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MULTIPLEX TELEPHONY.

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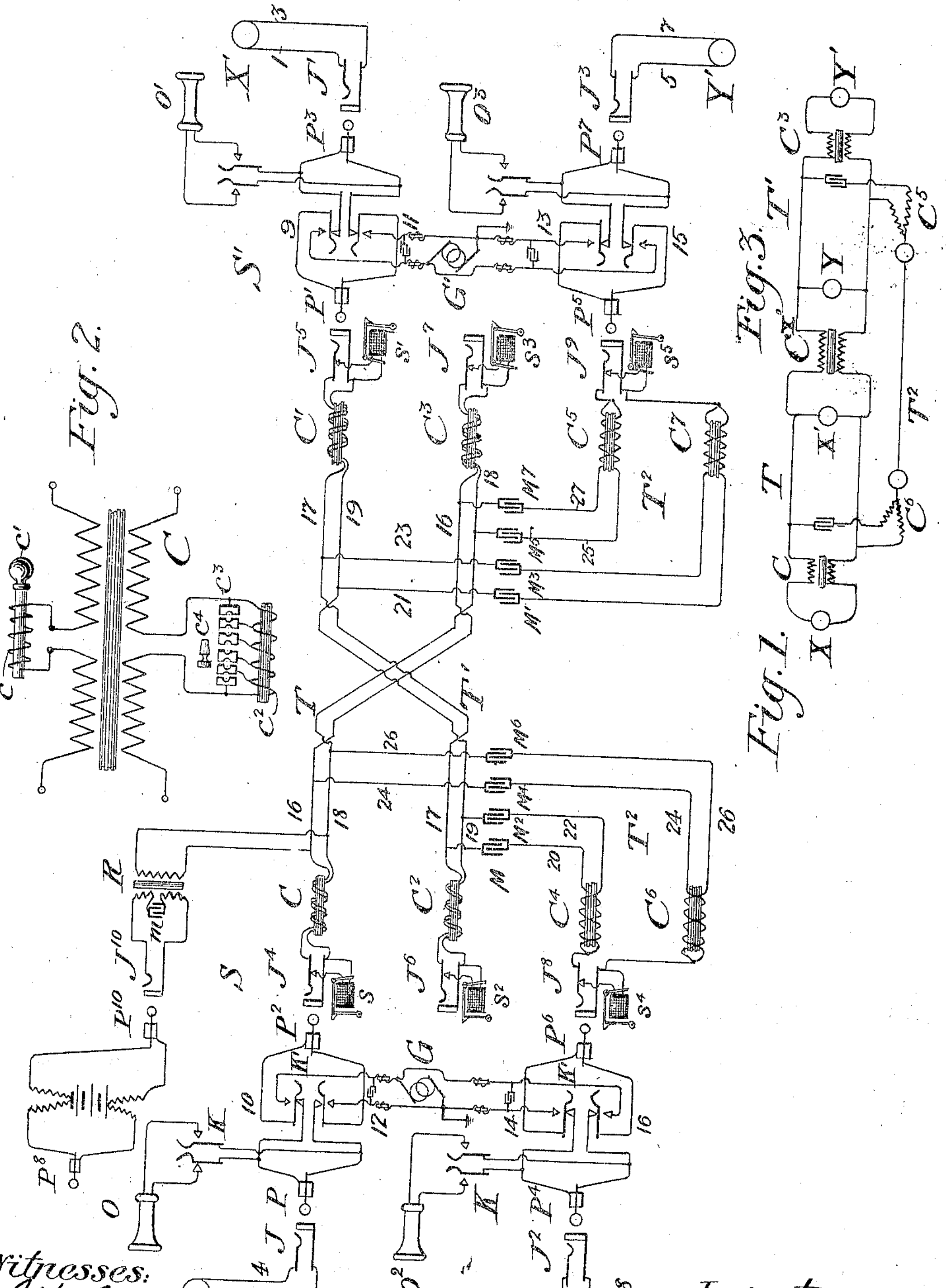

Fig. 1.

Fig. 2.

Fig. 3.

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MULTIPLEX TELEPHONY.

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To all whom it may concern:

Be it known that we, JACOB W. LATTIG and CHARLES LANE GOODRUM, citizens of the United States, residing, respectively, in Wyncote, Montgomery county, and in Philadelphia, Philadelphia county, Pennsylvania, have invented certain new and useful Improvements in Multiplex Telephony, of which the following is a specification.

Our invention relates to means for transmitting more than one telephonic communication over the same wires at the same time.

It has for its object the production of a system for such multiple transmission wherein a proper balance of the circuits is maintained, ordinary signaling-currents can be used without confusion of signals and without short-circuiting, the static capacity of pieces of apparatus whose associated parts have a difference of potential is reduced or neutralized, and other important ends are attained, which will sufficiently appear from the specification.

Referring to the accompanying drawing, Figure 1 is a diagram of a system embodying our invention as to its broad features, and Fig. 2 is a similar diagram showing one coil with means to neutralize or compensate its static capacity. Fig. 3 shows one form of composite circuit.

In Fig. 1, X Y and X′ Y′ are subscribers' stations, connected, respectively, to the central stations S S′. Between these central stations extend a pair of metallic trunk-lines T and T′, the former consisting of two wires 16 18 and the latter of two wires 17 19. These may be long-distance lines extending between distant points, or one may be a continuous circuit extending between distant points and the other may be composed of several shorter circuits connected up in tandem to form a return, as will be more fully pointed out hereafter, or both may be built-up circuits. At station S the subscribers' lines 2 4 and 6 8 terminate in spring-jacks J and J^2, and these subscribers are served by operators O and O^2, whose respective telephones are shown connected through their listening-keys K to the cord-circuits 10 12 and 14 16. The former circuit has terminal plugs P P^2 and the latter plugs P^4 P^6. Ringing-keys K′ are arranged and connected so that the operators can send alternating current from the generator G through the respective plugs P^2 P^6 to line. All of this apparatus and these local circuits are of any usual or desired type, forming no distinctive part of our invention. At the station S′ the subscribers' lines 1 3 and 5 7 terminate in jacks J′ and J^3, and all the other parts are lettered to correspond to the similar parts at station S, being distinguished by exponents of odd instead of even number. This system of numbering is uniformly adopted, all even numbers appertaining to station S and the odd numbers to station S′.

As shown in Fig. 1, the trunk T has its conductors 16 18 extending from the jack J^4 at station S to the jack J^7 at station S′. Associated with the first-named jack is a drop-annunciator s, connected so as to be cut out in the jack when a plug is inserted. Associated with the jack J^7 is a similar annunciator s^3, similarly connected. The trunk T′, extending from jack J^6 at station S to jack J^5 at station S′, is shown as similar to the trunk T, its terminal jacks being provided with drop-annunciators s^2 and s', respectively. Both these trunks are supposed to be properly transposed at suitable intervals throughout their lengths in the usual way, so that each individually will be free from disturbances. In addition, the two trunks are relatively and jointly transposed, treating each as a unitary conductor, for a purpose which will now appear.

According to our invention we combine the two trunk-lines, heretofore described, to form a third trunk or phantom circuit. This has heretofore been attempted in various ways and by divers persons, but to our knowledge has never been successfully accomplished. Since in a metallic circuit the slightest unbalancing produces a noisy line, particularly in these days of universal adoption of varying currents, it must be apparent that the difficulty in maintaining a phantom circuit composed in the manner we mention, free from noise, is much increased. According to our present invention, however, we find it possible not only to thoroughly isolate our phantom circuit so that there is no possibility of cross-talk, but to balance the lines once and for all, so that thenceforth all circuits are equally quiet, all signals are similarly received, and neither subscribers nor operators can possibly detect any difference between the real and the phantom circuits, except that transmission over the latter is a little louder, owing to lower line resistance. We attain our ends by taking a tap off from each side of each trunk-line at each end, uniting the corresponding pairs through a suitably-wound coil, and connecting up each pair as one conductor to one contact at a jack. Thus in Fig. 1 we take off the taps 20 and 22 from the conductors 17 and 19 at station S, carry them oppositely through the impedance-coil C^4, and unite them as one to the spring-contact of the jack J^8. Similarly, we take off the taps 24 and 26 from the conductors 16 and 18 of the trunk T, carry them oppositely through the double-wound impedance-coil C^6, and unite them as one to the sleeve-contact of the same jack J^8. At station S′ we take off taps 25 and 27 from the conductors 16 and 18 and carry them through the coil C^5 to the spring-contact of the jack J^9 and similarly take off taps 21 and 23 from conductors 17 and 19, carrying them through the coil C^7 to the sleeve of the jack J^9.

The jack J^8 is provided with an annunciator s^4, the same as those of the trunk-jacks J^4 and J^6. The jack J^9 has associated with it a similar annunciator s^5. These annunciators are all bridged across their respective circuits when the lines are idle, but are cut out when the lines are busy, either in the jacks or by suitable relays. It will be understood that the annunciators and their connections, as well as the coils and other pieces of apparatus, are all shown in the drawing in symbolic or conventional forms only. As our invention does not reside in or depend upon any particular type of apparatus, we have contented ourselves with illustrating it in the simplest manner possible. The trunks T and T′ are each complete and susceptible of use, as we have shown them, for talking and signaling both ways without regard to the length or character of the circuits connected with them at their terminals. On the other hand, the trunk T^2, which is a phantom circuit, depends for its balance and efficiency not only upon the proper equalization and transposition of its component circuits T and T′, but also upon the severance from the phantom circuit in its operation of the subsidiary connected circuits, which of course may be of variable length and possessed of dissimilar characteristics. This severance we may accomplish in several ways, two of which are illustrated. One is by the introduction of the coils C C′ C^2 C^3. The other is by the introduction of a repeating coil or coils R, this being resorted to particularly when a trunk is employed in connection with subscribers' lines deriving current from a centralized battery.

The coils C C′, C^2, and C^3 are all alike, each comprising a subdivided core of soft iron, which may be suitably returned upon itself to form a complete magnetic circuit, although shown in simple bar form. The windings are double, of an equal number of turns so disposed that their magnetic effects upon all parts of the core are the same. As indicated in Fig. 1, these are twin windings, the conductors being laid on together throughout their length. In practice it is preferable, however, to make what are called "layer" windings—that is, to wind one layer of one conductor, insulate the layer with paper or otherwise, then wind a second layer with the second conductor, insulate that and again wind a layer of the first conductor, and so on. The insulation resistance of the coil made in this way is very much higher than in the case of a twin-wound coil. In the latter the insulation between the two conductors is simply their individual insulation, at any point in which a puncture or breakdown is fatal to the entire coil, whereas in a layer coil the insulation between the sides of the line is due to the interposed layered resistance.

For currents passing through either trunk T or T′ individually as a metallic circuit—that is, in opposite direction through its component wires—there is substantially no retardation due to the coils, as the double windings neutralize each other in their magnetic effects on their cores. Moreover, we make the ohmic resistance of the coils as low as possible by using conductors of large size.

For currents passing over the trunk-lines T or T′, each as a single conductor—that is, over the component wire of each trunk in parallel—the coils C, C′, C^2, and C^3 offer sufficient retardation to prevent the passage of any but direct or very low frequency alternating currents. For voice-currents, therefore, and for all other currents of a reasonably high frequency sent over the phantom circuit that circuit is limited both as to its discharge of function and as to its liability to disturbance to those portions of the trunks between the coils mentioned.

In addition to the means for severing unused portions of the tangible trunks from the phantom circuit we provide means for preventing the extensions of the phantom circuit (20 22, 24 26, 21 23, and 25 27) from short-circuiting the said trunks. Such means comprise the coils C^4, C^5, C^6, and C^7, and the condensers M, M^2, M^4, M^6, and M′, M^3, M^5, and M^7. Each of these coils is wound with equal and opposite windings, preferably put on in layers, of low ohmic resistance, but having a considerable number of turns, as in the case of the other coils. The function of these latter coils is exactly the reverse of that of the first-named or trunk coils. Each coil, as C^4, has its two windings connected together at one end and the other ends connected to opposite sides of a trunk-circuit. Thus currents passing over the two sides of a trunk and over the phantom extension-wires in parallel will encounter no retardation effect, because the equal and opposite windings neutralize each other in their magnetic effect on the core. For currents passing over the two conductors of a trunk in opposite directions, however, the phantom coil C^4, C^5, C^6, or C^7 offers considerable impedance, sufficient to bar the passage of alternating currents of reasonable frequency.

The condensers M, &c., are inserted in the branches 20 to 27 in order to confine signaling-currents of low frequency or continuous in character to the respective plug-circuits over which they are sent, thus also preventing short-circuiting. We have found the use of these condensers to be essential, and we consider it an important part of our invention, because the coils C^4 to C^7 are of low ohmic resistance, and therefore the branches 20 22, &c., would otherwise seriously interfere with signaling over the trunks. We make these condensers each with a capacity preferably not exceeding two microfarads. It will be observed that in each branch current passing through the branch from one side of a trunk to the other would have to pass two condensers in series, which, by the rule governing capacities, would reduce the capacity of the branch to such an extent as to offer a very high apparent resistance to low-frequency currents. At the same time similar signaling-currents sent over the phantom circuit would find in each side thereof two condensers in parallel, giving ample capacity. The ultimate development of this idea is of course to so apportion the constants of the respective circuits that, while the phantom circuit might be approximately resonant for ringing currents of a given frequency, the series connection of the condensers in the branches 20 22, &c., would present a maximum resistance to ringing current over the trunks. In practice, however, we find that fine adjustments are unnecessary, the margin between the series and the parallel arrangement of capacities being wide enough so long as each capacity is not too high.

While we have shown our phantom circuit T^2 composed of the intermediate portions of two continuous trunks T and T′, we have stated that one or both of these trunks may be built up of shorter circuits. Such an arrangement is shown in Fig. 3. Here the stations X and X′ are connected by a metallic circuit, while stations Y and Y′ are similarly connected by a similar metallic circuit. These two circuits have their respective conductors joined through the two windings of a coil C^X similar in all respects to the coil C^4. Here the two circuits T and T′ are separated by the coil for currents in series through each; but for currents in parallel through the two sides of each circuit they are continuous and may form one side of a phantom circuit T^2, whose terminal branches are taken off through coils C^5 and C^6, as heretofore described. In all such cases we find that the static capacity of the lines is increased by the inclusion of these coils, for obvious reasons. Even in the arrangement shown in Fig. 1 the lumped capacity of each coil, being at one point in the line, is undesirable. We therefore provide means for decreasing the capacity of each coil or introduce a compensating self-inductance, which may be made as a part of the coil, but preferably is separate. We believe that the idea of reducing or compensating this localized or lumped capacity and the attainment of greatly-improved transmission thereby is original with us, and we shall present the same broadly herein.

Fig. 2 shows a diagraphic development of the coil C, with its equal and similarly-disposed windings. We break these windings, preferably at their middle point, to secure a good balance and interpose between the dissevered ends a coil possessing self-inductance. One of these coils is shown at c in Fig. 2, with an adjustable core c', which may be partly or wholly withdrawn to regulate the amount of iron in the core, and thereby the self-inductance of the circuit. Another form of coil is shown introduced in the middle of the other winding of the main coil C at c^2. In this case a plug-and-socket switch c^3 c^4, with several plugs, is used to cut in and out more or less turns in the coil c^2.

We do not wish to restrict ourselves to any particular form of compensating coil, as there are many forms that can be adapted for our purpose. We also find it quite possible to design a compensating coil without adjustments. All such variations are included in our invention.

In connecting up common-battery lines the coils C, &c., can be dispensed with, as we have stated. We have shown in Fig. 1 a repeating-coil R, whose secondary is connected to the conductors 16 18 and whose primary goes to the jack J^{10}. A condenser m is interposed to prevent magnetization of the core and lowering of the efficiency of the coil R. With this branch and its jack a pair of plugs P^8 P^{10} are employed, and the operation is the same as before described.

We do not consider it necessary to give a detailed statement of operation of our system in general, as this is apparent from the description. The results we have attained are commercial, and, as we believe we are the first to commercially perfect and make available a system of this character, we feel entitled to all equivalents that may be found for the specific forms we here present.

A feature of our invention which we have found of considerable practical importance, being, in fact, essential, if absolutely quiet lines are desired, is the arrangement of the ringing circuit to avoid cross-ringing. The idea is to prevent the low-frequency ringing current over one line from affecting the other. Condensers in the regular circuit—that is, the talking-circuit—as at M M^2 M^4 M^6, &c., are necessarily not exactly equal in capacity, it being almost impossible by ordinary commercial methods to make them perfectly uniform. Hence there is apt to be, due to the low frequency, a tendency to cross-ring from one line to the other, or, in other words, ringing in one line can be heard in the receivers of the other line. In attacking this problem the expedients of ordinary practice were of no avail, for the reason that this particular condition has apparently never arisen before. It has been proposed to use bridge-coils without condensers and to use bridged condensers without coils, (this arrangement, however, being inoperative, as it creates a short circuit for high-frequency voice-currents,) but so far as we know the combination we have arranged and which is herein set forth is original with us, and it is the first successful commercial arrangement that has been attained.

We have found that by bridging the ringing circuit with condensers and including in each side thereof a retardation-coil of a considerable number of turns between the condenser and the generator we can almost entirely, and, in fact, in many cases we do absolutely, remove the last trace of cross disturbance between the line. We ascribe this to the somewhat altered characteristics imparted to the current, the curve representing the alternations being smoothed off and approximating a sine curve.

Having thus described our invention, what we claim is—

1. In a system for the transmission of electrical currents having different characteristics, a wire-circuit composed of two conductors adapted to convey current through its component conductors serially, and a second or phantom circuit composed in part of said first-named circuit with its conductors in parallel and in part of a separate return-conductor, connected to both conductors of the first circuit by a branch wire bridged across the same, together with an electromagnetic coil and a condenser included in said branch and so connected as to impede the passage of either alternating or direct currents through said branch serially, substantially as described.

2. In a system for the transmission of electrical currents having different characteristics, a metallic circuit adapted to transmit currents over its conductors serially, and a second or phantom circuit composed in part of the conductors of the first circuit in parallel and in part of a separate return, a branch or bridge connected across the metallic circuit, an impedance-coil having its windings included serially in said branch and their middle point connected to the return-conductor, together with a condenser included in series with the coil in said branch, whereby the passage of either direct or alternating current through said branch from one side of the metallic circuit to the other is impeded, substantially as described.

3. In a duplex system of transmission, the combination of the following instrumentalities: two metallic all-wire circuits, each adapted for transmission over its own constituent conductors in series, bridges across each of the metallic circuits, each bridge containing a double differentially-wound coil, a pair of condensers in each bridge, one on each side of the coil, connections between the middle points of the windings of the corresponding coils appertaining to the two metallic circuits, and means to include talking or signaling apparatus in said connection, whereby in addition to the two metallic circuits a third or phantom circuit is produced, substantially as described.

4. In a telephone system, two metallic circuits as T and T', each terminating in a connective device, bridges across each of said circuits, a double and differentially-wound coil in each bridge, connections from the middle points of each corresponding pair of coils, as C^4 and C^6, to a third connective device, a pair of condensers in each bridge, one on each side of each coil, and means to bring talking and signaling apparatus into operative connection with said connective devices, substantially as described.

5. In a telephone system, line-circuits, double-wound coils having their respective windings included in said circuits, and means interpolated in the windings of each coil to increase the self-inductance of the coil and the circuit, substantially as described.

6. In a telephone system, a metallic circuit, a differential or neutral coil having its windings included therein, together with an auxiliary coil possessing considerable self-inductance connected to the first or neutral coil, substantially as described.

7. In a telephone system, a metallic circuit, a differential or neutral coil having its windings included therein, an auxiliary coil possessing considerable self-inductance connected to the first or neutral coil, and means for arbitrarily determining the coefficient of self-induction of said auxiliary coil at will, substantially as described.

8. In a duplex telephone system, two circuits, a bridge across each circuit, condensers in said bridges, a ringing circuit, means for connecting the same to the first-named cir-

cuits, and means in said ringing circuit to smooth down or modify the character of the ringing current to avoid very sharp or abrupt changes therein, substantially as described.

9. In a telephone system, a metallic circuit, a differential or neutral coil having its windings included therein, an auxiliary coil possessing considerable self-inductance connected to the first or neutral coil, and means to determine the number of active turns in said auxiliary coil, substantially as described.

In testimony whereof we have hereunto set our hands, this 19th day of February, A. D. 1904, in the presence of two subscribing witnesses.

JACOB W. LATTIG.
CHARLES LANE GOODRUM.

Witnesses:
MARY C. McCARTHY,
E. R. CONNELLY.