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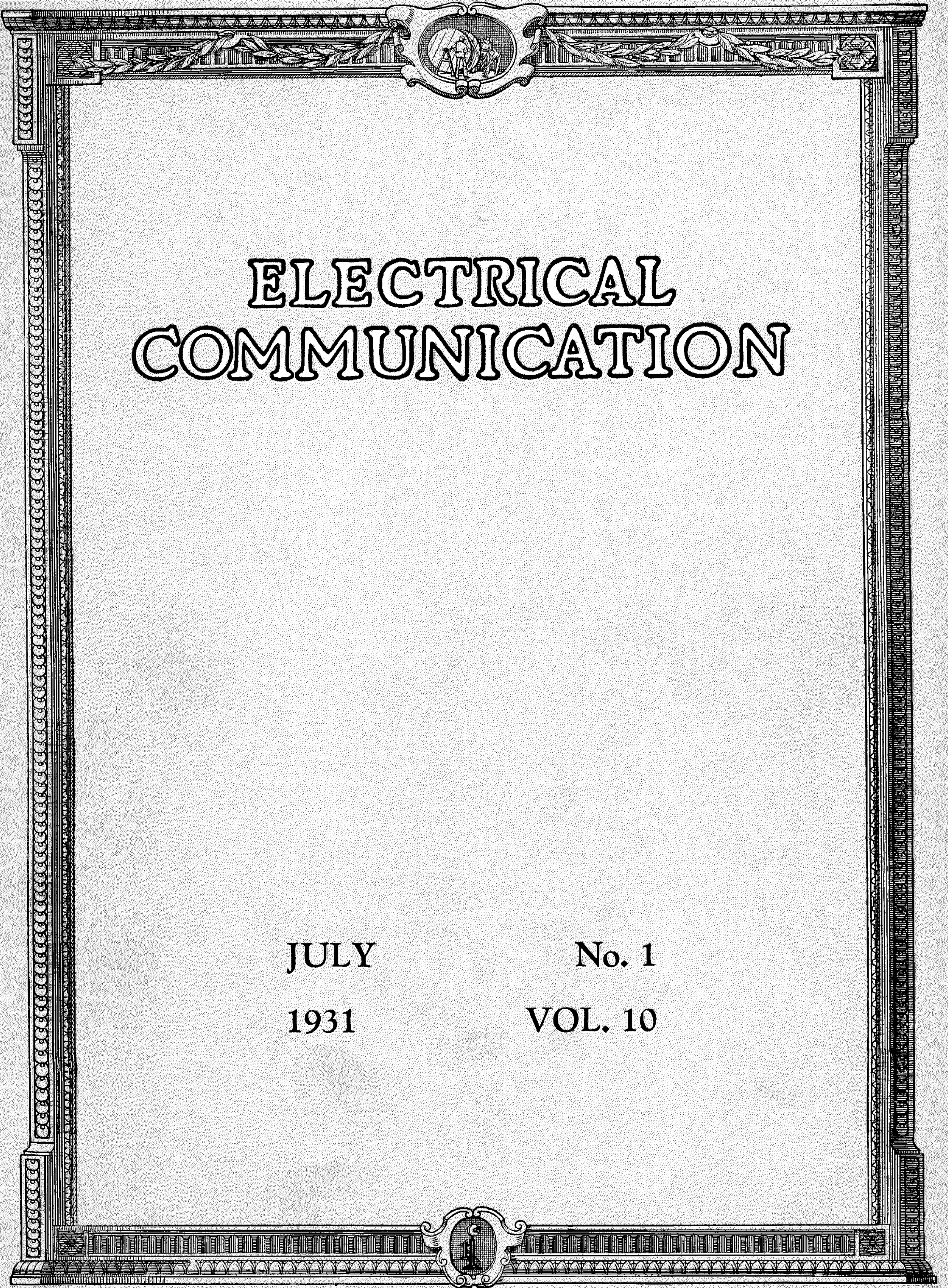

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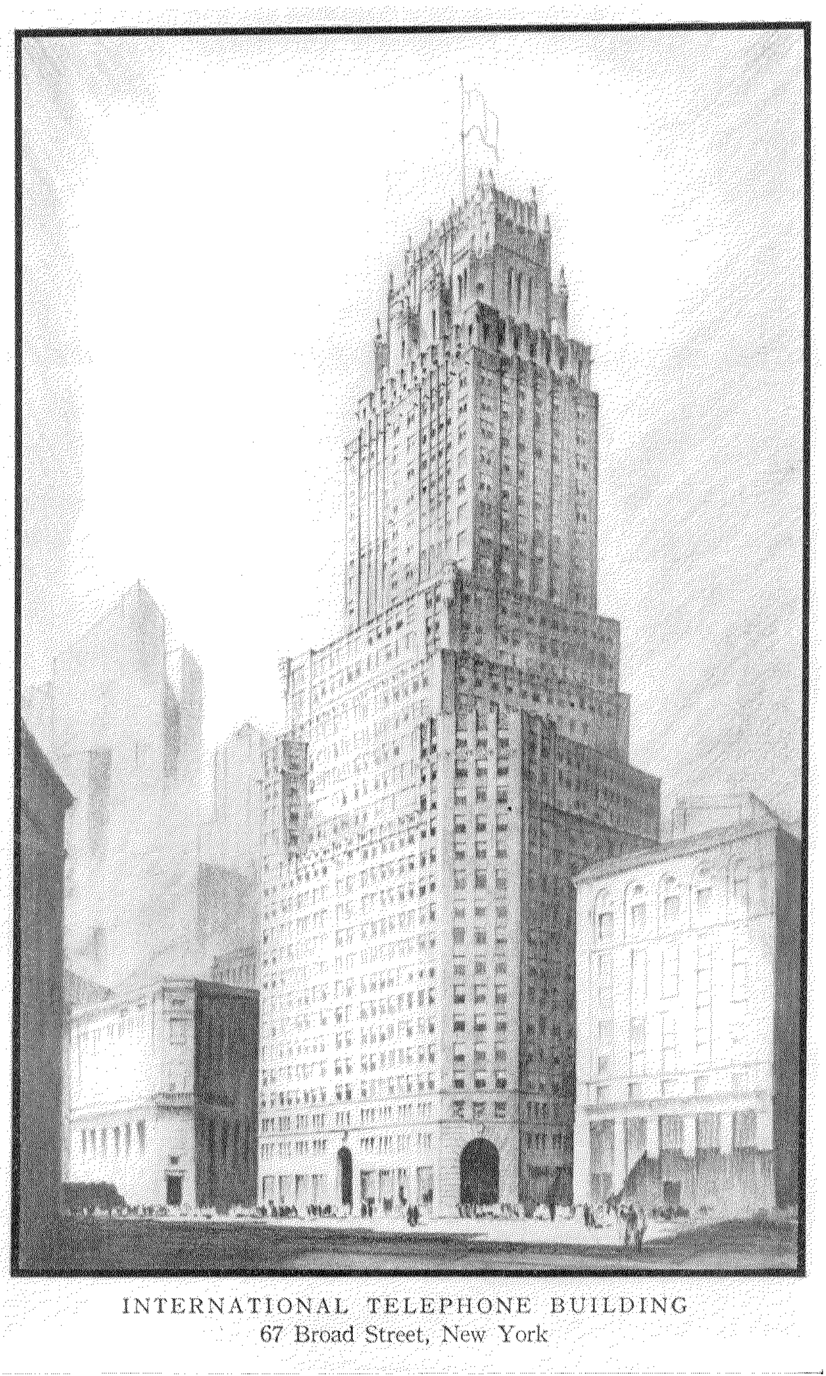


INTERNATIONAL TELEPHONE BUILDING
67 Broad Street, New York

The Single Side-band System Applied to Short Wavelengths

By A. H. REEVES

General Advantages of Single Side-band

THE theory of the "single side-band" principle of telephony was worked out by John R. Carson some years ago, and was first applied to carrier communication on wire lines, its chief advantage in this connection being that twice as many speech channels can be put into the same total band width as when using direct modulation with both side-bands. Since that date it has also been applied with considerable success to radio telephony on long wavelengths, in particular to the long wave New York-London commercial telephone circuit. It is, in fact, difficult to see how this circuit could be operated successfully without using the single side-band method, since, on long wavelengths, it would be a matter of some difficulty to obtain an antenna resonance curve passing both speech side-bands.

In radio work the halving of the band width given by the single side-band system assumed considerable importance as soon as the ether began to get crowded. An additional advantage for radio work is the increased efficiency due to suppressing the carrier and one side-band.

With the high power vacuum tubes now in use, at any rate of the water- or oil-cooled types, the factor limiting the transmitter output is the peak current or peak voltage on the plates of the tubes in the last stage of the transmitter. When this condition applies, it can easily be shown that, for a given peak power, an antenna gain in signal-to-noise ratio of at least 9 decibels is obtained by using the single side-band system, as compared with the use of transmitted carrier and two side-bands. A short analysis showing this result is given in Appendix I.

A further advantage, important in the case of a high powered transmitter, is the reduction of the power consumed when the carrier is suppressed. In the case of the low power modulation system, followed by stages of high frequency amplification, the last amplifier stage at least is usually of the class-3 type, i.e., the tubes in the last stage are biassed nearly to "cut-off." The anode currents in these tubes, therefore, are quite small in the absence of modulation, rising to peak values at intervals during speech, giving an average power consumption considerably less than that of the transmitted carrier method, where the anode currents do not change during modulation.

Difficulties of Application to Short-wave Work

The single side-band method has never yet been applied commercially to short wavelengths. The reason for this delay in what might seem to be an obvious application of the older art to the wavelengths now in use is probably twofold. In the first place, at any rate until recently, the saving of band width has not been a very important consideration on short wavelengths, as the total band width available at frequencies of the order of 10 to 20 megacycles is many times greater than that which was available on the long wavelengths.

The second reason has probably been the technical difficulty of obtaining local oscillators to re-supply the carrier frequency at the receiver in a sufficiently good state of synchronism with the suppressed carrier at the transmitter. If the re-supplied carrier frequency differs from the original carrier by more than about 20 cycles per second, noticeably bad quality—even when judged by the standards of "commercial" speech—inevitably results. At frequencies of the order of 60 kilocycles per second the synchronising problem presents no difficulty, necessitating merely a precision of one part in 3000. Any good local oscillator will give this stability of frequency quite easily over fairly long periods of time.

When the short-wave case is considered, however, it will be seen at once that the problem is much more difficult. On a wavelength of 15 metres the precision required amounts to one part in one million, a degree of frequency stability quite difficult to obtain on a "commercial" basis, even when using the most modern methods. It is, in fact, this synchronising problem which is the chief technical difficulty to be overcome in applying "single side-band" to short waves.

Advantages in Short-wave Work

Let us now consider some further advantages possessed by the single side-band method when used on short wavelengths which do not apply to the older long-wave case.

FADING

Short-wave fading may be divided roughly into two types:—

(1) Synchronous fading, in which all frequencies throughout the particular band width rise and fall simultaneously in amplitude.
(2) Selective fading, where the rise and fall in amplitude at the various frequencies in the range is more or less random.

With synchronous fading, without a local carrier oscillator, the extent of the resulting fade of the audio frequencies is double that when a local carrier oscillator is used, the fading being expressed in decibels. (This can easily be seen by referring to the expression for the audio voltage given in Appendix I.) This is a fairly important advantage, though not so great as it might at first appear. Modern practice in short-wave receiver design is such that the synchronous fading is already very largely taken care of by the use of some kind of automatic gain control. The effect of such a device, operated automatically by the carrier amplitude, is to change the gain of the receiver inversely with respect to the signal strength received, so that the resultant speech has a very nearly constant strength.

With an efficient automatic gain control practically the only noticeable effect of synchronous fading (except when it is very deep) is a change in the strength of the background noise. This noise fluctuation may, however, prove quite troublesome to a listener, so that the carrier suppressed system, which halves this noise fluctuation, has an advantage in this respect.

DISTORTION

It is, however, during selective fading that the suppressed carrier method gives the most noticeable improvement. By the older method the carrier frequency fades out almost completely for intervals of time sometimes approaching half a second, while the side-bands remain. The output of the speech detector, being intermodulation products of all the frequencies at the detector input, then shows second harmonics and other terms which may be considerably stronger than the fundamental speech frequencies. The resultant distortion is sometimes quite serious, this bad effect being most noticeable when some type of privacy system involving a frequency inversion is used.

This will be made clear by reference to the following example: Take the case of a simple inversion system in the range 300 to 3,000 cycles per second, in which 300 cycles is transmitted as 2,700, and vice versa. Consider a speech component at 1,900 cycles per second; after inversion we shall have 1,100 cycles, with which the transmitter will be modulated. In the receiving detector, when the carrier fades out selectively, the second harmonic at 2,200 cycles may be much stronger than the fundamental at 1,100; this resultant 2,200 cycles will be transformed into 800 cycles by the receiving inverter. We will have then at the receiving terminal a small fundamental frequency of 1,900 cycles, accompanied by a strong unwanted frequency at 800 cycles.

We must now take into account the fact that the ear seems to be disturbed much less by true harmonics or true intermodulation products of the original speech frequencies than by any other frequencies not having this relation. This effect is possibly due to the fact that the ear itself produces true intermodulation terms, and as the response of the ear is logarithmic, a few more harmonics do not have much effect. However this may be, experiment shows that any system producing undesired frequencies not having true harmonic relationship with the original speech, causes such noticeable distortion that a simple inversion system cannot be used successfully on short-wave radio links when there is serious selective fading.

It may be of interest to note here that to overcome this difficulty on the Madrid-Buenos Aires link, the International Telephone and Telegraph Corporation abandoned the simple inversion system, and is now using instead a displacement of the side-bands by 3,000 cycles away from the carrier. By this method the original amount of secrecy is maintained, but the harmonics and intermodulation terms produced in the receiving detector and elsewhere are no longer in the audible range. Displacing the side-bands in this way, while giving reasonable privacy with good quality, has the disadvantage of requiring double the usual band width.

The same remarks also apply to any secrecy scheme, in which frequencies are produced in the output of the receiving detector.

Increased Selectivity

A further problem which is not solved by the single side-band method itself, but which is easily solved at the same time, is that of increasing the selectivity of the receiver approximately to the theoretical limit. In order to receive the side-bands at "commercial" speech quality on the double side-band system, it is necessary, on theoretical grounds, to transmit and receive a band width of slightly less than 6 kilocycles. To receive the whole of this band, and this band only, requires, of course, a good stability of the transmitted carrier frequency and equal stability, accompanied by very accurate tuning, of the receiver.

At present, the best commercial receiver is designed for a band width of about 8 kilocycles, a margin of 1 kilocycle on each side of the transmitted band being necessary to allow for slight frequency changes in the transmitter and slight changes of tuning at the receiver. There are many commercial short-wave receivers in use, moreover, of which the band width is nearer to 12 or 15 kilocycles. It is true that this increase of band width does not appreciably increase the receiver background noise level, as the only noise needing consideration, as mentioned above, is that due to the noise impulses beating with this carrier; and the impulses spaced more than 3 kilocycles from the carrier produce audio frequencies which can be cut out at a later stage by introducing a low pass filter. Reducing the band width to the theoretical limit, however, may greatly reduce interference due to other stations, and thus make possible closer spacing between adjacent channels.

Interference with Adjacent Channels

Another advantage of the single side-band system is that the interference due to a side-band on receivers tuned to adjacent channels is less noticeable, in general, than the steady beat notes produced by neighbouring carriers.

Extra Gain When Selective Fading is Present

Lastly, as pointed out in Appendix I, during selective fading conditions a further gain in signal-to-noise ratio of up to 3 db. is frequently obtained.

A Commercial System

The object of this article is to describe one of the possible single side-band systems for use on short wavelengths, and to describe experiments carried out by the International Telephone and Telegraph Laboratories in conjunction with the Laboratories of Le Matériel Téléphonique, Paris, during the past year with this system, between the International Telephone and Telegraph Commercial Transmitting Station at Pozuelo del Rey, near Madrid, and an experimental receiving station at Trappes, near Paris. It is not claimed that the system to be described is by any means the only possible one, or indeed, that it is necessarily the best system for commercial telephony. Only the future can determine the relative merits of the various possible methods. It is claimed, however, that a commercial system has been worked out, and that the results so far obtained have been sufficiently successful for a fairly detailed description to be of interest.

A short general survey of the problem encountered will first be attempted, together with reasons for choosing, as a first experiment, the particular method detailed below. It is believed that in these experiments, synchronisation of the locally supplied carrier has, for the first time, been achieved automatically and for long periods of time. There are certain problems encountered in single side-band working which do not arise with the normal double side-band, transmitted carrier method, such as the reduction of unwanted frequencies, due to intermodulation in the transmitter to a sufficiently small value; these difficulties, however, are well known, and have already been studied during the single side-band work on long waves. For this reason, they will not be referred to in detail here. The fundamental new problem presented by short-wave single side-band is that of synchronisation, which, as already shown above, is not a difficult matter with long wavelengths, but with wavelengths of the order of 15 metres, presents a serious problem.

The Problem of Synchronisation

Independent Oscillator Methods

There are two means of attacking the general synchronising problem. The first is to use at the transmitter and the receiver, independent oscillators of which the frequencies are so stable that when once they are adjusted to differ by only one part in a million, they will maintain this relation for comparatively long periods of time. This method, although by no means impossible, raises a somewhat difficult design and operating problem, even if the most modern means are employed.

It is true that by using the best modern quartz crystal oscillators, with accurate temperature control, this frequency stability has been obtained and even exceeded in the laboratory, but it is quite a different matter to maintain this high accuracy under the conditions of commercial operation. The same remarks apply to the other available frequency standards of high precision, *e.g.*, magneto-striction oscillators, tuning forks, oscillators automatically controlled by precision clocks, and the best purely electrical oscillators, accurately compensated for frequency changes. A solution is probably possible by all these methods, but it is not considered that such solutions would be convenient from a commercial standpoint.

Pilot Methods

The second general method is by the use of some form of pilot signal transmitted in addition to the side-band and used automatically to synchronise the carrier supply oscillator at the receiver.

Let us consider in detail the possibilities of this method. Pilot signals may be divided into two classes:

(1) A pilot signal transmitted only during intervals when speech is absent.
(2) A continuously transmitted pilot signal.

The first type permits the use of the maximum energy supplied by the transmitter for the signal, but has the serious disadvantage that the resulting intervals during which there is no pilot may be longer than the minimum interval required to give the desired frequency control.

Any signal in the second category must fulfil two conditions:

(1) The peak voltage must be small compared with the peak voltage of the side-band; otherwise the available power in the side-band is appreciably reduced, and one of the chief advantages of the single side-band method begins to be lost.
(2) The presence of the pilot signal must not appreciably increase the band width required by the side-band.

We have, then, two classes of pilot signal fulfilling these conditions:

(*a*) A pilot signal at low frequency, by which is meant either a continuous wave modulated at low frequency, or two or more continuous waves beating together at a low frequency used as a synchronising signal.

In the term "low frequency" is included here the frequency given by a train of impulses. The resulting low frequency may be used in a number of ways, *e.g.*, an appropriate harmonic of the L.F. may be used as the required carrier, or the beat note may be used to drive a synchronous motor generator, the output frequency of which is suitably multiplied, and supplies the local carrier; but whatever method is used, the stages of frequency multiplication required make this system rather cumbersome for operating conditions, and furthermore, a small phase change in the low frequency gives some hundreds of cycles change in the high frequency. Also, a beat note dependent on the product of two or more transmitted continuous waves is more subject to synchronous fading than is a high frequency control signal.

(*b*) A pilot signal, consisting of one or more continuous waves of radio frequency, used directly to give or control the desired local carrier.

The continuous wave or waves may conveniently be at a frequency just outside the side-band, *e.g.*, 300 to 400 cycles on either side of the speech side-band. Or, if desired, a little of the original carrier may be transmitted, and used as the pilot signal. In any case, however, the peak power in the pilot signal should be at least

15 db. below the peak power of which the transmitter is capable. The utilisation of a signal of such weak power is not difficult from a signal-to-noise standpoint, owing to the fact that the signal is of one or more steady frequencies; circuits of very small band-widths may, therefore, be used to select them.

The band-width required for the side-band is about 3,000 cycles; but when choosing the band-width necessary for the pilot channel we have only to consider the maximum probable sudden fluctuation in transmitted frequency, *i.e.*, the fluctuation during the period in which the synchronizing circuit has not had time to take up this new stable position. A sudden fluctuation of 15 cycles per second is probably an outside limit, therefore, in the case of a reasonably good transmitter, so that the band-width required for the pilot signal is of the order of 30 cycles per second, *i.e.*, just one hundredth of the range required for the side-band.

As is pointed out in Appendix I, other things being equal, the energy in the background noise is proportional to the band-width, so that the ratio of signal-to-noise energies in the case of a pilot signal at a level 20 db. below the side-band will be just the same as the signal-to-noise ratio of the side-band itself. As the latter ratio must be, say, 10 to 15 db. for reasonably good speech, it is evident that the pilot will also be received under conditions in which the background noise does not prevent its utilisation.

WAYS OF USING A PILOT SIGNAL

Some different possible ways of using such a pilot signal will now be considered. As is shown in the sketch of Fig. 1, the possible methods can again be divided into two classes:

(1) The selection, amplification and use of the pilot as the local carrier frequency, either dirctly in the case when some of the original carrier itself is transmitted, or by adding or subtracting the required audio frequency.
(2) The pilot may be used to synchronize a local oscillator.

In considering the relative merits of these two methods, an inherent problem in short-wave work presents itself, viz., that of selective fading. Occasions will frequently arise when any one given frequency will fade out below the noise level, for periods of time sometimes approaching half a second in length. Therefore, if only one pilot is used, some form of time constant must be added, so that the locally supplied carrier will continue at the desired frequency during the fading periods. In practice this has been found to be one of the chief difficulties in the whole problem. When using the pilot signal directly, this time constant must take the form of a resonant circuit of very low damping—extremely low, in fact, as the resonant time constant required must be greater than half a second. Such a resonant circuit is, of course, very difficult to obtain, even when quartz crystals are used as the resonant element.

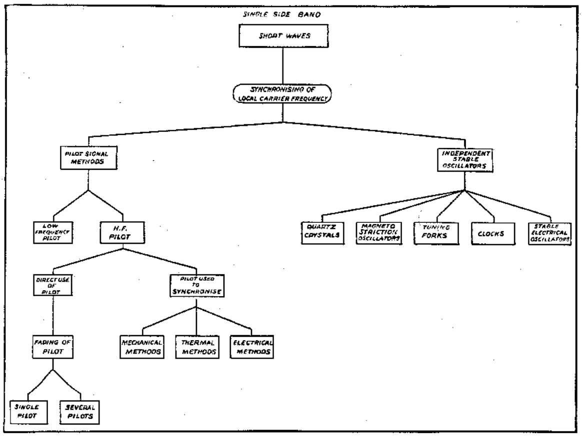
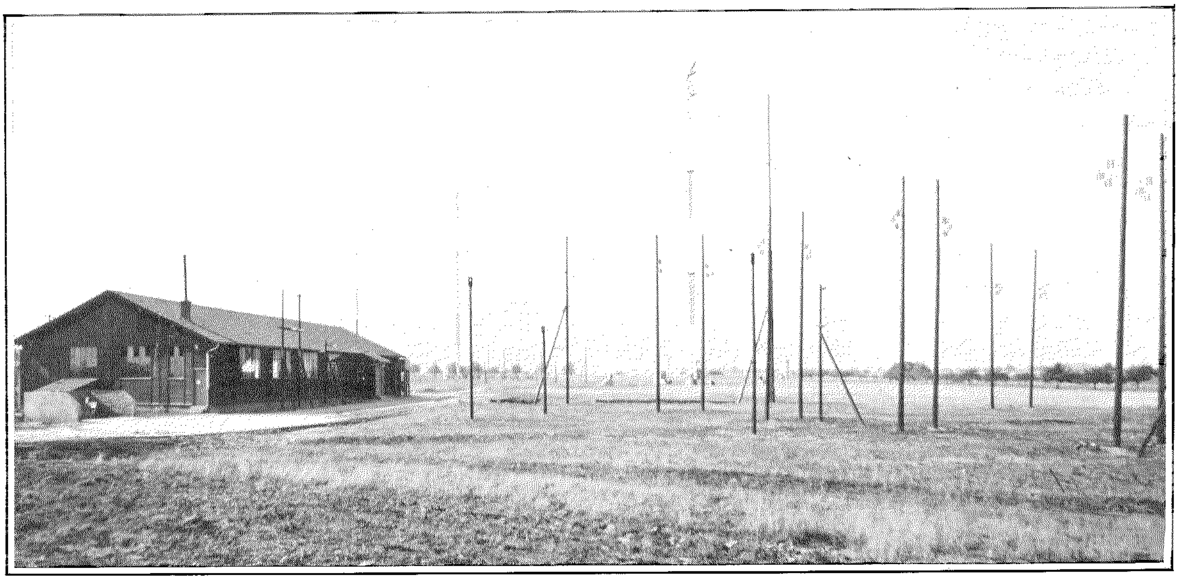


Figure 1

Even if such a resonant circuit were obtained, a large number would have to be used in parallel, with the resonance curves overlapping in order to cover the total probable fluctuation of the transmitted frequency. As this fluctuation must be assumed to be several hundred cycles in extent, and as the width of each resonance curve is less than half a cycle, it is clear that this solution becomes so cumbersome as to be impracticable.

Considerable improvement would, of course, be obtained by the use of two or more pilot signals, *e.g.*, two—one spaced at each end of the side-band. During selective fading these two pilots will only fade below the noise level simultaneously, at rare intervals, and for moments of very short duration. If arrangements are made, *e.g.*, by means of a relay, to use the greater of these two pilots to give the carrier, the time constant of the resonant circuit may



Radio Field Laboratory at Trappes. Antenna and Transmission Building.

be considerably reduced, but even then the solution is probably not a very practical one, at any rate whenever selective fading is present.

AUTOMATIC SYNCHRONISATION OF LOCAL OSCILLATOR TO THE PILOT

Let us now detail the second way of using a high frequency pilot signal, *i.e.*, by allowing it to synchronise automatically a local oscillator. In this case it is clear at once that the problem of the time constant is very much simplified. The possible methods logically divide themselves into three classes:

(1) The methods relying on mechanical means.
(2) Methods using thermal effects.
(3) Purely electrical methods.

Before going into further detail we will consider the general applicability of the three methods. In comparing their relative merits, the first question that immediately arises is the value of the time constant required. This depends on whether one or more pilot channels are used; if one only is employed, the time constant of the frequency control circuit must be such, at any rate during the fading out of the pilot, that the oscillator frequency does not change more than 20 cycles during the maximum period of time that the fade is likely to continue—in this case about half a second. On the other hand the time constant must not be so long that it does not follow the fluctuations in the received frequency. These latter changes are due to two sources: first, accidental changes in the transmitter itself, and secondly, frequency changes due to the transmission path.

The first type of change with any transmitter having a good master oscillator is always very gradual; in fact, a rate of change of a few hundred cycles in one hour is the maximum that is tolerated by present practice. Let us take 10 cycles per second per minute as the upper limit for this rate of change. At present there is little data concerning the second type of fluctuation; however, it is probably quite rare for this change, due to rapid alterations in the length of the transmission path to exceed 10 cycles per second about its normal value, and for this change to take place in a period of time less than 1 to 2 seconds. Let us take 10 cycles per second as the upper limit of the rate of change of frequency, due to the transmission path. Inasmuch as the total frequency change due to this latter fluctuation rarely, if ever, exceeds 10 cycles per second we see at once that this effect may be neglected altogether from the standpoint of "commercial" speech. We may take, therefore, the rate of change of 10 cycles per second per minute as the maximum in practice that the time constant of the frequency control circuit must follow. While considering the other limit, the constant must be such that the frequencies can never change by more than 20 cycles in half a second.

It will now be clear that between these two limits an apparatus can be designed satisfactorily by any of the three methods, *i.e.*, mechanical, thermal, or purely electrical circuits. Some mechanical method, such as rotating a vernier condenser on the oscillator, in accordance with the frequency of the received pilot signal, is perhaps the most obvious solution. When comparing such a scheme with the other two methods it is difficult to see its superiority; in fact it has a number of incidental disadvantages, such as the noise pick-up in the receiver from relay clicks, motor noises, etc. It is probable also that the proper maintenance of such equipment by ordinary operators would be less satisfactory than the maintenance of a system working on either of the other two methods.

Let us consider next the thermal methods. One convenient way of doing this would be to cause the pilot frequency to change the temperature control point of the thermostat of the local oscillator, which in this case could be of the quartz crystal type. The thermal time constant obtained in this way could be given a suitable value in accordance with the two limits fixed above. Such an oscillator would have the advantage of extreme immunity from all changes of frequency, except the one desired. In many respects, in fact, such a thermal system has a lot to recommend it.

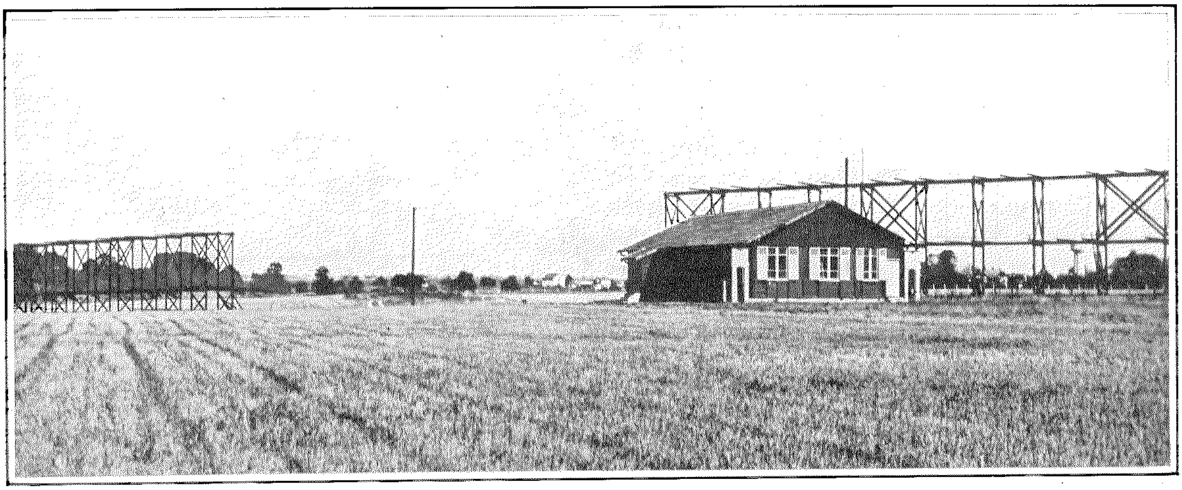
The frequency control can also be obtained fairly simply by purely electrical means, one of which, described in detail below, is the system used in the successful experiments which are now going to be discussed.

From the standpoint of "commercial" speech alone, the superiority of a purely electrical control method over the thermal system is doubtful. In the present case, the real reason that has governed the choice of system for preliminary experimentation is based on other considerations.

REASONS FOR CHOICE OF A PURELY ELECTRICAL METHOD

Considering the probable future development of radio during the next few years, it is almost certain that the single side-band method will be of utility, not only for commercial radio telephone links, but also for telegraphy, facsimile and television. It has been thought better, therefore, to start experiments on some system, the general methods of which will be applicable also at a later date to these other uses of radio.

In the case of these other applications it is not sufficient for the transmitted and received carriers to be synchronised with a precision of 20 cycles per second. This is true, of course, also, of high quality speech. For example, it is essential to avoid phase distortion, which can only be done by exact synchronisation of the frequencies and by keeping the phase variations between the two oscillators within narrow limits. This requirement at once rules out any method based on independent oscillators at each end of the link. It also practically rules out mechanical and



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thermal methods of using a pilot channel, as will now be explained.

In short-wave transmission, even when the signal is received by one path only, the phases of the side-band components are frequently distorted backwards and forwards about their normal values by this transmission path, which is not of constant length. If, however, reception by more than one route is prevented, the result is simply a variable "delay" introduced between the transmitter and receiver, *i.e.*, the phase distortion of each component is directly proportional to its frequency. Taking the case of a side-band 20,000 cycles wide in the range of 20 megacycles, this means that the phase change will be constant within 0.1 per cent. for all the side-band components and the pilot, and may be sufficiently compensated for by an equal phase correction at all frequencies. To achieve this result, it is necessary for the phase of the re-supplied carrier to follow the phase variations of the pilot signal.

These fluctuations may sometimes be quite rapid; hence it is essential under these conditions for the synchronising time constant at the receiver to be quite short, *i.e.*, of the order of a small fraction of a second—a time constant value very difficult, if not impossible, to obtain by a mechanical or thermal means. By electrical methods, however, it is comparatively simple to make the value of the time constant very flexible. It is probably quite easy to have it short enough to follow all variations met with in practice.

Although the system used by the International Telephone and Telegraph Laboratories, and described below, is not one of exact synchronisation, it is a purely electrical method, which can be changed at a later date when required, in order to synchronise exactly. Another desirable feature is for the time constant to be variable when following exactly the fluctuations of phase and frequency. Due to the transmission path, the constant must be quite short, but on the other hand during the fades-out of the pilot signal the time constant must be long enough for the oscillator to maintain its frequency and phase within the required limits. Clearly this can only be carried out by means of a time constant, the value of which is varied automatically during these fades-out. This particular feature is only obtainable at all easily by purely electrical methods.

By a mechanical means, we could, of course, make the time constant longer or infinite during the fades, *e.g.*, by cutting off the mechanical control of the tuning condenser altogether by means of a clutch; but such devices operate relatively slowly, and in any case, as stated above, the time constant cannot easily be made short enough by such means when the level of the pilot signal is high. It is very difficult to conceive of a simple way to vary the time constant by thermal methods.

Some Purely Electrical Methods

Let us next consider several possible purely electrical ways of changing the oscillator frequency or phase. Perhaps the most obvious solution is to use an iron core oscillator for changing the frequency by partially saturating the core. This method, however, is not suitable except at comparatively low frequencies.

A second possible means is to use the phenomenon possessed to some extent by any electrical oscillator, *i.e.*, a change of frequency with change of grid bias. By this method, however, it is difficult to obtain more than a very small frequency change. The third method, the one used in these experiments, is illustrated in Fig. 2.

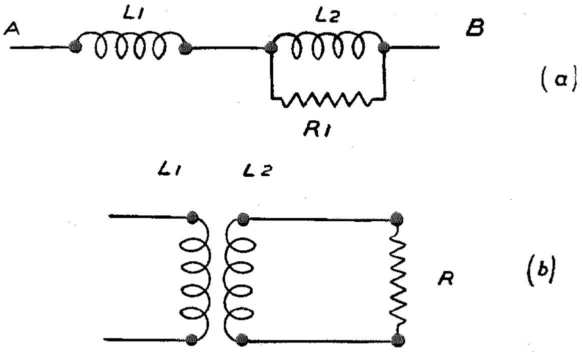

Figure 2

In 2 (*a*) a small inductance, shunted by a resistance, is connected in series with another inductance. It is clear by referring to Appendix II that the total effective inductance of the combination between points A and B depends on the value of the resistance. The same result applies, of course, to the circuit of 2 (*b*), except when the coupling between L-1 and L-2 is unity. When L-1 is the tuning inductance of a triode oscillator, the frequency of this oscillator will depend on the value of R. The resistance R may now be replaced by the plate-filament resistance of a second triode, in which case the oscillator frequency may, in general, be varied by changing the grid volts of the triode. It is this latter method that has been found the most convenient in practice in the experiments here described. A control triode of low plate resistance (about 2,000 ohms) is employed, and using a mean frequency of 500 kilocycles, a change of plus or minus 5% can easily be obtained.

The next question arising is how much frequency change is required. The answer to this depends, of course, on the degree of stability over fairly long periods of time (*e.g.*, 3 or 4 hours) of the transmitted frequency, and the average frequency of the receiving oscillator itself. If a quartz crystal be used to stabilise the first beating oscillator of the receiver (assumed to be of the superheterodyne type), and taking a reasonably good transmitter, experience has shown that a range of about plus or minus 3 kilocycles is sufficient to take into account the worst case. If the intermediate frequency in the receiver (or the first intermediate frequency in the case of more than two detectors) be taken as 500 kilocycles, this gives a necessary range for the oscillator variation of plus or minus 0.6 per cent. It is clear, then, that the control method explained above gives a range which more than amply fulfils the requirements.

DETAILS OF SYSTEMS ADOPTED

The frequency changing triode referred to above must now be controlled by the frequency of the pilot signal. The method of control, of course, depends on whether exact or approximate synchronisation is required. In these experiments the approximate case only has so far been attempted, and the circuit used for this is shown in its simplest form in Fig. 3. "A" represents the high frequency amplifier, first beating oscillator, first detector and first intermediate amplifier of the receiving set.

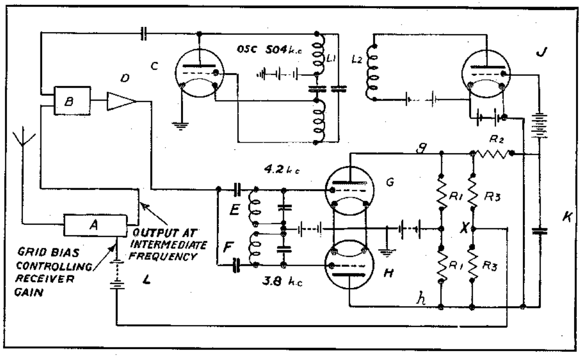

Figure 3

The resulting output at 500 kilocycles is applied to the rectifier B in combination with a little of the output of the synchronised oscillator C at which the average frequency is set (504 kilocycles); the output of rectifier B is passed through the low frequency amplifier D which has a resonance point at 4 kilocycles. The output of D is coupled loosely and equally to the two circuits E and F, tuning to 4.2 and 3.8 kilocycles respectively. The latter tuned circuits are connected as shown to the grids of the balanced rectifier system GH. The resonance curves of E and F are adjusted so that at exactly 4 kilocycles the losses due to the two circuits are equal and at a value of about 8 db. greater than the losses at the resonance points. If, then, the frequency of C is exactly 504 kilocycles, equal voltages will be applied to the grids of E and F, thus giving zero potential difference between the two plates of G and H.

When C differs from the incoming pilot by exactly 4 kilocycles, the potential difference between the plates of G and H is applied between the grid and filament of the control tube J, the plate coil of which is coupled to the resonant circuit of C. Assume now that for some reason the beat note between C and the pilot signal becomes slightly greater than 4 kilocycles; the plate current of rectifier G will now exceed that of H, thus increasing the negative grid bias on tube J, raising its plate resistance and hence lowering slightly the frequency of C—by this means tending to restore the beat note between C and the pilot to its original value of 4 kilocycles.

The essential principle of the synchronising action will now be evident; in practice it has been found easily possible by means of this circuit to cause the oscillator C to follow variations of the pilot signal amounting to plus or minus 5 kilocycles, the resulting beat note never differing by more than 20 cycles from the normal value of 4 kilocycles. Figure 3 also explains how the time constant is introduced into the frequency control circuit. The resistance R-2 is of the order of 5 megohms, and condenser K about 20 microfarads, giving a time constant of 100 seconds between impulsive voltage fluctuations across G H and the grid-filament of J.

Let us now consider another feature, shown in Fig. 3, which has been found essential to the successful operation of the system. It is, of course, impossible in practice for the characteristics of tubes G and H to be exactly similar; in other words, if the plate currents are exactly equal for one particular case in which the voltages across E and F are equal and at a certain level, the outputs of the rectifier tubes will not balance exactly when the voltage level on the grids is altered, although these two voltages may still be equal. Further, if exactly similar tube characteristics were obtainable, the exact balance condition between the two plate currents could never be used in practice. Some voltage difference is always necessary between *g* and *h* in order to give the desired frequency change on oscillator C.

If now the frequency remains unchanged, but the level of the pilot signal is changed, as occurs during fading, the potential difference between *g* and *h* will be changed correspondingly, with the resulting tendency to change the frequency of C; *i.e.*, the frequency of C will depend to some extent, not only on the frequency of the pilot signal, but also on its amplitude, a quite undesirable effect. To overcome this difficulty, due to the above two causes, an automatic gain control has been added. It is only necessary for a potential difference corresponding to the amplitude of the pilot signal (and not its frequency) to be used to control inversely the gain of the receiver in such a way that a very small change in this potential difference makes a considerable change in gain.

To achieve this result in the circuit of Fig. 3 the resistance R-3 is added, and the potential of the mid point X will be the average between that of *g* and that of *h*. When the beat is in the region of 4,000 cycles, therefore, at which point *g* and *h* change inversely and almost equally with frequency change, the voltage of X will depend almost entirely on the amplitude of the pilot and not on its frequency. X is connected to the battery L, which is used to counterbalance more or less the anode voltage of the rectifier tubes, thus providing a suitable controlling grid bias for one or more tubes of the receiver.

The gain control circuit is in fact very similar to that used to counteract the effects of fading in the normal double side-band type of receiver used by the I.T. & T. Corporation for short-wave work. By this means, when the pilot signal changes from a value only just above the noise level up to a level of 60 db. above this point, the 4 kilocycle volts applied to the grids E and F only change by about 10 per cent. The time constant of this automatic gain control circuit is made short enough to follow the most rapid type of fading met with in practice (neglecting, of course, the very rapid fading of more than twenty periods per second which sometimes occurs, but which is usually small in extent): a suitable value for this time constant has been found to be about one-twentieth of a second.

It is now evident that it is only when the pilot falls below the noise level that continuous control of the local oscillator is lacking. Taking the case when the pilot signal is reduced at the transmitter by 20 db. below the peak value of the side-band, and when conditions are such that the resulting signal-to-noise voltage ratio of the speech is of the order of 3 (a minimum value for a commercial circuit), the pilot at the receiver has rarely been found in practice to fall below the noise level for longer than one-tenth of a second, and as far as is known never longer than half a second. These figures, of course, are based only on results between Madrid and Paris covering a period of about five months and using a particular wave length (52 metres) with particular antenna systems at each end. It is thus difficult to say that the figures apply generally; this remains to be seen. The time constant of the frequency control circuit, made up of resistance R-2 and condenser K is sufficient to maintain the frequency of oscillator C well within the required limits during this worst case of fading lasting half a second.

Design of Complete Receiver

Having achieved sufficiently accurate synchronisation, the next question is the design of the receiver. It is clear that an ideal single side-band receiver should take account of the accurate frequency control available to reduce the band width passed by the speech circuits to the theoretical minimum of about 3 kilocycles. This can be done most conveniently by using the triple detection type of receiver, the first intermediate frequency being of the order of, say, 500 kilocycles, and the second intermediate frequency in the region of 50 kilocycles.

The first beating oscillator is controlled by a crystal, the second oscillator being controlled automatically by the pilot signal in such a way that the resultant second intermediate frequency never varies by more than 20 cycles. The band filters at 500 kilocycles have a margin of plus or minus about 4 kilocycles in addition to the width of the side-band plus pilot, thus giving a total band width of about 12 kilocycles; the final and high degree of selectivity is obtained by a band filter at the second intermediate frequency (50 kilocycles).

As the side-band frequencies at this stage have been properly stabilised, this second band filter can be accurately adjusted to cut off at exactly the points required to pass the side-band only. The receiver actually used in the tests described here is of such a design that the second intermediate frequency is, however, in the region of 20 kilocycles rather than 50, merely because 20 kilocycle apparatus was immediately available.

The next consideration in designing the complete receiver is the question of eliminating, so far as possible, the fading of the output speech. As has been remarked before, short wave fading may be divided roughly into two classes: synchronous and selective. During selective fading, in general, the average level throughout the whole side-band does not change considerably, and the gain of the receiver should, therefore, remain constant. When, on the other hand, synchronous fading appears, it is necessary to change the gain of the receiver inversely and, automatically to compensate for this.

Almost certainly the best method would be to use two or more pilot signals, *e.g.*, one placed on each side of the side-band. The average level of these two pilots will then give a good idea of the average level in the side-band itself, and, therefore, of the amount of synchronous fading present.

The frequency spacing of the two pilots may be so chosen that selective fading will not, in general, change their average very appreciably. If this latter average level were then used to control inversely the gain of the receiver used for the speech, it seems probable that the average speech output would remain substantially constant in most cases. This method, however, has not yet been tried out in the comparisons referred to. Another line of attack is based on the fact that, in general, selective fading is of short, and synchronous fading of longer, duration. If two separate automatic gain controls are used, one of very short time constant for the pilot channel only, as explained above, and the other of a time constant of the order of 30 seconds or more for the speech and the pilot channel, a fairly smooth speech level is found to result.

This type of smoothing is not perfect, however, as the assumption that the synchronous and selective types of fading have different time periods, is by no means always true. The outline of the complete circuit used is shown in Fig. 4. The constants are not, in every case, of the optimum values, but were determined by the apparatus that was immediately available.

The pilot signal used corresponds to a speech frequency of 3.47 kc. The reasons for this position of the pilot are two-fold:

(1) The maximum speech energy lies in the low frequency range below 500 cycles; it is, therefore, advisable to space the pilot as far as possible from these regions of maximum energy. In order to avoid an appreciable increase of band width, however, a distance of more than 400 or 500 cycles from one end of the side-band should not be exceeded.

(2) The audio output obtained in an ordinary receiver when listening to such a transmitter will give speech that is inverted and displaced by 400 cycles. Such an output is practically unintelligible, thus rendering the system private, although, of course, not secret, as an oscillating detector adjusted accurately at the correct frequency will always give straight speech. This latter objection, of course, also applies to any simple form of privacy system depending on inversion or displacement.

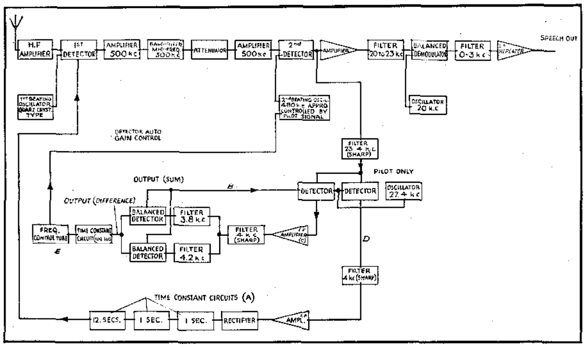

Figure 4

The pilot is normally at a level 20 db. below the overloading point of the transmitter. Owing to the very small band width used in the receiver for selecting the pilot, the resulting signal-to-noise ratio due to the pilot is about the same as that of the speech side-band, which is 10 or more decibels higher in level. It is thus easily sufficient to carry out any desired synchronising or gain-control processes. The necessary reduction of the peak value of the side-band to avoid overloading due to the presence of the pilot is very small (of the order of 0.1 db.) so that practically the full gain of the single side-band system is realised.

The automatic gain controls are similar to those already in commercial use in short-wave receivers developed by the Bell Laboratories and the International Telephone and Telegraph Corporation. The action consists simply of a rapid increase in grid bias voltage on a detector or amplifier in the earlier stage of the receiver whenever the D.C. output of the final detector to be controlled exceeds a predetermined limit. Such a change in grid bias reduces the gain of the tube in question until the final level is again at the correct value. In each case, between the output detector and the tube of which the gain is being controlled, there is inserted a time constant circuit of a value suitable to the particular function desired. The circuits A shown in Fig. 4 are built up in three sections in order to give a correct curve of output voltage against time, which is more suitable than can be obtained with a single section. The gains of the various detectors and amplifiers are adjusted so that the chief component of background noise in the final speech output is due to the grid circuit of the first high frequency amplifier; and the antenna is such that, except under unusual circumstances, the chief component of this first grid noise is caused by static. The same remark applies to the circuit of the pilot channel. The gains are such that, when no signal is being received, the static under conditions of minimum strength is beginning to affect the frequency control tube and also the two automatic gain controls. It is of no advantage to increase the gain beyond these limits, and it is evident also that this arrangement gives the best possible signal-to-noise ratio obtainable with the particular antenna used and under the given transmission conditions.

Synchronisation Limits

Even when receiving signals giving a final speech-to-noise ratio less than that required for a commercial circuit, but good enough for passing service messages, and even when the worst fading met with in practice is present, the pilot may still be kept 20 db. below the peak of the side-band, and the first intermediate frequency (500 kc. range) may change by about ± 5 kc. without changing the second intermediate frequency by more than 20 cycles. This limit clearly gives an ample margin. The transmitter frequency rarely changes by more than 1 kc. from its normal value, and a change of 2 kc. in the crystal beating oscillator is rare even when an accurate thermostat is not used.

The only other variable factor is the natural frequency of the 480 kc. oscillator when uncontrolled. This can easily be kept within one part in a thousand of its normal value, *i.e.*, 500 cycles. It is very desirable that the first beating oscillator be of a quartz crystal type, firstly to keep its slow frequency drift within the required limits, and secondly to avoid changes of frequency due to a change in signal strength when the latter is at a high level. On account, chiefly, of the action of the automatic gain control on the first detector, to which the beating oscillator is coupled, a change in frequency of the latter is, in general, caused by variations in the received signal, unless special care is taken to avoid this. The use of a crystal oscillator is not a serious objection, as a commercial receiver is not generally used for more than about three wavelengths.

Single Side-Band Transmitter

The block schematic of the transmitter used in these experiments is shown in Fig. 5. The problem was to evolve a transmitter design giving distortionless single side-band speech with sufficient stability but using, as far as possible, the existing double side-band equipment. The method of solving the problem may perhaps be of interest for illustrating the extreme flexibility of the low power modulation type of transmitter; it will be seen that the change-over from double to single side-band working can be carried out comparatively simply and rapidly.

The single side-band is obtained by modulation in three successive stages. The first two are at 19 and 250 kilocycles respectively, the modulators being balanced in each case, and the side-band being selected by appropriate filters. For the final modulation the existing harmonic generator of the transmitter was employed with the negative grid bias increased to a point such that, within certain limits, the voltage in the output harmonic was linearly proportional to the grid voltage. By this means, when the side-band output of the second balanced modulator is applied to the harmonic generator grid, this latter tube gives the second harmonic and acts as a modulator at the same time.

This third modulator is not balanced, and consists of a single tube, but a sufficient suppression of the carrier and the unwanted side-band is obtained by increasing the selectivity of the rest of the transmitter by sharply tuned circuits.

This type of transmitter circuit has been found to work quite well in practice.

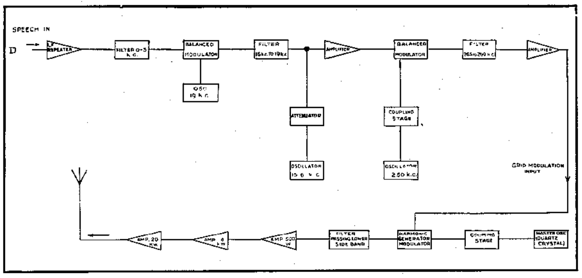

Figure 5

Tests Carried Out

During the period from April, 1930, to March, 1931, single side-band tests have been carried out by the International Telephone and Telegraph Corporation over the following three links:

(a) Buenos Aires to Madrid.
(b) Local tests at Madrid (Pozuelo to Griñon, 80 kilometres).
(c) Madrid-Paris.

As no single side-band transmitter had been installed at Buenos Aires, the tests on this link have consisted, so far, chiefly of experiments to check the automatic synchronising device, using the carrier of the ordinary double side-band transmitter as the pilot signal. The wavelength used was 15 metres.

During the second series of tests, viz., those between Pozuelo and Griñon, the complete system was tried out, using the provisional transmitter that has just been described. Although the distance was only 80 kilometres (between the Madrid transmitting and receiving stations of the Madrid-Buenos Aires link) the conditions were artificially made more or less similar to those prevailing on a commercial link by using directive antennae at both transmitter and receiver pointing in the wrong directions; by this means, the field strength and fading were found to be approximately those of the commercial Madrid-Buenos Aires link. For these local tests, a 30 metre wavelength was employed.

The final series of tests between Madrid and Paris, extending from November, 1930, to March, 1931, used the same transmitter as in the local Madrid experiments, but on wavelengths of the order of 30 to 52 metres. In each case the choice of wavelength was influenced solely by the transmission path conditions during the hours when experiments were possible. Owing to the exigencies of traffic, these hours were limited almost entirely to the period from 10 P.M. to 10 A.M.

Results of Tests

Buenos Aires to Madrid.—These tests, carried out with a receiver not yet in its final form, gave a maximum frequency difference between transmitted and re-supplied carrier frequencies of about 20 cycles per second, except during unusually heavy fading periods. No attempt was made to reduce the strength of the carrier below the normal value. These results were thought sufficiently promising, and showed that the system had good future prospects. On the other hand, the fact that adequate synchronisation could not quite always be obtained on account of severe fading, showed the necessity of some improved device to compensate for these severe fading periods.

Local Tests at Madrid.—Before the start of the second series of tests locally between Pozuelo and Griñon, the following two improvements were made:

(1) The first beating oscillator of the receiver was converted to the quartz crystal type as shown in Fig. 4.

(2) The automatic gain control B (Fig. 4) on the frequency control branch of the pilot circuit was improved by increasing the gain of the amplifier C so that any level of pilot signal between the measurement found in these local tests and the value only just above the noise would effect the frequency control tube equally. The output branch D of the pilot channel controlling the gain of the whole receiver through a comparatively long time constant had not yet been installed.

Test 1: Synchronism.—No long period stability tests of the synchronising device were attempted during these preliminary tests, but for periods of half an hour's duration a difference of 20 cycles per second between transmitter and receiver carriers was rarely exceeded.

Test 2: Speech Quality.—Except during the few occasions when the synchronism was not good enough, the speech quality was found to be quite satisfactory; in fact, during selective fading conditions, as had been foreseen, the quality was better than that given by the normal double side-band system.

Test 3: Improvement in Signal-to-noise Ratio.—This ratio was measured, both in the double and single side-band cases, at the final low frequency output by a standard volume indicator. As signal, a tone of 1,000 cycles was employed. Complete fades are, of course, frequently obtained in both the single and double side-band cases, so that exact measurement was difficult. An average value had to be estimated in each case, and the means of a number of observations taken. A further difficulty was the fact that, although the system was changed from double to single side-band, and vice-versa, as quickly as possible, the transmission conditions usually altered quite appreciably during the change-over periods. The results measured in this way showed a gain of 17 db. with the same peak power in the antenna in the two systems. This figure is considerably higher than the value expected theoretically: between 9 and 12 db. The cause of the discrepancy has not been satisfactorily explained.

Inasmuch as the type of fading is necessarily different when using the two systems, it is clear that the average value will not have exactly the same meaning in one case as in the other. It may be that the explanation lies here.

It is true that if the double side-band received carrier is only just above the noise level, the total noise received in this system will very appreciably depend also on the received band width, as explained in Appendix I.

As the band width of the receiver is about 20 kc. the maximum increase of the double side-band noise over that of the single side-band case would be

$$\sqrt{\frac{20}{6}} = 1.75 \text{ approximately}$$

i.e., about 4.5 db., giving a total gain from double to single side-band of about 16 db. In the tests referred to, however, the double side-band signal-to-noise ratio was never less than about 12 db., so that it seems that this latter possible explanation cannot apply.

Test 4: Speech Quality.—This was found again to be perfectly satisfactory, and better than during double side-band working.

MADRID-PARIS TESTS

Test 1: Synchronism.—In the absence of gain control D, Fig. 4, the synchronism was not always perfect, as the range of the fading (taking the minimum as the minimum value lasting more than half a second) frequently exceeded the control range of gain control B. To overcome this trouble, and at the same time to reduce the fading of the speech output, the separate control D was introduced, as shown in Fig. 4. By this means, the total range of the fading control on the signal was increased to a point such that the correct synchronising action never ceased for periods longer than about a quarter of a second.

The time constant E, Fig. 4, was quite sufficient to keep the oscillator frequency sufficiently constant during these short periods. At the beginning of March, 1931, during the stability tests on the complete system, covering ten consecutive nights, the re-supplied carrier frequency never differed from the suppressed carrier by more than 6 cycles per second, except for two or three moments when the transmitter was accidentally shut down—a result definitely better than had been hoped for.

Test 2: Speech Quality.—The received quality in Paris was found to be always as good as that obtained from the double side-band, and very definitely better during bad selective fading conditions.

Test 3: Signal-to-noise Ratio.—In these Madrid-Paris tests an improved type of signal was used. Instead of a single tone a noise-producing buzzer was employed giving audio frequency energy more or less evenly distributed throughout the whole speech spectrum. This type of signal was thought to be a much better imitation of speech from the point of view of fading than the single tone. The average result from a number of observations showed a gain of 12 db. when compared with the double side-band receiver with the automatic gain control off, and of 13 db. compared with the same receiver with its gain control on. This is evidently equivalent to increasing the power of the transmitter slightly more than 16 times. The peak powers in the antenna were carefully adjusted to be the same in the two systems. The curve showing one night's comparisons between the double and single side-band with the ratios plotted against time is shown in Fig. 6.

Test 4: Fading.—After the extra gain control D had been added the fading on the speech output was in general definitely less than the best that could be obtained with double side-band working with automatic gain control. Improvements showed that more particularly (as, in fact, all other advantages of single side-band working during bad selective fading) the usual automatic gain control on double side-band receivers is quite incapable of dealing properly with selective fading. When the carrier fades out the gain of the receiver is usually increased very considerably, giving a loud distorted speech output.

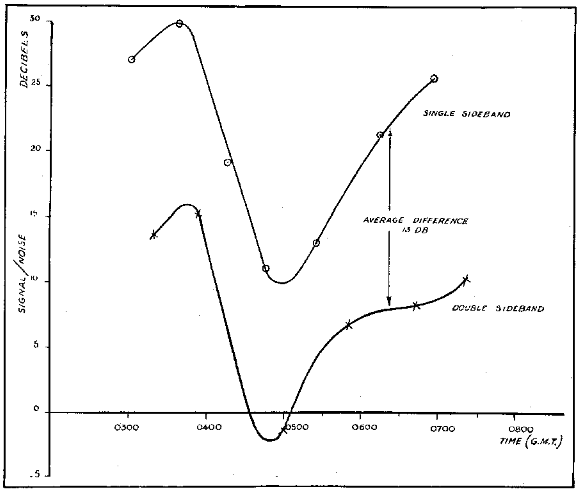

Figure 6

With the single side-band arrangements shown in Fig. 4, however, speech fading is very largely compensated for. The selective fading is usually found to be fairly rapid, so that the gain control D, working through a large time constant to the first detector of the receiver, has no time to operate. This is clearly the correct condition, as during selective fading the average power in the speech side-band is substantially constant. When synchronous fading occurs, however, it is usually of comparatively long duration, and thus operates control D, keeping the speech output fairly constant. The only way of making a really accurate comparison between two anti-fading devices is by a long series of observations over an extended period. From the results so far obtained, however, between Madrid and Paris it seems that the average fading, when using the present single side-band system, is about half that with the normal double side-band receiver, and during exceptionally bad conditions, the improvement is greater than this.

Test 5: Intelligibility—No accurate tests on the improvement of intelligibility were attempted, but on several nights rough comparisons were made by using short word lists, and changing over as rapidly as possible between the two systems. Improvement in the intelligibility was, of course, much more marked when the signal-to-noise ratio was low. One result which seems fairly clear, however, is that when the percentage intelligibility in double side-band is of the order of 20, the corresponding figure with single side-band working is usually between 70 and 80. In other words, a change from double to single side-band is capable of changing an uncommercial into a good commercial circuit.

Test 6: Stability of System.—As has been mentioned above, continuous tests, each lasting from two to three hours, were carried out on ten consecutive nights. Speech was used at regular intervals throughout all the tests, and the results showed a perfectly commercial circuit with good quality throughout the whole period, with no interruption whatever except during one or two short periods when the transmitter was shut down. It was actually unnecessary to touch the receiver at all throughout the tests, except for the preliminary tuning each night. Actually, however, when a frequency difference of 5 or 6 cycles was observed (usually once half-way through the night), the de-modulator oscillator was re-adjusted to restore the zero beat conditions.

Conclusion

The results obtained have definitely shown that one system of single side-band working, applicable commercially to short-wave links, has been evolved.

The author of this article wishes to acknowledge his indebtedness to Mr. C. W. Earp and Mr. H. T. Roberts, of the International Telephone and Telegraph Corporation, for their valuable assistance during the above experiments and the preparation of this paper.

APPENDIX I

Signal-to-Noise Ratio Improvement

In comparing the two systems let us assume equal peak voltages; and in the double side-band case, let the transmitter be modulated to 100 per cent.,

(1) DOUBLE SIDE-BAND CASE.

If the carrier is represented by

$$V \sin \omega t$$

then the peak voltage of each side-band is:

$$\frac{V}{2}$$

In the speech-producing detector of the receiver, let the audio voltage produced by beating each side-band separately with the carrier be represented by

$$\frac{KV^2}{2}$$

where K is, of course, a constant depending on the receiver, the transmitter, and the intervening circuit conditions. If now the phases of the side-bands with respect to the carrier are the same on arriving at the receiving detector as they were originally in the transmitter, the audio frequencies produced by each side-band separately with the carrier will be in phase in the detector output; the resultant is therefore

$$KV^2$$

Now let us consider the total background noise, the noise level being defined as that occurring when the incoming carrier is unmodulated. If the carrier energy in the speech detector is large compared with the noise energy picked up in the band width considered (this is always the case in "commercial" radio telephone circuits) then the only audio noise that need be considered in the output of the speech detector is that produced by noise impulses beating with the carrier. Thus the background noise voltage is:

$$KV\sqrt{\sum_{\omega-F}^{\omega+F} V^2}$$

where the noise input to the detector is

$$\sum_{\omega-F}^{\omega+F} V$$

and assuming in an ideal receiver that only frequencies from $(\omega - F)$ to $(\omega + F)$ are passed, where F is the highest audio frequency to be considered, and assuming also that the noise impulses arrive at random times. Hence the resulting signal-to-noise ratio R_1 is equal to:

$$\frac{V}{\sqrt{\sum_{\omega-F}^{\omega+F} V^2}}$$

(2) THE SINGLE SIDE-BAND CASE.

In order to give the same peak voltage at the transmitter as before, the tone which in the previous case gave 100 per cent. modulation must now be transformed into a single radio frequency of peak voltage 2V. Assume now that the peak voltage of the local oscillator re-supplying the carrier at the receiver is V_0; then the audio tone produced by the incoming side-band is $2KVV_0$ and the noise is:

$$KV_0\sqrt{\sum_{\omega-F}^{\omega+F} V^2}$$

Assuming that the receiver passes the upper side-band only in this case, then the signal-to-noise ratio R_2 will be:

$$\frac{2V}{\sqrt{\sum_{\omega}^{\omega+F} V^2}}$$

Assuming that the noise impulses are distributed evenly throughout the band width, then

$$\sum_{\omega-F}^{\omega+F} V^2$$

is double

$$\sum_{\omega}^{\omega-F} V^2 \text{, so that } \frac{R_2}{R_1} = 2\sqrt{2}$$

giving thus a gain of 9 db.

In the case of short wavelengths, however, there is another fact to be considered. During fading, selective phase distortion frequency occurs in the transmission path, causing the phase of one side-band with respect to the carrier, in the double side-band case, to be more or less random as compared with the phase of the other side-band. In this case the average resultant of the two side-bands will give an audio voltage of

$$\frac{KV^2}{\sqrt{2}} \text{ rather than } KV^2.$$

R_1 is then:

$$\frac{V}{\sqrt{2\sum_{\omega-F}^{\omega+F} V^2}}$$

giving an improvement due to the single side-band system of 12 db. In practice a gain of 9 to 12 db is obtained, according to the transmission conditions.

APPENDIX II

Variable Reactance Circuit

Referring to Fig. 2 (*a*), we have the following expression for the impedance (R+jX) between points A and B:—

$$R+jX = R_1\frac{\omega^2L_2^2}{R_1^2+\omega^2L_2^2} + j\left(L_1+L_2\frac{R_1^2}{R_1^2+\omega^2L_2^2}\right)$$

Micro-ray Radio

ULTRA short wave radio telephony and telegraphy, known as Micro-ray Radio, was demonstrated successfully between Dover and Calais on March 31st by the International Telephone and Telegraph Laboratories, Inc., of Hendon, England, in cooperation with the laboratories of Le Materiel Telephonique, of Paris, France. The equipment was largely developed by French engineers in the Paris laboratories.

The Micro-ray System employs transmitting and receiving antennae only 2 cm. in length. It has a wave length as low as 18 cm. and requires power of only one-half a watt. Micro waves are not subject to fading such as is encountered with other waves nor are they absorbed by rain or fog as are light waves. The conversations exchanged between Dover and Calais were of high quality and well up to the standard of the best telephone transmission.

The Micro-ray System opens up a veritable no man's land of additional radio accommodations since it makes available nearly one-quarter of a million Micro-ray channels even if each transmitter differs in wavelength to the same degree as is now necessary with ordinary transmitters. Furthermore, if it were physically possible to group such a vast number of stations together in the same locality they would still work perfectly without interference.

Apart from their obvious applications in a world-wide communication network such as that of the International System, a ray which is not affected by weather conditions such as fog and rain will very greatly extend the usefulness of lighthouses, especially at times when they are now least effective and are most needed due to poor visibility. For maintaining secret communication between aircraft and land and between ships of a fleet at sea, the Micro-ray offers fruitful possibilities. Other valuable applications will be the landing of aircraft in darkness or fog and dependable means for ships to locate each other in foggy weather. In the field of television also the Micro-ray should permit developments which are not practicable with the wave lengths hitherto available.

The *Electrical Review*,[1] under the caption "Short-wave Radio Telephony," in connection with the Micro-ray commented editorially:

"One of the major problems of radio communication today is the crowded condition of the ether. Indeed, the bogey of congestion is so menacing that serious attempts are being made internationally to evolve some workable scheme of virtually rationing frequencies, whilst it has also provided the impetus to explore the possibilities of the shorter wavelengths. The use of the 5- to 50-metre range is satisfactory for long-distance commercial communication, but, while the directive properties of short waves tend to simplify the avoidance of mutual interference, practical difficulties of application unfortunately increase progressively with increase of frequency. So acute did the situation become as to induce investigation even within the range of three metres, below which known technique does not appear to have been attended with any substantial degree of success. What was seemingly needed was some radical change in method, and it was an advance of that magnitude which was demonstrated successfully last week. . . . . . . as the culmination of work commenced about a year ago in a new field—so different from the existing one as to justify another name. Subject to entirely different conditions and necessitating a technique of its own, the extreme simplicity of the equipment and its ridiculously small power requirements mark a new epoch in the art of electrical communication."

For a description of the Micro-ray the reader is referred to *The Electrician* (issue of April 3, 1931, Volume CVI, No. 2757). It also contains an interesting editorial under the heading, "10-100 cm. Radio."

A distinguished group of officials of the British Government and Military and Naval Attachés from various countries, leading scientists, and representatives of the press attended a demonstration at Dover while a similar group of French

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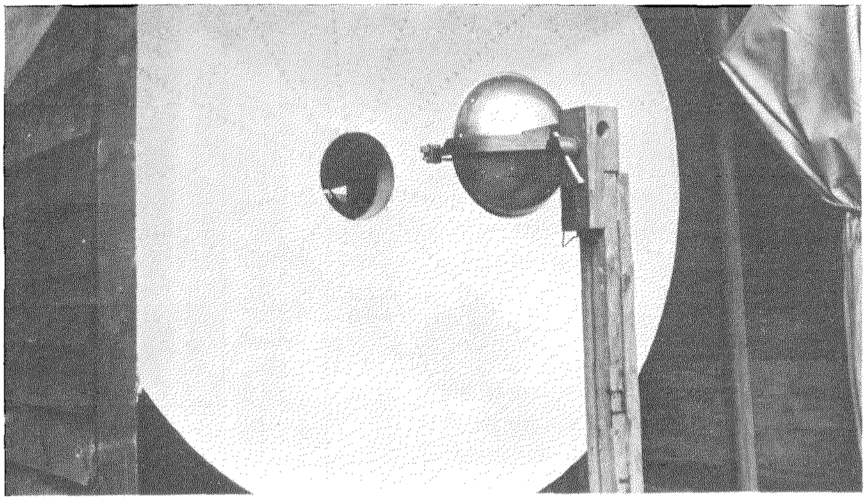
[1] April 10, 1931, issue.

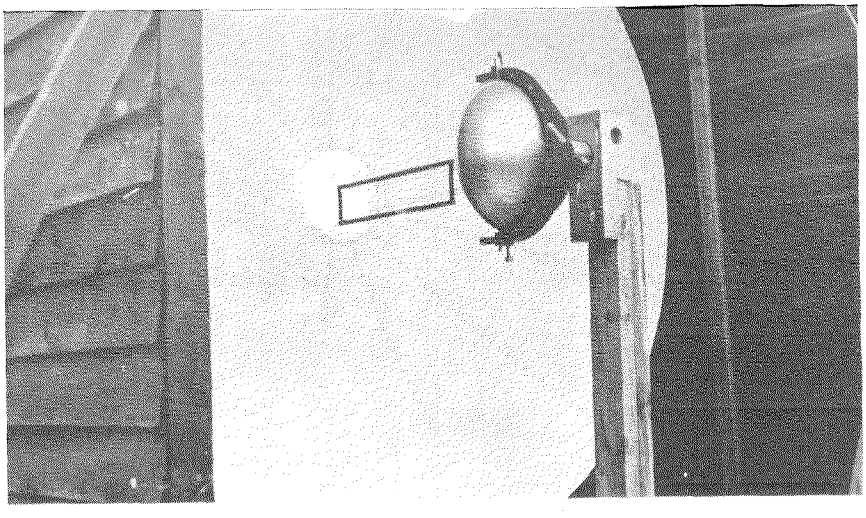
Government officials and guests came from Paris to Calais to participate in the demonstration. Later there was a luncheon in England at the Lord Warden Hotel where Mr. G. H. Nash, Executive Vice President of the International Telephone and Telegraph Laboratories, lectured on the Micro-ray System. In France there was a similar lecture by Mr. E. M. Deloraine of Le Matériel Téléphonique.

In addition to Messrs. Nash and Deloraine, credit for the new system is largely due to Messrs. Clavier, Darbord, Fournier, and Gibson.

The Transmitter



The Receiver



The large transmitting and receiving reflectors are 10 feet in diameter. Identical apparatus is used at each end.

The Practical Value of the Proximity Loss in Parallel Go and Return Conductors

By J. K. WEBB, M.Sc., A.M.I.E.E.

International Telephone and Telegraph Laboratories, Incorporated

IN the case of a cylindrical conductor isolated in space, or two concentric conductors carrying alternating current, there is a concentration of current towards the outer surface of the conductor, and the problem of calculating the increment of resistance due to this non-uniformity permits of a rigid mathematical treatment, there being general agreement as to its solution.[1] This will be referred to as the "simple skin effect." When, however, a circuit is formed by two parallel conductors, there is a further re-distribution of current due to mutual repulsion between the two magnetic fields, a phenomenon which is termed the "proximity effect."

While the increment of resistance due to this effect is considerably less than that due to the simple skin effect alone, it is by no means negligible in large gauge wire at audio frequencies, or in smaller gauge wire at the higher frequencies used in carrier communication. Due allowance, therefore, must be made when considering the design of circuits for such uses.

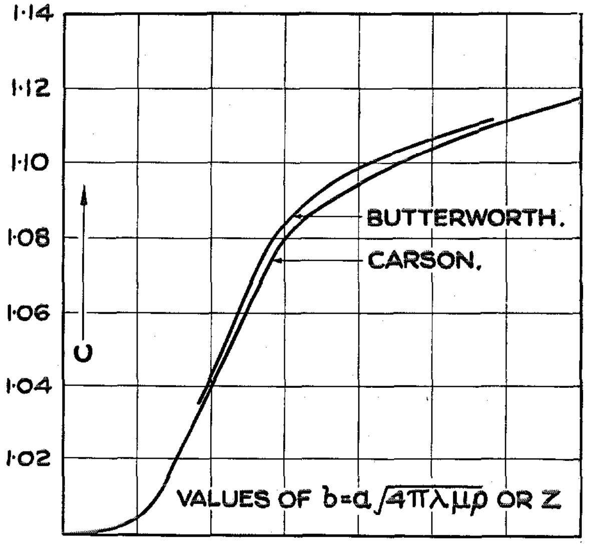


Figure 1—Comparative Values of Correction Factor "C" Calculated from Carson's and Butterworth's Formulae.

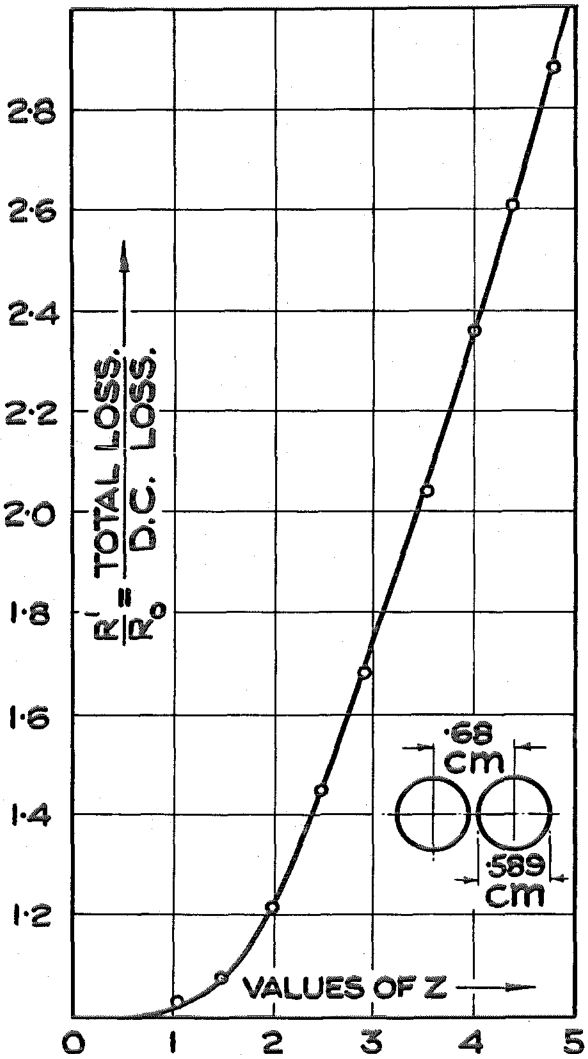


Figure 2—Curve of Total Loss Calculated by Butterworth's Formula Showing Observed Points.

To this end it is convenient to have a formula which can readily be applied to specific cases; but, since the mathematics of the problem present difficulties which make a perfectly rigid

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[1] Russell, "Alternating Currents," Vol. 1, Sec. Ed., P. 215.

solution unduly cumbersome for engineering application, the limits of error which may be introduced due to making simplifying assumptions must be carefully considered before the formula can be applied with confidence.

There are two important contributions towards the solution of the problem, the first by Carson,[2] and the second by Butterworth,[3] and a study of these papers shows that while Butterworth's formula is the simpler, Carson's analysis is perhaps the more rigid, but his formula involves considerable labour in its practical evaluation. It is therefore desirable to come to some understanding concerning the extent of the approximation to be expected from one or the other formula, and this can best be done by taking some specific case, calculating the value of the proximity loss by each method, and then comparing measured and calculated results.

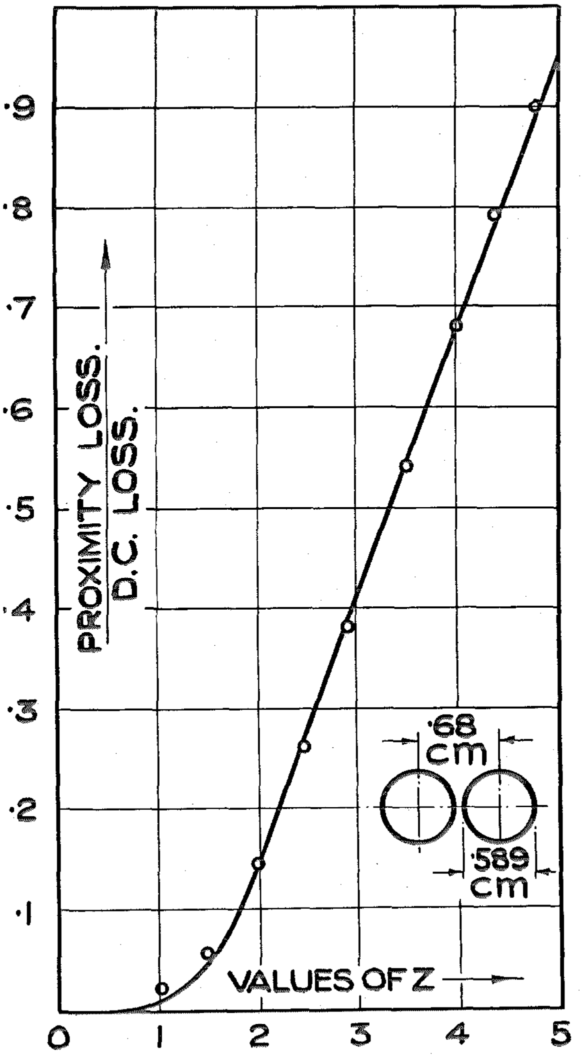

Figure 3—Curve of Proximity Loss Calculated by Butterworth's Formula Showing Observed Points.

Carson expresses the proximity loss as a "correction factor" C, which when multiplied by the effective resistance of the wire including the simple skin effect, gives the total resistance. This factor C approaches an upper limit C_m at infinite frequency in accordance with an asymptotic formula. Butterworth, on the other hand, gives the total effective resistance in the following terms:

$$R' = R_o \left\{ 1 + F_{(Z)} + \frac{G_{(Z)}}{1 - \frac{d^2}{D^2} H_{(Z)}} \cdot \frac{d^2}{D^2} \right\}$$

where R_o = D.C. resistance/cm. of single conductor in c.g.s. units.

$R_o(F_Z)$ = Increment of resistance due to simple skin effect.

d = diameter of either wire.

D = distance of their centres.

$Z = 2\sqrt{\omega / R_o}$

$\omega = 2\pi x$ frequency.

$F_{(Z)}$, $G_{(Z)}$, $H_{(Z)}$ are implicit ber and bei functions which have been tabulated as follows:

Z	$F_{(z)}$	$G_{(z)}$	$H_{(z)}$
0.0	0.000	0.000	0.0417
0.5	0.000326	0.000975	0.042
1.0	0.00519	0.01519	0.053
1.5	0.0258	0.0691	0.092
2.0	0.0782	0.1724	0.169
2.5	0.1756	0.295	0.263
3.0	0.318	0.405	0.348
3.5	0.492	0.499	0.416
4.0	0.678	0.584	0.466
4.5	0.862	0.669	0.503
5.0	1.042	0.755	0.530

The function $(1 + F_{(Z)})$ is also tabulated by Russell[4] for smaller increments of Z.

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[2] "Wave Propagation over Parallel Wires: The Proximity Effect," *Philosophical Magazine*, April 1921, Vol. 41, No. 244, P. 607.

[3] "Eddy Current Losses in Cylindrical Conductors with Special Application to the Alternating Current Resistance of Short Coils," N. P. L., Collected Researches, Vol. XVIII, 1924, Part VI, pp. 77-122.

[4] Ibid I, p. 233.

The last term of the formula takes account of the proximity loss.

On page 632, Figure 7 of Carson's paper, the correction factor C has been evaluated for the important practical case in which the separation of the wires is twice their diameter so that a comparison can be effected by calculating this curve from Butterworth's formula, which gives as the equivalent of Carson's correction factor

$$C=1+\left(\frac{G_{(Z)}}{1-\frac{d^2}{D^2}H_{(Z)}}\quad\frac{d^2}{D^2}\right)\Bigg/\quad(1+F_{(Z)})$$

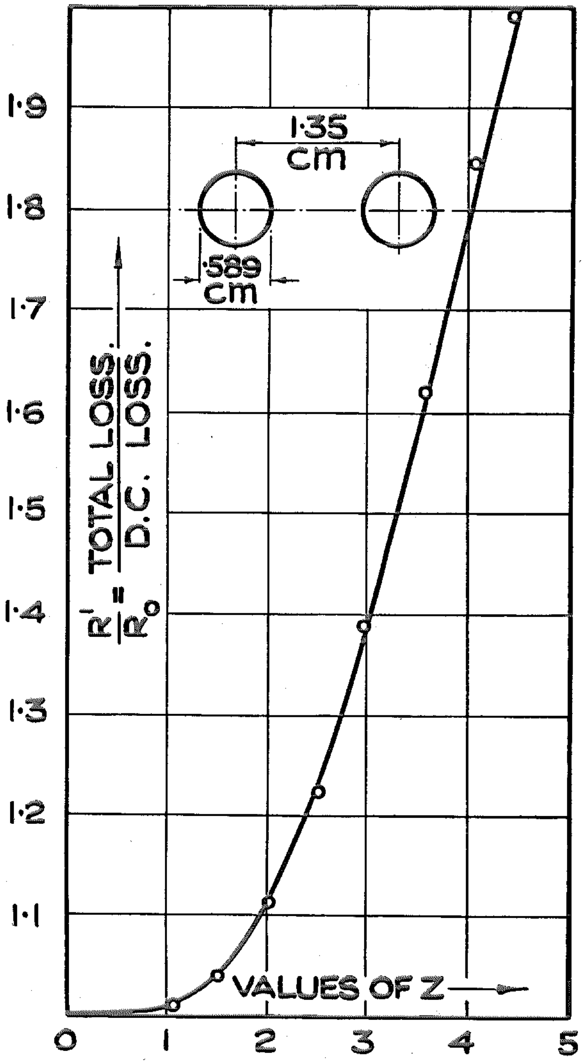

Figure 4—Curve of Total Loss Calculated by Butterworth's Formula Showing Observed Points.

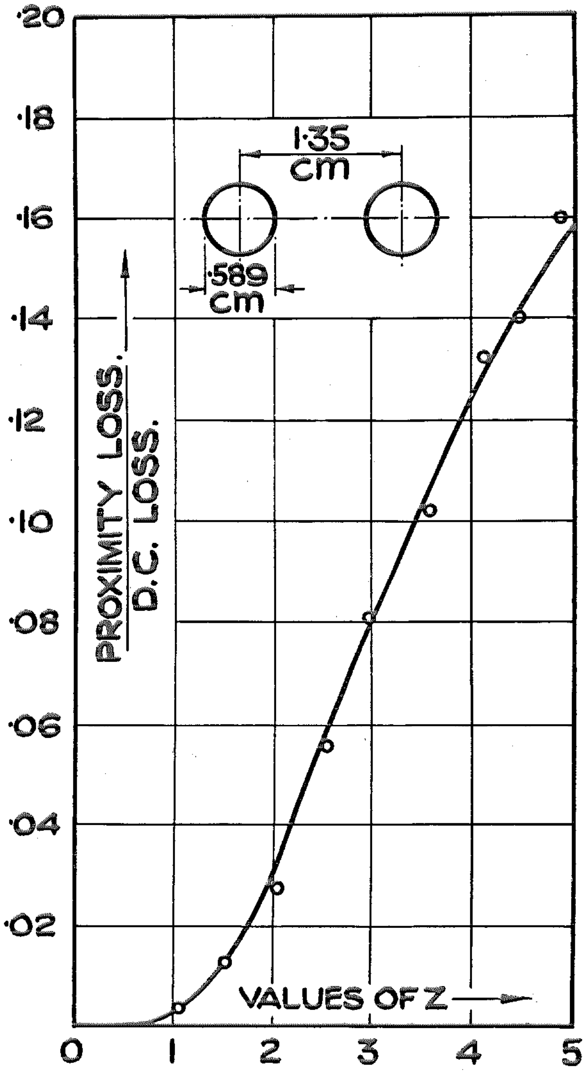

Figure 5—Curve of Proximity Loss Calculated by Butterworth's Formula Showing Observed Points.

It must also be noted that the argument Z of Butterworth's formula is the same as $b=\sqrt{4\pi\lambda\mu p}$ of Carson's, and that the practical range of frequencies and conductor sizes involves in general values of the argument up to about 5. The curves calculated from the two formulae have been reproduced in Figure 1 from which it is seen that they are practically coincident.

Results of Practical Tests

Experimental work was undertaken to determine how closely the measured and calculated values of the proximity loss were in agreement. The A.C. and D.C. resistance of a length of 3260 cm. bare copper wire of diameter 0.232″ (.589 cm.) arranged as a loop was determined at various frequencies ranging from 280 to 6000 p.p.s. by means of a special type of inductance bridge which has been developed in the Laboratories for measurements of this type.

The wire was mechanically stretched to remove kinks and accurately spaced, the ends being securely soldered to a mercury short-circuiting key, used in obtaining bridge zeros, the method of test being essentially one of double balance. Measurements were made at two spacings, the first with the wires as close together as practicable and the second at a normal distance. This particular section of conductor for example might be used on a long distance submarine telephone cable. The D.C. resistance of the loop was .0210 ohm on an average at room temperature, i.e., 6450 abohms/cm. Experimental points are shown in Figures 2, 3, 4 and 5, together with curves calculated from Butterworth's formula. In Figures 3 and 5, the points shown were obtained by subtracting from the total incremental loss the calculated value of the simple skin effect, the remainder being taken as the measured proximity loss. The deviation of the measured from the calculated values shown in Figure 5, it should be noted, is within the limits of the accuracy with which measurements could be taken, since bridge readings only to the nearest .0001 ohm could be obtained.

Conclusion

The general conclusion is that while either Carson's or Butterworth's formula may be safely used for the practical evaluation of the loss due to proximity effect in parallel conductors, the latter is preferred by the author on account of the greater ease with which it may be applied to specific cases.

Public Service of Phototelegraphy in Japan

By SANNOSUKE INADA

Director General of Telegraph and Telephone Engineering
Department of Communications, Japan

IN spite of the comparatively short time that phototelegraphy has been in practical use, it has already proved of vast importance for communication purposes.

In July, 1928, the Department of Communications of the Imperial Japanese Government issued a Departmental Ordinance, permitting the granting of licenses for the operation of private phototelegraph equipment to newspapers, on the condition that such equipment be used for the transmitting of newspaper publications. Upon the occasion of the Imperial Coronation of that year, the Osaka Mai-Nichi (Daily News), the Asahi (The Rising Sun) and the Nippon Dempo Tsushin-Sha (Telegraph News Agency) took advantage of this ordinance and equipped phototelegraph installations on their private lines. These installations were effectively utilized, with the result that the scenes of the Grand Coronation were transmitted to distant places with the least possible delay and were distributed by means of "Extras" to the public, who received the pictures with great excitement.

Shortly after this, our Department decided to open a public phototelegraph service between Tokyo and Osaka, adopting the N. E. system. The installation in both central telegraph offices and also in the Nagoya repeating station was finished in April, 1930. On the 20th of August, the inauguration of this service took place in the presence of notabilities, customers, and experts who were assembled at the two terminal offices. The ceremony was commenced by the passing of congratulations by Mr. Koizumi, the Minister of Communications, to Mr. H. Seki, the Mayor of Osaka, and this was immediately followed by a cordial reply and many other messages from the gentlemen present. All of the pictures and manuscripts transmitted during this occasion were received with excellent results and were handed over to the addressees. Since then the public service has been carried on with satisfaction.

The N. E. system was invented by Dr. Y. Niwa and Mr. M. Kobayashi, of the Nippon Electric Company, Limited, and a detailed description by Dr. Niwa* has been published. Subsequently, some improvements have been made and consequently a brief description of the equipments actually installed may be of interest.

Systems Employed

Actually two types of phototelegraph apparatus were installed for service between Tokyo and Osaka. One of these was designed to operate, at high speed, over the open-wire telephone wire, while the other was intended for operation on the 4-wire repeatered cable circuit and for use in case of interruption of the open-wire line. The former was called No. 1 Set and the latter No. 2 Set, and in the following description the mechanism and operation of the two types are common except where particularly indicated.

Sending Apparatus

At the sending terminal a pulsating light flux is produced by interrupting with a rotating toothed wheel the light emanating from the source, as shown in Figures 1 and 2. The picture to be transmitted is mounted on a drum in such a way that the pulsating light flux is projected on it.

The light is reflected from the picture onto a photocell and causes a picture current to be transmitted. After the picture current is amplified, there is sent out on the line a carrier current modulated in accordance with the respective brightness of the original and with the lower half of the frequency band eliminated by means of a high pass filter. The frequency of the carrier current is about 6000 cycles per second for No. 1 Set and about 1700 cycles for No. 2 Set.

With this equipment it is possible to transmit photographs, manuscripts, certificates, etc., in

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*Y. Niwa, "A System of Electrical Transmission of Pictures," *Electrical Communication*, April, 1930.

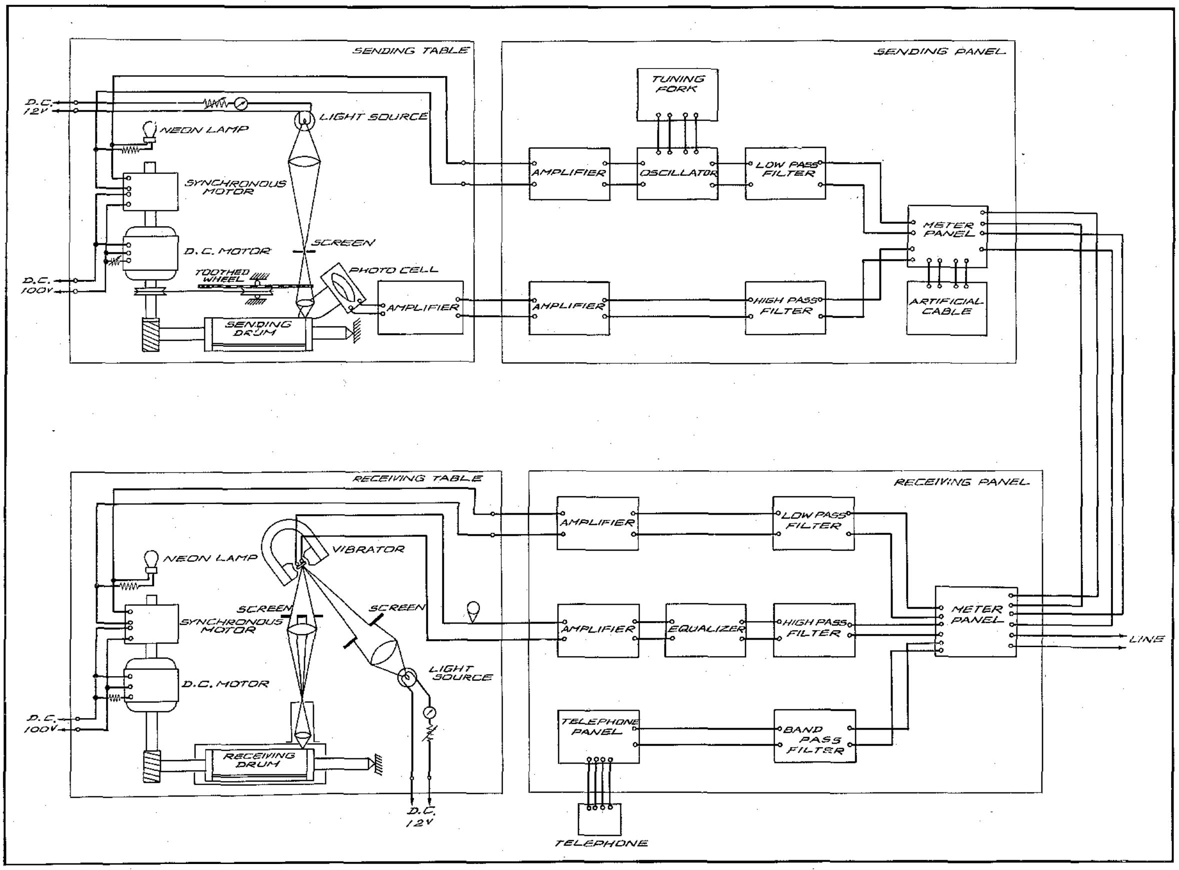


Figure 1—Schematic Diagram of No. 1 Phototelegraph Apparatus.

suitable size without being subjected to any special preparation beforehand; the largest size of the picture that can be transmitted is double that of cabinet size, that is, 18 x 26 cm.

If a picture is transmitted from a negative film by a transmitted light, higher efficiency of the light utilization may be obtained, but for simplicity and convenience the equipment was designed to be adaptable to reflected light.

The pitch of the scanning spiral is 6 lines per mm. and the time required for the transmission of the full size of 18 x 26 cm. is about 6 minutes with No. 1 Set and about 20 minutes with No. 2 Set.

Receiving Apparatus

A 50-watt incandescent lamp is used as the light source from which light flux is projected upon the reflecting mirror of the vibrator. If a part of the vibrating light flux is cut off by a screen, a definite relation is established between the intensity of the remaining light and the amplitude of vibration of the mirror. Now if this remaining light is collected by lenses and projected upon the film or printing paper mounted on the receiving drum, a spot of light, corresponding to the amplitude of the carrier waves received, is produced upon the sensitized film or paper. As the receiving drum operates in synchronism with the sending drum, the picture at the sending station can be completely received. (Figures 1 and 3.)

In the case of receiving a picture in negative film, a screen consisting of two square openings (Figure 4–N) is employed; then the light spot reflected from the mirror is intercepted by the center of the screen, as shown by the shaded portion in Figure 4–1, when no current is flowing in the vibrator. If, however, a carrier current flows in the vibrator, the reflected light

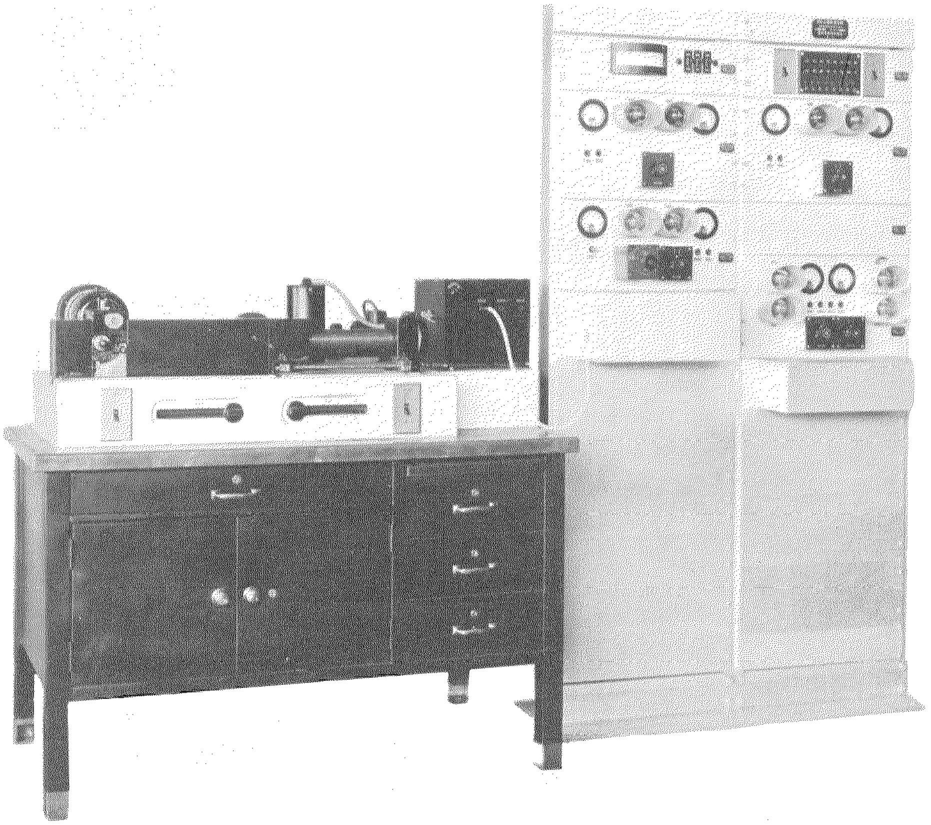


Figure 2—Sending Apparatus.

flux oscillates to both sides and passes through the right and left openings. As the larger the amplitude of oscillation the more will be the amount of the light passing through the openings, it is evident that the received picture will be in negative. In this case the optical part should be adjusted so that the deflected spot comes at its maximum amplitude, as shown in Figure 4-2.

Provided the screen has an opening at its central position (Figure 4-P), all the reflected light flux will pass through this portion. Now if current is flowing in the vibrator, it will be easily recognised that the greater the amplitude of oscillation of the light spot, the less will be the amount of light passing through the central opening; therefore a positive picture will be produced upon the sensitizing paper.

Curves in Figure 5 show the relation between the deflection of the mirror and the light volume passing through the openings in both cases above mentioned. The natural frequency of the vibrator for No. 1 Set is nearly 17,000 cycles and for No. 2 Set nearly 6,000 cycles.

Synchronizing Device

A synchronous motor, which is directly coupled with a D.C. motor working from an independent source at the sending office, is used for driving the drum. These two motors, in conjunction with corresponding motors at the receiving terminal, drive the sending and receiving drums in synchronism. Synchronizing current is generated at the sending terminal by a tuning-fork oscillator. A part of the output from this oscillator is employed to drive the synchronous motor at the sending end, and the remaining part is sent over the line, superposed upon the picture current. These two currents, since they differ in frequency, can be easily separated by the aid of a suitable filter inserted at the receiving end.

For the No. 1 Set, a synchronizing current of 200 cycles per second is employed while for No. 2 Set, 300 cycles is used on account of the increased attenuation at lower frequencies in cable circuits.

For satisfactory picture transmission the sending and receiving drums should be strictly maintained in their corresponding positions during operation while keeping their speeds in synchronism. In this instrument, the driving apparatus is running continuously; the sending or receiving picture drums are arranged so that they can be fitted on the driving shaft in their correct position during one revolution. Providing the speed remains constant, no matter how often the sending or receiving drums are started or stopped they will always be in the same relative positions. Hence it is necessary before starting to work, to ensure that the joint of the picture is in the correct position at the sending end as well as at the receiving end. This is done as follows: on the picture clip at the sending end is a white line, whilst the rest of the drum is black; on rotating the drum, without traversing it, a rush of picture carrier current indicating the white line will be sent to the circuit. At the receiving end the amplifier is switched so as to

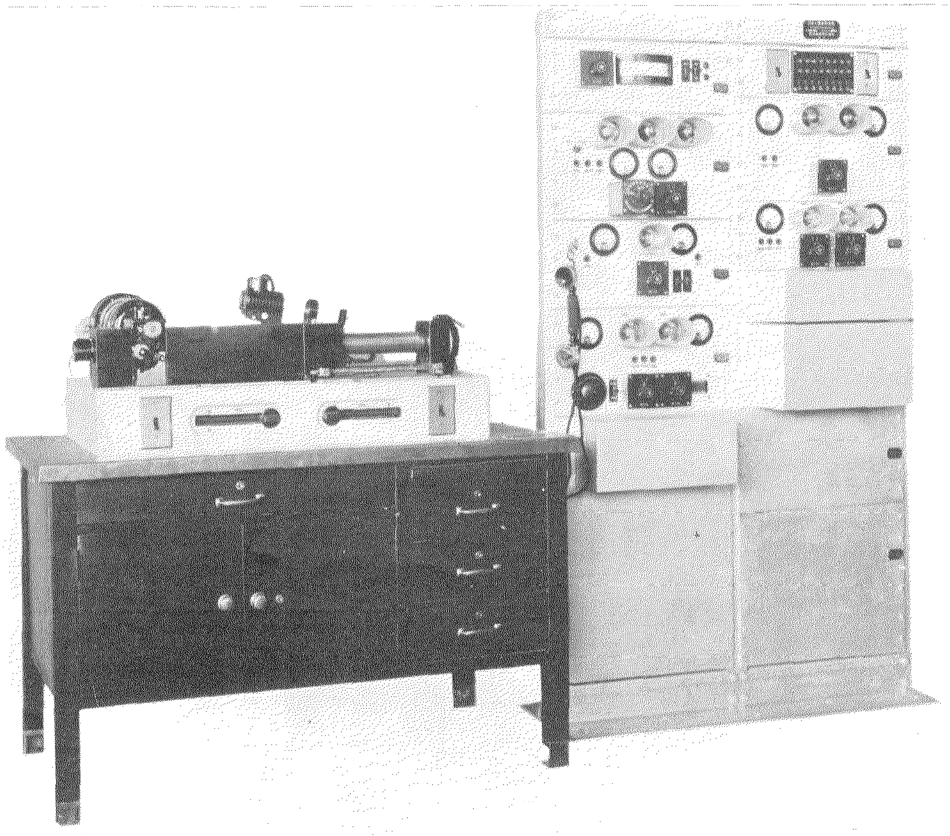


Figure 3—Receiving Apparatus.

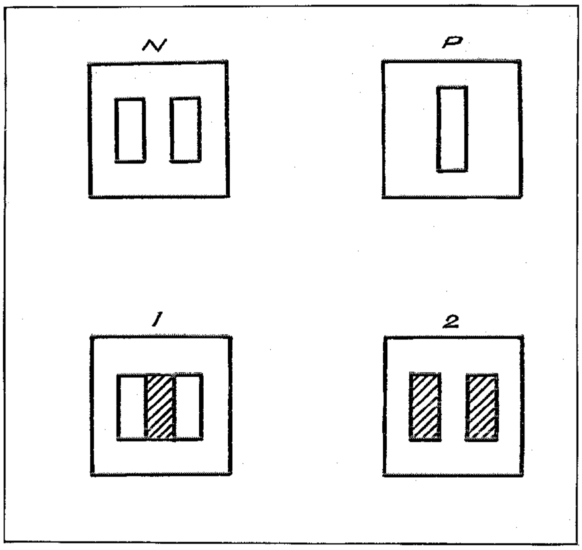


Figure 4—Intercepting Screen.

light a small neon lamp placed in the box; a tinted celluloid cylinder fixed on the same shaft as the receiving drum revolves round the lamp. If the drum revolves in coincidence with the sending drum, a black line on the celluloid cylinder comes to a hole of the box at the instant the neon lamp is lighted, therefore the light can not be seen when peeped at through the hole; if on the other hand a red or yellow light can be seen it is necessary to shift the phase in the proper direction by rotating the stator of the synchronous motor until the light is out of sight. This may be understood by referring to Figure 6.

Signalling System

Conversations over the line by the telephone apparatus provided with No. 1 equipment can be carried on even when a picture is being transmitted. If a signalling key is switched at the sending end so that the filament circuit of an oscillation valve is closed, a signalling current of approximately 1000 cycles is sent out to the line. At the receiving end this current, after being separated from the picture or synchronizing current by a band pass filter cutting off below 300 cycles and beyond 2000 cycles, is amplified, rectified and then passed to a relay which operates a bell. When the key is restored, the filament circuit is opened and the signalling current stops; the answering signal may be sent from the receiving end in the same manner. When the telephone receivers are removed from the hooks at both ends, the telephone circuit is closed so that conversation is possible.

In the case of No. 2 Set, telephone apparatus fitted with a loud speaker is usually connected to the line and conversations can take place except when a picture is being transmitted. When the picture transmission is to be started the line must be connected to the phototelegraphic apparatus instead of the telephone set by changing a switch, but listening can take place over one pair of the 4-wire cable circuit, while a picture is transmitted over the other. A carrier telegraph apparatus is also arranged for transmitting telegraph signals from the picture sending office to the receiving office without stopping the revolution of the motor.

Repeaters

In the case of No. 1 Set, the maximum transmission loss of the carrier current on the aerial line between Tokyo and Osaka is estimated to be about 35 db., consequently a repeater was inserted at the Nagoya Central Telephone Office in order to amplify the current. This

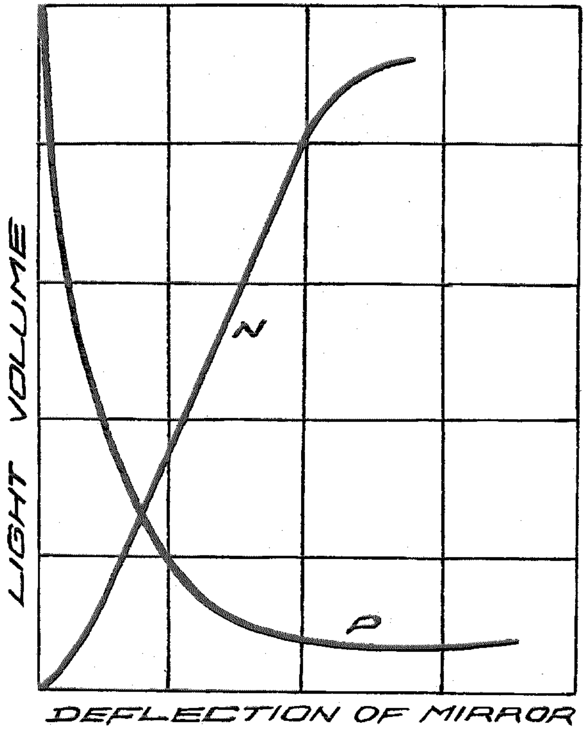


Figure 5—Relation Between Deflection of Mirror and Light Volume Passing Through Openings of Intercepting Screen.

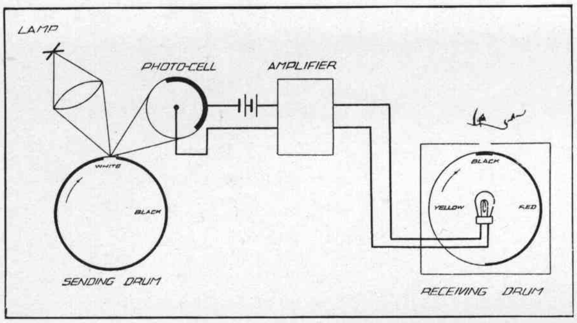


Figure 6—Schematic Diagram of Method of Adjusting Sending and Receiving Drum for Synchronism.

repeater was designed for one-way operation only and in order to save the trouble of manually changing the connection according to the direction of the picture current, an automatic changing system was devised utilizing the synchronized current transmitted from the sending office.

Figure 7 shows the schematic diagram of the repeater. VF is a band pass filter for the voice current, SF the low pass filter for synchronizing current, and PF the high pass filter for the picture current. The main part of the synchronizing current passes through the low pass filters SF, SF′, and is sent to the receiving end; the remaining part is rectified by the 102-D valve and operates the relays; with the result that when the relay R4 or R4′ is operated the input terminals of the amplifier are connected to the sending side and the output terminals to the receiving side. The gain of the repeater is about 25 db. for the 6000 cycle carrier current. The synchronizing current and the voice current are not amplified in this repeater because their transmission losses over the line are comparatively small. Figure 9 gives the attenuation-frequency characteristics for the two sections Tokyo-Nagoya and Nagoya-Osaka.

As to No. 2 Set, 4-wire repeaters are installed at Yokohama, Ejiri, Toyokawa, Kameyama, and Osaka on the cable circuit. The resulting attenuation between Tokyo and Osaka is about 8 db.

Line Arrangement

The arrangement of the aerial telephone line for No. 1 Set is shown in Figure 8, the length of which is about 600 km., and chiefly consisted of 4.00 mm. copper wire. The use of other kinds of wire was avoided as far as possible in order to

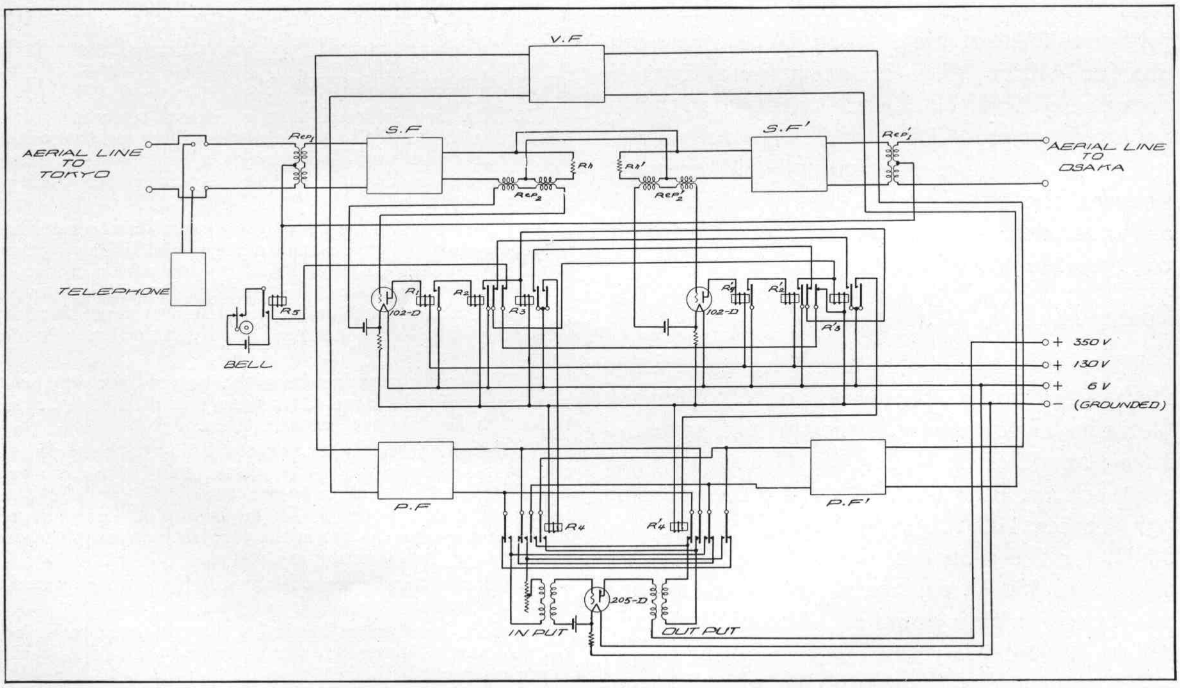


Figure 7—Schematic Diagram of Repeater.

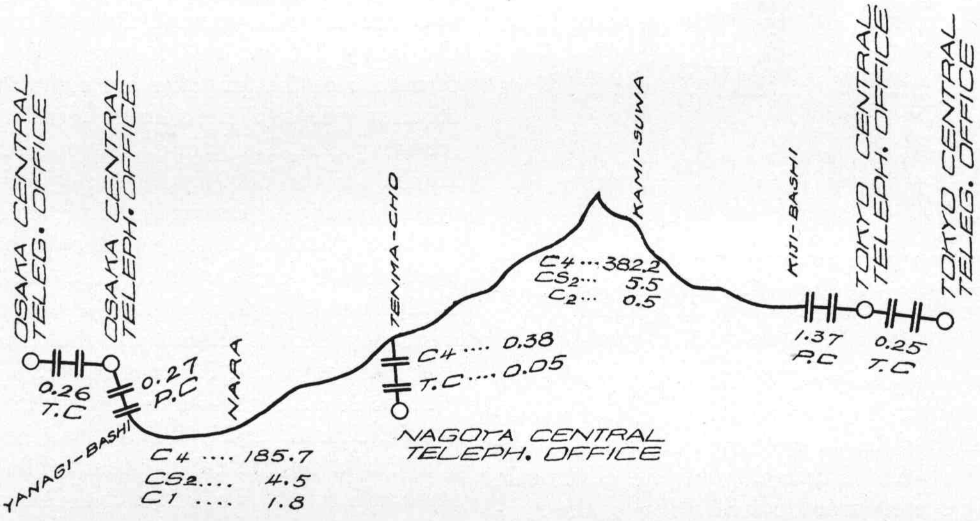


Figure 8—Arrangement of Aerial Telephone Line for No. 1 Set.

keep the characteristics of the line smooth and constant, that is, they must not vary appreciably throughout the transmission range and transmission must be free from echoes and other irregularities.

This line was carried by the same poles as the private toll line of the Nippon Dempo Tsushin-Sha on which picture transmission by the Siemens system (6500 cycle carrier current) is operated between Tokyo and Nagoya. In order to avoid inductive interference and crosstalk between the two circuits, they were separated as far as possible on the pole route and frequent transpositions were made.

Power Plant

The main parts of the phototelegraph system are fed by storage batteries, i.e., 6 V. for the filaments of tubes of the picture and synchronizing amplifier, 2 V. for the filaments of the photocell amplifier tubes, 12 V. for the scanning lightsources, 100 V. for the driving D.C. motors, 50 V. for the plates of the photocell amplifier tubes and 350 V. for the plates of the picture and synchronizing amplifier. The photoelectric cell in use, made by the Tokyo Electric Co., is a flat type gas filled potassium cell with a diameter of about 6 cm., the cathode being deposited with potassium hydride. The anode of the cell is connected to a 120 V. dry battery.

Precautions of Installation

From the point of view of obtaining the best quality in the received picture, great care has been taken in installing and wiring, expecially as to the following points:

1. The line is led into the central telegraph office through a 12-pair lead-covered paper cable from the central telephone office and connected to a terminal board and then by means of a lead-covered 2-pair rubber cable to the apparatus.
2. The batteries for the photocell amplifier are enclosed in a lead lined box to secure perfect shielding against extraneous disturbances and lead-covered wire is employed to the distributing panel. Furthermore, the wiring between the distributing panel and the apparatus is provided by a high grade rubber insulated wire guarded in a copper pipe.
3. The supply mains from the battery are separated as far as possible from other wiring in order to prevent induction disturbance between them.
4. The leads to the apparatus from the batteries for the filaments, the plates of picture and synchronizing amplifiers and the lightsource are high grade rubber insulated wires protected by an iron pipe. Similar precautions have been taken in the case of the wiring between the sending and receiving apparatus.
5. All the wire is separated carefully from power and lighting circuit.
6. Care is taken to minimize the electrical resistance of the joints of iron or copper pipes and each pipe section is perfectly earthed.
7. Oil layer is used to keep the storage batteries free from acid spraying.

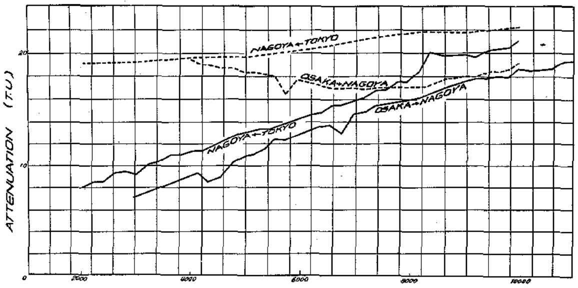


Figure 9—Attenuation-Frequency Characteristics of the Two Sections Tokyo-Nagoya and Nagoya-Osaka.

8. Special design is provided in the dark room for close shutting of light, ventilation, supplying and draining water, illumination, doors, double windows to hand over phototelegrams, and voice tubes.

9. Developing and printing can be done by convenient arrangements. Special dryer and washer are also provided.

Service

On the opening day of the public service, nearly 70 phototelegrams were accepted, most of which were in the nature of demonstrations, such as new fashions in dresses and trinkets, samples of goods, commercial advertisements, cinema stars, etc. But on the occasion of the great earthquake in the Izu district on November 26th, 1930, photograms of the pitiable state of the destroyed places, maps of the affected area, the wave forms recorded on the seismometer, etc., were transmitted. The cable circuit was interrupted by the earthquake and consequently the No. 1 Set, working on the open wire line, was operated during this time and over 90 phototelegrams were sent out without any undue delay. The authorities were, therefore, by this means advised almost instantaneously of the terrible conditions in the affected area and were able to arrange for the relief of the people suffering from the disaster.

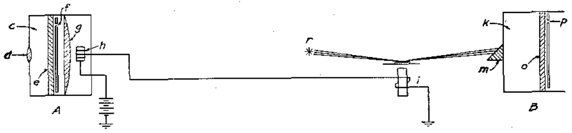
The charge between Tokyo and Osaka is 5.00 yen for the size up to cabinet size (18 x 13 cm.) and 8.00 yen for the larger size. The amount of traffic is nowadays relatively small, except in the case of some notable event, but with popularization of phototelegraphy and technical simplification of equipment and operation, the future of phototelegraphy will be assured.

Specimen of Picture Transmitted Over Nippon Electric Phototelegraph System Between Tokyo and Osaka

An Early Television and Picture Transmission Proposal

EDITOR'S NOTE: The television and picture transmission scheme herein described is of special interest inasmuch as it was devised in 1902, 29 years ago, jointly by Mr. J. L. McQuarrie, then Assistant Chief Engineer of the Western Electric Company and now Chief Engineer of the International Telephone and Telegraph Corporation, and by Mr. W. W. Cook, then Chief Engineer of the International Western Electric Company, London, England. At that time photoelectric cells, Neon lamps and vacuum tube amplifiers were, of course, not available; nevertheless, the scheme embodies the fundamental ideas of practical television and picture transmission. The description is taken verbatim from the original manuscript signed by J. L. McQuarrie and W. W. Cook.

The following is a description of apparatus designed for transmitting views or pictures to a distance, jointly invented by the undersigned during the period elapsing between September 29th and October 11th, 1902.



At the transmitting station (A) there is provided a dark chamber (*c*) having a suitable lens (*d*) in an opening at the front. Inside the chamber, exposed to light rays entering through the lens is a ground glass plate (*e*). Immediately behind this plate is a contrivance with a pin-hole opening (*f*) arranged to be rapidly and continuously exposed to every point on the surface of the plate. Next in order is a lens (*g*) adapted to focus light rays passing through the pin-hole to the center of the chamber at the rear. At this focal point there is provided a substance such as selinium (*h*) which is susceptible to changes of electrical resistance under varying intensities of light. The selinium or other responsive substance is included in an electric circuit which extends to the distant receiving station (B) where it is joined to an electromagnet or other device (*i*) capable of responding to changes of E.M.F.

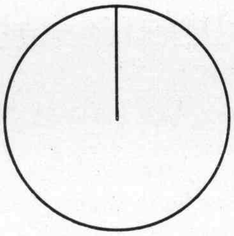
In the illustration an electromagnet is shown; the armature of which is fitted with a mirror.

A suitable dark chamber (*k*) is provided at (B); this chamber is equipped with a semi-opaque prism (*m*) at the rear. Inside the chamber is a ground glass plate (*o*) and in front of this plate is a device for exposing a pin-hole (*p*) to every point on the surface similar to that employed at the transmitting station.

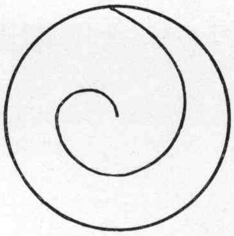
In the operation of the apparatus a source of light (*r*) is provided at the receiving station so arranged that its rays are reflected to the prism at the rear of the chamber by means of the mirror attached to the armature of the electromagnet. In tracing the sequence of events which occur in the use of the apparatus it will be observed that light rays reflected from the view pass through the small lens into the chamber at the transmitting station and are impressed on the ground glass plate therein. The pin-hole passes over the surface of the plate at a speed which enables it to cover the area in about one-sixth of a second, thus exposing all points on the plate's surface in rapid succession and permitting the light rays to pass into the large lens at the rear; these rays being more or less intense depending upon the degree of light or shade of the particular point of the view at which the pin-hole is located at a particular moment. It follows therefore that the selinium cell is subjected to light rays of varying intensity and this in turn causes corresponding changes in its electrical resistance, followed by similar variations in the strength of current in the electric circuit. The current changes are reproduced at the receiving station in the form of mechanical movement of the armature of the magnet and the beam of light which is reflected from the mirror attached to the armature is caused to waver in harmony with this motion. The reflected beam will then sweep across the surface of the semi-opaque prism located in the opening at the rear of the receiving chamber. When the light beam is at the upper edge of the prism practically all the rays will pass into the chamber and its interior will be illuminated; when the beam is at the lower portion of the prism none of the rays can enter and the chamber will be dark. As the beam moves across the prism a gradual change from a condition of light to one of darkness occurs inside the chamber. It will thus be seen that if the pin-hole at the receiving station is caused to move over the surface of the ground glass plate located within the chamber the particular point at which the pin-hole may be situated at a given moment will appear to the observer to be either light or dark depending upon the condition inside the chamber. If then the pin-holes at both stations are operated with synchronism the view impressed on the ground glass plate at the transmitting station will be reproduced on the plate at the receiving station.

The pin-hole mechanism may consist of two discs placed one in front of the other and arranged to revolve at proper speed; one of the discs may have an opening or slot cut across its face from the center to the periphery as in sketch (E) below, the other disc may have a spiral slot extending out from the center as in sketch (G).

If the speeds at which the discs are revolved bear the proper relation to each other, the effect of a spirally revolving pin-hole will be produced.



E



G

In place of the apparatus shown at the receiving station for deflecting the beam of light it is suggested that an electric arc be used and means be provided in the line for varying its intensity.

It is proposed that for the purpose of transmitting photographs or views of stationary objects a photographic plate be used at the receiving station and formed through the action of the mechanism. This may be accomplished with comparatively slow changes in the transmitting medium.

It is pointed out that for short distances a direct beam of light may serve as the medium of transmission between the two stations.

Ten Years of Full Automatic Telephone Service in Oslo

By M. L. KRISTIANSEN

Telephone Director, Oslo

SUMMARY—*This paper discusses the splendid results achieved by the Administration with rotary automatic after conversion from an inadequate magneto system. The equipment has completely fulfilled expectations and has made possible the introduction of several modern appliances and methods such as message rate instead of flat rate service, and "automatic subscriber" test machines. Operating expenses per line per year from 1921 to 1930 were reduced over 50%, and complaints per subscriber per year in 1929-30 decreased to 1.37.*

THE full automatic telephone system in Oslo, one of the largest of the Standard Electric Company's No. 7-A rotary automatic installations in one city in Europe, has now been in operation for ten years, the first of the nine exchanges being opened for service on January 23, 1921. The installation and reconstruction of the outside plant was started in 1916 and was not finished until 1927, the delay being due to the many difficulties arising from the war. The last exchange was cut over in November, 1927. The total number of subscribers' lines is now 36,000, with 48,000 subscribers' stations and 400 manual and automatic private branch exchanges.

The general layout of the system, the size of the exchanges in 1925, and the technical details have already been described,[1] but some of the experience gained from the actual operation of the system during these ten years may prove of interest.

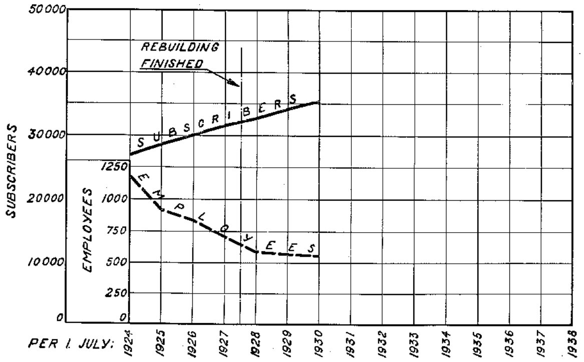


Figure 2—Subscribers' Lines and Employees of All Ranks.

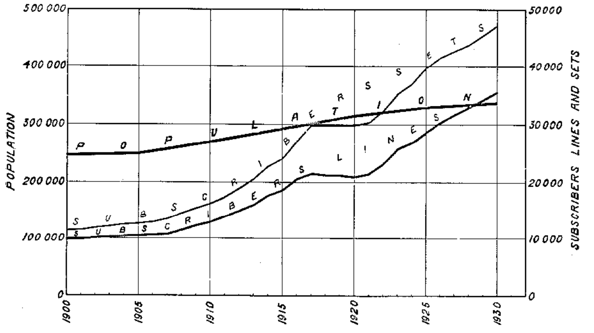


Figure 1—Population and Number of Telephones in the Oslo Area.

Before the introduction of the automatic system Oslo had a somewhat inadequate magneto system which was installed in 1896. In spite of considerable sums of money spent on its maintenance, the old system was very unsatisfactory during the last ten years of its operation. As soon as the first automatic exchange was opened for service, a decided improvement was evident and conditions continued to improve rapidly with the opening of each new exchange.

It is significant that during the actual transition period of six years not a single complaint was made in the newspapers against the new system or the work of transition. On the contrary the public was unanimous in its praise of the new system and specially requested to be connected with it.

Certain difficulties were expected due to the fact that a change was made from an old type magneto system which had outlived its useful life, to the most modern full automatic exchange system, without the usual intermediate step of manual central battery working. During the transition period the traffic between the automatic system and the manual exchanges was handled on a call indicator and semi-B basis.

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[1] M. L. Kristiansen, "Full Automatic Telephone System in Kristiania-Norway," *Electrical Communication*, Vol. III, No. 4, April, 1925.

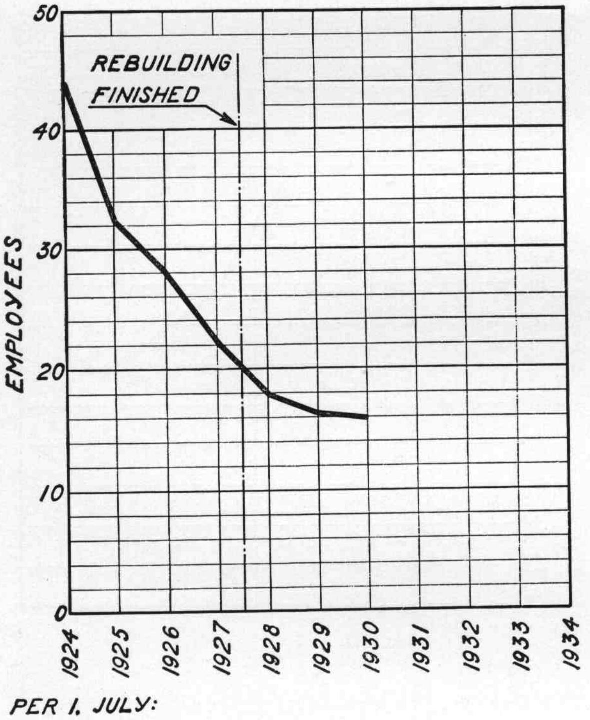

Figure 3—Employees per 1,000 Subscribers Lines.

Since the reconstruction, which was finished in 1927, there has been general satisfaction with the system and its operation. Both the subscribers and the Administration agree that the automatic system has fulfilled all that was expected of it and, at the same time, has made possible the introduction of several modern appliances and methods. The reduction in operating expense in connection with the introduction of a more equitable tariff—the message rate instead of the flat rate—has enabled the Administration to make the service cheaper, especially for the smaller and residential user, with the result that nearly 70% of the subscribers now have a cheaper telephone service than under the old and unsatisfactory manual system.

Referring to the curve in Figure 1, it will be seen that growth was stagnant from 1917 to 1921. This was primarily due to the inadequacy of the old exchange equipment, and was further accentuated by an increase of traffic during this period, when it was consequently found impossible to connect new subscribers. New subscribers could only be connected as old subscriptions were given up.

Figure 2 shows how the number of employees of all ranks and workmen has been reduced during the transition period, although the number of subscribers has increased.

Figure 3 shows the number of employees and workmen per 1,000 subscribers.

Figure 4 illustrates the improvement in the service after the conversion to the automatic system was finished. The complaints per subscriber per year show a decrease from 3.4 to 1.37. The curves in Figure 5 show the total number of faults per subscriber per year for outside lines, subscribers' station equipment and exchange equipment, also the sum of all these faults. As will be observed, the total number of faults in 1930 was 1.47 per subscriber. This figure includes faults found during routine tests, inspection, etc., i.e., faults or troubles which have not given rise to complaint from the subscribers.

The curve in Figure 6 shows the economic result, or the operating expenses per subscriber from year to year. From 1921 to 1930 these expenses have been reduced from 156 kr. to 69 kr. per annum, excluding interest and depreciation.

In the financial year 1929 to 1930, the com-

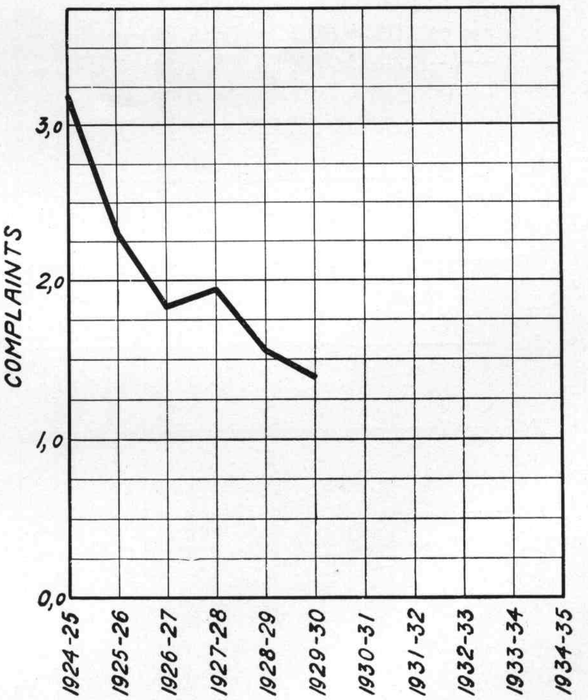

Figure 4—Complaints Per Line Per Year.

plaint and fault service shows the following figures:

Total No. of Complaints	47,694
Total No. of False Calls	7,452
Total	55,146
There were:	
Actual Faults	33,498
Faults and irregularities found during routine tests and inspection	17,554
Total faults and irregularities	51,052
No. of complaints per line	1.375

Total number of faults per line including faults and irregularities found on inspection and routine tests:

(1) Exchange faults	0.436
(2) Substation apparatus faults	0.797
(3) Outside Plant Faults	0.241
Total per line	1.474

The traffic figures are rather high, varying from an average of 4.2 in the satelite exchanges to 14.5 calls per day per line in the Centrum exchange (City) corresponding to 0.75 and 4.35 busy hour calls, respectively.

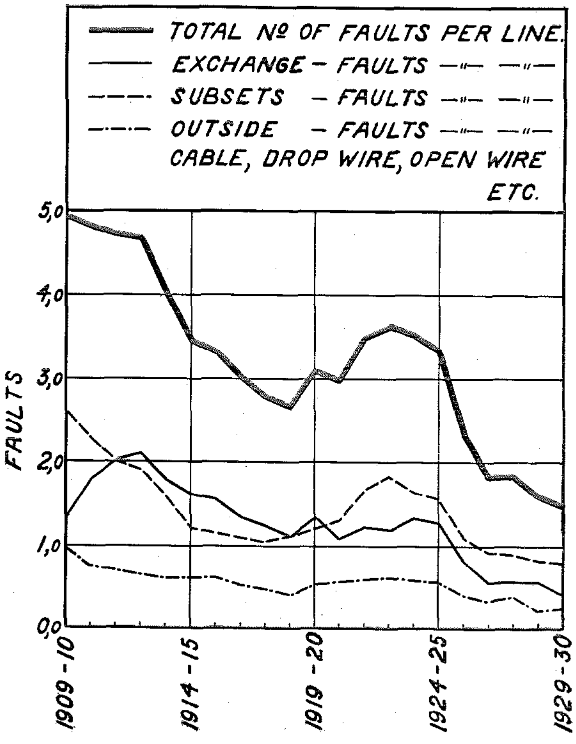

Figure 5—Faults Per Line Per Year.

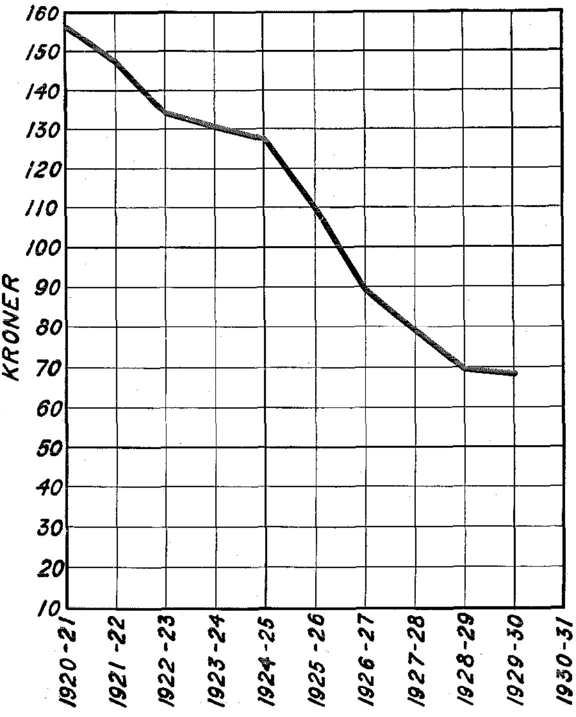

Figure 6—Operating Expenses Per Line Per Year.

The total number of calls in the year 1929–1930 was 110,702,448. During the same year 1,227,552 calls were sent through the exchanges by means of "automatic subscriber" test machines with the following results:

Effective calls	99.6%
Wrong Calls	0.2%
Lost Calls	0.2%

or an overall efficiency of 99.6%.

As a further illustration of the splendid operation of the system, during the month of February this year 1000 check calls were made from subscribers' stations in the Central Nord area, it being found by observation that no fault of any description occurred.

The new tariff which was introduced simultaneously with the cutting over of an exchange or a group of subscribers to the automatic system is made up of a fixed tariff of 108 kroner per year and 5 öre (minus a discount of 5%) per call.

In the financial year 1929–1930 the subscribers' use of the telephone was:

12%	of the subscribers made from	1 to 500	calls
23.4%	" " " "	500 — 1000	"
18.9%	" " " "	1000 — 1500	"
13%	" " " "	1500 — 2000	"
15.3%	" " " "	2000 — 3000	"
7.7%	" " " "	3000 — 4000	"
5.9%	" " " "	4000 — 6000	"
1.8%	" " " "	6000 — 8000	"
2.0%	" " " "	over 8000	"

Telephone Condensers

By R. E. W. MADDISON and S. CHAPMAN

Engineering Department, Standard Telephones and Cables, Limited

Introduction

In many branches of electrical engineering there is a large demand for a condenser of moderate cost, not requiring the extreme constancy in capacity and low power factor obtainable with mica or air condensers. This demand is met by a condenser having a dielectric of wax-impregnated paper, and electrodes of metallised paper or metal foil.

The number of such condensers used in the telephone industry is very great. For example, an 8,000 line step-by-step automatic telephone exchange requires about 15,000 paper condensers; and, in addition, one condenser is needed for each sub-set installed on the subscribers' premises. Large quantities also go into repeater and carrier equipments, as well as into radio transmitting and receiving sets. They are used to carry speech and signalling currents and, in conjunction with resistances, to quench the sparking which occurs at contacts on breaking certain types of inductive circuits.

The purpose of this paper is to describe the production and properties of paper condensers, but no discussion of the theories of dielectrics will be attempted.

Materials

For the manufacture of the type of condenser here being dealt with, there are three basic materials:

(1) The paper utilised as an interleaf to separate the electrodes, and to support the impregnating medium.
(2) The metal foil or metallised paper serving as the conductors or electrodes.
(3) The impregnating medium which, in combination with the paper, constitutes the dielectric between the conductors. The resulting dielectric is required to possess high electric strength, insulation resistance, and dielectric constant.

Paper

The paper employed in these condensers is prepared from rag stock, and is the thinnest and purest produced commercially. The thickness is from 0.007 to 0.020 mm., and a sample usually does not vary more than ± 0.001 mm. from the average. A 0.011 to 0.013 mm. paper would have a weight of 12–14 grams per square meter according to its density. The ash value is not greater than 0.5%. During manufacture, particular attention is directed towards producing a paper that is free from mechanical impurities (metallic particles), salts (chlorides), acid or alkali.

Electrodes

Paper condensers may be grouped in two classes:

(a) Foil type.
(b) "Mansbridge" type.

according to the nature of the material serving as the conductors or electrodes.

(*a*) *Foil Type*——

In this type, thin metal foil constitutes the conductor. In the early days of condenser manufacture tin foil was the only suitable material available, but it has been displaced to some extent by aluminium foil. Sometimes pure tin and sometimes tin-lead alloys are employed. In order to enable the tin to be rolled to the required thinness (about 0.012 mm.) a small percentage of antimony is added.

Within the last five years, aluminium foil (99% pure) rolled to an extraordinary degree of thinness has become available commercially. Foil 0.006 mm. can be obtained, but material about 0.008 mm. is generally employed. It is to be noted that this is about one-half the thickness of the paper employed in the condenser. The production of such thin foil as a uniform product on a commercial scale, is a remarkable achievement. Comparison of certain of the properties of tin and aluminium show the advantages of using aluminium.

	Tin	Aluminium
Density	7.3	2.7
Covering power per kilo in square meters for foil 0.010 mm. thick	13.8	37.2
Specific resistance at 20°C. in microhms per cubic centimeter	13.0	2.8

Although the price of aluminium foil per kg. is higher than that of tin, it is cheaper to use the aluminium on account of its greater covering power.

(*b*) *"Mansbridge" Type*——

G. F. Mansbridge[1] conceived the idea of utilising instead of foil a paper covered with a thin conducting layer of tin, in order to effect an economy of material.[2] The electrical conductivity of the metallised paper varies between 25% and 50% of that of a pure tin foil of the same thickness of metal, but it is sufficient for the purpose for which the paper is required. The Mansbridge paper is no thicker than ordinary condenser tissue, namely 0.012 mm. and weighs about 25 grams per square meter.

Recently it seemed as though the Mansbridge metallised paper would be displaced entirely by aluminium foil, but it appears that the former material has obtained a new lease of life in connection with recent developments in condensers for spark-quench circuits referred to hereinafter.

IMPREGNATING MEDIUM

Paraffin wax is the material generally used for impregnating paper condensers. Small quantities of other substances are sometimes added when it is desired to modify the physical properties of the wax. Materials of higher dielectric constant have also been found of use for impregnating purposes. The main advantage is that a smaller unit is obtained, but generally the electrical properties of the condenser are not so good as when paraffin wax alone is used. As in the case of the paper, the purity of the impregnating medium with regard to its freedom from mechanical impurities and acid is of great importance, and is carefully controlled.

Process of Manufacture

The following stages are passed through in the course of production of a condenser.

1. Winding of the unit.
2. Drying.
3. Impregnating.
4. Cooling.
5. Sealing.
6. Potting.

A power driven winding machine is employed. It is fitted with a revolution counter and adjustable friction brakes on the spindles carrying the rolls of paper and foil to prevent overwinding. Two metal foils separated by sheets of interleaving tissue are wound spirally, and the metal tapes which enable external connection to be made to the foils are inserted by hand at the most suitable positions as the winding progresses.

To produce a condenser having high insulation resistance, it is essential for the wound unit to be thoroughly dried before it is impregnated. Although drying may be carried out in various ways, one method frequently adopted is to place batches of wound units in ovens heated to about 110°C. After a certain time they are removed to heated pans and evacuated. The units are then impregnated and cooled under presses. When completely cooled, they are dipped in a bituminous compound which effectively seals and prevents them from absorbing moisture.

The harmful effect of moisture is well illustrated by the following results obtained on unsealed units.

(1) Exposure for one hour in an atmosphere of 50% relative humidity reduced the insulation resistance to 2/3 of its original value.
(2) Exposure for 16 hours in an atmosphere of 100% humidity reduced the insulation resistance to 1/400 of the dry value.
(3) Further exposure for 4 hours in an atmosphere of 50% relative humidity raised the insulation resistance to 15 times the value given in (2).

When the sealed units have cooled down, they are tested for capacity and insulation resistance. If they pass these tests, they are fitted with terminal plates, after which they are placed in their cans and completely covered with a bituminous compound.

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[1] E. P. 19451/1900.

[2] With regard to its manufacture, see F. Haigh, E. P. 24981/1911.

"Mansbridge" Condensers

The type of condenser invented by G. F. Mansbridge, employing metallised paper as conductors has become known by his name. The processes involved in preparing condensers of this type are no different from those for condensers utilising foil.

"Mansbridge" condensers possess a useful "self-sealing" property which deserves mention. If a breakdown occurs, it very often happens that the current which passes clears the fault by vapourising the tin round the puncture, thus leaving a small area of paper free from metal (Figure 1). This property is shared by foil condensers to a much less extent; but, if a breakdown occurs in one of them, an excess of current will sometimes remove a short circuit.

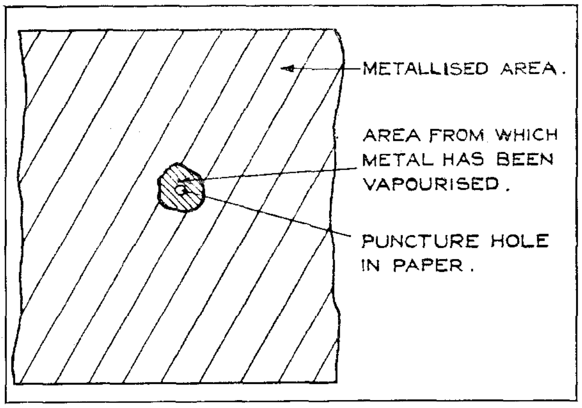

Figure 1

The reason why "Mansbridge" condensers possess this greater self-sealing property may be accounted for by the following theory: Owing to the relatively high resistance of the metallised paper, an arc is formed having a temperature sufficient to vapourise the exceedingly thin layer of tin whereas, in the case of foil, the temperature is not sufficient to vapourise the thicker layer of metal present. In the latter case, breakdowns usually result in the metal of one electrode being blown through the puncture hole in the paper and brought into contact with the other metal foil, thereby causing the short circuit. On the other hand, the breakdown voltage of a "Mansbridge" condenser having a dielectric of one interleaving tissue and one foiled paper is less than that of a tin foil condenser having a dielectric of two interleaving tissues. One foiled paper contributes to the electric strength an equivalent of about one half of that contributed by a plain interleaving tissue.

Ingenious use is made of the ohmic resistance of "Mansbridge" paper in the "inherent resistance condensers" employed in spark-quench circuits. When a coil is carrying current, energy is stored in its magnetic field, and this energy is dissipated as a spark when the circuit is broken. The spark produced at the contacts where the circuit is broken would rapidly destroy them if the inductance of the coil or the current passing through it were great. In order to dissipate the energy harmlessly, a condenser and resistance in series are placed across such contacts. The values of capacity and resistance required depend on the inductance and on the current carried by the circuit. A 200 ohm resistance and a 1 microfarad condenser are satisfactory for a circuit having an inductance of about ⅓ henry carrying a current of about 1 ampere.

The inherent resistance condenser unit consists of long narrow strips of "Mansbridge" paper separated by paper interleaves wound in the usual manner. The terminal connections, however, are made, one to the inner end of one foil, and the other to the outer end of the other foil. The electrical effect is as if the resistance of one plate were connected in series with the condenser.

Electrical Properties

ABSORPTION AND INSULATION RESISTANCE

Wax-impregnated paper shows to a marked degree the phenomenon of absorption common to all liquid and solid dielectrics. This may be described as a gradual soaking in of the charge to the inner layers of the dielectric.

Consider the case of a condenser with a perfect dielectric,[1] and suppose that at a certain instant the plates are connected to a source of constant E.M.F. Current will flow along the wires of the connecting circuit till the condenser is charged with a definite amount of electricity depending upon its capacity. The magnitude and duration

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[1] i.e., one which has an infinitely high resistance and in which no electrical losses occur. The nearest approach to this ideal is a good air condenser.

of this current, called the *normal charging current*, can be calculated, and are dependent upon the resistance and inductance of the connecting circuit as well as upon the capacity of the condenser. The inductance and resistance can be made quite small, so that the current falls to a negligible value in a very small fraction of a second. If the condenser has an imperfect dielectric, there will be added to the normal charging current a constant leakage current, called the *normal conduction current*, which will persist after the normal charging current has become negligible and so long as an E.M.F. is applied to the condenser. The magnitude of this current depends upon the value of the applied voltage (V) and upon the insulation resistance (R) of the dielectric, and is given by the expression $\frac{V}{R}$

When liquids or solids are substituted for gas as the dielectric of a condenser, a third current is observed. As mentioned above, the time required for the normal charging current to become negligible can be calculated. After this time has elapsed, a current which decays with time is found to be flowing. It is called the *anomalous charging current* or *absorption current*, and may take a very long time to disappear. When it has ceased, or can no longer be detected, the constant conduction current remains. A dielectric which exhibits the phenomenon of absorption, produces much the same effect as is obtained by connecting a resistance in series with a perfect condenser, that is to say, it retards the charging or discharging currents. Figure 2 shows the course of the absorption curve for a good paraffin-paper condenser.

Since a considerable time is needed for the steady conduction current, depending on the insulation resistance of the dielectric, to be reached, it is customary in practice to determine the insulation resistance of condensers after an arbitrary period of charging at 300 or 500 volts D.C. The time is usually one minute. The insulation resistance, which is slightly dependent on the value of the applied voltage, is usually expressed for 1 microfarad as the product of the measured resistance in megohms by the capacity of the condenser in microfarads. In the case of telephone condensers, another quantity known as the "absorption" or "electrification" is determined, and is obtained by prolonging the insulation resistance test for another minute. The difference between the galvanometer deflections, which measure the current flowing into the condenser, at the end of the first and second minutes is expressed as a percentage of the value at the end of the first minute.

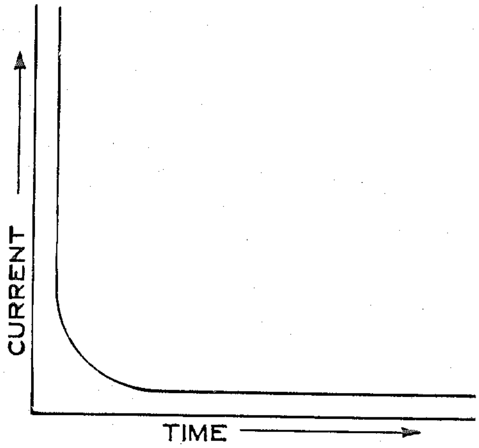


Figure 2

It has been found by experience that poor paraffin-paper condensers show a low absorption as well as a low insulation resistance; this is generally taken to indicate that conducting impurities such as moisture, which allow of a rapid leakage of the charge into the body of the dielectric, are present. There is no strict mathematical relationship between insulation resistance and absorption, but in good condensers high values of both are usually obtained. At a room temperature of 15°C. a good paraffin-paper condenser should possess an insulation resistance of 5,000—10,000 megohms per microfarad and an absorption of 25–30%. The insulation resistance has a fairly high negative temperature coefficient; a rise of 5°C. from 15–20°C. will decrease it by about 25%.

CAPACITY

The capacity of paper condensers for most telephone purposes is not usually required to be within fine limits; it is usually specified to within ± 10%. It is determined by charging the condenser with a 30 volt battery for ten seconds, and then discharging it through a ballistic galvanometer. For some circuits, particularly in repeater and carrier work where condensers are required to carry voice frequency or carrier frequency currents, the capacity has to be more accurately determined, and then the capacity measurement must be carried out on a Wien or Schering bridge at the working frequency of the condenser. The operation of most of the circuits employing paper condensers is not materially affected by capacity changes resulting from the effects of time and temperature.

From what has been said above regarding the phenomenon of absorption exhibited by these condensers, it will be appreciated that they will show a greater apparent capacity for currents of zero or low frequency than of voice or higher frequencies, since in the latter case the time available for the charge to soak into the dielectric during each half cycle is short. At high frequencies the absorption effect disappears and the true capacity approximating to the geometric capacity of the condenser is obtained. The change of capacity with frequency is continuous in the mathematical sense, and at high frequencies is asymptotic to the geometric capacity, *i.e.*, to the true capacity depending only on the geometric dimensions and disposition of the conductors, and the dielectric constant of the dielectric. The capacity-temperature coefficient for good paper condensers is usually negative. A variation in the value of the applied voltage has practically no effect upon the capacity.

POWER LOSSES

If a perfect condenser be connected to an alternating current supply, the current taken by the condenser will lead the voltage by 90°. In practice, however, all condensers are imperfect, so that the angle of lead is less than 90°, and a certain amount of power is degraded into heat within the condenser.

In the vector diagram, Figure 3, V and I represent the voltage and current vectors, respectively, ϕ the phase angle, and θ the phase displacement, or loss angle. If W represents the power in watts lost from all causes in the condenser, V the effective voltage at the terminals, and I_0 the current taken by it, then the power factor of the condenser is

$$\frac{W}{VI_0} = \sin\theta \ldots\ldots\ldots\ldots (1)$$

It is usual to regard a condenser as being

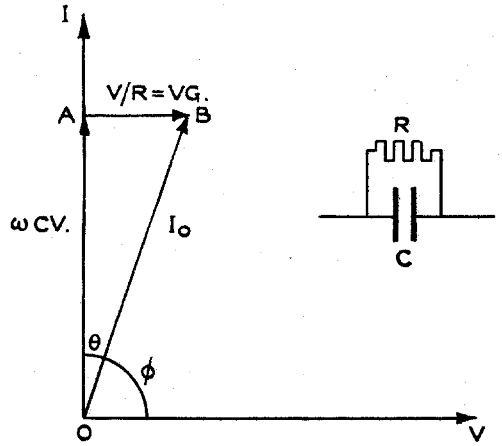


Figure 3

equivalent to a perfect condenser C shunted by a resistance R. Referring again to Figure 3, the current OB taken by the combination may be considered as the resultant of two components OA and AB; OA being the current equal to ω CV (where $\omega = 2\pi$ x frequency) taken by the perfect condenser C, and therefore at right angles to the applied voltage V; and AB being the current equal to $\frac{V}{R}$ taken by the shunt resistance R, and therefore in phase with the voltage. Instead of R, its reciprocal termed the conductance and represented by G, is sometimes used. We have then,

$$\frac{V}{R} = VG$$

From Figure 3

$$C = \frac{I_0}{\omega V} \cos\theta \ldots\ldots\ldots\ldots (2)$$

$$\text{and } \tan\theta = \frac{G}{\omega C}$$

When θ is very small,

power factor $= \sin\theta = \theta = \tan\theta$

The power factor may be expressed in terms of the conductance, G. thus

$$\sin\Theta = \frac{G}{\sqrt{G^2+\omega^2C^2}}$$

For small values of power factor, the expression $\frac{G}{\omega C}$ is a sufficiently close approximation, this being the tangent instead of the sine of the loss angle.

In good paraffin-paper condensers, the power factor is less than ½%, which is equivalent to a phase displacement of about 17 minutes. "Mansbridge" condensers exhibit a slightly higher power factor than foil condensers on account of the greater resistance of the electrodes. Combining equations (1) and (2) we have

$$\text{power loss} = W = \omega C V^2 \tan\Theta$$

The power loss may be expressed in terms of the conductance G thus,

$$W = V^2 G$$

For a parallel plate condenser having a plate area A and a dielectric thickness d, this becomes

$$W = \frac{V^2 A \delta}{d} \quad \ldots\ldots (3)$$

where δ is the specific alternating current conductivity of the dielectric.

It has been found by experiment that $\frac{G}{C}$ is independent of the size or shape of the condenser system, and is a function only of the dielectric material, the temperature, and the voltage gradient. The result may be obtained by the following approximate analysis.

If a condenser has a capacity C_0 when the dielectric is a vacuum, then its capacity C when a medium of dielectric constant $\mathcal{E}$ is substituted becomes

$$C = \mathcal{E}\, C_0 \quad \ldots\ldots (4)$$

For a parallel plate condenser

$$C = \frac{\mathcal{E}\, A \text{ x } 10^{-12}}{3.6\, \pi\, d} \text{ farads} \quad \ldots\ldots (5)$$

For small values of Θ,

$$\frac{G}{\omega C} = \frac{W}{V I_0} \quad \ldots\ldots (6)$$

$$\text{and } I_0 = \omega C V \text{ approximately} \quad \ldots\ldots (7)$$

From (5), (6) and (7)

$$\frac{G}{C} = \frac{3.6\, \pi\, \omega\, d\, W \text{ x } 10^{12}}{\omega\, \mathcal{E}\, A V^2} \quad \ldots\ldots (8)$$

Substituting (3) in (8)

$$\frac{G}{C} = \frac{3.6 \pi \delta \text{x} 10^{12}}{\mathcal{E}} = \text{constant x} \frac{\delta}{\mathcal{E}}$$

δ and $\mathcal{E}$ are specific for a given dielectric, and their values are dependent solely upon physical conditions, such as temperature, under which they are determined.

The losses occurring in a condenser are contributed from three sources.

(1) The resistance of the dielectric.
(2) The resistance of the electrodes.
(3) The A.C. conductance of the dielectric.

LIFE TESTS

No satisfactory test has yet been devised which will not only show the quality of the condenser at the time of test, but will also give some indication of its probable life under service conditions. It has been suggested that the measurement of the insulation resistance and/or the power factor immediately after the application of a high A.C. potential would be of value. The object of such a test would be to cause local heating at weak spots in the dielectric. A comparison of the values of the leakage or power factor before and after such a test might be an indication of the quality of the condenser. Permanent life tests on A.C. or D.C. (alone or superimposed) are of value in estimating the worth of a condenser, but such tests should be carried out in conjunction with determinations of insulation resistance and power factor. They have the great disadvantage of requiring a very long time, months or years, for their completion.

Telephone and Telegraph Statistics of the World

Compiled by Chief Statistician's Division, American Telephone and Telegraph Company

Telephone Development of the World, by Countries
January 1, 1930

	Number of Telephones			Per Cent of Total World	Telephones per 100 Population	Increase in Number of Telephones During 1929
	Government Systems	Private Companies	Total			
NORTH AMERICA:						
United States	—	20,068,023	20,068,023	58.12%	16.4	891,715
Canada	247,642	1,152,344	1,399,986	4.06%	14.2	65,452
Central America	11,892	12,739	24,631	.07%	0.4	974
Mexico	1,427	80,268	81,695	.24%	0.5	3,724
West Indies:						
Cuba	485	76,332	76,817	.22%	2.1	3,104
Porto Rico	404	11,856	12,260	.04%	0.8	—716
Other W. I. Places*	9,303	11,252	20,555	.06%	0.3	573
Other No. Am. Places*	100	11,309	11,409	.03%	3.2	1,214
Total	271,253	21,424,123	21,695,376	62.84%	13.0	966,040
SOUTH AMERICA:						
Argentina	—	279,990	279,990	.81%	2.5	40,410
Bolivia	—	2,507	2,507	.01%	0.1	—176
Brazil	§ 674	159,283	159,957	.46%	0.4	30,128
Chile	—	45,239	45,239	.13%	1.0	3,123
Colombia	2,297	26,075	28,372	.08%	0.3	5,972
Ecuador	§ 1,454	2,693	4,147	.01%	0.2	*—100
Paraguay	185	1,785	1,970	.01%	0.3	907
Peru	—	13,299	13,299	.04%	0.2	—566
Uruguay	—	29,022	29,022	.08%	1.6	893
Venezuela	§ 668	19,182	19,850	.06%	0.6	5,217
Other So. Am. Places	2,768	—	2,768	.01%	0.5	49
Total	8,046	579,075	587,121	1.70%	0.7	85,857
EUROPE:						
Austria	222,236	—	222,236	.64%	3.3	12,766
Belgium	259,673	—	259,673	.75%	3.2	33,828
Bulgaria	18,505	—	18,505	.05%	0.3	1,414
Czechoslovakia	142,413	15,294	157,707	.46%	1.1	13,399
Denmark (March 31, 1930)	13,309	328,490	341,799	.99%	9.6	10,751
Finland	1,314	120,750	122,064	.35%	3.3	7,273
France	1,056,034	—	1,056,034	3.06%	2.5	90,515
Germany	3,182,305	—	3,182,305	9.22%	5.0	231,875
Great Britain and No. Ireland	1,886,726	—	1,886,726	5.47%	4.1	127,040
Greece*	13,000	—	13,000	.04%	0.2	3,000
Hungary	100,590	—	100,590	.29%	1.2	7,431
Irish Free State (March 31, 1930)	27,992	—	27,992	.08%	0.9	1,054
Italy (June 30, 1930)	—	381,992	381,992	1.11%	0.9	48,935
Jugo-Slavia	66,863	—	66,863	.19%	0.4	* 5,000
Latvia (March 31, 1930)	42,189	—	42,189	.12%	2.2	7,742
Netherlands	284,433	—	284,433	.82%	3.6	28,944
Norway	† 111,238	* 77,000	188,238	.55%	6.7	3,341
Poland	102,465	83,637	186,102	.54%	0.6	*11,000
Portugal	7,877	26,681	34,558	.10%	0.6	* 5,000
Roumania	56,038	—	56,038	.16%	0.3	* 1,000
Russia (October 1, 1929)¶	331,252	—	331,252	.96%	0.2	38,437
Spain	—	184,542	184,542	.54%	0.8	38,209
Sweden	507,325	1,736	509,061	1.47%	8.3	23,310
Switzerland	268,714	—	268,714	.78%	6.7	24,466
Other Places in Europe*	93,255	19,712	112,967	.33%	1.3	5,460
Total	8,795,746	1,239,834	10,035,580	29.07%	1.9	781,190
ASIA:						
British India (March 31, 1930)	21,810	35,091	56,901	.16%	0.02	3,216
China*	90,000	66,000	156,000	.45%	0.04	1,000
Japan (March 31, 1930)	865,516	—	865,516	2.51%	1.4	54,197
Other Places in Asia*	105,795	16,796	122,591	.36%	0.1	9,151
Total	1,083,121	117,887	1,201,008	3.48%	0.1	67,564
AFRICA:						
Egypt	44,834	—	44,834	.13%	0.2	1,610
Union of South Africa#	108,937	—	108,937	.31%	1.4	6,629
Other Places in Africa*	81,023	1,314	82,337	.24%	0.1	8,507
Total	234,794	1,314	236,108	.68%	0.2	16,746
OCEANIA:						
Australia†	505,554	—	505,554	1.46%	7.9	28,854
Dutch East Indies	48,571	4,800	53,371	.15%	0.1	4,170
Hawaii	—	24,366	24,366	.07%	6.6	1,700
New Zealand#	161,041	—	161,041	.47%	10.3	8,500
Philippine Islands	5,832	17,072	22,904	.07%	0.2	1,488
Other Places in Oceania*	3,500	700	4,200	.01%	0.3	300
Total	724,498	46,938	771,436	2.23%	1.0	45,012
TOTAL WORLD	11,117,458	23,409,171	‡ 34,526,629	100.00%	1.8	1,962,409

* Partly Estimated. # March 31, 1930. †June 30, 1929. § January 1, 1929. ¶ U. S. S. R., including Siberia and Associated Republics
‡ Includes approximately 9,060,000 automatic or dial telephones, of which more than 50% are in the United States.

Telephone Development of Large Cities

January 1, 1930

Country and City (or Exchange Area)	Estimated Population (City or Exchange Area)	Number of Telephones	Telephones per 100 Population
ARGENTINA:			
Buenos Aires	2,300,000	149,968	6.5
AUSTRALIA:			
Adelaide	325,000	32,035	9.9
Brisbane	319,000	24,580	7.7
Melbourne	1,018,000	96,181	9.4
Sydney	1,239,000	118,269	9.5
AUSTRIA:			
Graz	164,000	8,719	5.3
Vienna	2,000,000	148,432	7.4
BELGIUM:			
Antwerp	519,000	34,813	6.7
Brussels	938,000	86,635	9.2
Liege	423,000	17,824	4.2
BRAZIL:			
Rio de Janeiro	1,500,000	44,144	2.9
CANADA:			
Montreal	975,000	187,985	19.3
Ottawa	183,000	37,750	20.6
Toronto	710,000	201,419	28.4
CHINA:			
Hong Kong	500,000	11,937	2.4
Nanking	500,000	2,749	0.5
Peiping	1,200,000	12,830	1.1
CUBA:			
Havana	650,000	52,659	8.1
CZECHOSLOVAKIA:			
Prague	732,000	38,869	5.3
DANZIG, FREE CITY OF	305,000	17,248	5.7
DENMARK:			
Copenhagen	790,000	136,528	17.3
FINLAND:			
Helsingfors	234,000	31,180	13.3
FRANCE:			
Bordeaux	264,000	16,207	6.1
Lille	208,000	14,301	6 9
Lyons	588,000	27,435	4.7
Marseilles	672,000	24,140	3.6
Paris	2,955,000	370,308	12.5
GERMANY:			
Berlin	4,330,000	515,175	11.9
Breslau	613,000	42,779	7.0
Cologne	725,000	68,967	9.5
Dresden	630,000	62,393	9.9
Dortmund	535,000	24,756	4.6
Düsseldorf	478,000	46,281	9.7
Essen	645,000	29,291	4.5
Frankfort-on-Main	623,000	65,606	10.5
Hamburg-Altona	1,590,000	173,828	10.9
Hannover	442,000	37,826	8.6
Leipzig	675,000	69,985	10.4
Munich	725,000	75,621	10.4
Nuremburg	494,000	36,924	7.5
Stuttgart	420,000	47,042	11.2
GREAT BRITAIN AND NORTHERN IRELAND (March 31, 1930):			
Belfast	420,000	15,138	3.6
Birmingham	1,115,000	49,805	4.5
Bradford	330,000	17,363	5.3
Bristol	410,000	17,933	4.4
Edinburgh	440,000	27,038	6.1
Glasgow	1,170,000	54,653	4.7
Hull	353,000	16,424	4.7
Leeds	505,000	20,952	4.1
Liverpool	1,165,000	55,091	4.7
London	7,740,000	675,783	8.7
Manchester	1,100,000	59,998	5.5
Newcastle	480,000	18,363	3.8
Nottingham	305,000	14,812	4.9
Portsmouth	290,000	6,993	2.4
Sheffield	515,000	18,049	3.5
Stoke-on-Trent	300,000	6,578	2.2

Telephone Development of Large Cities—(Concluded)
January 1, 1930

Country and City (or Exchange Area)	Estimated Population (City or Exchange Area)	Number of Telephones	Telephones per 100 Population
HUNGARY:			
Budapest	990,000	60,539	6.1
Szeged	127,000	2,560	2.0
IRISH FREE STATE (March 31, 1930):			
Dublin	396,000	15,350	3.9
ITALY:			
Genoa	628,000	22,516	3.6
Milan*	965,000	65,000	6.7
Rome	950,000	40,393	4.3
JAPAN (March 31, 1930):			
Kobe	755,000	28,938	3.8
Kyoto	755,000	33,439	4.4
Nagoya	905,000	27,834	3.1
Osaka	2,409,000	96,044	4.0
Tokio	2,295,000	136,546	6.0
LATVIA (March 31, 1930):			
Riga	378,000	15,745	4.2
MEXICO:			
Mexico City	950,000	47,165	5.0
NETHERLANDS:			
Amsterdam	749,000	47,048	6.3
The Hague	466,000	39,846	8.6
Rotterdam	597,000	40,158	6.7
NEW ZEALAND (March 31, 1930):			
Auckland	198,000	20,558	10.4
NORWAY (June 30, 1929):			
Oslo	250,000	45,353	18.1
PHILIPPINE ISLANDS:			
Manila	370,000	* 16,000	4.3
POLAND:			
Lodz	824,000	11,912	1.4
Warsaw	1,109,000	52,426	4.7
ROUMANIA:			
Bucharest	800,000	15,280	1.9
RUSSIA (October 1, 1929):			
Leningrad	1,840,000	63,104	3.4
Moscow	2,420,000	70,247	2.9
Odessa	435,000	4,886	1.1
SPAIN:			
Barcelona	845,000	32,848	3.9
Madrid	814,000	35,320	4.3
SWEDEN:			
Gothenburg	242,000	35,376	14.6
Malmö	120,000	17,454	14.5
Stockholm	415,000	126,529	30.5
SWITZERLAND:			
Basel	146,000	20,629	14.1
Berne	112,000	17,191	15.3
Geneva	131,000	20,132	15.4
Zurich	222,000	37,864	17.1
UNITED STATES: #			
New York	6,898,600	1,811,410	26.3
Chicago	3,360,000	987,891	29.4
Los Angeles	1,270,000	383,979	30.2
Total of the 8 cities with over 1,000,000 population	19,302,800	4,898,715	25.4
Pittsburgh	976,200	229,135	23.5
Milwaukee	708,100	155,209	21.9
San Francisco	642,300	262,019	40.8
Washington	500,000	163,343	32.7
Total of the 10 cities with 500,000 to 1,000,000 population	6,824,400	1,585,578	23.2
Minneapolis	487,700	131,907	27.0
Seattle	397,500	124,504	31.3
Denver	287,100	89,756	31.3
Omaha	226,200	65,150	28.8
Total of the 32 cities with 200,000 to 500,000 population	9,649,400	2,090,988	21.7
Total of the 50 cities with more than 200,000 population	35,776,600	8,575,281	24.0

* Partly estimated.

\# There are shown, for purposes of comparison with cities in other countries, the total development of all cities in the United States in certain population groups and the development of certain representative cities within each of such groups.

Telephone and Telegraph Wire of the World, by Countries

January 1, 1930

	Service Operated by (See Note)	Miles of Telephone Wire			Miles of Telegraph Wire		
		Number of Miles	Per Cent of Total World	Per 100 Population	Number of Miles	Per Cent of Total World	Per 100 Population
NORTH AMERICA:							
United States	P.	76,710,000	60.03%	62.4	2,300,000	32.37%	1.9
Canada	P.G.	4,476,213	3.50%	45.4	360,883	5.08%	3.7
Central America	P.G.	53,787	.04%	0.8	21,632	.30%	0.3
Mexico	P.G.	304,467	.24%	1.9	83,834	1.18%	0.5
West Indies:							
Cuba	P.G.	269,827	.21%	7.3	13,594	.19%	0.4
Porto Rico	P.G.	33,585	.03%	2.2	1,077	.02%	0.1
Other W. I. Places*	P.G.	41,472	.03%	0.7	4,606	.07%	0.1
Other No. Am. Places*	P.G.	22,000	.02%	6.2	10,000	.14%	2.8
Total		81,911,351	64.10%	49.0	2,795,626	39.35%	1.7
SOUTH AMERICA:							
Argentina	P.	895,835	.70%	8.0	207,817	2.92%	2.0
Bolivia	P.	5,292	.004%	0.2	4,791	.07%	0.2
Brazil	P.G.	452,411	.35%	1.1	108,587	1.53%	0.3
Chile	P.	134,281	.10%	3.0	39,430	.56%	0.9
Colombia	P.	43,790	.03%	0.5	20,759	.29%	0.2
Ecuador	P.G.	4,745	.004%	0.2	4,874	.07%	0.2
Paraguay	P.G.	6,006	.005%	0.7	2,223	.03%	0.2
Peru	P.	24,585	.02%	0.4	14,449	.20%	0.2
Uruguay	P.	45,327	.04%	2.5	6,465	.09%	0.4
Venezuela	P.G.	48,490	.04%	1.5	6,912	.10%	0.2
Other So. Am. Places	G.	5,287	.004%	1.0	754	.01%	0.1
Total		1,666,049	1.30%	2.0	417,061	5.87%	0.5
EUROPE:							
Austria	G.	656,177	.51%	9.7	46,731	.66%	0.7
Belgium	G.	1,111,514	.87%	13.8	29,814	.42%	0.4
Bulgaria*	G.	55,000	.04%	1.0	8,000	.11%	0.1
Czechoslovakia	P.G.	408,000	.32%	2.8	43,813	.62%	0.3
Denmark (March 31, 1930)	P.G.	930,766	.72%	26.2	7,191	.10%	0.2
Finland	P.G.	277,000	.22%	7.6	10,200	.14%	0.3
France	G.	3,570,000	2.79%	8.6	520,000	7.32%	1.3
Germany	G.	12,845,000	10.05%	20.0	304,000	4.28%	0.5
Great Britain and No. Ireland#	G.	8,390,000	6.57%	18.2	364,000	5.12%	0.8
Greece*	G.	19,000	.02%	0.3	31,000	.44%	0.5
Hungary	G.	361,100	.28%	4.2	51,400	.72%	0.6
Irish Free State#	G.	90,618	.07%	3.0	21,126	.30%	0.7
Italy (June 30, 1930)	P.G.	990,000	.77%	2.4	231,658	3.26%	0.6
Jugo-Slavia*	G.	110,000	.09%	0.7	58,500	.82%	0.4
Latvia (March 31, 1930)	G.	195,000	.15%	10.3	5,000	.07%	0.3
Netherlands	G.	* 686,000	.54%	8.8	28,000	.39%	0.4
Norway (June 30, 1929)	P.G.	532,000	.42%	18.8	29,374	.41%	1.0
Poland	P.G.	623,000	.49%	2.1	56,000	.79%	0.2
Portugal	P.G.	92,000	.07%	1.5	*20,000	.28%	0.3
Roumania	G.	169,795	.13%	0.9	47,518	.67%	0.3
Russia¶	G.	1,000,000	.78%	0.6	500,000	7.04%	0.3
Spain	P.	860,000	.68%	3.8	* 85,000	1.20%	0.4
Sweden	G.	1,170,000	.92%	19.0	51,500	.72%	0.8
Switzerland	G.	779,359	.61%	19.3	21,760	.31%	0.5
Other Places in Europe*	P.G.	305,500	.24%	3.5	30,400	.43%	0.3
Total		36,226,829	28.35%	6.8	2,601,985	36.62%	0.5
ASIA:							
British India#	P.G.	356,462	.28%	0.1	419,664	5.91%	0.1
China*	P.G.	330,000	.26%	0.1	120,000	1.69%	0.03
Japan#	G.	3,040,000	2.38%	4.8	206,000	2.90%	0.3
Other Places in Asia*	P.G.	299,100	.23%	0.2	139,600	1.96%	0.1
Total		4,025,562	3.15%	0.4	885,264	12.46%	0.1
AFRICA:							
Egypt	G.	195,380	.16%	1.0	37,048	.52%	0.2
Union of South Africa#	G.	396,000	.31%	5.0	40,000	.56%	0.5
Other Places in Africa*	P.G.	182,000	.14%	0.2	157,300	2.22%	0.1
Total		773,380	0.61%	0.5	234,348	3.30%	0.2
OCEANIA:							
Australia (June 30, 1929)	G.	2,278,000	1.78%	35.7	110,000	1.55%	1.7
Dutch East Indies	P.G.	218,636	.17%	0.4	20,805	.29%	0.04
Hawaii	P.	74,767	.06%	20.3	0	.00%	0.0
New Zealand#	G.	551,000	.43%	35.2	26,000	.37%	1.7
Philippine Islands	P.G.	46,081	.04%	0.4	10,087	.14%	0.1
Other Places in Oceania*	P.G.	7,600	.006%	0.5	3,900	.05%	0.2
Total		3,176,084	2.49%	4.2	170,792	2.40%	0.2
Total World		127,779,255	100.00%	6.6	7,105,076	100.00%	0.4

Note: Telegraph service is operated by Governments, except in the United States and Canada. In connection with telephone wire, P. indicates telephone service operated by private companies, G. by the Government, and P.G. by both private companies and the Government.
See preceding table.

* Partly estimated. # March 31, 1930. ¶ U. S. S. R., including Siberia and Associated Republics; partly estimated.

Telephone Development of Large and Small Communities—January 1, 1930

Country	Service Operated by (See Note)	Number of Telephones: In Communities of 50,000 Population and Over	Number of Telephones: In Communities of less than 50,000 Population	Telephones per 100 Population: In Communities of 50,000 Population and Over	Telephones per 100 Population: In Communities of less than 50,000 Population
Australia (June 30, 1929)*	G.	289,961	215,593	9.1	6.8
Austria	G.	167,842	54,394	7.2	1.2
Belgium	G.	182,833	76,840	5.6	1.6
Canada	P.G.	713,000	686,986	23.3	10.1
Czechoslovakia	P.G.	64,424	93,283	4.6	0.7
Denmark	P.G.	152,267	189,532	16.4	7.2
France	G.	616,978	439,056	6.9	1.3
Germany	G.	1,948,317	1,233,988	9.2	2.9
Great Britain and No. Ireland#	G.	1,361,000	559,000	5.6	2.6
Japan (March 31, 1930)	G.	507,401	358,115	3.7	0.7
Netherlands	G.	182,106	102,327	6.2	2.1
New Zealand (March 31, 1930)	G.	61,095	99,946	12.0	9.5
Norway	P.G.	63,824	122,964	15.8	5.1
Poland	P.G.	98,957	87,145	2.7	0.3
Sweden	G.	202,899	306,162	†21.0	5.9
Switzerland	G.	118,395	150,319	14.6	4.7
United States	P.	11,106,320	8,961,703	22.9	12.1

Note: P. indicates telephone service operated by private companies, G. by the Government, and P.G. by both private companies and the Government. See first table.

* Partly estimated.

\# March 31, 1930.

† The majority of this development is due to Stockholm.

Telephone Conversations and Telegrams—Year 1929

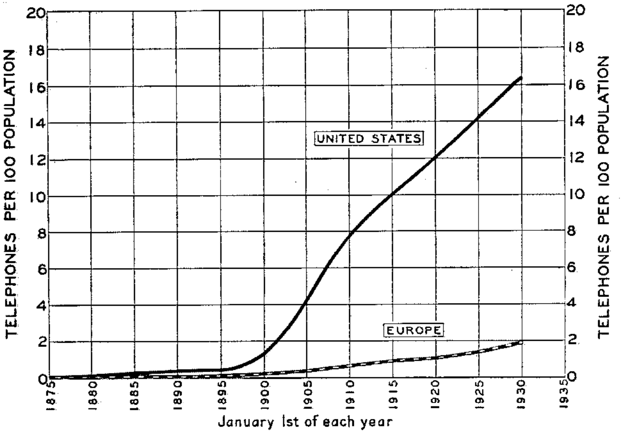
Country	Number of Telephone Conversations	Number of Telegrams	Total Number of Wire Communications	Per Cent of Total Wire Communications: Telephone Conversations	Per Cent of Total Wire Communications: Telegrams	Wire Communications per Capita: Telephone Conversations	Wire Communications per Capita: Telegrams	Wire Communications per Capita: Total
Australia	442,513,000	17,154,000	459,667,000	96.3	3.7	69.9	2.7	72.6
Austria	513,087,000	3,206,000	516,293,000	99.4	0.6	75.8	0.5	76.3
Belgium	203,361,000	5,843,000	209,204,000	97.2	2.8	25.3	0.7	26.0
Canada	2,525,000,000	15,680,000	2,540,680,000	99.4	0.6	257.7	1.6	259.3
Czechoslovakia	263,000,000	5,376,000	268,376,000	98.0	2.0	17.9	0.4	18.3
Denmark	525,630,000	2,118,000	527,748,000	99.6	0.4	148.6	0.6	149.2
France	790,887,000	37,545,000	828,432,000	95.5	4.5	19.1	0.9	20.0
Germany	2,599,000,000	30,200,000	2,629,200,000	98.9	1.1	40.6	0.5	41.1
Great Britain & No. Ireland	1,475,000,000	54,267,000	1,529,267,000	96.5	3.5	32.1	1.2	33.3
Hungary	171,569,000	3,804,000	175,373,000	97.8	2.2	19.9	0.4	20.3
Japan	3,071,000,000	58,721,000	3,129,721,000	98.1	1.9	48.8	0.9	49.7
Latvia	71,000,000	469,000	71,469,000	99.3	0.7	37.5	0.2	37.7
Netherlands	*470,000,000	5,026,000	475,026,000	98.9	1.1	60.4	0.7	61.1
New Zealand	328,626,000	6,943,000	335,569,000	97.9	2.1	212.0	4.5	216.5
Norway	244,000,000	3,450,000	247,450,000	98.6	1.4	86.5	1.2	87.7
Poland	582,833,000	5,823,000	588,656,000	99.0	1.0	19.2	0.2	19.4
Spain	379,000,000	#19,483,000	398,483,000	95.1	4.9	16.7	0.9	17.6
Sweden	773,000,000	4,035,000	777,035,000	99.5	0.5	125.7	0.6	126.3
Switzerland	214,703,000	2,820,000	217,523,000	98.7	1.3	53.2	0.7	53.9
Union of South Africa	204,700,000	5,984,000	210,684,000	97.2	2.8	25.9	0.7	26.6
United States	28,100,000,000	235,000,000	28,335,000,000	99.2	0.8	231.0	1.9	232.9

Note: Telephone conversations represent completed local and toll or long distance messages. Telegrams include inland and outgoing international messages.

* Partly estimated.

\# Year 1928.

TELEPHONE DEVELOPMENT IN UNITED STATES AND EUROPE



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Branches: Canton, Hankow, Harbin, Mukden, Peiping, and Tientsin, China.	
Compañía Standard Electric Argentina	*Buenos Aires, Argentina*
International Standard Electric Corporation, *Branch Office,*	*Rio de Janeiro, Brazil*
International Standard Electric Corporation of Mexico	*New York, N. Y.*
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Ferdinand Schuchhardt, Berliner Fernsprech-und Telegraphenwerk Aktiengesellschaft	*Berlin, Germany*
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