slightly with temperature, and to get exact equalisation at these frequencies, it is desirable to have available a variable section which can be adjusted to compensate for such changes. This takes the form of the elements L_7, L_8 and L_9 of Fig. 7, the latter, as will be seen, being a variable inductance. For normal temperatures the selector switch S should be set at *stud* 3. By moving the switch from one contact to the next one, the high frequency attenuation at 2 Mc/s is changed by about .5 db. The output of this equaliser is applied to ' CA ' Amplifier No. 4.

‘CA’ AMPLIFIER

Four of these amplifiers are used in the Vision Cable termination apparatus to compensate for part of the loss introduced by the equalisers. One amplifier is connected in circuit following Equaliser No. 2, one following Equaliser No. 3, one following Equaliser No. 4, and one following Equaliser No. 5.

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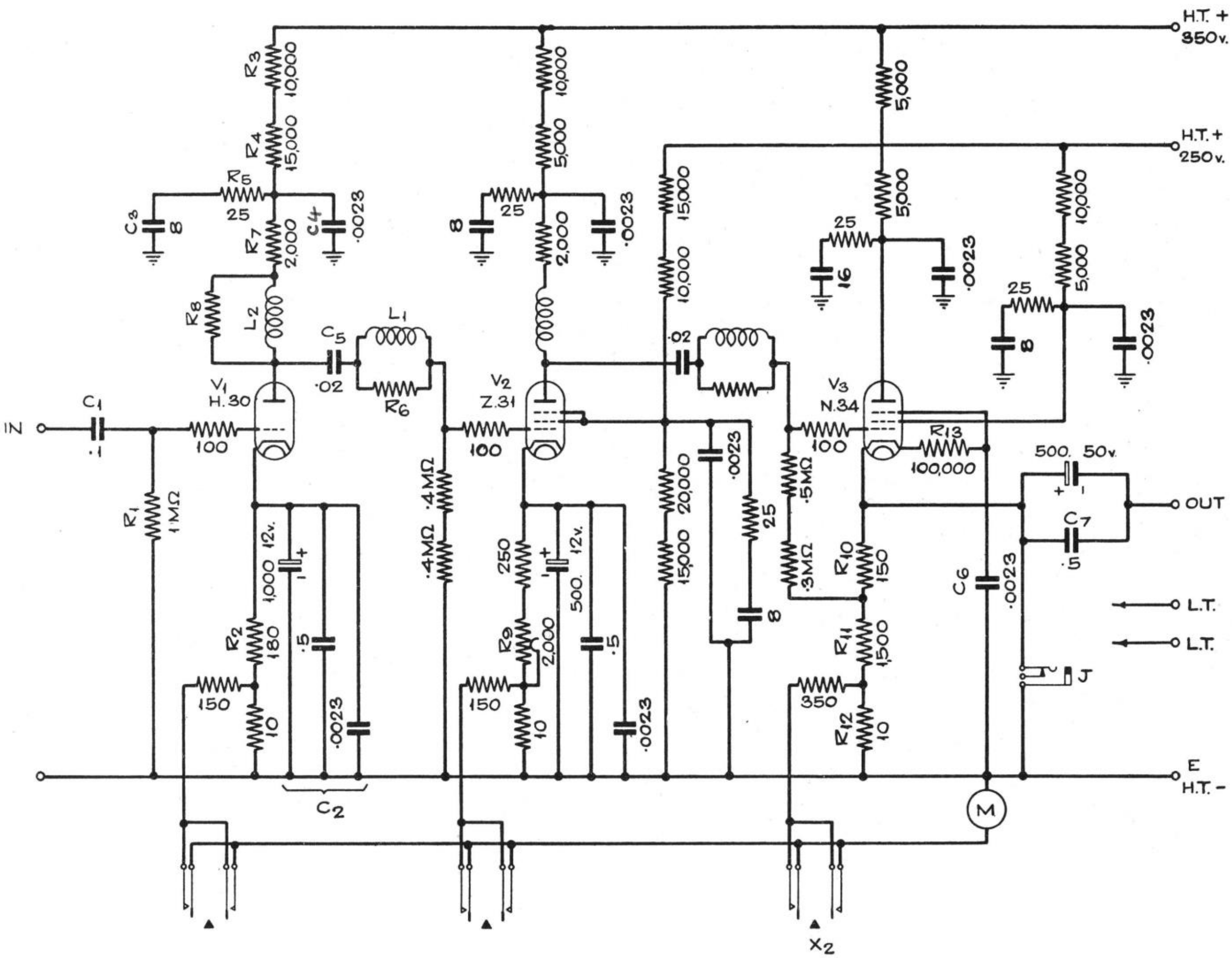

Figure 1. The 'CA' Amplifier.

Referring to the Circuit Diagram the input from the Equaliser is applied through the grid condenser C_1 and the grid resistance R_1 to the grid of the first valve V_1. The grid resistance R_1 is given a large value in order that the input impedance may be high, and that the termination of the preceding equaliser may be unaffected. The cathode circuit provided by the resistance R_2 is shunted by the condenser C_2 to provide normal automatic grid bias. The anode circuit is decoupled by the resistances R_3 R_4 and the condensers C_3 C_4. In theory a single condenser of large value, C_3, would be adequate to provide decoupling, but such condensers together with their leads have appreciable inductance at the upper frequencies in the vision frequency range and their impedance is therefore insufficiently low. To lower the impedance at the upper frequencies, a small condenser, exemplified in the present case by C_4 is connected, but this unfortunately will resonate with the inductance of the condenser C_3, and the resulting parallel tuned circuit between the anode circuit and earth has a high impedance at a particular frequency at the edge of the vision frequency range. To render this effect inappreciable, a small resistance R_5 is inserted, which has the effect of reducing the resonant impedance of the equivalent parallel tuned circuit. This occurs because the resonant impedance is given by the formula $Z = \frac{L}{CR}$ In this case, L is the inductance of the large condenser C_3, the capacity of which may be neglected ; C is the value of the small capacity C_4 ; and R is the value of the resistance R_5. It will be seen that as R increases, the value of the resonant impedance, Z, decreases, and the discrimination of the decoupling in favour of a very high frequency is largely eliminated.

The first valve, V_1, is a triode, since the level of the input signals is not very high and a quiet valve is therefore desirable at this stage. The inter-valve coupling contains the blocking condenser C_5, and the usual elements L_1 R_6, which give the coupling the configuration of a prototype low-pass filter. The filter is terminated at the sending end by the elements R_7 and L_2, the resistance R_8 being added to improve the phase response at the upper frequencies.

The output of V_1 is applied to V_2, the circuit of which is generally similar to that of V_1, except that a pentode can now be used instead of a triode, so that the necessary arrangements are required for feeding and decoupling the screen and suppressor grids. The cathode circuit of V_2 is arranged to provide automatic grid bias, but a portion of the cathode resistance R_9 is made variable so that the bias on the valve may be altered as a means of controlling the gain. The latter is in consequence continuously adjustable over a range from a minimum of 10 db to a maximum of 30 db. The resistance R_9 is brought out to a manual control on the front of the panel designated **Gain.** This method of gain control may be safely used, as the amplitude of the signal is quite low at the grid of V_2, and no appreciable harmonic distortion (which would manifest itself as a change of *gamma*) will be introduced by varying the bias of the valve.

The output from V_2 is applied to the third valve V_3, which is a cathode follower output stage. The anode circuit therefore contains no anode impedance, but is decoupled. The screen grid is fed normally. The cathode circuit contains the resistances R_{10}, R_{11} and R_{12}, which are unshunted by capacity, and so develop the necessary feed-back, while the grid resistance is returned to the junction of R_{10} and R_{11} in order to pick up the correct grid bias. The suppressor grid requires the same D.C. potential as the cathode, and is therefore connected to it by the resistance R_{13}. It is, however, held down to earth potential at the upper vision frequencies by the condenser C_6. The output is taken from the cathode of V_3 through the blocking condensers C_7, which hold off the steady positive cathode potential. The jack J_1 is provided for observation of the output on the Waveform Monitor, and under normal circumstances this should appear in the negative sense with synchronising signals acting positively, and should have a double amplitude peak of 0.23V.

'CB' AMPLIFIER

This amplifier is used in the Vision Cable Termination Apparatus to make good part of the equalisation loss, and the place in the circuit is between ' CA ' amplifier No. 4 and the Receiving Amplifier.

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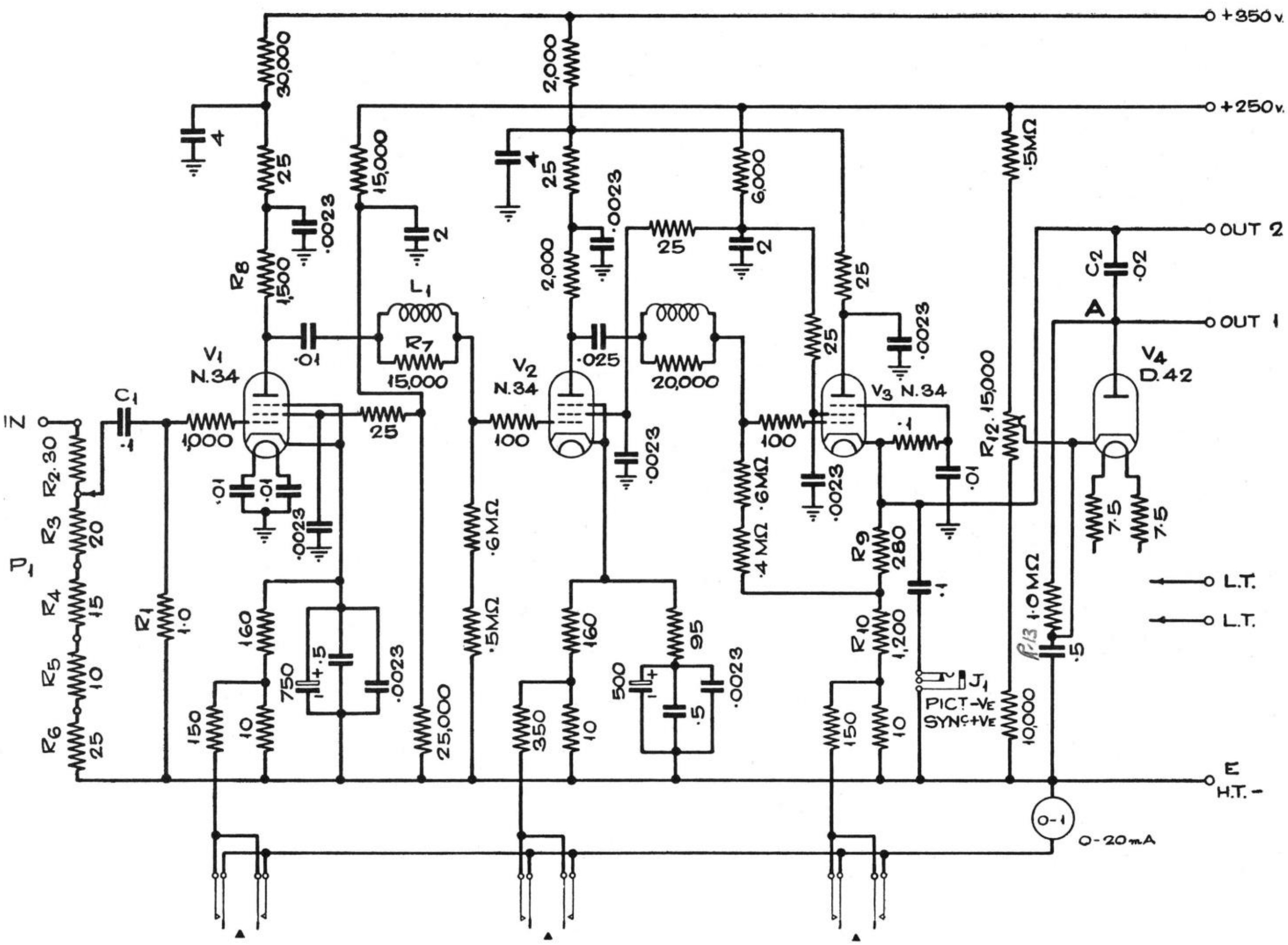

Figure 1. The ‘ CB ’ Amplifier.

Referring to the Circuit Diagram, the output from the preceding ' CA ' Amplifier is applied to the grid of the first valve via the usual elements C_1 R_1. A gain control is desirable, but the level in this amplifier is too high to permit of this being effected by means of a variable-mu bias, the adjustment of which would alter the gamma of the signals. The potentiometer P_1, consisting of the resistances R_2 to R_6, is therefore interposed between the input and the grid circuit of V_1. This potentiometer, which is brought out as a manual control, is designated **Gain,** and enables the amplification to be adjusted in four steps of approximately 3 db each. The cathode circuit of V_1 provides normal automatic grid bias. The anode circuit, which is decoupled in the normal manner, is coupled to the grid of the second valve V_2 by means of the usual elements L_1 R_7. This gives the coupling the configuration of a low-pass filter whose termination consists of the anode resistance R_8.

The circuits associated with the second amplifying valve V_2 are similar to those of V_1. The output from V_2 is applied to the third valve V_3, which is a cathode follower output stage. The anode circuit therefore contains no anode impedance, but is decoupled. The cathode circuit contains the resistances R_9 and R_{10}, which provide the necessary degree of feed-back, whilst the correct grid bias is secured by returning the grid resistance to the junction of R_9 and R_{10}.

The signals at the cathode of V_3 have a double amplitude peak of 6.6V, and are of the A.C. type, that is to say, the datum line corresponding to any particular part of the signal, such as a black, will float in accordance with the effect of the preceding amplifier characteristics on the original D.C. component of the signal. They are, however, in a sense D.C. signals, since they are superimposed upon the standing positive cathode potential of the valve V_3. The output of this amplifier will be applied to the Receiving Amplifier, the first valve of which has a characteristic which, though adequate to deal with vision signals having a double amplitude peak of 6.6 V, operating about a fixed datum line, is not long enough to deal with signals of this amplitude but having an unstabilised datum line. It is therefore necessary to eliminate the standing positive D.C. potential which accompanies the signals at the cathode of the valve V_3 and to stabilise the datum line of the resulting A.C. signals by restoring D.C. Since we are merely endeavouring to eliminate the float of the datum line of the A.C. signals, it is not necessary to incorporate any very elaborate method of D.C. restoration, and it will suffice to restore D.C. with respect to the troughs of the synchronising signals, which, in the circumstances, is the easiest course. The Receiving Amplifier will itself later in the chain restore D.C. with reference to black level, which is the more ideal method.

The characteristics of the D.C. input required by the Receiving Amplifier are as follows :—

Sync Level	..	..	+ 9.2 V
Black Level	..	..	+ 5.9 V
White Level	..	..	+ 2.6 V

The D.C. restoring circuit must therefore align the troughs of the synchronising signals upon a potential of + 9.2 V.

Returning to the Circuit Diagrams, the standing D.C. potential at the cathode of V_3 is eliminated by the condenser C_2, from which the signals are passed to the anode of the diode V_4. The cathode of the diode is returned to the potentiometer R_{12}, upon which a positive potential of 9.2 V, derived from the H.T. line, may be found. In parallel with the diode is the load resistance R_{13}. In operation the vision signals from C_2 are applied to the anode of the diode, and endeavour to make it more positive than the cathode, but as usual this is impossible, since if it becomes in the slightest degree more positive, the diode impedance rapidly falls and anode current flows. The effect of the anode current is to charge the condenser C_2 negative by an amount equal to the difference of voltage which the signal is trying to establish between the anode and cathode of the diode. This difference is therefore extinguished, and the anode always takes up the same potential, viz., 9.2 V, for each positive peak of the input signal. Since the positive peaks are the synchronising signals, they are all aligned, as desired, at the figure of + 9.2 V. At the anode of the diode, therefore, there appears the correct output which is required by the Receiving Amplifier, and the output is taken from this point.

The jack J_1 is provided between the cathode of V_3 and earth in order to permit of examination of the signals on the Waveform Monitor, and at this point they should be negative in sense, A.C. in character, and have a double amplitude peak of 6.6V.

BALANCED VISION CABLE TERMINATION APPARATUS
OPERATION AND MAINTENANCE

Operation

Switching On

(1) Close the iron-clad switch on the West Wall.

(2) Close the mains switch at the bottom of the centre fish plate, when the green indicator lamp just above it will light. This applies A.C., to the stabilisers (whose filaments become energised), to the negative rectifier, and to the main L.T. unit.

(3) Close the main switch of the L.T. unit at the bottom of the left-hand bay. This will energise all the heaters of the equipment, including those of the H.T. rectifiers, together with their appropriate thermal delays.

(4) Close the main switches of the two H.T. rectifiers, one on each bay. H.T. will be developed after the thermal delays have operated.

(5) Close the main switch of the Signal Monitor, which is a self-contained unit.

Adjustment of H.T. Voltages

(6) Check the output voltages of the H.T. Stabilisers as follows :—

Stabiliser No. 1, push button No. 4	350V
Stabiliser No. 1, push button No. 3	250V
Stabiliser No. 2, push button No. 4	350V
Stabiliser No. 2, push button No. 3	250V
Stabiliser No. 3, push button No. 4	300V
Stabiliser No. 3, push button No. 3	0V

If these voltages are not correct, they may be adjusted by removing the front cover of the appropriate stabiliser and adjusting the preset potentiometer labelled **Voltage Control.** It is particularly important that the output voltages of Stabiliser No. 2 should be correct, as from them we derive the fundamental settings of black level.

Adjustment of Peak Voltmeter

(7) Set the switch on the Peak Level Indicator panel to the position **Adj. Zero.**

(8) Adjust the preset potentiometer designated **Picture Zero** on the Peak Level Indicator until the picture peak voltmeter reads zero.

(9) Adjust the preset potentiometer designated **Sync Zero** on the Peak Level Indicator panel until the sync voltmeter reads zero.

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(10) Return the switch on the Peak Level Indicator panel to the position **Operate.**

Adjustment of Black Level

(11) Remove signal output from line amplifiers by unplugging any of the flexible inter-amplifier connectors behind the racks.

(12) Set the Receiving Amplifier Anode resistance key to the **low-resistance** position.

(13) Set the preset potentiometer designated **Adj. Ratio Control** of the Receiving Amplifier fully anti-clockwise.
The object of this is to elevate the potential of the cathode of the valve V_5 of the Receiving Amplifier to a potential more positive than black level, so that this valve will be inoperative at black level, and pure black level can therefore proceed from the cathode of V_4 of this unit, through the picture/sync ratio potentiometer, and finally through the valve V_6 to the Peak Level Indicator.

(14) Set the **picture/sync ratio** control of the Receiving Amplifier fully clockwise.

(15) Adjust the **black level** control of the Receiving Amplifier so that both peak voltmeters read zero.

(16) Reset the **picture/sync ratio** control of the Receiving Amplifier fully anti-clockwise.

Obviously if V_5 in the Receiving Amplifier is out of action, as stated above, there should be no change of potential along the picture/sync ratio potentiometer, and the adjustment of it from the clockwise position to the anti-clockwise position should not result in any change of the readings of the peak voltmeters. If a change is noted, repeat (13), (14) and (15) above.

(17) Set the **Adj. Ratio Control** potentiometer of the Receiving Amplifier so that the sync voltmeter reads + 1V and the picture voltmeter – 1V.
This adjustment is intended to set the cathode potential of the valve V_5 of the Receiving Amplifier to black level, so that the picture/sync ratio potentiometer will act upon picture signals only. In theory, therefore, the adjustment should be such that the two peak meters are about to show a change in reading. However, owing to the curvature of the foot of the characteristic of the valve V_5, it is desirable to adjust the cathode potential unit until it is 1V below black level, so that the blacks of the picture come upon the

Adjustment of Block Level (Contd)

straight portion of the characteristic and the foot is occupied by the first volt of synchronising signal downwards from black level. Hence the instruction to adjust until the sync voltmeter reads + 1V and the picture voltmeter − 1V.

(18) Set the **picture/sync ratio** control of the Receiving Amplifier to the position at which it is expected from experience that it will require to be set when the apparatus is finally set up.

(19) Adjust the **black level** control of the Receiving Amplifier until both the picture and sync meters read zero.

(20) Adjust the **bias** potentiometer of the 'CB' Amplifier until the anode current of V_1 of the Receiving Amplifier, as read on **push button 1** of this unit, is 60mA. (**30** on the meter).

If the apparatus is being used for all cable reception with, in consequence, the use of the low anode resistance of V_3 of the Receiving Amplifier, the above concludes the sequence of operations necessary for the adjustment of black level.

(21) *If the apparatus is being used for the reception of signals from the Highgate receiving station, the following additional operations should now be performed.*

Reconnect the amplifiers by replugging the flexible connector which was removed under (11) above in order to make the adjustment of black level, and obtain an input of black level and synchronising signals from the source, via the Highgate receiving station. Set the gain of the four 'CA' Amplifiers and of the 'CB' Amplifier until the sync meter reads 16.5. Now throw the key on the Receiving Amplifier to insert the high anode resistance of V_3, when, as described above, the black level will rise, and accordingly a reading will be obtained on the picture meter which formerly read zero, while the reading on the sync meter will now show a figure several volts less than 16.5. Readjust the black level control on the Receiving Amplifier until the sync meter once more reads 16.5. The black level has now been restored to its correct value. The picture meter will, in the absence of interference, return to zero, but in any case its readings are of no importance at this stage of the adjustment.

Adjustment of Signal Amplitude

(22) Reconnect the amplifiers by replugging the flexible connector which was removed for the adjustment of black level under (11) above, (unless this has already been done under (21)), and obtain Art Bars from the source.

(23) Plug the Waveform Monitor to the output jacks of the 'CA' Amplifiers Nos. 1, 2, 3 and 4, and adjust the gains of these amplifiers until the output double amplitude peak, as measured on the Waveform Monitor, is 230mV.

It should be noted that since the Waveform Monitor is required to measure unusually low voltages, the two stages of amplification (which are more usually connected to amplify two separate waveforms entering by two separate Y jacks, Y_1 and Y_2,) are in this apparatus connected in cascade. The gain switches therefore are in cascade, and gains of 1, 4, 10, 16, 40 and 100 are possible by appropriate mutual positions of the two switches. This, however, only applies when the input is plugged into the jack Y_1. The other jack, Y_2, places the input on the second stage of amplification only, and gains of 1, 4 or 10 are available by manipulating the appropriate switch.

(24) Plug the Waveform Monitor into the output jack of the 'CB' Amplifier, and adjust its gain until the output double amplitude peak is 6.6V.

(25) After this has been done, the sync meter should be reading 16.5V. If this is not so, make a small adjustment of gain on one of the early amplifiers.

(26) Adjust the picture meter also to read 16.5V, by means of the **picture/sync ratio** control of the Receiving Amplifier.

(27) The signals may now be offered to the Central Control Room on both the transmission and preview lines, so that they may make a final measurement of white, black and sync levels. If the black level is incorrect it should be corrected by adjusting the appropriate bias potentiometer on the Distribution Amplifier. If the sync level is not correct, it should be adjusted by altering the gain of one of the 'CA' Amplifiers. If the white level is not correct it should be adjusted by means of the **picture/sync ratio** control of the Receiving Amplifier.

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