No. 628,246. Patented July 4, 1899.

M. HUTIN & M. LEBLANC.

TELEPHONY.

(Application filed Dec. 6, 1897.)

(No Model.) 5 Sheets—Sheet I.

Fig. 1.

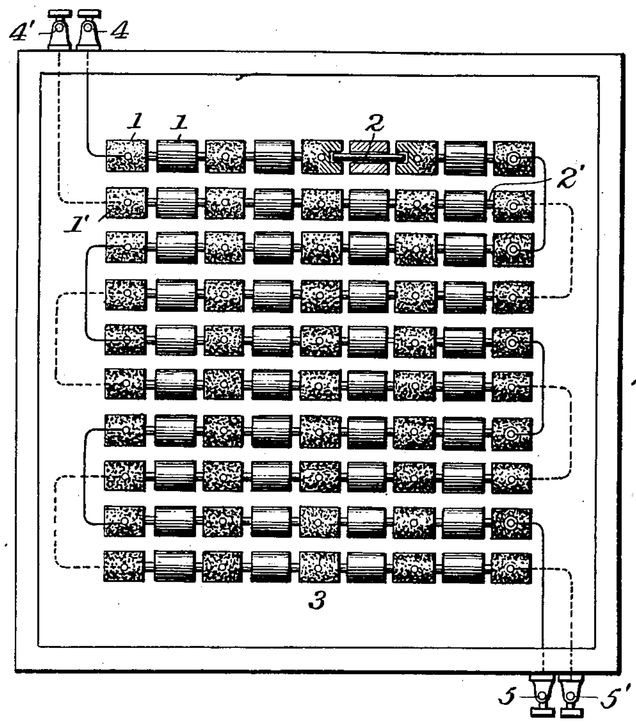
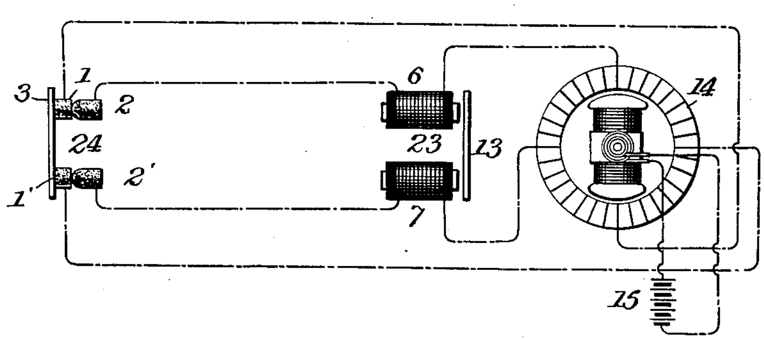


Fig. 4



Witnesses:
J. G. Hinkel.
F. T. Chapman

Inventors:
Maurice Hutin,
Maurice Leblanc,
By Joseph Lyons.
Attorney.

No. 628,246. Patented July 4, 1899.

M. HUTIN & M. LEBLANC.

TELEPHONY.

(Application filed Dec. 6, 1897.)

(No Model.) 5 Sheets—Sheet 2.

Fig. 2.

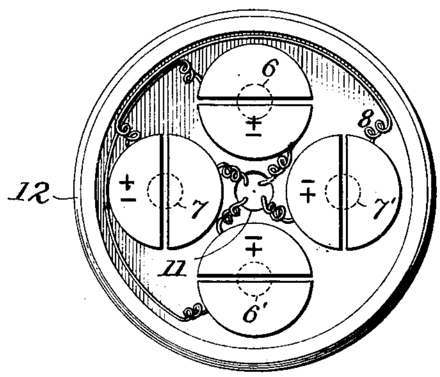
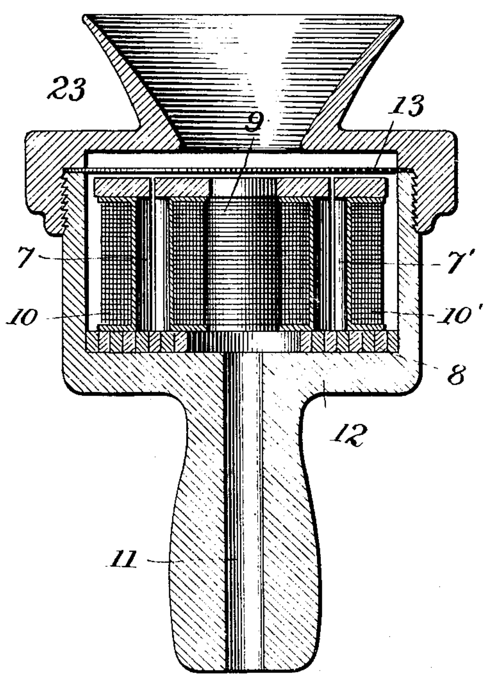


Fig. 3.



Witnesses:
J. G. Hinkel.
F. T. Chapman.

Inventors:
Maurice Hutin,
Maurice Leblanc,
By Joseph Lyons.
Attorney.

No. 628,246. Patented July 4, 1899.

M. HUTIN & M. LEBLANC.

TELEPHONY.

(Application filed Dec. 6, 1897.)

(No Model.) 5 Sheets—Sheet 3.

Fig. 7.

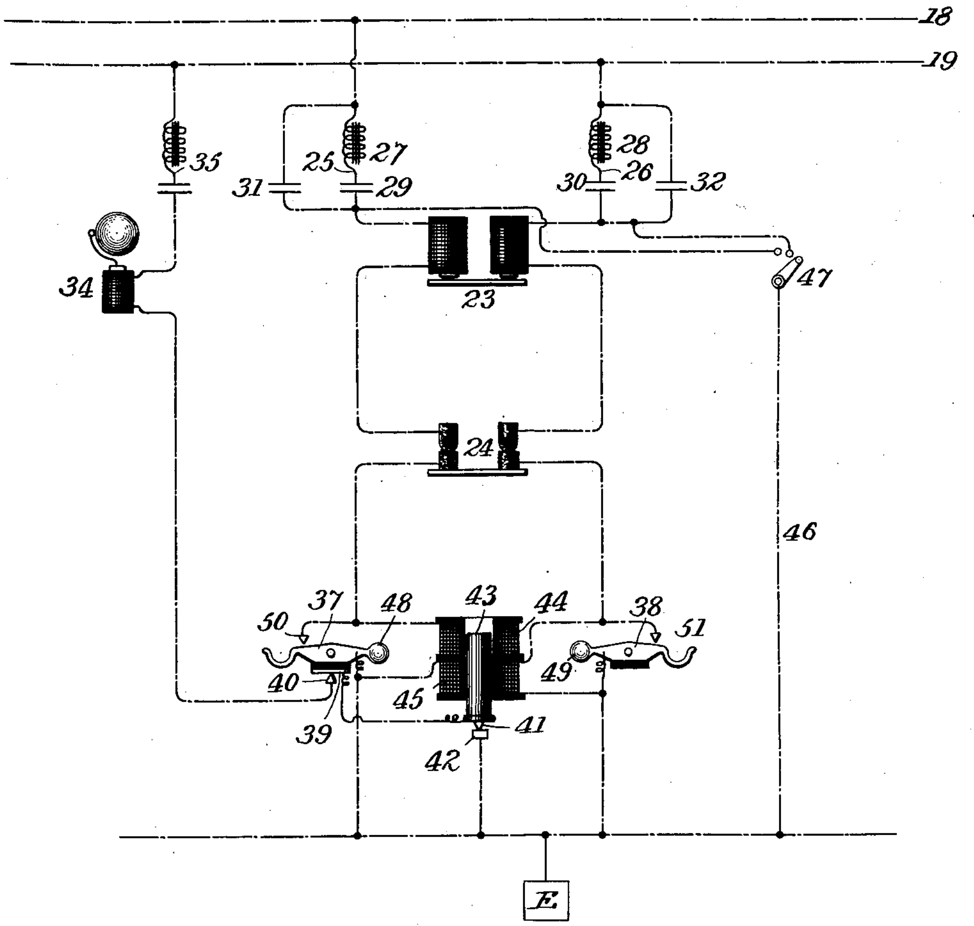
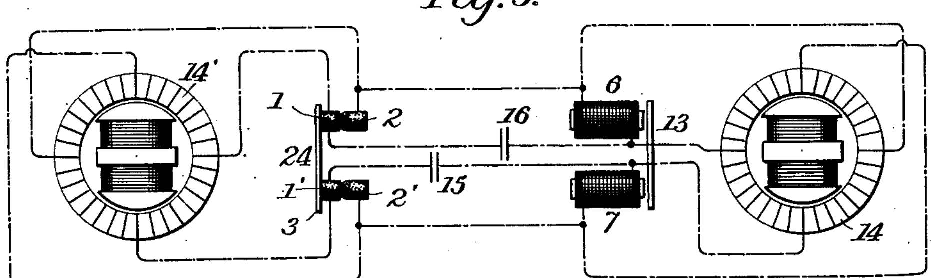


Fig. 5.



Witnesses:
J. G. Hinkel.
F. T. Chapman

Inventors:
Maurice Hutin,
Maurice Leblanc,
By Joseph Lyons. Attorney.

No. 628,246. Patented July 4, 1899.

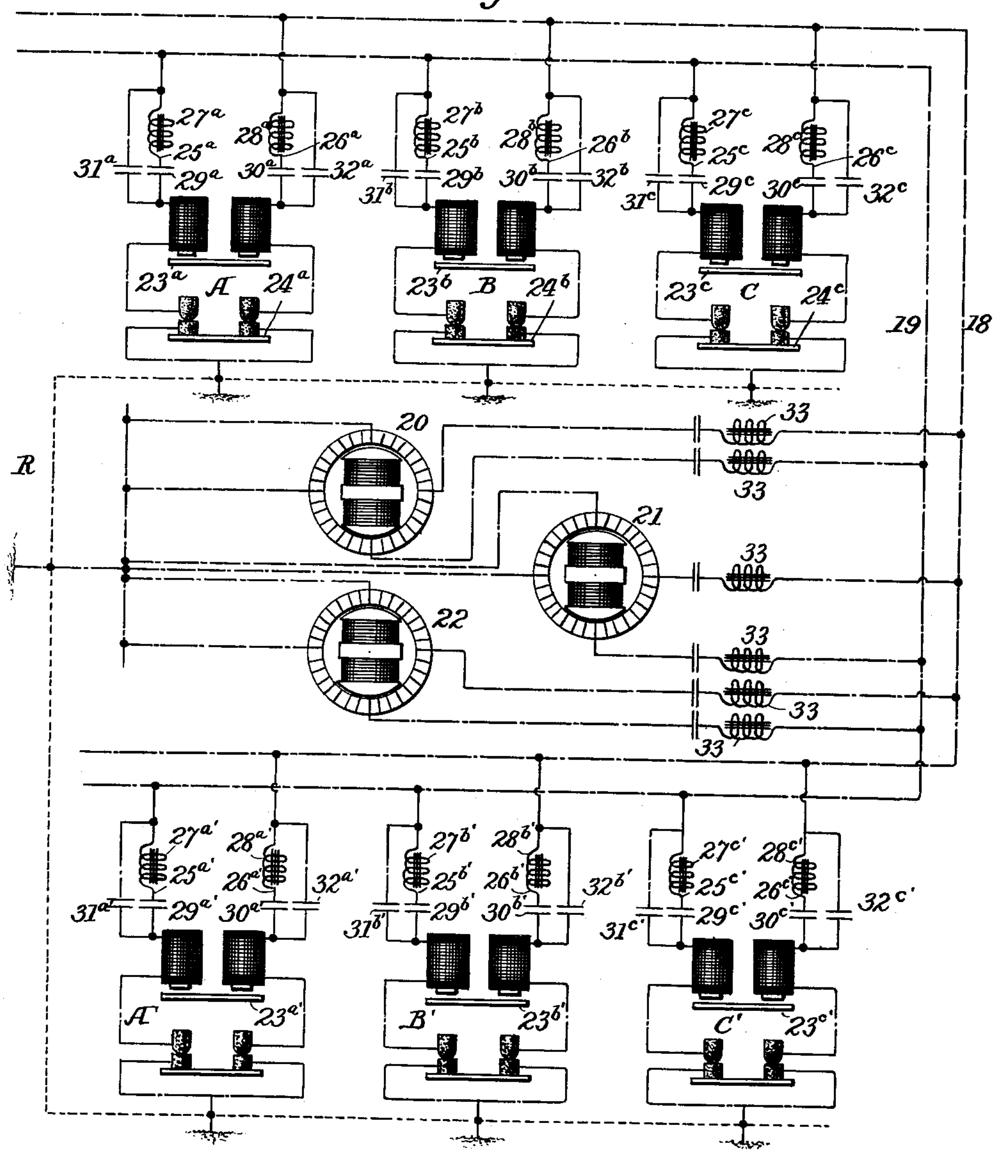
M. HUTIN & M. LEBLANC.

TELEPHONY.

(Application filed Dec. 6, 1897.)

(No Model.) 5 Sheets—Sheet 4.

Fig. 6.



Witnesses:

J. G. Hinkel.

H. T. Chapman

Inventors:

Maurice Hutin,

Maurice Leblanc,

By Joseph Lyons.

Attorney.

No. 628,246. Patented July 4, 1899.

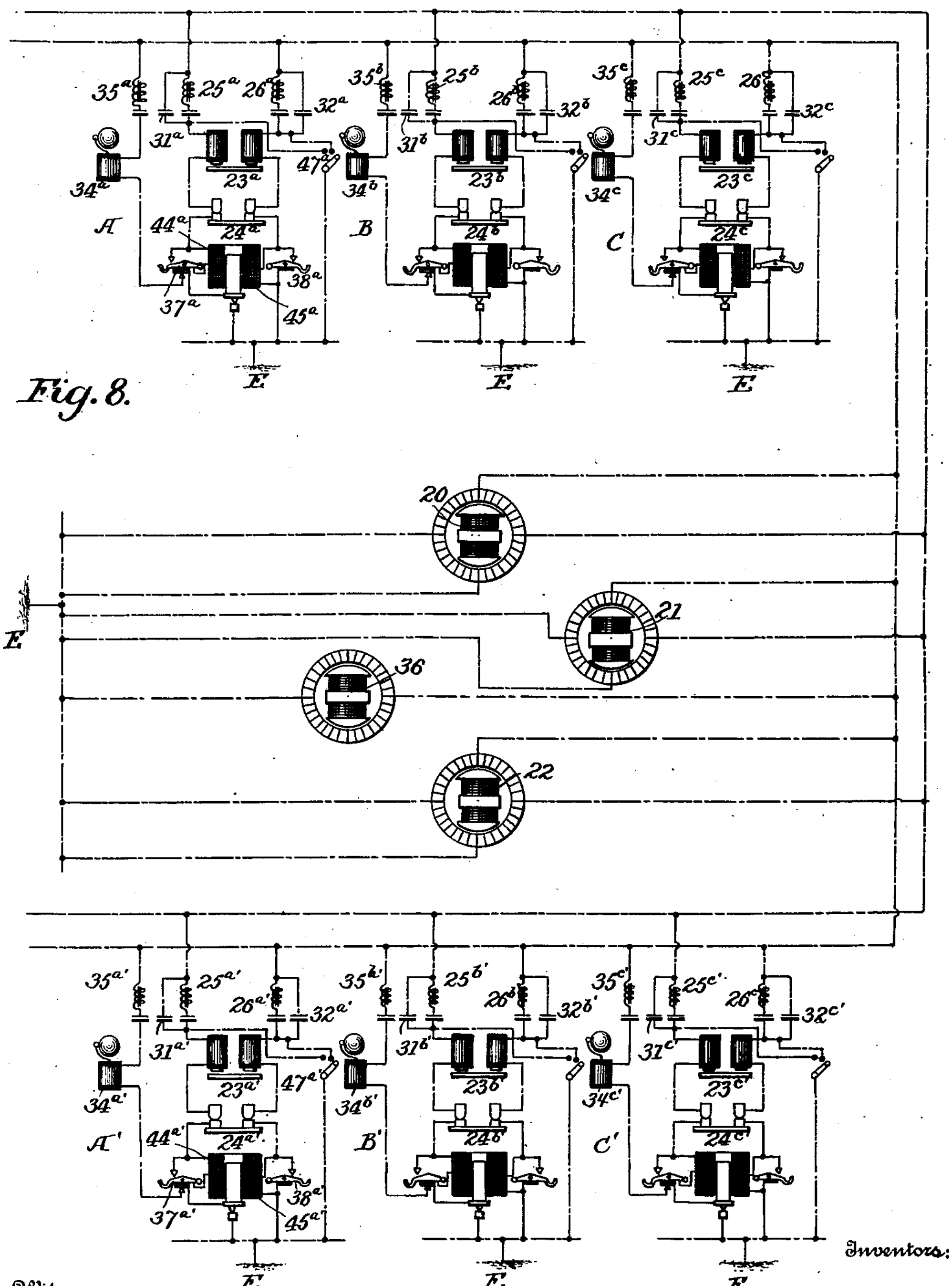
M. HUTIN & M. LEBLANC.

TELEPHONY.

(Application filed Dec. 6, 1897.)

(No Model.) 5 Sheets—Sheet 5.

Fig. 8.



Witnesses:
J.G. Hinkel.
F. T. Chapman

Inventors:
Maurice Hutin,
Maurice Leblanc,
By Joseph Lyons.
Attorney.

UNITED STATES PATENT OFFICE.

MAURICE HUTIN AND MAURICE LEBLANC, OF PARIS, FRANCE, ASSIGNORS TO THE SOCIÉTÉ ANONYME POUR LA TRANSMISSION DE LA FORCE PAR L'ÉLECTRICITÉ, OF SAME PLACE.

TELEPHONY.

SPECIFICATION forming part of Letters Patent No. 628,246, dated July 4, 1899.

Application filed December 6, 1897. Serial No. 660,911. (No model.)

To all whom it may concern:

Be it known that we, MAURICE HUTIN and MAURICE LEBLANC, citizens of the Republic of France, and residents of Paris, France, have invented certain new and useful Improvements in Telephony, (for which Letters Patent have been granted as follows: in France September 4, 1895, No. 250,067; in Germany September 13, 1895, No. 88,708; in Austria September 16, 1895, No. 46/2,018; in Hungary September 18, 1895, No. 5,660; in Belgium January 27, 1896, No. 119,552; in Switzerland January 31, 1896, No. 11,881; in Italy February 6, 1896, No. 40,845/138; in England January 29, 1896, No. 2,107, and in Spain February 7, 1896, No. 18,640,) of which the following is a specification.

Our invention has reference to a new method of and apparatus for telephonic transmission, which is applicable to simplex telephony as well as to multiplex telephony and is in the nature of an improvement upon the system of simplex and multiplex telephony shown and described in our Patent No. 596,017, granted on December 21, 1897. In the said former application we have shown that it is practicable to obtain telephonic transmission between two or more stations by normally charging or exciting the line, and thereby the transmitters and receivers, with alternating currents of a definite frequency and by modifying either the amplitude or the wave form of the normal currents by and in accordance with the sound-waves which are to be transmitted.

Heretofore, before the invention of the system of telephony set forth in our aforesaid application, telephone-lines or the transmitters associated therewith were either normally not charged or excited at all or, if normally excited, were so excited by continuous current, so that the invention shown in the said application is distinguished from all former systems by the use of normally-maintained alternating currents in the transmitters and receivers. In the said alternating-current system of telephony, however, the normal alternating currents had to be of such frequency as not to produce by themselves sufficient sound in the receivers to prevent the successful transmission of speech.

One part of our present invention differs from that set forth in our aforesaid patent in that the normal or exciting currents which are maintained are made to so act upon the receivers that no sound or, at least, no disturbing sound is produced by them whatever be the frequency of the currents employed so long as they are not modified by the action of the transmitters. For attaining this end we employ multiphase currents acted upon by a multiphase transmitter and actuating a multiphase receiver.

It is well known that the amount of energy transferred by any symmetrical system of multiphase currents is normally constant from instant to instant. It follows from this that it is possible to so organize a receiver that no appreciable vibration of its diaphragm is caused by the passage of the exciting multiphase currents if the effective value remains constant, while at the same time any suitable variation in the magnitude of the exciting-currents caused by creating voice-waves before a properly-arranged transmitter will set up vibrations in the receiver-diaphragm. We thus secure the advantages of the improved system of telephony disclosed in our above-mentioned patent and avoid the limitations of the same or the objections that might be urged against the same.

It will be seen that our improved system of telephony as thus far indicated involves the production by the action of a suitable transmitter excited by multiphase currents of certain electrical variations corresponding to the sound to be transmitted. We call such variations "speech-waves." These speech-waves in accordance with the above definition are in reality nothing but the variations of the effective value of the alternating exciting-currents of given frequency produced by the action of a transmitter upon these currents.

It will be shown more fully hereinafter that it is necessary that the exciting-currents in the receiver should be of the same frequency and of the same phase as the exciting-currents used at the origin for the excitation of the transmitter. We have discovered that speech-waves generated by the action of a transmitter excited by a current of a given frequency can be used to produce speech in a receiver only when the latter is excited by currents of the same frequency. If this condition is fulfilled, proper telephonic transmission results; but if the frequencies of the exciting-currents in transmitter and receiver, respectively, are different the receiver will cease to reproduce the sounds acting upon the transmitter-diaphragm. When these frequencies are different, the sounds produced by the receiver will be unintelligible, and if the difference of these frequencies becomes sufficiently great the receiver ceases to produce sound. These principles are utilized in our improved system of multiplex telephony. We generate at various transmitting-stations speech-waves in the manner above described, using at each transmitting-station exciting-currents of a different frequency and transmit these different sets of speech-waves over a single set of line-wires and cause each set of speech-waves to act upon a separate receiver, and we excite each of these receivers by alternating currents of a frequency corresponding to the frequency of the exciting-currents of the coördinated transmitter.

Suppose the frequency of the exciting-currents of a particular receiving-station to be ω. It is obvious that when several of the transmitters are in operation the receiver of this station may be exposed to the action of the speech-waves generated by an exciting-current of the frequency ω and also to the action of speech-waves generated by exciting-currents of other frequencies. It will hereinafter appear that the speech-waves generated by the exciting-current of the frequency ω will combine with the receiver exciting-currents of the same frequency to produce the proper sounds in the receiver, while the speech-waves generated by exciting-currents of other frequencies will practically fail to affect the receiver-diaphragm. It therefore appears that our invention contemplates the generation of a number of speech-waves by exciting-currents of different frequencies, the transmission of the speech-waves over a set of line-wires, and a combination of these speech-waves in a plurality of receivers with exciting-currents of frequencies so chosen that they will in each receiver reinforce or bring out the particular speech-waves to which it is desired that that particular receiver shall respond.

Our invention also comprises an improved call system particularly adapted for use in connection with our multiplex system just described, all of which will more fully appear from the following detail description with reference to the annexed drawings, in which—

Figure 1 is a view, partly in section, of an improved transmitter adapted for use in our system. Fig. 2 is an end view of the receiver with the mouthpiece and diaphragm removed. Fig. 3 is a central vertical section of the same. Fig. 4 is a diagram of our improved system of simplex telephony. Fig. 5 is an illustrative diagram of arrangement of apparatus serving as a basis for theoretical considerations. Fig. 6 is a general view of our improved system of multiplex telephony without the calling devices. Fig. 7 is a diagram of the complete equipment of a single station. Fig. 8 is a diagram of our improved multiplex system, including the calling devices.

In Fig. 1 is shown a microphone-transmitter 24, which may be of any preferred type, but is here shown as composed of a number of carbon blocks 1 1′, connected by carbon pencils 2 2′, mounted on the sounding-board 3 and arranged in two distinct circuits. In the form shown the blocks 1 and pencils 2 constitute a part of one circuit, having terminals at the binding-posts 4 5, while the blocks 1′ and pencils 2′ constitute part of another circuit, having terminals at the binding-posts 4′ 5′. Any vibration of the sounding-board will cause simultaneous and similar variations of the resistance of each of the two circuits. This structure represents, in effect, two microphones having a sounding-board common to both. It is evident that this is the equivalent of two entirely independent microphones, which are so arranged that both are affected by the same sounds simultaneously.

The construction of the receiver 23 is shown in Figs. 2 and 3. In this structure 6 6′ and 7 7′ are symmetrically-arranged soft-iron cores mounted on the soft-iron yoke-piece 8, which is composed of nested ring-laminæ, as shown. It will be seen that the free ends of the cores are enlarged to form pole-pieces. The cores, with their pole-pieces, are split to prevent eddy-currents. Each core is wound with a bobbin such as 9 10 10′, &c., the leading-in wires being carried through the opening 11 in the case 12, as shown in Fig. 2. The diaphragm 13 is similar to that used in an ordinary receiver. The bobbins upon the diametrically opposite magnet-cores 6 6′ are connected together, preferably in series, as are also the bobbins 10 10′, on the diametrically opposite cores 7 7′, constituting parts of two independent circuits whose coefficient of mutual induction is practically zero. The connections are so made that a current which will create a north pole in 6 or in 7 will create a south pole in 6′ or in 7′.

The arrangement and connections of our system in its simplest form will be understood by reference to Fig. 4. In this figure the transmitter 24 may be similar in form to the transmitter shown in Fig. 1, but is here more simply indicated as consisting of a diaphragm 3, a pair of contact-blocks 1 1′, and a second pair of contact-blocks 2 2′, bearing upon the contact-blocks 1 1′. The receiver 23 should preferably be of the form shown in

Figs. 2 and 3, but is here shown, for convenience of illustration, as consisting of the two bobbins 6 and 7, with their cores arranged in proximity to the diaphragm 13. The transmitter-contacts 1 2 are connected in series with the receiver-bobbin 6 and with one of the circuits of the two-phase generator 14, while the other pair of transmitter-contacts 1′ 2′ are connected in series with the receiver-bobbin 7 and with the other circuit of the two-phase generator 14. This two-phase generator may be of any ordinary type and may have its field-magnets excited from a source of direct current 15. It is designed to maintain upon the line and in the bobbins of the receiver quarter-phase currents of constant frequency and constant potential. Suppose the currents passing in the two circuits thus constituted when the transmitter-diaphragm is as rest to be represented by the equations

$$i = \mathrm{I} \sin. 2 \pi \omega t$$

and

$$i' = \mathrm{I} \cos. 2 \pi \omega t.$$

Since these currents are in quadrature and the two sets of receiver-magnet coils are displaced by ninety degrees, (see Fig. 2,) a rotary field will be produced in the receiver, and the attraction upon the diaphragm of the receiver will be constant. The diaphragm will be bent toward the cores to a certain extent, but will not vibrate so long as the sum of the energies of the line-currents is constant. The conductivities of the two circuits in which these currents i and i' flow will be practically the same and will be constant so long as the transmitter-diaphragm is at rest. When, however, the diaphragm is caused to vibrate, simultaneous and equal changes in the conductivities of the two circuits will be produced. Each of these conductivities will be equal to a constant plus a time function depending upon the sounds acting upon the transmitter or when K is the conductivity of each of the circuits, including the microphone-contacts

$$\mathrm{K} = \mathrm{C} + f(t).$$

Designating the electromotive forces generated by the alternator and acting upon these two circuits by

$$e = \mathrm{E} \sin. 2 \pi \omega t$$

and

$$e' = \mathrm{E} \cos. 2 \pi \omega t$$

and supposing the self-induction to be negligible in comparison with the resistance, the currents passing when sound is being transmitted will be

$$i = \mathrm{K}\, e \text{ and } i' = \mathrm{K}\, e',$$

or

$$i = [\mathrm{C} + f(t)]\, \mathrm{E} \sin. 2 \pi \omega t$$

and

$$i' = [\mathrm{C} + f(t)]\, \mathrm{E} \cos. 2 \pi \omega t.$$

The attraction developed on the plate will be

$$\mathrm{F} = k\,(i^2 + i'^2),$$

where k is a constant depending on the particular receiver, or, substituting herein the values of i and i' and reducing,

$$\mathrm{F} = k\, \mathrm{E}^2 [\mathrm{C}^2 + 2\, \mathrm{C} f(t) + f^2(t)].$$

In an ordinary telephone-receiver with a permanent magnet-core the magnetic fluxes are the sum of the magnetic fluxes developed by the permanent magnet and also by the telephonic current flowing in the coil. If g represents the first of these magnetic fluxes and $\varphi(t)$ the second, the attractive force acting on the diaphragm will be equal to

$$k' [g + \varphi(t)]^2 = k' [g^2 + 2\, g\, \varphi(t) + \varphi^2(t)],$$

where k' represents a constant. Of the terms of this equation g^2 is constant and $\varphi^2(t)$ is negligible, being the square of a small quantity, so that the term $2\, g\, \varphi(t)$ is the expression of the only attraction which causes appreciable motion in the plate.

Returning now to the equation for the force acting on the diaphragm in our improved system, in which the cores are of soft iron and have no permanent magnetism which we found to be

$$\mathrm{F} = k\, \mathrm{E}^2 [\mathrm{C}^2 + 2\, \mathrm{C} f(t) + f^2(t)],$$

we observe at once that it is of the same form as the equation just considered. The term $k\, \mathrm{E}^2 \mathrm{C}^2$ corresponds to the term $k'\, g^2$ in the equation of the ordinary receiver and represents the constant pull which is produced by the magnetism generated in the soft-iron core by the action of the two-phase currents when the volume of these currents is not varied by the transmitter. The second term $k\, \mathrm{E}^2\, 2\mathrm{C} f(t)$ corresponds to the term $k'\, 2\, g\, \varphi(t)$ in the equation of the ordinary receiver and represents the pull which reproduces speech. That it does reproduce speech is evident from the fact that it is a simple function of the vibrational period of the transmitter-diaphragm. The third term $k\, \mathrm{E}^2 f^2(t)$ corresponds to the third term $k'\, \varphi^2(t)$ in the equation of the ordinary receiver and is negligible, as in that case. This demonstration shows that a system constructed as shown in Fig. 4 will reproduce speech, and that the original alternating currents will not affect the receiver-diaphragm, so long as their values remain constant. We have thus shown how it is possible to provide a practical and operative simplex system, which may be excited by alternating currents of any frequency whatever, though we prefer in practice, for various reasons, to so design the generators in all of the systems described in this application that the frequencies of the exciting-currents are lower than the frequencies corresponding to the lowest tones within the range of the average human voice, but well within the limits of audibility. The system thus constructed is, however, open to the objection that for transmitting a single telephonic message four or at least three line-wires are required for a complete metallic circuit, and that even when a ground return is employed two line-wires must be used; but this disadvantage disappears when the system is multiplexed, as will be presently described; but before proceeding with this description it will be useful to consider what would be the result if, in a system such as has been above described, the alternating currents which excite the receiver had a frequency different from that of the alternating currents which excite the transmitter. To illustrate the effects which would be produced under these conditions, we have imagined the system shown in Fig. 5, in which 1 2 1′ 2′ are the microphone-contacts, as before, and 6 7 two of the coils of the receiver. These coils are fed with two-phase current of constant volume and of the frequency ω from the generator 14. Their terminals are also connected in multiple with the microphone-contacts through the line and the condensers 15 16. The microphone-contacts are fed with two-phase currents of the frequency ω' from the generator 14′. The condensers 15 16 are supposed to be of such capacity as to strongly oppose the passage of currents of the frequencies ω and ω' without materially opposing the passage of the superposed currents of the higher frequencies necessary for the production of speech.

The constant currents furnished by the generator 14 to the coils 6 7 may be represented by the equations

$$j = \mathrm{J}\ \sin.\ 2\ \pi\ \omega\ t$$

and

$$j' = \mathrm{J}\ \cos.\ 2\ \pi\ \omega\ t.$$

Suppose that the currents furnished by the generator 14′ to the microphone-contacts are practically constant and of the values

$$m = \mathrm{M}\ \sin.\ 2\ \pi\ \omega'\ t$$

and

$$m' = \mathrm{M}\ \cos.\ 2\ \pi\ \omega'\ t.$$

Suppose also that the resistance of each of the microphones is

$$\mathrm{R} = r + f'\ (t).$$

The difference of potential between the microphone-contacts and therefore the electromotive-force impressed upon each of the coils 6 and 7 by the generator 14′, supposing the self-induction of the circuits to be negligible in comparison with their resistance, will be

$$n = [r + f'\ (t)]\ \mathrm{M}\ \sin.\ 2\ \pi\ \omega'\ t$$

and

$$n' = [r + f'\ (t)]\ \mathrm{M}\ \cos.\ 2\ \pi\ \omega'\ t.$$

The electromotive forces expressed by the first terms of each of these equations—that is to say, the electromotive forces produced by the mere passage of the multiphase currents from the generator 14′ through the microphone-contacts will have no effect upon the receiver, owing to the presence of the condensers 15 16, whose capacities are too small to permit the passage of such currents. The electromotive forces represented by the second terms, however—that is to say the electromotive forces of variations of electromotive force produced by the variations of resistance of the microphones—will, being of sufficiently high frequency, cause currents to pass through the condensers to the receiver. There will therefore flow from the transmitter to the receiver currents whose volumes may be expressed by the formulas

$$x = \mathrm{X}\ f'\ (t)\ \sin.\ 2\ \pi\ \omega'\ t$$

and

$$x' = \mathrm{X}\ f'\ (t)\ \cos.\ 2\ \pi\ \omega'\ t,$$

where X is a constant depending on the conditions of the circuits, the electromotive force of the generator 14′, &c.; but the currents flowing in the receiver-coils when the transmitter is at rest are, as we have seen,

$$j = \mathrm{J}\ \sin.\ 2\ \pi\ \omega\ t$$

and

$$j' = \mathrm{J}\ \cos.\ 2\ \pi\ \omega\ t.$$

The pull on the plate 13 will then be

$$\mathrm{F}'' = \mathrm{K}'\{[\mathrm{J}\ \sin.\ 2\ \pi\ \omega\ t + \mathrm{X}\ f'\ (t)\ \sin.\ 2\ \pi\ \omega'\ t]^2 + [\mathrm{J}\ \cos.\ 2\ \pi\ \omega\ t + \mathrm{X}\ f'\ (t)\ \cos.\ 2\ \pi\ \omega'\ t]^2\}.$$

This reduces to

$$\mathrm{F}'' = \mathrm{K}'\ [\mathrm{J}^2 + 2\ \mathrm{J}\ \mathrm{X}\ f'\ (t)\ \cos.\ 2\ \pi\ (\omega - \omega')\ t + \mathrm{X}^2 f'^2\ (t)],$$

when K′ is a constant depending, among other things, upon the relative positions of the plate and the cores. If we compare this expression with those of the ordinary receiver and of the receiver in the first-described system, both of which equations are developed above, we see at once that the only pull which can produce audible sound is that which is represented by the term

$$\mathrm{K}'\ 2\ \mathrm{J}\ \mathrm{X}\ f'\ (t)\ \cos.\ 2\ \pi\ (\omega - \omega')\ t.$$

It will be seen that the intensity of the sound corresponding to such pulls will present two $\omega - \omega'$ beats per second. We find in practice that it is sufficient to give to this frequency $\omega - \omega'$ a value much below the lowest tones to be transmitted in order that the forces tending to modify these sounds shall render them unintelligible. The buzzing in the receiver, the intensity of which not being superior to that of the ordinary sounds heard in the telephone, does not interfere with the perfect comprehension of speech correctly reproduced. It follows from these considerations that in our system $(\omega - \omega')$ should be zero in order to reproduce speech with perfect clearness and that $\omega - \omega'$ must have a certain minimum value in order that the receiver may reproduce the sound in an intelligible manner. This requirement may be formulated in the following rule: Whenever the receiver is excited by currents of the same frequency as the transmitter, speech will be reproduced; but when there is a difference between the frequencies of the two exciting-currents and this difference attains a value above a certain minimum value, but much smaller than the frequency of the lowest tones of the human voice, the receiver will be practically silent. Our improved multiplex system is based upon the conclusion just reached. In its essential elements it comprises a number of transmitters and a number of receivers, preferably arranged in multiple upon one set of line-wires. Each transmitter is supplied with an exciting-current of a particular frequency and acts to send upon the line speech-waves produced by its action upon such current. The frequencies of these exciting-currents are so chosen as to bring the difference of their frequencies within the rule above enunciated. It is then arranged that each receiver is supplied with an exciting-current of a frequency equal to that of the transmitter to which it is intended that it should respond and with no other exciting-current. In such a receiver and in such a receiver only will the speech-waves produced by the action of this transmitter produce audible and articulate sound. Each receiver thus responds to the transmitter or transmitters excited by currents of the frequency of its own exciting-currents and to no others.

Fig. 6 is a diagram of our improved multiplex system. 18 19 are the conductors, carrying sine and cosine currents, respectively. The generators 20 21 22 supply, respectively, to this line currents of the frequencies ω ω' ω^2. The telephone-stations A and A′ are designed for the frequency ω, the stations B and B′ for the frequency ω', and the stations C and C′ for the frequency ω^2. The station A is provided with a two-phase receiver 23^a and a two-phase transmitter 24^a, whose circuits are connected in series between the lines and the common return, which may be through the earth, as shown, or may be through a return-wire R. (Shown in dotted lines.) The transmitter and receiver are preferably similar to those shown in Figs. 1, 2, and 3. Interposed in these circuits are the electric resonators 25^a 26^a, composed of the self-induction coils 27^a 28^a and the condensers 29^a 30^a. These condensers and self-induction coils are so adjusted that the branches in which they are located from line to earth are resonant for the frequency ω. In multiple with these resonators are placed the condensers 31^a 32^a, respectively, each of such capacity as to allow the speech-currents to pass, but to practically shut off currents of the frequencies ω ω' ω^2. The arrangement of the coördinate station A′ is the same as that of A, and the parts are correspondingly lettered. The arrangements at B and B′ are similar; but the coils 27^b 28^b $27^{b'}$ $28^{b'}$ and the condensers 29^b 30^b $29^{b'}$ $30^{b'}$ are adjusted to respond to the frequency ω'. The corresponding parts of stations C and C′ respond to the frequency ω^2.

In order to insure that the generators 20 21 22 shall furnish currents closely following the sine law, we prefer to place in each of their circuits powerful resonators 33 33, each tuned to the frequency of its particular generator. We also prefer to give to these generators a high internal impedance for reasons which will shortly appear. It will be seen that the normal effect of these generators is to supply to each of the transmitters and receivers through the tuned circuits 25^a 26^a, &c., sine and cosine currents of constant electromotive force and of constant volume. As we have shown above, these currents will have no effect upon the receivers. Suppose now that speech is delivered before the transmitter 24^a at station A. This will vary the volume of the current of the frequency ω flowing to earth at that station, and thus vary the output, and consequently the terminal electromotive force of the corresponding generator 20, which, as stated above, should have a high internal impedance. The result will be to superpose on the currents already flowing on the line those other currents, which we term "speech-currents," whose amplitude is a function of the time. These speech-currents will flow to earth through all of the condensers $31^{a'}$ $32^{a'}$ 31^b $31^{b'}$, &c., and through all receivers. In the receiver $23^{a'}$ these waves, since they come from a microphone excited by currents of the frequency ω, will combine with or be reinforced by the currents of the frequency ω already flowing to earth through the condensers $29^{a'}$ $30^{a'}$ and coils $27^{a'}$ $28^{a'}$ to produce speech, the action being essentially the same as in the form shown in Fig. 4 or as in the form shown in Fig. 5 in the special case where $\omega = \omega'$; but these speech-currents flowing to earth through the other receivers 23^b, &c., will in these other receivers combine with the currents of the frequencies ω' and ω^2 and will fail to produce speech in these receivers, as shown above in connection with Fig. 5, since the differences $(\omega - \omega')$, $(\omega - \omega^2)$, &c., fall within the values defined by the rule above enunciated. We thus arrive at a system in which n pairs of stations may be served over a single pair of wires with an earth-return or over three wires with a complete metallic circuit, each station being in connection with its coördinate station and independent of every other station on the line. While the number n may in theory be enormous, yet the practical difficulties of properly adjusting the resonant circuits will prevent it from becoming indefinitely large; but we find it possible by the use of our improvements to very materially increase the amount of service rendered by a pair of wires. In the system shown n has been taken as three for the sake of simplicity in the drawings; but in practice it may be greater, and we do not limit ourselves to any particular number of pairs of stations.

Fig. 7 shows a complete station in its preferred form with calling devices, while Fig. 8 shows a system consisting of three pairs of stations with generators, transmitters, receivers, calling-generator, call-bells, calling-switches, &c. In these figures, 23 24 and 23^a and 24^a, &c., are the receivers and transmitters, respectively, as before. 25 26 and 25^a

26^a, &c., are the selective or resonators, composed of the condensers 29 30 29^a 30^a, &c., and the self-induction coils 27 28 27^a 28^a, &c. 31 32 31^a 32^a, &c., are condensers in branch circuits, so proportioned as to allow the speech-currents to pass, while shutting off current of the frequencies ω ω', &c. E E are the earth connections, for which a common metallic return may obviously be substituted, as in the system shown in Fig. 6. 20 21 22 are the three two-phase generators delivering, as before, currents of the frequencies ω, ω', and ω^2, respectively. Thus far the system is the same as that already described in connection with Fig. 6; but it is necessary to provide some calling device, which, as shown more clearly in Fig. 7, may consist of a bell 34 of the well-known Abdank Abakanowicz type, or any other bell capable of being operated by alternating currents. These bells may be placed in branch circuits from one of the mains, as 19, in series with a resonator 35 and supplied with current from the auxiliary generator 36, as shown in Fig 8. This auxiliary generator may be of the single-phase type, furnishing currents of a frequency Ψ, which frequency is preferably lower than the frequencies ω, ω', and ω^2. The resonant branch circuits in which the bells 34^a $34^{a'}$ 34^b $34^{b'}$ 34^c $34^{c'}$ are included are all tuned to this frequency Ψ; but, as will appear below, these circuits all contain two interrupters or switches, and it is only when both of these are closed at any particular station that the bell rings.

Referring more particularly to Fig. 7, in which the parts are shown on a larger scale, 37 38 are hooks on which the receivers are hung, as we prefer to duplicate the receivers, as is well understood in the art. If a single receiver is used, the necessary single changes in the arrangement will be obvious. To avoid complicating the diagram, we have only shown the electrical connections for one of the receivers, which may obviously be connected in series or in multiple. The hook 37 carries on its under surface the insulated conducting-plate 39, and a contact-point 40, electrically connected to the bell 34, is so adjusted that when the receiver is on the hook the plate is in contact with the point. This plate 39 is electrically connected to the contact-point 41, normally held away from the contact-plate 42 by the core 43 of a solenoid. The contact-plate 42 is connected to earth. In order that the bell 34 may ring, it is evidently necessary that the point 40 touch the plate 39 and that the contact 41 touch the contact 42. To accomplish these results, it is necessary that the receiver be on the hook 37 and that the solenoid be sufficiently deenergized to allow the point 41 to bear upon the contact-plate 42. This solenoid is wound with two coils 44 45, connected, respectively, in series with the resonators 25 26 and with the transmitter and receivers. These coils are therefore normally energized at each station by the line-currents of the proper frequency; but the coils 44 and 45, as well as the transmitter and receivers, are shunted by the circuit 46, which is normally open, but which can be closed by the switch 47.

Suppose now that the operator at station A (see Fig. 8) desires to call the coördinate station A'. He closes the switch 47^a, which immediately forms a short circuit for the line-current of the frequency ω. The terminal voltage of the generator 20 drops and the coils $44^{a'}$ $45^{a'}$ at the station A', which can only be energized by the currents of the frequency ω from this generator, owing to the fact that they are in series with the resonators $25^{a'}$ $26^{a'}$, cease to hold up the core $43^{a'}$. The contact-point $41^{a'}$ accordingly drops onto the contact-plate $42^{a'}$. The branch circuit of the bell $34^{a'}$ is thus closed and the bell rings. At the same time the coils 43^a 44^a at station A are deënergized and the bell 34^a also rings; but at the stations B B' C C', which are not acted upon by currents of the frequency ω, but depend for their action upon currents of the frequencies ω' and ω^2, the coils of the solenoids are still energized, as the wire 46^a does not form a short circuit for currents of these last-named frequencies. In this way the conjugate stations only can call each other. The receivers are now taken from the hooks, which are retracted by any suitable device, as by the weights 48 49. The circuit of the bell is thus opened and at the same time the points 50 51 make contact with the hooks and cut out the coils 44 45, whose impedance would render conversation difficult. The bells then stop ringing and the line is ready for conversation. It will be understod that the essential feature of this calling apparatus is that a local circuit is closed at one station by short-circuiting at another station the line-currents of a given frequency. The use of a bell responsive to alternating currents in multiple with the line and energized by a low-frequency generator is not essential, though it forms a convenient arrangement and obviates the necessity of local batteries, nor is, indeed, the use of any bell essential, as the solenoid-core 43 forms itself a visual signal, which may in some cases be sufficient. It will also be understood that while we have described and illustrated our invention as practiced with symmetrical two-phase currents we are not restricted to the use of such currents. Nor are we restricted to the particular forms of apparatus shown and described, since these can be variously changed without departing from our invention. Thus it is obvious that in place of twin microphones other kinds of transmitters may be used and that any receiver capable of having a constant rotary field developed in it may be substituted, for the construction specifically shown nd described.

Having now fully described our invention, we claim—

1. The method of transmitting sound by

electricity which consists in producing upon a line alternating currents the sum of whose normal energy is substantially constant from instant to instant, and varying such energy by and in accordance with sound-waves, substantially as described.

2. The method of telephonic transmission, which consists in supplying a line-circuit with alternating currents the sum of the normal energy of which is substantially constant from instant to instant, modifying said energy by and in accordance with sound-waves, and translating the modified energy into sound-waves at a distant point, substantially as described.

3. The method of transmitting sound by electricity which consists in generating a plurality of dephased alternating currents, the sum of whose normal energy is substantially constant from instant to instant, causing simultaneous variations in the said currents by and in accordance with the sound to be transmitted, and translating the said variations into sound-waves, substantially as described.

4. The method of transmitting vocal and other sounds telegraphically, which consists in generating and supplying to a line-circuit dephased alternating currents, the sum of whose normal energy is substantially constant from instant to instant, modifying the amount of energy transferred by said currents by and in accordance with sound-waves, and translating the modified electrical energy into sound-waves at a distant point, substantially as described.

5. The method of transmitting local and other sounds telegraphically, which consists in producing, upon a line, currents by and in accordance with sound-waves, by the action of the latter upon alternating currents of a given frequency; combining the sound-currents thus produced, at a distant point, with alternating currents of the same given frequency, and translating the resultant current into sound-waves, substantially as described.

6. The method of multiplex telephony, which consists in producing upon a set of line-wires a number of sets of speech-currents, each by and in accordance with independent sets of sound-waves, by the action of each of the latter upon alternating currents of a different frequency; combining at a distant point or points, each set of speech-currents, thus produced, with alternating currents of such frequency as will combine with the speech-currents to reinforce the same, and translating the resultant currents into separate sets of sound-waves, substantially as described.

7. The method of multiplex telephony, which consists in generating a plurality of alternating currents of different frequencies, producing speech-currents from said alternating currents by and in accordance with independent sets of sound-waves, and combining the action of these speech-currents, in a plurality of separate receivers, with the action of exciting currents of such frequency as to reinforce, in each particular receiver, the action of one set of speech-currents, substantially as described.

8. The method of multiplex telephony which consists in generating a plurality of multiphase currents of different frequencies, impressing said currents upon line-wires, varying the impedance of a plurality of resonant shunt-circuits in accordance with the different sounds to be transmitted and thereby creating on the lines speech-currents, delivering said speech-currents to a plurality of receivers, and delivering also to each of the said receivers multiphase currents of one frequency only, corresponding in each to the frequency of the current in the shunt-circuit to which the particular receiver is to respond, substantially as described.

9. The method of operating a signal or signal-controlling device upon a circuit on which alternating currents of different frequencies are maintained, which consists in normally maintaining said signal in one position by the action of currents of one of said frequencies, and selectively shunting the currents of the said frequency when it is desired to operate the signal, substantially as described.

10. The method of multiplex signaling, which consists in maintaining upon a line alternating currents of different frequencies, maintaining each signal in one position by the action of currents of one of said frequencies, and selectively shunting the currents of a particular frequency when it is desired to operate a particular signal, substantially as described.

11. In a telephone system, the combination of a plurality of lines, with a multiphase receiver, a multiphase transmitter, and a generator of multiphase alternating currents, the sum of whose normal energy is substantially constant from instant to instant, all connected to the said lines, substantially as described.

12. In a telephone system, the combination with a source of alternating current the energy of which is substantially constant from instant to instant, a transmitter adapted to modify said energy in accordance with the sound to be transmitted, a connection from said transmitter to a set of line-wires, and a receiver connected to said line-wires, substantially as described.

13. A telephone receiving instrument, consisting essentially of a diaphragm and means for producing a rotary magnetic field in inductive proximity to the said diaphragm, substantially as described.

14. A telephone-receiver comprising a diaphragm, a plurality of soft-iron cores wound with coils for the reception of multiphase currents for the production of a rotary magnetic field, and a ring-yoke, common to all the cores, and composed of nested laminæ, substantially as described.

15. In a system of multiplex telephony, the combination with a set of line-wires, of means for simultaneously impressing thereon speech-currents by the action of transmitters upon alternating currents of different frequencies, receivers connected to said line-wires, and means for supplying to each receiver an alternating current of a frequency corresponding to that of the current acted upon by the particular transmitter to which it is to respond, substantially as described.

16. In a system of multiplex telephony, the combination of line-wires with a plurality of multiphase alternating generators connected thereto, transmitters and receivers, connections so arranged that each transmitter acts on multiphase currents of one frequency only to produce speech-currents, and means whereby each receiver is supplied with speech-currents, and with multiphase currents of one frequency only, substantially as described.

17. In a system of multiplex telephony, a plurality of receivers, means for supplying each receiver with speech-currents produced by the action of microphones upon multiphase currents of different frequencies, and means for supplying said receiver with multiphase currents of one only of the said frequencies, substantially as described.

18. In a system of multiplex telephony, a station comprising a transmitter and a receiver, a resonant circuit so adjusted as to allow to pass to said transmitter and receiver unmodified alternating currents of one frequency only, and another circuit so adjusted as to allow to pass to the said receiver speech-currents only, substantially as described.

19. In a system of multiplex telephony, the combination with line-wires, of a plurality of multiphase generators of different frequencies in multiple therewith, a plurality of transmitters and receivers, each connected in multiple with the said lines through circuits allowing currents of one only of the said frequencies to pass, and other circuits so adjusted and connected as to allow speech-currents to pass to the said receivers, substantially as described.

20. In a system of multiplex telephony, two or more line-wires, multiphase generators of different frequencies in multiple branches, for charging the line, and a plurality of stations, each having a set of branches resonant to one of said frequencies, each branch containing one winding of a multiphase receiver and one branch of a multiphase transmitter, in combination with means for admitting currents of higher frequencies than those of the line-currents to the receivers, substantially as described.

21. In a telephone system, the combination of a source of alternating current, an indicating device connected in a resonant shunt-circuit, a second resonant shunt-circuit tuned to the same frequency, and a key for opening and closing the second resonant shunt-circuit, and thereby operating the indicating device, substantially as described.

22. In a system of multiplex telephony, a plurality of generators of different frequencies connected to line, a calling device connected to line through a circuit resonant to one of said frequencies and through a switch, a second circuit, including a coil controlling said switch, resonant to another of said frequencies, a third circuit at a distant station resonant to the second of said frequencies, and means for closing said third circuit and thereby causing the signal to be actuated, substantially as described.

In testimony whereof we have signed our names to this specification in the presence of two subscribing witnesses.

MAURICE HUTIN.
MAURICE LEBLANC.

Witnesses:
EDWARD P. MACLEAN,
PAUL BOUR.