

# THE LONDON-SOUTH WALES TELEVISION LINK

by

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## **Introduction**

The opening of the B.B.C. Television Transmitting station at Wenvoe marked the completion of the first stage of providing the whole of the British Isles with a television service. The General Electric Co. Ltd., which had already taken a big part in extending the television network from London to other parts of the British Isles, was entrusted with the manufacture, installation and commissioning of the necessary equipment for the link from London to Wenvoe.

This link, which provides for simultaneous two-way transmission, employs a pair of 0.375" co-axial tubes for the transmission of a 405 line television system. It is divided into two separate sections, London — Bristol and Bristol — Wenvoe, the distances being approximately 120 miles and 45 miles respectively.

Each section consists of a control terminal, intermediate repeater stations and a remote terminal and has an independent supervisory system. The two sections are built-up and equalized individually so that if an extension from

Bristol to a new transmitter is required at some later date, the signal is already available at Bristol fully equalized for relaying.

As will be seen from Fig. 1 the route consists of 31 *Intermediate* stations and three *Terminal* stations. The intermediate stations are spaced approximately 5 miles apart and are normally not staffed except for infrequent routine maintenance visits.

For the purpose of supervision and maintenance London is the control station for the London — Bristol section and Bristol controls the Bristol — Wenvoe section.

To facilitate maintenance and to ensure freedom from interruption due to equipment failure, the amplifiers and associated line simulators are duplicated for both directions of transmission at each station.

The cable, building and power equipment also serve co-axial telephony systems over the same route, (the intermediate station equipment of which is similar in many respects to that of the television system).

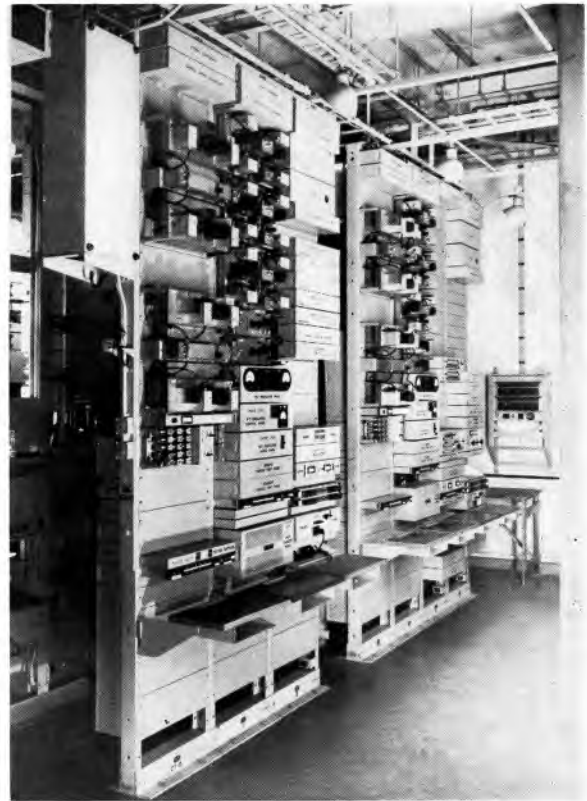
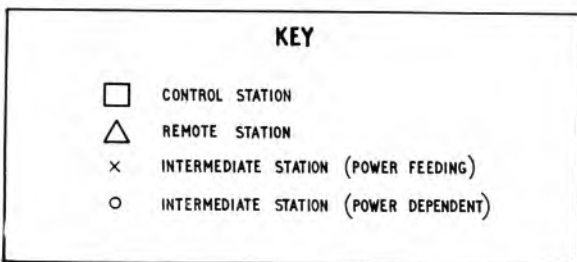


Fig. 2.—Complete control and remote terminal equipment at Bristol.

### Accommodation of Equipment

To maintain uniformity all equipment is mounted on standard British Post Office 1' 9" wide double sided racks.

### Control Stations

(London and Bristol)

The equipment at the control station, which is designed to cover a maximum of 23 intermediate stations and one remote station, is, with the exception of the main power transformer, mounted on four 10' 6½" high racks. The power transformer is mounted with its associated switch, fuses, ammeter and voltmeter on a small rack in the power room and supplies 350-volts AC for the equipment from a stabilised 200—250 volt AC mains supply

### Intermediate Stations

The racks at all intermediate stations are identical, facilities are provided to enable minor adjustments to be made to cover different station spacing and to enable the racks to function as *Power Feeder* or *Dependent* stations.

One 7' 6" rack at each station accommodates all the equipment for one system, with the exception of the local power transformer at dependent stations or the main power transformer at power feeding stations, these being mounted on a wall bracket and a small rack respectively.

### Remote Stations

(*Bristol and Wenvoe*)

The *remote terminal* equipment is similar at Bristol and Wenvoe but is mounted on three 7' 6" racks at Wenvoe where building space is restricted and at Bristol on three 10' 6½" racks, thus lining up with existing equipment.



Fig. 3.—Line equipment on right hand rack. The power unit and supervisory equipment are mounted at the rear.

At Wenvoe the equipment is in a specially screened room due to the proximity of the building to the transmitting aerial. At both *remote* stations a main power transformer of the type used at control and power feeding stations is mounted separately.

### Performance

The system carries a modulated 405-line television signal and has an overall gain of 24db. A vestigial sideband type of modulation is used, the basic video band being 0–3 Mc/s and the carrier frequency 1.056 Mc/s, the sidebands extend from 500 k/c/s to 4.056 Mc/s.

To enable a number of systems to be operated in tandem, the distortion of the signal in individual systems must be reduced to a minimum. When a picture which was transmitted over the London-Bristol-London loop was compared with a direct picture, the additional distortion could only just be detected by experienced observers.

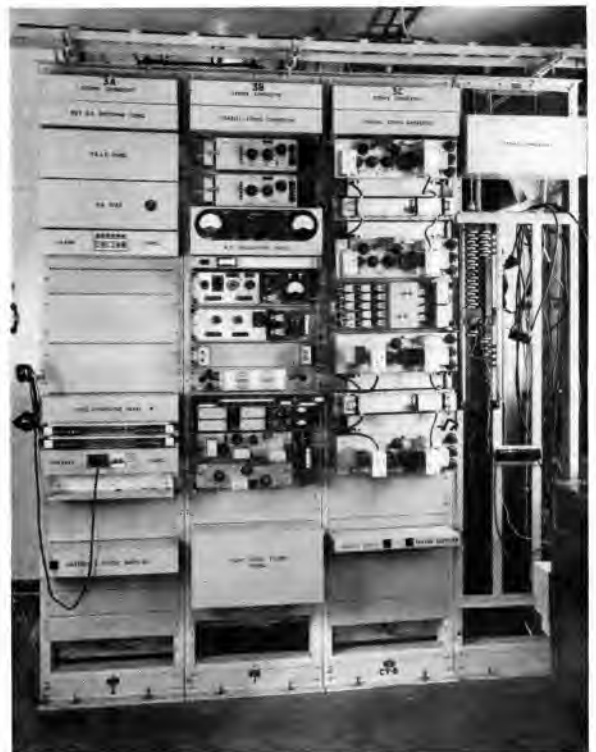


Fig. 4.—Remote terminal suite at Wenvoe. 7' 6" racks are used here as there is not enough headroom for the standard 10' 6½" racks.

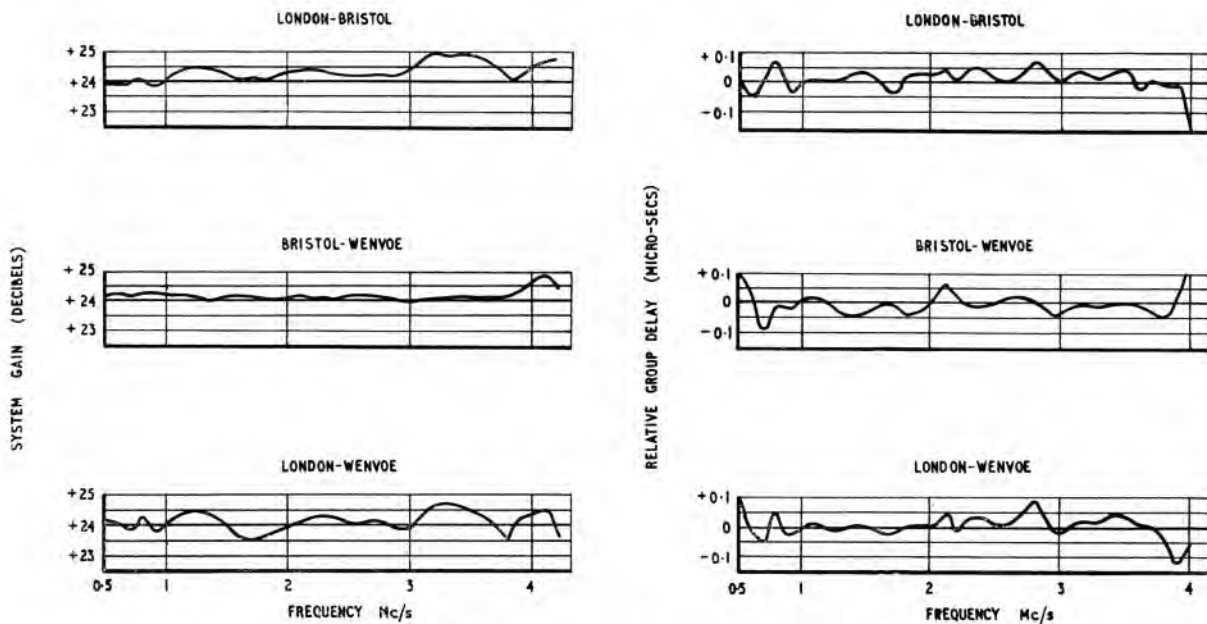


Fig. 5.—Measured characteristics of the system, overall and by sections.

**Gain/Frequency Response**

The gain/frequency characteristic of the London Bristol section over the band 500kc/s to 4.2Mc/s is flat within  $\pm 0.5$ db and the delay/frequency characteristic between 500kc/s and 3.8Mc/s within  $\pm 0.06$  micro-seconds. The measured characteristics are shown in Fig. 5, together with those of the Bristol—Wenvoe section and the overall characteristics for the whole London Wenvoe link.

The overall link performance for gain/frequency is flat within  $\pm 0.65$ db over the band 500kc/s to 4.2 Mc/s and for delay/frequency is within  $\pm 0.075$  micro-seconds over the band 500kc/s to 3.8Mc/s.

The band 60kc/s to 500kc/s is not at present being used but the equalisation is such that if the route is used for telephony circuits these can extend down to 60kc/s.

The characteristics of the two directions of transmission, using either normal or stand-by amplifiers and simulators, are very similar due to the uniformity of the equipment. This uniformity enables amplifiers to be changed without appreciably affecting the overall performance.

**Carrier/Noise Ratio**

The noise introduced by the system is well below the threshold of visibility, the R.M.S. noise level, as measured with a wide-band valve-voltmeter at the system output on the London Bristol section is 58db (relative to carrier level). The distribution of the noise in the frequency spectrum as measured with a selective receiver (bandwidth 4kc/s) is given in the table below :—

Frequency Mc/s	0.06	0.6	1.0	3.0	4.0	4.5
Noise in bandwidth of 4kc/s db relative to carrier level.	-95	-94	-90	-82	-77	-74

The effect of noise on the picture definition is appreciably less at higher frequencies than at lower frequencies.

**Crosstalk**

Crosstalk between the two directions of transmission is minimized by careful screening, decoupling of power supplies etc. The doors of the cast-alloy cable termination boxes are held firmly closed by a number of screws which must be tight for good results at the higher frequencies.

Results of crosstalk measurement on the different sections are given in the table below :—

	Frequency Mc/s	0.06	0.2	0.6	1	2	3	4	4.5
Carrier/	London-Bristol	69	78	86	78	75	65	62	71
Crosstalk									
Ratio	Bristol-Wenvoe	not	91	90	83	83	79	68	69
db	measured								
	London-Wenvoe	95	86	87	78	64	55	66	

## Harmonics

As the 2nd and 3rd harmonics of the carrier fall in the upper sideband and would produce pattern interference if of sufficient magnitude, a high degree of linearity is essential. The levels of the 2nd, 3rd and 4th harmonics relative to the carrier (with the latter at its normal working level) as measured on the London Bristol system were 57db, 58db and 69db respectively. Each line amplifier introduces a 180° phase change of the carrier which results in appreciable cancellation at alternate stations of the even harmonics.

## Overload

The transmitted carrier level can be raised to at least +24db (nominal level at line amplifier output) before over-loading takes place. The carrier is normally transmitted at a level of +15db.

## Inter-modulation

The inter-modulation between the carrier and pilot frequencies was found to be well below tolerable limits and in no case is the level of an inter-modulation product higher than 72db, relative to the carrier.

## Stability of Gain

As any variations in gain of the system would directly affect the brightness of the television picture, it is essential that the gain of the system should remain constant. Monitoring of the 308kc/s Pilot by means of recording voltmeters over seven days showed that short-term variations due mainly to supply voltage changes did not exceed  $\pm 0.1$ db when measured without any automatic gain regulation. Changes due to temperature were recorded, but these were too gradual to cause any variations on the picture screen.

With the automatic gain regulator in circuit any variations which might occur up to  $\pm 3$ db are reduced at the terminal to  $\pm 0.1$ db. In practice the normal small variations due to power supply fluctuations are virtually eliminated.

## Power Supplies

All the equipment is mains driven and the route is divided into sections of from one to five stations for the purpose of power supplies. One station per section is selected as a *Power Feeder* which supplies, along the co-axial tubes, up to two *Dependent* stations on either side of it with a 350-volt AC supply stabilised to  $\pm 1.0\%$ . Power is fed over the two inner conductors in parallel, using earth return.

At *power feeder* stations the supply is normally derived from the public mains supply and transformed up to 350 volts. In addition a stand-by is provided in case of failure of the public supply, the generator is driven by a diesel engine and is brought into service automatically should the voltage of the mains supply vary beyond pre-determined values. The stand-by equipment is fully automatic, starting-up in 8 seconds in the event of a power failure and shutting down after the mains have been restored and when the starter battery has been fully re-charged.

Each *Dependent* station takes a load of approximately 380 watts from the co-axial tubes and a further 70 watts is available at 230 volts AC for test equipment.

In addition to the 350-volt AC supply from the cable, the majority of *Dependent* stations can be operated from the local mains supply. A wall mounted transformer steps up the voltage to 350 volts AC and a switch enables either source of power to be selected without interruption of service; the station can then still be operational if the supply over the tubes has to be disconnected for reasons such as cable repairs etc. As a safety precaution against the 350-volt supply being connected to the tube whilst men are working on the cable, the switches controlling the cable power supply and the doors of the cable termination boxes are

provided with locks forming part of an interlocking system.

Each rack is equipped with a power unit operating from 275—350 volts AC and supplying the other panels with 4-volt AC and 6.3-volt AC for heaters, a 250-volt DC anode supply and 60-volt DC and 40-volt DC supply for the relay circuits. The range of input voltages allows for voltage drop in the cable which is of the order of 6 volts per mile in sections feeding two dependent stations and 3 volts per mile in cables carrying current for only one dependent.

All DC supplies are smoothed and may be adjusted independently by means of transformer tappings, metal rectifiers being used throughout. The supply to each panel is separately fused and all voltages and valve currents can be readily checked on a power test socket panel using the three meters mounted on the bay

The power unit also has a 230-volt AC output wired to a standard 3-pin socket, which may be used for test equipment, etc., requiring not more than 70 watts.

### **H.F. Transmission Path**

*Transmit terminal station.* The modulated video signal is combined with stabilised pilot signals of 308kc/s and 4340kc/s which are used for line monitoring purposes. Pilot stabilizers form part of the equipment. Input level variations of  $\pm 4$ db are reduced to  $\pm 0.1$ db. by A.G.C. action. The pilot frequencies are normally derived from carrier frequency generating equipment but can be derived if necessary from crystal oscillators mounted on the bay. The output of the combining network is fed to an amplifier having a gain of 27db. All line amplifiers, including the 27db transmit amplifier, are duplicated and incorporate pilot selector circuits, operated by the 308kc/s pilot. If, at any station, the normal amplifier fails, the associated pilot selector relay releases and initiates a changeover to the standby amplifier. If the pilot fails, amplifier changeover takes place at the stations affected by the failure but provided the normal amplifier is not faulty it will be brought back into circuit automatically when the pilot

is restored. As described later an indication of the amplifier failure is provided at the control station by the supervisory circuits.

The output of the transmit amplifier is fed to line via the cable termination box in which the H.F. signal and the 350-volt AC power supply are combined through high and low pass filters. Identical filters are used at the distant end to separate the power and the signal.

Co-axial U-link test points are provided at the amplifier and combining panel inputs and outputs and in the cable termination box to facilitate maintenance. A high impedance potentiometer across the amplifier output provides a means of monitoring the out-going signal.

### **Intermediate Station**

The incoming high frequency signal is separated from the AC power in the cable termination box, passes through the H.F. panel and on to the next station.

The high frequency panel carries a temperature equaliser and duplicated attenuator line simulators and amplifiers.

The temperature equaliser may be by-passed or switched into circuit by relays, thus enabling this control to be effected either locally or remotely. The route is originally lined-up so that it will be correctly equalised with all temperature equalisers by-passed at the highest temperature which is normally reached by the cable throughout the year. In the United Kingdom it has been decided that 22°C. is not likely to be exceeded and the London Wenvoe route has been lined-up on this basis. The mean temperature of the cable will normally be somewhere below this figure, according to climatic conditions, and a schedule has been prepared which lays down the order in which the temperature equalisers along the route are switched in as the temperature falls. The order of switching is designed to ensure that at all temperatures the equalisers in use are evenly distributed so that reasonable equalisation is maintained throughout the route. This is important as the signal/noise ratio could be adversely affected and in extreme

cases overloading could occur. A lowering of the temperature will reduce the attenuation in the same manner as would shortening of the cable. The reduction of attenuation is offset by switching in a temperature equaliser which is a network equivalent to 0.3 miles of .375 in. dia. tube. The change of temperature which will necessitate the switching in of one equaliser obviously depends on the length of the route. On the London — Bristol section (120 miles) a change of approximately 1.2°C. alters the attenuation to the extent of one equaliser. (The loss of a temperature equaliser is 0.7db at 308kc/s and 2.5db at 4340kc/s).

The line simulator is in four sections representing 0.2, 0.4, 0.8 and 1.6 miles of cable, and at each station the combination of sections in use is dependent upon the length of the preceding cable section, which may vary between 3 and 6 miles. The sections are mounted on seven separate formers individually enclosed in screened compartments, three of the sections being available for supplementary equalisers if necessary. Attenuator pads of 0.5, 1.0, 2.0 and 4.0db are mounted on the formers with the simulators, both networks on each former being wired to easily accessible tags for strapping up as required.

The line amplifiers have a sloping gain/frequency response which corresponds to the attenuation of six miles of 0.375 in. dia. co-axial cable at 22°C with a residual flat gain of 1.7db to cover the loss of supplementary equalisers. The design of the amplifiers employed was described in G.E.C. Telecommunications Vol. 5 No. 3, 1950.

The characteristics of the line amplifiers and simulators correspond so closely with those of the cable that supplementary, or mop-up, attenuation and delay equalisers are only required at the receive terminal stations. Filters, fitted at intervals along the route in the simulator compartments, increase the loss at low frequencies below the working range, where the amplifier gain slightly exceeds the loss of the cable.

All the high frequency circuits are carefully screened and the units are co-axially interconnected throughout to exclude external interference.

### Receive Terminal Station

The receive terminal equipment (Fig. 6) includes the normal line simulators and amplifiers, overall attenuation and delay equalisers, automatic and manual gain controls and filters which separate the pilots from the wanted signal.

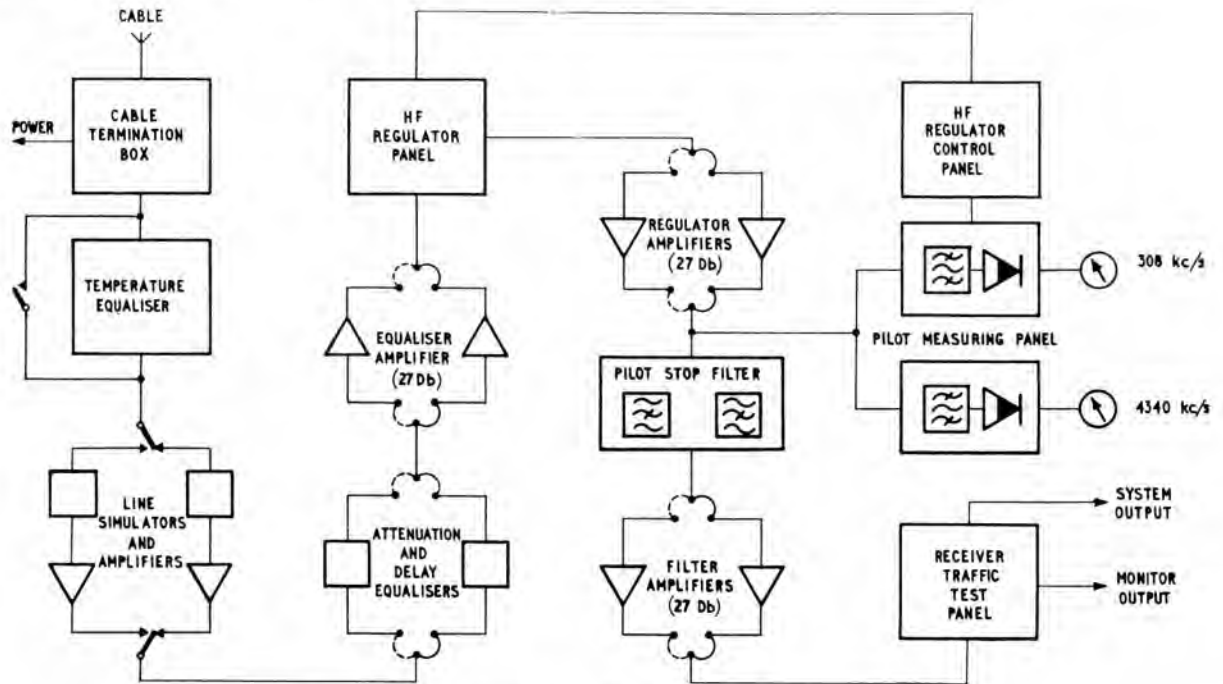


Fig. 6.—H.F. Transmission path at Receive Terminal Station.

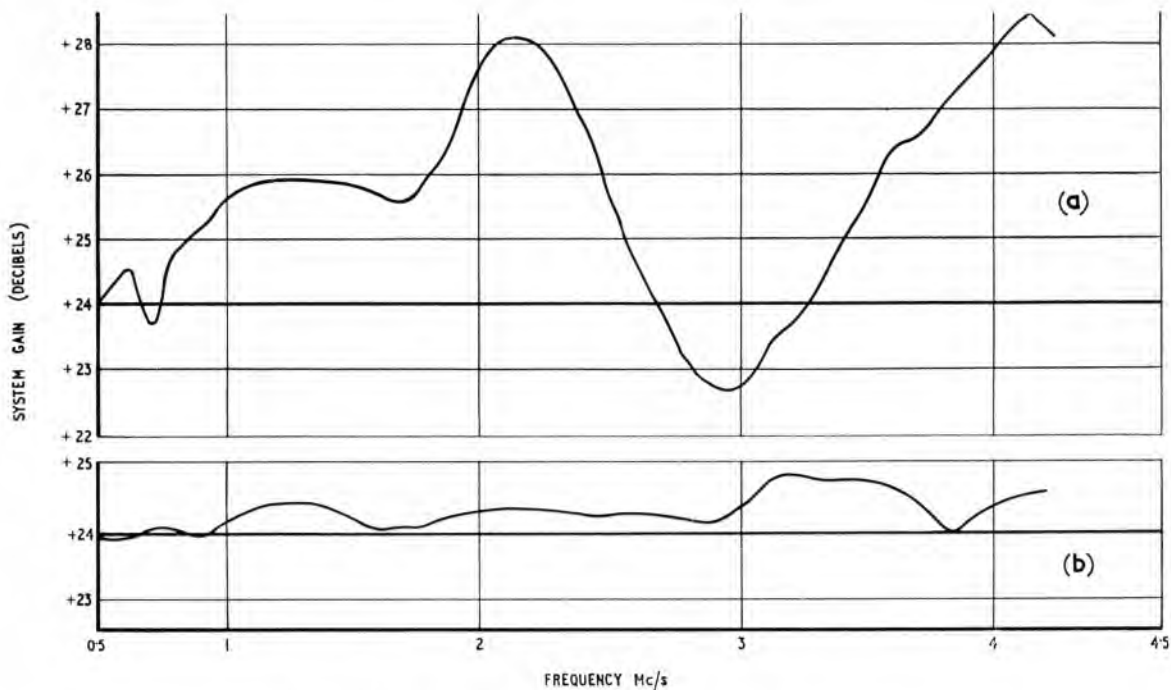


Fig. 7.—Gain/frequency characteristics, London Bristol section.  
(a) without equaliser, (b) with equaliser.

The equalisers are duplicated. The attenuation frequency response of the London Bristol section with and without the equaliser is shown in Fig. 7

Equalisation of the attenuation response also results in a smoothing out of the delay response, the two being independent to a certain extent. The delay equalisers which correct the phase/frequency characteristics are duplicated.

The attenuation equalisers are in both directions of transmission as regards reactive components. Slight resistive differences between the directions are catered for by altering resistors. An adjustment is available on these equalisers to ensure that the overall equalisation does not affect the relative levels of the pilots at 308 and 4340kc/s by more than 0.1db.

The delay equaliser is made up of a number of "all pass" networks of bridged-*T* configuration. Each section comprises two coils and three condensers, one coil and one condenser being finally

adjusted on site during the process of equalising. 14 sections were used on the London Bristol section and 7 on Bristol — Wenvoe.

Results before and after delay equalisation are shown in Fig. 8 for the London Bristol section. The rapid variations in the final curve are due to the overall attenuation equaliser response not being perfect. Any further improvement in the delay equalisation could only be achieved by a better attenuation equalisation. As the performance obtained at this stage was considered satisfactory, further equalisation was decided to be unnecessary

The amplifier following the equalisers has a gain of  $27 \pm 0.1$ db between 60kc/s and 4.4Mc/s. Attenuators of 2, 4, 8 and 16db included on the amplifier panel are used to build up the loss of the overall equalisers to 27db. The amplifiers are duplicated and the same types are used after the high frequency regulator and pilot stop filters, no pilot selectors are used, changeover to the standby being affected by means of removable U-links.

The automatic gain regulator is controlled by the 308kc/s pilot and line variations of  $\pm 3$ db are reduced to  $\pm 0.1$ db. Should the loss of the line vary beyond these limits the regulator is replaced automatically by the manual gain controls. An alarm is operated and the regulator must be manually restored when the fault condition has been removed. A fractional temperature equaliser is included in the regulator panel and the slope of the line response can be finely adjusted by switching in networks equivalent to 25%, 50% or 75% of a temperature equaliser. The levels of the two pilots can thus be equalised to within  $\pm 0.125$ db.

At the output of the regulator, the pilots are separated and the levels indicated on meters, the gain and slope is permanently monitored and remote switching of amplifiers and temperature equalisers can be observed. The pilot stop filter attenuates both pilot frequencies by more than 40db relative to the wanted signal.

In addition to the main system output, a low level output is provided for monitoring purposes and arranged so that changes of closing impedance do not affect the main transmission path.

### Supervisory System

Provision is made for the remote switching, at the

control terminal station, of high frequency amplifiers and simulators at all stations from main to standby, the equipment on both directions of transmission is changed over at the same time. Switching may be effected at individual stations or at a number of stations together. The control terminal can also remotely *lock in* all main amplifiers and switch temperature equalisers *in* or *out* one at a time.

A lamp panel at the control station shows at which stations the standby equipment is in circuit. The same panel, with a lamp for each station, can also be used to show at which station the temperature equalisers are in circuit.

The audio and DC signals used to give these facilities are carried on a four-wire circuit, using interstice pairs in the cable. The signals are amplified at each station and equalised at intervals along the route. All stations except the control have an audio selector and an oscillator, a different frequency being allocated to each station. A relay panel, mounted between the two high frequency panels, is, like the selector and oscillator panels, hinged to allow easy access to the wiring and components behind for maintenance purposes.

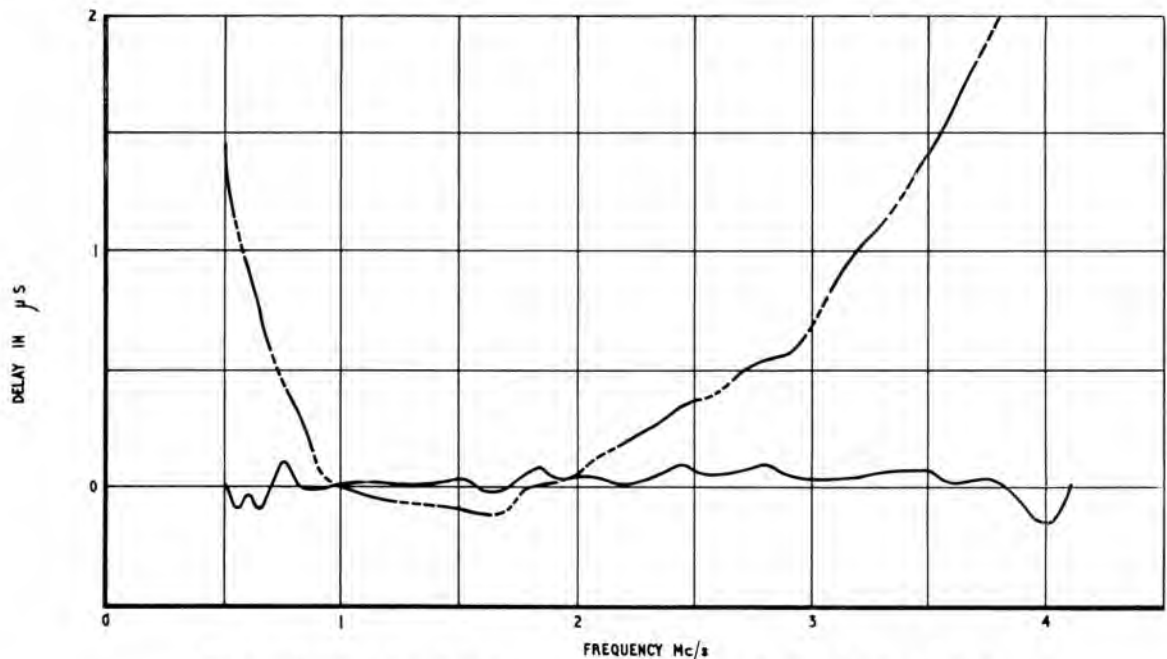


Fig. 8.—Results before (dotted curve) and after delay equalisation, London - Bristol.



Fig. 9.—The control and remote terminal equipment at Bristol.

Two un-amplified cable pairs are used to operate alarms at the control station in the event of power failure or low frequency amplifier failure at other stations. A *power monitoring panel* on each bay is connected to the power alarm pair and is controlled by the heater, anode and relay supplies. Anode current failure in the audio amplifier panel operates the low frequency amplifier alarm.

By means of a bridge circuit the control engineer can locate the station at which the alarm originates ,

a switch is turned to obtain zero deflection on a meter and the position of the switch then indicates the station concerned.

The same cable pairs are used to provide an indication of the mean cable temperature. Another bridge circuit is arranged to measure the loop resistance of the pairs, which will of course depend upon the temperature and in this case the position of the balancing switch directly indicates the cable temperature in degrees centigrade.

A 4-wire speaker circuit, amplified and equalised in the same manner as the supervisory pairs, provides contact between any two or more stations. The four single-stage amplifiers used in these circuits are of a standard design and are all accommodated on one panel. A second panel carries the associated line matching transformers, attenuators and equalisers. Each intermediate station has an audio selector, of the type used on the supervisory pairs, tuned to different frequencies as before , the control station, by transmitting a tone of appropriate frequency over the speaker, can ring an intermediate station by operation of the selector which completes buzzer and lamp circuits.

At *power feeding* stations the supervisory oscillator also provides a tone for ringing either terminal, both of which have banks of selectors of appropriate frequencies, one corresponding to each power feeding station. Dependent stations are able to ring the terminals via their respective power feeders, the presence of a DC voltage on the speaker circuit phantoms operating relays which switch the output of the power feeding station oscillator