BBC

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The Development of BBC Internal Telecommunications

by

J. M. CHORLEY, A.M.I.E.E.
(Designs Department, BBC Engineering Division)

and

J. S. NORWELL
(Lines Department, BBC Engineering Division)

BRITISH BROADCASTING CORPORATION

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FOREWORD

THIS is one of a series of Engineering Monographs published by the British Broadcasting Corporation. About six are produced every year, each dealing with a technical subject within the field of television and sound broadcasting. Each Monograph describes work that has been done by the Engineering Division of the BBC and includes, where appropriate, a survey of earlier work on the same subject. From time to time the series may include selected reprints of articles by BBC authors that have appeared in technical journals. Papers dealing with general engineering developments in broadcasting may also be included occasionally.

This series should be of interest and value to engineers engaged in the fields of broadcasting and of telecommunications generally.

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THE DEVELOPMENT OF BBC INTERNAL TELECOMMUNICATIONS

SUMMARY

In order to support the BBC television and sound broadcast services, a comprehensive network of telecommunications has been found essential. The British Post Office provides many of these facilities directly, but in certain circumstances the Post Office is prepared to permit the termination of circuits by renter's apparatus, provided it is 'type approved', and the BBC has found it advantageous to operate a number of services in this manner.

This monograph traces the development of BBC telecommunications, that is the telephone, telegraph, and facsimile services, and describes some of the equipment used, which has been designed by the Engineering Division. The way in which television and sound programmes are distributed is not dealt with here.

1. Introduction

The communication services between studio centres, transmitters, and offices of the BBC have developed continuously with the expansion of television and sound broadcasting. At first all the requirements were met by hiring standard facilities of the type the Post Office was able to provide, but as the domestic and overseas services grew, the supporting communication services expanded in quantity and complexity.

The equipment needed to provide the services required could not always be bought or hired, and this was particularly the case during the war when many services were expanding very rapidly; consequently some of the apparatus had perforce to be designed and produced by the Engineering Division of the BBC.

Throughout the period under review the planning of the services has been directed to achieve efficiency and the utmost economy in capital cost and in circuit rental costs; for example, some music circuits not in use all the time for sound broadcasting are used also for multi-channel telephony and telegraphy. Also, sharing is practicable between different types of user on a speech circuit when priority can be given to one user without a possibility of dispute with the other.

2. Telecommunications before 1939

2.1 *Early Developments*

The pre-war telecommunication services were provided for very simply. To support programme and engineering services of an urgent nature there was supplied a network of speech lines known as control lines. Traffic on these circuits dealt with the minute-to-minute control of programmes; such messages were (and still are) transmitted between studio centres and transmitters. The engineering messages were of short duration and consequently the lines could be available for use between private branch exchanges (PBXs) at main studio centres for most of the time. If these circuits were not available for traffic between offices, then the public telephone service was used instead. An indication of the extent of the pre-war (1939) PBX and control line network is shown in Fig. 1.

All the circuits were rented 'point to point', which means that satisfactory transmission of speech is guaranteed between terminal stations only. Such circuits can seldom be connected in tandem to form a network with good overall transmission. The installation of amplifiers at intermediate points was tried, but proved to be only a partial solution (as explained in the next section); and as the number of premises grew the problem of providing good communication became more acute.

2.1.1 *The Voice-switched Telephone Repeater*

In order to promote satisfactory speech transmission over lines connected in tandem, two-way repeaters were connected into circuit at intermediate points. The improvement that can be obtained in this way is limited, and some difficulty was experienced in maintaining the correct operating conditions for stable working of the repeaters. Consequently the BBC and a commercial firm developed a voice-switched repeater which did not require the provision of line-balancing networks. However, it did not prove possible to use this type of repeater universally in the network due to the fact that the level of speech at the input could not be controlled to close enough limits. After the war other solutions became possible.

2.1.2 *The BBC Voice Frequency Selective Ringing System*

In order to economize in the number of speech lines used a method was evolved (which is still in use) for allowing two different user groups to share a single line—for example, control room engineers and PBX switchboard subscribers. Such sharing is permissible only where the traffic density is not high. Priority is given to control room traffic, which is usually very urgent, being concerned with the minute-to-minute operation of the programme services. Fig. 2 shows the operation of the selective ringing system used for this purpose.

The telephone line terminates in control rooms at each end, and calls are made by applying a ringing frequency of 17 c/s to the line terminals. When not in use by the engineers the line is extended from the control room at each end, via the inner contacts of the answering jack, and a ringing converter panel, to the PBX switchboard. Thus, when either switchboard operator rings, the 17 c/s ringing tone from the PBX will be changed by the ringing convertor panel to, say, 700 c/s, and this tone will be passed to the line. At the receiving end the 700 c/s will have no effect on the control room calling equipment, but will be detected by the ringing convertor panel and changed to 17 c/s which will be used to ring the PBX switchboard. As the control room traffic has to be given priority, calls be-

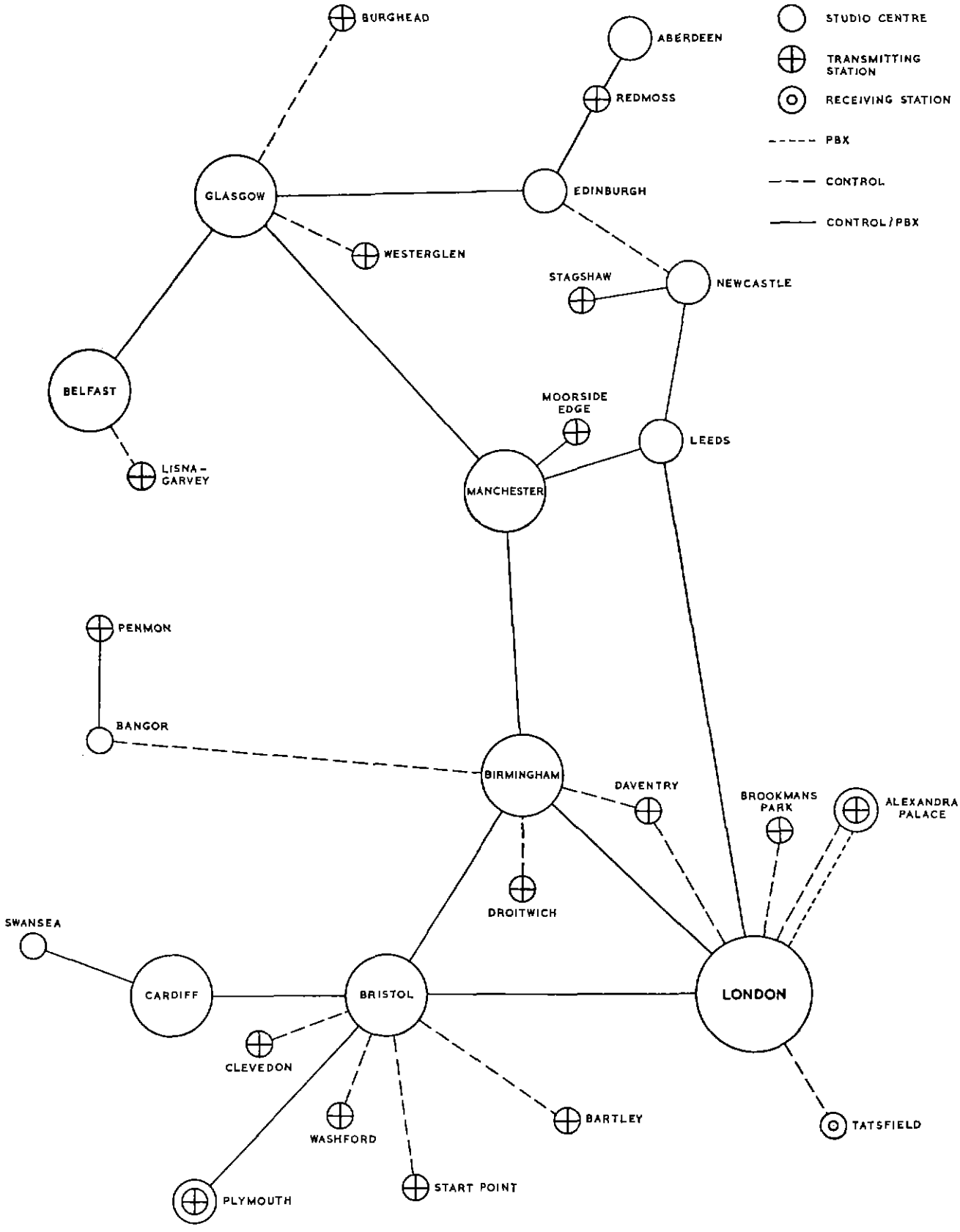


Fig. 1 — Indication of main pre-war communication network—PBX and control lines.

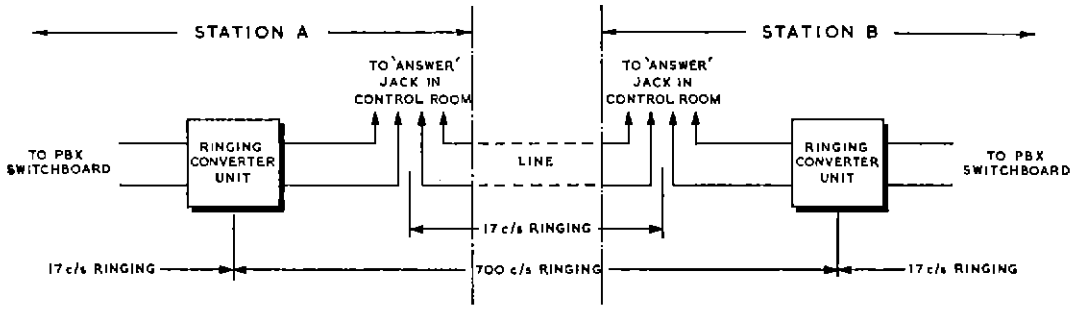


Fig. 2 — Frequency selective ringing system.

tween PBX switchboards will suffer interruption and a warning signal of 'line engaged' has to be sent to the switchboard operator. A further extension of this selective ringing system involves the use of two ringing convertors at each end of the line; this is done where two voice frequencies have to be used for ringing (usually 600 and 700 c/s), because a frequency of 17 c/s cannot be used, as for example when the telephone circuit is derived over a BBC carrier system.

The voice frequency ringing convertor and guard circuit (which prevents false operation by speech components) offers only a small attenuation in the speech path. A facility is provided so that the switchboard operator may be recalled from the distant end of a telephone line while a through connection is set up. The ringing convertor will operate satisfactorily on circuits where the transmission loss does not exceed 20 dB.

2.2 *News Services*

Before the war the BBC obtained its supply of news mainly from the news agencies in London for broadcasts in the domestic services and later also for the Empire services. In 1939, however, the BBC greatly expanded its news services during the period of growing international tension, and this meant the provision of new facilities for collecting and distributing news.

3. Developments during the War, 1939-45

3.1 *Expansion of the Telephone and Telegraph Services*

At the outbreak of war most departments of the BBC were evacuated from London to the provinces and Wood Norton Hall, near Evesham, became the country headquarters. As a consequence the communication services altered radically in their geographical distribution and at the same time expanded greatly.

The growth of the control line network was mainly due to the many additional transmitters that came into operation on the home and overseas services. Telephonic communication to all transmitters had to be as reliable as possible as many urgent and important messages had to be sent from a central control point. Reliability was enhanced by duplicating some communication lines, and by using more than one route from one point to another.

A considerable body of staff remained in London, and in the early part of the war the need for communications was most acute between London and Bristol, and also between London and Wood Norton. At the time it was not easy for the Post Office to provide all the telephone and telegraph facilities needed owing to the demands of the fighting services and government departments. Therefore, the BBC had perforce to make the best use of the facilities available. Among the facilities that the BBC rented from the Post Office was a large network of lines suitable for the transmission of music, and some of these lines were used to meet the need for more telephone and telegraph circuits by the application of carrier technique. The bandwidth available for use on these music* lines was from 50 to 7,500 c/s approximately. The first carrier system operated in this way was installed between London and Bristol, and carried a heavy load of inter-office telephone and telegram traffic.

A second carrier system, between London and Wood Norton, was required to carry heavy telephone traffic and also teleprinter messages consisting of news from the news agencies. In addition, the information taken from monitored foreign broadcasts had to be sent by teleprinter to various addresses in London. In 1943 the Monitoring Service was moved from Wood Norton to Caversham, near Reading (where it has remained ever since), and a very extensive communication service was provided for it (see Section 3.4).

The advantages of operating carrier systems between busy centres soon became very apparent. The main advantage was the provision of low-loss telephone circuits and with them a number of telegraph channels. There was also the advantage that the greater flexibility enabled changes in traffic patterns to be accommodated more economically than would have been possible with separately rented circuits. Also, additional telegraph channels could be, and were, provided quickly and at low cost. Taken over the years the cost of providing the multi-channel carrier systems is considerably less than the cost of renting the facilities from the Post Office.

3.2 *Early BBC-designed Carrier Systems*

The first carrier system designed by BBC engineers was

* This is the usual BBC term for programme circuits as defined by the CCIR.

provided in 1940 to give two telephone channels, one at audio frequencies and the other at carrier frequencies (1+1), between London and Bristol. It gave only somewhat intermittent service as it was connected to landlines often required to carry music. The line transmission bandwidth was about 6 kc/s, and, in the case of Channel 2, the carrier frequency and one sideband were transmitted. As there were no volume limiters in the speech channels the inter-channel crosstalk was somewhat excessive. The design was far from the optimum as all components were taken from a very limited wartime stock. However, the advantage of the low-loss speech channels led to the demand for, and immediate design of, a system of better performance in order to relieve the traffic congestion between London and Wood Norton. This second carrier system also provided two telephone channels but employed a single-sideband, carrier-suppressed system of transmission. Owing to supply shortages the filters and amplifiers were designed and built by BBC engineers, but the modulators, demodulators, limiters, and hybrid transformers were supplied by a well-known commercial firm.

The operation of this second carrier system was very satisfactory, and later the same year the first system operating between London and Bristol was replaced by a system of better performance. In this system the single carrier channel was designed for transmitting either speech or telegraph signals, and consequently the transmission of the telegraph signals involved the use of a 'tone-space' signalling system, so that when the channel was used for speech the teleprinter would not 'race'. The tone-space system was used only temporarily and later the tone-mark system was adopted in line with British Post Office practice.

In 1943 a second carrier telephone channel and two telegraph channels were added to the London/Wood Norton carrier system, and it is of interest to note that with this equipment the telegraph channels were derived from the speech channels at a frequency just above the upper frequency limit of each speech channel. This method has been continued in present-day BBC carrier systems.

Next, a carrier system was installed between London and Leeds which greatly improved communication to Manchester and the North. Many unorthodox arrangements were made under stress of war, such as the provision of a telegraph signalling circuit between London and Manchester which employed a direct-current signalling path with one leg via Oxford and the other via Daventry, with conversion to a voice frequency tone-space signalling system between Birmingham and Manchester. The circuit worked simplex, i.e. it was open in the direction south to north and this was the idle condition; the generation of a teleprinter signal at Manchester terminal automatically reversed the circuit.

Advantage was taken of the existence of unrepeatered (and therefore two-way) lines between busy centres to provide low-loss speech channels by the design and assembly of a 'Two-band Carrier System'. The bandwidth of the lines was about 5 kc/s, and transmission of speech in one direction used frequencies from about 200 c/s to 2·5 kc/s while in the other direction frequencies above 2·5 kc/s were used. Initially these two-band systems were installed between London and Daventry, Manchester and Leeds, and between Glasgow and Edinburgh. The apparatus was made in portable form and this type of carrier system has been used in various locations until quite recently.

3.3 *The BBC 'Tone-space' Telegraph System*

At the onset of the war the first telegraph channels were operated over two-wire speech circuits which made it necessary to employ a tone-space system, the method used at the time on the Post Office Telex system. Over these circuits either speech or teleprinter signals could be sent. In the BBC system the usual type of telegraph relay was employed at the sending end, but at the receiving end this relay was replaced by an electronic device. This consisted of a valve amplifier followed by a rectifier with two pentode valves (AL60s) in the output stage, working in push-pull into the teleprinter-controlling electromagnet. This arrangement proved very reliable and saved the time that would normally be taken in adjustments to electro-mechanical telegraph relays. This development was a precursor of more modern designs; during the last decade the BBC has dispensed with the normal telegraph relay through the introduction of a new BBC-designed electronic telegraph convertor (see Section 6).

3.4 *Telecommunications for the Monitoring Service at Caversham*

A Monitoring Service was established at the outbreak of war to keep a watch on foreign (especially enemy) broadcasting, and a listening post was set up at Wood Norton. The material received was translated and edited on the spot, and a daily 'digest' was sent by road to various destinations in London, but the most urgent material was transmitted over a teleprinter circuit to London, whence it was distributed by hand. The volume of material grew rapidly and so did the urgency of distribution. Consequently a further teleprinter circuit soon became necessary. In order to speed up distribution in London these two circuits, designated A and B, were connected to a manually operated switchboard to enable some twenty (and later forty) outstations to be connected as required: urgent material therefore reached its destination directly without hazardous and time-consuming transport in London.

When the Monitoring Service moved to Caversham in 1943 the telegraph services were further augmented. The Post Office installed two four-channel voice frequency telegraph systems; and, in addition to the A and B teleprinter services to London, there were provided inter-office telegram services between London and Caversham and between Caversham and Wood Norton, four news agency services, one service to the Ministry of Information, and one to the Cable and Wireless System. There was also provided a comprehensive telegraph service for an American monitoring unit which required connection to the United States and elsewhere.

A considerable amount of thought was given to the operation of the A and B broadcast circuits because, until the move to Caversham took place, instructions had to be

given over an 'order-wire' to the London operator as to which outstations were to be connected for the reception of particular messages. This was, of course, wasteful of time and staff, so a remote station-selection system was designed and installed by the Post Office. Station selection in London was effected (and still is) by remote control from Caversham using a signalling system employing uniselectors. After the stations have been selected by punching keys, an executive signal is sent, and the London outstations are then automatically connected. Should the setting-up process be done incorrectly the system is self-cancelling and the process has to be restarted. In order that the Caversham teleprinter operators may be made immediately aware if the line or the apparatus is faulty, the teleprinter 'local copy' in Caversham is actually obtained from signals returned from London; this feature is extremely valuable and prevents much waste of effort on the part of an operator. However, the short delay involved before receiving the 'local copy' is a little disturbing to operators unaccustomed to it. New equipment for this London outstation-selection system has recently been provided by the Post Office.

4. Planning and Provision of Post-war Telecommunications

4.1 *Service Requirements*

In 1944 a study was made of the probable future pattern of BBC communications. It was thought that the system would have to carry much more traffic than before, and many more premises would have to be given access to the system. It was predicted that there would be heavy traffic between London and the provinces because each Region was to provide more programmes of its own for the Home Service. Television would soon restart and probably expand rapidly, requiring good supporting communications; and also the overseas services, much increased in the war years, would be greater in extent than before the war. The Monitoring Service with its comprehensive teleprinter network would continue. All these services had studios and offices in many locations.

It was therefore decided that there must be provided between London and the main provincial centres an efficient network of telephone and telegraph services. Low-loss telephone circuits between main premises would be essential in order to give a satisfactory service on extensions to the many outlying premises. The teleprinter network was to provide a service, often supplementing the speech network, in order to cater for the needs of urgent programme and engineering services, and to take a share of messages between offices.

4.2 *Basis of Design of a System of Telecommunications*

Past experience had shown that the most reliable and efficient service of telephone and teleprinter circuits had been obtained using a multi-channel carrier system working over lines suitable for music rented from the Post Office. Low-loss speech channels could thereby be provided over long distances, using music lines of good reliability. Furthermore, since spare lines for music purposes were rented between all main premises, these could be pressed into service to sustain the carrier system should this be necessary. It was thought, too, that use might even be made of some circuits provided for music but not fully loaded for this purpose.

The decision to use music-type lines in conjunction with a specially designed carrier system meant that the following questions had to be answered. How many telephone and telegraph channels could be accommodated on a carrier system using lines of bandwidth 50 c/s to 8,000 c/s? What maximum transmission loss was to be allowed between outlying premises? What minimum bandwidth of the speech channel could be allowed for a good grade of service?

A series of Immediate Appreciation Tests[1] was made, from which it was found that for good transmission a band of frequencies extending from 300 c/s to 2,300 c/s was satisfactory provided the overall transmission loss between offices did not exceed 15 to 20 dB. These results were confirmed by a further set of Judgment Tests using artificial lines and telephones in the presence of an ambient noise level normally found in offices.

The next stage was to determine the number of speech channels likely to be required between main centres. For this purpose it was assumed that a good enough grade of service would be given if up to 50 per cent of all callers at the main centres had to wait no longer than ten minutes, and up to 5 per cent no longer than twenty minutes. These figures refer, of course, to periods of peak traffic. Calculation showed that circuit groups of three between London and the other main traffic centres would be needed to give this grade of service. It is of interest to note that the average duration of a BBC telephone call on long-distance circuits during the war was three to four minutes. In estimating the total circuit occupancy a figure of five to six minutes was used. This allowed for the more leisurely peacetime calls and for some other factors normally allowed for in setting up a call. The carrier equipment that was designed (see Section 6) provided three telephone and up to three telegraph channels.

In order to keep the overall transmission loss within the prescribed limit of 15–20 dB, four-wire circuits with amplifiers would be needed between main centres and some outlying premises.

It was calculated that telephone and teleprinter circuits provided in this way would be sound economically, and the system could easily be adapted to sudden changes in traffic demand.

4.3 *Provision of the Services*

The service given by the above network, which was to function day and night, was not thought (in 1944) to be sufficient to give the planned grade of service during the day because of the heavy office traffic. The existence of music lines for the Third Programme, which started in 1946, provided the opportunity to create a supplementary network of carrier systems. The Third Programme did not normally start daily until 6 p.m. and therefore these music

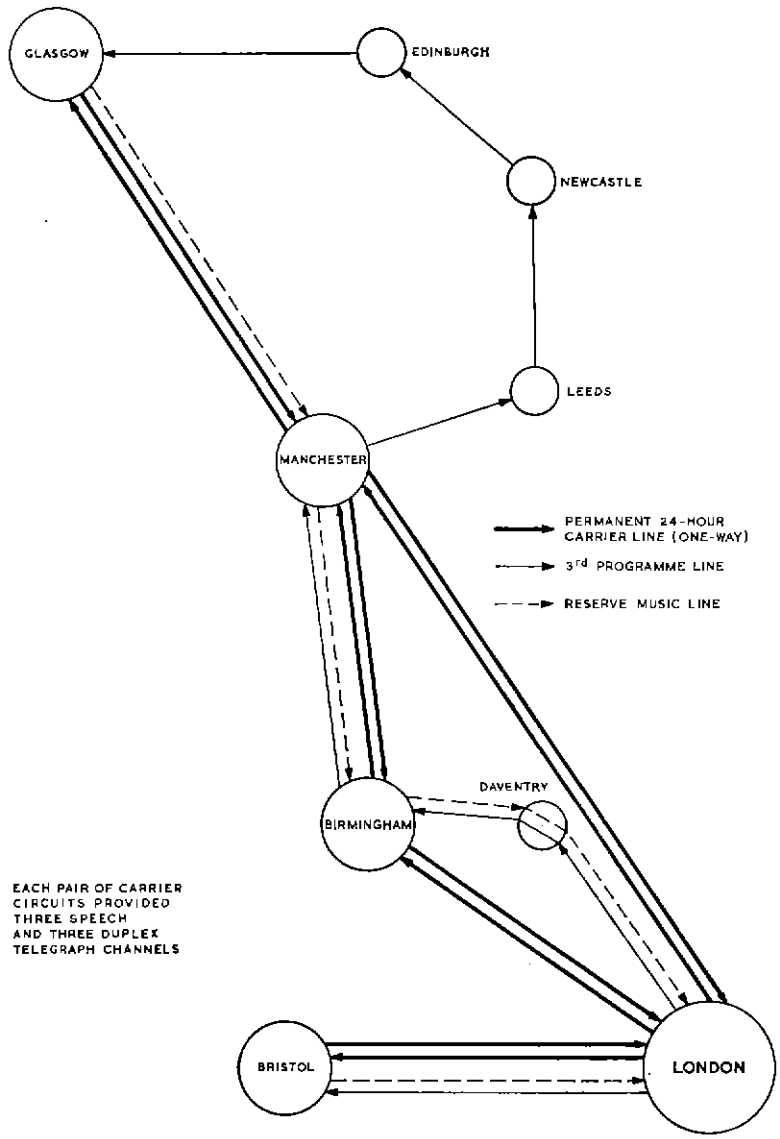


Fig. 3 — Post-war carrier network (1952).

lines outgoing from London, together with reserve lines incoming to London, provided this extra service economically during office hours. Occasionally these circuits had to be used in an emergency to maintain programmes, but the interruptions were seldom serious enough to cause intolerable dislocation.

Fig. 3 shows the network in service by 1952. On the carrier systems which provided a twenty-four-hour service were placed the engineering control services, programme presentation links, and teleprinter circuits for general administrative and special engineering use.

BBC carrier systems were provided between centres of heavy traffic. On the less important routes single telephone and sometimes teleprinter circuits were rented from the Post Office. The services provided can be summarized as follows:

(*a*) Inter-office speech and teleprinter channels.
(*b*) Engineering control circuits between main centres for minute-to-minute control of programmes.
(*c*) An 'omnibus' engineering service message channel linking the main centres and the BBC receiving station at Tatsfield. This service was called the Engineering Teleprinter Network (ETN).

4.4 *Subsequent Changes to the Original Plan*

The changes that have since occurred to the original plan have been due mainly to increased requirements of the BBC Television Service and of the News Division. (Present-day layout of the carrier systems can be seen in Fig. 4).

The Regions have made an increasing contribution to the Television Service, and this has meant the provision of more music lines, particularly for television sound from

early evening to close-down. These music lines are available for use in a communication network by day, in the same way as the Third Programme lines. A redeployment of the carrier system terminals was made in 1958 and a fourth telephone channel was added to the three provided on each carrier system. This was made possible because the bandwidth on many of the music lines extended from 50 c/s to upwards of 10,000 c/s instead of the original band of 50 c/s to 8,000 c/s.

Because the fourth channel may have a restricted frequency range, and because some circuits used as spares to replace a faulty normal circuit will not carry a fourth channel, it has been used as a Television Engineering Production control circuit and also for other engineering purposes.

The Engineering Teleprinter Network (ETN) has not been continued, due mainly to the difficulty in providing suitable personnel in control rooms to operate it. The channels once used by this network now augment the teleprinter services between the various Regions.

4.5 *A Code Ringing System*

A system of code ringing is often required which will enable three stations in tandem to communicate with each

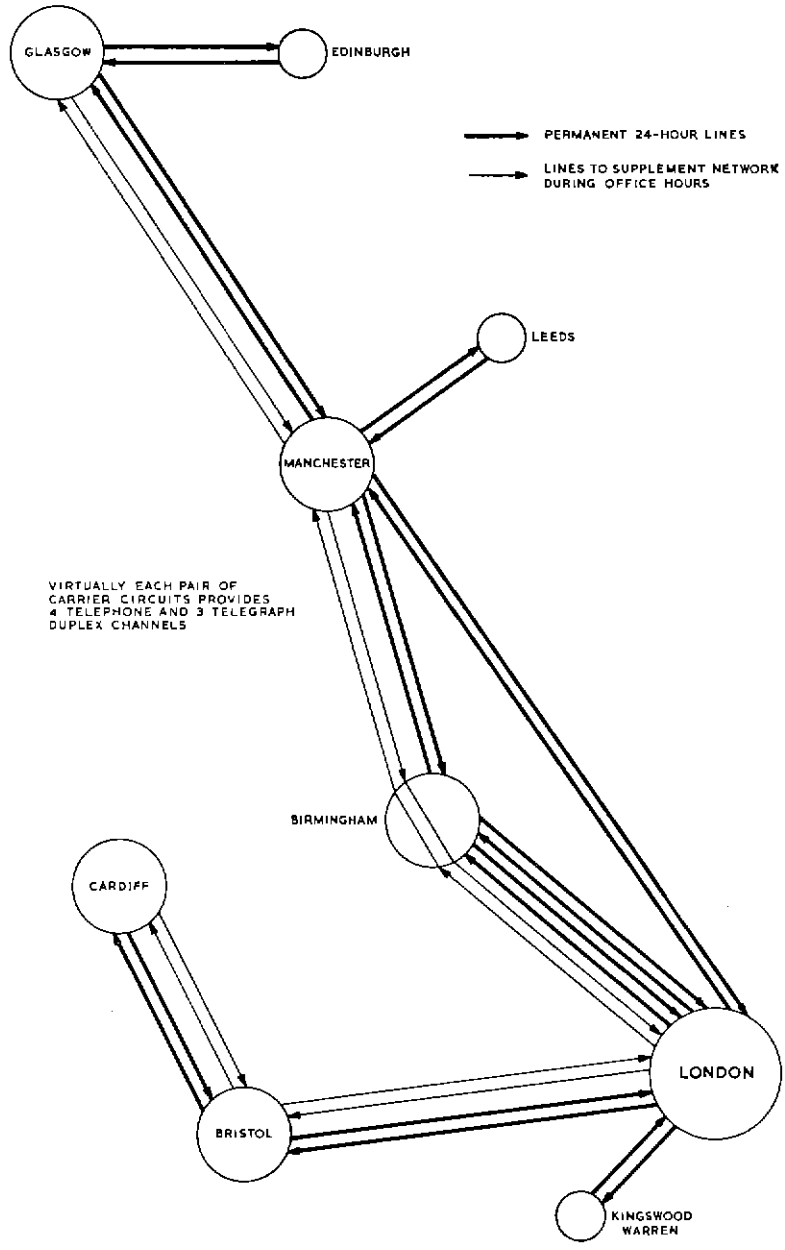


Fig. 4 — Layout of carrier network (1962)

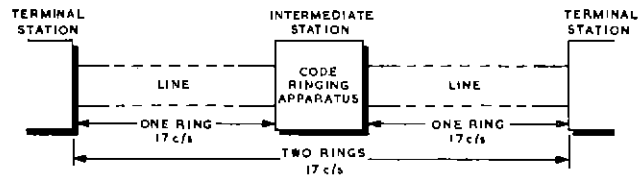


Fig. 5 — A code ringing system.

other. One ring at a frequency of 17 c/s is used between the terminal stations and the intermediate one, while two rings at the same frequency are employed to enable the terminal stations to call each other (see Fig. 5).

Code-ringing equipment is required at the intermediate station which, by means of relays, interprets the incoming code and passes the signal to the next station. It might be thought that a system of ringing bells (one, two, and three rings) would be all that is required, but such a system is impossible to work at busy stations or at stations where more than one code-ringing system is employed. The system described is normally operated by engineering staff at Studio Centre control rooms or at transmitters; the reason for this is that incorrect coding may cause false operation. However, such a system could be made suitable for use by operators at private branch exchanges if the code signals were sent automatically. Facilities are given so that if a call is made from one terminal station to the other and the intermediate station is already talking to the called station, then the intermediate station is rung. Thus the call is not lost.

5. Present-day Telecommunications

In Section 4 the disposition of BBC carrier systems is shown in Fig. 4; Section 5 sketches in a more complete picture of the telephone and telegraph communications as they existed in 1962.

5.1 *Telephony*

The telephone network in 1962 is shown in Fig. 6. The carrier system 'backbone' is marked in heavy lines and the circuits rented from the Post Office are shown in light lines; the number against the line indicates the number of circuits on any one route if more than one. The circuit length derived by BBC carrier is about 6,500 miles, while those directly rented have a mileage of about 5,000.

Many local short-distance circuits are used in London and larger regional centres, as would be expected. The London network, sketched in Fig. 7, is large and complex while the regional centre networks, for example Manchester shown in Fig. 8, are much smaller, although similar. All these circuits are rented directly from the Post Office and in only a few cases has it been found necessary to apply special treatment, such as repeaters, selective signalling, etc.

Many circuits—practically all those used for engineering purposes—terminate in engineering areas on single instruments or on BBC-designed engineering manual switchboards (see Plate I on page 15 showing an engineering manual exchange in the London control room). The majority, however—those used for inter-office calls—terminate on standard Post Office switchboards, ranging from the very small to the very large. They may be of the wholly manual type, i.e. a Private Branch Exchange (PBX) in which the operator has to perform all switching and connection of calls; or the automatic type, i.e. the Private Automatic Branch Exchange (PABX), in which a subscriber can himself dial other subscribers on the same private automatic exchange or subscribers on the network of associated private automatic exchanges. A subscriber may also dial out over the public telephone network. Many trunk calls, both incoming and outgoing, as well as subscriber inquiries, are, however, handled by the operators.

The capacities of these exchanges vary from some having only one line and a few extensions to the latest automatic installations with more than 3,000 extensions. There are four of the latest type of PABXs in London—at Broadcasting House, Bush House, Television Centre, and Avenue House—of which the largest, at Broadcasting House (shown in Plate II on page 15), caters for 14 long-distance Private Wires (PWs) and derived long-distance circuits, 122 local PWs, 196 public exchange lines, about 3,000 extensions, and 24 operating positions. Every weekday a very heavy load is handled, including more than 1,000 calls over the long-distance PWs alone. A typical regional PBX would have, say, 6 long-distance PWs, 4 local PWs, 20 exchange lines, about 250 extensions, and would have 5 or 6 operating positions.

The operating staff employed by the BBC at private branch exchanges numbers some 200 in all.

The capacities of these installations, and the facilities provided, were arrived at only after careful investigation and discussions by the appropriate BBC departments in conjunction with the traffic experts and engineers of the Post Office and of the manufacturers.

The type of traffic carried by the network reflects the wide range of the BBC's activities; it consists of (*a*) calls over 'control lines' between engineering centres for the immediate control of television and sound programmes; if an efficient service of broadcasting is to be maintained, delay in the connection of calls cannot be tolerated (*b*) rapid communication relating to programme matters—their planning and smooth running, and sometimes the 'cueing' of inserts into and out of composite programmes (*c*) ordinary administrative matters requiring discussion, giving information, or in cases where the 'personal touch' is important.

5.2 *Telegraphy*

All the Corporation's telegraph communications are carried by the teleprinter, with the exception of several facsimile circuits, mentioned in Section 5.3. The main telegraph network is sketched in Fig. 9.

The long-distance telegraph circuits are, like the long-distance telephone circuits, derived at voice frequency on the previously mentioned carrier systems. With but few exceptions they terminate at one end on a switchboard in

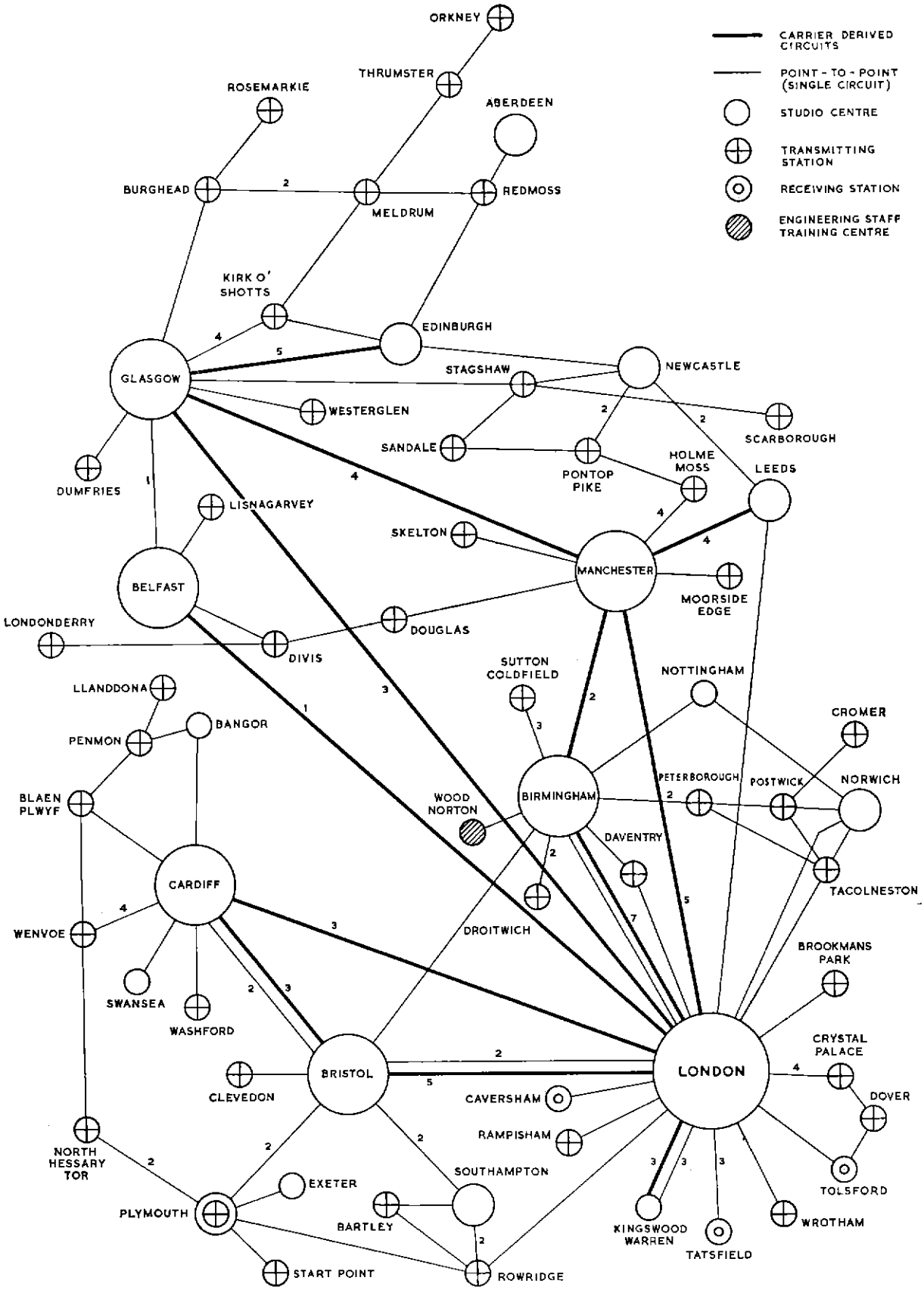


Fig. 6 — Telephone network 1962.

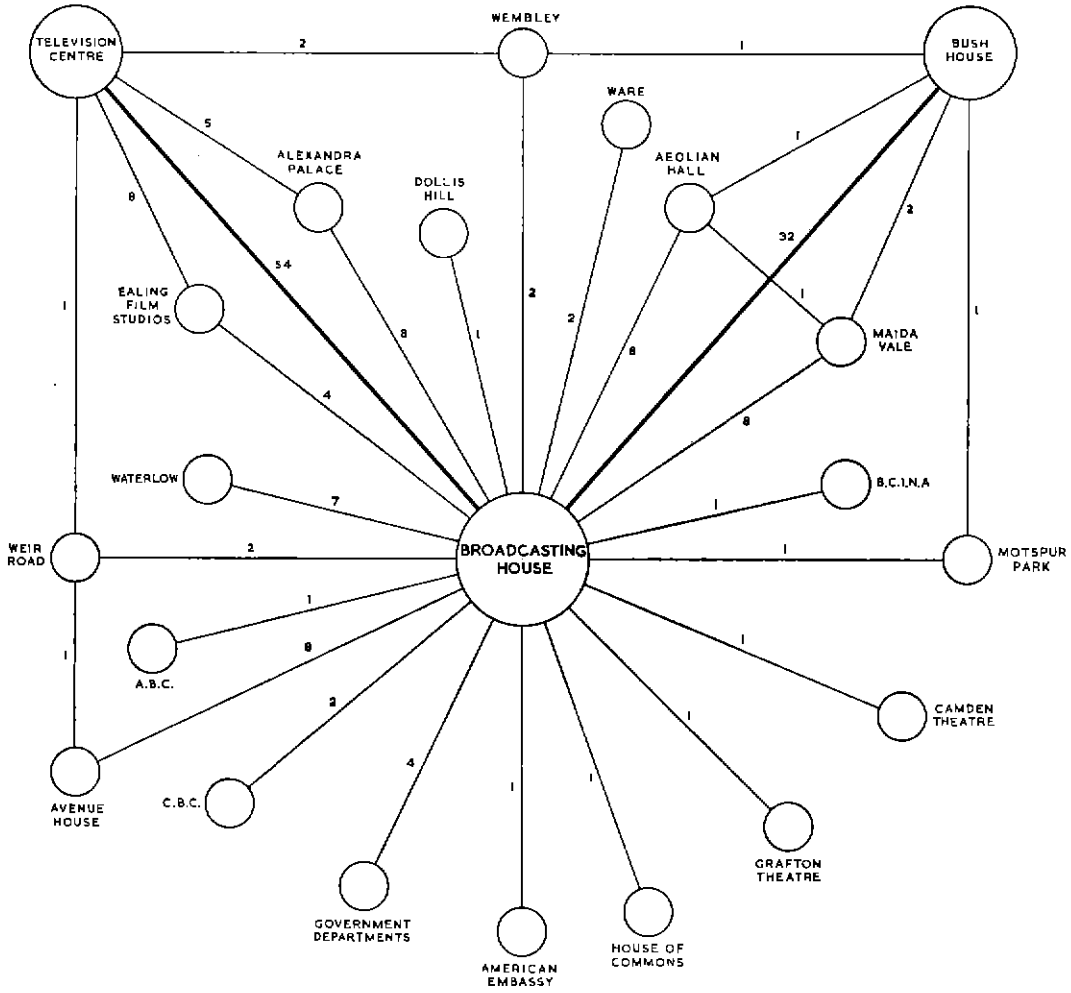


Fig. 7 — Main telephone lines in London.

London, and can therefore be connected to each other as well as to the local London circuits. The circuit mileage is about 2,600.

To complete the BBC's requirements for long-distance circuits, several are rented from the Post Office, as also indicated in Fig. 9, the mileage being about 200.

The London teleprinter network provides (*a*) communication between the many premises in central London and the outskirts, (*b*) reception of news from the news agencies, (*c*) distribution of BBC news services, (*d*) connection with other organizations (e.g. the cable companies). Access to the public networks by Telex (both internal and international telegrams and cables) is obtained through several Telex teleprinter machines rented from the Post Office. The teleprinter circuits in the London area are shown in Fig. 10.

Excluding Telex and circuits for the reception and distribution of news, most 'Private Wire' circuits terminate on a fifty-line teleprinter switchboard giving full intercommunication together with a 'broadcast' facility—that is, the facility for one teleprinter to send simultaneously to a number of others.

The main concentration of teleprinters in the London area—known as the London Teleprinter Unit—is housed in Broadcasting House. It comprises some twelve teleprinters, four automatic transmitters and (for convenience) the fifty-line switchboard; a phonogram room, in which telephone messages can be received for onward transmission by teleprinter, forms part of the suite. About 80,000 words are handled daily by a total staff of roughly forty. A smaller switchboard, located in another room, handles the more specialized foreign news messages.

The BBC owns and maintains some 200 teleprinters and automatic transmitters, plus the associated power and signalling supplies; other machines in use are supplied by news agencies as part of their service or are rented from the Post Office. By deriving its own telegraph channels, which it can do almost as a by-product of its derived speech channels, the BBC must necessarily operate them with its own terminal apparatus. It is free to choose from a wide range of equipment, either BBC-designed or commercially made, for the purpose of exploiting these channels to the best advantage for message or data transmission. A good

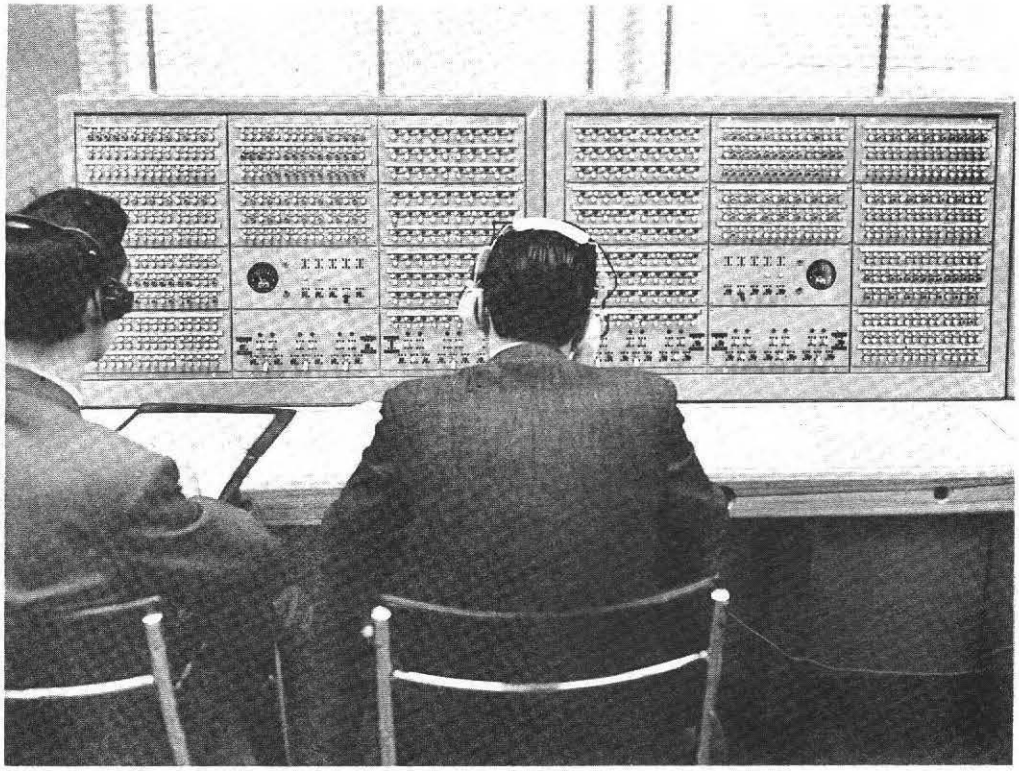


Plate I — Engineering Manual Exchange (EMX) in the Sound Control Room at Broadcasting House, London.

Plate II — Manual Board of Private Automatic Branch Exchange (PABX), Broadcasting House, London.

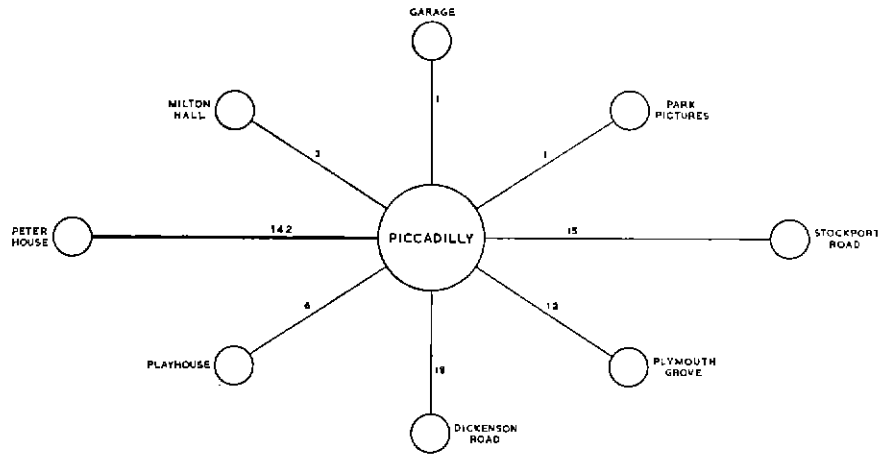


Fig. 8 — Telephone lines in Manchester.

grade of service is maintained by having highly trained mechanics readily available.

The normal maximum speed of transmission is the international standard of 66 w.p.m., except in the case of Reuters News Service and the computer peripheral equipment, which use 100 w.p.m. Automatic transmission enables the maximum speed to be maintained over long periods, and is used extensively, especially for news, where speed is all-important. Furthermore, when messages have to be sent over the commercial services, automatic transmission keeps charges to a minimum.

The type of traffic carried falls into two main categories, differing in content and immediacy, i.e. news and general (all other traffic). Until quite recently both services were carried by the same long-distance circuits; but because both types of traffic have grown very much, and tend to peak at about the same time, they have been allocated exclusive channels.

News traffic on the private network generally originates in the Central Newsroom and is distributed to other London premises; in addition, there is a fair amount from the Regions to London, and some between Regions. The messages vary very much in length, and may require transmission urgently at any time during the day or night; but if they are to remain 'news', they must suffer no delay. Format is not important.

The other category consists of the sort of message well known in any widespread organization—facts, figures, information, and general administrative traffic; there is, however, very little of what is found in most commercial organizations in large volume—orders for goods and so forth—because of the nature of the BBC's output. Here format is important.

No attempt is made to apportion costs, far less to debit any department; the internal service can only be run as a common shared service, but external telegrams and cables (through the Post Office for example) are charged to the department concerned.

5.3 *Facsimile*

The facsimile system has not found wide application within the BBC; it is used (*a*) when pictures are urgently required for transmission in a television news programme, (*b*) where conditions are such that the rapid transportation of photographs for television 'stills' is not possible, (*c*) to transmit certain news items in typescript from the London News Centre to the Television News studios for inclusion in a news bulletin, (*d*) to provide an internal telegram service at outlying premises where it would be uneconomic to employ a skilled teleprinter operator.

The facsimile machines employ electro-sensitive recording paper. One type of machine, using 100 lines per inch, is suitable for producing 'stills' for television, while another type, using 67 lines per inch, is suitable for sending typescript or hand-written messages.

5.4 *Summary of Services Provided*

Telephony

1. Engineering control between television and sound studios, control rooms, and transmitters.
2. Inter-office communication throughout the country.

Telegraphy

1. Collection and distribution of news material.
2. General inter-office messages throughout the country.
3. Computer applications.

Facsimile

1. Transmission and reception of 'still' pictures for television.
2. Transmission and reception of typescript, drawings, etc.
3. Sending of telegrams (internally).

5.5 *Assessment of Performance*

The network just described has been gradually built up since 1945, and has been in use long enough to prove that the original planning was sound. It provides adequately

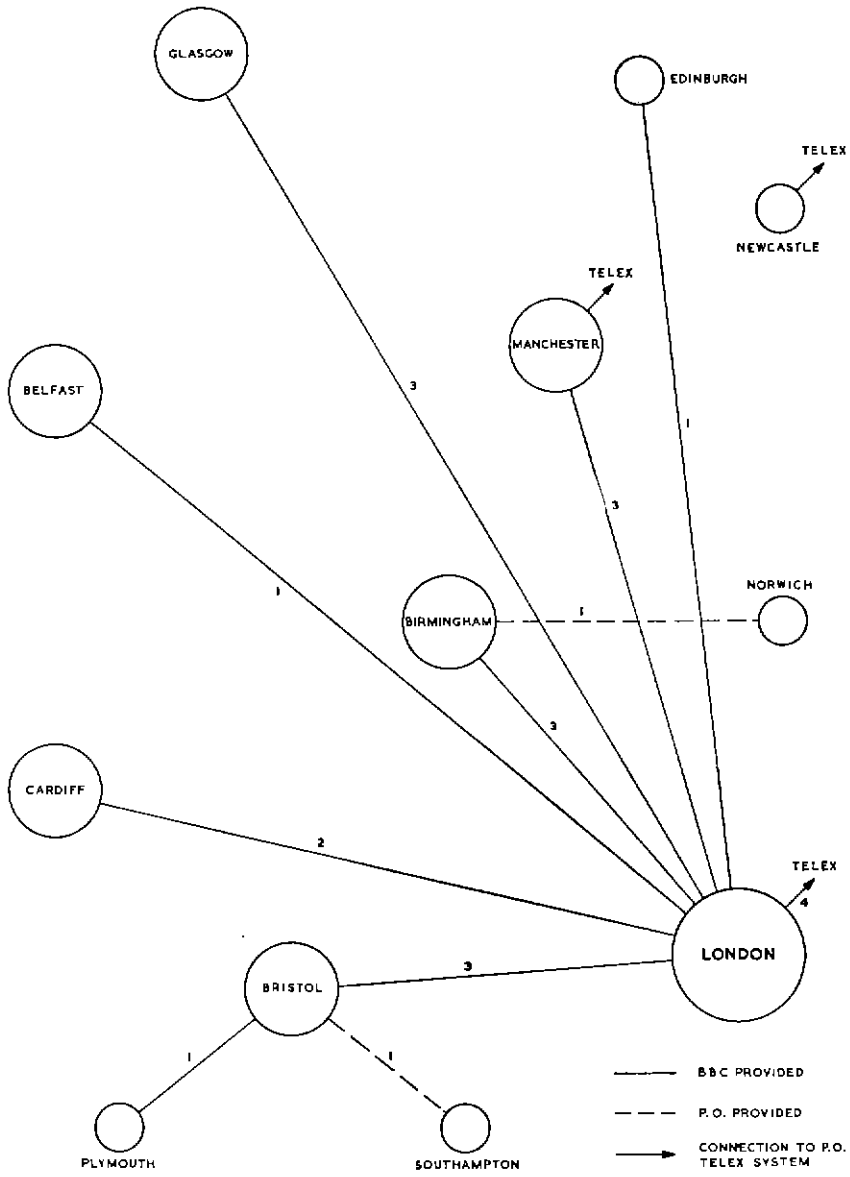


Fig. 9 — Main telegraph network.

and economically for the traffic load and in such a way as to allow for change and growth. The technical performance of the telephone and telegraph network between main centres has been good, and is satisfactory between outlying stations.

The teleprinter network has been able to handle easily all internal telegrams, and in addition to aid the telephone service by relieving it of traffic more suited to the teleprinter.

The equipment has been found equal to the changing demands made on it. The apparatus, which was designed, made, and installed by the BBC's Engineering Division, quickly proved reliable, so that the maintenance required compares favourably with that required for commercial equipment of a similar nature.

Great care is taken to ensure that in every respect the equipment comes up to the best standards of current practice outside, and is compatible, so that where two systems meet, as, for example, in connecting long-distance PWs to Post Office PBX switchboards, or BBC teleprinters to Post Office telegraph circuits, the performance of neither is impaired.

6. Special Equipment

6.1 *The BBC Telephone and Telegraph Carrier System*

6.1.1 *Outline*

The carrier equipment was originally designed to provide three speech channels, and also three telegraph channels, derived when required, using a carrier frequency just

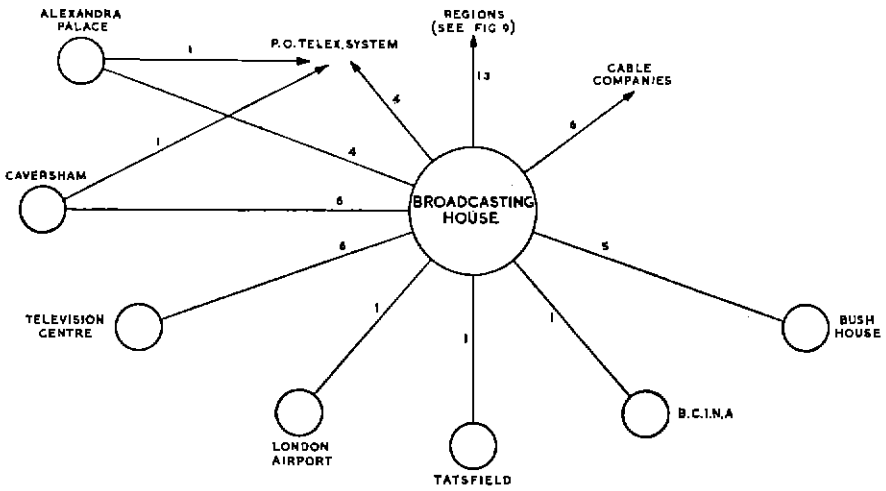


Fig. 10 — Teleprinter network, London area.

above the upper limit of each speech channel. Speech channel 1 is a physical channel, while speech channels 2 and 3 are derived at carrier frequencies. The system is designed to operate over music circuits transmitting frequencies in a band from 50 c/s to 8,000 c/s. Later, when circuits which transmitted frequencies from 50 c/s to 10,000 c/s or above became generally available, a fourth channel was added.

Each speech channel bandwidth is 2,400 c/s and this is reduced to about 2,000 c/s when a telegraph channel is derived over it. The speech when transmitted at carrier frequency is in the form of a single-sideband, carrier-suppressed signal. The channel loss between two-wire terminals is 3 dB. In order to economize in the frequency band occupied by the system on the line, the two carrier frequencies have been carefully chosen; the lowest carrier channel has a carrier frequency of 5,600 c/s and the lower sideband is transmitted, while the next higher channel carrier frequency is 5,400 c/s, the upper sideband being transmitted. With this method of design the lower audio frequencies (below 300 c/s) of each channel are cut, but this is an advantage for it prevents 'boominess'. The fourth channel makes use of a carrier frequency of 8,000 c/s and has a minimum bandwidth of 1,800 c/s, but this is often slightly extended as the music-type line may pass frequencies above 10,000 c/s.

Each telegraph channel has a bandwidth of 200 c/s, which is rather greater than the standard required for teleprinter working on 50 bauds. Some extra margin is therefore available when a number of telegraph channels are connected in tandem.

6.1.2 *Special Features*

A. CARRIER OSCILLATORS: The carrier oscillators generate frequencies of 2,600, 5,400, 5,600, and 8,000 c/s, the long-term stability being within 1·5 c/s of the nominal frequency. The oscillator makes use of a circuit that is basically a two-stage amplifier which is made to oscillate by the application of positive feedback, with a circuit incorporating an RC network. Temperature compensation is provided. Automatic switching is provided so that a change from working to spare units can be made.

B. TELEGRAPH CONVERTOR TGC/5: This apparatus receives the signal pulses at voice frequency and converts them to d.c. signals suitable for operating a teleprinter. Similarly the outgoing d.c. signals from the teleprinter are converted to voice-frequency signals (at a frequency of 2,600 c/s) for sending to the appropriate channel of the carrier systems or else direct to line. Conversion from d.c. to v.f. is done by a static relay, which is normal practice; however, the conversion in the opposite sense is effected by special means designed to involve the minimum distortion to the telegraph signals. The received pulses at voice frequency are passed through an Automatic Gain Amplifier which maintains a constant level of signal to the rectifier preceding the telegraph relay. In fact the signal level remains constant to within 0·1 dB at the output over a range of input levels of 20 dB.

C. ELECTRONIC TELEGRAPH CONVERTOR CO/7: This convertor was designed to eliminate the use of a telegraph relay in converting signals from voice frequency to d.c. to avoid the routine adjustments that have often to be made to such a relay.

The method used for conversion is seen in Fig. 11. If the input terminals C and D are at the same potential valve V_x will be conducting, and the potential difference across resistance R is such that valve V_y is biased beyond cut-off. The current in the load will therefore be in the direction from B to A. If now the potential of C is made negative, so that V_x is biased beyond cut-off, then the potential difference across resistance R is reduced to zero and hence V_y conducts. The direction of current through the load is from A to B and the current in the load reversed.

This convertor requires no routine adjustments, and only a fraction of the maintenance of previously designed convertors. Referring to the circuit of the convertor shown

in Fig. 12: during the period of a spacing signal (no tone) V_3 is made to pass current by cutting off V_2 with a standing bias rectified from 6·3 volts a.c. by MR1. When a marking signal appears the incoming tone is amplified by V_1 and rectified by MR2, thus opposing the bias potential and making V_2 conduct instead of V_3.

6.2 *Telegraph Test Equipment*

Telegraph distortion measuring equipment was designed and built by the BBC in 1945 and in 1947, because there was nothing suitable that could be bought at that time; indeed it is only recently that accurate measuring apparatus has been put on the market.

6.2.1 *Telegraph Distortion Measuring Set TDM/1*

In 1945 the only telegraph distortion measuring set that existed for use on testing circuits and equipment used by the BBC was provided by the Post Office to test the performance of a 12-channel system working between London and Aldenham, Hertfordshire, Aldenham being the centre for providing overseas programmes at that time. Both the tone-mark system and the BBC tone-space system had to be tested. In the case of the tone-space system the tone signals were mechanically keyed to line by the teleprinter while at the receiving end the signals operated a valve device which caused current to flow in the receiving teleprinter electromagnet.

A Portable Measuring Set TDM/1 was produced which enabled distortion to be measured on the tone-space and tone-mark systems.

A series of reversal signals was generated at the sending end. It produced alternate mark and space signals (reversals) of ratio 1:1, 2:2, 6:1, or 1:6. The 1:1 reversals consisted of a unit mark to unit space at a frequency of 34 c/s.

At the receiving end these signals, in the form of reversals of d.c. at 80 volts, were connected to a reversal indicator circuit. This indicator circuit produced a pulse of voltage on the occurrence of each signal reversal. The pulses, which were unidirectional, were applied to the vertical deflector plates of an oscilloscope. To the horizontal plates was also applied a sine wave at 68 c/s. Thus if no distortion were present all the pulses corresponding to the

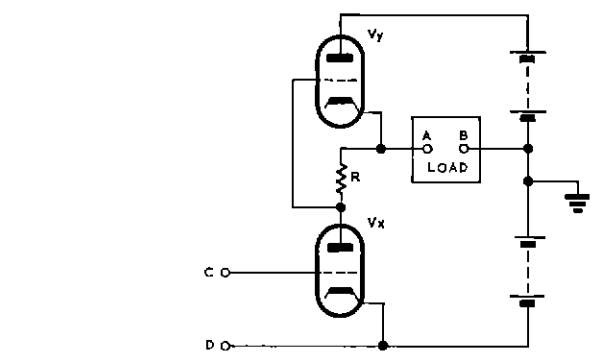


Fig. 11
Electronic Telegraph Convertor. Method of operation.

Fig. 12 — *Electronic Telegraph Convertor—Circuit.*

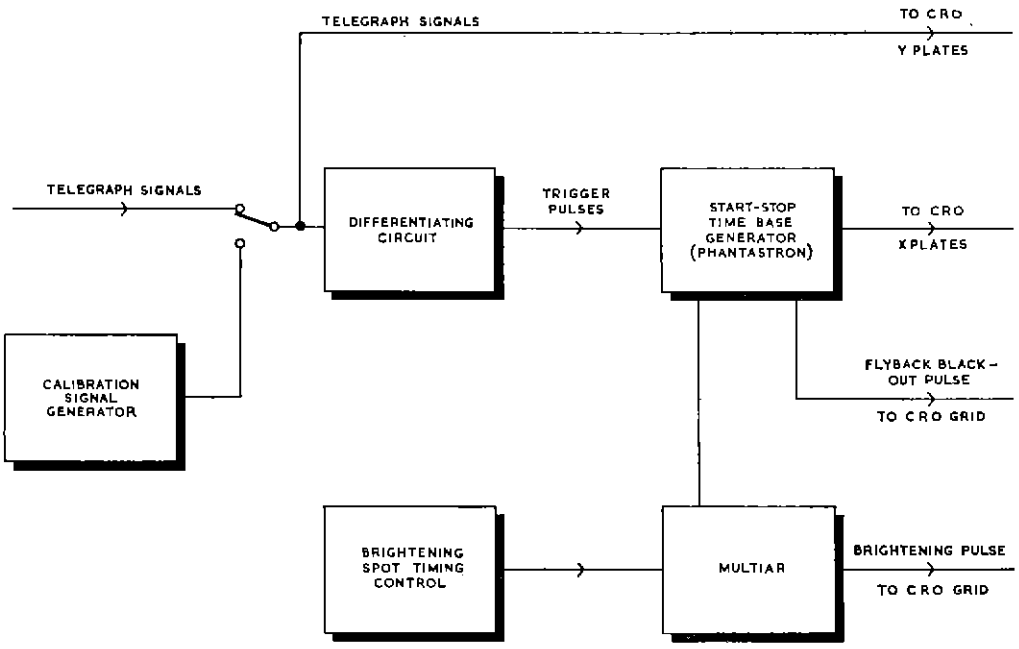


Fig. 13 — TDM/2. Simplified block schematic.

signal reversals would coincide, and the pulses would be separate if distortion were present. The degree of separation was an indication of the amount of distortion being measured. A maximum distortion of 45 per cent could be measured and a minimum of about 5 per cent.

The apparatus was not suitable for measuring small amounts of distortion (below 5 per cent) and could not measure distortion of telegraph signals (teleprinter characters). When the BBC tone-space system was discontinued the TDM/1 ceased to be used.

6.2.2 *Telegraph Distortion Measuring Set TDM/2*

This telegraph distortion measuring apparatus was designed to measure accurately small amounts of distortion, the equipment currently available (1947) being inaccurate when measuring distortion below about 10 per cent. The equipment could measure the distortion of signals being received at random as well as at regular intervals. Thus, for the first time the equipment could be used on circuits carrying traffic. It was entirely electronic and had no moving parts. The signals to be measured were displayed on an oscilloscope; a bright spot was moved to certain points on the displayed waveform, the results obtained being indicated on dials.

A description of this equipment is given elsewhere.[2] Briefly, telegraph signals were applied to a differentiating circuit (see simplified block schematic Fig. 13) which generated a pulse on each change from mark to space and vice versa. The negative incoming signal pulses were suppressed, and the positive pulses were then passed to a phantastron time-base generator,[3,4] this generator being the equivalent of the rotating cam-shaft of a teleprinter which is set in motion by the start signal of a teleprinter character. The output of the generator was applied to the X plates of an oscilloscope and the received telegraph signals were applied to the Y plates. The distortion of the displayed waveform was then measured by causing a bright spot to move along the trace to reference points on the waveform of the signal or teleprinter character being displayed. A multiar circuit was used for brightening the waveform of the trace; it produced a pulse at its output whenever two voltages applied to it reached an equal value, one voltage being obtained from the time-base generator and the other set by a chosen value of a calibrated potentiometer. The distortion was read directly in milliseconds with reference to the start signal of the character.

The equipment was accurate to within $\pm 2{\cdot}5$ per cent.

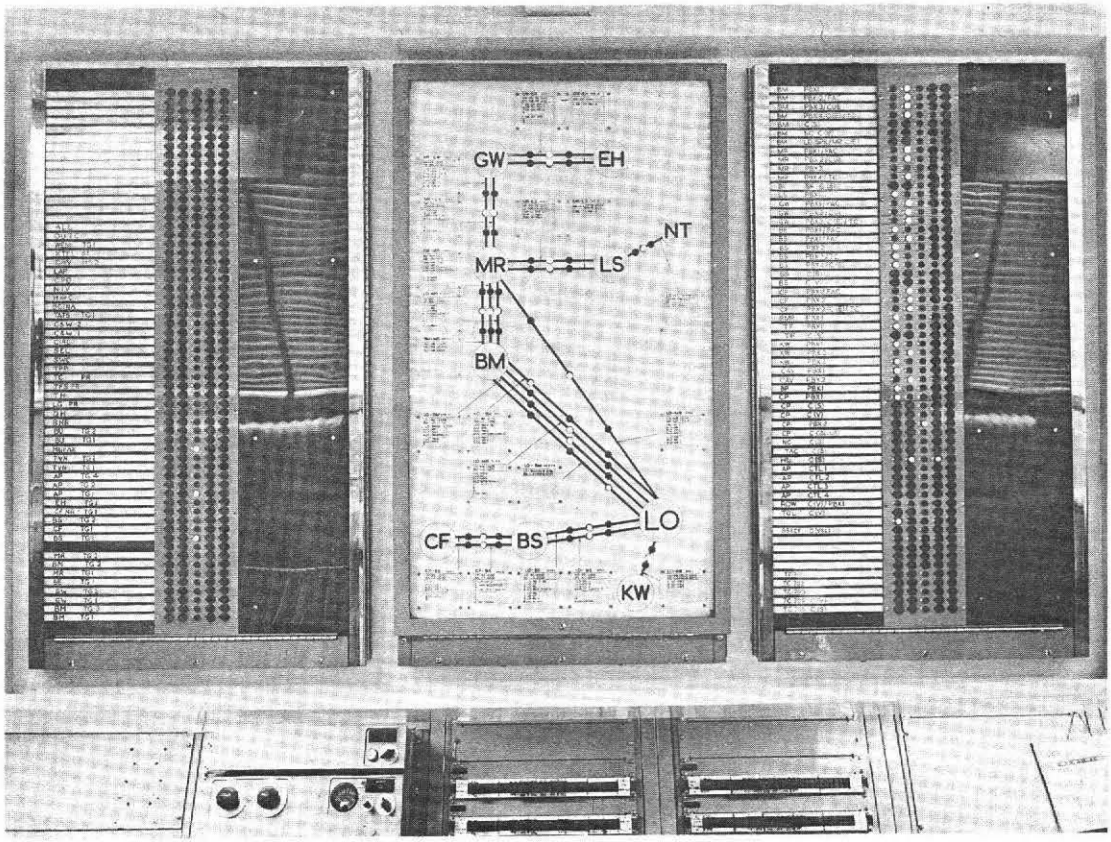
6.2.3 *Teleprinter Margin Tester TPMT/1*

This apparatus, also produced about 1947, tests the margin of a teleprinter by applying to it signals of known and increasing distortion until the teleprinter fails to register correctly. The margin tester type TPMT/1 produced repetitive signals and also waveforms representing words of specific distortions from zero in steps up to a maximum of ± 40 per cent.

The source of these signals was a rotating glass disc on which was printed the test information. This disc was produced in collaboration with the Post Office who had already gained experience with this form of signal generator in connection with the Speaking Clock. A beam of light modulated by the rotating disc was directed at a photo-cell. The electrical signals at the output of the photo-cell, being trapezoidal in shape and of varying amplitude, had to be regenerated (without affecting the intended time distortion) before being made to operate a teleprinter. The

RIGHT, *Plate III — Communications Room at Broadcasting House, London, showing Control Desk, testing apparatus, and main circuit interception equipment.*

BELOW, *Plate IV — Mimic diagram in Communications Room, London.*



usual 'line-feed', 'carriage-return', and 'space' signals were generated so that the test signals were printed conveniently by an unattended teleprinter in columns. The equipment gave a very satisfactory service to the end of its life.

Together with the TDM/2 described above the margin tester could be used for testing circuit distortion.

7. Trends and Developments

7.1 *Telephony*

The main direction of development is towards automation in so far as it can be applied economically to a private system of telecommunication of the size of the BBC's.

On the principal routes the magneto-generator system of calling and clearing between telephone switchboards is being replaced by an automatic system which, besides greatly easing operation and reducing unused line time, gives the maintenance staff quicker and more precise information about the state of the circuits. Photographs of the Control Desk, circuit intercepting, and testing apparatus in the Communications Room (Plate III), and also of a mimic diagram indicator (Plate IV) showing the condition of all circuits used for the carrier systems will be found on page 21.

Some of the older PBX switchboards are being replaced by more modern types permitting easier and speedier working. New developments such as the Auto Answering Equipment are being introduced. This automatic apparatus answers a call and records a message for subsequent playing back when the called subscriber returns.

7.2 *Telegraphy*

The teleprinter services are extending rapidly, both in numbers and in complexity.

Incoming news (see Section 2.2) has usually been received on a mixture of news agency, Post Office, and BBC machines of various types: but because of the advantages of standardization of types and of on-the-spot maintenance, effort is being made to have as many machines as possible owned by the BBC. On other private-wire circuits a change is being made to BBC-owned machines.

As indicated in the previous section, teleprinter traffic is being separated into the two categories of news and general, since both cannot be efficiently carried by one circuit. This is being carried out gradually, a group of circuits being assigned to each class of traffic, and it should result in a general improvement.

The expanding internal news distribution system now being provided calls for further diversity of methods; news material originates in the main London news centre and is transmitted simultaneously to about half a dozen locations in the London area only for the present. It seems probable that this system will be extended to the provinces.

The recent transfer of the London Teleprinter Unit to a more central location has given the opportunity of replacing the switchboard by a two-position board of greater capacity. This switchboard has been purchased from the Post Office and redesigned by the BBC to cater for the special conditions. The operating positions have also been redesigned in the light of experience: they have more facilities, with automatic operation and a better layout. A conveyor belt has been installed to speed up cross-office message handling.

Increasing use is being made of computers, for instance for audience research and for solving engineering problems, and the BBC has recently acquired one of its own. The peripheral equipment of this computer consists of teleprinter-type equipment; it will be maintained by the BBC.

Circuit-testing and traffic-sampling equipment is being produced and fitted to circuits—permanently if they are important, or as required if they are minor—to provide automatically the data required in traffic analysis, statistical fault control, planning, and so on.

7.3 *The Future*

In such a rapidly expanding field as telecommunications it is perhaps rash to try to predict events, and the authors of this monograph propose nothing bolder than a short-range forecast. It is quite safe to say that the value of telecommunications to the BBC will become quickly more obvious to potential users and that News Division is likely to continue to be the biggest single user.

The development by the Post Office of S.T.D. (Subscriber Trunk Dialling) is bound to make a great impact on the BBC telephone network, but it is not yet widely enough in operation for that impact to be assessed. As far as can be foreseen, it could supplement the existing network, which is showing signs of overloading, between the larger centres, and maybe replace private circuits entirely on some less-used routes. However, periodic reviews will continue to be undertaken and on the results further decisions will be made in order that communication may be speedy and economical.

Increased hours of sound broadcasting and a second television service will obviously make greater demands on communications, both telephone and telegraph, and in both volume and coverage.

The transmission of data will be required to and from the central computer recently acquired to handle statistics of all kinds and, as transmission will probably take place at night when other traffic is practically non-existent, the traffic load-factor of the telegraph system will be improved.

Awareness of the potentialities of the teleprinter and familiarity with what it can do will surely lead to still greater use, and to the diversion to it of much communication traffic now carried by the telephone but much more suited to the teleprinter. The rate of change is rather unpredictable, since it depends not only on the extension of the service to more locations and on the service given, but also on the education of staff in the proper use of each medium and their willingness to use it.

Investigations have been made into a wholly electronic system of routing and distributing teleprinter messages. Whilst this would have completely solved such problems, it was concluded that the form and size of our network, and the kind of traffic carried, was such that the cost of the system was not clearly justified at the time. However, this

method, or a very similar one, will have to be adopted one day.

8. Conclusion

The authors are aware that in selecting material for this monograph much that might have been of interest has had to be omitted. Items of historical interest or facts which illustrate the growth of communications from small beginnings to a large and complicated system are those which are recorded.

The telephone, telegraph, and facsimile services form only part of the whole network of BBC communications, which includes the transmission of television and sound signals from studios to transmitters.

9. Acknowledgments

The BBC wishes to acknowledge the co-operation of the Post Office and of manufacturers of telegraph equipment throughout the developments outlined in this monograph.

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CORRECTION TO ENGINEERING MONOGRAPH NO. 47

(VERTICAL APERTURE CORRECTION USING CONTINUOUSLY VARIABLE ULTRASONIC DELAY LINES)

Reference No. 2 (*page* 20) *should read:*

Gouriet, G. G., **Spectrum Equalisation,** Wireless Engineer, Vol. 30, No. 5, May 1953, p. 112.

Second line of Appendix (*page* 21)*:*

'Fig. 24' should read 'Fig. 27'.

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