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The Institution of Post Office Electrical Engineers.

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

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W. PRICKETT, A.M.I.E.E.

A Paper read before the London Centre of the Institution on the 11th April, 1949, and at other Centres during the following Session.

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1. INTRODUCTION.

The Post Office has been concerned with licensing Relay Companies since 1926; between 1935 and 1940 the engineering department did much experimental work on both audio and carrier systems of wire broadcasting but this work was suspended during the war years when the technical interests of the department in wire broadcasting had to be confined to matters arising in connection with defence, licensing and the provision of private wires for relay companies. Since 1947 it has been possible to resume some of the experimental work.

Although the present practice and future possibilities of wire broadcasting are of considerable interest to Post Office engineers there has hitherto been very little discussion of this subject within the Institution. A few papers on various general and special aspects of wire broadcasting have been published since 1934 but, with one or two exceptions*[1, 2], in publications which do not normally come to the notice of many members of the Institution of Post Office Electrical Engineers. Considerations of space permit only brief reference to the subject matter of some of these earlier papers. References are however noted throughout the present paper and listed in the bibliography.

The paper contains a review of the history of wire broadcasting up to the present time and includes an account of the part played by the Post Office in its development; future possibilities of wire broadcasting are considered particularly in relation to the telephone system. It is emphasised that these considerations are relevant to the present functions of the Post Office not only as the licensing authority for wire broadcasting but as the Department having many other related responsibilities: these include provision and maintenance of the line network used by many relay companies in obtaining much of their programme material; suppression of interference with reception of programmes broadcast by the B.B.C. for listeners in this country; and the protection of the telephone service from electrical interference. All these functions involve not only an appreciation of the present state of the art and of its historical background but consideration of possible future applications. In the discussion of such possibilities no forecast of official policy is implied.

2. TERMINOLOGY AND SYSTEMS.

2.1. "Wire Broadcasting."

In this paper the term "Wire Broadcasting" is used to describe the distribution of programmes using wire connections between central amplifiers and a number of listeners. The central amplifiers may be fed by line connections from the studio in which the programmes originate or they may be fed from a radio receiver.

* Numerical references are to the Bibliography at the end of the Paper.

Operators of wire broadcasting systems are authorised in their licence agreements with the Postmaster-General to operate specific wireless telegraph stations (and optionally to receive programmes at these stations by means of wires instead of by wireless telegraphy). In certain official publications[3, 4] these stations with their associated networks of distribution wires are called "Relay Exchanges" and the service given is described variously as "broadcast relaying service"[4], "relay service"[4] or, latterly, "wire broadcasting service"[5].

2.2. Audio Wire Broadcasting Systems.

Systems of wire broadcasting fall into one of two main categories, audio frequency systems and carrier systems. In audio systems the programme signals at audio frequencies from a radio receiver or from a line connection to the studio are amplified and transmitted at such voltage and power that they can be reproduced by the listeners' loudspeakers without any further amplification. It is obvious that in such a system only one programme can be conveyed at one time on one pair of wires to each listener. In the system, as widely used in this country, the number of pairs of wires teed into each listener's house is therefore equal to the number of programmes presented for choice. In an alternative arrangement which has been used on the Continent, there may be only one pair of wires by which each listener's loudspeaker is connected to a central point where the full choice of programmes is available and where the selection is made by switches remotely controlled by the listeners; but these are generally operated at low voltage and an amplifier is associated with the listeners' loudspeakers. Fig. 1 and Fig. 2 are schematic diagrams of such systems. The great economy and convenience of the first of these systems is in the need for little more than a loudspeaker and switch at the listener's premises; it is capable of giving reliable and good quality service with equipment which is cheap and simple to use; it is particularly advantageous where the listener has no electric power supply.

Audio systems commonly use open wire lines on which the programme signal voltage is allowed frequently to reach peak values of the order of 85V; the loudspeaker circuits may each present an impedance of 10,000 ohms with a resistive component of about 8,000 ohms so that the peak power fed to a loudspeaker near to the input end of the line is about 0.6 watt. An amplifier feeding 4,000 loudspeakers may therefore need to have a peak output power of about 2 kW. For services giving a choice from two or more programmes overhead cables, insulated and sheathed with polythene, are coming into use; these cables are made in star-quad form for two programmes and a double star-quad in a common sheath is used for four programmes[6]. They are generally run under the eaves of houses and are carried on suspension wires where it is necessary to bridge gaps between buildings or to cross streets.

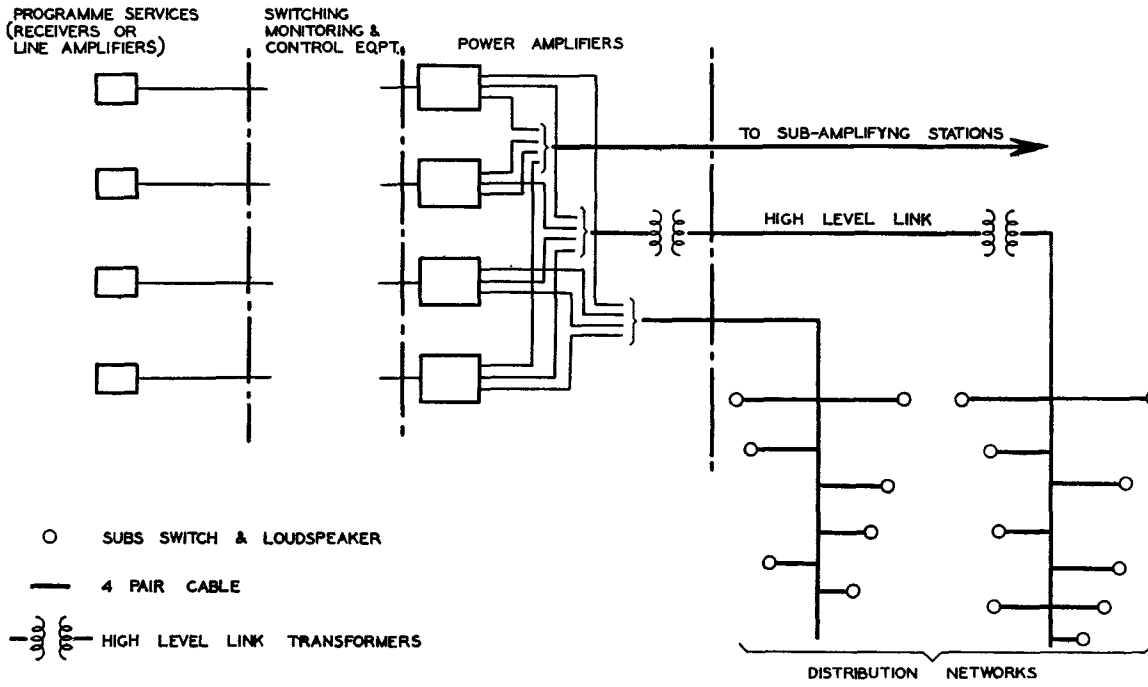


FIG. 1.—FOUR PROGRAMME AUDIO WIRE BROADCASTING SYSTEM.

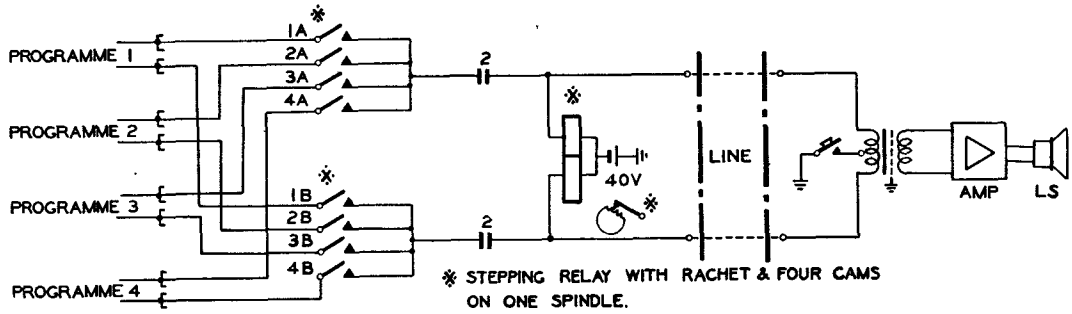


FIG. 2.—AUDIO SYSTEM WITH REMOTE SELECTION OF PROGRAMMES.

2.3. Carrier Systems.

At the expense of adding complication to the listener's equipment a carrier system enables several programmes to be offered for the listener's choice using only one pair of wires, teed from a single main feeder pair, to each listener. The central station equipment in this case may comprise a low power multi-channel transmitter operating with carrier frequencies from 20 kc/s to 150 kc/s or more. The listener must have a simple form of radio receiver which can be tuned to select the carrier modulated with the desired programme. With this system the number of programmes available for selection can be increased without adding to the cost of the wire distribution network. Moreover, it is possible to operate a carrier system using the telephone lines or electric power supply cables instead of a special wire network, without interfering with their normal use.

2.4. Carrier Systems Using Special Networks.

The development of these systems seems to have been confined mainly to this country where they are as yet only a small proportion of the total number of services. Several experimental systems have been proposed including some in which carrier channels are super-imposed on audio pairs. One carrier system already in use[7] is designed to provide six channels. The channel spacing is about 17 kc/s; double sideband amplitude modulation is used and the line voltage is limited to 2.0V (peak) per channel. A voltage of the order of 200 mV is available at the listeners' receivers which can therefore be less sensitive than normal radio receivers. Tuning circuits are pre-set and selected by a switch. Several thousand listeners can be fed from one high frequency amplifier. Overhead house-to-house wires of 18 S.W.G. are used; they are spaced two inches apart and insulated with

a thin covering of polythene. Fig. 3 is a block schematic of a system of this type.

Such carrier systems can provide up to six channels with a simpler line network of only one pair of wires compared with one pair per programme for audio systems. The cost of each listener's equipment is higher than for audio systems and the listener must have a power supply or use batteries but the audio power output is not limited by line attenuation.

2.5. Carrier System Using the Local Telephone Network.

With this system the local telephone network can be used for distribution of several programmes without interfering with the operation of the telephone service. Mention is made in sections 3.6, 3.7 and 3.8 of the use of such systems in Germany, in Sweden and in Switzerland, and in section 10 an experimental Post Office design is outlined.

The wire broadcast service can be extended to non-telephone subscribers by teeing at the end of a telephone line. Owing to the large proportion of underground cable in the telephone line network the line attenuation is high but in practice the sensitivity of the listener's receiver can be substantially lower than that of a broadcast radio receiver designed for local station reception. The power levels are of the following order: For each programme, one milliwatt to line at the exchange and one microwatt to each listener.

2.6. "High Level" and "Low Level" Systems.

Audio wire broadcasting systems may be of the "high level" or the "low level" type. The former type is that widely used in this country and elsewhere and in such systems the programmes are transmitted at such a level that the listener's loudspeaker may be operated directly from the transmission line without amplification. The term "high level" is also used to describe links between central amplifiers and remote distribution networks in which line losses are minimised by transforming the signal voltage to about six or ten times the normal distribution voltage. "Low level" audio systems have application where it is expedient to employ pairs in telephone cables for distribution and such a system was used in London in connection with defence services during the war. Similar systems are in use on the Continent. In such systems an amplifier must be associated with each loudspeaker. Links provided in telephone cables between main and subsidiary distribution amplifiers of audio wire broadcasting systems must be operated at low level and the power to the line is then limited to 5 milliwatts.

Carrier systems so far licensed for experimental operation or approved for full operation in this country and those developed elsewhere have been of the low level type. In this country the line voltage has been limited to 2 V peak per programme; amplitude modulation is used and both sidebands and carrier are transmitted so that receivers of straightforward design may be used.

2.7. Wire Broadcasting on Electric Supply Mains.

At an early stage in the development of wire broadcasting it was proposed that electric supply mains should be used for the transmission path for a carrier system. The chief advantage to be found in this method lies in the widespread distribution of underground electric supply mains, particularly in areas which are already fully developed and where a new underground network solely for wire broadcasting would be very costly.

There are technical difficulties in using electric supply mains for wire broadcasting, which tend to offset the advantage of having a widespread underground network already laid. For example, reflections are liable to result in irregular values of voltage along the feeders; the noise level is high; and difficulties in feeding high frequency energy across the power distribution transformers result in the need for a special main feeder to link the distribution

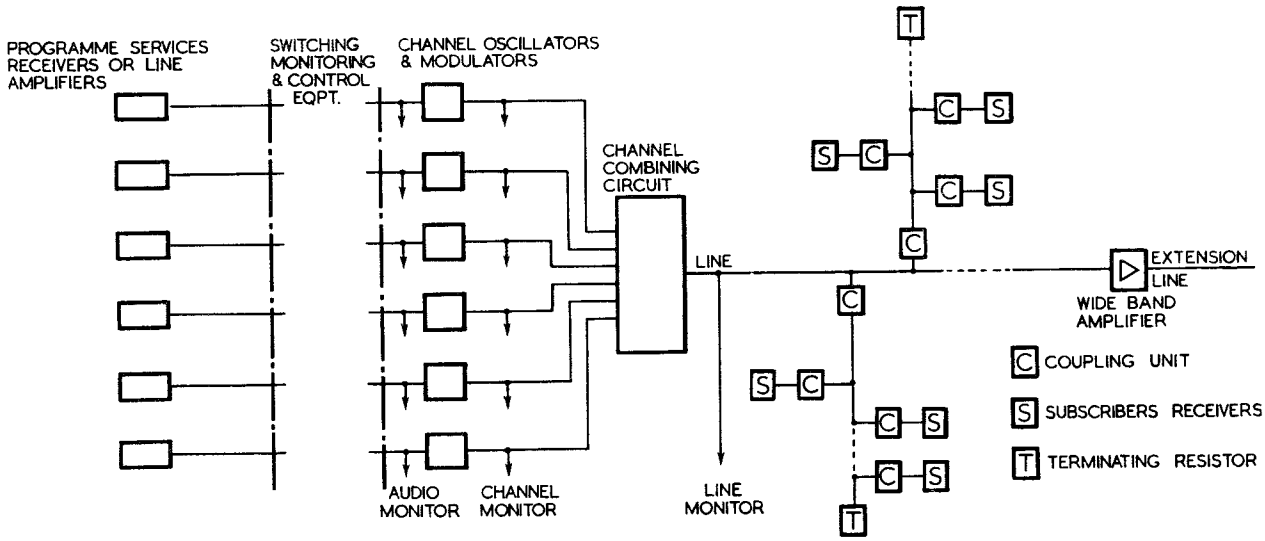


FIG 3.—CARRIER SYSTEM USING SPECIAL LINE NETWORK.

cables with the central station. At frequencies of the order of 20 kc/s, the surge impedance of typical power distribution cable using the bunched conductors and the sheath as a concentric cable is about 1 ohm. In a description of a system of this kind, 1 watt per programme is quoted as typical of the input power required for each distribution cable at the consumers' side of the distribution transformers[8]. This system used assymmetric sideband transmission. The extent to which technical difficulties make such use of supply mains impracticable or uneconomic has never been put to the test because commercial use of the system in this country has been precluded by the Electricity Supply Acts. These have specifically excluded the transmission of any telegram from the activities of power supply undertakings.

There has been some experimental use of overhead power mains abroad, notably in Switzerland[9], for boosting the radio field strength in valleys where the radio broadcast stations produce only a very weak field. In these systems a local transmitter of very low power (5 watts, for example) and operating on a frequency in the long wave broadcast band, is coupled to the low tension overhead electric supply mains, and normal receivers and aerials are used to receive the field radiated from the overhead distribution network.

3. HISTORY AND DEVELOPMENT OF WIRE BROADCASTING.

3.1. Early Transmission of Music by Wire.

Wire broadcasting is not merely a substitute for radio broadcasting. It was in fact in use many years before radio. Alexander Graham Bell used the transmission of music as well as speech to demonstrate the wonders of his newly invented telephone and it is on record that in 1878, Queen Victoria at Osborne, in the Isle of Wight, heard organ music over a wire connection from London during one of Bell's demonstrations[10]. An example on a scale more like that of wire broadcasting as practised to-day was the system of the London Electrophone Company which commenced operations about 1894 using the lines of the National Telephone Company. Through the electrophone exchange, telephone subscribers could hear the performance from a theatre or the service from a church which they could choose from among 30 places available for connection. In 12 years working the number of subscribers did not exceed 600. By 1919 there were 1,000 subscribers and to meet future growth arrangements were made for the Post Office to provide a new exchange for the Company. This exchange commenced working in 1920 and by April, 1922, there were more than 1,900 subscribers. About this time amplifiers were introduced at the exchange and experiments were being made with loudspeakers. Previously, when more than five or so groups of subscribers' headphones (the number varied with their distance from the programme source) were connected to each line from a particular source, further requests for the same programme had to be refused ; the amplifiers enabled some 50 subscribers to be fed from one programme line. With these limitations the electrophone system could not compete with radio broadcasting and between October, 1923, and October, 1924, the number of subscribers fell from 1,850 to 1,023. The Post Office agreement with the Electrophone Company terminated in 1925.

A similar service started in Budapest[11],[12] also in about 1894 appears to have been more ambitious and more successful. It originated some programmes in its own studio and issued news bulletins besides providing connections to theatres and the Opera House. In ten or twelve years working the number of subscribers grew to between 4,000 and 5,000 and the system progressed to take advantage of the development of valve amplifiers and to use loudspeakers. The "Theatrephone" in Paris was a similar system which also achieved a considerable measure of popularity.

The latest use of telephone lines in this way to enable subscribers in this country to hear music from local sources appears to have been in Bournemouth where, until the mid-thirties, a few subscribers continued to be connected to certain churches.

3.2. Growth of Broadcasting.

The earlier programme distribution systems, working without the aid of valve amplifiers, were limited in scope but in view of the later successful development of wire broadcasting it is remarkable that radio broadcasting, in the early 1920's, so rapidly surpassed the early wire systems in popularity. No doubt the novelty of radio and the relative simplicity and cheapness of early radio receivers and, especially, the immediate wider coverage of radio had much to do with this. Radio broadcasting achieved what the Electrophone type of system had failed to do in discovering and developing the great demand for broadcast programmes. As the demand grew, so the technique of broadcasting improved and listeners found it increasingly worth while to buy the more elaborate receivers which the radio industry produced. The amount which they were prepared to spend on broadcast listening soon grew to be more than sufficient to support systems of wire broadcasting, at least in urban areas and wire broadcasting began to develop again (though in a new form), in many urban areas, as a preferred alternative to direct radio reception. Preferred because it can be cheaper and more convenient, and often of better quality and free from interference.

3.3. Some Limitations of Radio Broadcasting.

The principle of using wire for all telecommunications except where distance or accessibility of one terminal, or the mobility of one or both terminals makes this impracticable, is one which does not appear to have had much influence on the solution of the wavelength problems which have complicated the organisation of broadcasting for the past 20 years.

Radio broadcasting has developed in many countries without regard to the possibilities of wire broadcasting, and many radio transmitting stations are situated where they will best serve the densely populated areas ; as a result radio broadcast services, operated within the scope of international agreements

which limit transmitter power and choice of wavelength, tend to be better in urban areas where wire broadcasting could be used with advantage, and poorer in rural areas where wire broadcasting tends to be uneconomic and is less likely to be valued for its relative freedom from interference.

The use of radio broadcasting as the primary means of reaching every listener has, so far, tended to limit the number and the quality of the programmes available for each listener, particularly in countries where the difficult shape and size of the areas to be served, or limited availability of wavelengths, add to the difficulties of giving adequate radio coverage. In such countries, the available wavelengths have been used to give the best service to urban listeners, leaving many rural listeners with inadequate reception, often of even one programme. Wire broadcasting, on the other hand, can offer a better choice of clear channels between studio and listener and could free programmes from much of the restriction at present imposed by shortage of wavelengths.

3.4. Development of Wire Broadcasting in the United Kingdom.

Wire broadcasting of radio programmes was not introduced in this country with a view to relieving congestion in available radio channels but as a development of the idea of an extension loudspeaker so that one good radio receiver could be shared among several listeners. This was first done in the village of Hythe near Southampton in 1924[11]. From a domestic extension loudspeaker the system expanded over a period of two years to some twenty neighbours and eventually to as many as 150 subscribers, but although the system continued in being until 1941, this number was never exceeded. The 150 subscribers, however, covered a wide area and the most distant connection involved 10 miles of wire.

In 1926 this first exchange received some publicity as a result of which the Postmaster-General licensed the proprietor to continue its operation ; other relay exchanges came into being as the commercial possibilities of wire broadcasting were appreciated. By the autumn of 1927 there were 10 relay exchanges with 446 subscribers. The subsequent growth of the industry in this country is shown in Table I, and in the curves of Fig. 4.

TABLE I.

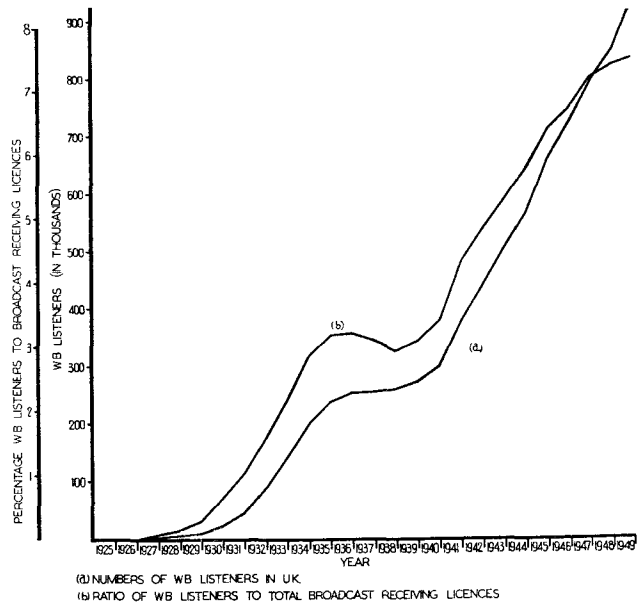
Date.	No. of Exchanges.	No. of Subscribers.
September 1927	10	446
December 1928	23	2,430
,, 1929	34	8,592
,, 1930	86	21,677
,, 1931	132	43,889
,, 1932	194	82,690
,, 1933	265	130,998
,, 1934	318	192,707
,, 1935	343	233,554
,, 1936	333	250,978
,, 1937	331	255,236
,, 1938	325	256,294
,, 1939	284*	270,596
,, 1940	284*	297,691
,, 1941	278*	309,420
,, 1942	277*	435,073
,, 1943	275*	494,559
,, 1944	274*	551,703
,, 1945	274*	634,474
,, 1946	283*	714,505
,, 1947	297*	793,582
,, 1948	314*	865,539
,, 1949	335*	921,461

* Excludes secondary or standby stations.

This progress is divided into four main stages. Up to 1929 the idea of the relay exchange was taking shape. From 1929 to 1934 there was a rapid expansion of the numbers of subscribers served by relay exchanges which were mostly operated in small units and by small firms. In 1936 the Ullswater Committee, in its report on broadcasting, recommended that the ownership and operation of relay exchanges should be undertaken by the Post Office, the control of programmes remaining with the B.B.C. The Government of the day, however, extended the licences of the companies for a further 3 years, during which time the Post Office would have the opportunity of gaining experience and of undertaking experimental work on wire broadcasting.

The effect of these circumstances on the development of the relay exchanges† is shown in the reduction of the number of exchanges and in the reduced rate of increase in the total number of subscribers during the period 1935 to 1938. Early in 1939 the then Postmaster-General announced that it had been decided that the licences of the operators of relay exchanges were to be extended for an additional 10 years. At the same time the Post Office was to commence the installation of equipment for operating a carrier wire broadcasting system over the telephone network. This was designed to use ordinary radio receivers supplied by the listener, and might later be extended to non-telephone subscribers. The main object of this policy was to encourage the development of wire broadcasting as a defence measure.

† The causes and effects of these circumstances have been discussed in detail in an article by R. H. Coase[11].



(a) NUMBERS OF W.B. LISTENERS IN U.K.
(b) RATIO OF W.B. LISTENERS TO TOTAL BROADCAST RECEIVING LICENCES

FIG. 4.—GROWTH OF WIRE BROADCASTING IN U.K.

The outbreak of war retarded the rapid growth which might have been expected in these new circumstances. Industrial effort had to be diverted to other activities; Post Office plans to install carrier systems in London, Birmingham, Manchester and Edinburgh were suspended and no new licences to operate relay exchanges in new areas were issued. As far as supplies of labour and materials allowed, however, existing relay companies could continue to extend in the areas in which they were already operating and between 1939 and 1945 the number of wire broadcast listeners increased by more than 130%, even though during the same period the number of exchanges fell from 284 to 274. From 1945 to 1947 the number of exchanges again began to grow, and the number of subscribers increased at a slightly greater rate than during the war period.

3.5. Development in the Colonies.

Wire broadcasting is being extensively developed in colonial territories, for broadcasting local programmes and for relaying programmes broadcast by the B.B.C. or broadcast from Australia or from America. In relatively undeveloped countries with limited programme resources, wire broadcasting brings obvious benefits in enabling many listeners to share the advantages of elaborate receivers and aerials for picking up distant transmissions, and it provides good individual and communal listening facilities for many who cannot afford an ordinary radio receiver. For example, in the Gold Coast[13] there are 18 wire broadcasting centres serving about 7,000 subscribers; in Nigeria[14] there are wire broadcasting services in 10 towns with a total of over 9,000 subscribers. The wire broadcasting system in Malta serves about 15,000 subscribers. These, with seven other territories include a total of more than 80 wire broadcasting centres serving over 42,000 subscribers.

3.6. Development in Germany.

Articles published in 1937[15] and 1941[16] give details of a carrier system designed for wire broadcasting over the whole of the German telephone network. A few audio systems had been growing in Germany up to 1934, when their further expansion was forbidden and development of wire broadcasting was made the responsibility of the German Post Office. Attention was first turned to using power supply mains as the most widespread of the possible transmission media. The technical difficulties to be overcome in using the supply mains were considered to make the project uneconomic, however.

The system finally designed for the telephone network had three carrier frequencies in the longwave broadcast band so that most of the existing receiving sets in Germany could be used. The line voltage at the receiver for quiet underground lines was 25 mV. Exceptionally, for noisy overhead lines a line voltage of 250 mV at the receiving point was considered necessary to maintain a signal to noise ratio of about 45db. A large number of subscribers was served before 1940 and the numbers grew considerably during the war, when the use of the service was extended by adopting the expedient of energising all pairs in a local telephone cable[17]. This was done by feeding a few pairs directly between one wire and earth, the other pairs being energised by induction. Owing to the high level at which the amplifiers had to be driven, the wideband amplifiers had to be replaced by channel amplifiers when this method was used. Since 1945 there has been a substantial return to the original carrier system.

3.7. Development in Sweden.

Another example of the extensive use of a carrier wire broadcasting system is in Sweden. Owing to its shape and size, it is not possible to arrange satisfactory radio broadcast coverage of the country, using the long and medium wave frequencies available, even for one programme. The radio service is therefore supplemented by an extensive system of wire broadcasting. The programme is fed from Stockholm over music circuits in the trunk network to the carrier transmitters. These in turn feed junctions to outlying exchanges through line amplifiers or local distribution amplifiers, which are connected to subscribers' lines at the main distribution frames. At the present time some 10,000 subscribers use the service, which extends from the island of Gotland in the Baltic to the river valleys over 600 miles north of Stockholm. Long term expansion of the present single programme service is expected to result in its use by some 700,000 licence holders (out of a present total of two millions), this being the estimated number who cannot count on satisfactory radio reception. Plans for a three channel system are well advanced and may have to be extended to cover those areas where one programme is satisfactorily received at present on long or medium waves, but where provision of additional programmes by radio (for example, using very high frequencies) may be found to be uneconomic compared with wire broadcasting.

3.8. Development in Switzerland.

In Switzerland at the present time, about 15% of the holders of broadcast receiving licences receive their programmes by wire. The greater part of these are served by systems operated by the P.T.T. using the telephone network, the remainder being served by a private company which operates a number of high level audio systems. The P.T.T. systems are mainly of the low level audio type and the desired programme is selected from five available at the telephone exchanges by a stepping relay remotely operated by means of a pushbutton associated with the listener's amplifier and loudspeaker; the wire broadcast programme is disconnected when the line is in use for a telephone call. The Swiss P.T.T. also uses a carrier system operated over the telephone network: This latter system, which has been under development for some years and at present serves about 10,000 listeners with a choice of 5 programmes, is being extended and will eventually be available at all telephone exchanges in Switzerland. The carrier frequencies fall in the long wave broadcast band so that ordinary radio broadcast receivers—provided by the listeners—may be used. The effective audio bandwidth available is about 7.5 kc/s and the channel spacing is 33 kc/s. The high frequency transmission characteristics of the type of cable used in the local networks

of the Swiss telephone system are such that it is practicable to use a carrier frequency as high as 307 kc/s.

In certain villages where the main radio broadcast stations give a weak field, a form of wire broadcasting is in use experimentally, in which the overhead power supply distribution network is energised by transmitters of 2 to 5 watts output and operating on frequencies between 150 kc/s and 250 kc/s. By this means, listeners living along the routes followed by the overhead mains are assured of good reception with ordinary radio receivers and aerials.

3.9. Development in Holland.

Wire broadcasting seems to have achieved greater popularity in Holland than in any other country. By about 1936 there were several private companies and municipal authorities operating wire broadcasting services. Most of the systems received the two Dutch National programmes by Post Office wire connections and one or more foreign programmes on their own radio receivers. The companies used their own overhead distribution networks (which latterly were being replaced by underground cables) and the municipal systems in the Hague and Rotterdam used the telephone networks. The former systems were of the high level audio type and subscribers needed only a loudspeaker with a switch. The latter were low level systems and subscribers required an amplifier ; where working telephone lines were used the listener had a push button for remote selection of the programme ; the programme was disconnected when the line was in use for a telephone call. Non-telephone subscribers were offered the service if spare lines were available.

Since 1941 the wire broadcast services have been operated by the Dutch Post Office. They are available to about 80% of the population, and are used by about 0.5 million broadcast listeners out of a total of about 1.8 million. Further expansion is taking place using a high level audio system.

3.10. Wire Broadcasting in the U.S.S.R.

In the U.S.S.R., according to an article published in America in 1947[18], substantial use is made of audio frequency extensions from communal receivers to individual listeners and for groups in public meeting places. The " radio centres " from which these audio distribution systems spread, are the terminations of radio networks comprising large central transmitters linked in tandem with smaller regional and district transmitters.

4. POSSIBLE FUTURE DEVELOPMENT OF WIRE BROADCASTING.

4.1. Some Advantages of Wire Broadcasting.

Wire broadcasting has come into wide use for many reasons the emphasis on which has varied with time, place and circumstances. In the early days of radio broadcasting, signal-to-noise ratio was poor in many places and receivers capable of good reception in such places were rare, expensive, bulky, and difficult to tune correctly ; many more sets were battery operated than to-day. Interference was naturally of greater significance where the programme field strength was weak and practical methods of suppressing interference had yet to be developed. Receivers with retro-action often made good reception in their neighbourhood impossible. These circumstances were probably responsible for the inception of the earlier relay services. Another factor which came into operation as the relay systems grew was the attraction of a trouble-free service in exchange for a small weekly payment. In towns, the erection of a satisfactory aerial, unscreened and clear of interference, has always been inconvenient particularly in large blocks of flats.

Considerations of economy and convenience will no doubt continue to influence the choice between radio reception and wire broadcast reception wherever wire broadcasting service is available. But, under existing conditions of wavelength congestion, wire broadcasting can offer additional advantages over radio broadcasting on long and medium wavelengths, by way of higher fidelity and wider choice of programmes.

4.2. Improved Fidelity.

Radio receivers generally available are designed to meet the conditions imposed by the limited number of medium and long wavelengths available for broadcasting. If reception is to be free from interference then the upper limit of audio frequencies effectively reproduced will be barely 4000 c/s. By using a receiver specially designed for reception in a strong field (not less than 2 millivolts per metre) from a local station, the fidelity can be improved to give effective reproduction of up to about 7000 c/s, but receivers with this performance are made only in small quantities, mainly for use in connection with relay services ; they are generally made for pre-set tuning to a single frequency in one band only, are provided with other special facilities, and are more expensive than the average domestic receiver.

The extent to which an increase in audio bandwidth is desirable has been and still is the subject of much controversy and investigation, and detailed discussion of this question is beyond the scope of the present paper. It may be said, however, that it is generally agreed that a wider band is more desirable than it is practicable to receive, in present circumstances, from long and medium wave broadcast stations. Also the opinion is widely held that there must be a considerable improvement in the performance of low-priced loudspeakers before the full advantages of a wider band could be realised.

The two methods which to-day offer higher fidelity listening are radio broadcasting on very high frequencies, and wire broadcasting. Very high frequency radio broadcasting has its own special limitations, and its potentialities in providing more programme channels of greater audio bandwidth have yet to be fully explored. To make use of very high frequency broadcasting the listener must purchase a new receiver which will be more complex, and therefore more costly than existing sets. On the other hand, where wire broadcasting has been introduced it has been possible to offer from two to six programmes with improved quality and at a cost which is attractive to the listener.

4.3. Provision of More Programme Channels.

The need for additional programmes is not universally acknowledged, but it must be remembered that the B.B.C. has hitherto had to work within the limits set by the wavelength shortage, and if facilities for more channels were available it might well be that new uses would be found for additional National or Regional programmes[19]. Moreover, it has been suggested that local programmes should be broadcast in New Towns[20]. The adoption of this suggestion and the inevitable extension of local programme broadcasting to other towns could be effected either by V.H.F. or by wire broadcast transmission; technically, both methods are suitable for such localised services, but more especially the latter. In wire broadcasting there is no problem like that of anomalous propagation ("freak reception") experienced in V.H.F. radio transmission. Also, the establishment in this country of the many V.H.F. transmitters which would be required to provide local as well as national and regional programmes would involve a most difficult problem in finding transmitting station sites; these must be not only technically satisfactory, but acceptable to the many interests concerned with local amenities, safety of air transport, agriculture, etc.

4.4. Equipment Required by Listeners.

An important consideration in any scheme for improving the quality or coverage of existing programmes or for introducing new programmes, is the extent to which listeners desirous of obtaining full benefit from such improvements, would need to modify or to replace their existing receivers. For those who would be unable or unwilling to do either, existing long and medium wave facilities would be needed for a long time to come.

From the listeners' point of view, the most acceptable way of increasing the number of programmes and of improving fidelity would be one which would enable all programmes to be received using equipment which is no more complex, and preferably less complex, than existing radio receivers; and without disturbance to the facilities at present provided by radio broadcasting on long and medium waves. Such provision already exists, in some degree, where multi-programme wire broadcasting is available.

Some carrier systems of wire broadcasting, using carrier frequencies falling in the long wave broadcast band, enable listeners to use ordinary radio receivers but the audio bandwidth is then limited by the selectivity of the receiver.

5. THE PRESENT ORGANISATION OF WIRE BROADCASTING IN THE UNITED KINGDOM.

5.1. Distribution and Density of Relay Companies' Subscribers.

The pillargraphs of Figs. **5** and **6** show the percentage of broadcast licence holders who in 1946 were also subscribers to relay companies, for the whole country, for Post Office Regions and for **17** towns in which the proportion was greater than 30% (Fig. **5**). The graphs of Fig. **6** show the percentages for the whole of each Region and include receiving licences in areas where wire broadcast service was not available.

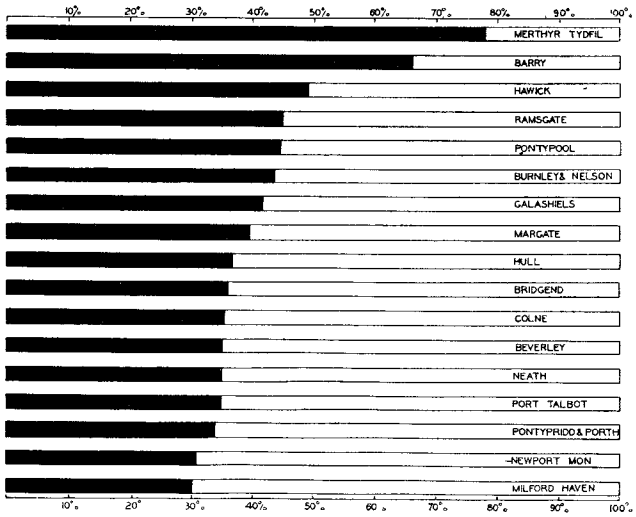


FIG. 5.—RATIO OF WB LISTENERS TO BROADCAST RECEIVING LICENSING IN CERTAIN TOWNS (1946).

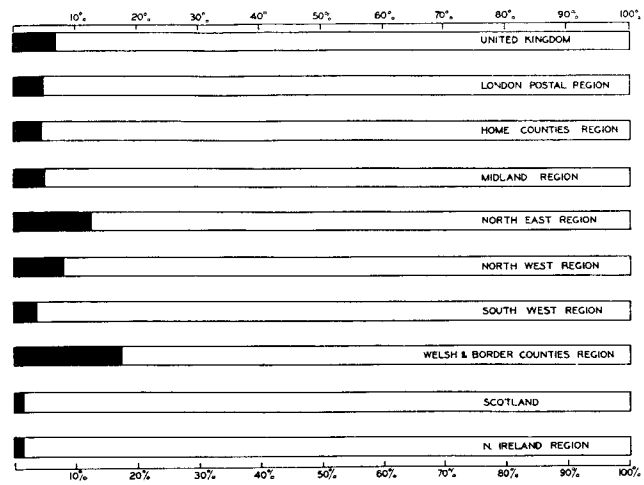


FIG. 6.—RATIO OF WB LISTENERS TO BROADCAST RECEIVING LICENCES IN P.O. REGIONS (1946).

The distribution and density of wire broadcast listeners throughout the country in 1947 is shown in Fig. 7. At 31st December, 1949, of the 12,181,300 holders of broadcast receiving licences in the United Kingdom, 921,461 (over 7½%) used wire broadcast services.

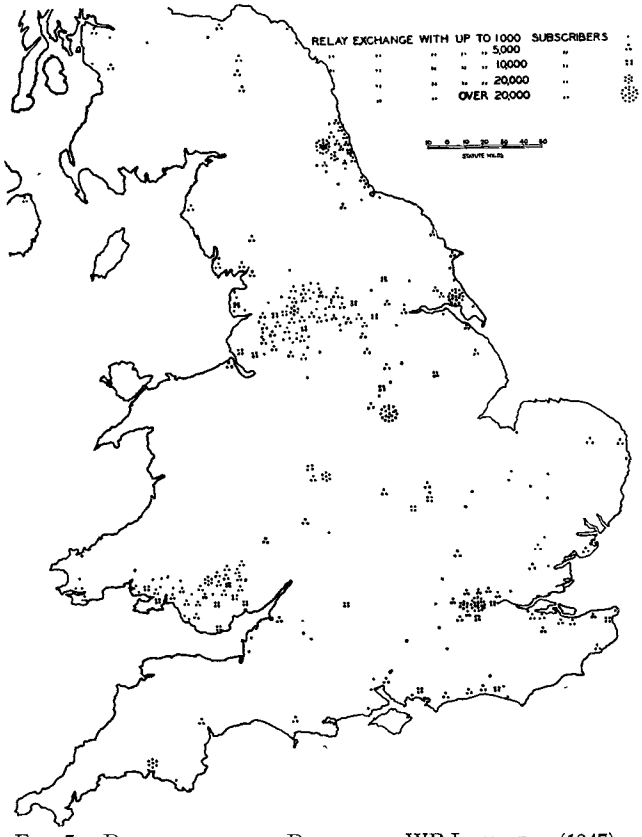


FIG. 7.—DISTRIBUTION AND DENSITY OF WB LISTENERS (1947).

Most of the services in this country give a choice of two programmes. Early in 1947, of 250 services (95% of the total), 16 gave one programme, 227 gave two programmes, four gave three programmes, and three gave four programmes. Some extension of facilities for four or more programmes has been made since that date, by new installations or by modification of older systems.

Under the terms of licence agreements made since 1939, subscribers must be able to choose one of two B.B.C. programmes: except for periods when sufficient programmes are not being transmitted by the B.B.C. for listeners in this country, one programme must be wholly B.B.C. and the second must include 75% of the alternative B.B.C. programme material available in each week; services giving three or more programmes must select two of their programmes from those being broadcast by the B.B.C. Other material may be received from foreign broadcast stations but may not be originated locally.

5.2. Use by Relay Companies of Post Office Lines.

Many companies rent Post Office circuits so as to obtain programmes by wire from a B.B.C. switching centre, or from a favourably situated radio receiving station. For reception of foreign programmes some of the larger companies have receiving stations intended eventually to feed local wire broadcasting networks in all parts of the country, over private wires rented from the Post Office. A typical layout of a Post Office network between a B.B.C. centre and a number of relay companies' stations is shown in Fig. 8. About 120 of these programme feeds are at present in use.

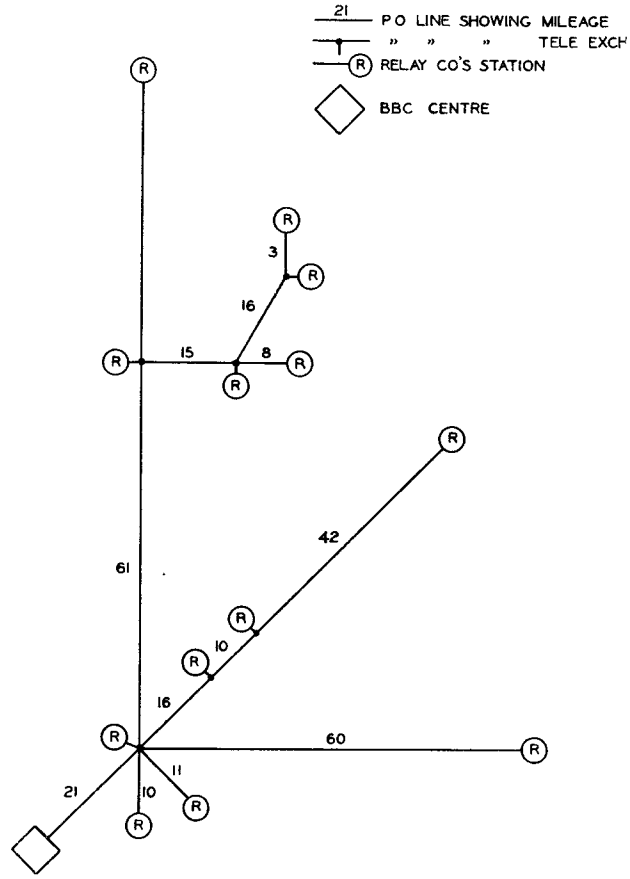


FIG. 8.—TYPICAL LAYOUT OF P.O. NETWORK BETWEEN A B.B.C. CENTRE AND A NUMBER OF RELAY COMPANIES' STATIONS.

In addition to these main programme feeds the relay companies rent many Post Office circuits for linking their central stations with subsidiary amplifiers or for connecting their local radio receivers to their central stations. The number of circuits of this kind at present in use in London alone is well over 500.

Where suitable line plant is available the private wire circuits rented by the relay companies are equalised to give a frequency characteristic flat to within 2 db over a band extending from 50 c/s to 6400 c/s. The technique of providing such circuits has been described by H. J. Marchant[21].

5.3. Licences and Technical Conditions.

Since the relay exchanges were first licensed, technical conditions have been included in the licence agreements. The conditions which have applied since 1938 are in two sections. One contains compulsory conditions the main purposes of which are to

ensure that wire broadcasting systems shall not become a source of danger nor interfere with the working of the telephone service; they are concerned not only with the conditions of operation of the licensees' own distribution network but with the operation of their plant as it affects Post Office lines rented for programme feeds or for links between the licensees' own stations. The other section contains recommended standards of performance for the licensees' plant.

Special conditions are applied to carrier wire broadcasting systems, and such systems are tested to ascertain that they are not likely to interfere with radio reception. There are also special conditions for distribution lines or station to station links at voltages greater than 60 V (R.M.S.).

6. LOUDSPEAKERS.

It is important that the cost of the loudspeakers shall be as low as possible consistent with adequate sensitivity, frequency response and freedom from undesirable resonances.

As already mentioned in section 4.2, it has been generally agreed hitherto, that the performance of low-priced loudspeakers was likely to limit the effect of improvements which might be achieved in other parts of transmission systems.

Prior to 1939 an inexpensive loudspeaker to give good quality reproduction in living rooms was designed in the Post Office[22]. The design has some features in which it differs from loudspeakers in general use. A heavily damped cabinet with an enclosed back is used and the cone suspension is designed to introduce as little stiffness and mass as possible. In spite of the use of relatively fragile suspension the loudspeakers passed stringent dropping tests and gave no trouble over a long period of use.

The design gives improved low frequency response compared with open cabinets for a given cabinet size. With a cabinet somewhat larger and heavier than those generally used, a satisfactory low frequency response is achieved, but above 4000 c/s more efficient radiation is desirable. Fig. **9** is taken from a paper by Messrs. West and McMillan[22] and illustrates frequency response curves for a loudspeaker of this type. Curve 1 shows the axial sound pressures for free space conditions and curve 2 the average sound pressures taken in a room 24 ft. × 12 ft. × 11 ft. 6 in. high and furnished to simulate a living room.

7. SOME DESIGN CONSIDERATIONS OF AUDIO FREQUENCY WIRE BROADCASTING NETWORKS.

In an audio system a large part of the capital is invested in the line network and it is important that the feeders shall be used efficiently. A measure of the utilisation of a feeder is the product $N \times l$ where N is the number of loudspeakers supplied from a feeder of length l for a specified maximum loss to the most distant subscriber. For a given value of Nl a large number of loudspeakers may be connected near to the transmitting amplifier or a smaller number may be connected further from the amplifier. In practice the distribution of load varies continually as listeners switch their loudspeakers on or off or change from one programme to another. However, by comparing several hypothetical arrangements a useful guide can be given to fitting a network to the distribution pattern of subscribers to make the best use of the line plant provided.

FIG. 9 —SOUND PRESSURE CURVES FOR A WB LOUDSPEAKER DESIGNED BY THE P.O. (1939)

It is convenient to consider the following three types of load distribution shown in Fig **10**. These are

(*a*) N loudspeakers distributed among n points along the feeder ; the ratio of the numbers of loudspeakers at successive distribution points being a constant k.

(*b*) N loudspeakers uniformly distributed at n equidistant points.

(*c*) N loudspeakers all connected at the end of the feeder.

(*b*) and (*c*) are special cases of (*a*) ; in (*b*) $k = 1$ and in (*c*) $n = 1$.

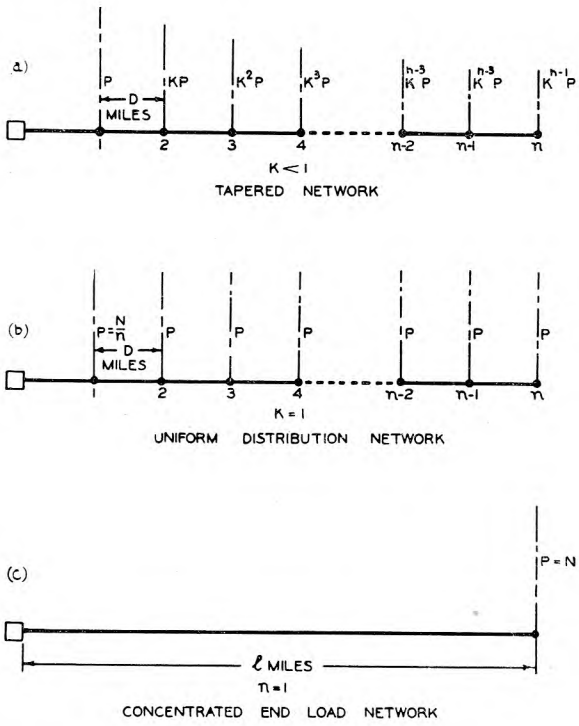


FIG. **10**.—IDEALISED AUDIO NETWORK. ANALYSIS OF LOAD DISTRIBUTION.

Neglecting all the primary constants of the cable except its resistance (R ohms/mile) and assuming that the loudspeaker loads (S ohms) are non-reactive it can be shown that the ratio of the line voltage (V^s) at the sending end to the line voltage (V_N) at the nth distribution point is given by :—

$$\frac{V_s}{V_n} = 1 + \frac{1}{n(k^n - 1)} \left\{ nk^n - \frac{k^n - 1}{k - 1} \right\} \frac{NlR}{S}$$

$$+ \frac{1}{n^2(k^n - 1)^2} \left\{ \frac{n(n-1)k^{2n+3} - (n^2 + n - 2)k^{2n+2} - n(n-1)k^{2n+1} + n(n+1)k^{2n} + 2(n-1)k^{n+2} - 2k^{n+1} - 2nk^n + 2k}{2(k+1)(k-1)^2} \right\} \left(\frac{NlR}{S} \right)^2$$

For uniform distribution of loads $k = 1$ and the above expression can be substituted by

$$\frac{V_s}{V_n} = 1 + \frac{n+1}{2n} \frac{NlR}{S} + \frac{1}{24n^3} (3n^3 + 2n^2 - 3n - 2) \left(\frac{NlR}{S} \right)^2$$

If all the loads are connected at the end of the feeder $n = 1$ and

$$\frac{V_s}{V_n} = 1 + \frac{NlR}{S}$$

Families of curves of Nl plotted against n for various values of k, for different values of maximum loss and for various conductors (Fig. **11**), can be used to assist in the design of an audio network.

In the idealised network of Fig. **12** there are 9 teeing points and the ratio k is 1.33 or 0.75 according to whether the feed is from X to Y or from Y to X. Reference to the curves of Fig. **11** shows that $Nl = 160$ if the feed is at X but is 340 if the feed is at Y. This means that with the same main and distribution feeders and with the same maximum line loss in either case 340 subscribers could be supplied from a feeding point at Y but only 160 could be supplied if the feed were at X.

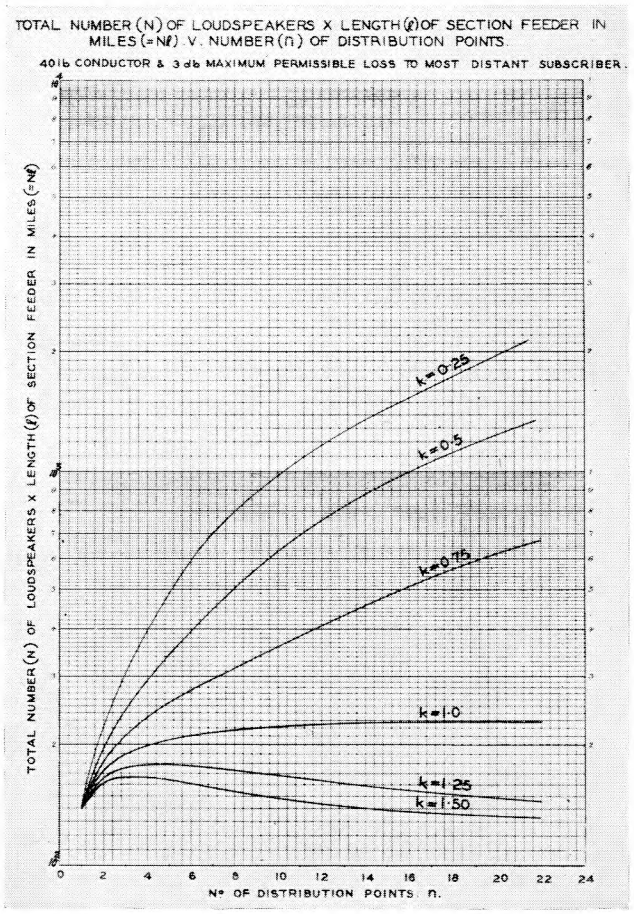


FIG. **11**.—IDEALISED AUDIO NETWORK. LOAD DISTRIBUTION CURVES.

Some preliminary calculations have been made taking into account all the primary constants of the feeders. These show close agreement with the foregoing results up to a frequency of nearly 2 kc/s. Above this frequency the attenuation is greater or less than the attenuation at lower frequencies according to the distribution of the load and length of the line. For example Fig. **13** shows the calculated attenuation-frequency characteristic for various numbers of subscribers all connected at the end of 1 mile of 40 lb P.C.Q.T. cable.

8. AUDIO SYSTEMS USING UNDERGROUND CABLES.

Wire broadcasting companies have made great improvements in recent years in the appearance of their overhead networks, but many local authorities

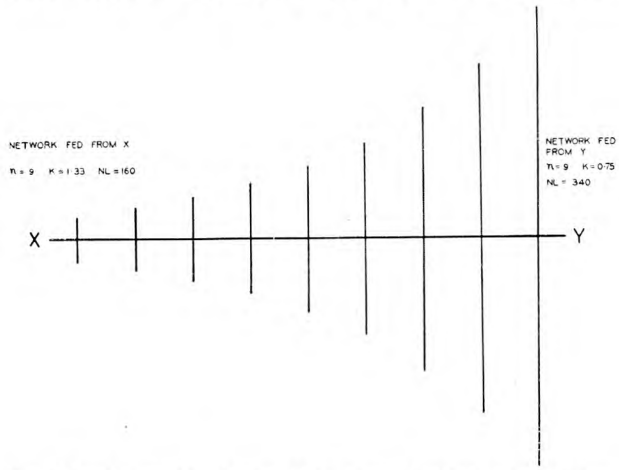


FIG. **12**.—IDEALISED AUDIO NETWORK. ILLUSTRATING EFFECT OF TAPERED AND INVERSE-TAPERED DISTRIBUTION OF LOAD.

are averse to the perpetuation and extension of overhead networks of any kind and some hope to secure the advantages of wire broadcasting without accompanying loss of amenities, by the introduction of wire broadcasting systems using underground distribution networks. Such a desire is particularly evident in the planning of new towns.

The demand for underground networks leads to consideration of the extent to which it is possible to operate underground cables for wire broadcasting in proximity to telephone cables and of the extent to which it is practicable for wire broadcasting cables to share routes, trenches, ducts or cables with telephone cables.

The report, published in 1946, of a Departmental Committee set up by the Ministry of Transport[23] recommends standards for the disposition under footways of underground services such as gas, electricity, water and telephones. The adoption or maintenance of these standards in many places would leave little room under foot-ways for additional services. For example, in the Report of the New Towns Committee[20] a foot-way and verge over 10 ft. 6 in. wide is regarded as necessary if district heating services are not to be relegated to the carriageway. In many built-up areas even where space could be found for new cable networks, the cost of laying them would be very high and great saving could be effected if new cables could be pulled into existing ducts or could share trenches with other services.

If ordinary lead covered cables were used for both telephone and wire broadcast services, it is unlikely that there would be any difficulty due to crosstalk even if the cables shared the same duct. Polythene insulated cables may, however, be used for either or for both services to avoid difficulties due to scarcity and cost of lead, and it is necessary to take this into

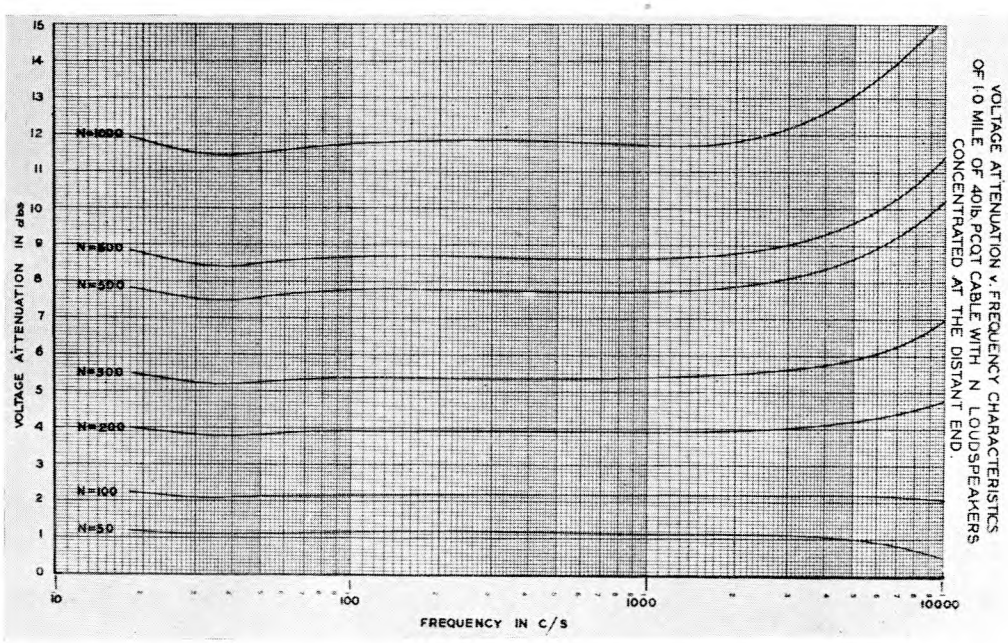


FIG. **13**.—IDEALISED AUDIO NETWORK. EFFECT OF LOAD DISTRIBUTION ON THE ATTENUATION FREQUENCY CHARACTERISTICS.

obtain the programme material from a radio receiver installed in the exchange : the complete video signal from the receiver was amplified before being transmitted to line. The sound system was to be similar to a high level audio system.

The design aimed at limiting the vision stages of the viewers' receivers to a synchronising signal separater, frame and line time base generators, and two rectifier valves, one for H.T. and the other for E.H.T. supplies ; a total of five valves excluding the teeing valve.

9.4. Later Investigations.

In later investigations, owing to crosstalk difficulties at the lower frequencies, consideration of video systems of transmission over coaxial cables has been suspended in favour of carrier systems. Video transmission on balanced pair has been considered but presents many difficulties, notably in the economic design of satisfactory balanced teeing units. Video systems also present difficult attenuation and phase equalisation problems due to the steep slope of the cable characteristics over the frequency band to be transmitted, and carrier systems are now regarded as the most promising.

In the development of the Outside Broadcast network set up for the B.B.C. the carrier frequency at present is 6.12 Mc/s with assymmetric sideband operation using the lower sideband. There would be many advantages, notably in connection with maintenance, in adopting the same system for a main distribution network and there would be no object in converting to any other frequency for final distribution.

Fig. **14** illustrates the design of a system suitable for the distribution of complete video signals as lower-sideband modulation of a carrier of frequency of the order of 6 Mc/s. With an input to line at 28 V (carrier peak), up to 200 viewers could be connected along $1\frac{1}{2}$ to 2 miles of cable having an attenuation of about 9 db/mile at 6 Mc/s (*e.g.*, 3/8 in. coaxial cable) before it would be necessary to insert an amplifier in the line. This system would provide a carrier input to each vision receiver at not less than 0.28 volts (carrier peak) across a 75 ohm receiver input transformer. There would be no difficulty in maintaining a satisfactory signal to noise ratio (not less than 28 db) with several line amplifier sections in tandem. Similar feeder systems could be teed through amplifiers from the main feeder in place of spurs to single viewers.

Fig. **15** shows the types of teeing unit suitable for this system, to maintain constant impedance along the feeders, the insertion and transfer losses being graded along the line so that the voltages fed to the viewers' receivers are kept within the limits indicated in Fig. **14**. The efficiencies quoted in Fig. **15** are an important consideration in a wire broadcasting system. The efficiency of a teeing unit is defined as the ratio of the power transferred to the viewer's line to the power taken from the main line.

The sound accompanying the vision in this system could be conveniently transmitted as modulation on

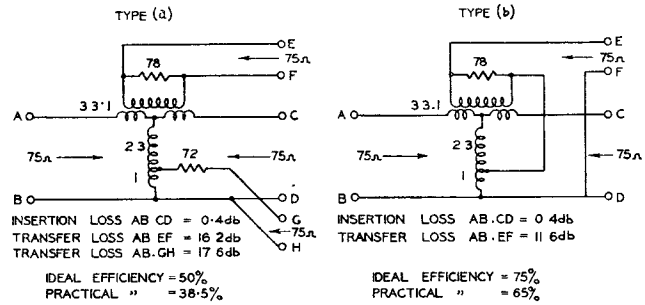
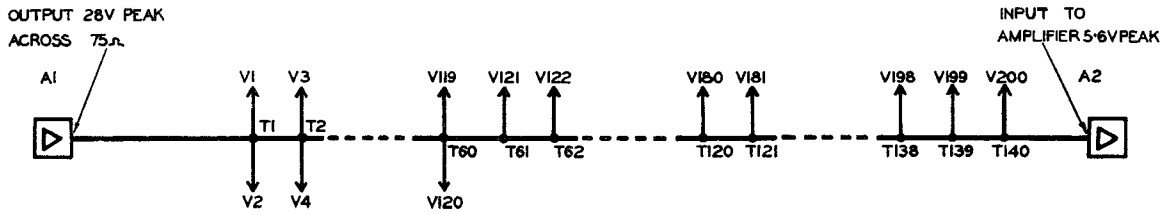


FIG. 15.—TEEING UNITS DESIGNED TO MAINTAIN CONSTANT IMPEDANCE ALONG A TELEVISION FEEDER.



TEEING UNIT NO.	T1	T2		T60	T61	T62		T120	T121		T138	T139	T140
VIEWER NO.	V1 V2	V3 V4		V119 V120	V121	V122		V180	V181		V198	V199	V200
TEEING UNIT TRANSFER LOSS db	25	25		25	20	20		20	16		16	16	16
TOTAL PRECEEDING LINE LOSS db	0	0		10	11	11		14	15		16	16	16
TOTAL PRECEEDING INSERTION LOSS db	0	0·05		2·95	3	3·05		5·95	6·0		7·7	7·8	7·9
LEVEL TO VIEWER BELOW 28V (PEAK)	25	25·05		37·95	34	34·05		39·95	37		39·7	39·8	39·9

TEEING UNITS { T1 – 60 TYPE (a) FIG. 15, INSERTION LOSS 0·05db TRANSFER LOSS 25db; T61–120 " (b) " " " 0·05db " " 20db; T121–140 " (b) " " " 0·1 db " " 16 db }

FIG 14.—DESIGN OF A DISTRIBUTION NETWORK FOR TELEVISION WIRE BROADCASTING.

a carrier of 2 Mc/s and a number of independent sound programmes could be transmitted on adjacent carriers.

A suitable listener's receiver would require 7 valves for the vision channel including synchronising, time base and E.H.T. circuits, plus 2 valves for a single sound channel, and a power supply rectifier—a total of ten valves in addition to the cathode ray tube.

10. WIRE BROADCASTING OF SOUND PROGRAMMES OVER THE TELEPHONE NETWORK.

10.1. Choice of System.

When the relative merits of audio and carrier wire broadcasting systems were first examined in the Post Office with a view to operating a wire broadcasting service jointly with the telephone service, the results of trials and cost studies favoured an audio system but changed conditions, after a lapse of more than ten years, have made it necessary to re-examine the problem. A system requiring a separate line network, such as an audio system, involves large capital expenditure on cables and on civil engineering labour to lay them ; it is therefore less to be preferred than a carrier system involving equal expenditure but mainly for internal equipment. Cables involve a high proportion of imported materials whereas the cost of internal equipment is largely the cost of industrial knowledge and skill.

10.1.1. *Effect of Underground Distribution.*

Another factor affecting the choice of system is the extent to which underground distribution must be used. There is an increasing demand from local authorities for underground distribution in residential areas. Development Corporations of new towns particularly are interested in the underground distribution of all services.

Existing audio and carrier wire broadcasting systems are operated on overhead networks, underground cable being restricted to short lengths of main feeders at a few road crossings. The general adoption of underground cable would be costly compared with existing overhead construction. The operation of audio systems on entirely underground networks would involve transmission and crosstalk problems some of which have yet to be fully investigated. There are also special practical problems in the making of teed joints. For a carrier system, underground distribution involves a large increase in line attenuation which must be compensated by amplification in the listeners' receivers, but there is less likelihood of trouble from interference picked up on incompletely balanced overhead lines.

10.1.2. *Mutual Benefits from Joint Development of Telephone and Wire Broadcasting Systems.*

The economic benefits which attend a high telephone penetration as a result of the full use of line plant are well known and these benefits could be increased or could be secured in advance of full telephone development, by operating a wire broadcasting system as an integral part of the telephone system. At present, two separate line networks, one for telephone service and one for wire broadcasting service, are developing side by side, competing for materials and labour, and each carrying its own burden of spare plant.

10.1.3. *Audio and Carrier Systems.*

The great advantage of an audio system lies in the simplicity and cheapness of the listeners' equipment. Against this must be set the cost of the line network especially when several programmes are provided. In joint underground development with the telephone service the reduction in cost of the line network is limited to the saving which could be made by sharing ducts.

A carrier wire broadcasting system can be superimposed on the telephone system by the use of filters of simple type. The filters are required to avoid any mutual interference between the two systems and to prevent exchange circuits from loading the wire broadcasting transmitters. The service can be extended from the end of a telephone line to several nearby listeners who are not telephone subscribers, using a short added line to each, but in many areas, the telephone network is so widespread that such teeing on a large scale would not normally be necessary. A system of this kind had a limited field trial in this country in 1939 and plans were made for its widespread adoption (Section 3.4) ; mention has already been made in sections 3.6, 3.7 and 3.8 of the use of similar systems in Germany, Sweden and Switzerland.

Detailed comparison of the cost of audio and carrier systems for association with the telephone systems involves the following factors :—

1. The degree of penetration to be expected for both services, in terms of the proportion of households to be served in different types of residential areas ; this gives the amount and type of line plant per subscriber.
2. The future cost of cables and labour taking into account probable developments in cable construction.
3. The proportion of underground cable to be included in the line network.
4. The number of programmes to be provided.
5. The cost of receivers for carrier systems taking into account developments in design and production such as the use of printed circuit techniques.

The answers to all these questions are somewhat speculative and will vary with local conditions but preliminary study suggests that for three or four programmes there is probably little to choose, on a cost basis, between an audio and a carrier system. For more than four programmes the balance goes in favour of carrier systems, so that the consideration of the proportion of expenditure on cable and civil engineering labour appears to be decisive in favour of carrier working.

When special local conditions are taken into consideration it would appear that a wire broadcast service on a nation-wide scale could best be provided by a combination of carrier and audio systems ; a carrier system on the telephone network forming the

major part but with conversion to audio working for service to blocks of flats or suitable contiguous property—such as rows of terrace houses—or where telephone density might be low. Alternatively, where telephone penetration is low and listeners are scattered, a local wide-band amplifier might be used to extend the carrier system beyond the range of normal teeing.

10.2. Design of a Carrier System for Operation on Telephone Lines.

10.2.1. *General Design.*

A simplified schematic diagram of an experimental system of this kind is shown in Fig. **16**.

The main points affecting the technical design are :—

1. The standard of quality required, in particular the audio bandwidth.
2. The number of channels to be provided.
3. The attenuation on local telephone lines.
4. The noise voltages on telephone lines.
5. The limitations imposed by the practical problem of associating the wire broadcasting system with the telephone service, in particular the need for filters at the exchange M.D.F. and at the subscribers' end of the line.

The design aims at an effective bandwidth of 8 kc/s and a distortion limit of 5% with 2 watts output. There are 8 channels, three of them in the long wave radio broadcast band. This will give experience of a wider range of problems than were involved in earlier Post Office designs which made provision for four programmes. One of the problems associated with the number of channels is the peak voltage to be handled by wide-band amplifiers. With unrelated carrier frequencies the power output per channel will be inversely proportional to the square of the number of channels, but fortunately a considerable improvement in power handling capacity can be made by using frequencies which are related to one master frequency and adjusting their phase relationships to give a reduction in the peak voltage.

10.2.2. *High Frequency Characteristics of Cables.*

The high frequency attenuation of local cables is shown in Fig. **17**. At 209 kc/s—the highest carrier frequency in the experimental system—the attenuation of 6½ lb. cable is 13.7 db per mile but considered in relation to local line limits, 20 lb. cable gives the highest possible attenuation of 41.8 db. In practice attenuation figures approaching this limit will occur only rarely. From an analysis of data on the attenuation of about 30,000 lines it is concluded that 99% of lines have an attenuation less than 28 db at 209 kc/s. The probability curve is shown in Fig. **18**.

Measurements of noise voltages present on lines indicate that a minimum signal to a listener's receiver of 10 mV will normally give a high standard of signal-to-noise ratio.

The exchange equipment can be satisfactorily isolated from the line for frequencies above about 50 kc/s, by means of an inductor of 10 mH in series with each wire. The inductors can be accommodated in the heat coil springs as shown in Fig. **19**.

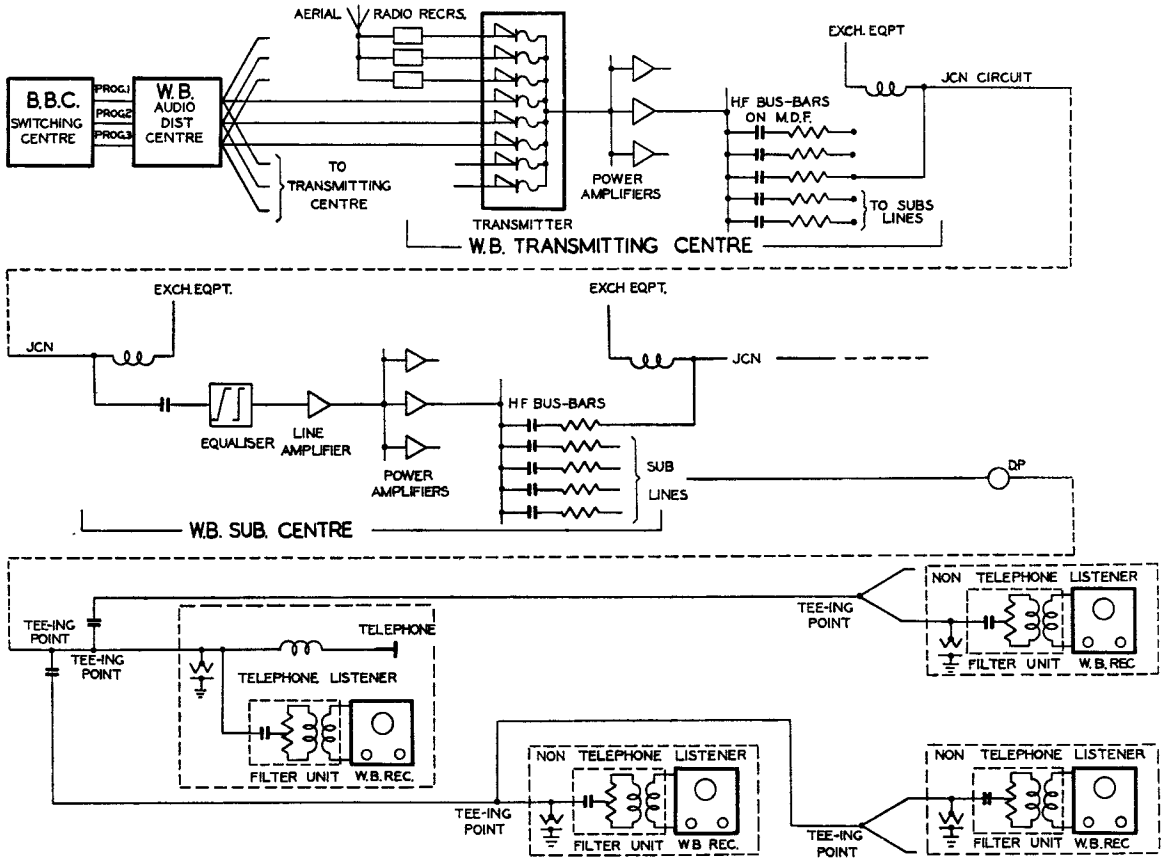


FIG. 16.—CARRIER WIRE BROADCAST SYSTEM SUPERIMPOSED ON THE TELEPHONE SYSTEM.

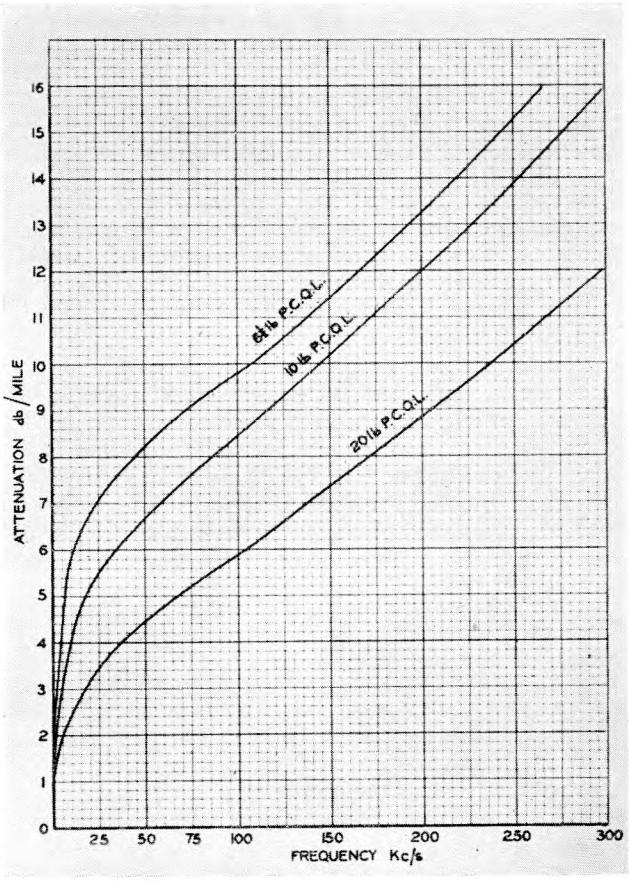
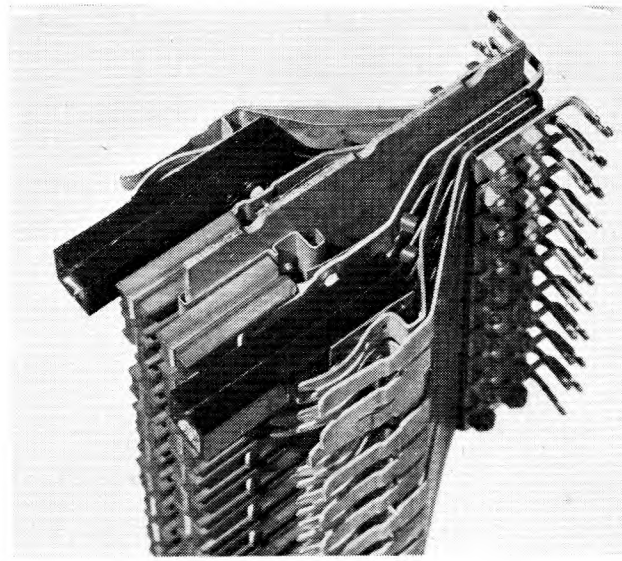


FIG. 17.—ATTENUATION OF LOCAL TELEPHONE CABLES AT CARRIER FREQUENCIES.



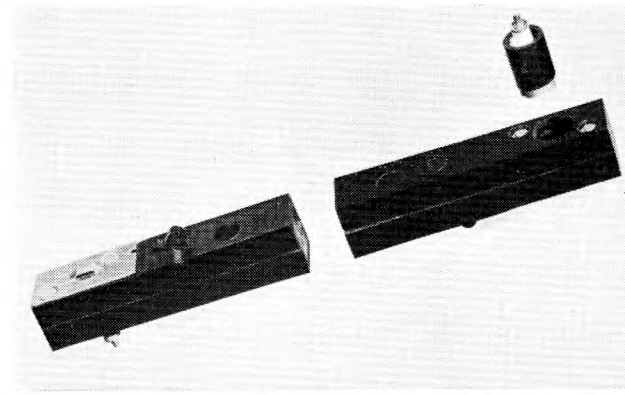


FIG. 19.—INDUCTOR AND HEAT COIL ASSEMBLY FOR CARRIER WIRE BROADCASTING SYSTEM.

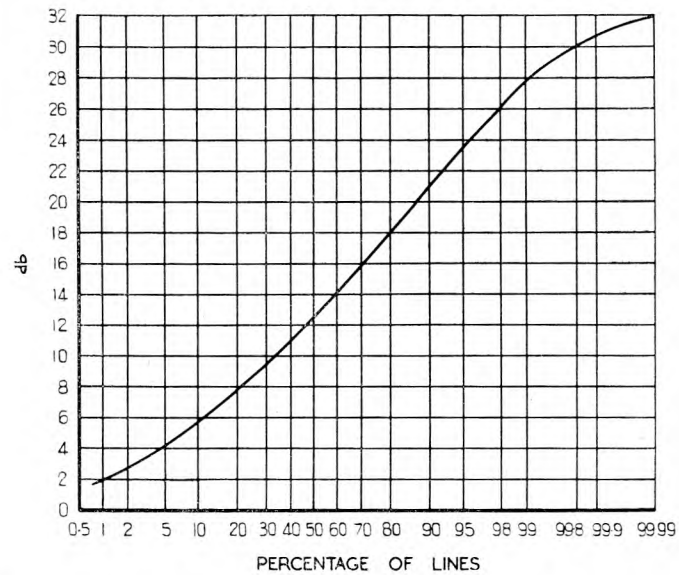


FIG. 18.—PROBABILITY DISTRIBUTION OF ATTENUATION OF SUBSCRIBERS LINES AT 209 KC/S.

The experimental system is designed for carrier frequencies of 55, 77, 99, 121, 143, 165, 187, 209 kc/s which are the 5th-19th odd harmonics of a master oscillator of frequency 11 kc/s. An alternative choice of frequencies would be the 5th-19th odd harmonics of 11.76 kc/s. This would give wider channel spacing and four channels in the long wave broadcast band one of which would be 200 kc/s. This would coincide with the frequency of the British long wave broadcast transmission and could carry the same programme.

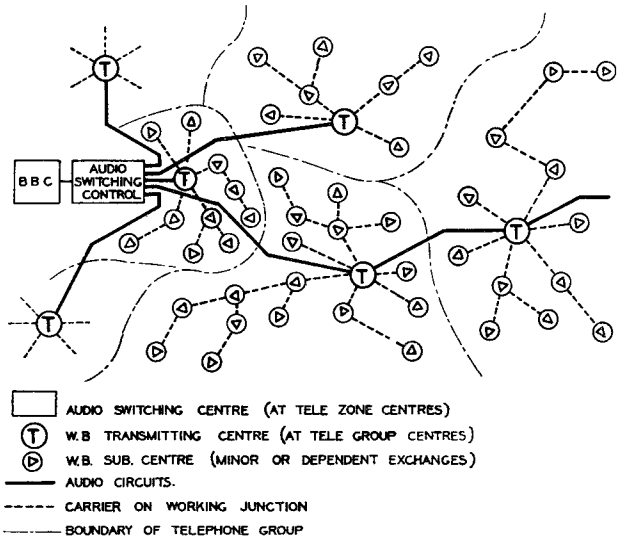


FIG. 20.—MAIN LINE AND JUNCTION NETWORK FOR CARRIER WIRE BROADCASTING SYSTEM.

10.2.3. *Main Network for a Nation-Wide Service.*

For large scale operation, wire broadcast transmitters would be required, in general, at Telephone Group Centres as shown in Fig. **20**. From these centres, transmission to wire broadcast sub-centres at minor and dependent exchanges would take place at carrier frequency over ordinary junctions, without disturbing their normal use. It would be necessary to use unloaded cable pairs with wideband line amplifiers spaced at approximately 6 mile intervals, up to a maximum of five amplifiers in tandem.

10.2.4. *Exchange Equipment.*

The wire broadcast transmitting centre equipment is shown in Fig. **21**. It consists of a programme control rack equipped with radio receivers, audio circuit terminations and switching and fading facilities ; a transmitter rack producing the 8 modulated carrier frequencies combined at one coaxial output ; and an amplifier rack accommodating a wide band power amplifier. All racks include testing, alarm and monitoring equipment. At a subcentre the amplifier rack only is required. At the M.D.F. connection is made to subscribers' lines by jumpers from H.F. tag blocks to the line jumper tags. According to the length of the line the sending end voltage is adjusted by selecting the resistance in the feed circuit. Fig. **22** is a circuit diagram of the carrier system transmitter.

10.2.5. *Listeners' Equipment.*

The listeners' equipment, shown in Figs. **16** and **23** consists of a protector, a low-pass filter in series with the telephone instrument, a terminating unit and a

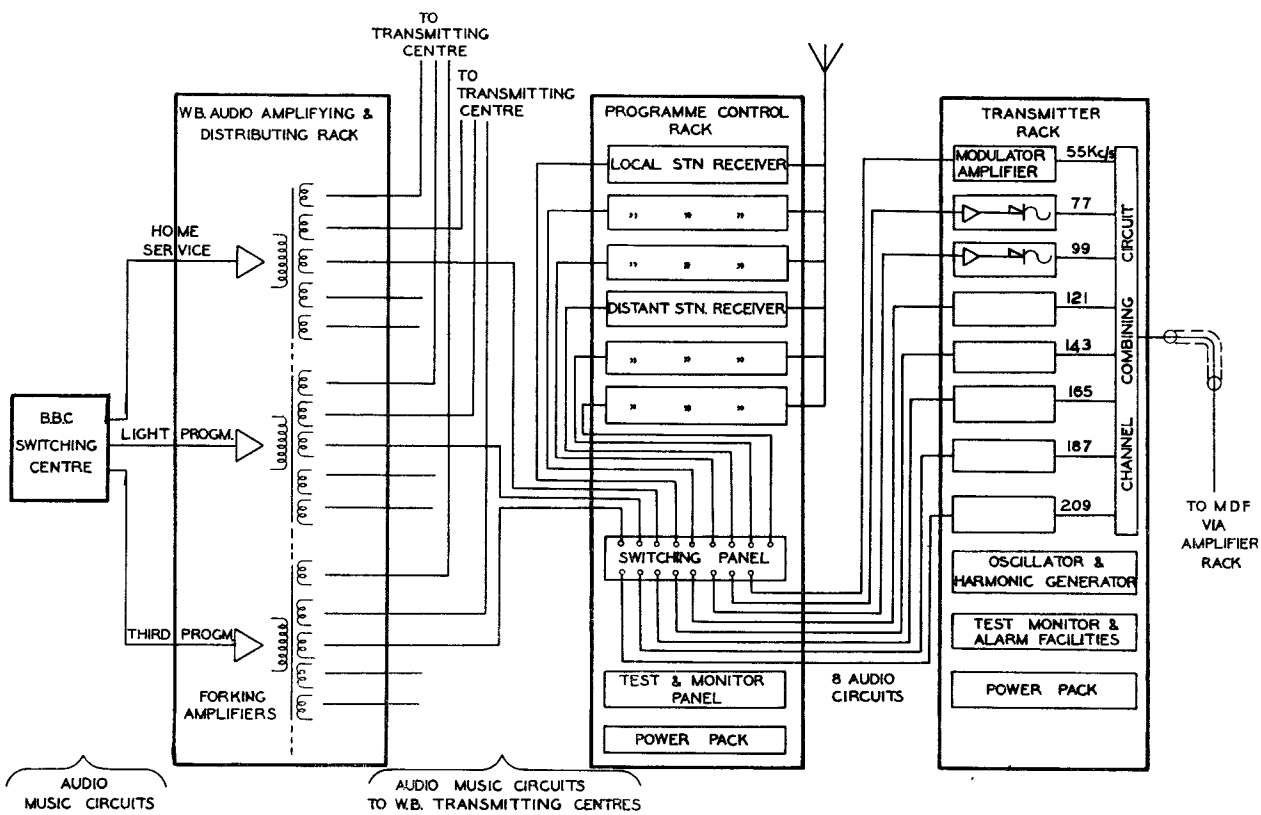


FIG. 21.—CARRIER WIRE BROADCASTING SYSTEM: TRANSMITTING CENTRE EQUIPMENT.

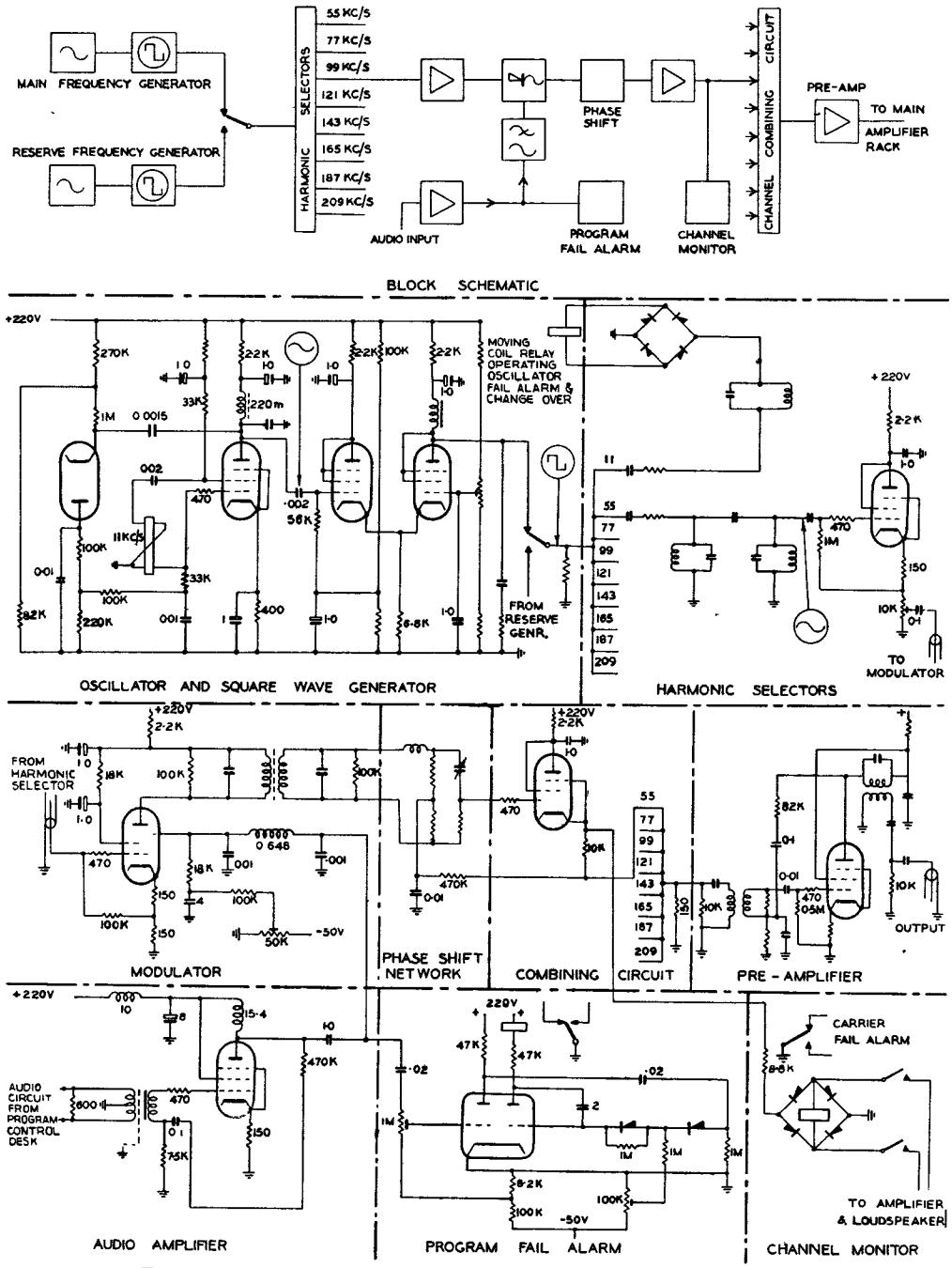


FIG. 22.—CARRIER WIRE BROADCASTING SYSTEM: TRANSMITTER CIRCUITS.

programme receiver. The protector is of the usual type fitted in telephone circuits. The terminating unit provides a band-pass filter for the carrier frequencies with an impedance of about 500 ohms and a transformer to change from the balanced circuit conditions on the line to the unbalanced connection to the receiver.

The receiver may be of the tuned radio frequency or superheterodyne type but for a large number of channels the latter is the more economical. A suitable 3-valve receiver, shown in Fig. **24**, has a fixed band-pass filter input circuit and tuning is effected by selection of preset condensers using push-buttons or a rotary switch. Automatic gain control is provided to equalise the signal level received on the different channels due to the limited adjustment at the exchange. This avoids the need to adjust the volume control on switching from one programme to another.

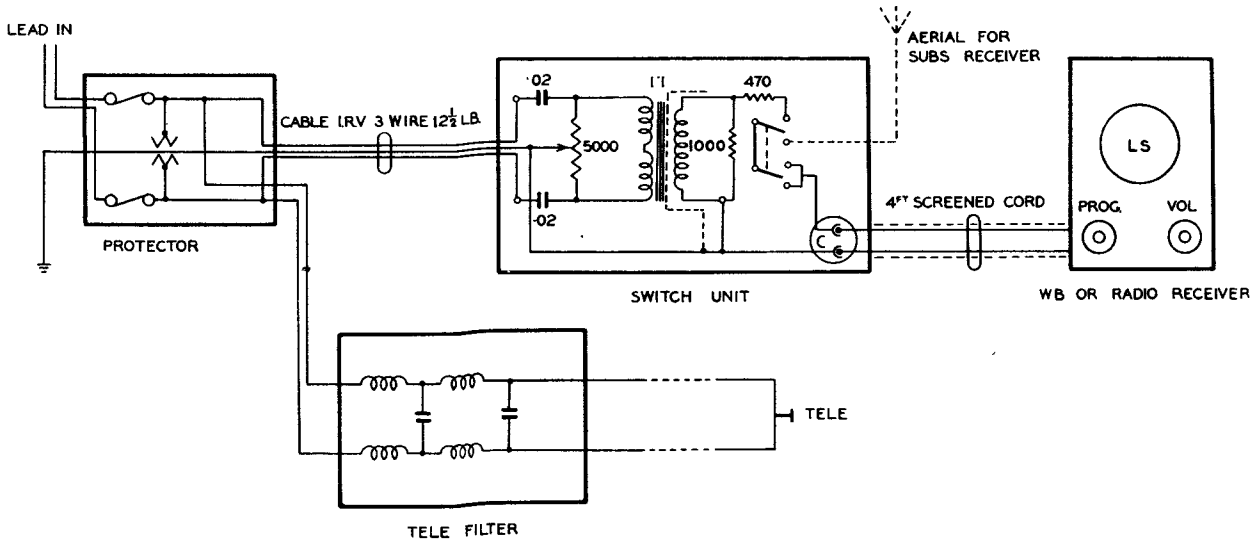


FIG. 23.—CARRIER WIRE BROADCASTING SYSTEM: EQUIPMENT AT LISTENER'S PREMISES.

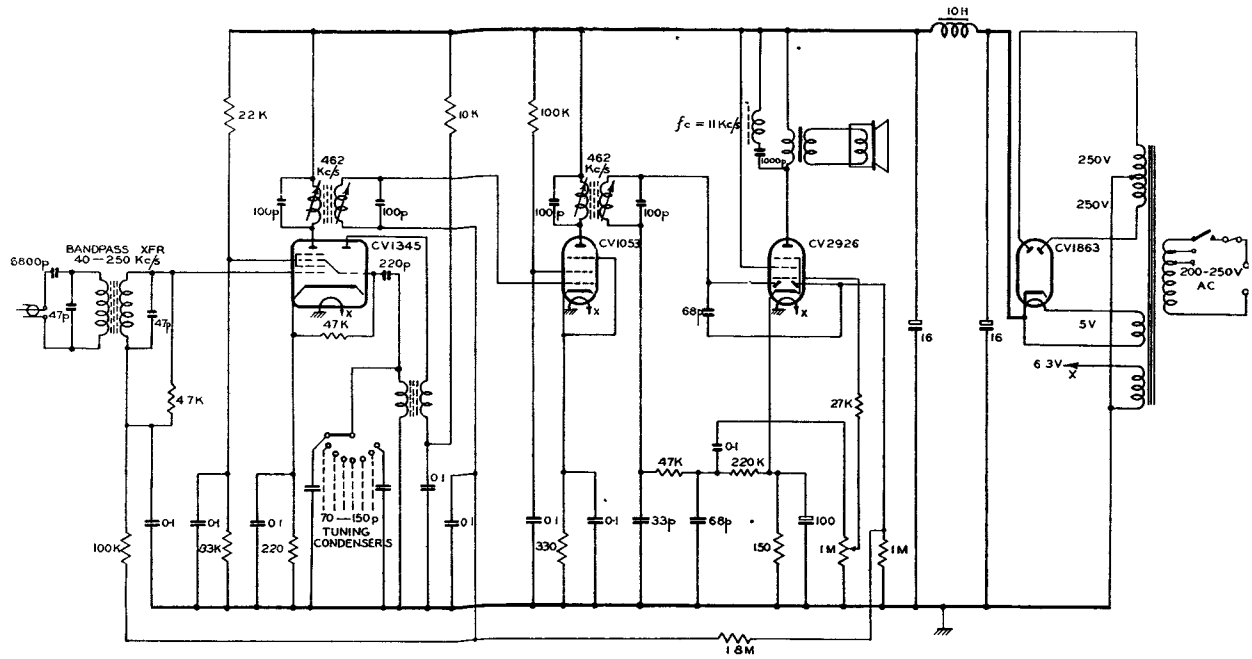


FIG. 24.—CARRIER WIRE BROADCASTING SYSTEM: LISTENER'S RECEIVER CIRCUIT.

11. CONCLUSION.

The problem of giving a wire broadcast service by a carrier system on telephone lines is not one which presents any fundamental technical difficulty; the problems are rather the practical day to day ones of operating the two services together and of deciding the optimum number and spacing of channels. It is emphasised that the design described is an experimental one intended to provide experience of these practical problems.

With regard to the more general aspects of the subject, the aim has been to examine the contribution which the wider extension of wire broadcasting might make toward better listening (and viewing), and to suggest ways in which this contribution might be made. The methods adopted must be satisfactory both technically and economically and in the latter connection it is important to take account of broad considerations of national economy involving supplies of materials and availability of various classes of labour. The effect on other public services is also an important consideration.

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