



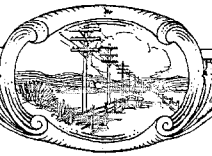
ELECTRICAL COMMUNICATION

*Short Wave Radio Telephone
Link Connecting Spanish and
South American Telephone
Networks*

FEBRUARY No. 4

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ELECTRICAL COMMUNICATION

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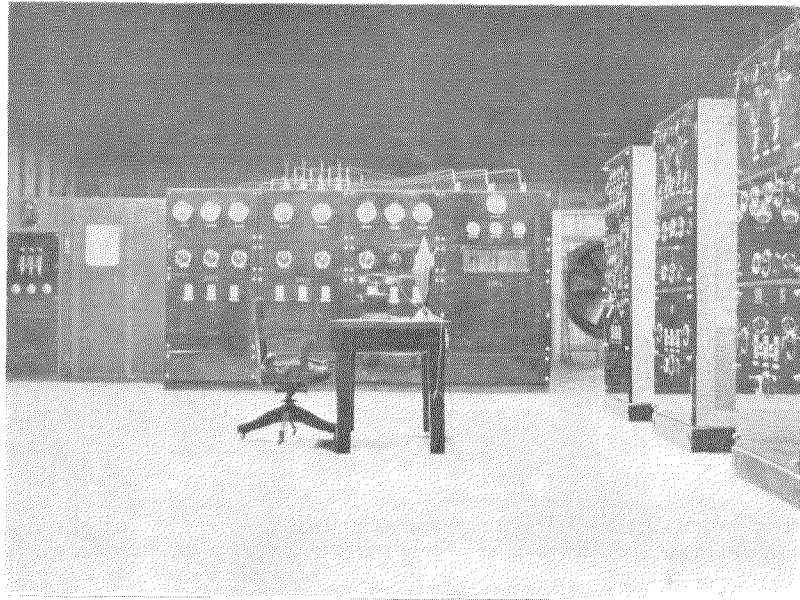
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Transmitter Room at Madrid, Madrid-Buenos Aires Radio Link

Introduction

By G. H. NASH

Executive Vice President, International Telephone and Telegraph Laboratories, Incorporated

FOR many reasons, the decision of the International Telephone and Telegraph Corporation to establish a short-wave connection between South America and Spain presented problems particularly attractive to those engaged in the provision of such a link. The plans called for connecting subscribers in certain South American telephone operating areas with the great Spanish telephone network and, in addition, through Spain to other European networks. The requirements of the whole project included telephone transmission of a high commercial order for a prescribed number of hours each day, and the provision of equipment capable of connecting at the transmitting end and at the receiving end with two- or four-wire long distance land circuits—the control positions being located at each end of the radio link. Further, it was stipulated that the equipment should be such as to make it difficult for speech to be overheard by those for whom it was not intended. The development was commenced in the Research Laboratories of the International System at a time when little was known regarding shortwave telephony. Consequently, new problems had to be faced in all parts of the equipment, i.e., both in the radio and in the low frequency sections of the undertaking.

The radio path extends from the vicinity of Madrid to the vicinity of Buenos Aires, the distance between the ends of the radio link being about 6,400 miles. This path cuts the meridian at the equator at about 34 degrees. In following thus an oblique line between the Northern and Southern hemispheres, it passes through zones notorious for atmospheric disturbances, and through the equatorial region where

radio transmission is particularly subject to fading. Devices for counteracting the effects of fading are accordingly installed, and in addition echo suppressor circuits for preventing the speech from being reflected at the distant ends form an essential part of the equipment.

When the requirements had been ascertained, the design of the equipment was begun in the Research Laboratories. Owing to the special nature of the problem, the Laboratories not only carried out the research work but, together with the manufacturing organisation of the International Telephone and Telegraph Corporation, they were responsible for the construction, installation, and testing of the complete equipment. On the other hand, the operating organisations in Spain and in Argentina undertook the work of designing and constructing the special buildings for the plant and for the attendant staff. They also constructed the directional antenna and the telephone lines for connecting the radio equipment with the telephone networks.

The training of the operating staff—a matter of great importance—was also dealt with by the operating organisations. To provide for commercial service over so vast a stretch of the earth's surface under such novel and exacting conditions, constituted a work of considerable magnitude, and its success is a matter of satisfaction to all who were concerned therewith.

So far as is possible within limited space the particulars contained in this issue of "Electrical Communication" are intended to impart technical and general details concerning a radio link that in many respects introduces a new era in telephonic communication. It is approximately twice the length of the North Atlantic link.

Madrid-Buenos Aires Radio Link and Its Wire Connections

By G. H. GRAY and N. K. FAIRBANK

Engineering Department, International Telephone and Telegraph Corporation

Introduction

ON October 12th, 1929, the communication facilities of the International System were very greatly extended by the opening for service of a short wave radio telephone link between Madrid, Spain, and Buenos Aires, Argentina. With the opening of this link it has been possible for the first time for the public to talk from their own telephone sets in South America to the Old World. The importance of this channel can hardly be overestimated, since it renders a "network" to "network" service as distinguished from point-to-point service between special booths, and is capable of connecting any telephone in the principal cities of Europe to any telephone in the principal cities of Argentina, Chile, and Uruguay.

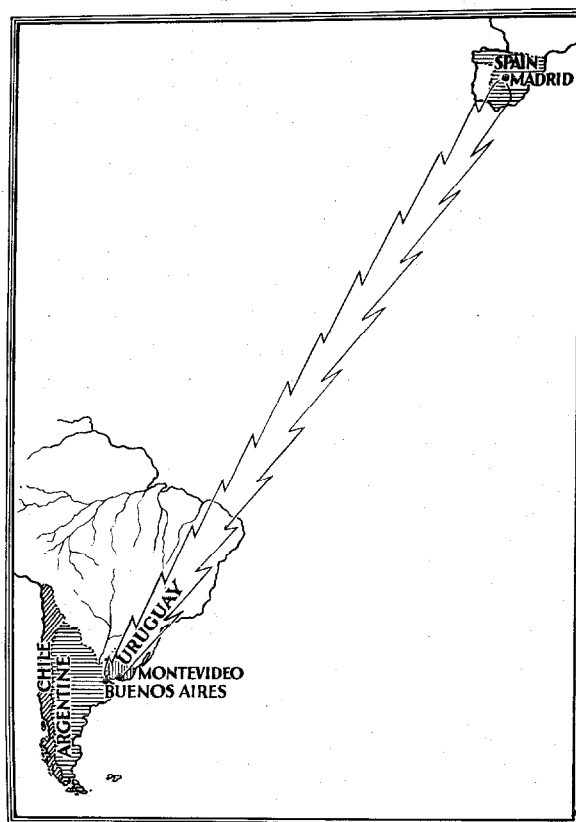
Reference to the map shows in part the extensive nature of the telephone systems served by the link. At the South American end, connection is made to 210,000 telephones in the Argentine Republic and 17,000 in Uruguay. At the European end, there are 155,000 telephones in Spain to which the service is available and there are no technical difficulties which prevent this service being extended to those areas in Europe which at present enjoy European International Communication.

It is of interest to note that the circuit is the second largest area-to-area link in the world, being exceeded in this respect only by the Great Britain-U. S. A. connection. It is, however, by far the longest area-to-area public telephone link in existence, covering approximately 6,400 miles (10,300 Km.) as against the 3,200 miles (5,150 Km.) from England to America, and is provided with a privacy system.

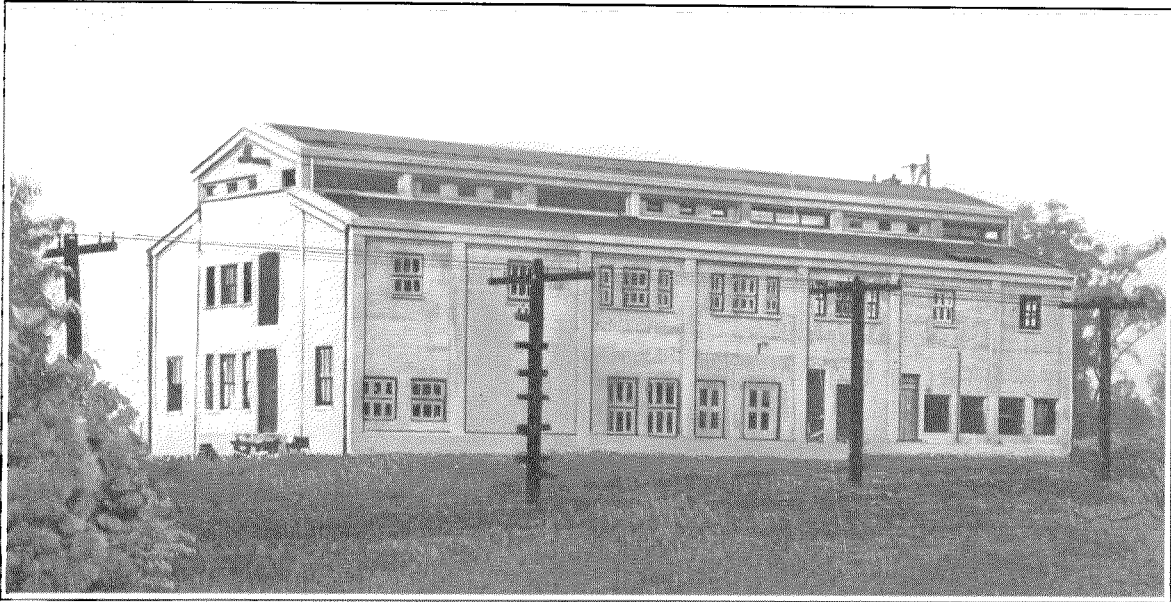
The terminals of the circuit are located at Madrid and Buenos Aires, respectively, and consist, at each end, of a transmitting station and a receiving station situated some distance apart and connected by land lines to the terminal equipment which is situated in the control office.

The transmitting station for the Madrid terminal is located at Pozuelo del Rey, about twenty-two miles (thirty-five kilometers) to the east of Madrid, and the receiving station at Grinon, about fifteen miles (twenty-four kilometers) to the south of Madrid. The transmitting and receiving stations for the Buenos Aires terminal are located respectively at Hurlingham and Platanos, each being some twelve miles (twenty kilometers) distant from Buenos Aires.

In order to give reliable service over the entire day, three wavelengths are used at each transmitter. Approximately a fifteen meter wavelength (20,000 Kc.) is employed during the day, a thirty meter wave (10,000 Kc.) at night, while



Spain-South America Radio Telephone Link.



Transmitting Station at Pozuelo del Rey.

a twenty meter wave is required for sunrise and sunset conditions.

A detailed description of the various units comprising the link is given elsewhere in this issue of *Electrical Communication*. The accompanying illustrations give general views of the Madrid and Buenos Aires transmitting and receiving stations.

At the present time traffic on the radio channel is approximately two calls per day and has been as high as nine calls per day.

It is proposed in this article to outline briefly the various wire facilities which are used to connect this radio link to the International Telephone Systems in Spain and South America. This will be considered in two parts, the present and the future. It may be stated at the outset that, almost without exception, the wire lines which may be connected with the new radio link are high grade, modern circuits well constructed and well maintained and capable of giving first class service.

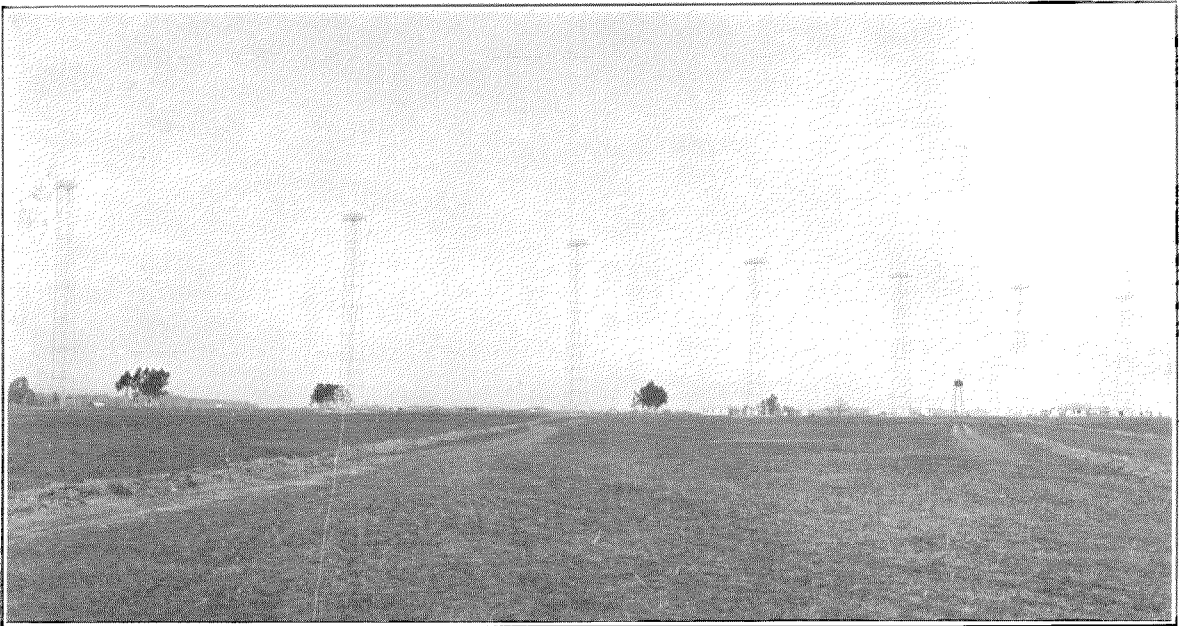
At present the service from South America is limited to some of the more important cities in Argentina and to Montevideo, Uruguay. In order to reach these cities, however, it has been necessary to meet and solve a number of new and very interesting problems. For

example, it has been necessary to place a cable under one of the widest rivers in the world, and to cross one of the highest mountain ranges in the world where, because of snow storms, train service is completely blocked for certain periods each year. Serious insulation difficulties are also encountered, such, for example, as in parts of Argentina where enormous cobwebs are blown into the circuits by the high winds, thus effectively short circuiting the wires.

Present Circuits

In Argentina, service can be given at present to 83 cities. Direct circuits are available to 15 or more of the important cities, these circuits varying from about fifty kilometers in length to approximately seven hundred kilometers. They consist mostly of copper wire about 2.8 mm. in diameter, which is a little larger than No. 12 N. B. S. Several of these circuits are equipped with through line repeaters. Between Buenos Aires and Bahia Blanca (805 kilometers) a three channel carrier current system is installed, while between Buenos Aires and Rosario (410 kilometers) there are two such systems.

The service to Montevideo is given over a subfluvial cable under the Rio de la Plata from Buenos Aires to Colonia, from which point an



General View of Transmitting Antennas at Buenos Aires.

open wire line takes the circuits into Montevideo. This cable was laid in the early part of 1929 and consists of a twelve quad, sixteen gauge, paper insulated non-loaded cable designed for operation on a four-wire basis. The twelve quad cable will therefore carry twelve simultaneous conversations or eighteen conversations if the phantom circuits are used.

The length of the cable, thirty-seven miles, is so great that it has been necessary to instal repeaters at each end in order to secure satisfactory speech volume. At present the repeater equipment for six circuits is installed, permitting six simultaneous conversations. Plans are under way for increasing the number of circuits in the near future. The cable has been equalised to improve the quality of transmission.

In Spain, connections can be made at Madrid to practically all the more important cities in the country and to many places of lesser importance (2,256 cities in all). The Spanish network consists of upwards of 222,350 kilometers of copper wire, mostly three mm. in diameter (slightly larger than No. 9 A. W. G.); 112 through line repeaters and 43 terminal repeaters are used in connection with this open wire network. Superposed upon these circuits out of Madrid there

are 13 three-channel carrier current systems, which add very appreciably to the message carrying capacity of the circuits. In addition, approximately 170 kilometers of toll cable have been placed between Barcelona and Valls. It is expected that this cable will be extended rapidly in the next few years so that Madrid and Barcelona and also Madrid and Irún (near San Sebastián) will be connected by cable.

Circuits are available from Madrid not only to the points mentioned in Spain, but to some other countries as well. For example, there are direct circuits to Lisbon, London, Paris and to other cities in France. At Algeciras, which has a direct circuit from Madrid, connections may be switched over a 24-mile submarine cable to Ceuta, Morocco, thus putting South America into telephonic communication with a third continent.

Future Circuits

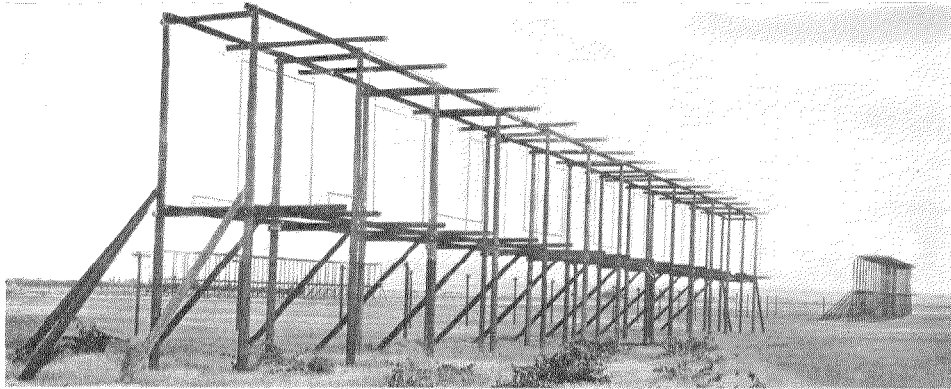
Connection to 30,000 telephones in Chile will soon be available by compositing the All America telegraph circuits from Buenos Aires to Santiago, a distance of over 1,300 kilometers. The circuit consists mostly of 2.9 mm. (No. 9 A. W. G.)

copper, except where cable has been installed over the highest portion of the Andes. The cable section is about sixteen kilometers in length and consists of a buried three quad, thirteen gauge, paper insulated cable with two quads loaded for carrier current circuits. The other quad is loaded for voice frequency only. In some of the more exposed open wire sections, where extra mechanical strength was required, 4.19 mm. (No. 8 B. W. G.) copper has been used instead of the 2.9 mm. wire. Also throughout long stretches a pole has been set between each two existing poles in order to guard against

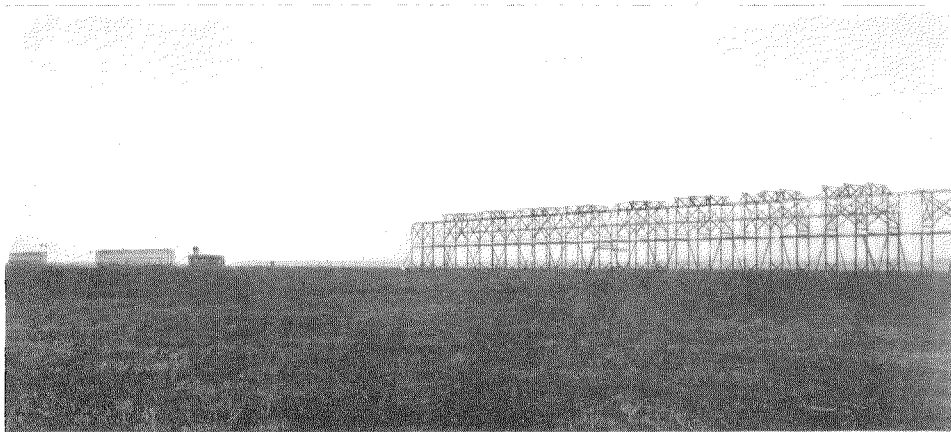
failure of the poles or wire. Superposed upon this circuit from Buenos Aires to Mendoza (about 1,000 kilometers) there is at present a single channel C-2-F carrier current system with one intermediate repeater. This system will be replaced in the near future, however, by a three channel system with three repeaters.

As the European network grows additional points will, of course, come into communication with Madrid and hence with South America.

Work is also under way on a radio link from Madrid to Tenerife, one of the Canary Islands. This island is being connected by a 35-mile



General View of Madrid Receiving Antennas.



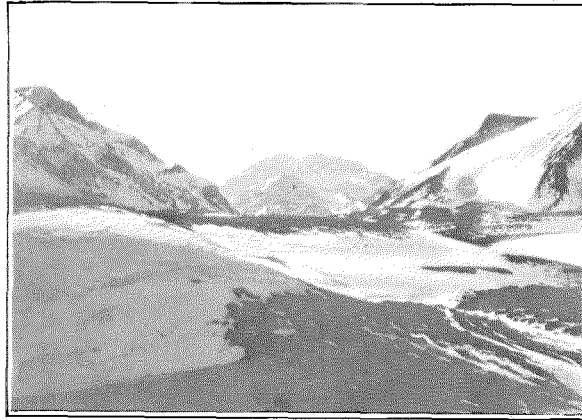
General View of Buenos Aires Receiving Antennas.

submarine cable with Las Palmas on the island of Gran Canaria. The message carrying capacity of this cable will be increased by the installation of carrier current apparatus.

In South America, connections to thirty additional cities in Argentina will be made in the near future. The extensions which are being made to the toll plant in Chile will also add many

other cities in this country to the network in the near future.

It is expected that, within two years, a radio link from Buenos Aires to Bogotá will add Colombia to the list of countries which may use the Buenos Aires-Madrid link, and it is entirely possible that similar arrangements may be made for some of the other countries.



Andes Mountains, Showing Country Traversed by South American Transcontinental Line.

The Use of Short Waves in Radio Communication

By E. M. DELORAINÉ

International Telephone and Telegraph Laboratories, Incorporated

THE rapid expansion in the interchange of knowledge, both commercial and intellectual, involved by modern civilisation, has necessitated an increasingly complete utilisation of the means of communication which science affords. The first attempts at the electrical transmission of sounds were directed towards the possibility of sending electrical impulses along conductors, and from these first experiments wire telegraphy and telephony were developed. From a scientific viewpoint the development of telephony constituted a notable advance over that of telegraphy. A further step was the superposition, particularly upon aerial lines, of several signals, which was accomplished by employing carrier currents modulated by the speech frequencies. Carrier frequencies as high as 30,000 cycles per second were so used, the use of higher frequencies being precluded by the excessive attenuation to which they were subject.

The facilities for long distance communication were still further increased by the discovery that electromagnetic waves having very high frequencies may be propagated through space without the necessity for an intervening conducting circuit. At first, frequencies of the order of 100 kilocycles per second (Kc/s.) were used in this way, but the means then available for producing these waves were such as to encourage the use of the lower frequencies lying between 10 and 100 Kc/s., particularly as these were found to be more suitable for long distance communication. Research in recent years has, however, enabled very much higher frequencies to be used commercially. These, comprising the frequency range from 3,000 to 25,000 Kc/s. (wavelengths from 100 to 12 metres), are known as "short waves," and since it has become possible to overcome the inherent difficulties involved in their use, the study of their properties has shown that by their use not only can the number of available channels of communication be increased, but that in certain cases communication can be effected which could only have

been carried out at much greater expense had long waves been employed.

It is usual when speaking of radio waves within the above wide limits of 10 to 25,000 Kc/s. to divide them into three categories, namely, long, medium and short waves. It is hardly necessary, however, to point out that the difference between these is not fundamental, but lies rather in the fact that certain fundamental properties become more or less pronounced as the frequency changes. In consequence of this, radio practice varies considerably in accordance with the type of wave employed.

The longest waves, the frequencies of which lie between 10 and 100 Kc/s. are suitable for long range international telegraphy on account of their reliability, and in spite of the fact that they are liable to interference from atmospheric disturbances. Within this range the waves having frequencies greater than 50 Kc/s. may be used for radio telephone transmissions, the London-New York Transatlantic telephone circuit being the best example of this.

Waves having frequencies between 200 and 2,000 Kc/s. are found to be best adapted for shorter distance transmission, and in particular to broadcasting. The lower end of this range possesses properties similar to those of long waves, being characterised by a comparatively large measure of reliability. With the higher frequencies, on the other hand, new characteristics make their appearance; in particular, considerable diurnal variations in the received field strength.

Finally "short" waves in the range of from 3,000 to 25,000 Kc/s. become more and more suitable for long distance communication as their frequency is increased, in spite of certain irregularities in transmission, the causes of which will be referred to later.

This rapid survey of the properties of electromagnetic waves shows that for the particular case of long distance radio telephony, medium waves are not suitable, but that either the upper

or lower ends of the frequency spectrum may be employed.

The differences between the propagation characteristics of short and long waves are explained by assuming that while long waves travel directly from the transmitter to the receiver, short waves received at considerable distances from the transmitter have suffered progressive reflection from a more or less well defined ionised layer in the upper atmosphere. Since the rays have not travelled near the surface of the earth, it is not possible to calculate the received field strength from an empirical formula, as can be done from the Austin-Cohen formula in the case of long waves; and in practice, field strengths may be obtained which are greatly in excess of those predicted by this formula.

A disadvantage experienced in the use of short waves lies in the way in which the received field strength varies in accordance with the time of day, the season of the year, and the distribution of light and darkness over the path of the transmission. The effect of such variations may be greatly reduced by the provision in the receiving system of an automatic volume control which adjusts the amplification in accordance with the strength of the received signal. Even when this is done, however, it is necessary when reliable communication over long periods is desired, to employ several frequencies suitably chosen for each particular case.

Owing to the fact that short waves are much less subject to interference from atmospheric disturbances, a very much higher signal noise ratio is obtained from a given signal strength than would be the case with long wave operation, and it is in consequence possible to work with receiving field strengths which would give signals too weak to be heard above atmospheric noise, were long waves employed.

A very great advantage gained by the use of short waves lies in the way they may be propagated in a predetermined direction in space. In order to obtain directive effects with long wave transmission, cumbersome equipment must be installed, of doubtful efficiency and at a very high cost, due to the fact that the size of the antenna necessary is related to the operating wavelength. For example, in order to obtain an effect similar to that given by a concave mirror

with light rays, it is necessary for the aperture of the mirror to be at least equal to twice the wavelength and, in consequence, a prohibitively large antenna network would be required when this is of the order of 5,000 metres.

The directive antennas employed in practice for short waves have a length and height of about 10 and 2 wavelengths, respectively. Such proportions, permissible when the wavelength is of the order of 10 metres, are quite impracticable for waves of the order of hundreds of metres in length.

The use of reflectors and directive antennas has become general in modern short wave practice and considerable progress has been made in their design. The systems at present in use give a gain of the order of 15 decibels over a non-directive system, thus considerably increasing the efficiency of radio communication.

Short wave transmission decreases somewhat the transmitter power necessary to secure communication over long distances, this being largely due to increased efficiency of the antenna on the higher operating frequency. The proportion of the power supplied to the antenna, which is actually radiated, lies between 10% and 15% when the longest waves are employed, and increases to about 70% with waves of the order of 15 metres in length.

Thus, when with very long waves, a power of 300 kw. is taken from the mains, 150 kw. may be supplied to the antenna, and of this, only 17 kw. is radiated, whereas with very short waves, 30 kw. from the mains may give 10 kw. to the antenna, of which 7 kw. is radiated. When account is taken of the fact that the latter power may be concentrated into a restricted angle by means of a directive antenna, the extent to which the short wave system is more efficient can be seen.

By the use of short waves, an enormously increased number of channels of communication is made available, and this constitutes perhaps the greatest gain that has resulted from their use. If the band of frequencies between 50 and 100 Kc/s. is considered, only 25 channels are available, even though the width of each frequency band is reduced to 2,500 cycles—the minimum required for commercial intelligibility—the carrier and one side band suppressed, and

no spacing allowed between adjacent bands. Against this, the present state of short wave technique permits the use of 200 telephone channels between 6,000 and 12,000 Kc/s., the spacing between adjacent carrier frequencies being 30 Kc/s. This number would be increased to 600 if the spacing were reduced to 10 Kc/s., a figure which should not be considered impossible of attainment in the light of present progress.

The utilisation of the 13–14 metre waveband, the lower limit of wavelengths used commercially, signifies the availability of about 40 new telephone channels, each occupying 40 Kc/s., a figure which may be soon reduced. Thus an additional metre utilised at the high frequency end of the spectrum gives more telephone channels than are available from the whole of the long waves suitable for long distance work.

The use of directive antenna systems previously mentioned must eventually increase still further the number of channels made available by the use of short waves.

In the consideration of this subject, it must, however, be remembered that in order to provide satisfactory operation over considerable periods it is necessary for one station to employ several wavelengths. This not only reduces the number of channels available, but also increases the cost of installation. Thus, since all new channels are likely to be utilised in the very near future, it is not certain if, in the present state of the art, short waves will be employed to the exclusion of long waves on all long distance circuits, or only for exceptionally long distances.

One of the difficulties experienced in short

wave operation is the necessity of maintaining the carrier frequency constant to a much higher degree of precision than is otherwise necessary. This is due to the fact that a given absolute frequency variation becomes a much smaller relative variation as the carrier frequency is increased.

Against this, the band of frequencies occupied by a given type of transmission (telephony for example), represents a much smaller fraction of the carrier frequency in the case of short waves; consequently, the problem of transmitting uniformly a band of frequencies is considerably simplified. When long waves are employed, the tuning of the antenna circuit does not permit the uniform transmission of the band of 2,500 cycles width necessary for telephony, whereas very wide bands can be satisfactorily transmitted on short waves. Due to this fact, aided by progress in receiving technique, one can visualise the simultaneous transmission of many different signals, the realisation of high speed telegraphic transmission, and finally the transmission of special signals requiring a greater band width than telephony.

The foregoing brief discussion shows the complexity of short wave transmission, where any advantage obtained is attended by some corresponding disadvantage. It also shows, however, the extraordinary fertility of this scientific field, and the considerable possibilities which the important advances already realised indicate to be reserved for the future.

The "Standard" Short Wave Radio Transmitters

By C. E. STRONG

International Telephone and Telegraph Laboratories, Incorporated

IN no phase of electrical communication has recent progress been more marked than in radio telephony. The discovery, a few years ago, of the value of short wavelengths for long distance transmission, opened up vastly extended possibilities for linking together the telephone subscribers of different continents. In the realization of a scheme of this kind, the engineer is faced with the problem of attaining in the design and construction of short wave transmitters and receivers the same standards of reliability and grade of service as have become accepted in repeaters and other telephone plant. The trend of modern radio practice in the design of apparatus to fulfill these requirements may be illustrated by a brief description of the short wave transmitting equipment recently developed by the International Telephone and Telegraph Laboratories, Inc.

The transmitter has been designed to include the features for trunk telephone service, inter-continental broadcasting, and high speed telegraphy. It is suitable also for multi-channel telephony, and simultaneous telephony and telegraphy, when used in conjunction with standard types of line carrier telephone and telegraph equipment.

The operating frequencies are of the order for which directional transmission is practicable; and, in general, for point to point service, the equipment is used with a directive antenna concentrating the radiation into a beam pointing in the direction of the receiving station. The power is sufficient to maintain an almost continuous telephone or telegraph service over great distances of the order of ten thousand kilometres.

To maintain continuous service it is necessary to change the operating frequency three or four times in twenty-four hours to suit the transmission conditions corresponding to different states of light and darkness along the trajectory of the waves. The equipment has therefore been designed to be capable of adjustment for opera-

tion at any frequency within the band useful for long distance directional transmission, which extends from about 5 to 20 mega-cycles. A special feature is the rapidity with which it is possible to change from one operating frequency to another. The time required is about five minutes.

As regards operating characteristics, special attention has been paid to securing very great frequency stability, freedom from carrier noise, deep modulation for telephony, and clear-cut signals for telegraphy.

In view of the rapid growth of the technique, the design has been made as flexible as possible by adopting low power modulation and a unit form of construction to permit of progressive extension to incorporate new developments. The general appearance of the set is illustrated in Figures 1 and 2 showing respectively the radio units and the power control board.

The power delivered to the antenna when working on continuous wave telegraphy at full load is about 12 kw. at 15 megacycles, being slightly less for the higher frequencies and slightly greater for the lower frequencies.

In telephony, the carrier power and the degree of linear modulation are interdependent, being determined by the limitation that the instantaneous peak power must not exceed 12 kw. As is well known, it is preferable to employ a given carrier-power deeply modulated than a higher power less deeply modulated, with the same peak power in each case, since by the former a better signal-noise ratio is obtained, owing to decrease in the background noise caused by the carrier-wave beating with atmospheric disturbances. The modulator circuits have therefore been designed to permit of 90% to 100% linear modulation. The carrier power must be limited to a quarter of the peak power, that is, to about 3 kw. for 100% linear modulation; but it may be raised to about 4.6 kw. for commercial operation, in which case the slight distortion of the speech peaks when modulating deeper than

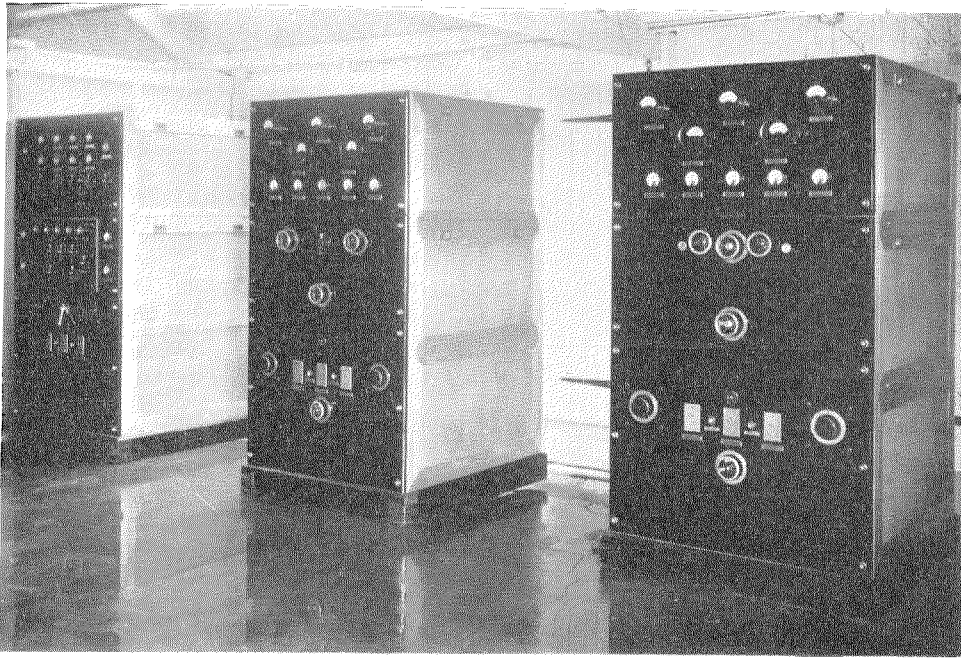


Figure 1—Type III Short Wave Transmitter—Assembly of Transmitter Units.

60%, can be tolerated. For tone modulated telegraphy, the carrier wave power is 4.6 kw. and is fully modulated.

The telegraph speed obtainable for continuous wave telegraphy with well shaped signals is at least 200 words per minute. The power drawn from the mains at full load on telegraphy or telephony is approximately 65 kw.

Very severe requirements are imposed on short-wave transmitters with regard to frequency constancy of the carrier wave, both in respect to dynamic stability, that is, independence of the frequency on keying and modulation, and as regards slow variations caused by changes of temperature or supply voltage, swaying of the antenna, etc. This constancy of frequency is essential, on account of the speech distortion caused by selective fading and interference phenomena which result from an unsteady carrier frequency, and also on account of the close spacing of channels in the short wave band. Stability of frequency during modulation

and keying is obtained by the use of a crystal-controlled master-oscillator, balanced coupling stage, and frequency multiplication system. Instability due to antenna sway is prevented by the use of successive highly balanced radio frequency amplifiers.

To obviate slow changes of frequency, the piezo-electric crystal is mounted in a special holder and is kept at a constant temperature by thermostatic control. The general form of the circuit is illustrated in the block diagram (Figure 3).

The master oscillator, operating through a coupling stage, drives a frequency multiplier consisting of two harmonic generators in cascade. The frequency multipliers excite the first of three successive stages of high frequency amplification.

The apparatus for modulation and keying is associated with the first of the three stages of high frequency amplification. Simplified schematics of the modulation and keying circuits

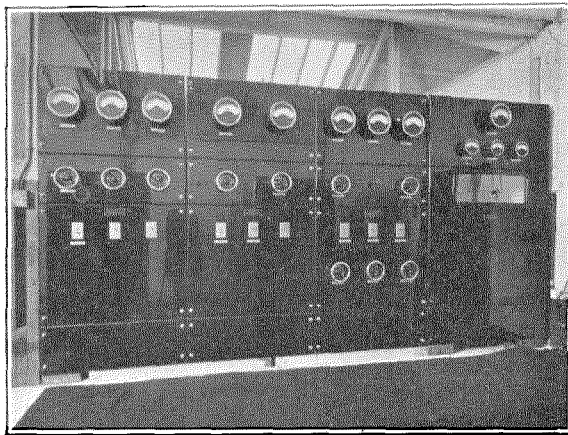


Figure 2—Type III Short Wave Transmitter—View of Power Board.

are shown in Figures 4 and 5. The system is one of low power modulation and keying, with subsequent amplification of the modulated or interrupted carrier wave. The purpose of the frequency multipliers is to lower the frequency of the master oscillator to a value at which quartz crystal control can be satisfactorily applied.

Low power modulation has been adopted as it has the same advantages over high power

modulation in a short wave equipment as have been found in the case of broadcasting transmitters. In addition the low power system seems more promising at present from the point of view of providing for new developments.

The transmitter has four pairs of input lines. Two pairs are for "main line" telegraph and telephone, and the remaining two are for "local test" telegraph and telephone. A key on the set switches over the modulator input and keying relay from the "main line" pairs to "local test" pairs. The change over from telephone to telegraph adjustment is by means of relays controlled by one key.

From Figure 3 it may be seen that the apparatus divides up into three main sections, i. e., (1) the apparatus for generating the constant frequency carrier at low power and for modulating and keying; (2) the first stage of power amplification; (3) the second stage of power amplification. In the assembly of the apparatus it was found convenient from many points of view to adopt the unit form of construction, each of the three main sections of the system being comprised in one unit. Figure 1 shows the three radio units. The unit on the left comprises

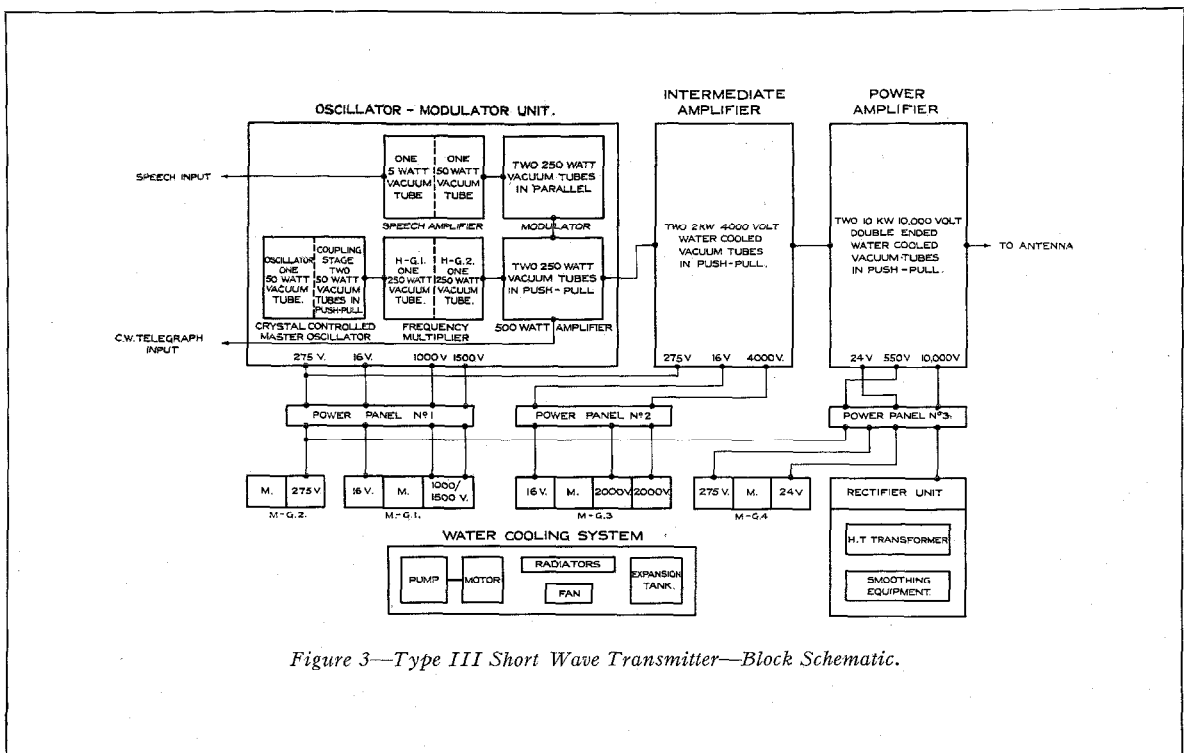


Figure 3—Type III Short Wave Transmitter—Block Schematic.

the carrier-generating, modulating, and keying apparatus, and is referred to as the Oscillator-Modulator unit. The unit in the centre is the intermediate amplifier, being the first stage of

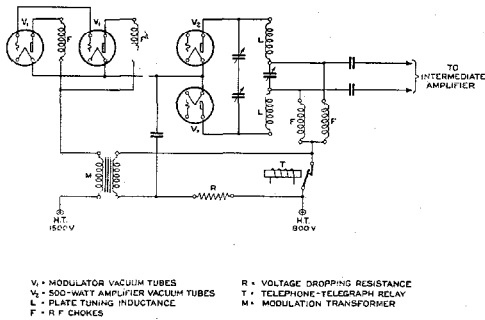


Figure 4—Simplified Schematic of Modulation Circuit.

amplification after the modulated amplifier. The unit on the right is the power amplifier.

Each of the three radio units has its own distinct panel in the power control board, and separate power plant.

For telephone operation, provision is made for monitoring with head phones at the output of each unit, to enable any wrong adjustment causing distortion to be very easily localised.

Among the advantages of the unit form of construction may be cited improved accessibility, flexibility for increase or reduction of power, flexibility for interchange of units in stations comprising more than one equipment, simplification of the problem of symmetrical distribution of apparatus, and certain advantages in circuit design including good shielding between stages and elimination of ground return currents between stages causing instability and carrier noise.

The improvement in accessibility arises from the fact that advantage has been taken of the possibility of separating the amplifying stages some distance from each other and connecting them together by transmission lines so that each amplifier—which must in itself be very compact to keep certain of the connections very short—can be made accessible from all sides.

The flexibility, above referred to, for increasing or decreasing the power renders it possible to work into the antenna either from the Oscillator-Modulator unit alone (the other

two stages being switched off entirely) or from the output of the intermediate amplifier, or lastly in the usual way from the power amplifier. By duplicating the oscillator-modulator, together with its associated power plant, a high degree of security against total failure of the service is obtained.

The units are coupled together by means of short transmission lines. Precautions are taken to obtain series feed current in the lines only, thus avoiding parallel line current returning from one unit to another through earth. The methods adopted have resulted in remarkable freedom from reaction between units, in freedom from stray earth currents, and in equality of the drives and impedance conditions for the valves on opposite sides of the balanced amplifiers.

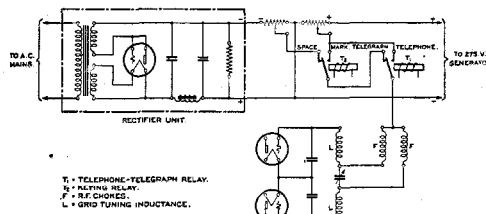


Figure 5—Simplified Schematic of Keying Circuit.

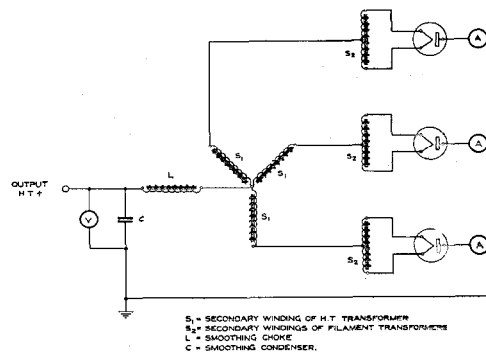


Figure 6—Simplified Schematic of H. T. Rectifier Circuit.

The units are built on frameworks of duralumin angle and are enclosed at the sides and backs by doors comprising frames of the same material covered by perforated aluminium sheeting. The front panels are of polished slate shielded on the inside by metal sheets. The units are each 6 feet 6 inches high (about 198 cm.), 3 feet 8 inches

wide (about 112 cm.), 4 feet deep (about 122 cm.).

The transmission lines forming the connections between units are carried on insulators mounted on the tops of the units, and are insulated from direct current by stopping condensers within the units. The power plant associated with and included in the equipment comprises four motor generator sets, a 10,000 volt rectifier (see Figure 6), and the power control board. The standard equipment is designed for operation from a 3 phase 50-60 cycle supply at a voltage between phases of either 220 or 415 as required.

The four motor generator sets provide the filament and grid voltages for all the valves, excitation of control circuits, and high tension plate supplies for the oscillator-modulator and the intermediate amplifier. The 10,000 volt rectifier supplies only the plates of the power amplifier.

A power panel is provided for each transmitter unit, and controls the power plant associated with that unit. The three power panels are lined up with the front panel of the rectifier to form one power board, as in Figure 2. The panels are of polished slate and are mounted on angle iron frameworks. Each power panel is 6 feet 6 inches high (about 198 cm.), and 2 feet 6 inches wide (about 76 cm.). The rectifier panel is 6 feet 6 inches high, and 3 feet 8 inches wide (about 112 cm.). The power board forms the front of an enclosure in which are located the H. T. transformer and the smoothing apparatus of the rectifier system.

The valves used in the Intermediate and Power Amplifiers are water-cooled, and a water-cooling system is included in the equipment. This system consists of a circulating pump, a small expansion tank, and an air blast cooler.

The Oscillator-Modulator unit with its associated motor-generators and power panel forms a complete low power transmitter known as the Type 1 transmitter. It delivers about 300 watts to the antenna for continuous wave telegraphy, and 200 watts for telephony. By the addition of the Intermediate Amplifier, with its associated motor-generator and power panel, and the water-cooling system, the Type II transmitter is formed which is capable of delivering to the antenna about 3 kw. for telegraphy and 0.83 kw. for

telephony. These telephony powers are based on 100% modulation. Finally the Type III set, herein described, is made up by the addition to the Type II equipment of the Power Amplifier with its associated power panel, machine, and rectifier. It will be seen that a Type I or Type II equipment may therefore be easily extended if it is desired to raise the power of the installation.

The equipment is started up or stopped, and all potentials are applied by means of push-buttons situated on the Power Board and duplicated on the front panels of the units. Control circuits are arranged in such a manner that it is impossible to start up the transmitter in a way liable to cause damage. No high tension voltages can be applied, for example, until the grid and filament voltages are at their proper levels.

The equipment is adequately protected by fuses, according to standard practices; other security provisions include overload relays in the high tension plate supplies, water flow devices to remove plate and filament voltages in case of failure of the water flow, water tem-

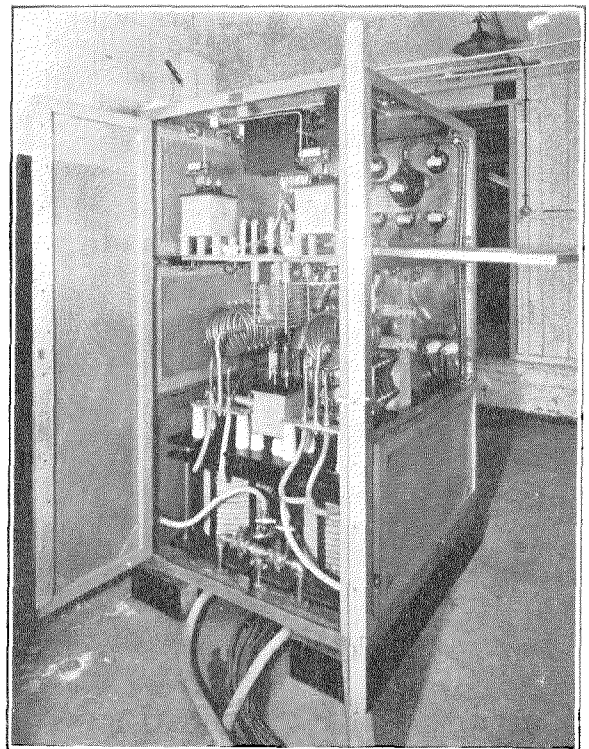


Figure 7—Rear View of Power Amplifier.

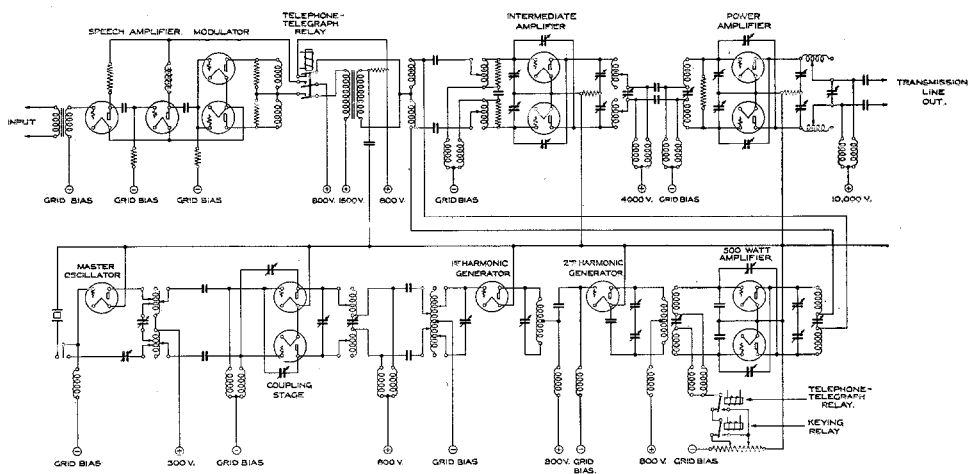


Figure 8—Type III Short Wave Transmitter. Simplified Circuit Schematic.

perature alarms, and gate switches on all high tension enclosures, including the radio units themselves.

The mechanical design of the higher powered radio units presented a difficult problem. It was necessary to preserve close symmetry, to keep certain leads short and yet to allow ample spacing to avoid flash over (which occurs very easily on the higher frequencies in the range), to provide for extreme rigidity, and lastly to use insulating materials sparingly in high frequency fields and only material of low dielectric loss. An idea of the construction adopted may be gathered from Figure 7.

The general form of the circuit of the transmitter given in the block diagram (Figure 3) is shown in greater detail in the simplified circuit of Figure 8.

The master oscillator employs a special 50-watt valve of high amplification-factor operated with the plate voltage reduced to 300. The oscillator may work as a self-excited oscillator or as a crystal controlled oscillator, according to the position of the switch in the grid circuit.

The crystals for the different operating frequencies are mounted in sealed brass holders contained in a specially designed box fitted with a heating element and thermostat. Four crystal

holders for four working frequencies are provided, and a selector switch is incorporated in the box to enable any one of the four to be put into operation. The box contains also four spare crystal holders complete with spare crystals which can be quickly exchanged with the normal holders in case of failure of any of the normal crystals. The spare crystals and holders are maintained dry and at the right temperature by storing them in the temperature controlled compartment and are ready for instant use on their correct frequencies.

The master oscillator is followed by the coupling stage (comprising two 50 watt valves) which amplifies the master oscillator output and acts as a buffer to prevent reaction on the oscillator from the following stages. Such reaction would cause slight instability of the carrier frequency arising from impedance changes during modulation and keying. The coupling stage is a push pull circuit having two variable balancing condensers which, together with the grid to plate capacities of the valves, form a balanced capacity bridge having the grid input circuit across one pair of opposite corners, and the plate output circuit across the other pair of corners of the bridge. When the capacity balance is correct there can be no reaction between the input and

output circuits. The amplifier is therefore stable against self oscillation, and in addition the master oscillator is completely separated so far as reaction is concerned from the succeeding stage.

The harmonic generators comprise two 250-watt tubes operating as amplifiers arranged for high distortion. For frequencies higher than 10 mega-cycles, both harmonic generators are used, but for frequencies below that value only one stage is required. The frequency is multiplied in each stage by 2 or 3, according to the frequency required.

The output of the frequency multipliers is a steady carrier at the frequency of transmission.

The next stage is the 500-watt amplifier which is the first of the three stages of high frequency amplification. It comprises two 250-watt valves in push pull. For telephony this stage is plate modulated, and for continuous wave telegraphy the keying operation is carried out in its grid circuit.

To secure a degree of linear modulation of 90% to 100% it is necessary that the low frequency modulating valves should be capable, without overloading, of impressing—across the plate circuit of the modulated high frequency amplifier—speech frequency voltages having peak values as high as the plate supply voltage of the modulated amplifier. This has been done, without resorting to step-up modulation transformers, by operating the modulating valves on a plate voltage about four times as great as the plate voltage on the modulated amplifier.

For continuous wave telegraphy, to ensure satisfactory operation for short waves, the 500-watt amplifier operates at 800 volts, which is well below the rated voltage of the valves.

For telephony, the plate voltage is reduced to about 400. By this means the carrier power is cut down to about a quarter of the peak or continuous wave telegraph power, when changing over from telegraphy to telephony.

The method of keying consists in throwing a high negative voltage on to the grids of the 500-watt amplifier from a small rectifier during "spacing."

The intermediate amplifier is of the push pull type, comprising two single ended, 2 kilowatt

water-cooled valves. The valves work at a plate voltage of 4,000.

The power amplifier comprises two 10-kilowatt

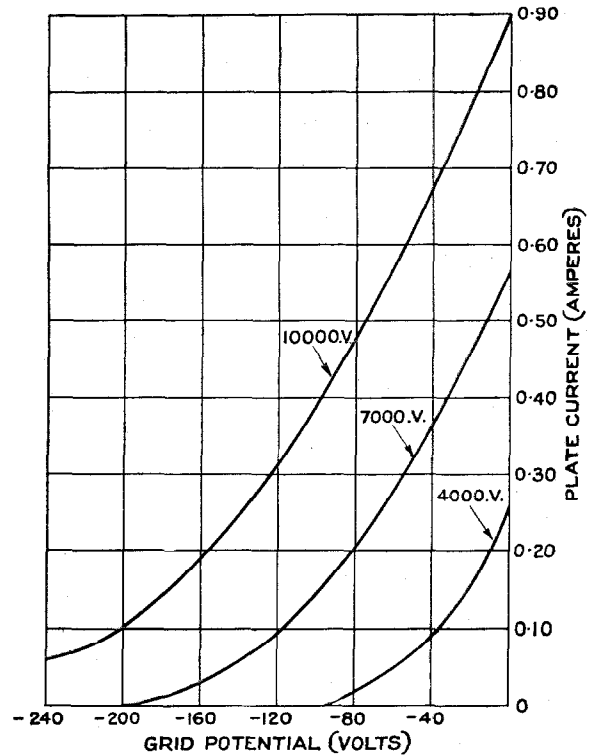


Fig. 9—Anode Current Grid Volts Characteristic—10 kw. tubes.

double ended valves working at 10,000 volts. The anode current grid volts characteristic of these tubes is shown in Figure 9.

The circuits of the two amplifiers are almost exactly the same, being similar also to the circuits of the 500-watt amplifier and coupling stage. Each amplifier unit comprises essentially a tuned grid circuit terminating the coupling line from the preceding stage, a tuned plate circuit coupled to the outgoing transmission line, and a pair of valves and balancing condensers. The balancing condensers are variable and are accurately adjusted to prevent any reaction from the plate circuit back to the grid circuit.

The grid circuit is loaded with a resistance to swamp the variable grid impedance, and forms the major part of the load on the preceding stage. The resistance also serves as the means of adjusting the drive on the grids when the preceding

stage is working into its correct impedance, and has its correct drive.

The grid and plate circuits are coupled to the incoming and outgoing transmission lines by condensers. The condensers are adjusted during the initial testing of the set to secure the correct impedance conditions, the grid condenser being adjusted to present an impedance of about 600 ohms at unity power factor to the incoming line. The plate condenser is adjusted to match the

impedance of the output circuit to a 600 ohms antenna transmission line.

As has been pointed out at the beginning, the main object in designing the transmitter was to produce an equipment capable of efficient continuous service in the extension of a telephone or telegraph system. A number of these equipments has been manufactured; some have already entered into commercial service, including the Buenos Aires - Madrid and the British end of the London-New York radio link.

Short Wave Radio Telephone and Telegraph Receivers

By E. H. ULLRICH and R. E. GRAY

International Telephone and Telegraph Laboratories, Incorporated

OWING to the favourable propagation of radio waves between 30 and 6 megacycles (i.e., of wavelength between 10 and 50 metres) over long distances, there is an ever-increasing demand for commercial receivers covering this range. To turn to advantage the lowness of level of atmospheric interference at these frequencies, such apparatus must be of high sensitivity and reliability. Particular attention has to be given to other points also; tube noise must be kept low despite the high amplification involved, and effective steps have to be taken to render condensers and valves non-microphonic. As it is possible to receive telephony commercially with a radio field strength of the order of one microvolt per metre, and with an antenna consisting of a rod one-half a wavelength in height, an indication is obtained of the minimum telephonic input signal for which provision has to be made. The overall amplification must be sufficiently great to deliver to a commercial telephone line a level of +5 decibels, reference volume being taken as six milliwatts. A telegraphic service can be carried on very successfully with still weaker radio field-strengths. The sets here described are, in consequence, made to operate with signals of a fraction of a microvolt per metre.

The equipment is designed for the reception of short wave radio telegraphic or telephonic signals. The telegraphic signals are delivered in the form of tone telegraph impulses for aural reception at low speeds, and in the form of double current impulses for transmission over a telegraph line, in the case of high speed reception. The receiver is capable of operating at speeds up to 300 words per minute with the Morse code.

Wavelength Range and Band-width

The operating wavelength of the radio receiver is continuously variable over the range 10 to 100 metres (30,000—3,000 kilocycles). Tuning is effected by means of variable condensers in conjunction with interchangeable coil units. Each

coil covers a considerable wavelength band, so that in many cases the desired change of wavelength can be effected by means of the tuning condensers alone. The band-width is from 200 to 5,000 cycles.

Description of Equipment

A block diagram of the whole receiver is given in Figure 1. The equipment comprises in brief a receiver proper working on the super-heterodyne principle, an automatic gain control for telephony, some auxiliary oscillators, a gain control entitled a "signal limiter" for telegraphy, and certain low frequency measurement and control apparatus. Two aerial connections are shown to the receiver to indicate diagrammatically that a directive antenna system is ordinarily employed. The combination of the signals picked up on a "collector" and on a "reflector" array is effected in the receiver itself, the energies from the two separate parts of the antenna system being brought to the receiver by two single-wire transmission lines so arranged that any high frequency voltages picked up in them both will oppose each other in the grid coil of the first detector, and will balance out.

To render unmodulated C. W. signals audible, a constant frequency 1,000 cycles oscillator is provided, and modulation of the C. W. signals themselves by the 1,000 cycle note is carried out

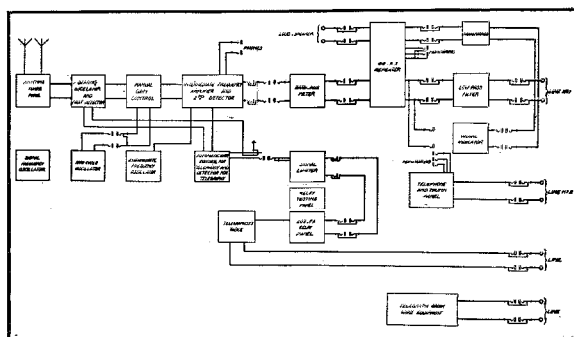


Figure 1—Block Diagram of Short Wave Radio Telephone and Telegraph Receiver.

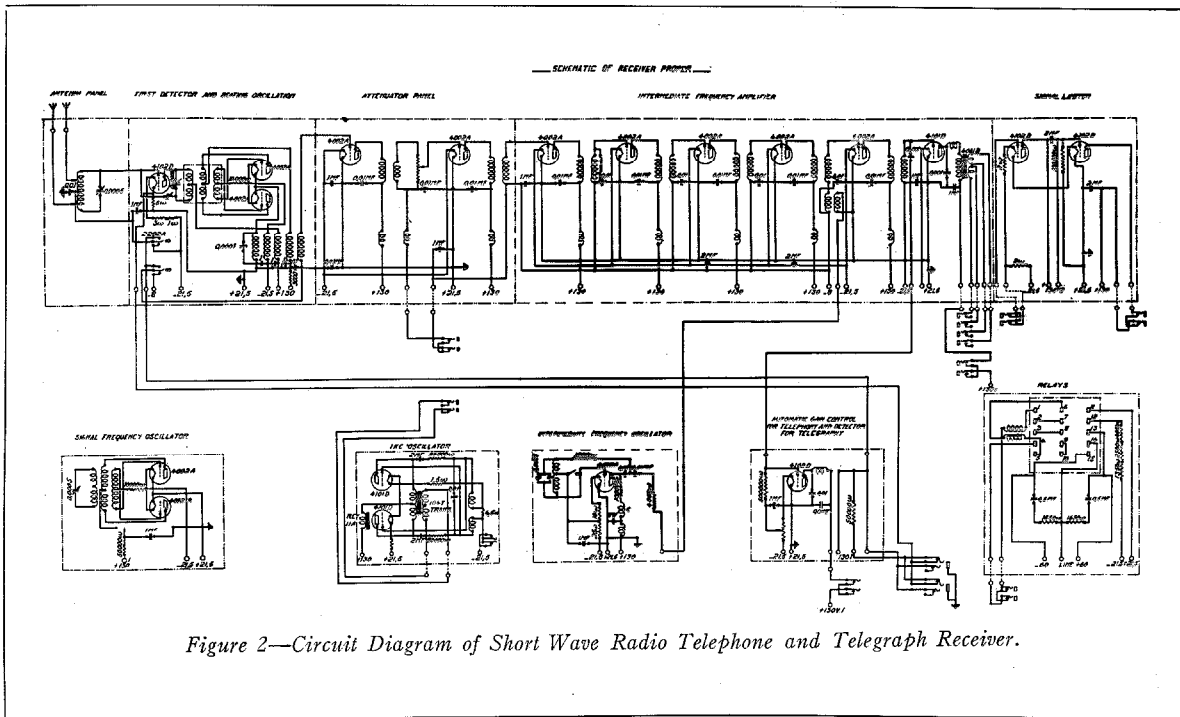


Figure 2—Circuit Diagram of Short Wave Radio Telephone and Telegraph Receiver.

at intermediate frequency. C. W. telegraph signals are, therefore, received in the output 'phones of the set as a keyed note of perfectly steady pitch. The circuit diagram of this oscillator is given in Figure 2. A variable frequency oscillator, that covers the band of the intermediate frequency amplifier, is provided. By this means it is possible to employ heterodyne reception of C. W. signals. Although reception by means of the 1,000 cycle modulation has the advantage that a very steady output frequency is obtained, even though the set be subject to violent mechanical vibration, or to very large variations of H. T. and L. T. supplies, it fails when any loud extraneous noise is produced in the receiver, since the noise itself is modulated by the 1,000-cycle note and acts as a substitute for the C. W. signal.

In ordinary commercial operation, the receiving set must be installed where electromagnetic interference is absent. When, however, the C. W. signal is so weak that it begins to sink into the atmospheric or tube noise, it is more easily readable by heterodyne reception. The Intermediate Frequency Oscillator, moreover, serves

another purpose; it is possible to check the band passed by the Intermediate Frequency Amplifier at any time and to adjust the Beating Oscillator so that, especially in the case of telephony, the intermediate frequency corresponding to the carrier of the distant station lies in the middle of the frequency band of the I. F. amplifier. The circuit diagram of this oscillator is given in Figure 2.

In order to facilitate exact tuning of the receiver, an oscillator at signal frequency is provided. If this oscillator is not employed, it is difficult to tune the set when fading is taking place. As the incoming carrier produces, when heterodyned in the Intermediate Frequency Amplifier by the Intermediate Frequency Oscillator, an audible output note, it is easy to adjust the Signal Frequency Oscillator to within a few cycles of the incoming carrier by simply tuning it to give the same audio note. The Signal Frequency Oscillator is strong enough to swamp the incoming waves and, by reason of the presence of a steady local signal, correct tuning of the receiver is facilitated. The circuit diagram of this oscillator is given in Figure 2.

After traversing the Intermediate Frequency

Amplifier, the signal follows one of two different paths according as it represents telegraphy or telephony. In the former case it passes through the "signal limiter," which is described more fully below, to the telegraphist's table, and thence to the line. In the case of telephony, it enters a band-pass filter, which serves to ensure the suppression of frequencies outside the band 200—5,000 cycles. Thence the signal passes into a standard 44-A-1 Repeater, which introduces a gain that may be varied up to 40 decibels. A volume indicator is provided to permit of the adjustment of the gain of the repeater to the proper value.

A layout drawing of the front view of the set is given in Figure 3.

Bay No. 1 is the battery supply bay and contains the meters, fuses, relays, etc., associated with the application of the various battery supplies to the radio receiver. The second bay contains the speech control apparatus, telegraph relay and order wire circuits. The third bay contains the signal frequency and intermediate frequency testing oscillators and the signal limiter. The last bay mounts all the panels comprising the radio receiver proper, namely, the antenna panel, first detector and beating oscillator, the intermediate frequency amplifier, the

automatic gain control and the testing jacks. The key to the numbers shown in Figure 3 is as follows:

1. Blank panels.
2. Meter panel.
3. Rheostat panels.
4. Condenser panel.
5. Alarm fuse panels.
6. Fuse panels.
7. Alarm lamps.
8. Resistance panels.
9. Relays.
10. Dry batteries panel.
11. 1,000 cycle oscillator.
12. 44-A-1 Repeater.
13. Volume Indicator.
14. Testing panel.
15. Jack Strips.
16. Telephone and Trunk panel.
17. Signal Frequency Oscillator.
18. Keys.
19. Intermediate Frequency Oscillator.
20. Signal Limiter.
21. Relay panel.
22. Antenna tuning panel.
23. Beating oscillator and 1st detector.
24. Intermediate Frequency Amplifier.
25. Jack Strip.
26. Operator's shelf.
27. Blank panel.
28. Shelf with drawer.
29. Manual Gain Control.
30. Filter.
31. Filter.
32. Transformers.
33. Automatic Gain Control and Detector for Telegraphy.
34. Antenna Lead-In panel.

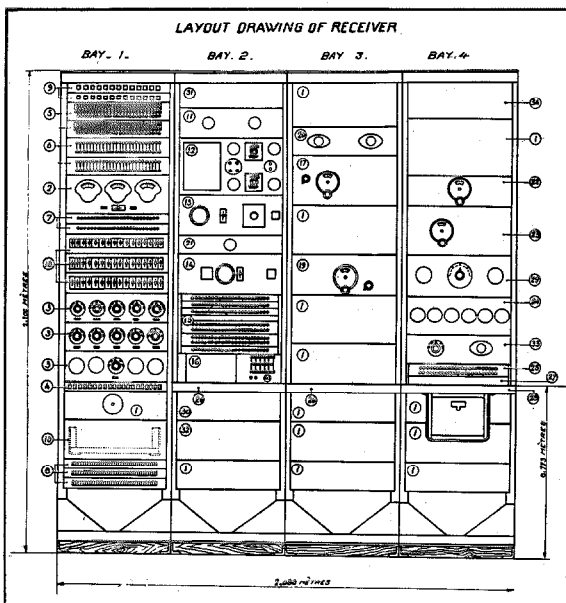
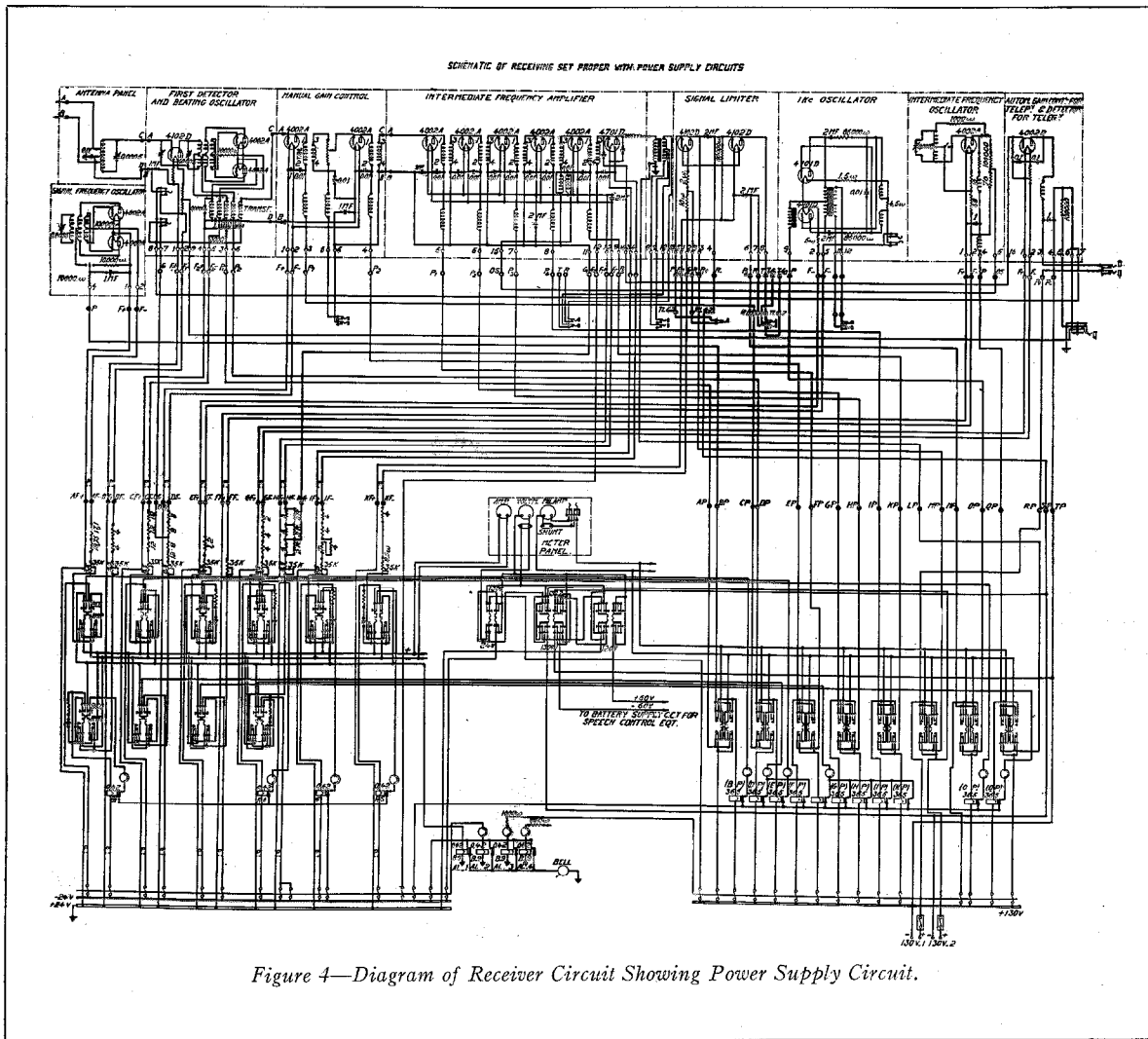


Figure 3—Layout Drawing of Short Wave Radio Telephone and Telegraph Receiver.

Antenna Panel

This contains the antenna tuning circuit which is designed for connection through a pair of transmission lines to a directive antenna array. The circuit consists of a single coil tuned by a variable condenser, the centre point of the inductance coil being grounded through a fixed condenser of 0.01 microfarads. The two transmission lines are connected to variable tapping points on the inductance, whereby the impedance



of the line may be matched, and the two lines balanced to earth. The inductance coil is replaceable, enabling the large frequency band to be covered.

The antenna panel is followed by a two-stage transformer coupled amplifier operating at the signal frequency. The coupling transformers are interchangeable and are tuned by variable condensers. This amplifier is not shown in the drawings or photographs of the receiver.

The Beating Oscillator and First Detector

In order that the receiver may be easy to operate, it is necessary that the tunings of the first detector grid circuit, and of the Beating

Oscillator should be quite independent—that there should, in other words, be no coupling between these circuits. For this reason, the Beating Oscillator voltage is introduced in the plate circuit and the signal voltage in the grid circuit of the first detector, which operates on the lower bend of the plate current grid voltage characteristic. It is, however, necessary to neutralise the grid-to-plate capacity of the detector tube by means of a small condenser, which is adjusted in the laboratory, but which is made variable so that it can always be readjusted in service. The adjustment can be checked by short-circuiting the input from the antenna, when there will be an appreciable change in the

plate current of the first detector, if the balancing condenser is out of adjustment.

The principle of symmetry, so important in short wave work, is preserved in the Beating Oscillator, which is "push-pull." This construction facilitates a perfect balance with the neutralising condenser, that is to say, a balance which is independent of the tuning of the set. As is well known, an arrangement, that is physically unsymmetrical, is usually at short waves electrically unsymmetrical, on account of the low impedance of any small capacity unbalances, and of the relatively high impedances caused by the inductance of the leads. The push-pull oscillator has, in addition, the advantage of added frequency stability—an important point when it is remembered that a variation of 10,000 cycles in 20 million is all that is required to tune to the neighbouring channel. The oscillator coil contains three windings, one of which is of copper tube, the other two—those connecting to the grids and plates of the tubes—being contained inside the first. By this means, the coupling between the coils is kept close to 100%, so that no coupled circuit effect is noticeable when the oscillator is being tuned. On the other hand, the "skin effect" causes all the high frequency currents to pass onto the outer copper tube, which is made of 5 mm. outer diameter copper, and, therefore, has reduced losses. By this means the decrement of the oscillator circuit is kept low and the frequency stability improved. The 3-winding oscillator coil is assembled as an interchangeable unit, several such coils being used to cover the wavelength range.

Intermediate Frequency Amplifier

The intermediate frequency amplifier operates at a frequency of 500 kilocycles, and has an amplification of about 100 decibels. Seven stages of transformer coupled amplification are provided.

The second detector operates on lower band of the anode current grid voltage characteristic.

The Gain Controls

A manual gain control is provided to permit of a variation of output level of 40 decibels in one decibel steps. In order to overcome the effects

of fading, an automatic gain control is provided. It can be thrown in or out of circuit by means of a switch. It contains a single 4102-D (high impedance) tube operating as a third detector with its grid connected to the grid of the second detector located on the intermediate frequency amplifier panel. A resistance of 100,000 ohms is connected in the plate circuit of the gain control tube, and a grid potentiometer is provided whereby the plate current of the tube may be adjusted. This tube fulfils two functions: first it operates as a gain control tube when working

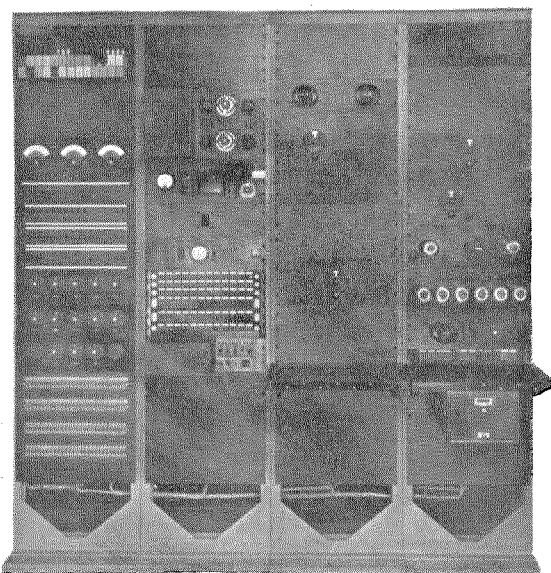


Figure 5—Front View of Receiver.

on telephony, and secondly as a detector tube when receiving high speed telegraphy. When operating as an automatic gain control tube, the drop in voltage across the 100,000 ohm anode resistance is applied to the grid of the first detector and first amplifying tube. An increase in the strength of the received signal causes an increase in the anode current of the gain control tube, and thus an increase in the negative grid bias applied to the first detector and first amplifying tube. This increase in the negative grid bias reduces the gain of the receiver and thus maintains a constant output level. When operating as a detector for high speed telegraphy, the voltage across the 100,000 ohm anode resistance is applied between grid and filament of the first tube of the signal limiter; the limiter in turn

operates a 209 FA relay and the high speed telegraph apparatus.

Signal Limiter

The signal limiter is in effect a two-stage resistance coupled amplifier which may be patched into the output of the telegraph detector when required, the limiter being provided with input and output jacks for this purpose. The circuit is that of a direct current amplifier thus enabling it to operate on the direct current impulses corresponding to the reception of continuous wave telegraph signals. The limiter employs two 4102-D (high impedance) tubes. The anode current of the second tube is limited to zero during spacing signals, and to 2.7 milliamperes maximum during marking signals.

The limiter is normally patched between the output of the third detector and the receiving relay, and the gain of the receiver is adjusted so that with the lowest received field strength, the marking current in the anode circuit of the second valve is not less than the minimum required to operate the receiving relay (2.3 milliamperes). Any increase in the field strength will then not cause the marking current through the relay to exceed 2.7 milliamperes, and consequently bad operation and chattering of the relay due to an excessive marking current is avoided.

Relay Panel

The relay panel mounts the receiving relay together with the associated circuit elements, designed to deliver double current impulses at ± 60 volts to the line. The relay is a standard 209 FA permalloy relay and is capable of operating at speeds up to 120 cycles per second corresponding to 320 words per minute in the Morse Code. The contacts of the relay are suitable for dealing with a current of about 20 milliamperes. The circuit elements associated with the relay include a "kick transformer" for sharpening up the action of the relay.

Battery Supply Circuits

The radio receiver and speech control apparatus require a filament supply at 24 volts with

the positive earthed. The total current drawn by the receiver with all tubes switched on is approximately 10 amperes. In the filament supply circuit to each panel there is an alarm fuse, a rheostat and a three-way key. When the key is in the non-locking position, an ammeter is connected in series with the filament supply to that panel, and when in the locking position the filament supply is cut off.

Alarm relays are connected in series with the filaments of the signal limiter and the three detector tubes, so that failure of the filament supply to any of these tubes causes an alarm lamp to light, and the alarm bell to ring. The voltage of the filament battery may be measured by depressing the 24-volt key and reading the voltage on the meter panel.

The main plate battery supply is at 130 volts with the negative earthed. The total current drain is approximately 0.15 amperes. In addition to the main plate battery, the automatic gain control tube and the first tube of the signal limiter each require a separate dry cell battery of 130 volts. These batteries are mounted on special shelves at the rear of the radio receiver. The current drain from each battery is about 0.5 milliamperes. These two special batteries are insulated from earth.

Alarm fuses are connected in the plate circuit of each tube, and alarm relays are provided in the plate circuits of all tubes except the detectors and the two signal limiter tubes. Failure of the plate current of any of these tubes operates an alarm lamp and the alarm bell. By means of a series of keys, the plate current of any tube may be read on a double range milliammeter provided on the meter panel. By operating the appropriate key, the voltage of each of the three plate batteries may be measured.

For telegraph purposes, a 120-volt battery with the centre point earthed, delivering the required value of line current, is supplied. Fuses for this battery are provided on the power supply bay.

A diagram of the whole receiver including power supply circuits and a front view of the receiver are given in Figures 4 and 5.

Thermionic Vacuum Tubes for Short Waves

By W. T. GIBSON

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THE advent of the use of short waves brought in its train many new difficulties for the vacuum tube designer, especially when the demand arose for more and more power. For small powers up to and including the 250 watt tube, the air cooled form of tube already used for long waves proved suitable also for short waves. However, the high power long wave water cooled tube which had reached a high state of perfection for wave lengths over 60 metres required various modifications for short wave working.

Vacuum tubes intended for very short waves retain the feature of an external anode cooled by a circulated liquid but must be specially designed in order that the following difficulties may be avoided:

1. Heating effects caused by high frequency losses in dielectrics.
2. Heating effects caused by the very large high frequency currents which are encountered, and the very high value of the high frequency resistance, due to skin effect.
3. External insulation difficulties due to the ease with which the air breaks down at very high frequencies.

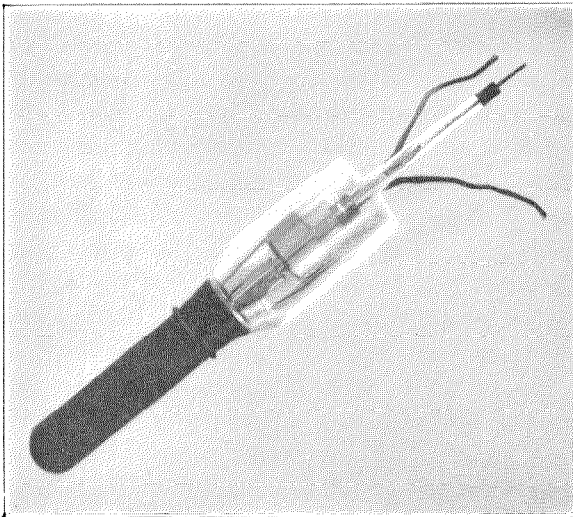


Figure 1—SS. 1966 Short Wave Vacuum Tube.

4. The demand for low electrode capacity.

The first trouble is one which probably causes the greatest difficulty in the design of these tubes.

The effect usually shows up at places where high electrostatic fields exist. If these fields pass through the glass envelope for example, the

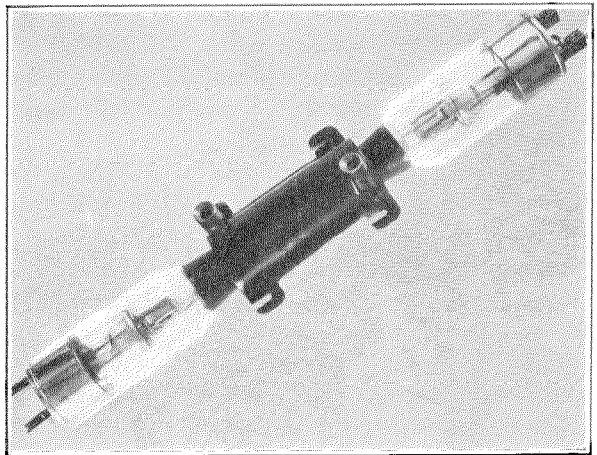


Figure 2—SS. 1968 High Power Short Wave Vacuum Tube.

dielectric loss which occurs is often sufficient to raise the temperature of the glass to the softening point very quickly, and a very characteristic failure is caused in which a small hole is made in the envelope, with the edges rounded and pointing inwards in accordance with the way the glass is pushed in by the air pressure, forming a kind of dimple. Very often, the shape of these holes is such as to indicate quite clearly the direction of the field at the point of failure.

Sometimes, the heating is not sufficient to cause an actual fusion of the glass but, on the other hand, long continued operation causes a small evolution of gas which ruins the tube. When the heating occurs quite close to one of the electrodes, there may be a considerable electrolysis of the glass which leads to an early failure, either by cracking or by "softening" of the tube.

In the same way, the use of dielectrics in the active part of the tube for supporting or separat-

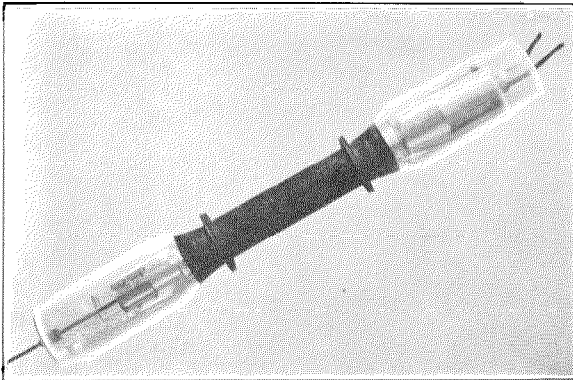


Figure 3—Experimental High Power Short Wave Vacuum Tube Ready for Pumping.

ing portions of the structure is very considerably limited. "Steatite" and other similar materials which are commonly used for such purposes may easily be melted into a vitrified mass if placed in such a position as to be subjected to an intense high frequency field.

On account of the difficulties enumerated a series of tubes for short waves have been developed, in which a special system of shielding has been incorporated. The use of the screen for the anode has been considerably extended. This screen is electrically connected to the anode within the tube and extends beyond the end of the copper glass seal. In long wave tubes for very high voltages this serves as a protection for the glass at the edge of the seal where piercing by electronic bombardment occasionally occurs. In the case of the short wave tube, however, the danger of piercing is not very great, but by means of this shield the intense field at the edge of the anode is removed from the glass and distributed uniformly round the vacuous space. At the same time, when necessary, the tubes are provided with shields on the grid and filament to distribute the field in the vacuum in the best manner possible, and to diminish the field which intersects the glass.

In the higher power vacuum tubes the anode is made with a glass bulb at each end, the grid being sealed into one end and the filament into the other. This arrangement improves the tube very much but considerably increases the difficulty of manufacture, especially the operations of sealing the filament and grid into the anode. The difficulty will be realised when it is con-

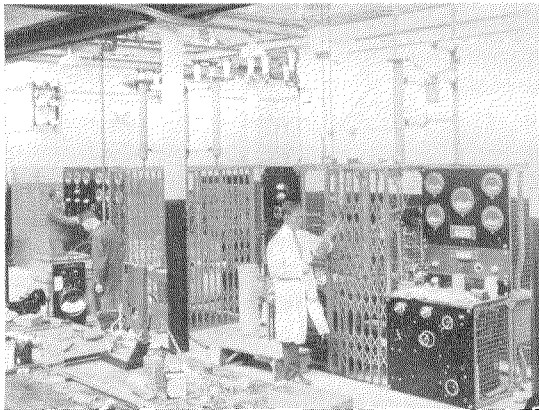
sidered that the glass blower has to manipulate the anode assembly with its two bulbs while sealing in each electrode, and that owing to the use of the screens in the anode it is impossible to see the far end of the electrodes in order to make sure that it is centrally situated. To overcome this difficulty, an ingenious method is employed; a small spark coil is connected between the anode and the electrode being sealed in, and a parallel spark gap is used of such a length that when the glass blower has sealed the electrode exactly in the correct position the spark passes over the auxiliary spark gap instead of within the tube. However, an entirely new design of tube is now being developed and will probably be soon available, in which the sealing-in is done in such a way that the electrodes are automatically centered during the operation.

The high values of high frequency currents and the magnitude of the factor of skin effect may cause so much heating of apparently quite large conductors within the vacuum tubes, that very special consideration has had to be given to the dimensions of the leads, and they have been designed so that the metal in physical contact with the glass does not carry current.

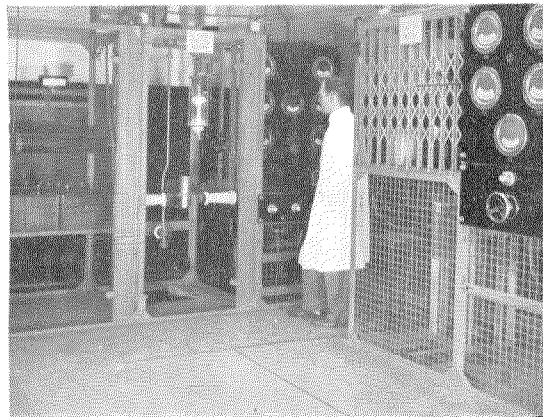
For the design of circuits and for easier operation it is very important that the capacity between the electrodes of short wave tubes should be kept down to as low a value as possible; the double-ended arrangement in which the grid and filament are brought out at opposite ends is one very effective means by which this capacity can be appreciably reduced. At the same time, since it gives an improved tube from the operating stand point, the tube with lower capacity is preferable because the high frequency currents through the leads are reduced.

With the double-ended type of construction it is possible to use a self contained water jacket or a separate water jacket through which the tube is inserted. The former method has been adopted for the following reasons:

1. A much more satisfactory water flow around the anode can be obtained.
2. There is less danger of breaking the tube when changing tubes.
3. There is less danger of flooding the transmitter when changing tubes.



High Power Vacuum Laboratory—High Voltage Testing Equipment.



High Voltage Rectifier and Pumping Stations—Vacuum Tube Laboratory Pumping Room.

4. A separate water jacket is of necessity extremely large and clumsy.

5. It is difficult to make water-tight joints at both ends of a separate jacket.

The combined water jacket has the disadvantage that it is more difficult to clean the anode if it becomes very dirty; this, however, is not a very serious objection because these tubes are operated in equipments where a closed circulating system is employed, and in order to avoid electrical leaks through the water supply, soft water, which leaves practically no deposit, is used. The connections to the water jacket are threaded for a standard pipe fitting, and it is a very simple matter to make the connections by means of a standard union.

The water jacket carries four lugs by which it can instantly be put into position or removed from the set. Of course, in the case of the low power tube, which is single-ended, a standard water jacket is used and the anode is inserted in the same way as the anode of a long wave tube, using a screw down ring to compress a packing ring which makes a water-tight joint with a bead on the top of the anode.

As these tubes are practically always used in push-pull arrangements, very great care is taken to insure that they have characteristics sufficient-

ly uniform to operate under the above mentioned exacting conditions without any difficulty.

The pumping arrangements for double-ended tubes are of necessity somewhat different from those for single-ended tubes, but by the methods adopted it is possible to secure for all these tubes a vacuum of the very highest order, such as is obtained in the long wave vacuum tubes.

These tubes have been tried out in commercial short wave transmitters, with highly satisfactory results, giving in all cases the required output with continuous operation.

Figure 1 is a photograph of the SS. 1966 short wave tube, Figure 2 the completed 1968 high power short wave tube, and Figure 3 shows an experimental short wave tube of higher power, ready to be pumped.

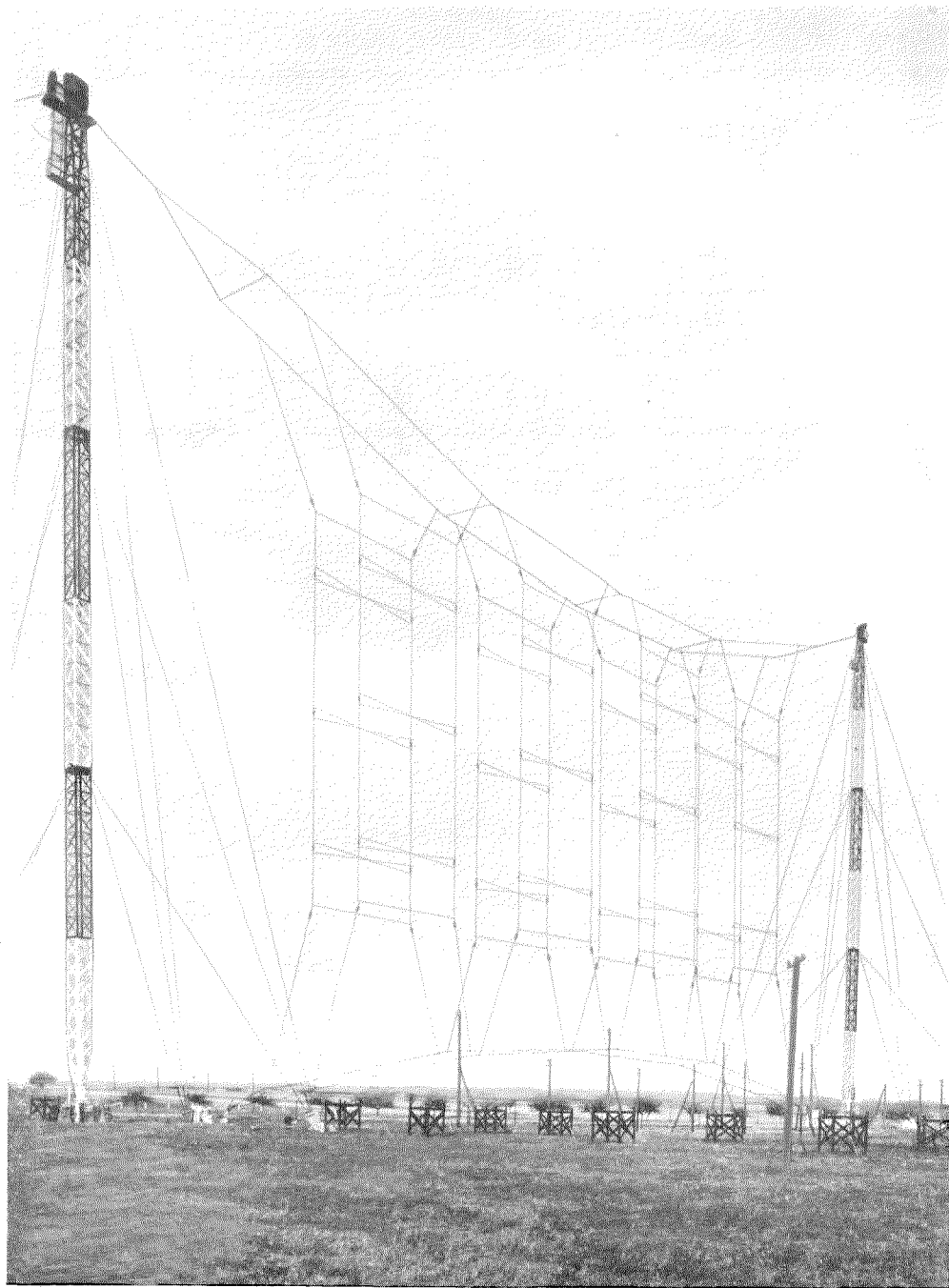
The following table gives some information on the characteristics of the various water cooled tubes which have been standardised. The values of the constants vary somewhat from tube to tube and the figures are given only as an indication. The maximum anode dissipation is that which the anode can support continuously with a rapid water circulation, and practically speaking is a function entirely of the anode dimensions and has nothing to do with the electrical characteristics of the tube. The maxi-

mum output given is only given as an indication of the power that can be obtained when operating as an efficient oscillator. The actual power ob-

tainable in any circuit depends on a number of factors and thus is limited by the method of operation.

STANDARDISED SHORT WAVE VACUUM TUBES

Tube	Type	Filt. volts	Filt. amps.	Emission	Anode volts	μ	R_p	Capacity in $\mu \mu f$			Max. anode dissipation continuous	Max. Output
								g f	f p	p g		
SS. 1966-2	Single-ended	14	24	2.6 amps.	4000-5000	23	8500	16	6	20	10 KW.	1 KW.
SS. 1966-3	Single-ended	14	36	4 amps.	4000-5000	23	7000	18	6	20	10 KW.	1.5 KW.
SS. 1968	Double-ended	22.5	41	5.5 amps.	8000-10000	40	6000	14	11	30	15 KW.	10 KW.
SS. 1971	Double-ended	20	64	9.5 amps.	8000-10000	18	3000	10	11	26	15 KW.	15 KW.



Fifteen-Meter Antenna Curtain with Masts Sixty Meters High—Type Used at Madrid.

Short Wave Directive Transmitting and Receiving Antennas

By E. H. ULLRICH

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and N. K. FAIRBANK

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AS is well known, radio waves are similar in physical nature to light waves, both being electromagnetic phenomena propagated through space by vibrations or disturbances in the ether. The two differ from each other only in the frequency with which the vibration occurs. Radio waves range in frequency from about 10 kilocycles to 10^5 megacycles. At the latter point radio waves merge into the infra red portion of the light spectrum.

Since radio waves are similar to light it is to be expected that they could be reflected and focused into a beam as are light rays. In fact, in Hertz's original experiments he used a parabolic reflector very similar to a light reflector. The wavelengths used in long wave radio communication, however, are so great that any type of reflecting or directive structure would be prohibitively large and expensive. It was not until short waves began to be used for radio communication that it became possible to build efficient and economical directive antennas.

The short wave antennas on the Buenos Aires-Madrid radio channel do not employ the parabolic reflector of Hertz. Another property of electromagnetic waves, that exhibited in the refraction of light, is made use of. If a simple vertical Hertz half wave antenna is excited by signals of its characteristic frequency, it will radiate disturbances into the ether. Viewed in a horizontal plane these disturbances will be equal in all directions about the wire. This is the condition shown in Figure 1-a. If now a second antenna is placed one-half wavelength from the first and excited in the same phase, it will be seen that in a direction normal to the plane of the two wires and at a point remote from the antenna the radiations will both add together. In the plane of the wires, the radiations from one antenna will be one-half wave behind those from the other and hence will completely cancel.

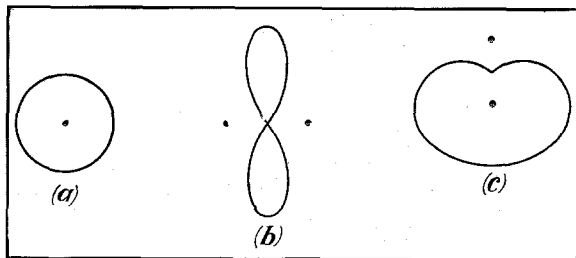


Figure 1—Antenna Radiation Patterns.

The distribution of field about such an antenna system is shown in Figure 1-b. It will be seen that with this arrangement radiations occur in either direction normal to the plane of the two wires.

If now two vertical antennas are placed one-fourth wavelength from one another and excited so that the voltage in one leads that in the other by 90° , the distribution of field shown in Figure 1-c occurs. In other words, the field cancels on one side of the antenna while it adds on the other, a reflector effect being obtained. By combining the effects shown in Figure 1-b and 1-c the elements of directive antenna employed in the Buenos Aires-Madrid channel is obtained.

All the transmitting antennas described below depend for their action on these principles. Instead, however, of employing only two phased radiators one-half wavelength apart, as shown in Figure 1-b, as many as sixteen are placed one-half wavelength apart in one plane, each being backed by its reflector, as shown in Figure 1-c. The reflectors are ordinarily parasitically driven by the radiator. In like manner, placing of properly phased conductors vertically above one another produces a similar directive effect in the vertical plane. The greater the number of superimposed radiators the sharper will be the vertical directivity.

The function of a transmitting antenna is to

radiate the output of the transmitter in the desired direction as efficiently as possible. The transmitting antenna of a point to point system should therefore be as directive as possible, both horizontally and vertically. The horizontal directivity is limited by the economical length of the antenna and the physical accuracy with which it can be directed toward the desired objective. The vertical directivity is limited by the economical length of the antenna and the physical accuracy with which it can be directed toward the desired objective. The vertical directivity should be about 10° to 15° for frequencies of 20,000 Kc. and about 20° for the frequencies of 10,000 Kc. Vertical directivity greater than this can be secured but results in a ray so sharply directed that its operation is erratic, due to sudden changes in the height of the Heaviside Layer.

If we consider the vertical wire A. B. C. D. . . OP (Figure 2) on which are present stationary waves and bend it according to the pattern of Figure 3, the currents will then be distributed

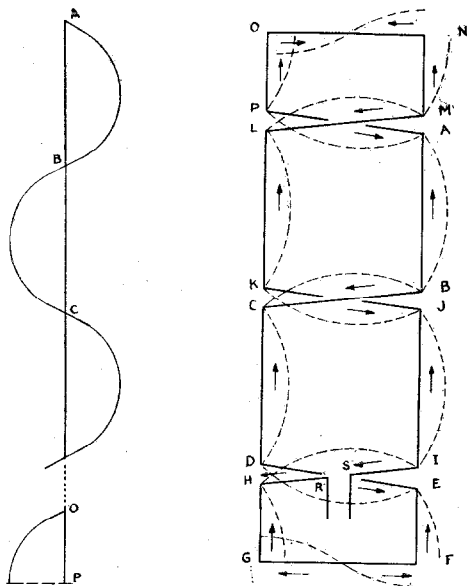


Figure 2—Figure 3—Vertical Wire (Figure 2) Bent According to Pattern of Figure 3, Illustrating Current Distribution.

as shown in Figure 3. It will be seen that in the vertical portions the currents are in phase, while in the horizontal portions the currents cancel out due to opposite phase. In the end sections O N and G F, the currents are equal and in reverse phase in each of these half sections. The radiation of the horizontal portions is therefore practically nil.

The arrangement shown in Figure 3 constitutes a group of vertical antennas in phase. The antennas of the Buenos Aires-Madrid channel consist in general of 6 to 8 groups of this type placed one-half wavelength from one another

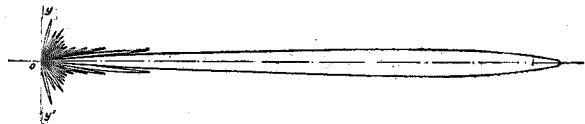


Figure 4—Distribution of Field in a Horizontal Plane of an Antenna Array Having Both Radiators and Reflectors.

in the same plane. Each of these groups is energized by high frequency transmission lines, consisting of two wires, at a point of current maximum such as R and S, and in such fashion that the current in the vertical sections is in phase for all groups. Behind this curtain is another similar antenna curtain which serves as a reflector. The horizontal directivity for such an array is shown in Figure 4.

Transmitting Antennas†

The antenna curtains and reflectors at Madrid are suspended on two cables between guyed masts 60 m. high (See Figure 5). A spreader consisting of a steel tube $\frac{\lambda}{4}$ wavelength long separates the cables supporting each curtain. The strain at the top of the towers is 5 tons and is automatically regulated by a counterweight. The two supporting cables are attached to winches in order that the curtains may be raised and lowered. A messenger cable to which a counterweight is attached maintains the tension at 5 tons when the antenna is being raised and lowered. The vertical wires of each curtain are kept in tension by counterweights acting through a system of pulleys. Very large factors of safety have been adopted and in no case does the tension in an element of the curtain exceed 150 kgms.

At Buenos Aires precisely the same antenna is employed as far as theoretical considerations

† Due to the speed with which this project was consummated, the transmitting and receiving antennas originally installed differ somewhat from the description given in this article. However, the final arrangements will be in effect in Madrid at about the time this issue of *Electrical Communication* reaches the reader, and not long thereafter, also, in Buenos Aires.

are concerned. Practically, however, the antenna curtains are suspended from 175' steel masts. Seven of these masts are employed for an antenna system consisting of three frequencies. The masts are anchored by means of head guys and the curtains can be raised and lowered completely independently of the head guys by means of winches. The method of feeding the antenna curtain, illustrated in Figure 6, differs slightly from that in use at Madrid. A view of the completed Buenos Aires antenna is shown in Figure 7. On any given frequency the gain of such a system over a single vertical half wave antenna is approximately 15 to 20 db.

Transmission Lines

The transmission lines which simultaneously feed all the antenna groups should satisfy the two following conditions:

(1) All the antennas should be excited by currents in the same phase and equal in magnitude.

(2) At no point in the line should there be reflection of energy back toward the transmitter.

If the antenna groups of the same curtain are excited by branch lines from the transmission line, it is necessary in order to satisfy the first condition that the length of transmission line be the same to each antenna element from the transmitter and that the branch lines be sym-

metrical. Since the speed of propagation is the same in the identical branch lines and the length of the latter are equal, the dephasing due to these equal distances will be the same for all groups of antennas.

To satisfy the second condition and avoid the presence of stationary waves on the transmission lines between the transmitter and the antennas, it is necessary to match the impedances of the transmission line in such a fashion that the line will be terminated by an impedance equal to its characteristic impedance.

Receiving Antennas

The directive properties of the antennas described in the first part of this paper were explained on the basis of a transmitting antenna. It will be seen that the theory is equally applicable to a receiving antenna. Assuming in Figure 1-b that the two antennas are so interconnected they are in phase for transmission, an incoming signal will produce a disturbance in each antenna. If the signal arrives from a direction normal to the plane of the two antennas the voltage induced in each wire will be in phase and the two resultant currents will add. If, however, the signal comes from any other direction, impulse will arrive at one antenna before it reaches the other with a result that the currents will not be in phase.

For various reasons, however, a transmitting

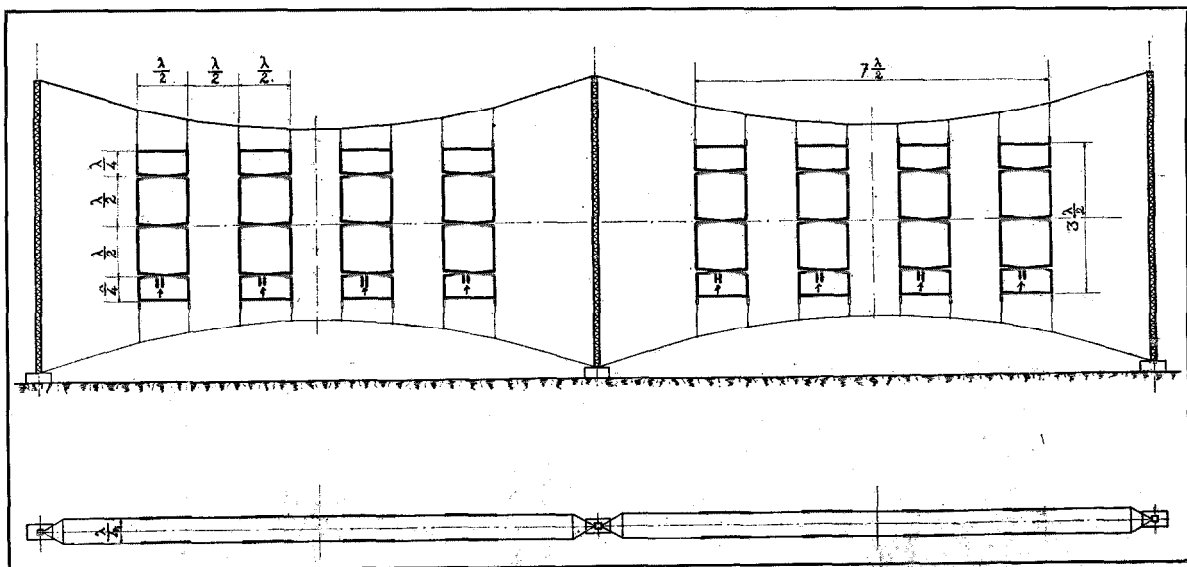
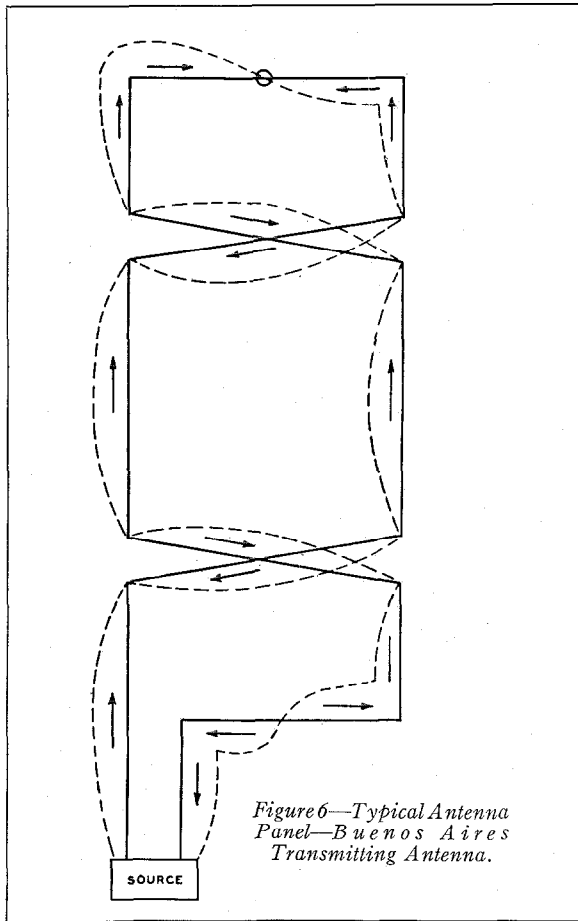


Figure 5—Plan of Madrid Transmitting Antenna.



antenna does not make a particularly satisfactory receiving antenna. It is desirable that the transmitting antenna deliver a ray very narrow in the vertical plane. It has been found that an incoming signal arrives at the receiver at all angles from horizontal to vertical, depending on the manner in which it has been reflected during its passage. The most common angle is between zero and sixty degrees from the ground and an efficient receiving antenna should be equally responsive over this range. The antenna is preferably constructed on a wood frame avoiding as much as possible the use of steel towers or other extraneous reflecting objects which will reduce the directional properties of the antenna by introducing unwanted reflections onto the antenna elements.

A type of antenna which answers these requirements is that shown in Figures 8 and 9. This type of receiving antenna is used both at Madrid and Buenos Aires. It consists essentially of a long wire so folded in space that the vertical elements act as signal collectors while the horizontal members act as interconnecting lines. Both vertical and horizontal members are each one-quarter wavelength long. The voltages induced in the vertical elements by the signal are equal, but the phase relations depend on the direction of approach of the wave. A signal from

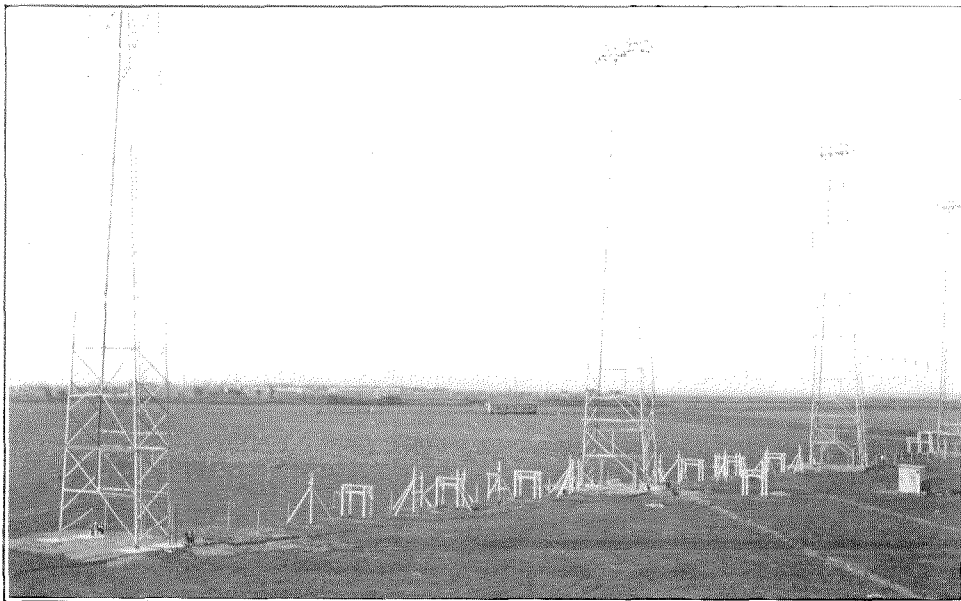


Figure 7—Buenos Aires Transmitting Antenna.

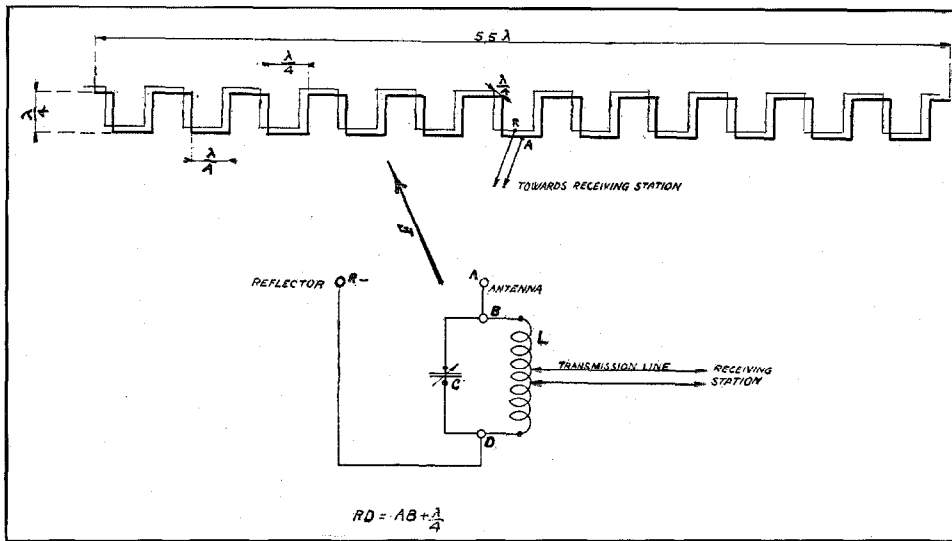


Figure 8—Directive Receiving Antenna of the Frame or Zigzag Type.

a direction broadside to the antenna causes, in the vertical elements, voltages which are all in phase. By alternately connecting the tops and bottoms of the vertical elements the wire currents caused by the signal voltages are also in phase and reinforce one another. The voltage and current relations for a broadside signal are shown in Figure 10.

A signal approaching end on to the array, however, produces an entirely different effect, since the incoming wave arrives progressively at each of the vertical members, producing out of

$$AB = MN = \frac{\lambda}{8} \quad BC = CD = DE = FG = \frac{\lambda}{4}$$

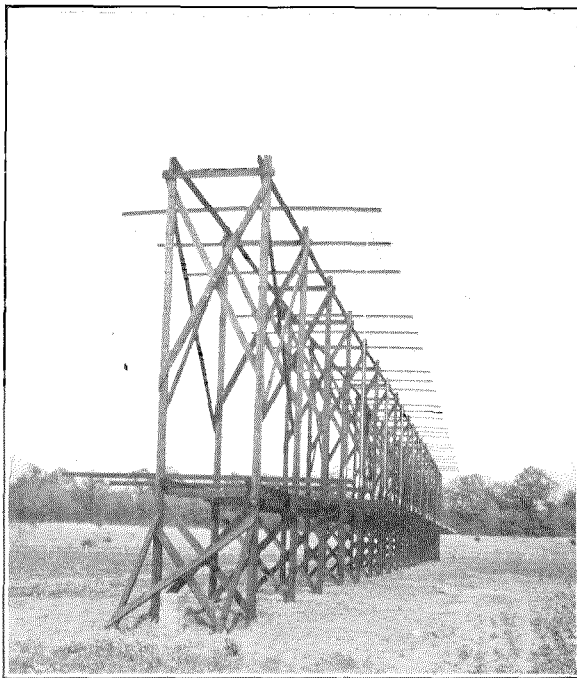


Figure 9—Zigzag Receiving Antenna.

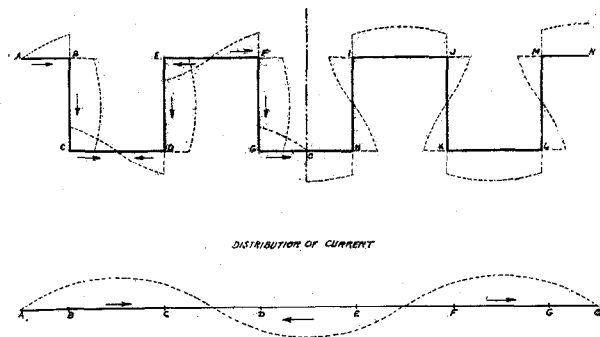


Figure 10—Distribution of Current and Voltage in a Frame or Zigzag Type of Antenna.

phase disturbances. Hence the wire currents are likewise not in phase and cancel one another. Another advantage of this antenna is that the current distribution to a broadside signal is such that a current node is found in the center of each horizontal section. Thus there is no current flowing in the horizontal sections and hence no loss due to the resistance of the wire.

The antennas of this type constructed on the

Buenos Aires-Madrid link have a total length of structure of five and a half wavelengths. They deliver to the receiver a signal about 15 db. higher than a single vertical half wave antenna. The improvement in the ratio of signal to unwanted static is likewise about 15 db.

Figure 8 shows a method of connecting such an antenna to the receiver. An oscillating circuit LC is connected on one side to the antenna and on the other side to the reflector between voltage maximum points such as A and R in such a fashion that the length of wire AB connecting the point A to the oscillating circuit is $\frac{\lambda}{4}$ shorter than the length RD connecting the reflector to the point D of the oscillating circuit. This is to say:

$$RD = AB + \frac{\lambda}{4}$$

When a wave of length λ arrives in the direction of the arrow F, it induces in the antenna and reflector, currents separated in phase by $\frac{\pi}{2}$ since the distance between the antenna and the reflector is $\frac{\lambda}{4}$. Hence at points A and R, which are voltage maximums, there will be equal voltages but dephased by $\frac{\pi}{2}$. These currents in order to reach the oscillating circuit will require a time proportional to the distance. Since the distance RD is greater by $\frac{\lambda}{4}$ than the distance AB, the voltage coming from the reflector will lag an additional $\frac{\pi}{2}$ and the oscillating circuit LC will be excited at the points B and D by two voltages of the same character and amplitude but dephased by π . If V is an absolute value of the voltage between the points AR, the voltage acting on the oscillating circuit LC will be equal to 2V. It is possible to arrange a number of other types of couplings.

Appendix

The following is a mathematical derivation of the principles of directivity which were explained in general terms at the beginning of the paper.

Let $A_1, A_2, A_3 \dots A_n$ be simple vertical antennas, placed in the same plane and constituting an antenna curtain (Figure 11). If these antennas are excited by currents in phase, the resultant field at a great distance from the curtain and in a direction perpendicular to the plane of the curtain, will be equal to the sum of the individual fields, namely $n \times h$, h being the field strength of one antenna. In the direction P_1 at an angle of θ from the plane of the curtain, the fields emitted by each of the radiators remain equal, but the track traversed by the radiation is no longer equal. Between antennas A_1 and A_2 this difference A_1a_2 is equal to $d \cos \theta$. If this distance A_1a_2 is not negligible relative to the wavelength, the field emitted by the antenna A_2 will arrive at a point P_1 at a great distance from the antenna curtain dephased from the field of antenna A_1 by an angle equal to $\frac{2\pi d}{\lambda}$

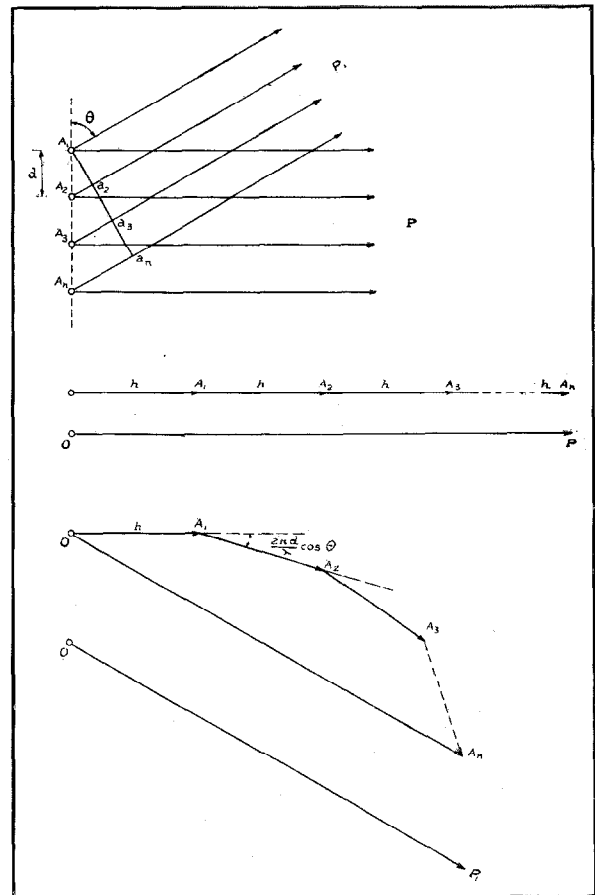


Figure 11—Directive Effect of Antenna Curtain.

$\cos \theta$. An identical calculation can be made from the field of the antenna $A_3, A_4, A_5 \dots A_n$. The resultant field at a point P_1 will therefore be equal to a sum of n vectors, each dephased with respect to the preceding by an angle of $\frac{2\pi d}{\lambda} \cos \theta$. The resulting vector OP_1 is always smaller than the vector OP , where P is a point in a direction perpendicular to the plane of the curtain. In certain directions of P the value of θ will be such that the polygon $OA_1, A_2, A_3 \dots A_n$ will be a closed figure. In such a case the vector OP_1 equals zero and there is no radiation in this direction.

The absolute value of the resultant field in the different directions can be found by the following equation:

$$H = h \frac{\sin \left(n \pi \frac{d}{\lambda} \cos \theta \right)}{\sin \left(\pi \frac{d}{\lambda} \cos \theta \right)}$$

The direction of the maximum field is found at the angle $\theta = 90^\circ$ and hence $H = nxh$. In other directions the strength of the field will be less, sharpness of the ray depending on the total length of the curtain.

A process of reasoning entirely analogous can be developed for the directivity in a vertical plane. This directivity is obtained by a superposition of a certain number of antennas. It will be seen, therefore, that one can obtain an emission narrowly defined in both vertical and horizontal planes.

Terminal Equipments for Short Wave Point to Point Radio Links

By F. de FREMERY and P. R. THOMAS

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IN order to secure satisfactory operation from a modern radio link, it is necessary to supply at the ends of the link terminal equipment which shall not only provide the necessary circuit arrangements, but shall also provide means for controlling its technical performance. The arrangements necessary for speech transmission are dealt with in this article together with a brief description of the facilities for technical operation and control of the circuit.

The usual radio link connection consists of two one-way radio channels working in opposite directions. These two channels are inter-connected at either end by means of land lines to form a two-wire connection, which may be extended to any of the standard types of telephone systems.

The simplest form of such a system is shown in Figure 1, in which two terminal stations designated East and West are connected through land lines to the radio transmitting and receiving stations, A and D in the case of the East terminal, and C and B in the case of the West terminal. Speech from the radio transmitter A is received by the the radio receiver at B, and that from the transmitter C is received by the radio receiver at D. It will be seen, when considering the terminations at East and West, that this is a special case of a four-wire circuit. The difficulties peculiar to the operation of a circuit of this type are that the attenuation of the radio paths are variable and that speech transmitted from either radio transmitter may in certain cases be received by either of the radio receivers. In the case in which speech is transmitted through the East terminal and the transmitter at A, and received by the radio receiver at D, there will be formed a local loop including the terminating set, the lines connecting the terminating set to the radio stations and the short

radio path between A and D. As the distance between the radio stations A and D may be small, the loss in this radio path would probably be very small when the radio wavelengths were the same or close together, and unless the network balancing the two-wire extension from the terminating set was exceptionally good, there would be singing round this local loop.

In cases where the attenuation in the radio paths A-B and C-D is small, and the balance of the lines and networks connected to the terminating sets at either end is not sufficiently accurate, there may be singing round the complete loop formed by the two uni-directional radio paths, their inter-connecting circuits and the terminating sets.

Anti-singing and Echo Suppressing Device

Even in the case when singing does not occur, the re-transmission of speech that passes across the hybrid coil at one end will appear as an echo at the other end. This echo will reduce the intelligibility and hence it should be suppressed.

The Bell Telephone Laboratories¹ have developed for prevention of singing and echoes in radio links a system which has been installed on the long wave transatlantic circuit between New York and London, and similar equipments have been designed for use on the short wave link between Madrid and Buenos Aires.

In order to prevent singing it is necessary to ensure that the attenuation round the whole loop shall always be greater than zero. The method of attaining this result is to arrange the circuit so that one or other of the paths is always inoperative. In the arrangement shown on Figure 1, a relay (a) is associated with the transmitting line which normally short circuits this line, thus

¹S. B. Wright and H. C. Silent, "The New York-London Telephone Circuit," *Bell System Technical Journal*, October, 1927.

preventing transmission and therefore singing round the loop. The amplifier detector is bridged across the transmitting line at some point before the short circuiting relay (a), and when speech enters the circuit the amplifier detector operates the relay (a) to remove the short circuit, thus allowing speech to be transmitted to the radio transmitter and so over the remainder of the circuit. In order to ensure that one of the paths is always blocked, a second relay (b) is arranged

preventing any disturbance entering the radio receiver and interfering with the talker or the apparatus controlled by his speech. The speech is transmitted over the radio link, received by the distant receiving station and enters the line connecting the receiver to the terminating set. This speech causes an amplifier detector to operate a relay (c) which prevents operation of the relays (a) and (b) controlled from the transmitting circuit.

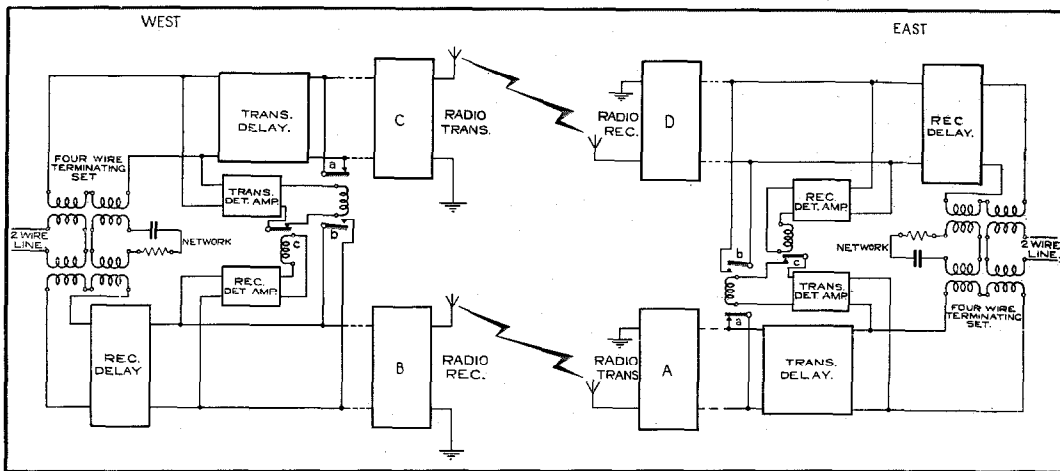


Figure 1—General Schematic of Complete Radio Link.

to be operated just before the relay (a) which removes the short circuit from the transmitting line; this second relay (b) short circuits the receiving line. In addition to these relays associated with the transmitting circuit there is an additional relay (c) associated with the receiving circuit to prevent the operation of the relay (a) controlling the transmitting circuit and relay (b) short circuiting the receiving circuit when speech is being received. This additional relay (c) is operated by an amplifier detector bridged across the receiving circuit at a point after that at which the line is short circuited during transmission. The equipment at either end of the four-wire circuit formed between the radio link and its interconnecting lines, is similar.

The operation of the circuit is as follows:

In the normal condition when there is no speech on the circuit, both the transmitting paths are short circuited. Speech entering one end of the circuit clears its own transmitting path and short circuits the receiving path, thus

Amplifier Detectors and Delay Networks

As mentioned above, the speech to be transmitted has to clear its own path and unless this clearing operation can be performed instantaneously part of the speech will be lost. It is possible to design an amplifier detector and relay train which operates so quickly that, although the initial part of speech is lost, it is not possible to tell that the whole has not been transmitted. This involves the use of a very sensitive detector amplifier. In practice there is always a certain amount of noise associated with speech on land lines, and somewhat more noise on radio circuits. This noise limits the sensitivity at which the amplifier detector can be operated, since if the amplifier detector were very sensitive, it might either be held permanently operated or subject to false operation by noise. When a somewhat insensitive amplifier detector operates the relay to clear the transmitting path, there is noticeable clipping of the speech although the operating

time of the combination is very small; the reason for this clipping is that the energy contained in the initial parts of speech may be very small and thus insufficient to operate the relays. The relays in this case do not start to operate until some time after speech has started and the amount lost is determined more by the characteristics of speech than by the operating time of the relays. One way of preventing this clipping of speech is to introduce between the input of the amplifier detector and the normally short circuiting relay, a network to delay the speech until after the relay has operated. The amplifier detector is then arranged so that it will not operate from the weak initial pulses of speech, but will operate when these have built up to some greater amplitude. The time lost during the building up of the speech currents is compensated for by the delay introduced by the network. By increasing the delay introduced and decreasing the sensitivity of the amplifier detector it is possible to arrange that only the peaks of speech shall be of sufficient amplitude to cause operation of the relays; the arrangement may then be subjected to noise, the amplitude of which approaches that of the peaks of speech, without false operation. A network having a delay of 20 or 30 milli-seconds is usually sufficient when dealing with the speech to noise ratios met with in a commercial circuit.

It has already been mentioned that the amplifier detector bridged across the receiving circuit is arranged to open the one connected to the transmitting circuit. This ensures that speech arriving at the radio receiver and passing across the terminating set into the transmitting circuit (owing to insufficient balance between the line and network) shall not cause false operation of the transmitting relays. It is necessary to make provision against false operation by noise occurring in the radio link, and the sensitivity of the receiving amplifier detector is thus limited. It is also necessary to ensure either that the amplitude of the received speech reaching the amplifier detector which controls the transmitting circuit shall be insufficient to operate the transmitting relay or that the relay controlled from the receiving side shall always be operated by the received speech.

The ratio of the speech energy available for

the two-wire line to that reaching the transmitting amplifier detector depends on the accuracy with which the impedance of the balancing network simulates that of the two-wire line. Since speech may be required over a large variety of circuits it is impracticable to provide balancing networks to simulate the impedance of all such lines. It is therefore evident that only a small discrimination can be relied upon between speech received from the land line which it is required to transmit and received speech which it is not required to transmit.

Since a very sensitive amplifier detector connected to the receiving circuit may be falsely operated by noise currents, it is desirable to provide means whereby only currents approaching the peak values reached by speech shall operate the relays. The provision of a delay network in the receiving circuit between the receiving amplifier detector and the terminating set will allow time for the speech voltage applied to the receiving amplifier detector to rise to some considerable value before this speech, after passing through the terminating set, can reach sufficient amplitude to operate the amplifier detector connected to the transmitting circuit. The relays associated with the receiving circuit thus have time to operate and disable those connected to the transmitting circuit, without unduly increasing the sensitivity of the receiving amplifier detector and so increasing the risk of false operation.

As in the case of the transmitting delay circuit, the length of the receiving delay circuit is determined by the maximum speech to noise ratio with which good operation is required, with the modification that "clipping" is not important. The speech to noise ratio in the receiving circuit is usually considerably worse than that in the transmitting circuit and for this reason it is desirable to make the receiving amplifier detector somewhat less sensitive than the detector transmitting amplifier. The first condition would lead to a delay network having a delay approximately equal to the operating time of the relay which is less than 5 milliseconds. In practice it is found that from 5 to 10 milliseconds delay with a less sensitive amplifier detector will switch any circuit which, from a talking point of view, has a speech to noise ratio within commercial limits.

Gain Control

The introduction of variable attenuators either side of the terminating set allows some discrimination to be obtained between the speech received from the radio receiver and that from the two-wire extension. The discrimination obtained depends on the effective loss between the receiving and transmitting amplifier detectors. Thus with any given condition of balance between the line and the network connected to the terminating set, the sum of the added losses must have some minimum value. The level of speech arriving from the line determines the setting of the transmitting attenuator, since this attenuation loss must be adjusted to load fully the radio transmitter. The loss in the receiving side is adjusted either to give a suitable output level or to the minimum value determined by the other conditions; the latter case only being necessary under bad noise conditions on the radio circuit.

Circuit Arrangements

Figure 2 shows the arrangement of the terminal equipments at Madrid and Buenos Aires in some detail. It will be seen that the two-wire extension is connected through an ordinary four-wire terminating set to the apparatus associated with the transmitting and receiving lines. Considering first the apparatus in the transmitting line, there is a gain control panel associated with a volume indicator, so that the technical operator can change the amplification in this circuit to keep the level of speech delivered to the line for the radio transmitter constant and sufficient to load fully the radio transmitter. The output of this gain control panel is connected to the input of one side of a four-wire repeater whose gain is so adjusted that its output shall be that required by the interconnecting line to the radio transmitter. Across the output of this repeater is bridged the input of the transmitting amplifier detector, which controls the relays associated with the transmitting path and the relay for short circuiting the receiving path. Next comes the transmitting delay network with its equaliser, low pass filter to limit the upper frequency to be transmitted, and repeater for compensating its attenuation at various frequencies. Next two repeating coils which include the short circuits

which is normally on the transmitting path for the prevention of transmission when there is no speech. The privacy equipment is located between these repeating coils and the line to the transmitting station.

At the receiving side of the circuit the line from the radio receiver is connected to one half of a four-wire repeater adjusted to increase the received level to that required for the operation of the equipment, and thence through the privacy equipment to a coil group which is arranged in connection with a relay panel to perform the switching operation. This coil group is connected to the receiving delay network and at the junction of these is bridged the receiving amplifier detector. The receiving delay network is associated with an equaliser and a repeater as in the case of the transmitting delay network and is then connected through a gain control panel and repeater to the four-wire terminating set.

It will be noticed that each separate part of the circuit is associated with a repeater. The object of this is to make both the delay network and privacy system each have zero attenuation, thus making it possible for them to be patched out of the circuit without affecting the transmission characteristics of the whole.

Voice Operated Relay Circuits

The relay switching is arranged in each case so that the break of the switching relay performs the switching operation. This reduces the operating time of the switchgear and thus minimises the lengths of the delay networks necessary for a given amplifier detector sensitivity. From the transmitting side transmission is normally prevented by the use of a short circuit, and the break of the relay will remove it. In the receiving side, however, the circuit is normally in the transmitting condition and it is required to interrupt transmission by breaking contact. From considerations of balance it is undesirable to break the circuit. To avoid this, two repeating coils are connected into this circuit, as shown on Figure 3. It will be seen that when the relay contact is made, these repeating coils are so connected that their windings are in series aiding, with their centre points joined. When the contact is broken the connection between the centre points is

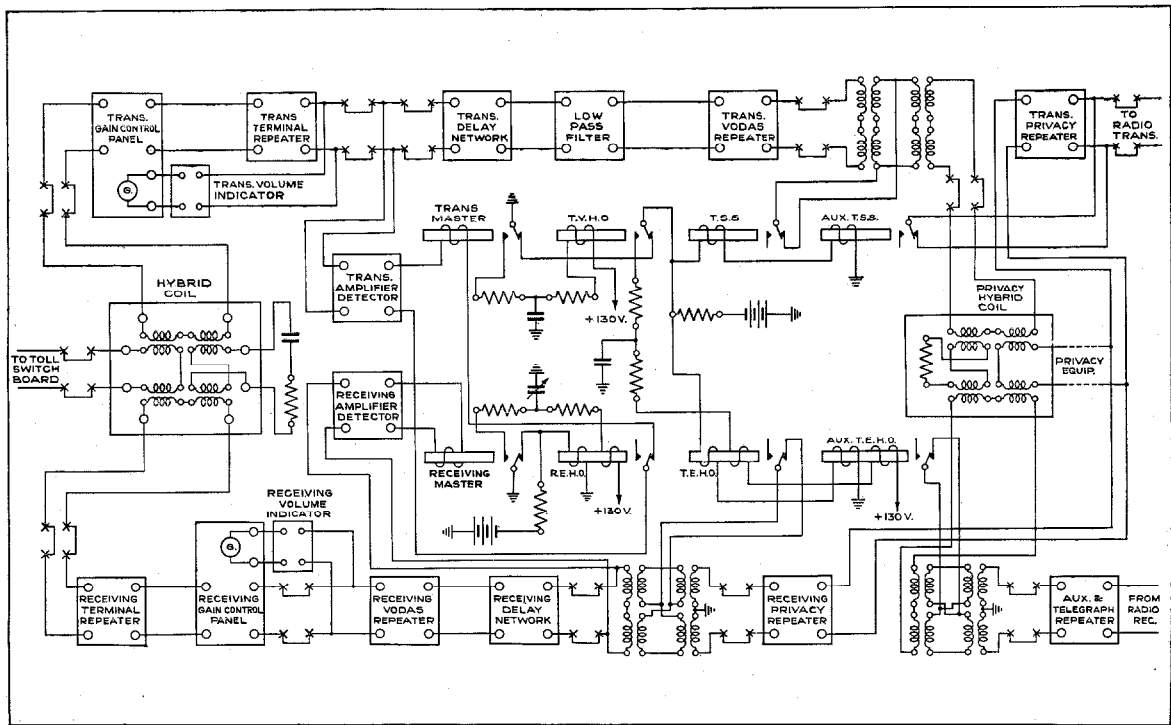


Figure 2—Terminal Equipments at Madrid and Buenos Aires.

severed and the windings of the coils are in series but opposing one another, so that the transmission of currents from one coil to the other is prevented.

Speech entering the terminating set from the two-wire side enters the transmitting half of the amplifier detector and operates the transmitting master relay. When the armature of this relay leaves its back contacts, relays TEHO¹, Aux. TEHO², TSS³ and Aux. TSS⁴ operate; when this armature makes its front contact relay TVHO⁵ operates. The operation of relay TEHO puts the coil group in the receiving circuit in a non-transmitting position. The operation of relay TSS removes the short circuit from the transmitting side and the operation of relay Aux. TSS removes a similar short circuit beyond the privacy equipment. During the operation of these relays speech has been traversing the transmitting delay network and can then pass through the remainder

¹ TEHO indicates Transmitting Echo Hangover.

² Aux. TEHO indicates Auxiliary Transmitting Echo Hangover.

³ TSS indicates Transmitting Singing Suppressor.

⁴ Aux. TSS indicates Auxiliary Transmitting Singing Suppressor.

⁵ TVHO indicates Transmitting Voice Hangover.

of the circuit and the privacy equipment to the radio transmitter. The receiving circuit is disabled between the radio receiver and the receiving amplifier detector, thus preventing either operation of the amplifier detector or interference of the talker by currents from the radio receiver.

The release of the relays operated by the transmitting master relay is controlled by the charge of condensers through resistances. The condensers and resistances associated with the contact of the transmitting master relay and the winding of the relay TVHO control the release time of relay TVHO which in turn controls the release of the TSS and TEHO relays. The TSS relays release immediately after the TVHO relay reaches its back contact, but the release of the TEHO relay is held up during the charging period of a condenser resistance circuit, thus ensuring that the transmitting path is blocked before the receiving path is opened.

The release time of the TVHO relay is so arranged that it will hold during pauses between words to reduce the number of times the circuit is switched during talking from this terminal. This relay must, however, release sufficiently

early to prevent clipping of the reply. Since the total transmission time of the circuit determines the time which elapses before a reply can arrive it is safe to make the TSS relay hold up for twice this time, thus allowing for the last word to reach the distant station and an instantaneous reply to return.

After speech in the transmitting path has ceased and the relays have released, speech may enter the receiving path and the receiving amplifier detector and operate the receiving master relay. The armature of this relay on leaving its back contact causes the REHO⁶ relay to operate and break the connection between the transmitting half of the amplifier detector and the transmitting master relay, thus preventing the speech operating this relay and the relay train controlled by it. The release time of the REHO relay is controlled by the charging of condensers which have previously been discharged by the action of the receiving master relay making its front contact. This release time is adjusted to take care of echoes in any circuit which may be connected to the two-wire side of the four-wire terminating set. The relay circuits shown on Figure 2 include only the operating connections and do not include either biasing windings or testing circuits.

The relays used in this equipment are all polarised telegraph relays of the same type which are very sensitive and operate quickly. A special panel is provided for adjusting these relays.

Switching of Privacy Equipment

The circuit is arranged to operate with a single privacy equipment which can be used alternatively in the transmitting and receiving sides since the system is always in a one-way condition. This assumes that the privacy systems at the two ends are complementary. Figure 2 shows the transmitting and the receiving circuits connected to the opposite sides of a hybrid coil arrangement, the network terminals being closed through 600 ohms. and the input of the privacy equipment being connected to the line winding. The output of the privacy equipment is connected to both transmitting and receiving circuits.

In the normal condition the transmitting cir-

cuit on both sides of this connection is short circuited by the TSS and the Aux. TSS relays, speech can then enter the privacy equipment from the receiving circuit and pass through the hybrid coil back into the receiving circuit without interfering with the transmitting circuit or being subjected to interference from this circuit.

In the transmitting condition the TSS and Aux. TSS relays are operated to remove the short circuits from the transmitting path. The TEHO and Aux. TEHO relays are also operated and prevent transmission from the receiving circuit entering the privacy equipment, and also prevent transmission from the privacy equipment to the remainder of the receiving circuit. Speech from the transmitting circuit can then pass through the privacy equipment to the radio transmitter.

It will be noticed that a repeater is placed between the output of the privacy equipment and the short circuit on the transmitting line to prevent this short circuit being directly on the output of the privacy equipment. A similar repeater is also used in the receiving circuit. The necessity of having a repeater in the transmitting circuit to isolate the privacy equipment from the

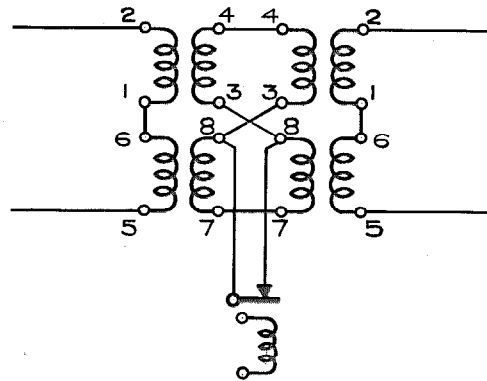


Figure 3—Special Coil Group for Receiving Circuit.

short circuit, renders it impossible to include one repeater in the privacy equipment instead of one in each line.

Monitoring and Control

The equipment for the switching and the control of the circuit is arranged with suitable monitoring apparatus. A technical operator monitors continuously on the circuit and adjusts the gain controls and amplifier detector sensi-

⁶ REHO indicates Receiving Echo Hangover.

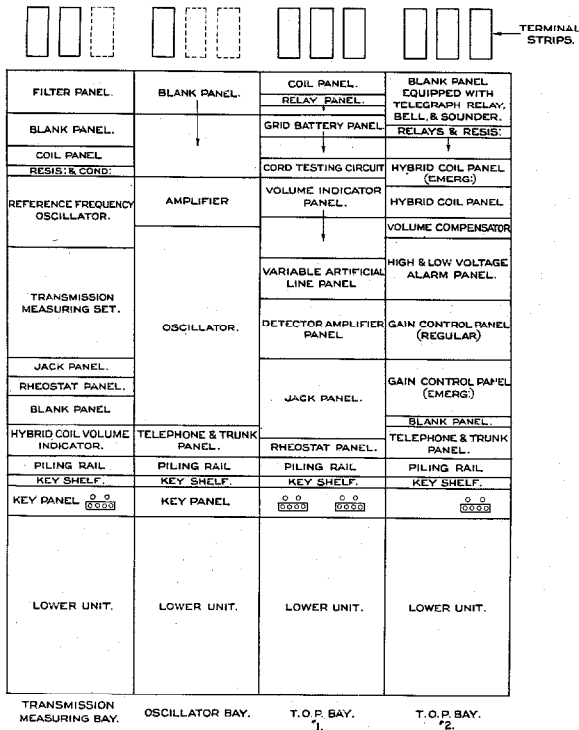


Figure 4—Technical Operator's Position—Front Equipment.

tivities to give the best service obtainable at any moment. The two-wire line is connected through to jacks on an operating position in a toll exchange and traffic is handled in a similar manner to that adopted on ordinary toll circuits.

Equipment

The terminal equipment apparatus is grouped on two racks, one comprising all the panels which require adjustment is known as the Technical Operator's Position, and the other is equipped with the voice operated apparatus and known as the V. O. D. A. S. rack. The privacy apparatus is grouped on a special rack and forms a complete unit apart from the terminal equipment.

Figure 4 shows the technical operator's position. It consists of four bays. The two bays on the left are equipped with transmission measuring apparatus and the two bays on the right comprise the gain control panels, amplifier detector panels and volume indicators, telephone and trunk panel, etc. By means of this apparatus the technical operator can monitor on the circuits at various points and has all important controls

within easy reach for making the adjustments required for optimum performance of the system under prevailing conditions.

From the technical operator's position order wire circuits run to the toll switchboard, toll testboard, the radio transmitting station and the radio receiving station, so that the technical operator can readily communicate directly with all operators and attendants at important points on the circuit. He can also communicate with the home as well as with the distant subscriber.

Figure 5 shows the V. O. D. A. S. rack, comprising a battery supply bay, delay network bays and a bay containing the voice operated switching arrangements with their testing apparatus. The relay testing apparatus comprises a testing and adjusting panel for the polarised telegraph relays and an echo suppressor testing panel for testing the operating hangover times of various relay trains.

Jack fields are provided on both the technical operator's position and V. O. D. A. S. rack. These jack fields permit easy testing of parts of the circuits and afford means by which the circuits can be modified to meet special requirements.

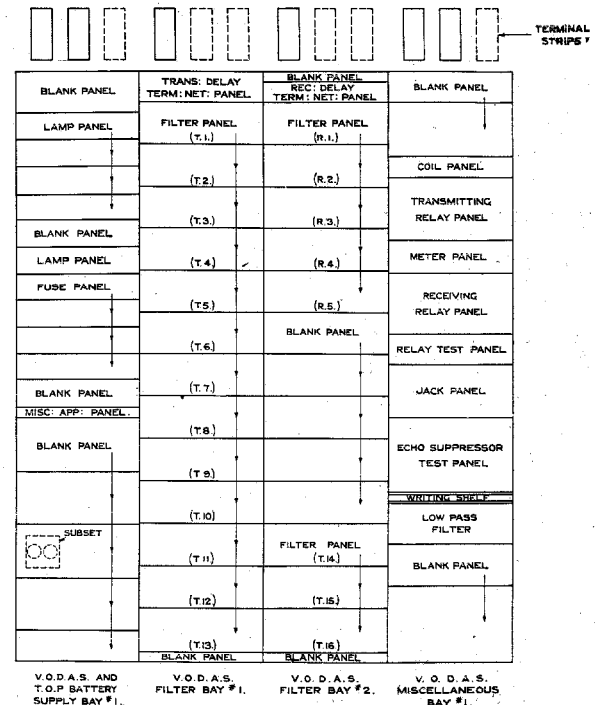


Figure 5—V. O. D. A. S. Rack—Front Equipment.

Inauguration of Madrid-Buenos Aires Radio Telephone Link

By FRED T. CALDWELL

Chief Engineer, International Telephone and Telegraph Corporation (España)

THE telephone service over the new Madrid-Buenos Aires radio link was officially inaugurated on October 12th, 1929. This date was peculiarly fitting for a ceremony of this nature, since it marks the "Fiesta de la Raza," on the occasion of which the Spanish speaking peoples on both sides of the ocean celebrate their common racial origin. On this day many high officials of the Spanish Government and diplomatic representatives of the Latin-American republics had gathered at Seville to take part in celebrations organized in connection with the Ibero-American Exposition, held in this historic city.

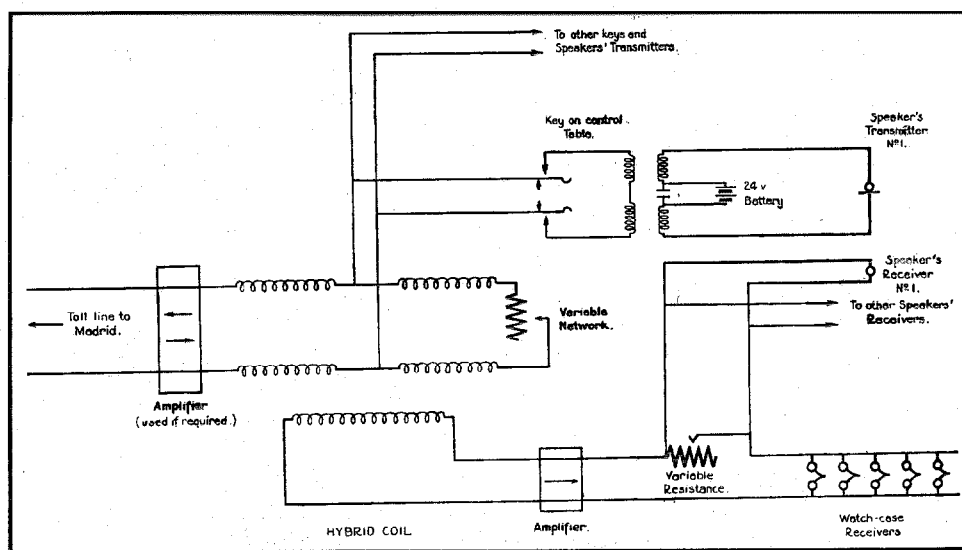
The programme of the inaugural ceremony involved an interchange of greetings between speakers in Seville and Buenos Aires, followed by similar conversations between Seville and Montevideo (Uruguay). Arrangements were also made so that a considerable number of guests in Seville, Buenos Aires and Montevideo could listen to the conversations of the speakers.

The set-up at the Spanish end of the radio link involved the use of four telephone circuits

between Madrid and Seville which were employed in the following manner:

Two carrier telephone channels were extended in Madrid from the toll test board to the technical operator's position in the radio terminal room. From the toll test board in the Seville toll office these circuits were extended over pairs in the trunk cable to the control table located in the Exposition sub-exchange, about one and a half miles from the toll office, where the demonstration was held. One of these circuits was used to extend the radio communication for the speakers; and facilities were provided at the control table in Seville and at the technical operator's position, so that in case of trouble on this circuit the communication could be switched instantly to the second.

In addition to these two circuits, which may be designated respectively as the regular and relief talking circuits, two order wires were established, using physical toll circuits. One of these order wires was set up to connect a telephone located on the control table at Seville directly with the Madrid technical operator's



Partial schematic of the Spain-Argentina-Uruguay telephone service.



Headquarters of the United River Plate Telephone Company, Ltd., Buenos Aires, where press representatives and Company officials participated in the inauguration of Spanish-South American telephone service.



Seville.—Presiding table at the opening of the transatlantic telephone service Spain-Argentina and Spain-Uruguay. From left to right: Mr. Lewis J. Proctor, Executive Vice-President; His Excellency Daniel García Mansilla, Argentine Ambassador to Spain; General Miguel Primo de Rivera; H. R. H. the Infante Don Carlos, Military Governor of Seville; His Excellency Cardinal Ilundáin, Archbishop of Seville; His Excellency Benjamín Fernández y Medina, Minister of Uruguay to Spain, and Mr. José Cruz Conde, Director of the Ibero-American Exposition.

position, and was also bridged in to the Madrid toll test board. This circuit was used by the engineers in charge of the control table and the technical operator's position, to coördinate the connection and switching of the talking circuits.

The other order wire was set up between the toll test board at the Seville toll office and the Madrid toll test-board, and during the demonstration attendants were bridged across this line at Córdoba and Ciudad Real, where the repeater stations on the Madrid-Seville toll lead are located. The object of this circuit was to facilitate maintenance of the talking circuits during the course of the demonstration, and was used for giving directions to the attendants at the above mentioned repeater stations.

The equipment installed at the Exposition

sub-exchange in Seville, where the demonstration was held, consisted of seven desk type telephones of the latest International Standard Electric design for use by the speakers, and a bank of 75 watch-case receivers for the guests. The transmitters of the speakers' telephones were wired individually to the control table and arranged so that the engineer in charge of this position could connect any one of them at will to the talking circuit, thus eliminating any possibility of interruption to the speeches. The receivers of the speakers' telephones were connected in the same circuit as the watch-case receivers and the entire receiver bank was arranged so that the talking circuit could be connected to it at the control table through an amplifier. The gain of this amplifier was regulated from the control table.

The manner of connecting the receiver banks and the speakers' telephones to the talking circuit is indicated in the circuit schematic. It is evident that with this arrangement the volume levels in the different parts of the circuit could be adjusted independently. It was considered desirable that the guests using the watch-case receivers at Seville should hear the local speakers at a volume level equal to or slightly less than that of the incoming speech, and this condition was easily secured by regulating the impedance of the terminating network to a point which would give just sufficient unbalance in the hybrid coil to provide the desired level in the receiver bank when one of the speakers' transmitters was in use.

The receivers of the speakers' telephones were

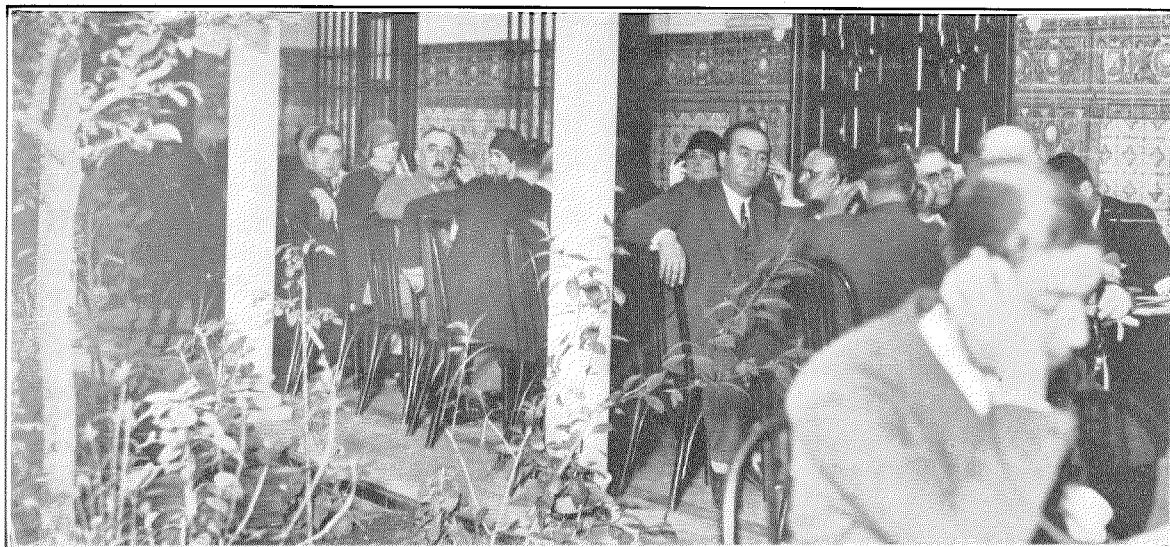
connected across a variable resistance in the manner shown, instead of being connected directly in parallel with the watch-case receivers, so as to compensate for the lower impedance of these receivers as compared with the watch-case receivers.

At the South American end of the link the set-up was more complicated, since in Buenos Aires the guests and speakers were divided into two groups located in separate buildings and, in addition, arrangements were necessary for extending the communication to Montevideo on the termination of the inaugural ceremony at Buenos Aires.

The main control table was located in the radio terminal room in the toll office of the United River Plate Telephone Company, Limited,



Official opening of the telephone service between Argentina and Spain.—Government House in Buenos Aires. From left to right: standing, Messrs. Valenzuela, Assistant Secretary of Foreign Relations; Benard, Manzano and Auzón. Seated, His Excellency the Minister of Foreign Relations, Dr. Horacio Oyhanarte; His Excellency the Minister of the Interior, Dr. Elpidio González; His Excellency the Spanish Ambassador, Mr. Ramiro de Naeztu. Seated, with their backs to the camera: Dr. Alfredo Martínez and Mr. Alejandro Funes Lastra, Assistant Director of Posts and Telegraphs.



Patio of the pavilion of the Compañía Telefónica Nacional de España, Ibero America Exposition, Seville, at the opening of the Spain-Argentina-Uruguay Telephone service.

in Buenos Aires, and provision was made for connecting either individually or simultaneously to the demonstration set-ups in Buenos Aires and Montevideo.

The Argentine and Spanish officials who took part in the demonstration were gathered at the Casa Rosada, or Government House, in Buenos Aires, where four telephones and sixteen watch-case receivers were installed for their use. The President of the Buenos Aires Press Association who was one of the speakers on the programme, and the majority of the guests, met at the Telephone Company's headquarters building where one hundred watch-case receivers were provided in addition to the speakers' telephones.

For the inaugural ceremony with Uruguay, sixty watch-case receivers were installed in the Government Palace at Montevideo, together with the usual arrangements of control table and speakers' telephones.

The circuit connecting Montevideo with Buenos Aires was one of those recently provided to give telephone service between the two capitals. This communication consists of a submarine cable some fifty kilometers in length, between Buenos Aires and Colonia, connecting at the latter point with land lines to Montevideo. The distance from Colonia to Montevideo is 223 kilometers, making the total length of the Buenos

Aires-Montevideo circuit almost three hundred kilometers.

The switching operations and maintenance of circuits involved in the demonstration were controlled by means of an order wire connecting the Government House, the demonstration room in the Company building, and the radio terminal room in Buenos Aires with the Colonia repeater station, and the toll office and Government Palace in Montevideo.

The ceremony was scheduled for 6 o'clock, Greenwich time, on the afternoon of October 12th. Shortly before this hour the communication was established, and the engineers in charge of the control tables at Seville, Buenos Aires and Montevideo conversed with each other and made final tests of the entire circuit set-up.

At the appointed hour the speakers and guests were seated in their places and the circuit was connected in Seville and in Buenos Aires to the telephones of the masters of ceremonies at the speakers' tables. Mr. Proctor, Vice President of the International Telephone & Telegraph Corporation, acting as master of ceremonies in Seville, opened the demonstration by addressing Captain Rock, Secretary of the International Telephone & Telegraph Corporation, who was acting as master of ceremonies at Buenos Aires, in the following terms:

"Good afternoon, Captain Rock; this is Seville, Mr. Proctor speaking."

Captain Rock answered:

"Good afternoon, Mr. Proctor; this is Buenos Aires, Captain Rock speaking."

Mr. Proctor then continued:

"Captain Rock, I am greeting you in the presence of His Highness the Infante Don Carlos, General Primo de Rivera, President of His Majesty's Government, His Eminence the Cardinal Archbishop of Seville, and other distinguished guests."

Captain Rock replied:

"I greet you in the presence of His Excellency Dr. Elpidio Gonzalez, Minister of the Interior of the Argentine, Dr. Horacio Oyhanarte, Minister of Foreign Affairs, and other distinguished guests, and I now have the honour of turning over the circuit to His Excellency the Minister of the Interior."

At this point the engineers at the control tables switched the circuit to the proper telephones, and General Primo de Rivera addressed the Argentine Minister of the Interior who replied in turn. Speeches were then exchanged between General Primo de Rivera and the Spanish Ambassador in Buenos Aires, the Argentine Ambassador to Spain and the Minister of Foreign Affairs of Argentina, and the Director of the Seville Exposition and the President of the Buenos Aires Press Association.

Before each of these speeches the circuit was connected to the telephones of Mr. Proctor and Captain Rock, who introduced the speakers.

Following the exchange of speeches between the Director of the Seville Exposition and the President of the Buenos Aires Press Association, Mr. Proctor again spoke, declaring that the inaugural ceremony for telephone service between Spain and the Argentine was finished and that this service would be open to the public as soon as the inauguration ceremony with Uruguay had been effected. Mr. Proctor concluded his remarks by requesting Captain Rock to extend the circuit to Montevideo. Captain Rock replied that he would immediately have the circuit extended to Montevideo.

At this point the circuit was switched through from Buenos Aires to Montevideo and so quickly was this operation effected that many of the

listeners were taken by surprise when they heard Mr. Hodges, acting as master of ceremonies in Montevideo, say:

"Good afternoon, Mr. Proctor, this is Montevideo speaking."

This second ceremony was effected in a manner exactly similar to the first, speeches being exchanged after introductions by Mr. Proctor and Mr. Hodges, between the President of the Spanish Government, General Primo de Rivera, and the Minister of Foreign Affairs of Uruguay, General Primo de Rivera and the Minister of Spain in Uruguay, the Minister of Uruguay in Spain and the Minister of Foreign Affairs of Uruguay, and finally the Director of the Seville Exposition and the President of the Press Association of Montevideo.

Mr. Proctor and other Telephone Company officials present received most cordial greetings from all of the high officials and other guests on the success of the demonstration, the precision with which it had been executed, and the remarkable clarity with which the speeches in both directions had been heard.

Following the ceremony the service between Spain and the Argentine and Uruguay was declared open to the public and an opportunity was afforded to the various representatives of the press who were among the guests at Seville, Buenos Aires and Montevideo to converse over the circuit. These conversations continued for a considerable time and the speakers were enthusiastic in their praise of the facility which this radio telephone link affords them.

Since the demonstration, the circuit has been available for commercial traffic. The operating method followed is somewhat similar to the despatch method, there being a line operator and two report operators at each end of the circuit. The line operators remain cut-in on the circuit at all times. Between conversations they pass orders and reports over the circuit and they are responsible for connecting subscribers to the circuit in turn and timing the conversations. The timing is done by means of a stop-watch and allowance is always made when the subscribers have any difficulty in understanding one another.

The report operators occupy positions adjacent to the line operator on the left and right and are

responsible for passing reports to the subscribers and preparing them for connection to the circuit.

Up to the present this service is available only to Spain, the Argentine, and Uruguay, but it is planned before long to extend the service to other countries in Europe and South America.

The importance of this telephone link can readily be appreciated when one considers the extensive commercial relations existing between Spain, Great Britain, France and other European countries on the one hand and the great republics of South America on the other hand.

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