BALANCED PAIR CABLE

SECTION 3

BALANCED-PAIR CABLE EQUALISATION EQUIPMENT

Introduction

The equipment described in this Section is used for the equalisation of the attenuation and phase characteristics of sections of balanced-pair cable used for the transmission of television signals. This type of cable comprises two conductors, laid up so that there is an approximate balance with respect to earth and to other conductors. If such a pair is terminated in a repeating-coil, the longitudinal components of an interfering signal are by-passed to earth. The better the balance of the cable, the smaller are the circulating noise components due to external sources which are transmitted through the repeating-coil. The term ' balanced-pair ' covers a wide variety of types of cable, ranging from a paper-insulated telephone pair to a special low-loss cable. Where a relatively short unrepeatered link is required, a balanced-pair circuit can often be used with advantage. The upper limit of line length that can be employed is set by considerations of signal-to-noise ratio and varies from 0·5 to 8 miles, depending on the type of cable.

The equipment described was originally designed to equalise sections of the 1-inch balanced cable of characteristic impedance 186 ohms, used in the London area. This cable serves a number of frequently-used O.B. points, and P.O. exchanges. Such a P.O. exchange may be then linked to an O.B. point by a temporary balanced-pair circuit. With the equalisation of the 1-inch cable in view, the apparatus was designed to equalise sections up to a total length of eight miles. The ' average' equalisation required per unit length of this cable is known, and fixed equaliser sections provide coarse correction for any given length of the cable. The overall equalising characteristic is then adjusted by means of fine equalisation-control units. In order to facilitate setting-up, the coarse equalisers are labelled in terms of the length of 1-inch cable for which equalisation is provided. With other types of balanced-pair cables, the mileage calibration is not directly applicable.

The equalising apparatus is arranged on a number of panels, each suitable for 19-inch bay mounting. In addition to the equalisers, a number of level-raising amplifiers TV/A/1 are used with the equipment. A complete set of apparatus occupies almost all the mounting space of one standard 7-foot bay.

General Description

The units on the bay are listed below, together with a reference to the detailed description of each unit. Where a Section number only is given, it is to be found in this Instruction (V.5).

Unit	*Coded Title*	*Description*
Line panel termination	TV/LTP/1A	Section 4
Fixed equalisers	TV/EQ/7, 8, 17	Section 5
Variable equalisers	TV/EV/1, 2	Section 6
Variable phase equalisers	TV/EQ/6, 6A	Section 7
Amplifiers	TV/A/1	Instruction V2, Section C
Stabilised power supply units	SPS/7	Instruction V4, Section C
	SPS/4	Instruction V4, Section A

The layout of the units on the bay is shown in Fig. 3.1.

A block-schematic diagram of the bay equipment is shown in Fig. 3.2. The incoming balanced pair is extended from the G.P.O. termination by means of two flexible coaxial cables used as a balanced pair, i.e. the two ' inners ' are used as a pair. These cables terminate at the Line Termination panel TV/LTP/1A, on two Musa Plugs. Where suitable apparatus is provided, the direction of transmission can be reversed by connecting a sending amplifier to these two plugs. Under normal receiving conditions, the cable is extended to the input of the first equaliser Type TV/EQ/7 or TV/EQ/17. These equalisers have identical equalising characteristics and the one fitted is determined by considerations of required input impedance, as discussed below. In a number of installations, the line termination panel is of a non-standard type.

The input impedance of the equaliser TV/EQ/7 is 186 ohms, whilst that of the TV/EQ/17 is 100 ohms. The latter value is close to the characteristic impedance of a telephone pair at frequencies above 300 kc/s approximately. Thus the type of equaliser fitted at a particular installation is determined by the type of cable most often used. A resistive matching pad, working between impedances of 100

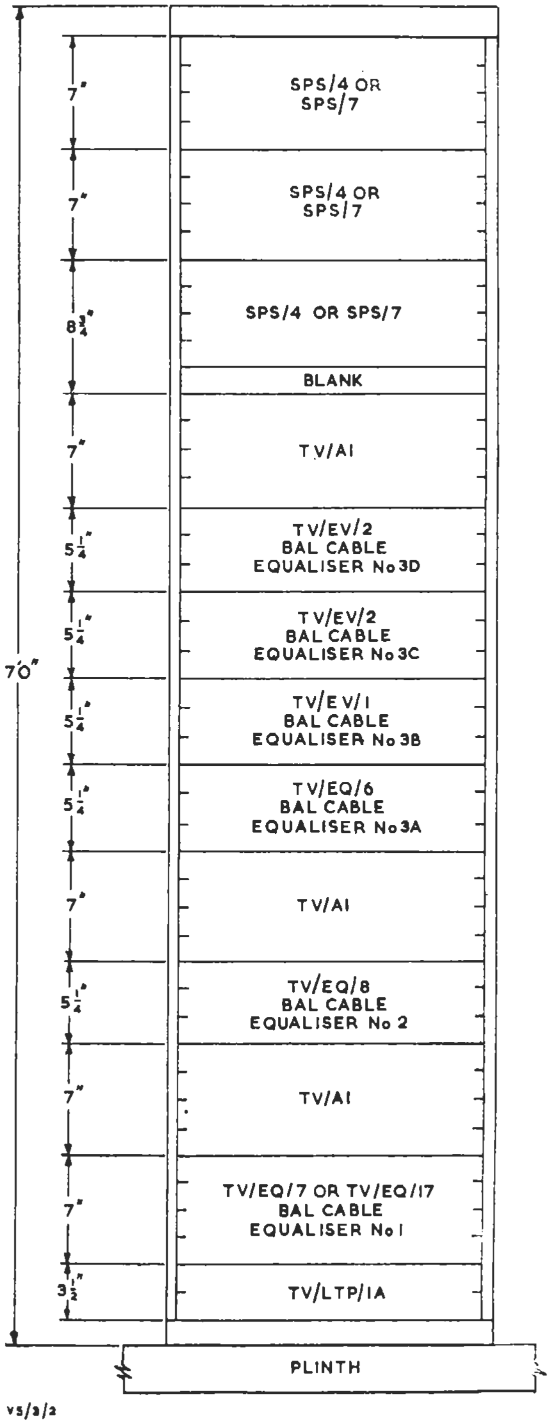

Fig. 3.1. Balanced-Pair Cable Equaliser. Bay Layout

and 186 ohms is fitted at the line-termination panel, and this can be used before either equaliser to give an input impedance equal to that of the other. Where cables of other characteristic impedances are employed, e.g. 140 ohms, alternative matching pads will be required.

The first equaliser is designated BAL. CABLE EQUALISER NO. 1 and houses the repeating-coil termination for the incoming line. It also houses two fixed constant-resistance equalisers, each providing correction for a 2-mile section of line. These are, however, not identical. One equaliser ('2-mile equaliser') provides full-range correction. The other ('2-mile resonant equaliser') provides high-frequency correction only. The necessary low- and medium-frequency correction for a standard two-mile section is added by the variable equalisers. The reason for this arrangement is as follows. The 'fine' equalisers are such that they can only correct for a characteristic falling at high frequencies. Thus the fixed equalisers must not provide too much l.f. and m.f. correction under any circumstances. To this end, the l.f. and m.f. correction is omitted from one of the fixed 'two-mile' equalisers, namely the '2-mile resonant equaliser'. The 'over-correction' envisaged could arise with a section of cable whose characteristics depart from the average, or with an incoming signal which has been incorrectly equalised at some preceding point in the chain.

By using the two 2-mile equalisers in tandem, a cable section of four miles can be equalised. In this case, as explained above, additional low- and medium-frequency correction must be inserted by the subsequent fine-control equalisers. If the 2-mile correcting sections are not to be used, they are replaced in the programme chain by loss pads having a loss equal to the low-frequency insertion loss of the sections they replace. The overall loss is some 30 db.

The output signal from the equaliser is fed to an amplifier TV/A/1, the input impedance of which is set to 100 or 186 ohms according to whether the equaliser is Type TV/EQ/17 or TV/EQ/7. The amplifier is normally set to give an output signal of between 0·8 and 1·3 volt d.a.p. into a load of 75 ohms.

The second equaliser is designated BAL. CABLE EQUALISER NO. 2, and is designed to work between 75-ohm terminations. It comprises three sections; (a) a 2-mile equaliser, with full-range correction, (b) a 1-mile equaliser with full-range correction, and (c) an equaliser correcting for the low-fre-

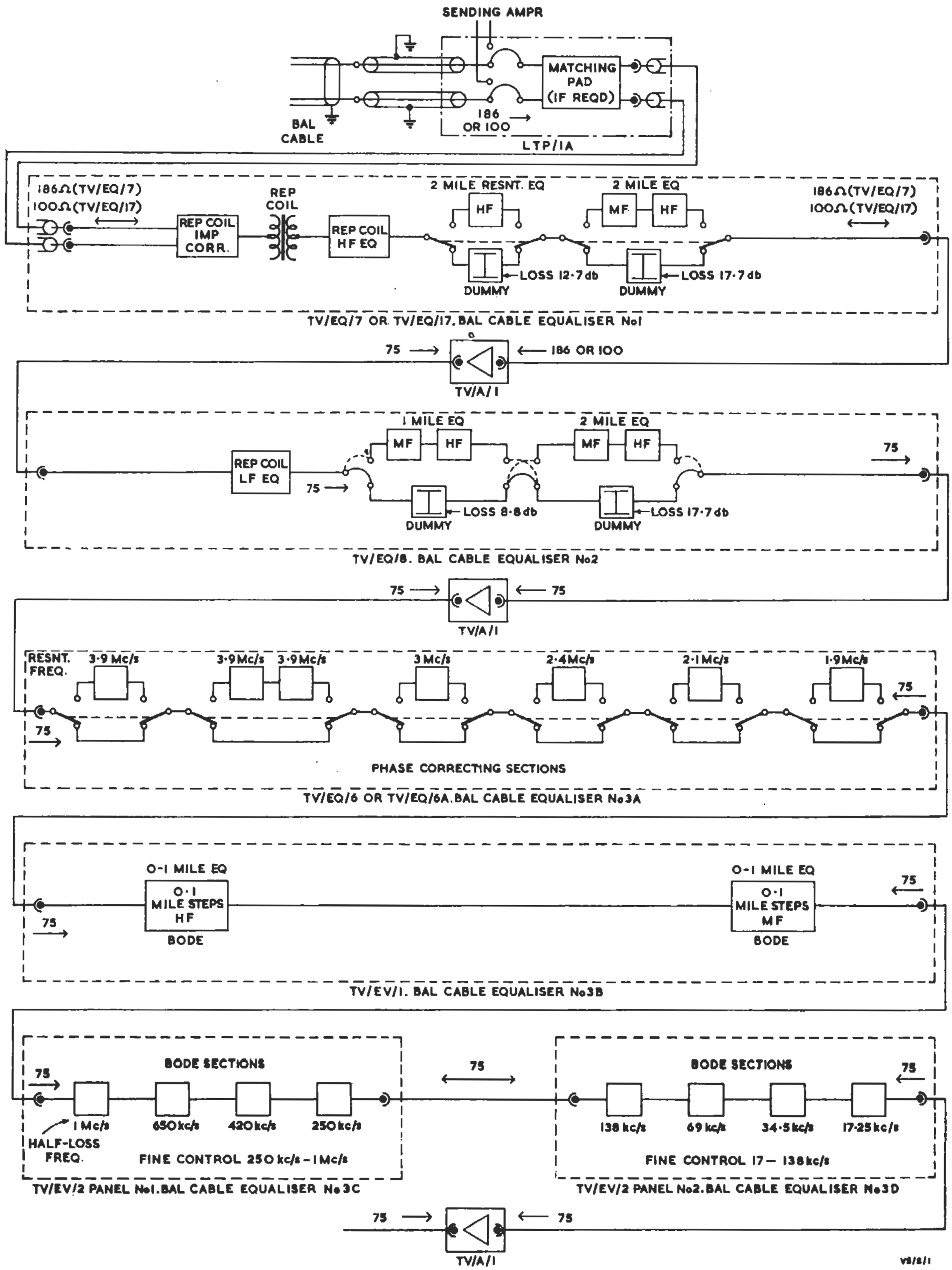

Fig. 3.2. Schematic Diagram of Balanced-Pair Cable Equalising Equipment

quency response of the repeating coil. This latter equaliser consists of a non-constant resistance half-section followed by a constant-resistance section. The non-constant resistance section is placed immediately after the amplifier, and does not affect the performance of the other sections provided that they themselves are correctly terminated. If this condition is not fulfilled a mismatch results with multiple reflections between the mismatch points, and hence distortion of the output signal. If the 1-mile and 2-mile equalisers are not used, they can be replaced in the chain by loss pads having a loss equal to the low-frequency insertion loss of the units they replace. The overall loss of the equaliser is then some 38 db, and this is offset by the succeeding amplifier TV/A/1. The pads can, however, be omitted if desired, thereby reducing the overall loss.

The third equaliser is designated BAL. CABLE EQUALISER NO. 3A, and is Type TV/EV/6 or TV/EV/6A. These equalisers are almost identical and are designed to work between 75-ohm terminations. Each comprises six constant-resistance sections of the all-pass type which can be switched into circuit individually when required. These introduce a delay decreasing progressively with frequency. Each section is characterised by the resonant frequency of the tuned circuits embodied in the network. The resonant frequencies employed are 3·9 Mc/s, 3 Mc/s, 2·1 Mc/s and 1·9 Mc/s. In order to provide a substantial decrease of delay at high frequencies, two sections having resonant frequencies of 3·9 Mc/s are used in tandem in the second position.

The fourth equaliser is designated BAL. CABLE EQUALISER NO. 3B, and is Type TV/EV/1. This equaliser works between 75-ohm terminations and it provides equalisation for sections of cable having lengths up to 1 mile. It comprises two sections, one controlling the medium-frequency correction and the other high-frequency correction. These sections are constant-resistance Bode-type networks. Equalisation can be varied in steps, each corresponding to the correction required for 0·1 mile of cable. Unlike the preceding equalisers, the TV/EV/1 does not have a constant zero-frequency loss; this loss varies with the control settings. The minimum zero-frequency loss is 8·8 db, occurring in the ' 1 mile ' condition. In the ' 0 mile ' condition, the loss is constant at all frequencies and equal to 20 db. The gain of the succeeding amplifier, TV/A/1, must thus be set according to the working conditions.

Preceding the final amplifier is the equaliser TV/EV/2, which is mounted on two panels, designated BAL. CABLE EQUALISER NO. 3C and BAL. CABLE EQUALISER NO. 3D respectively. The equaliser provides fine adjustment of the equalising characteristic. It comprises eight constant-resistance Bode sections in tandem. Each section has minimum loss at very high frequencies, and a loss at low frequencies variable up to 2·5 db relative to high frequencies in 0·25 db steps by means of a single control. The attenuation decreases smoothly with increasing frequency and the shape is similar for all sections. The frequency at which half the maximum attenuation occurs is characteristic of each section, and this ' half-loss frequency ' is used to distinguish between sections. It is a characteristic of the Bode equalisers that the degree of equalisation can be changed, *without* alteration to the half-loss frequency. The half-loss frequencies employed are 17·25 kc/s, 34·5 kc/s, 69 kc/s, 138 kc/s, 250 kc/s, 420 kc/s, 650 kc/s and 1 Mc/s. As the basic loss varies to a small extent with the control settings, the gains may have to be re-set according to the working conditions.

Operational Notes

In setting up the equipment for use with the 1-inch balanced pair cable, the first requirement is to obtain the circuit length, because the coarse controls are scaled in terms of mileage. A close approximation can be found from a measurement of the d.c. loop resistance, and is given by

$$\text{Length} = \frac{\text{measured loop resistance}}{17{\cdot}6} \text{ miles}$$

Similarly, the length of the types of cable can be found from a knowledge of this resistance per unit length. For example, the length for STC 140-ohm cable is given by

$$\text{Length} = \frac{\text{measured loop resistance}}{44} \text{ miles}$$

The attenuation at 3 Mc/s of the STC 140-ohm cable is about 14 db per mile. The attenuation of the 1-inch balanced pair, for which the equipment was designed, is about 8 db per mile at 3 Mc/s. Thus, as a first step, the settings required for the 140-ohm cable can be obtained by multiplying the length of the 140-ohm cable by 14/8 = 1·75.

The noise from the first valve of the first amplifier is usually the limiting factor in determining the signal-to-noise ratio. It is thus important to keep the level of the incoming signal fed into this amplifier as high as possible. This applies particularly at the high frequencies where it is to be expected that the incoming signal will have been attenuated most by the line over which it has been transmitted. It is therefore imperative that the minimum absolute attenuation at these frequencies be introduced before the first amplifier.

If, for example, equalisation is required for four miles of cable, it is normally preferable that two 2-mile equalisers before the first amplifier should be used rather than one before and one after the first amplifier. When the former arrangement is employed there is little attenuation at the higher frequencies due to the rising characteristics of the equalising sections. In the latter arrangement there is a loss of 17 db at all frequencies due to the dummy pad before the first amplifier. Consequently, the higher frequencies are attenuated by this amount and the signal-to-noise ratio degraded correspondingly. It is, of course, true that by using equaliser sections preceding the first amplifier the signal-to-noise ratio at medium and low frequencies is degraded, but it must be remembered that this can be more readily tolerated because of the lower line losses at these frequencies.

For similar reasons, the input attenuator of the first amplifier should be operated with the minimum of loss. For instance, if a gain of 33 db is required from the first amplifier, it is preferable to operate with the amplifier in the 30-db gain position with no loss in the input attenuator, rather than with the amplifier in the 40-db gain position with 7-db loss in the input attenuator. In the former case, the gain will be 3 db less than that required, but it should be possible to increase the gain accordingly in a later amplifier.

In the second cable equaliser, connections between the various sections are made by means of Musa connectors. This equaliser incorporates a 1-mile equaliser section and a 2-mile equaliser section, with provision for the insertion of dummy loss pads if required. These dummy loss pads are used only when it is desired to achieve rapid switching between one equalisation condition and another; the use of the dummy ensures that there is no need to alter the gain of the succeeding amplifier. If this rapid switching facility is not required the dummies should not be employed. This increases the signal level at the input of the second amplifier and helps to improve signal-to-noise ratio in a manner similar to that described above.

Setting-up Procedure

The settings of the mileage-calibrated equaliser controls are first set to equalise the equivalent length of 1-inch balanced-pair. The amplifier gains are then adjusted using a suitable test signal covering the full range of signal amplitude.

The gain of the first amplifier depends upon the following:

(1) Sending level relative to 1-volt d.a.p.
(2) Low-frequency line loss.
(3) Matching pad losses (if any).
(4) First equaliser losses.

The input attenuator is normally set to zero for the reasons explained above, and the sending level and the first amplifier gain are then adjusted so that the signal at its output is between 0·7 and 1·4 volts d.a.p. into a load of 75 ohms.

The low-frequency line loss may be calculated by assuming it to be due entirely to the resistance of the line measured at d.c. (R). With a sending impedance of Z_s and a receiving impedance Z_r the loss is given by

$$20 \log_{10} \frac{Z_s + Z_r + R}{2Z_r} \text{ db.}$$

The gain of the second amplifier will normally be set to give 1 volt d.a.p. into a 75-ohm load at its output. It may be assumed that the repeating-coil l.f. equaliser introduces a loss of some 12 db. If the 1-mile equaliser is introduced, the low-frequency loss increases to 20 db approximately. If the 2-mile equaliser is employed, the low-frequency loss increases to approximately 30 db. If both the 1-mile and 2-mile equalisers are in circuit the loss will be some 40 db.

The gain of the third amplifier will be primarily dependent upon the settings of the Bode equalisers preceding it. The maximum loss occurs when there is no frequency discrimination in these equalisers, and it is then 44 db. The nominal maximum gain of the amplifier is 40 db., so that additional gain may be required from the second amplifier. The minimum low-frequency loss is some 29 db and this may be taken as the minimum gain setting likely to be used in practice. The settings employed are adjusted on test to give an output signal of 1 volt d.a.p. into a matched load.

Adjustment of the fine-control equalisers is made as follows:

(1) With a broad line-bar waveform test signal (15 microseconds duration or greater) the sections in equalisers 3(C) and 3(D) (TV/EV/2)

with half-loss frequencies of 17·25, 34·5, 69, 138, 250 and 420 kc/s should be adjusted to give the best shape of the bar. The amount of correction at each of these half-loss frequencies should be such that no overshoot is produced following the rise or fall of the bar. In carrying out this procedure it may be necessary to go back and make slight alterations to settings previously obtained in order to obtain a good bar and line-synchronising pulse wave-shape. The two equaliser sections with half-loss frequencies of 650 kc/s and 1 Mc/s should then be adjusted. Assuming that the sending pulse has a rise-time of less than 0·1 microsecond, the rise-time of the received pulse should be about 0·17 microsecond.

(2) If the rise-time is appreciably greater than 0·17 microsecond it is likely that the equalised bandwidth is something less than 3 Mc/s and it may be desirable to add additional steps of the 0 to 1·0 mile variable equaliser (TV/EV/1). If this is done, it is necessary to repeat item (1) above, at each fresh setting of the 0 to 1·0 mile equaliser. The final pulse shape should have a rise-time of about 0·17 microsecond and may have an overshoot of about 20 per cent at a ringing frequency above 3 Mc/s.

(3) The controls of the phase equaliser 3A (TV/EV/6 or 6A) are then adjusted to reduce the overshoot to minimum; the overshoot amplitude should be less than 10 per cent of the picture-pulse amplitude.

(4) Using a field-bar test signal, low-frequency correction can be introduced by means of the repeating-coil l.f. equaliser. The controls are normally preset, and should not require adjustment in operational use. The gain setting of the subsequent amplifier must be adjusted if an alteration to the correction is made.

By utilising the pulse technique described above, it should be possible to produce an amplitude/frequency response flat within 0·25 db from 50 c/s to 1 Mc/s, and within 0·5 db from 1 Mc/s to 2·8 Mc/s. These figures apply to the 1-inch balanced cable employed in the London area, but it may not always be possible to produce similar figures with other high-grade balanced-cables, as the equipment was not specifically designed to deal with these. With a telephone pair it may not be possible to produce the same degree of high-frequency correction, and indeed, it may be desirable to accept a somewhat degraded h.f. response in order to achieve a better signal-to-noise ratio.