THE AUSTRALIAN POST OFFICE

COURSE OF TECHNICAL INSTRUCTION

Engineering Training Section, Headquarters, Postmaster-General's Department, Melbourne C.2.

COAXIAL LINE AND SUPERVISORY EQUIPMENT

(ELECTRON TUBE TYPE)

PREVIOUSLY CP 226

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1. INTRODUCTION.

1.1 Coaxial cables are capable of being used for the transmission of very wide frequency bands, and for this reason, their main application is the transmission of large groups of voice frequency channels or television programmes. One coaxial tube is used for each direction of transmission, and with repeaters spaced at about 5.75 miles intervals, frequencies up to 6MHz are used, and up to 1260 voice frequency channels or one 625 line television programme relay can be provided. With repeaters spaced at about 2.75 miles intervals, frequencies up to 12MHz can be used and 2700 voice channels or a T.V. programme channel and up to 1200 voice channels can be provided.

1.2 At the time of writing only valve type coaxial systems are in use, but future systems will be transistor operated. A number of manufacturers have supplied valve type equipment but, in general, this paper is based on Siemens and Halske equipment.

2. COAXIAL CABLE - CONSTRUCTION AND CHARACTERISTICS.

2.1 Construction. (Fig. 1) A coaxial tube consists of an inner copper wire conductor surrounded by an outer copper conductor formed into a cylindrical tube. Two layers of steel tape and two layers of paper complete the coaxial tube.

In the coaxial tube in general use, the diameter of the inner conductor is 0.104″, and the inner diameter of the tube is 0.375″. Polythene discs spaced at 1.3″ intervals hold the inner conductor in place.

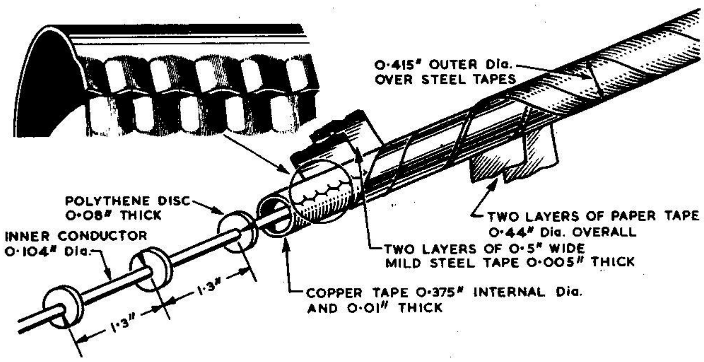


FIG. 1. BRITISH DIMENSIONED COAXIAL TUBE.

2.2 In general, more than one coaxial tube is included in the cable, and the tubes are laid-up around a core consisting of paper insulated 20 lb pair or quad conductors which are used for control, supervisory and alarm circuits. A 20 lb paper insulated carrier quad is placed in the space between each tube. A helical lapping of at least two thicknesses of paper is applied over the composite cable, and if required, one or more layers of 10 lb or 20 lb paper insulated quads can be made around the cable with a final double lapping of paper.

2.3 Fig. 2 shows the make up of a typical 4 tube coaxial cable and typical cable lay-ups for 2,4, and 6 tubes cables are shown in Table 1.

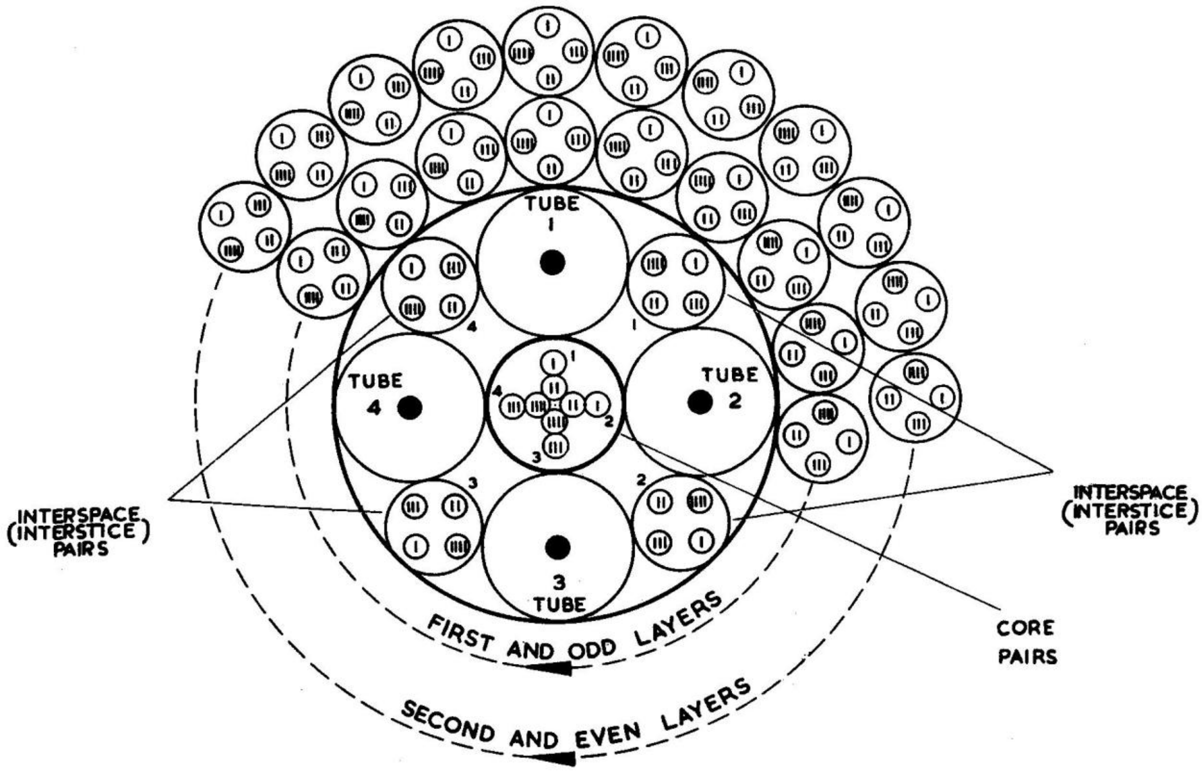


FIG. 2. MAKE UP OF 4 TUBE COAXIAL CABLE.

Number of Tubes in Cables	Core Space			In each Outer Interspace Between Coaxial Tubes	Layers Pairs as Required - Local Type		
	Centre	1st Layer	2nd Layer		1st Layer	2nd Layer	3rd Layer
2	Nil	Nil	Nil	5-20lb Carr. & Junc. Quads	24-20lb Quads	30-20lb Quads	36-20lb Quads
4	4-20lb Twin Pairs	Nil	Nil	1-20lb Carrier Quad	40-10lb Quads 27-20lb Quads	46-10lb Quads 33-20lb Quads	52-20lb Quads 39-20lb Quads
6	2-20lb Trunk Quads	8-20lb Trunk Quads	Nil	1-20lb Carrier Quad	48-10lb Quads 34-20lb Quads	54-10lb Quads 40-20lb Quads	60-10lb Quads 46-20lb Quads

TABLE 1. TYPICAL CABLE LAY-UP – 2, 4 AND 6 TUBE CABLE.

2.4 The completed coaxial cable is usually sheathed with lead alloy, but where the cable is subject to severe power induction and alternative sheath of aluminium alloy is used to increase the screening.

As the majority of faults are caused by mechanical damage, special precautions are taken to protect the cable. When the likelihood of damage is great the cable is armoured with steel tape or some form of outer wire protection. Most unarmoured cable is plastic covered to give a certain degree of protection. Fig. 3 shows standard "buried" cables with 4 and 6 coaxial tubes. The four tube cable has first layer pairs only and is plastic covered. The six tube cable has no layer pairs and has an aluminium sheath.

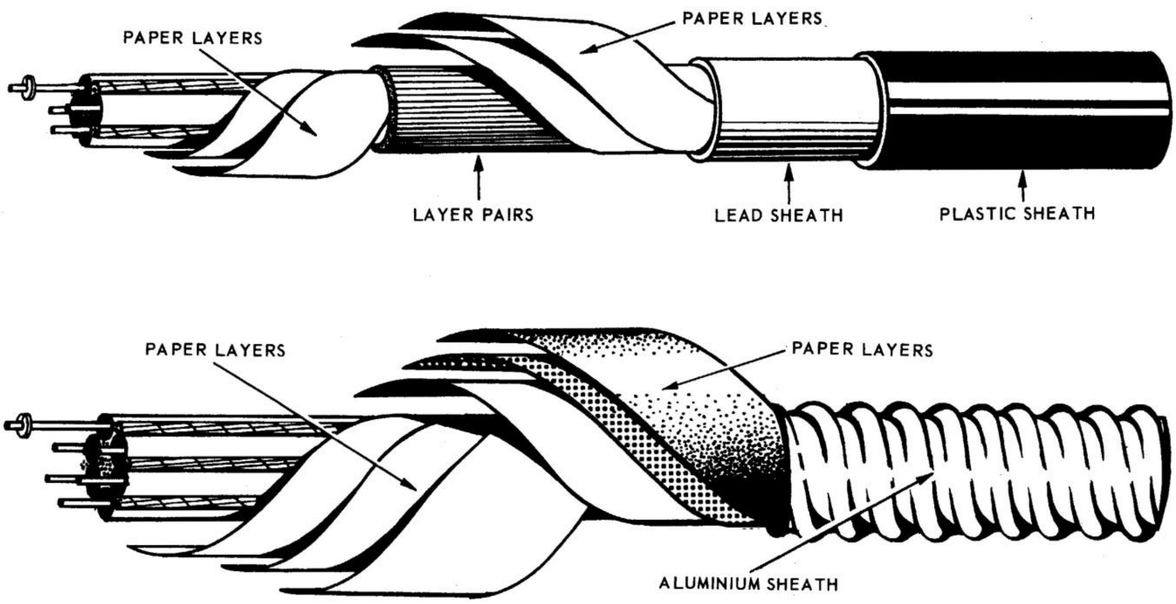


FIG. 3. TYPICAL 4 AND 6 TUBE COAXIAL CABLES.

2.5 Coaxial cables are laid for feet down, and after back-filling, the route is marked by tall posts bearing warning notices drawing attention to the hazard of high voltage distribution on the cable.

2.6 Characteristics. The tube characteristic which has the greatest effect on the quality of the broadband frequencies transmitted on a coaxial tube is impedance. Regularity of impedance is an essential feature of a coaxial tube, and although irregularities may be due to variations in the dielectric or conductivity of the conductors, it is more usual to be caused by changes in the tube dimensions. Most of the changes occur after manufacture, and are due to careless handling or poor workmanship causing a reduction in tube size, with a consequent increase in capacitance. For this reason extreme care is exercised in laying and jointing coaxial cable.

An impedance versus frequency response for a typical coaxial tube is shown in Fig. 4. The tube has a nominal characteristic impedance of 76 ohms, but below about 1MHz the impedance rises above this nominal value.

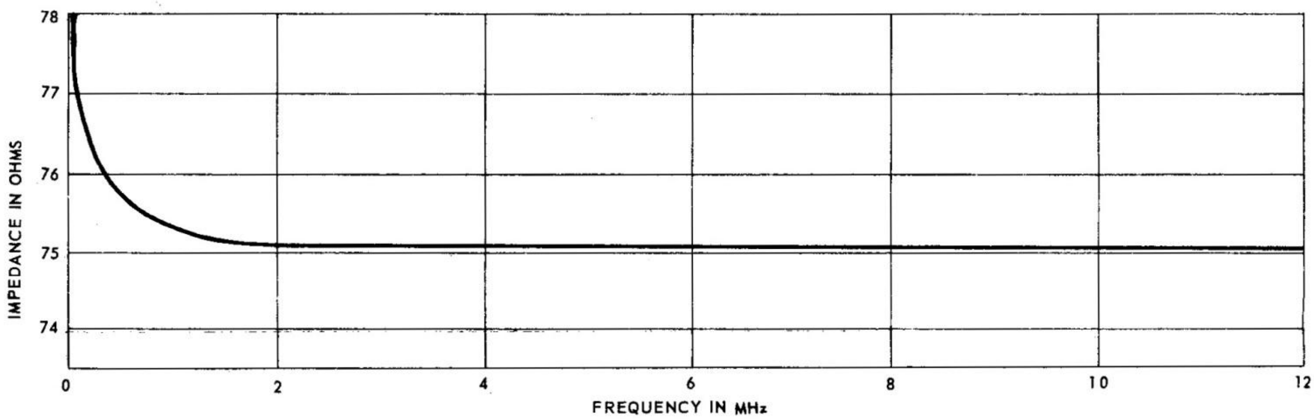


FIG. 4. IMPEDANCE - FREQUENCY RESPONSE FOR TYPICAL COAXIAL TUBE.

The attenuation constant of the coaxial tube rises sharply with increasing frequency. Fig. 5 shows an attenuation versus frequency response for a typical coaxial tube having a cable temperature of 50°F. A flat frequency versus gain response is achieved by the use of equalisers at each repeater station and at the receive terminal. Equalising amplifiers at these stations also compensate for the effect of temperature changes on cable attenuation. These amplifiers are under the control of a line pilot frequency.

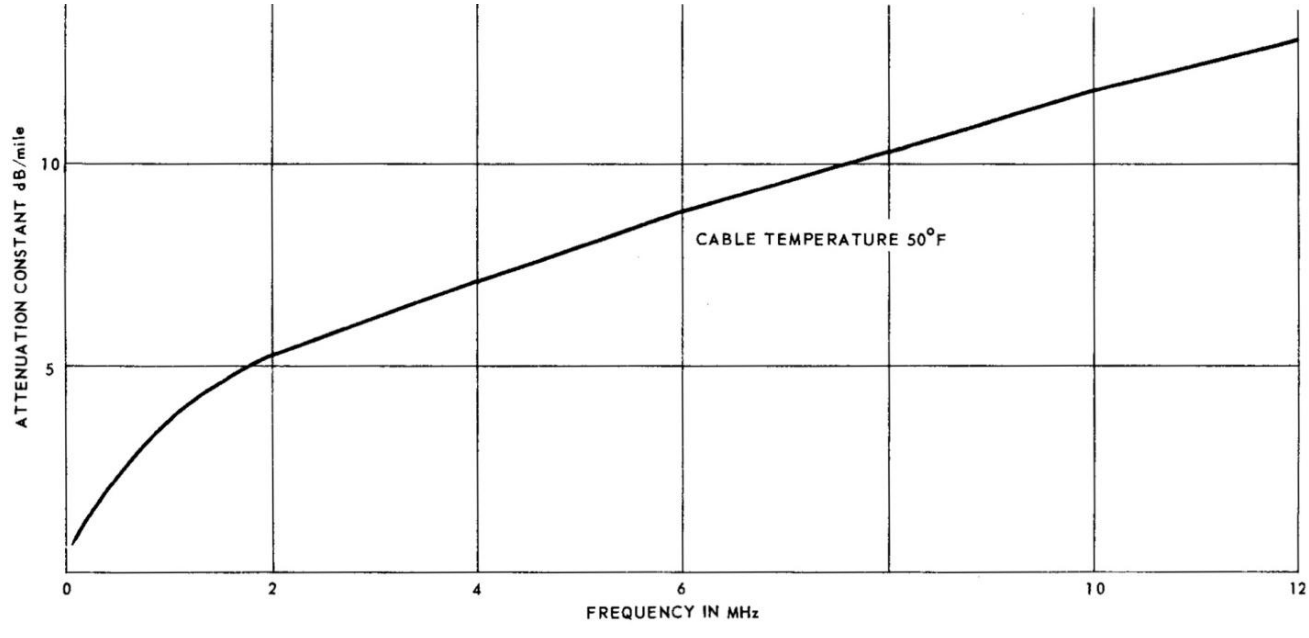


FIG. 5. ATTENUATION - FREQUENCY RESPONSE FOR TYPICAL COAXIAL TUBE.

Table 2 shows the effect of temperature on attenuation constant of a coaxial tube, at frequencies of 0.06, 1, 2, 10 and 12MHz. The attenuation constant is shown for temperatures of 50°F, 59°F and 60°F and the differences in attenuation constant between 50°F and 68°F are indicated. This temperature variation is much greater than would be experienced in practice, but indicates the need for equalising amplifiers under the control of a pilot frequency, to compensate for the effect of cable temperature variation.

FREQUENCY MHz	ATTENUATION db/mile at 50°F	ATTENUATION db/mile at 59°F	ATTENUATION db/mile at 68°F	DIFFERENCE IN ATT. CONSTANT db/mile 50°F - 68°F
0.06	0.9176	0.928	0.938	0.0204
1	3.75	3.795	3.84	0.085
2	5.315	5.36	5.43	0.115
10	11.84	11.95	12.1	0.26
12	13	13.207	13.24	0.34

TABLE 2. EFFECT OF TEMPERATURE ON ATTENUATION CONSTANT.

Far-end Crosstalk attenuation between tubes should be 110dB, or better, over the frequency range to be used. Because of the tube construction it is normally found that a value of about 110bD exists at 60KHz but as the frequency increases an improvement in crosstalk reduction occurs. Crosstalk generally increases again at 40-50MHz.

The insulation resistance between the inner and outer conductors of a tube should be at least 15,000 M ohms/mile. For the test a direct voltage of up to 500 volts is applied for a period of one minute, with the coaxial cable at a temperature of 65°F.

This specification has to be met, because power for some repeater stations is fed from terminals or other repeaters, over the inner conductors of two tubes. Because of the power feed circuit arrangement an alternating voltage of up to 600 volts exists between the inner and outer conductors of one tube.

2.7 Use of Paper Insulated Pairs. It is not possible to give any set plan for the use of core, interspace (interstice) and layer pairs of coaxial cable, because the use of these pairs varies with different coaxial routes, and also from section to section on the one route.

In general the core pairs are allocated for alarm and supervisory purposes. In a number of cases additional layer pairs supplement the core pairs in providing the alarm and supervisory functions.

The interspace quads are the only carrier quads provided, and these are often used as bearers for twelve channel cable systems which provide wayside trunk circuits along the coaxial cable route.

The layer pairs are used for minor V.F. trunk circuits and also for order-wire circuits associated with the coaxial cable system route. Usually a number of the pairs are V.F. loaded to decrease attenuation.

2.8 Cable Terminals. At the coaxial cable terminals, the equipment associated with power feeding and gas pressure alarms is added. Fig. 6 shows the cable pothead frames, power feeding rack, cable terminal rack and gas pressure alarm equipment at a typical repeater station. The four tube coaxial cable is terminated at the cable pothead frame, and the tubes are extended with single lead covered air spaces coaxial tubes to gas tight terminations. Connection is made from these terminations to the power feeding rack with connectors and semi-flexible solid dielectric coaxial cable.

The paper insulated pairs required at the station are extended with a cable tail to a cable terminal rack. At this point they can be distributed for use as supervisory and alarm pairs, minor trunk cables, or bearers for cable carrier systems. At some older installations all paper insulated pairs are taken to the cable terminal rack, and through connected or distributed locally at this point.

Typical gas pressure alarm equipment is shown at the right of the illustration. At later installations this equipment is situated in an entrance porch; this enables the lines staff to perform normal maintenance inspections etc. without entering the equipment room.

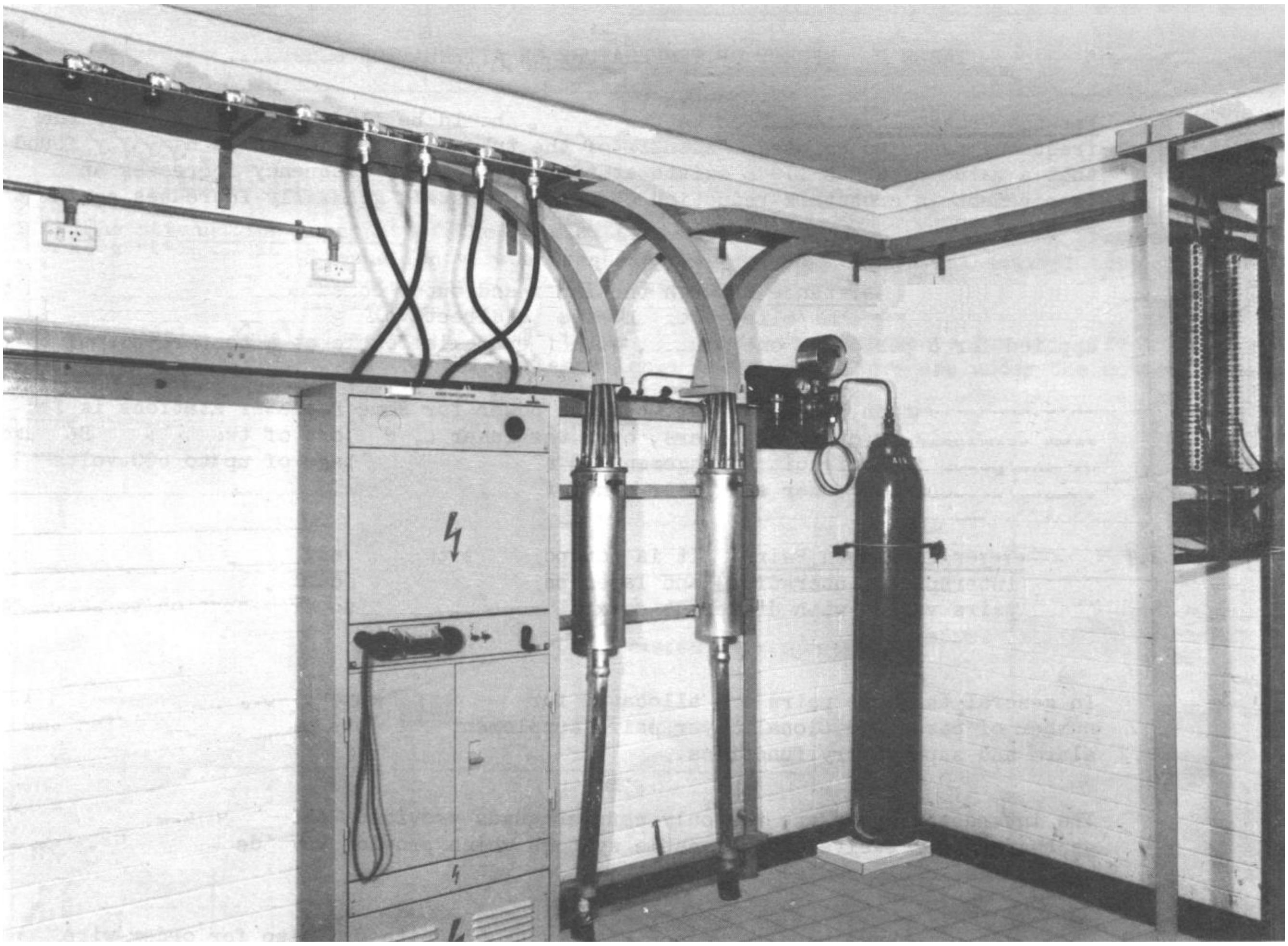


FIG. 6. CABLE TERMINATION AND POWER FEEDING RACK AT REPEATER STATION.

3. HIGH FREQUENCY LINE AND EQUIPMENT.

3.1 The high frequency line and equipment of a coaxial cable system can be divided broadly into three categories:-

(i) Terminal Line Equipment.

(ii) Repeater Line Equipment.

(iii) Repeater Sections. (Cable between terminal and repeater or repeater and repeater).

3.2 The terminal line equipment consists of transmitting line amplifier equipment and receiving line amplifier equipment. Early coaxial line equipment is valve operated and later equipment is transistor operated, but the same general principles apply in both cases.

The functions of the transmitting line amplifier equipment are to amplify the signals for all channels to a suitable level for transmission to the cable, to equalise for any distortion produced by the station cabling, and to inject the line pilot frequencies (for example, 308kHz, 4092kHz and 6200kHz) which are transmitted together with the signal. Various pilot frequencies are used for line regulation and supervision and details are given in Section 9.

The receiving amplifier equipment functions are to amplify the low level received signal, and under the control of the received pilot frequencies, obtain an overall flat frequency response. The equipment compensates for irregularities caused by changes in cable temperature and the effect of changes in ambient temperature on components or ageing of circuit components. An alarm is introduced by the pilot supervisory equipment if the degree of pilot level deviation indicates a fault condition.

3.3 The basic function of the repeater line equipment is to correct, by amplification and equalisation, for the attenuation caused to the broadband signal frequencies during transmission over the repeater sections.

Repeater stations are divided into two types:-

(i) Attended (Main) repeater stations.

(ii) Unattended (Dependent) repeater stations.

Attended repeater stations are fully regulated, and the repeater line amplifier equipment is similar to the receive terminal line equipment, but with the addition of supergroup drop-out facilities.

Unattended repeater stations provide for amplification and supervision of both directions of transmission. An equalising line amplifier is associated with a line pilot frequency, for example, 6.2MHz, and automatic and/or manual regulation facilities are provided.

3.4 The repeater sections (coaxial tubes between stations) are used as bearers for the broadband signal frequencies. In addition, the power required to operate the line amplifiers and supervisory equipment at unattended repeater stations is fed over the inner conductors of the coaxial tubes, from attended stations (repeaters or terminals) equipped with no-break A.C. power supply equipment.

3.5 Fig. 7 shows a simplified block diagram of a 6MHz coaxial line system. Three pilot frequencies, 308kHz, 4092kHz and 6.2MHz are injected at the transmitting terminal and provided supervision and regulation at repeaters and terminals. Power filters at terminals and repeaters enable power to be fed over the cables to unattended repeaters. Facilities for the dropping and replenishing of supergroups is provided at attended repeater stations.

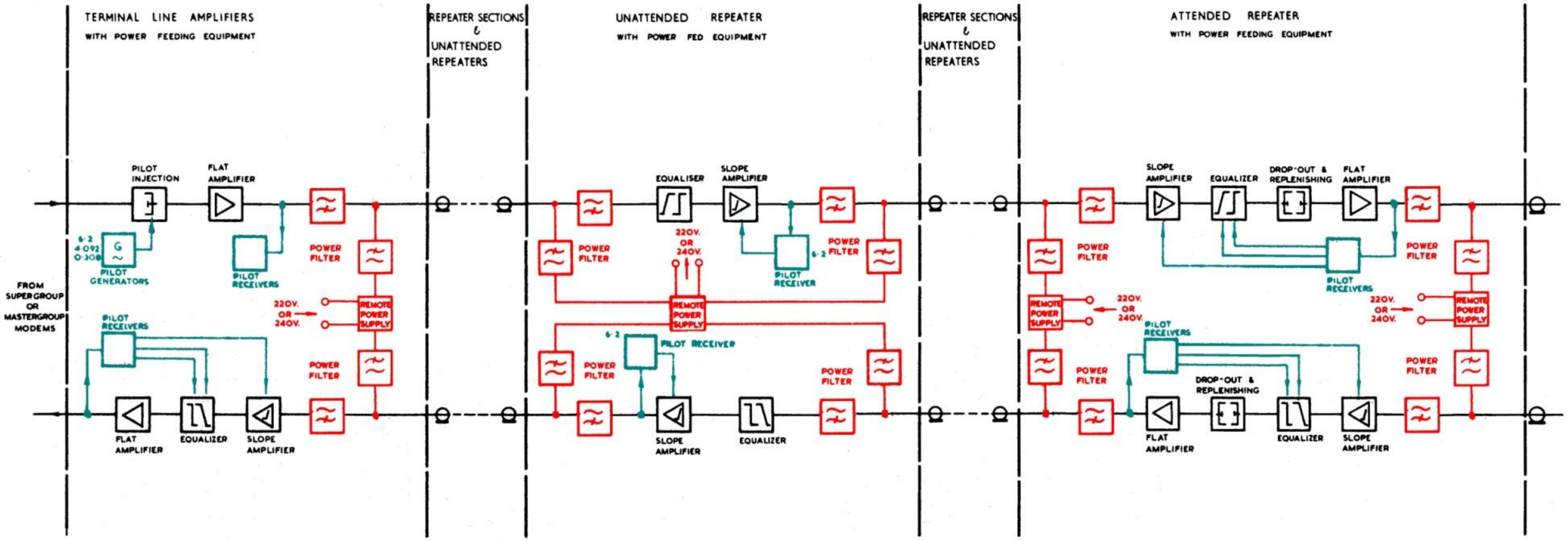


FIG. 7. SIMPLIFIED BLOCK DIAGRAM OF 6MHz COAXIAL LINE SYSTEM.

The three pilot frequencies are injected and transmitted with the line frequencies from the supergroup modems. A pilot receiver at the output of the flat line amplifier monitors the transmitted pilot levels.

The received pilot frequencies are used for supervision and regulation of the received signal frequencies.

Power from a no-break supply can be fed to up to six unattended repeater stations.

Only the 6.2MHz pilot frequency is used for supervision and/or regulation of the received signal frequencies.

High voltage power is received from the feeding source and is transformed to a voltage suitable for local use. Unless the repeater is the last in the power feeding section, the voltage is also transformed to a higher voltage and applied to the next repeater.

The three pilot frequencies are used for supervision and regulation for both directions of transmission. Similar equipment to that at the receive terminal is used by the regulation circuits.

Additional equipment can be added to allow drop-out, and in some cases replenishing of selected supergroups.

Power from a no-break power supply can be fed to up to six unattended repeaters on either side of the attended repeater station.

4. TERMINAL LINE EQUIPMENT.

4.1 The terminal line equipment used with a coaxial system can be broadly divided into transmitting and receiving amplifiers, and each of these can be further subdivided to show associated pilot regulation equipment, standby equipment, etc.

The terminal line equipment is generally designed to suit the transmission of 900 voice channels, 960 voice channels, 1260 voice channels or television programme. Frequencies up to 4.028MHz are used for the 900 and 960 channel systems and frequencies up to about 6MHz are used for the 1260 channel system and television programme transmission.

4.2 A block diagram of typical valve type terminal line equipment is shown in Fig. 8. This equipment is suitable for multi voice channel system working, and minor amendments are necessary for T.V. transmission.

Detailed descriptions of the transmitting and receiving terminal line equipment are given in Sections 5 and 6 respectively.

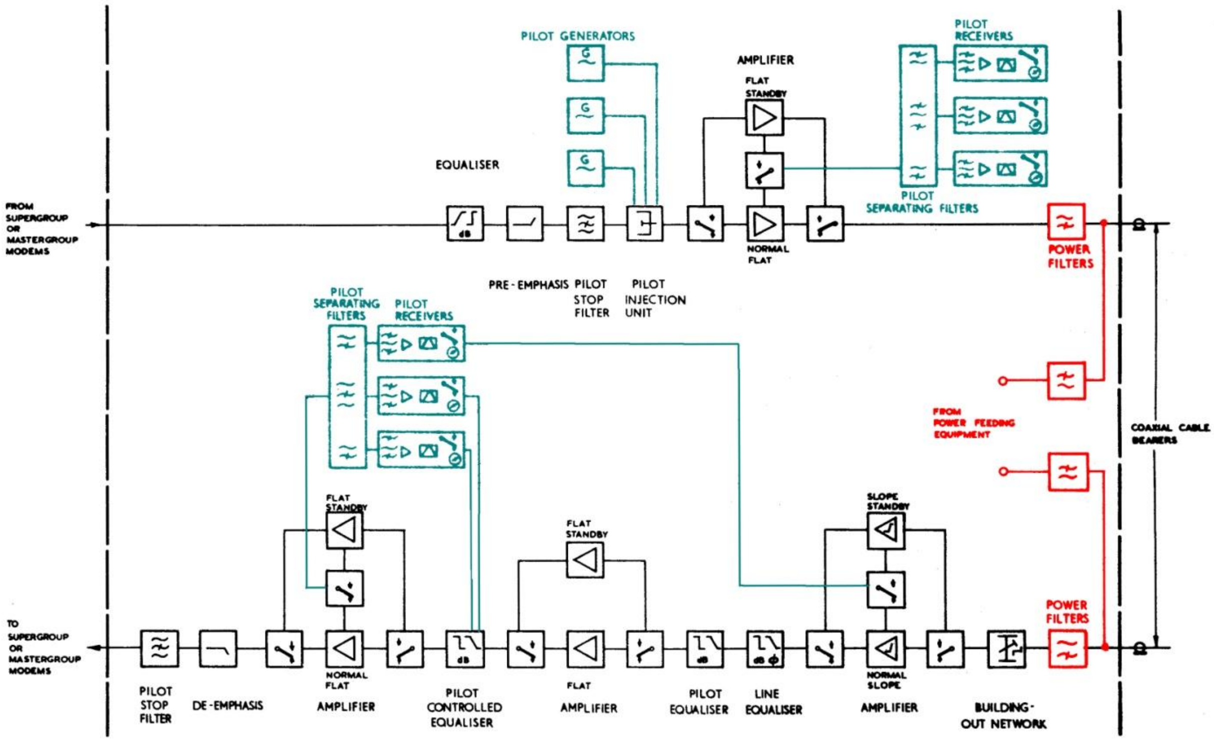


FIG. 8. SIMPLIFIED BLOCK DIAGRAM OF TERMINAL STATION LINE EQUIPMENT.

4.3 Standby Equipment. Because of the large numbers of channels involved, and because of the importance of television transmissions, a no-break changeover facility to a standby amplifier is provided for each valve type amplifier in the circuit. The changeover is made by manual switching which "fades" the standby amplifier into the circuit, after switching to a position which allows a check to be made on its operation. As a further safeguard against interruption, due to valve failure, each amplifier has two valves operating in parallel in each stage. The removal of one parallel valve during operation has little effect on the amplifier gain.

In practice it has been found that the slight change in level brought about by amplifier changeover or removal of a valve has a detrimental effect on the operation of telegraph and data transmission circuits so indiscriminate changeover and valve removal must be avoided.

Provision is made for the anode current of individual valves to be checked at measuring jacks, and individual visual indicators included in the screen grid circuits indicate whether the valves emission is satisfactory or not.

5. TRANSMITTING TERMINAL LINE EQUIPMENT.

5.1 Transmitting Line Amplifier Rack. Fig. 51 shows a typical transmitting amplifier rack. When associated with older type supergroup modem equipment, with an output level of -59.1dBr per channel, and auxiliary flat amplifier, situated on the transmitting line amplifier rack, precedes the equipment shown to give the required input level. The line frequencies are applied from the frequency translating equipment or the auxiliary amplifier to a station line equaliser. This equaliser has the reverse frequency versus attenuation response to the station cabling, from the modulator rack to the transmitting amplifier rack, and so compensates for frequency distortion occurring in that cable.

5.2 A pre-emphasis unit, to improve the signal to noise ratio, follows the station line equaliser. The frequency versus attenuation response of the pre-emphasis unit is designed to improve the signal to noise ratio for the particular signal transmitted. For this reason a different pre-emphasis unit is used for a carrier telephone system compared to that used for television programme transmission. The pre-emphasis unit is preceded by a measuring hybrid to enable the incoming signal level to be checked.

When the bearer is used to transmit frequencies from 312-4,028kHz (900 channels), the pre-emphasis unit is replaced with a pad.

Fig. 9 shows the frequency versus attenuation response for a pre-emphasis unit used in conjunction with a 1260 channel system. Fig. 10 shows the frequency versus attenuation response for a unit used with a T.V. programme system.

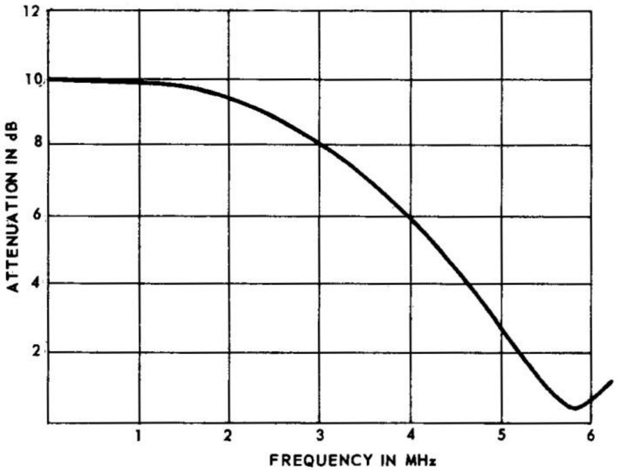


FIG. 9. TYPICAL PRE-EMPHASIS FREQUENCY/LOSS RESPONSE- MULTI-CHANNEL SYSTEM

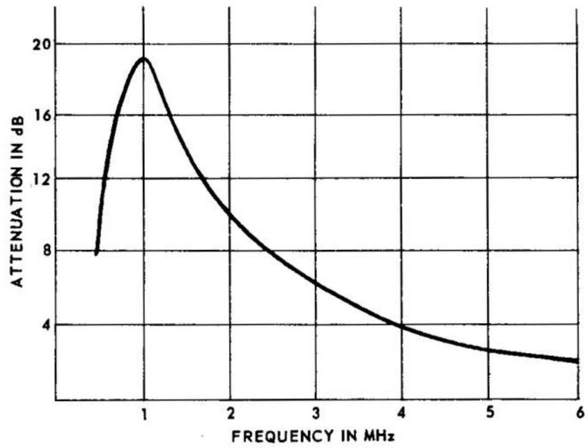


FIG. 10. TYPICAL PRE-EMPHASIS FREQUENCY/LOSS RESPONSE- TELEVISION

5.3 Following the pre-emphasis unit, a pilot stop filter of 0.308MHz is added to prevent unwanted voltages of this frequency from interfering with the pilot regulation circuit. If required, the pilot stop filters for 4.092MHz and 6.2MHz can also be added at this point. An attenuation equaliser is added to compensate for frequency distortion caused by the addition of the filters, and when used for T.V. transmission a delay equaliser is also involved.

5.4 The three line pilot frequencies 0.308MHz, 4.092MHz and 6.2MHz are injected at the pilot injection unit and transmitted with the line frequencies. Each pilot is injected at a fixed level with respect to the nominal signal line-up level. A pilot distributor is added to enable the pilot generator to supply up to three systems. An additional input circuit (Measuring Signal Input) is provided in the pilot injection unit, to enable test frequencies to be applied to the line equipment without interrupting normal transmission.

5.5 The line frequencies are applied to the line amplifier via a changeover switch which gives a no-break changeover from the regular to the standby line amplifier. The line amplifier has a flat gain versus frequency response from 60kHz to 6MHz. This is due largely to the use of negative feedback over all stages and a negative feedback equaliser in the first stage.

5.6 At the output of the line amplifier, the three pilot frequencies are monitored on a pilot receiver unit. In this way the pilots not only provide supervision and regulation at the repeaters and the receive terminal, but also provide supervision of the pilot generators and transmitting terminal line amplifier.

5.7 Fig. 11 shows a diagram of typical normal and standby line amplifiers with associated changeover switch and pilot receivers. A six pole, four position switch is used. A switching pole is associated with the input and output of each amplifier and also the input to the pilot receiver. The sixth switch pole controls the pilot receiver alarm circuit. The unidirectional rotary switch positions are designated as follows:-

(a) OPERATION. (b) CHECKING. (c) STANDBY. (d) CHECKING.

With the switch in the "OPERATION" position the normal line amplifier is connected in circuit, and the output of this amplifier is monitored by the pilot receiver equipment. The standby amplifier is terminated at the input and output with 75 ohm terminations.

To check the standby amplifier prior to changeover, the switch is moved to the "CHECKING" position. This leaves the normal amplifier in circuit, but connects the input of the standby amplifier to the circuit input, via a 640 ohm resistor, and connects the output of the standby amplifier to the pilot receiver circuit for checking. The pilot receiver indicates fault conditions, if any, but the alarm circuit is disconnected by switch 6. When the standby amplifier is operating satisfactorily, the switch is advanced to the "STANDBY" position, and the standby amplifier takes over from the normal amplifier, which is terminated at the input and output with 75 ohm resistors. To check the normal amplifier before switching back, the switch is moved forward to the "CHECKING" position. Then the normal amplifier is switched to the input circuit via 640 ohms, and its output is taken to the pilot receiver circuit for checking. The standby amplifier continues to operate in the through circuit until the switch is returned to the "OPERATION" position. Resistors used in the switching circuit to "fade" one amplifier in and the other out of circuit are not shown.

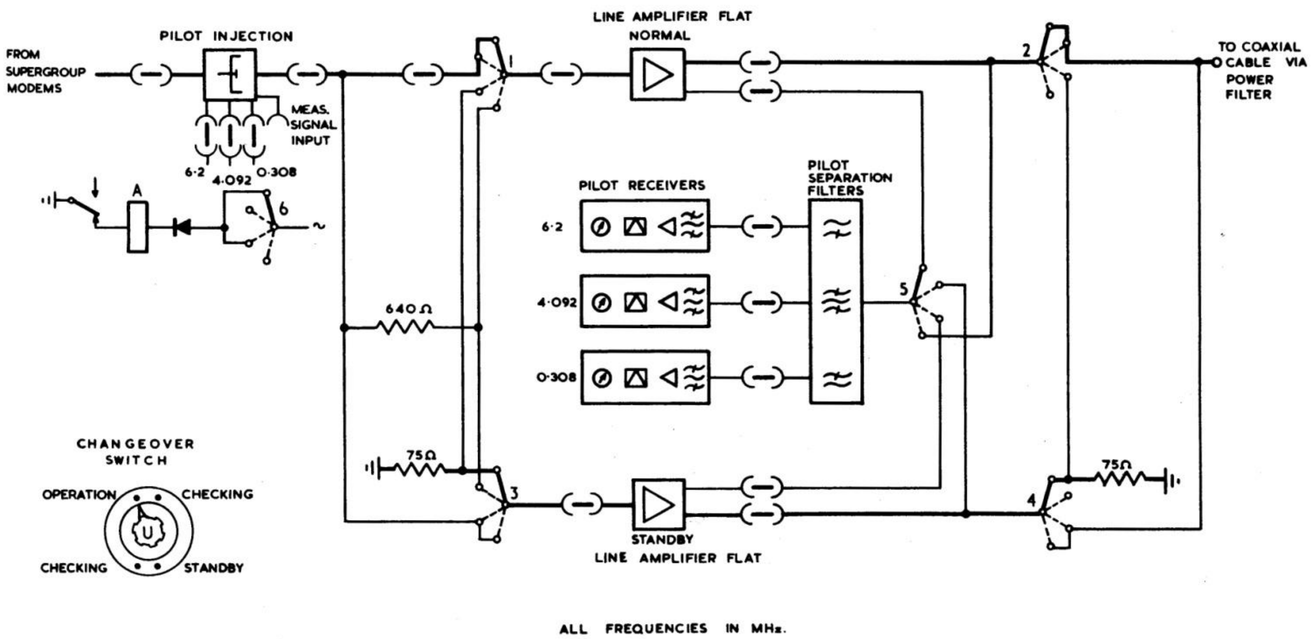
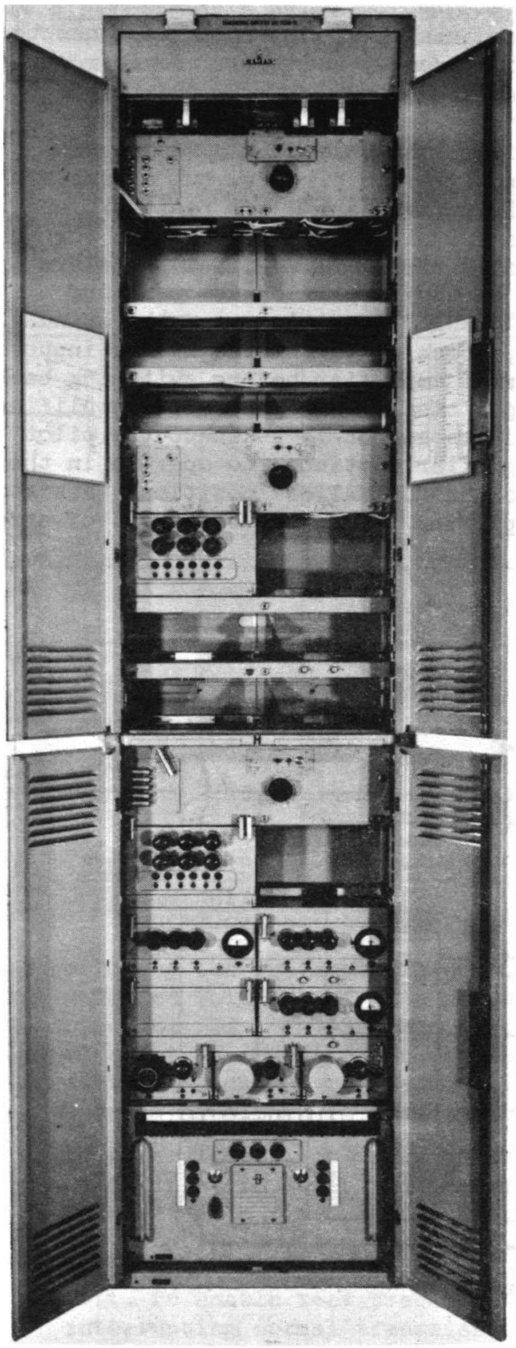


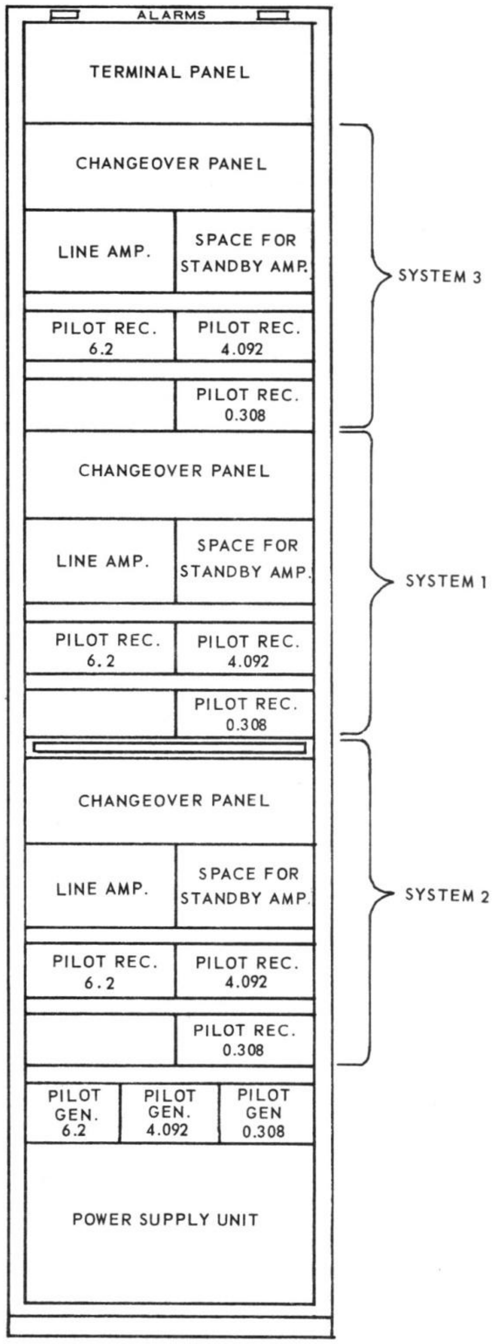
FIG. 11. MAIN ELEMENTS OF LINE AMPLIFIER CHANGEOVER CIRCUIT.

5.8 The line frequencies are applied from the line amplifier to the coaxial tube via a power filter. This separates the high line frequencies from the 50Hz power frequencies, which are fed over the coaxial tubes. Details of power feeding are given in Section 10.

5.9 Fig. 12 shows a typical transmitting line amplifier rack. The rack can carry the equipment for up to three systems (Fig. 12(b)). The capacity of the rack is reduced when auxiliary amplifiers are used, as these are situated in the space for one system. In the rack shown the operating system occupies system 2 position and the auxiliary amplifier is in the system 1 position.



(a)



(b)

FIG. 12. TYPICAL TRANSMITTING AMPLIFIER RACK.

6. RECEIVING TERMINAL LINE EQUIPMENT.

6.1 Receiving Amplifier Rack. A black diagram of a typical receiving amplifier rack is shown in Fig. 52. The receive equipment is more complex than the transmit equipment because of its many functions, which are:-

(i) To raise the received signal to the required power level for transmission to the demodulating equipment.

(ii) To obtain an overall flat frequency versus attenuation response.

(iii) To obtain an overall flat frequency versus delay response.

(iv) To apply de-emphasis so that the frequency response of the broadband is normal again (that is, to compensate for pre-emphasis introduced at the transmitting terminal).

(v) To pick off the pilot frequencies for control regulation and supervisory equipment, but prevent these pilots being applied to the demodulating equipment.

6.2 The incoming line frequencies are passed via the power feed filters to a building-out network. The purpose of this network is to allow short repeater sections to be "built out" electrically so that they fall within the regulating range of the line amplifier. The nominal repeater spacing is about 5.75 miles for transmission of frequencies up to 6MHz. A typical building-out network has four sections with characteristics for up to 0.25 miles, 0.5 miles, 1 mile and 2 miles of coaxial cable.

6.3 From the building-out network the line frequencies are passed via a changeover switch to the line amplifier. This four stage equalising amplifier is designed to compensate for the loss versus frequency characteristics of a cable section of about 5.75 miles. To compensate for the effect of variations in temperature on the cable a variable equaliser network is included in a negative feedback circuit, and is controlled by a pilot regulation circuit associated with the 6.2MHz pilot. This amplifier is called the slop amplifier or "E" amplifier.

A no-break changeover facility to a standby amplifier is provided by a changeover circuit similar to that described for the transmitting amplifier. When switched to the "Checking" position, the 6.2MHz pilot receiver is placed across the output of the standby amplifier, which takes a parallel feed of the line frequency input. When the 6.2MHz pilot registers 0dB deviation from its nominal value the standby amplifier gain is satisfactory, and changeover can proceed.

6.4 When used for television programme transmission the line amplifier and changeover switch are followed by an echo attachment. This unit, in conjunction with the following line amplifier, obtains an overall flat frequency response. The line equaliser is sometimes termed a "mop-up" equaliser, as it compensates for frequency distortion remaining after the line amplifier. An amplifier and pad are associated with the line equaliser.

When used for telephone transmission the echo attachment is not required, as the line equaliser is sufficient to give suitable delay and attenuation equalisation.

Equalisation by the echo attachment and the line equaliser is achieved by the echo principle. The signal is passed via a delay ladder network where a number of echo voltages, either leading or lagging with respect to the basic signal, can be selected. By adding the various echo voltages to the main signal, delay distortion and frequency distortion are reduced to a minimum.

6.5 The equalised line frequencies are applied from the line equaliser to the pilot equaliser which has a flat loss to the signal frequencies. The loss to the pilot frequencies can be varied by narrow band equalisers.

If a line section is equalised to within about ±0.5dB by the previous equalising circuits, it is possible that the voltage of the line pilots may vary from their nominal value with respect to the signal, by amounts up to this tolerance. The function of the pilot equalisers is to regain correct pilot level to signal level ratio, before transmitting the line frequencies to the receive terminal equipment.

6.6 Fig. 13 shows, in chart form, the level of the equalised line frequencies (red) and the relative level of the pilot frequencies with respect to their required level, before application to the pilot equaliser.

Each pilot equaliser provides and adjustment of pilot level in five, 0.1dB steps. An additional narrow peak equaliser is provided for the 6.2MHz because this pilot is picked off at all repeater stations. Although the gain of the repeater line amplifier is only affected by about 0.6dB because of the bridging pick-off filter, this error becomes cumulative over a number of sections and requires additional equalisation.

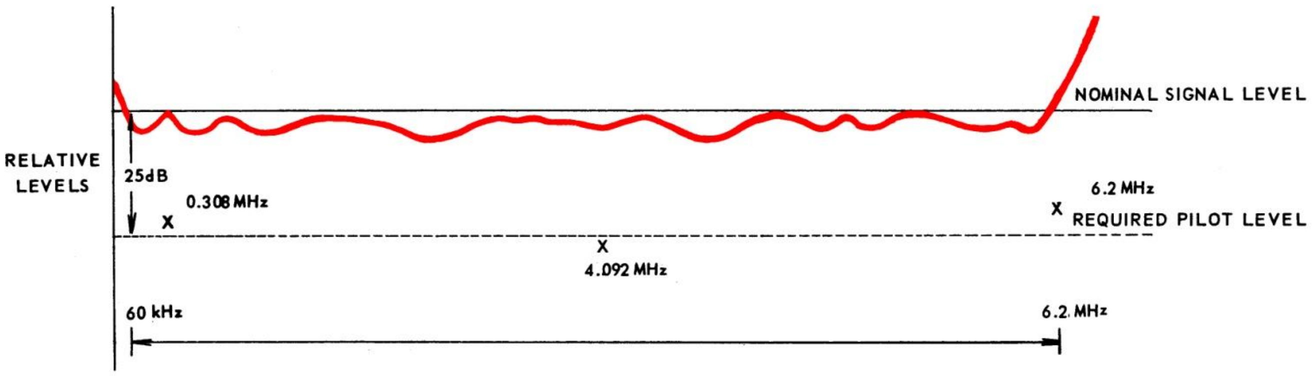


FIG. 13. SIGNAL AND PILOT LEVELS AT THE INPUT TO PILOT EQUALISER.

At the output of the pilot equaliser the pilot frequencies have the required level with respect to the nominal signal level. An attenuator, not shown in the block diagram, is incorporated with the pilot equalisers, but offers flat loss over the range from 60kHz – 6.2MHz.

6.7 Following the pilot equaliser a three stage flat line amplifier (G1) restores the line frequency level, after attenuation in the preceding equalisers. A changeover switch at the output and input of the flat line amplifier gives a no-break changeover facility to a standby amplifier. The changeover circuit is similar to that described for the transmitting line amplifier. Parallel valves are provided for each stage, and visual indicators are provided in the screen grid circuit to give an indication of the emission for each individual valve.

6.8 The pilot controlled equaliser which follows the flat amplifier, corrects, in the first section, for errors in level due to overall tube aging. In the second section it corrects for variations in level due to variations in ambient temperature.

Although a combination of the three pilot voltages gives the necessary control it can be considered that the 308kHz pilot controls the first equaliser section, and compensates for all valve aging occurring between the previous fully regulated repeater and the receiving terminal station. Control of the second equaliser is brought about by the 4092kHz pilot, and compensation for variation in amplifier gain caused by variations in ambient temperature is made over a range of about 108°F.

A third equaliser, provides a fine adjustment which compensates for the operating characteristic of the thermistor in the line amplifier regulating circuit. The operating region of the thermistor is set at the time of installation.

Either a fixed loss or a variable loss attenuator, is used at the output of the pilot controlled equaliser, for impedance matching purposes.

6.9 For voice channel transmission an attenuation pad follows the pilot controlled equaliser. The pad has an attenuation of 14.8dB and replaces the delay equaliser used with television programme transmission. In a typical system, the delay equaliser can be adjusted to equalise for up to fourteen repeater sections.

6.10 The signal is applied from the attenuation pad or the delay equaliser (T.V.) to a measuring input circuit, which is provided to enable a test frequency to be applied to the line equipment, without causing interruption to the operating circuits. The measuring input is isolated from the through transmission path, to prevent disruption to service, due to faulty operating technique.

6.11 A changeover switch and flat gain line amplifier (G2) follow the measuring hybrid. This amplifier is identical to the line amplifier following the pilot equaliser, and similarly, its function is to compensate for losses accrued in the preceding equalisers and attenuators. A no-break changeover to a standby amplifier is made with a circuit similar to that described for the transmitting amplifier.

The changeover switch unit, at the output of the line amplifier, also includes circuitry to pick off the pilot frequencies. The pilot regulation and supervision equipment is similar to that used at attended repeater stations, and is detailed in Section 9.

6.12 Following the pilot pick off point, a de-emphasis unit is inserted in the circuit. This unit is complementary to the pre-emphasis unit at the transmitting terminal, and restores the signal frequencies to their original relative values. For the 900 voice channel system, an attenuator is used in place of the de-emphasis unit, as pre-emphasis is not applied at the transmitting terminal.

6.13 The final item of equipment in the receiving path is a pilot stop filter unit. For multi-channel systems a 308kHz stop filter only is used, but for T.V. transmission, stop filters of 308kHz, 4092kHz and 6200kHz are installed. The pilot stop filters prevent the pilot frequencies from interfering with the signalling circuits of adjacent channels, or with the composite T.V. signal.

The output of the Receiving Amplifier is wired in hard dielectric coaxial cable to the appropriate telephone or television demodulating equipment.

6.14 Rack Layout. A typical receiving amplifier rack is of cabinet construction, approximately 8′ 7″ high by 2′ wide by 9″ deep. A terminal strip at the top of the rack carries the coaxial cable terminal strips.

Power supplies for the active equipment is obtained from a regulated power source situated at the base of the rack.

Each unit of equipment is mounted on a slide-in chassis and is connected to the rack cabling by blade contacts.

The rack layout of a typical receiving amplifier rack is similar to that of an attended repeater (Fig. 17), with the exception that dropping facilities are not required.

7. REPEATER EQUIPMENT.

7.1 The nominal repeater spacing on a coaxial line system suitable for frequencies up to 6.2MHz is about 5.75 miles.

Two types of repeaters are used; Unattended (Dependent) Repeater Stations and Attended (Main) Repeater Stations. These names refer to the type of repeater equipment used rather than to station staffing.

7.2 Unattended Repeater Stations. A maximum of twelve consecutive unattended repeater stations is followed by an attended repeater station. The number of consecutive unattended repeater stations is limited by the power feed arrangements, as the power supply system, at an attended station can supply up to six unattended repeater stations on either side. (Power supply details are given in Section 10).

The gain of the line amplifier can either be adjusted by hand or automatically controlled by a regulator associated with the 6.2MHz pilot. As a general rule each alternate unattended repeater station is equipped with automatic pilot control.

7.3 Fig. 14 shows a block diagram of a typical unattended repeater station. A line amplifier is provided for each direction of transmission. The line frequency band incoming from the coaxial tube passes via a power filter to a building-out network. As for a terminal station, this network is used to artificially extend the length of a short repeater section so that its loss falls in the regulating range of the equalising amplifier.

The transmitted signals pass from the building out network via a changeover switch to a four stage line amplifier. This amplifier is similar in circuitry to the equalising amplifier described for the receiving amplifier rack, and at a regulated unattended repeater is under the control of the 6.2MHz pilot. At an unregulated repeater the 6.2MHz pilot provides supervision only, and manual gain control is used.

A no-break changeover to a standby amplifier is provided, and parallel valves are used to lessen the possibility of interruption to service.

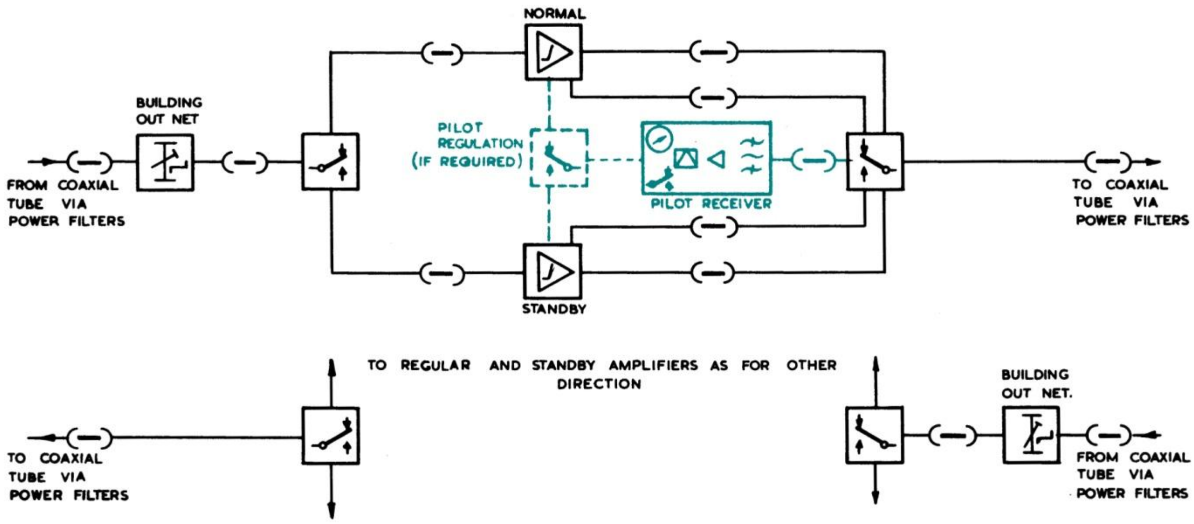
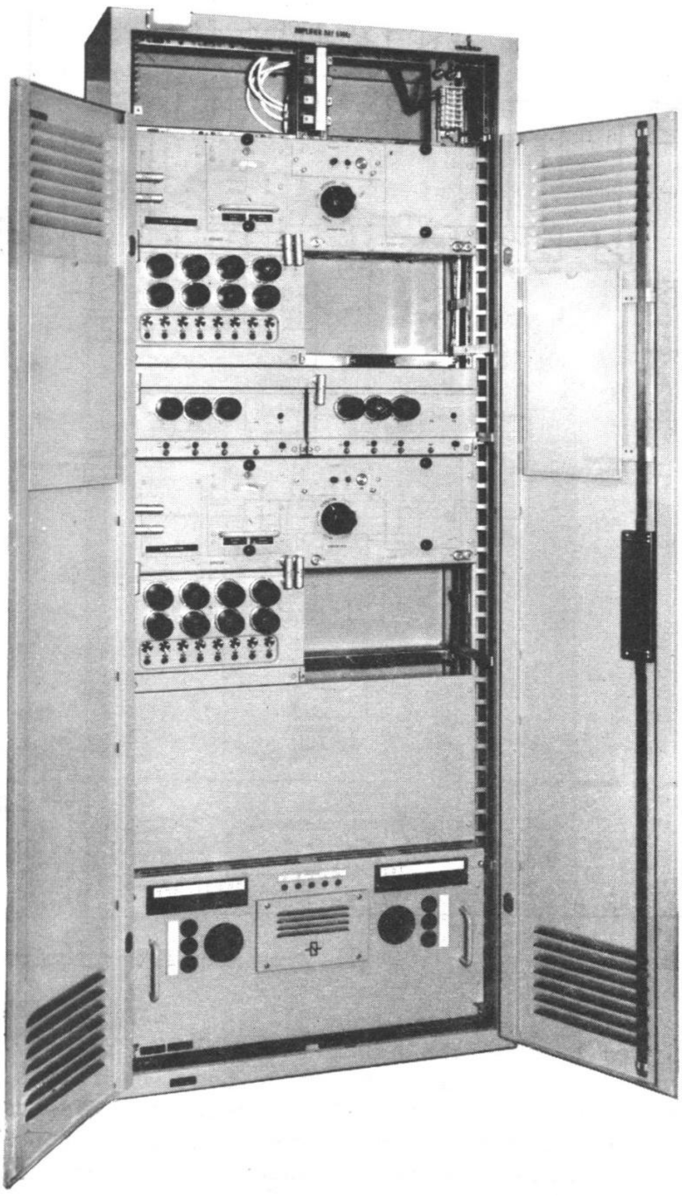
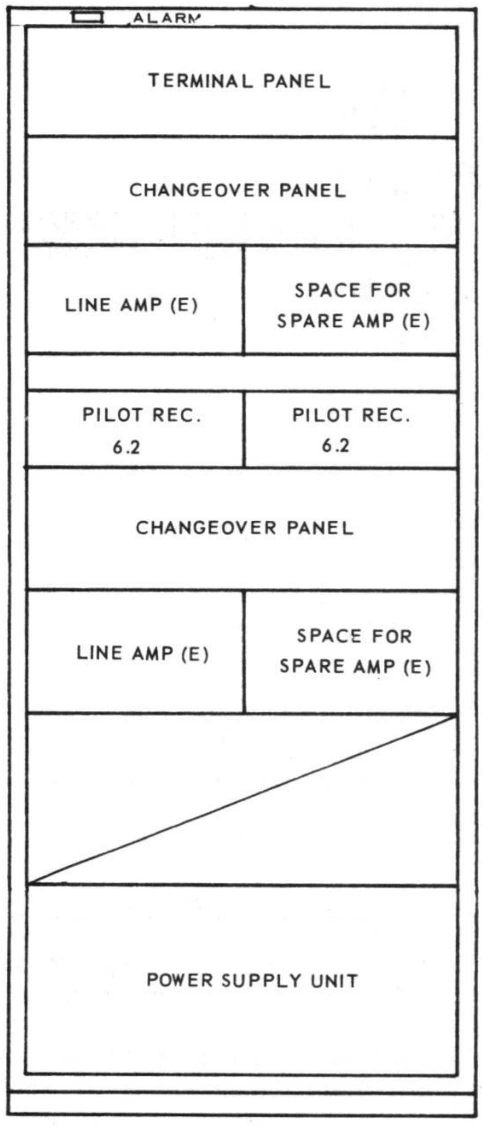


FIG. 14. BLOCK DIAGRAM OF TYPICAL UNATTENDED REPEATER STATION.

7.4 A typical unattended repeater station line amplifier rack is illustrated in Figs. 15 (a and b). The amplifiers for each direction, together with the facility for changeover to a standby amplifier, are accommodated on the one rack. Pilot indicators are not provided with the pilot receivers, but the pilot level can be checked with a suitable portable meter.



(a)



(b)

FIG. 15. RACK LAYOUT FOR TYPICAL UNATTENDED REPEATER.

7.5 Attended Repeater Station. In addition to the line amplifier rack for each direction of transmission, an attended repeater station can provide power feed to up to six unattended repeater stations in either direction. Also, if necessary it can provide drop-out and replenishing facilities for a number of supergroups. When used for T.V. programme transmission, the equipment is very similar to that of the receiving line amplifier rack for T.V. transmission.

7.6 Fig. 16 shows a block diagram of a typical attended repeater station with remote power feed circuits to both sides, and access to a dropping rack where drop-out and replenishing of supergroups is made. (Details of Dropping and Replenishing are given in Section 8).

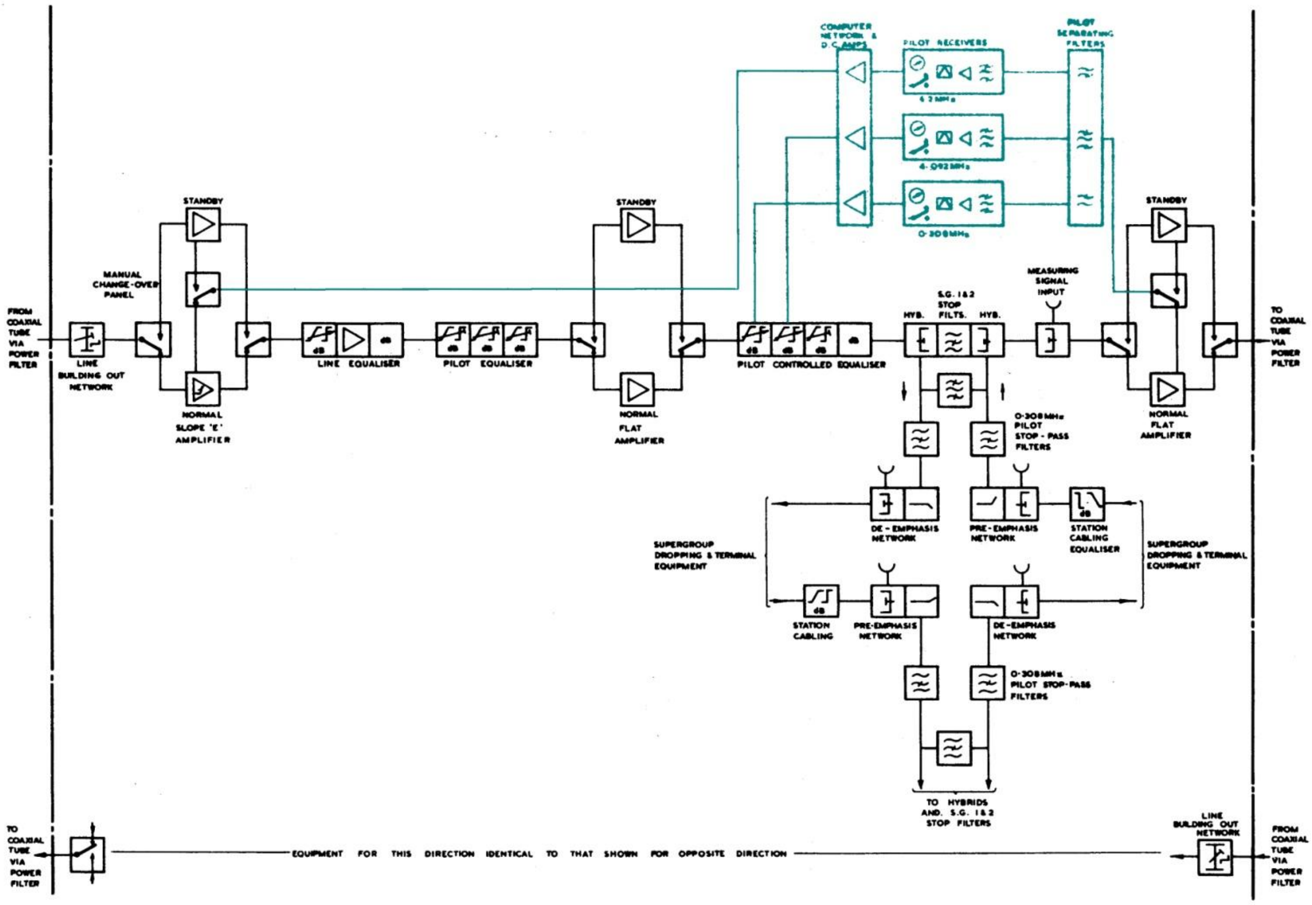


FIG. 16. BLOCK DIAGRAM OF TYPICAL ATTENDED REPEATER STATION.

7.7 The attended repeater equipment is identical to the receiving line amplifier equipment from the building-out network to the pilot controlled equaliser.

The pilot controlled equaliser is followed by a hybrid and filter unit to allow drop-out and replenishing of supergroups. The 308kHz pilot "stop-pass" filter prevents the 308kHz pilot passing to the supergroup terminal equipment but directs it for transmission to the next section. The supergroup 1 and/or supergroup 2 stop band filters prevent the frequencies for these supergroups being passed to the next section when replenishment of these supergroups is made.

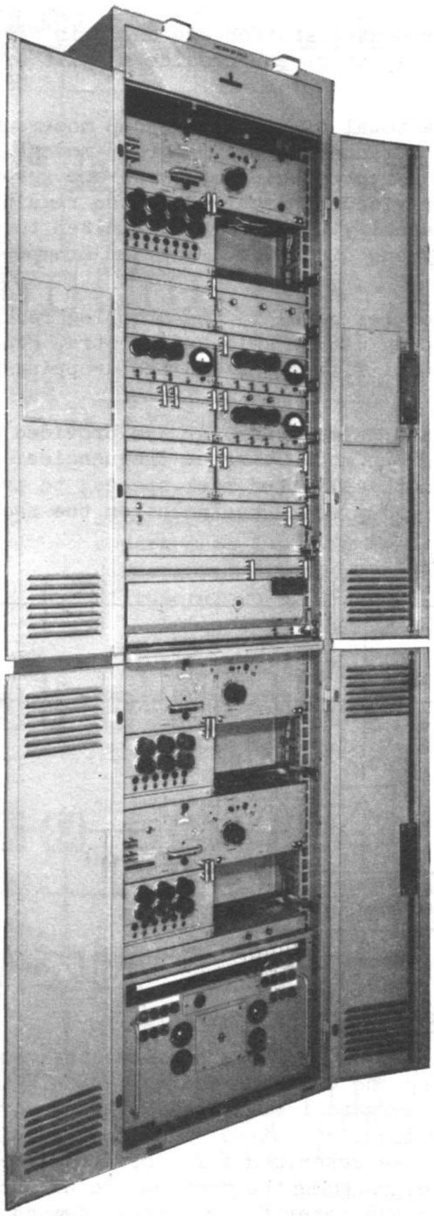
From the drop-out equipment the signal is passed via a measuring input circuit and flat gain line amplifier, with associated standby equipment, through the power filter to the coaxial tube.

The pilot regulation equipment is identical to that used at the receive terminal and is detailed in Section 9.

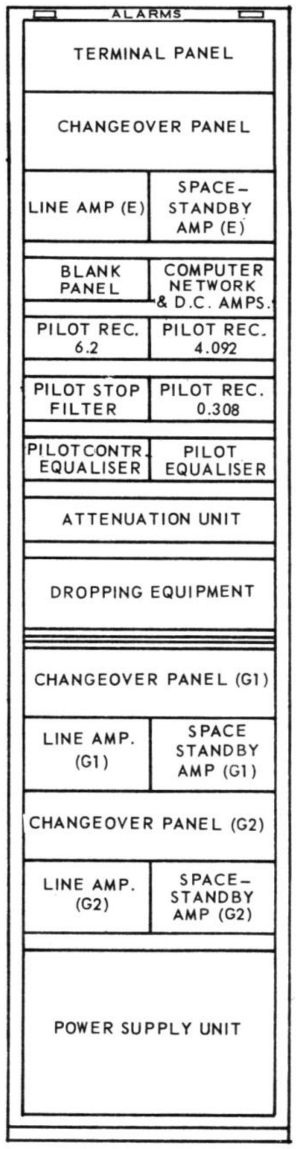
No-break changeover facilities to standby amplifiers are provided in a similar manner to that used in the terminal line equipment. It is important to avoid indiscriminate changeover, as the very slight break in transmission is sufficient to cause distortion to telegraph and data transmission circuits. Changeover should only be made at a time of light traffic, and with the permission of the Line Control Station.

7.8 In the drop-out circuit a de-emphasis unit is inserted to restore the line frequencies to their original relative values; this compensates for the pre-emphasis unit at the transmitting terminal. A pre-emphasis unit is inserted in the replenishing path to improve the signal to noise ratio for the composite signal transmitted to the next section. In the replenishing path, a station cabling equaliser compensates for frequency distortion occurring in the station cable. The equaliser has a reverse frequency versus attenuation response to the station cabling from the modulator rack to the repeater rack. Measuring hybrids are provided to allow a check on transmitting and receiving levels for the terminal equipment.

7.9 The rack layout of a typical attended repeater is shown in Fig. 17 (a and b). One line amplifier rack is required for each direction of transmission. The rack layout is similar to that of a receive terminal, but with the addition of supergroup drop-out facilities.



(a)



(b)

FIG. 17. RACK LAYOUT FOR TYPICAL ATTENDED REPEATER.

8. DROPPING AND REPLENISHING FACILITIES (BRANCHING).

8.1 We saw in the paper "Introduction to Broadband Carrier Telephony", that supergroups and groups can be used for interconnection between terminals and intermediate stations and between one intermediate station and another. At attended repeater stations on a coaxial bearer it is possible to "drop" supergroups 1 and/or 2 and "replenish" supergroups 1 and 2. In addition it is possible to drop and supergroup without replenishment.

When dropping facilities are required at an attended repeater station, a special "dropping rack" (branching rack) is provided. In this rack the dropped supergroups are separated and translated to and from the basic supergroup position. The carrier frequencies for supergroups in the range 3 to 16 can be inbuilt in a typical dropping rack and the carrier frequency for supergroup 1 is obtained from the group carrier supply rack.

8.2 The arrangements for dropping at an attended repeater station are shown in Fig. 16. The dropping decouplers included in the main repeater path provide a split of all the supergroups to the dropping rack.

A typical dropping rack has rack spaces for a total of six supergroup modem units. These spaces are wired and allocated in such a manner that supergroup modems 1 and 2 can be provided twice, to allow dropping and replenishing of those supergroups. Supergroup modems in the range 3-16 can be provided as required in the remaining spaces, within the limitations of the rack capacity. The rack is limited to a maximum dropping capacity of five supergroups for any one direction. Typical examples are given in Para. 8.3.

All of the supergroups are applied to a decoupler panel in the dropping rack. At this point the supergroups required for dropping can be selected by strap connections. Fig. 18 shows the main elements of the line amplifier racks and the dropping rack at a dropping station.

A regular and standby 124kHz driving source and pulse generator are provided on the dropping rack to produce the necessary supergroup modem carrier frequencies. Carrier selection filters and amplifiers are added in the allotted rack spaces, to provide the carrier frequencies required by the supergroup modem equipment on the rack.

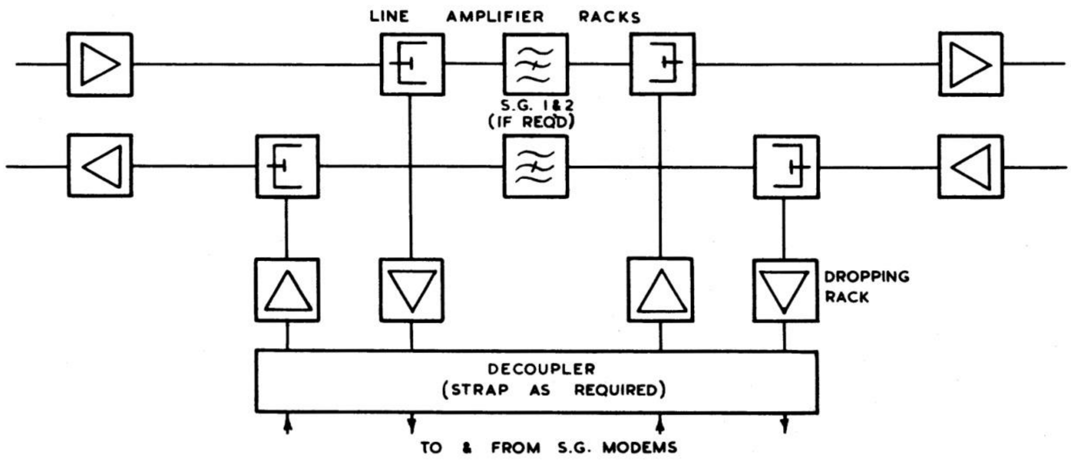


FIG. 18. MAIN ELEMENTS OF EQUIPMENT AT A DROPPING STATION.

At some intermediate attended repeater stations, a dropping rack with the facilities listed in para. 8.3, is not capable of meeting the dropping and replenishing requirements. In these instances it is necessary to install separate supergroup modem equipment to meet the large demand for local circuits. The supergroup modem equipment is carried on racks identical to those described for a broadband terminal. At some stations a dropping rack is capable of handling the drop-out requirements for one direction and separate supergroup modem racks cater for the heavy demand in the opposite direction.

8.3 In the coupler panel, strap connections are made to allow any supergroup to be dropped and also supergroups 1 and 2 to be replenished, if required. Typical examples of dropping and replenishing facilities are given.

- Dropping of supergroups 1 and 2 and three other supergroups from one direction only. Fig. 19 shows a typical examples.

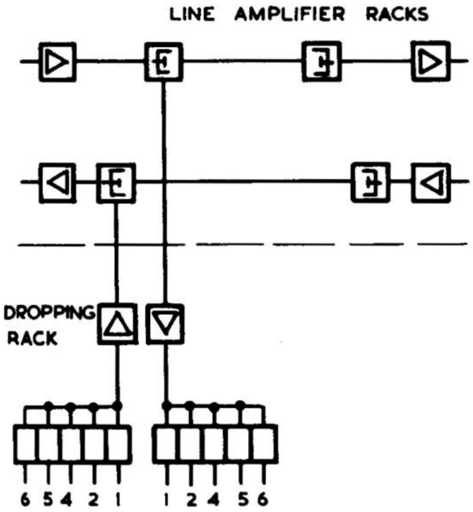


FIG. 19. DROPPING OF SUPERGROUPS 1, 2, 4, 5 AND 6.

- Dropping of a total of five supergroups (including supergroups 1 and 2) for both directions. Fig. 20 shows a typical example.

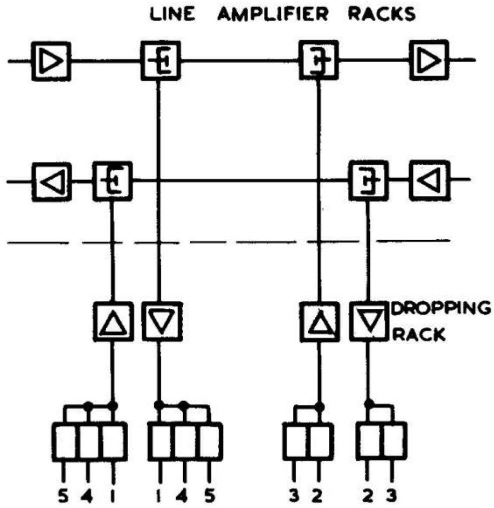


FIG. 20. DROPPING OF SUPERGROUPS 1, 4 AND 5 FROM DIRECTION "A" AND 2 AND 3 FROM DIRECTION "B".

- Dropping of a total of five supergroups (including supergroups 1 and 2) from both directions, with replenishment of supergroup 2. Fig. 21 shows a typical example.

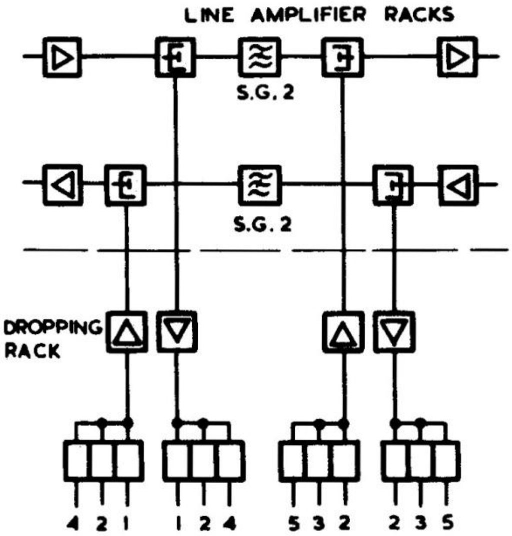


FIG. 21. DROPPING OF SUPERGROUPS 1, 2, and 4 FROM DIRECTION "A" AND 2, 3 AND 5 FROM DIRECTION "B" (REPLENISHING OF SUPERGROUP 2).

- Dropping of a total of four supergroups (including supergroups 1 and 2) from both directions, with replenishment of supergroups 1 and 2. Fig. 22 shows a typical example.

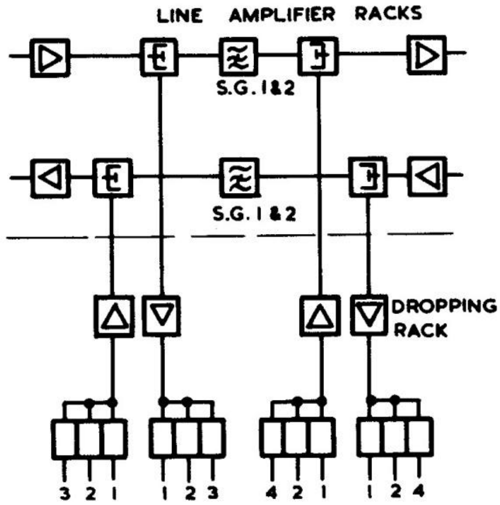


FIG. 22. DROPPING OF SUPERGROUPS 1, 2 AND 3 FROM DIRECTION "A" AND 1, 2 AND 4 FROM DIRECTION "B" (REPLENISHING OF SUPERGROUPS 1 AND 2)

9. LINE PILOT REGULATION AND SUPERVISION.

9.1 The three line pilot frequencies commonly used by 4MHz and 6MHz broadband systems, are 0.308MHz, 4.092MHz and 6.2MHz. Alternative frequencies of 4.142MHz and 6.142MHz are sometimes used instead of 4.092MHz and 6.2MHz, respectively and an additional pilot frequency of 60kHz is used with some systems. In transistor operated line equipment, it is expected that one pilot frequency of 4.287MHz will be used for regulation and supervision.

9.2 The pilot frequencies are injected at the transmitting terminal at a fixed known level, with respect to the signal level, and are part of the composite signal transmitted to line. The pilot frequency level is nominally 20dB below the signal level.

Fig. 23 shows in simple block diagram form, the principles of line pilot regulation and supervision, for one direction of transmission.

The three pilots are injected at the input to the flat line amplifier at the transmitting terminal. At the output of this amplifier, pilot receivers monitor the pilot transmission level, and give an indication of the degree of deviation from the nominal level. Failure of, or a decrease in, pilot level by about 4.3dB, causes disabling of the pilot regulation circuit and introduces an alarm.

At unattended repeater stations the 6.2MHz pilot is used for supervision. However, it is common for each alternate unattended repeater station to be equipped with automatic gain regulation of the slope line amplifier under the control of this pilot. This compensates for attenuation changes due to temperature variations in the two preceding repeater sections. In some systems the "4MHz" pilot is used to control the slope amplifiers at each repeater and at the receive terminal.

All three pilots are picked off at attended repeater stations and the receive terminal, and are used for regulation and supervision. As at regulated unattended repeater stations, the 6.2MHz automatic regulation circuit controls the slope line amplifier, to correct for the effects of cable temperature changes. The 308kHz pilot automatic regulation circuit compensates for valve ageing between the previous fully regulated station and the local station. The 4092kHz pilot automatic regulation circuit compensates for variations in ambient temperature, over a range of about 14°F to 122°F.

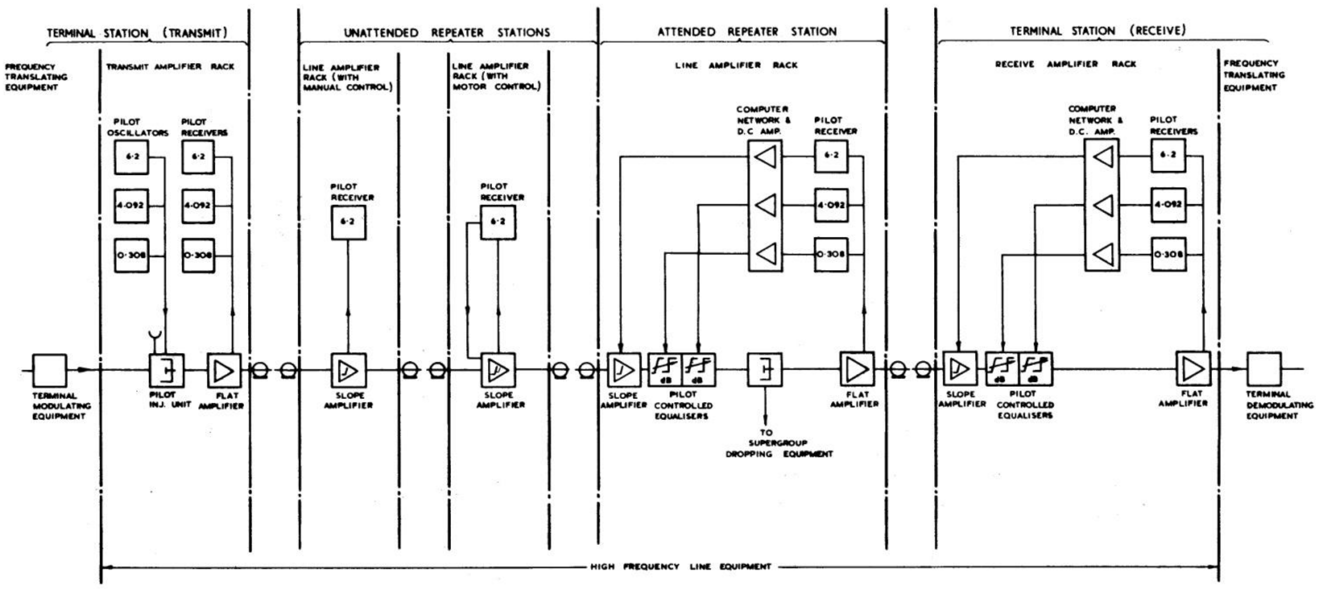


FIG. 23. SIMPLIFIED BLOCK DIAGRAM OF H.F. LINE PILOT REGULATION AND SUPERVISION.

9.3 In the pilot injection unit, the three pilots are added to the line frequencies at a fixed known level with respect to the signal level. An additional input circuit is provided for injection of test frequencies, which can be transmitted to line with the system line frequencies. This signal input circuit is isolated from the transmission path, to prevent interruption to the transmitted frequencies due to faulty operating techniques.

9.4 Fig 51 shows a pilot separating filter at the output of the flat line amplifier in the transmitting amplifier rack. This filter provides a high impedance bridging path to apply the three pilots to the pilot receivers. The pilot separating unit consists of a high pass filter which selects the 6.2MHz pilot, a band pass filter for the 4.092MHz pilot, and a low pass filter for the 0.308MHz pilot.

The three pilots are applied to their respective pilot receivers, and are used to supervise the pilot generators and the flat line amplifier.

9.5 Pilot Receiver. Each pilot receiver consists of a sharply tuned band pass filter, to select the required pilot frequency, and apply it to a pilot amplifier. The rectified output of the pilot amplifier and a regulated reference voltage are jointly applied to a comparison circuit, where, if the pilot is at its nominal value, no deviation is indicated on the pilot level meter.

A simplified schematic of a typical pilot receiver circuit is shown in Fig. 24. The output of the pilot amplifier is transformer coupled via diodes SC1 And SC2, through a resistor to a polarised relay G. A regulated reference voltage (+100V) is applied through a resistor to the other winding of the relay G, and when the pilot is at its nominal level, the rectified output of the pilot amplifier is equal and opposite in polarity to the regulated reference voltage. The relay contact remains in the neutral position. A meter bridged across this circuit as shown, registers any pilot level deviation.

A decrease in pilot level causes current through the load resistor and relay, in such a direction as to cause the meter to indicate a pilot level deviation below the nominal value. The degree of deviation is indicated in dB below the nominal value, and when the decrease is about 4.3 dB or more, relay G operates to the M contact. The circuit to the pilot failure alarm lamp is closed; relay A disables the pilot regulation circuit.

An increase in pilot level causes current through the resistor and relay in such a direction as to cause the meter to indicate a pilot level deviation above the nominal value. Alarm conditions are not introduced for deviations above the nominal value, as theses are not likely to be encountered.

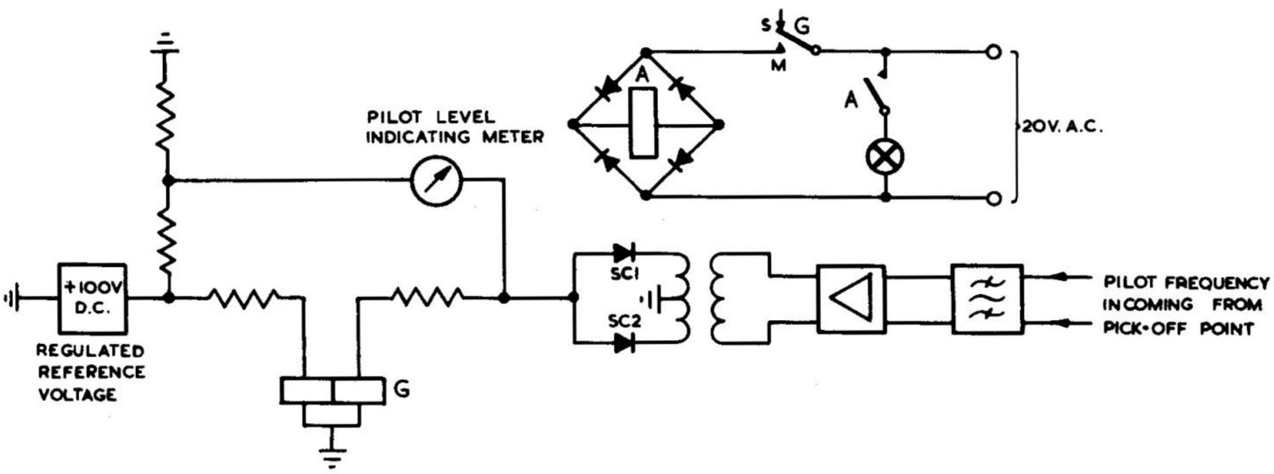


FIG. 24. SIMPLIFIED SCHEMATIC - PILOT RECEIVER CIRCUIT.

9.6 Only the 6.2MHz pilot is used for regulation and supervision at unattended repeater stations. At each alternate unattended repeater station, automatic pilot control is not used, and periodically the gain is manually adjusted.

Fig. 14 shows the 6.2MHz pilot receiver bridged across the output of the line amplifier via the changeover unit. At a station with automatic regulation, the pilot level controls a regulator network in the feedback circuit of the slope line amplifier.

Fig, 25 shows the main elements of a typical pilot receiver and regulator. The circuit operation of the receiver is the same as described for the pilot receiver at the transmitting terminal, except that small deviations in pilot level bring about automatic control of the slope line amplifier.

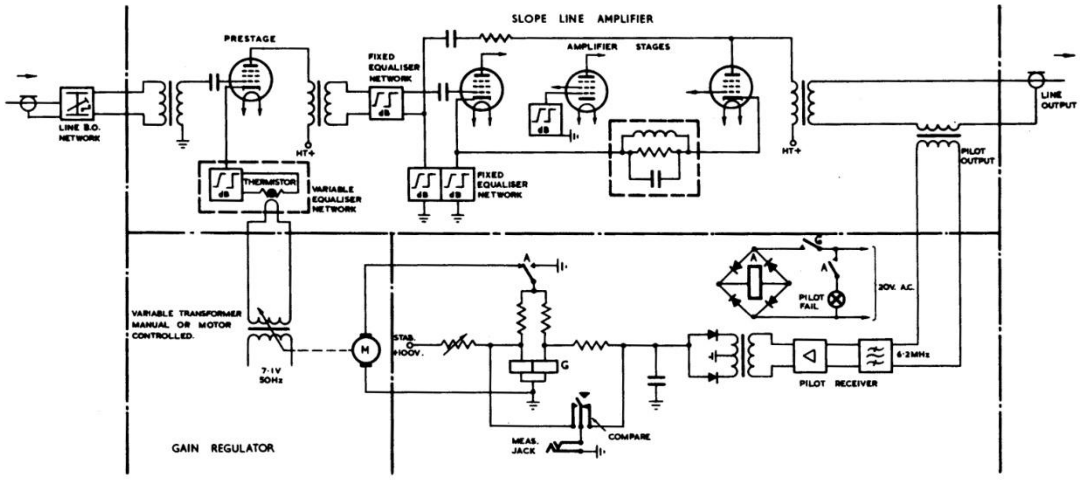


FIG. 25. MAIN ELEMENTS OF 6.2MHz PILOT RECEIVER AND REGULATOR.

9.7 When the rectifier pilot voltage is equal and opposite to the stabilised reference voltage (+100V), zero P.D. exists across the regulator motor. A deviation in pilot level, due to a change in line attenuation, causes a difference in potentials between the rectified pilot and the reference voltage. This results in a P.D. across the motor which drives clockwise or anti-clockwise, according to the polarity.

A system of gears driven by the regulator motor varies the coupling ratio of transformer T1, which controls the AC heater current of a thermistor. The thermistor is included in the negative feedback network of the slope line amplifier, and the change in thermistor resistance effectively increases or decreases the amplifier gain to compensate for line attenuation changes. The regulating action continues until the rectified pilot voltage is equal and opposite to the reference voltage. When the pilot level meter indicates 0dB deviation from the nominal value the slope line amplifier gain has compensated for the line attenuation change.

When a continuing variation in line attenuation causes the regulator motor to drive to an extreme of adjustment the appropriate limit switch operates to cut the motor drive for that direction, and introduces an alarm. Because of the polarity of the rectifier, a circuit is provided for motor drive in the reverse direction should the applied polarity change due to a change in incoming pilot level.

When the incoming pilot level drops in level by an amount greater than 4.3dB, relay G operates to the M contact and closes the circuit to operate relay A and a pilot fail alarm lamp. Contacts of relay A disable the pilot regulation circuit.

The pilot level deviation can be read on a meter plugged into the measuring jack. The stabilised reference voltage is adjusted by observing the voltage reading on a meter plugged into the measuring jack when the compare key is operated.

9.8 At the receive terminal and attended repeater stations, the three pilots are picked off at the output of the flat line amplifier, and applied via the pilot separation filter to their respective pilot receivers. Details of the pick off circuit are shown in Figs. 52 and 16 respectively.

To avoid a tendency for the pilots to interact or hunt in their control, a computing network is added in the circuit. For example when an increase in temperature alters the frequency versus attenuation characteristic of the cable (Table 2), and an increase in line loss results, all pilot frequencies indicate a decrease in level. Each pilot receiver supplies a voltage to the computing network which supplies an operating voltage to the slop line amplifier regulation circuit only, as this circuit is designed to compensate for cable attenuation changes. Other conditions produce D.C. outputs designed to correct the level deviation, but avoid hunting of pilot controls.

In general the 6.2MHz pilot circuit controls the regulation circuit in the slope amplifier, the 4092kHz pilot circuit controls a variable equaliser to compensate for changes in ambient temperature and the 0.308MHz pilot circuit controls a variable equaliser to compensate for valve ageing. In practice the computer network assesses the relative pilot levels at any time, and applies regulating voltages to the required circuits, so that a combination of all voltages is used for control.

A typical computer network circuit is shown in Fig. 26. Each output is followed by a D.C. amplifier to provide the current necessary to drive the regulator motor.

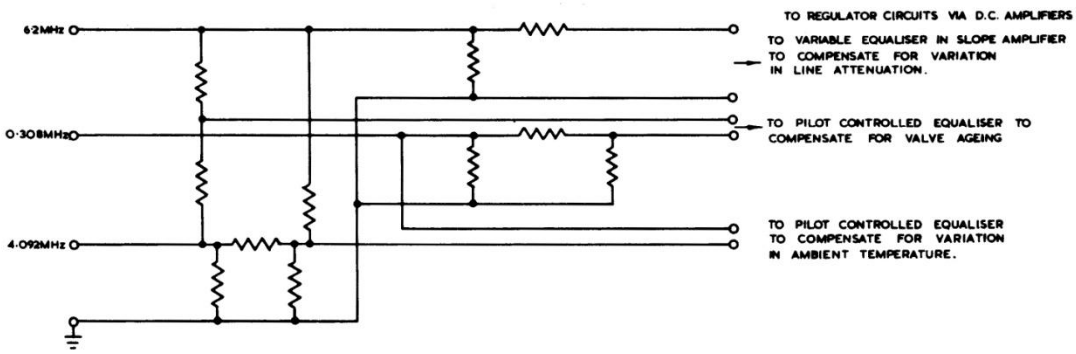


FIG. 26. TYPICAL COMPUTER NETWORK.

9.9 Fig. 27 shows a schematic circuit of a typical degenerative equaliser which, under the control of the 6.2MHz pilot regulation equipment, varies the gain of the slope amplifier. The regulation range of a typical slope amplifier is shown in Fig. 28.

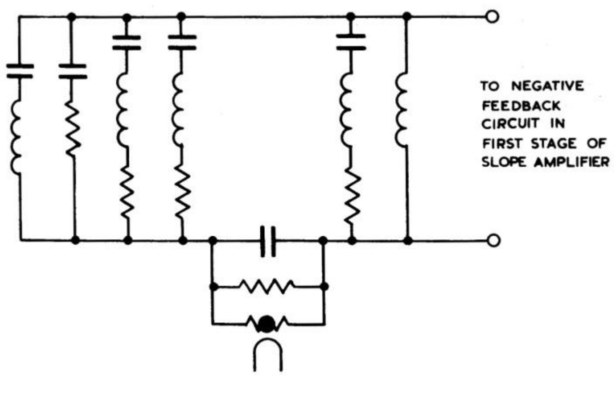


FIG. 27. REGULATING EQUALISER - SLOPE AMPLIFIER.

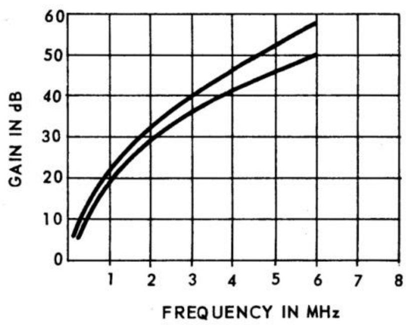


FIG. 28. TYPICAL REGULATING RANGE - SLOPE AMPLIFIER.

9.10 A simplified schematic of a typical 308kHz pilot controlled equaliser is shown in Fig. 29. The heater current for the thermistor is controlled by the regulator motor and variable transformer according to pilot level deviation. The resulting changes in thermistor resistance bring about varying attenuation versus frequency response curves for the equaliser.

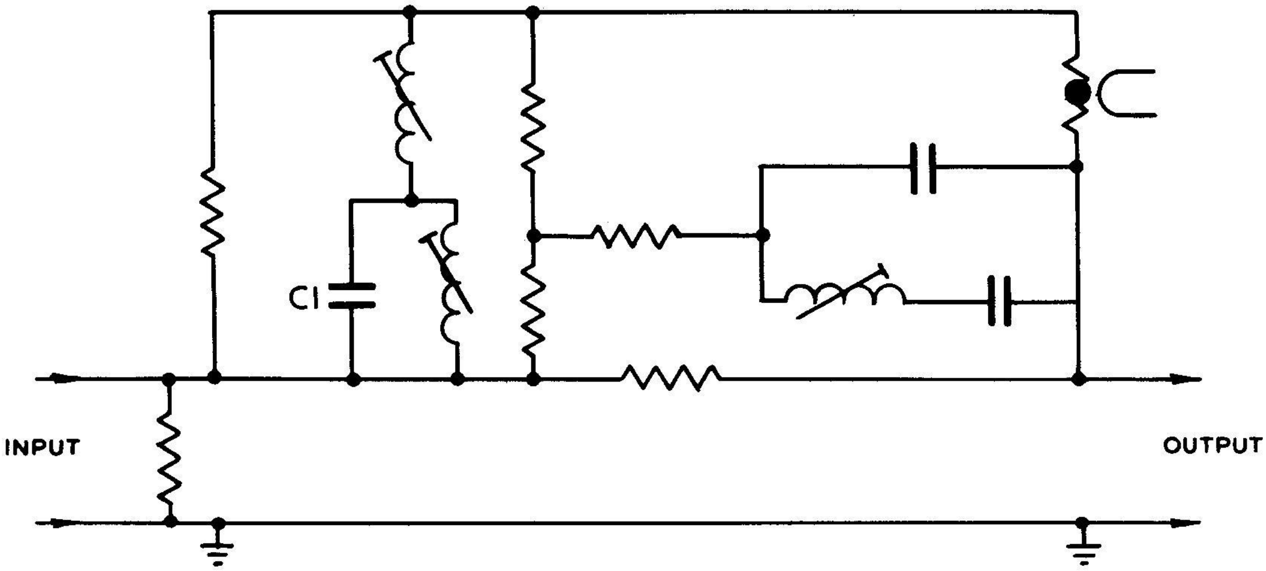
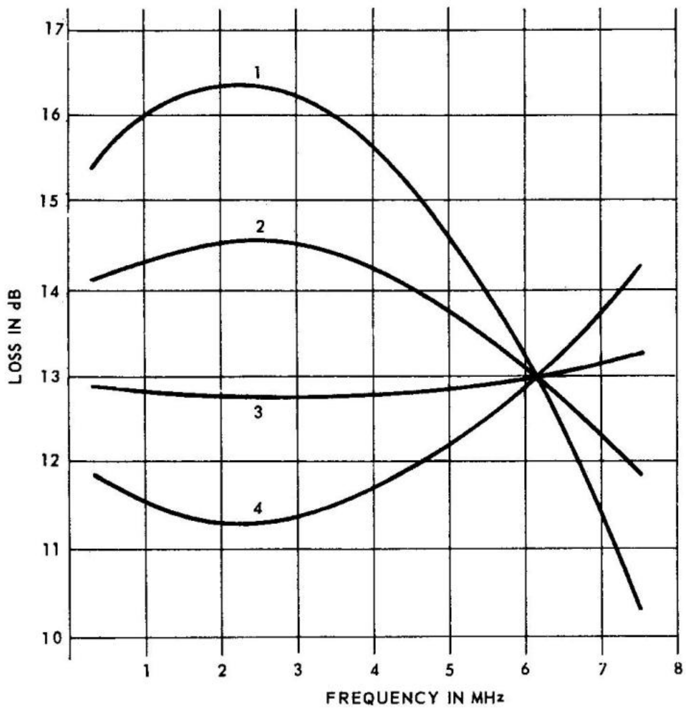


FIG. 29. SIMPLIFIED SCHEMATIC - 308kHz PILOT CONTROLLED EQUALISER.

A number of typical equaliser responses for various settings of the control are shown in Fig. 30.



CURVE	CONDUCTANCE
1	> 16.3 mA/V
2	16.3 mA/V
3	13.5 mA/V
4	12 mA/V

FIG. 30. TYPICAL FREQUENCY VERSUS ATTENUATION CHARACTERISTICS OF 308kHz PILOT CONTROLLED EQUALISER.

9.11 Fig. 31 shows a simplified schematic of a typical 4092kHz pilot controlled equaliser. Variations in thermistor resistance, under the control of the regulation circuit, brings about variation in the frequency versus attenuation response of the equaliser. A number of typical frequency versus attenuation response curves are shown in Fig. 32.

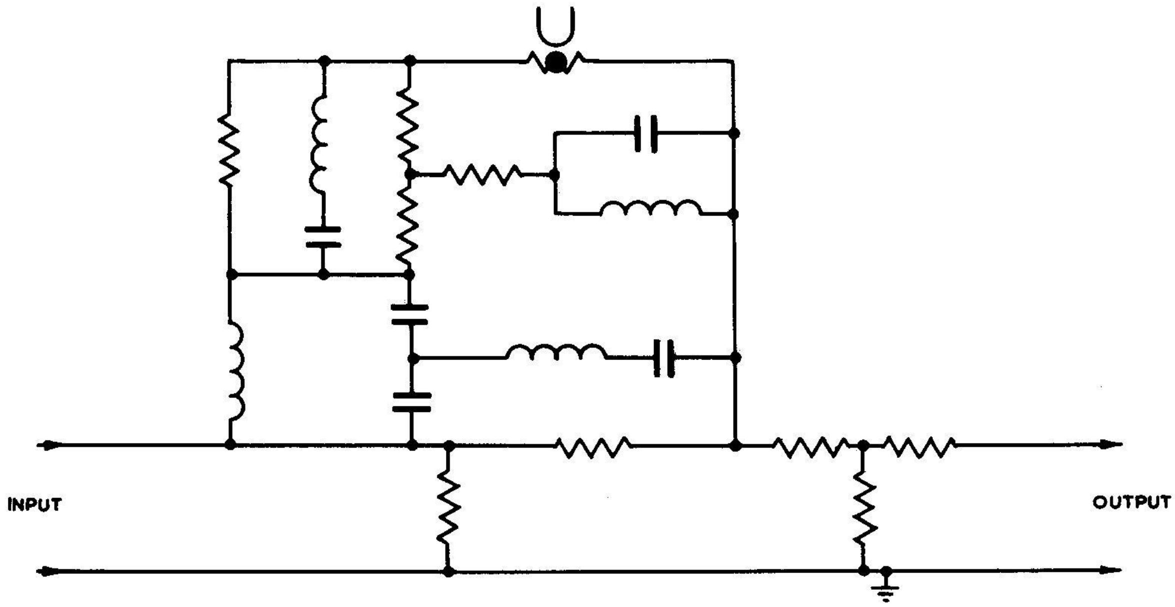


FIG. 31. SIMPLIFIED SCHEMATIC - 4092kHz PILOT CONTROLLED EQUALISER.

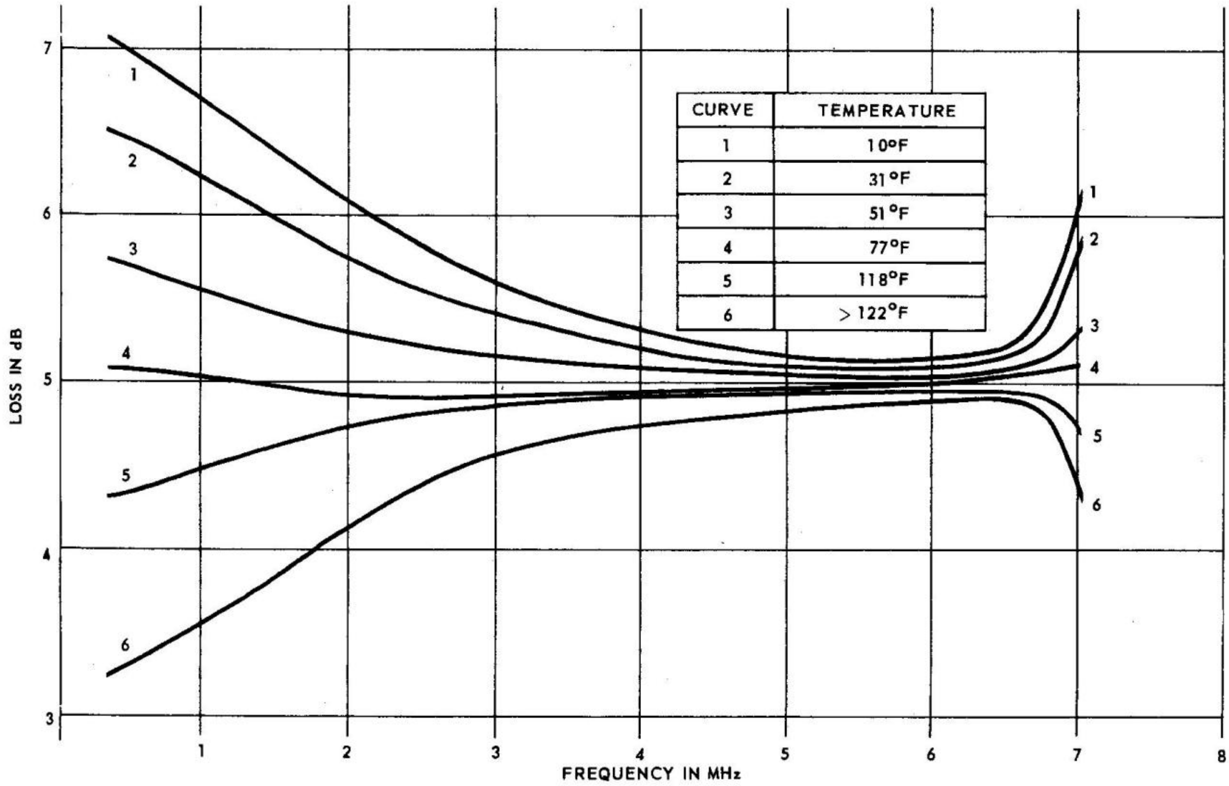


FIG. 32. TYPICAL FREQUENCY VERSUS ATTENUATION CHARACTERISTICS OF 4092kHz PILOT CONTROLLED EQUALISER.

10. REMOTE POWER SUPPLY EQUIPMENT.

10.1 To provide a reliable power source to all stations on a coaxial cable route, power is supplied to unattended repeater stations from terminal and attended repeater stations equipped with no-break A.C. power supply equipment.

The power required to operate the amplifiers and supervisory equipment at the unattended repeater stations is fed over the inner conductors of the coaxial tubes from an attended station. This method of providing power to the unattended repeater stations is more economical and more reliable than generating power at each unattended station, or using the local A.C. mains supply.

10.2 Assuming a load not in excess of 220 V.A. for each "fed-station", an attended repeater can feed up to six unattended repeater stations in each direction, and a terminal station can feed up to six stations in the one direction. With repeater spacings of 5-6 miles, this gives about a 30 mile power feeding section in one direction.

Fig. 33 shows typical power feed capacities when the maximum number of stations are supplied from each feeding station. It can be seen that the number of consecutive unattended repeater stations is limited to twelve, because of the power feeding requirements.

When more than one system operates in the same coaxial cable, a separate power feed is used for each system. The advantages of this are that a fault condition in one power feed has no effect on the others, and any system used for T.V. transmission can be switched off when out of use for a prolonged period. The communication system and its power feeding system use the same pair of coaxial tubes.

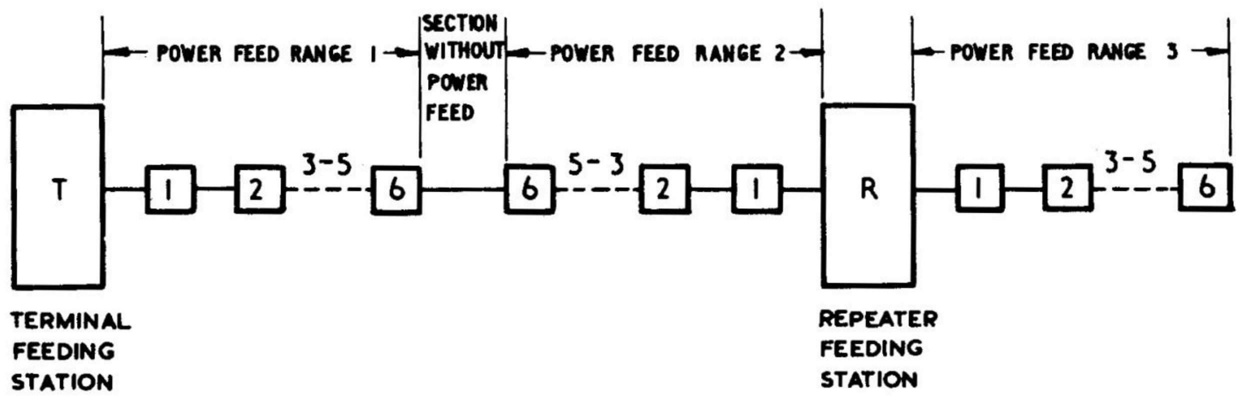


FIG. 33. TYPICAL POWER FEEDING CAPACITIES.

10.3 The feeding station requires a regulated, single phase voltage of 240V from a no-break power supply. The equipment is designed for 50Hz operation, but generally a frequency of about 48Hz is used because of the slip in the no-break converter. This frequency is held within close tolerances.

The power required at a feeding station depends on the number and the power requirements of the stations to be fed, and also the power requirement of the feeding station. An attended repeater station feeding six stations in either direction requires a power output of about 6 K.V.A. However, a large number of power feeding stations supply power to a considerable amount of local terminal equipment, so the power rating of typical no-break plants in use at coaxial stations ranges from about 15 K.V.A to 50 K.V.A.

10.4 A typical power feed arrangement is shown in Fig. 34. At the feeding station (attended repeater) the regulated 240V obtained from the no-break A.C. supply plant is supplied via a 240/220V auto transformer to the power feeding rack. In modern power equipment the 240V is supplied direct to the power feeding rack. There the voltage is stepped up and applied to the inner conductor of two coaxial tubes, via the low pass section of power separating filters. These filters separate the power supply from the high frequency transmission equipment.

The secondary of the power feeding transformer is earthed at the centre tap, and typical voltages used are 600V from centre tap to either inner conductor giving 1200V from inner conductor to inner conductor. It should be noted that the coaxial outer conductor is at earth potential, so that 600 volts exists between inner and outer conductors of each tube.

At the fed station (unattended repeater) the high voltage power (for example, 1040 volts) is taken from the inner conductors of the tubes via power separating filters, and applied to a step-up auto transformer. This restores the voltage between the two inner conductors to the original 1200V for transmission to the next unattended repeater station. A secondary winding steps the voltage down to the 220V or 240V required for the local power circuits.

At the last power feed station, the inner conductors of the coaxial tubes not used for power supply, are taken to earth via the power separating filters. It should be noted that power separating filters are installed on all cable sections where there is no power feeding. Their functions are to protect the high frequency transmission equipment from longitudinal voltages caused by faults in nearby power lines or lightning strikes, and also maintain standard conditions for line equalisation and cable termination.

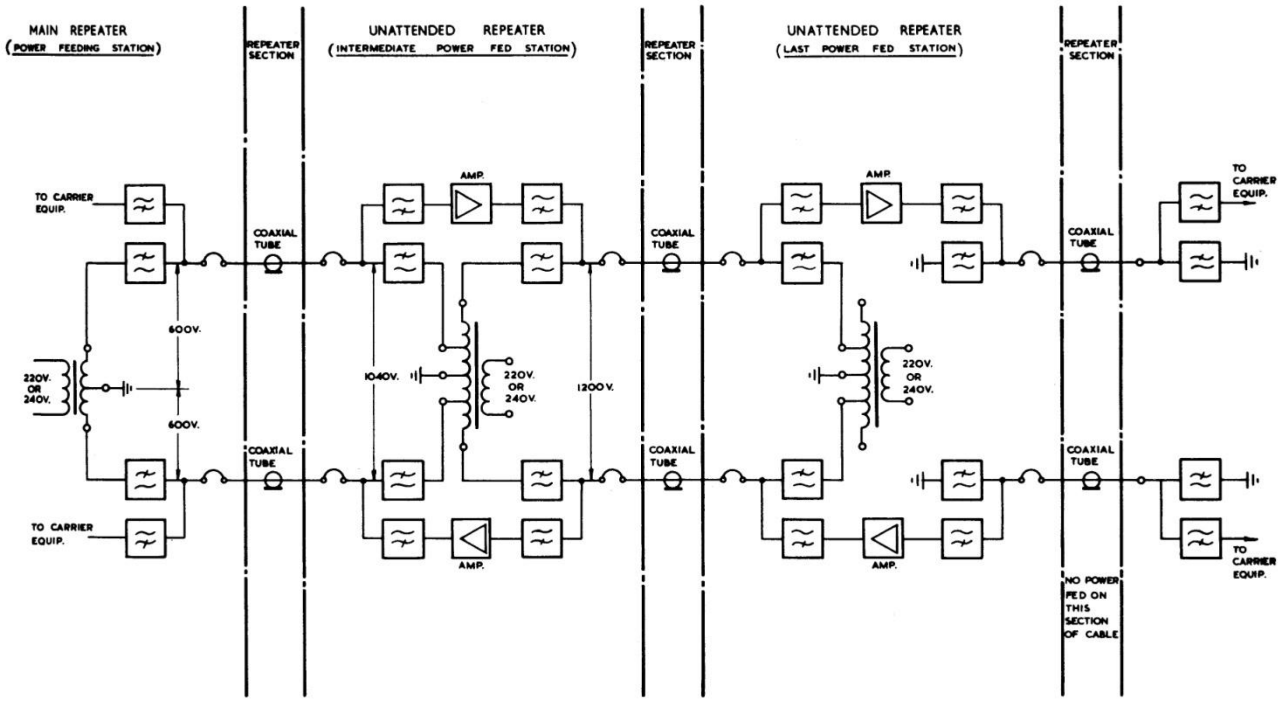


FIG. 34. TYPICAL POWER FEEDING ARRANGEMENTS FROM ATTENDED REPEATER.

10.5 Mobile power units are provided on some routes to supply power in emergency circumstances. It is possible to make extensive repairs on a section of cable while still maintaining high frequency transmission. To do this the high voltage power must be removed from the affected section.

Fig. 35 shows how power can be removed from one repeater section to allow cable repair. At the fed station preceding the faulty section, (3-4), a dummy load simulating the load of the remainder of the normal power feeding section, terminates the power feed. At the station beyond the faulty section, the correct voltage is injected from the mobile generator to feed power to that and subsequent stations.

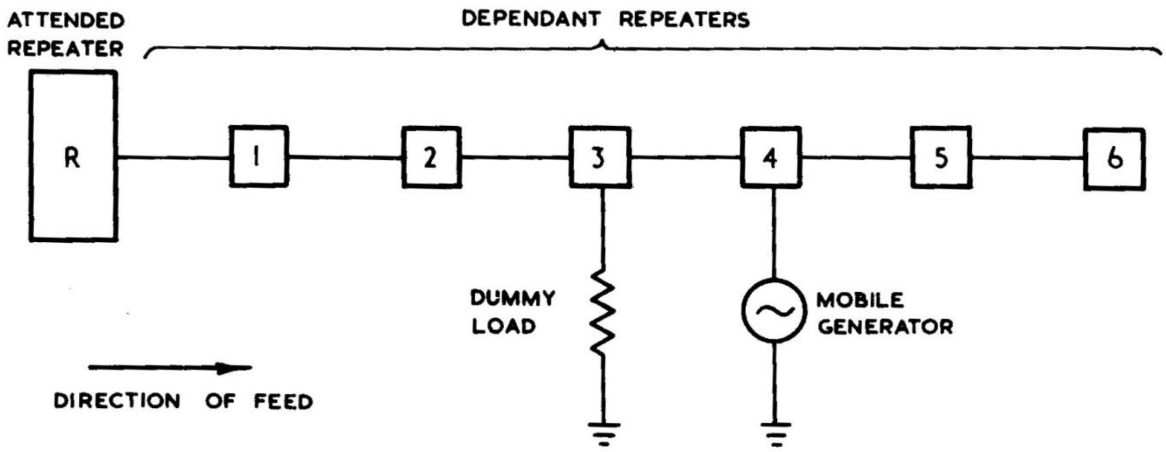


FIG. 35. REMOVAL OF POWER FROM SECTION 3-4 IN WHICH A CABLE FAULT HAS DEVELOPED.

10.6 Supervisory equipment is provided at the feeding and fed station to protect the equipment and coaxial cable from damage due to large feeding currents, unbalanced currents in the two tubes, and high voltages under fault conditions. Alarms are introduced to indicate the fault condition.

A simplified schematic of the supervisory equipment at the feeding station is shown in Fig. 36. The following facilities are provided:-

(i) An alarm when an underload greater than 0.4KVA exists; power feeding continues under this condition.

(ii) An alarm and automatic disconnection of power feeding for an overload greater than 0.4KVA. The disconnect time varies from about 30 seconds for an overload of 1KVA to about 100 m/seconds for an overload greater than 4KVA.

(iii) Simple adjustments for setting the sensing circuits, depending on the normal power feeding load for that route section.

(iv) "ON" and "OFF" switches to control the remote power feeding. During cable repair operations, inadvertent or unauthorised reconnection of the power feeding is prevented by a key locked power switch.

It should be noted that mains interruption of less than 100 m/seconds do not cause disconnection of the power feeding.

10.7 To set the power feed in operation the non-locking switch, "ON", is depressed. This closes the circuit to relay A which operates via the power switch control lock and the 1 amp. And 25 amp fuses. Relay A locks up via its contact A1, OL1 and the non-locking switch "OFF". At A2 the circuit is closed to apply 220V via the supervisory transformer to the supply transformer where it is stepped up to 1200V.

The supervisory circuit consists basically of an overload and underload detection circuit bridged across the supply. The rectified output voltage of the supervisory transformer is equal and opposite to the rectified regulated 220V when normal load current is drawn. A decrease in load current causes a decrease in the rectified output voltage from the supervisory transformer, but the rectified 220V supply remains constant. If the underload is 0.4KVA or greater, current in the detection circuits causes the operation of a relay, which brings in an alarm to indicate underload conditions.

An increase in load current results in an increase in the rectified voltage output from the supervisory transformer, and if the overload is 0.4KVA or greater, current in the detection circuits operates a relay (OL) which introduces an alarm. OL1 opens the circuit to relay A which disconnects the power feed at A2.

A KVA meter associated with the detection circuits registers the power drawn by the load. The adjustment for underload and overload detection is made using the normal load value as a reference. The sensing adjustments, to control alarm and "throw-out" values, are made at the time of installation, or if any permanent load change is introduced.

Power feed can be removed by operating the non-locking switch "OFF", which opens the circuit to relay A. A.C. to the supply transformer is removed at A2.

A 1kHz low pass filter, situated between the main fuse and the supervisory equipment, eliminates some of the harmonics caused at the terminal by the non-linear load, such as rectifiers. This filter supplements the low pass line filter, to ensure that high frequencies from the power equipment are separated from the coaxial line frequencies.

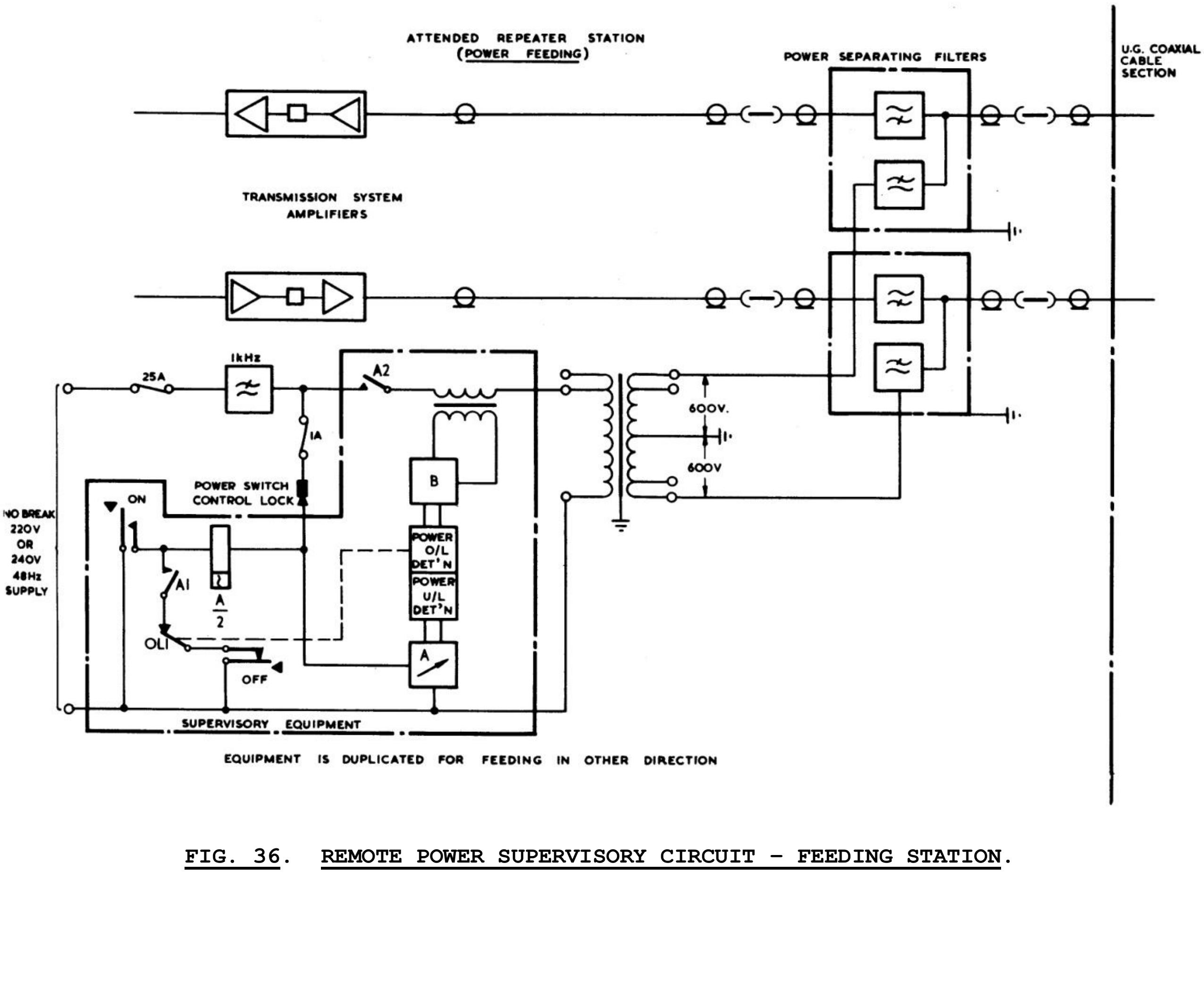


FIG. 36. REMOTE POWER SUPERVISORY CIRCUIT - FEEDING STATION.

10.8 Safety Features. When coaxial cable repair work is necessary, it is essential for the safety of the linemen concerned to remove the high voltage from the cable. On most coaxial routes provision is made to provide unattended repeater power, in an emergency, from local A.C. mains or from mobile power feeding plant.

The power feeding racks incorporate a control lock which prevents the power feeding unless a special key is fitted. Separate keys are provided for each power feeding system and these keys are not interchangeable. A typical power feed supervisory unit is shown in Fig. 37. Provision is made for the supervision of two power feeds from this unit.

When cable repair work is necessary, the lineman in charge requests disconnection of the high voltage feeding at the appropriate feeding station. After disconnection he is given the key from the control lock which he places in a metal box provided at the station. He then locks the box with his own padlock. When cable repairs and testing are completed, the lineman in charge returns the control lock key to the officer in charge at the station, who reconnects the remote power feeding.

At the power feeding and power fed stations, the equipment containing the high voltage connections is clearly marked to indicate the hazard. All control devices outside the cover plates are safe to touch and the cover plates can only be removed with the aid of tools.

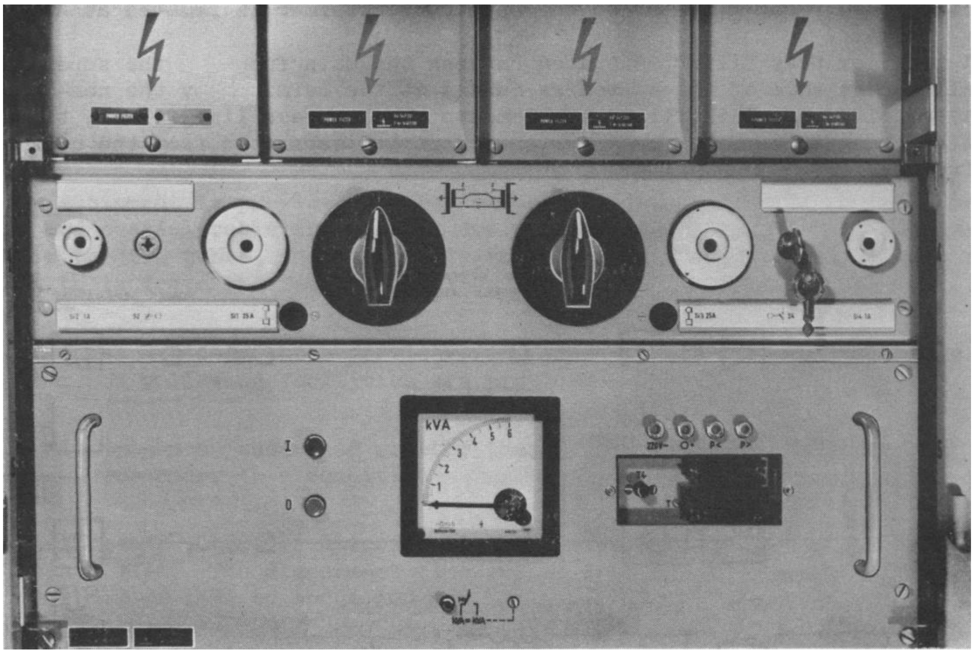


FIG. 37. PART OF POWER SEPARATION FILTERS AND POWER SUPERVISION EQUIPMENT.

10.9 A simplified schematic of the supervisory equipment at a power fed station is shown in Fig. 38. The following facilities are provided by the supervisory and changeover panels.

- An alarm and automatic disconnection if the unbalance of current in each coaxial tube is greater than 10%. This unbalance could be caused by a cable fault or induction.
- An alarm and automatic disconnection if the voltage supply to the equipment increases by 10%. This increase could be caused by the disconnection of other stations along the power route.
- Automatic changeover to the local A.C. mains supply in the event of failure of, or throw-out from, the remote feed.
- A safety switch to short circuit the station supply and cause disconnection of the high voltage power feed.

The incoming high voltage is transformed to 1200V for application to the next unattended repeater station, and to 220V to operate the local power equipment. The tube current unbalance and high voltage detection circuits are transformer coupled from the high voltage supply. A tube current unbalance in excess of 10%, or a voltage increase greater than 10%, maintained for at least 0.5 second, causes operation of the relay H. The contact H1 closes the circuit to relay X which operates, and holds via X1, and at X2 places a 2 ohm shunt across the 220V output from the remote power feed. The increased load causes power feed disconnection at the feeding station.

Failure of the 220V from the remote power feed allows relay A to release. Contact A1 opens the circuit to the remote supply, and A2 applies local power via a voltage stabiliser to the local power equipment. The local supply is supervised by relay B.

A safety switch, when operated places a short circuit across the 220V supply from the remote power feed, and the increase in load current causes disconnection of the high voltage at the power feeding station.

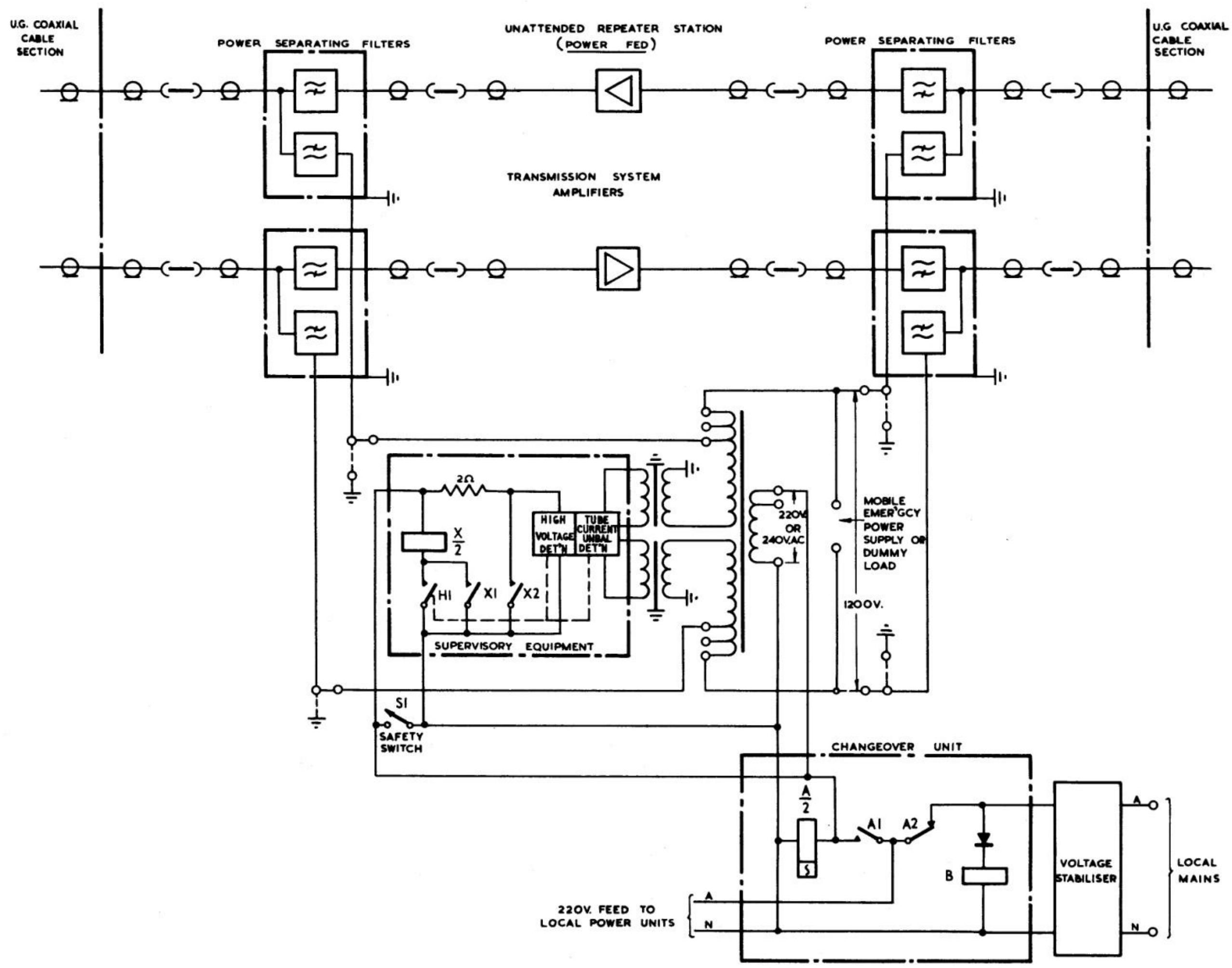


FIG. 38. REMOTE POWER SUPERVISORY EQUIPMENT - FED STATION.

11. REMOTE SUPERVISION OF UNATTENDED REPEATER STATIONS.

11.1 To give adequate supervision of the coaxial system all line equipment (including gas pressure equipment) at an unattended repeater is placed under the continuous supervision of an attended station. In addition order wire circuits are provided to give service communications between all stations.

These facilities are provided over paper insulated pairs in the cable. The actual pairs used are determined by the requirements for a particular route, but in general they are selected from the core and layer pairs.

The principles and block diagram of the coaxial line equipment provided by the various manufacturers are very similar but considerable differences exist for the supervisory equipment associated with their systems. The broad principles of some of the supervisory equipment in use is covered in this paper. If additional information is required, reference should be made to the company handbooks or to local instructions.

11.2 Order wires. Two types of order wires are normally provided. They are termed "short haul" and "long haul" order wires.

The short haul order wire operates either on a two-wire or four-wire basis, and gives communication to and between the intermediate unattended repeater stations.

The long haul order wire operates on a four-wire basis and gives communication to and between attended stations. Amplifiers are used at each attended station to provide satisfactory transmission quality, and a system of selective calling is incorporated.

11.3 Gas Pressure Alarms. The constant pressure gas alarm (G.P.A.) system is used extensively on trunk and junction cable routes, and is applied to coaxial cable routes. The system consists of making a cable network gas tight, by eliminating as many leaks as possible, and then installing contactors at regular intervals to short circuit an alarm pair or pairs when the gas pressure drops to a pre-determined value. Another advantage of the G.P.A. system is that while gas pressure is maintained within the cable, it is difficult for water to penetrate the sheath. This is particularly applicable to coaxial cables, which because of their construction, offer little resistance to the passage of water along the cable.

In general, gas feeding equipment is installed at each repeater station (attended and unattended) and three sets of contactors are installed between repeaters. These are installed at the ¼, ½ and ¾ points of each repeater section. At each repeater station a set of contactors are associated with the high pressure gas reservoir, and operate when the reservoir drops to a predetermined value.

Selected terminal or attended repeater stations are made G.P.A. supervision stations. And a line length up to about 50 miles can be supervised from these points. Fig. 39 shows a typical four wire alarm circuit and the indicating and location equipment at a supervision station. Provision is made for locations on four G.P.A. systems. The operation of any contactor closes the circuit to introduce an alarm. Positive location of the contactor position is made by means of a wheatstone bridge. The resistance to each contactor is automatically converted into the contactor location, and indicated by means of a lamps on the supervision unit.

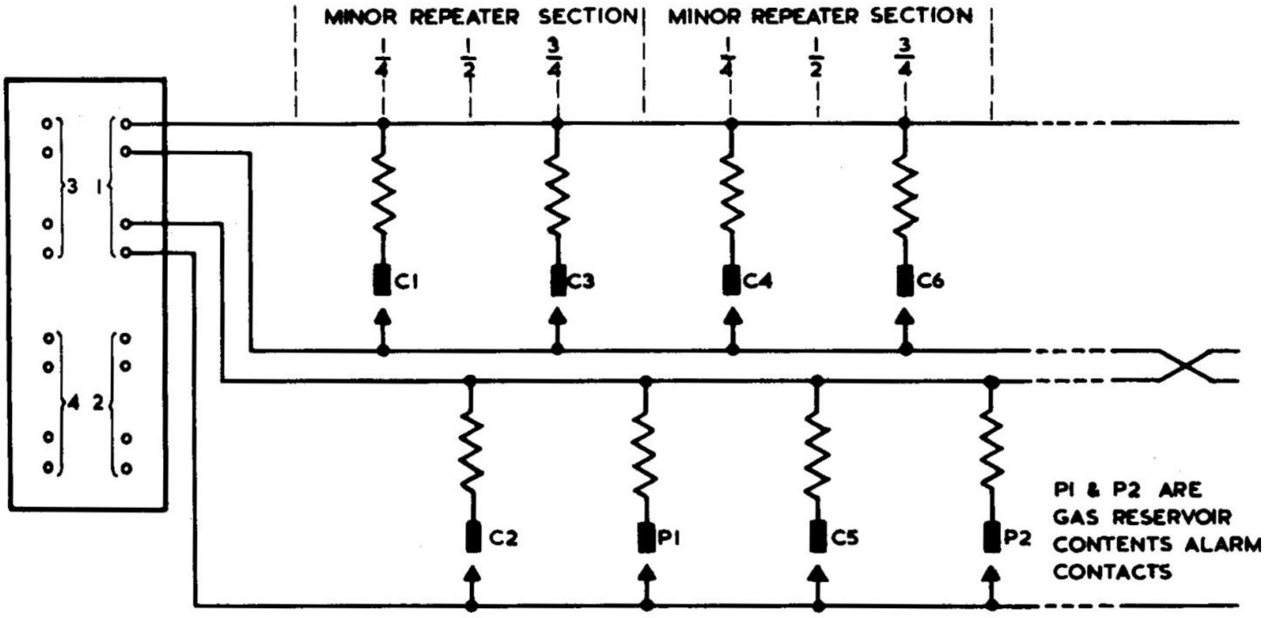


FIG. 39. 4-WIRE G.P.A. ALARM CIRCUIT.

11.4 Supervision of Line Equipment. Although the various manufacturers of coaxial line equipment use different methods to achieve equipment supervision, some general principles hold for all types. Firstly the coaxial route is divided into supervisory sections with an attended station (either a terminal or a repeater) supervising a number of unattended repeater stations. Secondly, the remote supervision section and the power feeding section usually coincide, so that all power feeding stations are supervising stations. Thirdly, information from the unattended repeater stations is applied to an indicator unit at the supervising station in such a manner that the station and the type of fault can be identified.

Siemens and Halske Supervision. Fig. 40 shows the operating principle of the remote supervision equipment used by Siemens and Halske on their valve type line equipment. This system transmits, over a cable pair, indications in the form of 50Hz pulse telegrams from a "substation" unit located at the unattended repeater station to a "central station" unit located at an attended repeater station or terminal station. The substation units and the central station unit contain step-by-step selector switches which run in synchronism during the transmission of pulse telegrams. A fault condition at any supervised station initiates conditions for the transmission of a pulse telegram. The pulse telegrams contain the indications to be transmitted, beginning with an identification of the sending station from the first set of contacts (station identification contacts), and followed by identification from the second set of contacts (fault identification contacts), of the fault or unstandard condition at the unattended station.

Circuit safeguards prevent the display of false information due to non-synchronous stepping of the selectors, or simultaneous sending of pulse telegrams from two or more stations on the route, which would mask each other. The pulse telegram is received by all other substations, and is used to block the substation units from sending pulses until the transmission path is clear again. Any indications about to be transmitted are stored and transmitted subsequently. Time delay circuits set for different periods at each station ensure that, should there be more than one station waiting to send a telegram, telegrams are transmitted in sequence.

Each central unit can cater for either 10 substations each sending 25 signals, 11 stations each sending 24 signals, or 12 stations each sending 12 signals.

The basic remote supervision system requires two cable pairs, one pair being for an indicating line, and the other for a supervisory line.

The indicating line is used to send the 50Hz pulse telegrams from the substation units to the central station indicating equipment, of which more than one may be connected in parallel. The supervisory line is used to continuously monitor the state of readiness of the substations to send pulse telegrams. The supervision is arranged by sending a 50Hz signal at approximately 18 to 50 volts, depending on the line length from the last unattended station in the supervision section, and receiving this voltage at the central controlling station to operate a relay in the indicating apparatus. Should a fault occur at any substation, which would prevent transmission of a pulse telegram (for example, power failure) the 50Hz supervisory feed is interrupted, and the central controlling station responds by lighting all the station identification lamps and automatically sending an interrogation signal. This causes all substations to send a pulse telegram in turn, which extinguishes the associated station lamps. The station where the power failure occurred cannot send a pulse telegram, and the appropriate station lamp remains lit on the indicating panel, to identify the faulty substation.

So that the central station can make a check of the unattended stations, an interrogation signal consisting of a long pulse (approximately 1,500 m.s.) of 50Hz signal can be sent from the central station, to initiate the sending of pulse telegrams from the substation units. A time delay circuit, which is set for a different period at each substation unit, ensures that the indicating pulse telegrams are sent in sequence from unattended stations. The interrogation signal is sent automatically on failure of the supervisory line, and also on reconnection of power at a central station, following a power failure at that station. A push button key allows for a manual operation of the interrogation when required.

Transmission and Evaluation of Impulse Telegram. Each time of equipment requiring alarm extension facilities at an unattended station, is equipped with a relay which extends an earth under faulty conditions to a contact of the selector device. This initiates the start condition, which results in stepping of the selector and application of pulses of 50Hz to the indicating line. The pulses are received by the central station monitoring equipment, where a selector steps in synchronism with the substation selector. At each step, the selector switch at the substation tests a contact. Should there be an earth present on the contact, the pause before sending the next pulse is lengthened from the normal 60 m.s. to 210 m.s. At the central station, this lengthened pause is sufficient to allow the release of a relay which holds over the normal 60 m.s. interval. This results in operation of the G or P relay connected to the contact of the selector on which the wiper is resting, and allows evaluation of the calling station and fault condition. A typical impulse telegram is shown in Fig. 40 in which station 2 has sent fault condition 3.

For station identification, an earth is permanently connected to the station identification contact assigned to the particular station.

Alarm Extension Details. The following alarm conditions are sent from the unattended repeater stations to the central monitoring stations.

- Repeater hut door open
- Remote power supply fail
- Local mains supply fail
- Signal voltage fail
- Anode or heater voltage fail
- Valve fail A-B direction
- Valve fail B-A direction
- Pilot fail A-B direction
- Pilot fail B-A direction

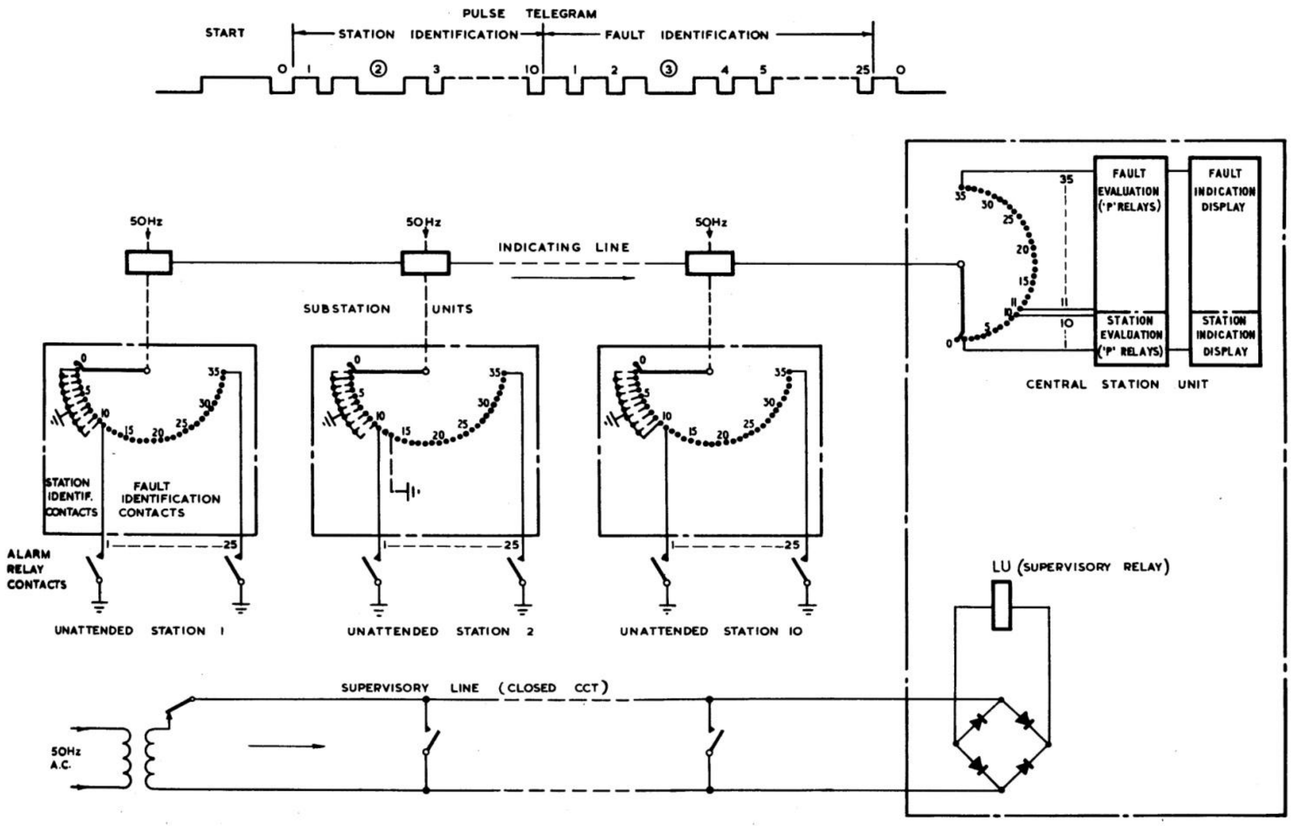


FIG. 40. PRINCIPLES OF OPERATION OF REMOTE SUPERVISION (S & H).

The face layout of a typical indicating unit is shown in Fig. 42, When a fault occurs in the supervised section, white flags are displayed on the unit to give station and fault identification. An alarm lamp associated with each station indicator lights when the particular station is waiting for the opportunity to transmit a pulse telegram.

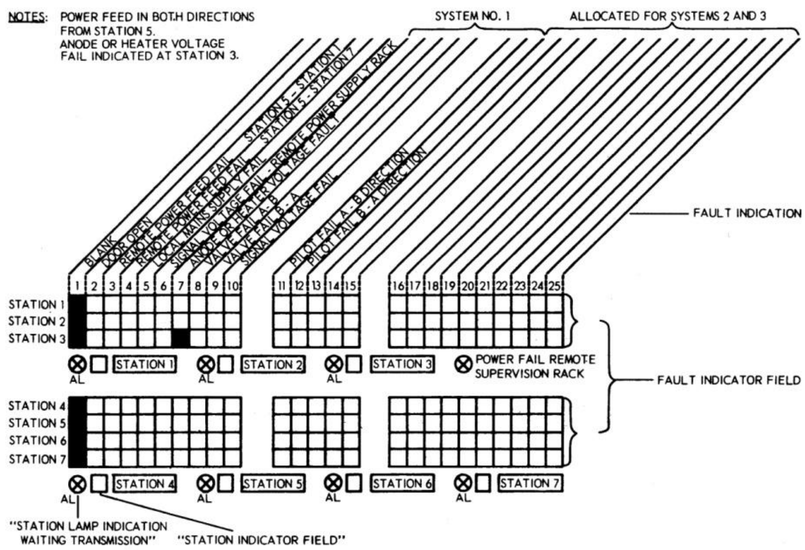


FIG. 41. CENTRAL STATION-RECEIVE INDICATION PANEL.

Felten and Guilleaume Fermeldeanlagen (F.G.F.). The remote supervision system provided by this manufacturer uses combinations of five or six voice frequency tones, to bring about station and fault indications. When five tones are used, a total of 10 unattended repeater stations can be supervised, and up to six fault indications can be made. A single tone is used to define the type of fault, and a particular combination of two tones is used for station identification. When six tones are used a total of 15 unattended stations can be supervised, and up to six fault indications can be made. The frequencies used for five tone operation are 453Hz, 609Hz, 820Hz, 1104Hz, and 1486Hz. The sixth frequency, used for six tone operation, is 2000Hz.

Figs. 42 and 43 show the arrangement of a typical supervision circuit. The main elements of the attended supervising station are shown in Fig. 42, and those of the unattended supervised station in Fig. 43.

Two V.F. loaded cable pairs are used for connection between the controlling attended repeater station and the supervised unattended repeater stations. In the attended control station a "control unit" transmits to the unattended stations, over the "call line" cable pair, successive combinations of two of the voice frequencies generated in the control unit. Two electronic switches controlled by a pulse generator apply these frequencies to the calling cable pair. The supervision unit at each supervised station responds in turn to its particular two frequency code, and connects to the "return line" cable pair a local multi-frequency tone generator which is controlled so that, if there is a fault, the particular frequency corresponding to that fault is not transmitted.

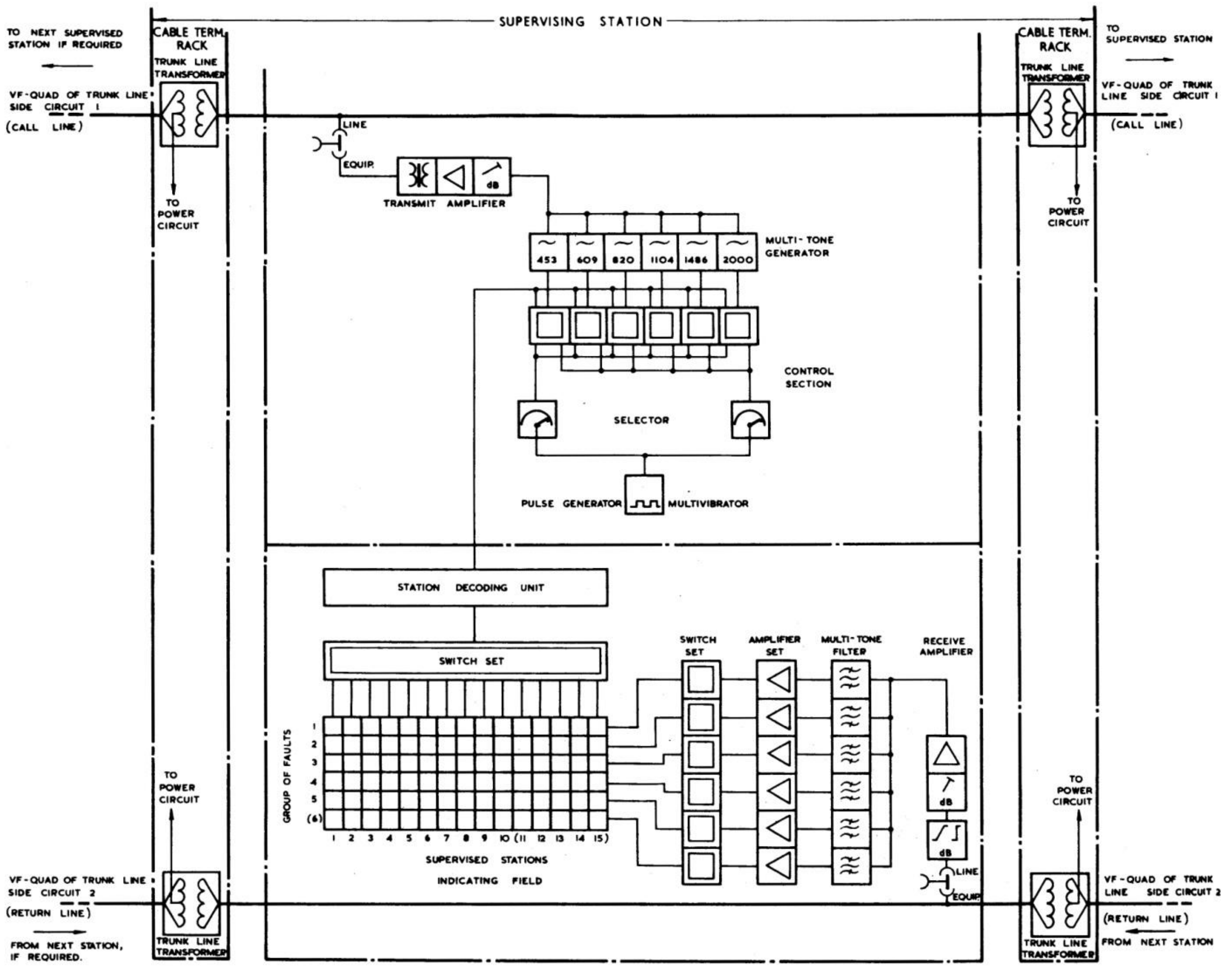


FIG. 42. MAIN ELEMENTS OF F.G.F. REMOTE SUPERVISION (SUPERVISING STATION).

The return signals on the "return" line are received at the attended controlling station and applied via the switching set to the "indicator unit". This unit also receives the code transmitted on the calling line and both signals are decoded by the indicator unit. Any fault is registered on a rectangular array of visual indicators, which show the unattended stations horizontally, and the types of faults vertically.

The following types of faults are indicated by the signals transmitted from an unattended station.

- Building door-lock contact open or order wire answering key not in "OFF" position.
- Tube failure in line amplifier, or anode current in line amplifier shows excessive departure from normal.
- Pilot failure in A-B and B-A direction or slope equaliser in A-B and B-A direction at extreme upper or lower limit.
- Coaxial power feeding failure on one or more tube pairs.

Power for the remote supervision equipment is fed from the controlling station over a phantom circuit derived on the calling and answering cable pairs.

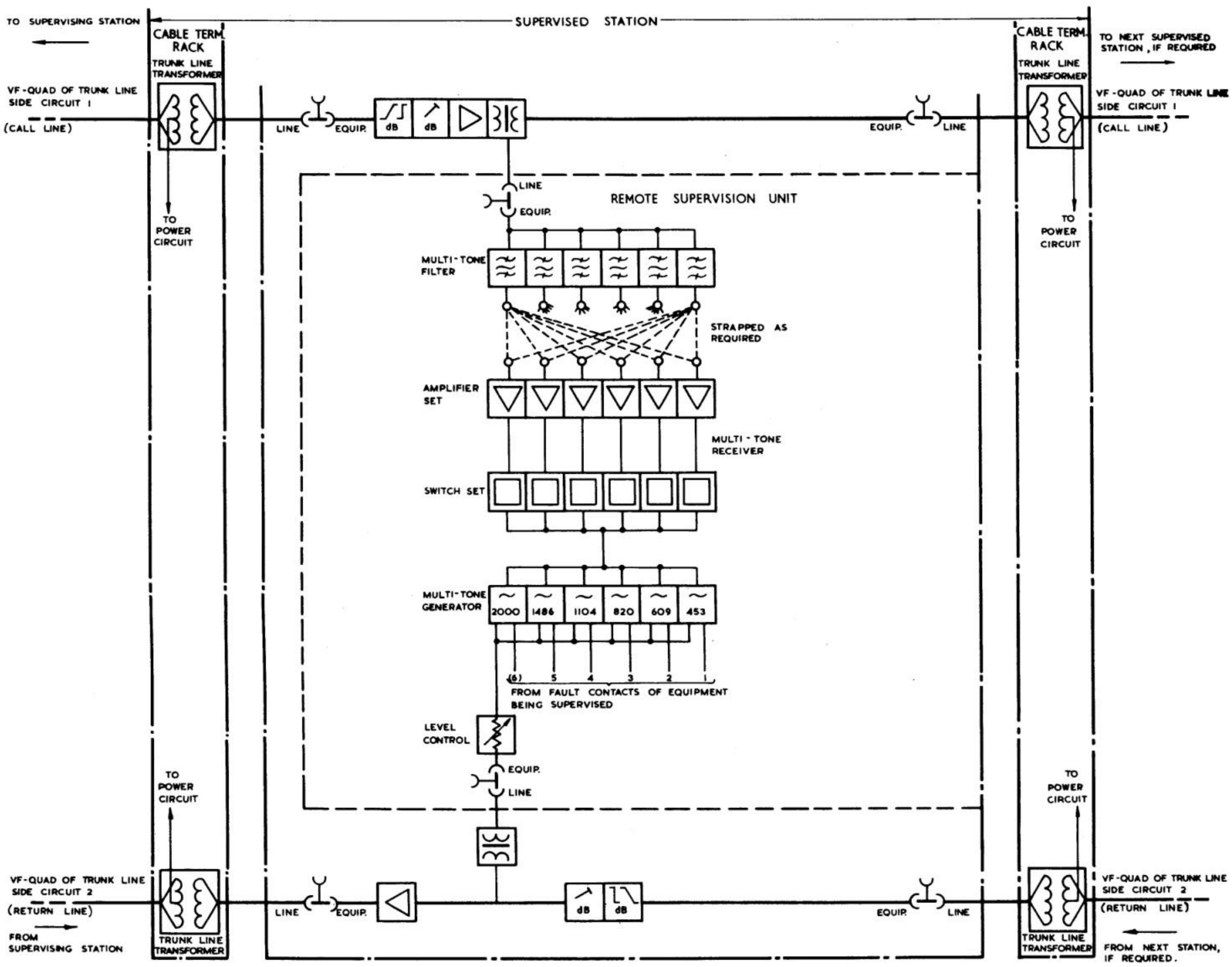


FIG. 43. MAIN ELEMENTS OF F.G.F. REMOTE SUPERVISION (SUPERVISED STATION).

Standard Telephone and Cables (S.T.C.). Supervisory and alarm equipment is installed at each station to provide alarm indications for the following general faults:-

- Power failure.
- Pilot deviation in the A-B direction by more than ± 2dB.
- Pilot deviation in the B-A direction by more than ± 2dB.
- H.T. or valve failure in the working or standby amplifiers.

Provision is made for these alarm conditions to be displayed locally at supervising attended stations. At unattended repeater stations, provision is made for the alarms to be displayed locally and also extended for remote indication at one or more supervising attended stations. Facilities are provided at the supervising stations for identification of the station and the particular alarm condition. Fig. 44 shows the alarm circuits at a minor repeater. The alarm conditions brought about by valve emission or high tension failure in any amplifier are signalled over one interstice pair. Another two pairs are used for the two pilot deviation alarms, and a further pair is used for the power failure alarm.

In addition to these faults being signalled to the attended stations, alarm display panels at the local station give an indication of the alarm condition.

The relays with the prefix HTF are included in the H.T. circuits of the various regular and spare line amplifiers; the relays A.F. and B.F., when operated, indicate valve failure in the regular and spare amplifiers; the relays PFR and PFM indicate receive pilot failure and transmit pilot failure respectively.

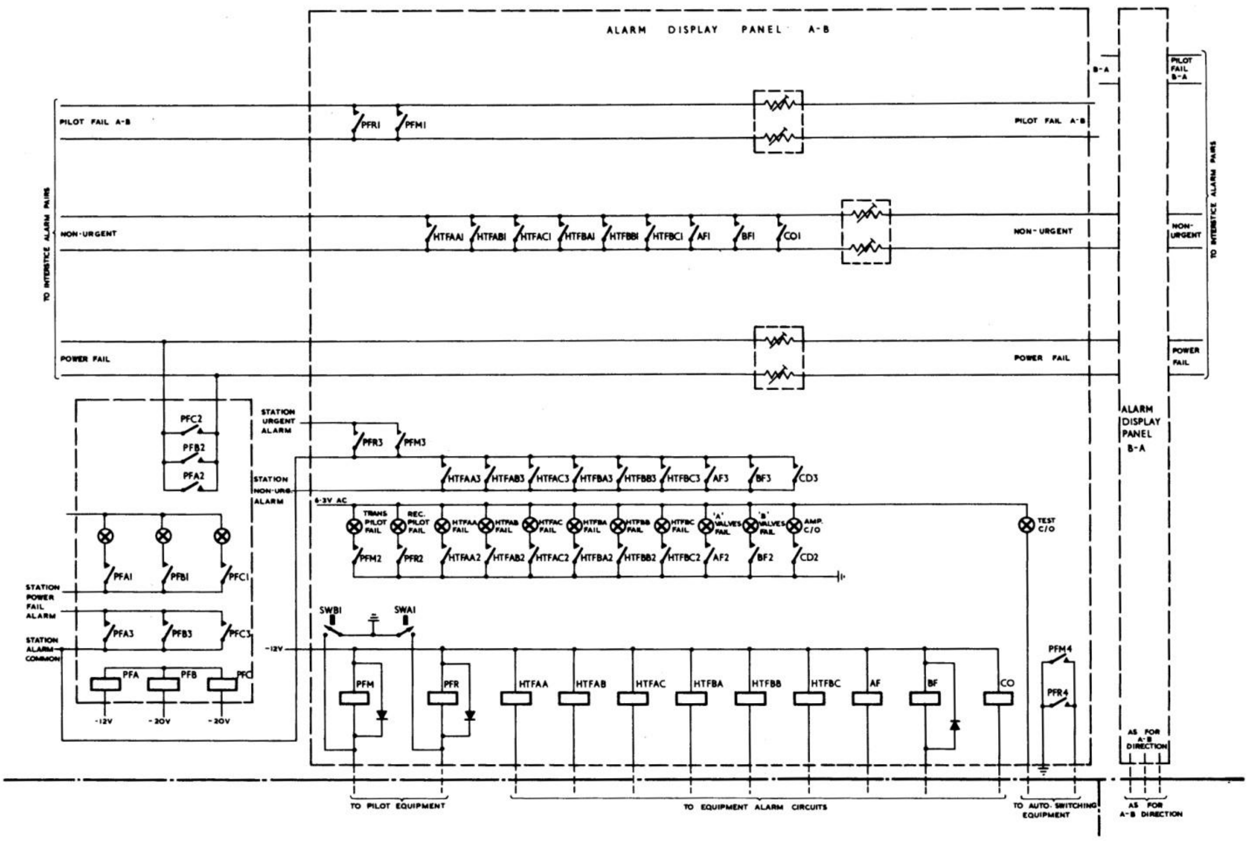


FIG. 44. ALARM CIRCUITS - MINOR REPEATER (S.T.C.).

Alarm locations are made by means of a Wheatstone bridge circuit. The bridge is used to locate faults at two terminals and up to 38 intermediate repeaters. To simplify locations the route is normally divided into sections, and the location equipment is designed to cater for two terminals locating for two main repeaters. This gives three main sections each with a maximum of 12 dependent repeaters as shown in Fig. 45. The sections are called 1^{st}, 2^{nd} and 3^{rd} sections, and the stations are numbered from 0 to 13.

When more than 38 intermediate repeaters are in use on a route, intermediate main repeaters are equipped with location equipment, and work in conjunction with the terminals or other locating repeaters.

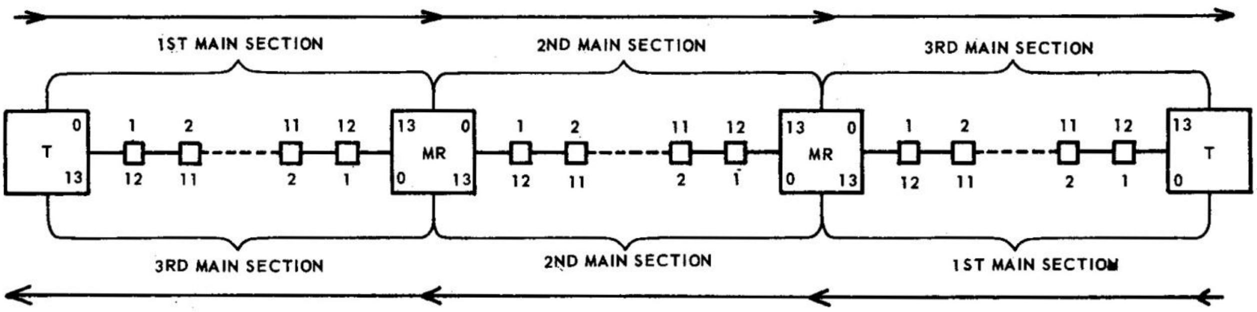


FIG. 45. NUMBERING OF SUPERVISORY SECTIONS.

A simplified schematic of the alarm location circuit at an attended station is shown in Fig. 46. Four master alarm relays UA (urgent alarm A-B), UB (urgent alarm B-A), NU (non-urgent alarm) and PFC (power fail alarm) are included to indicate the type of alarm being given.

With all keys on the panel normal, the relays are connected via rectifiers, between one wire of the appropriate alarm pair and -130V. The other wires of the alarm pairs are commoned via key contacts to +130V. When a fault occurs at a station and the alarm pair is bridged, the appropriate relay is operated. This operates the power, or urgent or the non-urgent station alarm, and lights a lamp on the alarm location panel. If the fault is at the terminal station, a lamp on the display panel also indicates urgent and non-urgent alarms. A power supply failure operates the power fail alarm extension.

If the fault is not at the terminal, the appropriate alarm location key should be operated (ALM. LOCATE URG. A-B, ALM. LOCATE URG. B-A, ALM. LOCATE NON-URG. Or ALM, LOCATE POWER).

One set of contacts on each key (KA5, KB5, KC5 or KD5) silences the station alarm by interrupting the circuit for the master alarm relay, and transfers one interstice wire of the appropriate pair to one terminal of a Wheatstone bridge; another set (KA6, KB6, KC6 or KD6) connects the other interstice wire of the pair to another terminal of the bridge; a third set (KA7, KB7, KC7 or KD7) lights a white ALM. LOCATE lamp adjacent to the appropriate alarm lamp on the alarm location panel. Additional contacts on the keys (KA8, KB8 and KC8) ensure that only one interstice pair is connected across the bridge at one time.

As shown in Fig. 46 the alarm loop forms one arm of the bridge when the appropriate ALM. LOCATE key is operated. Operation of one of the meter sensitivity keys connects the meter M1 across the bridge as a detector, and applies 130V across the other two terminals of the bridge. With the bridge balanced the setting of the controls indicates the location of the faulty station.

The bridge circuit will locate faults at the two terminals, and up to 38 intermediate repeater stations, that is, two main repeaters and three main sections each with 12 dependent repeaters. To cater for less than this number of dependent stations the alarm loops are built out at main stations.

The standard resistance of the alarm loop is 540 N ohms, where N is the number of repeater sections between the locating point and the fault. Potentiometer RV4 and potentiometer RV1 are used to calibrate the bridge against cable temperature changes. Potentiometer RV4 provides the coarse control, and is normally set initially for a particular section, and potentiometer RV! Gives the fine control adjustment. Potentiometer RV2 is engraved 1^{st} MAIN SEC. 2^{nd} MAIN SEC. and 3^{rd} MAIN SEC. RV3 is engraved 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, and 13.

In operation, potentiometer RV2 is adjusted to give a balance when an artificial fault is put on an alarm pair at the beginning of the main section where the fault has occurred. (The operation of the RELEASE-MARK key to the MARK position at a main station produces the artificial fault conditions.)

The artificial fault is then removed and, without disturbing the setting of RV2, the bridge is re-balanced by means of RV3. The setting of RV3 indicates the number of the repeater station in the main section (indicated by RV2) at which the fault has occurred.

When the fault has been located and is receiving attention, the appropriate key is operated to ALM. REC. ATT. This procedure lights the white REC. ATT. Lamp (via contacts KA4, KB4, KC4 or KD4) and restores the circuit for the alarm relay which operates. However, the station alarm does not sound, since the circuit is broken by contacts of a key (contacts KA3, KB3, KC3 or KD3). When the fault has been cleared, the loop is removed from the interstice pair, and the alarm relay is released. One set of contacts then completes a circuit for the station alarm to indicate that the fault has been cleared. When this occurs the key is restored to its normal position.

The fault location procedure described is for balanced fault conditions. The alarm circuits can be arranged to apply an earth to one side of the interstice pair and locations are made on an unbalanced basis. The standard resistance of the alarm loop is then 270 N ohms, and the bridge circuit is amended to give correct locations of sections of repeaters, for the settings of RV2 and RV3.

To ensure that a zero balance can always be obtained on the bridge the alarm circuit should be regularly calibrated. The calibration compensates for cable temperature variations and can be carried out according to the manufacturer's instructions.

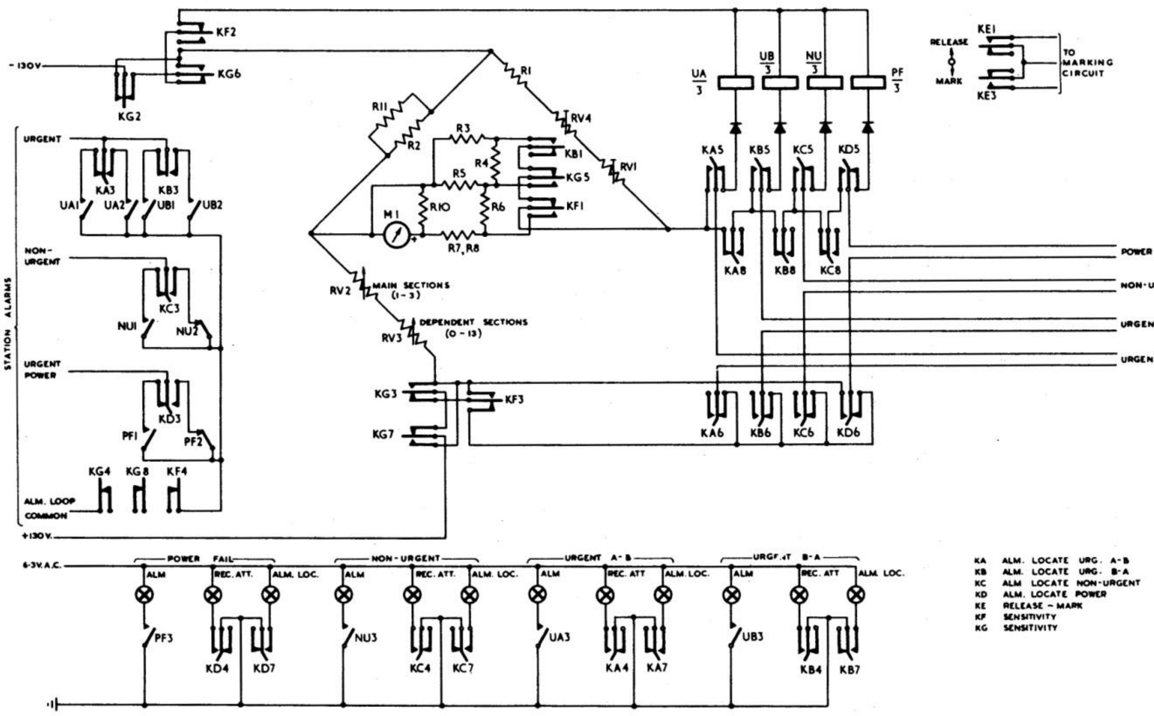


FIG. 46. ALARM LOCATION CIRCUITS. (S.T.C.).

12. REMOTE SUPERVISION OF UNATTENDED REPEATER STATIONS.

12.1 We saw in the paper "Introduction to Broadband Carrier Telephony", that a large number of the broadband systems in the Australian network use microwave radio bearers. At terminal stations and intermediate dropping stations it is often necessary to locate the microwave radio equipment some distance from the carrier equipment. (Broadband terminal equipment)

Where this separation exists, the connection between the radio equipment and the carrier equipment is made with a coaxial cable tail and associated line equipment.

The radio tail amplifying equipment is normally situated on auxiliary amplifier racks. One rack is situated in the radio equipment station and the other in the broadband carrier equipment station.

A typical auxiliary line amplifier rack accommodates up to ten line amplifiers. The total of ten amplifiers can be made up of ten flat amplifiers or ten slope (equalising) amplifiers or any combination of flat and slope amplifiers up to a total of ten. In addition dropping hybrids and supergroup 1 and 2 stop band filters are provided to allow for dropping and replenishing of selected supergroups.

Fig. 47 shows the main elements of typical flat amplifier equipment. In addition to the flat gain amplifier a station line equaliser and level adjusting pads are included.

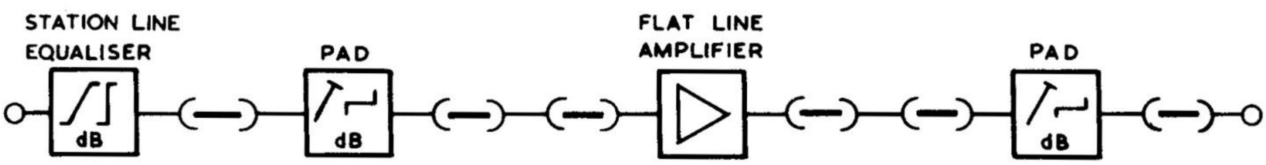


FIG. 47. MAIN ELEMENTYS OF FLAT AMPLIFIER (AUX. AMP. RACK.).

Fig. 48 shows the main elements of typical slope amplifier equipment. In addition to the amplifier a building-out network and level adjusting pads are provided.

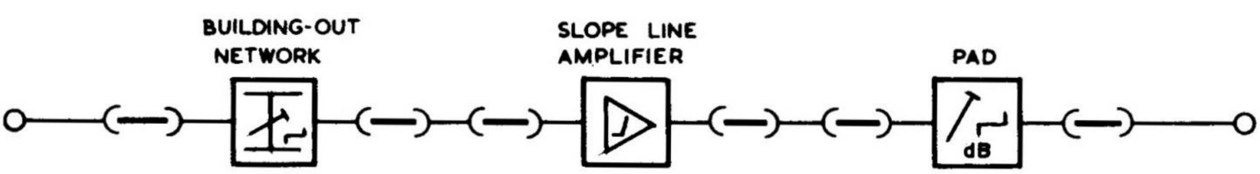


FIG. 48. MAIN ELEMENTYS OF SLOPE AMPLIFIER (AUX. AMP. RACK.).

12.2 A typical connection between a radio telephone terminal station and a carrier equipment station is shown in Fig. 49. The baseband frequencies from the supergroup modem equipment are applied to the line amplifier via a station line equaliser and a level adjusting pad. The station line equaliser is adjusted to compensate for frequency distortion occurring in the station cabling between the supergroup modem rack and the auxiliary amplifier rack. A level adjusting pad at the output of the flat amplifier is adjusted to obtain the required transmission level. A level of -11.3dBr is a typical transmission level. Standard power supply filters are associated with the coaxial tube. Remote power feeding is not always used but the power filters provide protection for the high frequency equipment from longitudinal voltages caused by power faults or lightning strikes.

At the radio telephone terminal station the baseband frequencies are applied to the slope amplifier via a building-out network. A coaxial tube shorter than the standard 5.75 mile section can be built-out to electrically simulate this length. The output of the slop amplifier is applied via a level adjusting pad to the radio telephone terminal. A level of -45dBr is typical at this point.

Similar circuit components with similar functions are used in the opposite direction of transmission. For this direction the station line equaliser compensates for frequency distortion occurring in the station cable between the radio terminal and the auxiliary amplifier rack. A level of -20dBr is typical at the radio telephone system output and this is raised to -11.3dBr for transmission to the coaxial cable. For modern supergroup modem equipment the input level to the supergroup demod. Is -33dBr.

For older type supergroup modem equipment, with an output level of -59.1dBr, two flat amplifiers are operated in tandem to obtain the required level of -11.3dBr at line. The station line equaliser of the second amplifier is not necessary.

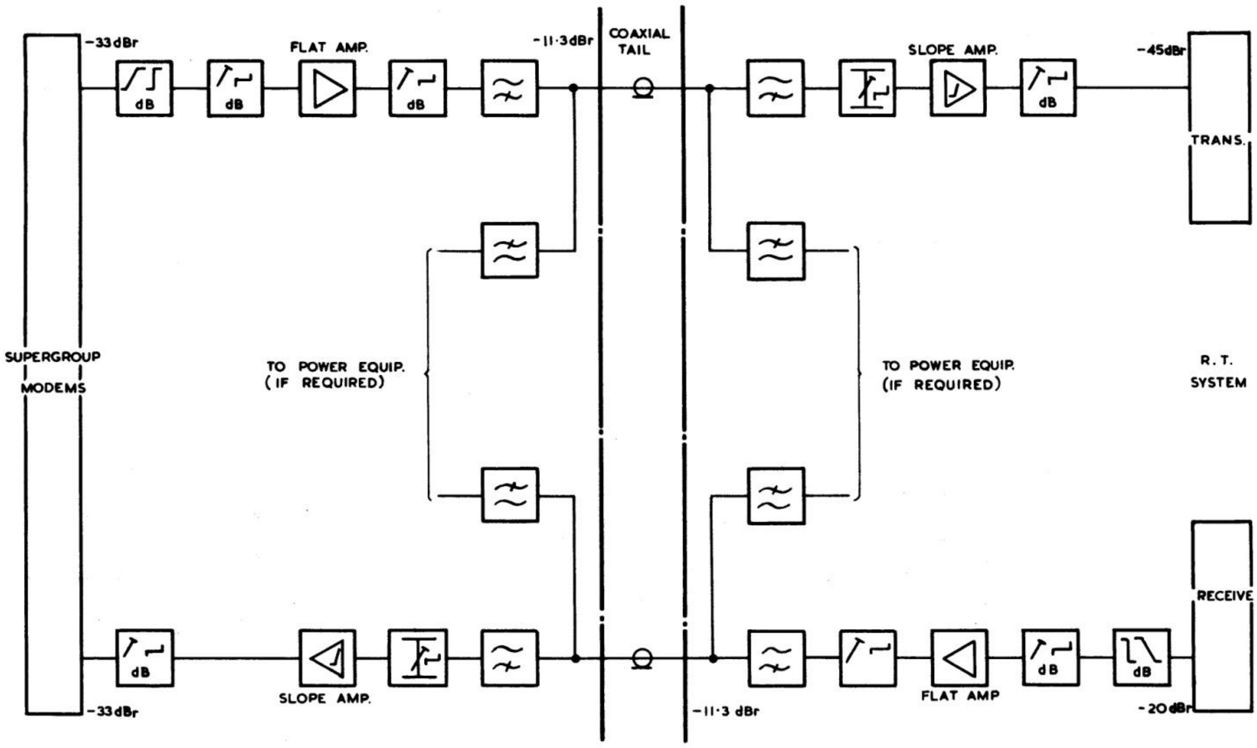


FIG. 49. COAXIAL TAIL CONNECTION - RADIO EQUIP. TO CARRIER EQUIP.

12.3 Fig. 50 shows typical circuit arrangements for dropping and replenishing of supergroups at a radio relay station. The supergroup modem equipment is located at the carrier equipment station and is remote from the radio equipment.

The dropping equipment, situated on the auxiliary amplifier rack at the radio relay station, is cabled into the through circuit between the two radio telephone terminals. The parallel feeds of the supergroups are taken to the carrier equipment station by coaxial tails and associated equipment. The transmit and receive equipment for each direction is identical to that described in Para 12.2.

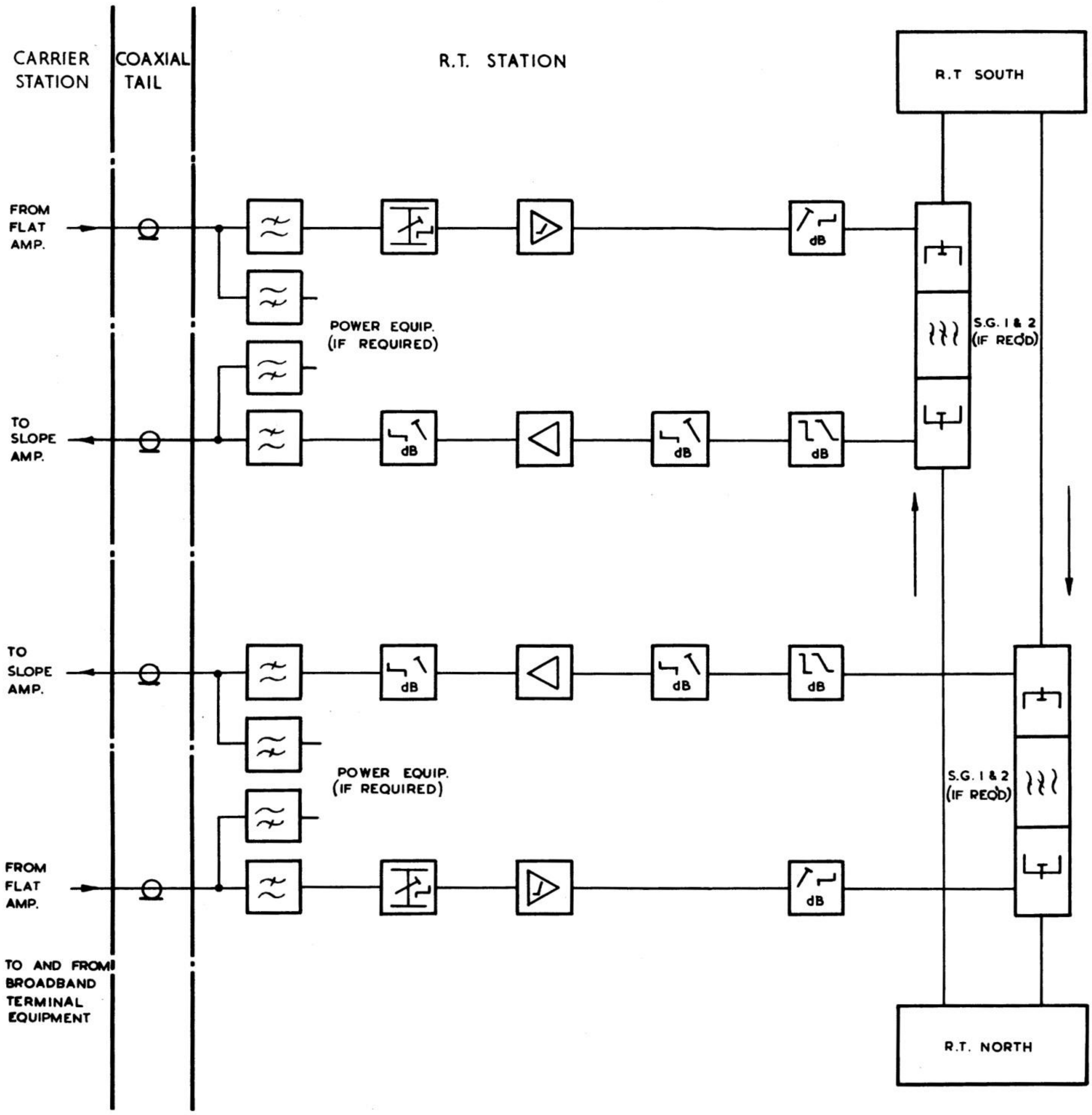


FIG. 50. COAXIAL TAIL CONNECTION DROP-OUT OF SUPERGROUPS.

13. TYPICAL EQUIPMENT. (SCHEMATICS)

13.1 Because of the complexity of coaxial line equipment, it is difficult to include typical circuits of all types of equipment. If additional circuit details are required, reference can be made to the various manufacturers handbooks.

The receive terminal line equipment and the repeater station equipment is similar in circuitry but is generally too detailed to be included in this paper. The transmitting terminal line equipment is less complex and can be shown in detail.

13.2 Fig. 53 shows the detailed schematic circuit of a typical transmitting amplifier rack.

The incoming frequencies from the supergroup or mastergroup modem equipment is applied via the station line equaliser to a pre-emphasis and hybrid unit. The measuring access point associated with the hybrid is isolated from the transmission path so that faulty measuring techniques do not cause interference to the system channels. From the hybrid the line frequencies are applied to an equaliser which compensates for the characteristics of the following pilot stop filters.

The three pilot frequencies are injected, with the line frequencies, at a hybrid type pilot injection unit. The pilots are supplied from individual highly stable crystal oscillators. Each crystal is included in a temperature controlled oven. The oscillator outputs are applied via a pilot frequency distributor circuit to the pilot injection unit.

The line frequencies are applied via a changeover unit, to the flat line amplifier. The three stage line amplifier employs parallel valves in each stage, to reduce the possibility of amplifier failure. Supervisory indicators are included in the screen grid circuits to indicate valve failures. The "wideband" feature of this amplifier is obtained by equaliser circuits included in the anode loads and in feedback paths.

The output of the line flat amplifier is split to enable pick-off of the three pilot frequencies. The line output and the pilot pick-off outputs are taken via the changeover unit to the coaxial cable bearer and the pilot separating filters respectively.

The three pilot frequencies are broadly separated by the pilot separating filters which precede the three pilot receivers. The individual pilots are selected by the band pass filters at the input of each pilot receiver. In the pilot receiver the received pilot is amplified in a three stage amplifier, then rectified and applied with the stabilised reference voltage to a comparison circuit and pilot level indication meter. A brief outline of this circuit is given in Para. 9.6. The detailed circuit (fig. 53) shows a push-button test key which, when operated, allows a check on the accuracy of the stabilised reference voltage. The stabilised voltage is adjusted by the rheostat RV1.

Alarm relays included in the H.T. circuits of the pilot receiver amplifier valves provide alarm facilities to indicate failure of any valve.

14. *TEST QUESTIONS.*

1. *Briefly describe the construction of a typical coaxial tube.*

2. *Describe the make-up of a typical four tube coaxial cable and give reasons for the use of various types of cable sheaths.*

3. *Which tube characteristic has the greatest effect on the quality of transmitted broadband frequencies and what precautions are taken to ensure that this characteristic remains constant?*

4. *State the range of frequencies transmitted on a coaxial line for a 1260 channel broadband system.*

5. *What is the approximate repeater spacing for a 6MHz coaxial system?*

6. *Draw a simplified block diagram of a typical transmitting terminal line equipment and state the function of each component.*

7. *State any precautions necessary before changeover from regular to standby equipment is performed.*

8. *State the line pilot frequencies used by a typical coaxial cable system and state the basic function of each pilot.*

9. *With the aid of a simplified block diagram describe the path of the received line frequencies from the coaxial line to the supergroup or mastergroup modem equipment.*

10. *What is the function of the building-out network at the input to the coaxial system receive terminal line equipment.*

11. *Why is it necessary to add pilot stop filters at the output of the coaxial cable system receive terminal line equipment?*

12. *Draw a block diagram of a typical unattended (minor) repeater station and state the function of each component shown.*

13. *State the pilot regulation and supervisory facilities provided at unattended repeater stations for a typical coaxial cable system.*

14. *Draw a simplified block diagram of a typical attended (main) repeater station. State the function of each component shown.*

15. *Describe how dropping and replenishing of supergroups is made at attended repeater stations.*

16. What limitations exist as to the numbers of supergroups that can be dropped and or replenished at a repeater station?

17. State any advantages gained by the dropping and replenishing facility provided by coaxial cable systems.

18. With the aid of a simple diagram show how supergroups 1, 2 and 3 can be dropped in one direction and supergroups 1, 2 and 4 from the other direction.

19. Briefly describe the operation of a typical pilot receiver.

20. With the aid of a simple diagram show how the line pilot frequency is used to control the gain of the slope amplifier.

21. Draw a simple diagram to show typical power feeding capacities for a coaxial cable system.

22. What are the advantages of power feeding from main repeaters and terminal stations to other repeater stations.

23. With the aid of a simple sketch show how power from a mobile generator can be used to supply power to a portion of a power feed section.

24. List the facilities provided at a typical power feeding station.

25. List the facilities provided at a typical power fed station.

26. What advantages are gained by the use of a gas pressure alarm system on a coaxial cable.

27. State the facilities provided by, and briefly describe, the supervisory system associated with the following coaxial cable systems.

(i) Siemens and Halske.

(ii) F.G.F.

(iii) S.T.C.

28. With the aid of a simple diagram describe how power is fed from a main repeater to minor repeaters in each direction.

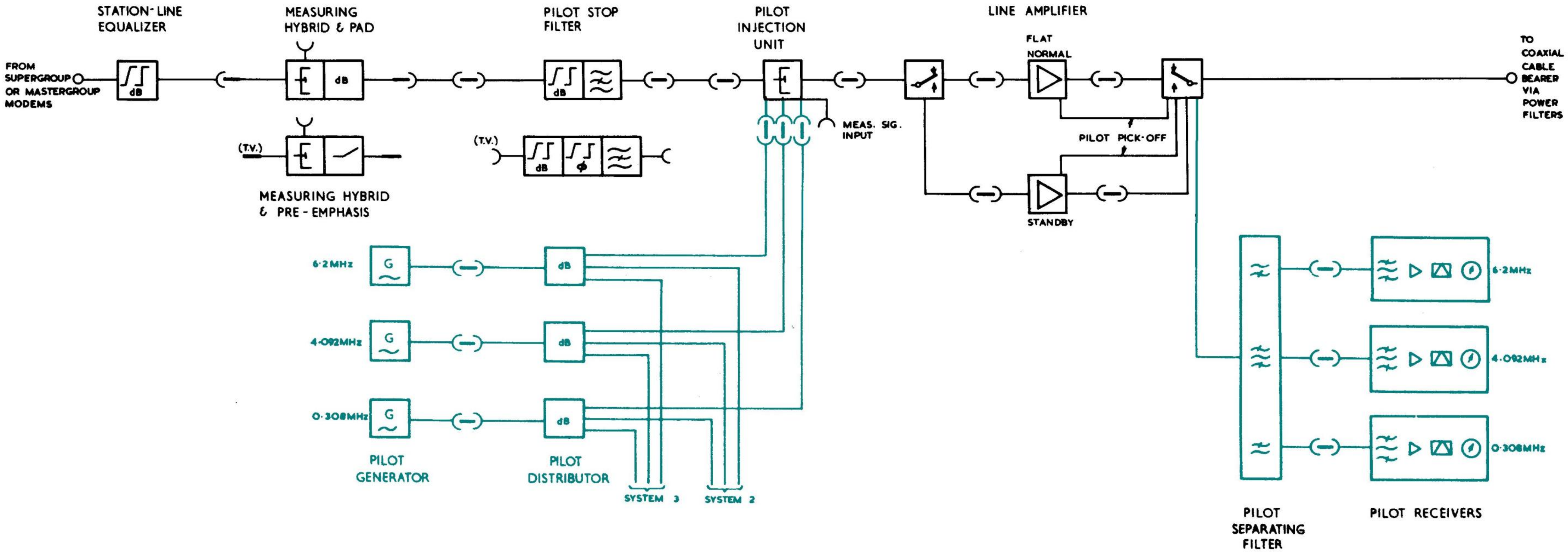


FIG. 51. BLOCK DIAGRAM OF TYPICAL TERMINAL TRANSMITTING LINE EQUIPMENT.

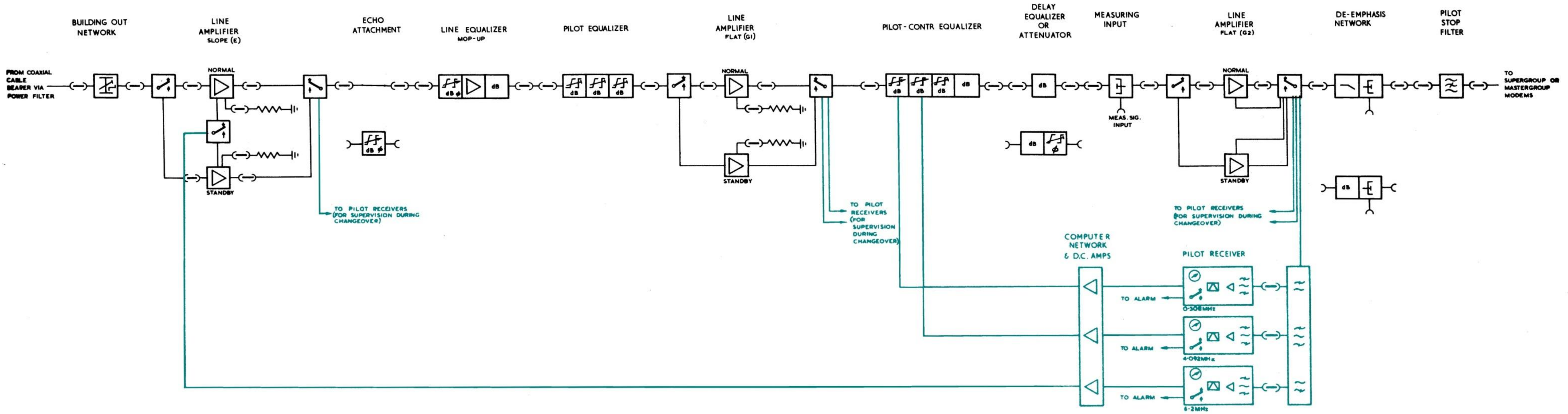


FIG. 52. BLOCK DIAGRAM OF TYPICAL TERMINAL RECEIVING LINE EQUIPMENT.

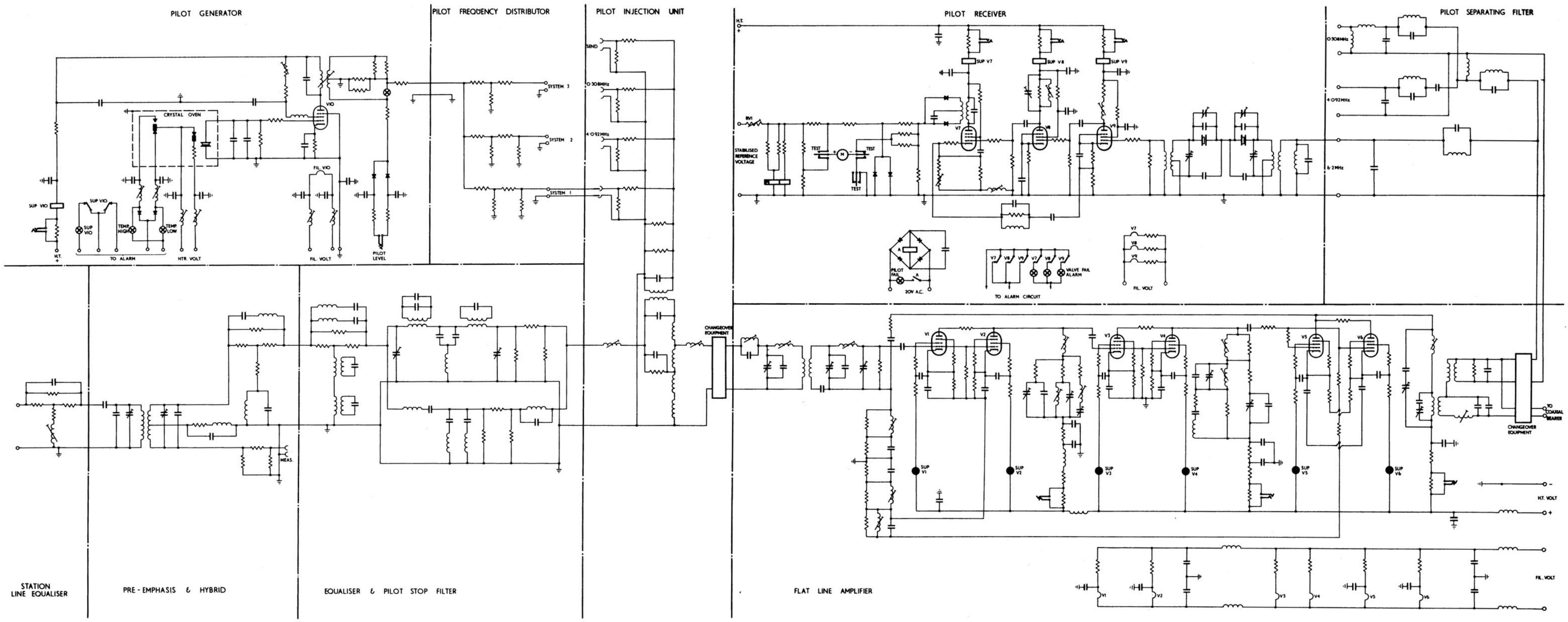


FIG. 53. CIRCUIT DETAILS - TYPICAL TRANSMITTING AMPLIFIER RACK.

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