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Entrance to the French P.T.T. 30 kW Eiffel Tower Television Station.

Electrical Communication in 1938

EDITOR'S NOTE.—*This Review, while international in scope, is not intended to cover comprehensively communication activities in all countries of the World—the subject is far too vast. Emphasis, in general, is placed on European developments and activities in which Companies in the International Telephone and Telegraph Group, to some extent at least, participated. It is believed, nevertheless, that the following pages give a fairly inclusive indication of the advances achieved in various phases of the communication art and its allied applications during the year* 1938.

GENERAL

THE telephone, affording as it does a means of instantaneous exchange of ideas regardless of distance or country, makes the peoples of the world neighbours in a real sense. Technically, it is possible to-day to interconnect any two distantly located subscribers ; and a stage has been reached where the development of national and international telephony is dependent mainly on economic considerations and rapidly obtainable subscribers' connections. In the solution of this present day phase of the problem, the evolution of the machine switching art doubtless will play a leading part, as will also economy in providing the necessary allied transmission facilities.

Despite many outstanding developments in machine switching, long distance transmission and international radio communication, it is an interesting fact that, from the viewpoint of the telephone subscriber's initiation of a call, only three fundamental stages have been generally introduced since the birth of the telephone in the 1870's :

(1) Local battery manual service,
(2) Common battery manual service, and
(3) Automatic telephone service (as yet applied only partially to toll operation).

If the average lay subscriber were asked whether automatic telephony from his viewpoint represents a completed development, he probably would answer affirmatively. In machine switching areas it is, however, ordinarily necessary for the subscriber to employ a different method in placing local calls as compared with toll calls. The former in many cases represents a wholly automatic method ; the latter, at the present time, a manual method or, unless automatic ticketing is available, an incompletely automatic method. In limited areas where each subscriber is given a message register, where the distances are short, and where all tariffs are multiples of a common unit, multiple metering on a timed basis may be used as a substitute for automatic ticketing, but obviously such a system lacks the flexibility and general utility of automatic ticketing. It is becoming increasingly apparent, moreover, that no method of long distance operation can be considered completely automatic from the viewpoint of the telephone subscriber (or from that of the Administration or Operating Company), unless all the usual requirements for local machine switching operation are met, and the equivalent of the information afforded by the toll ticket, employed in manual operation, is supplied. In the contrary case, toll service is obviously inferior to local service, judged by automatic standards.

Considered from the viewpoint of Administrations or Operating Companies, notable developments—such as have been attained in machine switching by automatic toll ticketing as well as national dialling ; in toll transmission by broad band (coaxial cable) or multi-channel, multi-conductor cable systems ; and in radio, by ultra-short wave multi-channel systems—afford means for furnishing a secret, rapid and truly comprehensive automatic service to subscribers, not only on local calls but also on toll or long distance calls. Furthermore, the newer machine switching and transmission systems are inherently more economical than the older ones. Thus, with facilities available for furnishing greatly improved systems at reasonable rates, conditions, at least in many countries, would seem to be ripe for an accelerated development of the long distance and toll services comparable with the achievements in local networks.

The introduction of automatic toll ticketing recalls to mind discussions that arose in the early days of automatic telephony as to the merits and subscriber-appeal of fully automatic versus manual telephony. To-day, not only in local, but also in toll operation, subscribers' reaction has proved that they, as well as Operating organizations, prefer purely automatic working. Obviously the same considerations apply in favour of systems including automatic toll ticketing as compared with other methods: (1) semi-automatic working with manual toll ticketing; and (2) fully automatic working with time and zone metering, capable, however, of furnishing only an integrated record of charges rather than essential detailed data on individual calls.

The telephone world is indebted to the progressiveness and foresight of the Belgian "Régie des Télégraphes et des Téléphones" for having been the first to try out and introduce automatic toll ticketing; and, hence, from the viewpoint of the subscriber's initiation of toll calls inaugurating, in the year 1937 and more particularly in 1938, what may be termed the fourth stage in telephone advancement, making it possible for the subscriber to employ precisely the same methods and achieve the same results in the toll and long distance, as well as in the local field,—wholly automatically.

Automatic Ticketing as a desideratum is not new; its reduction to practice, however, was long regarded as impracticable. The fact that it was developed by two organizations in the group of companies contributing regularly to *Electrical Communication*—Bell Telephone Manufacturing Company, Antwerp, and Les Laboratoires, Le Matériel Téléphonique, Paris—seems appropriate inasmuch as the International Telephone and Telegraph Group of Companies is the largest single supplier of automatic telephone equipment outside of the U.S.A. Other outstanding contributions of the International System, it is interesting to note in passing, include National Dialling, the first practical demonstration on March 31st, 1931, of Micro-ray Radio across the English Channel, Single Side-Band Short Wave Radio and Ultra-short-wave Multi-channel Radio (Belfast, Ireland—Stranraer, Scotland), as well as the provision of the first 12-channel carrier-on-cable system placed in commercial service and the 30 kW Eiffel Tower Television Transmitter, the most powerful at present in operation.*

SUBSCRIBERS' EQUIPMENT

Subscriber set developments have been directed towards two main objects: (1) higher grade of transmission; (2) reduction in maintenance cost in the field by (a) improved protection of the components against the effects of dust and humidity, and (b) provision for greater ease of maintenance.

Higher transmission quality, to which much attention has been directed during the last years, holds first rank in the development of the subscriber set components. General recognition, moreover, is being given to the fact that judgment based on results obtained by voice and ear testing teams may lead to very erroneous appreciation of the efficiency of subscriber sets. Testing methods for the finished products, accordingly, have been modified so as to eliminate the human factor, and to-day the approach is by the most up-to-date laboratory technique.[7]

1938 saw the completion by Standard Telephones and Cables, London, of the development of a telephone handset receiver of substantially improved transmission quality for use by the British Post Office. Field trials of receivers with similar features gave very satisfactory results, and the new receivers are now being produced in quantity. A correspondingly improved head receiver is also being made. Similarly, the Bell Telephone Manufacturing Company, Antwerp, is about to place on the market an improved capsule type receiver for use in its standard handset. This capsule receiver also is of higher quality than the present one, whilst retaining the same efficiency. Results, in all these cases, have been achieved by the application of electrical network theory to the acoustic design, and by the use of the most

* See references 1 to 6 at the end of this Review.

suitable magnetic materials selected from the wide range now available.

Considerable development work has been done by Standard Telephones and Cables towards producing a telephone transmitter with less frequency distortion and less non-linear distortion; important contributions along these lines have been made by British Post Office Researches (unpublished). Development work continues.

ROTARY AUTOMATIC SYSTEM

The year 1938 witnessed a remarkable expansion of Rotary equipment, the Rotary automatic system now being installed in 960 exchanges and 42 countries. The total number of lines installed or on order at the end of 1938 was 2 250 000, a net increase for the year of 125 000 lines.

The largest Rotary network—the Paris City area—was converted in 1938 to 100 per cent. automatic operation. This conversion was handled by Le Matériel Téléphonique, Paris.

Two Rotary exchanges (5 400 lines) also were placed in service in the Paris Suburban area, bringing the percentage of automatic operation to 70%. There still remain six offices (22 200 lines) to be cut into service, all of which are under construction, to complete this stage of the conversion to automatic service.

Transformation of the Paris Regional area to automatic operation was started in 1938. Three offices (6 200 lines) of the "center" type and one satellite (50 lines) were placed in service, while one "center" type (800 lines), three "sub-center" type (1 900 lines) and six satellite (590 lines) offices are in process of construction.

Orders received for the new 7-A2 type Rotary equipment included Belgium, Brazil, New Zealand, Norway, Peru, Rumania, Switzerland and other countries.

The 7-D type Rotary system, designed primarily for small towns, continues to find increasing application.

Further development of the Oslo suburban and regional networks took place with the cut-over of the 2 600 line Stabekk exchange and thirteen exchanges with 4 910 lines in the Drammen area.

AUTOMATIC TICKETING

Progress in the development and application of automatic ticketing in 1938 greatly surpassed that of 1937. At the end of the latter year, 14 650 lines equipped with this facility were on order or installed; the figure at the end of 1938 reached 134 240 lines. This remarkable increase is due mainly to the decision of the Belgian Régie to introduce automatic ticketing in the Brussels network: all multi-fee connections, outgoing from Rotary exchanges installed in the city of Brussels, will be controlled by printer registers producing tickets containing the number of the calling party, the number of the called party, the duration of the conversation in minutes, the basic tariff, the time of day and the date. The plans involve the progressive automatization of the whole of Belgium and were adopted by the Belgian Régie after the successful field trial of automatic ticketing between Bruges and Blankenberghe.

Brussels will be the first capital city to adopt automatic subscriber-to-subscriber dialling for toll and rural services, coupled with a printed record of each connection, providing all the data formerly obtained by manual ticketing methods.

A further step in the application of automatic ticketing systems was achieved with the cut-over of a new 7-D exchange in Ostend, Belgium, on June 17th. In addition to providing a printed record of outgoing multi-fee connections, the Ostend equipment includes number identification equipment for outgoing no-delay toll connections handled manually. This number identification equipment displays, in front of the toll operator, the calling party number which is obtained from the identification equipment associated with automatic ticketing. Special trains of selectors, formerly used for checking the number of the calling subscriber, are therefore not required.

The Hungarian Telephone Administration also has decided to introduce automatic toll service in Hungary. Automatic ticketing equipment will be utilized, involving Budapest, Pápa and Miskolc.

In accordance with the policy of the Japanese Ministry of Communications, the use of automatic equipment not requiring the intervention of an operator is being extended. Equipment now in process of manufacture provides for the calling subscriber first dialling the toll number and then that of the distant party; also for recording automatically the calling and called subscriber's numbers, the duration of a conversation, the date, etc.

NATIONAL DIALLING

In Holland, Rotary equipment in The Hague is being arranged to provide national dialling facilities. These exchanges were amongst the first to be provided with Rotary equipment and were originally designed for semi-automatic operation with automatic distribution of calls to operators, who completed connections by means of key sets on which the required number was depressed.

The semi-automatic equipment was later converted to full automatic; the original switches are still in service. The introduction of national dialling facilities is accomplished by the addition of new traffic paths and the segregation of outgoing automatic toll calls from local calls. Provision for the introduction of automatic ticketing of outgoing toll calls is made for subscribers who request details of their telephone account.

The complete automatization of The Hague zone or district also is progressing. Rotary equipment will be installed in the important towns of Leiden and Delft.

In Zurich, Switzerland, a new full automatic national toll exchange was cut-over on May 1st and an extension is in process of manufacture. The equipment now handles the full automatic outgoing toll traffic from the entire Zurich network, comprising 65 exchanges, to five other Swiss networks, including 80 exchanges. When the extension is completed, connection will be made to 11 different networks.

The first installation in France of "subscriber-to-subscriber toll dialling" was completed by Compagnie des Téléphones Thomson-Houston during 1938 between the two large step-by-step areas of Rouen and Le Hâvre.

STEP-BY-STEP

Rapid progress has been made in Great Britain in the automatic conversion programme, particularly with regard to the special plans for rural services.

During the year ended September 30th, no fewer than 393 automatic exchanges were opened for public service, and of these 346 were of the rural unit type. The elimination of the smaller and older manual exchanges also progressed considerably, and the year saw the completion of the two-thousandth small unit automatic exchange.

Standard Telephones and Cables, Limited, completed a large programme of automatic equipment during the year, including the equipment for the exchanges serving the large suburban areas of Finchley and Ealing, as well as Albert Dock, the exchange serving its North Woolwich factory. Over 1 000 unit type equipments also were supplied for rural service.

For the Commonwealth of Australia, over 11 000 lines of equipment are in process of manufacture, including the central office equipment for Fremantle and for Redfern, the exchange serving the new factory of Standard Telephones and Cables (Pty.), Limited, Australia. Step-by-step equipment also was supplied for the central office and two satellites in Colombo, Ceylon.

The development of the telephone networks of the United River Plate Telephone Company, Limited (Argentina), and of the Chile Telephone Company, both of which are comprised in the International Telephone group of companies, necessitated provision during the year of over 30 000 lines of equipment for new exchanges and other purposes.

During 1938, 2 080 French villages were equipped with semi-automatic rural switchboards constructed by Compagnie des Téléphones Thomson-Houston, and operating on R-6 system principles. At the end of the year, there had been installed for the French P.T.T. 233 700 lines of R-6 equipment in 6 673 offices.

CROSSBAR SWITCHING SYSTEM

Following the successful trial of a Crossbar Switching System installation in Brooklyn, New York City, the first full sized installation of this system was placed in service during July in the Grand Central area of New York City.

The Crossbar System, developed by the Bell Telephone Laboratories, Inc., replaces the Panel System for new installations.

COMMUNICATION SYSTEMS—GENERAL

The successful operation of 12-channel

carrier-on-cable systems in Great Britain, where they have been used on a large scale, has aroused widespread interest, and many Administrations are considering such systems in their Toll Planning. A stage has now been reached where the C.C.I.F. is considering the standardization of some of the more important features. Coaxial cable systems, too, are becoming of sufficient importance for some preliminary discussions leading to standardization of fundamental operating requirements by the C.C.I.F.

Echo suppressors for voice frequency circuits have normally been applied at an intermediate point. The application of carrier systems to cables necessitates the location of the echo suppressors at the terminals ; the new problems thus created have been actively pursued and new types of suppressors evolved and given final trials.

The progress of television during the year necessitated thorough study of associated transmission systems. Much was accomplished in this allied transmission field.

The operation of toll circuit terminal and repeater equipments from power mains without the use of rotating machinery continues to arouse considerable interest. Improvements in dry rectifiers, electrolytic condensers, voltage regulating devices and emergency automatically starting prime-mover plant enable high efficiency equipments to be realized.

Progress was made during the year in the long-distance dialling art. Applications of agreed principles are now in hand in various countries.

In the field of transmission testing apparatus, much was accomplished in the provision of simplified equipment with increased frequency ranges and direct reading facilities. Progress also was made with the operation of this type of equipment from A.C. mains.

PROGRESS IN WIRE TRANSMISSION SYSTEMS

The 4-core coaxial cable network in Great Britain was extended ; 218 km were completed in 1938, whilst a further 132 km are under construction. Thus 550 km route length between London and Newcastle is nearing completion. Between London and Birmingham 40 coaxial circuits have been in regular service since last summer, and 40 more were added during December. Furthermore, a large group of circuits between London and Manchester will be brought into service towards the middle of 1939. Between Manchester and Leeds, 48 circuits, with terminal and repeater equipment built to a later design, are now undergoing field trials.

The 12-channel multi-conductor system in Great Britain also was extended considerably during the year. The laying of 1 265 km of cable was completed, and a further 1 820 km is under construction. Over 3 760 km of 12-channel cable are now completed or under construction, representing a route length of over 1 880 km.

In addition to underground cable schemes, 12-channel carrier telephone equipment has been successfully applied to submarine cables, linking Great Britain with Holland and with Ireland.

Paralleling these installations of important new types of cables, normal loaded trunk cables were completed or under construction in Great Britain with a total length of 3 713 km as compared with 3 225 km in 1937.

A 12-channel carrier cable from Antwerp, Belgium, to Roosendaal, Holland, has been manufactured and the installation is scheduled for completion in March, 1939. The plan is to extend these circuits to Rotterdam, Holland, where the necessary cables between Roosendaal and Rotterdam already exist. Multi-channel carrier cables also have been laid in Holland between Goes and Roosendaal, Eindhoven and Hertogenbosch, Utrecht and Amsterdam, Deventer and Leeuwarden, making in all a total of 400 km of route length over which these modern cables are available. Later extensions to this system, covering a further 400 km of route length, have been planned.

In the above countries, the multi-channel carrier cables are designed solely for carrier circuit operation ; in Rumania, however, a combined 12-channel and normally loaded 2-wire cable has been completed between Bucharest and Ploesti (60 km), and an extension of this cable to Brasov (a further 110 km) is proceeding.

In France, the Paris–Bordeaux coaxial cable has been proceeded with, and work was commenced on the French section of a London-Paris 12-channel cable system. The submarine cable portion of this installation will be essentially of the same design as the land cables.

In Switzerland, a number of cable circuits has been equipped with single channel carrier telephone systems.

A project is in course of realization for operation on the (Anglo-Belgian) St. Margaret–La Panne submarine cable of thirty systems each comprising one voice and two carrier telephone circuits.

In other European countries, progress continued. Long-distance telephone networks were extended in accordance with plans which have been followed during the past few years, employing loaded cable systems and carrier on open-wire lines.

The Japanese telephone network now includes several thousand kilometres of non-loaded cable. A notable accomplishment is the Tokyo to Hoten (Mukden) line extending across the Chosen Strait (270 km) to Chosen (Korea), and thence to Hoten, Manchukuo. The multi-core submarine carrier cable (paper insulated) contains fourteen pairs of 2.0 mm wire divided into two groups of seven pairs each, each group working in opposite directions. Special shielding is provided between each group. Two of the three repeater stations, equipped with carrier repeaters, are situated on islands in the Strait. Highly successful results have been achieved and greater use of this type of cable is anticipated for submarine application.

Open-wire carrier equipment of new design was provided for operation in Norway, Finland, Russia, Rumania, Jugoslavia, Czechoslovakia, Bulgaria, Palestine, India, Malaya, South Africa, Australia and New Zealand.

Mention should be made of an important open-wire carrier system which is to be installed in Australia between Sydney and Melbourne (approximately 1 000 km), a 12-channel carrier system for this route being now in process of manufacture.

Voice Frequency telegraph systems continue to play a major part in the development of telegraph networks. Equipment of this type has been provided for the realization of numerous projects.

CRYSTALS

Applications of piezo-electric quartz crystals in oscillators and filters increased further during the year. Employment of these crystals has now become a recognized technique in high stability oscillators, as well as in bandpass filters for frequencies of the order of 60 to 120 kc/s in cases where characteristics appreciably more precise than those obtainable with condenser and inductance networks are required.

In consequence, methods of production and of measurement of quartz plates have been further improved, and quartz plates are now produced on a commercial manufacturing basis. It is fully expected that this comparatively new electrical element will play an important part in the design of future systems.

C.C.I.F.

The recommendations passed by the Technical Commission meetings at Oslo, in June 1938, showed that notable progress has been made by the C.C.I.F., particularly along the lines of (*a*) the European Toll Switching Plan ; (*b*) Guiding Principles for Long Distance Dialling ; and (*c*) Guiding Principles for the application of Carrier-on-Cable Systems.

The sub-committee on the European Switching Plan held a number of meetings ; and, based on examination of data supplied by numerous Administrations and Operating Companies, the Oslo meeting recommended certain revisions and expansions of the general instructions for the European Switching Plan. At this same meeting, general agreement was arrived at on a number of points fundamental to the international application of toll dialling. Likewise, agreement was reached on certain important points relating to application in the European network of the latest multi-channel, multi-conductor carrier-on-cable art.

In order to expedite the handling of urgent questions involving the rating of telephone circuits and the application of carrier technique to cable circuits, sub-committees were appointed to hold meetings at intervals between general Commission and Plenary Assemblies. Thus, the work of various Administrations and Operating Companies can be closely followed up and co-ordinated.

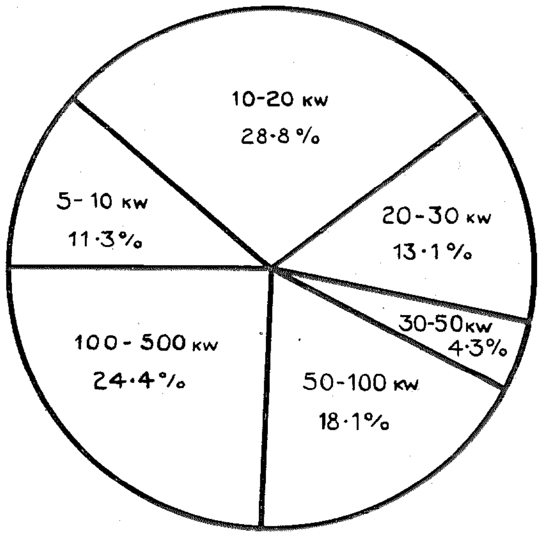
Two of the above mentioned sub-committees held meetings in London during December, 1938. The sub-committee on the rating of telephone circuits met from December 5th–10th inclusive, and outlined a detailed programme of tests to be made by the SFERT laboratories in order to learn whether the correlation between articulation plus received volume and repetition rate might be utilized for the determination of rating without resort in all cases to the repetition rate method. Repetition rate is still considered the best criterion for determining the performance of a telephone connection; the difficulty and cost involved in obtaining rating by this method, however, make it highly desirable to develop a more readily applicable method such as the one now under study. The sub-committee on carrier-on-cable met from December 12th–17th inclusive; basic principles for the application of carrier on coaxial cable were discussed and a number of fundamental points settled. Thus it should be possible to maintain development work in progress in various countries along lines sufficiently similar to permit of ultimately evolving systems suitable for universal application on the continent of Europe.

The 1st and 2nd C.R.'s completed a revision of the "Recommendations" concerning the protection of cables against electrolysis and interference. These new recommendations were submitted to all Administrations and Operating Companies for a postal vote and, if passed, they will come into force as of January 1st, 1939.

A special sub-committee was appointed to study means of providing a more rapid international service. Questions on this subject are now under active consideration by this committee and by the various Administrations and Operating Companies adherent to the C.C.I.F.

RADIO BROADCASTING (INCLUDING SPEECH INPUT EQUIPMENT)

While the technical development of broadcasting systems has by no means reached finality, progress in 1938, as in 1937, was characterized mainly by the continued exploitation of existing technique. Outstanding, probably, are the emphasis laid on high overall efficiency and the adoption in all new medium wave transmitters of one or other of the high efficiency modulation systems; for example, the use of high-power final stage Class B



Distribution of Power Rating in a Group of 160 *Medium and Long Wave Broadcasting Stations of* 5 *kW rating and upward in the European Region.*

modulating amplifiers, or low power modulation with separate amplifiers for different components of the modulated wave, as in the Doherty circuit.

Outside the U.S.A., the first high power Doherty type station is the 50 kW Broadcasting Station of the Municipality of Buenos Aires, placed in service in the spring of 1938.

In Europe, medium wave broadcasting is now established on the basis of a power of approximately 100 kW for nearly 25% of all main stations. A number of such high power stations are in course of construction, including a 100 kW at Start Point, England, a 100 kW in Sweden, two 100 kW in Norway, a 120 kW in Lithuania and a 120 kW in Ankara, Turkey. Meeting a demand for still higher power involves a problem which will have to be settled at the forthcoming European Broadcasting Conference to be held in Switzerland in the spring of 1939. At present, by international agreement, no European station is normally entitled to use more than 120 kW. In the United States the maximum station power normally licensed has so far been restricted to 50 kW, but here also there is a definite demand for the allocation of higher power, a rating of 500 kW being advocated as not unreasonable.

Recent developments in quartz crystal

technique have resulted in the installation of independent crystal drives at B.B.C. stations sharing a common wavelength. This system has replaced the distribution over telephone circuits of driving tone generated by a tuning fork oscillator at a master station, and has resulted in improved reception from the synchronized transmitters. Each crystal oscillator has a frequency stability of the order of one part in 10^7 over a period of 24 hours. In order to maintain beats between the carrier waves of the respective stations at a very low frequency, inter-station frequency checks are made once or twice daily so that any necessary adjustment can be made.

The use of anti-fading aerials is now an accepted feature of all new medium wave broadcasting stations. Such aerials may be of either the high mast type with no top-capacity loading, or of the type with a rather shorter mast combined with a capacity crown connected to the top of the mast through an inductive reactance. In all cases the height of the current loop above ground is about 0.25λ to 0.3λ. The actual height of the radiating element is not less than approximately 0.4λ, corresponding to an electrical length of 0.5λ to 0.57λ.

An American development, which appears to be assuming some importance, is the use of aerial arrays for medium-wave broadcasting, designed to control the shape of the horizontal diagram in order to supply increased field strengths in certain areas and to avoid creating unnecessarily strong field strengths in others. Typical examples are the three-element arrays at WOR (Carteret, N.J.), and at WLW (Mason, Cincinnati, Ohio).

Short-wave long distance broadcasting continues to grow in importance, and practically every European country either has installed or is planning to install equipment for broadcasting to its nationals on other continents. The B.B.C. is adding further high-power transmitters to its "Empire" station at Daventry, where five new aerials are to be erected, two to serve Central America, and the other three South America. A central drive room is being built to house the crystal drive equipment for the whole station. The output channels provided will enable any number of transmitters up to twelve to be fed independently with any required frequency, while provision is also being made for the synchronous operation of up to four transmitters from the same crystal.

The new Rome station, comprising two 100 kW and one 50 kW transmitters, is nearing completion. One of the 100 kW short wave broadcasters (installed by Fabbrica Apparecchiature per Comunicazione Elettriche for the E.I.A.R.) was inaugurated October 31st, 1938.

In the United States the Columbia network has made special provision for short wave broadcasting to Europe, and the very successful relaying in European countries of programmes thus transmitted is an established feature.

Expansion of the Indian broadcasting system has made good progress; there are now eight short wave regional stations in regular operation, rated at 5 kW to 10 kW. In addition, a central station at Delhi radiates a news service and general interest items which are relayed through the regional stations. The furnishing of a broadcasting system in India is attended with peculiar difficulties, not only because of the enormous territory to be covered and economic considerations, but also because of the problem of providing suitable programme material for a country which has twelve distinct main languages and some four hundred dialects. Since, in country districts, it is quite out of the question for each family to acquire its own receiver—even the cheapest receiver is beyond the means of the average native and, in any case, power supplies and battery charging equipments are very scarce—a scheme of "communal" village listening has been instituted. Under this system a village is supplied with a battery operated loud speaking receiver equipment, permanently tuned, and switched on at set hours by means of clock-switches. While the cost of such an equipment is borne by the local administration, the actual supply and maintenance devolves on the broadcasting authorities themselves. The latter are thus in the unusual position of being directly responsible for both transmission and reception.

The provision of local broadcasting services by countries situated in the tropical zones has hitherto been restricted by the lack of a suitable band of wavelengths. The medium waveband used so effectively in the temperate zones is useless in tropical regions owing to the high static noise level, while the short wavelength broadcasting bands were primarily intended for long distance working and suffer from skip-distance effect at a comparatively short radius from the transmitter. In view of these difficulties, the Cairo Telecommunication Conferences in 1938 made provision for local broadcasting in the tropical zones in the frequency bands between 2 300 kc/s to 2 500 kc/s (130.4 m–120 m), 3 300 kc/s to 3 500 kc/s (90.91 m–85.71 m), and 4 770 kc/s to 4 965 kc/s (62.89 m–60.42 m). By the use of these "intermediate" bands it is hoped to avoid both the high static level of the medium waves and the skip-distance limitation of the short waves. It is yet too early to estimate the effect of this change in promoting local broadcasting in tropical regions.

Development in studio and speech input equipment was concentrated on providing mains-operated equipment in a manner such that each unit is self-contained and furnished with its own power transformers, rectifier and smoothing equipment. The tendency is to rely on prime-mover equipment only in cases of mains failure.

In the acoustical treatment of studios, it might almost be said that two schools of thought have arisen. One holds that the acoustics of a studio are best controlled by geometrical factors, i.e., the shape and size of the room, and the provision of surfaces at suitable angles. The other school concentrates on the nature and absorbent power of the surfaces, rather than on the geometrical disposition. Excellent results have been obtained by both methods.

The new centralized studio system of the Belgian Institut National de Radiodiffusion at Brussels, supplied by the Bell Telephone Manufacturing Company, Antwerp, was cut into service during 1938. This is a typical example of European practice, and provides no less than seventeen separate studios, a number of which may participate simultaneously in the broadcasting of a play. This use of a number of studios for a single programme item may be contrasted with the general practice in the United States of employing, whenever possible, only one studio per item. From the technical viewpoint, the specialized use of studios is intimately bound up with the previously mentioned question of studio acoustics.

Broadcasting House, Glasgow, Scotland, was opened in November, with ten studios, a control room and offices. The largest studio has a volume of 182 000 cu. ft. and will accommodate an orchestra of 100 players.

In Switzerland new studios are being put into service at Zurich and Lugano, employing negative feed-back amplifiers of the type adopted by the I.N.R. in Brussels and by R.A.V.A.G. in Vienna.

In Denmark a new broadcasting house will be erected in Copenhagen containing 20 studios, the largest of which will be of 280 000 cu. ft. capacity, and accommodating an orchestra of 100 and a chorus of 110 singers. The equipment will be supplied by Standard Electric A/S, Copenhagen.

TELEVISION

Great Britain is the only country in the world having a regular commercial television service: the British Broadcasting Corporation is furnishing a four-hour daily service, including out-of-door events. In France, vision broadcasting, both studio and film, is now taking place two hours daily, five days a week, from the Eiffel Tower transmitter.

Television Standards.—Progress towards the adoption of common standards for television services can be recorded for the year 1938.

Great Britain, France and Germany all adopted positive modulation and uniformity of synchronizing signals. The number of lines used, however, differs: 405 in Great Britain; 455 in France; and 441 in Germany. Italy is believed to be following the German practice.

No definite standards have so far been adopted in America. The last R.M.A. recommendations call, contrary to the European standards, for negative modulation; also for spacing of the vision and sound carriers of approximately 4.5 Mc as soon as single side-band operation of the vision transmitter is practicable.

Wire Transmission.—Thus far, with the exception of the 180 line visio-telephone service involving Berlin, Munich, Nuremberg and Hamburg, Germany, no regular long distance transmission of television images has been realized.

In the U.S.A., following the completion of satisfactory telephone and television tests over the New York—Philadelphia coaxial cable arranged for one megacycle transmission, additional equipment was added to permit transmission up to two megacycles. Tests using this frequency band are now in progress.

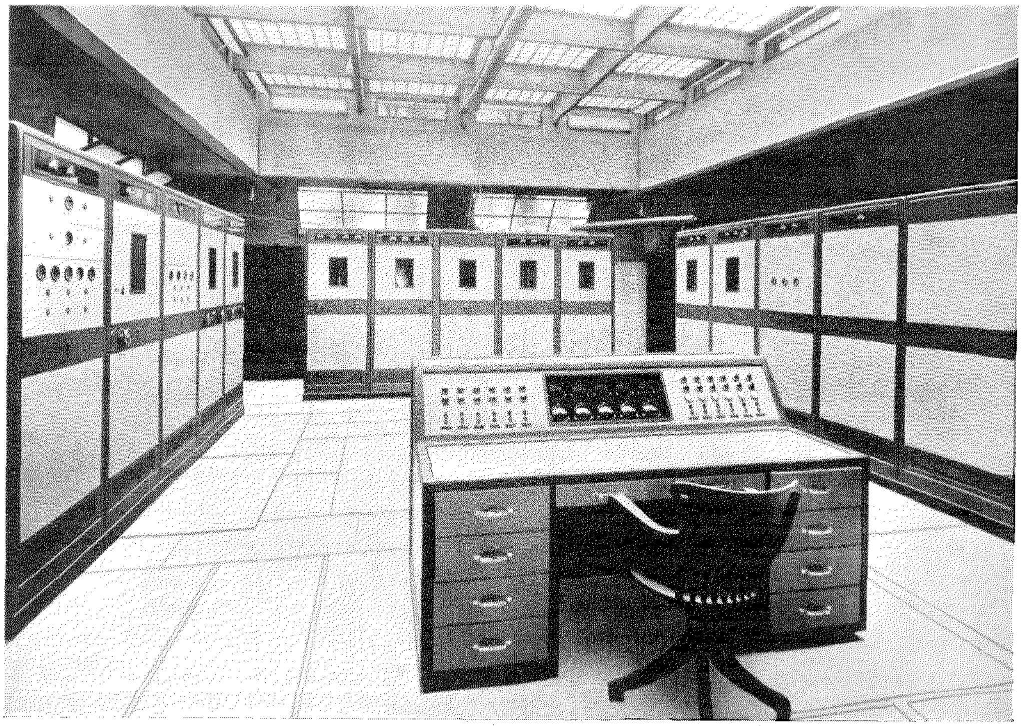
In Great Britain, experiments are being conducted on the transmission of visual signals over ordinary telephone lines. To date, successful pictures have been received over distances of 2–3 miles, and it is hoped to extend this range to four miles or more. Thus many important sources of programmes may be linked to the balanced-pair television cable encircling Central London. Considerable work also has been done towards the realization of long distance television transmission over coaxial cables.

An order for a television terminal equipment was received by Societá Italiana Reti Telefoniche Interurbane for the Rome Television Station.

Radio Links.—Some consideration has been given to the use of radio links for television transmission over distances of a few hundred kilometres. No definite plans have been formulated and it is not felt that this problem will be solved in the near future.

Scanning Systems.—Iconoscopes are used almost exclusively for vision transmissions. For film scanning, Fernseh employ mechanical film scanning giving very good images and also a dissector tube using the Farnsworth principle which, in the case of films, gives images comparable with the iconoscope images.

Television Transmitters.—In France, the Eiffel Tower vision transmitter, ordered by the French P.T.T. from Le Matériel Téléphonique, was inaugurated by the P.T.T. Minister on April 8th. The output power was raised to 30 kW and a new antenna placed in service at the end of 1938. Good reception has been reported all round Paris and also on the south coast of England. The quality of the pictures compares favourably with those from other transmitters in operation.



Eiffel Tower 30 kW Television Transmitter installed for the French P.T.T. by Le Matériel Téléphonique, Paris.

The Eiffel Tower transmitter is completely A.C. operated. Good stability is obtained by the use of inverted amplifiers, and phase shift is minimized by proper dimensioning of the circuits of the last stage. The response is flat within a few db. and the overall time delay is constant within a few hundred microseconds.

In Germany, a transmitter adapted to the new German standard is under test.

During the Berlin Radio Exhibition in August, all demonstrations were based on the new standard but were made by local wire connections or from a 100-watt transmitter.

In Italy, a 2 kW television transmitter was ordered for Rome. Fernseh will supply the scanning equipment.

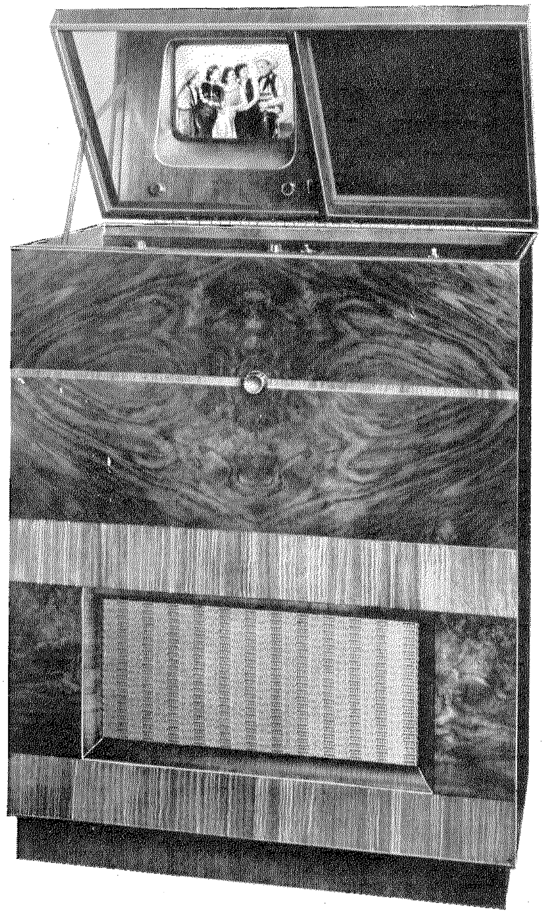
Television Receivers.—The 1938 Berlin, London and Paris Radio Exhibitions, held in August and September, showed important effort towards the commercialization of television receivers, particularly in the case of the London Exhibition.

At the Berlin Television Exhibition, Fernseh, Telefunken, Tekade, Loewe and Lorenz showed various home-type models of television receivers and also projection-type receivers for large audiences. Of the receivers in operation, the majority were made by Fernseh.

Fernseh demonstrated a projection type receiver giving very good 10′ × 12′ images. Telefunken showed projection type receivers giving approximately 3′ × 4′ images. A Lorenz projection type receiver producing a smaller image also was demonstrated.

At the London Radio Exhibition, at least twenty radio set manufacturers demonstrated television receivers at their stands. About 100 television receivers were in operation. Kolster-Brandes, Limited, demonstrated three types: a console receiver (No. 780) with twenty valves producing a picture 10″ × 8″ for direct viewing; a similar receiver (No. 790) but more sensitive, incorporating an all-wave radio receiver, and arranged for viewing in a mirror type cabinet utilizing 26 valves in all; and a table type receiver (No. 800), employing 17 valves and providing a picture 7″ × 6″.

Most of the receivers in operation at the London exhibition were of the direct viewing type, only a few using mirror viewing. The quality was very uniform, the receivers demonstrated by Kolster-Brandes being amongst the best.



Kolster-Brandes No. 790 Television and All-Wave Receiver.

Projection type home receivers giving images between 18″ × 15″ and 24″ × 20″ were also demonstrated by Baird, Marconi, Philips and Scophony. The image of the Baird receiver was black and white, while the images of the other projection type receivers were of a light greenish-yellow colour.

At the Paris Radio Exhibition, about fourteen television receivers were demonstrated by five firms, two of them only offering receivers for sale.

During 1938, the trend in television receiver construction was towards the reduction of the size of the cabinet with respect to the image dimensions. This was accomplished mainly by decreasing the length of the cathode-ray tubes.

The number of valves in television receivers was reduced appreciably. Most receivers utilized between thirteen and twenty.

The majority of the receivers used magnetic type cathode-ray tubes; an important proportion, however, still employ electrostatic type tubes.

The prices of the television receivers shown at the London exhibition ranged between 21 guineas for 4″ × 3½″ direct viewing types and 220 guineas for the 20″ × 24″ projection type.

It is estimated that the number of television receivers in service in England at the time of opening of the London exhibition was between 8 000 and 10 000, and that at least the same quantity was sold during the exhibition.

COMMERCIAL RADIO

During the past few years much effort has been directed towards the application of single side-band working to short wave transoceanic telephony, and it is now possible to state that this method of communication has become fully commercial. Single side-band circuits are now in regular use between Great Britain and the United States, California and Hawaii, and Holland and the Dutch East Indies. Similar circuits are planned between the U.S.A. and Germany, and the U.S.A. and Switzerland. In at least two cases the system in use is not merely single side-band, but "twin channels," i.e., two channels are fed from one transmitter using side-bands on opposite sides of a common suppressed carrier. The circuit improvements obtainable through single side-band working in reduction of fading effects and improved quality are likely to be of special value during the period of poor transmission conditions, due to sun-spots, anticipated about 1940.

Development of the Multiple Unit Steerable Antenna (M.U.S.A.) is continuing, and arrangements are being made for the erection of such aerials in Great Britain and Germany. The British Post Office is actively proceeding with the construction of a M.U.S.A. system near the town of Rochester, Kent, England. The ultimate equipment of this station will include a total of sixteen aerials, and will provide for a total of twelve channels during times of favourable radio conditions. The German equipment provides for the initial installation of a six-unit M.U.S.A., with the possibility of increasing the number to twelve units at a later date.

Apart from its commercial utility, the M.U.S.A. system is of value in the study of propagation conditions. The Bell Telephone Laboratories, Inc., report, for example, that considerable lateral change in the angle of arrival of a signal occurs on occasion—sometimes as much as fifty degrees off the great circle bearing of the transmitting station.

On June 21st, direct commercial telephone service was established between Chile and Japan through the co-operation of the Japanese Government and the Compania Internacional de Radio de Chile, an associated company of the International Telephone and Telegraph Corporation. New diamond loop antennae were constructed in Santiago, Chile, pointed on Tokyo, and the powers of the transmitters in the two cities were raised to 8 kW and 10 kW, respectively. The wavelength on the west-bound transmission is 23 metres; in the other direction, from Tokyo to Santiago, the wavelength is 23.5 metres.

The use of the ultra-short wave band for commercial purposes is to some extent limited by the general requirement of optical visibility along the propagation path. Nevertheless, there are circumstances in which this band is of great value. For example, the 9-channel U.S.W. telephone link between Belfast in Northern Ireland and Stranraer in Scotland has been in continuous service since August, 1937. The British Post Office and the French P.T.T. have decided to supplement their cross-channel cable service by an 18-channel U.S.W. link initially equipped for 9 channels. This equipment will contain "weak talker" devices and other improvements over the Belfast-Stranraer system, and will operate on wavelengths between 3.6 and 4.9 metres.

A direct ultra-short wave service between England and the Scilly Islands was inaugurated in 1938 and a 6-channel U.S.W. link, manufactured by the Nippon Electric Company, Ltd., is being installed between Aomori Prefecture and Hokkaido in Japan, a distance of 75 km.

This Aomori-Hokkaido link is of interest since it contains a broadcast circuit equipped with a compressor and an expander. An even longer 2-channel U.S.W. link has been in operation for some time between England and the Channel Islands, a distance of 136 km.

In addition to its use in fixed services, such as in the examples quoted above, the ultra-short wave band is now being extensively used for mobile services, and also by the broadcasting companies for short distance radio links to "outside broadcast" points to which wire communication is not available. An interesting application to mobile services is the adoption of the ultra-short wave police system, originally developed in the U.S.A., by police authorities in Norway, Sweden, Finland, Hungary and Holland. The outstanding application of ultra-short waves, however, is in the field of aviation communication and aids to navigation rather than to general commercial radio link working.

MARINE RADIO

For many years radio equipment of ships was almost entirely governed by the compulsory regulations of the various maritime countries, applied in the interests of safety of life. There is now, however, a strong and growing tendency to equip ships to an even greater extent than the regulations demand. This tendency arises primarily from appreciation of the fact that radio, quite apart from its "safety of life" aspect, can provide valuable assistance to the navigator. It is significant that practically every new deep-sea ship is now fitted as a matter of course with a radio direction finder, irrespective of whether or not her tonnage or service is such as to bring such fitting within the compulsory regulations. Moreover, on many large sea-going vessels, the radio direction finder is regularly operated by the navigating officer as part of his normal duties rather than by the radio staff. The same tendency appears in the case of the "voluntarily equipped" class of vessel, such as the trawler or the small coasting vessel, which, in addition to being fitted with the skipper-operated radiotelephone equipment, already accepted as a commercial necessity, now frequently has a direction finder as well. Progress in this direction has been greatly stimulated in recent years by the growth of the extensive system of radio beacons, over three hundred in number, serving European and North American waters.

The radio equipment for the new Cunard-White Star super-liner *Queen Elizabeth* will be provided and installed by the International Marine Radio Company, Ltd., (an associate of the I. T. & T. Corp.), the suppliers of corresponding equipment for her sister ship, the R.M.S. *Queen Mary*. The installation will follow the same general lines as the I.M.R.C. equipment which has been found so effective in the earlier ship (enabling her to handle on her maiden voyage the record traffic of 175 000 paid words of telegraph traffic, 291 radiotelephone calls, and $11\frac{1}{2}$ hours of broadcast programme), and will include the feature of separate transmission and operating rooms with complete remote control of keying, power, and wavelength from the combined operating and reception room. The radio equipment in the new Cunard-White Star liner *Mauretania* will be required to meet the same high standard of performance set by the *Queen Mary* installation.

The first passengers' radio telephone service installed in British cross-Channel ships was introduced in March, 1938, by the International Marine Radio Co., on board the new British and Irish Line's motor vessels *Leinster* and *Munster*. This service, which was inaugurated by an exchange of radiotelephone greetings with the *Queen Mary* in mid-Atlantic, marks an important advance in communication facilities for passengers travelling between England and the Irish Free State.

The ship-to-shore low power telephone service to trawlers continues to show an increase in traffic, and facilities are now provided at coast stations in the north-east of Europe for the extension of such calls over the ordinary subscribers' network. In the absence of any special arrangements, these calls are handled on a simplex basis.

The application of ultra-short wave sets to harbour craft with means for selective calling is arousing interest in ports, where the use of the more usual marine wavelengths is attended with difficulties.

In common with other services, marine radio has been affected by the revision of the General Radio Regulations at the Cairo Telecommunication Conferences (1938). The general effect of this revision is to reduce to some extent the frequency bands open to marine traffic, while at the same time excluding all other traffic from the more important bands. So far as ships are concerned, the frequency bands normally used have been only very slightly modified; and because of the rather special economic and technical difficulties surrounding marine radio, only a relatively low standard of frequency stability is required of marine transmitters which work in these ship bands. Ships using other frequencies to which they are legitimately entitled, but which are outside the bands just mentioned, are required to have high grade transmitters with frequency stability equal to that of a land station. While this directly affects only a relatively small percentage of ships, chiefly those of the passenger-carrying class, it is likely to have a considerable indirect effect on the design of all ship transmitters, in order to ensure that low frequency-stability transmitters are not used outside of certain narrow bands in which such operation is permissible.

AVIATION RADIO

While the use of radio as an aid to navigation is of increasing importance in the marine field, it is of paramount importance in the aviation field, and progress during 1938 has been very largely concerned with this aspect. Directional receivers are now fitted to almost all transport aircraft, sometimes in conjunction with discharge aerials for the suppression of rain and snow static. Frequently the directional loop aerials are mounted in streamlined casings; in some of the latest designs, the nose of the aeroplane is made of non-conducting material and, in these cases, it is possible to mount the loop system in the nose of the machine instead of externally and in a special casing. The study of different methods of using the properties of directional aerials to obtain bearings is still being vigorously pursued, and further improvements have been made in the R.C.5 Standard-Busignies Automatic Radio Compass, the inherently higher accuracy and operating speed of which make it specially interesting.

The advantages of the medium wave Adcock system of direction finding have long been known, but the commercialization of the system was slow, chiefly due to inherent difficulties in obtaining good balance between the component aerials and in avoiding pick-up in the horizontal connecting leads. That these difficulties have now been overcome is well illustrated by the experience of the French Air Ministry with a semi-portable Standard-Adcock equipment supplied by Le Matériel Téléphonique, Paris. This equipment is mounted in a motor van and uses a pick-up system of insulated tubular metal mast aerials connected to the goniometer through screened aperiodic transformers and tubular transmission lines. The time required to complete the erection of a station is less than six hours, including the surveying necessary to ensure that the planes of the aerial pairs are accurately at right-angles to one another, that all the masts are accurately vertical, and that the corner masts are rigorously equidistant from the centre point, together with careful laying of the earth mats and any necessary levelling of the site. The accuracy of bearings and freedom from night effect secured with this semi-portable equipment are fully equal to those obtained from a well constructed permanent Standard-Adcock system.

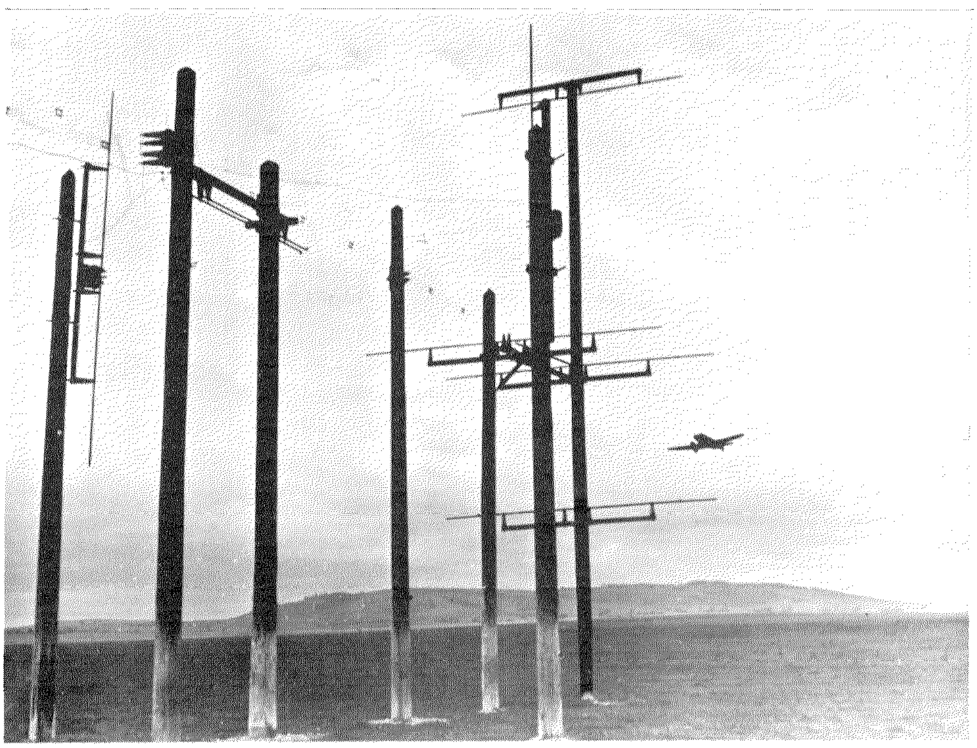
For direction finding on medium wavelengths by ground stations, various forms of the Adcock system are to-day being widely applied. The impulse system of transmission, evolved as a means of overcoming night-error, appears to be losing favour. The use of Adcock direction finders, which depend on the vertically polarized component of the received signal, has reacted on the transmitting equipment used by aircraft. With the high air speeds now in use the weighted trailing aerial becomes practically horizontal and emits only a very small signal component with vertical polarization. It is, therefore, electrically preferable to employ a short fixed-aerial giving a larger proportion of vertical polarization, this preference being strongly reinforced by mechanical considerations. Since, however, the radiation efficiency on medium wavelengths of such fixed aerials is rather low, their adoption has been accompanied by a demand for higher transmitter power in order to maintain signal strength. This tendency to increased transmitter power is apparent both in Europe and America, as is also a tendency to confine operation to spot-wavelengths. Modern aircraft transmitters are thus considerably more complicated than those of a few years ago and, in the interest of safety, many of the larger transport planes carry a small emergency transmitter in addition to their main equipment.

The application of the Adcock system to short waves continues to be the subject of much study, particularly in connection with long-hop trans-oceanic flights, and is in regular use by one of the American air lines. Whether complete reliance can be placed on such a system still remains to be established, and the increasing traffic on all air lines has forced the investigation of other methods.

Radio air navigation on the North American continent has long been based on the fixed AN course-beacon system, and is now further aided by the use of aircraft direction finders as an auxiliary to the course beacons. In Europe an extensive triangulation system of non-directional radio beacons has been laid out to facilitate navigation over the principal routes for aircraft equipped with direction finders or radio compasses. Trials are also being made with rotating beacons, but no definite conclusions have yet been reached as to the value of this innovation.

Probably the outstanding feature of aviation radio to-day is the rapidly developing application of the ultra-short wave band due to its well-known advantages for this class of service.

The first use of the ultra-short wave band for aviation services was for instrument landing systems, and now nearly all the principal airports in Europe are fitted with the Lorenz system of instrument approach. Work in



View showing Air-France pilots being trained in instrument landing at the Troyes aerodrome. The system uses an instrument landing system developed by Les Laboratoires, Le Matériel Téléphonique, Paris, and consists of an ultra-short wave beacon giving a sharp line of approach to the landing ground over a distance of 25 km, two ultra-short wave markers showing the horizontal position of the aeroplane along the axis, and one ultra-short wave glide path beacon. The latter, during descent, gives the aeroplane accurate indications of the glide path to be followed, thus enabling the aeroplane, with drawn curtains, to be piloted safely to ground. The complete aeroplane receiving equipment is compact and weighs only 14 kg.

America is progressing rapidly along similar lines and, whilst the results are not yet finalized, there is a general tendency to use shorter wavelengths than in Europe in order to avoid interference between adjacent stations. In Australia a similar type of equipment has been used for point-to-point navigation along lines similar to the AN beacon system; the advantage claimed is complete freedom from false courses. The marker beacon installations, used initially for providing fixes along the instrument approach beacons, are finding universal application for procuring fixes along the AN systems in America and for marking obstructions. They have also been used in a modified form for the purpose of defining exactly the cone of silence over the AN beacon transmitters in view of the fact that the cone of silence produced by the beacon itself is a negative rather than a positive indication.

As an outcome of experiments extending through the end of 1936 and the year 1937, Les Laboratoires, Le Matériel Téléphonique, Paris, have developed an improved space track or instrument landing system for aircraft. Three ultra-short wave channels between 33 and 38 Mc are used; all transmitters are controlled by low temperature coefficient quartz plates and use selenium type rectifiers. After a preliminary demonstration in February, 1938, before French officials, the new system was selected by Air-France, the French Air Transport Company, for training their pilots in instrument landing (see illustration, p. 219). On December 2nd, 1938, a very successful demonstration was given of the qualities of the system, and of the training of Air-France pilots before the experts of the International Air Traffic Association (I.A.T.A.), an organization comprising representatives of all European Air Traffic Companies. Great interest was expressed by the visitors, and the indications are that this new French system will find wide application in the near future.

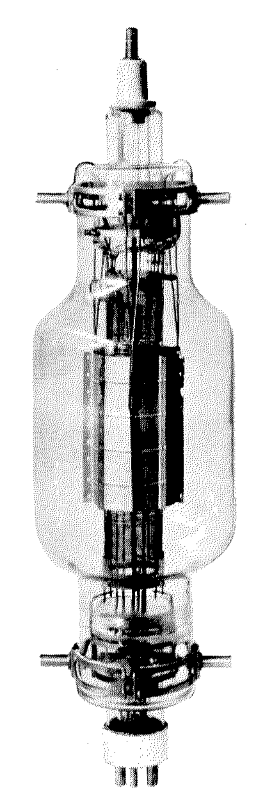
Work is being done in both Europe and the United States to ascertain the coverage of low power ultra-short wave equipment for purposes of airport traffic control. In addition to freedom from interference from other stations, a great gain in signal-to-noise ratio is being found under conditions of snow and rain static. Allocations for nearly all aircraft services have now been made in the ultra-short wave band, and it is certain that development of suitable apparatus for aerodromes and planes will proceed rapidly.

The utilization of ultra-short waves for the measurement in an aircraft of its height above ground represents an outstandingly interesting development. The ordinary altimeter is subject to variations depending on the prevailing atmospheric conditions so that it is necessary to apply corresponding corrections, the magnitude of which may alter, unknown to the pilot, during flight. An instrument with a response indicating directly the height above the actual ground, therefore, should be of great value. The acoustic depth sounding devices now fitted on many ships are of this nature, their response being proportional to the time taken by a signal emitted from the ship to return to the ship after reflection from the bed of the sea. Such devices are not readily applicable to aircraft, but ways are now being found of applying the same principle by using radio waves rather than acoustic waves. Since the velocity of radio waves is much greater than that of acoustic waves—186 000 miles/sec. as against 0.2 miles/sec.—the time interval is too short to be measurable with the required accuracy, and recourse is therefore had to the measurement of some change in the character of the signal proportional to the length of path. An example of such an altimeter system is that demonstrated by the Western Electric Company during the year under review. In this altimeter the emitted signal is frequency modulated, and the change in signal character, used to measure the height, is the average instantaneous difference in frequency between the emitted wave and the wave received after reflection from the earth. The equipment operates on a frequency of several hundred megacycles, and is reported to give accurate readings at heights as low as about ten feet. Experimental work on a rather similar system also is proceeding in Japan, and elsewhere studies are being made of altimeter systems which likewise use ultra-short wave emission, but measure the height by reference to the change in phase of the carrier or any modulation imposed on the carrier.

VALVES

Whilst several new valve developments were achieved in 1938, the general tendency was to extend previous knowledge of constructional methods to produce a wider range of valves, particularly in the case of valves operating at ultra high frequencies and capable of providing considerable output at frequencies of the order of 150 megacycles. In general, advances in the field of frequencies greater than 150 Mc were not very extensive; Standard Telephones and Cables, however, were successful in producing micromesh types of valves yielding an output of 15 to 20 watts at a frequency of 240 Mc. For operation with these valves, the S.T.C. valve laboratory developed a multiple valve oscillator, and prospects of obtaining greater output at the higher frequencies are promising.

Investigations into the properties of water-cooled valves for high frequencies continued. Several valves, of a range of such valves produced by Les Laboratoires, Le Matériel Téléphonique, are being used in the Eiffel Tower Television Transmitter.



1 *kW Double-Screen Valve*

A number of manufacturers recently have shown interest in valves of the cooled anode type in which water cooling has been replaced by forced air-blast cooling. Standard Telephones and Cables recently placed a 1 kW radiation-cooled double-screen valve on the market. This valve is capable of dissipating 1 kW on the anode and uses anode potentials up to 2 500 volts.

In wide-band transmission systems, a recent tendency is to employ a larger number of repeaters than previously; the valves used in the repeaters are smaller and are tested to more exacting limits. The Bell Telephone Laboratories, Inc., recently demonstrated such a system with valves of small dimensions and very low operating powers; valves for this purpose also are being developed by Standard Telephones and Cables. In general, there is a tendency to use the multi-electrode valve in preference to the more conventional triode.

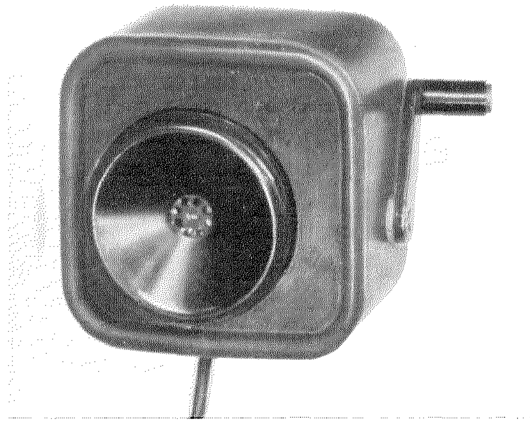
The advent of regular television services has increased the demand for high-vacuum cathode-ray tubes and, as a result, a variety of large screen high-vacuum tubes has been produced. Interest lately has been centred round high-vacuum tubes with magnetic focussing, and this type of tube is now being produced by a number of firms. For vision amplifiers, special valves have been developed and, it is interesting to note, the requirements for such valves are very similar to those of valves for wide band transmission systems. The need for small cathode-ray tubes for general oscillographic purposes also has become apparent, and Standard Telephones and Cables have developed a small tube with a 3″ screen, as well as a monitor tube for use in cathode-ray oscillograph and triple tube units.

Speech input equipment has developed along the lines of quality rather than power output, requiring valves of high quality with respect to noise and constant characteristics. For the production of the necessary valves with low noise, low microphonicity and close test limits, the introduction of special methods and equipment was required.

The broadcast receiving valve has undergone a number of modifications and a tendency exists to standardize on the American type octal base valves. Other developments worthy of note are the low noise multi-electrode valves, and improved frequency changers.

SOUND POWERED TELEPHONES

The Bell Telephone Laboratories, Incorporated, have developed a Sound Powered Telephone requiring no battery supply for its operation. Speech transmission and reception are effected by means of a small balanced armature arrangement, and signalling by a small hand-driven rotor acting in the magnetic



Sound Powered Telephone.

field of the balanced armature structure. The rotor generates 1 000 p : s tone, which operates on the receiver of the called instrument.

This new type of telephone, despite its rugged construction, weighs less than 2 lb. Since it renders primary batteries with their inherent maintenance difficulties unnecessary, this type of instrument should find considerable application for marine and military purposes, temporary service in connection with construction projects, and general portable use.

TELEGRAPH

A steady increase occurred in the general appreciation of Teleprinter systems by Administrations and private users alike. One reflection of this growing interest is revealed by the active measures taken by several European Administrations towards telegraph reorganization. A further indication is afforded by the resolution, adopted at the 1938 Cairo Telecommunication Conferences, providing for the setting up of a special Committee of the C.C.I.T. to study the technical and economic considerations involved in the provision of international subscribers' teleprinter services.

Widespread interest was displayed in projects involving both manual and automatic switching of private, national and international circuits equipped with Teleprinters. One of the largest and most important of these projects matured in Czechoslovakia where switching equipment, designed and manufactured by the Bell Telephone Manufacturing Company, Antwerp, was installed in Prague and Brno. This equipment forms the nucleus of a public Teleprinter switching network covering the whole country. Each exchange area consists of one automatic and one manual exchange, with a manual toll position at Prague for the supervision of international calls. Local subscribers, toll line subscribers and junctions are connected to the automatic exchanges, whilst the manual exchanges are used for providing broadcast service and facilities for long period connections between certain of the subscribers. The metering of calls is accomplished by automatic ticket registers which print on tickets the number of the calling and called subscribers, the time, date and period of effective call.

The use of Teleprinter systems was considerably extended by British railway companies superseding Morse operation on a number of main line circuits. An important project planned by The London and North Eastern Railway involves the supply of Creed Teleprinters and automatic switching equipment to provide intercommunication between 25 initial stations located in the area between Manchester, York, Ipswich and London. The switching equipment, which was designed and manufactured by Standard Telephones and Cables, London, is arranged to handle heavy traffic over open-wire lines.

Plans for the provision of similar switching systems by other British railway companies are under consideration.

The process of consolidation effected by European Administrations in the extended use of Teleprinters is exemplified by the fact that the British Post Office and the French P.T.T. each acquired, during 1938, 200 additional Creed No. 3 Teleprinters.

The Teleprinter Exchange facilities connecting Great Britain, Germany, Holland, Belgium, Denmark, Switzerland and Czechoslovakia, are utilized by a relatively small though growing number of business organizations. Strong grounds exist for the belief that, upon the removal of anomalies in technique and the establishment of a uniform and more attractive tariff scale for international calls, a spontaneous and universal growth of Telex will follow.

In Great Britain, a striking increase took place in the demand for rented point-to-point Teleprinter Services. Over 900 Creed Teleprinters were acquired during 1938 by the British Post Office for such services.

Creed Teleprinters were supplied to the New Zealand Post and Telegraph Department to form the nucleus of leased wire services.

Interest in Stock Exchange and News teleprinter services was well maintained. Numerous machines were supplied to cater for new subscribers to such services in London, Liverpool, Alexandria, Bombay, Johannesburg and Sydney.

The Press and News Distributing Associations in the British Isles displayed an increasing tendency to discard Morse for Teleprinter equipment, use being made under heavy traffic conditions of multi-channel voice frequency telegraph systems.

Evidence of progress in the use of the Teleprinter system by Meteorological services for the transmission of weather reports is furnished by the greatly increased number of machines supplied for installation at aerodromes in Great Britain and several other countries.

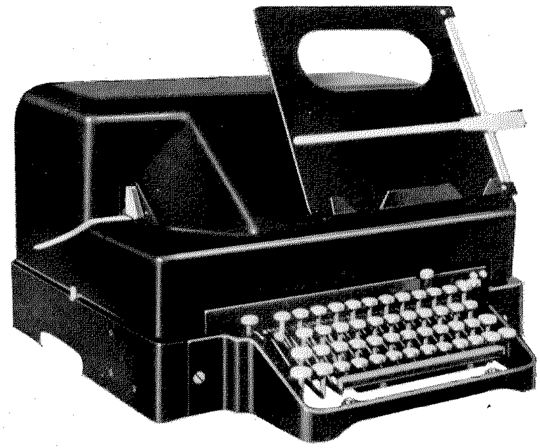
A new transmitting and receiving Tape Teleprinter,[8] designated Model 10-B, was developed by Creed and Company, Limited. Consistent progress was made in perfecting existing Teleprinter systems.

In the radio printer field, a "built up" character Radio-printer,[9] utilizing seven frequencies, was developed by Les Laboratoires, Le Matériel Téléphonique, Paris. Field trials, were highly successful.

FACSIMILE TRANSMISSION

Picture or facsimile transmission over wire or radio circuits has come to be regarded as a normal function of communication systems, and the development of facsimile transmission for domestic use is now engaging considerable attention.

A recent development of this character, known as Facsimile Broadcast, is undergoing tests in the U.S.A. by more than twenty broadcasting stations specially licensed by the Federal Communications Commission. It visualizes commercial broadcast transmitters being used during non-programme hours for the transmission of condensed news items and pictures, reception taking place in the home in the form of a miniature newspaper. In its present form, reception can be effected either by a special facsimile recorder or by an additional unit connected to an existing broadcast receiver. The received signal appears at the recorder in the form of normal newsprint feeding from a paper roll on the recorder. One system utilizes black print on white paper, and another, red print on black paper.



New Creed Model 10-B Teleprinter.

SELENIUM RECTIFIERS

The forecast in last year's review of increasingly diverse applications of selenium rectifiers has been amply justified. New rectifier apparatus has been developed for welding, plating, cinema arc projectors, electric vehicle charging, lift control, etc. Standard Telephones and Cables, London, are now constructing a 14 000-ampere rectifier for electro-plating purposes, and the British Broadcasting Corporation has installed two large equipments for supplying plate current in its new Empire short wave station at Daventry.

Further advances in all-mains telephone supply rectifiers were achieved during the past year. An outstanding development of Le Matériel Téléphonique, Paris, is a new scheme of voltage regulation which maintains constant voltage irrespective of load or supply fluctuations.

TOTALISATORS

The growing use of electrically operated totalisators on racetracks seems worthy of mention as indicating another adaptation of telephone apparatus and principles to systems for rapidly communicating results to the public.

The Union Totalisator System is manufactured by Standard Telephones and Cables, Limited, London, which installed nineteen equipments of this type in 1938, and a total to date of eighty.

PUBLIC ADDRESS

With more general recognition of its advantages, interest in Public Address equipment is increasing. There are indications, too, that architects are tending to give more consideration to acoustic characteristics. It may consequently be expected that, in the future, Public Address or Speech Reinforcement systems will be utilized with greater effectiveness.

Air Raid Precautions schemes and staff calling arrangements for large buildings and factories are calling for high powered Public Address equipment operating a large number of loudspeakers. During the year, installations were made by Standard Telephones and Cables, London, for the Westinghouse Brake and Signal Company at Chippenham; for the Fairey Aviation Works at Hayes; for the S. T. & C. Factory, New Southgate; and for the Southampton Fire Station, where automatic means are employed for changing over to battery and motor converter supplies in case of mains failure.

Public Address systems were used in conjunction with General Post Office lines for relaying programmes on a large scale to a number of centres. Examples are a programme relayed from Glasgow to Ayr, Paisley, Falkirk and Edinburgh; and one, over 150 miles of land line circuit, between Limerick and Drogheda.

A permanent loudspeaker installation is now in use at Westminster Abbey. It includes a large number of low-powered loudspeakers.

Contributing to the marked success of the 34th International Eucharistic Congress, held in Budapest, May 22–29, 1938, was the Public Address equipment. Standard Electric Company Limited, Budapest, handled the transmission and sound engineering problems and supplied all microphones and amplifiers with associated mixers, as well as the line amplifier and some of the loud speakers and power amplifiers.

A number of interesting Public Address installations was designed and supplied by other Companies of the I. T. & T. group notably the Bell Telephone Manufacturing Company, Antwerp, and Le Matériel Téléphonique, Paris.

RAILWAY SYSTEMS

The development of the Standard railway signal interlocking system was completed in 1938, and an order obtained for the interlocking of the important London and North Eastern Railway junction at Doncaster, England. The system is designed to enable a signalman to handle traffic with the maximum flexibility consistent with complete safety, and incorporates motor-driven switch-gear of the type used in Rotary automatic telephone systems.

The total number of contacts involved in the interlocking of a particular area with this system approximates one-seventh of the number required in the older panel systems at present in use. Actual control of interlocking is effected from a control desk in the form of a track plan of the area with miniature switches mounted at points corresponding to the signals, etc., to be controlled. This geographical layout of the control panel gives the signalman a clear record of the state of the track and relieves him of the necessity of remembering the sequence of point and signal operations required for setting up any desired route.

FIRE ALARM SYSTEMS

The London Fire Brigade, in 1930, installed a Standard-Gamewell Fire Alarm System at the Southwark Area as an experiment. It is still in service, and, having proved satisfactory similar systems have been installed in the new Headquarters Area and also in one of the important Divisions in the City. Orders have now been received for the remaining five Divisions of the London Fire Brigade.

New Fire Alarm systems have been supplied and installed in Belfast, Rugby and Dagenham. The Belfast system consists of 110 street boxes together with equipment in the Headquarters station and three substations. The Rugby system consists of 30 Fire Alarm and Ambulance Boxes and station equipment. The system at Dagenham consists of 64 Fire Alarm and Ambulance Boxes and station equipment.

In the Dagenham and Rugby stations, a new feature is the incorporation of a Control Desk as a part of the Fire Alarm Switchboard.

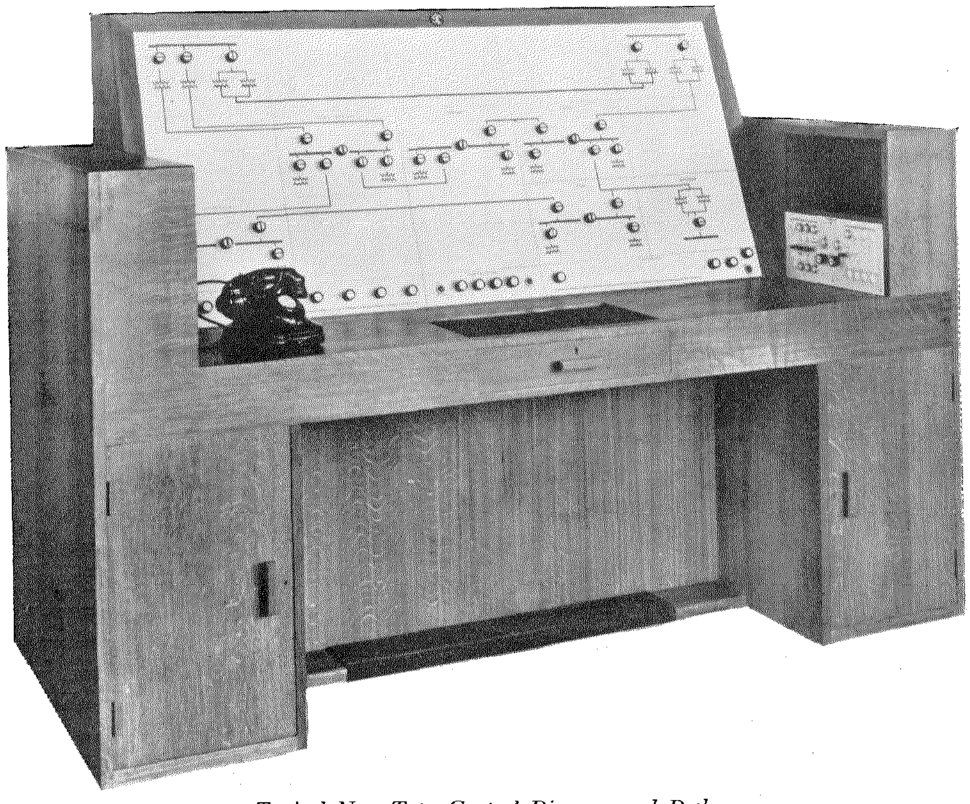
REMOTE CONTROL AND SIGNALLING SYSTEMS

Remote control and indicating systems employing variable frequency metering for the control of one or more sub-stations over a single pair of wires are rapidly consolidating into an essential feature of power transmission, distribution and railway electrification.

Developments include various apparatus unit designs, notably the combined control key and indicating lamp, which enables the size of control diagram boards to be kept to a minimum without loss of clarity of the diagram for operating purposes. This is an important factor when a large number of substations must be controlled from one control room. A typical new type control diagram and desk is illustrated in the accompanying illustration.

The D.C. bias multi-service system, reported last year for the control of street lighting, has been further developed to control "off-peak" loads and air-raid warning devices. An important development applies the same principles to high tension cables between sub-stations and renders interconnecting pilot wires unnecessary.

The Nippon Electric Company, for some years, has produced remote control and power line carrier telephone apparatus. The Company is now manufacturing carrier telephone equipment for operation over a 110 000-volt line, including means for remote control over the same channel of oil circuit breakers, and quick acting battery switching and protective features.

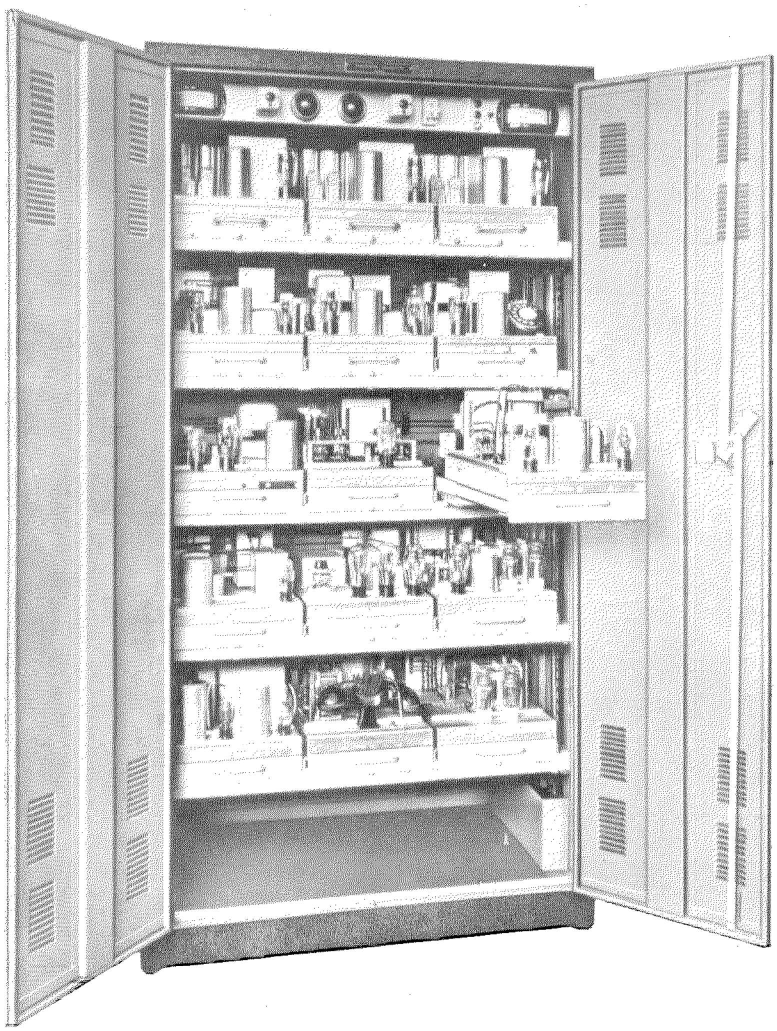


Typical New Type Control Diagram and Desk.

For remote control, a standard 2-stage synchronous system is used. The carrier current is modulated by four frequencies. The equipment will be placed in operation early in 1939.

POWER LINE CARRIER

Compagnie des Téléphones Thomson-Houston, Paris, during 1938, manufactured and installed over thirty high tension telephone carrier and selective protection equipments on French power distribution networks varying in voltage from 60 000 to 220 000 volts. The most recent installation is that on the system of the Société de Transport d'Energie Centre-Ouest (SATECO), serving Eguzon, Distré, Angoulême, and Bordeaux. The distance between extreme points of the network is 600 km.



220 *kV Power Line Telephone Carrier Equipment* (*with cover removed*) *of the type installed by Compagnie des Téléphones Thomson-Houston, Paris, on Power Distribution Networks.*

POWER CABLE

The power cable field shows evidence of considerable activity in the so-called super-tension range or class. The problem of transmitting large units of energy is promoting two distinct lines of system development.

On the one hand, Power Supply Companies are more disposed to employ higher transmission voltages due to the cost of switchgear, capable of handling larger amperage, and of reactors for limiting fault current. This tendency is accentuated by the practice of interconnecting power stations. They are, consequently, raising their maximum transmission voltage from 6.6-kV to 33-kV and from 20-kV to 60-kV or 132-kV. Enquiries for 150-kV and 220-kV cables, in fact, are becoming relatively common, and practical realization of some of the schemes under consideration may be expected in the near future. During 1938, for example, Holland commenced installing a 150-kV system.

On the other hand, there are certain cases in which high amperage per transmission circuit may be economically justifiable; for example, where the transmission line must be installed in existing duct lines. Demand is, therefore, also arising for an increase in the current carrying capacity of supertension cables, i.e., for higher operating temperatures.

To the requirements for higher voltages and higher operating temperatures must be added an increasing demand for improved resistance to surges, transients, etc., which are more apt to occur in power systems including high electrostatic capacity cables connecting a number of generating stations separated by considerable distances.

Oil-filled cables continue to give satisfactory service and are being installed in considerable quantity, and solid type cables are gaining more and more favour, particularly for 60-kV transmission at moderate amperage. There are, nevertheless, signs of keen competition arising from "pressure" cables for high voltages, high operating temperatures, etc.

Towards the end of 1937, a 132-kV gas-filled cable was installed for trial in the British Grid, and this cable has apparently given satisfactory service. Objections raised to this type of cable are alleged limitations with respect to impulse (surge) strength and high amperage. The latter limitation is deducible from the high thermal resistance of the gas filling the interstices. It remains to be seen how far these disadvantages can be eliminated by subsequent development. Other types of gas-filled cable are known to be approaching commercial production.

Up to 1938 the Hochstadter pressure cable—there are some seven installations at 60-kV to 110-kV in service—suffered from the restriction that the cable had to be enclosed in a high pressure, welded steel pipe. Such pipes are none too acceptable to Power Transmission engineers; they, for example, have impeded the exploitation of the Oilstatic Cable in the U.S.A. Now, however, the pressure cable has appeared in a self-contained (double lead sheath) form and two installations of this modified type are in progress in England. The claim for this type is that it can be produced for simultaneous working at high electrical stress and high operating temperature. These two characteristics afford advantages comparable with or greater than the oil filled cable, and are obtained without added expense, and awkward (from a space point of view) feeding points, or the need for subsequent maintenance of oil levels, etc. It is also claimed that the impulse strength of this type of cable is superior to that of the others.

The probabilities are that the characteristics of the three above-mentioned fundamental types of cable will be modified by further developments. Accurate forecasting of their future relative merits is therefore, obviously impossible.

In the Laboratories of Standard Telephones and Cables it is believed that the performance of any type of supertension cable will be determined largely by the insulating materials available and by the processes employed in constructing the finished insulation. During 1938, therefore, much work was carried out on the production of impregnated paper of high dielectric strength, low dielectric loss and other desirable characteristics. In particular, an effort was made to improve the economics of commercial processes for manufacturing acetylated styrenated paper. The introduction, in 1939, of this material into supertension cable design may produce radical changes in the performance of various types of cable. Cable system performance is also becoming more and more dependent on the behaviour of the joints and incorporated terminations. The number of styrene joints and terminations installed during the past year increased considerably and the indications are that this increase will be accelerated.

In the general dielectric field, further development took place in synthetized or polymerized dielectrics. None of these, however, has so far made great progress commercially. One of the more notable materials of this class introduced during 1938 is Polythene, i.e., polymerized ethylene.

I. T. & T. OPERATING TELEPHONE COMPANIES

Telephone operating subsidiaries of the International Telephone and Telegraph Corporation gained more telephones in 1938 than in any other year in their history. They have reported a net increase of 76 080 telephones for the year. The previous record gain was in 1929 when the net increase was slightly more than 70 000 stations.

The large system of the United River Plate Telephone Company in Argentina contributed a gain of approximately 25 850 stations. The Shanghai Telephone Company, with a net increase of 17 860 telephones for the year, regained not only the number of telephones withdrawn from service during the hostilities around Shanghai in 1937 but added several thousand more to advance to the highest development in its history. The Rumanian Telephone Company gained 11 800 telephones, the Chile Telephone Company 7 200, the Mexican Telephone and Telegraph Company 5 500, and the systems in Peru, Southern Brazil, Cuba and Puerto Rico reported substantial increases relative to their size.

Along with the Shanghai Company, the I. T. & T. telephone operating companies in Argentina, Chile, Southern Brazil, Peru, Mexico, Rumania and Puerto Rico had all achieved a new record high development at the end of the year.

Furthermore, new record levels of toll and long distance telephone usage were established in the territories served by these companies. They show that approximately nine per cent more domestic and international long distance calls were completed in 1938 than in the previous year which, for most of the I. T. & T. telephone operating companies, was a record year for toll traffic.

Approximately 71% of all telephones in I. T. & T. operating companies are now automatic. More than 63 000 stations were converted to dial operation in 1938, principally in Rumania, Argentina, Chile and Peru.

Despite the variety of conditions involved in the operations of the telephone companies, about 80% of all service orders received in 1938 were completed within three days.

In the construction and extension of facilities, the 1938 projects included the following: In Argentina, 21 000 lines of step-by-step automatic equipment were installed; radiotelephone service was extended to Algeria, French Morocco and Tunisia; international telephone service was opened with 51 central offices in Uruguay; connection was established through construction with the telephone network in three important northern provinces, providing Argentina with a complete national system. In Rumania, five additional cities were cut-over to Rotary automatic operation; also, the first step in an extensive long distance underground cable programme was taken when a 65 km section of underground toll cable was cut into service between Bucharest and the important oil centre of Ploesti. Two cables of the most modern design and suitable for 12-channel carrier operation were placed over this route and extensions to Brasov and Buzau are in process of manufacture. In Chile, 5 000 lines of automatic equipment were added in Santiago and Valparaiso; a 400 km toll circuit was constructed between Santiago and La Serena, connecting the important naval base of Coquimbo with Santiago; and radio telephone service was opened with Japan. In Rio Grandense Province, Brazil, work is in progress on a new 220 km toll line linking Porto Alegre with the important interior town of Santa Maria.

IN MEMORIAM

The death on June 11th, 1938, of Ministerialdirektor Karl Höpfner of the German Post Office, well-known internationally for his important articles in technical journals and his valuable contributions to the development of long-distance telecommunications, is regretfully recorded. As Chairman of the Third "Commission de Rapporteurs"—a position in the C.C.I.F. to which he was appointed in 1927—Herr Höpfner was closely associated with communication experts in many countries. A man of vision and great ability, he impressed all with whom he came in contact by his impartiality, his unfailing kindliness, and charm of personality.

On November 15th, 1938, a great French scientist—André Blondel—passed away. Mr. Blondel was born at Chaumont in 1863, and gained international recognition for his important and far-reaching contributions to the science of electrical engineering. To his credit may be placed a number of inventions, including the oscillograph for measuring the instantaneous value of an electric current, holophane globes and radiogoniometer, as well as contributions of a fundamental nature in the field of electric power transmission, electric alternators and motors, photometry, wireless telegraphy, acoustics, submarine signalling, etc. He presided over both national and international committees and commissions; and, in recognition of his services, he was elected Membre de l'Académie des Sciences in 1913, and Commandeur de la Légion d'Honneur, as well as Honorary Member of The Institution of Electrical Engineers, London, and of the American Institute of Electrical Engineers, New York. He was also awarded the Kelvin and Mascart Medals.

The careers of Takesaburo Akiyama, Chairman of the Board of Directors of the Nippon Electric Company, Limited, Tokyo, and of Fumio Shida, Managing Director of the Nippon Electric Company, Limited, are briefly outlined in the October, 1938, issue of this journal. Officers and members of the International System throughout the world knew and, in some cases, worked intimately with these distinguished gentlemen. Both were held in high esteem and affectionate regard, and their passing has caused keen sorrow and a deep sense of loss.

The International System and the community, on November 12th, 1938, suffered a severe loss in the passing of Clarence Hungerford Mackay, whose career is given in outline elsewhere in this journal.

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The Application of Automatic Ticketing to Step-by-Step Systems

By E. P. G. WRIGHT, M.I.E.E.,

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TICKETING ASSOCIATED WITH P.A.B.X. EQUIPMENTS

FOLLOWING on the introduction of automatic ticketing for toll calls in the Bruges rotary area by the Belgian Régie,[1] the first installation of automatic ticketing has now been made with step-by-step equipment.

This new installation is not concerned exclusively with toll calls but serves to provide detailed information as to the origin and destination of traffic passing from a private to a public service. The necessity for some automatic means for recording the details of this type of traffic has grown up with the general increase in the distance over which the subscriber is permitted to dial. In the past, it has been possible to prevent long distance calls being established without reference to the P.A.B.X. attendant by means of the discrimination of equipment responding to one or a series of digits. More generally, unauthorized connections to the public service are controlled by causing all such calls to be established by the attendant.

The purpose of the automatic ticketing equipment as used with a P.A.B.X. is not to prevent the establishment of long distance calls, but to provide a written record of such calls, including the identity of both parties and the time of making the calls.

The method of identifying the calling extension depends on the use of a tone connected to the third wire by the outgoing relay group in substantially the same manner as that used with the rotary system. The identity of the called party is obtained from the digits as they are dialled. In addition to the time at which the call occurred, the identity of the exchange line is also recorded. The installation referred to could not be arranged to indicate the duration of calls because of the fact that the standard director type exchange in the London area does not provide any signal when the call is answered other than the discontinuance of the ringing tone. In the case of P.A.B.X. equipments connected to provincial type exchanges, however, the direction of current from the transmitter battery is reversed at the time of answer, a condition that could be used to start the timing switch for recording the duration of the call, i.e., up to the time of release.

USE OF TICKETING APPARATUS FOR SERVICE OBSERVATION

A similar application of automatic ticketing could be used with step-by-step equipment to eliminate the work of an observation operator in providing a detailed record of calls originating from one or a number of lines. In such cases the ticketing equipment would be installed in the public exchange and associated either with the subscriber's line circuit or with the first selectors serving the lines on which observation is required. The record so obtained would indicate the number of calls made, the identity of the party called, the time elapsing while the called subscriber is being rung and the duration of the conversation. If identification is applied throughout the area, the ticketing equipment may be used for the observation of incoming as well as outgoing calls. As the ticketing apparatus is arranged with plug connections,

[1] "Automatic Ticketing of Telephone Toll Calls," by L. B. Haigh; and "Automatic Printing Register for Telephone Call Recording," by L. Devaux; *Electrical Communication*, April, 1937.

the observation service can be readily moved from one exchange to another.

NUMBER CHECKING

Subscriber identification has other more important possibilities in connection with a no-delay toll service. The operation of "no-delay" or demand positions assumes that the provision of toll lines is sufficient to enable a large percentage of calls to be completed without asking the caller to replace his instrument and await the connection. Since such calls are not reversed, the identification information given by the subscriber cannot be checked by the call reversal process. In fact, on a "no-delay" call, the operation of checking the identity of the calling subscriber often consumes as much time as is required to obtain the wanted toll subscriber. The difficulty which the operator experiences in identifying the caller is increased on P.A.B.X. lines, especially as the latter may be unaware of the number of the particular exchange lines being utilized. If the caller is using a night-line number, it may not be in the same consecutive group as the main P.A.B.X. number, so that the toll operator may become involved in a rather complicated search.

With the identification circuits, the "demand" positions on the toll board may be fitted with number indicators carrying as many as 7 or 8 digit wheels. These indicators are set up automatically under control of the identification circuits and involve minimum effort for the operators. Such an arrangement has already been introduced with rotary equipment at Ostend.

THE PRINTING OF OPERATORS' TICKETS

The recent trend of development visualizes the use of voice frequency dialling over long distance circuits, and considerable progress has already been made in introducing 50-cycle and other similar arrangements for dialling over shorter toll lines. It seems worthy of emphasis that the combination of operator toll dialling and subscriber identification facilities makes it a possibility that the practice of producing toll tickets automatically, without special effort on the part of the toll operator, will find rather wide application in the future. Not only can such an arrangement provide relief to the operators with the probability of a more efficient service, but, in addition, advantage may be taken of the ability of the machine to calculate the exact charge for calls thus established by the operators. The charge for a call is dependent on the location of the exchanges of the calling and called parties, the duration of the call, and the time of the day or night when the call is made. All these data are at the disposal of the machine, and the actual calculation can be completed and printed on the ticket within a period of a few seconds.

In much the same way that demand operation is initially introduced over a few routes during the slacker periods of the day—and generally finds increasing application as the line plant grows—it may come to pass also that subscriber toll dialling will commence on a few routes carrying a relatively large amount of traffic. The installation of subscriber identification circuits makes it practicable to produce tickets automatically wherever subscriber toll dialling is possible, and the facility can be extended if and when desired.

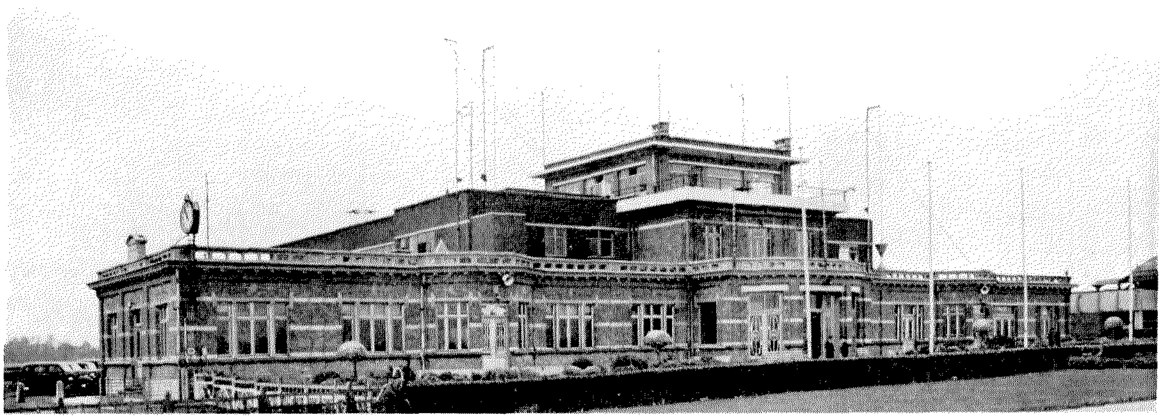
SUBSTITUTION OF TICKETING APPARATUS FOR MULTI-METERING

Another application of automatic ticketing is concerned with the handling of quite short toll traffic of the type introduced in many areas with the aid of multi-metering equipment. Although very comprehensive schemes have been adopted in different areas, there are certain difficulties in introducing multi-metering facilities with some step-by-step equipments. For example, some exchanges employ a message register with a locking contact which is designed to hold the message register in its operated condition for the duration of the call; and, in order to permit several operations, the circuit conditions must be radically altered. Similar changes must be incorporated if the message register is arranged to operate from a booster potential unless the message register is designed to release on the normal exchange voltage. These difficulties are avoided with automatic ticketing, which provides the further advantage that the discriminating equipment can be more readily centralized because there is no longer any necessity for passing back-metering impulses over two-wire junctions. Furthermore, some telephone Administrations are under an obligation to supply their subscribers with details of calls exceeding a certain value; but such calls, with multi-metering equipment, can be handled only with the assistance of an operator, whereas, with automatic ticketing, no special treatment is required.

In the application of automatic ticketing to step-by-step equipment, the same general principles can readily be applied as those already introduced in the field in connection with the rotary systems. In many step-by-step exchanges, release is controlled from the outgoing relay group, thus providing direct access to the third wire and consequently simplifying the process of identification. On the other hand, the general use of mixed digit number schemes in step-by-step areas tends to make more difficult the determination as to when the complete number has been dialled. This difficulty can be overcome at minimum expense by arranging for the process of identification to commence only when the answering signal is received.

Evidently, there is considerable scope for the application of automatic ticketing, not only in connection with toll traffic but also within multi-exchange networks for promoting more efficient operation. The production of a printed traffic record in effect provides a new technique which seems destined to prove advantageous to Administrations and private companies in the solution of their maintenance and traffic problems.

Portion of stand of Fabbrica Apparecchiature per Comunicazioni Elettriche at the Milan Radio Exhibition, 17th–25th September, 1938. It included commercial radio transmitters and receivers, and pictures of the Rome 100 kW Short Wave Broadcaster installed by F.A.C.E. for the E.I.A.R., the Italian Broadcasting Company. This broadcaster was inaugurated on 31st October, 1938.



Administration Building—Belgian Air Ministry, Brussels.

Airport P.A.B.X. Network

By R. T. RINGKJOB

Bell Telephone Manufacturing Co., Antwerp, Belgium

INTRODUCTION

THE Belgian Administration for Civil Air Transport operates four airports, located at Brussels, Antwerp, Ostend and Zoute. Regular national services, both freight and passenger, are handled through them as well as considerable international traffic.

To be successful, conveyance by air must meet the same regularity and safety requirements as other types of transportation. No means of achieving this result must therefore be neglected.

Particularly important in reducing uncertainties in air travel and ensuring a smoothly functioning organization is direct telephonic or telegraphic intercommunication between airports for service purposes. Thus, the latest reports of weather conditions can be made available immediately prior to the departure of an airplane, loss of time in establishing a toll connection over the regular national communication network being avoided. Similarly, last minute information as to freight awaiting transportation, freight space available, supplies required, passenger lists, etc., can be rapidly transmitted.

Recognizing the great value of direct intercommunication, most large airports now operate their own lines to other flying centres. The Brussels airport, for example, has direct lines to Amsterdam, Cologne, Paris and London. Service messages are transmitted by means of teleprinters, which are particularly suitable for this type of operation.

The four national airports at Brussels, Antwerp, Ostend and Zoute have had the advantage of a separate telephone network for several years. Until recently, magneto pony switchboards were utilized at each flying field, a few local battery subsets being installed at the most important points. The old ring-down methods, with the inherent disadvantages of manual operation, did not, however, satisfy the exigencies of the Administration, and it was decided to install a modern private automatic exchange system, which would give any station at any airport access to any station at any other flying field without the intervention of an operator.

The Administration accordingly ordered four P.A.B.X.'s including interworking equipment from the Bell Telephone Manufacturing Company, Antwerp. The system was placed in operation early in 1938, and has given very satisfactory results.

Interworking amongst the four airports involved special problems, due partly to their wide separation, and to the necessity of equipping the loaded cable pairs with voice frequency repeaters. Inasmuch as ordinary D.C. dialling could not be used, it was found necessary to resort to 50 cycle signalling, applying the same principles as in automatic long distance dialling systems.

The purpose of the present article is to describe some design and operating features of the P.A.B.X. system installed in the Belgian airports.

EQUIPMENT

TABLE I

Location	Type of P.A.B.X.	Stations		Trunks	Tie Lines
		Cap.	Eqpt.		
Brussels	7035	50	40	3	3
Antwerp	7011	6	6	1	1
Ostend	7011	6	6	1	1
Zoute	7011	6	6	1	1

Table I contains data on the P.A.B.X. equipments installed at the four airports. The P.A.B.X.'s (Nos. 7011 and 7035) are of standard Bell Telephone design, and have been described in detail previously.[1] A view of the 7035 board installed in Brussels is shown in Fig. 1.

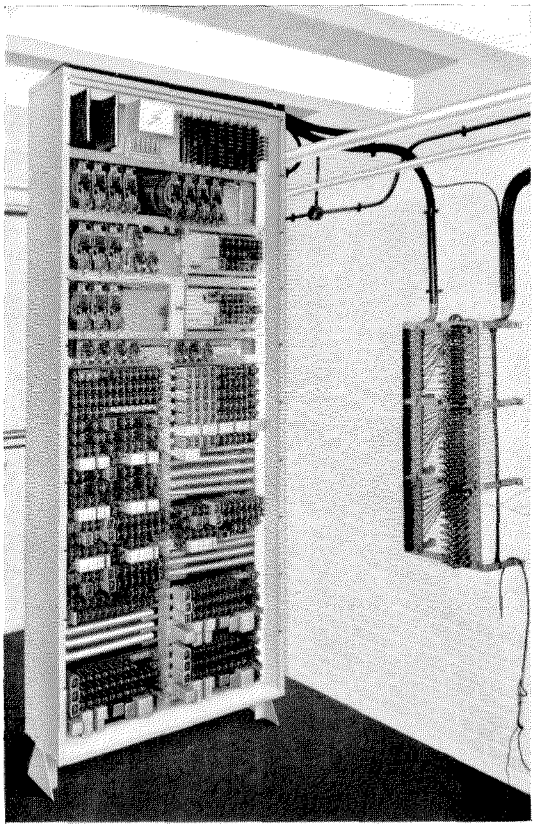


Fig. 1—No. 7035 P.A.B.X. installed in Brussels Airport.

JUNCTION DIAGRAM

Fig. 2 illustrates the fundamentals of the system and the routing of the different classes of calls. It will be seen that each station, without the intervention of an operator, has access to all other stations in the entire network.

All P.B.X. stations have automatic outgoing service to the local city exchanges or to the toll office.

In the 7035 P.A.B.X., incoming city and toll traffic is handled by an attendant, who extends such calls to the local stations by means of a high speed cordless attendant's set.

The 7011 boards are unattended. Any P.A.B.X. stations can answer incoming calls and transfer them to the interested party by means of the well-known call back and transfer feature.

The circuits are designed so that a city connection in one P.A.B.X. cannot be extended via a tie line to a subscriber in another P.A.B.X.

TIE LINES

The location of the four P.A.B.X.'s is indicated in Fig. 3. The Brussels P.A.B.X. is connected by means of one tie line to each of the three other boards. The Brussels P.A.B.X., therefore, serves as a tandem point, and a connection between any two of the outlying P.A.B.X.'s passes via Brussels and makes use of two tie lines.

The tie lines are rented from the Telephone Administration and are included in the main toll cables between the various towns. The characteristics of these lines are given in Table II. In Ghent, two of the tie lines are provided with voice frequency repeaters with 50 cycle by-passes.

50 CYCLE DIALLING

Due to the distances between the various P.A.B.X.'s, it would not be feasible, as already mentioned, to operate the tie lines on a D.C. signalling basis. Dial impulses, as well as other necessary signals, are therefore transmitted by means of 50 cycle alternating current.

[1] "Private Automatic Branch Exchanges," by W. Hatton and R. T. Ringkjob, *Electrical Communication*, January, 1936.

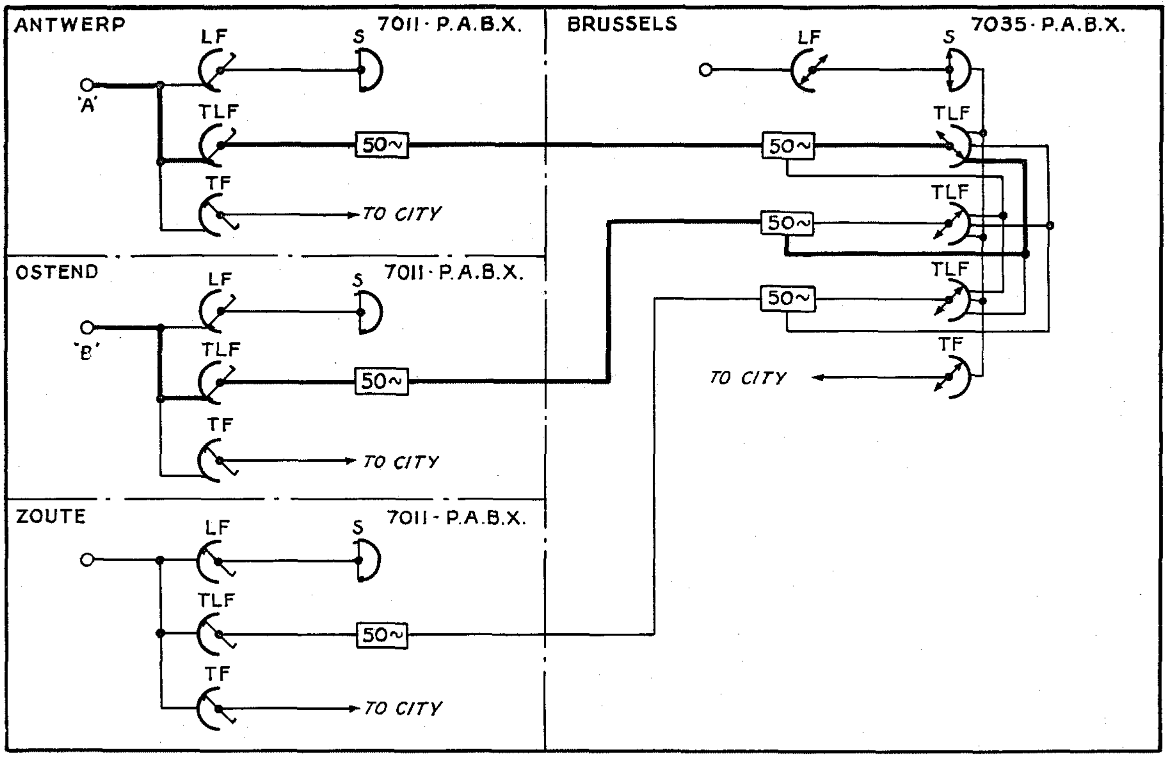


Fig. 2—Junction Diagram.

The principles of the receiving and sending circuits are substantially the same as those used in automatic long distance telephone practice.[2] Special precautions were necessary to obviate impulse distortion.

In ordinary toll connections, the originating dial impulses are transmitted by a home register; hence, the stepping conditions at the receiving end are relatively uniform. In the P.A.B.X. network, however, the originating substation is connected directly to the outgoing end of the tie line, the stepping relay of which re-transmits the substation dial impulses to the distant end. Fast and slow dials, long and short lines, as well as poorly insulated lines on the flying fields, therefore, all have a direct repercussion on the impulse transmission.

To overcome these difficulties, specially designed impulse correctors are included at the tandem point and, also, in the receiving portion of each tie line.

It may be of interest to note, incidentally, that a tandem connection is built up on the principle of forward dial impulses. A short 50 cycle starting impulse engages a distant tie line circuit, and a connection is broken down by

TABLE II

	Line	Distance in km	Diameter in mm	Loading
Brussels—Antwerp	Phantom	50.9	1.8	177/63 mH at 1830 m
Brussels—Ostend	,,	126	1.5	,, ,,
Brussels—Zoute	,,	126	1.5	,, ,,

[2] "A Field Trial of 50 Cycle Signalling on Toll Lines," by W. Hatton, *Electrical Communication*, October, 1936.

means of a long 50 cycle impulse sent out when the originating party hangs up.

NUMBERING SCHEME

The whole system was worked out on the basis of uniform numbering, i.e., a subscriber is always called by the same number regardless of the location of the calling station. On purely local calls, however, the prefix is omitted. The numbering scheme is shown in Table III. On local calls, the local number (1 or 2 digits) is dialled on receipt of dialling tone. On tie line calls, the first digit of the prefix is dialled; after receipt of the second dialling tone (from the distant tie line), the remaining two (or three) digits are sent.

TABLE III

	Directory Number	Prefix	Local Numbers
Brussels	99–10 to 99–59	99	10–59
Antwerp	66–0 to 66–5	66	0–5
Ostend	77–0 to 77–5	77	0–5
Zoute	88–0 to 88–5	88	0–5

In Fig. 2, the heavy lines indicate an established connection between station "A" in Antwerp and station "B" in Ostend. In this case, when "A" removes the receiver, he receives dialling tone from his local link and dials "7." The tie line finder hunts for and picks up the calling line, releases the local link and sends out a short A.C. impulse which engages the distant tie line circuit in Brussels. The latter sends back dialling tone, and "A" now dials the remaining digits, say "74."

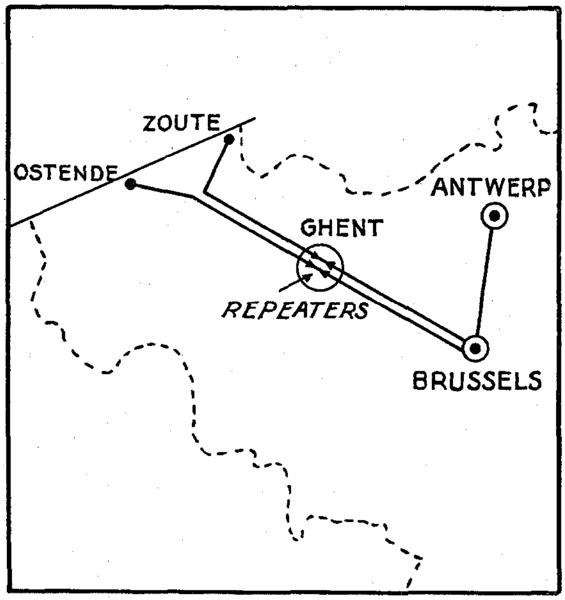


Fig. 3—Tie Lines.

The "7" directs the Brussels tie line finder to the outgoing tie line to Ostend and, during the interval between "7" and "4," the latter circuit transmits a short A.C. impulse to the tie line circuit in Ostend.

The last digit "4" is received on the tie line finder in Ostend (re-transmitted and corrected by Brussels); thus, subscriber No. 4 is selected.

Subscriber "B" (No. 4) is rung in the usual manner and, upon removing the receiver, conversation ensues.

When "A" hangs up, a long A.C. impulse is sent out, and all circuits are released.

On connections between Brussels and outlying P.A.B.X.'s, and vice versa, the second figure of the prefix serves no useful purpose and is suppressed.

POWER PLANT

Since reliability is of paramount importance, all P.A.B.X.'s are provided with a storage battery, trickle charged from a selenium rectifier. There is, consequently, no danger of service interruptions due to mains supply failure.

The 50 cycle signalling power supply is taken from the public lighting network. A 50 cycle reserve generator forms part of each installation.

Each P.A.B.X. is provided with a 50 cycle vibrator, which is operated from the P.A.B.X. battery and which is automatically cut into service if the mains supply fails.

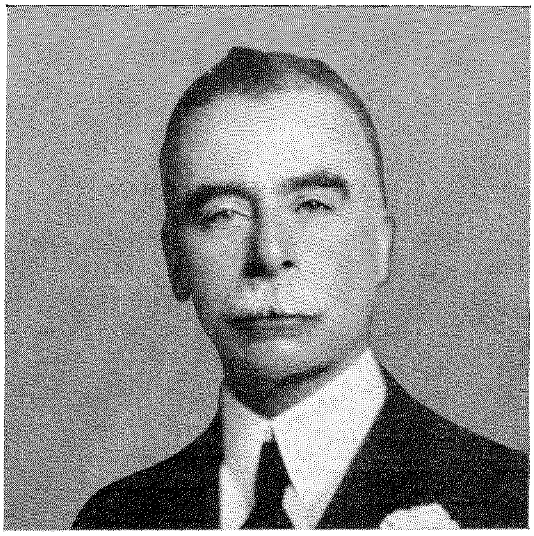
TELEPRINTER SERVICE

Associated with each P.A.B.X. is a voice-frequency operated teleprinter for the transmission of service reports. Teleprinter service is established between any two P.A.B.X.'s by first dialling the number of the Telex operator and then switching over to the printer.

The circuits also are arranged in a manner such that the teleprinter at any P.A.B.X. can intercommunicate with teleprinters at the Direction for Air Transport in Brussels via the city junctions and the regular toll lines.

CLARENCE HUNGERFORD MACKAY (1874-1938)

CLARENCE HUNGERFORD MACKAY, Chairman of the Board of Directors of the Postal Telegraph and Cable Corporation, President of the Commercial Cable-Postal Telegraph System, and a director of the International Telephone and Telegraph Corporation, died on November 12th, aged 64 years.



The son of the late John W. Mackay who in collaboration with James Gordon Bennett entered the electrical communications field in 1883 by laying cables across the Atlantic in competition with the powerful Jay Gould group and who in 1886 established the Postal Telegraph Cable Company, he became President of the Mackay System of telegraphs and cables on the death of his father in 1902. His contributions to progress in the world of electrical communications included the completion of the first trans-Pacific cable between the United States and the Far East in 1904, and the first New York-Cuba cable in 1907. During the same period, the Mackay System consolidated its position in the Atlantic by contracts with the German Cable Company, operating between New York and Emden, and by laying two additional cables, one connecting with the Azores, and so serving Southern Europe ; the other linking New York and Ireland, serving Great Britain and Northern Europe.

In 1928, negotiations between the Mackay Companies and the International Telephone and Telegraph Corporation resulted in a merger of the Mackay System with the International System. In the previous year the Mackay interests had acquired operating rights in the Federal Radio Company, thus becoming the first communications service in the world to operate radio, cables and telegraph lines under one management.

Mr. Mackay's interests outside his business activities were very diverse. A keen sportsman and an exceptionally fine shot, he had over sixty cups and trophies to his credit.

Reputed to have one of the world's finest private collections of armour, he also had an outstanding collection of pictures, tapestries and rugs. He was a director of the Metropolitan Opera Company, trustee of the Metropolitan Museum of Art, and Chairman of the Philharmonic-Symphony Society of New York. It was under his wise guidance that the Philharmonic Orchestra won its unique place in the world of music.

Among his many public services were his active interest in hospitalization work, and gifts aggregating $2 000 000 for educational purposes, including the erection and maintenance of the University of Nevada —Mackay School of Mines, a memorial to his father.

Mr. Mackay received numerous decorations, among which were : Officer of the French Legion of Honour ; Knight Commander of St. Gregory ; Commander of the Order of the Crown of Italy ; Cross of Knight Commander of the Order of the Crown of Belgium ; and Officer of the Order of Orange Nassau of Netherlands. His name will long be remembered, not only for his business and civic activities, but also for his generous support of the arts and sciences through which he made important contributions to cultural development.

Proceedings of the International Telephone Consultative Committee (C.C.I.F.)

COPENHAGEN, JUNE 11th–20th, 1936.
English Edition.

IN line with previous practice* the International Standard Electric Corporation has published an English translation of the proceedings of the XI Plenary Meeting of the C.C.I.F. held at Copenhagen, June 11th–20th, 1936. The form of the present translation differs from that of former years in that, for the most part, only changes in and additions to the previous (1934) volume, resulting from the 1936 Copenhagen decisions, have been included. Since a large portion of the recommendations and information contained in the 1934 edition still remains in force, it was thought best to deal solely with new or modified material. Thus changes in existing recommendations are clearly indicated.

The present volume comprises 388 quarto pages, uniform in format with previous volumes, and includes the following sections :

GENERAL.
PART I. Protection.
PART II. Transmission and Maintenance.
PART III. Operating and Tariffs.
PART IV. List of Questions set for study by the XI Plenary Meeting.
PART V. Composition of the Commissions of Rapporteurs of the C.C.I.F.
PART VI. List of C.C.I.F. Recommendations in force on January 1st 1937.
APPENDIX. Summary of Principal Recommendations made by the 3rd 4th and 5th C.R.'s at their meeting in Oslo, June 20th to July 2nd, 1938.
INDEX.

An important feature of the new edition is the index, which has been enlarged and revised to cover all material in the 1934 as well as in the 1936 edition. The new index co-ordinates both volumes, indicating where recommendations and information may be found in both the English and French editions, also whether material is new, modified or maintained unchanged.

Owing to the large demand, the customary nominal charge, to cover the cost of production will be made for copies of the new edition.

Requests for copies should be addressed to the International Standard Electric Corporation, Connaught House, Aldwych, London, W.C.2. or 67, Broad Street, New York City. A limited number of copies of the 1934 edition can also be supplied.

* "Proceedings of the International Consultative Committee on Long Distance Telephony," *Electrical Communication,* October 1932, July 1933 and April 1936.

Transmission Testing Apparatus for 30-10 000 p : s Communication Systems

By R. E. HERRICK, B.Sc., and H. MELLING, B.Sc., B.Eng.,

Standard Telephones and Cables, Limited, London, England

1.0 *INTRODUCTION*

A PAPER[1] presented before the Institution of Electrical Engineers in March 1924 dealt with the then contemporary aspects of the telephone maintenance and testing problem, and discussed in some detail the planning, economic, engineering and theoretical questions involved. It is interesting to note that, in general, the tests cited still apply on voice frequency long distance systems, indicating the soundness and far-sightedness of the work done up to that time.

The purpose of the present article is to outline, from the European viewpoint, developments in apparatus design and testing methods during the past fifteen years, including a brief exposition of the situation at the beginning of the period.

The description deals mainly with voice and broadcast frequency testing equipment, the primary reason being that testing methods and design have now to a considerable extent been rationalized and stabilized for frequencies of 30–10 000 p : s. It is planned in a subsequent article to consider in more detail the situation pertaining to measurements at higher frequencies.

Controversial questions involving maintenance methods, organization and the economics of the problem are not discussed. They, however, are important factors which have guided the lines along which development has proceeded.

It seemed advantageous to subdivide the article into sections corresponding, respectively, to the apparatus developed for one class of test. This arrangement was chosen because the same general development problems are encountered regardless of whether the apparatus is intended for factory testing, for installation and initial testing of the cable and associated repeater stations, or for routine maintenance of the system after it has been put into service.

It is not proposed to deal with testing equipment especially developed for use during manufacture, but the whole ground of installation and initial testing of a system, as well as service routine testing, will be covered.

2.0 *INSTALLATION AND MAINTENANCE TESTS*

The following tests must be made either during the installation of a system (as part of the installation procedure) or after completion of the installation as acceptance tests, in order to ensure satisfactory overall quality of the completed system. For the proper maintenance of a system, some of these tests must be made at regular intervals on a routine basis.

2.1 *Capacity Unbalance and Capacity Deviation Measurements*

During installation of a cable, the cable pairs at the various cable joints must be connected so that the capacity unbalances between the pairs produce a minimum of crosstalk.

It is thus necessary to make a very large number of capacity unbalance measurements between the various cable pairs and between the cable pairs and sheath before making the joints. Capacity deviation measurements also are required to ensure that the mutual capacity of all the circuits in the cable is sufficiently close to the mean mutual capacity. As any

[1] "Transmission Maintenance of Telephone Systems," by P. E. Erikson and R. A. Mack. *Journal of The Institution of Electrical Engineers*, 1924, Vol. 62, No. 332.

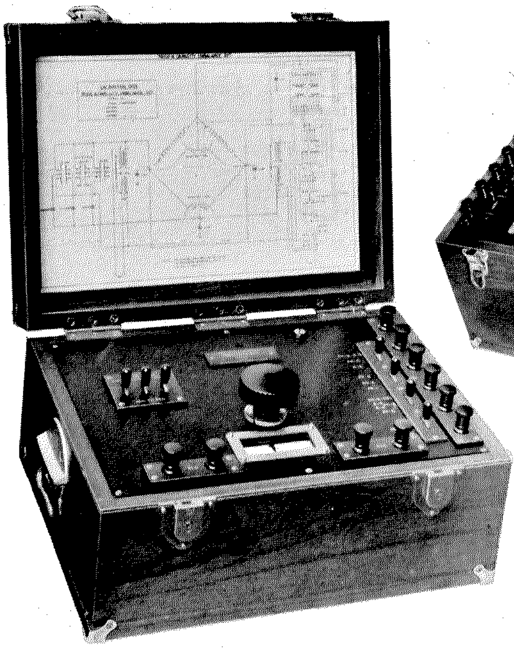


Fig. 1—74100-A Capacity Unbalance Set.

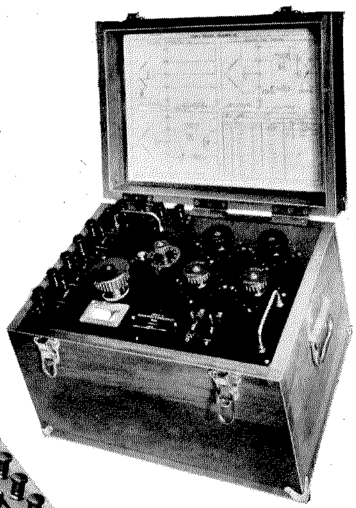


Fig. 2—74100-A Auxiliary Condenser Box.

to measure at regular intervals the transmission efficiency of each circuit and to check the specified performance. Consequently, transmission measuring equipment is installed in each repeater station.

2.4 Measurement of Cable Impedance

To guard against faults which may occur in the laying or loading of cable, it is necessary to determine whether the characteristic impedance of the cable and the specified requirements are met.

large capacity deviations critically affect the singing point of the repeaters, it is important that the limits of deviation imposed be properly met.

2.2 Crosstalk Measurements

The cable having been installed, crosstalk measurements between the various cable circuits, physical or phantom, are required in order to make certain that interference to conversations due to crosstalk will be negligible. Similar tests in the various repeater stations also are necessary to ensure that the cabling and apparatus do not cause crosstalk of a serious order.

2.3 Measurements of Transmission Efficiency

It is essential that the cable and associated repeaters, networks and kindred apparatus provide the desired performance both as to power transference and frequency characteristics. For maintenance purposes, it is usual

2.5 Measurements of Impedance Unbalance

When two-wire circuits are converted to four-wire circuits for the purpose of repeatering, or when four-wire cable circuits are converted to two-wire switchboard circuits, the necessary hybrid coil may be the cause of singing round the four-wire circuit.

The performance of the hybrid coil is to a large extent controlled by the degree of impedance matching which can be achieved between the two-wire circuit and an associated network connected with the coil. Apparatus must be provided for this determination.

2.6 Noise Measurement

Apparatus for checking freedom from interference other than crosstalk between the telephone circuits is essential. Such interference may be caused by close association of the cable with electric power circuits, electric railways, etc., or it may be introduced from the repeater station power supply circuits.

3.0 APPARATUS FOR INSTALLATION AND MAINTENANCE TESTING

The following seven subdivisions outline the development situation on certain sets, produced during the period under review for installation and maintenance measurement purposes. In view of the fact that the modern transmission measuring set has a very wide range of application in connection with both initial system and maintenance tests, it seems appropriate to devote the major part of the present article to consideration of this class of equipment.

3.1 Capacity Unbalance

To facilitate capacity unbalance measurements, two special portable sets of robust construction have been evolved: the 74100 type Capacity Unbalance Set, and the 74100 type Auxiliary Condenser Box (Figs. 1 and 2).

The Capacity Unbalance Set consists essentially of a retardation coil ratio arm bridge and a differential air condenser. Suitable switching facilities enable capacity unbalance between side to side, phantom to side, side to earth, and phantom to earth circuits of a cable quad to be determined directly.

The Auxiliary Condenser Box is used in conjunction with the Capacity Unbalance Set and enables the capacity deviation of the pair and phantom circuits from a standard capacity (predetermined by the operator) to be measured directly on the differential condenser of the Capacity Unbalance Set.

The Unbalance Set measures unbalances with an accuracy of $\pm$ 2 $\mu\mu$F, and the actual unbalance measurable is $\pm$ 1 900 $\mu\mu$F. Capacity deviation measurements may be carried out to an accuracy of $\pm$ 50 $\mu\mu$F.

Both these sets were developed as a result of accumulated field experience, and have been designed to combine speed and accuracy of measurement with minimum re-clipping of the test leads on the actual wires of the cable.

The 74100 type Oscillator, which is completely self-contained, has been specially designed for use with these sets. It is a single frequency oscillator with two low current consumption tubes arranged in push-pull, and possesses output and output impedance characteristics suitable for the efficient operation of the sets under all conditions.

3.2 Crosstalk Sets

The measurement of crosstalk is fundamentally one of attenuation measurement, i.e., determination of the ratio of the power in the disturbed to the disturbing circuit. It might be expected, therefore, that some similarity of method would exist between crosstalk and attenuation measurements. Such indeed was the case initially, the substitution method of measurement being common to both. The trend of crosstalk measurement, however, has not been so much towards increased accuracy but, rather, towards maintaining the accuracy of the original substitution method (well illustrated in the 74050–A Crosstalk Set) over a wider attenuation and frequency range.

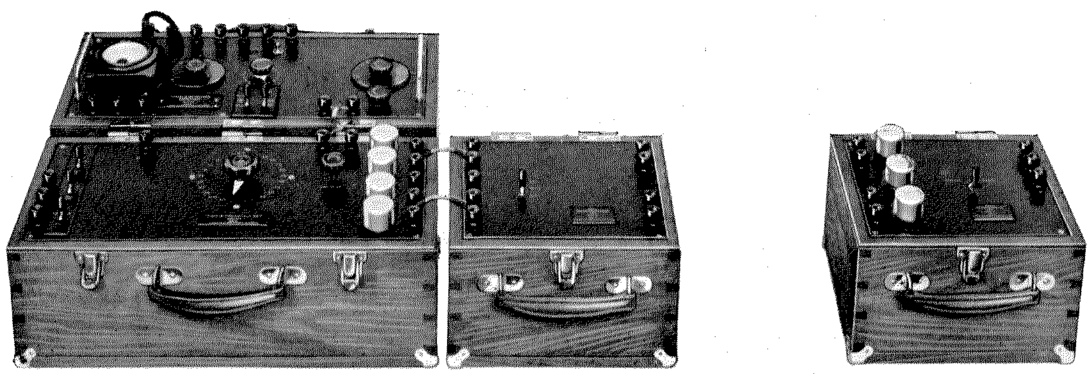


Fig. 3—74101-A Crosstalk Set, Amplifier, PH-S Unit and Terminating Unit.

A decade ago toll cable practice called for a crosstalk set capable of measuring crosstalk down to 10 Crosstalk Units, equivalent to 100 db. attenuation. The set in general use for such measurements was the 74050–A Crosstalk Set. Utilizing the substitution method, the observer listened alternately to the crosstalk tone and the disturbing tone, the latter being heard via a variable attenuator calibrated in crosstalk units. The attenuator was adjusted until the two tones were judged to be of equal loudness, the reading of the attenuator being the magnitude of the crosstalk. The set included a balanced retardation coil for measurement of phantom to side crosstalk. The limitation of accuracy was obviously set by the subjective nature of the method, while the minimum value of 10 crosstalk units was determined by the sensitivity of the telephone receiver and the observer's ear. Carrying out measurements in noisy locations also presented difficulties.

With improvements in cable technique, particularly the introduction of screened broadcast pairs, the demand arose for a crosstalk set capable of measuring pair-to-pair crosstalk down to a fraction of a crosstalk unit, and incorporating means for visual rather than aural balance of the disturbing and the crosstalk tone. Such a set involved an attenuation measurement of 126 db. on balanced circuits, and the problem was further complicated by the presence on most cable pairs of transverse and longitudinal noise voltages of a magnitude seriously interfering with measurement of fractional crosstalk units. The new set, developed and coded as the 74101 type Crosstalk Set (Fig. 3) provides for crosstalk measurements over a range of 7 000–0.5 crosstalk units (approx. 43–126 db.), at any frequency between 200 p : s and 25 kc/s.

This set retains the substitution method which, for measurement of high attenuation, is still the simplest and the most accurate.

Naturally, crosstalk measurements as low as 0.5 crosstalk units would not be possible without a high gain amplifier, inasmuch as the extremely weak crosstalk currents must be raised to levels capable of being heard in a telephone receiver. Further, where visual indication is required, the amplifier must have sufficient gain to give a meter reading. The 74102–A Crosstalk Detector Amplifier was accordingly developed. By the operation of a key, it can be utilized in three distinct ways:

(*a*) As a flat amplifier (200–3 000 p : s) for measurements with a complex testing tone, e.g. the human voice or some special buzzer such as the 74020–C Test Set, which gives crosstalk results closely approximating to those obtained with the voice.

(*b*) As a tuned amplifier capable of being tuned to any frequency between 500 p : s and 2 500 p : s, thus enabling unwanted line noises to be rejected.

(*c*) As a detector amplifier for carrier frequency measurements.

In order to obtain high accuracy with the 74101 type crosstalk set at the high attenuations involved, the circuit was made as simple as possible; no facilities, therefore, were included for phantom to side crosstalk measurements. A separate unit was developed for phantom to side measurements in conjunction with the side to side crosstalk set. This unit, which has a high degree of balance, is coded as the 74101–A Phantom to side unit.

The above group of modern voice frequency crosstalk measuring apparatus was completed by the design of the 74101–A Terminating Unit, suitable for terminating the circuits under test. Fig. 3 shows the complete kit.

3.3 Transmission Measuring Sets

The apparatus provided for this purpose consists essentially of a source of A.C. tone which is transmitted into the cable or apparatus to be measured, and a transmission measuring set to measure the power level at various points on the system. For routine maintenance measurements such apparatus is ordinarily included in the test rack equipment in each repeater station whilst, for installation and fault diagnosing, additional apparatus in portable form is usually desirable.

(*a*) *Early Sets*

Typical apparatus, prior to 1924, consisted of the 74002 type Oscillator and the 74001 type Transmission Measuring Set. They were designed for measuring line and exchange losses at a single 1 000 p : s frequency. The oscillator included a carbon microphone coupled to a receiver by a tuned bar, whilst the transmission measuring set was of the substitution type in which the circuit under test and a variable attenuator were switched in turn between the oscillator and a head receiver. The attenuator was adjusted until the tone heard in the receiver was equal to the tone heard when the line under test was connected in circuit. The reading of the attenuator then indicated the loss in the circuit under test.

The accuracy of this combination was limited by the poor waveform of the oscillator and the sensitiveness of the ear of the tester at various power levels, the latter being important because of the low power levels at which the apparatus must be used. It was also restricted in its range by the fact that it was a single frequency device, and was not suitable for attenuation measurements on looped circuits. It was, furthermore, a low impedance device adaptable only to "loss" measurements, its design precluding the taking of "level" measurements at various points on a toll cable circuit.

(*b*) *Use of the Thermocouple and Thermionic Valve*

A great advance in the design of transmission measuring apparatus was achieved by the use of the then recently developed vacuum tube, and the application of the thermocouple junction. The oscillator then became a valve-operated device with greatly improved waveform and stability of frequency and output, whilst the measuring panel took the form of an A.C. valve-amplifier followed by a valve-rectifier operating a sensitive D.C. microammeter. It was possible, furthermore, by means of the thermocouple, to check the level at which the testing power was sent into the circuit, and a standard sending level of 1 milliwatt was adopted. This sending circuit was also used to calibrate the amplifier-rectifier, the gain being adjusted for a certain predetermined deflection of the D.C. meter. The amplifier was preceded by a calibrated attenuator which altered the overall gain by a known quantity. Measurement was carried out by connecting the circuit under test (into which a 1 milliwatt tone was sent) to the amplifier, and adjusting the overall gain by means of the calibrated attenuator until the D.C. meter again gave the predetermined deflection. Hence the circuit attenuation was indicated by the reading of the calibrated attenuator.

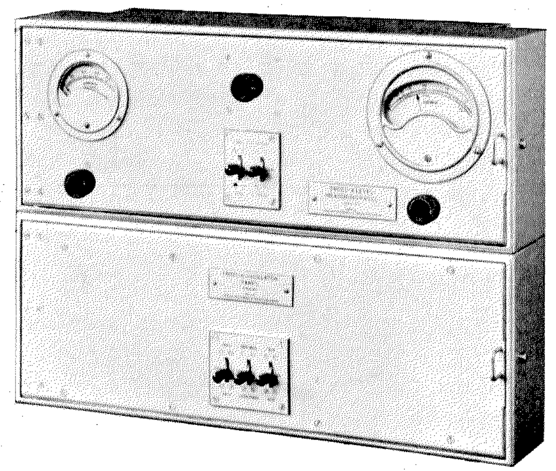


Fig. 4—74022-*A Level Measuring Panel and* 74021-*A Oscillator.*

In addition to the advantage of visual as compared with aural indication, this new combination represented a marked advance as regards increased accuracy in making measurements, adaptability to obtaining readings at low levels, and the facility of conducting tests at predetermined levels.

Originally these sets were designed to operate from 24-volt exchange batteries, and the 74003 Type Transmission Measuring Set enabled equivalents as low as 30 db. (the set was calibrated in miles of standard cable) below 1 milliwatt to be measured. This set was, however, still restricted to single or narrow band frequency measurements.

With the advent of valve repeaters it became both necessary and advantageous to design sets operating from 130-volt and 24-volt repeater station batteries, whilst improvements in coil design made it possible to extend the voice frequency measuring range over 200 to 3 000 p : s. It was necessary, owing to variation in oscillator output and amplifier gain with frequency, to make calibration adjustments at each frequency. Sets were then manufactured for installation in the test position of each repeater station. The 74004 type Transmission Measuring Set (which included numerous switching facilities) marked the stage where this type of apparatus was installed in repeater stations and used for maintenance purposes.

At the same time special sets were developed for measuring repeater gains, the 74002–A and 74003–A Gain Sets being typical examples. They operated on the substitution principle, an attenuator being inserted in front of the repeater and its reading adjusted until the transmission equivalent of the circuit equalled that in the calibrated position. Measurement was generally made with a 1 000 p : s valve oscillator and the detecting device usually was a thermocouple or an amplifier detector, although in some circumstances the telephone receiver still continued to be employed.

The introduction of broadcast circuits made it necessary to extend the frequency range of the apparatus over 30 to 10 000 p : s. Improvements in coil and circuit design enabled the amplifiers, oscillators and sending circuits to be suitably modified.

The culmination of this phase of development was reached with the 74006 type Transmission Measuring Set and the 74010–B Oscillator. These were sets of very high performance, and were adopted as standard equipments for routine maintenance measurements. They may be seen side by side in a great number of repeater stations throughout the world. The measuring set offered facilities for transmission measurements over the range + 20 db. to – 30 db. referred to 1 mW, special provision being included for the measurement of repeater gains and for talking and setting up measuring circuits in repeater stations. The accuracy of measurement was ± 0.2 db. over the frequency range 30 to 10 000 p : s and ± 0.1 db. from 200 to 3 000 p : s. The oscillator was extremely stable and was very closely and accurately calibrated over the whole frequency range, thus providing means for precise measurements in the region of the cut-off frequency of cable and filter circuits.

It was also possible to make voltage or "level" measurements by designing the amplifier of the transmission measuring set with a high input impedance so that it consumed negligible power from the circuit under test. The performance of a toll circuit could thus be checked simultaneously at all repeater stations throughout the cable length by sending standard power into one end of the circuit and bridging a transmission measuring set across the line at each repeater station.

It was, however, necessary to carry out calibration adjustments at each frequency; hence, though achieving highly accurate performance, the time occupied in taking a number of frequency runs was still a serious factor.

For special measurements, installation and acceptance test work, transportable counterparts of these two sets were used—the 74008–A Oscillator and the 74100 type Transmission Measuring Set. The latter was particularly adapted to measurement work on toll cables.

(*c*) *Direct Reading Sets*

As toll circuits multiplied and the number of repeaters in the stations increased, speed of testing became more and more important, especially for routine measurements. With the then existing sets the number of adjustments on the oscillator for each frequency setting might be as many as six or seven, whilst the transmission measuring set required three adjustments, i.e., calibration of the oscillator for sending purposes, and adjustments (two) in connection with the amplifier calibration. Measurements were consequently slow and laborious, especially where frequency runs had to be made, whilst extreme accuracy of measurement achieved by these sets was not always necessary.

Clearly, for the rapidly growing number of necessary routine measurements, testing equipment both simple and rapid in operation was required, though not necessarily highly accurate in performance. To meet this demand, the 74021 type Oscillator and 74022 type Level Measuring Panel were developed (Fig. 4). The oscillator was designed to give seven fixed frequencies (spaced throughout the voice frequency spectrum from 200 to 3 000 p : s) by the simple operation of a key. This eliminated the necessity for a calibration chart and numerous dial settings for each frequency; and, whilst the oscillator did not have exactly constant output with frequency, the outputs were sufficiently level (within about 2.0 db.) to enable the level measuring set to be easily operated. Setting the oscillator was therefore greatly expedited, while the performance, though not as good from the viewpoint of frequency stability and flexibility as the 74010 type, was adequate for its purpose.

The 74022 type Level Measuring Panel represents the beginning of a further stage of measuring set development and was the first "direct reading" transmission measuring set to be produced. By this is meant that it was the first set to have the indicating meter calibrated directly in decibels or nepers, and requiring calibration at a single frequency only. It also incorporated a metal rectifier in place of a thermocouple for sending purposes, thus further obviating calibration. The operation of this set, therefore, was extremely simple, calibration adjustments at different frequencies not being required. The set covered the frequency range 200 p : s to 3 000 p : s and measured levels from + 15 db. to − 35 db. referred to 1 mW with an accuracy of ± 0.5 db.

This combination increased the speed of maintenance measurements tenfold and, although the performance was not as precise as that of the 74006 type Transmission Measuring Set and 74010-B Oscillator, it was found to be adequate for routine measurements. The panels also were smaller and simpler, while the space occupied and the cost of the equipment was considerably reduced.

The advent of these direct reading sets was brought about by the following developments in technique :

(1) Improved coils, enabling amplifiers with a very flat characteristic to be developed. The modern feed-back amplifier, of course, has made possible further improvements in this direction.

(2) Production of " shaped pole " meters in which the current deflection law is such that an approximately evenly divided decibel or neper scale can be achieved.

(3) Application of the metal rectifier meter, a useful instrument for the measurement of alternating currents. Though not so accurate, and possessing inherent disadvantages, due to the temperature coefficient and self capacity of the rectifier, it was found possible to substitute it for the thermocouple junction in voice frequency measurements of this nature. The three main disadvantages of the thermocouple, viz., fragility, delicacy

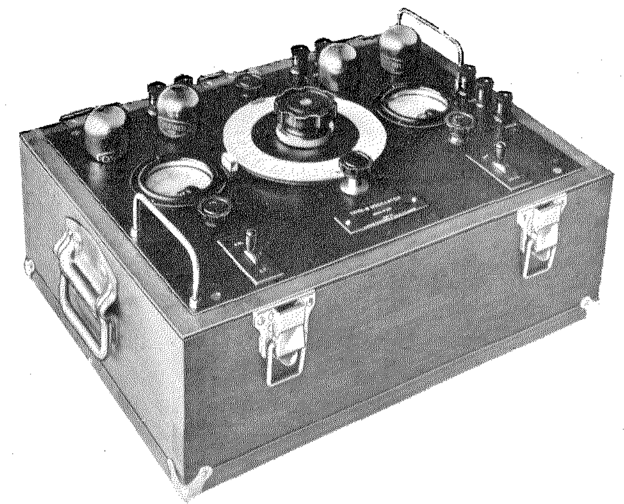


Fig. 5—74101-B Oscillator.

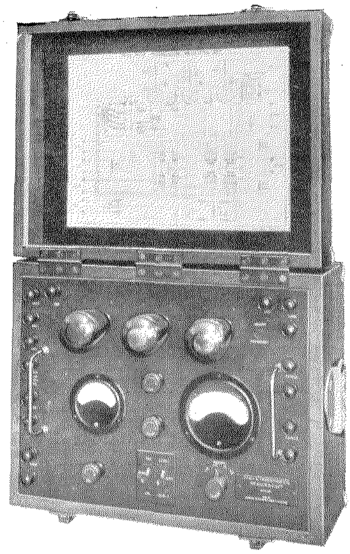


Fig. 6—74101-N Transmission Measuring Set.

and expensiveness of the associated direct current meter, and the necessity for direct current calibration, were overcome by the use of the rectifier although, as previously stated, the latter introduced errors of its own. It was found, however, to be satisfactory for certain types of transmission measuring equipment; and, as development proceeded, it became possible, by careful circuit design, to extend its use over the whole voice frequency range up to 10 000 p : s without introducing serious errors.

The success of the direct reading combination was so marked that it was clearly necessary to proceed further with the development of sets of this type. The next combination to appear was the 74101 type Heterodyne Oscillator (Fig. 5) and the 74101 type Transmission Measuring Set (Fig. 6). The Heterodyne Oscillator introduced further simplification in operation since it incorporated a single dial engraved directly in frequency, enabling all frequencies in the 30 to 10 000 p : s band to be obtained with an accuracy of ± (2% ± 2 p : s). It also had an output constant within 0.25 db. over the entire frequency range, and was thus suitable for measuring frequency characteristics without alteration of the sending adjustment. The transmission measuring set was similar in design to the 74022 type, employing a constant gain amplifier, a metal rectifier, and a "shaped pole" meter engraved direct in decibels or nepers. It covered the range 30 to 10 000 p : s, measuring from + 15 db. to − 45 db. referred to one milliwatt with an accuracy of ± 0.25 db. The apparatus was in portable form and was the first measuring combination of any accuracy to be really light and suitable for transportation from station to station. It also had the advantage of covering broadcast circuit requirements.

The simplicity and speed of operation of this pair of sets were of course in advance of any of the preceding sets. A frequency-level characteristic could be obtained by merely rotating the dial of the heterodyne oscillator through the required frequency range and noting the reading of the meter of the measuring set. Despite the fact that the accuracy was inferior to that of the highly precise 74006 type Measuring Set, the advantages of the new sets were instantly appreciated and they began to be used under all circumstances where speed of operation justified the sacrifice of extreme accuracy.

Sets similar in circuit and performance were then designed for rack mounting, viz., the 74201-A Heterodyne Oscillator and 74201 type Transmission Measuring Set. They are being used as a standard in smaller repeater stations where apparatus of greater precision and higher cost is not economically justified. The transmission measuring set includes means for sending constant voltage for lining up broadcast circuits, and also low level sending facilities for measuring repeater gains.

The next step was the production of two sets of precision sufficient to warrant their use in large repeater station for more accurate work, whilst retaining the simplicity of operation of the direct reading feature. These sets, the 74102-A Heterodyne Oscillator (Fig. 7) and the 74102 type Transmission Measuring Set (Fig. 8), have been installed in a number of major repeater stations in Europe with very satisfactory results. A brief summary of their specifications and method of operation will serve to indicate the level which the design of direct reading transmission measuring equipment has reached.

74102–A Heterodyne Oscillator

Output : 0.3 W into 600 ohms. Constant with frequency to within ± 0.1 db.
Harmonic Content : Less than 2%.
Frequency Range : 30–10 000 p : s.
Accuracy of Frequency : ± (2% + 2 p : s).
Scale Law : Linear to 100 p : s. Logarithmic 100 p : s to 10 000 p : s.

The scale is engraved on a dial of a specially designed high grade condenser. This latter forms the tuning element of one of two high frequency oscillators operating at a nominal frequency of 100 kc/s. These two oscillators are jointly modulated by means of a double-balanced metal rectifier circuit, and the voice frequency output is applied to a push-pull amplifier producing the necessary output level.

74102–A Transmission Measuring Set

Sending Facilities : The set when used with the above oscillator delivers the following power levels :

(*a*) 1 milliwatt, – 10 to – 50 db. referred to 1 mW in steps of 10 db., into a 600 ohm circuit from an internal impedance of 600 ohms;

(*b*) 0.775, 1.55, 2.1 and 4.0 volts from a low internal impedance (constant voltage sending) into a 600 ohm circuit.

The accuracy of the sending level is ± 0.2 db. over the frequency range 30 to 10 000 p : s.

Receiving Facilities: The set measures levels between + 25 and – 50 db. referred to 0.775 volt over the frequency range 30 to 10 000 p:s. A 600 ohm termination is provided for use when it is required to measure transmission equivalents. The accuracy is ± 0.2 db. over the whole frequency range and is considerably greater when measurements are carried out at 1 000 p : s.

The set is equipped with a direct reading meter covering a range of 15 decibels, the meter having shaped poles to give an evenly divided scale, whilst the amplifier has a flat frequency characteristic so that calibration is necessary at one frequency only before taking a frequency run. The sending circuit employs a metal rectifier meter to indicate the power level; by suitable circuit design, this meter has been found to give results nearly as good as the thermocouple. It requires no preliminary direct current calibration.

A comparison of the adjustments necessary with this combination and with the 74010 type Oscillator and 74006 type Transmission Measuring Set serves to indicate the simplicity and speed of operation attained. (See Table I.)

It must be borne in mind that the absolute accuracy of the old type of set has still not been achieved in these new sets; and, in particular, the 74102-A Heterodyne Oscillator does not compete with the 74010 type Oscillator where frequency, accuracy and stability are of the greatest importance. Experience has shown, however, for the great majority of toll system measurements, that the accuracy of the new equipment is ample, whilst the facility of taking a frequency characteristic by simply rotating the oscillator condenser dial and reading the meter of the transmission measuring set has

TABLE I.—COMPARISON OF ADJUSTMENTS

Oscillator

	74010 (*older type*)	74102 (*newer type*)
Preliminary Adjustment	Nil	Zero beat calibration (setting of one dial).
Setting of Frequency	Adjustment of Feedback resistance, four condenser dials, and a switch from a calibration chart.	Rotation of one dial until correct reading is noted.
Control of Output.	Adjustment of dial at each frequency.	No adjustment necessary if constant output required at each frequency, after initial adjustment of one knob.

Transmission Measuring Set

	74006 (*older type*)	74102 (*newer type*)
SENDING.	Two preliminary adjustments for calibration of thermocouple and adjustment of one knob at each frequency.	Adjustment of one knob at initial frequency setting only.
RECEIVING		
(*a*) *Calibration.*	Throwing of key and adjustment of one dial at each frequency.	Throwing of key and adjustment of one control at a single frequency only.
(*b*) *Measurement.*	Throwing of key and adjustment of one dial at each frequency.	Reading indicated directly on the decibel (or neper) meter unless levels vary by more than 15 db., when one dial has to be operated.

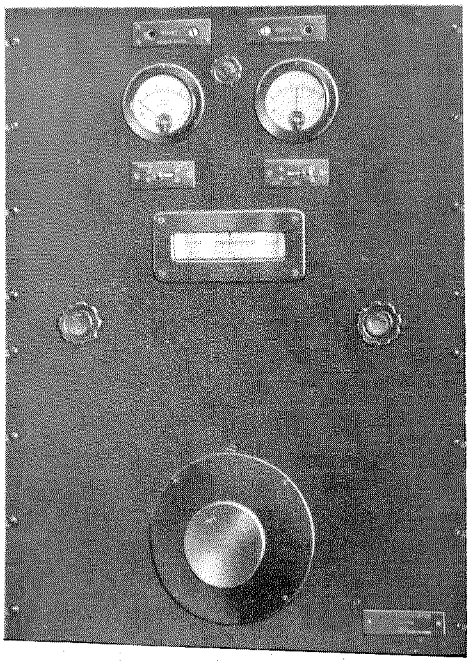


Fig. 7—74102-A Oscillator.

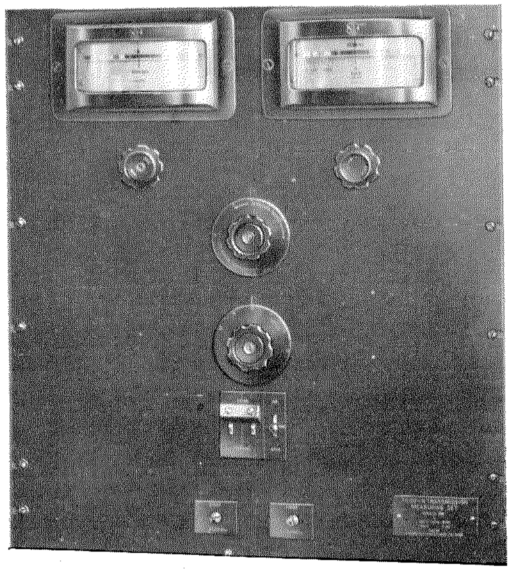


Fig. 8—74102-A Transmission Measuring Set.

proved to be a very great labour-saving and, therefore, an economic advantage.

(*d*) *Automatic Level Recorders*

The logical development of these advantageous direct reading sets was the recording of frequency characteristics automatically on a chart, thus eliminating any necessity for taking and recording columns of readings. This facility is of particular importance when lining up international cable circuits since it enables a record of the circuit performance to be taken at the frontier of each transit country, and forms concrete evidence of the condition of the circuit in the domain of each Administration.

From the facilities offered by the Heterodyne Oscillator and the direct reading type Transmission Measuring Set it will be clear that, if the oscillator frequency condenser is mechanically driven, and the movement of the receiving meter is simulated on a recording meter with a chart moving in synchronism with the speed of the condenser, it will be possible to record on the chart of the latter meter the frequency-level response characteristic of any circuit. In the completed recorder the vertical time lines of the chart are engraved in frequencies corresponding to those transmitted by the oscillator, and the horizontal lines are engraved in decibels or nepers to correspond with the readings of the transmission measuring set meter.

The 74102 type Automatic Level Recorder (Fig. 9) is designed to provide these facilities and is built around the 74102-A Heterodyne Oscillator and 74102 type Transmission Measuring Set. It is mounted on two racks, one containing the sending and the other the receiving equipment, and is arranged to operate from the normal repeater station batteries.

The Heterodyne Oscillator is mounted on the sending bay immediately below the 74102-A Driving Panel. The latter includes a governor-controlled electric motor for driving the oscillator condenser, together with suitable relay equipment.

On the receiving bay is fitted the Transmission Measuring Set and, immediately above, the 74102-A Recorder Amplifier panel, which contains the recording meter, together with a suitable amplifier for repeating the reading of the transmission measuring set meter.

To conform with the standardized requirements of the C.C.I.F., laid down to ensure interworking, the speed of the electric motor driving the oscillator condenser, and the clockwork motor driving the recording meter chart, are synchronized so that the time to run from zero frequency to 10 000 p : s is 121.2 seconds. The precise C.C.I.F. requirements relating to the frequency time scale law have also been achieved.

The apparatus is arranged so that the sending equipment may be located at one terminal and receiving equipments at the principal stations along the cable. The sending equipment then controls the taking of a record ; arrangements are such that, when the oscillator condenser passes the zero frequency mark, a signal of 1 300 p : s and of 1.5 seconds duration is transmitted along the line under measurement. This signal trips relays in the circuits of each receiving equipment and starts the recording meters, thus ensuring that they are in synchronism with the oscillator condenser.

Single button starting and automatic restoration at the completion of a record are employed. The total time required for taking a complete record and restoring the level recorder to rest is 3 minutes. When this time is compared with that required with the old step-by-step method, the great advantage of the instrument in busy stations will be appreciated.

Quite apart from the advantages of speed and the provision of comprehensive and permanent records of line characteristics, the new method tends to reduce conversation between repeater stations on the circuits under test.

This apparatus is accurate to approximately $\pm$ 0.5 db.—sufficient for most routine measurements—and is arranged so that it may be operated manually to give improved accuracy when desired.

An additional panel equipped on the sending rack enables singing point frequency characteristics to be taken when required (see section 3.5), whilst the Level Recorder is equipped with a suitable telephone panel, link panel and battery supply circuit for making easy connections to circuits.

These sets are installed in a number of the large repeater stations in Europe and have been found to greatly speed up the routine maintenance of the toll and broadcast circuits.

(*e*) *Mains-Operated Sets*

The present trend in the operation of repeater

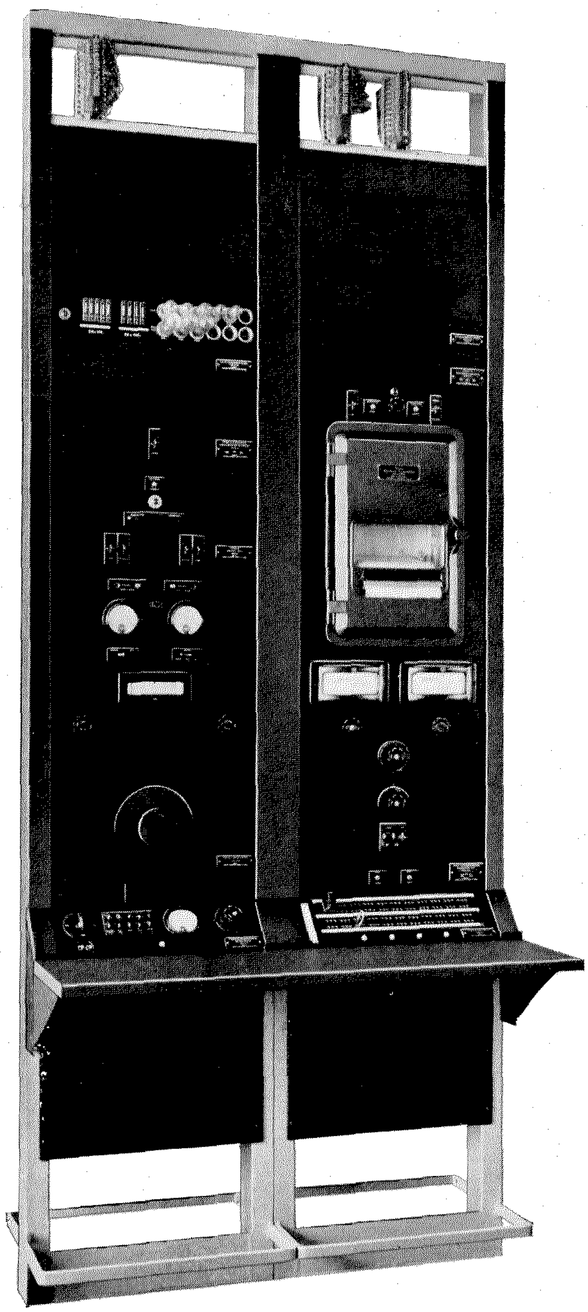


Fig. 9—74102-A Automatic Level Recorder.

stations is towards the use of high voltage A.C. mains rather than accumulator batteries. To meet these conditions, two mains-operated sets have been produced, the 74104 type Heterodyne Oscillator (Fig. 10), and the 74109 type Transmission Measuring Set (Fig. 11). They are the mains-operated counterparts of the 74101–A Heterodyne Oscillator and the 74101 type Transmission Measuring Set previously described. In addition to providing the same facilities as these sets, they are light and portable, and cover the frequency range of 30–10 000 p : s and the level range of + 25 to — 45 db. with an accuracy of ± 0.25 db. These sets are also being produced in rack mounted form for small repeater stations.

The 74109-A Transmission Measuring Set does not provide sending facilities. A separate set, coded the 74101-A Sending and Impedance Unbalance Unit, however, is supplied ; it provides for sending 1 mW, low levels for gain measurements, and constant voltages from low impedances. As explained in section 3.5, this unit also serves for making singing point measurements.

Work is at present proceeding with the conversion of the 74102-A Automatic Level Recorder, to enable the whole range of measuring equipment to be available in mains-operated form.

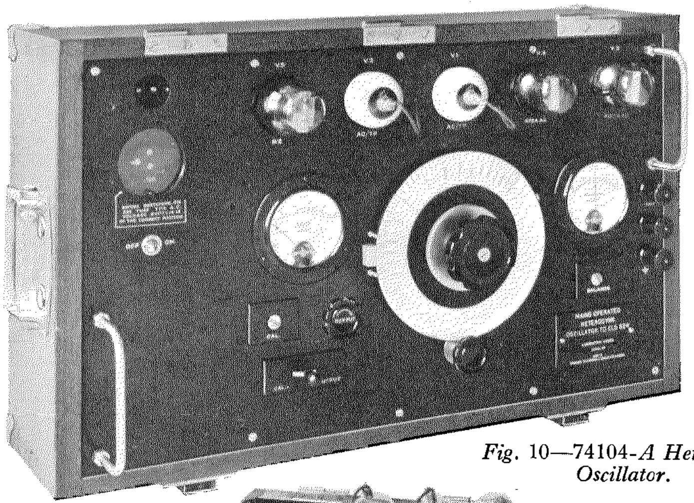


Fig. 10—74104-A Heterodyne Oscillator.

Fig. 11—74109-A Transmission Measuring Set.

3.4 Impedance Bridges

Two types of bridge have been developed for impedance measurements. The earlier was the 74001-B Impedance Bridge. It was a portable instrument built in three units, consisting of an inductometer, a resistance box containing the ratio arms, and a fixed air cored inductance. The design consisted of an ordinary bridge circuit with resistance ratio arms. The measuring arm contained the resistance decade; and, according to the angle of the impedance to be measured, the inductance elements were switched into either the measuring or unknown arm, thus enabling positive or negative angles to be measured. In each case simultaneous switching of resistances enables the resistance of the inductometer and fixed inductance to be compensated for. This bridge gave direct indication of the cable impedance in terms of series resistance and series reactance. The frequency range covered was approximately 200 p : s to 2 800 p : s with an accuracy at 800 p : s of about ± 1% on effective resistance and ± (1% + 0.001) henry on effective reactance.

While fundamentally simple and easy to operate, the bridge contained certain mechanical and electrical deficiencies. The three units were somewhat cumbersome and not particularly well adapted to easy transportation. In addition, the decreased accuracy at the top of the frequency range hardly made it suitable for measurements on modern loaded repeater circuits. To meet more exacting requirements a new type of bridge, the 74102-A Impedance Bridge (Fig. 12), was introduced. This bridge is built in a single unit and, being housed in a solid teak box, is much more suitable for transport than the older type. The ratio arms are formed by a balanced hybrid coil, whilst the measuring elements are resistance decades accurate to ± 0.1% and a capacity decade accurate to 0.5%. These two elements are arranged in parallel for negative angle measurements, whilst for positive angle measurements the capacity decade is in parallel with the unknown impedance.

The cable impedance is therefore measured in terms of parallel resistance and reactance. Greater accuracy and a wider frequency range are attained as compared with the 74001-B type and the mechanical construction is more modern. The design is such that the calibrated condenser decades, resistance decades, or hybrid coil may be disconnected and used for other purposes when desired.

3.5 Impedance Unbalance Measuring Sets

1. *Principle of Design*

All these sets employ the well-known properties of the three-winding transformer or hybrid coil. A source of tone and an amplifying detector are connected to the coil in a manner such that, when perfect balance obtains between the impedances connected to the bridge arms of the coil, no tone is transmitted to the amplifier. If, however, the balance of the impedances is disturbed the amplifier receives tone and it can be shown that, provided the coil input level of the source of tone is known, the output of the amplifier, when calibrated, can be made to measure the impedance unbalance of the two

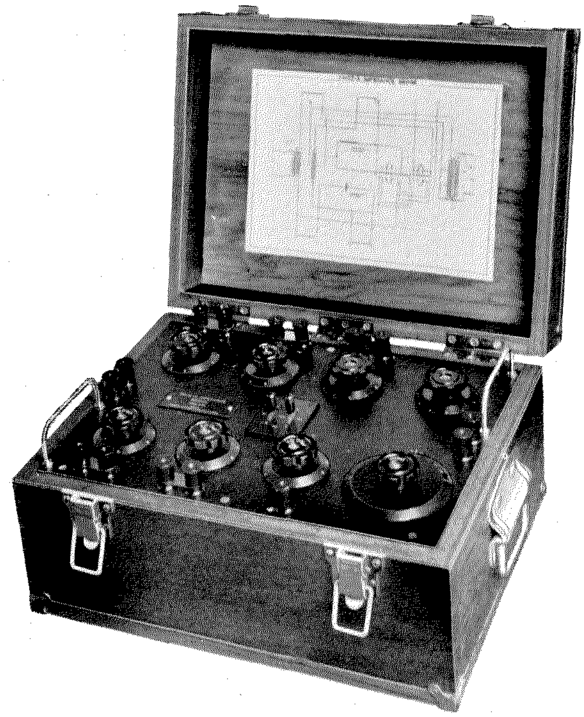


Fig. 12—74102-A Impedance Bridge.

impedances directly. Impedance unbalance is defined as 20 Log $\frac{Z_1 + Z_2}{Z_1 - Z_2}$ decibels, where Z_1 and Z_2 are the two impedances in question. The line and network to be tested may therefore be connected across the bridge arms of the hybrid coil and the unbalance determined by means of the amplifier.

2. *Measuring Sets*

A comparatively early set incorporating these principles was the 74100 type Impedance Unbalance Measuring Set. This set contained a suitable hybrid coil, a thermocouple sending circuit for determining the level of tone applied to the coil, and an amplifier detector of adjustable gain to measure the singing point. The detector was a valve rectifier followed by a D.C. microammeter, and the amplifier was operated on the substitution principle in a manner somewhat similar to the 74006 type Transmission Measuring Set, described in section 3.3. Calibration was effected by connecting a pair of resistance spools of known unbalance across the hybrid coil and adjusting the gain of the amplifier until the meter pointed to a specified mark. The impedances to be measured were then connected to the hybrid coil and the gain of the amplifier adjusted, by means of a dial engraved in decibels, until the meter again gave the same reading. The engraving on the dial then read the singing point directly. This set covered the frequency range 200 to 3 000 p : s and measured singing points from 0 to 40 db. It required adjustment of the sending circuit and recalibration of the amplifier at each frequency and was heavy to transport and somewhat tedious to operate.

The advent of the direct reading transmission measuring set opened up a field for a much simpler set, for it was clear that the sending and receiving portions of such a set could be used for singing point measurements provided an external hybrid coil was used. The 74101 type Impedance Unbalance Attachment was therefore produced in 1935 for use with the 74101 type Transmission Measuring Set. The sending circuit of the transmission measuring set was used to send a known level into the coil, and the receiving circuit to read off the singing point directly in decibels or nepers. Calibration of the receiving circuit of the transmission measuring set was performed by connecting resistances of known unbalance across the coil and adjusting the gain so that the transmission measuring set meter read the correct singing point.

This panel represented a great advance over the 74100 type Impedance Unbalance Measuring Set. It decreased the time of operation inasmuch as all the advantages of the 74101 Transmission Measuring Set, i.e., simple adjustment, direct reading and calibration at one frequency only, were available. The size and weight were radically reduced (from 100 lb. for the 74100 Impedance Unbalance Set to 18 lb. for the 74101 type Impedance Unbalance Attachment). This new panel covered the frequency range 300 to 5000 p : s, measured singing points from 0 to 45 db., and was provided with an impedance matching switch which enabled singing points to be measured accurately over the impedance range 500 to 3 000 ohms.

In 1936 the necessity for providing constant voltage sending on transmission measuring sets prompted the omission of the impedanc matching switch since, when constant voltage i applied to the hybrid coil, the voltage develope across the amplifier terminals is independent o the characteristic impedance of the circuit an only dependent on the unbalance. Simultaneously, the frequency range was extended t cover 30 p : s to 10 000 p : s and the hybrid coi balance improved so that singing points up t 55 db. could be measured. The 74102 typ Impedance Unbalance Attachment, designe for rack mounting and consisting of a simpl panel $3\frac{1}{4}'' \times 19''$, furnished these facilities. I was associated with the 74102 type Automati Level Recorder and made possible singin point measurements and frequency-singing poin characteristic recordings with the simplicit that now obtains on ordinary level and los measurements.

For portable purposes the circuit was embodied in the 74101 type Sending and Impedance Unbalance Unit (Fig. 13), a set which wa designed for use with the portable 74101 o 74109 type Transmission Measuring Sets.

It will be noted that the development tren has resulted in the production of a very smal and cheap attachment, suitable for use in con junction with the modern direct reading trans mission measuring set and heterodyne oscillato Thus both the cost has been reduced an operation simplified.

3.6 Noise Measuring Sets

Since noise present in a telephone circui reduces the intelligibility of the conversation it is essential that every means be adopted t keep the noise level within reasonable limits This is achieved both by study of the interferin sources, i.e., power lines, traction circuits telegraph circuits, faulty metallic contacts, etc. and by investigation of methods for the reduc tion of their interference with the communica tion circuit. In order that the required in telligibility may be attained, the tolerable nois on any toll telephone circuit has now bee determined and limits imposed. For all thi work some simple, accurate, and portable forn of noise measuring set is indispensable.

Until recently no unit, which enabled th noise level on a telephone circuit to be simpl stated, was in general use. However, when th

C.C.I.F. definition of psophometric E.M.F. was issued, and when the same body prepared a specification for a line noise meter, or psophometer, the art of noise measurement took a considerable stride forward.

Previously noise measuring sets had been of the subjective type, the observer adjusting some "standard noise" until, in his opinion, it was as loud as the circuit noise. All sets based on this method were subject to the personal errors of the particular observer, a large number of tests by different observers being required to render the result free of such errors. It should also be noted that this method gave a measure of the loudness and not the intelligibility reduction factor of the noise.

The psophometer, as defined by the C.C.I.F., departed from this subjective method and took the objective form. It was an attempt to produce an electrical system equivalent to the complex acoustic-electric system of the human ear and the telephone receiver. As such it must of necessity remain a somewhat crude approximation; nevertheless, providing its basic limitations are recognized, it forms a very valuable instrument and possesses the virtue of giving adequately consistent results.

The specification of the C.C.I.F., stated in general terms, calls for an instrument capable of measuring any psophometric voltage between the limits of 0.05 mV and 100 mV. The psophometer consists of a calibrated valve voltmeter designed to meet special requirements, and should contain a filter network associated with the measuring instrument. The function of this filter network is to "weight" every frequency in accordance with its interference value relative to 800 p : s. Such filter circuits are commonly referred to as Weighting Networks, and the weighting factors of two such networks have been specified by the C.C.I.F. One weighting network is intended for psophometric measurements upon commercial telephone circuits, and the other for similar measurements upon circuits used for the transmission of broadcast music.

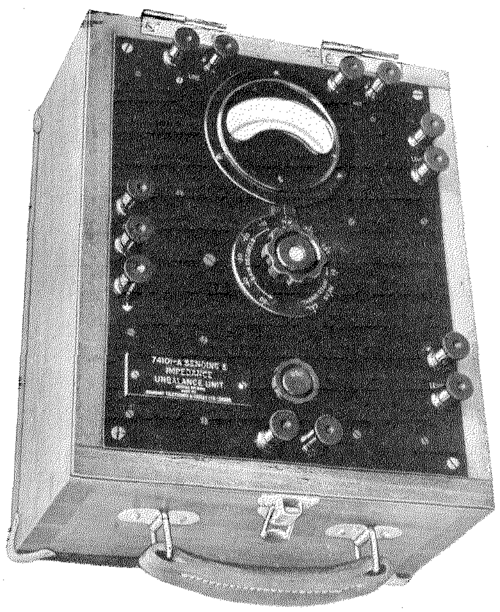


Fig. 13—74101-*A Sending and Impedance Unbalance Unit.*

The 74100-A Psophometer (Fig. 14) was

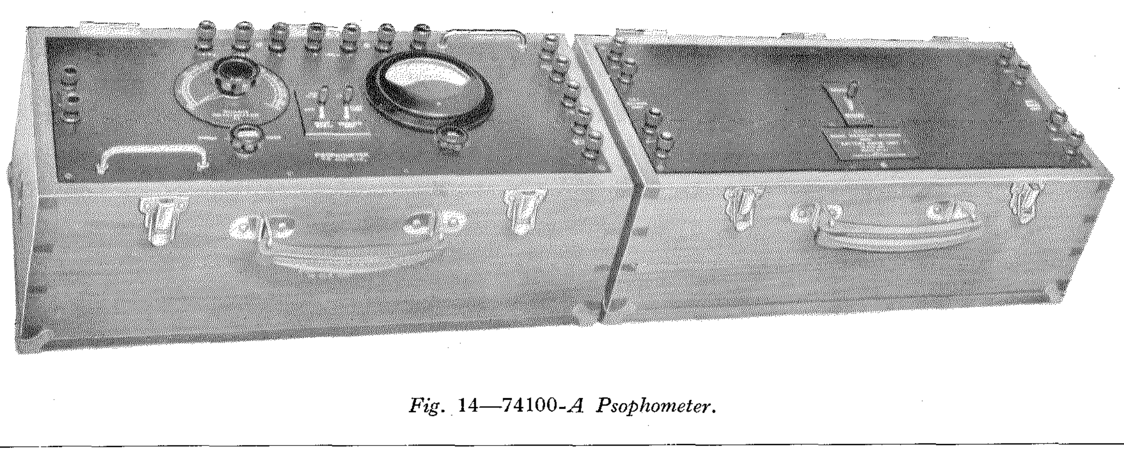


Fig. 14—74100-*A Psophometer.*

developed to meet all the requirements of the C.C.I.F. and to provide certain additional facilities.

For ease of handling and maximum application, the 74100-A Psophometer has been divided into two units. One unit is a calibrated valve voltmeter with a flat response from 50 p : s to 15 000 p : s ; the second unit contains filter networks designed to give the C.C.I.F. weighting for both telephone and broadcast circuits, together with a battery noise circuit which permits noise measurements being made upon direct current circuits. An octave filter can also be used in place of the C.C.I.F. Weighting Network.

The measuring range at the psophometer is from 0.02 mV up to 1 500 mV. An interesting feature is a self-contained calibration circuit whereby the amplifier gain is checked by a feedback method.

Owing to the high gains required, it is impossible to operate the valves in the set from noisy power mains, or from repeater station batteries. It is therefore essential that they should operate from small capacity portable batteries ; the 74100-A Psophometer is suitably arranged for such operation.

3.7 Oscillators

In the foregoing, particularly in section 3.3, some indication has been given of the general trend of oscillator design. Development progress has been traced from the pre-valve days of the buzzer type of oscillator, to the present time when the heterodyne oscillator with its direct frequency control on a single dial and its flat output characteristic is predominant in the field of voice frequency measurement. The advantages of speed and simplicity of operation of this oscillator have been noted and general comment has been made on its suitability for use with modern direct reading transmission measuring sets.

No mention has been made of the experimental and theoretical work which has been done on general oscillator circuit design, since it was considered that any detailed description of the highly involved and often laborious investigations which have contributed to the successful production of a stable and accurate heterodyne oscillator would be outside the scope of the present article.

It seems desirable, nevertheless, to sketch the main considerations which govern the design of these oscillators, and to attempt to give an indication of the problems involved.

The fundamental characteristics of a modern oscillator would seem to be :

(*a*) *Frequency Stability*

Constancy of frequency at any setting. Calibrations, whether involving charts or engravings on dials, must have both long period and short period stability. This stability must hold under all reasonable conditions of temperature and battery supply.

Brief and totally inadequate mention of factors such as the temperature co-efficient of coils and condensers in the oscillatory circuit, of the ageing of both, and of the necessity for careful circuit design must suffice to indicate the complexity of the problem.

In the case of the heterodyne oscillator, further complications are involved by the fact that the utilized beating frequencies are often ten times greater than the maximum output frequency ; also, in level recorders, the frequency scales must follow closely defined laws and must be very accurately reproducible.

(*b*) *Constancy of Output*

The output must have good short period stability under all conditions encountered in practice and must, in addition, have a flat output frequency characteristic.

Amplifier and modulator, as well as oscillator, design are involved in this problem. In the modern heterodyne oscillator, the output variation from 30–10 000 p : s is often less than 0.1 db.

(*c*) *Good Wave Form*

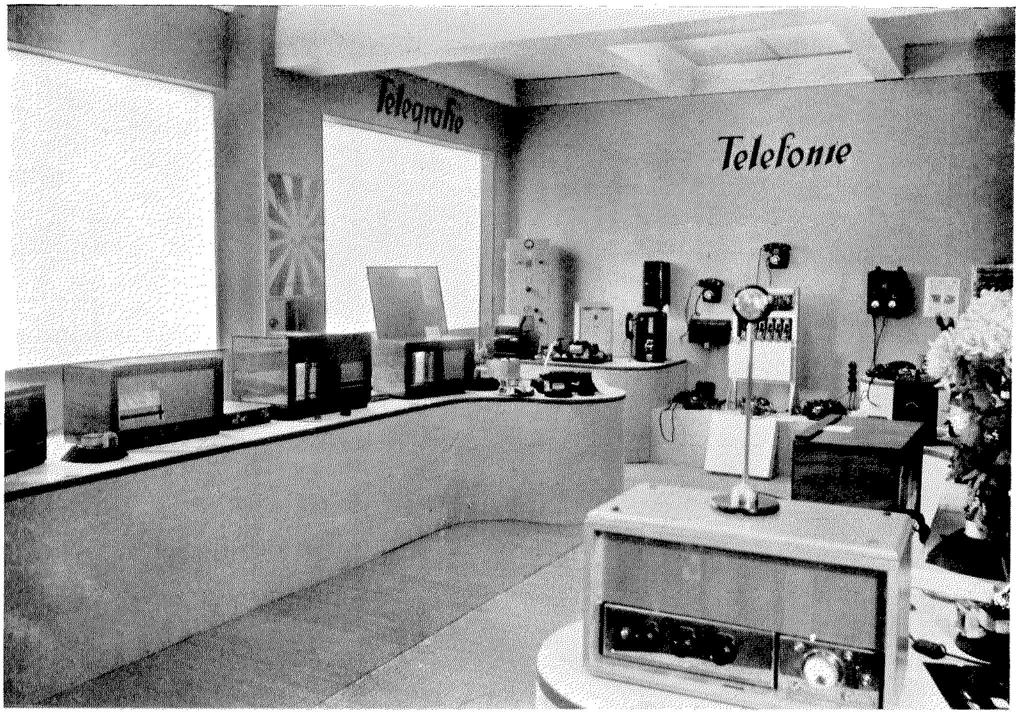
The oscillator output must not contain a high percentage of harmonics of the frequency to be transmitted.

Amplifier and filter design and the consideration of levels throughout the circuit, together with careful attention to the modulator, are the chief factors involved.

CONCLUSION

As explained in the introduction to this article, it was the rather ambitious aim of the authors to cover the whole ground of installation and maintenance testing of Voice Frequency Telephone Systems from the point of view of apparatus design. It has unfortunately not been possible to include detailed descriptions of individual sets or even to describe at any great length the problems encountered during development. It is hoped, however, that the picture which has been presented will be of interest to telephone engineers and will convey some impression of the progress which has been made in the art of Transmission Measurement.

No bibliography is appended to this article and space limitations prevent individual acknowledgment amongst the great international family of research and development engineers who have contributed to the progress herein recorded. Their names will be found in a multitude of technical journals in almost every known language. Since, however, the earlier sets in particular followed the general technique of the Bell Telephone Laboratories, Inc., the authors take pleasure in acknowledging the help and inspiration received from them, both directly and indirectly.



Section of Bell Telephone Manufacturing Company (The Hague, Holland) exhibit at the Utrecht Fair, 7th–16th September. Telephone Sets, small type P.A.B.X.'s, Railway Control Systems, Radio Receiving Sets and Army and Navy radio equipment were featured.

Edinburgh-Aberdeen Cable

Special Construction Methods Used at the River Crossings

By H. BIRKBY,

Superintendent of Construction (External), Standard Telephones and Cables, Limited, London, England

PROJECTS recently completed for the British Post Office include the Edinburgh - Aberdeen 12 - channel carrier-on-cable system, covering a distance of approximately 123 miles and comprising two 12 quad 40 lb. cables.

The route crossed the River Tay at Dundee and The Firth of Forth at Queensferry. Inasmuch as a road bridge for the cables was not available at either of these places, interesting installation problems were encountered. The means by which they were solved is described briefly in this article.

RIVER TAY CROSSING

Cable Manufacture

Since five subfluvial cables had previously been laid in the River Tay, it was decided in the present case to use a subfluvial cable.

The length specified for each "Go" and "Return" cable was 1.87 miles with a total additional 0.5 mile of spare cable for maintenance purposes. It was accordingly decided to manufacture each cable 2.12 miles in length, i.e., 1.87 miles anticipated length to be installed plus 0.25 mile spare.

The cable cores were made up in the same manner as for the land cable except that the conductors were specially insulated to meet subfluvial requirements. A double lead-antimony alloy sheath, with a layer of compound separating the two sheaths, and single wire armouring, were specified.

In order to meet transmission requirements, each cable was manufactured in 12 lengths of 320 yards each. The necessary tests were carried out on each length in the core stage, after which a single lead sheath was applied. The two drums, each containing a single length, were mounted adjacent to one another and further tested. These two lengths were then jointed together and the cable from one drum coiled over the cable on the other drum, thus forming a double length of approximately 640 yards on one drum. Each cable comprised six such double lengths. Each two of these lengths were again subjected to tests and jointed together, making three slings each approximately 1 280 yards in length, and these were finally tested and jointed together.

Each complete cable was finally coiled in one length on a large drum, the dimensions of which were :—

Body diameter	60 in.
Overall diameter	106 in.
Width between flanges	40 in.
Overall width	51 in.

The conductors were jointed by means of copper ferrules ; the wire joint was insulated with the papers insulating the two conductors jointed together, the papers being tied in position. The wire joints were staggered over a length of 6 ft. 6 in. The lead-antimony sleeve, when placed in position and the V edges soldered, had the same diameter as the cable itself.

For mounting the large drum containing the completed lengths of single lead-sheathed cable and for passing the latter through compound tanks to the lead press for the second sheathing, special plant was installed. From the lead press the double sheathed cable was taken once round a take-up drum, over a coiling sheave and down to the floor of the shop. Here it was coiled, each layer being covered with sheets of plywood cut to shape.

In the final stage, the protective materials were applied. After passing through a compound bath, the cable was lapped with two layers of paper, again compounded and served

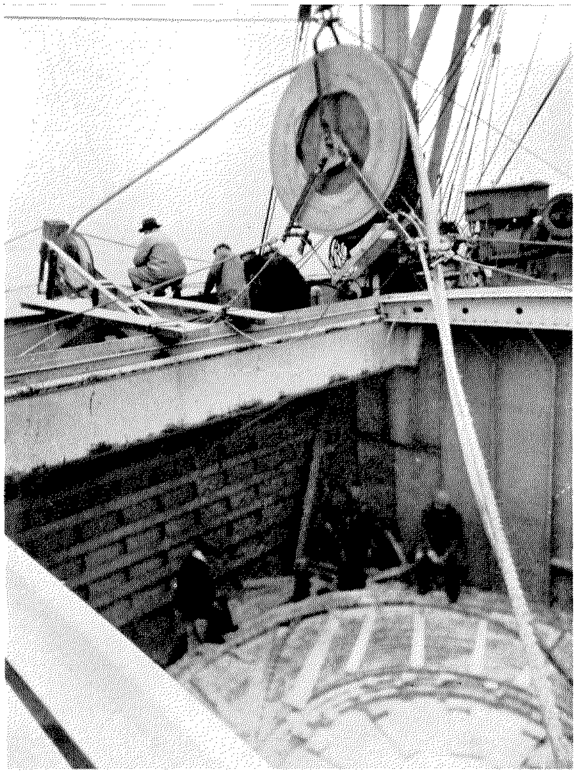


Fig. 1—River Tay Crossing—Paying out Cable via Large Sheave and Special Jockey Sheave.

with jute yarn, armoured with 24–0.232 in. diameter galvanized iron wires, coated with two layers of compound and two servings of compounded yarn, and white-washed overall.

The diameter of the cable at various stages of manufacture was:

Over 1st lead sheath	1.165 in.
,, 2nd ,, ,, ...	1.425 in.
,, papers	1.46 in.
,, jute	1.87 in.
Over wires	2.23 in.
,, outside jute	2.53 in.

Cable Installation

Consideration of all the problems involved indicated that it was desirable to lay the cables direct from the vessel used for transporting them to site. A motor vessel, the *Glamis*, having a draught of only 6½ feet, was, therefore, chartered for the work and was brought alongside the factory at North Woolwich to receive the cable. Completed lengths of 3 837 and 3 843 yards, respectively, were coiled in separate holds of the vessel on which suitable paying-off gear was installed at the same time.

It was decided to commence the laying of each cable at the north (Dundee) side.

The cable routes to be followed were first plotted and buoyed with the aid of a motor launch, four buoys being placed to mark the East or GO cable and five to mark the West or RETURN cable. At a time dictated by the tide, the West cable was first laid. The cable end was prepared and a grip attached; it was then passed up and around the overhead 4 ft. 6 in. diameter cable sheave and through a special fitting of jockey sheaves and cable stopper (Fig. 1). A line having been run to shore by the motor launch, the pulling-in rope was drawn on board and attached to the cable grip, the end of the cable being pulled ashore by the land cable gang. Whilst this operation was in progress it was necessary to employ a launch to hold the *Glamis* in position against the strong tide, a precautionary measure that was also necessary during the actual laying of the cable. The vessel then moved across the river at an average speed of 3.25 miles per hour, the

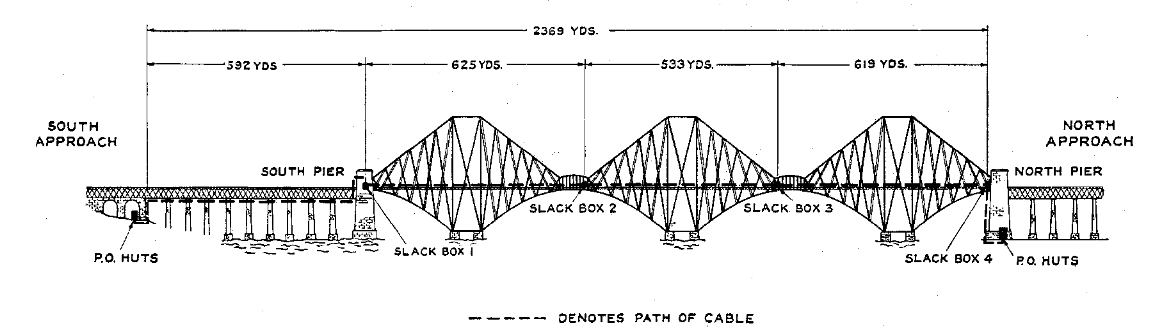


Fig. 2—Diagrammatic View of Forth Bridge and Cable Installation.

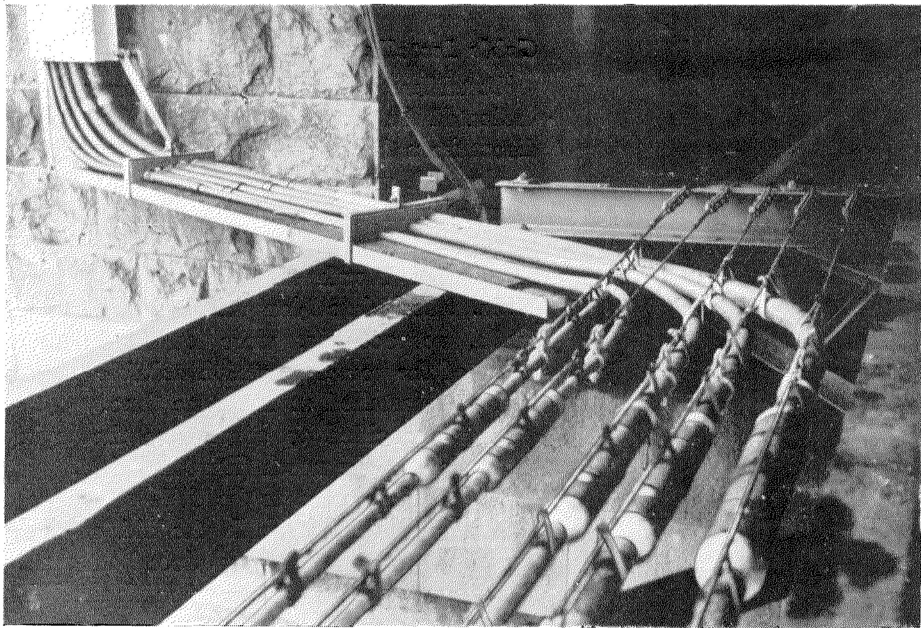


Fig. 3—Forth Bridge — End of horizontal aerial run on G.I. strand on south viaduct and commencement of rise on south pier.

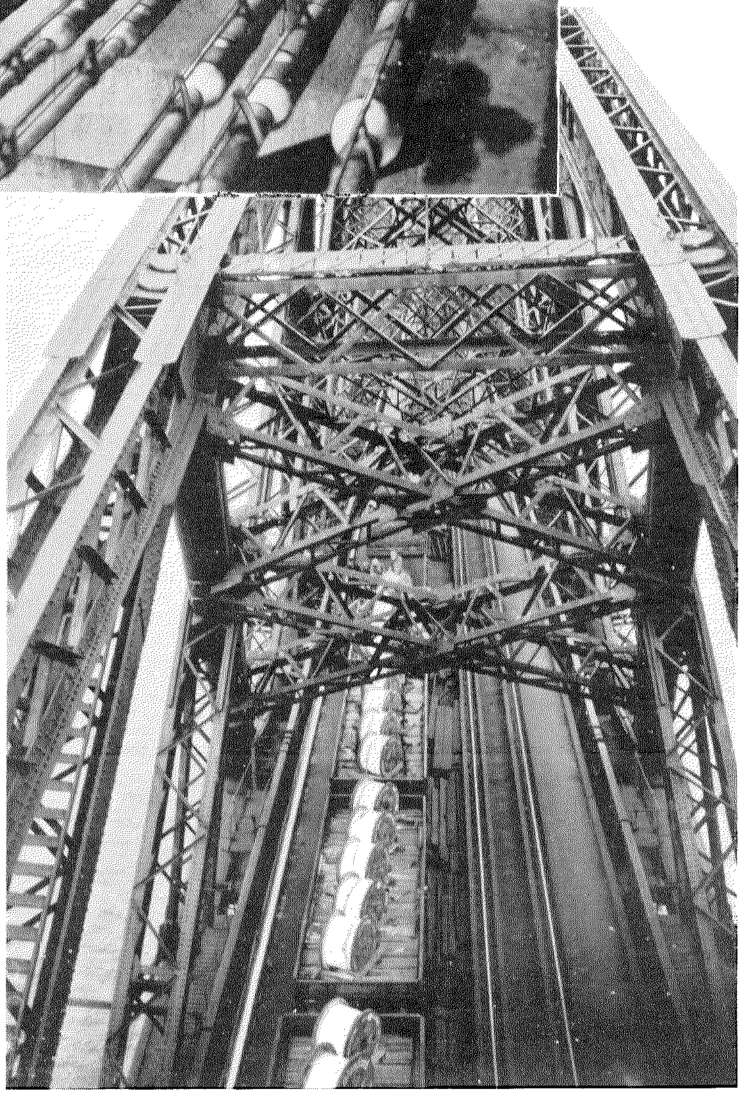


Fig. 4 — Forth Bridge — Laying cables from trucks (view taken from top of south pier).

cable being paid-out meanwhile. The *Glamis* hove to approximately 75 yards from the south shore and, after measuring the length of cable required, the surplus portion was cut off. After sealing both the cut ends, the cable was landed in a manner similar to that adopted for the north side.

The next day a similar procedure was adopted for laying the East cable.

The actual lengths of subfluvial cable installed were 3390 and 3 109 yards, respectively, the surplus length being handed over to the Post Office for maintenance purposes. It had previously been established that variation in length would not materially affect transmission values. At each side of the river the cables were drawn through ducts leading to existing manholes, the cables being anchored by iron brackets and cement work to the rock beds of the river walls.

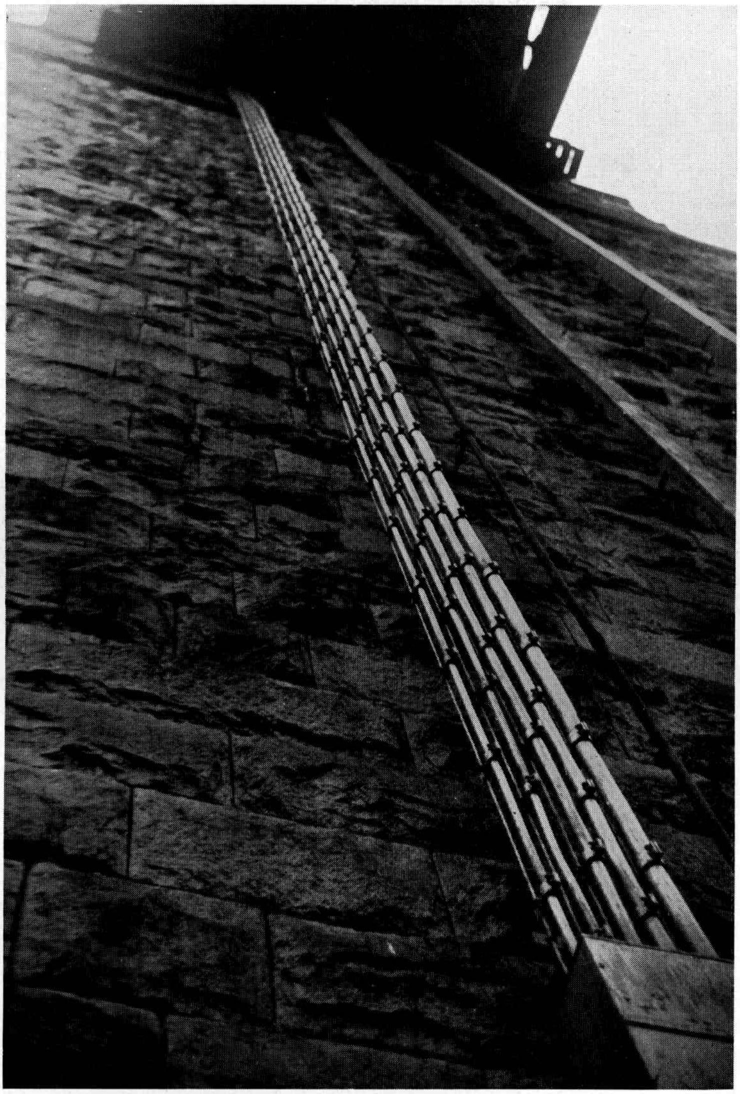


Fig. 5—Forth Bridge—Vertical Suspension on North Pier.

THE FIRTH OF FORTH CROSSING

Owing to the rocky nature of the bed of the Forth, the use of subfluvial cable was not possible, and it was necessary, therefore, to lay the cables across the renowned Forth Bridge carrying the railway line to the north.

The Forth Bridge, which was completed in 1890, is approximately $1\frac{1}{2}$ miles in length and consists of two main spans of 1 710 feet and two smaller spans with an approach viaduct at each end. The height from high water mark to the top of the cantilevers is 360 feet and to the railway track 130 feet. Owing to the gales frequently encountered in this district, the bridge was constructed to withstand a wind pressure exceeding 60 lbs. per sq. ft.

Apart from inherent difficulties in placing cables with various types of support on such a structure, the problems of vibration and expansion and contraction needed careful consideration.

On the east side of the bridge, five cables had been installed some years ago but trouble had developed due to the effect of vibration, etc., and it was decided to replace them with three new cables (one 160 pair 40 lb., one 54 pair 70 lb., and one 30 pair 70 lb., all multiple twin type) to be installed on the west side in con-

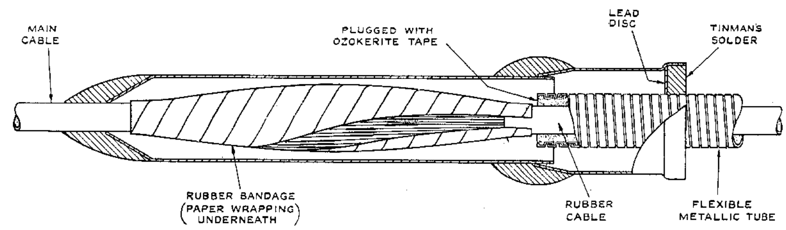


Fig. 6—Plug Joint used for Connecting Lead-covered Cable to Rubber-sheathed Cable enclosed in Flexible Metallic Tubing.

junction with the two 12-quad carrier cables forming part of the main Edinburgh–Aberdeen project. All five of the new cables were sheathed with lead-antimony alloy. Sections to be installed on the cantilever portion of the bridge were in addition to be served with compounded hessian to lessen the effect of vibration.

For the purpose of this description, the bridge may be considered to be divided into three portions: the south viaduct of 592 yards; the main cantilever portion of 1 777 yards between the south and north piers; and the north viaduct of 350 yards (Fig. 2).

Cable Installation

The cable route commences in cable huts near the foot of the south approach to the south viaduct. Leaving the ducts near the cable huts, the route proceeds up the wall of the south viaduct and along the understructure girder-work, passes out to the wall of the south pier, rises vertically for 35 feet, passes round the inside of the pier archway, and then down 14 feet to the level of the permanent way. From this point the cables are installed in an iron trough at the side of the railway track for a distance of 1 777 yards to the north pier, where they pass through and drop down and round the outside of the side girders to a platform immediately beneath the permanent way. From this platform they are vertically suspended for 120 feet and pass into a manhole at the foot of the north pier, whence a short distance in ducts completes the route. The total cable route length is approximately 1.46 miles.

Dealing with the sections of the route in more detail: The cables rise approximately 30 feet from the ducts at the south approach; they are clamped every two feet to G.I. strands fixed to the wall and are protected by a suitable casing. Then for 570 yards the cables are suspended, by means of "Elder" type rawhide suspenders with wire clips, from G.I. strands erected on brackets bolted to the understructure of the viaduct at 20-foot intervals. A boarded footway with handrail existed on this understructure but it was necessary to remove the handrail to enable the cables to be lifted into position. Since this portion of the bridge was 130 feet above water-level and the work was carried out under gale conditions, great care was required to avoid accidents.

It was next necessary to negotiate the rise and fall from this understructure to the cantilever portion at the south pier (Fig. 3). Here the cables were protected with flexible metallic tubing and were securely clamped to racks with cork bedding for damping vibration. Arriving at the permanent way the cables for some 1 780 yards were laid in a galvanized iron trough 6$\frac{5}{8}$ in. wide by 9$\frac{3}{8}$ in. deep, fitted with covers having two side lips secured by iron straps bolted round the whole. This troughing had already been provided; before the cables were placed in position, three layers of $\frac{1}{4}$ in. felt were laid in the bottom of the trough to aid in the all-important object of damping out vibration.

Cabling operations on this portion of the route had to be carried out in conjunction with the railway authorities, Sunday afternoon being the only time when single track working could be arranged in order to permit of using the other track for the cable trucks (Fig. 4). As an indication of the difficulties encountered, it might be mentioned that part of this cabling work was done in an 80-mile gale, and the emptied drums had to be nailed to the trucks to prevent their being blown on to the line.

The felt-bedded trough, in which the cables were placed, was finally filled with a special compound as a protection against cable damage by rubbing caused by the almost constant vibration set up by passing trains. This compound, which consisted largely of French chalk, was not sufficiently liquid for pouring or bailing, but the application of heat rendered it sufficiently plastic to be scooped out of the container. Some 35 tons of the compound, supplied in 1 cwt. tins, were used. This, together with about 14 tons of firing, was taken out on a ballast train on a Sunday afternoon and distributed as conveniently as possible on the six-foot way along the length of the trough. The railway authorities limited the number of braziers in use at any one time to six. A suitable type with special heating containers was designed; it could be placed on boiler plates in the six-foot way with no danger of being fouled by passing trains, or of the container falling from the brazier during heavy vibration. While the compound was being heated, constant stirring was necessary to prevent caking or burning. When sufficiently hot it was carried to the trough and, with the aid of scoops, a layer of compound was placed on top of the felt bedding, the cables being lifted and then pressed down into the compound. As compound was added, it was tamped down so that each cable individually was surrounded by compound.

From the end of the trough the cables were laid under the bridge structure on hangers and then dropped vertically down the granite buttress of the north pier, 120 feet to the ground level (Fig. 5). Five suspension strands were secured at the top by iron wall and girder fixings, and at the bottom by anchor irons. They were further secured by iron brackets at 15-foot intervals for the whole length of the suspension to prevent swinging during windy weather. It proved somewhat difficult to arrange adequate support at the top of this suspension as the total weight of cable, suspension strands, and fittings was about $3\frac{1}{2}$ tons. The under-girders of the bridge to which the weight could be attached safely were at that particular point subject to a 5-inch movement due to expansion and contraction, which would have resulted in the cables fouling the iron edge of the permanently slung footway with consequent sheath damage. It was finally decided to combine two alternatives, using the wall fixing partly to take the weight and definitely to position and terminate the strands, while a secondary and moveable suspension of steel eyebolts was brought out from the wall fixing to the main girders a few feet above. The cables were

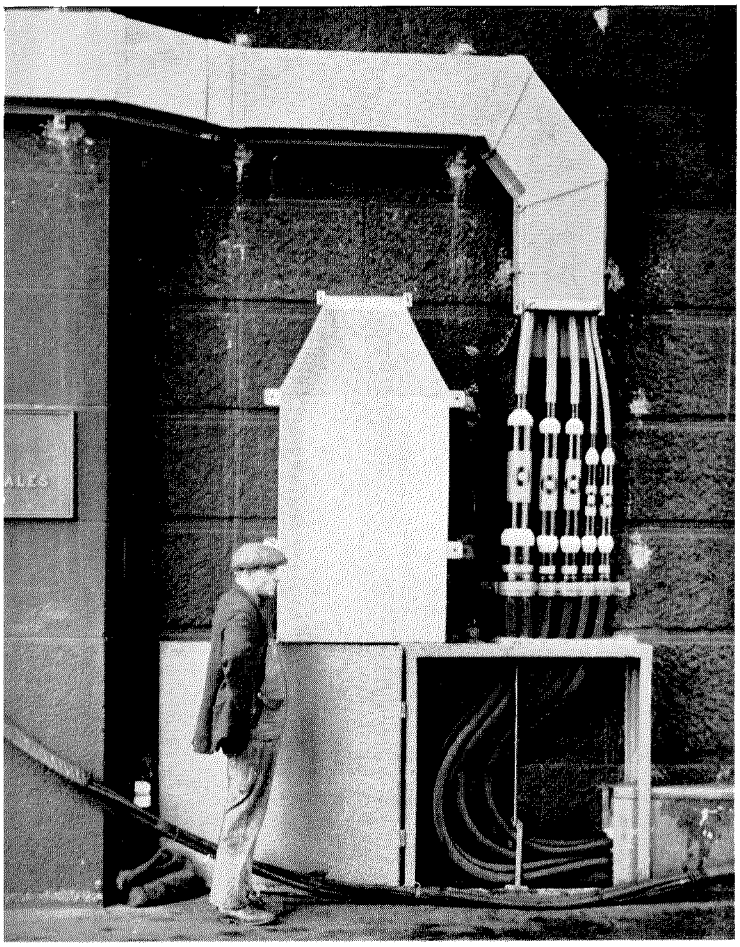


Fig. 7—Forth Bridge—Joints and Slack Box at South Pier.

clamped to the strands at 2-foot intervals and, at the foot of the run, suitable protection against mechanical damage was provided.

In all, 68 lengths of cable were placed, totalling some $7\frac{1}{4}$ miles ; 46 cable joints were made in addition to the 40 "plug" joints referred to hereinafter.

In the cantilever portion of the bridge, the cable is laid in troughing divided into three main lengths with cable slack boxes to take flexible connections at each end and at two intermediate points, the four positions coinciding with the "broken" points of the bridge. The movement (expansion and contraction) at each intermediate position is about ten inches and is allowed for in the construction of the bridge, the end of one cantilever section sliding in and out of the adjacent section without actually forming a gap when fully contracted. At the north and south piers, the movement is only five inches and takes place on large steel rollers fitted into recesses in the piers.

The working principle of the slack boxes is as follows :

At one end of a section of the main trough and at the beginning of the next section are enlarged portions described as joint boxes. Between the two adjacent ends of the joint boxes is a still larger portion, six feet in length, known as a slack box. The end of one joint box is a fixture to one end of the slack box, whilst the opposite joint box is so designed that, during contraction and expansion of the bridge, it slides backwards and forwards in the slack box without actually emerging. The lead-covered cables terminate in the joint box and are connected by means of plug joints to rubber-sheathed cables encased in flexible metallic tubing, sufficient slack being left to prevent any tension being placed on the cables during the period of maximum contraction of the bridge (Figs. 6 and 7). All these special flexible tube plug connections, twenty in number and ranging from 14 to 28 feet in length, were made up, air pressure tested, fitted with rubber cable sheathed cores, and transported to the various positions they were to occupy on the bridge by means of ladders lashed to barrows.

Electrical testing work was carried out in the normal manner, and sustained air pressure tests were made on sections of cable between slack boxes.

CONCLUSION

Grateful acknowledgment is due to British Post Office engineers and to The London and North Eastern Railway officials for their co-operation in facilitating the successful conclusion of the Edinburgh–Aberdeen cable installation, part of which was accomplished under hazardous conditions, without mishap to any of the personnel.

New 3-Channel Open-Wire Carrier Telephone System and its Application in Norway

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INTRODUCTION

THREE-CHANNEL Carrier Telephone systems designed to provide three additional speech circuits on an open-wire pair have been in operation for several years and, owing to their widespread application and the amount of literature available on the subject, their fundamental principles of operation are well known.

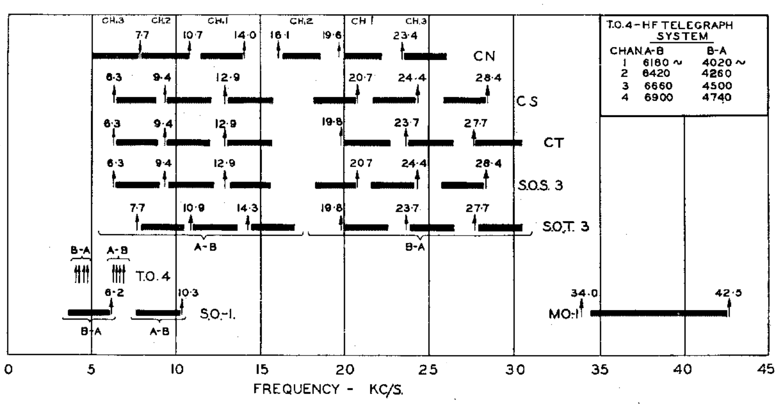


Fig. 1—Frequency Allocation of Open-Wire Carrier Systems.

The earliest systems of this type to be utilized in large numbers were known as the CN.3 and CS.3 Carrier Telephone systems and were described in an article in this journal in 1929.[1] These two systems of the single sideband, suppressed carrier type were essentially similar but their carrier frequencies and the consequent location of the transmitted sidebands in the frequency range were "staggered" so that a system of each type could be operated on the two side circuits of a phantom group or on two pairs on the same pole route with comparatively simple transpositions and without intelligible crosstalk.

Although minor alterations have been made, including the addition of a CT. type with different frequency allocation, these systems have remained substantially the same for the last ten years. Recent improvements in technique, however, and the ever-increasing demand for more exacting performance led to the redesign of the equipment. This article describes the new 3-Channel Carrier Telephone equipments, the first three of which have recently been installed in Norway.

[1] "Carrier Current Systems and Their World-Wide Application," by J. S. Jammer, *Electrical Communication*, April, 1929.

FREQUENCY ALLOCATION

Two systems, known as the SOS.3 and SOT.3, are available, differing only in their frequency allocation (Fig. 1.)

The SOS.3 type uses the same frequencies as the former CS. systems, while the SOT.3 system uses a new frequency allocation in the low group, or A–B direction of transmission, and the same as the CT. type system in the high group or B–A direction.

The SOT.3 frequency allocation allows a newly developed 4-channel high frequency carrier telegraph system, occupying the range 4 kc to 7 kc, to operate on the same open-wire pair.

CIRCUIT ARRANGEMENTS

The circuit arrangements of the systems supplied to Norway are illustrated in schematic form, Fig. 2 showing the terminal and Fig. 3 the repeater connections.

Referring to Fig. 2, the voice frequency speech currents enter the circuits via a pad and then pass through the ringer and 4-wire

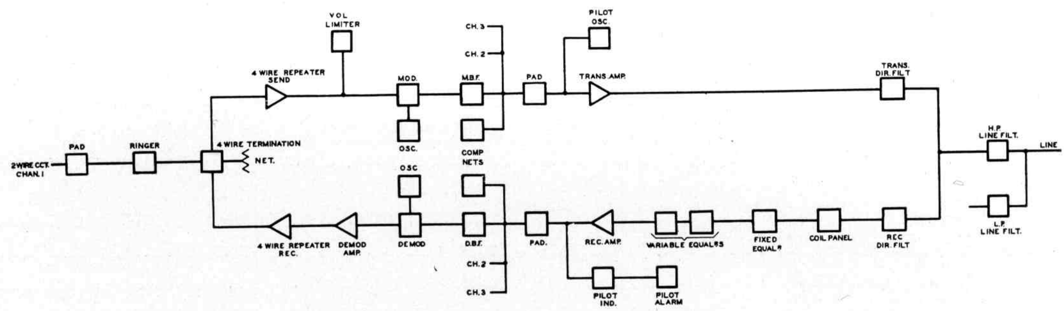


Fig. 2—SO.3 System. Terminal Schematic.

terminating set. The pad circuit is utilized in a special way in Norway, details of the arrangement being given later. The transmitting path goes via one-half of a 4-wire repeater to the modulator, across the input of which is bridged a neon tube voltage limiter. This prevents the passage of excessive peak voltages which might overload subsequent portions of the circuit. The presence of this limiter is not noticeable to the user of the circuit.

The modulator employs metal type rectifiers and is similar to that illustrated and described in a previous article in this journal,[2] so that a detailed description is not now necessary except to state that the relative level of unwanted components from the modulator is much lower than on the older type of equipment. The output from the modulator is taken to the modulator band filter which selects the required sideband. The band filters employ "resonant units" each comprising an inductance coil, a fixed condenser and a small variable trimming condenser, and each unit is carefully adjusted to resonance or anti-resonance before the filter is assembled. Very accurate filters can be made in this way and, by means of equalization incorporated in the modulators and demodulators, good quality can be obtained within quite close limits.

From the three modulator band filters, which are connected in parallel with each other and a compensating network, the outputs pass through a pad to the transmitting amplifier and

[2] "Bristol–Plymouth 12-Channel Carrier System," by Col. A. S. Angwin and R. A. Mack, *Electrical Communication*, October, 1937.

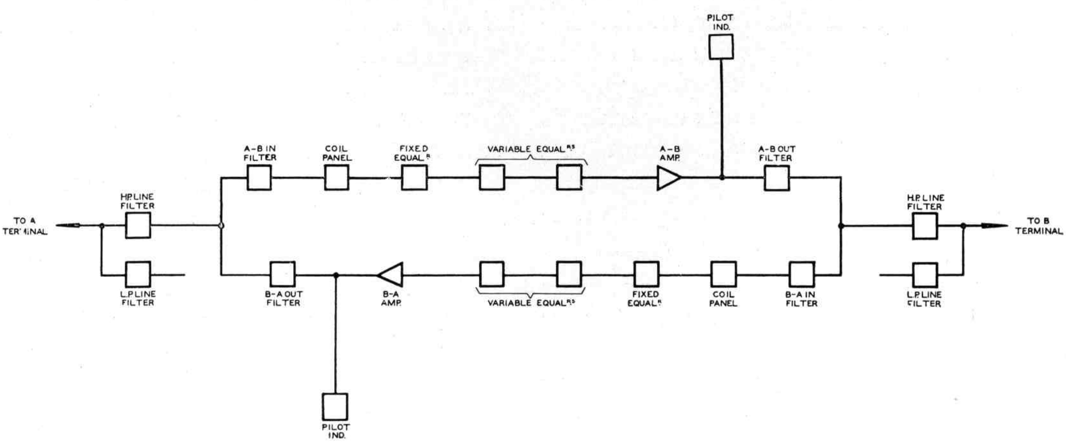


Fig. 3—SO.3 System Repeater Schematic.

thence through a transmitting directional filter and so to line through the high-pass line filter.

The transmitting amplifier, which is also identical with the receiving amplifier, is of the feedback type and is similar in principle to that described in the article on the Bristol–Plymouth 12-channel system already referred to. The maximum gain is 50 db. and the output power capable of being handled is approximately 23 db. above 5.9 mW although the normal operating level is + 18 db. (approximately 2 nepers) above reference telephonic power. The input and output impedances are 600 ohms. Variations in gain are obtained by 5 and 10 db. pads connected in circuit by U-links in conjunction with a potentiometer which is continuously variable over a range of 14 db.

It may be noted that when the SOT.3 system is required to operate on the same pair as a 4-channel H.F. telegraph system, high and low pass telegraph separating filters are necessary between the high pass line filter and the

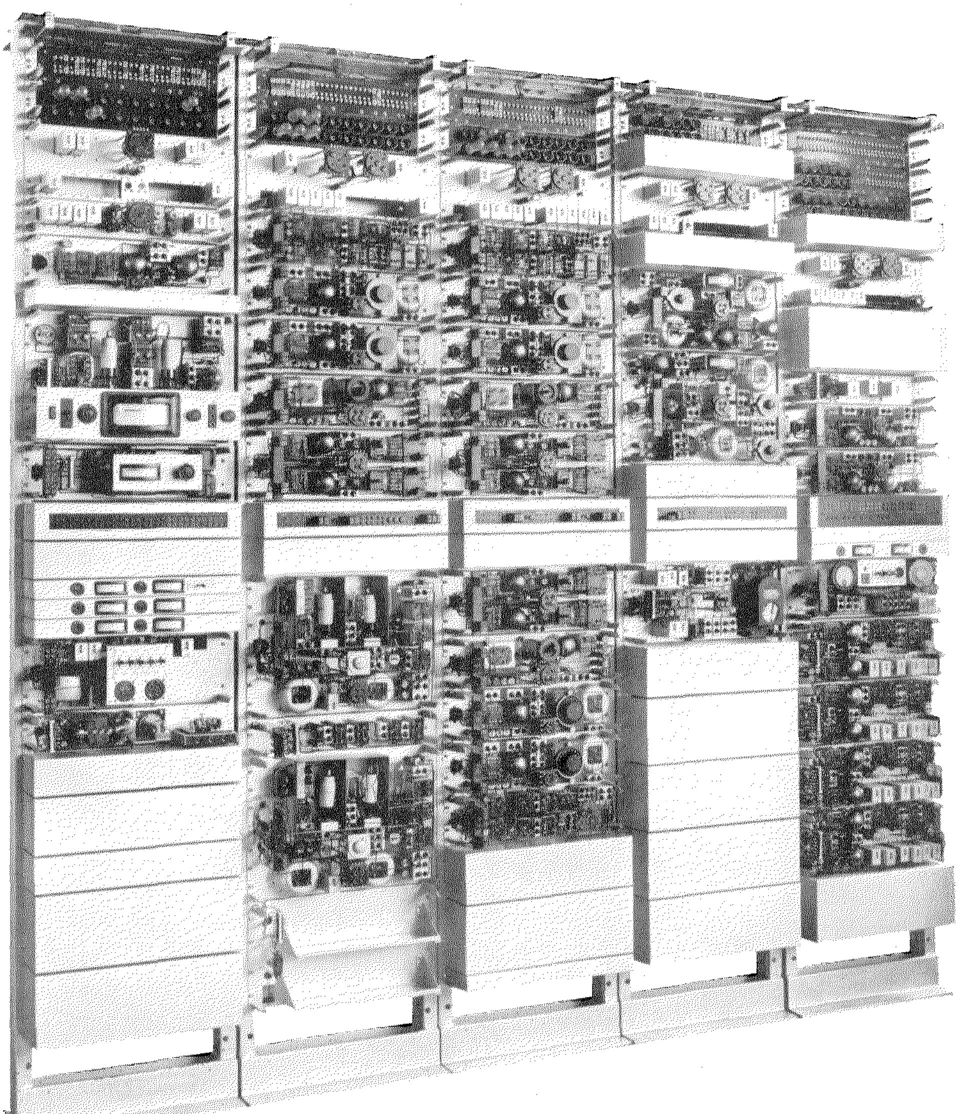


Fig. 4—SOT.3 Terminal (8′ 6″ bays)—Front View with Covers Removed.

telephone system directional filters. The Norwegian systems, however, are not operating on this basis.

The receiving portion of the circuit commences at the receiving directional filter, followed by the basic equalizer which is designed to compensate for losses near the cut-off frequencies of the receiving directional filter and the corresponding transmitting directional filter at the other terminal or nearest repeater station, and, in addition, for the deviation in loss with frequency of 100 miles of 4 mm copper, open-wire line. Two more variable equalizer panels are located between the basic equalizer and the receiving amplifier; and, by means of simple U-link connections, these can be arranged to give changes in equalization of approximately 1 db. per kc in steps of 0.1 db. per kc over the frequency range occupied by the group of three channels. Unless there is some

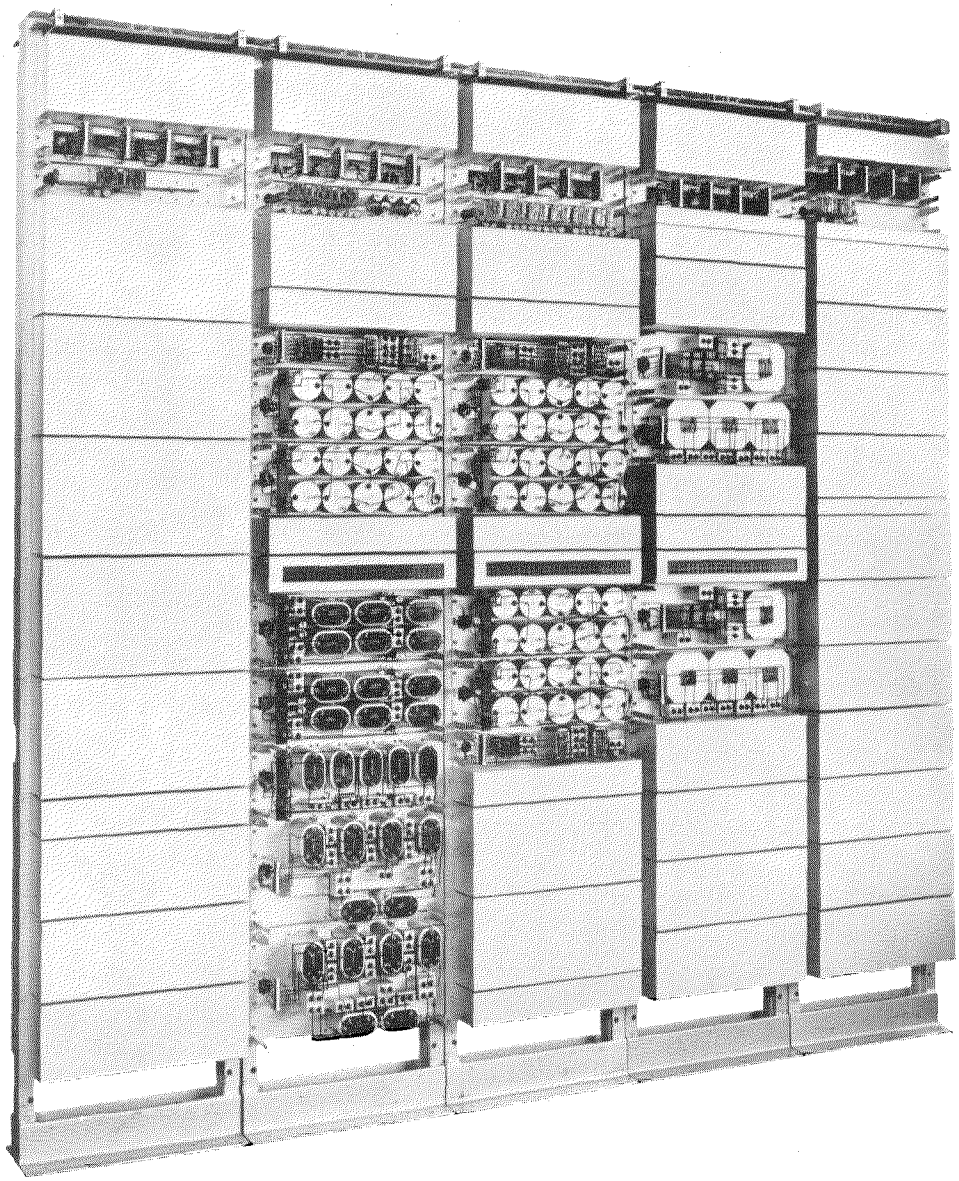


Fig. 5—SOT.3 Terminal. Rear View with Covers Removed.

Fig. 4-A—Equipment Layout—Front, corresponding to Fig. 4.

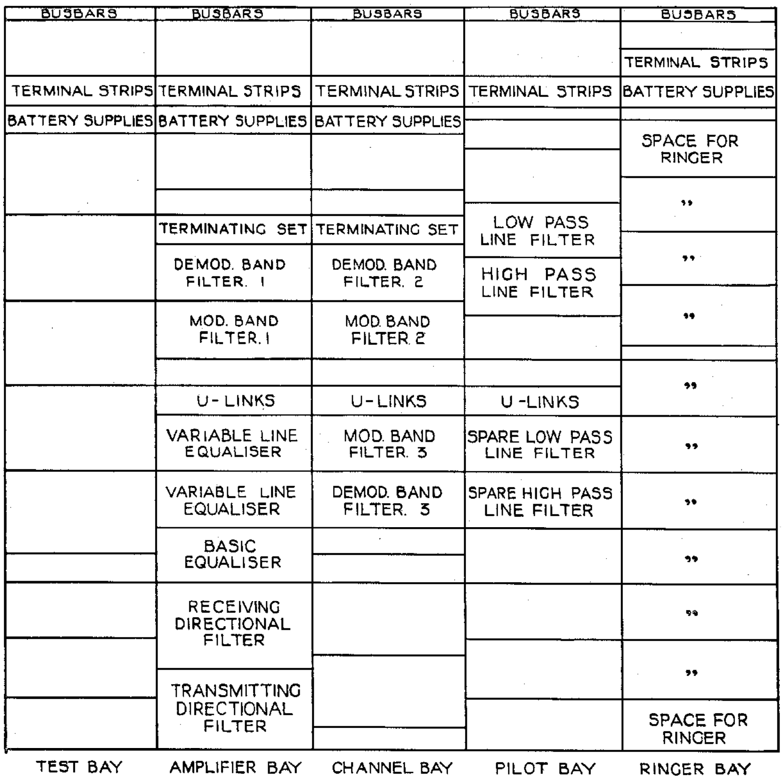


Fig. 5-A—Equipment Layout — Rear, corresponding to Fig. 5.

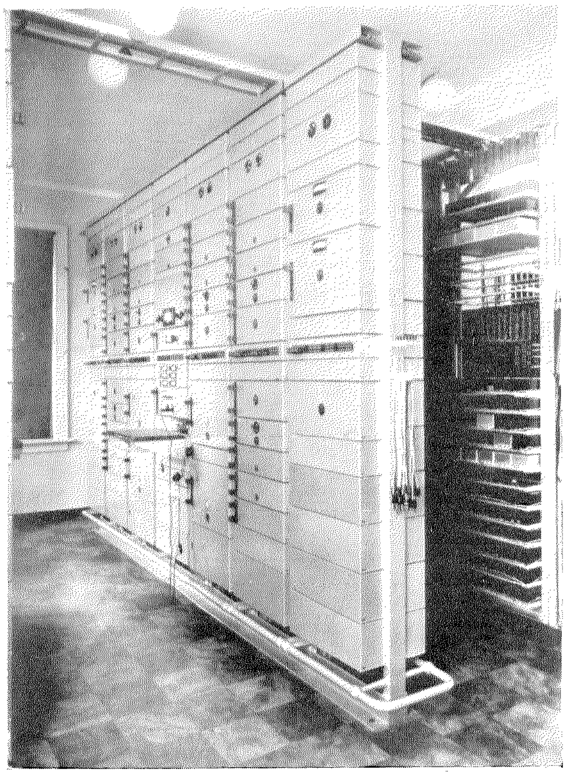


Fig. 6—SOS.3 and SOT.3 Terminals at Notodden (8′ 6″ bays).

very serious irregularity in the line, therefore, very good overall quality can be obtained because all normal deviations in the loss/frequency characteristic can be compensated.

Abnormal deviations can be equalized by means of special channel equalizers which are inserted at the input to the modulator and output of the demodulator. Provision is made for these panels on the bay, but in Norway they have been found to be unnecessary and therefore have not been connected in circuit.

After passing through the basic and variable line equalizers, the carrier currents are amplified in the receiving amplifier and then go through a 6 db. pad to the three demodulator band filters and associated compensating network. The output from each band filter is applied to the demodulator, which is similar to the modulator in design but which also incorporates a low-pass filter to eliminate unwanted frequencies above the voice range. The voice frequency currents are amplified by the demodulator amplifier and, if necessary, by the receiving half of the 4-wire repeater, and then pass through the terminating set of the 2-wire line and ringer.

The sending portion of the ringing panel is quite simple, consisting principally of a relay operating on the 20 p : s ringing current from the switchboard which sends 500 p : s current interrupted at 20 p : s to the carrier equipment. The receiving portion incorporates several new features which render it more stable than the old type and less liable to false operation on speech. A high impedance circuit is bridged across the 2-wire line and a small portion of the incoming current is amplified and passed to three tuned circuits which contain metal type rectifier elements. These three circuits are tuned to 500 p : s, 600 p : s and 750 p : s, respectively, and relays connected in the D.C. side of the rectifier bridges are operated accord-

Fig. 7—SOS.3 Terminal at Kristiansand (10′ 6″ bays).

ing to the composition of the incoming waves. Thus, 500 p : s current, either interrupted or continuous, causes the corresponding relay to operate ; and, providing no 600 or 750 p : s currents are present, the ringer operates and transmits 20 p : s to the switchboard. If the 500 p : s current is spasmodic or if 600 or 750 p : s frequencies are present, which would be the case with speech, the delay on the 500 p : s relay is sufficient to render the ringer inoperative and, as an additional safeguard, the quick-acting relays in the 600 and 750 p : s circuits would operate and effectively form a "guard" to prevent operation of the ringer.

REPEATER CIRCUITS

Fig. 3 shows a schematic of a repeater, one of which is located at Kristiansand on the Notodden–Stavanger SOT.3 system. This follows well-established principles of carrier telephone repeater design and the components are identical with those described above in the receiving portion of the terminal. Incoming high frequency currents pass through the high-pass filter of the line filter set to the directional filters which separate the high and low transmission groups. A transformer connects the balanced directional filters and unbalanced basic and variable equalizers, which in their turn are connected to an amplifier. The output from the amplifier goes to the output directional filter and high-pass line filter to line. The reverse direction of transmission is similar.

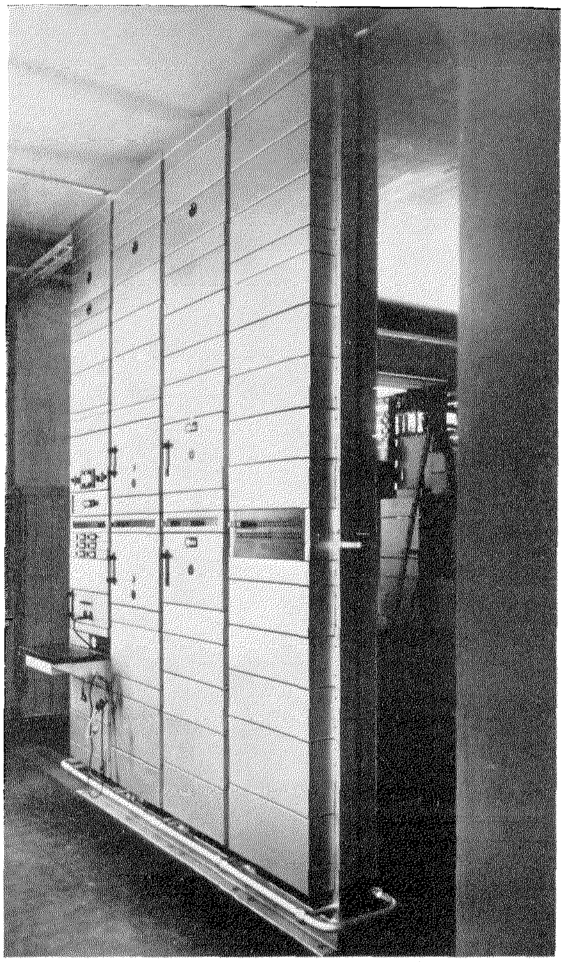


Fig. 8—SOT.3 Repeater at Kristiansand.

PILOT CHANNEL

Pilot channel equipment is used to indicate the change in line attenuation due to weather changes or other circumstances. On the systems described herein a manual pilot is used, i.e., the changes in gain settings of receiving amplifiers and repeaters are controlled by the maintenance staff manually instead of by attenuation inserted or removed automatically from the input circuit of these amplifiers by means of rotary switches, which in turn are controlled by the level of the pilot current itself.

The pilot current is a single frequency current introduced at the input to the transmitting amplifier. The frequency is chosen to be approximately in the middle of the range of the directional group, the higher of the two available frequencies generally being used. For example, in the A–B direction on the SOT.3 system, a frequency of about 14.25 or 10.85 kc would be used, preferably the former. The pilot frequency is actually located at about 50 p : s outside the carrier frequency in order to avoid interference with the channels in the same direction of transmission. As this is near the cut-off of the adjacent band filters the impedance facing the output of the pilot oscillator is liable to large changes with a small change in pilot frequency and this would consequently affect the output power. The pad between the band filters and terminating amplifier is therefore inserted to mask this impedance change and minimize the effect of the filter impedance. The pad at the output of the receiving amplifier and input of the pilot indicator panel serves a similar purpose.

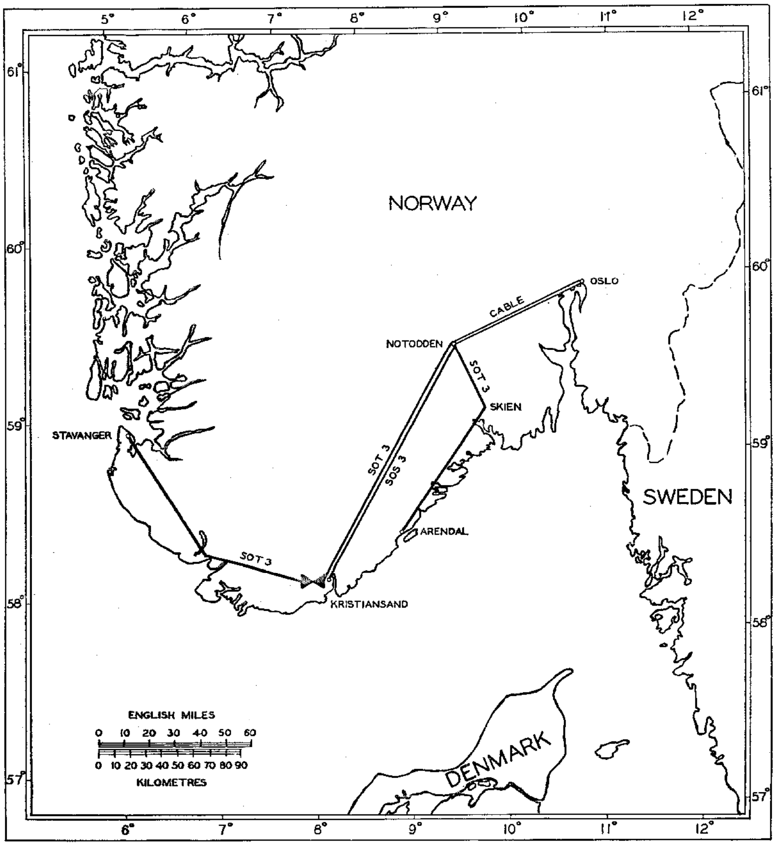


Fig. 9—Map showing Routes of New Systems.

The pilot current is transmitted at a level of approximately 1 mW at the output of the transmitting amplifier or about 25 db. below the maximum speech power on any one channel at this point.

At the repeater the pilot level is continuously indicated by a suitable meter, which is connected in the output circuit of the pilot indicator panel. This panel consists of a sharply tuned input circuit of high impedance followed by an amplifier, and, although similar in function to the older type of indicator panel, is much improved in stability by the incorporation of feedback in the circuit. Only a very small portion of the pilot current is absorbed by this panel, almost all of it passing on to succeeding repeaters and the terminal where similar indicators are located.

At the terminal, an alarm panel is also connected in the pilot indicator circuit. The chief feature of this panel is a sensitive polarized relay which closes one or other of its contacts if the pilot level changes by more than a pre-determined level, usually $\pm 1\frac{1}{2}$ db. After a suitable delay to allow for momentary surges, the alarm is given and the maintenance personnel alter the gain setting of the receiving amplifier until the pilot indicator reading is restored to normal. In general, the gain of the amplifier at a repeater station is not changed except under instruction from the control terminal, although experience may prove other methods of procedure to be more suitable in particular cases.

Owing to the severe climatic conditions experienced in Norway and the consequent variations due to sleet and ice, a pilot channel is essential even on short, one-section systems such as Notodden–Arendal.

EQUIPMENT

The equipment is mounted on both sides of rack frameworks 8′ 6″ or 10′ 6″ high, according to the height of the apparatus room. Bays 10′ 6″ high have been provided at Kristiansand and Stavanger and 8′ 6″ high at Notodden and Arendal. Aluminium finish is used throughout on racks and components.

Fig. 4 shows a front view of an 8′ 6″ terminal

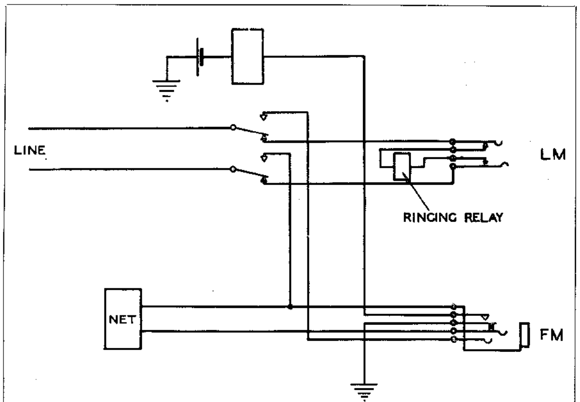


Fig. 10—Terminations for Physical Lines.

with the panel covers removed. A key to the apparatus panels is given in Fig. 4-A. Figs. 5 and 5-A show the arrangement of apparatus on the bays viewed from the rear.

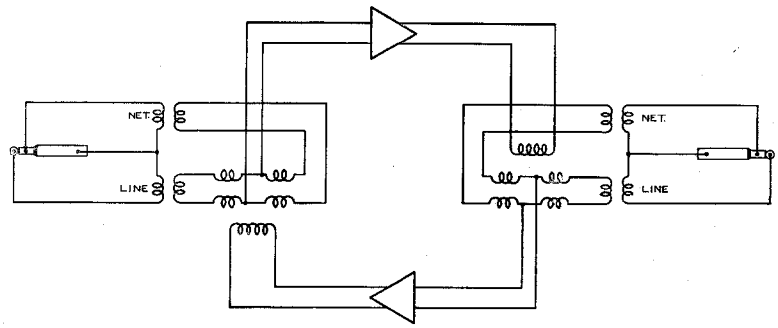


Fig. 11—*Cord-circuit Repeater.*

It can be seen that the general principles adopted are as follows: Battery bus-bars are located at the top of all bays followed by fuse and lamp panels; below them is placed the miscellaneous apparatus associated with plate circuit alarms, fuse alarms, etc.

The main apparatus panels are arranged so that apparatus which requires to be handled is as far as possible within easy reach of the maintenance staff. On the particular terminal shown, the channel apparatus, line amplifiers, equalizers and directional filters occupy two bays, while the pilot channel equipment and normal and spare line filter sets are mounted on another bay. The ringer bay mounts the normal and spare 500 p : s oscillators and ringer test panel, and has space for 13 ringers, i.e., sufficient to equip four 3-channel terminals and one spare ringer panel. A second ringer test panel is provided on the rear of this bay when the rear is equipped with ringers.

The main feature of the test bay is the Transmission Measuring Set which measures losses and levels from – 30 db. to + 30 db. over the whole voice and carrier frequency range utilized by the system. An 800 p : s oscillator is provided for testing purposes. The

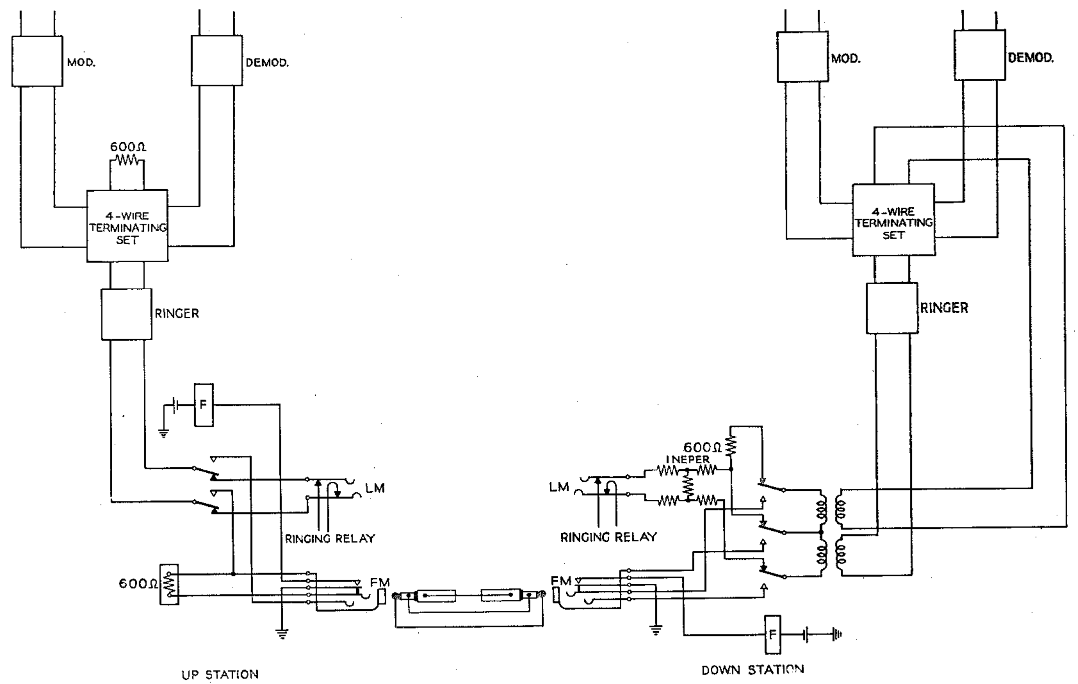


Fig. 12—*Terminations of 3-channel Carrier Telephone Circuits.*

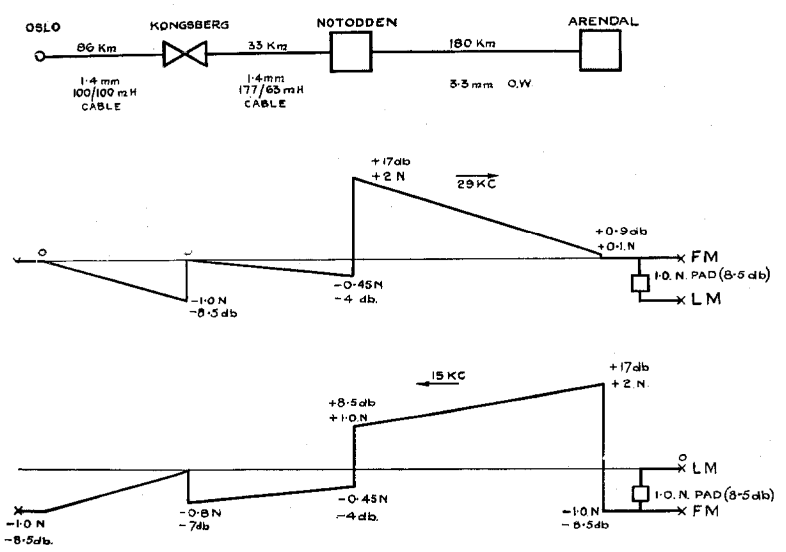


Fig. 13—Typical Channel Line-up, Oslo–Arendal.

system can be adequately maintained by these means; facilities are provided, however, to enable the T.M.S. to be used with a high frequency oscillator, if necessary.

One test bay will serve two terminals if the line-up of the bays is convenient. An example appears in Fig. 6, which shows two terminals at Notodden with the test bay in the centre.

The layout of the apparatus on 10′ 6″ bays differs slightly from that already described and is illustrated in Fig. 7, which shows the SOS.3A terminal at Kristiansand. The left-hand bay is the ringer bay and is similar to the 8′ 6″ bay except that 19 ringers can be equipped, i.e., sufficient for six terminals and one spare. The channel bay mounts the channel apparatus for all three channels but the arrangement differs from that adopted for the shorter bay. Thus, the three 4-wire repeaters are mounted above the U-link panel, while below are the three demodulator amplifiers and then the modulator and demodulator oscillators. Static equipment which does not require adjustment, such as the channel panels and band filters, is on the rear of this bay. The pilot equipment is mounted on the same bay as the line amplifiers, equalizers and directional filters. The test bay is similar to that already described. The line filters are mounted on a separate line filter bay in this station, together with the line filters for the Notodden - Stavanger repeater.

There are very few connections between the various bays. Little difficulty would therefore be encountered in removing the system to another position within the station or to another location should occasion arise.

REPEATER EQUIPMENT

The repeater equipment at Kristiansand is shown in Fig. 8. This has been provided with its own test bay which is capable of serving four repeaters. Normally, a high frequency oscillator with the seven frequencies of 4.5, 6.5, 8, 15, 20, 28 and 40 kc is equipped on this bay, but, since a high frequency oscillator already existed at the station, it has been omitted at Kristiansand. The amplifiers, equalizers and directional filters are mounted on the next bay followed by the pilot apparatus bay and the carrier line filter bay.

BATTERY SUPPLIES

The normal 24 V and 130 V station battery supplies are used, the current drains being as follows:

	24 *V* *Amps.*	130 *V* *Amps.*
One Terminal including 4-wire repeaters, ringer and manual pilot equipment	8.5	0.42
Testing equipment when required . .	1.25	0.03
One Repeater including manual pilot	5.2	0.18
Testing equipment when required . .	1.25	0.03

APPLICATION OF SYSTEMS IN NORWAY

The routes on which the first three systems of this type have been installed in Norway are shown in Fig. 9.

One SOT.3 system operates on one side of a phantom group between Notodden and Arendal, a single channel DA. system being on the other side-circuit between Notodden and Skien.

A second SOT.3 system operates between Notodden and Stavanger with a repeater at Kristiansand. Between Notodden and Kristiansand, this system works on the same phantom group as the Notodden–Kristiansand SOS.3 system. A carrier broadcast channel is also operating on one of these circuits in the frequency range above the telephone system. The distances between the stations are approximately as follows:

	Miles	*Kilometres*
Notodden–Arendal	112	180
Notodden–Kristiansand	175	280
Kristiansand–Stavanger	156	250

The line consists of 3.3 mm copper on the Arendal route and 4.0 mm copper on the Kristiansand route; intermediate lengths of cable are loaded for operation at carrier frequencies.

All the terminals at Notodden are "B" terminals, i.e., they transmit the high group of frequencies and receive the low. Between Notodden and Oslo, the derived voice frequency channels go forward in 2-wire cable circuits with repeaters at Kongsberg. The ringers for these nine channels are located in Oslo.

The carrier circuits in Norway are not lined up in the manner usually employed for pad switching or "tail-eating" terminations. Figs. 10, 11 and 12 illustrate the method of switching interurban lines pending completion of the 4-wire circuits which are in course of construction.

SWITCHING PRINCIPLES

The broad principles on which the present switching arrangements for the routes in question are based are as follows:

No 4-wire circuits or repeaters are used and the number of 2-wire repeaters is kept at a minimum. These repeaters are located in the middle of circuits and not at the ends. Where terminal repeaters are necessary, cord circuit repeaters are used, connected as shown in Fig. 11. Each physical circuit is provided with a simulating network for use with cord-circuit repeaters and carrier channels. To simplify switching, the 4 leads normally associated with line and network are reduced to 3 leads, one of which is common, so that three conductor plugs and cords can be used. The method of connecting this network and the associated LM (long line multiple) and FM (repeater multiple) switchboard jacks are shown in Fig. 10. Physical lines of the order of 1 neper (or 8.5 db.) equivalent are not repeatered; if the loss is much greater, however, they are repeatered and lined up to 1 neper (or 8.5 db.).

The terminations of carrier channels are shown in Fig. 12. These channels are lined up to zero equivalent from FM jack to FM jack but operate on an "up" and "down" station basis, the "down" station having a pad of 1 neper (or 8.5 db.) inserted between the LM jack and terminating set. Thus, levels throughout the systems in the direction "up" to "down" are normal on a zero equivalent basis, but levels in the direction "down" to "up" are arranged to give correct transmitting and carrier repeater outputs when the input to the terminating set is − 1 neper (or − 8.5 db.). This means that the transmitting gain is

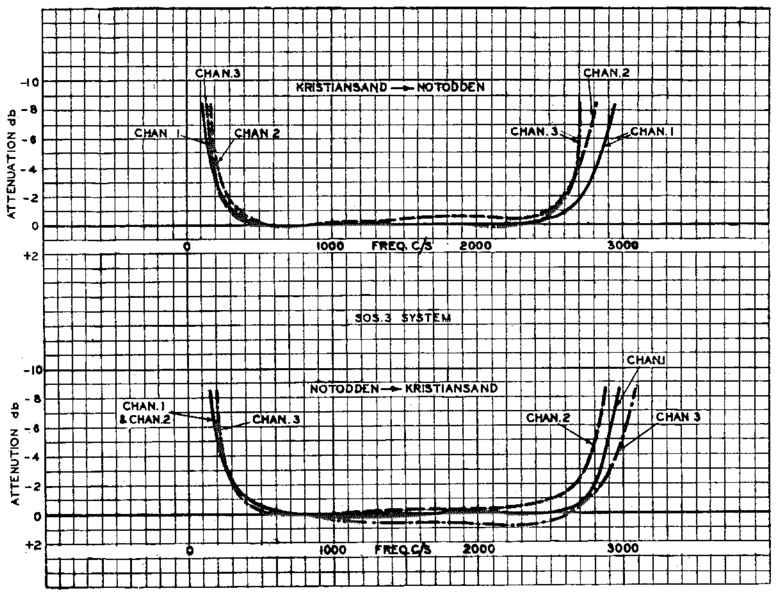


Fig. 14—Overall Quality—Notodden–Kristiansand.

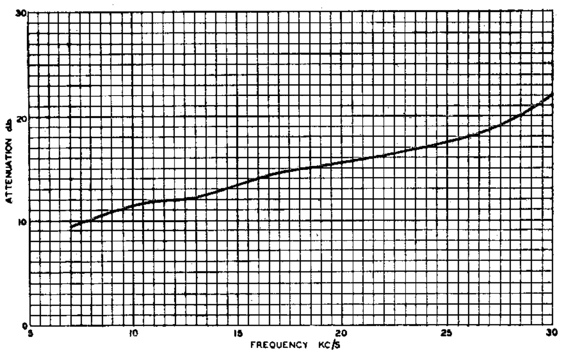


Fig. 15—*Open-wire Line Attenuation—Notodden–Kristiansand.*

normally 2 nepers (17 db.) in the "up" station and 3 nepers (25.5 db.) at the "down" station. All carrier circuits terminating in Oslo are operated as for an "up" station, but places such as Trondheim and ultimately Kristiansand will have LM and FM jack circuits of both "up" and "down" type.

OPERATION OF SWITCHING CIRCUITS

The operator always answers on the LM jack, which is also used for terminating calls and local connections. A straight-through physical to physical trunk connection, not requiring a cord-circuit repeater, is completed by patching from LM to LM jacks. If the connection involves coupling two physical lines through a cord-circuit repeater, the operator connects the repeater (Fig. 11) across the two sets of FM jacks (Fig. 10), thus terminating both sides of the repeater with the correct networks. The cord-circuit repeater is normally set to give a gain of 1 neper (or 8.5 db.).

For terminating calls on a carrier channel the LM jacks are employed, but to connect an "up" to a "down" carrier channel or vice versa, the connection is made with a straight three conductor cord between the FM jacks, the overall equivalent being thus maintained at 1 neper (or 8.5 db.). The general rule is to plug first into the "up" station jack in order to secure the network for the "down" station without leaving the latter open.

A physical line would normally be connected to an "up" carrier channel via a cord-circuit repeater and the FM jacks. If a cord-circuit repeater is not available a direct connection can be made, the balance at the "down" end, which is normally quite good (due to the pad or the correct network), maintaining the singing margin of the channel. The levels throughout the carrier system, however, will be approximately 8.5 db. lower than normal. To couple a physical circuit to a "down" carrier channel a direct connection is made from the physical FM jack to the carrier FM jack. The balance on the hybrid coil is perfect and the levels throughout the systems are correct.

LINE-UP OF CIRCUITS

Fig. 13 shows the levels on a typical carrier channel on the Oslo–Arendal system after applying the above principles. The level of – 0.45N (– 4 db.) at the 4-wire terminating set at Notodden was chosen partly because it enabled the Kongsberg repeaters to operate with an output at zero level and partly because a convenient testing power of 1 mW – 4 db. is available from the transmission measuring set. Special precautions had to be taken regarding the ringers and ringer test sets, as at the "down" stations these were effectively transmitting at a level of – 1 neper (– 8.5 db.) and receiving at zero, whereas at the "up" stations the converse was the case. It was actually found in practice, however, that operation is satisfactory if the ringers are set to operate at a level of – 0.45N (– 4 db.) for both transmitting and receiving. This avoids difficulty in spare ringer adjustments and ringer test panel settings at stations where both "up" and "down" terminals are installed.

OVERALL QUALITY

Typical overall quality measured between 4-wire terminating sets on the carrier channels is shown in Fig. 14; the corresponding measured line attenuation is shown in Fig. 15.

NOISE MEASUREMENTS

The noise on the channels was measured with a 74100 type Psophometer and was found to consist chiefly of D.C. telegraph and radio interference. The noise, however, was quite small and only on channel 2 at Kristiansand was a value of 2.0 mV exceeded on occasions as a result of severe radio interference, a disturbing E.M.F. of 3.0 mV being measured at times on this channel. This was due to temporary unbalance conditions existing on the open-wire lines in question and would not be experienced with these lines in their normal condition. Otherwise the noise at Arendal and Kristiansand did not exceed 0.22 mV on any channel measured at receiving toll test board level. On the longer repeatered circuit between Notodden and Stavanger, noise measured at Stavanger was :

Channel 1	0.4 mV
Channel 2	0.14 mV
Channel 3	0.14 mV

As was to be expected from a system employing feedback amplifiers, no appreciable interchannel crosstalk could be detected.

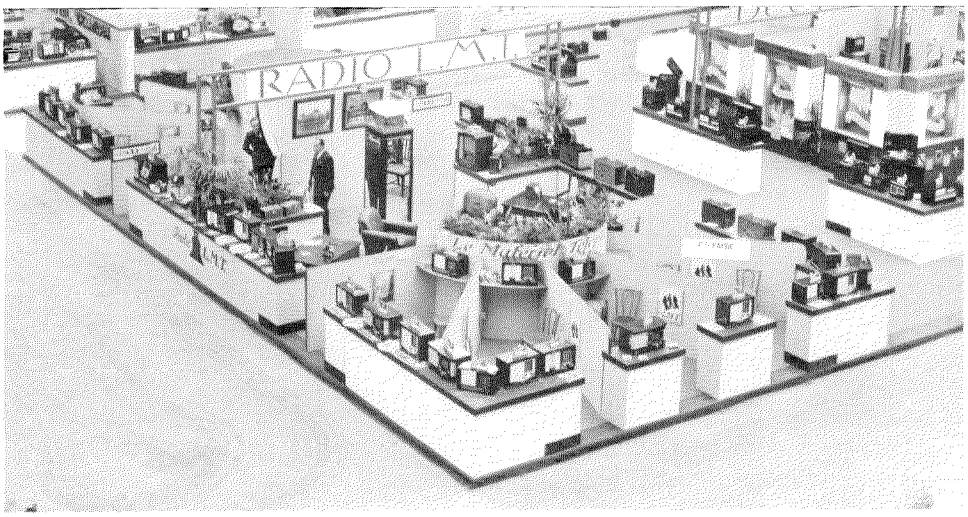
CONCLUSION

The systems described above have been in operation for approximately one year and are giving excellent service. The new features incorporated in the equipment, notably the stabilized amplifier and pilot equipment, static modulators and variable line equalizers have proved very satisfactory. In addition, the replacement of jacks by U-links in the transmission circuits and the introduction of level measurements have greatly facilitated testing and maintenance compared with the older type of systems.

It may be mentioned that two more systems are being installed—one between Kristiansand and Stavanger and the other on the Lilleström–Trondheim route with a repeater at Lillehammer.

Finally, the authors wish to express their appreciation to Mr. A. Wager of the Norwegian Telegraph Administration for his collaboration.[3]

[3] " Forbedring av Langlinjetransmisjonen," by Ved. avd. ing Alf Wager, *Tekniske Meddelelser fra Telegrafstyret*, October–December, 1935.



Paris Radio Show, "Grand Palais," September, 1938. *Le Matériel Téléphonique Radio Receiving Set Stand with Television Booth in centre. Additional displays included Television, Radio Goniometry, High Power Radio Tubes, Piezoelectric Crystals, Cathode Ray Tubes, Hot Cathode Mercury Vapour Rectifier, Selenium Rectifiers with Transformers, Rotary Automatic Telephone System (working model), Teleprinters, Photoelectric Smoke Detector built to the order of Cie. Maritime Sud-Atlantique for the S.S. "Pasteur," as well as Photoelectric Automatic Counters, Luxmeters, Photographic Exposure Meters, etc.*

A 1 000 *watt L.M.T. Public Address System supplied the main loudspeakers throughout the Exhibition. Its output was also used to modulate a high frequency current which was fed to the stands of all exhibitors for demonstrating their sets.*

Theoretical Relationships of Dielectric Guides (Cylindrical) and Coaxial Cables*

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PROVISION in a single cable of a large number of communication channels, or a television bandwidth, at present necessitates resort to a special type of cable composed of two conductors cylindrically coaxial. It is interesting to note that another solution, utilizing the propagation of electromagnetic waves through a dielectric guide limited by a metal sheath, can be envisaged. This type of guide may be constituted by a single cylindrical tube consisting, internally, solely of a dielectric cylinder through which transmission of the electromagnetic waves is effected. Recent investigations, especially the remarkable researches[1, 2] of engineers of the Bell Telephone Laboratories, New York, have disclosed the possibilities of this new method of propagation. In the present article, the results obtained by the American authors are freely used with a view to showing their theoretical relationships with the modes of propagation in coaxial cables. Attenuation values are compared for both cases, and in the case of dielectric cables, these values are compared for each type of wave on the basis of the respective frequencies which theory indicates would yield optimum operating conditions in a cable of given diameter.

Propagation through dielectric guides, provided consideration be confined to cables of practical dimensions, implies the use of oscillations of extremely high frequencies—hyper-frequencies—corresponding to waves only a few centimetres in length. Their applications, obviously, are dependent on the development of a centimetre wave technique—a technique involving production, modulation, amplification, and demodulation, and imposing numerous new and difficult problems. Thus, the general application of hyper-frequency waves in dielectric cables can hardly be visualized for some years; nevertheless, exploration of the characteristics of this new transmission facility, both from the viewpoint of the very great bandwidth which may be transmitted and simplicity of the propagation medium, evidently is potentially highly useful.

A previous issue of ELECTRICAL COMMUNICATION included articles [3, 4] by Professors J. Saphores and L. Brillouin on certain theoretical aspects of dielectric cable propagation. As to hyper-frequency technique, Les Laboratoires, Le Matériel Téléphonique, Paris, started research on the problems involved in 1929, and it will be recalled that a demonstration was made in March 1931 of a two-way radio telephonic link on a wave 17 cm in length across the English Channel [5, 6, 7]. Interest in the hyper-frequency technique was greatly increased by the publication, in 1936, of Dr. Southworth's important experiments[2] on the subject. At a meeting of the Société de Physique in Paris, November 18th, 1938, the major properties of E_0, H_0, H_1 waves were demonstrated with an 8 cm wave oscillator, and the propagation of a 2.5 cm wave in a dielectric cable 18 mm in diameter also was shown. The experimental apparatus used on this occasion will be described in a later issue of ELECTRICAL COMMUNICATION.

* * *

The problem under consideration in this article starts with the study of the propagation of electromagnetic waves in a dielectric cylinder bounded by a metal sheath. This study is extended to show the relationship existing between the above kind of propagation and that

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* The present paper is based on two articles in *Bulletin de la Société Française des Electriciens :*

"Théorie des câbles diélectriques cylindriques et relations avec la théorie des câbles coaxiaux," by A. G. Clavier, April, 1938.

" Etude complémentaire sur les coefficients d'atténuation dans les câbles diélectriques cylindriques et les câbles coaxiaux," by A. G. Clavier and V. Altovsky, September, 1938.

[1] For numbered references, see end of this article.

which occurs in a coaxial cable. Part I is devoted to general properties and frequency limits ; Part II to consideration of attenuation coefficients.

PART I: EQUATIONS—FREQUENCY LIMITS

1. General

In order to determine as a first approximation the general characteristics of the propagation of electromagnetic waves in dielectric guides, the dielectric may be considered as perfect (zero conductivity) and the sheath as a perfect conductor (infinite conductivity).

An electromagnetic wave is characterized at each point of the propagation path by a vector electric field $\vec{E}$ and a vector magnetic field $\vec{H}$ which, under the assumed conditions, are related as indicated by the well-known equations :

$$\varepsilon \frac{\partial \vec{E}}{\partial t} = \operatorname{curl} \vec{H}, \qquad (1)$$

$$-\mu \frac{\partial \vec{H}}{\partial t} = \operatorname{curl} \vec{E}; \qquad (2)$$

ε is the dielectric coefficient and μ the permeability of the medium involved.

Equations (1) and (2) are valid in both the electrostatic and electromagnetic C.G.S. systems of units, as well as in the practical system.

They imply that $\vec{E}$ and $\vec{H}$ have zero divergences, and must be used in conjunction with the boundary conditions which are derived from the fundamental laws of electromagnetism (Ampere and Faraday) and which, in this case, require that, on the surface between the dielectric and the metal sheath, the electric vector be normal and the magnetic vector tangential.

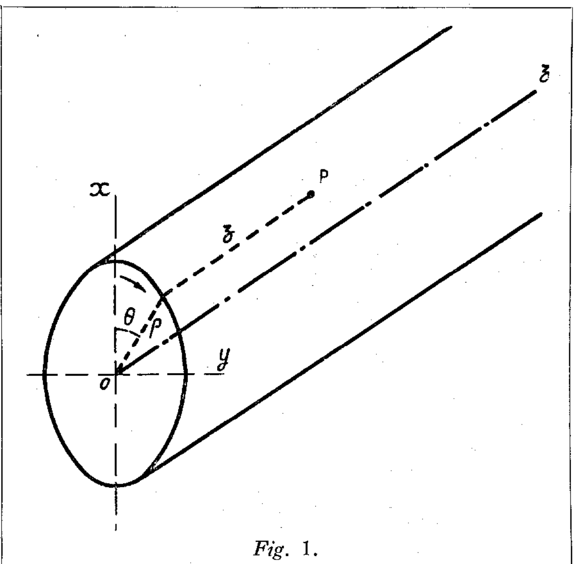

Fig. 1.

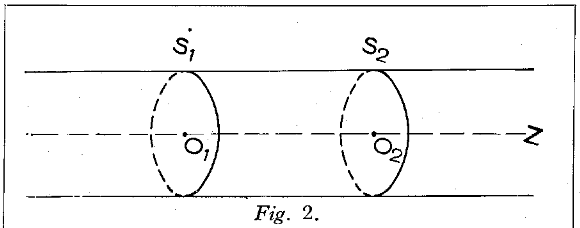

Fig. 2.

Since the problem under consideration involves cylindrical symmetry, the application of cylindrical coordinates ρ, θ, z is indicated. Such coordinates are represented in Fig. 1, as is also the positive direction of the angle of rotation.

It will be recalled that if A_ρ, A_θ, A_z are the components of a vector A, the curl components are expressed by :

$$\operatorname{curl}_\rho A = \frac{1}{\rho}\frac{\partial A_z}{\partial \theta} - \frac{\partial A_\theta}{\partial z}, \qquad (3)$$

$$\operatorname{curl}_\theta A = \frac{\partial A_\rho}{\partial z} - \frac{\partial A_z}{\partial \rho}, \qquad (4)$$

$$\operatorname{curl}_z A = \frac{1}{\rho}\left\{\frac{\partial}{\partial \rho}(\rho A_\theta) - \frac{\partial A_\rho}{\partial \theta}\right\}, \qquad (5)$$

$$\text{and div. } A = \frac{1}{\rho}\frac{\partial}{\partial \rho}(\rho A_\rho) + \frac{1}{\rho}\frac{\partial A_\theta}{\partial \theta} + \frac{\partial A_z}{\partial z}. \qquad (6)$$

2. Energy Considerations

Let us consider the dielectric volume V bounded by two cross-sections S_1 and S_2 and the metal sheath (Fig. 2). The electromagnetic energy in this volume at a given time is obtained by the summation in V of $\frac{1}{8\pi}(\varepsilon E^2 + \mu H^2)$.

According to Poynting's theorem :

$$\frac{1}{4\pi}\int_S [\vec{E} \times \vec{H}] dS = -\frac{\partial}{\partial t}\frac{1}{8\pi}\int_V (\varepsilon E^2 + \mu H^2)\, dV. \qquad (7)$$

We are only interested in fields which vary periodically with time, so that the mean value of the total flux of the Poynting vector $\frac{1}{4\pi}[\vec{E} \times \vec{H}]$ in a period is zero. There is no flux, however, passing through the metal sheath. The mean value W_m of the flux through S_1, S_2, and therefore any cross-section, in direction $0z$, is constant and gives a measure of the flux of energy along the cable.

Separation is then indicated of $\vec{E}$ and $\vec{H}$ into cross-section components $\vec{E_s}$ and $\vec{H_s}$ and axial components $\vec{E_z}$ and $\vec{H_z}$. W_m is expressed by means of $\vec{E_s}$ and $\vec{H_s}$ only :

$$W_m = \overline{\int_S \frac{1}{4\pi} [\vec{E_s} \times \vec{H_s}] \, dS}, \qquad (8)$$

and requires $\vec{E_s}$ and $\vec{H_s}$ to coexist in order to ensure propagation along the cable axis.

3. *Separation of different types of progressive waves*

In view of the above, equations (1) and (2) may be written as follows :

$$\varepsilon \frac{\partial \vec{E_s}}{\partial t} - \text{curl}\ \vec{H_s} = \text{curl}\ \vec{H_z} - \varepsilon \frac{\partial \vec{E_z}}{\partial t}\ , \qquad (9)$$

$$-\mu \frac{\partial \vec{H_s}}{\partial t} - \text{curl}\ \vec{E_s} = \text{curl}\ \vec{E_z} + \mu \frac{\partial \vec{H_z}}{\partial t}\ . \qquad (10)$$

Since we are considering progressive waves along the axis $0z$, all vectors $\vec{A}$ occurring in our problem should be of the form

$$\vec{A_s}\ .\ e^{j(\omega t - \gamma z)}, \qquad (11)$$

in which $\vec{A_s}$ is dependent on coordinates ρ and θ only.

$$\omega = 2\pi f, \qquad (12)$$

$$\gamma = \frac{2\pi}{\lambda'} = \frac{2\pi f}{v'}; \qquad (13)$$

f is the frequency, λ' the length of wave along $0z$, v' the phase velocity along $0z$.

Hence

$$\frac{\partial \vec{A}}{\partial t} = j\,\omega\,\vec{A}, \qquad (14)$$

$$\frac{\partial \vec{A}}{\partial z} = -j\,\gamma\,\vec{A}\ . \qquad (15)$$

As our problem is to find $\vec{E_s}$ and $\vec{H_s}$, which are expressed in terms of the axial components by means of the linear differential equations (9) and (10), the solutions can be considered as resulting from the superposition of the three following cases :

(*a*) $H_z = 0$ and $E_z = 0$ everywhere in the cable ;
(*b*) $H_z = 0$ everywhere in the cable ;
(*c*) $E_z = 0$ everywhere in the cable.

4. *Non-existence of wave for which $H_z = E_z = 0$ in a dielectric cable—The coaxial cable type of wave*

In case H_z and E_z are assumed to be zero everywhere, equation (5) combined with equation (10) yields the relation :

$$\frac{\partial}{\partial \rho}(\rho E_\theta) - \frac{\partial E_\rho}{\partial \theta} = 0\ ; \qquad (16)$$

a corresponding relation applies for the H components.

On the other hand, the divergence condition for the E vector in this case would yield (see Equation 6) :

$$\frac{\partial}{\partial \rho}(\rho E_\rho) + \frac{\partial E_\theta}{\partial \theta} = 0. \qquad (17)$$

This means that E depends on a two-dimensional potential $U(\rho, \theta)$:

$$\rho E_\theta = -\frac{\partial U}{\partial \theta}\ e^{j(\omega t - \gamma z)}, \qquad (18)$$

$$E_\rho = -\frac{\partial U}{\partial \rho}\ e^{j(\omega t - \gamma z)}\ ; \qquad (19)$$

U, according to (17), verifies Laplace's equation :

$$\nabla^2 U = 0 \text{ (two dimensional)}\ ; \qquad (20)$$

and, since E is normal to the boundary, U must be constant on the boundary and therefore at all other points, according to a known property of such potential functions.

There is thus no possible wave in a dielectric cable for which H_z and E_z are simultaneously zero everywhere.

On the other hand, this type of wave can exist when there is another metallic boundary inside the sheath and, in this case, U must be constant on each of the boundaries. A well-known instance is exemplified by the coaxial type of cable, in which the only possible form of the potential U is known to be given by the logarithmic law of distribution :

$$U = -A \log \rho + B, \tag{21}$$

A and B both being constants.

The fundamental properties of this type of wave are easily derived from consideration of equations (9) and (10). E and H are reduced to components E_ρ and H_θ.

Equations (9) and (3) combined yield the relation :

$$\varepsilon \frac{\partial E_\rho}{\partial t} = -\frac{\partial H_\theta}{\partial z}, \tag{22}$$

and, from equations (10) and (4),

$$-\mu \frac{\partial H_\theta}{\partial t} = \frac{\partial E_\rho}{\partial z}; \tag{23}$$

$$\text{hence } \varepsilon\mu \frac{\partial^2 E_\rho}{\partial t^2} = \frac{\partial^2 E_\rho}{\partial z^2}. \tag{24}$$

The same relation applies for H_θ. It shows that the wave is propagated with a speed

$$v = \frac{1}{\sqrt{\varepsilon\mu}}, \tag{25}$$

equal to that of light in a homogeneous dielectric medium with coefficients ε and μ.

Applying equations (14), (15) to (22), and (19), it is found that :

$$E_\rho = \sqrt{\frac{\mu}{\varepsilon}}\, H_\theta = \frac{A}{\rho} e^{j(\omega t - \gamma z)}. \tag{26}$$

In this case it is easy to pass from the equations relating to the vector fields to those involving difference of potential V between the two conductors and the current I in one or the other conductor.

Let a and b be the radii of the interior and exterior coaxial conductors, respectively.

Inasmuch as there is no axial dielectric current to consider, it immediately follows that :

$$2\pi\rho H_\theta = 4\pi I = 4\pi \mathbf{I}\, e^{j(\omega t - \gamma z)} \tag{27}$$

which, for A, gives :

$$A = 2\sqrt{\frac{\mu}{\varepsilon}}\, \mathbf{I}; \tag{28}$$

then, from (21) :

$$V = \mathbf{V} e^{j(\omega t - \gamma z)} = 2\sqrt{\frac{\mu}{\varepsilon}} \log\frac{b}{a} \cdot e^{j(\omega t - \gamma z)}. \tag{29}$$

$$\text{Hence } \frac{V}{I} = \frac{\mathbf{V}}{\mathbf{I}} = 2\sqrt{\frac{\mu}{\varepsilon}} \log . \frac{b}{a} = Z; \tag{30}$$

Z is the characteristic impedance of the coaxial cable.

Similarly, the well-known Kirchhoff equations for the case of a coaxial cable without dissipation may be derived from the above equations.

5. *Waves in dielectric cables for which $H_z = 0$ everywhere (E waves)*

From the condition $H_z = 0$, the following simplification ensued in the first two relations included in equation (9) :

$$\varepsilon \frac{\partial E_\rho}{\partial t} + \frac{\partial H_\theta}{\partial z} = 0, \tag{31}$$

$$\varepsilon \frac{\partial E_\theta}{\partial t} - \frac{\partial H_\rho}{\partial z} = 0. \tag{32}$$

This yields, according to (14) and (15) :

$$E_\rho = \frac{\gamma}{\omega\varepsilon} H_\theta = \sqrt{\frac{\mu}{\varepsilon}} \frac{v}{v'} H_\theta, \tag{33}$$

$$E_\theta = -\frac{\gamma}{\omega\varepsilon} H_\rho = -\sqrt{\frac{\mu}{\varepsilon}} \frac{v}{v'} H_\rho. \tag{34}$$

The vectors $\vec{E_s}$ and $\vec{H_s}$ evidently are perpendicular. Equations (33) and (34) should be compared with equation (26) obtained in the case of the coaxial cable.

These relations, together with equation (10), enable the cross-section components to be expressed in terms of the derivatives of E_z. It is found that :

$$j k^2 E_\rho = \gamma \frac{\partial E_z}{\partial \rho}, \tag{35}$$

$$j k^2 E_\theta = \frac{\gamma}{\rho} \frac{\partial E_z}{\partial \theta}, \tag{36}$$

$$-j k^2 H_\rho = \frac{\omega\varepsilon}{\rho} \frac{\partial E_z}{\partial \theta}, \tag{37}$$

$$-j k^2 H_\theta = -\omega\varepsilon \frac{\partial E_z}{\partial \rho}. \tag{38}$$

Assuming

$$k = \sqrt{\omega^2\varepsilon\mu - \gamma^2} = 2\pi f \sqrt{\frac{1}{v^2} - \frac{1}{v'^2}} = 2\pi \sqrt{\frac{1}{\lambda^2} - \frac{1}{\lambda'^2}}; \tag{39}$$

λ is the wavelength corresponding to the frequency f in the homogeneous dielectric medium characterized by the coefficients ε and μ.

The variation of E_z, in ρ and θ co-ordinates is then governed by the equation of divergence

$$\text{div.}\ \vec{E} = 0. \tag{40}$$

This yields, with E_ρ and E_θ replaced by their equivalents in (35) and (36),

$$\frac{\partial^2 E_z}{\partial \rho^2} + \frac{1}{\rho}\frac{\partial E_z}{\partial \rho} + \frac{1}{\rho^2}\frac{\partial^2 E_z}{\partial \theta^2} + k^2 E_z = 0. \tag{41}$$

Substituting :

$$E_z = \mathbf{E}_z \cos(n\theta - \varphi)\ e^{j(\omega t - \gamma z)}, \tag{42}$$

where $\mathbf{E}_z$ is a function of ρ only ; then

$$\frac{d^2\mathbf{E}_z}{d\rho^2} + \frac{1}{\rho}\frac{d\mathbf{E}_z}{d\rho} + \left(k^2 - \frac{n^2}{\rho^2}\right)\mathbf{E}_z = 0. \tag{43}$$

This is a classic Bessel equation, the solution of which is written in the form :

$$\mathbf{E}_z = A_n J_n(k\rho) + B_n Y_n(k\rho); \tag{44}$$

J_n and Y_n are Bessel functions of the first and second kinds and of the n^th^ order.

The function Y, being infinite for $\rho = 0$, is not suitable for the present purpose. On the other hand, φ in equation (42) can be made equal to zero by a proper choice of axis. Accordingly, for E_z, the following expression is obtained :

$$E_z = A_n J_n(k\rho).\ \cos n\theta.\ e^{j(\omega t - \gamma z)}. \tag{45}$$

Equations (35) to (38) would then give the expressions for the cross-sectional components.

It is thus found that E waves can exist in dielectric guides provided the boundary condition on the surface between the dielectric and the metal sheath be satisfied. This, if the cable has a radius b, requires that $(k \neq 0)$:

$$J_n(kb) = 0. \tag{46}$$

A particular E wave is characterized by its law of distribution along a circumference centred on the cable axis (value of n), and by its law of distribution along the radius in a cross-section (rank of the root of equation (46) which the particular value of kb verifies).

6. *Waves in dielectric guides for which $E_z = 0$ everywhere (H waves)*

The condition $E_z = 0$ leads to a group of relations analogous to the group obtained for $H_z = 0$. Thus (33) and (34) become :

$$E_\rho = \frac{\omega\mu}{\gamma} H_\theta = \sqrt{\frac{\mu}{\varepsilon}}\frac{v'}{v} H_\theta, \tag{47}$$

$$E_\theta = -\frac{\omega\mu}{\gamma} H_\rho = -\sqrt{\frac{\mu}{\varepsilon}}\frac{v'}{v} H_\rho. \tag{48}$$

The cross-sectional components are expressed in terms of the derivatives of H_z by the following equations :

$$j k^2 E_\rho = \frac{\omega\mu}{\rho}\frac{\partial H_z}{\partial \theta}, \tag{49}$$

$$j k^2 E_\theta = -\omega\mu\frac{\partial H_z}{\partial \rho}, \tag{50}$$

$$-j k^2 H_\rho = -\gamma\frac{\partial H_z}{\partial \rho}, \tag{51}$$

$$-j k^2 H_\theta = -\frac{\gamma}{\rho}\frac{\partial H_z}{\partial \theta}. \tag{52}$$

The divergence equation for H_z yields the same relation as (41) for E_z. It follows directly that :

$$H_z = B_n J_n(k\rho)\cos n\theta\ e^{j(\omega t - \gamma z)}. \tag{53}$$

H waves can thus exist in dielectric cables, provided the boundary condition be satisfied. This requires that $(k \neq 0)$:

$$J_n'(kb) = 0, \tag{54}$$

$k J_n'(k\rho)$ being the derivative of $J_n(k\rho)$ with respect to ρ.

A particular H wave will thus be characterized, as in the case of E waves, by the value of n and the rank of the root kb of equation (54). The value of n governs the law of distribution of vector amplitudes along a circumference in the cross-section, centred on the cable axis. The rank of the root of equation (54) governs the law of distribution along the radius in a cross-section.

7. *Lower frequency limits of E and H waves*

In the type of waves studied in connection with coaxial cables, vectors E_z, E_θ, or H_ρ were not encountered. The boundary condition on the surfaces separating the dielectric from the conductors is thus automatically fulfilled, and the problem of a frequency limit does not arise.

For E and H waves in dielectric cables, however, conditions (46) and (54), respectively, must be satisfied. Let us confine our analysis to the first acceptable solution ($\neq 0$) of these equations, calling it r_n (or r_n' for (54)).

Then $kb = r_n$ (or r_n') ; (55)

that is : $$2\pi f \sqrt{\frac{1}{v^2} - \frac{1}{v'^2}} = \frac{r_n}{b} \quad . \qquad (56)$$

Equation (56) shows that the phase velocity v' in the cable must always be greater than the free velocity of light v in the dielectric medium considered.

The lowest value of f, that is f_{mn}, corresponds to an infinite value of v' and, consequently,

$$f_{mn} = \frac{kv}{2\pi} = v \frac{r_n}{2\pi b} \quad . \qquad (57)$$

This frequency f_{mn} in the medium ε, μ, corresponds to a maximum wavelength such that

$$\lambda_{Mn} = \frac{2\pi b}{r_n} \quad . \qquad (58)$$

Tabulating values r_n and r_n' in accordance with the curves of Fig. 3,

n	0	1	2 ......
r_n	2.4	3.8	5.1 ......
r'_n	3.8	1.8	3 ......

the following remarks can be made :

1. Wave H_1 permits of the use, for a cable of given radius, of the lowest frequencies.

2. Waves H_0 and E_1 have the same lower limiting frequencies, as indicated by the mathematical relationship $J_0' = -J_1$.

3. From the viewpoint of the most immediate application the waves to be considered are E_0 and H_0, representing a fundamental

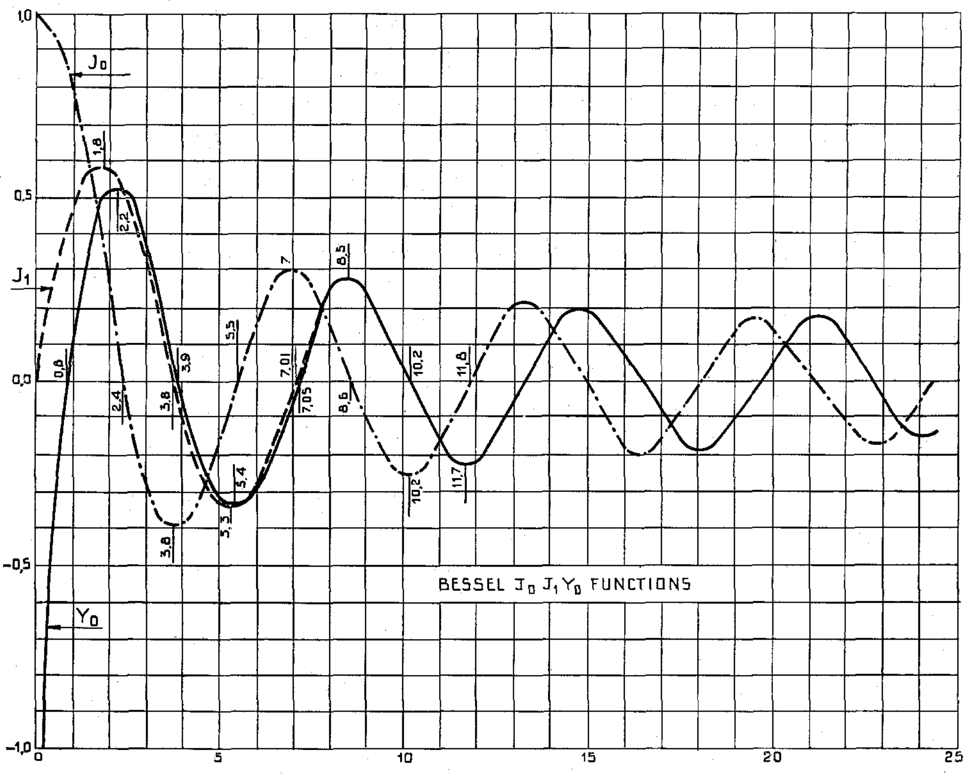

Fig. 3.

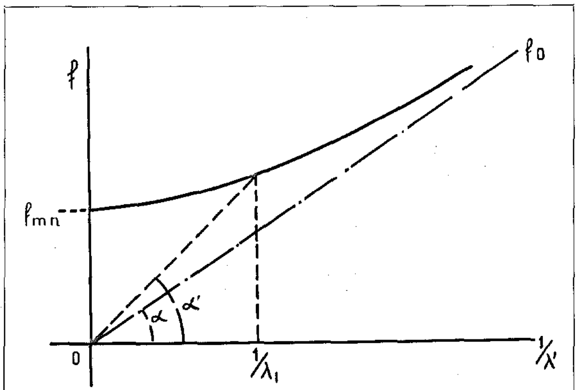

Fig. 4.

type, and H_1 waves which give the most favourable lower frequency limit.

4. In all cases the limiting frequency corresponds to a wavelength λ_{Mn} in the free dielectric medium which, according to (58), is of the same order of magnitude as the cable diameter. Propagation through dielectric cables, provided consideration be confined to cables of practical dimensions, therefore, implies the use of oscillations of extremely high frequencies, corresponding to waves only a few centimetres in length.

The lengths λ_M given above are wavelengths in an unbounded homogeneous medium characterized by coefficients ε and μ. If c be the velocity of light in a vacuum (coefficients ε_0 and μ_0), the corresponding wavelengths are :

$$\lambda_M^0 = \lambda_M \frac{c}{v} = \lambda_M \sqrt{\frac{\varepsilon}{\varepsilon_0} \cdot \frac{\mu}{\mu_0}} = \frac{2\pi b}{r_n} \sqrt{\frac{\varepsilon}{\varepsilon_0} \cdot \frac{\mu}{\mu_0}}. \quad (59)$$

Thus the substitution of a dielectric ε, μ for ε_0, μ_0 makes possible the use of lower frequencies for a dielectric cable of given diameter. However, the controlling consideration is the attenuation of the energy transmitted along the cable, governing the maximum possible cable length between successive repeater stations of given gain. This problem will be discussed in Part II.

8. *Phase and Group Velocities*

In the case of a coaxial cable without dissipation, the wave is propagated with a speed $v = \frac{1}{\sqrt{\varepsilon\mu}}$ independent of the frequency. Both phase and group velocities are equal to the speed of light in a homogeneous medium characterized by coefficients ε and μ.

For E and H waves, however, the phase velocity v' has been found to be greater than the free velocity of light in the medium considered. Equations (56) and (57) show that :

$$k = 2\pi f \sqrt{\frac{1}{v^2} - \frac{1}{v'^2}} = \frac{2\pi f_{mn}}{v} ; \quad (60)$$

$$\text{whence} \quad \left(\frac{f_{mn}}{f}\right)^2 = 1 - \left(\frac{v}{v'}\right)^2 . \quad (61)$$

The curve linking $\frac{f_{mn}}{f}$ to $\frac{v}{v'}$ is thus a circle of radius 1.

Equation (61) is equivalent to :

$$f^2 = f_{mn}^2 + \frac{v^2}{\lambda'^2} \quad . \quad (62)$$

It relates f to $\frac{1}{\lambda'}$ and corresponds to the curve of Fig. 4, on which is also represented the frequency f_0 corresponding to the wavelength λ' in the free medium ε, μ.

For the same wavelength λ_1 in the free medium and along the cable, the phase velocities are :

$$\tan \alpha = v \quad (63)$$

$$\tan \alpha' = v'. \quad (64)$$

It may be seen from Fig. 4 that v' is always greater than v and approaches v for very small values of wavelength λ'.

As for the group velocity v_g, which must be considered when modulated signals are to be transmitted along the cable, it is easily derived from equation (39) :

$$k^2 = \omega^2 \varepsilon\mu - \gamma^2,$$

in which k^2, according to (60), is a constant for a cable of given diameter.

$$\text{Hence} \quad \frac{2\omega d\omega}{v^2} - 2\gamma . d\gamma = 0, \quad (65)$$

$$\text{so that} \quad v_g = \frac{d\omega}{d\gamma} = \frac{v^2}{v'} . \quad (66)$$

Since the phase velocity v' is always greater than v, the group velocity v_g is always less than v, the speed of light in the free medium characterized by coefficients ε and μ.

9. *Propagation of E and H waves in coaxial cables*

Though no $E_z = H_z = 0$ wave can exist in a dielectric cable, E waves ($H_z = 0$; $E_z \neq 0$) and H waves ($E_z = 0$; $H_z \neq 0$) can exist in coaxial cables. The solution (44) applies in this case, provided the boundary conditions are satisfied. Functions Y_n should here be retained, since the variable ρ now has a lower limit equal to the radius a of the interior conductor.

For E waves, the boundary conditions imply that:

$$A_n J_n(ka) + B_n Y_n(ka) = 0, \quad (67)$$

$$A_n J_n(kb) + B_n Y_n(kb) = 0. \quad (68)$$

Hence $$\frac{J_n(ka)}{Y_n(ka)} = \frac{J_n(kb)}{Y_n(kb)} . \quad (69)$$

For H waves, a corresponding relation to (69) is found; that is:

$$\frac{J'_n(ka)}{Y'_n(ka)} = \frac{J'_n(kb)}{Y'_n(kb)} . \quad (70)$$

Assuming a known ratio for $\frac{b}{a}$, equations (69) and (70) can be solved graphically. If, for instance, $\frac{b}{a} = 3.6$, the following values for kb and, consequently, for λ_M are found:

Type of wave	E_0	H_0	H_1
kb	4.26	4.6	1.54
λ_M	$1.47b$	$1.4b$	$4b$

As in the case of dielectric cables, the H_1 type of wave is the most favourable as regards frequency limitation.

Part II: ATTENUATION COEFFICIENTS

10. *Method of approximating the attenuation coefficient*

In the foregoing analysis, the dielectric is considered as perfect (zero conductivity) and the metal as a perfect conductor (infinite conductivity). The vector fields are propagated without attenuation, and the mean flux of energy in a period through any cross-section is constant. The vectors, therefore, all contain a factor $e^{j(\omega t - \gamma z)}$ in which the coefficient γ is real.

Consideration will now be given to the case of a propagation loss small in comparison with the mean flux of energy. Accordingly the factor $e^{j(\omega t - \gamma z)}$ is changed into $e^{j(\omega t - \gamma z) - \alpha z}$ in which α is the attenuation coefficient.

If α be sufficiently small compared with γ, the results of the foregoing analysis may be considered as an initial satisfactory approximation provided the exponential factor be modified as indicated above.

Let any component be written as follows:

$$A = \mathbf{A}\, e^{j\omega t} . e^{-(\alpha + j\gamma) z} . \quad (71)$$

The mean flux of energy in a complete cycle is then expressed by:

W_m = Real component of:

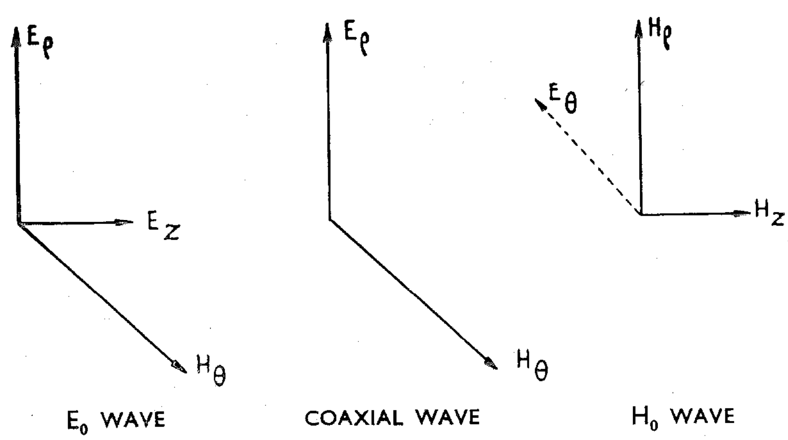

Fig. 5.

$$\frac{1}{8\pi} e^{-2\alpha z} \int_{(S)} (\mathbf{E}_\rho \mathbf{H}_\theta^* - \mathbf{E}_\theta \mathbf{H}_\rho^*) \, dS, \qquad (72)$$

$\mathbf{H}^*$ being the conjugate complex quantity of $\mathbf{H}$.

Let us call the value of the real component of the integral $\mathbf{W}_m$. It does not depend on z, so that:

$$-\frac{dW_m}{dz} = 2\alpha \mathbf{W}_m e^{-2\alpha z} \quad . \qquad (72a)$$

Provided zero loss be assumed in the dielectric, the energy loss $-dW_m$ per length dz is equal to the heat dissipation in the copper in a complete cycle. This heat dissipation can be obtained by means of Lord Kelvin's "skin-effect" theory, and takes the form $\mathbf{Q}_m e^{-2\alpha z}. dz$;

$$\text{hence, } \alpha = \frac{\mathbf{Q}_m}{2\,\mathbf{W}_m} \qquad (73)$$

11. Mean flux of energy W_m for the coaxial cable wave and E_0 and H_0 dielectric cable waves

Let us first examine the coaxial cable type of wave, and the E_0 and H_0 modes in the dielectric cable, as regards attenuation due to heat dissipation in the copper only.

These types of waves are characterized by the field components represented in Fig. 5. Moreover, the components are related by the following equations in Part I:

$$E_0 \text{ wave } (v' > v) \qquad E_\rho = \frac{v}{v'}\sqrt{\frac{\mu}{\varepsilon}}\, H_\theta; \qquad (74)$$

$$\text{Coaxial wave } (v' = v) \qquad E_\rho = \sqrt{\frac{\mu}{\varepsilon}}\, H_\theta; \qquad (75)$$

$$H_0 \text{ wave } (v' > v) \qquad E_\theta = \frac{v'}{v}\sqrt{\frac{\mu}{\varepsilon}}\, H_\rho. \qquad (76)$$

In a cross-section, the field components do not vary along a circumference centred on the cable axis. They vary along the radius according to the following laws of distribution:

$$E_0 \text{ wave} \qquad \mathbf{E}_z = A\, J_0(k\rho)$$

$$\mathbf{E}_\rho = \frac{\gamma}{jk} A\, J_0'(k\rho); \qquad (77)$$

$$\text{Coaxial wave } \mathbf{E}_\rho = \frac{A}{\rho}; \qquad (78)$$

$$H_0 \text{ wave} \qquad \mathbf{H}_z = A\, J_0(k\rho)$$

$$\mathbf{H}_\rho = \frac{\gamma}{jk} A\, J_0'(k\rho). \qquad (79)$$

In the above expressions v' is the phase velocity along the cable and:

$$\gamma = \frac{2\pi f}{v'} = \frac{\omega}{v'} = \frac{2\pi}{\lambda'}, \qquad (80)$$

$$k^2 = \frac{\omega^2}{v^2} - \gamma^2 = \omega^2\left[\frac{1}{v^2} - \frac{1}{v'^2}\right]; \qquad (81)$$

v is the velocity of light in the free dielectric medium characterized by coefficients ε and μ.

From equation (72) and the above relations, the following values of $\mathbf{W}_m$ are obtained for the three different types of waves:

$$E_0 \text{ wave} \qquad \mathbf{W}_m = \frac{1}{4}\frac{v'}{v}\sqrt{\frac{\varepsilon}{\mu}}\int_0^b \mathbf{E}_\rho^2\, \rho\, d\rho; \qquad (82)$$

$$\text{Coaxial wave } \mathbf{W}_m = \frac{1}{4}\sqrt{\frac{\varepsilon}{\mu}}\int_a^b \mathbf{E}_\rho^2\, \rho\, d\rho; \qquad (83)$$

$$H_0 \text{ wave} \qquad \mathbf{W}_m = \frac{1}{4}\frac{v'}{v}\sqrt{\frac{\mu}{\varepsilon}}\int_0^b \mathbf{H}_\rho^2\, \rho\, d\rho. \qquad (84)$$

It is assumed in these expressions that such quantities as $\mathbf{E}_\rho$ are taken as equal to the modulus of the corresponding expression (77). This assumption will be adhered to in all the following sections.

When the calculations are completed, there result expressions of $\mathbf{W}_m$ in terms of the amplitudes of the vectors on the surface of the outside conductor, as follows:

E_0 wave:

$$\mathbf{W}_m = \frac{1}{8} b^2\, \mathbf{E}_\rho(b).\ \mathbf{H}_\theta(b)$$

$$= \frac{1}{8} b^2 \frac{v}{v'}\sqrt{\frac{\mu}{\varepsilon}}\ \overline{\mathbf{H}_\theta(b)}^2; \qquad (85)$$

Coaxial wave:

$$\mathbf{W}_m = \frac{1}{4} b^2 \log\frac{b}{a}\, \mathbf{E}_\rho(b)\, \mathbf{H}_\theta(b)$$

$$= \frac{1}{4} b^2 \log\frac{b}{a}\sqrt{\frac{\mu}{\varepsilon}}\ \overline{\mathbf{H}_\theta(b)}^2; \qquad (86)$$

H_0 wave:

$$\mathbf{W}_m = \frac{1}{8} b^2 \frac{vv'}{v'^2 - v^2}\sqrt{\frac{\mu}{\varepsilon}}\ \overline{\mathbf{H}_z(b)}^2. \qquad (87)$$

12. Approximate values of current for the three types of waves considered

For an E_0 wave, the total axial dielectric current is related to the magnetic field on the surface of the conductor by the equation :

$$4\pi \mathbf{I} = 2\pi b \mathbf{H}_\theta(b). \quad (88)$$

The metal sheath is assumed to be thick enough for the magnetic field to be considered as zero in the copper at a certain distance from the interior surface. Thus the total current in the copper is also equal to $\mathbf{I}$, that is :

$$\mathbf{I} = \frac{1}{2} b \mathbf{H}_\theta(b). \quad (89)$$

It flows in the axial direction.

A similar consideration gives the current in the case of the coaxial cable. Provided the axial dielectric current be considered as negligible, the current has the same value in both conductors and is expressed the same as in (89).

For the H_0 wave, however, the only magnetic field component which exists on the surface of the metal sheath is H_z. The current flows in a circular direction, and its value per length dz is given by :

$$4\pi \mathbf{I}_\theta = \mathbf{H}_z(b).\, dz\,, \quad (90)$$

$$\mathbf{I}_\theta = \frac{1}{4\pi} \mathbf{H}_z(b)\, dz. \quad (91)$$

13. *Variation of current with frequency for constant mean flux of energy*

When constant mean flux of energy is assumed for the three types of waves, the values for the magnetic field components on the interior surface of the metal sheath (or exterior conductor in the case of the coaxial cable) are obtained from equations (85) to (87) :

E_0 wave

$$\mathbf{H}_\theta(b) = \frac{1}{b}\sqrt{8\mathbf{W}_m\sqrt{\frac{\varepsilon}{\mu}}}\sqrt{\frac{v'}{v}}\ ; \quad (92)$$

Coaxial wave

$$\mathbf{H}_\theta(b) = \frac{1}{b}\sqrt{\frac{4\mathbf{W}_m}{\log\frac{b}{a}}\sqrt{\frac{\varepsilon}{\mu}}}\ ; \quad (93)$$

H_0 wave

$$\mathbf{H}_z(b) = \frac{1}{b}\sqrt{8\mathbf{W}_m\sqrt{\frac{\varepsilon}{\mu}}}\sqrt{\frac{v'^2-v^2}{v\,v'}}\,. \quad (94)$$

From the values of currents found in section 12, it follows that when constant mean flux of energy is assumed :

(*a*) the current decreases with frequency for the E_0 wave, since v' decreases as shown in Part I. The value of the current tends towards a limit for very high frequencies, as v' tends towards v ;

(*b*) the current remains constant for the coaxial wave ;

(*c*) the current decreases with frequency for the H_0 wave. In this case, however, the value of the current tends towards zero for very high frequencies.

This property of the H_0 wave is highly important. The current in this case does not depend on a magnetic field component which is essential to the propagation of energy in the direction of the axis of the cable. The component on which it depends, H_z, tends to disappear when the frequency is greatly above the lower limit for a cable of given radius. For such a frequency the phase velocity in the cable is very close to the velocity of light in the free dielectric medium considered.

14. *Dissipated energy in the copper for a length dz of cable*

The high-frequency resistance of the current path may be deduced from Lord Kelvin's "skin-effect" theory. Accordingly, for the three cases considered :

E_0 wave $$R = \frac{1}{b}\sqrt{\frac{\mu_2 f}{\sigma_2}}\, dz, \quad (95)$$

Coaxial wave $$R = \left(\frac{1}{a} + \frac{1}{b}\right)\sqrt{\frac{\mu_2 f}{\sigma_2}}\, dz, \quad (96)$$

H_0 wave $$R = \frac{(2\pi b)^2}{b\, dz}\sqrt{\frac{\mu_2 f}{\sigma_2}}. \quad (97)$$

μ_2 is the coefficient of permeability and σ_2 the coefficient of conductivity of the metal sheath.

The resistance is thus seen to increase as the square root of the frequency.

The dissipated energy in the copper for a short length dz of cable in which the current may be considered as constant is expressed by $\frac{1}{2} R \mathbf{I}^2 e^{-2\alpha z}$.

It can be written, as assumed in Section 10 : $\mathbf{Q}_m e^{-2\alpha z}.\, dz$, $\mathbf{Q}_m$ being equal to :

E_0 wave

$$\mathbf{Q}_m = \frac{1}{8} b \sqrt{\frac{\mu_2 f}{\sigma_2}} \; \overline{\mathbf{H}_\theta (b)}^2 \; ; \quad (98)$$

Coaxial wave

$$\mathbf{Q}_m = \frac{1}{8} b^2 \left(\frac{1}{a} + \frac{1}{b}\right) \sqrt{\frac{\mu_2 f}{\sigma_2}} \; \overline{\mathbf{H}_\theta (b)}^2 ; \quad (99)$$

H_0 wave

$$\mathbf{Q}_m = \frac{1}{8} b \sqrt{\frac{\mu_2 f}{\sigma_2}} \; \overline{\mathbf{H}_z (b)}^2 \quad (100)$$

For constant mean flux of energy in the cross-section, the following expressions apply:

E_0 wave

$$\mathbf{Q}_m = \frac{1}{b} \sqrt{\frac{\varepsilon\mu_2}{\mu\sigma_2}} \sqrt{f} \frac{v'}{v} \mathbf{W}_m ; \quad (101)$$

Coaxial wave

$$\mathbf{Q}_m = \frac{1 + \frac{b}{a}}{2 b \log \frac{b}{a}} \sqrt{\frac{\varepsilon\mu_2}{\mu\sigma_2}} \sqrt{f} \mathbf{W}_m ; \quad (102)$$

H_0 wave

$$\mathbf{Q}_m = \frac{1}{b} \sqrt{\frac{\varepsilon\mu_2}{\mu\sigma_2}} \sqrt{f} \frac{v'^2 - v^2}{vv'} \mathbf{W}_m . \quad (103)$$

15. Attenuation coefficients for the three types of waves considered

The attenuation coefficients due to the dissipated energy in the copper are equal to $\frac{\mathbf{Q}_m}{2\mathbf{W}_m}$ (see section 10).

For the coaxial cable type of wave, the well known expression for the attenuation coefficient is obtained; that is:

$$\alpha = \frac{1}{4} \sqrt{\frac{\mu_2 \varepsilon}{\mu\sigma_2}} \; \frac{1 + \frac{b}{a}}{b \log \frac{b}{a}} \sqrt{f} \quad . \quad (104)$$

It appears as the product of three factors: the first $\left(\frac{1}{4}\sqrt{\frac{\mu_2\varepsilon}{\mu\sigma_2}}\right)$ depends on the material constituents of the cable; the second $\left(\frac{1 + \frac{b}{a}}{b \log \frac{b}{a}}\right)$, on the geometrical dimensions; and the third $(\sqrt{f})$ on the frequency utilized.

The second factor is the product of $\frac{1}{b}$ and a function of $\frac{b}{a}$ which passes through a minimum for

$$\frac{b}{a} = 3.6 \quad . \quad (105)$$

In this case of minimum attenuation,

$$\alpha = \frac{1}{4} \sqrt{\frac{\mu_2 \varepsilon}{\mu\sigma_2}} \; . \; \frac{3.6}{b} \; . \; \sqrt{f} \quad . \quad (106)$$

For the case of a coaxial cable with copper conductors ($\sigma_2 = \frac{1}{1724}$ *E.M.U.*) it is found, when α is expressed in db. per km, F in Mc per second, and b in cm:

$$\alpha = 1.08 \times \frac{1}{b} \sqrt{F} \quad . \quad (107)$$

It should be noted that no dielectric losses have been considered.

In the case of an E_0 wave, the attenuation coefficient follows directly from (101):

$$\alpha_{E_0} = \frac{1}{4} \sqrt{\frac{\mu_2 \varepsilon}{\mu\sigma_2}} \; \frac{2}{b} \; \frac{v'}{v} \sqrt{f} . \quad (108)$$

$$\text{Since } \frac{v'}{v} = \frac{1}{\sqrt{1 - \frac{f_m^2}{f^2}}} , \quad (109)$$

the coefficient in this case passes through a minimum for a frequency equal to $f_m \sqrt{3}$. This is due to the fact that, whilst the resistance keeps on increasing with frequency, the current decreases for constant flux of energy and tends towards a limit, as shown in section 13.

For the H_0 wave, the attenuation coefficient is found to be:

$$\alpha_{H_0} = \frac{1}{4} \sqrt{\frac{\mu_2 \varepsilon}{\mu\sigma_2}} \; . \; \frac{2}{b} \; . \; \frac{v'^2 - v^2}{vv'} \sqrt{f} . \quad (110)$$

It decreases as frequency increases. Though the resistance increases, the decreasing current tends towards zero and its diminution more than compensates for the increase in resistance.

16. *Attenuation coefficient in the case of H_1 wave*

It has already been pointed out that, amongst the different waves of a higher order, H_1 waves possess the advantage that they can be used at lower frequencies in a dielectric cable of given diameter. It is of interest, therefore, to study the value of the attenuation coefficient of this type of wave.

The energy lost in the copper involves two current components in this case, a circular component and an axial component. The attenuation coefficient may be expressed as :

$$\alpha_{H_1} = \frac{1}{4}\sqrt{\frac{\mu_2 \varepsilon}{\mu \sigma_2}}\,\frac{2}{b}\sqrt{f}\;\frac{\left(\dfrac{f_m}{f}\right)^2 + \dfrac{\dfrac{1}{k^2 b^2}}{1 - \dfrac{1}{k^2 b^2}}}{\sqrt{1 - \left(\dfrac{f_m}{f}\right)^2}} . \qquad (111)$$

This coefficient is the sum of two terms : the first (as in the case of H_0) decreases continuously with frequency ; the second (as in the case of E_0) passes through a minimum at $f = f_m\sqrt{3}$. The result is a very flat curve in the vicinity of the minimum value, which is located at $3.15 f_m$.

17. *Use in dielectric cables of a dielectric other than air*

As seen above, attenuation values in dielectric cables are affected by the type of wave, the frequency utilized, and the nature of the material constituents. Let it be assumed that, for the sheath, copper with a coefficient of conductivity equal to $\frac{1}{1724}$ *E.M.U.* is used. How the propagation characteristics are influenced by the nature of the dielectric will now be considered.

Attenuation values are easier to compare on the basis of those frequencies which, for each type of wave, yield optimum operating conditions in a cable of given diameter.

In so far as the E_0 wave is concerned, preference obviously would be given to the frequency of minimum attenuation which, as has been shown above, is equal to $\sqrt{3}$ times the lower frequency limit.

The same applies to the H_1 wave, for which minimum attenuation occurs in the vicinity of three times the lower frequency limit.

No minimum attenuation, however, exists for the H_0 wave. It is then convenient to select $m = \frac{f}{f_m}$ as a parameter ; values 2, 4 and 9 have been adopted for m in the following discussion.

The relations given below are derived for the different operating frequencies thus envisaged : α is expressed in db. per km ; b and λ are in cm ; and λ is the wavelength in a vacuum or dry air, corresponding to the frequency utilized. $\frac{\varepsilon_1}{\varepsilon_0}$ is the ratio of the dielectric coefficients of the cable dielectric and of dry air.

$$E_0 \text{ wave} \quad m = \sqrt{3} \quad \begin{cases} \alpha = 100 \sqrt[4]{\dfrac{\varepsilon_1}{\varepsilon_0}}\,\dfrac{1}{b^{3/2}} \\ \lambda = 1.5\, b \sqrt{\dfrac{\varepsilon_1}{\varepsilon_0}} \ ; \end{cases} \qquad (112)$$

$$H_1 \text{ wave} \quad m = 3 \quad \begin{cases} \alpha = 57 \sqrt[4]{\dfrac{\varepsilon_1}{\varepsilon_0}}\,\dfrac{1}{b^{3/2}} \\ \lambda = 1.16\, b \sqrt{\dfrac{\varepsilon_1}{\varepsilon_0}} \ ; \end{cases} \qquad (113)$$

$$H_0 \text{ wave} \quad \begin{cases} m = 2 & \begin{cases} \alpha = 33 \sqrt[4]{\dfrac{\varepsilon_1}{\varepsilon_0}}\,\dfrac{1}{b^{3/2}} \\ \lambda = 0.83\, b \sqrt{\dfrac{\varepsilon_1}{\varepsilon_0}} \end{cases} \\ m = 4 & \begin{cases} \alpha = 10 \sqrt[4]{\dfrac{\varepsilon_1}{\varepsilon_0}}\,\dfrac{1}{b^{3/2}} \\ \lambda = 0.41\, b \sqrt{\dfrac{\varepsilon_1}{\varepsilon_0}} \end{cases} \\ m = 9 & \begin{cases} \alpha = 3 \sqrt[4]{\dfrac{\varepsilon_1}{\varepsilon_0}}\,\dfrac{1}{b^{3/2}} \\ \lambda = 0.18\, b \sqrt{\dfrac{\varepsilon_1}{\varepsilon_0}} \ . \end{cases} \end{cases} \qquad (114)$$

The preceding equations show that the use of a dielectric other than air $\left(\frac{\varepsilon_1}{\varepsilon_0} > 1\right)$ gives operating frequencies which decrease in the

TABLE I

DIELECTRIC LOSS OF VARIOUS MATERIALS AT VERY HIGH FREQUENCIES

Dielectric Material	Dielectric Coefficient	tan θ to 10^{-4}						
		300 m 1 Mc/s	75 m 4 Mc/s	25 m 12 Mc/s	6 m 50 Mc/s	3 m 100 Mc/s	1.50 m 200 Mc/s	0.60 m 500 Mc/s
Sodium Chloride ..	5.6	—	—	—	0.2^R	0.16^R	0.2^R	0.3^R
Transparent Quartz ..	4.2	1.1^H	—	1.1^H	1.1^R	1.0^R	—	—
Opaque Quartz	3.9	—	—	—	1.2^R	1.1^R	2^R	2^R
Mica	7	1.7^H	—	1.7^H	1.6^H	1.6^R	2^R	2^R
Ultra-Calan	7.1	1.1^H	—	1.1^H	1.2^R	1.1^R	—	—
Trolitul	2.2	—	—	—	1.5^R	1.5^R	4^R	4^R
Condensa C	80	—	—	—	3.8^R	3.5^R	—	—
Condensa F	40	—	—	—	—	—	5^R	5^R
Micalex	8.2	18^H	—	18^H	—	18^R	—	—
Hard Rubber	3	64^H	—	107^H	120^R	150^R	230^R	—
Bakelite	2.8	160^H	—	220^H	450^R	500^R	—	—
Pertinax	5.4	280^H	—	720^H	900^R	$1\,000^R$	$1\,000^R$	—

(R): L. Rohde, "Zeits. f. techn. Physik," Vol. 16, No. 12, 1935, p. 637.
(R): L. Rohde and H. Schwartz, "Hochfrequenztech. u. Elektroakust.," Vol. 43, No. 5, 1934, p. 156.
(H): H. Handrek, "Zeits f. techn. Physik," Vol. 15, No. 11, 1934, p. 491.

ratio $\sqrt{\frac{\varepsilon_0}{\varepsilon_1}}$. Concurrently, however, attenuation due to losses in the copper increases, the attenuation coefficient varying as $\sqrt[4]{\frac{\varepsilon_1}{\varepsilon_0}}$. Losses in the dielectric itself, nevertheless, are predominant. They give rise to a supplementary attenuation coefficient which is equal to $\frac{\mathbf{Q}_d}{2\mathbf{W}_m}$ in which $\mathbf{Q}_d$ is the loss in the dielectric per unit length.

For instance, in the case of wave E_0, it is found that:

$$\mathbf{Q}_d = \frac{\pi}{2}\sigma\, b^2 \frac{v'}{v}\sqrt{\frac{\mu}{\varepsilon}}\ \mathbf{E}_\rho(b).\ \mathbf{H}_\theta(b). \tag{115}$$

This dielectric loss, thus expressed in terms of the amplitudes of field components on the surface of the conductor, results in an attenuation coefficient α_d equal to:

$$\alpha_d = 2\,\pi\,\sigma\frac{v'}{v}\sqrt{\frac{\mu}{\varepsilon}}, \tag{116}$$

σ being the coefficient of conductivity of the dielectric considered.

Similar calculations, applied to H_0 and H_1 waves, yield the same expression.

Since losses in the dielectric are generally studied as a function of the angle of loss, it is convenient to express σ in terms of the angle θ:

$$\sigma = \tfrac{1}{2}\,\varepsilon f \tan\theta. \tag{117}$$

Table I contains a list of recent tests on various dielectric substances at relatively high frequencies. It will be seen, *assuming that the angle of loss does not vary greatly from* 60 *to* 1 *cm* wavelength, that the value 2×10^{-4} represents an optimum value for the tangent of this angle of loss. It is probable, however, that absorption bands will manifest themselves in this region of the spectrum of electromagnetic waves.

This value has been utilized by V. Altovsky in the preparation of Plate I. It gives attenuation coefficients in db. per km, due to the dielectric, in terms of the radius of the cable for the various types of waves envisaged.

Reference to Plate I shows that attenuation due to losses in the dielectric, with the assumed angle of loss, reaches values too great to be considered for application. Thus, in the present state of the art, it is very likely that air will be used as the dielectric for the propagation of waves in dielectric cables.

18. *Comparison of attenuation due to losses in the copper for the various types of waves*

Let us first compare the attenuation due to loss in the copper for the coaxial type of wave and the E_0 wave, which are closely analogous as regards the distribution of field components.

Minimum attenuation for the coaxial cable is obtained for $\frac{b}{a} = 3.6$. In this case:

$$\alpha = \frac{1}{4}\sqrt{\frac{\mu_2\varepsilon}{\mu\sigma_2}}\,\frac{3.6}{b}\,\sqrt{f_1}\,. \qquad (118)$$

With E_0 waves giving minimum attenuation ($f = f_m\sqrt{3}$), it has been found that:

$$\alpha = \frac{1}{4}\sqrt{\frac{\mu_2\varepsilon}{\mu\sigma_2}}\,\frac{2.5}{b}\,\sqrt{f_2}\,. \qquad (119)$$

Comparison of equations (118) and (119) shows that attenuation in the coaxial cable remains lower than in the dielectric cable of the same diameter (E_0 wave) for frequencies up to half of the optimum E_0 frequency. It must not be forgotten, however, that dielectric cables have the obvious advantage of dispensing with the interior conductor and insulators.

Attenuation coefficients of the major different

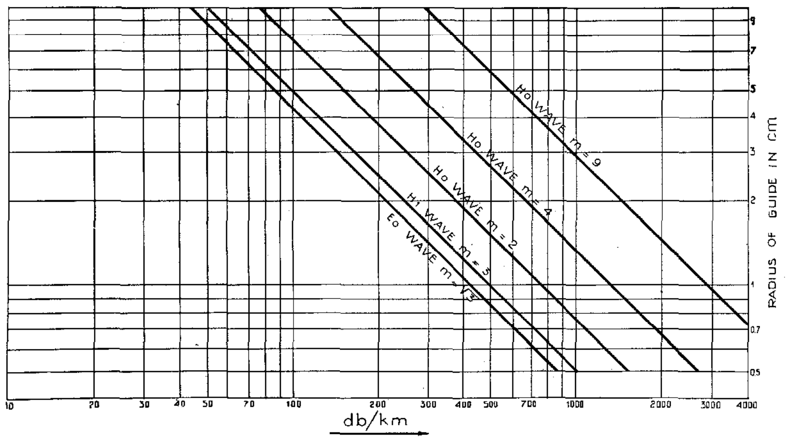

Plate I—Attenuation due to dielectric loss (assuming tan θ=2.10-4).

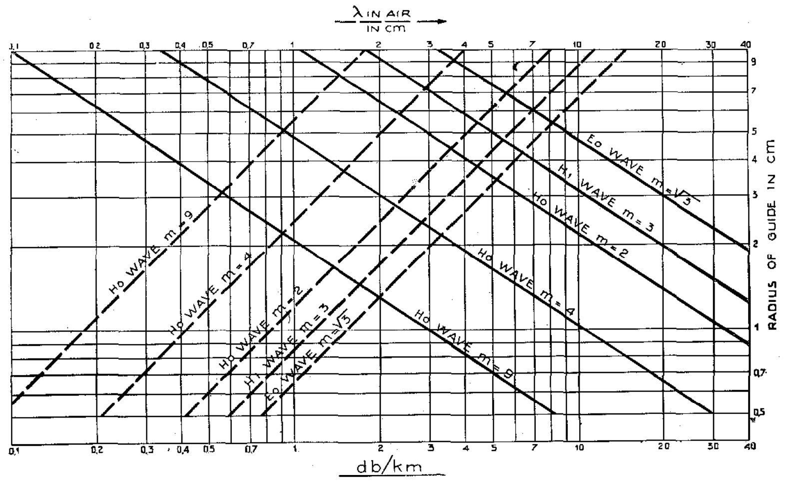

Plate II—Optimum operating wavelengths of different types versus guide radius (broken lines) and corresponding attenuation due to copper loss (full lines).

types of waves in a dielectric cable of given radius are given in Plate II.

For a cable of 1.5 cm radius, it will be seen that the minimum attenuation for the H_1 wave is 30 db. per km. If an attenuation of this magnitude be considered too high for application, an H_0 wave may be employed. With the latter, it is at least theoretically possible to obtain an attenuation less than a predetermined value, provided waves of sufficiently short length can be produced and applied. In a cable of 1.5 cm radius, for example, it is possible to procure an attenuation which is less than 6 db. per km by using an H_0 wavelength of 0.6 cm.

The order of the magnitudes involved in particular cases can readily be derived by reference to Plate II.

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ERRATA

Electrical Communication, Vol. 17, No. 2, October, 1938.

" Irregularities in Telephone and Television Coaxial Cables " :

Page 174, equation (44), second line, in denominator, $2\ \alpha\ 2\ l$ should read $2\ \alpha^2\ l$.

Page 185, equation following (95), second term in brackets, should read $e^{(-2\gamma-j\alpha')x}$.

" Notes on the Effects of Irregularities in Coaxial Cables on Television Transmission " :

Page 189, equation (1), "s" should be replaced by "S."

Page 191, first column (equation following Fig. 5) should read

$$n = \frac{\alpha_2}{\alpha_1} \quad \frac{\varepsilon}{\triangle} \, .$$

Electrical Communication, Vol. 17, No. 1, July, 1938.

" Cairo Telecommunication Conferences " :

Page 5, second column, sub-heading " Article 39 § 1" should read "Article 31 § 1."

Page 13, first column, fifth paragraph : "fixed stations" should read "land stations" ; last sentence of same paragraph should read "For these ships 550 kc are reserved between 4000–23000 kc (75–13.04 m)."

Page 15, second column, second line (following the colon), should read, "83.40 kc (3 597 m), 3 490 kc (85.96 m), 4 165 kc (72.03 m) and 6 792 kc (44.17 m)."

Voice-Operated Level Control System for Telephone Networks

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INTRODUCTION

WHEN appreciable circuit noise is present, the operation of any telephone system is seriously impaired. A minimum permissible value is thus fixed for the signal/noise ratio. In the case of a radio telephone link the question thus arises of maintaining this signal/noise ratio for minimum transmitter carrier power, since an increase in the latter is usually unobtainable except at appreciable expense. The signal for any given carrier power increases with the depth of modulation. It is, therefore, always desirable to operate close to maximum modulation. The speech level of conversations on ordinary telephone networks, however, depends on several factors, including the length of the subscriber's line, the condition of the microphone, and the strength of the speaker's voice, so that there may be differences of as much as 30 db. in the levels of conversations. Thus, if the radio transmitter has been lined up to avoid serious overloading on the high levels, its percentage modulation may be 30 db. below the optimum on the low speech values, with a corresponding reduction in signal/noise ratio at the listening point. The question, therefore, arises how this undesirable loss of the order of 30 db. may be avoided.

The solution at present adopted almost universally is to employ a "technical operator" —an operator whose duty it is to increase the low-frequency gain of the transmitter on low speech levels. This method of dealing with the problem, in cases where a VODAS equipment is not used, requires a corresponding reduction of the receiver gain by the distant operator, as otherwise "singing" conditions may prevail. In cases, however, where the radio link is short, such a technical operator may not prove in on financial grounds ; it may be cheaper to instal a cable—particularly with multi-speech channels, which might necessitate as many operators at each end as there are channels. Under such conditions, therefore, if a transmitter gain control device be used at all, it must be completely automatic in its action. It must, moreover, be capable of unattended operation over periods (in general) of at least several days ; it must be simple enough not to require highly skilled labour in fault finding, and it must not contain too many components of limited life. Some additional requirements are discussed in more detail below.

In view of its importance, Les Laboratoires, Le Matériel Téléphonique, have devoted considerable effort to the solution of this problem. The Voice-operated Level Control System finally evolved is described in this article, together with the results of field and other tests.

TRANSMITTER VARIABLE-GAIN DEVICE

The fundamental requirement of a voice-operated level control system is that the voltage giving the automatic control of the transmitter low-frequency gain shall be a function of the average peak voltages of the speech, integrated over a pre-determined interval of time. This time-constant "T" should preferably have three principal values : (*a*) During *rising* speech, a value small enough to reduce the gain before serious overloading is noticeable, e.g., between 5 and 500 milliseconds. This meets the conditions obtaining when a conversation begins. During the idle period the control may have been in the position of maximum gain, and it must react immediately the service period starts. (*b*) During *falling* speech level, a value large enough to avoid appreciable smoothing out of the natural level fluctuations occurring at syllable frequencies ; but not so large as to lose the benefit of the device for an appreciable period when the average speech level falls. A value of from one to three seconds appears suitable. In practice, a fall of transmission level may occur when a conversation begins immediately after ringing tone has been sent over the line. (*c*) After cessation of speech, a value as high as possible—in order to procure the correct gain when the speech recommences, thus avoiding the slight initial distortion that will otherwise occur while the correcting process is taking place. It is desirable that, when a talker pauses to give his correspondent an opportunity to reply, the control should lock. There will then be no danger of even the slightest distortion due to overloading when the talker recommences speaking. The arrival of speech must, however, immediately unlock the device, so that at the end of a conversation a new call will encounter the short time-constant considered under (*a*). In this condition, "T" should not be less than about 20 seconds and, if it is not infinite, the gain should drift in the absence of speech towards that point from which it is most rapidly corrected when the speech reappears, i.e., towards maximum gain.

OVERALL CIRCUIT EQUIVALENT

In the absence of a VODAS, the circuit equivalent of the link has usually to be kept constant to within $\pm$ 1 or $\pm$ 2 db. Variations of the receiver gain must therefore be equal and opposite to the variations of transmitter gain. There are two classes of device to accomplish this automatically: (*a*) That which uses the received speech itself to control the transmitter and receiver gains, having at the receiver an "expander" of characteristics exactly compensating those of the "compressor" at the transmitter. The chief objection to this scheme as a solution to the present problem is that it limits the practicable compression ratio at the transmitter to a figure of about 2 : 1. If a greater value be used—10 : 1, for example—a 20 db. change at the transmitter will give only 2 db. at the receiver. The receiver expansion ratio of 10 : 1 thus required will multiply any accidental fluctuations in the received level by a factor of 10. Such fluctuations, therefore, must be kept within $\pm$ 0.1 db.—a very difficult requirement to fulfil on a radio link. (*b*) That class of device which uses at the transmitter some form of "pilot" in addition to the speech. Such a pilot signal, which, for example, may be a steady frequency near the signal band, can be arranged to convey to the receiver accurate information as to the instantaneous gain and, in addition, to effect at the receiver the gain control necessary to compensate for these changes.

Perhaps the simplest of the possible ways of using a pilot signal of this kind is the method described below, i.e., the application at the input of the transmitter gain-control device of a steady frequency in addition to the speech. An increase of transmitter gain caused by a fall in speech level thus increases the output pilot amplitude in the same ratio as the transmitter gain is increased; and the selection and use of the pilot (and not, as is usual, the received carrier) to control the receiver gain can be arranged to reduce the latter by approximately the same amount as that by which the transmitter gain has been raised.

Thus the transmission equivalent variations of (*a*) above, due to slight apparatus and propagation instabilities have been overcome; in fact, not only can their multiplication, occurring in the first method, be avoided, but they can actually be considerably reduced. The receiver gain will automatically adjust itself to a value such that the received pilot amplitude is constant, regardless of changes in the apparatus line-up or in propagation. Since the pilot has a constant level at the input of the transmitter, the circuit equivalent will therefore also be constant.

For the provision of an automatic receiver gain control the method has, further, an advantage over the use of the carrier; it compensates not only for changes in propagation and H.F. circuit constants, but also for accidental variations in low-frequency gain at both ends of the link.

The optimum frequency for the pilot depends on the conditions,—in particular, on the total bandwidth available. In the apparatus described in this article, a steady frequency of 3 500 p : s is used—just outside the speech band, of which the upper limit in this case is 3 000. The pilot and speech frequencies are thus far enough apart from the speech to make separation by a very simple filter an easy matter; at the same time, the total bandwidth is not seriously enlarged.

This system was designed for experimental use on the Belfast-Stranraer radio link and the pilot frequency of 3 500 p : s was selected as being most suitable for this job. In view of the general tendency to increase the bandwidth of speech frequencies effectively transmitted, and in particular the recent recommendation of the C.C.I.F., applying to carrier systems on non-loaded cables, that the bandwidth effectively transmitted shall extend at least from 300 to 3 400 p : s, it is clear that a pilot frequency of 3 500 p : s will not be sufficiently separated from the top speech frequency to enable a simple filter to be used. It is proposed, however, to adapt the Voice-operated Level Control System by using a pilot frequency of about 3 900 p : s to enable it to be used with the most modern equipment.

SOME DESIGN FEATURES

The Transmitter Variable-Gain Circuit

The requirements of this part of the apparatus vary with the particular circuit to be dealt with, but the following details may be taken as fairly typical :

(*a*) A gain variation of 20 db. ;
(*b*) An extra total harmonic content, due to the variable gain device, not exceeding $2\frac{1}{2}\%$ under the worst conditions.

In addition to the above, the action of the automatic L.F. gain control at the transmitter must neither unduly change the speech circuit input impedance nor the overall frequency characteristics ; neither must it introduce appreciable extra background noise into the received signal.

Perhaps the four simplest possible types of device capable of fulfilling the requirements are those described briefly below :

(1.) Pads applied to the incoming line by mechanical relays operated in correct sequence automatically as a predetermined function of the speech amplitude. In this method the question immediately arises as to how to select the appropriate relay to be actuated at a given moment to produce the level desired. Selection mechanically by the relays themselves is not, in general, a satisfactory solution ; the operation of relays is liable to produce clicks, and the passage of the rectified and amplified speech current through marginal relays, for example, involves the use of an accurate type of relay appreciably adding to the total cost of the equipment. A number of devices have been suggested and tried for this purpose, but probably the best is to use a separate valve with an appropriate bias to actuate each relay,—again not a particularly simple or economical way of solving the problem. There is, moreover, another consideration. Although some difference of opinion still exists in certain engineering circles, there is now little doubt, speaking generally (and despite obvious exceptions), that the replacement of mechanical devices by others functioning entirely by electronic means—e.g., a valve of reliable design—is accompanied by an improvement in reliability, ease of meeting prescribed limits, and facility of maintenance. It is, therefore, considered that the addition, as above indicated, of a number of relays to each channel of the circuit should be avoided, if possible.

(2.) The use of a variable-mu valve, biassed automatically as a function of the speech input, is perhaps the most obvious solution of all. It has the advantages of requiring (in the normal case, where a speech amplifier has to be added in any event) no extra valves, relays, or other special devices ; and no appreciable change of input impedance is involved as the gain is varied. There is, however, a rather serious disadvantage ; as shown in Appendix I, if a total distortion of $2\frac{1}{2}\%$ is not to be exceeded, the input level, using a typical existing form of valve, is limited to about 30 db. below 1 milliwatt—a value too low in many cases, since it would often entail an extra stage of L.F. gain.

(3.) Another fairly successful method involves the use of a metal rectifier in shunt across a suitable impedance point of the incoming line. This type of device is already in use for similar purposes and has several advantages ; for example, a considerable range of attenuation can be obtained without excessive distortion if the D.C. bias on the rectifier is arranged to be large compared with the A.C. swing. In general, however,

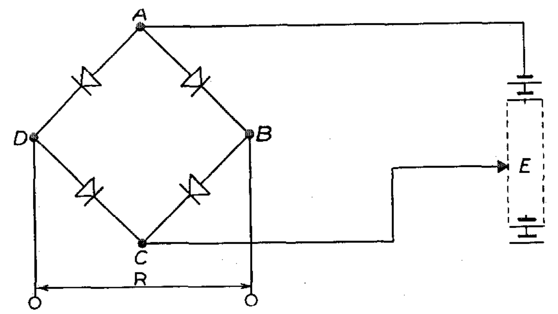


Fig. 1.

a special valve is required to provide the variable bias for the rectifier. It is therefore doubtful if the method has any advantages, for general application, over the circuit used in the apparatus to be described below—the principle of which will now be explained.

(4.) The device finally adopted in the present equipment consists simply of a valve having a low impedance plate circuit in shunt across the incoming line at a high impedance point. In a typical valve used for this purpose, the plate impedance may be varied from 9 000 ohms to a very high value by a change of grid bias of 7 volts. With suitable circuit design, the result is a variable pad across the line having an attenuation range from 0 to 30 db.

As the curve of plate voltage versus plate current, in general, has much less curvature than the usual grid volts plate current characteristic, for a given distortion, a larger input voltage swing is allowable than in method (2) above. As shown in the appendix, if the latter be given an upper limit of $2\frac{1}{2}\%$ for example, the maximum input level is -7.5 db.—as compared with -28.5 db. for the typical variable-mu ("receiving" type) tube. For this reason the "plate shunt" method has been chosen instead of one of the alternative solutions.

The Variable Time-constant

Using the variable "loss" device of (4) above, a convenient means of changing the time-constant of the control action is to vary the grid leak or grid condenser (to ground) of the tube in shunt—the "absorber" tube. The switching in and out of appropriate resistances or condensers by means of relays would, of course, provide a possible solution to the problem—but not a good one, since either accurate marginal relays or, alternatively, a series of extra valves or other non-linear devices would have to be used to actuate the relays at the correct moments. The method would therefore be rather complicated without being particularly reliable. A much better solution is to use some circuit relying entirely on non-mechanical components. One such device—that used successfully in the tests described below—is illustrated in principle in Fig. 1. It is, in effect, an electrically variable grid leak. Four balanced metal rectifiers are connected in bridge formation as shown. If battery E be applied between A and C in the non-conducting sense of the rectifiers, every arm of the bridge will have a very high resistance. The effective resistance between points B and D will, therefore, also be high. If E be now reversed, all the bridge arms will be conductive; hence the resistance across B-D will be much lower. As the rectifiers are approximately balanced, moreover, battery E can cause no appreciable voltage to appear between B and D—the only effect is a change in resistance. We have thus a variable grid leak—varying in practice from at least 5 megohms (with suitable, readily available rectifiers) to a minimum value of the order of 50 000 ohms; and the control voltage E can be obtained, according to any desired law, from the rectified speech itself.

Details of the Experimental Apparatus

The transmitter level control device is shown in outline in Fig. 2. The incoming speech line is applied through a step-up transformer B_1 and blocking condenser D to the grid of the L.F. amplifier tube C—and thence through an extra stage of amplification A to the modulator. Shunting the grid of C is the plate of the triode E—a triode of low impedance type. When E is biassed to give plate-current cut-off it has no effect, and stage C gives its full normal gain. When the bias, however, is such as to produce a minimum impedance in E, there results a shunting effect of the order of 30 db. on the line circuit.

To obtain a fairly wide range of attenuation while reducing the changes in line termination impedance to satisfactory limits, it can easily be shown that an improvement is effected by adding the two resistances G and H.

To control the grid bias of E—and therefore the loss introduced by the shunting action of the plate of this tube—some of the speech output from A, at a level of 20 volts or more, is applied as shown to the metal rectifier R_1, biassed by V_1, so that no current flows until the speech peaks reach a predetermined value (e.g., 30 volts). The rectified output voltage is then applied in series with battery V_2 and the rectifier network R_2, R_3, R_4 and R_5 to the grid of E. V_2 has a value just sufficient when acting alone to cause cut-off in E. R_1 is connected in a sense such that the rectified speech causes the grid of E to become less negative. Before speech starts, therefore, E will have no shunting effect on the input to C. The amplifier is thus giving its maximum gain. This condition continues until the speech peaks exceed the value of V_1 (30 volts). Beyond this point (arranged to correspond to the maximum correct modulation of the transmitter) any further increase causes rectification in R_1, a lower negative voltage on E, and a corresponding rapid increase (from zero) in the shunting action of the plate circuit of E on the input of C. The output of A will thus tend to be reduced to the predetermined value—a value such that current is again only just beginning to flow through rectifier R_1.

Let us now consider the detailed action of the variable grid leak presented by the rectifier network R_2, R_3, R_4 and R_5. As pointed out, the application of a D.C. voltage difference between points J and K will cause no *voltage* difference between L and M; but it will cause a change in the effective resistance in the path between these two latter points,—and, therefore, in conjunction with the large condenser N, a change in the time-constant of the control by the speech of the grid voltage of E. As shown in Fig. 2, the D.C. voltage changing the resistance between L and M is caused by the speech itself (from transformer P rectified in R_6 and R_7). The connections are such that an increase in speech level causes a reduction of this resistance and therefore a shorter time-constant. In the absence of speech, battery V_3

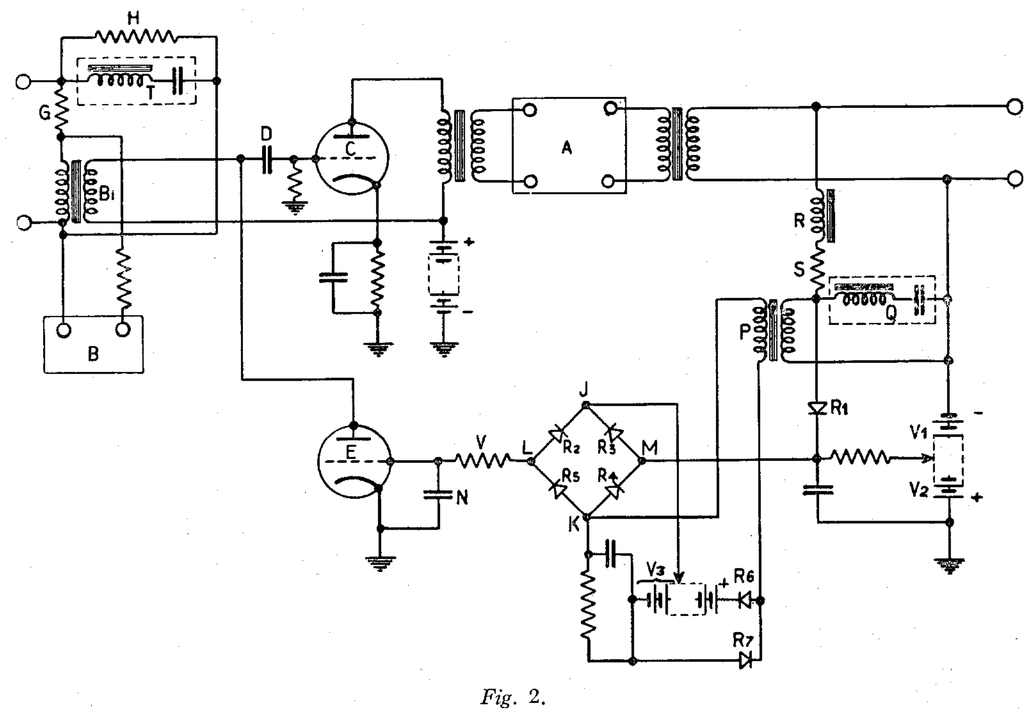


Fig. 2.

is alone applied between J and K—and it is of a value and sense sufficient to make all four rectifiers substantially non-conductive. As soon as speech ceases, therefore, the time-constant is high (25 seconds or more); but the step-up ratio of transformer P is such that speech at the weakest level capable of operating the device (15 db. below maximum) is sufficient to reduce the time-constant to a value not greater than 3 or 4 seconds. In this way two of the three desirable features of time-constant variation are obtained.

Let us now consider speech at minimum level —and the gain, therefore, at a maximum. If the speech then suddenly rises to its maximum value, the D.C. voltage between J and K also rises abruptly. There is thus, momentarily, a very low effective resistance between L and M —much lower than that due to a "minimum" talker. A third time-constant of very low value is thus brought into action—a value that can easily be reduced to 300 milliseconds or less, thus confining any blasting to a period so short as not noticeably to affect the good performance of the circuit.

In practice, of course, there are not three values only of the time-constant but an infinite number, each corresponding both to the actual speech level and to its rate and direction of change. The above analysis, nevertheless, gives an outline of the three major changes involved, together with the desirable operating features introduced by them.

As will be seen from Fig. 2, speech from P is rectified, not by one rectifier alone but by the two rectifiers R_6 and R_7, arranged in "back-to-front" formation. The object is two-fold: (*a*) To prevent excessive difference in time-constant between steady operation at maximum and minimum speech levels; and (*b*) to prevent damage to the rectifiers themselves under the condition of a sudden rise from minimum to maximum level—a change that otherwise would give rise to a momentary reverse voltage of several hundred across a single rectifier. In the "back-to-front" arrangement, the reverse peak voltage of each rectifier is absorbed—and therefore limited—by the other. Furthermore, after a certain voltage has been reached, the rectified current from the second rectifier starts opposing that of the first, thus giving a limiting action to the extent of the changes in time-constant at different speech levels.

As already pointed out, in the absence of VODAS equipment it is necessary not only to control the transmitter modulation (or amplifier output if there is no radio or carrier equipment involved), but also to compensate accurately at the receiver for any changes in transmitter gain. In the system herein described this is carried out by the introduction and amplification, along with the speech in the automatically variable loss device, of a steady pilot frequency just outside the speech range. This pilot is introduced from the oscillator B (Fig. 2) at the point shown. At the receiver, this pilot frequency is selected by a sharply tuned circuit at the output and caused to operate the receiver automatic gain control—in place of the received carrier that usually performs this function.

Irrespective, therefore, of the extent of the transmitter gain reduction, the pilot is reduced in exactly the same proportion; and, since the function of the pilot at the receiver is to adjust the gain of the latter to give a constant output, the receiver gain is invariably raised by the same amount as the transmitter gain is lowered. A constant circuit equivalent is thus obtained within the limits of operation of the automatic gain control.

The pilot level adjustment, in general, is of the order of 6 to 10 db. below the weakest normal talker; in this way, excessive transmitter power is never absorbed merely for radiation of the pilot frequency.

It is necessary to avoid feeding back the pilot in order that the required long time-constant may follow speech cessation. For this reason, the inductance-capacity combination Q, series-tuned to the pilot frequency, is shunted across the output of A. Q is decoupled from A by choke R and resistance S to prevent appreciable deformation of the frequency characteristic of A at the highest frequency in the band passed.

Another consideration is that, in general, normal speech from the incoming line may contain an appreciable component at the pilot frequency. To prevent such components from becoming mixed with the pilot and thus operating the receiver gain control, it is essential that they be filtered out before the speech arrives at the control device of the transmitter. Filtering, of course, must be effected prior to the introduction of the pilot frequency into the speech. The circuit T, series-tuned to the pilot, is therefore shunted directly across the incoming line,—the constants being arranged so that its effect in the speech range passed is negligible.

The principle of one form of receiver circuit is shown in outline in Fig. 3. The L.F. output from radio receiver A is applied through filter B (tuned sharply to the pilot) and transformer C to an extra L.F. amplifier tube D, which thus amplifies the pilot only. The amplified pilot from D is rectified by E and causes a D.C. voltage across resistance F. The latter voltage is then applied at points G in series with the normal bias required for maximum gain of the one or more H.F. stages of the receiver,—and in such a direction that increase of pilot voltage reduces the receiver gain. The time-constant circuit K is added to filter out the pilot frequency from the gain-control leads. A marginal bias is obtained from battery H, preventing rectified current from flowing until a predetermined pilot voltage has been reached.

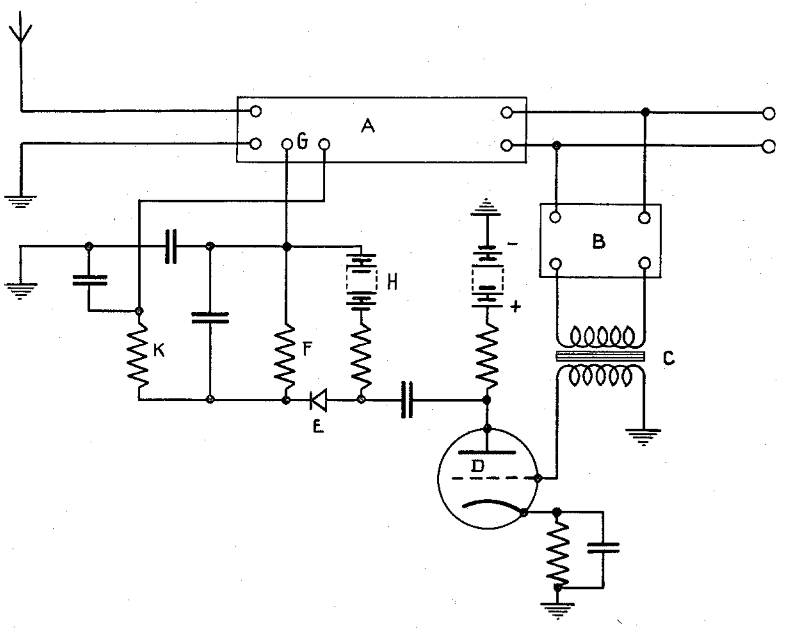


Fig. 3.

The gain of the receiver thus tends to adjust itself automatically, in accordance with the usual automatic gain control methods, to give the predetermined level.

Conditions for Overall Circuit Stability

The fundamental rôle of the receiver gain control by the pilot frequency is to maintain a substantially constant circuit equivalent and thus minimize the danger of singing around the circuit. The remedy sought for, therefore, must be automatically applied in *all* conditions met with in practice—during the transition periods as well as when the final automatic gain adjustments for any particular speech level have been effected. In this connection the worst condition that requires consideration occurs immediately after a sudden fall in input level from a high value. At such moments the receiver gain is initially high ; and, if it remains unchanged after the weaker speech has caused a rise in the transmitter gain, the overall circuit may momentarily be in a singing condition. As in all similar cases, to prevent this possibility, speed of action of the "remedy" must always be substantially greater than the maximum rate of arrival of the condition to be corrected ; in other words, during falling speech level at the transmitter, the time-constant of the control of the receiver gain by the pilot must be substantially less than the minimum time-constant under these conditions of the control of the transmitter gain by the speech. Such an adjustment is easily obtained in practice—by giving a time-constant to the receiver gain control of 1/10 second or less ; in fact, as small a value as possible consistent with absence of speech distortion and stability of operation.

As pointed out below in the discussion of some experimental results, such regulation of these two relative time-constants was found essential for successful working under traffic conditions.

EXPERIMENTAL RESULTS

An experimental equipment designed on the lines described above was tried out on traffic in one direction on one of the circuits of the 9-channel ultra-short wave radio link between Belfast and Stranraer. This link forms part of the trunk telephone system connecting England and Ireland; it was very suitable for the tests in view and they were made possible by the kind permission and co-operation of the British Post Office.

The chief results obtained are outlined below:

Test 1. Degree of Modulation Control at Transmitter

The apparatus was adjusted to give maximum allowable transmitter modulation from the usual line-up tone, i.e., 11.5 db. below 5.9 milliwatts. With this setting, tone 15 db. down from the above level gave a modulation 3 db. below maximum, thus corresponding to a control of 12 db. on an input change of 15 db.

Test 2. Improvement in Signal-Noise Ratio

	Signal-noise without Level Control	Signal-noise with Level Control	Improvement
(*a*)-Tone at "line-up" level	43 db.	48 db.	5 db.
(*b*)-Tone 15 db. below "line-up" level	28 db.	43 db.	15 db.

Signal-noise ratios were measured on a volume indicator, the ratio corresponding to the gain introduced to obtain the same deflection when noise alone was present as when the signal was being received.

An apparent extra improvement above the theoretical figure (zero on full tone and 12 db. on tone 15 db. down) was thus measured. It had a value of 5 db. in the case of the strong tone and 3 db. with the weak tone. This was due to the fact that the long time-constant circuit (coming into action on switching off the tone) was adjusted so that, during the first two seconds elapsing after the tone was switched off and before a noise measurement could be made, the transmitter gain increased by 5 db. and 3 db. for the strong and weak tone conditions, respectively. The true long time-constant—about 20 seconds—did not come into operation until the end of this two-second period. This extra improvement in the measured figures is due to the fact that the noise level measured is not that obtaining *during* the speech. Nevertheless, it corresponds to a real improvement under operating conditions, since the circuit noise is reduced at the time when it is most noticeable, viz., during gaps between speech periods of one or more seconds' duration.

Test 3. Constancy of Circuit Equivalent

The final curve used for the traffic tests is indicated in the following table:

Input Tone	Output Tone	Circuit Variation
−11.5 db. (with respect to 5.9 milliwatts) ..	−2.5 db.	0 db. (basic figure)
−16.5 db.	−7	+0.5
−21.5	−12	+0.5
−26	−17.5	−0.5
−31.5	−22.5	0
−36.5	−28	−0.5
−51.5	−43	−0.5

Test 4. Time-Constants

Various values for the time-constants involved were tried out under traffic conditions. The following values were found to be quite suitable at the transmitter:

(*a*) *Tone rising to maximum from* 15 *db. down:* 0.25 seconds to reach 1 db. from final value.

(*b*) *Tone falling from maximum to* 15 *db. down:* 2.5 seconds to reach 3 db. from final value.

(*c*) *Tone* (*maximum value*) *switched off:* 2 seconds for transmitter gain to rise 5 db.; and a further 20 seconds for the gain to rise an additional 3 db.

At the receiver, the time-constant of the control of gain by the pilot was such that, for any given sudden change in the pilot amplitude, the receiver gain took up substantially its final value within about 1/10 sec.

Test 5. Speech Quality on Traffic

Observers could not detect whether the control device was in or out of circuit—judging from the quality alone, apart from the improvement in signal-noise ratio.

Test 6. 2-Wire-to-2-Wire Trials Between Belfast and Glasgow Repeater Stations

(*a*) *Circuit Stability.* The increase in the Glasgow Repeater gain required to reach the singing point was measured with the control equipment both "off" and "on." The figure was the same in each case, viz., 19 db.

With a direct loop (no termination) the results were + 0.5 db. and – 3 db., respectively. (The reason for this difference between the two conditions of working was not traced.)

(*b*) *Echoes.* A test conversation was held between the Belfast and Glasgow repeater station attendants with the control equipment in circuit. No echo could be observed either by these attendants or by two engineers monitoring on the circuit.

(*c*) *Ringing* (*modulated* 500 *p* : *s*). Special tests were carried out to determine whether the new equipment caused any troubles in this connection. No such troubles were encountered.

A further test was made to check the correct operation of the transmitter level control on normal speech immediately after cessation of the ringing tone. Speech almost immediately after ringing was found to be quite satisfactory.

Test 7. Traffic Trials

As a result of the success of (preliminary) Test 6 above, the British Post Office gave permission for the control equipment to be used during the normal traffic period in the direction Belfast-Glasgow. Its operation was therefore observed continuously for several hours, during which period its adjustments were left untouched. The circuit was in use almost continuously. The results were quite satisfactory, the new apparatus causing no difficulty of any kind. The ringing, also, operated satisfactorily.

During the test period, calls were made under many different conditions from Grimsby, London and elsewhere.

ACKNOWLEDGMENT

In conclusion the author wishes to express his indebtedness to Mr. E. H. Ullrich of Les Laboratoires, Le Matériel Téléphonique, Paris, both for his work as originator of one of the fundamental design features and for his valuable help in criticizing this article ; to Mr. M. Capelli of Standard Telephones and Cables, Ltd., London, for his important help in connection with the experimental work ; and to the British Post Office engineering staff for their co-operation, which made possible the trials of the system under traffic conditions.

APPENDIX

DISTORTION IN VARIABLE GAIN DEVICES

1. THE VARIABLE-MU TUBE

Let us express the grid-voltage plate-current curve of the tube in question in the form : $i = I_0 + ae + be^2$, neglecting higher terms when dealing with the comparatively small voltage swing involved in the practical case considered. If, now, $e = u + v \sin \omega t$,

then $i = I_0 + a(u + v \sin \omega t) + 2\,buv \,.\, \sin \omega t + bu^2 + bv^2 .\, \sin^2 \omega t = I_0 + a(u + v \sin \omega t) + 2\,buv \sin \omega t + \frac{bv^2}{2}(1 - \cos 2\,\omega t) + bu^2.$

Hence the ratio $\frac{\text{2nd harmonic}}{\text{fundamental}} = r = \frac{bv}{2(a + 2bu)}.$

Now $\frac{di}{de} = \lambda = a + 2be = a + 2b(u + v \sin \omega t) \simeq a + 2\,bu$

as "v" is small compared with "u,"

and $\frac{d^2i}{de^2} = 2b = \frac{d\lambda}{de}$; hence $r = \frac{v.1.d\lambda}{4\,\lambda\, de}$.

But in a variable-mu tube, $\frac{1.d\lambda}{\lambda\, de}$ is substantially constant within the working range ; let its value be "α" ;

hence $r = \frac{\alpha v}{4}$.

Consider a typical variable-mu tube, in which a change of bias of $1v$. changes the voltage gain by 10% (on load). In this case, $\alpha = 1/10$ per volt; hence $r = v/40$.

For the second harmonic to be $2\frac{1}{2}$% of the

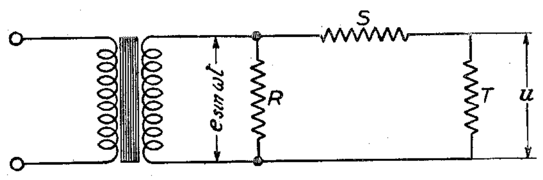


Fig. 4.

amplitude of the fundamental, it is necessary that $v = 1$ volt (peak) or 0.64 volt (R.M.S.). Hence with a grid impedance of 300 000 ohms, the power is 1.36 μ-watts. This is a level of 28.5 db. below 1 milliwatt ; a value which must not be exceeded if the 2nd harmonic distortion is not to be greater than $2\frac{1}{2}\%$ of the fundamental.

2. *THE "LEVEL CONTROL" CIRCUIT*

The principle of the new variable loss circuit is shown in Fig. 4, where the variable effective resistance T represents the impedance of the absorber tube E of Fig. 2. The voltage across T is proportional to $\frac{T}{S + T}$ if that across R be assumed constant.

In a typical tube (the tube used in the experiments described), T may be varied from a value exceeding 1 megohm to 9 000 ohms without departing from the desirable portion of its curve.

Hence if S be 300 000 ohms, the voltage range across T is $\frac{9\,000}{309\,000} = 0.029$, i.e., a range of about 30 db. This variation is obtained by changing the bias on the tube by about 7 volts.

Let us now consider how much non-linear distortion is caused by the absorber tube, at the same time as the variable loss of 30 db.

Distortion due to the "Absorber" Tube

Let the input voltage across R (Fig. 4) be : $e \sin \omega t$;

then, $e \sin \omega t = Si + u$.

As use is being made of the square-law portion of the curve $i = b\ (\mu v + V + u + E)^2$, it follows that : $i = b\ (A + u)^2$.

Hence

$$0 = Sb\ (A + u)^2 + (u + A) - (A + e \sin \omega t)$$

and

$$A + u = \frac{-1 + \sqrt{1 + 4Sb\ (A + e \sin \omega t)}}{2Sb}.$$

As "e" is always much smaller than A,

$$2Sb\ (A + u) = -1 \pm (1 + 4SbA)^{\frac{1}{2}}$$

$$\left[1 + \frac{1}{2}\,\frac{4Sbe \sin \omega t}{1 + 4SbA} + \frac{\frac{1}{2}(-\frac{1}{2})\ (4Sbe \sin \omega t)^2}{1.2\ \ (1 + 4SbA)^2}\right]$$

approximately, considering the first three terms only.

Therefore "r" $= \left(\frac{\text{2nd harmonic}}{\text{fundamental}}\right)$ will be :

$$\frac{(-\frac{1}{2})}{2} \cdot \frac{4Sbe}{1 + 4SbA} = \frac{Sbe}{1 + 4SbA}.$$

In a typical tube of the type used, A is of the order of 100, and Sb has a value of 0.0185, approximately,

hence $r = 0.0022e$.

For the 2nd harmonic to amount to $2\frac{1}{2}\%$ of the fundamental, therefore, "e" will have a value of 11 volts. This is, in consequence, its limiting peak value ; it corresponds to a level of 7.5 db. below 1 milliwatt if the grid impedance is 300 000 ohms as before—21 db. higher than in the case of the variable-mu tube considered above.

High Frequency Transmission Line Networks*

By ANDREW ALFORD,

Mackay Radio and Telegraph Company Inc., New York

BY high frequency transmission line networks will be meant those networks which are installed along feeders of high frequency transmitting and receiving antennae for the purpose of performing a variety of services, such as matching of impedances of antennae and feeders, separation of frequencies, filtering of harmonics, control of phase, division of power, etc. While some of the functions of these networks can be carried out with networks built up of lumped inductances and condensers, it has been found more practical to employ networks made of sections of transmission line of the same construction as the feeders themselves. The latter types of networks are preferable not only because they are, generally speaking, more rugged and more likely to remain in proper adjustment when exposed to the elements, but also because their performance, in the usual case, may be calculated with greater accuracy and the parameters on which their electrical properties primarily depend are linear dimensions which may be measured on the job, in feet and inches with steel tape, more simply and more accurately than the inductance of a coil or the capacity of a condenser in weatherproof housings could be measured under the same circumstances.

Transmission line networks made up of sections of transmission line may be subdivided into two groups, namely, those in which sections of line are used as impedances and those which are built up of "re-entrants."

To the first group belong such familiar networks as the so called building-out sections, quarter wave shorts, etc.

To the second group belong networks made up of "re-entrants," which will be discussed in the present paper.

The transmission line network, referred to as a re-entrant network, or simply re-entrant, is shown in Fig. 1. This network consists of two sections of transmission line joined at their ends in such a way as to form a closed loop.

If one of the two sections, for instance *A B*, is designated as the main transmission line or feeder, while the other line *A C B* is called the branch, then the branch line starts or branches off at some point *A* of the main line and rejoins or re-enters the same line at some other point *B*. Hence the name re-entrant.

The electrical properties of a re-entrant network depend primarily on the lengths of the two limbs of the network expressed in terms of the wavelength, electrical degrees or radians; that is, on the electrical lengths θ_1 and θ_2 of the two limbs of the network.

The secondary parameters of the network are the attenuation coefficients (γ) of the waves travelling along the limbs of the network, the angles at which the branch line joins with the main line, the relative geometrical dimensions of the network and the spacing between the conductors of the transmission line.

In practice it is ordinarily sufficient to make most of the calculations on the basis of the two primary parameters, namely, θ_1 and θ_2, and to take account of attenuation only when investigating the regions in which the network behaves as a filter or when it is required to find the losses in the network. The effect of angles at which the branch line meets the main line is treated as a correction which usually is so small as to be negligible. Finally the effect of radiation interaction between the various wires of the network is usually also negligible since the spacing between the line conductors is ordinarily quite small in comparison with the dimensions of the network.

From the above discussion it follows that the mathematical solution which is of practical interest should take into account only three

* Paper presented at the Spokane (Washington) I.R.E. Meeting, September, 1937.

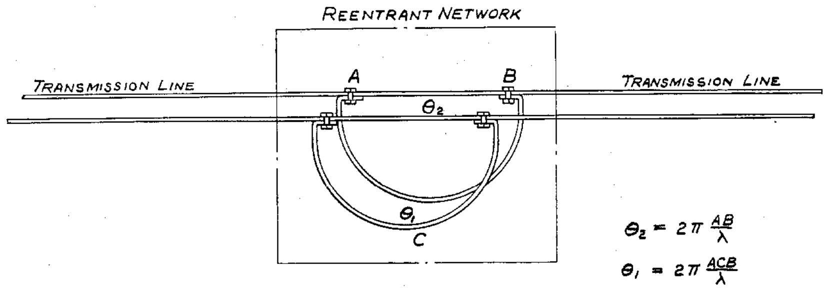


Fig. 1.

lished. A travelling wave F_0 emerges from the oscillator and proceeds along *OSC-A* toward the re-entrant. Along the same section of the transmission line there also exists a travelling wave B_0 which travels in the opposite direction and which may be called the back wave. The latter is the result of reflection of F_0 at A and also of transmission of the back waves B_1 and B_2 travelling along the limbs through junction A. Along the section of transmission line B-Z_0 there travels only a forward wave F_3, which is the result of transmission through junction B of waves F_1 and F_2. Along this section of line there is no back wave because F_3 is not reflected at Z_0 and there is no oscillator at Z_0 to start a new wave. The problem is to determine the amplitudes and the phases of these various waves with reference to some assumed amplitude and some arbitrarily fixed phase.

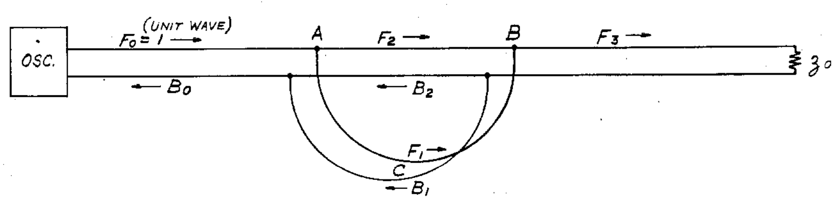
In order to avoid ambiguities it has been found convenient to assume that the amplitude of F_0 is unity and that the phase of this same wave as it arrives at A is zero. If these values

parameters of the re-entrant, namely, the electrical lengths θ_1 and θ_2 of the two limbs and the attenuation coefficient γ.

It may appear that what is really required is not one solution but a number of different solutions, each starting from the beginning and each one dealing with a different set of conditions under which the re-entrant network may be used. Fortunately, this is not the case. The only problem which need be solved from the beginning is an auxiliary problem which is relatively simple. Once this has been accomplished the more complicated ones met with in practice may be worked out without any particular trouble and certainly without going through the steps which are necessary for solving the fundamental auxiliary problem.

This auxiliary problem, which serves as a kind of key to all others, is illustrated in Fig. 2. In this figure a re-entrant is inserted into a transmission line which at one end is fed with an oscillator delivering waves of length λ and, at the other end, is terminated into its surge impedance Z_0. This whole scheme will be designated as arrangement A.

In this arrangement the following set of conditions prevails after the steady state has been estab-



$$(1)\quad F_3 = Ge^{jg} = \frac{4\left[\left(\frac{1}{a}+\frac{1}{b}\right)-(a+b)\right]}{ab-8-\left(\frac{a}{b}+\frac{b}{a}\right)+9\frac{1}{ab}}$$

$$(2)\quad B_0 = Re^{jr} = -\frac{3ab-8+\left(\frac{a}{b}+\frac{b}{a}\right)+\frac{3}{ab}}{ab-8-\left(\frac{a}{b}+\frac{b}{a}\right)+9\frac{1}{ab}}$$

$$(3)\quad a = e^{-(j+\gamma)\theta_1}$$

$$(4)\quad b = e^{-(j+\gamma)\theta_2}$$

THE PHASE OF UNIT WAVE AT "A" IS TAKEN AS ZERO.

γ IS THE ATTENUATION COEFFICIENT.

Fig. 2.

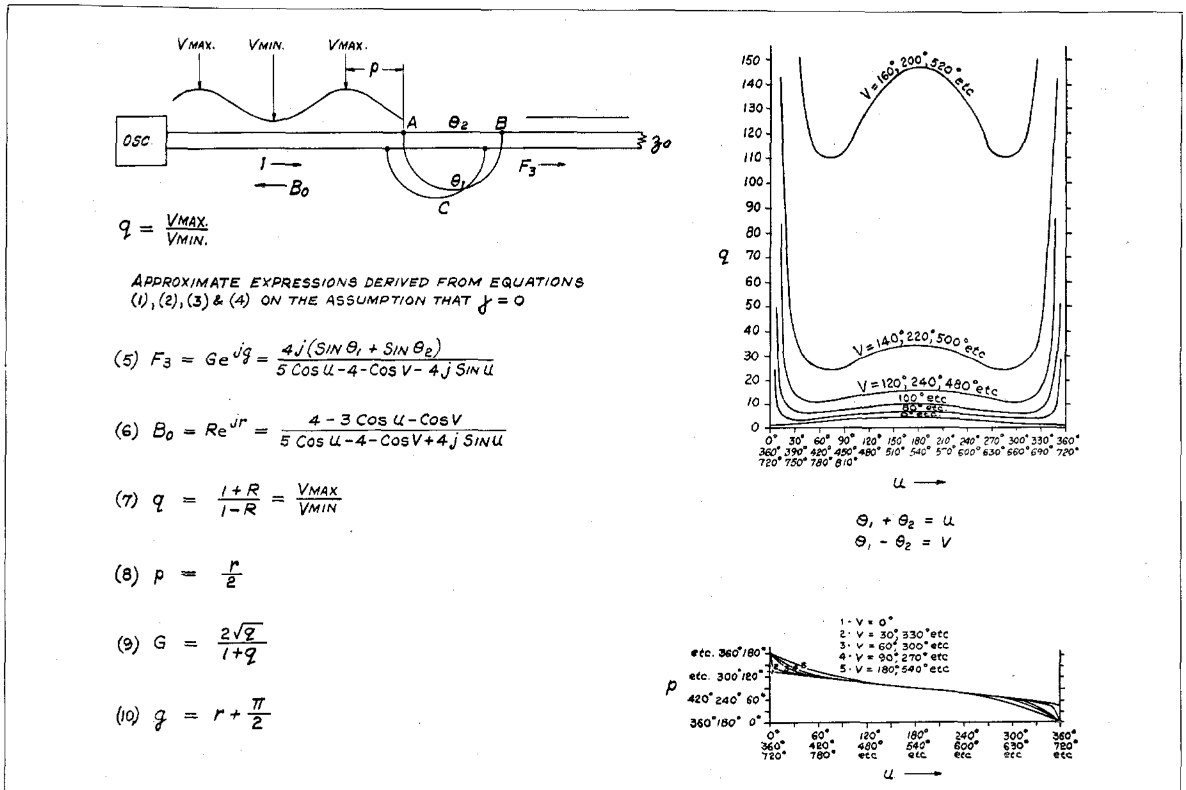


Fig. 3.

are thus postulated, then all other amplitudes and phases become perfectly definite and the solution of the whole problem is unique so that the answer may be written once and for all without any arbitrary constants.

Since the algebra of this problem is fairly lengthy, the actual solution will be omitted but some of the more pertinent results are given in equations (1), (2), (3) and (4) in Fig. 2. In these equations the amplitudes and phases are those of voltages and not of currents. The phase of F_3 given by equation (1) is the phase of F_3 as it starts from junction B. Similarly, the phase of B_0 is the phase of this wave as it emerges from junction A.

Expressions for F_3 and B_0 may be expanded into a rather formidable looking aggregation of circular and hyperbolic functions, both real and imaginary, and are not very well suited for getting a quick picture of the electrical properties of the network.

Fortunately, if γ be neglected, these equations become relatively very simple and are still quite accurate except at several critical points at which γ becomes a primary parameter. The simplified equations are given in Fig. 3.

For the purposes of visualizing the behaviour of the network, it is often more convenient to deal with some quantities which can be observed directly rather than with the amplitudes and phases of the various travelling waves which are given by equations such as (5) and (6). Thus, in place of dealing with the amplitude and the phase of the back wave B_0, the author prefers to work with two subsidiary quantities, namely q and p. q is the so called standing wave ratio; that is, the ratio of the loop voltage V max. to the node voltage V min., and p is the so called position parameter or the distance between voltage maximum and the nearest point of the network. The relations between q and p, and R and r, are given by (7) and (8).

Inasmuch as there are no standing waves along B–Z_0, the amplitude G of the transmitted wave may be observed directly. Equation (9) shows the relation between G and q, and equation (10) the relation between g and r. Since relations (9) and (10) are very simple, there are only two quantities which need be plotted; all other pertinent quantities can then be obtained at once. The two sets of curves in Fig. 3 show how q and p depend on the perimeter $u = \theta_1 + \theta_2$ and the difference $v = \theta_1 - \theta_2$ of the network. These curves are quite accurate except in one respect, namely, the curves which correspond to very small values of v do not reach very large values of q as might be inferred from this figure. This deviation is due to the action of γ, the coefficient which has been neglected. As a matter of fact, no curves with small values of v are shown in this figure. The following properties are immediately apparent from the figures:

(1) In general, all re-entrants produce standing waves along *OSC-A*. The only exception is a degenerate case $\theta_1 = \theta_2 = 180°$ and its equivalents.

(2) Re-entrants with $v = \theta_1 - \theta_2 = 180°$ produce very large values of q and consequently small values of G—see (9).

(3) Re-entrants with $\theta_1 + \theta_2 = 360°$ also produce very large values of q and consequently small values of G—see (9), except when $\theta_1 - \theta_2 = 0$.

The fact that a re-entrant can produce any desired value of q in Arrangement A has an immediate practical application to the problem of matching of the impedance of a load such as an antenna to the surge impedance of a transmission line. This and other applications are based on the following theorem which, for convenience, may be called the reciprocity law for standing waves. This law holds for any network in which dissipation is negligible, whether it be a re-entrant or not. The proof of this theorem is fairly lengthy and is omitted, but the result is stated in terms of a picture in Fig. 4. In words this reciprocity law may be stated as follows:

If a non-dissipative network according to Arrangement A, producing standing waves of ratio q and position parameter p, be inserted into a line on which there already exist standing waves of the same ratio q, this combination will result in a reflectionless line provided that the place of insertion be such that the distance between the network and one of the voltage maxima is equal to p.

When a network is assymmetric in some respects such that its oscillator end in Arrangement A differs from its end nearer Z_0, the theorem still holds provided that in transferring the network from Arrangement A into Arrangement B, the latter be reversed so that its oscillator end in Arrangement A points away from the oscillator in Arrangement B.

In view of this law the problem of eliminating standing waves from a given transmission line by means of a re-entrant is a relatively simple matter. For example, suppose it be required to eliminate standing waves from a long transmission line with 600 ohm surge impedance which feeds a simple "V" antenna. The first step is to determine the standing wave ratio q and the position of one of the voltage loops along the line near the load. Let us say the value of q which has been found is 3. The next step is to select a re-entrant

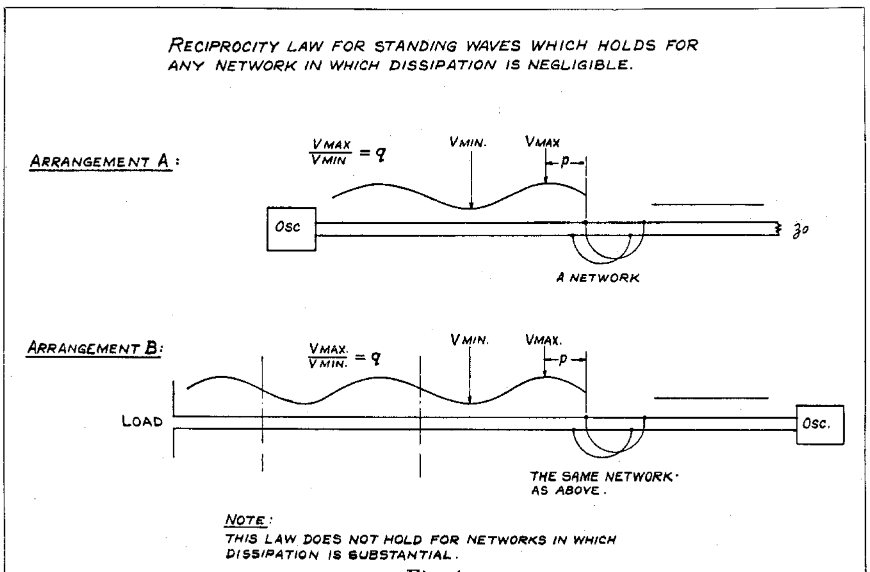


Fig. 4.

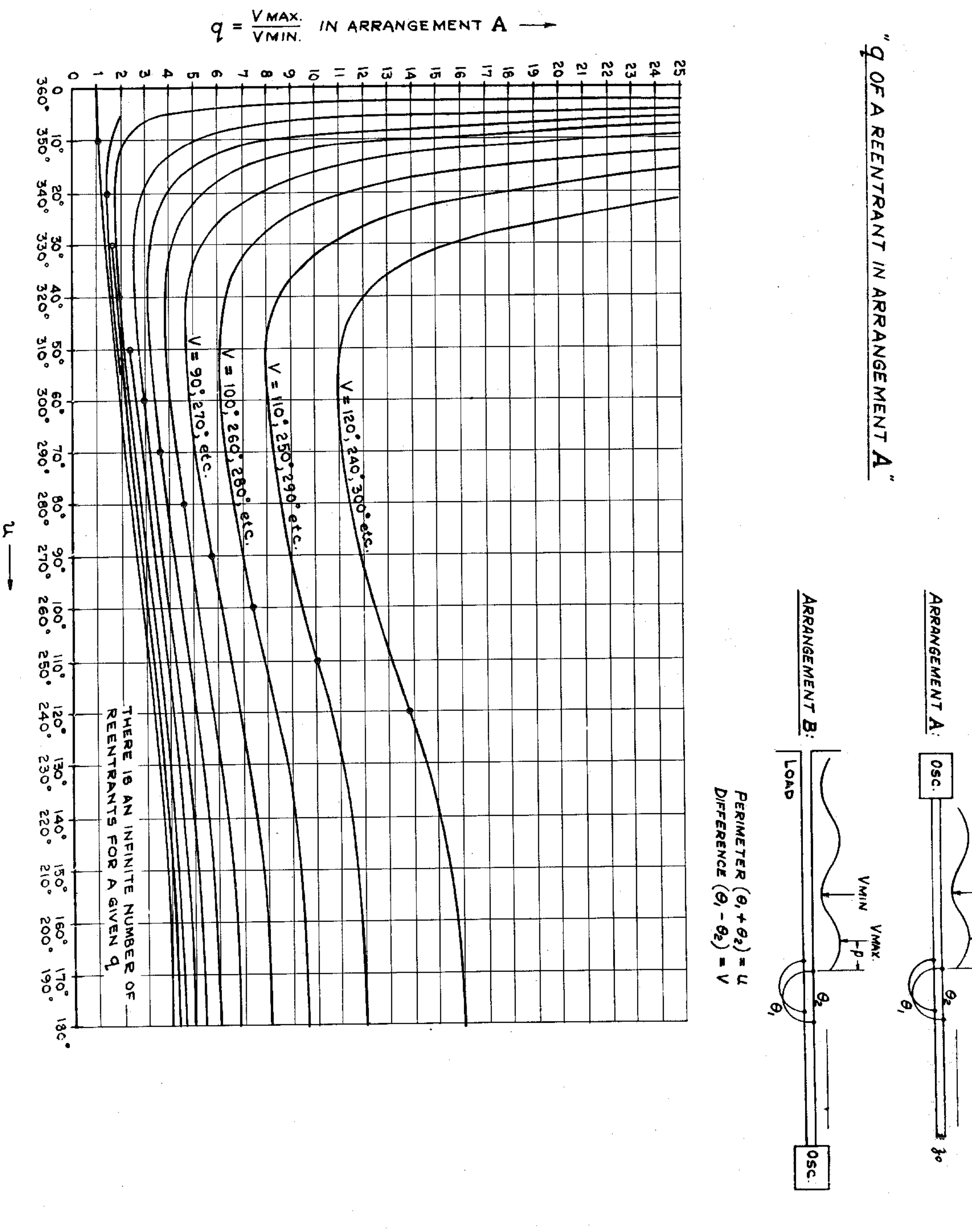

"q OF A REENTRANT IN ARRANGEMENT A"
q = VMAX. / VMIN. IN ARRANGEMENT A →
V = 90°, 270° etc.
V = 100°, 260°, 280° etc.
V = 110°, 250°, 290° etc.
V = 120°, 240°, 300° etc.
THERE IS AN INFINITE NUMBER OF REENTRANTS FOR A GIVEN q
u →
ARRANGEMENT A:
VMAX. / VMIN. = q
OSC.
VMIN.
VMAX.
p
θ1
θ2
ARRANGEMENT B:
LOAD
VMIN
VMAX.
OSC.
PERIMETER (θ1 + θ2) = u
DIFFERENCE (θ1 - θ2) = V

Fig. 5.

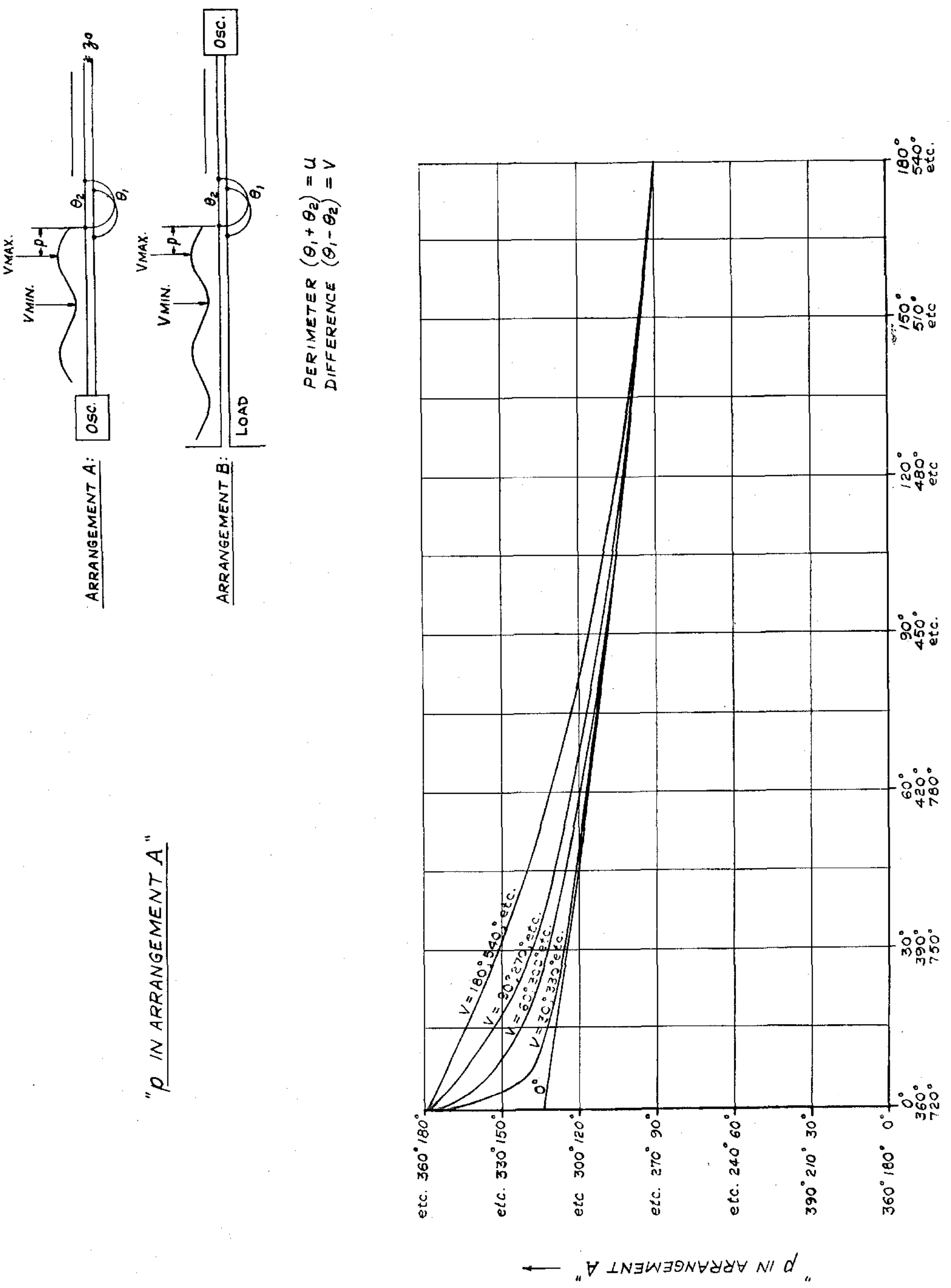

ARRANGEMENT A:
OSC.
VMAX.
VMIN.
p
θ_1
θ_2
Z_0
ARRANGEMENT B:
LOAD
PERIMETER $(\theta_1+\theta_2)=U$
DIFFERENCE $(\theta_1-\theta_2)=V$
"p IN ARRANGEMENT A"
V = 180°, 540° etc.
V = 90°, 270° etc.
V = 60°, 300° etc.
V = 30°, 330° etc.
0°
etc. 360° 180°
etc. 330° 150°
etc 300° 120°
etc. 270° 90°
etc. 240° 60°
390° 210° 30°
360° 180° 0°
0° 360° 720°
30° 390° 750°
60° 420° 780°
90° 450° etc.
120° 480° etc
150° 510° etc
180° 540° etc.
U →
"p IN ARRANGEMENT A" ←

Fig. 6.

which would produce standing waves of ratio $q = 3$ in Arrangement *A*. Such a selection may be made by means of curves already shown in Fig. 3 and reproduced on a larger scale in Fig. 5, in which only one-half is shown, with an additional scale to take care of the other half. It is obvious from this figure that an infinite number of re-entrants will result in $q = 3$; not all, however, have convenient shapes. A particularly suitable one is, therefore, selected. Then the only other question which remains to be settled is, how far from the voltage maximum along the feeder this particular re-entrant should be installed. The question is answered immediately by the p curves of Fig. 3, reproduced on a larger scale in Fig. 6, in which also only one-half is shown, with an auxiliary scale added.

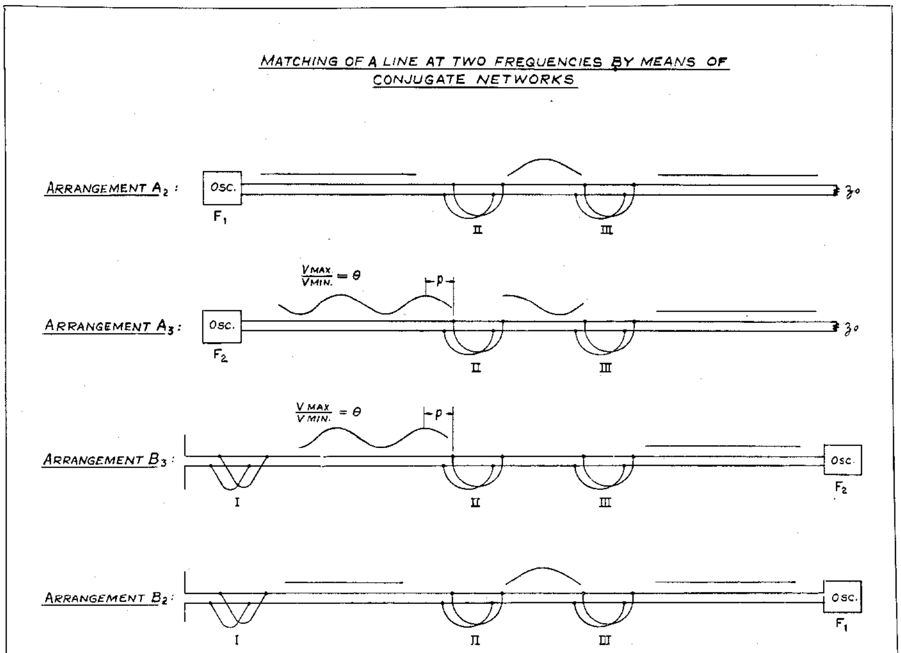


Fig. 8.

Consideration thus far has been given to one frequency only. When dealing with more than one frequency, the concept illustrated in Fig. 7 is quite useful. This figure shows two networks which may be called conjugate; that is, two paired networks which, at the frequency F_1 in question, produce no standing waves in Arrangement *A* except between these networks. In view of the reciprocity law for standing waves it is clear that any two networks, which when used singly in Arrangement *A* produce the same value of q, can be made conjugate by proper spacing. This principle applies to any networks with negligible dissipation, whether re-entrant or not. In particular, it is clear

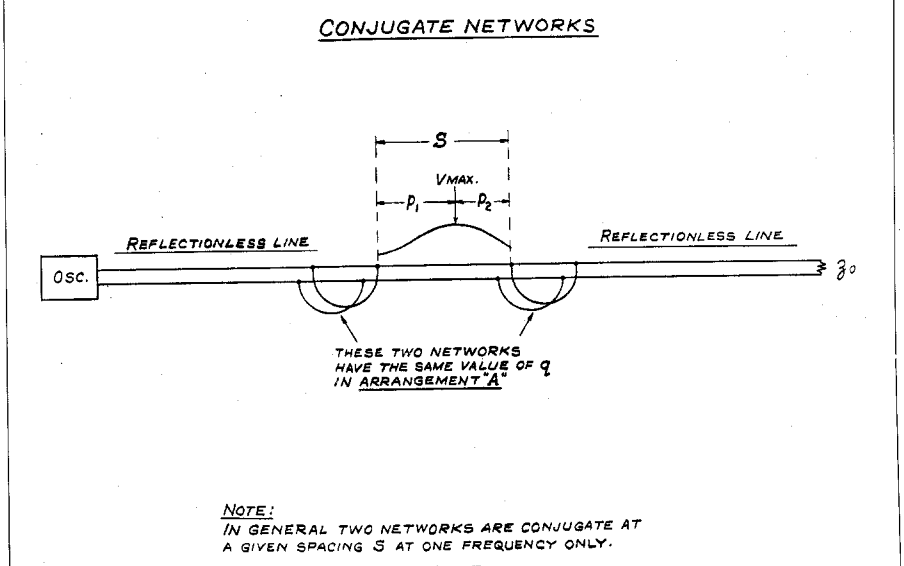


Fig. 7.

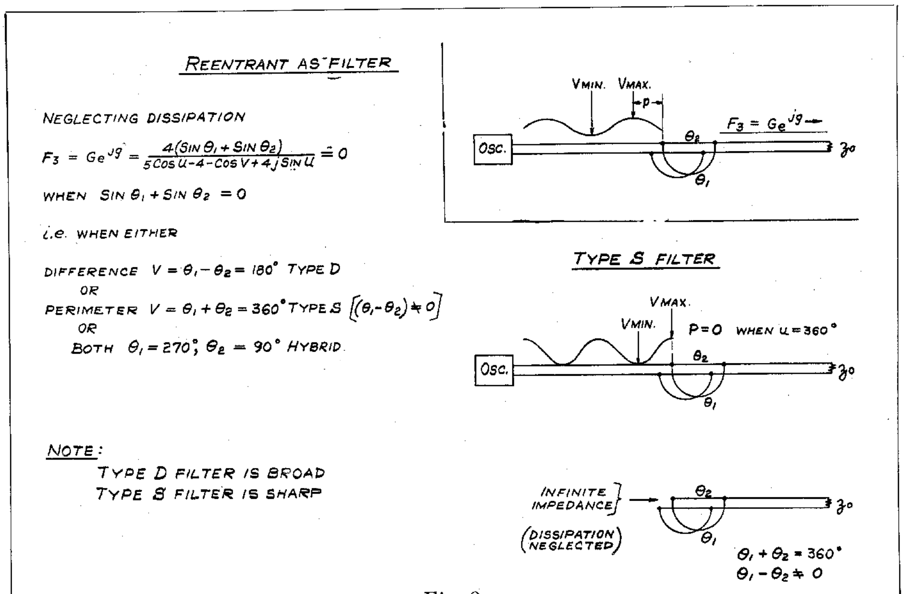


Fig. 9.

that two re-entrant networks with equal values of q are conjugate when the spacing between them is equal to the sum of their p's $\pm$ 180° times an integral number. In general, two networks, even when they are identical, are conjugate with a given spacing S between them only at one frequency; for, even though the q's of two identical networks remain equal at all frequencies, the sum of their position parameters, i.e., 2 p, is not independent of frequency.

For this reason two networks which are conjugate at some frequency F_1 in general behave as shown in Arrangement A_2 in Fig. 8, and in Arrangement A_3 at some other frequency F_2. The constants of the standing waves, i.e., q and p, which result in Arrangement A_3 at frequency F_2, may be calculated from values of q and p of the individual networks, and thus the behaviour of any pair which is conjugate at frequency F_1 may be predicted at any other frequency F_2. It is also possible to select among conjugates at frequency F_1 that pair or pairs which at another given frequency F_2 will result in a prescribed standing wave ratio Q.

This fact, in view of the reciprocity law for standing waves, provides the solution for the problem of matching at two frequencies. For example, suppose that at frequency F_1 the

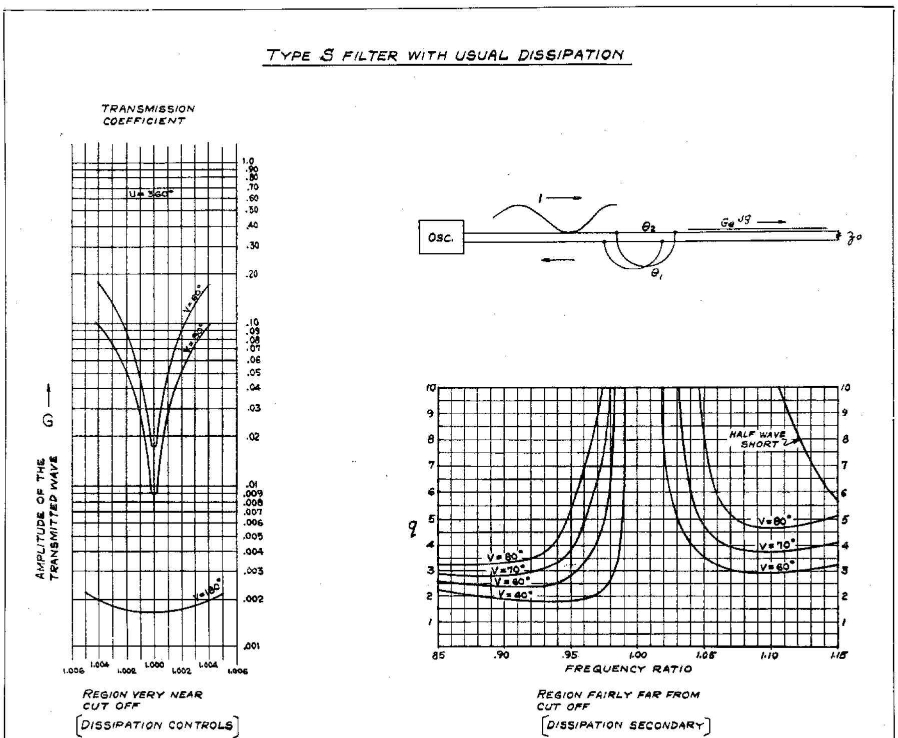


Fig. 10.

feeder is already matched by means of re-entrant I and that it is proposed to match the feeder also at some other frequency F_2. Then it is only necessary to ascertain the ratio Q of standing waves along the feeder at frequency F_2 between the oscillator and the re-entrant I, and to find the position of the voltage maximum. These quantities can be measured. The next step is to select among the conjugate networks at frequency F_1 a pair which would produce the ratio Q in Arrangement A_3. This pair, when installed along the feeder at the proper point which, of course, can be predicted, will produce a reflectionless line at frequency F_2 without disturbing the match which was already attained at frequency F_1 by means of re-entrant I. The principle just described is applicable to all kinds of networks, whether re-entrant or not. In particular, it is applicable to networks of the impedance type, for example, of the building-out section variety. The pertinent solution for the latter case may, in fact, readily be obtained from the formulae for the re-entrants by degenerating the latter into impedances. This may be done by letting $\theta_2 = 0$.

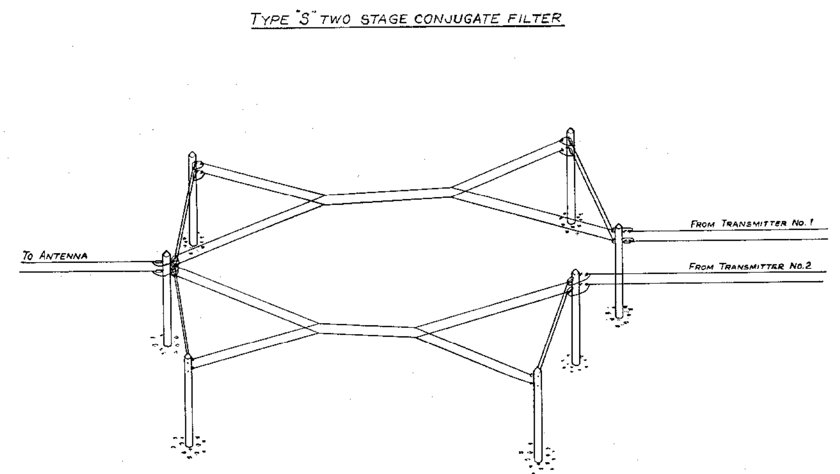


Fig. 11.

Next we wish to consider re-entrant networks as filters. From the equation for F_3, already given in Figs. 2 and 3 and reproduced in Fig. 9, it may be seen that the amplitude G of the transmitted wave becomes zero (γ is neglected) when either $\theta_1 - \theta_2 = 180°$ (type D or difference filter) or when $\theta_1 + \theta_2 = 360°$ (type S or sum filter). Generally speaking, type D filters are relatively broad, while type S filters are relatively sharp.

The properties of both types of these re-entrant filters are possibly worth describing in some detail; but, because of the limited time available, we will restrict ourselves to Type S filters.

One of the properties of type S filters follows immediately from p and q curves, which have already been shown in Figs. 3, 5 and 6. From these curves, when $\theta_1 + \theta_2 = 360°$, $p = 0$, that is, the voltage loop in Arrangement A occurs at one of the terminals of the filter, a condition which holds regardless of the value of $(\theta_1 - \theta_2)$ as long as the latter is different from zero. It also follows from these curves that the back wave B_0 is equal to the unit wave. In more familiar terms of impedance, this means that the impedance looking into the Type S filter is infinite (γ is neglected). These conditions prevail at the cut-off frequency. As the frequency is varied, the value of q falls off very rapidly. When $V = 70°$ the filter causes only a very moderate amount of reflection at frequencies of the order of 1.05 or 0.95 times the cut-off frequency, as may be seen from Fig. 10.

The behaviour of the sum filter in the immediate neighbourhood of the cut-off frequency is also shown in Fig. 10. In this latter region the behaviour of the network depends largely on the attenuation constant γ, and it is necessary to select some definite value of this parameter to get any picture at all. The value of γ assumed in plotting these curves corresponds to the usual attenuation in open air lines, namely, 0.5 db. per 1 000 feet at 10 megacycles. The value of γ decreases with frequency so that at the higher frequencies the networks are somewhat sharper. This is because γ involves the attenuation per wavelength and not per foot.

The following type of networks, shown in Fig. 11, have been used by the Mackay Radio and Telegraph Company for the purpose of feeding a single antenna with two high power transmitters operating simultaneously. A network of this type consists of four type *S* filters, 1, 2, 3 and 4. Two filters, 1 and 2, on one side of the network are designed to block frequency F_1. The other two filters, 3 and 4, on the opposite side of the network, are designed to block frequency F_2. The first two filters are conjugate at frequency F_2, while the other two are conjugate at frequency F_1. This arrangement provides two stage filtering together with the convenience that feeders are reflectionless on the transmitter side of the network, provided the transmission line is reflectionless on the antenna side ; thus, no additional matching is required.

Such networks should be installed near the transmitting building in order that only a single long feeder carrying two frequencies simultaneously to the antenna will be required.

The two stage filtering provided for in these networks is not really necessary. In fact, high power transmitters have been operated with single stage filters of both type *S* and type *D*. From the constructional point of view, however, it has been found that the two stage filters are as simple as single stage filters with smaller conjugates for matching the transmitter side of the feeders.

The Company experience has shown that 5% separation between frequencies of two transmitters is quite sufficient for satisfactory operation of these networks. The degree of filtering obtainable under practical conditions is such that less than 5 watts of energy, and ordinarily only a fraction of a watt, from transmitter No. 1 operating at 40 kW gets into transmitter No. 2. At the same time, the loss in the network at the transmitted frequencies is around two or three tenths of a decibel.

Standards in Refrigeration and Air Conditioning

By GLENN MUFFLY*, Springfield, Ohio, U.S.A.

EDITOR'S NOTE.—*It is felt that this article will be of interest to communication engineers in view of the application of air conditioning to telephone offices located in areas where adverse climatic conditions are encountered.*

AN amount of work done in refrigeration may be given in one unit as conveniently as another, but the *rate* at which the work is done happens to match the 24 hours of the day if we use the " Ton " of 2 000 pounds and the American practice of figuring 144 Btu's as the heat required to melt a pound of ice. This gives us 12 000 Btu's per hour, or 200 Btu's per minute as the Ton rate of removing heat or transferring it. In translating the American standards mentioned herein, one should keep in mind the 2 000 pound Ton and the arbitrary 144 Btu's per pound, though it is a common practice to omit mention of the Ton rate and speak only of Btu/hour.

Since this short article cannot go into details of the Standards mentioned, I refer to the Standards themselves for such details, limiting this to an explanation of why they were adopted.

The Standard Method of Rating and Testing Mechanical Condensing Units[1] applies to complete " Condensing Units " only, not to a compressor, a motor, or a condenser. It was needed because of the fact that comparatively few compressors are now being sold separately, and the old " Standard Ton " method of rating a compressor at the fixed temperatures of 5° F. and 86° F. has no application to a unit required to operate at some other evaporating temperature and at whatever condensing temperature the condenser of the unit would reach under the required operating conditions.

If we compare the " Standard Ton " rating of a compressor to the brake-horsepower rating of an engine, then the "Condensing Unit" rating would compare with the rating of an automobile in miles per gallon of fuel. The result is given in Watts input to the motor or motors of the unit and in Btu's per hour of work done under the specified temperature conditions. If a manufacturer furnishes a very efficient motor or an over-size condenser on his unit sold under a particular catalogue number, he is entitled to whatever gain of efficiency is obtained thereby. Another make of condensing unit may have a more efficient compressor and a less efficient condenser, but show the same "overall" results, in which case the ratings will be the same.

The new Standard provides for ratings of any unit at any one or all of four different temperatures, as represented by the saturated vapour temperatures corresponding to the pressure measured at the suction inlet connection to the condensing unit, these temperatures being minus 10, plus 5, 20 and 40 degrees F. The unit is operated in a 90° F. room, whether air or water cooled, as water cooled units may be partly air cooled. If water cooled, the ingoing water supply is held at 75° F. during test and the flow regulated to give 85, 90, 90 and 95 degrees F. outgoing water for the respective evaporating temperatures.

The report of such a test includes the name or symbol of the refrigerant used ; the A.S.R.E. rating group (evaporator temperature) ; the capacity in Btu/hour ; the motor input in

* Past President of American Society of Refrigerating Engineers and at present General Chairman of the Joint Committee on Rating Commercial Refrigerating Equipment, in which the Refrigeration Division of the National Electrical Manufacturers' Association (NEMA), the Refrigerating Machinery Association, the Air Conditioning Manufacturers' Association and the American Society of Heating and Ventilating Engineers are joined under sponsorship of the American Society of Refrigerating Engineers for the purpose of establishing Standards.

[1] Published by the American Society of Refrigerating Engineers, 37 W. 39th St., New York, and is available for 15 cents.

watts; the gallons per hour of water used (if water cooled); and all of the necessary identifying data on the unit. These data are all that a prospective buyer requires in addition to the catalogue description, which naturally includes dimensions, weight and a list of the accessories furnished. A comparison of competing units on this basis, taking into account the cost differences, enables the buyer to make his selection.

By rating in Btu's per hour we eliminate the differences that formerly existed between the ratings of various manufacturers, some of whom assumed 12 hours per day as the maximum operating time, some 18, etc. The capacity given is for full-time operation and the buyer compares the various makes on an even basis, making what allowance he wishes for reserve capacity.

Another recently adopted Standard[2] is the "Standard Method of Rating and Testing Air Conditioning Equipment." It has a similar objective in giving the buyer the over-all figures on input and output of a "Unit" or a "System." In this case it is necessary to specify in more detail the kind of "Unit," which may be a complete system, just a Cooling Unit, a Heating Unit, etc.

Where refrigeration is involved the methods and results are made to conform to the above described Standard Method of Rating Mechanical Condensing Units.

Twenty-five definitions are given to clarify the terms used in describing various types of units and systems sold in the air conditioning field, there being "Cooling Air Conditioning Units," "Heating Air Conditioning Units" and "Air Conditioning Units," which last type of unit both heats and cools, the definition in effect being:

An Air Conditioning Unit is a specific air treating combination consisting of means for and control of ventilation, air circulation, air cleaning and heat transfer, and including control means for the maintenance of temperature and humidity within prescribed limits. In other words, it is the unit doing a complete air conditioning job.

A still more recent Standard in air conditioning is based on the above and applies to applications of such equipment. It is known as the "Code of Minimum Requirements for Comfort Air Conditioning" and was written by another joint committee sponsored by the American Society of Heating and Ventilating Engineers and the American Society of Refrigerating Engineers. The object is to give contractors a standard for estimating air conditioning jobs to ensure satisfactory performance.

Two other Standards[3] refer to household electric refrigerators as follows:

"Standard Method of Computing the Gross Volume, the Net Food Storage Volume and the Food Shelf Area"—a self-explanatory title—was adopted on May 18, 1931. Main points are that a space or shelf must have four inches or more of height or width to be counted as food storage space or shelf area. The drip pan may be counted as food space and shelf area only in case the system is not of the automatic defrosting type and the drip pan is removable.

"Test Code for Mechanically Operated Household Refrigerators" is a test procedure based on average cabinet air temperatures of 38° F. in a 70° room, 43° F. in a 90° room and 46° F. in a 110° room. The code gives locations at which temperatures are to be taken, methods for determining the ice freezing rates, report forms and the procedure to be followed in tests.

The American Standards Association Safety Code for Mechanical Refrigeration, prepared by Sectional Committee B-9 under sponsorship of the American Society of Refrigerating Engineers, is now in process of revision, the present Code having been approved by A.S.A. in October, 1930. It covers safety devices, quantities of various refrigerants allowable in various locations, piping and factors of design having to do with safety. The object is to have such a standard in a form that can be adopted or followed by city, state and national regulating bodies. It has been the subject of much discussion, originally in connection with the

[2] Prepared by the Joint Committee on Rating Commercial Refrigerating Equipment, and available from the American Society of Refrigerating Engineers for 20 cents.

[3] Prepared by the Technical Committee of the Refrigeration Division of NEMA, and available in one publication identified as No. 37–41 at a price of 40 cents from the National Electrical Manufacturers' Association, 155 E. 44th St., New York.

regulation on multiple systems in residence buildings and more recently regarding the classification of refrigerants and proposed adoption of various safety devices. The growth of air conditioning has also been a factor in the demand for revision of this code.

It may be of interest to note that the American Society of Refrigerating Engineers now has a number of new standardization projects under way in the Standards Committee and in joint committees with other organizations. They include: Refrigerated Trucks and Buses; Rating and Testing Refrigerant Expansion Valves; Rating and Testing Self-Contained Drinking Water Coolers; and Fruit and Vegetable Precooling.

In all of this standardization work the object is to set up methods of measuring and factors of safety or of performance, not to standardize design details that may be improved upon. The refrigeration industry is so active that standards must be subject to frequent revision or addition to cover new types of apparatus.

While the A.S.R.E. is considered the authority on refrigeration in the United States, the growing uses for refrigeration call for co-operation with other organizations, both commercial and technical.

Compania Standard Electric Argentina exhibit of radio valves in the show window of Sociedad Anonima Radio Argentina (Radiar), Buenos Aires. The Radiar building is located in one of the principal thoroughfares of the city and the display attracted great interest. The central view shows the transmitter building housing the 50 kW W.E. (Doherty) broadcaster recently installed by C.S.E.A. for Radio Municipal (LS-1). The valves shown are types used in LS-1, Radiar and other stations.*
Both the Compania Standard Electric Argentina and Sociedad Anonima Radio Argentina are International System companies.

* "Broadcasting Station LS-1—Buenos Aires," by R. E. Coram, A. W. Kishpaugh (Bell Telephone Laboratories) and W. H. Capen (Int. Tel. & Tel. Corp.), *Electrical Communication*, July 1938.

Recent Telecommunication Developments of Interest

Marseilles Toll Board.—An interesting type of toll board has been designed and manufactured by Le Matériel Téléphonique, Paris, for Marseilles, and will be placed in service in 1939.

The construction of the switchboard sections is novel in that they are of the all-metal type—streamlined—and with a cream-tinted enamel finish, the metal trimmings, position numbers, etc., being chromium plated. The finish of the switchboards can be readily maintained in a manner similar to automobile bodywork.

The switchboard sections are of the two-piece unit construction, consisting of an upper and lower unit per each two-position section. The rear doors, non-removable, are arranged to slide one behind the other along two tracks.

The installation will consist of two lines of switchboards of 28 sections (56 positions), each provided with a belt conveyor which will carry the tickets edgewise and require very little space between the plugshelf and pilot lamp rail (85 mm high × 27 mm deep).

Provision is made for C.L.R. operation on the "A" positions. "B" positions are provided for incoming and tandem traffic, a special feature of which is the use of triple cord circuits for tandem traffic. This will enable the setting up of connections between 4-4 wire, 4-2 wire, or 2-2 wire circuits for tandem working. Incoming or "B" traffic is handled by means of keysending over automatic switching trunks for connections to the Marseilles automatic area.

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Anglo - French Ultra - Short Wave Radio Links. — As a result of a year's continuous operation of the 9-channel Ultra-Short Wave radio link between Belfast and Stranraer, the British Post Office and the French P.T.T. have placed a joint order for a similar system to be installed for use across the English Channel. It will have an ultimate capacity of eighteen channels with nine equipped initially, and will embody a number of improvements, including a "weak talker" device ensuring full modulation of the transmitter at low incoming speech levels. This device, in the case of a weak talker, is capable of giving an improvement of 10 db. in signal-to-noise ratio.

The equipment normally will be operated directly from A.C. mains, the necessary D.C. power being obtained from selenium rectifiers. A standby 15 kW Diesel engine will automatically take over the load within one minute of any failure of the mains supply.

Each group of nine channels will have its own transmitting and receiving directive aerial system. Each antenna, both transmitting and receiving, will give a gain of approximately 18 db. over a simple half wave antenna. The antennae will be vertically polarized for transmission from England to France, and horizontally polarized in the opposite direction. The operating wavelengths in one direction will be 3.6 and 4.4 metres and, in the other, 3.95 and 4.9 metres.

The circuits will be continued over landline cables on a 4-wire basis to the nearest repeater stations, where switching on and off of the radio equipment will be done by a remote control system. Facilities for maintenance, testing, and monitoring will be built into the equipment and will be utilized only by an attendant visiting a station at intervals.

The equipment will be located in unattended terminal stations with optical visibility between them. It will be manufactured by Standard Telephones and Cables, Limited, London, and Le Matériel Téléphonique, Paris.

● ● ●

500/135 Watt Tone Modulated Radio Beacon.—A Radio Beacon Transmitter, designed specially for marine or air navigation purposes, has recently been developed by Standard Telephones and Cables, Limited, in conjunction with the International Marine Radio Company, Limited, London. It is coded HB.1 and has a power rating into the aerial circuit of 500 watts C.W., or 135 watt M.C.W. or telephone carrier, and a frequency range of 240–350 kc/s.

The main requirements of radio beacons are absolute reliability, under all circumstances and at all times, and simplicity of operation, since the personnel employed will not normally be skilled radio operators.

The HB.1 500/135 watt radio beacon conforms with these requirements admirably, being capable of continuous, unattended operation. The transmitter itself is tropically-finished throughout and is of generous design with ample operating margins provided for all components.

In order to achieve reasonable simplicity, complex monitoring and failure circuits have been avoided. A small wall mounting fault indicator, however, gives audible and visual alarm of:

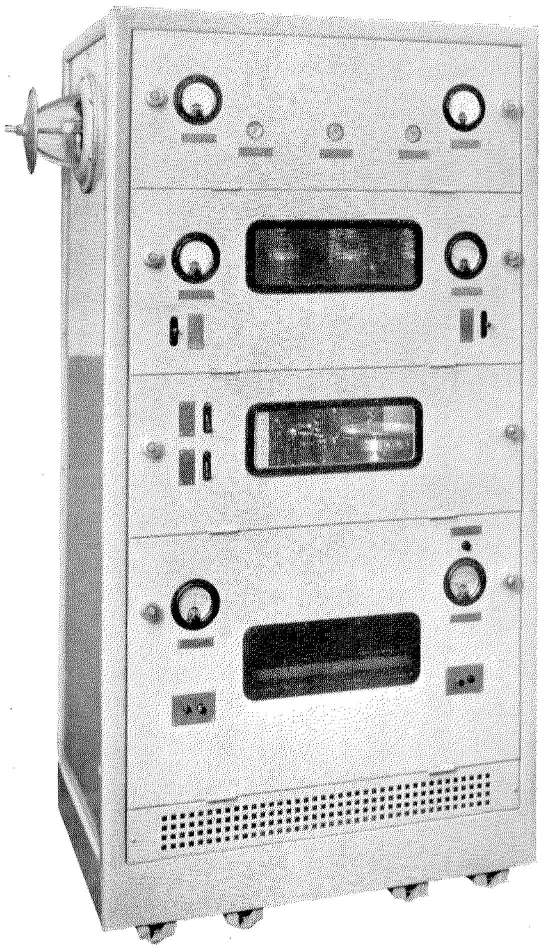
(1) Carrier failure.
(2) Modulation failure.
(3) Code sender failure.
(4) Mains failure.

To ensure uninterrupted service a duplicate 500/135 watt transmitter can be provided, complete with power equipment, code sender, R.F. unit, and fault indicator. A changeover unit, common to both transmitters, immediately switches the aerial and power supplies from the operating transmitter to the stand-by transmitter, or vice versa, in the event of a fault.

Telephone facilities are available as an emergency service.

The performance of the beacon conforms with the rigid requirements of this type of service. M.C.W. or telephone carrier may be modulated 80%; amplitude distortion under this condition is not more than 5%. The radio frequency stability is better than 0.005% with crystal control and 0.05% with auto-oscillator control. The harmonic radiation conforms with C.C.I.R. requirements.

Code sender control is effected by an electrical or 8-day hand-wound ship's type chronometer (per diem accuracy $\frac{1}{2}$ second) readily accessible for adjustment when required. The code sender is motor driven and can be set up to transmit any desired code of signals by simple adjustments which may readily be effected on site by a mechanic or operator. It is therefore an easy matter to change the code signal at any time, should this be required. The power consumption of the transmitter is approximately 1.5 kilowatt.



HB.1—500/135 W Tone Modulated Radio Beacon Transmitter.

Extensive trials of the HB.1 beacon have been conducted in the New Southgate radio laboratories of Standard Telephones and Cables, Limited, over a lengthy period with the transmitter operating under "fog" conditions, i.e., transmission every six minutes. The equipment has been subjected to tests under extreme temperature and humidity conditions to ensure satisfactory design for operation in tropical countries.

The transmitter, complete with rectifier power unit, clock control and code sender unit, and radio frequency apparatus, is housed in one standard cabinet 5′ 0″ high × 2′ 8″ wide × 1′ $10\frac{1}{2}$″ deep, weighing approximately 900 lb.

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