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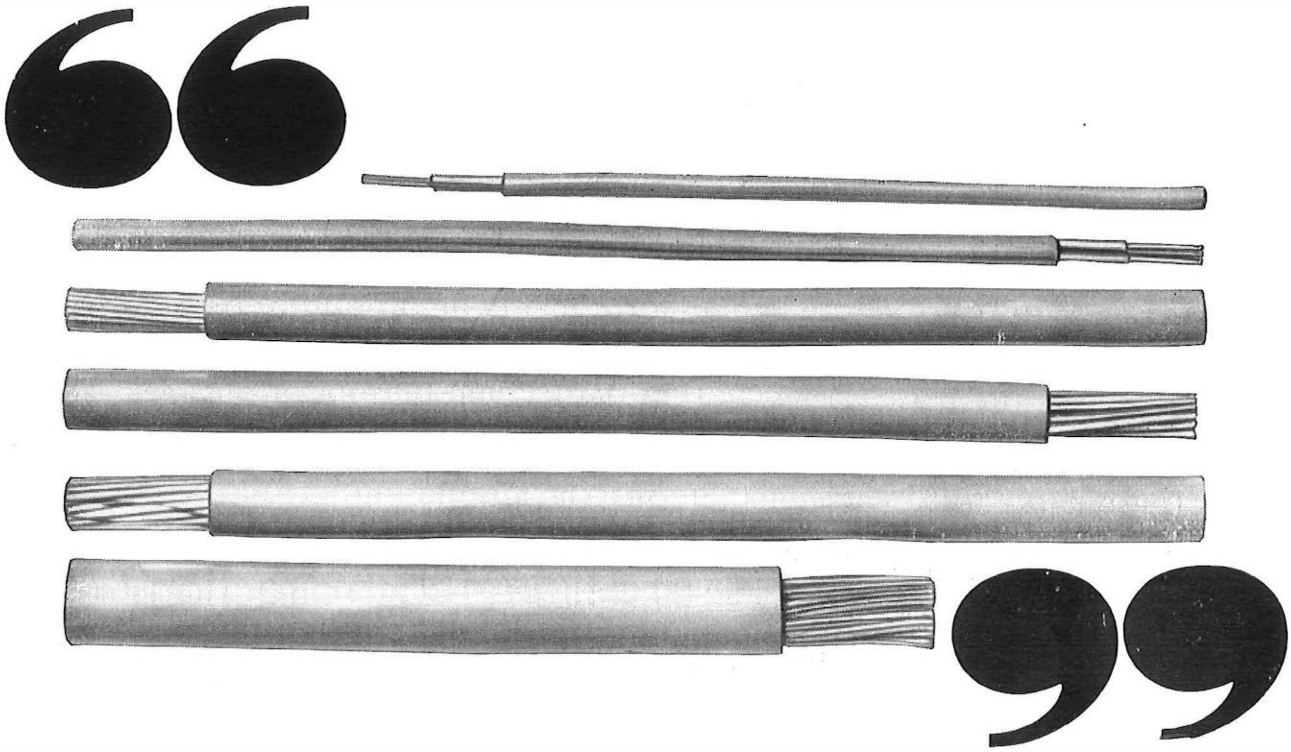

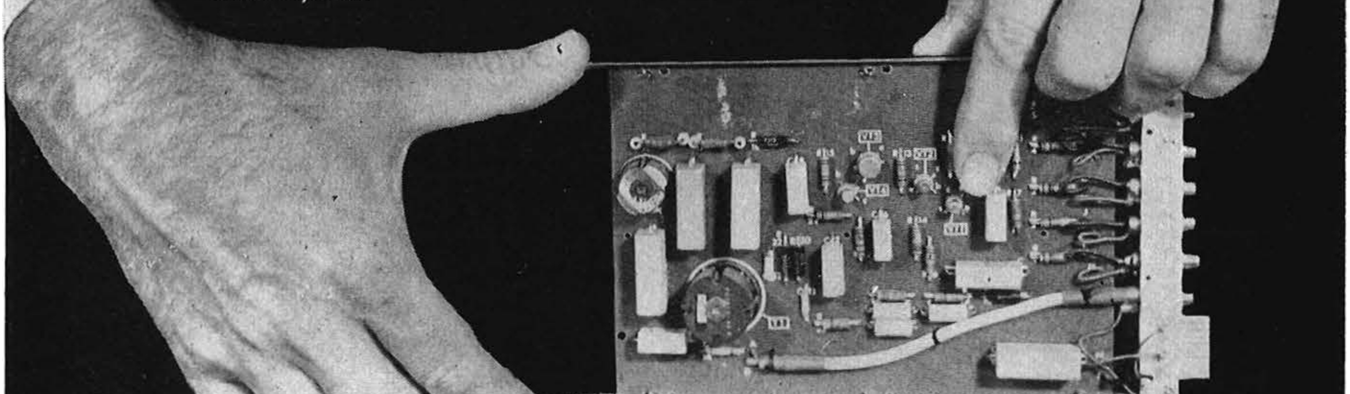


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The Post Office Electrical Engineers' Journal

EDITORIAL

The rapid growth of satellite communication has created a need for a third aerial at Goonhilly earth station. This new aerial, which comes into service in the near future, is specially designed for use with synchronous satellites and incorporates many novel features which result from operational experience at Goonhilly and other earth stations. An important article in this issue compares the construction of the new aerial with the two already in service at Goonhilly. The development of satellite services shows little sign of slackening and this issue also contains a summary of the conclusions of the recent international conference concerned with the allocation of frequencies for satellite communication, as well as an article discussing the possible use of satellites for maritime communications.

By its very nature a quarterly journal is not able to convey up-to-the-minute news but, when space permits, the *Journal* includes a selection of press notices. By the time these are published some of the items have inevitably lost their topicality but it is hoped that they still help the reader to maintain contact with the broader aspects of Post Office business. These items are always based on official British Post Office press notices and can be considered authoritative. A further source of news of a rather different kind can be found in *Regional Notes* and it is pleasing to note that the flow of suitable material for this section of the *Journal* is steadily increasing.

The Large Steerable Aerials at Goonhilly Earth Station

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Goonhilly has changed from a low-capacity experimental earth station, operating only a few hours a week via low-altitude satellites, to a high-capacity station giving continuous commercial service via geo-stationary synchronous satellites. The earth-station aerials and associated radio and control equipment have evolved to meet the new requirements. The basic radio performance standards have not, however, changed radically, nor are they expected to in the near future. Salient features of the new third aerial are described and compared with those of the two older aerials.

INTRODUCTION

Three large steerable aerials have been built at Goonhilly earth station in the ten years of rapid development and growth of satellite communications that has followed the TELSTAR experiments.[1] Although many of the basic design requirements[2] have not changed significantly in this period, the latest aerial, Aerial No. 3, designed and built by Marconi Communication Systems Ltd., is quite different from either of the earlier aerials. In this article, the nature of the major design differences are identified, the underlying reasons for them are explained and the expected advantages are considered.

Aerial No. 1, designed by Husband & Co. and the British Post Office (B.P.O.) Research Department, was an outstandingly successful adaptation of an existing front-fed radio-telescope design for tracking fast-moving experimental satellites in inclined orbits.[3] In 1965 it was successfully modified[4] to work with the first operational INTELSAT satellite in a 24-hour synchronous equatorial orbit, and in 1969 was again adapted to work to the INTELSAT III satellite[5] stationed over the Indian Ocean. It has a reflector which is small by current standards, and this, together with the lack of adequate accommodation for equipment, especially the low noise amplifiers (l.n.a.s), has always presented formidable operational problems. Nevertheless, current plans for Goonhilly include commercial operation of this veteran aerial for at least another five years.

Aerial No. 2, built by Marconi Communication Systems Ltd., is based upon a Husband & Co. design that was made available to British industry by the B.P.O. at a time when no British manufacturer or consortium of manufacturers had ever built a complete earth station. The design was intended to provide adequate accommodation for all equipment needed for the estimated growth of traffic during a 20-year design life. Originally designed as a front-fed aerial, it was adapted by the tenderer to accommodate a Cassegrain feed-system.* At that time, the dominance of the 24-hour synchronous orbit for civil communications had not been completely established, so the ability to track relatively fast-moving satellites in sub-synchronous orbits was included in the specification. In general, flexibility was the keynote of the design. Although it was designed for operation with the INTELSAT III generation of satellites it will also be possible for this aerial to continue carrying some of the transatlantic traffic via the INTELSAT IV satellite after the third aerial has been brought into service.

Aerial No. 3, illustrated in Fig. 1, is one of five similar aerials designed and built by Marconi Communication Systems Ltd. Designed specifically for tracking satellites having a 24-hour synchronous orbit, it embodies the results of wide operational experience at Goonhilly and other earth stations. The salient features are the reinforced-concrete tower, which provides on three floors a total of 250 m^2 of accommodation for radio equipment, and the high-level azimuth bearing. The tower is surmounted by a rotating platform which carries the aerial driving machinery, and provides 52 m^2 of accommodation for the low-noise amplifiers. Equipment rooms in the tower are served by an internal lift, and access to the moving accommodation is via an external lift carried by the rotating structure. Annexes at ground level house mains power switchboards and air-conditioning plant. The technical features include the first use at Goonhilly of an aluminium

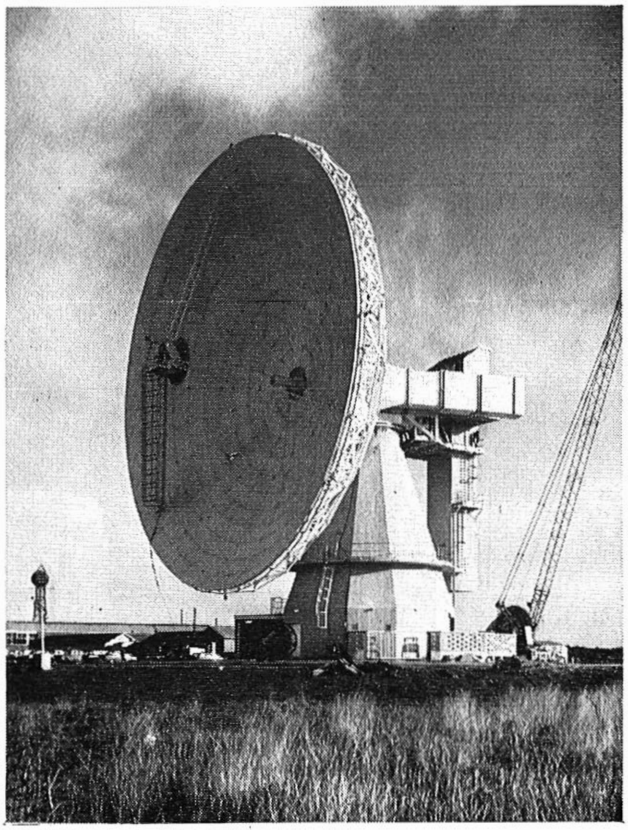

FIG. 1—Goonhilly Aerial No. 3.

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* Cassegrain feed-system—radiation from an aperture in the main reflector is collimated by a front-mounted sub-reflector and reflected by the main reflector.

reflector to reduce the movable weight, low-power movement machinery, stationary low-noise amplifiers, a new design of azimuth bearing and an ingenious new elevating screw-mechanism.

Some of the more important factors that have influenced the development of earth station aerials are:

(*a*) the successful development and launching of large satellites into the 24-hour synchronous orbit,

(*b*) the relative stability of international agreements on the major technical parameters relating to earth-station equipment, and

(*c*) the need to minimize maintenance out-of-service time and to provide adequate access to all equipment.

A summary of the major characteristics of the three aerials at Goonhilly is given in the Appendix.

ELECTRICAL PERFORMANCE

In communication systems the quality of circuits is influenced by the ratio of signal power to noise power. For a given satellite system, the received signal power is proportional to the earth-station aerial gain, G. But, because of the very high propagation-path loss, the received signal power is extremely low and may be only slightly above the level of noise in the receiving system. The receiving-system noise is represented by the physical temperature, T, at which the thermal noise power available from an equivalent resistor is equal to the system noise. The ratio of the two parameters G and T can therefore be used as a measure of the performance of an earth-station receive system. Conventionally, G/T is referred to the input of the l.n.a., and international agreement requires the system G/T, at the operational receiving frequency f GHz, to be

$$40.7 + 20 \log_{10}\frac{f}{4}\,\text{dB},$$

when measured under clear-sky conditions, in light winds, at the operational elevation angle.

The primary aerial design-objective must be attainment of the requisite gain-to-noise-temperature ratio (G/T). This means that the aerial itself must have high gain, but low noise. In addition, the design must enable the telecommunication equipment to be mounted so that its noise contribution to the system can be minimised, and so that the required radiated power can be generated economically. It must also enable essential maintenance work and periodic overhauls to be carried out without loss of service.

The major factors which govern the attainable gain at the input of the l.n.a. are:

(*a*) the aperture area and profile accuracy of the reflecting surfaces,

(*b*) the aperture blockage introduced by the feed system and any secondary reflector,

(*c*) the spillover of the signal at the edges of the reflecting surfaces, the scattering of the signal from the feed or sub-reflector structure and the diffraction at the edges of the reflector,

(*d*) phase errors and cross-polarization,

(*e*) the insertion losses of the waveguides between the primary feed and the first receiving amplifier, and

(*f*) the mis-matches which occur both in the waveguide assembly and between the physical components and free space.

The net gain is determined by the extent that the losses associated with (*a*)–(*f*) above can be minimised in the design.

Ideally, the gain should be independent of the reflector elevation angle, but unless the design provides adequate stiffness, gravitational effects distort the reflector shape and feed or sub-reflector supporting structures, thus reducing the gain as the elevation angle is changed from that at which the shape was set.

The main components of system noise are:

(*a*) noise collected by the main lobe of the aerial,

(*b*) noise collected by spillover at the main and sub-reflectors, side lobes and reflexions from aperture-blocking components, and

(*c*) thermal noise generated by losses in feed and waveguide components.

The total system noise (T) comprises the components listed in (*a*)–(*c*) above plus a contribution from each of the amplifying stages, dominated by that from the first amplifier. All noise contributions are summed and expressed as the equivalent noise temperature at the input of the l.n.a. Component (*a*) depends on the elevation angle and is greatest near the horizon. This component comprises galactic noise and noise originating primarily in water and oxygen in the atmosphere. The received noise level from both these sources varies with frequency, and cannot be altered by aerial design, unlike the other noise components which can be minimized by good design.

With a front-fed aerial, the effects of spillover are worse when the aerial is operating at high elevations because the spillover is directed toward the noisy, relatively hot earth instead of the cold sky, whereas spillover past the Cassegrain sub-reflector gives greatest noise at low elevations. However, the sub-reflector blocks the aperture more than the front feed. In general, the more convenient location of l.n.a.s, and the shorter waveguide connexion between feed and l.n.a.s that are possible with the Cassegrain design have been the major reasons for its choice. The overall efficiency of a Cassegrain aerial can be improved slightly by deliberate distortion of the sub-reflector profile from the true hyperboloidal shape so that unavoidable tapering of the illumination of the sub-reflector gives roughly uniform illumination of the main reflector, which is also mis-shaped slightly from the paraboloidal to correct the phasing of the electromagnetic wave front.

For Aerial No. 3, the overall efficiency is expected to be about 72 per cent, and the resultant gain 60·3 dB at the centre frequency of the receiving band (3.95 GHz). The corresponding system noise temperature at 5° elevation, assuming a contribution of 20°K from the l.n.a. and other receiving stages, will be about 75°K. In practice, the noise temperature of the l.n.a will rarely exceed 16°K, and, therefore, G/T is expected to exceed 41 dB. The efficiencies and gains of Aerial Nos. 1 and 2 are 55 per cent, 58·5 dB and 67·6 per cent, 60 dB respectively.

STRUCTURAL MATERIALS

Mild steel, stainless steel, aluminium and its alloys, reinforced or pre-stressed concrete and metal-sprayed plastics have all been used in the construction of the aerials. Mild steel is widely used as a structural material because it is cheap, strong, and easy to fabricate and weld. If thoroughly protected against corrosion it can be used for main structural members and reflector frameworks, but re-painting is difficult if it is used for the reflector membrane. High-grade stainless steel is resistant to corrosion, but is tough and difficult to work. It costs about eight times as much as mild steel and is, therefore, too expensive for main structural members, but is attractive for reflectors because it will retain its shape for many years without corrosion and need never be painted.

Relative to mild steel, the cost of aluminium and its alloys is six to eight times greater; the density and modulus of elasticity, E, are each about a third, and the temperature coefficient of linear expansion is double. The lighter weight is attractive because loads on bearings, and the size and cost of driving systems, can all be reduced. Unfortunately, the lower value of E increases the volume of material required for a given stiffness, and great care is required to avoid failures from structural fatigue. Pure aluminium is very

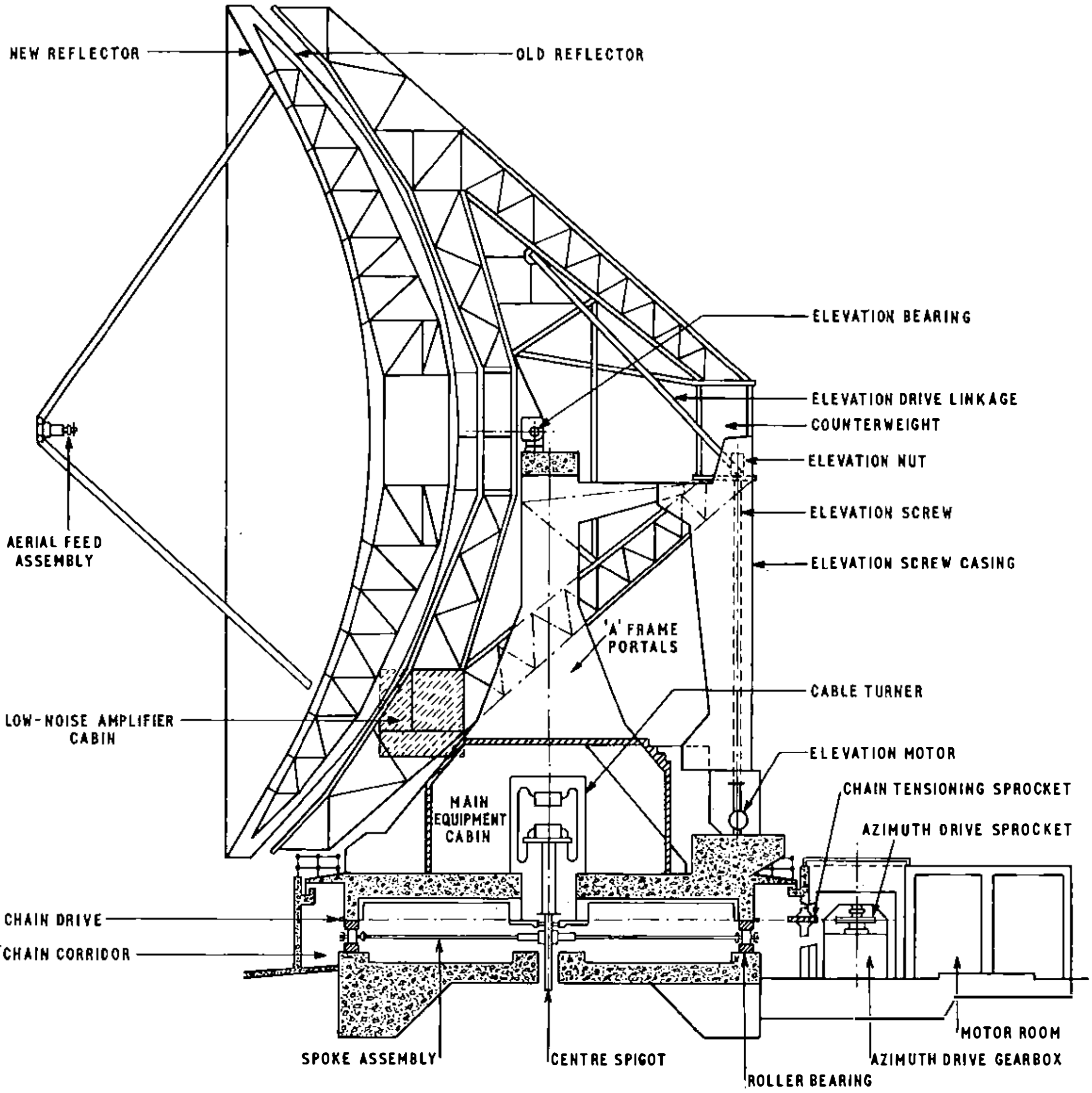


FIG. 2—Sectional view of Goonhilly Aerial No. 1

resistant to corrosion, but is too soft for structural purposes. More suitable aluminium alloys are difficult to weld, are less resistant to corrosion, and therefore require protective coatings. These factors tend to restrict its use to the construction of alloy reflector panels faced on both sides with pure aluminium.

Reinforced concrete is bulky, but cheap, and relatively easy to cast into large complicated shapes which can be built in sections and joined together. Its life can easily exceed 60 years provided that all steel reinforcement is covered adequately to protect it from corrosion. It is suitable for the construction of aerial mounts, but requires expensive pre-stressing or post-stressing to enable very great tensile loads to be carried. The rigidity and mass of large concrete structures enables them to resist the effect of high winds, but when used for components of the rotating structure, the structural savings are largely offset by the cost of the larger bearings and mechanical driving components.

Metal-sprayed plastics have been used for reflectors of small aerials up to about 14 m in diameter but, as far as is known, not for larger aerials.

STRUCTURAL DESIGN

Ideally, the aerial should be able to operate in all weather conditions. Economically, it may be acceptable for the aerial to work with a slightly degraded performance, or even to be taken out of service for isolated short periods, to avoid the high cost of extending the design for rare extreme wind conditions. It may be necessary to stow the aerial with its reflector facing the zenith to minimize wind loads and ensure its survival in these extreme conditions. Structural deflexions about the movement axes are equivalent to steering errors and can be cancelled by auto-tracking, but it is not possible to compensate for loss of gain arising from defocusing of the reflector caused by wind or gravitational distortion of the structure. An operational aerial should track a satellite with an error not exceeding one minute of arc to minimize loss of gain, and, therefore, a very stiff structure is required.

A relatively deep, rigid backing-framework is needed to give the required stiffness, and must be supported on bearings which allow the reflector to be tilted. Adjustment facilities are usually incorporated so that the reflector can be accurately shaped and set. The weight of the reflector must be counterbalanced to reduce the driving-system torque. Elevation bearings should be firmly mounted and accurately aligned. The whole assembly must withstand thrust loads along the line of the elevation axis and radial loads arising from gravitation effects, wind and overturning moments. Axial and radial loads on the azimuth bearing are not usually excessive and can be carried by standard bearings. Overturning moments can be quite high and can present design problems, especially with tower mounts.

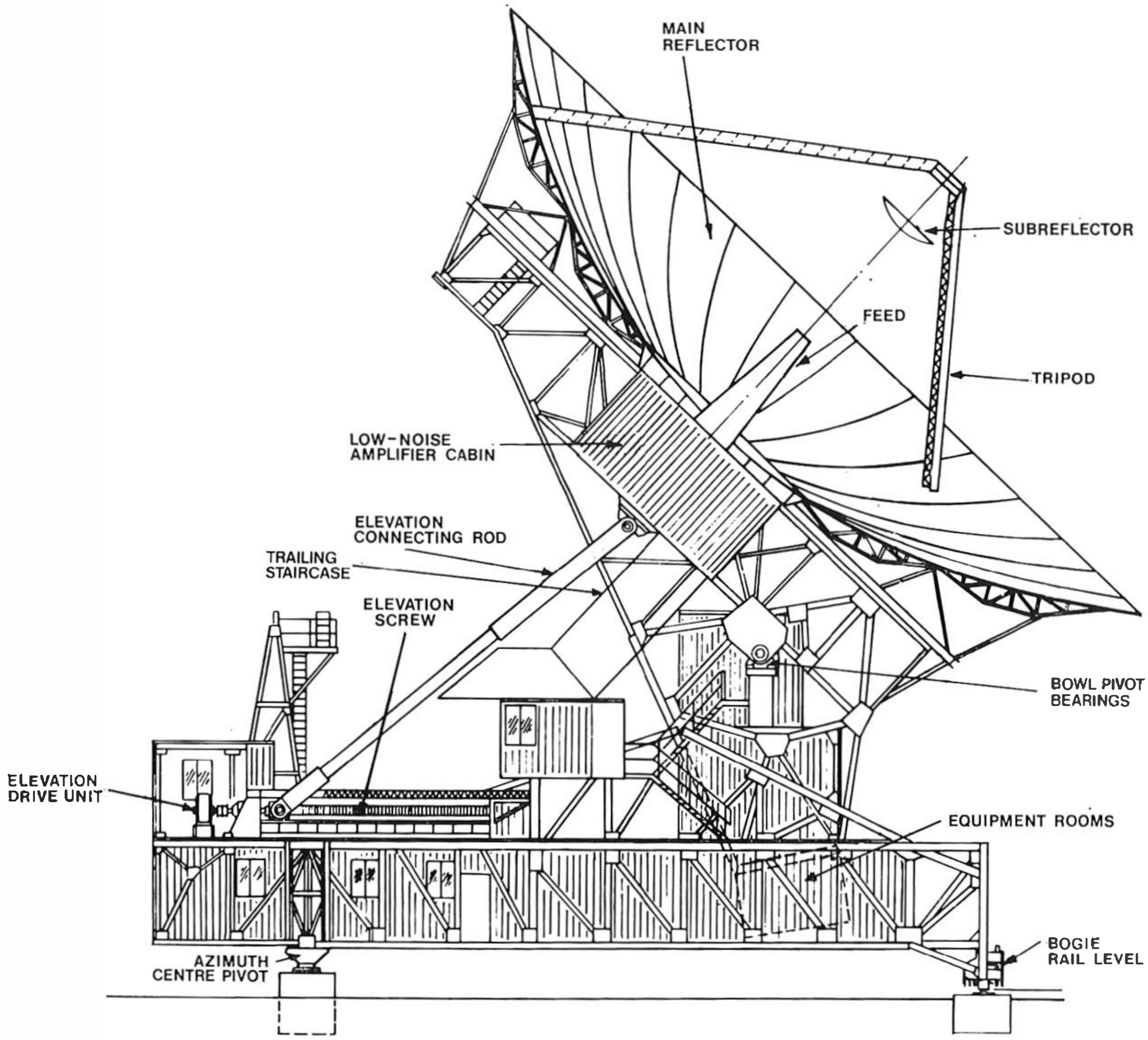


FIG. 3—Sectional view of Goonhilly Aerial No. 2

Aerial No. 1 (Fig. 2), has a reinforced-concrete mount comprising three A-frames erected on a low-level horizontal turntable 12·8 m in diameter. The A-frames are joined at the top by a post-tensioned crossbeam which carries the elevation bearings. The main equipment cabin encloses the base of the A-frames, which severely restricts space available for equipment.

Aerial No. 2 (Fig. 3) may be described as a strong rotating steel box, straddled by a steel gantry which carries the elevation bearings and reflector.

For Aerial Nos. 1 and 2, the inherent strength of the steel reflector surfaces contributes to the structural stiffness. This is derived mainly from a large-diameter, deep, steel framework. Overall stiffness is achieved by tack-welding and/or bolting 3·3 mm sheet-metal panels to backing frames to form the shaped surface. Continuous welds are avoided because they cause unacceptable buckling of the surface. These heavy reflector structures also carry the l.n.a. cabins and require correspondingly stout bearings and relatively high-power driving machinery.

Aerial No. 3 (Fig. 4) has a tapered, reinforced-concrete tower with an immensely strong neck which was post-stressed so that it could withstand all the dynamic loads. The rotating superstructure is fabricated from mild steel and carries stiff, lightweight reflector panels mounted separately on a steel backing-structure. These panels comprise 2 mm stretch-formed aluminium sheets, riveted to die-cast aluminium-alloy stiffeners. A relatively-small diameter, accurately-machined hub-cone provides a stiff, central reflector datum. All connexions in the reflector trusses are bolted to avoid stresses that could be built-in by welding. The weight of the l.n.a. cabin is not carried by the reflector.

AZIMUTH BEARING

The azimuth bearing of Aerial No. 1 (Fig. 5(*a*)) consists of 54 tapered rollers running between two accurately-machined and levelled manganese-steel tracks, 12·8 m in diameter. The rollers are mounted at the ends of a tubular-steel spider pivoted at the centre of the track. The central pivot has two double-row, self-aligning spherical roller-bearings, one to centre the spider and the other to centre the rotating platform of the aerial. Simple facilities are provided for changing rollers. This robust, high-precision bearing system was designed for high-speed tracking, and seems to be capable of giving reliable operational service for many years.

A tower type of construction was considered for Aerial No. 2, but none of the crane-type bearings (Fig. 5(*b*)) then available was suitable because of the difficulties involved in their replacement should they become faulty. It was clear that the overturning moments would have to be carried by a relatively small-diameter bearing, and the risk of its failure causing long out-of-service time could not be accepted.

Aerial No. 2 has, in fact, a cheaper azimuth bearing

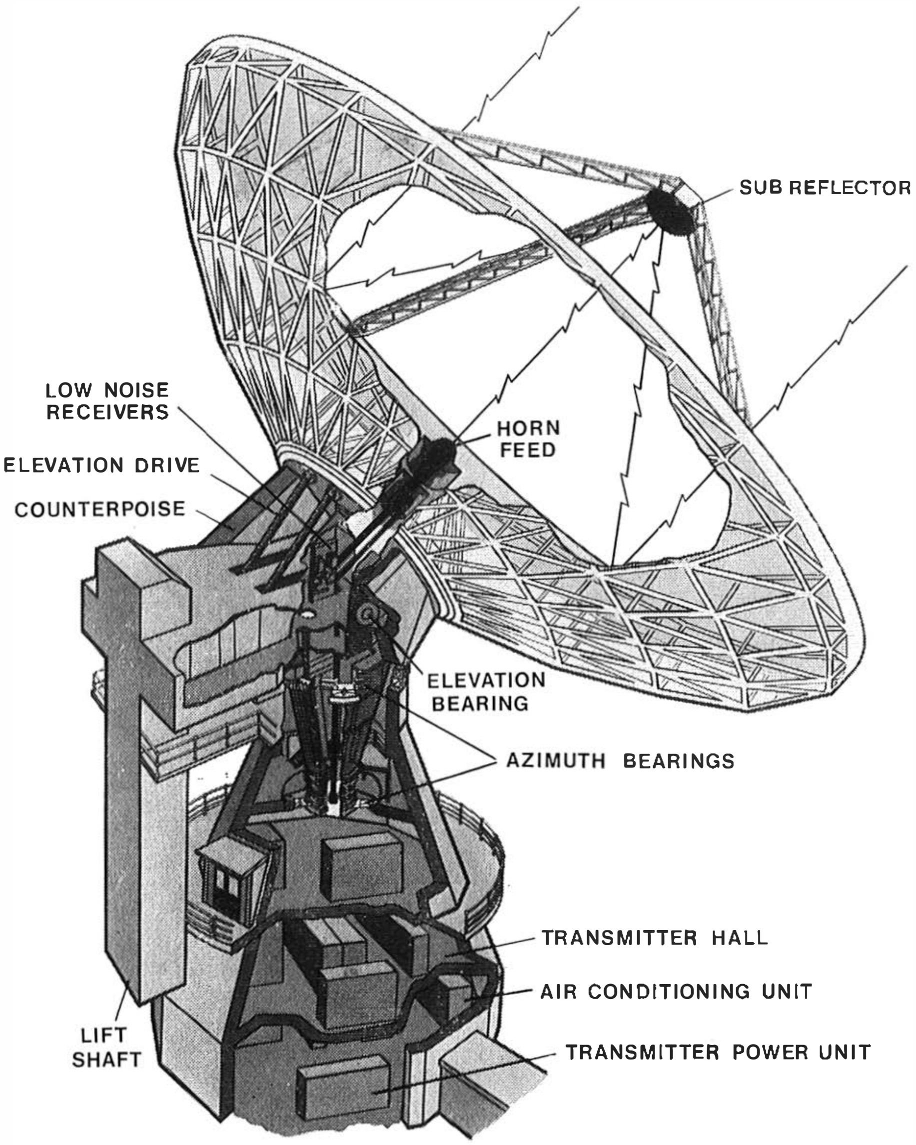


FIG. 4—Goonhilly Aerial No. 3

(Fig. 5(*c*)) which shares the moving load between two driven bogies which run on accurately-levelled curved rails and a fixed pintle* having self-aligning spherical-roller thrust-bearings.

Although the bearings, rollers and bogies of Aerial Nos. 1 and 2 are unlikely to fail within the design lifetime because of their very robust construction, any major fault might require a fairly long time for repairs, but the facility for tracking by means of sub-reflector or primary feed deflexion (beam swing) provides the possibility of service continuing during repair.

The position and design of the azimuth bearing has a critical effect on the design of the whole aerial. Most of the hazards previously associated with high-level azimuth bearings have been eliminated in the Aerial No. 3 design by mounting the rotating platform on a vertical, tapered kingpost, 5·5 m in length, so that the overturning moments are taken by the long, post-stressed tower-neck (Fig. 5(*d*)). Radial loads on the upper part of the kingpost are taken by a bearing, 3·8 m in diameter, and an oil-immersed bearing at the lower end, 1·3 m in diameter, carries radial and thrust loads. Both radial bearings comprise six plain polytetrafluoroethylene (p.t.f.e.) pads mounted on adjustable self-aligning shoes. The lower bearing also has p.t.f.e. thrust pads on the underside of the kingpost. Loads on individual bearing shoes and pads can be relieved so that replacement can be made without taking the aerial out of service. An oil-spraying system protects the upper bearing ring against corrosion. The only obvious disadvantage of this new system is the restriction of space at the azimuth-bearing level which has been largely overcome by provision of the external lift.

It is still too early for a reliable assessment of the relative merits of the high- and low-level bearing designs, but the advantages of a lightweight reflector are obviously also applicable to the latter. The advantages of the wide and stable base which simplifies the design for high wind loads and overturning moments should not be disregarded.

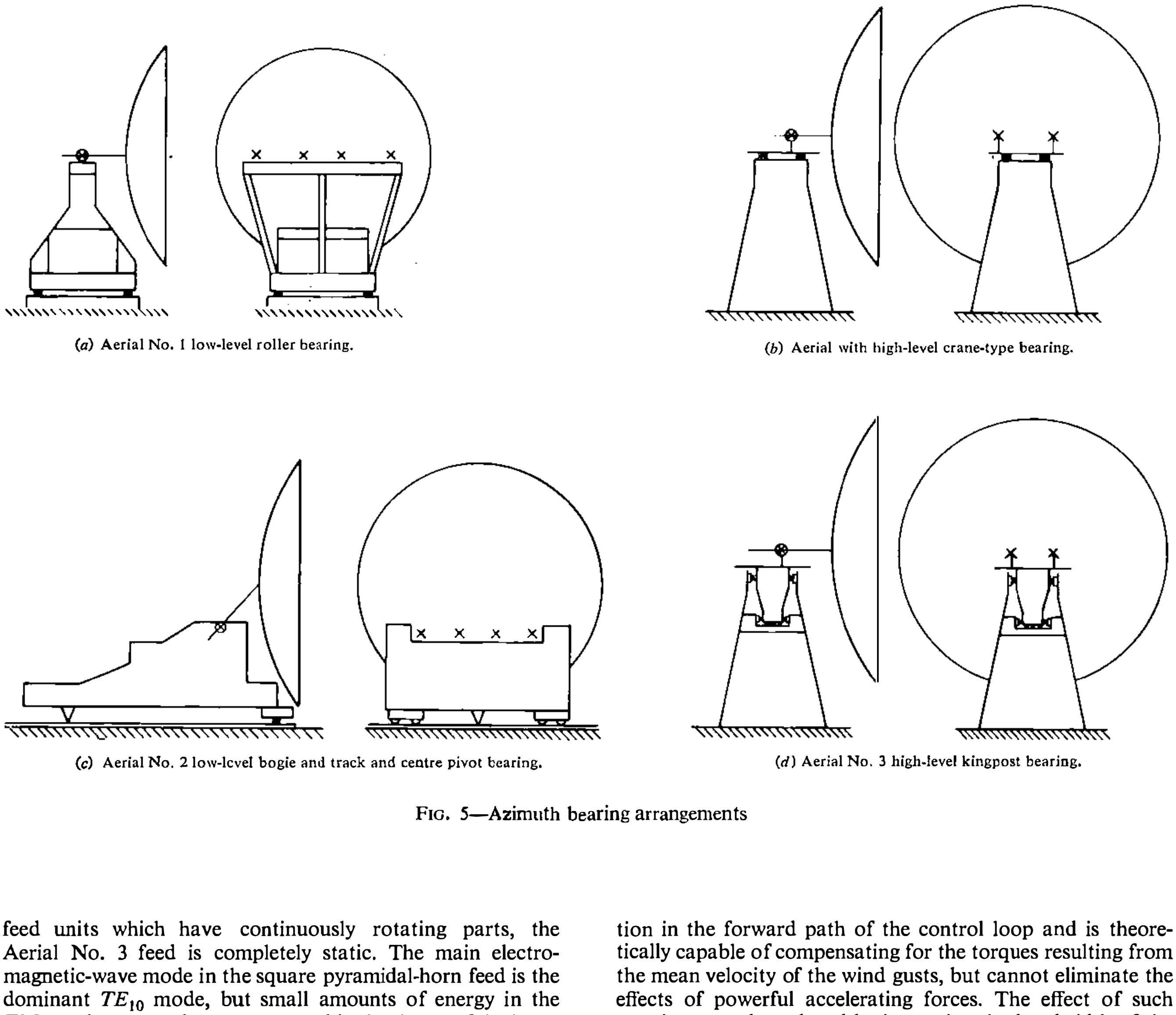
ELEVATION BEARINGS

The lightweight reflector of Aerial No. 3 enables the load to be carried by only two bearings on a short elevation axis. Built-in jacking facilities allow the bearings to be relieved of their load and replaced with minimum out-of-service time. A multiplicity of elevation bearings, as in the designs for Aerial Nos. 1 and 2, can ease the design of a stiff reflector framework. In any event, self-aligning, spherical roller-bearings are essential, and at least one of them must take the axial thrust-load as well as its share of the radial load.

THE FEED AND TRACKING SYSTEM

The essential components of the Aerial No. 3 feed and tracking system are shown in Fig. 6. Unlike the Aerial Nos. 1 and 2

* Pintle—pin of a hinge or bearing.



(a) Aerial No. 1 low-level roller bearing.

(b) Aerial with high-level crane-type bearing.

(c) Aerial No. 2 low-level bogie and track and centre pivot bearing.

(d) Aerial No. 3 high-level kingpost bearing.

FIG. 5—Azimuth bearing arrangements

feed units which have continuously rotating parts, the Aerial No. 3 feed is completely static. The main electro-magnetic-wave mode in the square pyramidal-horn feed is the dominant TE_{10} mode, but small amounts of energy in the TM_{12} and TE_{12} modes are generated in the throat of the horn, to shape the feed pattern. When the longitudinal axis of the feed horn is in line with the satellite direction, only these three modes are present. However, when there is a small pointing error, the field pattern is displaced and orthogonal TE_{20} and TE_{02} modes are generated. Energy in these modes at the beacon frequency is extracted and processed to give tracking-error analogues. One mode is used for control of movement to reduce the tracking error in azimuth, the other mode controls elevation movement.

The phase reference for the error channels is obtained by extracting the beacon signal from the output of the first amplifier via a 20 dB cross-coupler. A frequency converter followed by a narrow-band tracking receiver form the phase-reference channel, and a similar common channel is shared, by time-division switching, between the azimuth- and elevation-error channels. Phase-sensitive detectors at the output of the tracking receivers generate control signals which are amplified and processed in the servo amplifier to produce control signals for thyristor units. These govern the speed and direction of the driving motors which move the reflector to minimize or eliminate the tracking error.

Although the steady-state angular velocities and accelerations required to follow the daily movements of a 24-hour synchronous satellite require only a simple servo system, more elaborate arrangements are required to deal with the high accelerations associated with strong gusts of wind. The servo system used for Aerial No. 3, Fig. 7, has two stages of integration in the forward path of the control loop and is theoretically capable of compensating for the torques resulting from the mean velocity of the wind gusts, but cannot eliminate the effects of powerful accelerating forces. The effect of such transients can be reduced by increasing the bandwidth of the servo system, but a compromise is necessary to limit the error arising from receiver noise which becomes more significant with increasing bandwidth.

A secondary local feed-back loop improves the overall stability of the tracking loop. For this purpose, a control signal proportional to the angular velocity of the aerial is produced by a tacho-generator coupled to the motor shaft. Its output is combined in the servo amplifier with the main control signal derived from the radio beacon.

In the event of prolonged failure of the tracking electronics, the tracking receiver output can be replaced by programmed tracking data from the on-line computer which will act as a standby for all the aerials at Goonhilly.

For manual control of the aerial, one of the integrating networks is switched out-of-circuit to convert the main loop to positional control, thus increasing the stability margin available for the greater range of velocity changes that might be demanded during re-positioning of the aerial for maintenance or re-acquisition of a satellite. Extremely accurate gear-trains are used to connect conventional coarse/fine pairs of synchro-transmitters to the aerial movement axes. Their windings are linked with those of similar command synchros on the control console. When a demanded angle is set up on the command synchros, the phase difference between the windings at aerial and console creates an error analogue which is reduced to zero by the driving motors. A resolving accuracy of 0·01° is achieved. Independent resolver synchros,

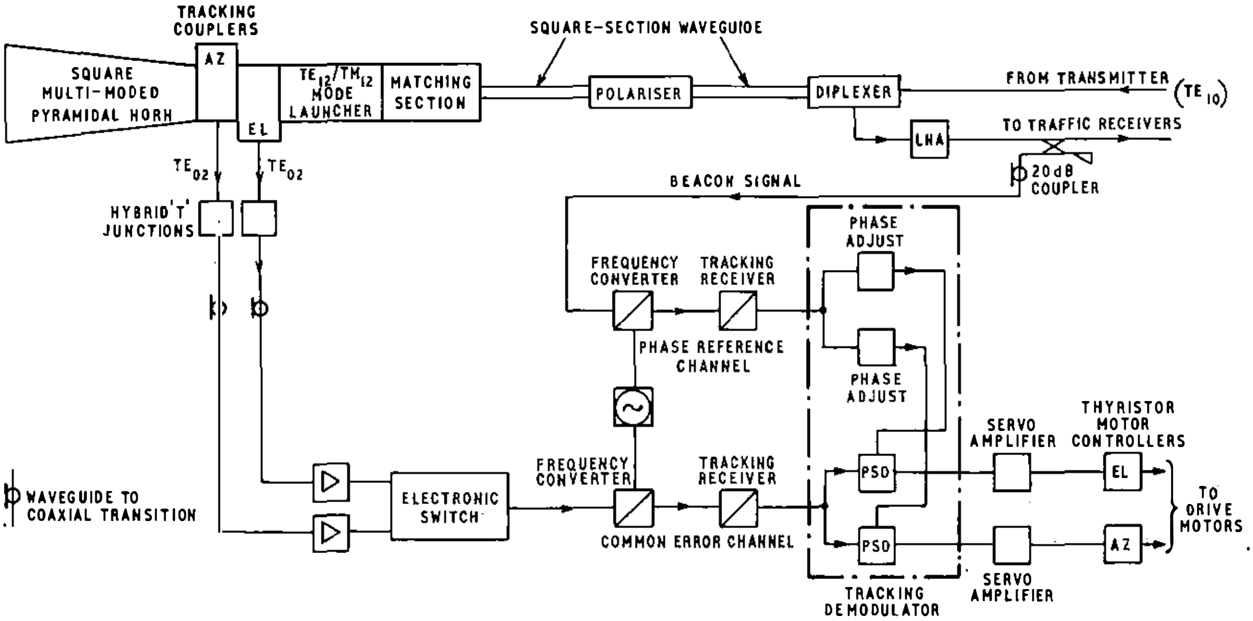


FIG. 6—Aerial No. 3 feed and tracking system

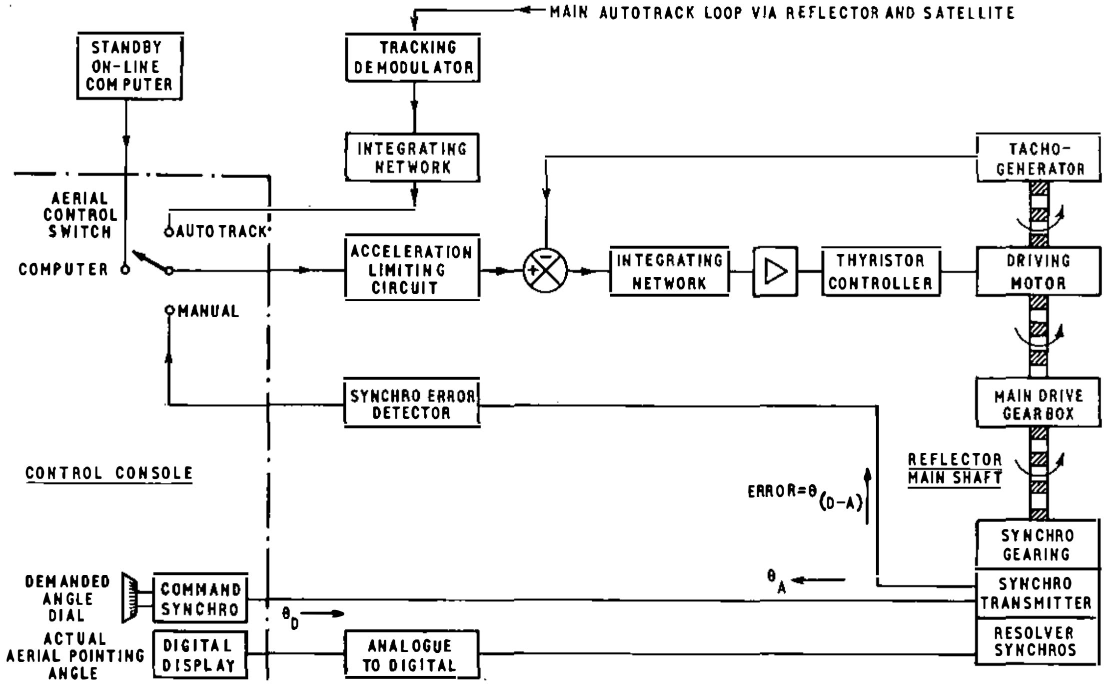


FIG. 7—Aerial No. 3 control system

also geared to the main shaft, drive analogue-to-digital converters to enable the aerial pointing-angle to be displayed digitally at the control console.

Like Aerial No. 2, Aerial No. 3 has an independent auxiliary tracking facility to enable the aerial to remain in service for periods of several hours whilst the main reflector movement facilities are shut down for maintenance or minor bearing renewals. For this purpose, the sub-reflector can be tilted by servo-controlled hydraulic rams to steer the main beam within a range of ±20 minutes of arc, but some loss of gain is inevitable. Normally the sub-reflector is locked in its central position, but when required, the output of the tracking demodulator can be switched from the main servo amplifier to the auxiliary servo system which controls the sub-reflector movement. In this way, the satellite can be tracked by the resulting deflexion of the beam.

The G/T of an aerial system is defined for clear, still weather conditions, but adverse winds will obviously introduce steering errors and consequent loss of effective gain. The expected performance of Aerial No. 3 is shown in Fig. 8.

DRIVE TRANSMISSION SYSTEM

The maximum power of the steering motors is set by the maximum aerial velocity and acceleration required in the most adverse weather conditions. As the tracking capability of Aerial No. 3 has been restricted to that appropriate for tracking 24-hour synchronous satellites, twin 1·5 kW, servo-controlled, d.c. motors are adequate, but if one fails, the tracking accuracy can still be maintained in wind speeds up to 70 per cent of the maximum specified. When higher speeds are required for re-positioning the reflector, the drive is transferred to 15 kW a.c. motors, as shown for the azimuth system in Fig. 9.

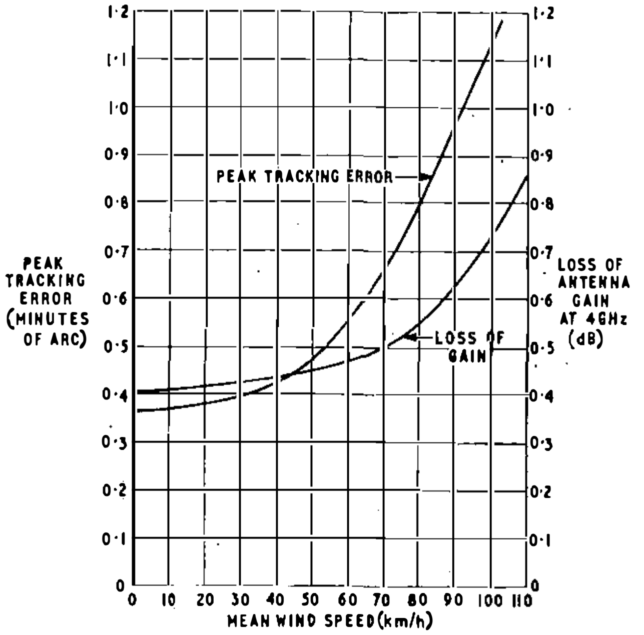


FIG. 8—Variation of peak tracking-error and aerial gain with changes in mean wind speed, for Aerial No. 3

As in Aerial No. 2, backlash is minimized in the gearbox design and its effects in the azimuth drive are controlled by counter-torque operation of the dual motors. These motors and associated gearboxes are mounted on the rotating platform, and the driving pinions engage with a large fixed ring-gear that surmounts the tower.

The final stages of Aerial No. 3 dual elevation-drives incorporate novel screws and crossheads (large nuts). The screws, which do not rotate, form a link of variable length between crossheads fixed to the rotating platform and the reflector. Each screw is drawn longitudinally through its rotating crosshead by the reaction of a continuous train of re-circulating steel balls which move through the helical channel formed by a gap between the threads of the screw and crosshead. As the crosshead is rotated by the drive from the motor, the balls enter the channel at one end, are drawn through the crosshead, discharged at the other and pushed around the loop to the channel entrance. The device has very high efficiency, with low inherent friction which simplifies the design of a stable but sensitive servo system. Each drive transmission system includes dual multi-plate disc brakes that are applied automatically if there is a failure of the motor power supply.

Comparison of this modern low-power system with the 75 kW installation that drives Aerial No. 1, or the dual 11 kW system of Aerial No. 2, shows clearly that substantial economies have been achieved in driving motors, control gear and the mechanical transmission systems. The major savings arise from the reduction of weight, the exclusion of high tracking-velocities from the specification and the use of solid-state devices instead of rotating machinery for the control of variable-speed d.c. motors.

EQUIPMENT ACCOMMODATION

The Aerial No. 3 design reverts to the philosophy originally envisaged in the B.P.O./Husband design for Aerial No. 2 in that the l.n.a.s are mounted in-line with the elevation axis in a cabin that rotates in azimuth but does not tilt. The stationary main and reserve l.n.a.s are linked with the feed via a short length of flexible waveguide approximately on the elevation axis, and a straight waveguide which moves with the reflector. By comparison with Aerial No. 2, the reflector diameter has been increased from 27·4 m to 29·6 m to compensate for the slight increase of loss in the receive waveguide. The high-power transmitters and low–high frequency changers are housed on the lower floors of the tower, whilst the high–low frequency changers are located in the central building.

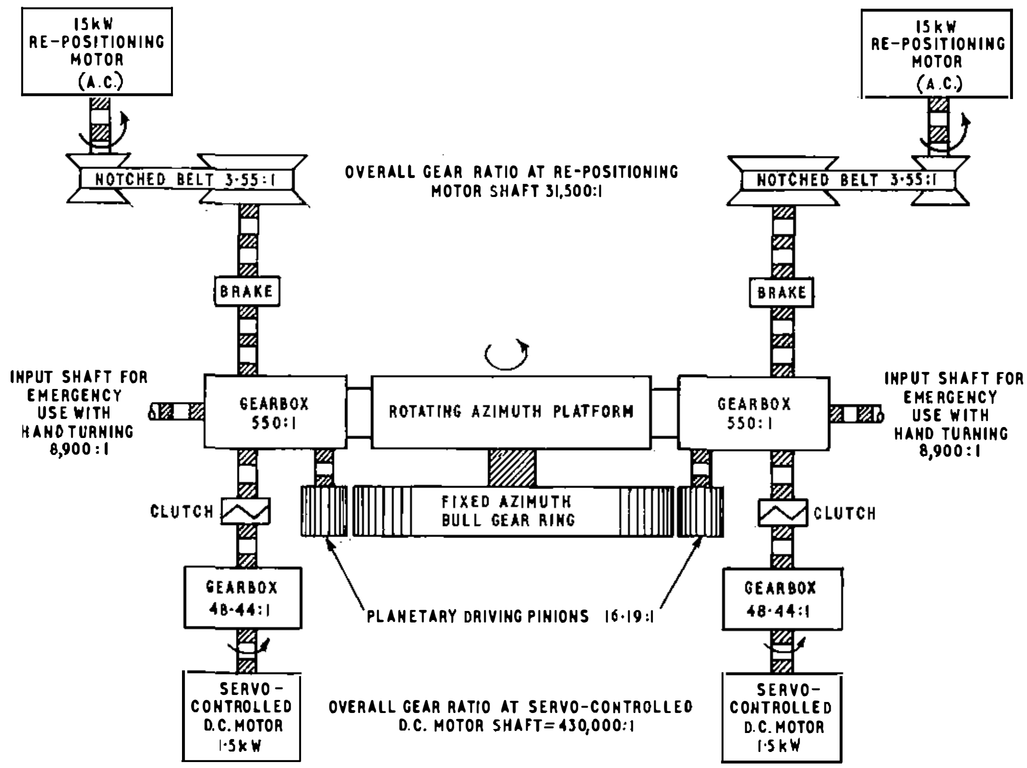


FIG. 9—Aerial No. 3 dual azimuth driving system

Brief reference has already been made to the shortcomings of the accommodation for the l.n.a.s on Aerial No. 1. They are located in cabins at the base of the feed supporting-structure and move with the reflector as it is elevated. The total weight of the cabins and their contents must be restricted severely to avoid gravitational distortion of the reflector. Moreover, it would hardly be practicable to provide safe access for personnel to these cabins at elevation angles greater than about 9°.

The problems of access to the l.n.a. cabin of Aerial No. 2, which is behind the apex of the main reflector and tilts with it, was solved by provision of a trailing staircase, with self-levelling treads, giving access to a pivoted floor in the cabin. A section of the floor is kept level automatically, but the l.n.a.s are mounted inconveniently on a cabin wall that is vertical when the reflector faces the horizon, and horizontal when the reflector points to the zenith.

FUTURE DEVELOPMENTS

Aerial No. 3 is fairly typical of aerials that have been provided at earth stations in recent years. Studies have included consideration of aerial mounts with movement axes that are not horizontal and vertical, but no general advantage is obtainable for satellites in 24-hour synchronous orbits. The economy attainable by tracking solely by sub-reflector deflection is now almost within reach, but the general availability of fully-steerable aerials allows greater flexibility in the positioning of satellites, and a greater margin of orbital drift, when required. Designers have considered folded horn aerials and offset Cassegrain feeds, but it seems doubtful whether the attainable improvements would justify the cost. Feed systems with multiple sub-reflectors to eliminate waveguide losses have been built, as have aerials which combine the advantages of a lightweight reflector and an azimuth bearing at ground level. It seems reasonable to predict that current designs for aerials operating in the 4GHz and 6GHz bands will not change radically in other ways in the near future. There is no doubt that these frequencies will continue to be used in the next generation of INTELSAT satellites and they may also be used for some regional schemes.

For some applications there may also be scope for aerials with multiple feeds and hemispherical reflectors working to several satellites simultaneously. The advent of regional schemes, including mobile services and the introduction of higher operational frequencies, will probably lead to the use of smaller aerials. In general, for a given aerial, the increase of propagation path loss as the frequency is increased could be counterbalanced by the increased gain of the aerial provided that proportional profile accuracy could be maintained. Current opinion suggests that highly-directional satellite aerials will enable the satellite to make a greater effective power contribution to the system, and that earth station aerial diameters will be reduced. In consequence, excessively narrow aerial beam-widths will not impose too stringent requirements on tracking systems, and the attainable profile accuracy will be tolerable. In the higher frequency bands the greatly increased attenuation, caused by rain, will force system designers to increase the margin relative to clear sky conditions. If the incidence of local storms requires space-diversity working, with receiving aerials several kilometres apart, then the existing demand for simpler and cheaper steerable aerials will be intensified.

ACKNOWLEDGEMENTS

The authors are grateful to Marconi Communication Systems Ltd. for permission to reproduce parts of drawings and photographs on which the illustrations are based.

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APPENDIX—Summary of the Features of Goonhilly Aerials

Feature	Aerial No. 1	Aerial No. 2	Aerial No. 3
Aerial geometry Main reflector shape & diameter (m) Sub-reflector diameter (m)	Front fed Paraboloid, 26 —	Cassegrain Quasi-paraboloid, 27·4 Quasi hyperboloid, 2·1 (Reflectors specially shaped to give high illumination efficiency)	Cassegrain Quasi-paraboloid, 29·6 Quasi-hyperboloid, 3 (Reflector specially shaped to give high illumination efficiency)
Focal length (m)	9·2	9·1	9·5
Net aerial gain at 4,165 MHz (dB)	58·5	59·8	60·3
Net aerial gain at 6,055 MHz (dB)	61	62·7	63·0
G/T at 5° elevation at 4,165 MHz, (dB)	39·9	40·7	41·3
Reflector	Mild steel centre surrounded by stainless steel	Mild steel centre surrounded by stainless steel	Aluminium panels

Feature	Aerial No. 1	Aerial No. 2	Aerial No. 3
Reflector r.m.s. profile accuracy (mm)	1·02	1·02	1·02
Method of profile measurement	Templates at works and on site during building. Subsequently, antenna theodolite and ground-based theodolites	Templates at works. Range-finder and bars of known length on site	Manufacturing jig at works. Range-finder and bars of known length on site
Method of profile adjustment	Jacks at petal junctions 2·3 m from rim, and 57 links on each petal	Struts on panel corners, with oversize holes and studs for local surface areas	Stainless-steel panel adjusters of 3 types fitted at corners of panel
Sub-reflector r.m.s. profile accuracy, (mm)	—	0·05	0·13
Weight on elevation bearings, (tonne)	416 (4 bearings)	332 (4 bearings)	234 (2 bearings)
Weight on azimuth bearings, (tonne)	1,102	952 with 486 on centre pivot and 233 on each bogie	336
Tracking method	Conical scan of whole received beam	Mode-conversion scanning—conical scanning at beacon frequency only	Static auxiliary-mode system using beacon frequency
Feed spin rate (r.p.m.)	900 (range 480 to 1,800)	About 420 (range 200 to 1,000)	Static
Operational wind speed (km/h)	76, mean hourly, gusting to 106	76, mean hourly, gusting to 106	76, mean hourly, gusting to 106
Diameter of azimuth track or bearing (m)	12·8, low-level precision rollers and track	45·7, low-level, two bogies running on standard track with centre pivot	3·8 and 1·3, spaced 5·5 vertically apart in kingpost at high level
Accuracy of azimuth track level	± 0·13 mm	± 0·5 mm	± 20 seconds of arc
Azimuth drive	Controlled 75 kW d.c. motor driving a chain via gearboxes	Thyristor-controlled pairs of 11 kW d.c. motors driving bogie gear trains via differential gearboxes	Twin-drive thyristor-controlled motor units each comprising: 15 kW a.c. motor for slew mode, 1·5 kW d.c. motor for tracking mode, driving planetary pinions round a static ring gear via gearboxes
Elevation drive	Controlled 75 kW d.c. motor driving a screw via gearing. As screw rotates, a connecting rod, attached to a crosshead on the screw, pulls or pushes the reflector	Thyristor-controlled pair of 11 kW d.c. motors driving a screw, crosshead and connecting rod via a differential and other gearing	Twin-drive thyristor-controlled motor units driving re-circulating ball screws via gear boxes. Motor units as for azimuth drive
Azimuth range (degrees)	± 250 relative to South	93 to 299 East of North	± 270 relative to South
Elevation range (degrees)	0 to 100	−1 to 47. Can be operated from 45 to 90 by changing the length of the con-rod, a built-in facility	−2 to +92
Azimuth velocity (degrees per minute)	120	10	15, slew mode, 1, tracking mode
Elevation velocity (degrees per minute)	30	5	15, slew mode, 1, tracking mode
Tracking accuracy (minutes of arc)	Within 1	Within 1	Within 1
Tracking modes	Full auto-track Program tape control Manual control, velocity and position	Full auto-track Main servo auto-track (with sub-reflector locked) Manual control, velocity and position Facility provided for accepting input from tape control unit	Main servo auto-track Sub-servo auto-track Manual position Manual velocity Program track Stow sequence

The Design and Planning of the Junction Network

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The design and planning of the junction network is undertaken by the Telecommunications Regions in the United Kingdom. This article outlines the methods adopted by the South Western Telecommunications Region. These methods have been adjusted to match the high rate of growth in the network, and the increasing range of transmission systems. The types of transmission system used are reviewed, with an indication of the way they are selected to meet the individual requirements of each junction network route.

INTRODUCTION

The junction network forms a vital part of the British Post Office (B.P.O.) telecommunications network, being utilized by all telephone traffic between local exchanges (see Fig. 1). Much of this traffic is carried on direct links or via junction tandem exchanges and the remainder is routed via the main network[1] which is reached via junction network circuits known as trunk junctions. Each local exchange is connected to its group switching centre[2] (g.s.c.) and, if the amount of telephone traffic justifies it, to other local exchanges. The decision to connect two local exchanges by a direct route is normally based on the comparative cost of line-plant for the direct route and of line-plant and switching-equipment for the corresponding indirect routing.

Responsibility for the design and planning of the U.K. junction network is vested in the Telecommunications Regions of the B.P.O. This articles is concerned with the junction network in the South Western Telecommunications Region (S.W.T.R.)

The present size of the network in the S.W.T.R. is as follows:

number of local exchanges	758
number of g.s.c.s	37
number of authorized junction network circuits	51,300

The location of the g.s.c. area boundaries has an important bearing on the length of the junction network circuits and Fig. 2 shows the distribution of S.W.T.R. junction network circuits with route length.

In recent years, there have been many developments influencing the junction network which have improved its performance and, at the same time, helped to reduce the cost per circuit. The S.W.T.R. is, at present, investing £2·7 million per annum in line-plant for the junction network to meet a 10 per cent per annum growth in traffic.

TRANSMISSION PERFORMANCE

When the United Kingdom routing and transmission plan[3] was formulated, the objective was generally to provide high-quality transmission, and, at worst to provide an acceptable transmission performance. The major factors on which the transmission performances of a telephone connexion depends are:

(*a*) the telephone set,
(*b*) the local lines between the telephone set and the local exchange,
(*c*) the equipment in local exchanges,
(*d*) each circuit in the chain used to link local exchanges,
(*e*) the equipment in intermediate switching exchanges.

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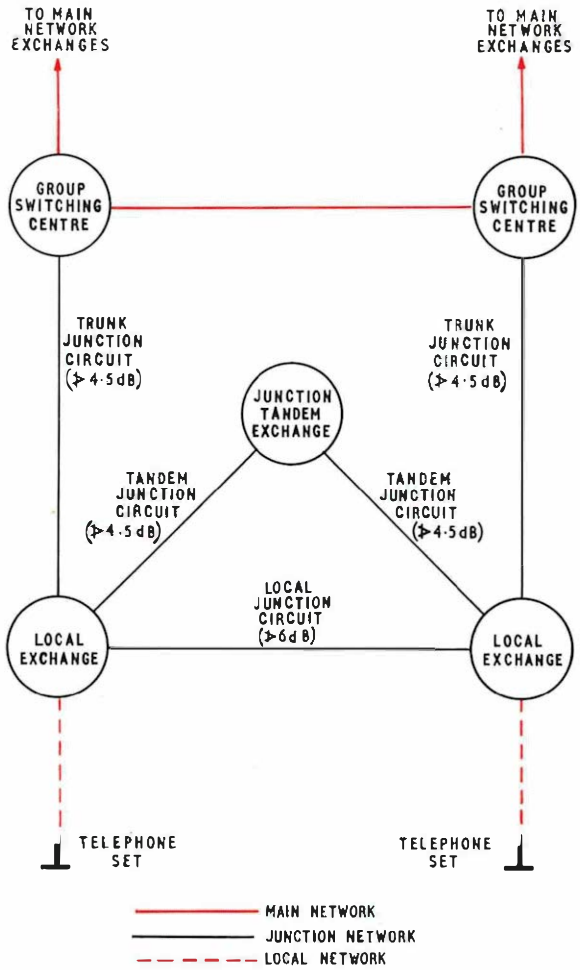


FIG. 1—Junction network routing and transmission plan

The overall permissible transmission loss of a connexion needs to be apportioned between all elements to the best economic advantage. The great majority of the capital invested in the telephone network resides in local networks and, accordingly, these are designed to be as economic as possible. Once the standards for the local network have been established, it is possible to determine the standards for the links between local exchanges to ensure satisfactory overall performance.

In the United Kingdom, the present standard is that the overall nominal loss between local exchanges should not exceed 19·5 dB. Within this total, each class of circuit is assigned a particular nominal maximum transmission loss.

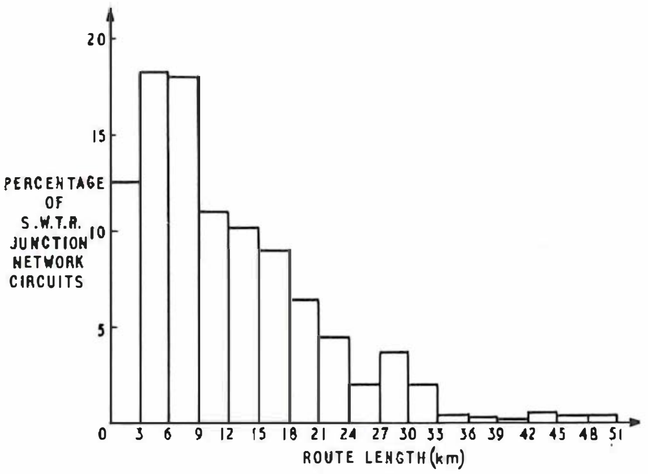


FIG. 2—Distribution of S.W.T.R. junction network circuit route lengths

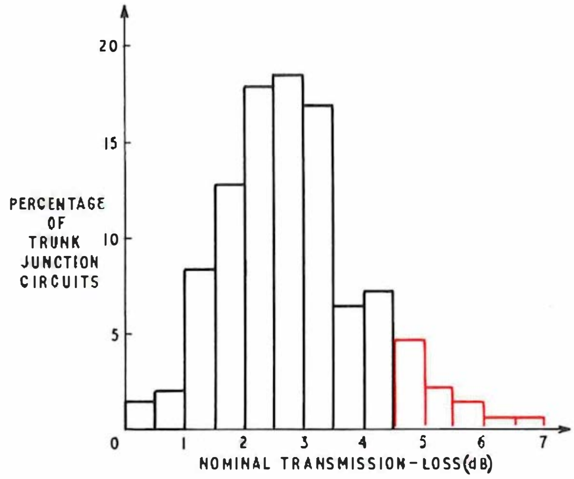


FIG. 3—Distribution of non-director area trunk junction circuit transmission losses

The limits for junction network circuits are shown in Fig. 1. The achievement of a high average transmission performance relies on the fact that only a small proportion of the circuits will, in fact, have a transmission loss equal to the limiting loss. This point is illustrated by Fig. 3, which shows the distribution of non-director area trunk junction circuit transmission losses. The transmission limit for this class of circuit is 4·5 dB but, in practice, the mean value is 2·8 dB.

Although the transmission limit for trunk junction circuits is 4·5 dB, the area of the distribution shown in red in Fig. 3 indicates that, over the years, expedient measures have sometimes been taken resulting in trunk junction circuits with a nominal transmission loss greater than 4·5 dB. Investigations have shown that the number of trunk calls during which transmission difficulty is encountered would be reduced by about 13 per cent if these circuits were improved to 4·5 dB. For this reason, capital expenditure is being devoted to bringing these circuits up to standard.

TRANSMISSION SYSTEMS

The transmission systems used for the junction network are:

(*a*) audio systems—amplified or unamplified using multi-pair cables,
(*b*) pulse code modulation (p.c.m.) systems routed over multi-pair cables,
(*c*) frequency division multiplex (f.d.m.) systems using coaxial cables or microwave radio-relay systems.

Audio Systems

Multi-pair cables are used for junction network audio systems. Each conductor is of annealed copper (0·63 mm diameter) insulated with an open lapping of paper string and overlapped lapping of paper. The insulated conductors are formed into quads and then stranded in layers. For economic reasons, the cable sizes have been rationalized and contain between 28 (two layers) and 1,040 pairs (13 layers). Each cable size has one more layer than the previous, and the number of pairs in any given cable are given by the formula $2n(3n + 1)$, where n is the number of layers in the cable. A polythene sheath is used together with an aluminium-foil moisture barrier. When cables are joined together, each conductor is soldered to the appropriate conductor in the second cable.

In the past, 0·9 mm and 1·27 mm diameter conductors were provided for junction network circuits. Standardization on the finer-gauge 0·63 mm conductors has reduced the amount of expensive copper per circuit in new cables. The increase in transmission loss is overcome by the use of simple, inexpensive transistor amplifiers. When amplification is necessary, 2-wire amplifiers are provided. Only one 2-wire amplifier[4] is used per circuit. Two types of 2-wire amplifier are available, i.e. negative-impedance amplifiers and hybrid amplifiers. The negative-impedance amplifier is the cheaper and is, therefore, normally provided if practicable. In very exceptional circumstances, 4-wire amplifiers are provided.

The limiting length of each type of audio system using 0·63 mm conductors is given in Table 1.

TABLE 1

Audio System	Maximum Route Length (km)	
	Trunk and Tandem Junctions	Local Junctions
Unloaded cables	3·3	3·6 Note 1
Loaded cables—88 mH/1·83 km	9·9	13·2
Negative-impedance 2-wire amplifier at end of circuit	16·0	21·0
Negative-impedance 2-wire amplifier at mid-third of circuit	—	32·1
Hybrid 2-wire amplifier (end connected) ..	20·0	23·3
Hybrid 2-wire amplifier (mid-third of circuit)	36·6	39·9

Notes:
1. Standard loading is applicable to all audio cables exceeding 3·6 km in length.
2. The amplified circuits use 88 mH loaded cables at 1·83 km spacing.

P.C.M. Systems

The p.c.m. system used by the B.P.O. in the junction network[5] provides 24 telephone circuits on two pairs of wires, one pair for each direction of transmission, using a gross bit-rate of 1·536 Mbit/s. Existing audio cables are suitable for use with p.c.m. systems but there are some restrictions on the use of the smaller cables resulting from crosstalk difficulties. Regenerators are provided at 1·83 km intervals and they replace the loading-coils located at these points. Additional regenerators are provided if the cable encounters impulsive noise generated by an exchange which would introduce errors in the digital pulse-stream.

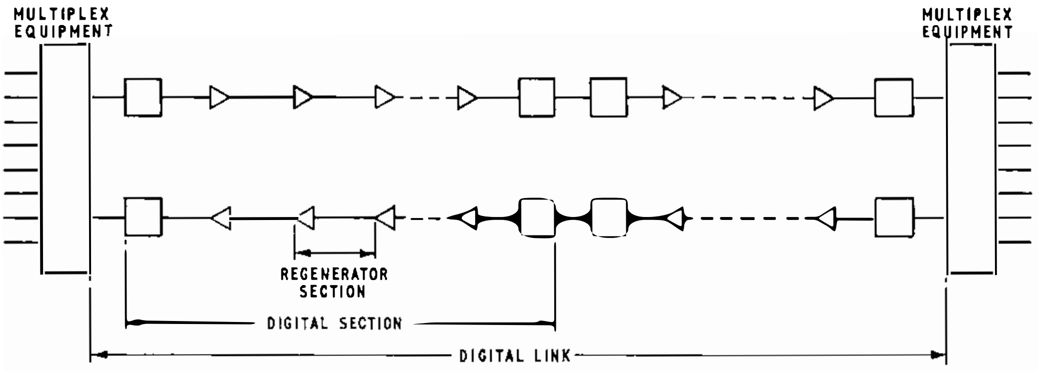


FIG. 4—Junction p.c.m. system arrangement

The arrangement of a junction p.c.m. system is shown in Fig. 4. Power is fed to the regenerators over the phantoms formed by the two pairs in each quad. Using the 0·63 mm conductors, up to seven dependent regenerators may be fed from a line-terminating equipment. Standby digital-sections are provided to ensure speedy restoration of service in the event of a digital-section developing a fault.

Signalling facilities are provided as a basic feature of the p.c.m. system and often a circuit may be provided without the need for any other signalling relay-sets.

F.D.M. Systems

F.D.M. systems used for junction network circuits may be routed over coaxial-line systems[6] or microwave radio-relay systems.[7] Often, the f.d.m. systems are provided for the joint use of junction- and main-network circuits. Sometimes the provision of f.d.m. systems is justified for the sole use of circuits between local exchanges or between a local exchange and its g.s.c.

The 11 GHz frequency band is now being utilized for microwave radio-relay systems. This band is most suitable for relatively short links and is likely to be used more in future for links between local exchanges, or between a local exchange and its g.s.c.

PLANT-PROVISION PERIODS

It costs less to meet junction network requirements by providing plant by instalments. The size and frequency of the instalments are determined by the type of plant, the number of circuits involved and the growth rate.

Audio Plant

The cost of the duct is only a quarter of the cost of the excavation work required to place it in the desired position. The excavation work often disrupts the life of the local community and has numerous other undesirable side effects. For these reasons, the frequency of provision for duct and cable jointing chambers is normally as low as once every 20 years. In special circumstances, such as for routes over bridges, plant is provided to meet the requirements for even longer periods than 20 years.

The normal frequency of provision for audio cables is once every six years. This frequency is not rigid and can be adjusted to make the most efficient use of existing duct and cable layout. Economic studies have shown that where more than 80 circuits per annum are required, a higher provision frequency should be seriously considered. Conversely, when only a few circuits per annum are required a lower provision frequency should be considered. If a cable can be mole-ploughed directly in the ground, avoiding the need for duct provision, a frequency as low as once every 20 years is appropriate.

P.C.M. Systems

The provision periods for p.c.m. system plant are:

(*a*) *Cable pairs;* Sufficient cable pairs are diverted into repeater cases to meet the requirements for digital sections on the cable for 10 years.

(*b*) *Digital sections;* Line equipment and line terminal equipment is provided to meet the digital section requirements for five years.

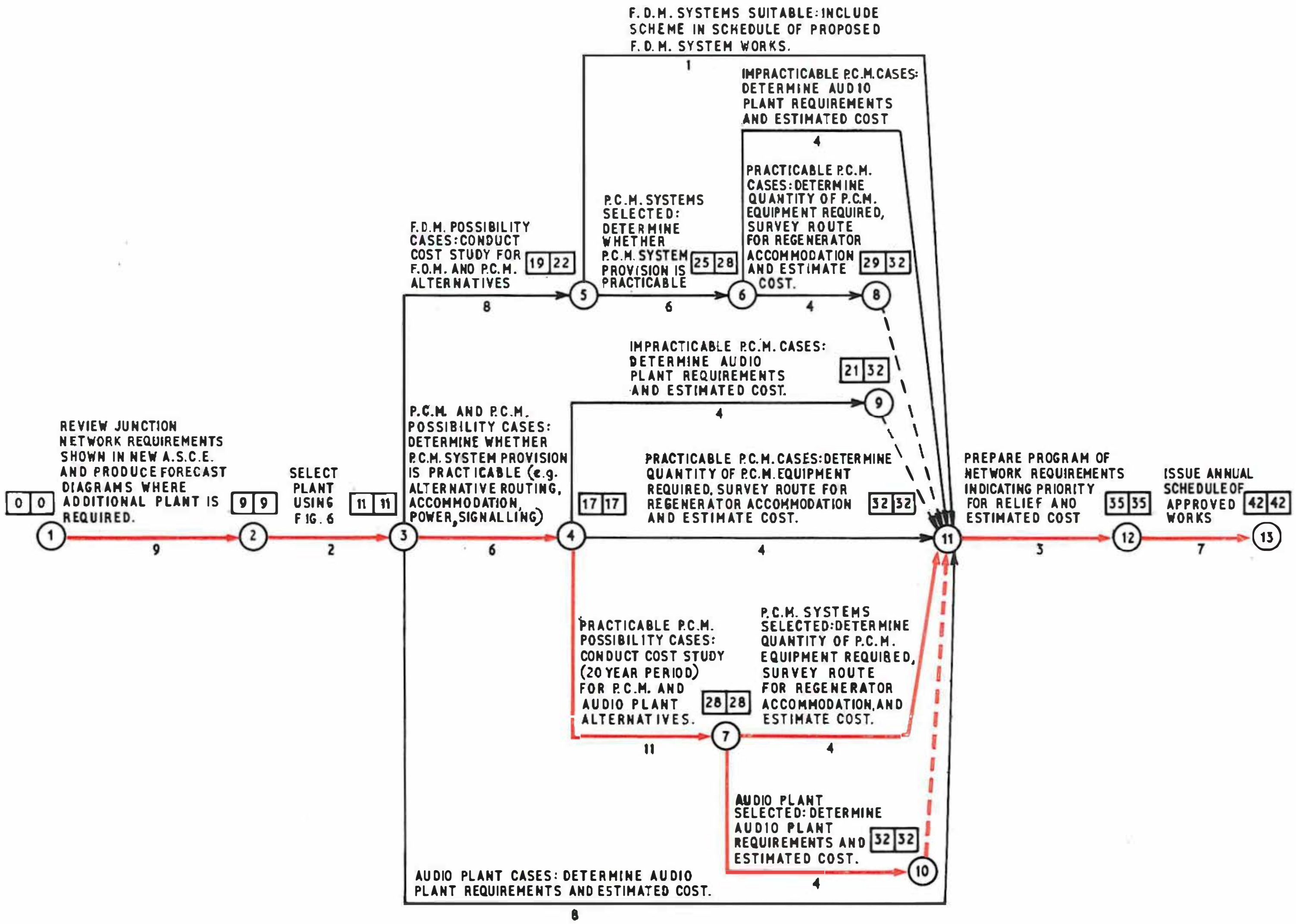
(*c*) *Multiplex equipment and signalling units;* Where practicable, multiplex equipment and signalling units are provided to meet the requirements of a station for one year and six months, respectively.

JUNCTION NETWORK PLANNING

In October of each year, a new edition of the annual schedule of circuit estimates (a.s.c.e.) is published. This document details the forecast requirements for junction network circuits over a five-year period commencing the following April. The forecasts are given in terms of routes representing groups of circuits between exchanges. When the new a.s.c.e. is published, a review of the junction network is undertaken to determine where additional plant is required to meet the forecast circuit requirements over the coming five years. It is necessary to look this far into the future because of the time needed between planning a scheme and getting it operational. The circuits relating to a given route appearing in the a.s.c.e. can follow a number of alternative physical paths involving different nodes of the network. It is, therefore, essential to use a routing plan showing which sections of the network are used by each a.s.c.e. route when the annual network review is undertaken. In addition to the a.s.c.e. requirements, an allowance is made on each section for private and miscellaneous circuits. This is normally 20 per cent of the junction network circuits. The end product of the review is a list of sections of the network which require additional plant.

The critical-path method diagram shown in Fig. 5 illustrates the way in which the S.W.T.R. converts the list of sections requiring additional plant into the annual schedule of approved works. This annual schedule of approved works lists the type and quantity of plant which will be provided to meet the requirements of the network. It also details the cost of the work and how the expenditure is divided between financial years. The detailed planning work then commences.

For audio schemes, surveys and estimates are completed within two years from the date when the annual schedule of approved works is issued. This makes it possible to install the cables during the year prior to the year in which they are required and the duct in the year prior to this. Each scheme is



Notes: 1. Activity durations are shown in units of one week
2. The critical path is in red

FIG. 5—Junction network planning critical path method diagram

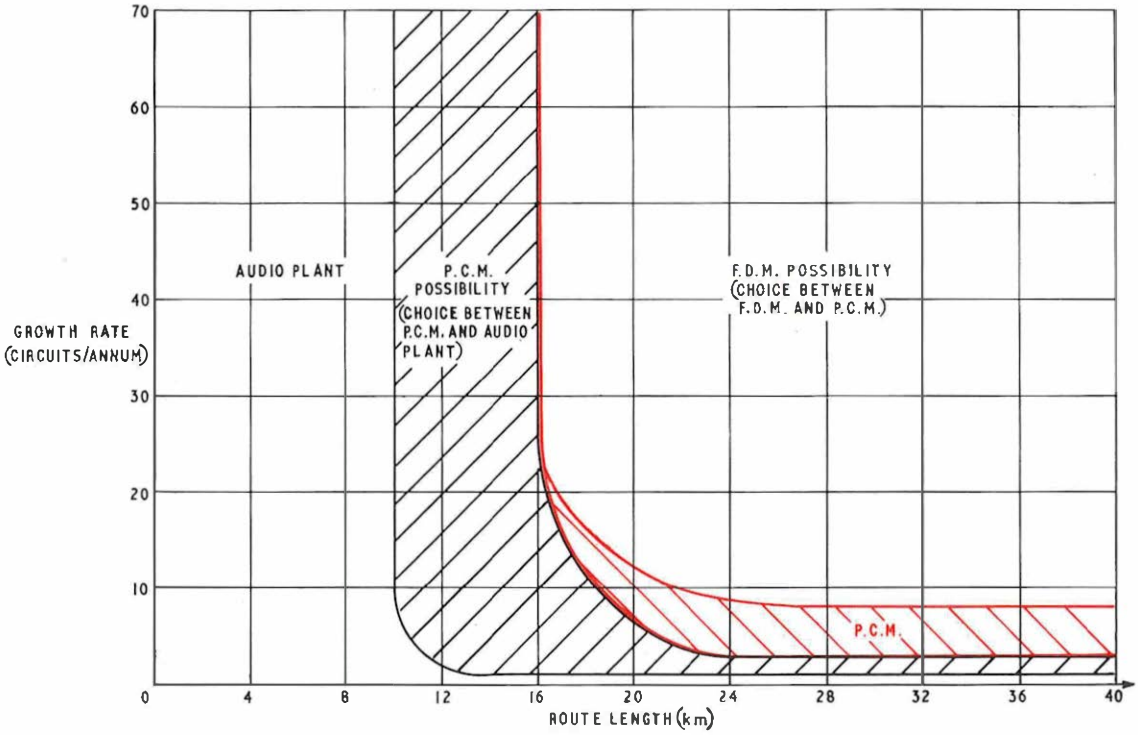


FIG. 6—Graph used for the initial selection of p.c.m. schemes

appropriately programmed so that each activity is phased to meet the ultimate objective of providing the plant by the time it is required. The total time allowed to complete a schedule of approved works in $3\frac{1}{2}$ years.

For p.c.m. systems, the equipment is ordered about two years before it is required for service.

LINE-PLANT SELECTION PRINCIPLES

When a requirement for additional junction network line-plant arises, it is necessary to ensure that the plant provided to meet this requirement is technically satisfactory and the most economic. The type of signalling equipment required for these additional circuits is dependent upon the type of line plant selected. Economic studies must, therefore, consider both the line plant and signalling equipment. Alternative routing of circuits is considered when undertaking the technical adjudication. The normal method of alternative routing is to divide a traffic route between two or more cables so that not more than two-thirds of the circuits are in any one cable. To achieve true alternative routing the cables should be on physically diverse routes. The line-plant selection system used by the S.W.T.R. ensures that an intensive planning effort is made to select the most economic type of plant, bearing in mind future developments.

The initial selection of p.c.m. schemes is made by reference to the graph shown in Fig. 6. This indicates broadly whether p.c.m. system provision may be an economic proposition. The graph is divided into four zones—audio plant, p.c.m. possibility, p.c.m., and f.d.m. possibility. The action to be taken is dependent upon the zone in which the parameters of the particular scheme lie:

(*a*) *Audio-plant zone;* audio plant is provided unless special circumstances exist such as excessively high duct costs and construction problems,

(*b*) *P.C.M. possibility zone;* an economic study is undertaken before a decision is made to provide either audio plant or p.c.m. systems,

(*c*) *P.C.M. zone;* p.c.m. systems are provided if practicable.

(*d*) *F.D.M. possibility zone;* f.d.m. systems are considered but p.c.m. systems normally prove to be the better choice in this range.

In practice, a given scheme often encompasses a number of sections of the network involving several routes and so the appropriate growth rate (circuits/annum) is not immediately apparent. If the total route length is less than 10 km, audio plant is selected. If the scheme can be made to lie in a zone relating to p.c.m. or f.d.m. systems by ignoring one or more of the shorter routes, this is adopted. Provision of p.c.m. or f.d.m. systems on these longer routes enables the existing audio plant to be used for growth on the shorter routes.

The positions of the zone boundaries in Fig. 6 are influenced by such factors as the maximum route length of audio systems (Table 1), signalling system limits and experience gained from economic studies previously undertaken. The individual circumstances of each case are so varied that a transitional area must exist between the zones in which one type of plant will always be more economic than another. The possibility zones are used to cover these marginal cases.

CABLE-ROUTE CONSTRUCTION

When audio cable is to be provided, the planner is able to chose from a number of alternative types of cable-route construction i.e. cable in duct, moleploughing the cable and aerial cable. The particular type of cable-route construction to be adopted for any given section of a route is determined by service and economic considerations and with regard to any peculiar physical or geographical local conditions.

Local knowledge may indicate that cable in duct is the only practicable form of construction. An example of this situation is when the route passes through urban areas. However, where any doubt exists, the type of cable-route construction to be adopted is determined by the selection process shown in Fig. 7. If duct is to be provided, significant savings can be made if it is practicable to moleplough the duct directly in the ground. Moleplough cable would normally be considered impracticable if it would prove to be an encumbrance to further plant provision on the route within 20 years of installation.

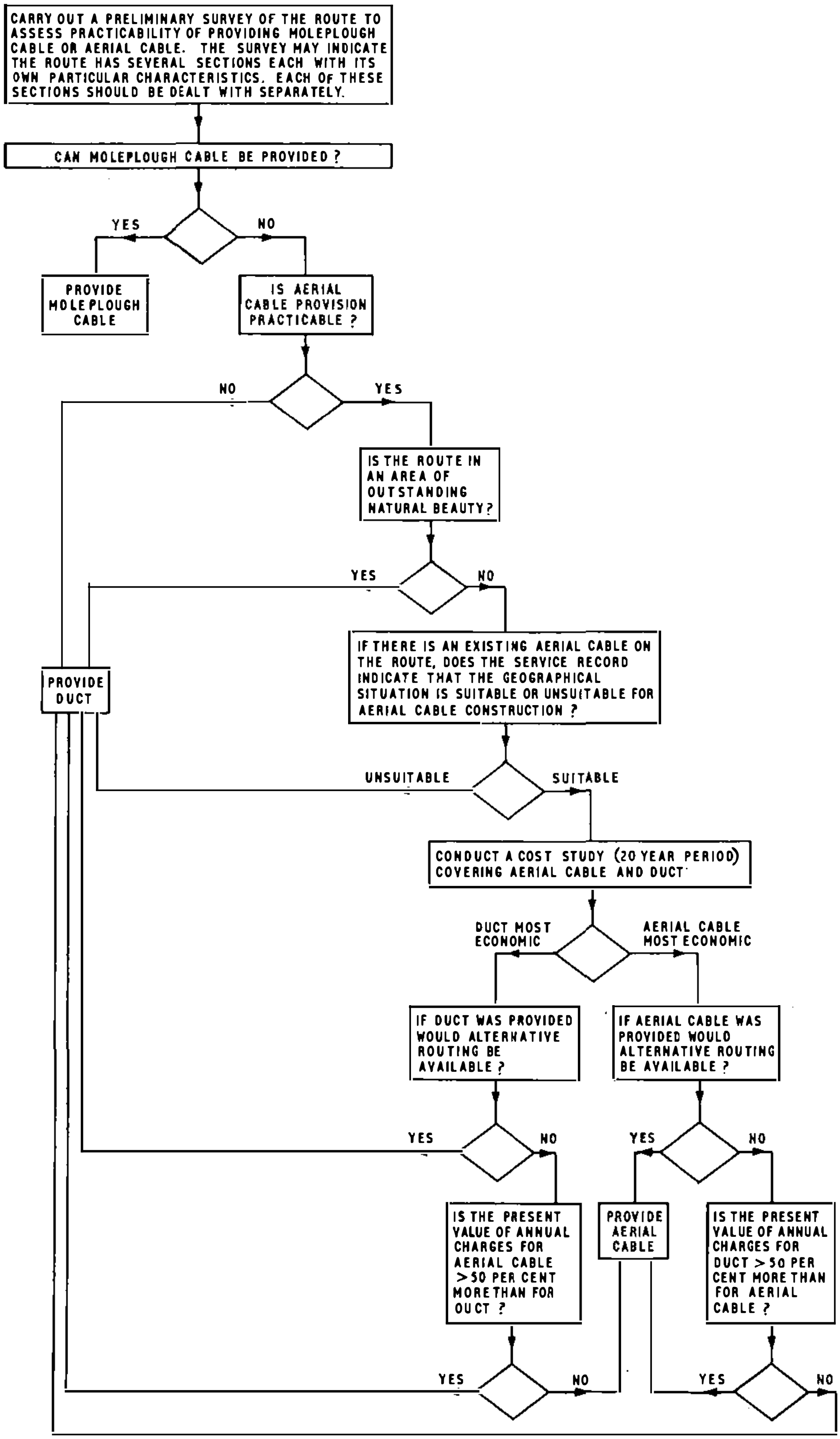


FIG. 7—Cable-route construction selection

Subaqueous cables can be used to avoid lengthy routing by land, but a special investigation has to be carried out bearing in mind service requirements,

CONCLUSIONS

The size of the junction network is growing rapidly (approximately 10 per cent per annum) at a time when the range of transmission systems is also expanding. When additional line plant is provided, it is, therefore, vitally important to give careful consideration to the type of plant to be adopted bearing in mind current and future developments. P.C.M. systems are steadily becoming more economic and their sphere of application is increasing. If circuits using p.c.m. systems could be switched at a tandem exchange without the need for decoding and encoding, further economic advantage would be gained and these systems would then prove valuable for the high proportion of junction network circuits less than 10 km in route length (Fig. 2). Experimental p.c.m. tandem exchanges are at present being evaluated.

The annual review of junction network requirements is rapidly becoming more involved as the network and range of plant grow. The S.W.T.R. is adopting a systematic approach which could be easily transferred to a computer. A computer network analysis system is being developed and shows promise of providing other useful information such as signalling details for exchange design and amplifier requirement forecasts. This could prove to be a valuable aid to the junction network planner in undertaking a task which becomes more complex every year.

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The Leighton Buzzard Electronic Exchange

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U.D.C. 621.395.345.001.6

The Leighton Buzzard Exchange is unique in many respects. Originally it housed the first and only working TXE 1 Exchange. Recently, however, the capacity of the exchange has been increased by the addition of two TXE 2 units which interwork with each other and the TXE 1 exchange, via a TXE 6 unit. This article briefly describes some of the unusual commissioning and design problems encountered and their solutions.

INTRODUCTION

The electronic exchange provided at Leighton Buzzard, which was described in a former article,[1] has recently been extended and now comprises three different types of electronic switching systems; a TXE 1 exchange (the initial installation), two TXE 2 units[2] and a TXE 6[3] incoming selector unit which provides junction access to the three multiple units.

Both the TXE 2 system and the TXE 6 system use reed relays in the switching path but the original systems were designed to replace different parts of the existing telephone network. The TXE 2 system has been used as a complete replacement for small Strowger exchanges (e.g. unit automatic exchanges) and the TXE 6 was developed to be used as an extension or partial replacement of the larger Strowger exchanges.

The TXE 1 exchange was provided initially with a multiple capacity for 3,000 subscribers and a switching network of four sections. The original concept was to provide for growth to 6,000 multiple capacity by the addition of two further subscriber units, each with a multiple capacity of 1,500, and to extend the existing junction units. An increase in calling rate could have been allowed for by the addition of a further section. For several reasons, this plan was abandoned, and equipment was not ordered for the extension.

Since the community of interest lies outside the town of Leighton Buzzard, some 80 per cent of the total traffic switched by the TXE 1 exchange is junction traffic. The incoming traffic has grown at a faster rate than the total traffic. This, coupled to the fact that the incoming switching-unit is the most difficult to extend, has meant that this part of the TXE 1 exchange has restricted the growth of the system.

Owing to the growth rate at Leighton Buzzard, which has become a commuter area for London, it was necessary to plan an extension of 2,700 multiple numbers. This added multiple allowed for future growth plus part of an adjacent exchange area, together with all the 800 subscribers on the TXE 1 exchange level 4 which would have to be moved to the new unit. This move was required to create spare switching-capacity in the TXE 1 exchange, and so allow the provision of trunks from other units which would have to be connected as incoming junctions on the TXE 1 exchange. (This is shown in the block diagram of Fig. 1.)

TXE 6 INCOMING SELECTOR UNIT

In order that the new and extension equipment should form one exchange, single junction groups were needed from adjacent exchanges. This required some form of switching-stage equivalent to a group selector. At this time, the TXE 6 reed group-selector was being developed and appeared to meet all the requirements.

The TXE 6 unit is a common-control system and was designed as a means of extending Strowger equipment with electronic equipment. It consists, basically, of two parts; a unit for receiving digits at 10 pulses per second (p.p.s.),

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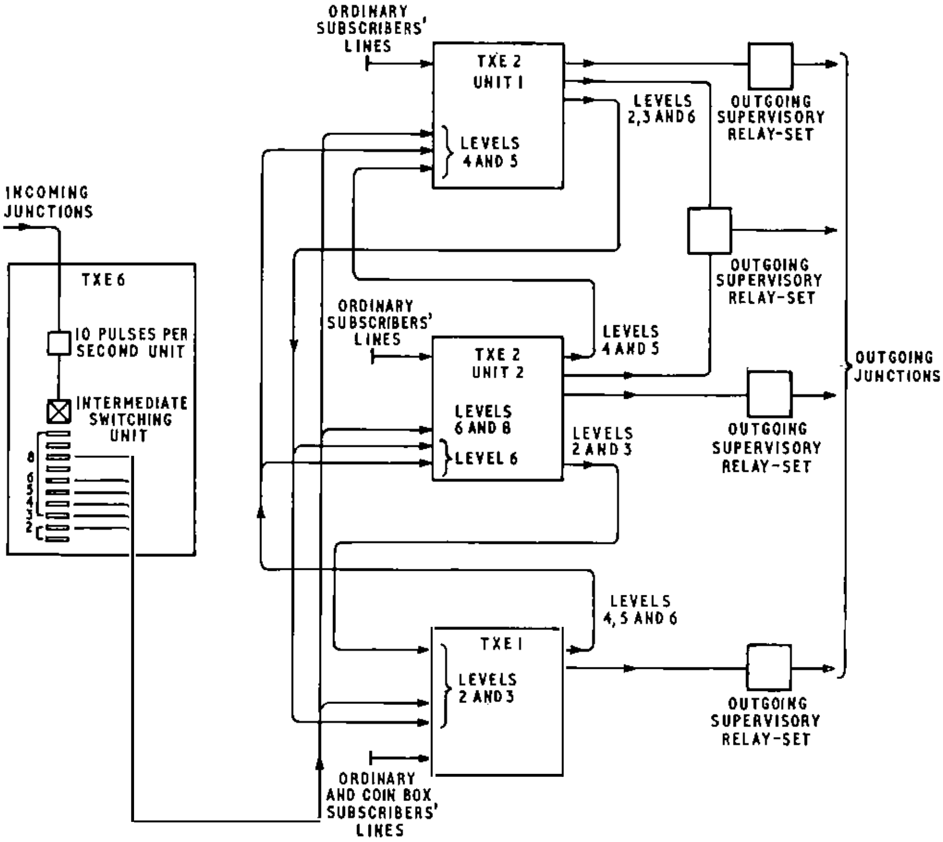

FIG. 1—A simplified block diagram of the Leighton Buzzard Electronic Exchange

followed by a two-stage cross-point-switch. The 10 p.p.s. unit is the interface, converting information from dialled pulses, in Strowger form, to fast parallel signal conditions for the reed group-selector registers (see simplified trunking diagram Fig. 2). The 10 p.p.s. unit is equipped with four controls and on each there are 96 access-circuits making a total input of 384 junctions. The intermediate switching-unit also has four controls each of which is divided into two parts. Each part controls a switching unit of 48 inlets and 200 outlets arranged over 10 levels. This gives a total of 1,600 outlets over the ten levels or 160 trunks per level. The outlets are graded over the four controls. A feature of the TXE 6 unit is that two equipment levels can be combined to give an availability of 40 trunks from any one level. This facility has been used at Leighton Buzzard.

NUMBERING SCHEME

To enable the subscribers on level 4 to be transferred from the TXE 1 exchange to the first TXE 2 unit, without a number change, part of this latter unit was planned to have a four-digit numbering scheme. To allow for the future growth of the exchange, the remainder of the extension was planned using a five-digit numbering scheme. The final numbering scheme is shown in Table 1.

The second TXE 2 unit also acts as a tandem switching-unit for local-dialled junction calls within the charge group.

All incoming calls are routed via the TXE 6 unit. As the exchange has a mixed four- and five-digit numbering scheme, and to make allowances for the fact that the first digit is used in switching the TXE 6 unit, the thousands digit of four-figure numbers has to be re-inserted on calls to both the TXE 1 exchange and the first TXE 2 unit. This allows a uniform number-length to be received by the respective registers on all types of call. This is achieved on the TXE 2 unit by using the digit-insertion facility of the type-2 register, and by a circuit modification on the TXE 1 exchange incoming registers and translator.

TABLE 1

System	Number range	Multiple size
TXE 1 exchange	2,000– 3,999	2,000
TXE 2 Unit 1	4,000– 4,999 59,000–59,399	1,400
TXE 2 Unit 2	66,000–66,999 67,000–67,299	1,300

DOUBLE-UNIT FEATURES

On the TXE 2 units, combined outgoing-junctions have been used to make more efficient use of the junction groups, by using some features of the present TXE 2 double-unit system. These are the dual-access supervisory relay-sets and the C-switch selector adaptor equipment. The C-switch selector adaptor circuit allows junctions to have either exclusive-access or dual-access from each unit. However, the TXE 1 exchange still maintains its own discrete outgoing routes.

Special combining circuits had to be designed for centralized service observation, trunk offering, etc., in order that these facilities could cover the whole exchange without having discrete junctions for each unit. Also, the incoming supervisories of the TXE 2 units were modified to present a backward-busying condition to the TXE 6 unit. A special conversion-circuit was introduced into the TXE 1 exchange to generate similar conditions.

COMMISSIONING

Each unit was commissioned as an individual exchange with allowance being made for combined junction routes. The protracted installation period of 30 months was mainly

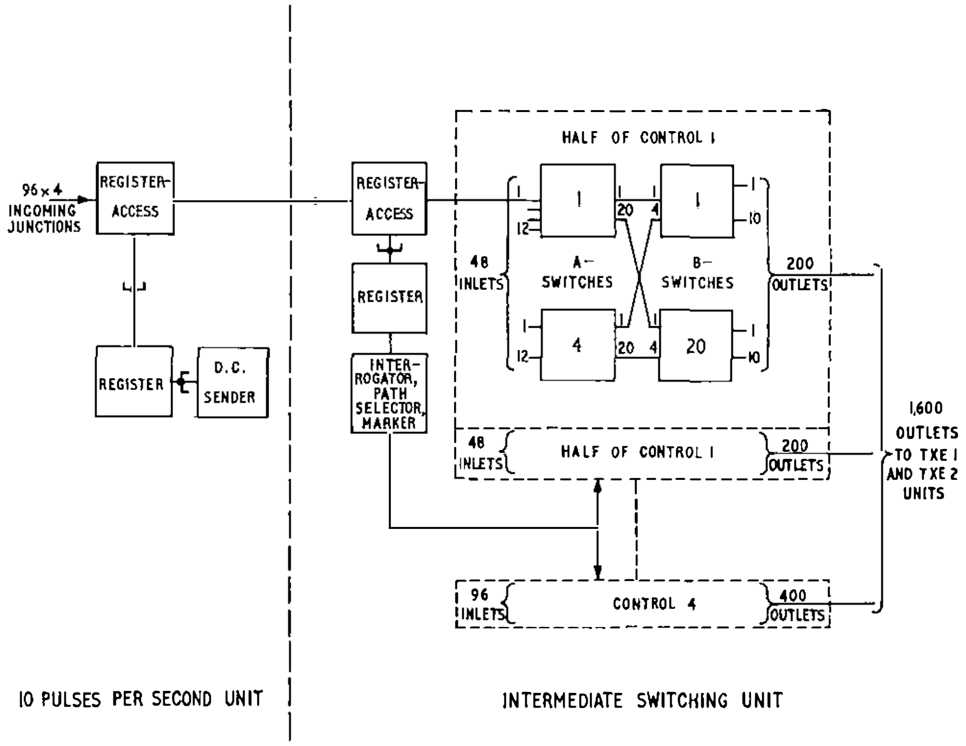

FIG. 2—Simplified trunking diagram of the TXE 6 unit

caused by the problems presented by the integration of three different electronic systems. Although each unit was tested and proved in isolation, it was not until the overall system was tested that incompatabilities between units revealed themselves. For example, the TXE 1 exchange junction relay-sets performed satisfactorily over junction routes to distant Strowger exchanges but not over trunks to the TXE 2 units. Increased sensitivity of the TXE 2 system to transient line conditions meant that false pulses were received and registered as digits, thereby causing failures on calls routed over TXE 1 exchange to TXE 2 unit trunks. This necessitated modifications to the TXE 1 exchange.

Further difficulties arose on the TXE 6 unit to TXE 2 unit trunks. Normally, when a TXE 2 incoming supervisory relay-set is seized by a junction from a distant exchange, a capacitor is discharged through pulse transformers in the calling-number generator field (CNG), which indicates to the common equipment that a junction is calling. This capacitor is recharged at the end of the call, on release of the incoming supervisory relay-set. At Leighton Buzzard, the TXE 2 incoming supervisory relay-sets are connected to the TXE 6 unit outlets. Compared to those of the usual outgoing junction relay-sets, this later unit has a very fast clear-down time which is shorter than the recharge time of the CNG capacitor in the TXE 2 unit. This resulted in the follow-on call being abortive. The problem was overcome by arranging to recharge the CNG capacitor during the call holding-time of the previous call and not during the clear-down time.

To ensure that the individual units would perform satisfactorily in the overall tests, a program of calls was sent through each unit with the British Post Office call sender[4] using standard acceptance figures. On analysis of the results from the TXE 2 unit 1, it was found that outgoing junction calls were concentrated on supervisory relay-sets which were connected to the first C-switch, and very little traffic was offered to the tenth C-switch. Investigation proved this to be attributable to shortcomings in the design on the C-switch selector adaptor circuit, and this, coupled with the fact that all outgoing junctions had been given dual-access from each unit, restricted the normal cyclic selection of outgoing supervisories.

The problem was overcome by connecting some outgoing supervisory relay-sets exclusively to each unit. This involved re-jumpering the trunk connecting frame but the possibility of encountering service difficulties under fault conditions was greatly reduced, as, in this mode of operation, the C-switch selector adaptor circuit allows the cyclic selection of individually connected relay-sets prior to the choosing of dual-access supervisory relay-sets.

The whole complex was finally tested with calls being passed from all inputs to all outputs using the normal 20,000 calls, with 54 failures or less as an acceptance figure. All failures had to be carefully analysed to eliminate those attributable to the TXE 1 exchange. Much of the final call-through had to be performed in low traffic periods to avoid overloading the working exchange. Following a complex three-hour change-over period during the night of 18 August 1971, the extension was brought into service and has been working normally ever since.

THE FUTURE

The immediate plan for this exchange is to extend it by means of a further TXE 2 unit of 2,500 multiple capacity. This will be trunked from level 7 of the TXE 6 unit and will mean that all available levels on this unit will have been used. As for the long term, the current proposal is for a complete replacement by a TXE 4[5] exchange system.

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An Improved Design for a 2-wire Hybrid Repeater

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The design of an improved 2-wire hybrid-type repeater and of an associated line-terminating network is discussed in relation to the transmission and signalling requirements of a 2-wire amplified audio circuit. The design described allows circuits to be provided on a prescriptive basis. Measurement of complex impedance/frequency characteristics, necessary with earlier designs, is replaced by a simple technique using standard test equipment. Circuit provision and fault localization are greatly simplified by this technique.

INTRODUCTION

Amplified audio circuits in the junction network can be provided on a 2-wire basis more economically than on a 4-wire basis. However, circuit-stability and good attenuation/frequency characteristics are more difficult to achieve on 2-wire circuits. Further complications arise from the need to ensure that the amplifying and associated equipment does not degrade the circuit-signalling performance.

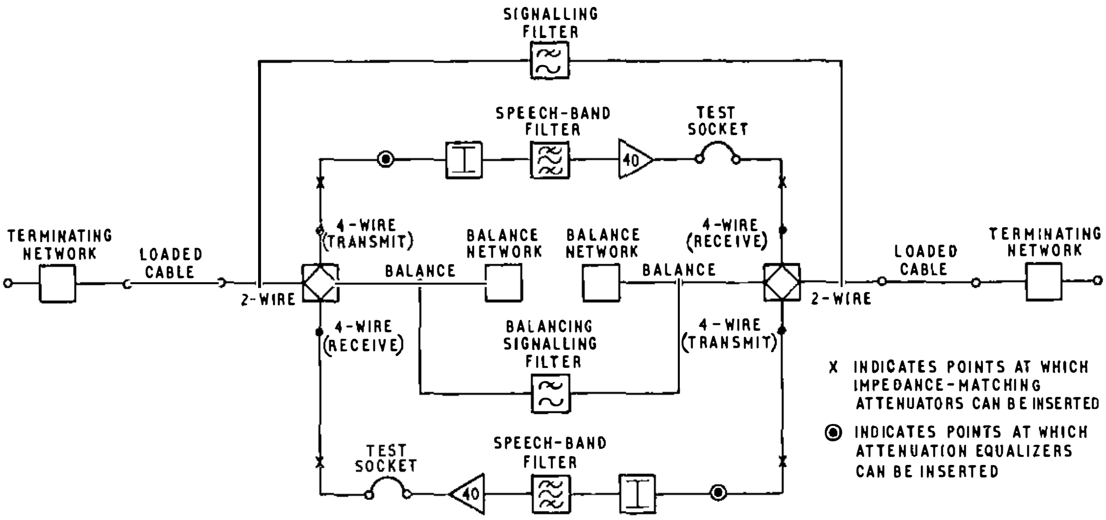

FIG. 1—2-wire audio circuit with hybrid-type repeater

This article sets out some of the design considerations and techniques involved in the current British Post Office (B.P.O.) design of a hybrid-type 2-wire repeater and associated line-terminating networks.

CIRCUIT DESCRIPTION

A diagram of a 2-wire amplified circuit with a hybrid-type repeater is shown in Fig. 1. The circuit is terminated at each end with a terminating network which presents an impedance equal to the cable's characteristic impedance, and which allows the passage of d.c. signalling currents, including dialling pulses.

The salient features of the hybrid repeater are given below.

Hybrids

The hybrids are of the transformer type, having nominal 2-wire and balance impedances of 1,200 ohms and 4-wire impedances of 600 ohms. The method of winding the transformers is such that the hybrids have a high degree of self-balance. The addition of capacitors gives the hybrids high-pass filter characteristics with cut-off frequencies of approximately 200 Hz.

Balance Networks

When an external cable is connected to the 2-wire terminals a complex balance network is required so that an adequate 4-wire to 4-wire hybrid loss is obtained in the speech band from 300 Hz to 3,000 Hz. Provision of an adequate balance at out-of-band frequencies is not practicable.

When the 2-wire terminals on one side of a repeater are connected directly to exchange equipment, a 600-ohm compromise balance is used. The impedances presented by the 4-wire terminals of the hybrid are then 300 ohms, and impedance-matching attenuators of approximately 7·5 dB loss are fitted to restore the 600-ohm impedances required at these points.

Speech-band Filters

At out-of-band frequencies, particularly near the cut-off frequency of the cable, it is necessary to provide sufficient

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loss in the loop path so that the circuit is unconditionally stable. This is accomplished by incorporating filters which also prevent signalling frequencies from reaching the amplifiers. Compromise attenuation equalization for 0·63 mm and 0·9 mm loaded cables is provided by shaping the speech-band filter response in its pass band.

Signalling Filter

This is a low-pass filter with a cut-off frequency of approximately 200 Hz. In the current design it is connected in parallel with the 2-wire terminals of the hybrid to provide a signalling path through the repeater. This filtering arrangement has distinct advantages over that of earlier designs.

Balancing Signalling Filter

This filter is identical to the signalling filter. It is connected in parallel with the balance terminals of the hybrid to preserve the 4-wire to 4-wire hybrid loss.

Amplifiers

It is essential to provide adequate masking between the speech-band filter and the hybrid so that the filter will give its design loss irrespective of the line and balance impedances. It is also necessary to terminate the hybrid correctly with 600 ohms for signals received at the 2-wire terminals. Attenuator values for 3 dB loss circuits of maximum length are too small to perform these functions unless a high-gain (40 dB) amplifier is used.

Test Sockets

Measurement of the modulus and angle of cable and balance impedances is tedious and does not give a direct evaluation of the 4-wire to 4-wire hybrid loss. The test sockets allow the latter to be measured with normal transmission test-equipment to give a precise indication of the balance and cable conditions. Both the total or half-loop losses can be measured.

AMPLIFIED AUDIO CIRCUIT DESIGN

Amplified audio circuits are provided over 0·63 mm and 0·9 mm cable loaded with 88 mH coils at 1·8 km spacing, and of lengths up to the crosstalk limit of the cable on either or both sides of the repeater. The optimum insertion loss of such circuits is 3 dB (between 600-ohm impedances), with a margin of stability of at least 1 dB. The insertion loss/frequency characteristic of the circuit must be within $-0{\cdot}5$ dB to $+3{\cdot}0$ dB of the loss at 800 Hz.

The Ideal Circuit

The ideal circuit, in which all impedances are perfectly matched at all frequencies and no energy reflexions occur in any part of the circuit, will be considered first. A practical design will then be considered which can be achieved by allowing tolerable departures from these ideal conditions.

If the terminating networks are closed with 600-ohm resistances at the ends of the circuit (Fig. 1), then the cables are terminated by their characteristic impedances at all frequencies, and the same impedances are presented at the 2-wire terminals of the hybrids. Ideal symmetrical hybrids can be terminated at their 4-wire terminals with appropriate equal complex impedances, to present loads equal to the characteristic impedance of the cable at their 2-wire terminals. Then, speech energy arriving at the 2-wire terminals of one hybrid divides equally between the 4-wire transmit and 4-wire receive paths, and is absorbed without reflexion. Half the energy is absorbed in the output impedance of one amplifier, and is lost. The other half controls the release of speech energy from the second amplifier. No energy passes to the balance. The output of the amplifier is presented to the 4-wire receive terminals of the other hybrid where it divides equally between the balance and the 2-wire path. To achieve this, the impedance of each balance is made equal to the characteristic impedance of the cable connected to the 2-wire terminals of the hybrid. Half the energy is then absorbed in the balance, and half is transmitted into the cable. No energy passes across the hybrid to the amplifier input. Energy arriving at the end of this ideal circuit is totally absorbed in the terminating impedance. The two cables may be of different type, each requiring only an appropriate balance impedance. The total circuit losses consist of the cable attenuations and 3 dB loss in each hybrid.

Effect of Departures from the Ideal Conditions

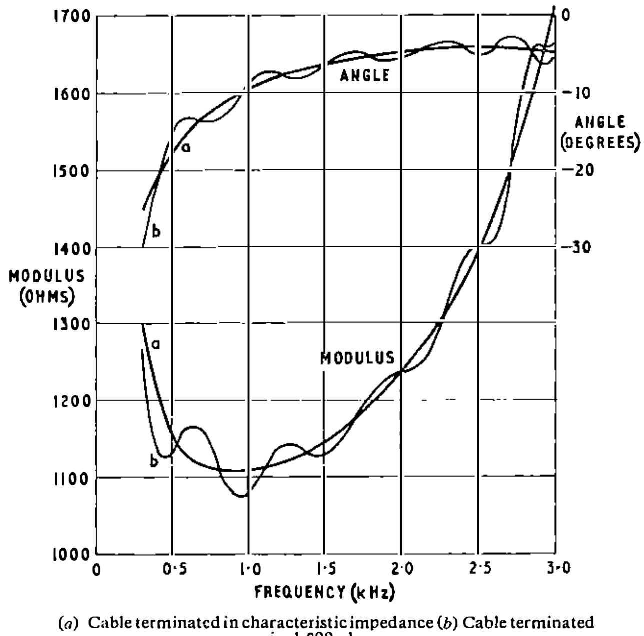
Incorrect end-terminations will cause reflexion of some of the energy arriving at the far end of the circuit. This reflected energy will be amplified in the return direxion after having suffered phase and amplitude changes whilst passing along the cable. A further reflexion will occur at the sending-end of the circuit, so that energy will rejoin the original signal at the transmit amplifier input.

A similar situation occurs if the balance does not match the cable impedance. Energy is reflected by the balance network back into the hybrid where it divides between the two 4-wire paths. The forward signal is thus the sum of a number of signals of the same frequency but differing in amplitude and phase. The phase relationship between the reflected signal and the direct signal varies with frequency and length of cable, so that the reflected signal is alternately in and out of phase with the direct signal, over the frequency band. The resultant signal exhibits an amplitude ripple which can only be controlled by the use of correct termination and balance impedances.

Resistive, instead of complex-impedance terminations on the 4-wire terminals of the hybrids result in mismatch losses at the 2-wire terminals, but provided that a reasonable impedance match is maintained, and the far ends of the cables are correctly terminated, this effect is negligible. Loaded cable has a sensibly constant impedance modulus over the speech frequency band and a reasonable impedance match can be obtained.

4-Wire to 4-Wire Hybrid loss

This can be calculated, for any set of impedances, as the sum of two losses, the loss with the balance connected and the 2-wire terminals disconnected (*trans-hybrid loss*), and the



(*a*) Cable terminated in characteristic impedance (*b*) Cable terminated in 1,200 ohms

FIG. 2—Impedance/frequency characteristics of typical loaded cable with half-section terminations

return loss of the balance impedance against the impedance presented at the 2-wire terminals.

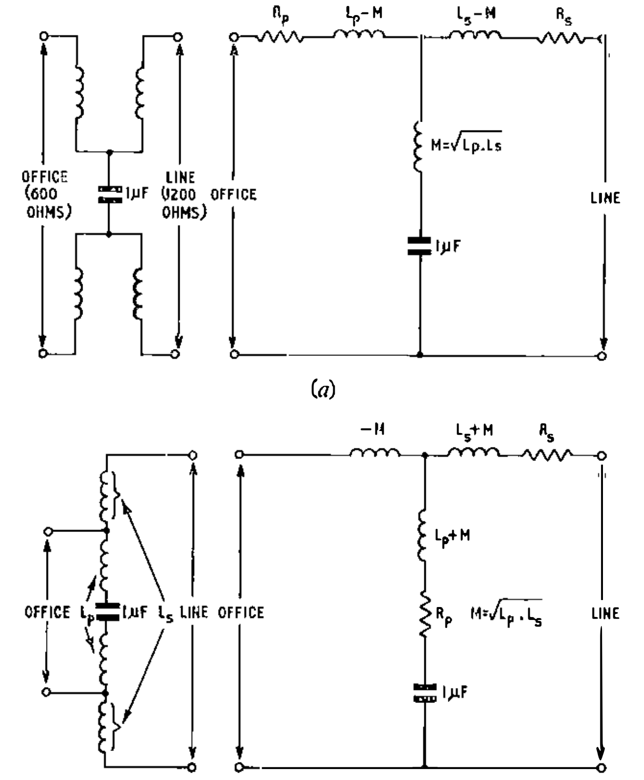
The *trans-hybrid loss* is approximately 7 dB when transformer losses are taken into account, but there is a small variation with frequency when the balance impedance is complex instead of being purely resistive.

The return loss between two impedances is a measure both of their departure from equality and of the relative level of energy reflected at the junction of two impedances. It can be evaluated from the formula:

$$\text{return loss} = 20 \log_{10} \left| \frac{Z_1 + Z_2}{Z_1 - Z_2} \right| \text{dB},$$

where Z_1 and Z_2 are complex impedances. The return loss approaches infinity as the two impedances become equal, and falls rapidly as they depart from equality.

A minimum value of 4-wire to 4-wire hybrid loss is required so that control is maintained over the amplitude of the end-to-end frequency response ripple whieh depends on the degree of match of the impedances presented at the 2-wire and balance terminals.



(*a*) Conventional d.c. connected transformer and equivalent-circuit. $L_p \simeq 0{\cdot}75$ H, $L_s \simeq 1{\cdot}5$ H, $R_p \simeq 16$ ohms, $R_s \simeq 32$ ohms, $M \simeq 1{\cdot}06$ H.
(*b*) D.C. connected auto transformer and equivalent circuit. $L_p \simeq 1{\cdot}5$ H, $L_s \simeq 0{\cdot}375$ H, $R_p \simeq 28$ ohms, $R_s \simeq 14$ ohms, $M \simeq 0{\cdot}75$ H.

FIG. 3—D.C. connected line-matching transformers

The impedance presented at the 2-wire terminals is the characteristic impedance of the cable which will ideally have a modulus and angle which vary smoothly with frequency. This is illustrated in Fig. 2 which also shows the ripples which occur in the impedance/frequency characteristics due to reflexions resulting from incorrect termination. Similar ripples occur when loading coils are omitted from a cable or when cable junctions are not correctly built-out. The characteristics deviate by approximately equal amounts above and below the characteristics of the correctly-terminated cables. Deviations in both directions produce the same reduction in return loss against the characteristic impedance. Since the number of ripples in a given frequency band varies with circuit length, it is not practicable to construct a balancing network which will match the ripples. Therefore, the optimum balance is one which has an impedance equal to the characteristic impedance of the cable. The ripple amplitude must then be controlled by the terminating-network impedance.

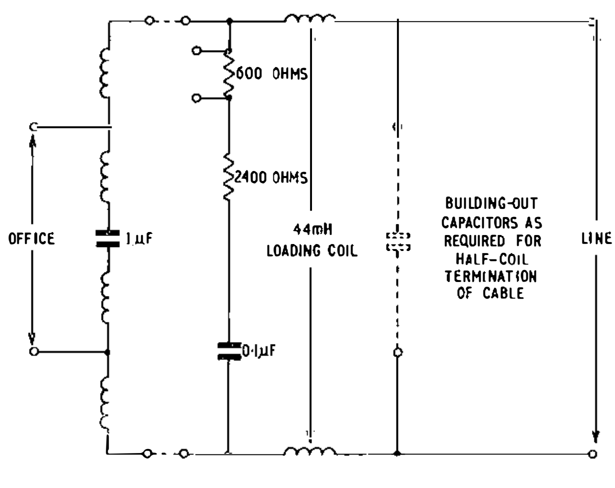
Terminating Network

In earlier designs, the line termination consisted of an impedance-matching transformer connected for d.c. signalling. This is shown in Fig. 3(*a*) together with its equivalent circuit which is drawn in an unbalanced configuration for simplicity. From the equivalent circuit it can be seen that the series inductance is small and gives negligible degradation of dialling pulses. The shunt path is a series resonant circuit with a resonant frequency of, typically, 155 Hz. This also is not significant as regards distortion of dialling pulses. At speech frequencies the line impedance is nominally matched to 600 ohms. Calculation of the impedance/frequency characteristics looking into the line terminals when the office terminals are closed with 600 ohms shows that the series resonant circuit across the transmission path causes the angle of the impedance to become highly positive at low speech-band frequencies. At the higher speech-band frequencies the modulus cannot rise to meet that of the cable.

In arriving at a solution to the problem of providing an adequate impedance termination for the cable it must be borne in mind that dialling pulses and d.c. signals must not be affected. Transmission losses must also be kept to a minimum, since for each extra 1 dB of loss in the 2-wire path, there must be 2 dB of extra gain in the repeater loop path, and stability is more difficult to achieve. In the solution adopted the impedance terminating the line gives a return loss of at least 20 dB against the line impedance in the 300 to 3,000 Hz band.

Fig. 3(*b*) shows the d.c. connected auto-transformer used in the new terminating network, and the equivalent circuit. The advantages of this type of transformer are that the series resonant circuit is damped by the primary winding resistance, the loop resistance is reduced to a small value in spite of the increased inductance adopted for the windings and transformer losses are minimized in both the signalling and speech bands.

Fig. 4 shows the complete circuit of the line terminating network including the half-value loading coil which, together with the appropriate building-out capacitors, forms a half-coil termination for the cable. The modulus of the impedance of a half-coil terminated line decreases with increase of frequency and can be matched to a sufficient degree by shunting the transformer with a resistor-capacitor network. The office-side

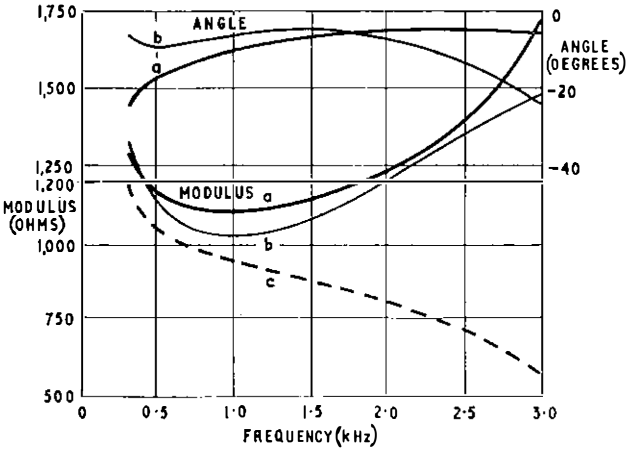


NOTE:-THE 600-OHM RESISTOR IS SHORT-CIRCUITED WHEN TERMINATING 0·9mm CABLES

FIG. 4—Line terminating network

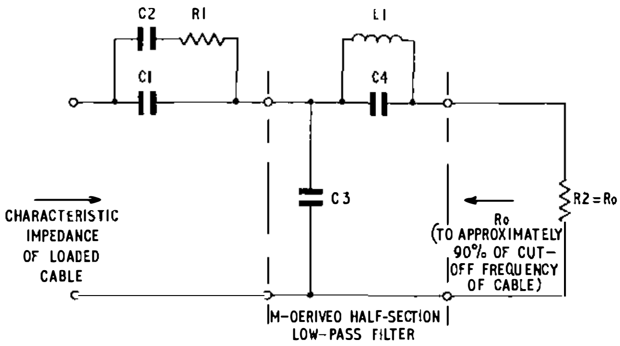
inductance of the transformer is a minimum of 1·5 henry, so that the resonant frequency of the d.c. connected transformer is reduced to approximately 100 Hz. As a result, the impedance angle remains negative to a lower frequency, and the required impedance match is obtained.

The impedance/frequency characteristics are shown in Fig. 5.



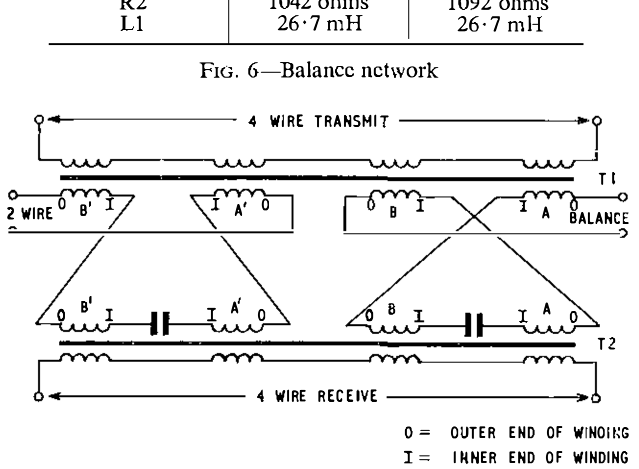
(*a*) Characteristic impedance of half-section termination (*b*) Line side of terminating network including building-out components with office side terminated in 600 ohms (*c*) Modulus of the cable impedance built-out to a half-coil termination.

FIG. 5—Impedance/frequency characteristics of typical loaded cable and terminating network



Component	Component Values for Cables Loaded with 88 mH at 1·8 km	
	0·63 mm Cable	0·9 mm Cable
C1	0·79 μF	1·47 μF
C2	0·47 μF	0·22 μF
C3	0·0257 μF	0·0234 μF
C4	0·0424 μF	0·038 μF
R1	1800 ohms	1800 ohms
R2	1042 ohms	1092 ohms
L1	26·7 mH	26·7 mH

FIG. 6—Balance network



Note: Coils marked AA′, BB′ on each transformer are wound as pairs. A and B coils are wound on opposite sides of the bobbin.

FIG. 7—Construction of a balanced hybrid circuit

Balance Network

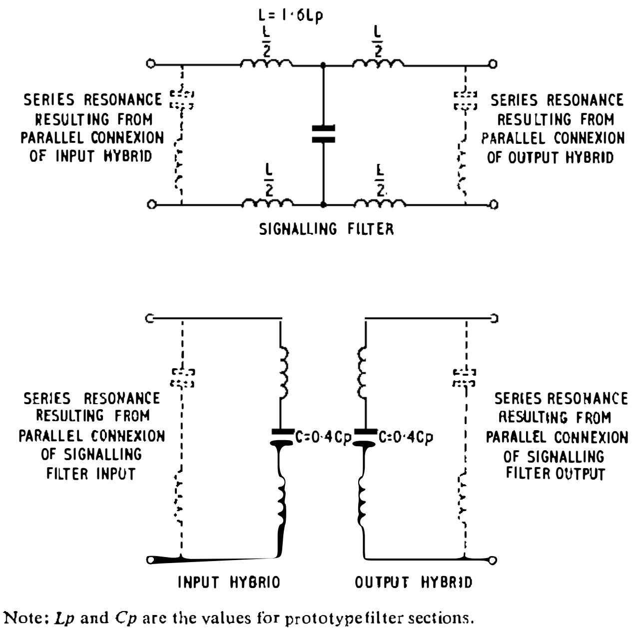
A convenient configuration of a balance network to match loaded cables is an *m*-derived half-section low-pass filter ($m = 0{\cdot}6$), with one pair of terminals terminated with the appropriate resistance and a capacitive reactance in series with the other terminals to present an impedance equal to the characteristic impedance of a loaded cable up to approximately 90 per cent of the cut-off frequency. The network is illustrated in Fig. 6. This gives component values suitable for 0·63 mm and 0·9 mm cables loaded with 88 mH at 1·8 km spacing. Return losses of at least 40 dB against the characteristic impedance of a cable having a half-section termination are obtained with these networks.

The balance is normally set to the values shown in Fig. 6, but in practice, C3 and C4 may be varied to obtain the best results for a particular cable.

The effect of changes in the balance components is most easily observed by measuring the half or total 4-wire loop losses.

Hybrid Circuit and Signalling Filter

In the construction of the transformers used in the hybrid, each winding is made up of four coils which are wound in pairs on opposite sides of the bobbin, the bobbin being reversed on the mandrel before each new pair of coils is wound. The coils are then connected so that each half-winding, consisting of one coil from each pair, is balanced about its centre-point, and the two half-windings are identical. Fig. 7 shows how two transformers are used to form a hybrid circuit; the balanced windings of transformer T2 are connected to the balanced inner-ends of the windings of transformer T1. The 2-wire and balance windings of a hybrid connected in this way have identical impedances and are equally balanced about earth. All the stray reactances are

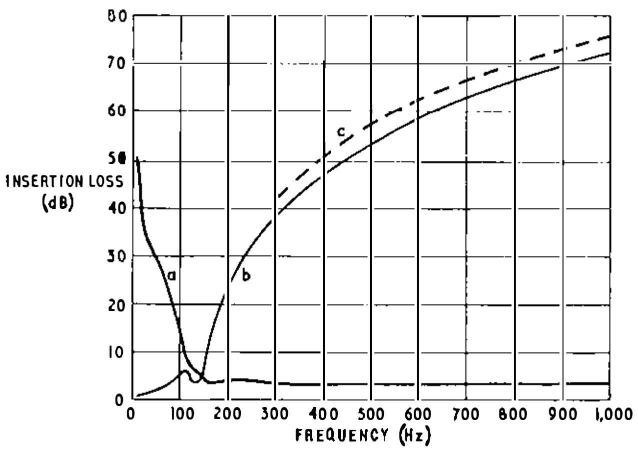


Note: *Lp* and *Cp* are the values for prototype filter sections.

FIG. 8—High and low-pass filter pair

balanced by virtue of the physical construction of the transformer. The 4-wire to 4-wire loss of this hybrid, with equal impedances connected to the 2-wire and balance terminals, is extremely high (90 dB), and may be neglected when calculating transmission losses.

Capacitors are connected at the balanced centre-points of transformer T2 to convert the hybrid circuit into a simple prototype high-pass filter. In the new design, the signalling filter has been connected in parallel with the hybrid terminals so that improved filter responses can be obtained for both filters. Fig. 8 illustrates this. The filters must have approximately equal cut-off frequencies. Each prototype filter presents a series resonance across the terminals of the other filter of the pair. If the series reactance in each filter is increased in value by 0·6 of the value for a prototype filter, this is equivalent to adding an *m*-derived half-terminating section to each filter. This occurs on both sides of the signalling filter and to the 2-wire sides of both hybrids, and is repeated on the balance sides of the hybrids.



(*a*) 2-wire input to 4-wire transmit of input hybrid.
(*b*) 2-wire input to 2-wire output via signalling filter.
(*c*) 2-wire input to 4-wire transmit of output hybrid via signalling filter.

FIG. 9—Signalling-filter insertion losses

The losses from the 2-wire terminals on one side of the repeater via the hybrid and signalling filters are shown in Fig. 9. The source impedance is that of the cable with a terminating network closed in 600 ohms.

Band-pass Filter and Attenuation Equalizer

The band-pass filter consists of a conventional *m*-derived band-pass filter section ($m = 0 \cdot 5$) with frequencies of infinite attenuation at 200 Hz and 4,250 Hz, in tandem with a prototype high-pass filter section which has a cut-off frequency of 175 Hz. The design impedance for the filter is 600 ohms. The insertion loss/frequency response is given in Fig. 10. The attenuation equalizer illustrated in Fig. 11 is a

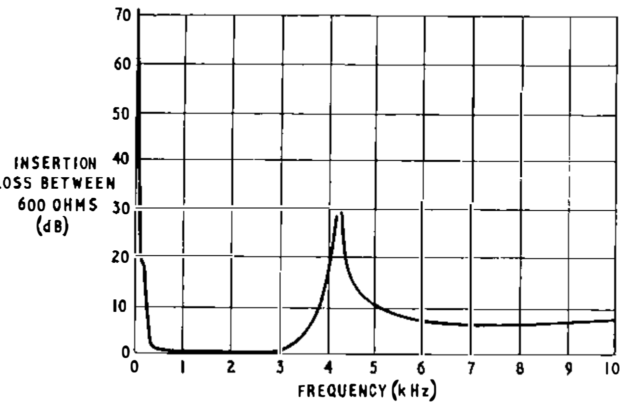


FIG. 10—Bandpass filter response

simplified bridged-T network which is inserted in both directions in the 4-wire path, when required. Resistors for three values of basic loss are provided. The equalizer is terminated under all conditions in 600 ohms by the circuit attenuator, so that the impedance presented at the input terminals is also 600 ohms and the impedance terminating the hybrid terminals is not affected by the equalizer. The loss of the equalizer is also independent of the source impedance.

Total Loop Loss

Measurement of the loss round the 4-wire path, with a circuit set up for the required overall loss, is a complete check of the balance, cable and line-terminating impedances. The loss round the 4-wire path is the sum of the losses across the hybrids, the attenuators and the band-pass filters, minus the gain of the two 40 dB amplifiers. The total loss must be of a high order so that loop signals, rejoining the main signal, do not cause significant ripple in the insertion loss/frequency characteristic. Voltage addition of two signals of the same frequency must be considered since amplifiers are voltage-controlled devices. Two signals, 35 dB apart in level, will produce a ripple amplitude of $\pm 0 \cdot 2$ dB. This figure is chosen as the design maximum.

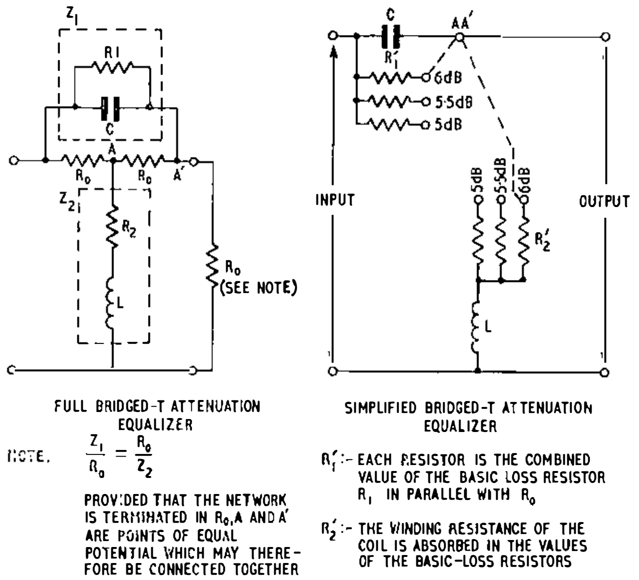


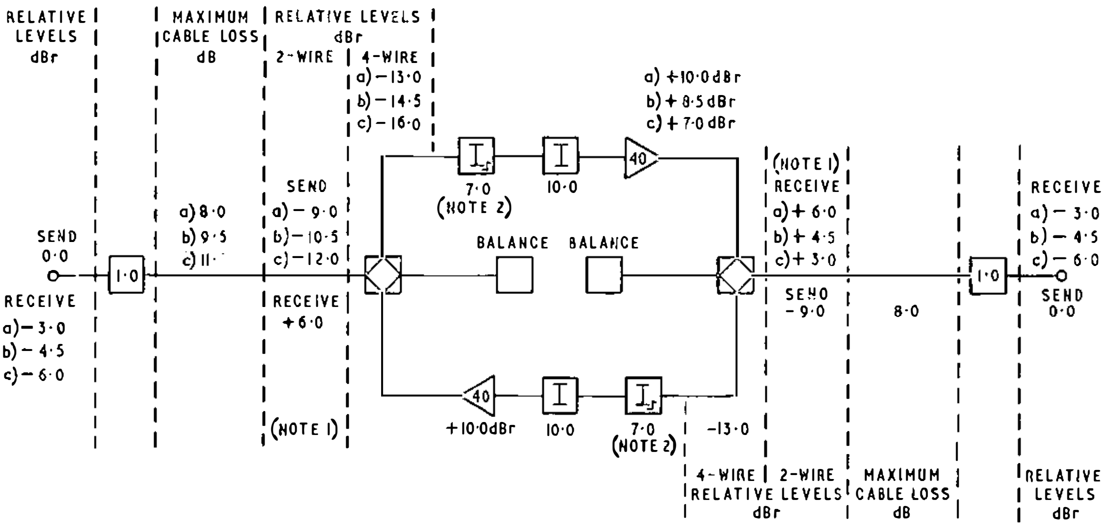
FIG. 11—Bridged-T attenuation equalizer

The attenuator values are governed by the cable losses and the overall circuit loss requirement. The maximum length of cable which can be connected to one side of a repeater depends on the crosstalk performance of the cable and on the overall circuit loss requirement in relation to a maximum amplifier output test level of +10 dBm. For example, it is not possible to provide a circuit of 3 dB overall loss when the cable loss on one side of the repeater is more than 8 dB, without exceeding the maximum output level.

Fig. 12 shows the maximum cable losses (*a*), (*b*), and (*c*) which can be connected to a repeater for three overall circuit loss values. The maximum level difference on the cable occurs at the 2-wire terminals of the hybrids where, for a 3 dB loss circuit, there is a level difference of 15 dB. The maximum cable loss is 8 dB and this is the limit for local-type cables in terms of crosstalk. For trunk-type cables, level differences up to 22 dB are permissible. For economic reasons, circuits greater than 32 km are unlikely to be provided by audio plant, and this length coincides with the length of a 3 dB loss circuit of maximum cable loss using 0·63 mm cable, with the repeater mid-connected. The total loop loss round the 4-wire path for such a circuit is now considered.

For balance impedances precisely equal to the characteristic impedance of the cable, the return loss of the cable impedance at the 2-wire terminals, against the characteristic impedance of the cable, is twice the transmission loss of the cable plus at least 20 dB for the return loss of the terminating network. To this is added approximately 7 dB for the *trans-hybrid loss* and 7 + 10 dB attenuator loss. This gives a total of 60 dB, which is reduced to 20 dB by one amplifier. (The in-band loss of the band-pass filter is absorbed in the attenuator loss). Identical conditions exist on the other side of the repeater so that the total loop loss is expected to be of the order of 40 dB.

These conditions should exist on a circuit of any length, since 1 dB change of line loss results in a 2 dB change of return loss and a 2 dB change in gain of the 4-wire loop path. The balance impedance, however, departs slightly from that of the characteristic impedance of the cable (40 dB return loss). Even with only this small error it is not possible to exchange gain in the 4-wire loop path, on a one-to-one basis, with return loss in the 2-wire path. When the return loss of the cable against the actual balance impedance is calculated, the minimum total loop-loss at any frequency is found to be only 35 dB for this maximum length 3 dB loss circuit. Advantage might be taken of the additional return loss provided by the higher loss circuits by allowing appropriately increased maximum cable losses on both sides of the repeater. For example, for a 6 dB loss circuit with 11 dB of cable loss on one side of the repeater, it might be possible to allow, say, 9·5 dB of cable loss on the other side, but the performance would need to be checked in practice as no guarantee can be given. Fig. 12, therefore, should be taken as representing the planning limits for transmission for 2-wire hybrid-type circuits, provided that the required margin of stability is obtained.



Note (1) The crosstalk limit for the cable must not be exceeded (15 dB level difference for local-type cables, 22 dB level difference for trunk-type cables).
(2) Minimum nominal attenuator setting for design objective of 35 dB minimum total loop loss.

FIG. 12—Maximum cable losses and associated transmission levels at 800 Hz for 2-wire hybrid-type circuits

SIGNALLING PERFORMANCE

The new design introduces significant changes in the signalling path. To check that these would not change the signalling performance, the behaviour of the circuit was simulated in a computer program. A signal consisting of trains of ten dialling pulses of normal make/break ratio in alternate periods of one second was considered. This signal has a fundamental frequency of 0·5 Hz. The changes in amplitude and the phase shifts for harmonics up to 200 Hz were calculated for transmission of the signal over the existing and new designs. The waveforms were then summated in the load. There was virtually no difference between the performance of the two designs.

The d.c. loop resistances of components in the signalling path are 17 ohms for the line terminating network and 218 ohms for the signalling filter. Taken in conjunction with the loop resistance of cable and loading coils, these values make it possible to signal over a line having a loss of 20 dB.

D.C. polarization of the coils in the signalling filter causes the inductance of these coils to decrease. It is necessary to take into account both the change in filter losses which occur when the inductance is reduced, and the difference in impedance of the signalling filter as compared with that of the balancing signalling filter which is not carrying d.c. A maximum change of inductance of 10 per cent is permissible. This does not occur until the d.c. current exceeds 25 mA, i.e. when cable losses are less than 7 dB.

CONCLUSION

A design for a hybrid-type 2-wire repeatered circuit has been described which operates with cable losses of between 7 and 20 dB. The performance limits for circuits of this design are predictable and setting-up procedures are largely prescriptive. A simple measurement of 4-wire loop losses serves to check the impedance/frequency characteristics of cables, cable terminations and balance networks, and it is expected that this will become an important line-up and maintenance aid.

Computer techniques have been used extensively both in design and in producing performance figures for manufacturing purposes.

Humans and Postal Engineering

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All machines designed for the postal business have men or women to operate or use them, either postal workers, counter clerks or the public. This article describes scientific studies being undertaken to improve the man/machine interface in postal engineering.

INTRODUCTION

No matter how complex or simple the mechanisms of engineering systems are, they must serve as inanimate extensions of man's limited physical capabilities. Proper matching at the man/machine interface is clearly implicit in good engineering design. It is generally recognised that the postal business is labour intensive, and although the mechanization program reduces much of the physical effort previously required in sorting offices, it seems improbable that automation can be complete in the forseeable future. The postal worker will remain a prime part of the system, and much of postal engineering design is orientated to serve his needs in making his work more easy and efficient.

Much of the ergonomic work carried out so far within the British Post Office (B.P.O.) Postal Headquarters has been concerned with engineering developments in parcel concentration and mechanized letter offices. These are nodes within the sorting and distribution system, where capital investment in machinery can improve productivity. It is because the cost effectiveness of these engineering systems is partly dependent upon good matching of man and machine that considerable effort is being directed towards these critical areas. Research activities into the man/machine interface in postal mechanization were outlined in earlier articles in this Journal[1].

ERGONOMICS

The term ergonomics was coined after the last war by a group of experimental psychologists and physiologists who had moved partly away from the traditional self-sufficient world of academic theory to apply their knowledge of man to real-life industrial and military problems. Its etymology (*ergo*, work; *nomos*, law) suggests restricted application of its component disciplines, but in practice, the full range of anatomy (structure), physiology (function) and pyschology (behaviour) are used. On the western side of the Atlantic the term *human factors* is used, but in Europe ergonomics is more usual.

There is an ill-defined area of interplay between disciplines and techniques from the life sciences and engineering, including cybernetics (communication within the animal and machine) and operational research (interdisciplinary problem solving). Problems in general are best tackled without the inhibitions and limitations of specific disciplines and techniques, especially when considering such complex fields as man/machine systems.

MAN THE UNCERTAIN MACHINE

To the physiologist, man is basically a system of powered levers. The heights, lengths and angles of his movements can be measured directly, and their study is called anthropometry. The dynamics of body movement involve the sequential occurrence of three events, namely, information reception, central processing, and motor action, all of which can be monitored.

Messages to and from the brain, and the electrical events associated with muscle contraction, consist of localized ionic disturbances propagated along nerve- or muscle-fibre surfaces. Such activities can be examined by monitoring electrically at the surface of the body by a technique known as electromyography. The observation of uptake (intake minus output) and excretion (especially that of oxygen uptake and urinary analysis), can yield information regarding the immediate past history of muscular and nervous stress.

Objective physiological measurement, although adequate in describing the mechanics in a limited way, is unable to explain the more complex automatic actions which account for behaviour as we know it. This lies essentially within the realms of psychology. Here, experimental results are necessarily statistical in nature. The luxury of a single variable is not for the psychologist, but statistical techniques have been developed, prompted largely by the uncertainties of response met in the multivariable systems of the life sciences, so that repeatable results may be obtained in carefully-controlled experiments. Both disciplines of psychology and physiology contribute to ergonomics.

ANTHROPOMETRY

Questions such as the position of controls, and work station layouts, clearly require a knowledge of the physical characteristics of the intended operator. Many studies have been completed, and the results published, giving the statistics of body dimensions of particular groups of people. Many of the most detailed are of American origin, and most concern military personnel, that is, fit young men.

Unfortunately, measurement techniques often differ between different laboratories and direct comparisons may be unreliable. Where reliable data does exist, it may not be applicable to other populations. Fig. 1 illustrates one potential source of error in height measurement, where it will be seen that in the late afternoon the height of the subject is apparently less than that of the morning. This is due to the progressive flattening of the intervertebral discs and increasing curvature of the spine which occurs during the day. The variation can be as much as 30 mm. For measurement purposes, this can be minimized by slight traction applied to the base of the skull as shown.

Nutritional, ethnic or even narrow regional differences may, by themselves, result in differences between otherwise apparently homogenous populations. As far as British postal ergonomics is concerned, a perennial question is just what are

† Planning and Mechanization Department, Postal Headquarters.

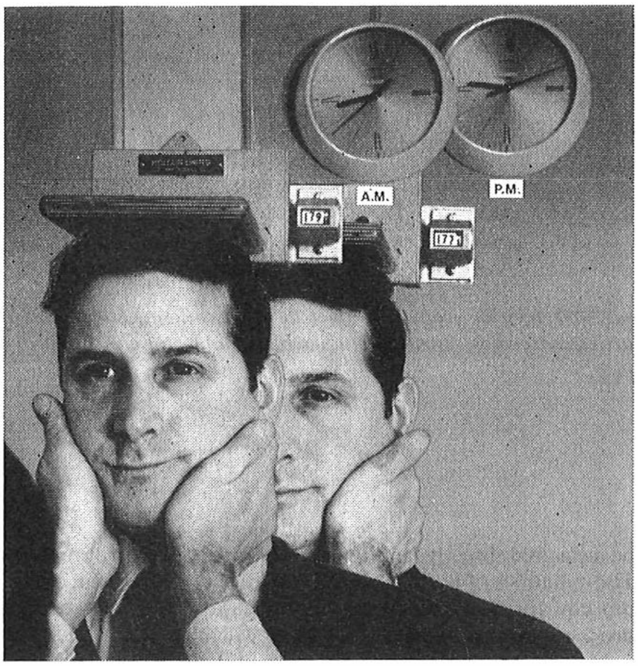


FIG. 1—A composite photograph showing the measurement of diurnal variation in stature

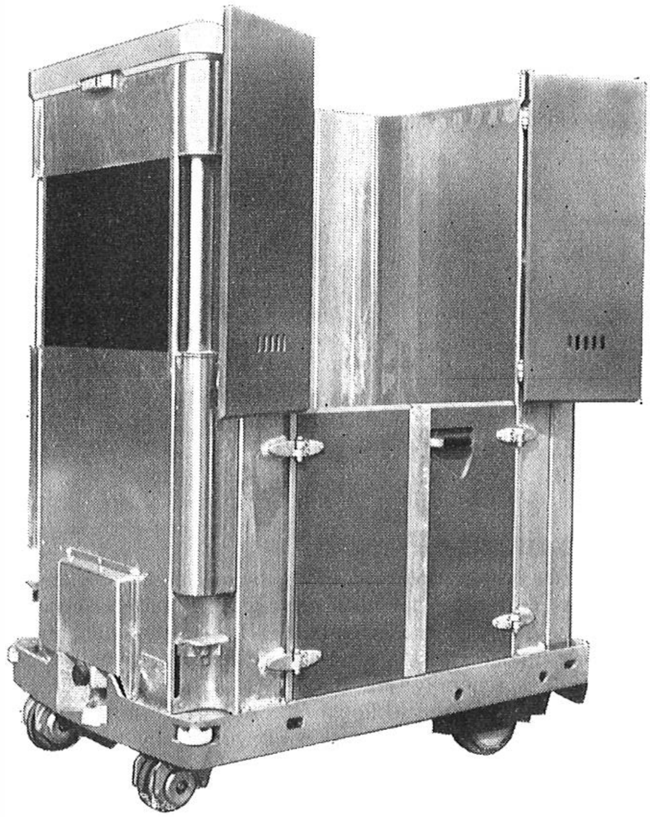


FIG. 2—The all-purpose mail trailer equipment

the characteristics of the British postman? A recent statistical study by one of the authors set out to probe this problem. An examination of clothing-demand data for approximately 100,000 British postmen was strongly suggestive that they may be up to 50 mm shorter than the average soldier quoted in American literature.

One example of the direct use of body-dimension data concerned the re-design of the chain between a cash carrying-case and the wrist. From a knowledge (American) of the distribution throughout the population of male hand lengths, wrist diameters and closed fist circumferences, the specifications for an improved design have been written. The ergonomically designed linkage will, unlike its predecessor, satisfy all but the most abnormally shaped American hands, and on the assumption that British hands are not too different, be satisfactory on this side of the Atlantic.

Sometimes a knowledge is required of body dimensions in the dynamic sense where, for example, questions of load support and body stability arise. The design history of this next example not only illustrates this requirement, but also how the interplay between the ergonomist and engineer in design evolution can result ultimately in a sound, functionally-engineered product.

Part of the parcel concentration scheme, involves the transportation of mail in units larger than mailbags. A previous study had indicated container dimensions which would maximize the volume usage of the bulk carrier transport. Arising from these dimensional specifications was the ergonomic question of how easily could these containers be hand-filled with parcels. The limits of functional reach of typically short, medium and tall individuals, determined by experiment, and inscribed as arcs on a mock-up of the early design, showed it was unsatisfactory.

The design of the container has evolved considerably from the early prototype, assisted by ergonomic advice not only on questions of filling, but also on position and shape of handle, and tractive effort required to push. The latest (but not final) model is shown in Fig. 2. Stable-type doors enable the back of the container to be reached, without the operator being forced to lean over a horizontal barrier as formed by drop-down doors in an earlier design.

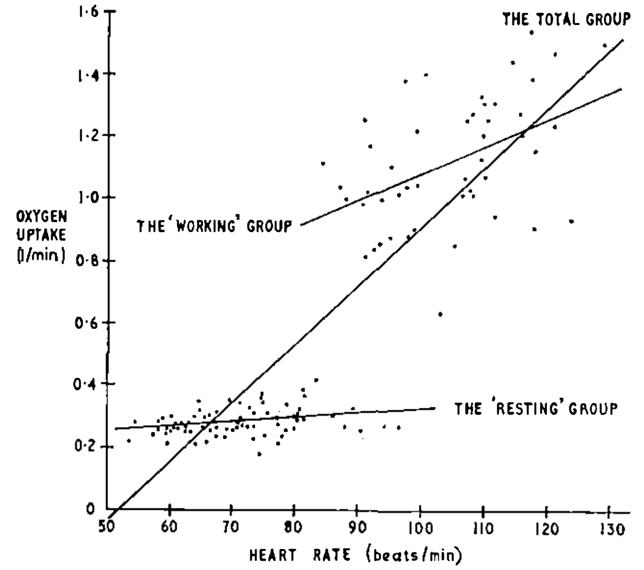
SUPPORT SYSTEMS OF MAN

Skeletal muscle action is dependent (and ultimately limited by) the biophysical properties of the pulmonary (lung) and cardiovascular (heart) systems. The measurement of the oxygen uptake provides a useful index of the total metabolic cost of work, but it is the heart rate which usually indicates the current level of physiological stress. Stress level (as given by heart rate) is of greater importance to the individual, but does not always provide an objective measure of work.

Oxygen uptake may be measured indirectly by determining the volume flow and component-gas concentrations of inspired and expired air. From this, the metabolic cost (measured in kilocalories) may be calculated. To be of any real value, the procedure requires the use of a most careful technique.

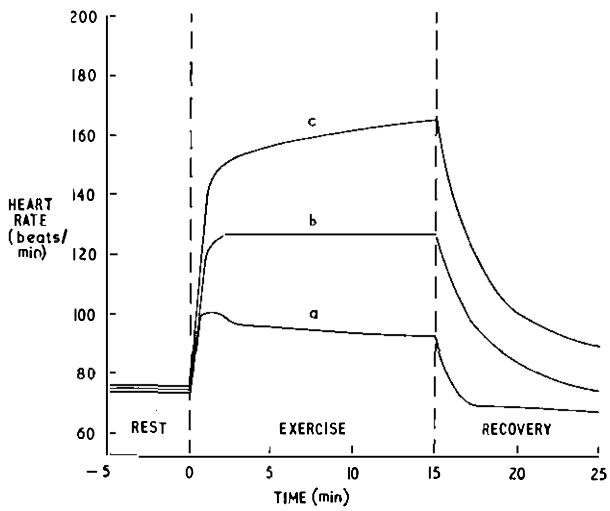
Under very moderate work loads, there is a correlation between heart rate and oxygen consumption, and hence energy expenditure. At higher work loads, due mainly to the nonlinear efficiency of the heart, the correlation becomes less definite. Also, heart rate is affected by the immediate pre-history of the work load. These effects are shown in Figs. 3 and 4. This has very important consequences in deciding the physiologically correct durations of work and rest periods at particular work levels.

As the heart muscle-fibres contract, minute electrical disturbances are propagated which can be detected anywhere on the body surface. The waveform shapes and amplitudes from different sites around the thorax are invaluable to the cardiologist, but for the purposes of work physiology, all that is required is a knowledge of the inter-beat intervals. This may be achieved automatically by means of appropriate instrumentation, and with minimal disturbance to the subject, by the placement of an electrode on the chest. A simple procedure is to measure the pulse rate by palpation at the wrist, but clearly the subject is less able to work at the same time. This method can be unreliable since the heart rate and pulse rate at the wrist may not, for a variety of reasons, be the same.



The resting group comprises eight males aged 42 to 57 years, lying, sitting and standing. The working group, the same subjects, walking on a treadmill at 5 km/h with a 16 kg postbag. There is a wide variation in heart rate of the resting group, and poor correlation between heart rate and oxygen uptake in the working group

FIG. 3—Correlation between heart rate and oxygen uptake



(*a*), (*b*) and (*c*) represent the patterns of heart rates experienced by individuals of decreasing fitness working at a set level, or alternatively of an individual working at increasing levels

FIG. 4—Individual heart rate during work and recovery

To provide an ergonomic reference of work stress and energy expenditure to guide future postal engineering design, the oxygen intake and heart rates of a group of light-industrial workers have been examined under a variety of conditions, including carrying a postbag containing a 16 kg load. These are shown in Table 1.

These techniques have also been used to determine the best heights for outlets from parcel sorting machines for loading into containers. Two studies were undertaken. The first assumed that the container could be raised or lowered by some mechanical means to ease the packing operation. The second, that the container would have to be filled without mechanical level-control. From these, the difference in cost in terms of effort was determined. In this series of experiments, the objective physiological measurements were supported by the results of a subjective psychological questionnaire of the subjects' reactions to working at different heights. Psychological and physiological agreement is comforting. The results of the first part of the experiment are shown in Fig. 5, and indicate that the outlets, under the operating conditions assumed in this experiment, should be higher than usually found in practice.

It should be mentioned that in the matter of loading containers, a poorly designed work environment, causing unnecessary fatigue of the packers, would almost certainly result in poor packing, and it is estimated that a 1 per cent reduction in packing density could cost £100,000 annually in extra transportation costs when the parcel service is fully containerized. Ergonomics has economic overtones, and is sound business sense.

MAN'S MECHANICAL DYNAMICS

Oxygen uptake and heart rate are whole-body and temporal averaging measures which provide no information on

TABLE 1
Oxygen Uptake and Energy Expenditure
24 subject trials; mean, standard deviation (s.d.) and coefficients of variation (c.o.v., expressed as a percentage) under different work conditions.

Measurement	Statistical parameter	Conditions				
		Supine	Sitting	Standing	Walking 5 km/h	Walking 5 km/h with 16 kg postbag
Oxygen uptake (litres/minute)	mean	0·263	0·28	0·305	1·003	1·264
	s.d.	0·036	0·043	0·048	0·042	0·182
	c.o.v.	13·7	15·4	15·7	14·2	14·4
Energy Expenditure: (kilocalories/hour (kcal/h))	mean	76·45	81·29	88·19	291·02	366·44
	s.d.	10·19	12·15	13·23	39·23	50·67
	c.o.v.	13·3	14·9	15·0	13·7	13·8
as percentage of lying supine	mean	—	106·5	115·6	411·6	517·5
	s.d.	—	8·4	10·24	48·0	53·4
	c.o.v.	—	7·88	8·86	11·7	10·3
kcal/h/kg of lean body mass	mean	1·302	1·387	1·432	5·022	6·322
	s.d.	0·138	0·187	0·208	0·303	0·387
	c.o.v.	10·6	13·5	14·5	6·04	6·12
kcal/h/m² of body surface	mean	39·99	42·62	46·24	154·78	194·94
	s.d.	4·37	6·18	6·75	12·43	17·18
	c.o.v.	10·9	14·5	14·6	8·03	8·81

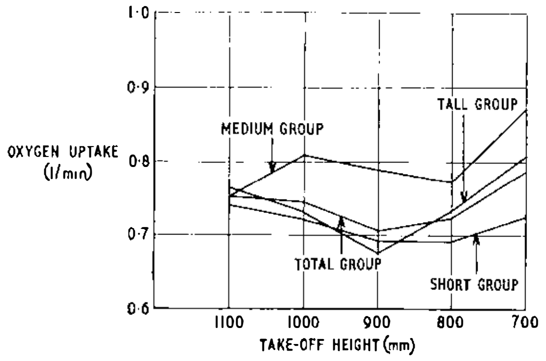


FIG. 5—Oxygen uptake and parcel take-off height

localized activity in the body. Nervous and muscular activity can, however, be examined in fine detail by sampling the attendent electrical activity in localized regions of muscle, brain or nerve.

Muscle physiology and electromyography is still a developing field of research, but it is generally agreed that up to moderate levels of activity there is an empirical linear relationship between the voltages generated and the force exerted. Beyond moderate levels of activity, individual motor units can no longer be identified and the electromyographic recording becomes confused.

In ergonomic practice, the advantage with electromyography is that this electrical activity can also be sampled from the surface of the skin with electrodes which can be affixed with adhesive tape. There is no discomfort to the subject, and their presence need not restrict the subjects' movement. The activity from any number of different sites on the body may be simultaneously examined.

Fig. 6 shows an example of particular patterns of electromyographic activity recorded from sites overlying main muscle groups of the arms, shoulders, back and legs on both sides of the body. The subject was simulating parcel container filling by receiving parcels from a fixed height and forming a column of blocks. This was repeated using a different parcel-reception height. Each burst of activity represents one placement cycle, and it is apparent that by a visual inspection of such a record it is possible to specify a particular working arrangement that minimizes the electrical activity arising from the muscle work of any particular part of the body.

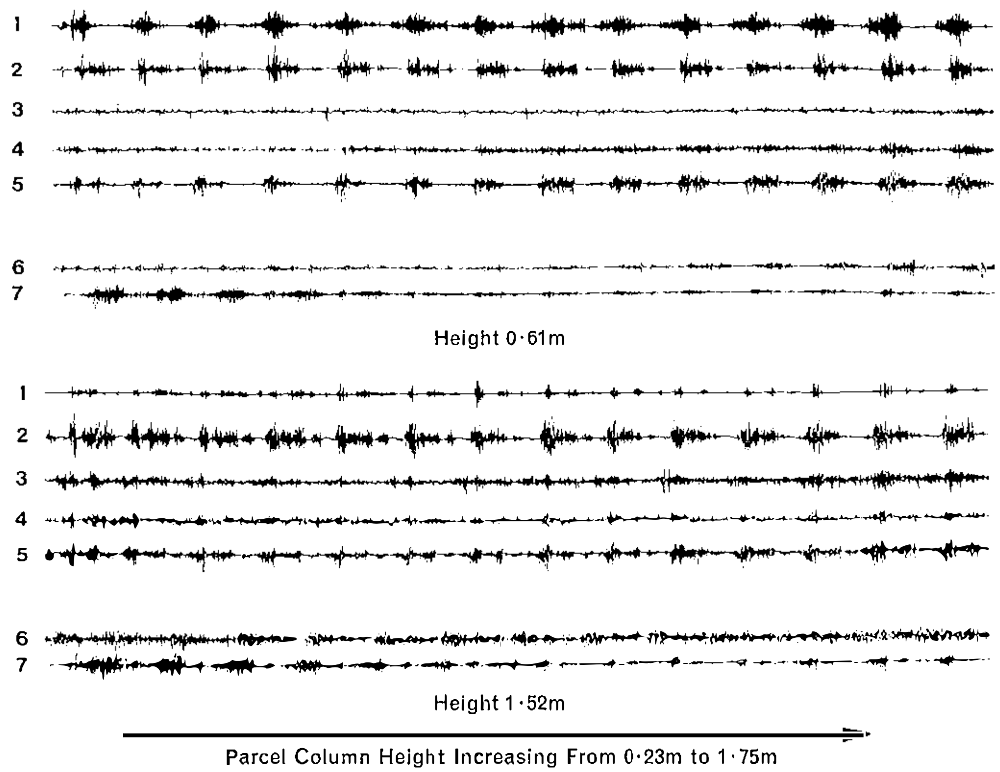
Once a particular working arrangement has been chosen which minimizes oxygen uptake (total energy expenditure), it could happen that this is achieved only at the expense of overworking particular muscles. (Winking requires less energy expenditure than tapping with the hand, but would be more fatiguing.)

MAN'S PREDICTABLE BEHAVIOUR

Psychology, as the prime behavioural science, has applications beyond that of machine design alone, bearing on questions such as operator selection, training and working patterns, but only its application to machine design is mentioned here.

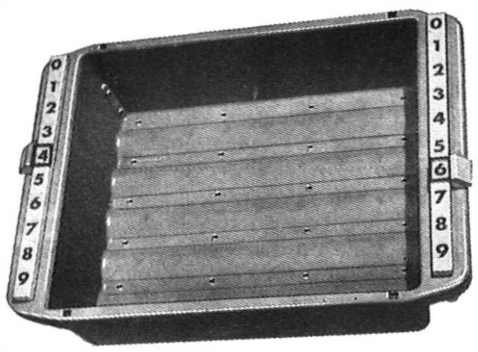
A mass of data has accumulated from experimental psychology regarding man's behaviour and performance under different conditions. Fairly straightforward questions such as the effect of illumination levels on work, and the importance of shape on the legibility of alphanumeric displays have been extensively investigated and documented. The results can be immediately applied in engineering design. It is of course important that the designer be aware that apparently trivial detail might be vital in deciding the effectiveness of the man-machine combination.

The design of alphanumeric symbols is an area where this data collation has been completed. The study, which was concerned with the shape and layout of a numeric coding system to be used on letter trays, is illustrated in Fig. 7.



1, Right thigh, 2, left arm, 3, left shoulder, 4, the back, 5, right forearm, 6, right shoulder and 7, left thigh

FIG. 6—Electromyographic activity from different parts of the body



The shape and layout of the figures, illustrated here on a proposed method of coding letter trays, are in accordance with published results of several studies concerning symbol characteristics and legibility

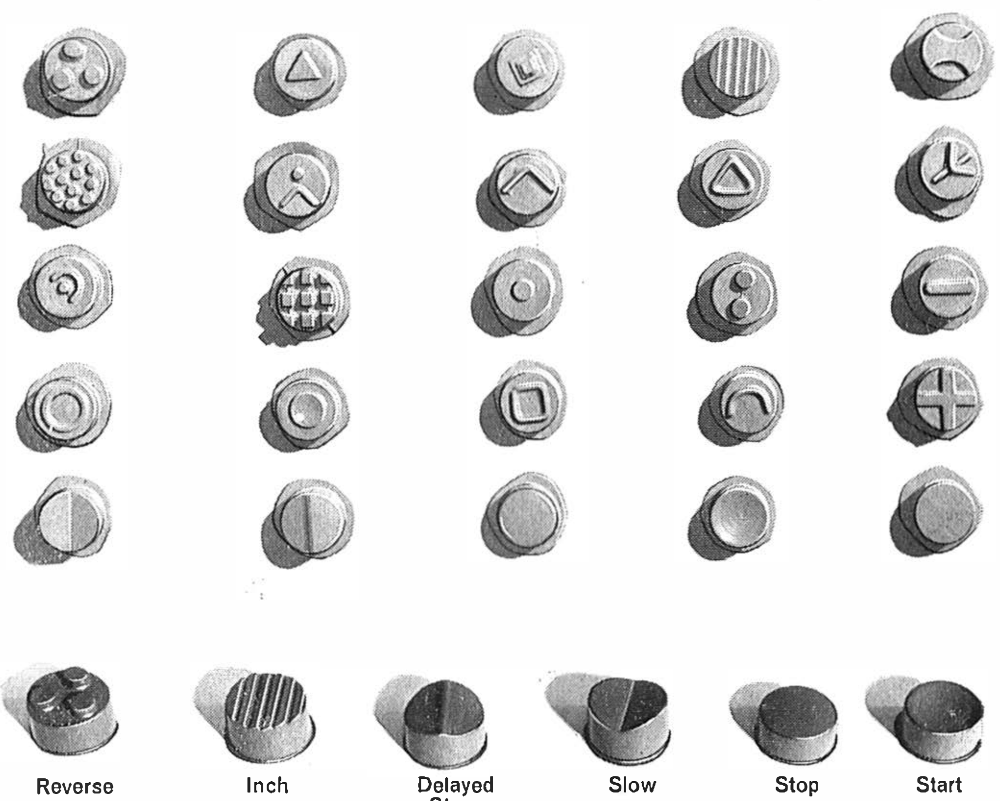
FIG. 7—Letter-tray coding

Experimental psychology has something to say about each and every feature such as the figure height/width ratio, stroke width, colour, brightness and contrast etc.

Not all questions can be resolved by theoretical work alone, especially where the question concerns attitudes or preference in connexion with something novel. When psychological experimentation becomes necessary, there is always the problem of choice of experimental subjects, and whether particular results are applicable to the type of people concerned. There are certain advantages in using as subjects, people who are disinterested in the sense that they are unconnected with the application of the experimental results. Over-eager volunteers and pressed men make bad subjects.

Push-buttons are common on postal machinery, serving a variety of different functions in machine control including start, stop, inch and reverse. They are all colour coded, and for obvious reasons it was considered desirable that each push-button should have a different shape. It was considered that in the British population at large there might be some natural associations between particular shapes and functions. For this reason a test was conducted to determine if any associations existed between any of twenty-five shapes and any of six machine functions. The twenty-five original shapes are shown in Figure 8, together with the six shape/function asscciations finally chosen. Such an experiment, although complete in itself, needs to be continued to involve actual postal workers and postal maintenance staff before final standardization. This would ensure that any additional associations acquired from B.P.O. experience have not modified the situation.

Probably one of the most fundamental decisions affecting postal mechanization has concerned the degree of independence of the man from the machine. In many other postal organisations the system is such that the operator is required to work at a pace dictated by the machine. Machine pacing of the operator is fairly common in industry, but in the B.P.O., an early decision was made to use unpaced systems in sorting. From the study of output rates of paced and unpaced systems, there are good theoretical reasons, and mounting evidence from controlled trials in industry, that unpaced working yields higher outputs at lower error rates. Fig. 9 shows the frequency distribution of parcel-sorters sorting-times from 16,000 observations at different offices of two-man outward sorting. Its shape is fairly typical of human performance in repetitive tasks. It will be seen from the figure the impossibility of constructing a paced system with a frequency distribution of operating times having a lower mean than the unconstrained distribution.



The upper group shows the original 25 shapes, and the lower the six shape/function combinations chosen

FIG. 8—Push-button shapes and machine control functions

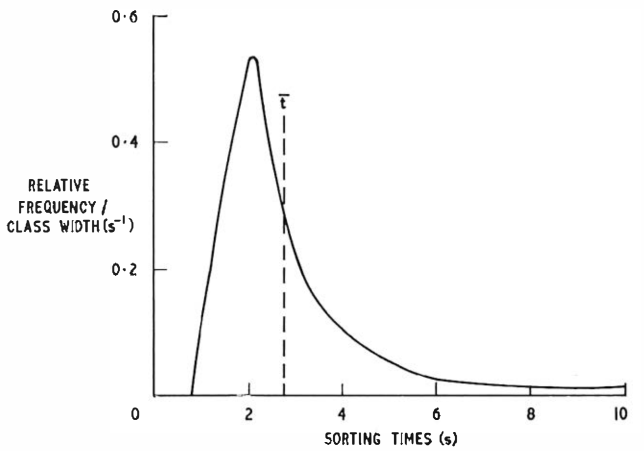


FIG. 9—Frequency distribution of sorting times

STUDIES IN HAND

At the moment, the parcel sorting machines potential throughput is more than twice that of the sorters feeding it. One conceptually easy solution to this mismatch is to provide two sorting inlets feeding each machine, and this engineering development is now well advanced. Clearly, the feeds could operate in strict rotation, or randomly of each other, but in either case, without an impossibly long queue between individual feeds and their common outlet, there will be an interaction between sorters, where one either waits or is frustrated by the other. A psychological experiment is under way to determine how these effects modify performance. It is believed that much will depend upon certain personality characteristics of the person experiencing the situation, and the experimental design includes a multivariable analysis of several of these factors.

Another approach to the problem of parcel sorting is to examine the component activities of human performance in carrying out the sorting task. We have little information in this area apart from the gross sorting distribution times. There is little doubt that the present parcel sorting position is far from ideal, and several studies are under way examining different aspects aimed at short-term and futuristic solutions.

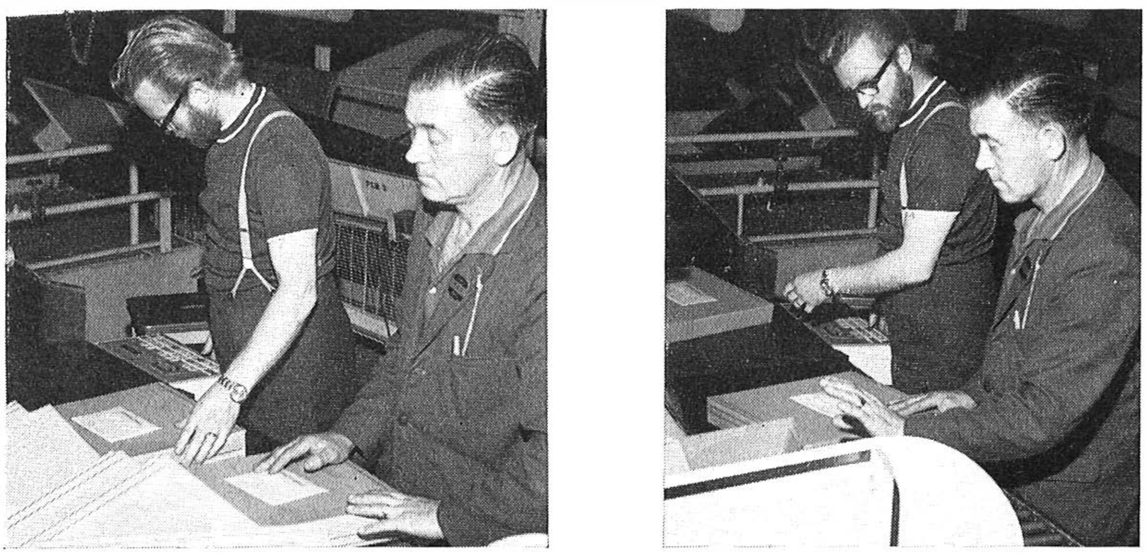
As can be appreciated from Fig. 10, in reading and coding, the coder is obliged to oscillate visually between the parcel and coding box. The regular geometry of coding-button layout arises, as with many other machines, including the typewriter, from a combination of factors including manufacturing convenience, tidy engineering and tradition. Such arrangements pay no recognition to the design of the hand supposed to operate it. Anthropometric considerations apart, it is clear that there is a relationship between the number of key positions and the uncertainty of position of any one. This uncertainty may be reduced by using serial keying and fewer key positions. The strategy of serial keying is being examined for a parcel concentration office and an ergonomic design of keyboard will follow.

Another development which is being evolved with the new coding box, is a tactile indication that the machine is ready to accept the next parcel. Currently, this is provided by the illumination of a green light on the coding box, and this means the coder must divert his eyes from the parcels. The arrangement with the tactile indication is that the coders hand should rest on the coding box. Raising of a thumb bar or palm support signals the operator to code, and also brings the hand into a position of readiness. Alternatively, simply locking the keys to prevent coding might be used.

THE POSTMAN

In the postal system, mechanization has eliminated much of the heavy lifting and carrying work required of staff, with the exception of the postman on his delivery rounds. One might imagine that foot complaints would be fairly common, but this appears not to be the case. The medical statistics collected over the past three years show that the most common reason for premature retirement of postmen is back injury. This fact alone is not surprising, since in the population at large, back injury is very common, taking second place only to psychosomatic illness as a reason for premature retirement. However, the frequency of occurrence with postmen is on the average almost three times that of telecommunications staff, and a statistical test shows the difference to be highly significant.

It is not possible to positively implicate the postbag, nor, at the moment to indicate where such injuries occur. Of course, a higher incidence is inevitable in postal staff due to the nature



The coder alternates his visual attention between parcel addresses and the coding box. There is insufficient tactile feedback from geometrically-regular-shaped keyboards to enable the operator readily to seek and locate the appropriate button without visual aid

FIG. 10—Coding in parcel sorting

of the work, but there is an obvious need to mechanise in a way that minimizes human effort and discomfort.

CONCLUSION

The application of ergonomic principles of engineering design is necessary to achieve adequate matching of man and machine, and achieve the most efficient and comfortable operation. A considerable amount of basic information already exists regarding the physiological and psychological characteristics of the human, and can, with advantage, be immediately applied in engineering design. More complex psychological questions involving the attitudes and performance of a restricted population group have to be examined by controlled experimentation before selecting between engineering alternatives prior to machine detail design.

Bibliography

An easily readable introductory text on ergonomics, which also contains an extensive bibliography, is provided by MURRELL.[2] Papers of ergonomic interest often appear in physiological[3] or psychological[4] journals, and there are two journals explicitly devoted to ergonomics as seen on the Western[5] and Eastern[6] sides of the Atlantic. Of interest to the non-specialist user of ergonomic methods is a journal[7] published in co-operation with the Ergonomics Research Society. Information can be rapidly obtained by contacting the practitioners, several groups of individuals having declared interests[8] in particular areas of ergonomics.

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Post Office Use of Mobile-Radio Systems

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A practical approach to the planning and engineering of a mobile-radio system for the use of telephone area staff is outlined in this article and factors influencing design are examined. An original system, designed by Chester-area personnel, to overcome the problems of providing the required area of coverage in North Wales is described.

INTRODUCTION

Mobile-radio systems have been used by the British Post Office (B.P.O.) for a number of years,[1] but it is only comparatively recently that their potential has been realized nationally. The simplest installation employs a single fixed radio station (base station) controlled from one operator point, (control station). Such systems can give radio coverage of population centres and enable mobile staff to be controlled whilst they are in the base-station service area. However, since transmission is limited to a little beyond line of sight, most telephone areas cannot be covered from one radio-station site and, furthermore, access to the system is likely to be required by more than one control.

A mobile-radio system can produce appreciable savings in lost circuit time, man-hours and vehicle miles amounting to an average of one man-hour per day for each equipped party. At the current man-hour rate and with 60 units in the field, this could produce a saving of almost £60 per working day in man-hours alone.

A satisfactory system provides a rapid means of communication between mobile staff and their control at all times and some examples illustrating the convenience and ease of administration are:

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(*a*) recalling or diverting staff to more urgent work as it arises,

(*b*) requesting an underground plant watcher to visit the working site of another undertaker to investigate reported damage,

(*c*) enabling staff to obtain assistance when necessary and at short notice,

(*d*) moving maintenance parties rapidly from fault to fault, this being particularly useful during storm or serious breakdown conditions, and

(*e*) obtaining greater flexibility and efficiency from staff and plant.

REQUIREMENTS FOR B.P.O. PRIVATE MOBILE-RADIO SCHEMES

At present, six two-frequency v.h.f. radio channels are allocated for exclusive B.P.O. use (see Table 1) and these are shared by telephone areas throughout the U.K.

Each base-station transmitter/receiver is assigned one of these channels and base stations sharing the same frequencies are sufficiently far apart to reduce mutual interference. Mobile stations can be switched to operate on any of the six channels to allow inter-area working. Amplitude modulation with 12·5 kHz carrier-frequency separation is used. The base station equipment is normally arranged so that the transmitter may be remotely controlled from a distant control

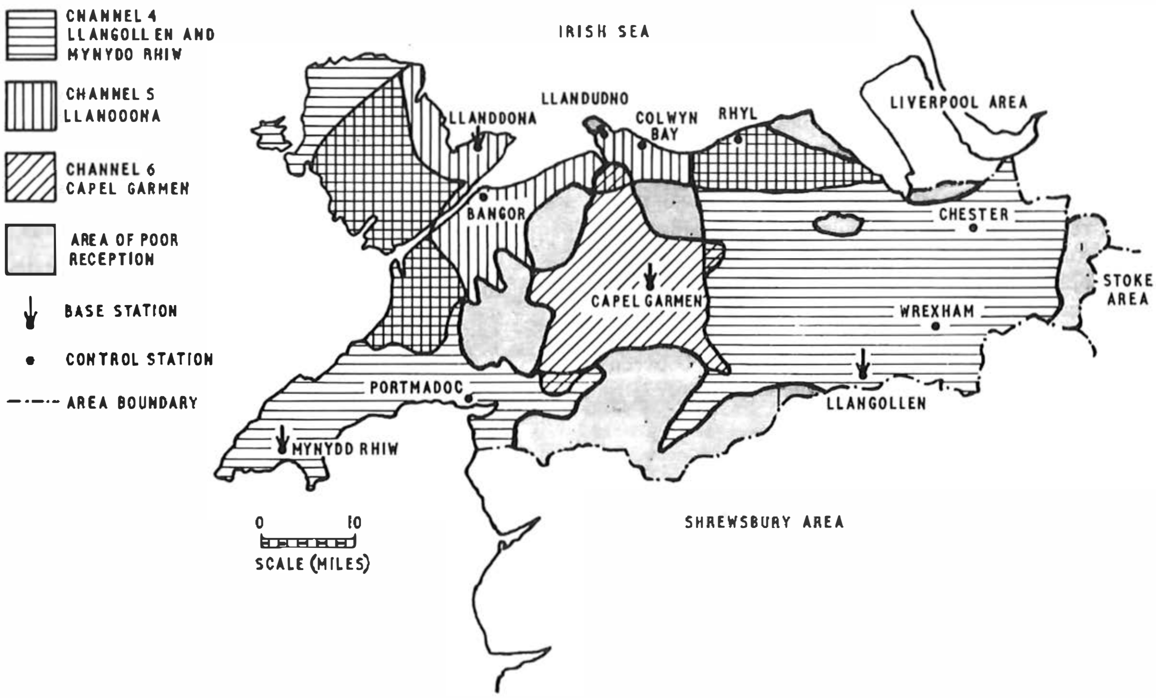

FIG. 1—Base-station service areas in the Chester area system.

station. A remotely-controlled *talk-through* facility is usually provided which enables the base station to be used as a repeater for inter-mobile working by connecting the audio output of the base-station receiver, at a suitable level, to the transmitter input. This facility is useful after normal working hours when the control point is not manned. Any failure of the control circuit normally results in automatic switching to *talk-through* so that communication is maintained. Radio equipment must comply with performance specifications laid down by the Ministry of Posts and Telecommunications and is normally purchased by competitive contract from one of a number of manufacturers.

SYSTEM PLANNING

The following considerations must be taken into account in planning:

(*a*) The system should not be more sophisticated than is necessary to ensure adequate performance and ease of operation.

(*b*) Standard radio and control equipment must be used wherever possible with the minimum of modification.

(*c*) Mobile-radio equipment should only be provided for vehicles or staff when it will result in a positive efficiency improvement in the B.P.O. service.

(*d*) The number of mobiles on one network should not be too great otherwise efficiency is reduced, 30-40 being about optimum in a B.P.O. system.

(*e*) Radio coverage is important only where telephone plant exists and some blind spots, due to local screening, have to be tolerated.

(*f*) Equipment and line-plant costs should be minimized consistent with obtaining maximum efficiency from the system.

SITE SPOTTING

Existing radio sites are normally the first choice for base stations but the B.P.O. owns very few suitable sites and it is normally necessary to share. This policy has economic advantages but can lead to interference problems.

To find the minimum number of sites providing useful radio coverage most economically, a map is prepared showing

TABLE 1

Channel Number	Mobile Station Transmit Frequency (MHz)	Mobile Station Receive Frequency (MHz)
1	71·675	85·175
2	71·650	85·150
3	71·700	85·200
4	71·6625	85·1625
5	71·6875	85·1875
6	71·6375	85·1375

districts where radio coverage is required. Areas are marked on a one inch to a mile Ordnance Survey contoured map where radio coverage is (*a*) essential, (*b*) important and (*c*) unnecessary. Existing radio sites are marked on the map and certain unsuitable sites eliminated at this stage.

Theoretical surveys from the most promising sites are made and the predicted service areas, drawn to scale on transparent sheets, laid over the appropriate map to help determine the most economical combination of sites to provide acceptable radio coverage. The cost of landlines linking base stations and control stations and any special equipment required, such as that for lightning protection must also be considered. Where the terrain is very irregular, or where important areas lie on the edge of the estimated service area, it is best to make practical field-strength tests from the selected stations using frequencies, powers and aerial positions similar to those proposed for the final installation.

FACTORS AFFECTING RADIO-SYSTEM DESIGN

Aerial Systems

To achieve maximum system range, the base-station aerial should be as high as possible and remote from high obstacles. Separate omni-directional aerials are normally provided for the transmitter and receiver and are essential if *talk-through* facilities are to be provided. The aerials are usually 50-ohm, centre-fed, folded dipoles, vertically polarized and side mounted on booms from the mast or tower. They are connected to the equipment by 50-ohm coaxial feeder cable having an attenuation of about 0·065 dB/m. A feeder cable, of about half this loss is used where a long feeder is necessary, say over 40 m.

Increased aerial gain can be achieved by stacking aerials vertically and feeding them in phase. Two or four stacked dipoles give an all round, horizontal, gain of about 3 or 6 dB respectively. Radiation in the vertical plane is reduced by this arrangement but this is not important for land mobile services. The horizontal polar diagram can also be modified by critically spacing the aerial from the mast or by using horizontal arrays to give a gain of about 3 dB in certain directions and reduced radiation in others. The effective radiated power (e.r.p.) must not exceed 25 watts, the licence limit, even when gain aerial arrays are employed.

Since a mobile-radio station uses the simplex mode of operation, only a single quarter-wave whip dipole is required. This simplifies the installation and avoids any directional characteristics introduced by twin aerials. Since the number of mobiles greatly exceeds the number of base stations, any economies or simplifications achieved in a mobile installation are valuable.

Precautions Against Lightning Damage

If a base station is situated on a rocky hill top of high earth resistivity, it is possible that the potential of the earth with respect to a distant point may rise to a value of several-thousand volts. This usually happens during lightning storms but can occur at other times. A telephone cable provides a low-impedance discharge path and may, thus, endanger personnel and plant. In these circumstances, the line needs to be isolated from local earth at all base stations, signalling earth being extended to the site over the phantom pair. Voice-frequency signalling can be used to achieve d.c. isolation but this is more expensive and fault prone. Where previous damage has occurred due to lightning, it is desirable to terminate the pairs on encapsulated isolating transformers. The d.c. signalling conditions are repeated from the line to the remote control panel by reed relays, the operate coils of which are similarly isolated. The isolating units are designed to withstand a voltage of 30 kV but breakdowns still occur on some exposed sites. Other expensive solutions employing special cable and duct are available in extreme cases and, as a last resort, a radio link may be considered. However, the Ministry of Posts and Telecommunications restricts the use of radio links to conserve the frequency spectrum and the cost of lightning protection would need to be very high to justify their use.

THE SYSTEM IN THE CHESTER AREA

In Chester Area, there are six Repair Service Controls[2] (R.S.C.), which are responsible for local cable faults within the capability of a faultsman jointer. A central External Plant Maintenance Control (E.P.M.C.), at Llandudno controls main and junction cable maintenance and plant watchers for the whole area and takes over some of the local cable faults from R.S.C.s.

Radio coverage of most of the area is possible from four sites (see Fig. 1). There is a need to interconnect the six R.S.C.s, the E.P.M.C. and four base stations in such a way that each R.S.C. has access to radio stations covering its own area, and the E.P.M.C. at Llandudno has radio access to the entire telephone area.

For radio coverage, the Chester area is divided into two sections, east and west and a separate omnibus speaker is provided for each section (see Table 2).

The R.S.C. areas of Chester, Wrexham and Rhyl, in the east, can all be served by the one base station at Llangollen. Because of the irregular terrain, three base stations are required to cover the western section, which includes the mountains of Snowdonia. Both Llanddonna and Capel Garmen base stations must be used to obtain coverage of Colwyn Bay R.S.C. area and Bangor R.S.C. area is served by Llanddonna, Mynydd Rhiw and Capel Garmen. Portmadoc R.S.C. area is covered by Mynydd Rhiw and Capel Garmen base stations.

The E.P.M.C. has separate access to east and west and as an optional extra, full conference is possible by operation of an east-west linking switch.

The same radio frequency cannot be used for adjacent and overlapping areas as interference can occur resulting in an audible beat note. However, the same radio frequencies are used for the Llangollen and Mynydd Rhiw base stations because the radio service areas do not overlap. All the western base stations radiate simultaneously on their respective frequencies, so that a mobile-radio station can select the best channel for any particular location. In order to call a particular mobile station, the operator speaks the call sign of the station required.

LINE TRANSMISSION

Fig. 2 shows a simplified block diagram of the line transmission circuits used in the Chester Area system. The main links interconnecting control points are 2-wire physical circuits which result in substantial plant economies and simplified design by providing a common highway for speech transmission in both directions compared with the alternative 4-wire bridge type omnibus circuit. All the base stations except Llanddonna are connected to the omnibus circuit via an amplified 4-wire circuit.

The transmission plan adopted aims to ensure that speech signals between any base station and any control station have the correct nominal level for the arrival point regardless of source. This ensures that full modulation of each base-station transmitter is achieved, and control stations need not readjust their volume controls when handling calls from different base stations. The balancing of levels is accomplished by the use of level-balancing hybrid transformers (l.b.h.).

Level-Balancing Hybrid Transformers

The trans-hybrid loss of a conventional terminating hybrid (t.h.) transformer, shown in Fig. 3 with a balance network suitable for a loaded-cable pair, can be reduced by changing the impedance of the balance. The high-loss path between the 4-wire receive (4WR) and 4-wire transmit (4WT) can, therefore, be used as a transmission path and the attenuation adjusted to balance the transmission levels at a branching

TABLE 2

Section	Number of Mobiles	Controls (R.S.C.s)	Base Station	Base Station Authority	Channel Number
East	34	Chester Wrexham Rhyl	Llangollen	B.B.C.	4
West	30	Portmadoc Colwyn Bay Bangor	Mynydd Rhiw Capel Garmen Llanddonna	Police Electricity Board Police	4 5 6

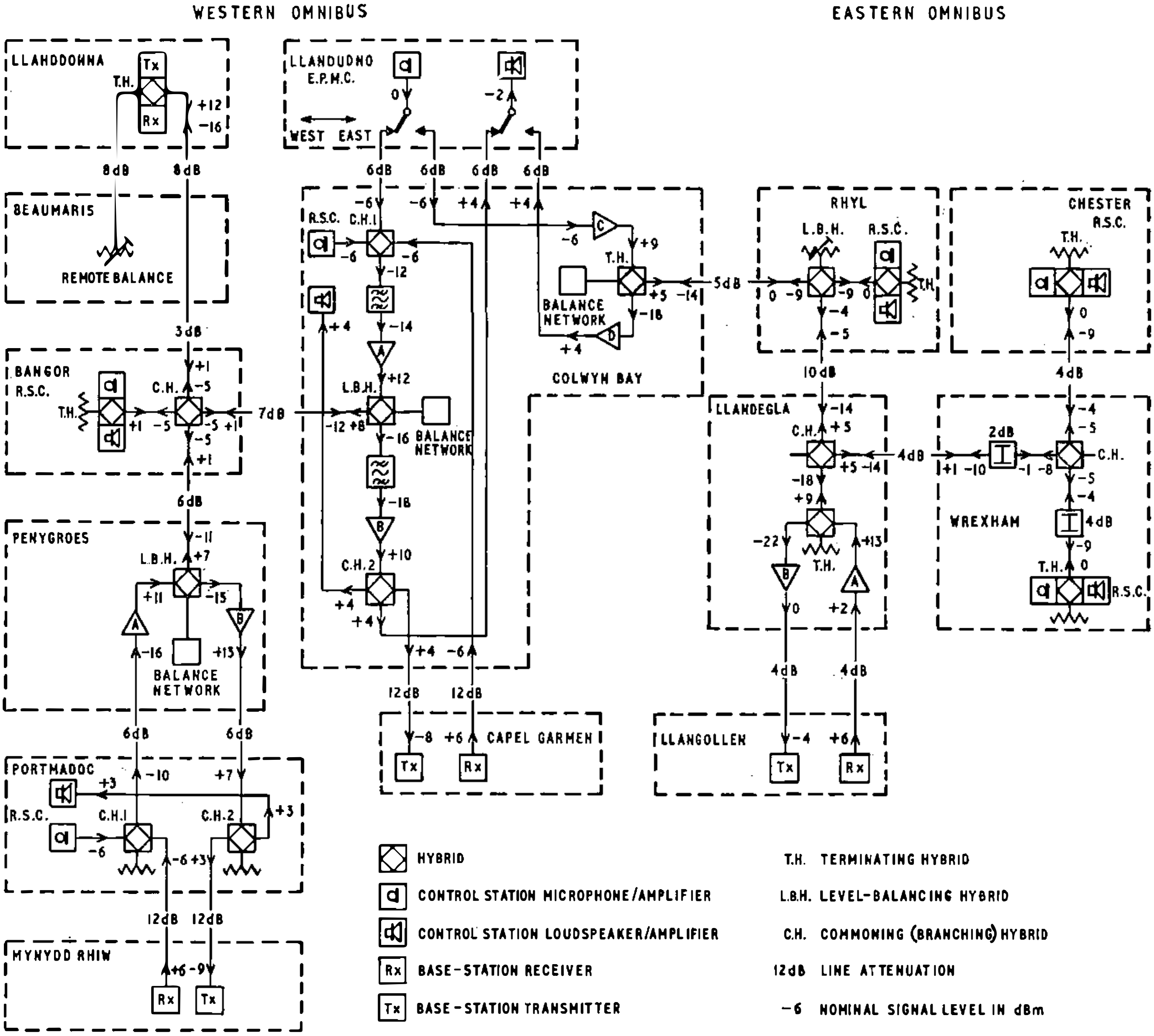

FIG. 2—Simplified block diagram of transmission system.

point on a 2-wire omnibus circuit. The l.b.h., therefore, acts as a branching network with three 2-wire branches, corresponding to 2-wire (2W), 4WR and 4WT. The loss between 2W and 4WR and also between 2W and 4WT is normally about 4 dB. The loss between 4WR and 4WT can be adjusted by varying the impedance of the balance.

As an example, at Rhyl, (Fig. 2) signals from Llandudno E.P.M.C. arrive at the input of the l.b.h. at a nominal level of 0 dBm. There is a 4 dB loss between the 4WR and 2W terminals and, hence, this signal leaves for Llangollen radio transmitter at a level of −4 dBm. A similar signal from Rhyl R.S.C. into the 4WT terminals also has a level of −4 dBm at the 2W terminals. Thus, both signals modulate the transmitter equally. However, signals from the radio receiver at Llangollen arrive at the 2W terminals at a level of −5 dBm and suffer equal loss in the hybrid so that the levels in the direction of Llandudno and Rhyl are equal at −9 dBm. To make the transmitted signal from Rhyl have the same level, a loss of 9 dB is required between the 4WT and 4WR terminals. The trans-hybrid loss may be adjusted to this value by choice of the balance network.

An accurate balance of impedance is essential if a high trans-hybrid loss is required at all frequencies. The attenuation/frequency response of the 4WR to 4WT path is affected by the accuracy of balance, but in the case considered, where the required trans-hybrid loss is only 9 dB, a simple resistive balance provides a satisfactory characteristic over the speech band. Also, nearly all transmission paths include loaded pairs which limit frequencies outside the working range.

The l.b.h. on the Bangor side of Colwyn Bay operates close to the practical limit of balance with a trans-hybrid attenuation of 28 dB. An accurate balance impedance at all frequencies is, therefore, required to ensure that the attenuation/frequency response is reasonably flat without any pro-

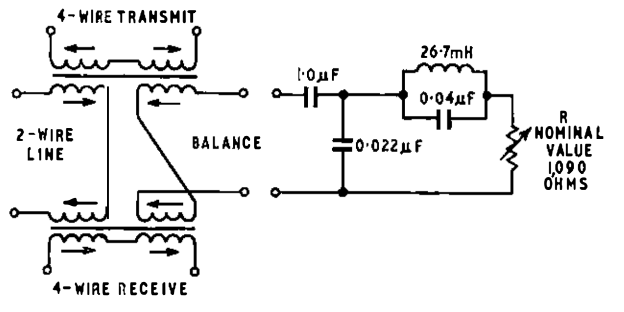

FIG. 3—Conventional hybrid transformer and balance network for loaded cable.

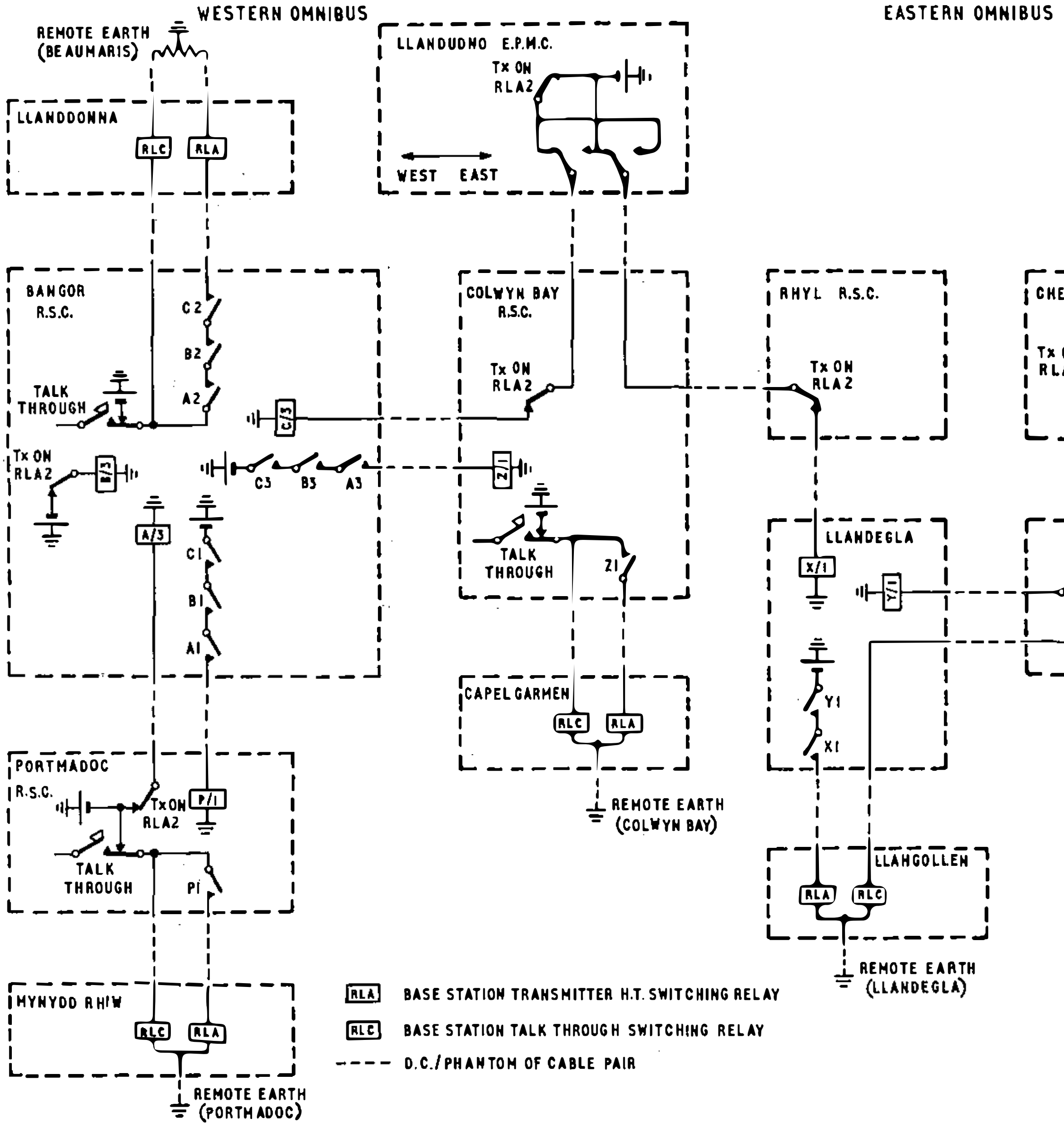

FIG. 4—Simplified block diagram of signalling system.

nounced peaks or troughs. Band-pass filters (b.p.f.) limit the response at frequencies outside the working range of 300–3,000 Hz as signals originating in Colwyn Bay and routed trans-hybrid have no loaded cable in their path. Without b.p.f.s, high-level signals at frequencies outside the working range could cause overloading of amplifier B, and high-frequency side-tone at the station originating the signal.

The remaining l.b.h. at Pen-y-Groes also requires a high trans-hybrid loss (26 dB) but b.p.f.s were not required as all transmission paths include loaded pairs. A variable resistor in the balance network is adjusted to provide the required trans-hybrid loss.

Western Omnibus Circuit Transmission

Four 2-wire circuits are commoned at Bangor on a commoning hybrid (c.h.). This is a conventional hybrid transformer with the connexions to the balance-pair winding reversed and the insertion loss is about 6 dB between any two ports. The c.h. at Bangor is used as a focal point for lining-up the western section. The nominal input level to this c.h. is the same (+1 dBm) for signals from any of the seven stations. The signal level received at any point in the Western omnibus network is the same regardless of its source (see Fig. 2).

Eastern Omnibus Circuit Transmission

It is not economic or practicable to achieve full inter-control-station working with complete equality of signal levels. Since the system is primarily designed for communication between control stations and mobiles, signals received at one control from another control need only be of sufficient level to indicate that the system is in use. The manual gain control on the loudspeaker-amplifier may be increased, if desired, for inter-control working.

The nominal input level to the Llangollen transmitter is −4 dBm for signals originating from any of the four control stations in the eastern section. The focal point for lining-up is the c.h. at Llandegla from where two 2-wire branches connect with the control stations and an amplified 4-wire circuit connects with the base station.

The l.b.h. at Rhyl balances signals exchanged between Colwyn Bay, Rhyl and Llangollen and, on the Wrexham–Chester branch, the three lines are commoned at Wrexham using a c.h. Signals between control stations and mobiles are at nominal levels but, between Chester and Wrexham, signals are 3 dB below nominal level. Signals exchanged between the Colwyn Bay–Rhyl branch and the Chester–Wrexham branch are 23–26 dB below nominal but this is satisfactory for monitoring.

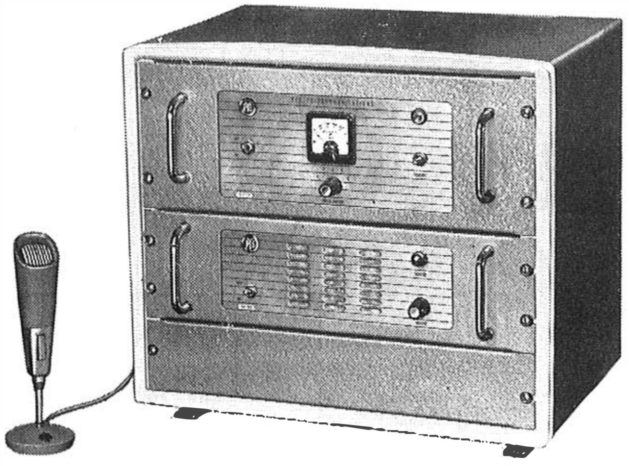

FIG. 5—Base-station equipment.

FIG. 6—Mobile-station equipment.

Stability

A conventional amplified circuit can oscillate if the gain around the amplified loop exceeds the losses. Each omnibus network of the Chester Area scheme is inherently stable because no amplified loop path normally exists over which oscillation can take place, regardless of the trans-hybrid loss, as amplifiers are confined to 4-wire circuits and separate radio frequencies are used for transmit and receive paths. In effect, the 4-wire circuits are extended to the mobile via two separate unidirectional radio channels. Since the mobile operates in a switched simplex mode, there is no transmission path through mobile equipment. An exception arises if the optional east–west linking switch is operated, resulting in conditions similar to a 2-wire amplified circuit between the t.h. and the l.b.h. in Colwyn Bay. Instability is prevented, however, by attenuating the linking path, and by providing an accurate balance termination for both hybrids.

LINE SIGNALLING

Direct-current signalling is used for remote switching of the transmitters and for *talk-through*, at base stations. All signalling paths normally carry current, the removal of which effects switching. The system is, therefore, fail safe, as line failure or control-station power failure results in the affected base station switching to *talk-through*, and mobile-to-mobile transmission can continue. Control stations can also continue to operate by using hand-portable mobile equipment. Each base station can be manually switched to *talk-through* by one nominated control station.

The loop resistance of the signalling path must not exceed 2,000 ohms for the control circuit used. Simplified line-signalling arrangements are shown in Fig. 4 in which all paths carry current and all relays shown in the figure are normally operated. Relays RLA and RLC at each base station control transmitter h.t. switching and *talk-through*, respectively.

In order to transmit, the control-station operator operates a switch on his handset which operates relay RLA in the controller panel (switch and relay not shown in the diagram). Contact RLA2 removes current from the line and releases relay RLA at the remote base station(s). The actual sequence of operations depends upon the control station. Operation of the *talk-through* key at a nominated control station releases relays RLA and RLC at the appropriate base station.

RADIO AND CONTROL EQUIPMENT

All base- and control-station units are standard production items intended for 2-wire operation. Local modification was necessary to adapt to the signalling and transmission modes adopted. Characteristics of the system of special interest are detailed below.

Base Station

The receiver (see Fig. 5) has a maximum nominal output level of +20 dBm and the output level remains constant, within ±2 dB, when the r.f. input level varies from 4 microvolts (terminated) up to 100 millivolts. The output level falls to about +14 dBm for 1 microvolt input and to about +8 dBm for 0·5 microvolt. Thus, the amplifiers and the transmitter modulators, on *talk through*, only have to cater for variations in audio level of about 12 dB. The normal mute setting is at 1 microvolt r.f. input level, and the minimum output level is then only about 6 dB below nominal. For a 1 microvolt input signal, the signal-to-noise ratio of the output signal is better than 12 dB.

The minimum audio input level required by the transmitter (also shown in Fig. 5) is −20 dBm and the unmodulated carrier power output is 25 watts.

Control Station

A constant-volume amplifier (c.v.a.) is incorporated in the controller at each control station. This ensures that the audio output does not exceed a nominal level and a change of 30 dB in the input level results in a change of less than 6 dB in the output. The c.v.a. thus prevents overloading of line amplifiers as speech levels vary and also maintains a consistently high modulation level of the base-station transmitter which contributes to the good signal-to-noise ratio at mobile receivers.

The control-station loudspeaker-amplifier is capable of delivering 1 watt output for an input level of −20 dBm at the 2-wire line terminals. Since the lowest nominal control-station input level in this system is −9 dBm, at Chester, there is at least 11 dB gain in hand.

Mobile Station

The fully-transistorized mobile unit (see Fig. 6) can operate on up to 10 channels but only three are used in the Chester area. The rated transmitter power output is 5–8 watts. The nominal audio-frequency output of the receiver is 2 watts and it is capable of delivering 0·5 watt for an r.f. signal input of 0·5 microvolt, modulated 30 per cent at 1 kHz. The signal-to-noise ratio at this level of input signal exceeds 8 dB which represents the threshold of acceptable intelligibility.

MODIFICATIONS TO EQUIPMENT

The base-station transmitter and receiver installations are unmodified but it was necessary to modify the controller panels for the control stations, and the remote control panels for the base stations. The two transformers comprising the terminating hybrid were split into two separate line trans-

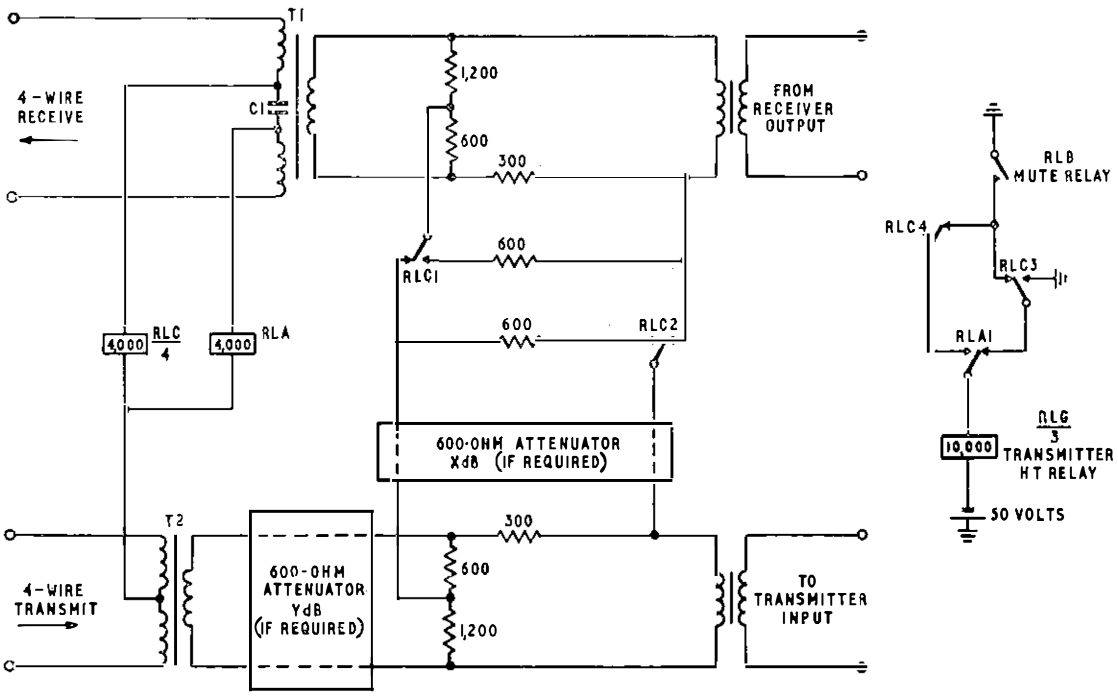

FIG. 7—Circuit diagram of a 4-wire base-station remote control panel.

formers at 4-wire base and control stations. The signalling circuit was rewired at all stations. A circuit diagram of the modified base-station remote control panel is shown in Fig. 7.

A resistance hybrid was designed to provide a switchable *talk-through* path from receiver output to transmitter input without teeing loss or mismatch. The insertion loss from receiver output to line or from line to transmitter is approximately 4·0 dB. The insertion loss from receiver output to transmitter input via the *talk-through* path is 19 dB. Encapsulated attenuators can be inserted as required to cater for local level requirements.

When the base station is switched to *talk-through*, the transmitter h.t. relay is under the control of the receiver mute relay. This modification was introduced to prevent overrunning the transmitter which is not rated for continuous operation.

Llanddonna Base Station

It was planned to provide an unmodified 2-wire remote control panel at Llanddonna, using a conventional terminating hybrid but the attenuation between Beaumaris exchange and Llanddonna was greater than expected and the high trans-hybrid loss required in the hybrid (38 dB) could not be achieved with a conventional balance network. Alternative solutions were examined and rejected because of line shortage and equipment accommodation problems. Therefore, a satisfactory balance termination was required for the hybrid at Llanddonna. The solution was the use of an identical 2-wire pair to extend the balance to Beaumaris exchange. This pair was already required to extend the exchange earth to the base station for protection purposes. A fixed balance resistor of 1,860 ohms at Beaumaris exchange raised the trans-hybrid loss to 50 dB which was more than satisfactory. The balance resistor was centre-tapped to the exchange earth for signalling purposes. The circuit arrangement is shown in Fig. 8.

Talk-through at Llanddonna is achieved by shunting the balance pair with a resistance selected on test to reduce the trans-hybrid loss to the required level.

Llangollen Base Station

The hilltop site at Llangollen is shared with the B.B.C. but, as it is not possible to share their building and mast accommodation, the base-station equipment is mounted within a modified cable-flexibility cabinet (see Fig. 9) and the aerials are mounted on a 20 m stout pole.

EXPERIENCE WITH THE SYSTEM

Occasional bursts of music have been picked up by the Llanddonna receiver. This was found to be due to signals from a Polish broadcasting transmitter being received at abnormally high levels. The phenomena has recurred several times, normally on bright, sunny days.

Co-channel interference has also been experienced at the Llangollen base station. This is from B.P.O. mobiles sharing the same frequency in Sheffield area. This condition can occur when transmission conditions are favourable and the interfering mobile is on high ground.

The system has proved itself capable of improving efficiency by saving time and trouble of the users, most of whom are now dependent upon the system.

FUTURE DEVELOPMENTS

Selector-level access to the network could be provided at, say, Bangor and Chester. This would, for example, permit communication from the public network to an external working party on emergency work after normal hours of

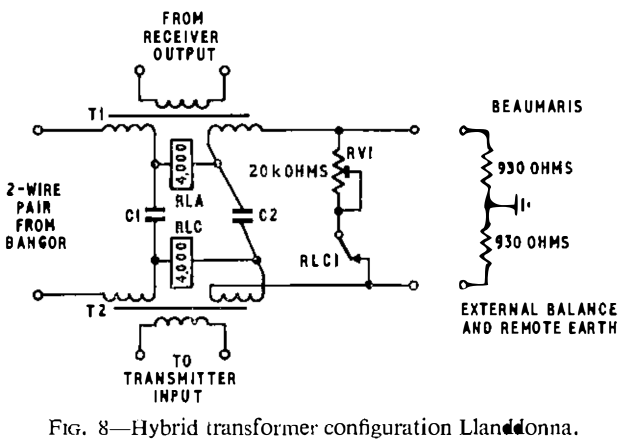

FIG. 8—Hybrid transformer configuration Llanddonna.

duty. It would be necessary to seek a relaxation of current license conditions for this facility to be permitted.

A selective calling system would overcome the present need to maintain a listening watch at the mobiles. Suitable systems are now available and could cost about £30 per mobile. Some care would be required in the selection in order to ensure that the signalling equipment circuits were compatible with the radio equipment.

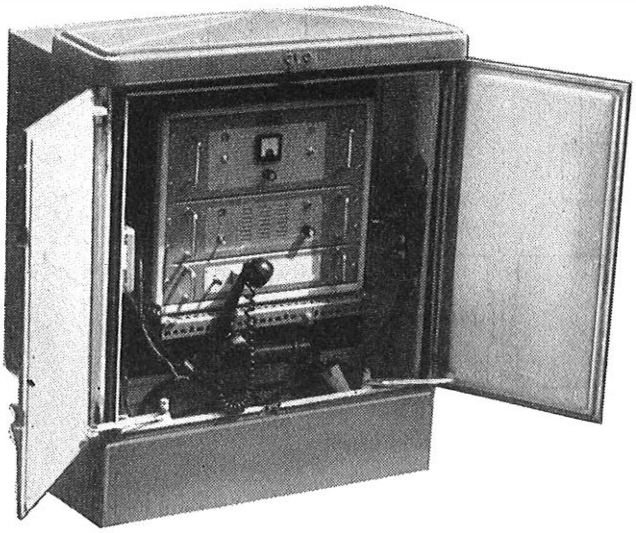

FIG. 9—Base station at Llangollen mounted in a cable-flexibility cabinet.

The increasing popularity of private mobile radio has resulted in a serious shortage of available channel frequencies. There is little prospect of further reducing bandwidth, below 12·5 kHz, in the near future.[3,4]

There have recently been considerable improvements in equipment designed for the u.h.f. band. Small pocket sets have been developed[5] which may be operated away from a vehicle. These would be useful in areas of restricted parking or for staff working on foot. Although the range of operation is shorter with u.h.f., the coverage of a built-up area is generally superior to v.h.f. It has recently been demonstrated that u.h.f. channel spacing could also be reduced to 12·5kHz.[6] This would, theoretically, double the number of channels now available, but owing to interference problems, full spectrum capacity is unlikely to be achieved in practice.

CONCLUSIONS

Economic and administrative advantages can be achieved by use of mobile-radio systems within the B.P.O. Owing to the mountainous terrain of Chester area the requirements of the system described are not typical, but they do demonstrate most of the difficulties likely to be met elsewhere.

Experience with the system has shown that a number of controls and base stations can be grouped together economically and efficiently on an omnibus system using largely unmodified radio equipment. However, some ingenuity is necessary in the line-transmission network design and two basic configurations are used, west and east. Variations on this concept could be adapted to other situations where coverage is required of more than one base station area or multiple controls, or both. The principle could also be applied to some physical omnibus circuits.

The transmission orientation is the reverse of conventional 2-wire–4-wire–2-wire amplified-circuit practice and the method used to obtain uniform modulation levels at base stations is an innovation peculiar to this system, at present.

ACKNOWLEDGEMENTS

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Book Review

"Mehrfachregelungen: Grundlagen einer Systemtheorie; Zweiter Band (Multivariable Control Systems: Foundations of a System Theory; Vol. 2)." Helmut Schwarz. Springer-Verlag, Berlin/Heidelberg. xi+456 pp. 193 ill. DM124.

This volume approaches the analysis and synthesis of control systems, with multiple inputs and outputs, by means of the state-variable model, an approach which, although applicable to dynamic systems in general, has been pioneered and developed by control theorists.

The general introductory chapter covers linear continuous-time and discrete-time systems with time-invariant or time-varying parameters, systems incorporating pure time delays and non-linear systems being treated briefly. A chapter on linear vector spaces and matrix functions deals with the more advanced mathematical concepts useful in the state-variable approach. The third chapter considers various special problems in analysis, such as, achieving an efficient realization when the system is specified by giving the rational transfer function from each input to each output and problems associated with stability, controllability, and observability are also considered. The last chapter deals with systems designed to be optimal according to various criteria and has a section on the Kalman-Bucy approach to linear filtering and prediction of random signals.

The book is suitable for university courses and for providing a sound theoretical background for practising engineers. There are a few references to physical structures, but the author makes it clear that he has confined himself to the essential principles and has not set out to give fully worked-out examples for particular physical realizations. Although this is undoubtedly an excellent textbook, it will interest only those with a knowledge of German, since most of the important work on control systems has come from the U.S.A., and material in English is readily available.

W. E. T.

Allocation of Radio Frequencies for Satellite Communication Services

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In order that communication by satellite may be planned for the future, it is essential that the use of the available frequency spectrum be controlled by international agreement. The frequencies allocated by the recent international conference permit the continuing use of presently-available bands and determine the bands in which research and development must be concentrated for the future.

INTRODUCTION

Ten years have passed since the first major satellite communication experiments were carried out, using Telstar and such pioneering earth stations as Goonhilly, and the use of satellites to relay long-distance circuits has become an accepted practice. In the early days, one of the major problems was to find adequate frequency bands for this newcomer in a radio spectrum that seemed already crowded with terrestrial services. The problem was tackled at a conference of the International Telecommunications Union (I.T.U.) which was held in Geneva in 1963. The agreed solution was for the space services to share certain frequency bands below 10 GHz with terrestrial services, chiefly microwave line-of-sight radio-relay systems. These arrangements, and the procedures laid down to facilitate frequency-band sharing, have worked remarkably well, but it has been evident for some time that space radio services must soon outgrow the framework set up in 1963 if their development is not to be impeded. Many new facilities are needed.

Another I.T.U. conference met recently to provide a framework of international regulations for the development of space radio services during the next ten or twenty years; this World Administrative Radio Conference for Space Telecommunications (WARC-ST) met in Geneva between 7 June and 16 July 1971. Provision was made for the expansion of existing services and for the introduction of many new ones. Some of these services, such as radio astronomy and satellite broadcasting, are of little direct concern to the British Post Office; others are of great interest and these are reviewed in this article. The new provisions come into force on 1 January 1973.

FIXED-SATELLITE SERVICE

First come the new provisions for the communication-satellite service for fixed earth stations, now to be called the *Fixed-Satellite Service*.

New Frequency Bands for Use in the Near Future

New frequency bands have been allocated as follows:

(*a*) 10·95–11·2 GHz, 11·45–11·7 GHz and 14·0–14·5 GHz. The first two bands are to be used for the downward links, satellite to earth station, and the third band is for the upward links. Equipment for use in this part of the spectrum is already under development, and these bands are likely to be taken into use for inter-continental and regional services in the mid-to-late 1970s, to relieve pressure on the 4 and 6 GHz bands, which are already in use. The 10·95–11·2 GHz band may also be used for upward links in I.T.U. Region 1 (i.e. Europe, U.S.S.R.-in-Asia, Middle East, and Africa), and one possible such use is for signal feeds to broadcasting satellites. All of these bands will be shared with terrestrial services.

(*b*) 12·5–12·75 GHz. This frequency band has been allocated world-wide for the Fixed-Satellite Service, but there are differences in the permitted manner of use in different parts of the world. For most countries in Region 1, it is allocated exclusively for the space service and may be used for either direction of transmission; this band should prove to be of great value for services to low-capacity small earth stations, in locations, like city centres, where interference would render impracticable the use of a band shared with terrestrial services. In Region 2 (North and South America) the band may be used for upward links only, and is shared with terrestrial services. In Region 3 (Asia exluding U.S.S.R. and the Middle East and Australasia) it is also shared with terrestrial services but it may be used for downward links only.

(*c*) 17·7–21·2 GHz and 27·5–31·0 GHz. The first of these bands is to be used for downward links, and the second for upward links. The lower 2·0 GHz of each band is to be shared with terrestrial services, and the remainder is to be exclusive to the space service. Very directional antennas are physically small at these high frequencies and can be mounted on quite small satellites. These bands are capable of accommodating communication systems of very large traffic capacity. Unfortunately, radio propagation conditions deteriorate as frequency rises and it may be costly to overcome this relative disadvantage. For this reason, it may be doubted whether these bands will be taken into regular commercial service before the end of the decade.

New Frequencies for Future Development

Additional frequency bands were allocated for the Fixed-Satellite Service at even higher frequencies, higher indeed than had ever been allocated for any radio service (i.e. above 40 GHz). These bands were as follows:

40–41 and 50–51 GHz
92–95 and 102–105 GHz
140–142 and 150–152 GHz
220–230 GHz
265–275 GHz

These frequencies have been chosen to avoid parts of the spectrum near 60, 120 and 180 GHz where attenuation in the atmosphere due to molecular resonances is particularly high; nevertheless, absorption will be substantial under clear-sky conditions and severe when cloud or precipitation is present. It may be doubted whether these frequencies will come into commercial service within 10 or even 20 years, but these allocations will serve the very useful purpose of concentrating equipment and system development on particular bands, to prepare the way for use when the bands below 40 GHz are fully loaded.

Frequencies for Use in Remote Areas

Finally, two narrow frequency bands (2,500–2,535 and 2,655–2,690 MHz) have been allocated for the Fixed-Satellite

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Service but only in Regions 2 and 3, and a third band, 11·7–12·2 GHz is limited to Region 2. The 2·5 GHz bands are intended for use in remote areas, where small, cheap earth stations might be used to link isolated communities, say in Canada, Alaska or Australia, with the outside world. The 12 GHz band is limited to down-links for domestic systems. All these bands are to be shared with terrestrial services.

The WARC-ST also revised the sharing criteria and co-ordination procedures which had been laid down by the 1963 conference for use where a frequency band is allocated for both space and terrestrial services, and extended them to cover the newly-allocated shared bands. Exceptionally, criteria were not determined for the band 14·0–14·4 GHz, where a fixed-satellite up-link band shares with the radionavigation and radionavigation-satellite services; the problem was referred to the C.C.I.R.* and should be resolved at the next Plenary Assembly, in 1973.

MARITIME MOBILE SERVICE

The other space-radio service with which the Post Office is directly involved is the service to ships. A new service definition, the Maritime Mobile-Satellite Service[1], was laid down and frequency bands were allocated for it, as follows:

(*a*) 1,535–1,542·5 MHz and 1,636·5–1,644 MHz. The first band is to be used for downward links and the second for upward links. (In addition, two adjacent bands, 1,542·5–1,543·5 MHz and 1,644–1,645 MHz may be used by satellites serving either ships or aircraft). The object of these shared bands is to cater, for example, for joint search and rescue facilities for the aeronautical and maritime services. It seems likely that satellite communication services to ships, using these bands will be in commercial operation within five or ten years.

(*b*) 157·3125–157·4125 MHz and 161·9125–162·0125 MHz. These two frequency bands have been earmarked for a safety and distress service using satellites. They correspond to four duplex channels, Nos. 86, 27, 87 and 28, of the present v.h.f. International Maritime Radiotelephony Service. If these bands were used for satellite services, the operating plan of the service would have to be rearranged to clear these channels and it has, therefore, been decided to refer the matter to the next I.T.U. Maritime Conference (1974).

(*c*) Another band, 406·0–406·1 MHz, has been reserved for a low-power emergency position-indicating radio-beacon system using space techniques that could serve both ships and aircraft. These allocations, lower in frequency than the main communication bands near 1,600 MHz, will be technically more suitable for use in small ships and survival craft; unfortunately, it was not possible to allocate sufficient bandwidth in this part of the spectrum for regular communication services to ships.

The following frequency bands have also been allocated for Mobile-Satellite Services, including services to ships:

43–48 GHz
66–71 GHz
95–101 GHz
142–150 GHz
190–200 GHz
250–265 GHz

The use of such high frequencies poses many different problems, technical and economic, and it may be doubted whether they will be used by the merchant navy in the near future.

INTER-SATELLITE SERVICE

The following frequency bands have been allocated for direct links between one satellite and another, regardless of the kind of service which the satellites provide:

54·25– 58·2 GHz
59·0 – 64·0 GHz
105·0 –130·0 GHz
170·0 –182·0 GHz
185·0 –190·0 GHz

These frequencies are located in parts of the spectrum where signal absorption by atmospheric gases is particularly high, due to molecular resonances. This will ensure that there will be little danger of interference between space and terrestrial services if a later I.T.U. conference should decide to allocate the same frequencies to terrestrial services also. The commercial application of inter-satellite links may be some way off, as yet, but experimental work is to begin with the Applications Technology Satellite, Series F(ATS F) satellite, to be launched in 1973.

PREVENTION OF INTERFERENCE BETWEEN SPACE SYSTEMS

The prospect of significant interference between satellite systems, remote in 1963, had become quite real by 1971 and precautions must be taken to control it. The requirement of the earlier conference for the advance publication of information on future systems has now been elaborated into a procedure to optimize the utilization of the geo-stationary orbit, in which most satellites will be placed. There will be three phases in the registration of a proposed new geo-stationary system:

(*a*) An administration planning to set up a new satellite system is required to publish preliminary details through the I.T.U. some years ahead of the start of service. This will give other administrations an opportunity to see whether their own systems, in service or planned, could be affected by the new system.

(*b*) Discussions are held between administrations concerned in order that the characteristics of the various systems, such as operating frequencies, satellite location, service areas and modulation parameters, may be adjusted so as to reduce potential interference to an acceptably low level.

(*c*) Technical details of the new system, agreed by the various interested parties, are registered by the I.T.U.

To provide a firm technical basis for these negotiations, the WARC–ST laid down certain technical standards for geo-stationary satellites. Satellites must be designed so that:

(*i*) they can, if necessary, be kept at their nominal orbital station within $\pm 1\cdot 0°$ in longitude, and

(*ii*) the direction of maximum antenna gain can be maintained, if necessary, to within ± 10 per cent of the beamwidth, relative to the nominal position, or $\pm 0\cdot 5°$ if that is greater. This does not apply to antennas which serve the whole visible earth.

These requirements are within the present state of the art, but it will contribute significantly to the efficient use of that unique resource, the geo-stationary orbit, if all satellites can achieve them.

CONSEQUENTIAL CHANGES IN TERRESTRIAL SERVICES

The new frequency allocations for space services could not be made without some consequential changes in the allocations for terrestrial services. The new allocations which bear on Post Office plans for line-of-sight radio-relay services are mainly those between 10 and 13 GHz and those in the vicinity of 20 GHz. When the details of the changes have been fully worked out, it is unlikely that the repercussions of the WARC–ST upon Post Office terrestrial services will be serious.

* C.C.I.R.—International Radio Consultative Committee.

Reference

1 POPE, D. G., Prospects for a Maritime Satellite Communication Service (in this issue).

Terminating External Cables in Telephone Exchanges

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The methods of terminating external cables in telephone exchanges have changed as the cables themselves have changed and as works practices have altered to take advantage of new materials and techniques. Current developments are reviewed and future trends examined.

INTRODUCTION

External cables which provide telecommunications links between telephone exchanges, or between customers and telephone exchanges, are extended into the exchange buildings up to a point which may be regarded as the interface between the external and the internal cabling; this point is the main distribution frame (m.d.f.). It provides a means of terminating both external and internal cables in such a way as to allow for the growth of both to proceed separately as determined by the relevant economic and engineering factors: it provides a means of cross-connecting any point on the *line* side (the external side) to any point on the *exchange* side (the internal side) and a convenient point for the insertion of protective devices and for obtaining access for isolating and testing purposes. The m.d.f. is the point at which a cable pair carrying a circuit changes its identity; on the line side it is identified with the cable in which it is contained (e.g. it is given a cable-pair number); on the exchange side it is given a circuit number, e.g. a customer's telephone number.

MAIN DISTRIBUTION FRAMES

With the integral type of m.d.f., which was standard for many years, the construction was such that when ironwork was provided to increase the accommodation on the line side it automatically increased that on the exchange side also. An m.d.f. of this design is now known as the pre-rack type and is illustrated in Fig. 1. The rack type m.d.f.[1], which is the current standard, is designed so that the ironwork portion of one side can be erected independently of its counterpart. Fig. 2 shows a typical rack-type m.d.f.

Cable pairs are terminated on fuse mountings fitted to the vertical bars on the line side of the m.d.f. It was usual to fit 11 fuse mountings to each vertical of the pre-rack type and the lowest was normally used for trunk and junction circuits, the remaining 10 being used for terminating local cables. On rack-type m.d.f.s a maximum of 10 fuse mountings is provided on each vertical. With some exceptions, a notable one being London Telecommunications Region, the primary identification of the cable pairs of local distribution cables is by reference to the vertical bar on which the cable is terminated. The vertical bars are usually identified with labels marked in an alphabetic series, i.e. A, B, C, . . . AA, AB, AC, . . . etc., and the pairs are usually identified numerically from the top of the bar to the bottom. A label or signwriting on each fuse mounting indicates the group of pairs terminated on it.

In the exceptions referred to above, the primary identifica-

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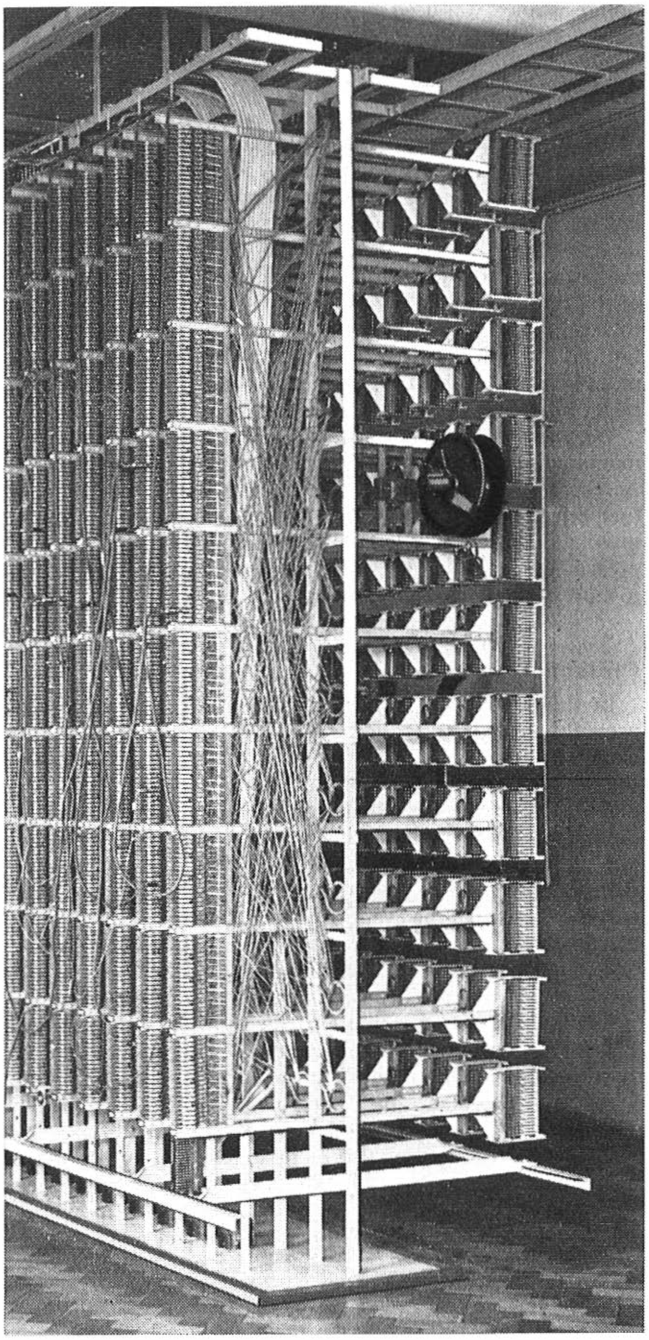

FIG. 1—Pre-rack type m.d.f.

tion of the pairs for customers' circuits is by reference to the main cable in which the pairs are contained. Trunk and junction pairs are always identified by reference to the cable in which they are contained. Labels or signwriting on each fuse mounting indicates the appropriate main-cable code and the group of pairs terminated on it. Trunk and junction pairs terminated on the lowest fuse mounting of each vertical bar of pre-rack frames were often cabled so that the fuse mountings were in a horizontal group.

Fuse Mountings

The actual point of termination of an external cable pair is on a fuse mounting fitted on the line side of the m.d.f. and, normally, the conductors are soldered to tag-extensions of the fuse-retaining springs. Up until 1962, fuse mountings were designed to accommodate 20 pairs, i.e. 40 fuses, and two such types in common use were the British Post Office (B.P.O.) Nos. 4001 and 4028. The 4001 was used primarily for terminating local cables and the 4028, because of its superior insulation resistance, was used initially for trunk and junction cables only. Latterly, however, the 4028 was used for all classes of circuit. When used for trunk and junction work it was normally enclosed in a protective metal cover.

The current standard fuse mounting is the B.P.O. No. 8064 (A or B) which accommodates 40 pairs. It comprises a stack of 20 mouldings clamped together by two screwed rods. Each moulding, known as a *biscuit*, accommodates two pairs and has springs to hold the fuses on one side and connexion tags for cable pairs and jumpers on the other. The A-type fuse mounting is provided with a triangular mounting plate to enable it to be fitted to pre-rack m.d.f.s.; the B-type is designed to be fitted to the modern rack-type m.d.f. by means of its bottom clamping plate. Introduction of this type of fuse mounting has doubled the number of cable pairs which may be terminated on each m.d.f. vertical.

With the use of modern materials in its construction the manufacturing costs of the fuse mounting have been kept low. A recent value analysis report suggests that costs could be further reduced if a single moulding was used instead of the present 20 separate biscuits. This might also overcome the present tendency for the fuse mounting to bow due to distortion in the individual biscuits.

Protective Devices

In the past, three forms of protective device[2] have been provided on the m.d.f. On the line side, a fuse was inserted in each conductor of each pair by means of spring clips fitted to the fuse mounting. On the exchange side, spark-gap electrodes and heat coils were provided on the arrestor strip between the exchange equipment and the jumper to the line side. The spark-gap electrodes were intended to protect the equipment from damage due to lightning discharge and the heat coils earthed the line in the event of a current overload. Spark-gap electrodes and heat coils have been dispensed with in exchanges because, since very few lines are now carried for any distance by open wires, the risk of damage occurring is negligible. Protection is now provided for any long overhead lines at the customer's premises and at the distribution pole. In the exchange, the arrestor has been replaced by a connexion strip having contact springs through which access can be obtained for testing.

Access for testing can also be obtained by inserting special test clips in the fuse mounting in place of the fuses. The fuses used are of the quick-acting spring-loaded type although the continuing need for fuses of any kind is under review.

CABLES

With the exception of small local distribution cables containing up to 100 pairs (B.P.O. Cable Polythene Twin), paper

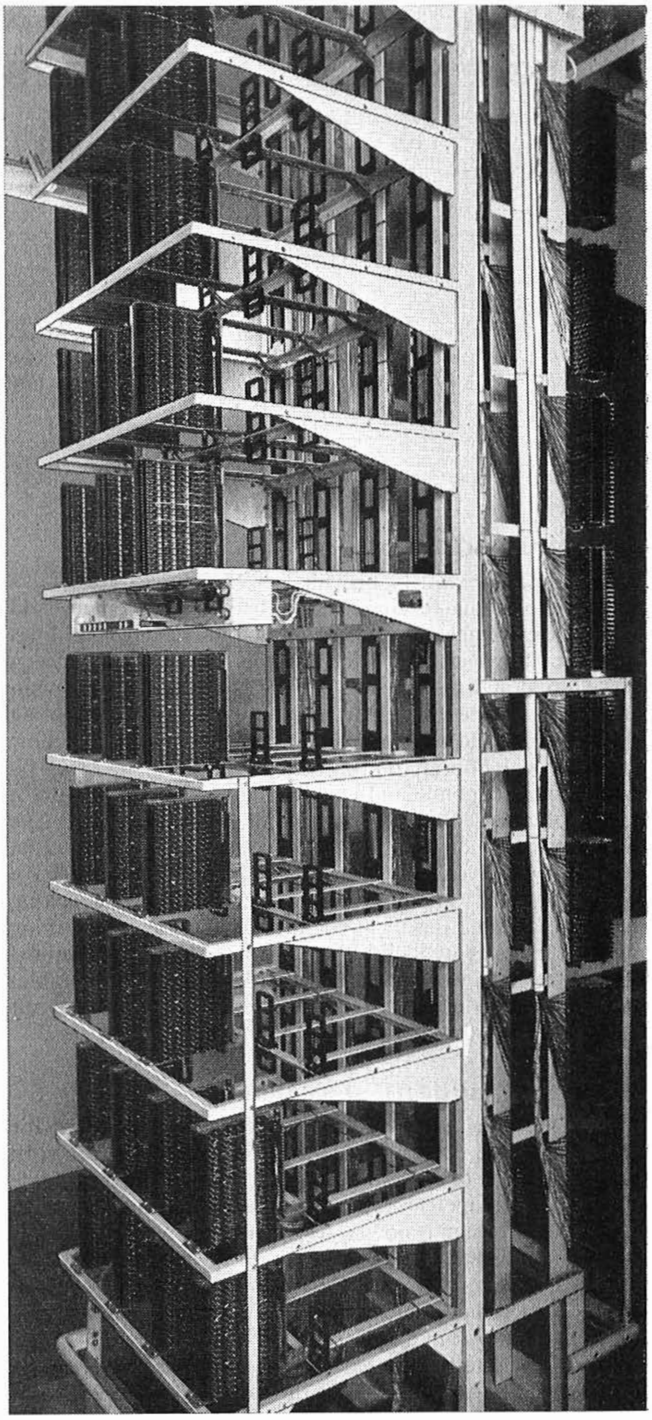

FIG. 2—Rack-type m.d.f.

is used to insulate the conductors of most external cables because it is cheap. It is not, however, a suitable material for insulating conductors which have to be terminated on the m.d.f. because it is not sufficiently robust and its insulation resistance is unstable when in the open atmosphere. Because of these limitations, it is necessary to joint on, to a paper-insulated cable, a short length of cable which is suitable for termination. One type of cable, which was manufactured exclusively for this purpose, had enamelled-copper conductors in quad formation lapped with silk and wool, was impregnated with wax and sheathed with lead (Cable E.S. & W.C.Q.). A later type (Cable P.V.C. No. 7) had p.v.c.-insulated tinned copper conductors and was also sheathed with lead. Such terminating cables were provided in pair sizes which corresponded with those of the standard sizes of external cable except that the maximum size of terminating cable was

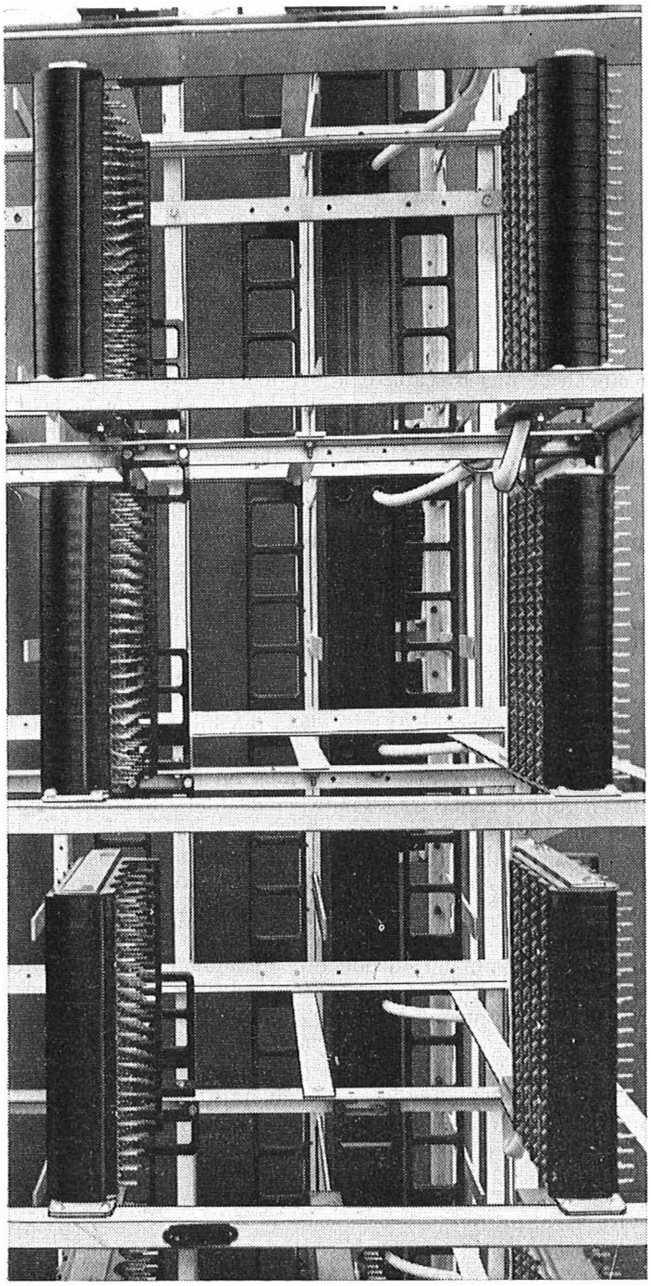

FIG. 3—Rack-type m.d.f. showing trunking

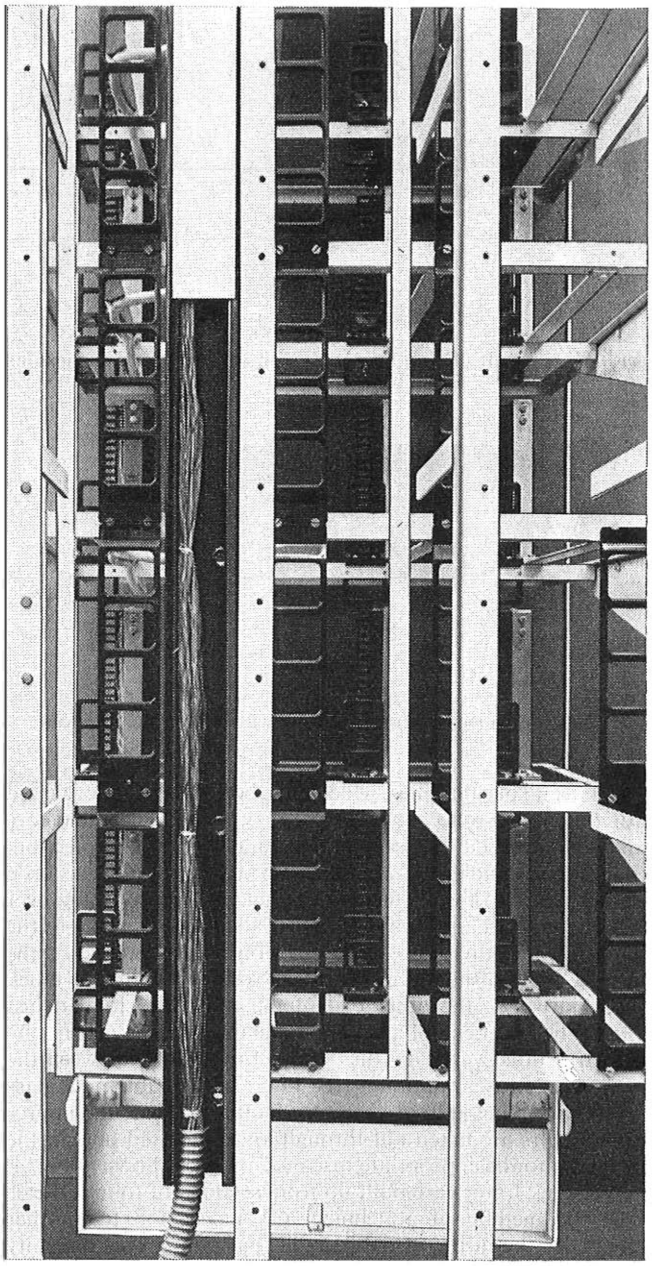

FIG. 4—Rack-type m.d.f. showing fuse mountings and cable pairs being brought out from trunking

200 pairs (latterly 400 pairs), the normal capacity of a m.d.f. vertical bar. The small polythene-insulated distribution cables are terminated directly on to the m.d.f.

The present practice with paper-insulated external cables is to joint them to a full length of the corresponding size of polythene-insulated and polythene-sheathed cable which is then terminated on the m.d.f. Cable Polythene Unit Twin is used in this way for terminating local cables and Cable Polythene Quad No. 5 for trunk and junction cables. The core of the terminating cable is divided into groups of the same size as the capacity of the m.d.f. verticals. The conductors are normally the same gauge as that of the external cable. Cable Polythene Quad No. 5 is soon to be made with 0·5 mm ($6\frac{1}{2}$ lb/mile) conductors instead of 0·63 mm (10 lb/mile) as hitherto.

Protecting Cables on the M.D.F.

Plastic-insulated cables terminated on m.d.f.s are liable to accidental damage, particularly thermal damage such as by contact with hot soldering irons or splashes of solder. The early practice of lacing the cable-forms with twine does not provide protection from thermal hazards or from the simple mechanical damage to which the modern small-diameter, thin-wall, polythene-insulated cable is vulnerable. Cable forms are sometimes lapped with adhesive p.v.c. tape for additional protection but it is often difficult to carry out this operation, it is time-consuming, and, after a time, traces of adhesive on the exposed surfaces of the tape gather dust and the cable forms become unsightly as a result. Lappings of tape are also used to support the cable forms on the ironwork members. At the supporting positions, the ends of the tape tend to become detached from the lapping, reducing the effectiveness of the support and, again, appearing unsightly.

There is an increased protection problem with the large (over 400 pairs) polythene-insulated cables which are now being terminated. It is common practice to remove the sheathing of such cables at a point near the m.d.f. (e.g. in the cable trench) and divide the core into suitably-sized groups which are then taken away to the appropriate vertical for termination on the fuse mountings. (This procedure avoids the need for a break-down joint and the point of division of the core is a suitable place to install a pressurization air-

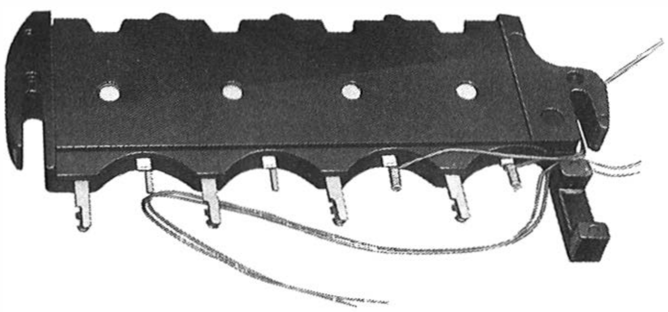

FIG. 5—Segment of fuse mounting with wire-wrapped connexions

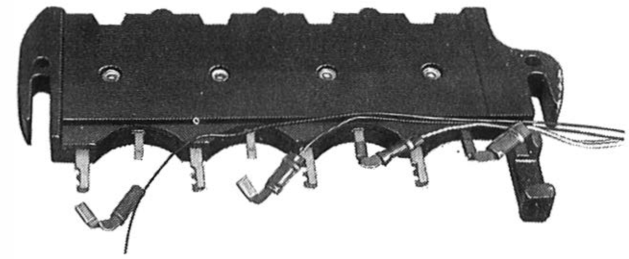

FIG. 6—Segment of fuse mounting with snap-on connectors

block using plastic cones, which have been specially developed for this purpose, to contain the epoxy resin.) The cable core may be exposed for several feet and requires protection. Lapping with adhesive tape could be provided but it has been found better to thread flexible, corrugated, p.v.c. tubing over each group of pairs from the foot of the m.d.f. vertical to the point of core division. At the division point, the end of the tubing is encapsulated in the epoxy resin when the air-block is constructed; the other end of the tubing is situated just inside the lower end of a length of rectangular plastic trunking which is fitted vertically on the m.d.f. ironwork between the columns of fuse mountings (see Fig. 3). The cable pairs pass up the trunking and, at each fuse-mounting level, the appropriate pairs are taken out through a grommetted hole in the trunking to the appropriate fuse mounting, as shown in Fig. 4.

Pre-rack frames are built up from sections of four verticals and the method of attachment of one section to another precludes the fitting of trunking at that point. This difficulty can be overcome by fitting double-size trunking in alternate vertical spaces so that one trunking serves two verticals. This arrangement suits the termination of local cables because these are normally large enough to take up the capacity of a complete vertical and, thus, only two groups of cable pairs need to enter the lower end of the double-size trunking. The size of the trunking must be limited so that it does not cause undue obstruction of the m.d.f. for jumpering and other operations. This limitation makes it difficult to accommodate trunk and junction cables because these are usually smaller than local cables and the resulting discrete groups of pairs take up more space than the same number of pairs in a single group. A solution to this problem is still being sought; one possibility is to provide a flared skirt at the lower end of the trunking because it is at this point that the difficulty arises, disappearing towards the upper end as the pairs are taken out to fuse mountings.

Terminating the Conductors

It has always been standard practice to terminate cable pairs on the fuse mountings strictly in accordance with the colour scheme of the cable so as to form a numerical sequence running, usually, from the top to the bottom of the vertical bar. This entails identification of each cable pair by means of numbered collets and, usually, by means of an electrical continuity test before the wires are actually terminated. This procedure, which is very time-consuming, was found necessary because it was difficult to follow the colour scheme of the cable when forming out the groups of pairs to serve each fuse mounting.

It would clearly speed up termination work if no preliminary identification of pairs was necessary, the pairs of each unit being terminated in a random order after being formed out in the neatest and most convenient manner to suit the circumstances. To gain any advantage from random terminating, a means of rapidly identifying the cable pairs and marking them in the vertical-bar sequence is necessary. This need can be met by cable-pair identification equipment[3] with a digital display which has been developed and is now on field trial. The trial includes the use of the equipment on schemes where random termination and jointing are being employed.

For transmission reasons, it is very important (particularly in randomly-terminated schemes) that the cable pairs are not split when terminated. The core of a modern polythene-insulated cable tends to fly apart when the sheath is removed. If the core is not securely trapped it is very likely that the pairs will become untwisted and split-pair terminations could result. The springiness of polythene-insulated pairs is a common feature but long lays of the twisted pairs contribute to the untwisting problem. In the past, lays of 375 mm have been seen in some cables but now a maximum lay length of 125 mm has been included in the cable specifications.

When making soldered connexions on fuse mountings a fair amount of care is necessary when dealing with conductors with thin-wall polythene insulation. There is a great tendency for the insulation to melt and run back and it is easily damaged by accidental contact with a hot soldering iron or solder splashes. A method of making the connexions which did not require the use of heat would greatly reduce the risk of damage. With the introduction of aluminium as a conductor material[4] the need for an alternative method of connexion has become more urgent. Aluminium oxidizes quickly when exposed to the atmosphere and cannot, therefore, easily be soldered. Any new method of making connexions also needs to be suitable for copper conductors, particularly those of 0·32 mm diameter which are now coming into general use.

Wire Wrapping

Wire-wrapping techniques have been in use for a number of years for the termination of internal cables[5, 6]. These cables have tinned-copper conductors with a fairly thick-walled p.v.c. insulation and the elongation of the conductor before breaking is of the order of 10–15 per cent. This enables them to withstand the force which must necessarily be applied to cut, strip and wrap the conductor in a single operation. Aluminium conductors have an insulation thickness of 0·15–0·2 mm and an elongation before breaking of only 1–2 per cent. If such a conductor is drawn through a wrapping tool head to strip the insulation the surface tension of the conductor may be destroyed. With elongation so low, if the surface tension is broken the conductor is liable to break also. Wrapping heads are available for aluminium but the conductor has to be cut and stripped first which detracts from the economic advantage of having a tool which will cut, strip and wrap in a single operation. Nevertheless, some success has been achieved in this direction. The use of an aluminium alloy which has an elongation similar to that of copper is being investigated and this, it is hoped, would go some way towards solving the problem.

It has been said earlier that aluminium oxidizes rapidly when exposed to the atmosphere. If this oxide film were present between the adjacent faces of conductor and tag a high-resistance connexion would result. Since a wrapped connexion means having an exposed length of conductor round a tag one might wonder how such a situation could be tolerated. It can be, because the basic principle of wire wrapping is that the points of contact in the joint are gas-tight and, thus, oxidization cannot occur. It is because the wrapping tool has to lay the conductor round the tag with sufficient force to achieve this that the conductor is liable to be broken.

There are, at present, no defined standards of acceptability for aluminium wire-wrapped connexions. The matter is currently under investigation in the B.P.O. and standards will need to include contact resistance, pull-off tension and the ability to unwrap the conductor without it breaking. Initial results achieved with various types of wrapping head show a contact resistance of about 4 milli-ohms with a pull-off tension of about 44 N. Tags of differing sizes are included in the assessment in order to determine the optimum cross-section. Fig. 5 shows wire-wrapped connexions on a fuse-mounting biscuit.

It is not possible, at the present time, to use wire-wrapping techniques on small-gauge polythene-insulated conductors because of the adhesion between the polythene and the conductor which occurs when the insulant cools after extrusion. The degree of adhesion varies along the conductor length. The wrapping tool has to overcome this adhesion before it can strip the insulation off and the force required often exceeds the breaking strain of the conductor. This is an unsolved problem which needs to be overcome before wire wrapping can be considered satisfactory for 0·32 mm and 0·4 mm conductors which make up the vast majority of line-side terminations on the m.d.f.

Snap-on Connectors

The use of snap-on connectors is another possibility that is being investigated. These are specially-designed terminals that are crimped on to the ends of the conductors, the other end being a snap-on fit to a tag on the fuse mounting (see Fig. 6). So far, the success of crimping on to single 0·5 mm aluminium conductors has been very limited. The connector has to be very small because of lack of space on the fuse mounting and so there is little scope for varying the position of the tines which pierce the insulant and make contact with the conductor so that they do not cause the conductor to break. The pressure applied to the crimping tool has to he rigidly controlled and this means an expensive tool which renders the technique less financially attractive. Nevertheless, this avenue is still being explored.

FUTURE TRENDS

Another possible future development is the termination of petroleum-jelly-filled cables[7] on the m.d.f. Petroleum jelly is introduced to prevent the ingress of moisture should the cable sheath become fractured. The addition of the jelly was found to degrade the mutual capacitance between the pairs and, in order to restore this parameter to the same value as for non-filled cables, cellular polythene was adopted as the conductor insulation[8]. These two new features bring problems of their own. Handling a jelly-filled cable can easily lead to contamination of the m.d.f., its equipment and the surrounding floor. If the jelly is not completely removed it attracts dust which could be a future cause of trouble. Also, cellular polythene is not so robust as solid polythene and it requires more careful handling.

The spread of the petroleum jelly is aggravated by the incompatibility between the capacity of the fuse mounting and the make-up of the cable. Although fuse mountings accommodate 40 pairs, the basic unit in a unit-type cable is 25 pairs and this results in a high degree of cable-core division to make up 40-pair groups of pairs to be taken to the individual fuse mountings. The adoption of a 50-pair fuse mounting would correct this but the arrangement of cable on each m.d.f. vertical would need further consideration. It would have to be decided whether the capacity of each vertical should remain at 400 (i.e. 8×50) pairs or whether it should be increased to 500. If the former were adopted it would mean a redesign of the m.d.f. and if the latter, the vertical capacity would no longer be a sub-multiple of the cable size as it generally is now.

An experimental cable scheme is being carried out which includes the installation of a prototype 50-pair fuse mounting. These have been fabricated from the 40-pair type but the thickness of each biscuit has been reduced with suitable adjustment to the contact springs. Considerable design work would be required before a 50-pair termination could be produced in quantity.

Mention was made earlier of randomly-terminated cables using cable-pair identification equipment and ignoring the colour scheme completely. If this is acceptable, it is feasible to consider a terminating cable with unit markings only. The use of random termination would reduce the need to handle the cable pairs and so further lessen the risk of contamination by petroleum jelly.

A number of branches in Telecommunications Headquarters are interested in the design and facilities provided by the termination and the development work will be a co-operative effort. Compatibility between the external cable and the termination would lead to worthwhile savings and seems essential if jelly-filled cables are to be terminated.

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Prospects for a Maritime Satellite Communication Service

D. G. POPE, C.ENG., M.I.E.E., M.I.E.R.E.†

U.D.C. 621.396.946: 621.3.029.62

During 1971, an allocation of frequency bands for a maritime-satellite service was made for the first time. This allocation followed a period of study and tests which showed the technical feasibility of a maritime-satellite system. Before a service can be set up, however, it is desirable that international agreement be reached on the technical characteristics of the system to be adopted. In this article, some of the key factors in choosing these characteristics are discussed.

INTRODUCTION

At the World Administrative Radio Conference for Space Telecommunications (WARC–ST) 1971, an allocation of frequency bands[1] was made for the first time for the maritime-satellite service. The principal allocations, consisting of two exclusive bands, each of 7·5 MHz, plus two 1 MHz bands shared with the aeronautical satellite service, were made in the so-called L-band between 1,535 and 1,660 MHz.

These allocations came after studies and tests had been carried out by some of the principal maritime nations, including the United Kingdom, to determine the feasibility and economic viability of a maritime-satellite service. The result of this work showed the undoubted technical feasibility of a satellite system but an assessment of the economic aspects was rather more difficult. No attempt is made here to determine probable tariffs; these would be determined by market survey of potential demand, by the characteristics of the future system and on the cost of establishing and maintaining the system. Some broad comments on the order of costs may, however, be appropriate.

To cover costs, tariffs charged initially would probably have to be higher than those in force, at the time, for services using conventional media. On the other hand, the present h.f. services[2], in spite of efforts to avoid it, are steadily deteriorating because of increasing congestion. This deterioration would accelerate if a scheme of concessionary calls to ships' crews (at present under consideration by some Scandinavian shipping companies, to aid recruitment of seamen) became general practice, because this could increase demand by a factor of 5 to 10. The present service would not be capable of meeting such a demand.

Thus, although charges for a service using satellites might be higher, at least initially, the improved quality of service and the wider range of services possible might compensate to a large extent. In the later phases, when the majority of the world's shipping was converted to the satellite system, it would be more efficiently used and this would be reflected in the charges made. Automation of the service to ships would enable the Radio Officer to be released from watchkeeping duties; this would result in considerable saving.

In view of the increasing congestion, there is a need to consider the detailed planning and provision of a maritime-satellite service. Such a service is inherently international and an international body needs to be formed having the authority to manage, finance and control it. This body would establish operational and technical standards, and plan and provide successive phases of satellites as they became necessary. A model for such an organization is INTELSAT which performs these functions for the point-to-point satellite-communications system at present in use.

The organization of an international service may take considerable time and is likely to be complicated by the mixture of commercial interest in the ship terminals and that of telecommunications administrations in the space sector and the shore-based terminals. Further time must be allowed for the development and construction of suitable satellites and of equipment for the ship and shore-based terminals. It seems unlikely, therefore, that the establishment of a fully-operational service will take place much before 1978.

Useful experience may be gained before an operational system becomes available by making use of suitably-equipped experimental satellites such as the Applications Technology Satellite, Series F (ATS–F) planned by N.A.S.A.* for launch in early 1973 or by making temporary use of spare capacity in any other suitably-equipped satellite.

Maritime nations such as the U.K. need to develop and test equipment for a maritime-satellite service so that a firm basis of experience can be used when discussing technical standards internationally. Some preliminary maritime-satellite tests have been conducted by a number of countries, using frequencies around 160 MHz, and an outline of the U.K. tests follows.

UNITED KINGDOM MARITIME-SATELLITE TESTS

During the second half of 1970, a series of maritime-satellite tests were conducted by the Post Office, the Home Office, the University College of Swansea, radio manufacturing and operating interests, and shipping interests. The Cunard-Brocklebank container ship *Atlantic Causeway* was equipped to operate at v.h.f., via the N.A.S.A. experimental satellite ATS–3, to Burnham Radio Station.

A choice of two manually-controlled crossed-yagi aerials,

† Telecommunications Development Department, Telecommunications Headquarters.

* National Aeronautical and Space Administration (U.S.A.).

having half-power beam-widths of 40° and 60°, was available. The ship was roll-stabilized and, although roll did not normally exceed 5° at cruising speed, the pitch was often of the order of 10–12°. The beam-widths of the aerials were adequate for these movements and the system as a whole had a performance that came close to that expected from theory. The systems tested—telephony, direct-printing telegraphy (telex), facsimile and selective calling—performed well and tests of speech processing when using narrow-band frequency modulation gave sufficiently encouraging results to justify further work to refine the system.

On the whole, the exercise gave a valuable insight into the problems that can be expected in a maritime-satellite system and the experience should provide a firm foundation for any future tests that may be required.

SERVICE REQUIREMENTS

A properly-designed maritime-satellite system would provide virtually fade-free links capable of carrying a number of communications facilities, examples of which are:

(*a*) consistently good-quality telephony, adequate for connexion into the inland network,

(*b*) direct-printing telegraphy, giving access to the inland telex networks,

(*c*) provision of news services, entertainment and educational material,

(*d*) facsimile for the transmission of weather maps,

(*e*) data transmission, and

(*f*) selective calling.

Provision of teleprinters and selective-calling systems would open up the possibility of automating telegraphic communications to ships in the same way that teleprinter messages can be sent to unattended offices. This would release the Radio Officer from watch-keeping duties and enable him to take over the essential servicing of the complex electronic equipment on board the ship in addition to that in the radio room. On many ships the need to employ an electronics officer for these duties is becoming urgent and the conversion from Radio Officer to Electronics Officer appears to be a natural step. Saving in the costs of an additional officer would be around £5,000 a year for pay, training, accommodation and subsistence. On the smaller ships, which normally make very few calls each year, this saving would more than offset the higher costs of calls made via the satellite system.

It is assumed that adequate facilities for dealing with distress calls will be provided during the transition period when a mixture of satellite and terrestrial systems is in operation. If and when maritime communications are provided exclusively by satellite a speedy and efficient means of alerting shore-based search and rescue stations could be provided and these, in turn, would alert ships known to be in the vicinity of any distressed vessel.

SATELLITE ORBITS AND COVERAGE AREAS

Ideally, continuous coverage of the globe up to latitudes of about 80° North and South would be desirable, to cover the normal trading routes and the areas where deep-sea fishing vessels operate. There are many satellite orbit configurations which would give this coverage but most have the serious drawback that the satellite moves relative to an observer on the earth's surface. For instance, a series of satellites in polar 24-hour orbit will give full global coverage but the satellites appear to move in either a North-Westerly or South-Westerly direction at an angular velocity of about 20° per hour over most of the more densely-used shipping areas. This relative movement would lead to difficulties in establishing communication by a ship, unless an insensitive omni-directional aerial were used, to switching difficulties as one satellite sets below the horizon and a new one appears over the horizon at a different azimuthal angle, and to Doppler effects from the continuously-varying range between satellite and ship.

Satellites in the geo-stationary orbit, i.e. an equatorial orbit at 22,300 miles above the earth's surface, are virtually stationary with respect to a point on the earth's surface. The angle to the satellite from a ship can be obtained readily from tables or graphs if the difference in latitude and longitude between the ship and the sub-satellite point is known. This permits the use, on the ship, of aerials having appreciable gain compared with an omni-directional aerial so long as the ship's angular movements at sea when pitching and rolling, etc. do not exceed the beamwidth of the aerial. Where a stabilized aerial platform is used, the aerial beamwidth should be greater than the residual angular movement of the aerial.

Unfortunately, the coverage of geo-stationary satellites is unsatisfactory at latitudes much beyond 70° North and South and, although this covers the majority of the areas used by ships, some important fishing grounds will not be served. Nevertheless, satellites in geo-stationary orbits are the most likely to be used for a maritime-satellite service, at least in the early stages.

SATELLITE LINK PARAMETERS

Of the four links shown in Fig. 1, those between the shore station and the satellite (*a*) and (*b*), will probably operate at s.h.f. One of the principal reasons for this is to conserve the L-band allocation for use on the satellite-to-ship path but, in addition, by using shore-station aerials of some 30–40 ft in diameter and receivers having low noise temperatures, the following advantages can be obtained:

(*i*) The satellite power used in the satellite-to-shore-station path can be minimized.

(*ii*) In both paths, a high carrier-to-noise ratio can be used to avoid degrading the signal in the satellite-to-ship path or the ship-to-satellite path.

In the ship-to-satellite paths (*c*) and (*d*), the frequency used for normal communications will be that allocated for the maritime service around 1,600 MHz. Because of limited satellite power and the relatively low gains available from practical ships' aerials, the satellite-to-ship path (*c*) is the most critical of the four and is the path that determines, to a very large extent, the size of satellite required for a given number of telephone circuits.

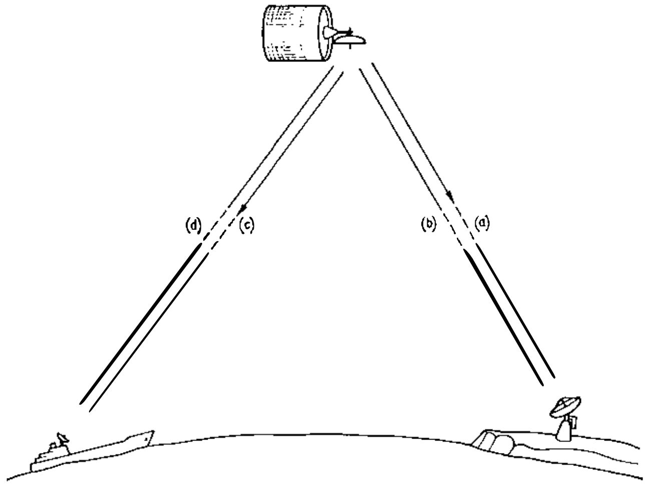


FIG. 1—Maritime satellite transmission links

The transmission equation for each of the links shown in Fig. 1 is:

$$P = (C/N_0) + L_p + M + k + L_m - G_T - G_R + T \quad . \quad . \quad (1)$$

where P = the transmitter power, minus losses (dBW),

(C/N_0) = ratio of r.f. power to system-noise-power density measured at the demodulator input (This may be written as C/kT.) (dB),

L_p = path loss between isotropic aerials (dB),

M = fading margin (dB),

k = Boltzmann's constant (dBW/Hz/°K),

L_m = miscellaneous losses (dB),

G_T = transmit-aerial gain relative to an isotropic aerial (dB),

G_R = receive-aerial gain relative to an isotropic aerial (dB) and

T = the receive-system noise-temperature referred to the input of the receiver (dB).

Of these parameters (C/N_0), G_T, G_R and T are under the control of the system designer and, by an optimizing process, can be arranged to obtain the required quality of service at the lowest overall system cost. The other parameters are either constant or dependent on the frequency allocated.

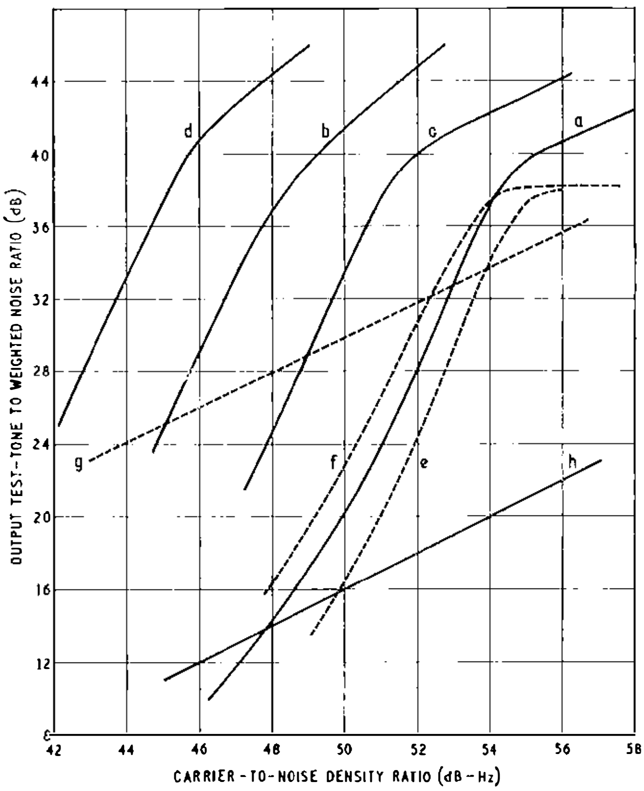
The satellite power per communication circuit should be as low as possible, consistent with the desired quality of transmission, so that the number of circuits required through the satellite can be achieved while using the smallest—and therefore the cheapest—satellite possible. To obtain the required degree of reliability for a world-wide maritime service, some 12 satellites may be required over a 10-year period to provide three working satellites with spares in orbit and back-up spares on the ground. Since a suitably-designed satellite would cost around £5–12 million, including launching, it is evident that the satellite power must be efficiently used to keep tariffs to a reasonable level. As shown above, the lowest power per channel can only be achieved by using the most efficient modulation method, i.e. one having the lowest carrier-to-noise density ratio for a given quality of service, by employing the highest aerial gains possible within the constraints of the service, and by using a receiver having the lowest practical system noise-temperature.

Modulation Methods

Of the service requirements listed earlier, telephony is the most demanding in terms of bandwidth and power. Assuming that data rates greater than 2,400 bit/s are not required, the other services can readily be accommodated within a telephony channel.

Because of the more demanding requirements of telephony, much has been done to determine the least satellite power required per telephony channel to give adequate quality of speech. Most of this work has been done in connexion with aeronautical satellite studies, in which the criterion has been intelligibility rather than the quality of speech. These channels are used by experienced operators for passing routine air-traffic-control messages. The optimum in this case often results in speech that has reasonably high intelligibility but is usually heavily clipped (reduced speech-power peak-to-mean ratio), truncated (reduced audio range), and has a signal-to-noise ratio of, perhaps, 6–12 dB.

The quality of telephony required for extension over telephone networks for use by members of the public must be considerably better. The C.C.I.R.* recommends that the final objective for the minimum signal-to-weighted-noise ratio



Key to modulation methods

(*a*) F.M. discriminator with pre-emphasis (unprocessed)
(*b*) F.M. discriminator with pre-emphasis (companded)
(*c*) F.M. phase-lock loop with pre-emphasis (unprocessed)
(*d*) F.M. phase-lock loop with pre-emphasis (companded)
(*e*) P.C.M. 4-phase p.s.k.
(*f*) Delta 4-phase p.s.k.
(*g*) Pulse-duration 4-phase p.s.k.
(*h*) A.M. single sideband

FIG. 2—Theoretical comparison of demodulator characteristics

to be met for at least 90 per cent of the time should lie in the range 30–35 dB or, if speech-processing techniques are used, should have a subjective quality equivalent to this.[3] Although this objective is desirable, it is unlikely that it can be achieved economically for some time and a ratio of 27 dB is assumed here. This is equivalent to a test-tone-to-weighted-noise ratio of 38 dB.

The channel bandwidth allocation for use at 1,600 MHz has not yet been decided but it is likely to be 50 kHz. Making allowances for frequency instability and for appropriate guard bands between the channels, a usable bandwidth of about 29 kHz remains. A number of modulation methods have been studied and Fig. 2 shows a comparison between these methods in terms of test-tone signal-to-noise ratio against carrier-to-noise density. In each case a test-tone-to-weighted-noise ratio of 38 dB was aimed for and a bandwidth limitation of 29 kHz was used. The speech bandwidth and peak-to-mean ratio assumed were 300–3,000 Hz and 10 dB respectively.

From this comparison, a number of modulation methods show themselves to be broadly comparable at 38 dB test-tone-to-weighted-noise ratio although frequency modulation using a phase-lock-loop demodulator (f.m.–p.l.l.)[4,5,6] and delta modulation using 4-phase, phase-shift-keying (delta 4-phase (p.s.k.)[6,7] have sufficient advantage to make them the most attractive of the analogue and the digital methods respectively.

The delta system is assumed to employ a digital compandor. Theoretical studies have shown that if analogue compandors are used with the f.m. systems, a considerable subjective improvement can be gained in signal-to-noise ratio; this will give the f.m. systems a pronounced advantage as curves (*b*) and (*d*) in Fig. 2 show. Tests of this form of speech processing

* C.C.I.R.—International Radio Consultative Committee.

coupled with f.m. systems are planned in early 1972 to determine whether or not the theoretical advantage can be realized in practice. The effect of compandors is to give a subjective improvement in signal-to-noise ratio of 10–15 dB. If the use of compandors gives anything approaching the theoretical improvement when used in practice, then f.m.–p.l.l. using compandors (*d*) will be clearly superior. The lower power requirements of this method would theoretically permit four or more channels to be carried in the satellite (neglecting intermodulation) for every one channel possible using other modulation methods and satellite costs per telephone channel would be reduced accordingly.

Compandors

Commonly-used syllabic compandors operate by compressing the volume range of syllabic speech at the sending end of a link by a ratio of 2 : 1 in dB with respect to a predetermined *unaffected level*. At the receiving end, the speech volume is expanded by the same ratio. The expansion process has the effect of reducing noise that has been introduced after compression. This gives some improvement in the audio signal-to-noise ratio during speech but the greatest improvement occurs during lapses in speech when a considerable reduction is made in the background noise level. The overall subjective improvement can be as high as 20 dB.

With the exception of the Lincompex[7,8] equipment, compandors are not normally used on amplitude-modulated links to mobile stations because expansion is controlled by the received audio levels and any unwanted variation in level between transmitter and receiver would be exaggerated by the expander. These level changes could take place because of fading or variations in the effective aerial gain with the movement of the ship. For frequency-modulated systems, however, this objection would not apply and a significant subjective advantage may be gained. The overall subjective audio-signal-to-noise ratio (S_A/N) obtained using 2: 1 compandors may be obtained from the empirical formula:

$$S_A/N \text{ subjective} = S_A/N + \tfrac{5}{6}U - \tfrac{2}{3}N - \tfrac{1}{6}S,$$

where S_A/N is the mean audio-signal-to-noise ratio,

U is the *unaffected level*, assumed here to be 0 dBm0*,

S is the mean signal level (dBm0) during speech, and

N is the mean noise level (dBm0).

The quality of speech to be expected from such a system is that of an audio frequency of bandwidth 300–3,000 Hz with no peak clipping. The peak-to-mean ratio of speech after compression would be 9–10 dB.

AERIALS FOR SATELLITES AND SHIPS

Determination of the optimum aerial design for the satellite and the ship is probably the most important of the problems remaining to be solved. In equation (1) it was shown that the required satellite power is inversely proportional to the product of the transmit and receive aerial gains, showing that high-gain (narrow-beamed) aerials on both ship and satellite are desirable; this applies particularly to the satellite-to-ship path. There are practical limits to the narrowness of the beams that can be used. The satellite beamwidth is governed by the coverage area required—usually the whole visible earth. This may be covered by a single beam (17° beamwidth, 17 dB gain). Proposals have, however, been made for increasing the efficiency of the satellite by using aerials of higher gain, coverage of the oceans being obtained by a number of narrow beams which together cover the whole area (see Fig. 3). This second method calls for the complexity of a steerable phased array and the facility for switching communication channels to beams covering specific areas as required. A separate narrow beam would be needed to scan the whole ocean area for ships wishing to set up calls. An appropriate beamwidth might be 5° (gain 27 dB).

On the ship, there are constraints on the narrowness of the aerial beamwidth which can be used, owing to the ship's movements in roll, pitch, yaw, course changes and changes in the geographical position of the ship. The aerial must be capable of pointing to the satellite at all times and there are numerous ways of overcoming the ship's movements to achieve this. If an omni-directional aerial is used, the satellite will always be *in beam* but such an aerial, being isotropic, is very insensitive and satellite powers would have to be high.

If the aerial platform were stabilized against the ship's movements and an auto-tracking system were used to lock the aerial pointing direction on to the satellite, then a narrow-beamed, high-gain aerial could be used, needing far less satellite power per channel. The narrowness of the beam would be limited by the combined inaccuracies of the stabilizing and auto-tracking equipments but, more particularly, by the physical size of the aerial and platform in the severely-limited space suitable for such an aerial on board ships. The beamwidth achievable by this means might be limited to about 5°. The large size and weight of the aerial, the need to have access for maintenance and the scarcity of sites on ships giving a clear all-round view would almost certainly demand the provision of duplicated aerials, one on each side of the ship.

This solution is unlikely to be adopted because the cost of such an installation would be excessive for the majority of users. The final solution is likely to lie somewhere between these extremes, possibly a combination of multiple spot beams from the satellite and one of the following on the ship:

(*a*) A low-gain aerial having a beam-width of, say, 60° (6 dB gain at beam edge), enough to allow for all ship's movements for all likely users. Periodic resetting of the pointing angle to the satellite would be required.

(*b*) A group of medium-gain aerials of, possibly, 40° beam-width (beam edge gain 9 dB), each pointing to a different part of the upper hemisphere to give complete coverage. A satellite beacon sensor could be used to scan the output from each aerial and to switch, to the radio equipment, the aerial giving the highest output. This could be sufficiently compact to be sited on a mast-head or for half of the array to be mounted on each side of the ship.

(*c*) A higher-gain aerial having, say, a 15° beam (beam-edge gain 18 dB) and some simple form of aerial semi-stabilization (e.g. stabilized to within $\pm 5°$ of the horizontal) to reduce the effect of the ship's pitching and rolling movements and to allow several hours steaming before the mean pointing angle to the satellite needed to be reset. This would require manual resetting of pointing angles to the satellite every few hours. It is assumed that changes in course and movement in yaw would be compensated by coupling the azimuthal control to the ship's gyro-compass.

These are only a few possibilities; no doubt others will emerge as the maritime countries work on this problem. The importance of the choice of aerials can be seen by comparing the omni-directional solution (no stabilizing or pointing problems but no gain) with the semi-stabilized solution (some complexity in stabilization and periodic manual pointing but 18 dB gain). The second solution would provide 64 times the number of channels possible using the first solution, for the same satellite power (neglecting inter-modulation effects).

* See C.C.I.T.T. White Book, Mar del Plata 1968, Volume III, Recommendation G162 for definition. (C.C.I.T.T.—International Telegraph and Telephone Consultative Committee.)

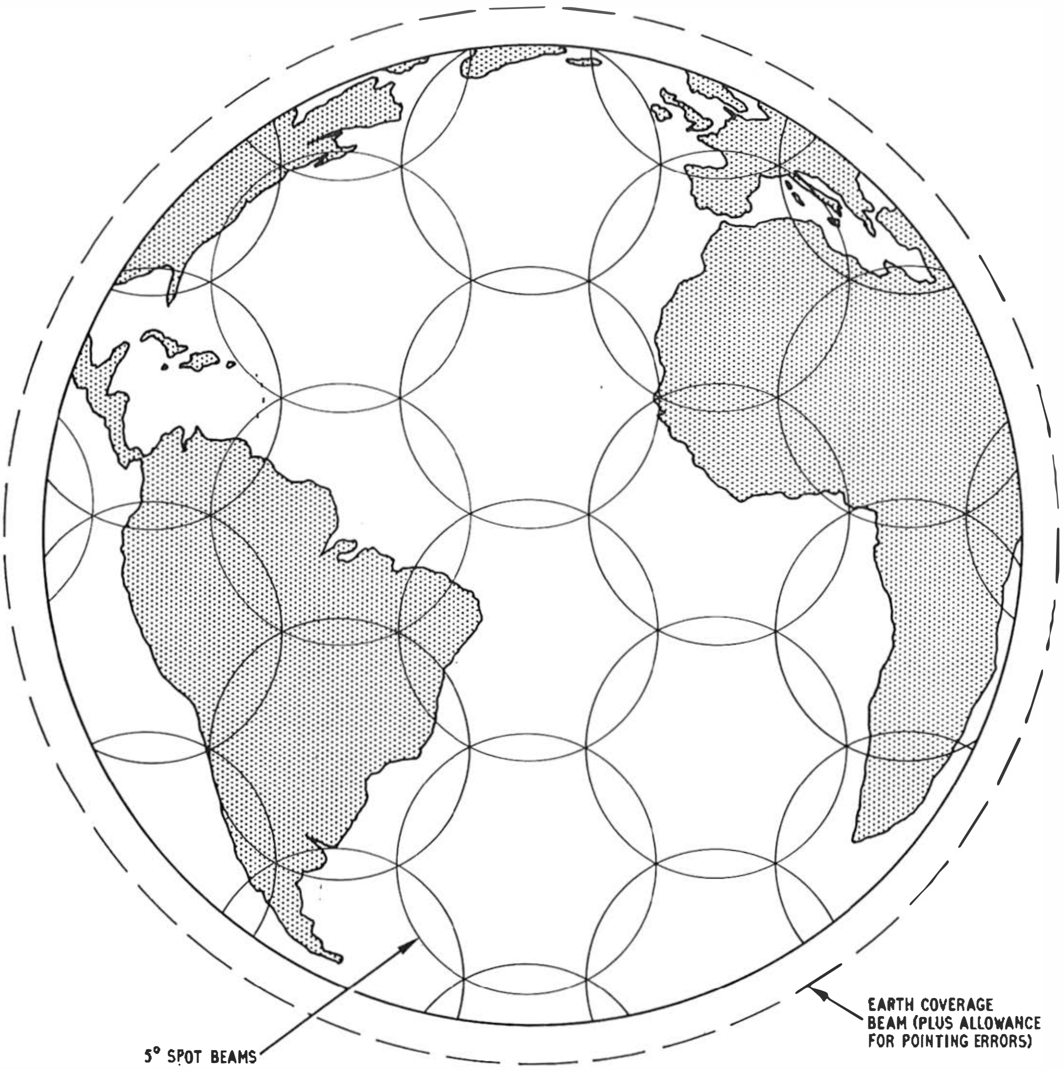


FIG. 3—Typical satellite coverage areas from a geo-stationary satellite at longitude 30° West

CONCLUSIONS

With the recent allocation of frequency bands around 1,600 MHz for maritime-satellite communication, the way is open for the development of a world-wide communication service for ships. Before this can be set up, it would be most desirable that international agreement be reached on the technical characteristics and on the operation of the service. In addition, an international administration should be established, capable of financing and controlling the system and of planning successive phases of satellite provision as they become necessary.

Tests have been conducted between ship and shore using a satellite operating at 160 MHz and these have given valuable experience and some confidence in the results of the theoretical studies which have been conducted.

There are two principal technical problems which will need study and development. These are the aerial systems to be used on the ships and the satellite, and methods of speech processing and modulation. There is a third problem, that of allocating channels flexibly to ships and coast stations, but this has not been discussed in this paper.

It is not likely that a fully-operational service will be available much before 1980 but it is highly desirable that a pre-operational system should be developed and established sooner, so that confidence in plans for a fully-operational system can be gained in advance.

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Notes and Comments

New Year Honours

The Board of Editors offers congratulations to the following engineers honoured by Her Majesty the Queen in the New Year Honours List:

Mechanization and Buildings Department, Postal Headquarters	G. P. Copping	Staff Engineer	Officer of the Most Excellent Order of the British Empire
International and Maritime Telecommunications Region	A. E. N. Wase	Senior Executive Engineer	Member of the Most Excellent Order of the British Empire
North Eastern Telecommunications Region	A. S. Bryce	Technical Officer	British Empire Medal

J. S. Whyte, M.Sc.(Eng.), C.Eng., F.I.E.E.

John Whyte joined the Post Office Research Station at Dollis Hill in 1939, becoming an Assistant Engineer in 1948 and an Executive Engineer in 1950.

Part of his early career in the Post Office was spent at the Radio Laboratories, Castleton, South Wales, where he led a team responsible for developing test equipment for microwave links. It was there that John Whyte and his colleague Robert White developed the aptly-named "white noise measuring equipment" which was eventually standardized internationally for transmission system testing.

Returning to Dollis Hill in 1957 he worked on a variety of research projects in the radio and line communication fields, notably on pulse-code modulation and data transmission. In 1965 he was seconded to H.M. Treasury to take charge of the Computer Division, in which post he was responsible for the introduction of computers in Government departments, advice to Government concerning the rationalization of the computer industry and the use of operational research techniques by administrative departments.

On his return to the Post Office in 1968 he was appointed Deputy Director of Engineering with special responsibilities for Long-Range Studies, with its wide-ranging technical, economic and sociological aspects. In this field he has made outstanding contributions to the formulation of Post Office exchange switching system modernization policy and plans.

In his new role of Director, Operational Programming, John Whyte will find many opportunities to help the telecommunications business to meet the challenges of the years ahead. Those who know him are confident that his broad outlook, critical judgment and outstanding ability will enable him more than adequately to meet those challenges. We hope, too, that in spite of the heavy pressures of Post Office business, he will find at least a little time to enjoy his hobbies of mountaineering and photography.

W.J.B.

L. Thomas, C.Eng., M.I.E.E.

The appointment of Leslie Thomas as Controller in charge of Factories Division, Purchasing and Supply Department, will be no surprise to his innumerable friends in the Post Office and industry.

He started as a Youth-in-Training at Swansea in 1939 and spent the early years of his career as a radio engineer, first at Criggion Radio Station and later at Headquarters on various aspects of microwave links, leading to the rebuilding of the original London–Birmingham 900 MHz link in 1955. As S.E.E. in the Main Lines Branch he was responsible initially for the commissioning of cable and microwave links and later for the planning and development of the North Sea cable scheme. During this period he attended the Joint Services Staff College.

In 1964 he moved to the External Telecommunications Executive as A.S.E., where he tackled with limited resources the daunting task of planning and maintaining the rapidly growing international cable and satellite network.

Appointed Staff Engineer, in Purchasing and Supply Department, in 1968 he set about building a new Works Contract Control Branch with characteristic zeal and flair for organization. His drive, initiative and clear understanding of the overall problems, coupled with a forthright but friendly manner, rapidly earned him the respect and confidence of industry. During the last four years he has helped, encouraged and coerced industry to overcome the problems of introducing new exchange systems and building up manufacturing and installation capability to meet P.O. needs.

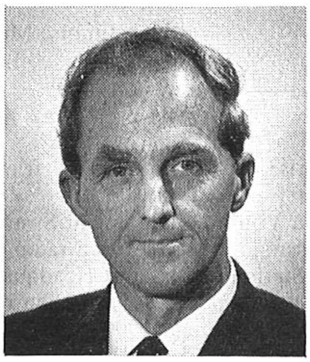
This recent experience will be invaluable as head of P.O. Factories, where Les will have the opportunity of putting into practice much of what he has preached to industry; we wish him well in his new task.

E.D.

A. B. Wherry, B.Sc.(Eng.), C.Eng., M.I.E.E., M.B.I.M.

The appointment of Brian Wherry as Controller Trunk Planning L.T.R., has been welcomed by his many friends at Headquarters and in the Regions, recognizing that N.P.D.'s loss was L.T.R.'s gain.

A product of the West Country, a fact he never made any attempt to conceal, Brian came to the Post Office in Plymouth as a youth in 1942. After seven years, which included a spell overseas in H.M. Forces, success in the limited competition brought him as an A.E. to London and the portals of the Engineering Department, Equipment Branch. In the succeeding years he steadily built up his reputation as an expert in the exchange planning field. By 1969, he had become widely known and respected, not only at Headquarters and in the Regions, but also overseas, where from time to time he had



been seconded to advise other administrations, notably in Hong Kong and Nigeria.

Re-organization translated him to Network Planning Department where, soon to become an A.S.E., he was able to bring to bear his fund of expertise and enthusiasm to the formulation of Headquarters planning policy and guidance to his friends in the Regions in planning a network of a size and growth he could never have imagined when he joined the Post Office as a youth in Plymouth.

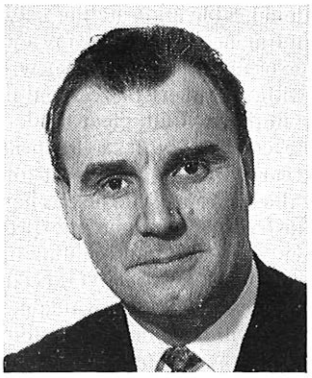
There is no doubt that Brian will devote all his talents and his loyalties to his new work and we wish him every success.

A.C.E.

A. F. Beardmore, M.Sc., B.Sc.(Eng.), C.Eng., M.I.E.E., M.B.I.M.

The promotion of Alex. Beardmore to Controller Planning with responsibilities for the long-term shaping of postal operations and marketing in L.P.R. has made history as it is the first occasion that an engineer has secured a postal controllership in this predominantly operational region.

Alex. entered the Post Office as a Youth-in-Training at Dollis Hill in September 1948, and after passing the Open E.E.'s



competition in 1957 he joined the acoustics group and later gained valuable experience in the design and development of electronic equipment.

His first introduction to postal mechanisation came with his promotion to Senior Executive Engineer in 1963 when he was transferred to the Postal Engineering Section of R Branch. Here he played a significant part in the development of early letter coding desks and translators.

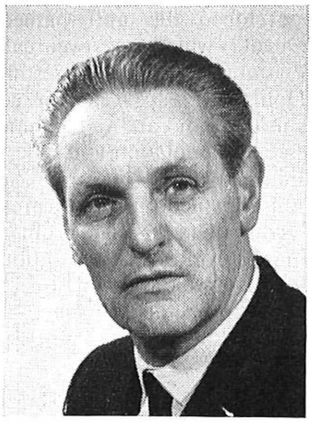
He joined the L.P.R. in 1967 as Regional Engineer responsible for the engineering, installation and commissioning of postal mechanisation and accommodation services in some of the largest postal buildings in the country.

His vast knowledge of postal-code sorting and the enthusiasm and determination with which he tackles any job will stand him in good stead in his new post. His cheerful personality and firm decisive manner have made him extremely popular with all his colleagues in the L.P.R. who wish him every success in the future.

T.H.A.M.

F. A. L. Goddard

Frank Goddard entered the Post Office in 1935 after an apprenticeship with heavy machinery engineers and spent some years on automatic telephone exchange construction in the South East Telecommunications Region. After wartime work around the London area, he changed to power work mainly in L.T.R. but also throughout the country. He had by now qualified for both A.M.I.E.E. and A.M.I. Mech.E. After a short spell of secondment to the Ministry of Transport he returned to the Post Office in 1948 and joined the Factories Department.



Appointed S.E.E. in 1957 he continued to develop and introduce modern processes into P.O. factories. Early in 1966 a transfer to E.T.E. H.Q. brought him into contact with telegram switching equipment for new international switching centres. The expansion of postal engineering saw him appointed in 1967 as a Regional Engineer to the then Wales and Border Counties Region. Planning, installation and progress control of new mechanized offices quickly introduced him to the problems of integrating postal, operating and engineering staffs.

Frank has a great capacity for work and a cheerful way of taking on any job so his appointment to Staff Engineer at PHQ/PMB2 where he will be responsible for both R & D and maintenance of postal mechanisms should suit him well.

Letter to the Editor

Dear Sir,

It was with great interest that I read, in the October issue of the *Journal*, the article by E. E. L. Winterborn on "Aluminium Conductor Cables in the Telephone Distribution Network" and the article by J. Pritchett entitled "Development of Cables for the Changing Network" which appeared in the following issue. I am certain that many readers will, like myself, have found in these articles a very useful account of the developments which have affected cable design, the reasons for these changes, and an insight into the types of cables which may be introduced during the next few years. In both of these articles reference was made to the introduction of fully-filled cables into the exchange—cabinet part of the network and it is upon this matter that I should like to express an opinion.

Cable pressurization is a means of monitoring the condition of a cable sheath and, in the event of a defect arising, protecting the cable core from the ingress of moisture and possible loss of service whilst providing facilities for the localization of the defect. Joints of course receive the same degree of protection. Cable pressurization does however require the installation and maintenance of a dry air supply at the exchange.

The introduction of fully-filled cables will radically change this situation, the jelly filling will protect the cable core and if the cable sheath becomes defective will prevent water flowing through the cable and affecting joints. Past experience has shown that joints are the most vulnerable part of the network and a second line of protection, preferably a filling compound, is essential in order to delay the deterioration of a joint and thus give the maintenance staff an opportunity to detect, locate and clear a defective closure before it seriously affects service. The proposal, albeit a late choice, to use the air tube as a means of pressurizing joints is unlikely to be economically acceptable as it will necessitate the provision of a dry air supply at the exchange even if all cables are fully-filled. It will also mean that maintenance staff must retain their present methods for locating pressure leaks at joints but must rely on regular insulation testing for monitoring the condition of the cable core.

Equipment known as Local Line Insulation Routiners (L.L.I.R.) is already in use at the majority of Repair Service Controls for monitoring the non-pressurized portion of the local network of TXS exchanges. This equipment, of course, tests the whole of the line so that a change to a fully-filled network will require no additional testing facilities on TXS exchanges although it will become even more important to ensure that the routiners are used regularly and that action is taken to locate and clear the defects they reveal. The provision of L.L.I.R. facilities at TXE and TXK exchanges will become an absolute necessity.

Referring now to the difficulties experienced in terminating fully-filled cables on a main distribution frame (m.d.f.) I agree in principle with Mr Pritchett when he says that there is no reason why the terminating length should not be unfilled. Such a termination would be preferable to the exchange maintenance staff who can hardly be expected to welcome the prospect of jelly impregnated cable permanently on the m.d.f. even if the majority of it is protected by plastic troughing or tubing. I cannot however, for the same reasons as I oppose the pressurizing of joints on fully-filled cables, accept the suggestion that this length should be pressurized. An alternative which would be acceptable to the maintenance staff, and, with the introduction of machine jointing, would I think be economically acceptable, would be to keep the terminating length as short as possible, preferably m.d.f.—cable chamber or at most m.d.f.—exchange manhole and make a joint to a fully-filled cable at this point. Such a joint should of course be filled and the provision of water blocks either end the unfilled section would be a necessary insurance against the possibility of water entering the cable core from a flooded exchange.

The development and introduction of new cable designs is undoubted evidence that the cable development engineer is taking full advantage of the exploitation of new materials and processes available to him. This policy is of advantage to both the Post Office and the cable industry but it often presents problems to the development engineer employed on jointing and joint closure techniques which are not easily solved.

The final proof of a new product or technique is undoubtedly its performance in the field and for this we rely to a very large extent on the skill of the jointing staff. Perhaps we should therefore bear in mind that whilst standardization has its drawbacks, too rapid advance can result in field staff being presented with such a proliferation of alternatives as to destroy the incentive to produce the high quality of workmanship which is necessary to maintain such a complex network.

Yours faithfully,

E. N. HARCOURT

Service Division, Sv5.1.1.,
Telecommunications Headquarters,
207 Old Street,
London EC1V 9PS

Publication of Correspondence

The Board of Editors would like to publish correspondence on engineering, technical or other aspects of articles published in the *Journal*.

Letters of sufficient interest will be published under "Notes and Comments". Correspondents should note that, as it is necessary to send copy to the printer well before publication date, it will only be possible to consider letters for publication in the July issue if they are received before 23 May 1972.

Letters intended for publication should be sent to the Managing Editor, *P.O.E.E. Journal,* Post Office Factories Headquarters, Bovay Place, London, N7 6PX.

Notes for Authors

Authors are reminded that some notes are available to help them prepare the manuscripts of the *Journal* articles in a way that will assist in securing uniformity of presentation, simplify the work of the *Journal's* printer and draughtsmen, and help ensure that authors' wishes are easily interpreted. Any author preparing an article for the *Journal* who is not already in possession of the notes is asked to write to the Managing Editor to obtain a copy.

It is emphasized that all contributions to the *Journal,* including those for Regional Notes and Associate Section Notes, must be typed, with double spacing between lines, on one side only of each sheet of paper.

Each circuit diagram or sketch should be drawn on a separate sheet of paper; neat sketches are all that are required. Photographs should be clear and sharply focused. Prints should preferably be glossy and should be unmounted, any notes or captions being written on a separate sheet of paper. Negatives or plates are not needed and should not be supplied.

Model Answer Books

Books of model answers to certain of the City and Guilds of London Institute examinations in telecommunications are published by the Board of Editors. Details of the books available are always given at the end of the Supplement to the *Journal*. The Board of Editors has reduced the price of Line Plant Practice A to 37½p (42½p post paid).

The Telecommunication Principles B Answer Book is out of print at the moment but a reprint is in preparation and an announcement will be made in the *Journal* when it becomes available.

Articles on Current Topics

The Board of Editors would like to publish more short articles dealing with topical subjects. Authors who have contributions of this nature are invited to contact the Managing Editor.

Journal Back Numbers

The Carlisle Associate Section have surplus back numbers of the *Journal* dating from 1927 (Volume 20). They wish to dispose of these and would give first preference to other Associate Sections who may wish to complete their own sets. They also wish to obtain any copies of the *Journal* prior to July 1925. Readers interested in these items should contact; The Chairman, I.P.O.E.E. Associate Section, Post Office Telephones, Stocklund House, Castle Street, Carlisle CA3 8BA.

Your Journal

Over 38,000 copies of each issue of the *Journal* are printed. Inevitably, some do not reach their intended destination. The distribution system has recently been completely revised to try to improve the service that we give our readers. If something does go wrong and your copy does not reach you, the following notes tell you what to do.

External non-Post-Office readers

Subscriptions for all non-Post-Office readers at home and abroad are dealt with by the Subscription Agent at 2–12 Gresham Street. Subscriptions can run for any period of four issues and, with the last issue, a renewal slip is included which should be returned with a remittance if you wish to continue to receive the *Journal*. If any queries arise it helps, although it is not essential, if you can quote the period for which your subscription has been paid. Subscriptions can be made direct, or, if you prefer it, through a bookseller dealing with periodicals.

Corresponding and retired members of the I.P.O.E.E.

These members receive their *Journals* directly by post. The membership list is maintained by the General Secretary of the Institution. If any corresponding or retired member is not receiving his *Journal* regularly or wishes to notify a change of address, he should write to the General Secretary, I.P.O.E.E., 2–12 Gresham Street, London EC2V 7AG, stating the category of membership.

Post Office staff who are members of the Institution

Members of the Institution receive the *Journal* as part of the services paid for by their subscription. Copies are actually distributed by *Journal* local sales agents, but the agents merely act on the instructions of the local secretary of the Institution who is responsible for maintaining the membership roll. Any member of the Institution who is not receiving his *Journal* regularly should, therefore, inform the local secretary. The local secretary should also be advised of changes of official address by the member concerned. It is emphasised that the subscriptions paid by members of the Associate Section do not include payment for the *Journal*. Associate Section members only receive the *Journal* if they pay for it separately by deduction from pay, or by cash, and they should arrange for this by contacting their local Sales agent.

Post Office staff who are not members of the Institution

Members of the Post Office staff who are not members of the Institution may pay for the *Journal* by deduction from pay, or by cash, and receive the *Journals* from *Journal* sales agents. There is a sales agent in every Telephone Manager's Office and in every Regional H.Q., Postal or Telecommunications. Usually the agent is situated in a domestic or literature duty. In T.H.Q. there is an agent in every Department or Division, in the appropriate domestic duty. Complaints about non-receipt or changes of address should be made to the sales agent. The enquiry point in the Area, Region, Division or Department should be able to tell you the name of the local sales agent. In cases of difficulty write to the *P.O.E.E. Journal*, 2–12 Gresham Street, London EC2V 7AG, and we will forward your letter to the sales agent.

Post-Graduate Awards 1971

Each year the Post Office makes a number of post-graduate awards to selected staff. The awards are tenable at universities which have facilities for research or advanced studies in subjects relevant to Post Office problems and activities. These awards cover not only telecommunications science and engineering, but also such areas as computers, management, industrial and business administration, marketing, etc., where post-graduate work would be of direct benefit to the Post Office. In appropriate cases the awards enable the holders to qualify for M.Sc. or Ph.D. degrees, but the primary objective is to further research and development expertise of special value to the Post Office. Awards made this year are listed below.

The following Officers have all been awarded a one-year M.Sc. Course in Telecommunications Systems at the University of Essex:

Mr. W. H. Rodger, Executive Engineer, Research Department, Telecommunications Headquarters.

Mr. T. J. Matthews, Executive Engineer, Research Department, Telecommunications Headquarters.

Mr. K. I. Vincent, Executive Engineer, Research Department, Telecommunications Headquarters.

Mr. P. V. Milton, Executive Engineer, Telecommunications Development Department, Telecommunications Headquarters.

Mr. D. Johnson, Executive Engineer, Telecommunications Development Department, Telecommunications Headquarters.

Mr. K. R. Harrison, Executive Engineer, Telecommunications Development Department, Telecommunications Headquarters.

Mr. C. J. Heginbotham, Executive Engineer, Network Planning Department, Telecommunications Headquarters.

Mr. A. R. Valdar, Executive Engineer, Network Planning Department, Telecommunications Headquarters.

Mr. J. K. Hawkins, Executive Engineer, Network Planning Department, Telecommunications Headquarters.

Mr. C. R. South, Executive Engineer, Guildford Telephone Area, South Eastern Telecommunications Region.

Mr. M. Collins, Telecommunications Management Entrant, Management Services Department, has been awarded a one-year M.Sc. Course in Administrative Sciences at City University.

Mr. I. A. Jackson, Executive Engineer, Telecommunications Development Department, Telecommunications Headquarters, has been awarded a one-year M.Sc. Course in Industrial Administration at the University of Aston, Birmingham.

Mr. D. G. Bennett, Executive Engineer, Research Department, Telecommunications Headquarters, has been awarded a one-year M.Sc. Course in Operational Research and Management Studies at Imperial College, London.

Mr. A. F. Mitchell, Executive Engineer, Research Department, Telecommunications Headquarters, has been awarded a one-year M.Sc. Course in Control Systems at Imperial College, London.

Mr. K. H. Kolb, Executive Engineer, London Telecommunications Region Headquarters, has been awarded a one-year M.Sc. Course in Operational Research and Management Studies at Imperial College, London.

Mr. T. R. Tysoe, Telecommunications Management Entrant, Management Services Department, Telecommunications Headquarters, has been awarded a one-year M.Sc. Course in Operational Research and Management Studies at the London School of Economics.

Mr. T. J. West, Executive Engineer, Post Office Data Processing Service, has been awarded a one-year M.Sc. Course in Computer Science at the Institute of Computer Science, London University.

Mr. S. C. M. Wright, Executive Engineer, Telecommunications Development Department, Telecommunications Headquarters, has been awarded a one-year M.Tech. course in Engineering Design at Loughborough University.

Mr. R. Peacock, Executive Engineer, Edinburgh Telephone Area, has been awarded a one-year Master of Business Administration Course at Strathclyde University.

Mr. H. T. Liu, Assistant Executive Engineer, Research Department, Telecommunications Headquarters, has been awarded a one-year M.Sc. Course in Communications Engineering at the University of Manchester, Institute of Science and Technology.

Mr. J. Morris, Executive Engineer, Post Office Data Processing Service, has been awarded a one-year M.Sc. Course in Management and Business Studies at the University of Warwick.

Mr. K. Hodson, Executive Engineer, Telecommunications Development Department, Telecommunications Headquarters, has been awarded a one-year M.Sc. Course in Communications Engineering at the University of Manchester, Institute of Science and Technology.

Mr. K. G. Parr, Assistant Executive Engineer, Telecommunications Headquarters, has been granted a two-year award to study the Perception of Flicker at the University of Essex.

Mr. R. A. Startin, Executive Engineer, Research Department, Telecommunications Headquarters, has been granted a three-year award to study devices for high digit-rate microwave systems at University College, London.

Mr. G. C. Cater, Assistant Postal Controller II, North West Postal Region, has been awarded a one-year M.Sc. Course in Management (Diploma for Advanced Studies) at Salford University.

Mr. R. M. Ollin, Assistant Postal Controller II, North West Postal Region, has been awarded a one-year M.Sc. Course in Administrative Sciences at City University.

Mr. P. M. Stables, Assistant Executive Engineer, Postal Mechanization and Building Department, Postal Headquarters, has been awarded a one-year M.Sc. Course in Systems Engineering (Control/Computer Engineering) at Surrey University.

Mr. D. A. Gray, Executive Engineer, South Eastern Telecommunications Region Headquarters, has been awarded a two-year M.Sc. Program at the London Graduate School of Business Studies.

In addition, Mr. H. R. B. Mothersole, Executive Engineer, Research Department, Telecommunications Headquarters, has been granted a two-year award at the University of Essex leading to an M.Sc. in Telecommunication Systems by part-time study.

Institution of Post Office Electrical Engineers

Annual Awards for Associate Papers, Session 1970–71

The Judging Committee having adjudicated on the papers submitted by the Local Centre Committees, prizes and Institution Certificates have been awarded to the following in respect of the papers named:

Prize of £25:
G. D. Rudram. Technical Officer, Worthing Centre. "The Small Electronic Exchange TXE2."

Prize of £10:
C. P. J. Knapman, Technical Officer, Bristol Centre. "Voice Frequency Remote Control System A."

Prize of £5:
W. J. McKittrick, Technical Officer, Belfast Centre. "Craigavon Broadband System."

The Council of the Institution is indebted to Messrs. R. H. Adams, S. T. E. Kent and M. T. Turnbull for kindly undertaking the adjudication of the papers submitted for consideration.

Retired Members

The following members, who retired during 1971, have retained their membership of the Institution under Rule 11(a):

F. C. Haliburton, O.B.E., 9 Innisfree Close, Hookstone Drive, Harrogate, Yorkshire.
F. W. J. Webber, 32 Hillside Avenue, Worthing, Sussex.
H. Stanesby, 21 King George Avenue, Bushey, Herts, W32 3NT.
N. V. Knight, 3 Atha Court, Whielden Street, Amersham, Buckinghamshire.
G. A. C. Mason, 32 Rockingham Road, Yardley, Birmingham, B25 8RG.
L. W. Lovegrove, "San Paula" Bath Road, Sonning, Reading, Berkshire.
H. H. Bicker, 4 Harbottle Avenue, Gosforth, Newcastle-on-Tyne, 3.
J. A. Livingstone, 71 Newstead Avenue, Orpington, BR6 9RW.
Robert F. McLusky, 80 Wickham Hill, Hassocks, Sussex.
R. S. Salt, 27 Farm Fields, Sanderstead, Surrey.
J. W. Barrett, 67 Lankers Drive, Harrow, Middlesex.
J. Balcombe, 28 Goddington Lane, Orpington, Kent.
F. A. Hough, "Byways" Viggory Lane, Horsell, Woking, Surrey.
R. N. Palmer, 34 Hillview Terrace, Edinburgh, EH12 8RB.

A. B. WHERRY
General Secretary

Additions to the Library

Library requisition forms are available from Honorary Local Secretaries, from Associate Section Centre Secretaries, and representatives, and from the Librarian, I.P.O.E.E., 2–12 Gresham Street, London, EC2V 7AG.

Members are reminded that Prize Essays, Associate Section Prize Papers, and various unpublished papers are held in the library for loan, and that a list will be sent on request. Field Medal award-winning papers are also held for loan and are listed in the Supplement to the Library Catalogue.

5034 *Analysis Bar Charting*. J. E. Mulvaney (Brit. 1969).
A simplified Critical Path Analysis Technique primarily intended for manual use.

5035 *Estimating the Heat Requirements for Domestic Buildings*. J. J. Barton (Brit. 1969).
Essentially a reference book with which the heat requirements for any domestic building can be calculated. Includes metric heat-loss tables.

5036 *110 Semiconductor Projects for the Home Constructor*. R. M. Marston (Brit. 1969).
Sets out to introduce the reader to new devices by experiment rather than theory. 110 different circuits are described and the operation of each one is explained in simple and concise terms.

5037 *Semiconductors for Engineers*. D. F. Dunster (Brit. 1969).
A guide to the semiconductor devices which are used in modern electronics. Intended to assist the understanding of the ideas behind the working of these devices. Particular emphasis on their function as circuit elements.

5038 *Questions and Answers—Colour Television*. J. A. Reddihough (Brit. 1969).
A simple, practical account of colour television transmission and reception for the enthusiast, technician and service engineer.

5039 *Principles of Colour Television Systems*. C. R. G. Reed (Brit. 1969).
Aimed at readers who have a good general knowledge of black-and-white television but little knowledge of colour systems. Well suited to student technicians and technician-grade engineers.

5040 *Management. Its Nature and Significance*. E. F. L. Breck (Brit. 1969), 4th Ed.
Presents a simple study of the management process in nature and in action designed particularly for those coming face to face with management for the first time.

5041 *Critical Path Method*. A. T. Armstrong-Wright (Brit. 1969).
Provides a sound knowledge of the basic techniques of the system and the necessary means for putting this knowledge into practice.

5042 *The Effective Use of Computers in Business*. P. A. Losty (Brit. 1969).
A simple, clear, comprehensive, layman's guide to computers with an emphasis on their implications for the business in preference to how they work.

5043 *How Computers Do It*. D. G. Moursand (Amer. 1969).
Designed to aid the reader in learning how to use a computer, and the essential ideas of how computers do what they do.

5044 *Numerical Analysis: The Mathematics of Computing. Volume 1*. W. A. Watson, T. Philipson and P. J. Oates (Brit. 1969).

Intended to be read with, or perhaps following, a mathematics course at G.C.E. A Level or O.N.C. standard.

5045 *The Hi-Fi and Tape Recorder Handbook.* G. J. King (Brit. 1969).
Information on the various kinds of high-fidelity audio equipment, their choice, operation and servicing. Will appeal to all enthusiasts.

5046 *Theory of Communication.* A. E. Karbowiak (Brit. 1969).
Primarily for students specializing in Communication (Electrical) up to B.Sc. Honours standard.

5047 *Telephony and Telegraphy A.* S. F. Smith (Brit. 1969).
An introduction to telephone and telegraph instruments and exchanges. A complete text for both the telephone and telegraph aspects of the syllabus for the City and Guilds of London Institute examination in Telephony and Telegraphy A.

5048 *Technological Forecasting and Long-Range Planning.* R. U. Ayres (Amer. 1969).
A readable and useful approach to the important subject of forecasting the future trends and specific developments in various areas of technology.

5049 *More Small Bore Heating.* T. Stanley (Brit. 1969).
How to design and install single-pipe and two-pipe systems. The book gives alternative designs for central heating in a terraced house, semi-detached, bungalow and a larger detached house.

5050 *Signal Theory.* L. E. Franks (Amer. 1969).
A clear, logical, and unified approach to the modern techniques used in signal analysis and signal processing problems. Includes many practical illustrative examples.

5051 *Electronic Counting: Circuits, Techniques, Devices.* Mullard Ltd. (Brit. 1967).
Intended to help engineers to use electronics to solve their counting problems as simply or as cheaply as possible.

5052 *Colour Television: A Background to Colour Tube Adjustments for the Service Engineer.* Mullard Ltd. (Brit. 1968).
Describes the correct adjustment of colour purity and convergence essential for a high quality colour picture.

5053 *Management Behaviour.* W. Lamb and D. Turner (Brit. 1969).
Written primarily for those practising the science and art of management in a commercial or industrial environment. Directed towards achieving a greater understanding of interpersonal relationships and the identification of skills and aptitudes for management.

5054 *Information Retrieval.* R. Meetham (Brit. 1969).
A wide-ranging account of the information handling business, starting with the essential nature of communication and progressing through the importance of writing and books, to the computer-dominated information centres of the future.

5055 *Questions and Answers: Automobile Electrical Systems. 2nd Ed.* A. J. Coker (Brit. 1969).
Intended for reference by owner drivers and others interested in the electrical equipment and wiring of cars. Includes over 80 wiring and constructional diagrams.

5056 *Hydrofoils and Hovercraft.* B. Gunston (Brit. 1969).
Well-illustrated book on new vehicles for land and sea—what they are, how they work, what has been achieved, and their prospects in an age of jumbo jets and giant tankers.

5057 *Motor Manuals Volume 8: Automobile Brakes and Braking Systems.* T. P. Newcomb and R. T. Spurr (Brit. 1969).
Very well-illustrated book on the braking of vehicles including sections on continental cars and caravan brakes. Also a section on the history of brakes which will be of interest to the veteran and vintage car enthusiast.

5058 *Electric Wiring (Domestic) 7th Ed.* A. J. Coker.
A reliable guide to the practical aspects of domestic electric wiring. Well illustrated.

5059 *Transistor Audio and Radio Circuits.* Mullard Ltd. (Brit. 1969).
Intended as a manual for established and practical circuits for radio receivers, radiograms, record players, tape recorders and hi-fi equipment.

5060 *Telecommunications—The Booming Technology.* R. Brown (Brit. 1969).
Describes the complicated world of telegraphy and telephony, television and radio, communication satellites and space communication.

5061 *Work Study in the Office 4th Ed.* H. P. Cemach (Brit. 1969).
An excellent book for the purpose of introducing the subject of work study to those engaged in administration.

5062 *Business Administration—An Introductory Study.* O. S. Hiner (Brit. 1969).
This study of modern business enterprise provides a textbook for use with those courses designed to give pre-experience training in business and management.

5064 *Vehicle Operation and Testing.* J. G. Giles (Editor) (Brit. 1969).
Describes present-day practice over a wide field of vehicle testing, not only to meet statutory and other requirements in the areas of safety, noise and air pollution, but also as an aid to improving comfort, visibility and performance. Assumes only a basic engineering knowledge.

5065 *Worked Examples in Electrical Engineering 4th Ed.* W. T. Pratt (Brit. 1969).
This collection of 232 worked examples is primarily intended for students of H.N.C. and Part B of the I.E.E. Examination.

5066 *Principles of Pulse Code Modulation.* K. W. Cattermole (Brit. 1969).
A definitive account of this important technique which is rapidly acquiring a position of central importance in the telecommunications field.

5067 *Understanding and Using Unijunction Transistors.* S. Hoberman (Amer. 1969).
A well-illustrated book designed to give the reader a full understanding of the peculiarities, operation, and applications of the unijunction transistor.

5068 *Organization and Manpower Planning, 2nd Ed.* G. McBeath (Brit. 1969).
Brings together all the component parts of organization and manpower planning, from the influence of business economics on organization structures to the individual requirements of personal career developments.

5069 *Managing with Statistics.* T. W. Lewis and R. A. Fox (Brit. 1969).
Designed to meet the needs of those taking management courses or professional examinations which include statistics as a compulsory subject and who are making a study of statistics for the first time.

5070 *Motor Vehicle Engine Servicing.* A. W. Judge, 3rd Ed. (Brit. 1969).
Deals with the servicing, maintenance and overhaul of engines in the small to medium types of vehicle.

5071 *Handbook of Practical Electronic Tests and Measurements.* J. D. Lenk (Amer. 1969).
Self-contained guide to all the practical electronic test and measurement procedures encountered by working electronics technicians.

5072 *Electricity: An SI Advanced Level Course.* Nelkon (Brit. 1970).
Designed to cover the new A-level syllabuses in Electricity and Atomic Structure and uses SI Units throughout. Contains many numerical examples.

5073 *Radio and Line Transmission Volume 2.* G. L. Danielson and R. S. Walker (Brit. 1963).
Covers the syllabus of the City and Guilds of London Institute Technicians' Certificate examinations in Radio and Line Transmission B.

5074 *Radio and Line Transmission Volume 3.* G. L. Danielson and R. S. Walker (Brit. 1969).
Covers the syllabus of the City and Guilds of London Institute Technicians' Certificate examination in Radio Communication C.

E. DOHERTY
Librarian

Regional Notes

Northern Ireland Directorate

Apprentices' Prize Day, 1971

The second annual apprentices' prize day in Northern Ireland was held in the Regional Training Centre on 24 November 1971 when the prizes were presented by His Excellency The Lord Grey of Naunton, G.C.M.G., K.C.V.O., O.B.E., Governor of Northern Ireland. Our distinguished visitors included Mr. A. W. C. Ryland, C.B., Chairman, Board of the Post Office Corporation and Mr. F. H. Edwards, Assistant Secretary, Post Office Engineering Union.

The inauguration of an apprentices' prize day on a Regional basis is unique in the Post Office and was largely due to the Director, Mr. G. H. Coates. The organizing committee includes representatives from the Post Office Engineering Union, the motor transport section, Belfast telephone area and the regional training centre under the chairmanship of the Regional Engineer. Prizes are awarded to the first three apprentices in each of the three years of the training scheme for trainee technician apprentices, whilst in the motor transport section a prize is given to the best apprentice mechanic. In determining the prizewinners, the following factors are taken into account:

(*a*) technical achievements,
(*b*) training course results,
(*c*) practical work,
(*d*) training officers' assessment.

Finally, the first six apprentices in each of the three years are interviewed by the Belfast Telephone Manager and Regional Engineer who select the best three in each year. The Regional Motor Transport Officer makes the final selection for the best apprentice mechanic.

In addition, two perpetual trophies presented by Mr. C. W. Bailey, Regional engineer and Mr. C. Thirlwall, Regional Motor Transport Officer, are awarded to the telecommunications apprentice of the year and to the motor transport apprentice of the year.

Results for the year 1971 were as follows:

First year trainee technician apprentices:

First prize	M. Kavanagh	Belfast area.
Second prize	A. T. Jess	Belfast area.
Third prize	I. J. Keay	Belfast area.

Second year trainee technician apprentices:

First prize	T. Gilpin	Portadown area.
Second prize	T. W. Armstrong	Coleraine area.
Third prize	D. N. Ruddell	Portadown area.

Third year trainee technician apprentices:

First prize	J. McDowell	Belfast area.
Second prize	W. J. McCue	Belfast area.
Third prize	N. J. McDonnell	Belfast area.

Apprentice mechanic (motor transport):

First prize	J. J. Murray	Belfast area.

Telecommunications apprentice of the year shield:

J. McDowell Belfast area.

Motor transport apprentice of the year shield:

J. J. Murray Belfast area.

Each year the Belfast Branch of the Post Office Engineering Union makes a substantial cash award to encourage apprentices to compete with one another in a general knowledge and trade union affairs quiz competition. This year Mr. F. H. Edwards, Assistant Secretary of the Post Office Engineering Union presented prizes to the first three apprentices in an exceptionally well supported competition:

First prize	N. Sherwin	Belfast area.
Second prize	A. J. Hill	Belfast area.
Third prize	S. J. McGrory	Belfast area.

After the presentation of prizes, the guests and apprentices were entertained to afternoon tea which was followed by a conducted tour of the Regional Training Centre. Included in this tour was a visit to our Telecommunications Museum which proved to be of great interest.

We are proud of the success of our apprentices' prize day scheme and believe that the resulting encouragement to the apprentices and the opportunity of meeting their parents make the event very worthwhile.

T. H. Lloyd

Bomb damage at Armagh non-director exchange

At 11.27 hours on Saturday, 21 August 1971, a severe explosion wrecked Armagh non-director exchange.

In a single incident it caused the most serious disruption to service encountered during a campaign of terrorist attacks against telephone exchanges in Northern Ireland. Once again, engineering emergency services went into action to restore vital communication links. Over the past year some 15 telephone exchanges have suffered bomb damage; six of these have been completely destroyed. In one case an unexploded bomb was uncovered by engineers while restoring service.

Armagh exchange provided service for some 1,500 subscribers in the cathedral city of Armagh about 38 miles south-west of Belfast. It was a remote non-director exchange housed on the ground floor of a two-storey building opened in 1962. It had a working multiple of 1,900 and an additional 400 contract multiple was almost ready for service when the explosion occurred.

Three heavy explosive charges had been strategically placed at points on the ground floor and a large amount of essential equipment was destroyed (Fig. 1). Record cards had been used to start a fire beside the main distribution frame (m.d.f.) and the fire brigade hosed down the m.d.f. with water to extinguish it. There was widespread damage in varying degrees throughout the apparatus room rendering the exchange completely ineffective as a working unit.

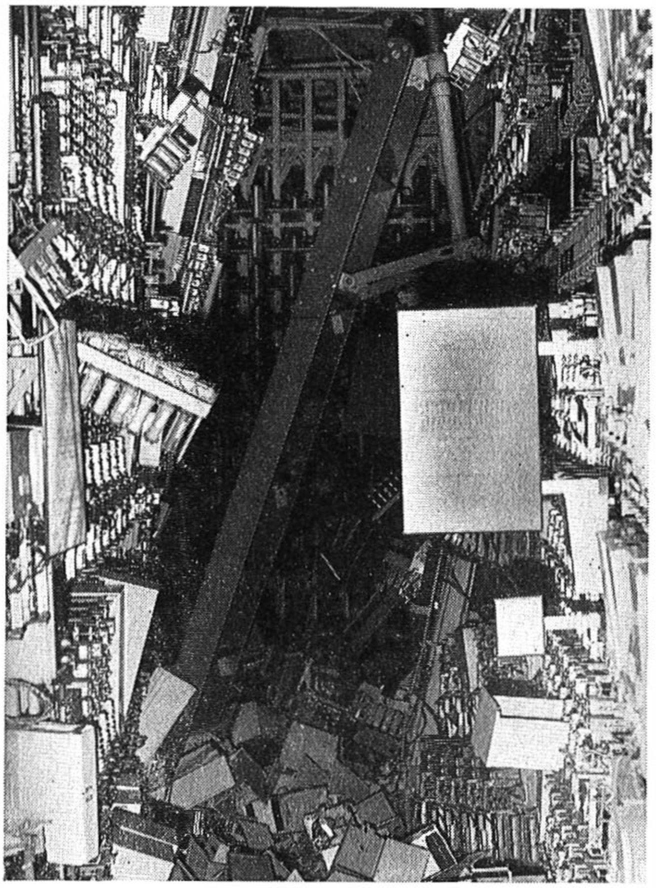


Fig 1.—A section of the apparatus rack after the bomb blast

FIG. 2—Armagh non-director exchange after the bomb blast

The effect of the explosion on the building was mostly confined to the ground floor where windows, doors and walls were blown out (Fig. 2); the floor and ceiling were also damaged. On the first floor, damage to the building was less severe, consisting in general of cracked walls and ceilings. Fortunately, the building was of steel-framed construction and the structural engineers were satisfied that the building structure was re-usable. The apparatus room was temporarily restored by erecting a corrugated iron enclosure lined with hardboard. The repeater station, pulse code modulation equipment, and batteries on the first floor were apparently undamaged. New power equipment, not yet in service, was also unaffected.

After essential lines had been given service by connecting them directly to the local exchange of the group switching centre at Portadown, immediate arrangements were made for the provision of a 400-line mobile non-director exchange (m.n.d.x.) at Gough Army Barracks about half a mile from the non-director exchange. Fortunately, duct space was available for the provision of the necessary cable to the site and the first m.n.d.x. was ready for service on 24 August. Armagh has a high proportion of business subscribers and as connexions were added to the mobile exchange, serious congestion developed. Further relief was given by the provision of a second 400-line m.n.d.x. which was brought into service on 21 September.

Meanwhile, plans for further expedient and permanent restoration were being examined and the usual factors of cost, availability of equipment and programming were considered. There were the additional problems of security and the restoration of the building to allow replacement of the permanent exchange equipment. It was finally decided to seek authority to install a TXE2 exchange in the existing building as the permanent replacement. A 4,000 multiple TXE2 unit could be accommodated in the existing apparatus room, and still leave space for an expedient installation of Strowger equipment at the rear of the room. Thus, building repairs could be carried out on one section of the room in preparation for the permanent equipment, concurrently with work proceeding on the expedient. A further advantage gained from the use of TXE2 equipment would be the doubling of the multiple capacity of the apparatus room and site.

Planning of the expedient proceeded on the assumption that sufficient old equipment could be salvaged, augmented as necessary with a small automatic exchange and other locally available equipment, to provide an 1,800 multiple component with reasonable traffic-carrying characteristics. Ancillary equipment would not be used. A satisfactory layout of the equipment was achieved at the rear of the room, although some slight relaxation of standard gangway dimensions was found necessary. Power was available from the new plant, and the m.d.f., although damaged, was re-usable for expedient purposes. Modifications to equipment for provision of suitable common services were devised by regional and area staff.

Installation of the Strowger expedient exchange commenced on 15 September. The maximum number of staff consistent with efficiency was employed on site and co-ordinated into a highly effective team. Cabling and terminating were completed with great rapidity using a wire wrapping machine.

On 23 November Mr. A. W. C. Ryland, C.B., visited the exchange, and congratulated all concerned on their efforts and achievements in restoring service under appalling difficulties.

The 1,800 multiple non-director expedient exchange was opened for service on 19 December. A number of unusual difficulties and faults attributable to the effects of bomb blast were encountered and cleared during the progress of the work.

A special order was placed with the Plessey Group for a 2,400 multiple TXE2 exchange. Detailed requirements were forwarded to Plessey on 10 December 1971 and since then they have given full co-operation in expediting the contract. Installation is due to commence at the end of February 1972 with a ready-for-service date of October 1972, a reduction of 11 months on average periods.

W. J. GAWLEY

North Eastern Region

Replacement of a Large Duct-seal

An investigation into a report of a defective duct-seal (Fig. 1) at a major repeater station revealed that the 54-way lead duct-seal installed in the 1930s had been constructed of a thinner lead sheet than normal and this was tearing away at the edge and round the points where lead sleeves had been plumbed to it.

It was clearly impracticable to renew or reinforce the existing lead sheet by new lead strips, plumbed between the polythene sheathed cables; and the alternatives were either to divert the cables temporarily, renew the sheet in one piece, and then restore the cables to their original positions, or, to provide a completely new lead-in and duct seal from the manhole, and divert the cables permanently. The estimated cost of these alternatives was between £10,000 and £15,000 and, not only would the work take many months to complete, but it would necessitate the interruption of every main trunk and coaxial cable into Leeds.

Experiments with Post Office caulking glands showed that these could be sawn in half lengthwise and reassembled round a cable using "Jubilee" clips. The screwed caps could be similarly replaced and screwed on normally.

FIG. 1—The old duct-seal

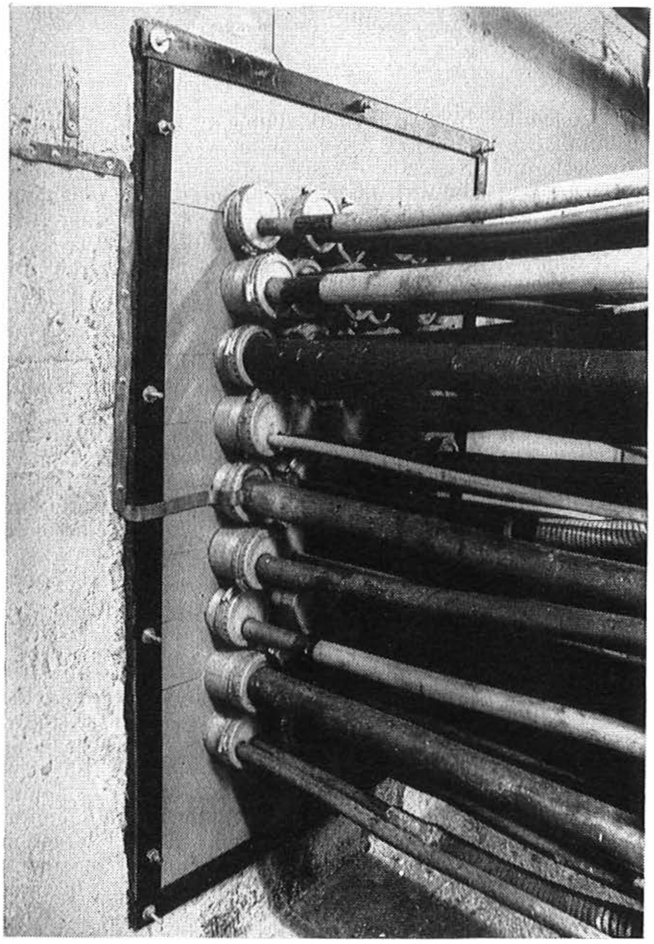


FIG. 2—The new duct-seal

A short piece of polyvinylchloride (p.v.c.) pipe with an eighth-inch wall could be split down one side and sprung over the largest-size cable and glued inside the gland with Post Office Compound No. 21. This solved the problem of putting glands round cables and the only difficulty was making a ductseal.

Measurements of the octagonal ducts behind the old duct-seal showed that a short piece of pipe left protruding from the reassembled gland could be slid into the ends of the octagonal ducts and spaced so that the gland caps could still be unscrewed and replaced. A normal p.v.c. duct-seal was marked out, drilled, and cut into horizontal strips by the local Post Office staff. A steel clamping-frame was bolted to the wall round the duct nest and, by careful painstaking work by a jointer and his mate, the strips were fitted between the glands and clamped by the frame.

The space of about 1 in–1½ in between the sheet and the face of the octagonal ducts was then filled with a proprietory epoxy resin, similar in consistency to condensed milk, which flowed into all the interstices forming a solid mass which then set hard. The resin was poured at the rate of one gallon at a time as the strips were built up, to allow dispersal of the heat generated in the resin during setting. Small leakages were stopped with Post Office mixture No. 2 to retain the resin until it had set.

The completed job (Fig. 2) has cost less than £900, and in both appearance and function the seal is in no way inferior to a standard duct-seal.

J. R. LEACH

South-Western Region

Suspension Bridge Constructed for Post Office Cables over the Chudleigh By-pass

Changes in the construction program of the Chudleigh by-pass, after work had commenced, called for a major interruption scheme for Post Office cables at short notice. Seven main underground cables and one junction cable were involved over a distance of 380 ft. The estimated high costs for interrupting the route demanded a study of every possible alternative and produced the idea of a purpose-built suspension bridge to carry the existing cables.

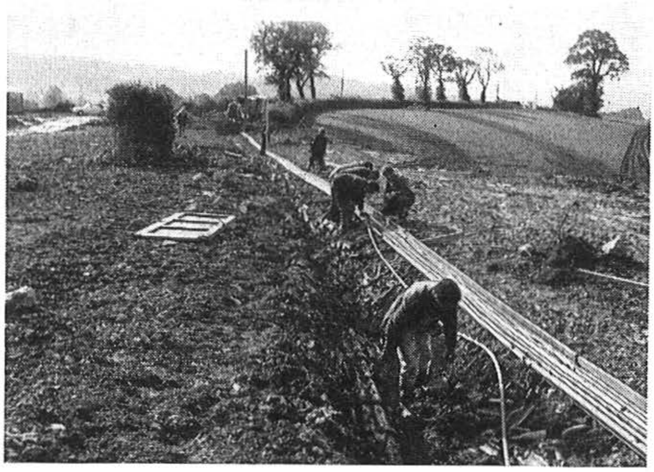


FIG. 1—Cables being shifted from the broken ducts to the troughing

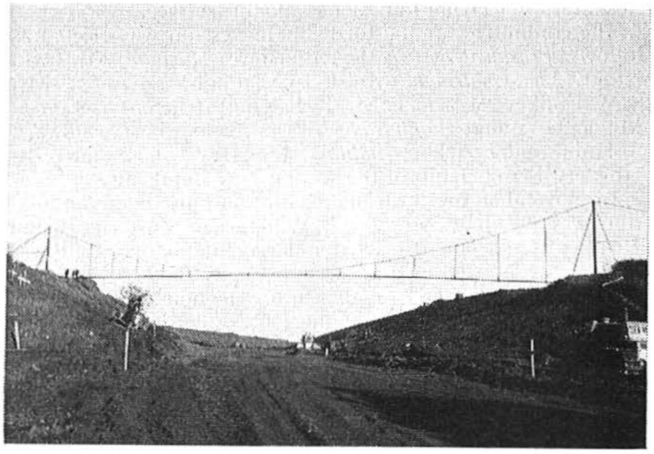


FIG. 2—The completed suspension bridge

Messrs. Holland, Hannan and Cubitts Ltd produced detailed calculations and technical drawings for a bridge, the Post Office supplying the details of ducts and cable weights.

Drawings were available by 7 September 1971 and excavation of the three two-way multiple ducts was commenced shortly after. Two Rendhex hexagonal masts were pile-driven into positions 384 ft apart. Larssen troughing, laid out between the masts, was jointed into a continuous length by lapping and secured by nylon nuts. Post Office staff broke off the exposed ducts and transferred the cables into the prepared trough (Fig. 1), to which a metal lid was tack welded.

Delay in obtaining the purpose-made catenary steel prevented further work until November 1971. The length of 32 mm stranded wire rope (s.w.r.) was calculated to produce a 32·4 ft sag at the centre of the span and to include 204 ft for back anchors. Reeving thimbles at each end provided means of tensioning and anchorage.

Pulley sheaves, on H-section girders, topped the masts of 49·88 ft and 34·89 ft; a difference in levels producing the height variation. Sixteen millimetre s.w.r. side stays anchored to angle-driven H-girders steady the mast, while the main anchors consist of 4 in × 12 in × 12 in H-piles sunk 6 ft below ground and embedded in concrete. The troughing is attached to the catenary by 17 6 mm s.w.r. hangers at 22·6 ft spacing. Ground anchors were fitted to stabilize the bridge against possible "galloping". The provision of a suspension bridge (Fig. 2) resulted in considerable savings of Post Office labour. The maintenance of the old route resulted in no loss of circuits, no loss of air pressure and no interruption to development schemes and also enabled adherence to the contractors revised time-table.

F. R. STANDEN
C. FITZROY

Associate Section Notes

Aberdeen Centre

Our first meeting of the session was held in the conference room at Telephone House on 27 October 1971. The talk, given by Mr. H. C. Stevenson of Telecommunications Headquarters Scotland, was on "Preparation for Interview." The talk was heard by a large audience who found it very informative and interesting. The second meeting was a talk given, this time, by a local associate section member—Mr. D. Duncan—on "Datel." This talk was given on 24 November.

J. H. McDonald

Cambridge Centre

The rearranged annual general meeting of this Centre was held on 27 October 1971, in the north lounge of Brooklands Avenue local government offices canteen.

Thirty-five members attended this meeting. The meeting proposed a vote of thanks to the outgoing committee and in particular to Mr. J. Acker, who retired from his post as treasurer after giving four years valuable service.

The committee for the forthcoming session was elected as follows: *President:* Mr. A. E. Patterson; *Chairman:* Mr. C. F. Nunn; *Vice-Chairman:* Mr. L. A. Salmon; *Treasurer:* Mr. S. W. Tookey; *Secretary:* Mr. R. S. King; *Assistant Secretary:* Mr. P. J. Young; *Committee:* Messrs. A. Newberry, Stewart, S. Hunt, and J. Acker; *Auditors:* Messrs. J. Clark and P. R. Howlett. Membership of the section now stands at 209.

In November, an illustrated lecture on pulse code modulation was given by Mr. C. G. Williams of Eastern Region Headquarters. This attracted a large attendance, and was thoroughly enjoyed by all.

Meetings arranged for the future include a lecture on Hi-Fi, a qualifying round of the Land-Line quiz and a visit to Rolls Royce Motors Ltd. It is hoped that these and other meetings will be well supported.

P. Young

Edinburgh Centre

The first meeting of the session, a talk entitled "Informal Insight into Hi-Fi," was scheduled to take place on 6 October but owing to illness the speaker cancelled this at very short notice. Since a great deal of interest had been shown in this subject it has been decided to try and fit the talk in sometime later in the session.

On 4 November 1971 Mr. H. J. Whitehead, Personnel Division, Telecommunications Headquarters, Scotland, presented a talk "Diamonds in Industry." The speaker illustrated his very interesting talk with slides and a colour film, also diagrams showing the make-up of different types of diamond. Although concentrating on the industrial diamond, some time was also spent discussing diamonds used in the jewellery trade.

Thirty members visited the British Broadcasting Corporation (B.B.C.) colour television studios, Glasgow, on the evening of 1 December. The party was shown the various pieces of colour equipment and the latest techniques being used, and then saw the studios control rooms, etc. The visit concluded with a period of questions, and answers by three B.B.C. engineers.

It is regretted that our proposed weekend visit to London in April has had to be cancelled because of security restrictions.

M. K. Finland

Exeter Centre

With our average attendance being 110 for the first two meetings of the winter program, the Centre continues to show its interest in the subjects selected by the committee, an interest which has been appreciated by the speakers.

Our speaker for October was Tony Soper, Naturalist and Preservationist (British Broadcasting Corporation television) who presented his program, "Coastal Wild Life." Filmed mainly around the Devon and South Wales coast, seals were the main theme for the evening, ending with an interesting question time.

"Concorde" by F. G. Clark, Publicity Manager, British Aircraft Corporation (B.A.C.), Filton, was a most informative lecture for November. A series of slides and a short film brought us to grips with this supersonic aircraft. Its reliability, a 15-year period between overhauls, was a most impressive fact, clearly B.A.C. has every confidence for the future.

It is hoped that the remainder of the winter program will be as enthusiastically supported.

In the summer program it is proposed to include a social visit to London, this being the first of its kind for the Centre. Other visits which are anticipated are as follows: Esso Oil Refinery, Fawley, Southampton; Hurn Airport, Hants; Appledore Shipyard; Decca Navigation, Brixham.

Our congratulations to Colin Knapman for his award winning paper "Voice Frequency Remote Control System A" presented as an Associate Section Paper Award 1970–71, it not only does Colin credit for a well presented dissertation, but gives inspiration to Centre members who may just need that extra push.

E. Soper

Glasgow Centre

At the time of writing, we are almost halfway through the 1971–72 session, and have enjoyed with much interest two talks and one visit.

The talks were "This is our Business" by Mr. W. Chatwin, Deputy Telephone Manager, Glasgow Area and "Diamonds" by Mr. H. J. Whitehead, Personnel Division, Telecommunications Headquarters, Scotland. Although quite different in subject matter; one explaining the fascinating manoeuvres, both financial and administrative, with a large business organization such as ours, and the other dealing in the main with the hard facts regarding the application of diamonds in industry, both talks were most informative and illuminating.

Our one visit so far has been to the Department of Trade and Industry, National Engineering Laboratory, East Kilbride, Glasgow. As this was an evening visit it was not possible to cover all divisions within the Laboratory. The members present, however, were most impressed by what they did see, which included the use of air bearings in industry, hydrostatic transmission for vehicles, hydrostatic extrusion and high pressure and optical methods.

We look forward now with enthusiasm to the remainder of the 1971–72 session.

R. I. Tomlinson

Gloucester Centre

The committee of the Gloucester Centre has been fairly active of late providing for its members a variety of events. The first of these, held on 28 October, was a lecture by two representatives from Modern Telephones Ltd. on private automatic branch exchange crossbar systems. Although not of a high technical content, this lecture was well presented and gave those present a good appreciation of these systems which are now being installed. Afterwards members were able to inspect various types of equipment on view. About 50 attended this evening lecture which was held at Gloucester.

On 18 November a party of 29 members travelled by coach to London, to the Houses of Parliament, there they were met by the Member of Parliament for Gloucester, Mrs. Sally Oppenheim. A tour of the Houses of Parliament then followed. After lunch 22 of these were fortunate to obtain tickets to the Public Gallery in the House of Commons to watch a debate, the remainder visited Faraday Building. This was a most successful visit and can be recommended to any centre which has not yet had the opportunity.

For the last day of November we organized our own "Any Questions?" evening on a form similar to that of the British Broadcasting Corporation program. This was held at the Kings Head Hotel, Cirencester and was attended by over 100 members, wives and friends. The panel consisted of

Mrs. Daphne Neville (currently with Harlech television), Mr. W. Audry (retired clergyman and author of *Thomas the Tank Engine* and an authority on railway matters), C. W. Barnett, Esq. (ex-England and Gloucestershire County Cricketer) and Dr. G. R. Dickson (Principal of The Royal Agricultural College, Cirencester).

The Chairman was J. A. Stocks, M.A. (Head Master of Sir Thomas Ricks' School, Gloucester). A varied selection of questions, on both serious and light-hearted subjects were submitted by our members, which helped to contribute to a most enjoyable and successful evening.

This meeting concluded our 1971 program. Another varied program is prepared for 1972 and we hope that this too will continue to meet with success and be of interest to our members.

P. G. WHITE

Hereford Centre

The annual general meeting was held at the Spread Eagle Hotel, on 29 November 1971 and was followed by a steak supper.

The following officers were elected:

Chairman: Mr. E. W. Ballinger; *Vice-Chairman:* Mr. S. J. Cound; *Secretary:* Mr. L. Evans; *Assistant Secretary:* Mr. A. J. Charles; *Treasurer:* Mr. L. J. Knight; *Auditors:* Messrs. W. J. Merrick and M. Powell; *Committee:* Messrs. J. Bethell, F. Dykes, L. Higgins, M. G. Frost, N. Innes, H. Holt, P. A. Williams, G. Vanston, K. Manning, M. Parry, C. J. T. Brace, W. Wilkinson, K. Lee, D. Till, and N. Deeley.

Membership of the section now totals 123. In 1971, one well supported successful visit was undertaken to W. D. and H. O. Wills cigarette factory at Bristol. The following talks were given which were illustrated by slides: "Talk on Telephone Engineering Centres" by Mr. M. R. Clough, "Is there a need for Civil Engineering in the Post Office?" by Mr. P. Sayers, and "The Development of the New Hereford Trunk Centre at Barton Road" by Mr. A. Hayward and Mr. D. Garner.

The first dinner and dance was held on 1 October 1971 at the Green Dragon Hotel, Hereford, with the Mayor and Mayoress and Mr. and Mrs. C. T. Lamping (Regional Liaison Officer) as guests. This proved to be a very enjoyable evening.

Details of the 1972 program have to be finalized, but it is hoped to include visits to the Hereford Town Hall and to the Birmingham Post Office Tower and a talk by Dr. P. R. Bray on "Underwater Submarine Cables" and one on the "Weights and Measures Department."

L. EVANS

Sheffield Centre

The new committee has been gratified by the increased support of the membership at meetings held during the first half of the 1971–72 session.

A party of 26 members visited York University on 5 October 1971 where Dr. Coombes gave us a glimpse into the future by presenting his paper "The advent of the intelligent machine."

Our Telephone Manager, Mr. R. H. Thompson, who this year is also Chairman of the Sheffield centre of the Institute of Electrical Engineers addressed the centre on 13 October 1971. His subject was "Telecommunications" and there followed a tour of the main switching centre at Eldon House during which some members were called upon to assist.

On 22 October 1971, a party of 24 members visited the British Overseas Airways Corporation (B.O.A.C.) headquarters at Heathrow. This was our second visit to B.O.A.C. and we are hopeful that there is scope for a third.

Mr. Forster of Telecommunication Headquarters presented his paper on pulse code modulation before an audience of 35 members on 11 November 1971. Not only did he deal with fundamentals but he also covered future developments and usage.

Mr. J. Hornsby presented a paper entitled "From Valves to Transistors" on 7 December 1971; 51 members attending this meeting. Mr. Hornsby was at one time at the Technical Training College, Stone and will be known to many outside the Sheffield centre.

K. H. BARKER

Southampton Centre

The Southampton Centre had an unfortunate beginning to the 1971–72 session, when the first visit was found to be scheduled on the same evening as the Post Office Engineering Union meeting for discussion of the new superannuation scheme. There was, in consequence, a poor attendance for the visit to International Business Machines research laboratory at Hursley. This was followed by a visit to the British Broadcasting Corporation (B.B.C.) television centre in September. In October a party visited the British Transport Port authority and had a five hours conducted tour of the Southampton docks. Also during October the chairman of the Southampton section gave an illustrated talk on subscriber trunk dialling. There were no visits during November but we had a very interesting talk on "Live Line Working" by Mr. Howell of the Southern Electricity Board. In December, a party visited Thornycrofts boat yards and spent a very enjoyable morning touring these yards, at the end of this visit the Secretary was presented with a book on the history of the Thornycroft yards; this made a most welcome addition to the section's library. During the forthcoming months so far arranged are visits to B.B.C. South offices and B.B.C. Radio Solent offices and the Ice Show at Wembley, talks on electronics in automatic telephone exchanges and the miniturized A.C.9 signalling system.

G. A. HOLYOAKE

Post Office Press Notices

Cardiff "Turnkey" Project

A new administrative block, part of a big Head Post Office under construction at Cardiff, is expected to be ready for occupation in April.

This is the Post Office's biggest "design-and-construct" project so far, and the first for a complete head office incorporating office block and mechanised letter and parcel sorting offices. John Laing Construction Industrial Engineering Branch has a £2½ million contract for the building and much of the equipment. Letter sorting machines, coding desks and other equipment supplied separately will be added later. The building is on a 9½-acre former sports field, on the main Penarth road about three-quarters of a mile from the town centre.

Work started in October 1970 and the project is scheduled to be completed by September this year. The main structure of the building, which has 200,000 square feet of floor space, is complete and installation of equipment by Laing has reached an advanced stage. The parcels concentration office will have a central console from which one man will be able to control the flow of parcels through the office.

Trunk Circuits Increase

New telephone trunk circuits installed by the B.P.O. in 1971 totalled 12,032. This represents a 12·7 per cent increase in the number of trunk telephone circuits working in the U.K.—to 106,942 at the end of 1971.

Britain Doubles Communication Links to Europe

Three new high-capacity undersea telephone cables linking Britain with Europe will be in service by the end of May, announced Mr. Edward Fennessy, Managing Director of Post Office Telecommunications in January.

The cables, each capable of handling up to 1,260 telephone calls simultaneously, are part of a huge £7 million communications package for four cables across the North Sea, which will more than double existing telephone, telegraph, telex and data transmission links with Europe by the middle of next year.

At present, links to Europe are provided by 22 low-capacity telephone cables and a special microwave radio "hop" across the English Channel at Dover. Together these give just over 4,300 telephone circuits. The new North Sea cables—the fourth comes into service in June 1973—provide an additional 5,000 circuits.

The rate of growth in the European sector is spectacular. For example, of the 61,800 international telephone calls made each day 50,700 are to Europe. Last year 18 million calls went to Europe, three-and-a-half million to the rest of the world.

In the mid-1960s Britons made seven million telephone calls a year to Europe, while people on the Continent made nearly six million to the U.K. By 1975 this traffic will increase sixfold on the mid-1960 level—with 39 million calls to Europe and 39 million coming in to the U.K. The picture for telex is similar. A total of 19 million incoming and outgoing calls in 1965 will increase to 90 million by 1975.

The installation of the four new North Sea cables, provided under a seven-nation agreement on the initiative of the British Post Office, is only a single step towards meeting the exploding demand for communications with Europe.

"We are also planning to expand substantially our international 'gateway' exchange capacity," said Mr. Fennessy. Customers in London, Edinburgh, Birmingham, Glasgow, Liverpool and Manchester are already able to dial their calls direct to all Common Market countries and to Norway and Switzerland. As the new international "gateway" exchange at Wood Street, London—recently brought into service—is extended during the next two years international subscriber dialling will become available from other major centres in the provinces. The number of countries available by ISD is also being increased rapidly. In 1974 the Post Office is to to extend the microwave radio link with France. The extension, on the same Dover–Fiennes route as the existing link, will provide 1,800 extra telephone circuits with room for expansion up to 3,600. A new cable is also planned with France for 1976.

"The increasing telecommunications contact with Europe is a barometer by which we can measure Britain's increasing commercial and social ties with the Continent," said Mr. Fennessy. "We are today providing the communications hardware which will meet this growth and improve existing services."

Riding the Millimetric Waves

To assist in meeting the explosive growth expected in telecommunications in the next twenty years the Post Office and the Science Research Council have begun what is probably the largest microwave-propagation study yet to be mounted anywhere. This project could have a major influence in opening up the 10–100 GHz range of the radio spectrum (wavelengths down to 3 mm) to new microwave telecommunication system use.

The propagation study is based on the Post Office Research Station at Martlesham Heath, near Ipswich. The SRC Radio and Space Research Station, in addition to participating at Martlesham, is carrying out supporting research at Slough. The Post Office needs to study the problems of transmitting radio waves at these super-high frequencies because its existing radio-relay network, operating at frequencies of 2, 4 and 6 GHz, is now approaching congestion and the higher frequencies offer a much greater message-carrying capacity. As frequencies rise above 10 GHz, transmissions are increasingly affected by the weather: heavy rainfall can cause serious signal fading; and the temperature stratification that occurs on clear evenings in still air can occasionally produce multiple transmission paths that could adversely affect microwaves carrying high-speed digital signals.

The object of the study just begun—in which a network of experimental radio transmitters has been set up in East Anglia between Martlesham and Mendlesham—is to find out just how radio transmissions at these millimetric wavelengths are affected by the weather and what can be done to avoid disruption of service. It will take further the studies carried out previously by the Post Office Research Department at Dollis Hill, and the Radio and Space Research Station. This work has led to effort being directed at two specific systems:

(*a*) An 11 GHz system transmitting digital information at rates of about 100 Mbit/s on several microwave carriers and suitable for line-of-sight path lengths of about 30 km. Intended for use at existing stations on the Post Office's present extensive network in the United Kingdom, it will be capable of early exploitation. One link is already in operation, between Plymouth and Caradon Hill television transmitter, operating in an analogue mode.

(*b*) A 20 GHz system transmitting digital information at rates of up to 500 Mbit/s on several microwave carriers and suitable for path lengths of 5 to 10 km. This short hop system will use low-power, solid-state microwave equipment whose small size and low weight should lead to radical simplification of installation design. The Post Office envisages poles up to 24 m high, with the equipment housed in pole-top units which could be lowered to ground level by winch and cable inside the pole, similar to some lighting columns used on motorways and large intersections. The poles—much less obrusive than lattice steel towers—would stand by the roadside at appropriate intervals. Particular attention being paid to the environmental amenities aspect of the design.

A longer-term possibility is the use of frequencies of 50 to 100 GHz for local distribution, over distances of up to 1 km. This could make it possible to develop a system covering a residential area and providing telecommunication services to individual houses.

More Trunk Calls

Telephone users in Britain made 422 million trunk calls in the three months ended December 31—an increase of 11·9 per cent on the same period in 1970.

The proportion of calls dialled direct by customers also rose, from 77·6 per cent in the last quarter of 1970 to a new peak of 81·9 per cent during the last three months of 1971.

Extension for Supercable

The biggest telephone cable in Europe, planned by the Post Office to link London, Birmingham and Manchester by the mid-1970s, is to be extended to Leeds. Carrying some 100,000 telephone calls simultaneously, the 230-mile cable will form a new high-capacity spine for Britain's fast-growing trunk telephone network. Construction work on the first stage of a massive cable-laying operation—the installation of 110 miles of underground duct to carry the supercable between London and Birmingham—is due to begin this year.

The London–Birmingham section, is planned to come into service in 1975, with the Birmingham–Manchester link follow: ing in 1976. The complete cable will be working by 1977 with the opening of the Manchester–Leeds section. The new cable is only three inches in diameter, yet it will carry nine times the number of telephone calls of any cable in use in Europe today. Because of its huge capacity this new communications highway is to be specially protected from accidental damage and from the risk of electrical or radio interference. The cable will avoid major centres of population to keep well clear of other telephone cables and underground utilities, and will be laid nearly four feet deep—almost twice the usual depth.

Britain's trunk network is growing rapidly. There are more than 100,000 circuits already in operation, and the Post Office is providing an additional 12,000 circuits each year. The supercable will improve existing communication services and cope with expansion into the early 1980s. While construction work is in progress the Post Office plans to lay two ducts, so that a further high-capacity system can be provided quickly to meet the demands of the '80s.

Post Office engineers have evolved new cable-laying techniques so that the cable can be laid faster and with more efficiency than existing methods. These include the design of a completely new vehicle to draw cable into the underground duct in lengths of up to a third of a mile—twice the distance of normal cable-laying. Post Office engineers have installed a supercable at Marlborough, Wilts, to gain practical experience of cable-laying with the new techniques and to test the cable under operational conditions. Underground duct has been laid over a 6·8 km route and a test section of the new cable installed. Tests will continue throughout the year. A number of innovations, such as new manhole designs, are being tried out.

The Supercable is a 60 MHz coaxial system. It consists of 18 coaxial pairs over which it is possible to operate nine both-way 60 MHz line systems suitable for telephony, data, television, or a combination of all three. The cable has a capacity of 97,200 circuits compared with the 16,200 circuits available on the 12-tube, 12 MHz coaxial cables now in use.

The 60 MHz line system, using frequency division multiplexing, is a bold extension of the 12 MHz coaxial system. Each of the nine pairs of coaxial tubes exploits the frequency spectrum from 4 to 60 MHz in which twelve 900-circuit broadbands can be assembled to give a capacity of 10,800 telephone channels—four times the number provided by each of the six pairs of coaxial tubes in existing 12 MHz cable systems.

The Choice for Telecommunications

The Post Office had some very important decisions to make in the currently controversial area of telephone switching policy, said Mr. Bill Ryland, Chairman of the Post Office, speaking to the Telecommunication Engineering and Manufacturing Association.

The debate was whether the system for the '70s should be the new large electronic exchange (TXE 4) or some advanced type of electromechanical equipment (crossbar).

"We are all agreed that we should dispense with the old fashioned type of electromechanical equipment (Strowger) as soon as possible," said Mr. Ryland. "We are agreed that in the meantime we need more modern systems. . . . It is accepted that the TXE 4 project must go ahead for final, rigorous and realistic validation. The issue is whether it is necessary and practicable to look also at some alternative—if only as an insurance.

"We are having discussions with some firms in TEMA about this. I want those discussions to be meaningful and satisfying."

Price, commented Mr. Ryland, was a key question for any new or modified switching system. It would have to be one that would enable the Post Office to use the system not only for new requirements but also for replacing the obsolescent, so that the network could be modernized and up-dated.

The Post Office must be assured that the prices quoted initially would not go up, as so often happened with vast technological projects. It must come down as design improvements and productivity economics took effect. There must be a convincing and demonstrably realisable cost reduction programe, fully acceptable by all. The Post Office could not risk being faced with unavoidable cost increases which it could not afford and which the customer could not stomach.

Whatever was done, said Mr. Ryland, it had to be in tune with giving the customer the faster, quieter and more faultless service he wanted, with a wider range of facilities, and at the lowest possible price.

"Our product is service. If it satisfies at a price which carries conviction as value for money, people will want more of it. That's where expansion and prosperity lie."

Last year, he said, telephone service was given to a million more people, more than 1,000 million more calls were handled than in the previous year, the quality of the automatic service—local and trunk—was better, and a profit was made of some £93 million, all of which was ploughed back for expansion and development. Productivity in telecommunications since 1963–64 had been so good that the price index had risen by less than in the Retail Price Index.

Contracts in delay were halved, and further progress had been made since then, but three-quarters of the increase in the waiting list was due to delays in the completion of contracts by manufacturers.

The Post Office and the telecommunications manufacturing industry were faced, said Mr. Ryland, probably more acutely than any industry, with the problem of reconciling the pace of technological change with the need to provide the customer with the most up-to-date service at reasonable cost.

New 'Phone Booths for Stations

New open-style telephone booths are being installed at Waterloo Station, London, in place of the old wooden telephone boxes. Now the Post Office is discussing with British Rail a program for the installation of booths at other stations.

So far 34 booths have been installed at Waterloo and another 13 are go go in shortly to replace the old wooden telephone boxes. Already they have proved popular with travellers. In a special survey people using the booths said they found them more convenient, cleaner and easier to use than the wooden boxes with folding doors.

The open-plan design is also a deterrent to vandalism and enables travellers to keep their luggage beside them when telephoning.

"Telephones at stations get a great deal of use and the old wooden boxes are not really suitable for the demands of the 1970s," said Mr. Edward Fennessy, Managing Director of Post Office Telecommunications. "We are looking at ways of bringing the telephone service on stations into line with the needs of the times, and booths have some very real advantages over old-style boxes with doors. They are easier to use, particularly for people with luggage, are cleaner and much more convenient. With no doors there is slightly more background noise, but our user survey confirms that this is more than offset by the advantages."

The booths, separated by panels which run from the ceiling to about three feet from the ground are illuminated by fluorescent lighting. The international sign for the telephone, a handset on an illuminated circular background, is displayed above each booth to make identification simple for regular travellers and foreign visitors. The telephone equipment, and fixtures for holding directories, remain unchanged. British Rail are co-operating with the Post Office by redirecting their public announcement loudspeakers away from the open booths. Since introducing the new booths at Waterloo telephone calls have risen by 30 per cent.

The design used at Waterloo will form a basis of a new national design for public telephone booths on railway stations. There are about 1,700 callboxes on railway stations, most of them the wooden box type which have been in service for up to 30 years. Booths will be installed at main-line terminal and other stations as these are modernized.

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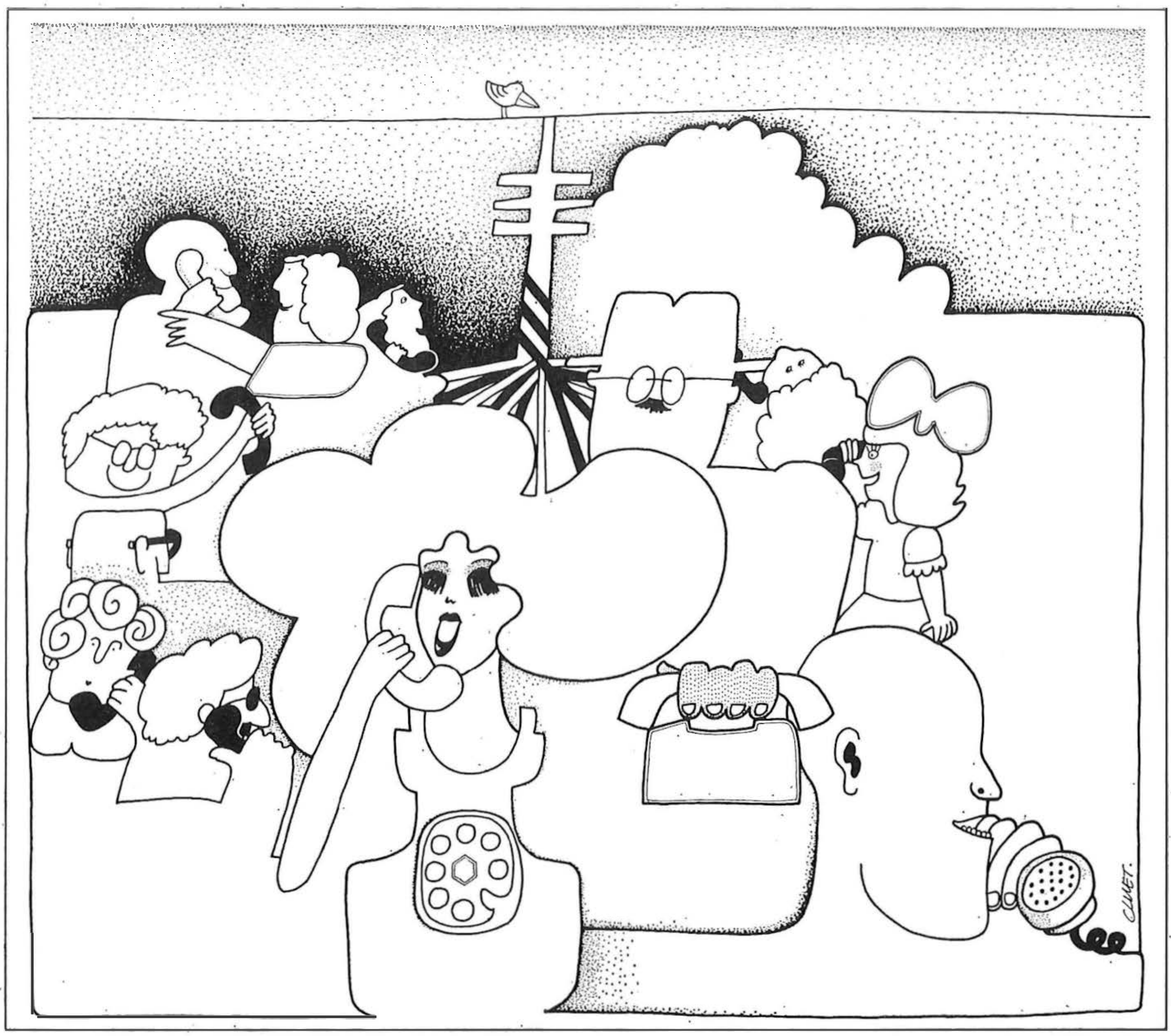
Model Answer Books

Books of model answers to certain of the City and Guilds of London Institute examinations in telecommunications are published by the Board of Editors. Details of the books available are given at the end of the Supplement to the Journal.



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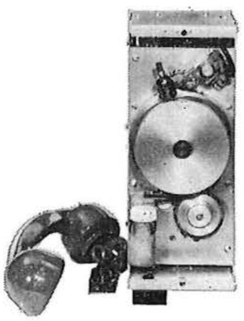

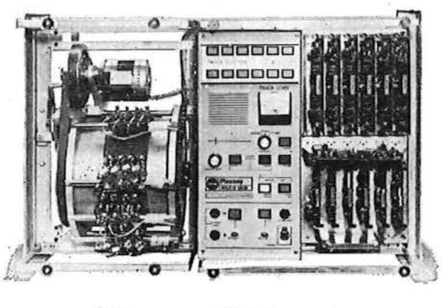

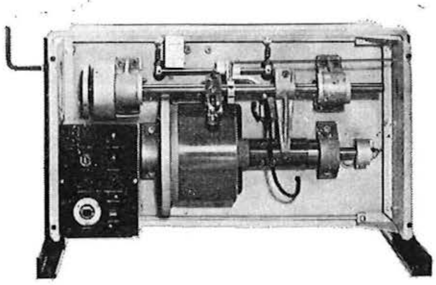

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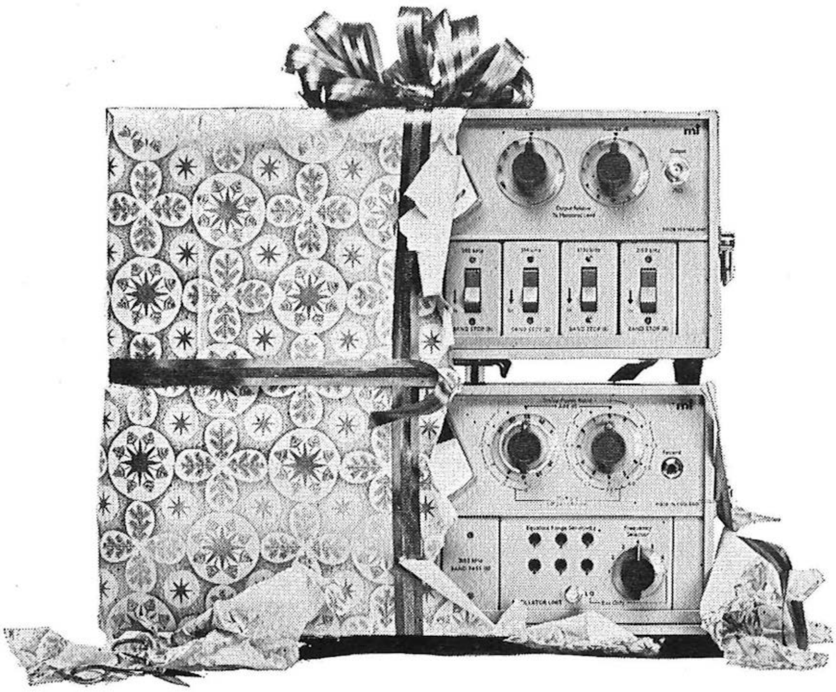

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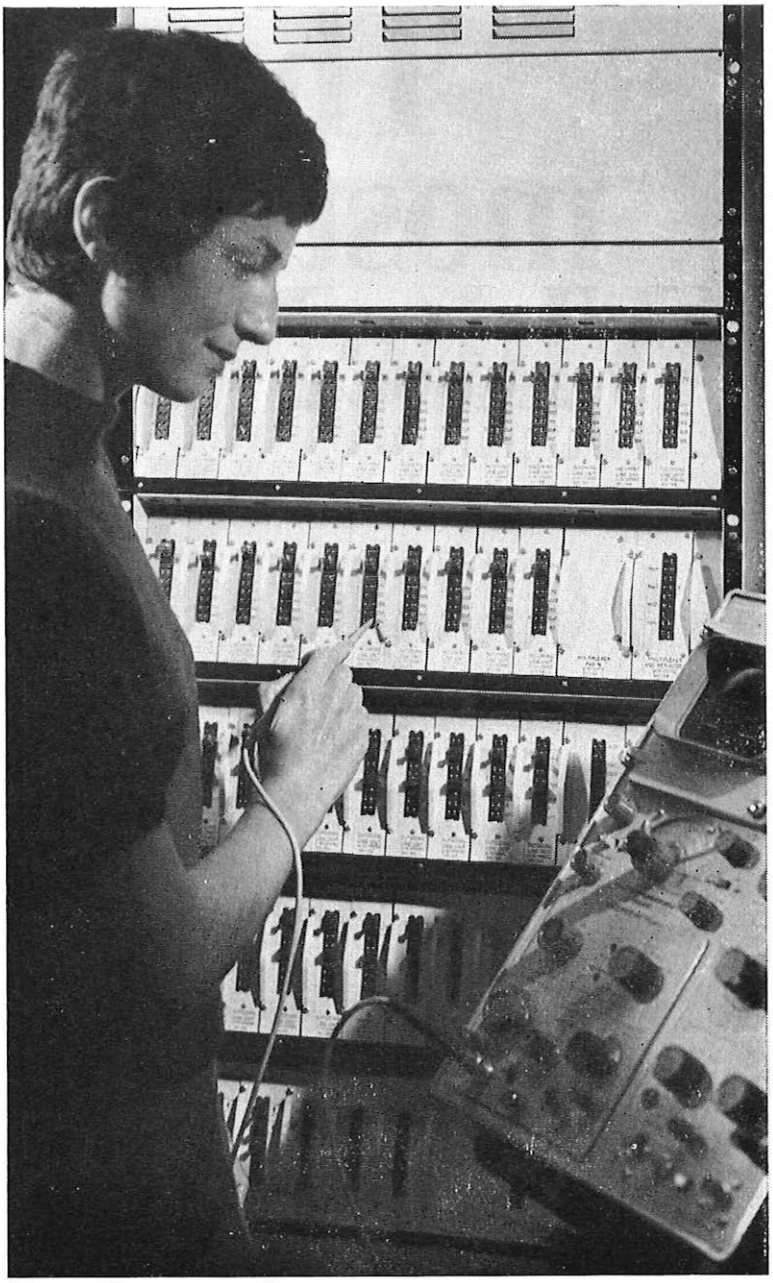

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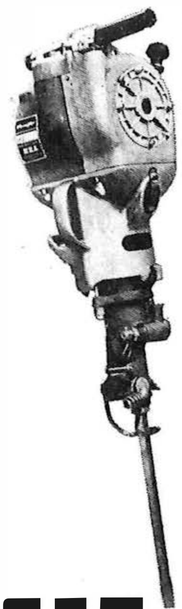

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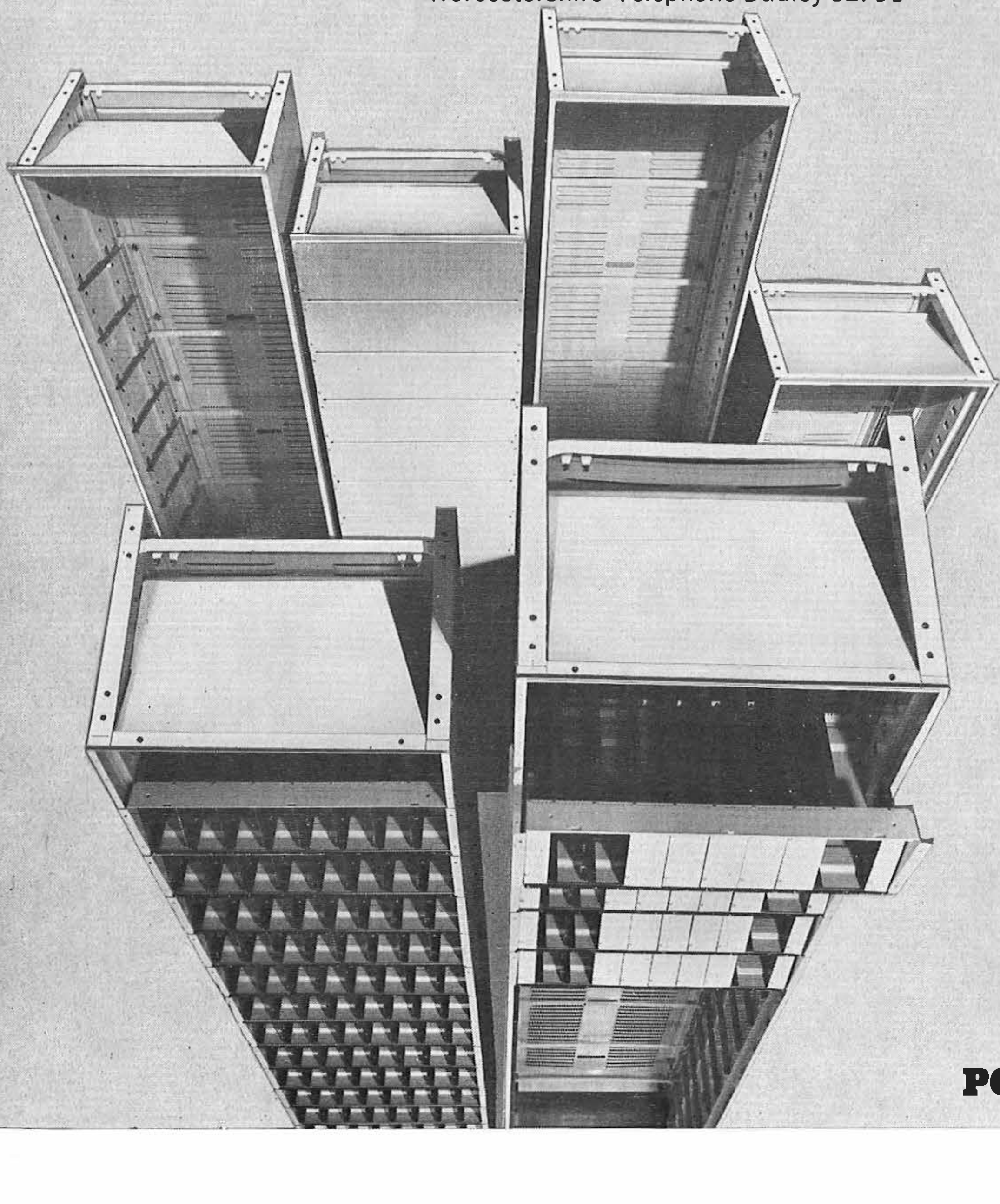

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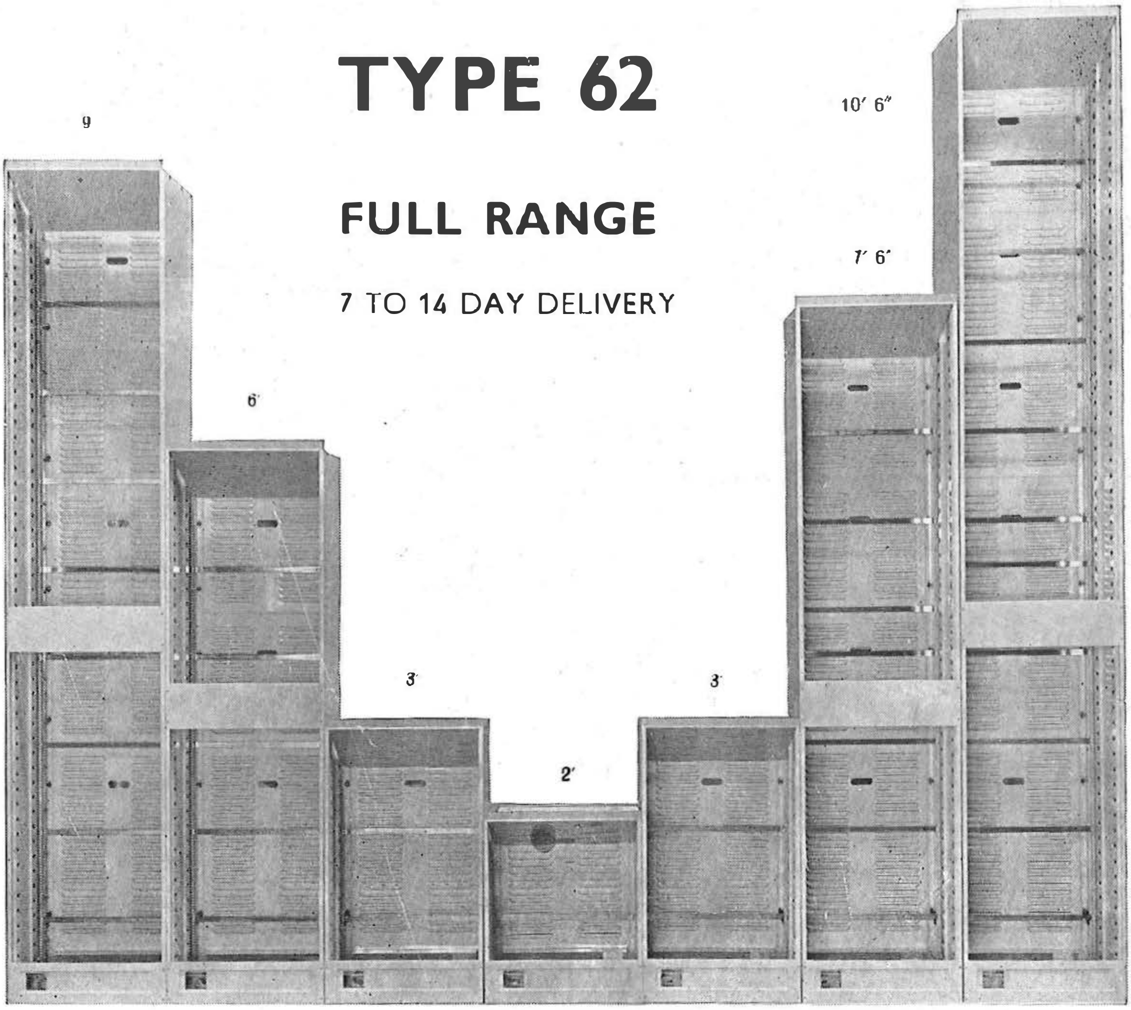

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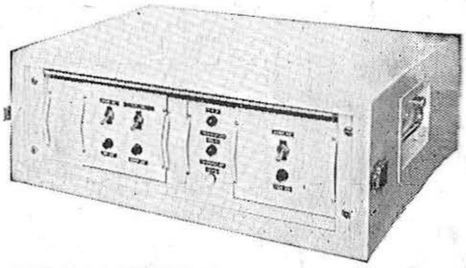

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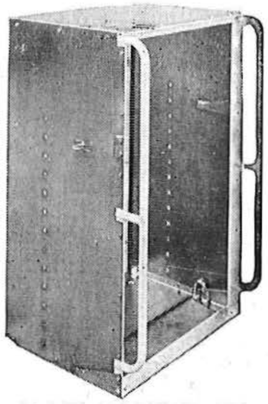

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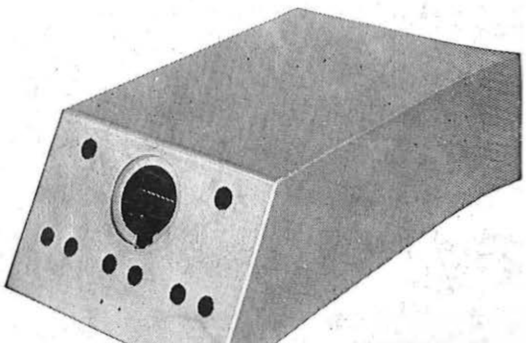

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