G. O. SQUIER.

MULTIPLEX TELEPHONY AND TELEGRAPHY.

APPLICATION FILED NOV. 5, 1910.

980,357.

Patented Jan. 3, 1911.

Fig. 1.

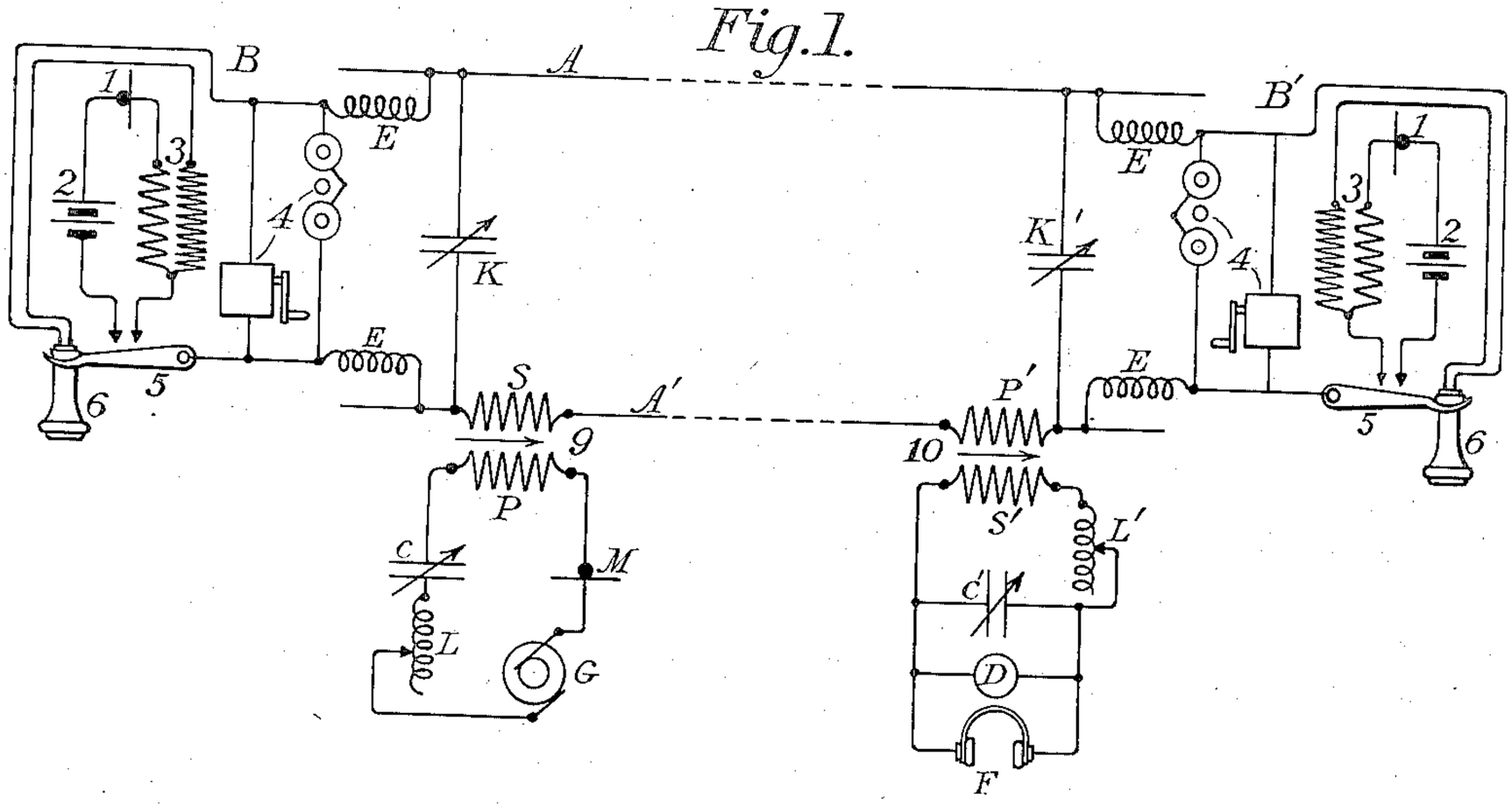


Fig. 2.

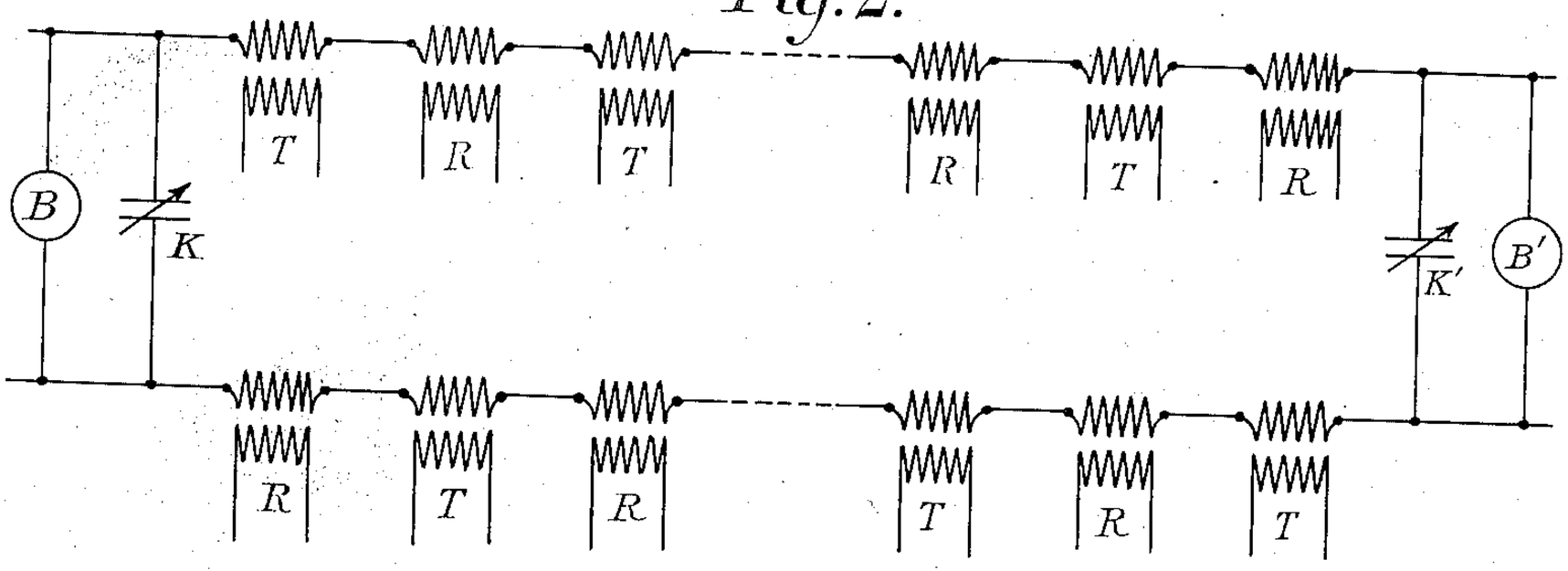
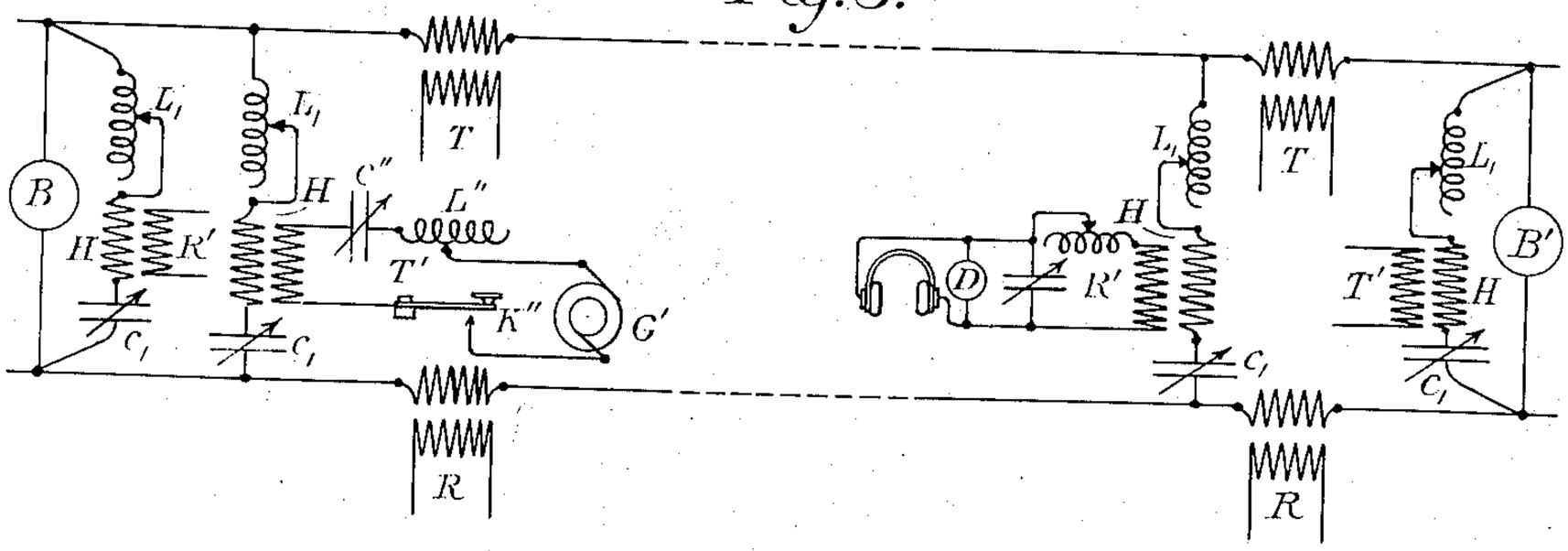


Fig. 3.



Witnesses

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MULTIPLEX TELEPHONY AND TELEGRAPHY.

980,357. Specification of Letters Patent. **Patented Jan. 3, 1911.**

Application filed November 5, 1910. Serial No. 590,802.

(DEDICATED TO THE PUBLIC.)

To all whom it may concern:

Be it known that I, GEORGE OWEN SQUIER, major in the Signal Corps, U. S. Army, a citizen of the United States, and residing at Washington, District of Columbia, (whose post-office address is War Department, Washington, District of Columbia,) have invented certain new and useful Improvements in Multiplex Telephony and Telegraphy, of which the following is a specification.

This application is made under the act of March 3, 1883, chapter 143, (U. S. Statute XXII, p. 625,) and the invention herein described and claimed may be used by the Government of the United States or any of its officers or employees in the prosecution of work for the United States or by any person in the United States without the payment of any royalty thereon.

This invention relates to multiplex telephony and telegraphy and has as its object the simultaneous transmission of a plurality of telephonic and telegraphic messages over a single telephonic circuit.

A further object of the invention is the disposition of the various elements in such a manner as to eliminate all "cross-talk" or other harmful effects of one message upon another.

A further object is to impress electric waves or oscillations of such different frequencies upon the circuit as to make possible the selection and complete independence of the various messages.

A further object is to superimpose upon a standard battery telephone circuit, as now commercially used, one or more additional telephonic and telegraphic circuits without any interference of the various messages.

In accomplishing the above results use is made of electromagnetic waves or oscillations of high frequency guided by wires.

In the whole range of electromagnetic waves, which may be looked upon as a spectrum extending from the ultra-violet rays on the one hand to the exceedingly slow oscillations, such as are used on long submarine cables, on the other hand, use has been made of all parts for various purposes with the exception of two well defined intervals, one extending from a frequency of about 3×10^{12} of the extreme infra-red, to 5×10^{19}, which are the shortest electromagnetic waves yet produced by electrical apparatus,—and another interval extending from about 100,000 cycles per second to about 15,000 to 20,000 cycles per second. This latter range of frequencies represents a practically unexplored field which I have found by experiment to be very useful in solving the problems of multiple telephony and telegraphy upon wire circuits.

When reference is made in this application to high frequency waves or oscillations, it is understood to mean oscillations with a frequency above human audition, or ultra-sound frequencies.

The limit of audibility being a physiological function is well known to vary considerably, but it is in the neighborhood of 15,000 to 20,000 cycles per second.

By employing ultra-sound electromagnetic wave frequencies as the vehicle for transmitting telephonic and telegraphic messages, it is evident that all harmful effects to any element of the battery telephone apparatus are immediately removed, since not only are any such effects very minute, in character, by virtue of the high period of the oscillations, but also, even if there were any effects in the telephone receiver, or transmitter, or any other part of the apparatus, it could not be detected by a human being, since the natural limitations of the ear afford a most effective and sure separation between all frequencies above 15,000 to 20,000 per second on the one hand, and all frequencies below 15,000 to 20,000 and down to about 16 per second, which is the lower limit of audibility. Therefore, a fundamental principle of this system may be said to be, from one viewpoint, the utilization of this unalterable characteristic of the human ear.

With such frequencies as are used in ordinary battery telephony the so-called phenomenon of "skin effect" is comparatively small, and the current is fairly well distributed throughout the cross-section of the conductor. As the frequency increases the skin effect becomes more pronounced and the energy appears to be more and more transmitted or stored in the ether surrounding the conductor. For this reason the battery telephone current is largely a conduction current through metal, and the ohmic resistance of the wire is one of the principal elements which limits long distance telephony at present, whereas in commercial wireless telegraphy, in which frequencies from 100,000 up

to several millions are used, the impressed energy is chiefly radiated into the ether.

In the intermediate range from say 20,000 to 100,000 and above the energy is largely carried by the ether; but is still sufficiently linked to the conductor to prevent excessive radiation into the ether. The conductor while carrying but a small part of the energy at its surface nevertheless acts as an efficient guide for the high frequency electromagnetic waves. In accordance with these principles, use is made of these efficiently guided electromagnetic ether waves as a vehicle to carry the telephonic or telegraphic message.

In accomplishing the above it has been found necessary and sufficient to combine the engineering practice of wireless telegraphy and telephony with the engineering practice of wire telegraphy and telephony. Since wireless engineering deals with frequencies much higher than ordinary telephony, it is obvious that different dimensions for capacities and inductances must be used, for instance, whereas the ordinary telephonic practice makes use of condensers with capacity of several microfarads it is here necessary to use capacities of the order of magnitudes of thousandths of a microfarad and inductances of millihenries.

The present invention makes use of the types of apparatus, engineering methods, etc., now practiced in the wireless art and applies them to the transmission of electromagnetic waves along wires, with the result of an enormous increase in efficiency of such transmission over the ordinary method employing antennæ at transmitting and receiving stations. The circuits employed in this invention are ordinary telephonic circuits, such as now used in wire telephony and telegraphy, and are very poor radiators of electromagnetic energy; in fact, the regular twisted-pair paper-insulated lead-covered telephonic cable affords a circuit for such electromagnetic waves which produce a very closely bounded system and the energy is principally conveyed in such a circuit in the minute layer of ether separating the two metallic conductors. In this manner, and by these means, a most efficient system of directive high frequency telegraphy and telephony is attained, and also any interference between neighboring circuits operated by this system is eliminated, so that a plurality of such circuits may be brought to the same switch board with no harmful interfering effects.

It is old in the art to use high frequency oscillations and modify these in accordance with speech vibrations by affecting some electromagnetic constant or constants of the circuit in which the oscillations take place. It is possible to change the capacity, the inductance or the resistance of such a circuit or combinations of these, and while I do not wish to limit myself to any one of these, I have found that it is very convenient and effective to change the resistance by a suitable telephone transmitter such as a microphone transmitter of the usual types employed in ordinary telephonic work. Having modified these oscillations suitably they are transmitted over the line to a receiving station where they are then received in a suitable selective circuit containing a detector for high frequency oscillations, any detector, such as used in wireless telegraphy or telephony, being satisfactory so long as it is a quantitative or integrating detector. By means of suitable translating means the oscillations are then transformed into telephonic currents, all of which is described more in detail hereafter.

Since a plurality of high frequency waves of different frequencies may be impressed on the same line and since these may be selectively separated from each other by suitably tuned circuits, it is obvious that multiplex telephony may be accomplished. Also, for the reasons stated above, it has been found that these high frequency waves may exist on the same line with ordinary battery telephone currents without in any way affecting them, and thus this system of multiplex telephony may be applied to the usual telephonic circuits without the presence of harmful effects, such as "cross-talk" or other disturbances.

It has been found necessary, in order to obtain efficient results, to make use of such detectors as are commonly found in the wireless telegraphic art. Attempts have been made at multiplex telephony, but I have found these inoperative for the reason, among others, that no detector or equivalent device has been used. These detectors are not used because of any greater sensitiveness to electrical energy than resides in the telephone receiver itself, but because the energy, being in the form of rapid oscillations, cannot affect the telephone or other indicating device. These rapid oscillations cannot sensibly affect the telephone because the diaphragm in its motion must reverse with the reversal of the current and the deflecting impulse if applied directly to the telephone receiver will be first in one direction and then in the other with a frequency so high that the diaphragm cannot follow or respond. Furthermore, if the diaphragm should respond with this frequency the effect would not be audible. Also, in the case of the ordinary telephone, on account of the large self-inductance of the instrument, the high frequency E. M. F. generated by the waves would produce in a telephone receiver only extremely weak currents. I have found it necessary, therefore, and consider it an important part of my invention to make use of some form of integrating detector to

transform these rapid oscillations into effects which can be manifested by the indicating instrument.

In the drawings forming a part of this specification several modifications for the circuit connections are shown.

This application is closely related to my co-pending application, Serial Number 590,801, filed November 5, 1910, in this, that use is made of high frequency electromagnetic waves or oscillations to act as a vehicle for the telephone or telegraph messages which oscillations are impressed upon the same line as carries the telephonic currents from an ordinary local battery telephone set. This application differs from said co-pending application essentially in this, that the various sources of high frequency current modified in the proper manner are inserted directly in series with the line circuit, whereas in the co-pending application these sources of high frequency currents are bridged across the line.

In the drawings forming a part of this specification several modifications for the circuit connections are shown, and in said drawings, Figure 1 illustrates a form of circuit in which a single high frequency oscillatory telephonic message is impressed upon the line by a series connection. Fig. 2 shows a modification of Fig. 1 and contains a plurality of transmitters and receivers connected to the line. Fig. 3 illustrates still a further modification.

Referring to these figures in detail Fig. 1 shows a common metallic circuit for ordinary telephony, across which is bridged the ordinary telephone sets B and B′. These telephone sets include the usual apparatus as in present use in local battery telephone circuits, there being shown a microphone transmitter 1 with its local battery 2 and the primary of the transformer 3. Also there is shown connected in the usual way the ringing circuit 4 and the switchhook 5 with the receiver 6. The secondary of the transformer 3 is bridged directly across the line wires A and A′ when the receiver is off the hook. The invention is not in any way connected with the details of this telephone connection, any of the usual circuit connections being suitable and the one described being given merely as an illustration. In series with the telephone sets B and B′ and connected directly in the line circuit is the secondary S of the transformer 9, the primary P of which transformer is contained in a circuit including the high frequency generator G, the microphone M, the variable condenser C and the variable inductance L. At another point of the line, which represents the receiving station, is placed the primary P′ of a transformer 10, this primary being directly in series with the battery sets in the same manner precisely as the secondary S of the transformer 9. The secondary S′ of the transformer 10 is connected in series with a variable inductance L′ and a variable condenser C′. In shunt to the condenser C′ is placed a detector D of any suitable type, such as, for instance, the Audion. In operative connection to the detector D is the telephone head-piece F. Bridged across the line as shown are the two variable condensers K and K′. These condensers are of such small capacity as to interpose very high impedance to the ordinary telephonic currents set up by the telephone sets B, but, being of dimensions of some thousandths of a microfarad, interpose practically no impedance to the high frequency currents developed by the generator G.

The operation of this system is as follows: Currents set up in the usual way by the telephone transmitter set B will be transmitted over the line to the receiving station placed at any desired and convenient point. High frequency currents developed by the generator G and modified by the microphone M are also impressed upon the line simultaneously therewith. Although these currents exist on the line at the same time, they exert no influence upon each other whatsoever, and the ordinary telephonic messages pass through the primary P′ of the transformer 10 without in any way operatively affecting the tuned circuit L′ C′, this circuit being tuned to the frequency of the oscillations developed by the generator G. The high frequency currents, however, are unable to affect the transmitter B, being of ultra-sound frequency, and furthermore are practically, if not totally, unable to pass through this set because of its high impedance. The high frequency oscillations set up in the circuit L′ C′, retaining the modifications impressed upon it by the microphone M, are then transformed by the detector D, giving a reproduction of speech in the telephone F. As shown in this figure, the local generator circuit may be tuned to the frequency of the generator G by means of the condenser C and the inductance L, and this is particularly desirable where the power of the generator is limited. This also affords a convenient method of diminishing the output of the generator, this being accomplished by throwing the circuits slightly out of tune. The transformers 9 and 10 are also made in such a manner as to give a variable coupling, this being most readily accomplished by making one coil slide within the other or one coil swing within the other, although any other well known method may be used.

The generator circuit may be modified in various ways without in any way affecting the principle of the invention. The same is true also of the receiver circuit. Various modifications for both the generator circuit and the receiver circuit are given in my co-

pending application, Serial Number 590,801 cited above. It is to be understood that any of the circuits there shown may be substituted for the ones herein. If desired, choke coils E may be placed in series with the telephone circuit to give this a higher impedance for the high frequency circuits. In practice, however, this has not been found to be necessary.

Fig. 2 shows a circuit in which a plurality of transmitter and receiver circuits are connected in series in the line, the action of each one being similar precisely to that described in connection with Fig. 1. The transmitters and receivers have been indicated diagrammatically only and are indicated by the reference characters T and R, it being understood that any suitable form of generator circuit or receiver circuit, such as shown in Fig. 1, or in my co-pending application Serial Number 590,801 being useful in this relation. The telephone battery sets B and B′ are indicated diagrammatically only, but it is to be understood that such connections as are shown in Fig. 1 should be used. In practice it would be desirable, of course, to have an equal number of transmitters and receivers at each end of the line, and for each transmitter circuit there will be a receiver circuit tuned to the same frequency.

Fig. 3 shows still a further modification, which is a combination of series connected high frequency circuits in Figs. 1 and 2, with the bridge connections shown in my co-pending application, Serial Number 590,801 mentioned above. In this figure there are shown connected in series relation the two transmitters T and the receivers R, and connected across in bridge to the line are shown two transmitters T′ and two receivers R′. In these bridge connections there are shown variable inductances L_1 in series with variable condensers C_1 and transformer coils H. These bridge connections are the same whether used in connection with a transmitter circuit or a receiver circuit. A typical form of transmitter circuit is shown at T′ where G′ indicates the high frequency generator in series with a variable inductance L″, variable capacity C″ and signaling instrument K″. This circuit is then inductively connected to the bridging circuit by the transformer H. The receiver circuit shown at R′ is similar in every respect to the receiver circuit shown in Fig. 1, being tuned to the frequency of the transmitter with which it is to communicate. By means of the variable inductance and variable capacity in the bridging circuits, it is possible to tune a pair of these with the line to the frequency of the oscillations to be used, and, of course, a different period or frequency will preferably be used for each and every transmitting circuit, whether it be connected in bridge or in series with the line. It is apparent from the above that by the arrangement of this Fig. 3 I am enabled to transmit simultaneously a large number of telephonic messages and obtain thereby an efficient and useful multiplex telephone system, the whole being attained by impressing high frequency currents upon the usual metallic circuit for local telephone sets without in any way affecting the transmission or reception of these ordinary telephone circuits.

Although I have described my invention as being adapted for telephonic work, it is obvious that the same may be used for telegraphic work. This is indicated in Fig. 3, where a signaling instrument is shown as an ordinary telegraphic key. In many cases it is not desirable to completely break the circuit of the generator G′, and in this case various expedients may be used, such, for instance, as shown and described in Fig. 3 of my co-pending application, Serial Number 590,801. In Fig. 3 it is not necessary to use the condensers K and K′ shown in Figs. 1 and 2, for the bridging circuits afford paths of low impedance for the oscillations developed by the series connected generators and the condensers C_1 prevent short circuiting of the sets B and B′.

It is obvious that the telephone sets B and B′ may be dispensed with, in which case all the communication will be carried on by high frequency currents, still making multiplex telephony possible. In this case, the Figs. 1 and 2 may be modified by eliminating the condensers K and K′ and short circuiting the line wires at the extreme ends.

Although several modifications have been described in detail in this specification, it is obvious that many changes may be made without departing from the spirit of the invention, and I therefore do not wish to be limited to the exact connections shown, but

What I claim as my invention is the following:

1. In a multiplex telephone and telegraph system, the combination of a pair of line wires, battery telephone sets bridged across said wires, a high frequency generator connected in series in said line; a receiver for high frequency oscillations connected in series in said line as and for the purpose described.

2. In a multiplex telephone and telegraph system, the combination of a pair of line wires, battery telephone sets bridged across said wires; a source of high frequency electric waves connected inductively in series relation in said line, means for modifying said electric waves; a receiver tuned to said high frequency electric waves and connected in series relation in said line.

3. In a multiplex telephone and telegraph system, the combination of a pair of line wires, battery telephone sets bridged across said wires, a source of electric waves of

ultra-sound frequency connected in series relation in said line, a signaling instrument for modifying said oscillations, a receiver tuned to said source of high frequency electric waves and connected in series relation in said line, a detector for electric waves in said receiver circuit and a telephone operatively connected to said detector.

4. In a multiplex telephone and telegraph system, the combination of a pair of line wires, a plurality of sources of high frequency oscillations connected in series relation in said line, a signaling instrument for each source of high frequency oscillations for modifying said oscillations; a plurality of receiver circuits, each tuned to the frequency of one source of high frequency oscillations and connected in series relation in the line, an integrating detector in each receiver circuit and a telephone operatively connected to each detector.

5. In a multiplex telephone and telegraph system, the combination of a pair of line wires, a condenser of small capacity bridged across each end thereof, battery telephone sets bridged across said wires, a high frequency dynamo in series with a variable condenser, a variable inductance, a telephone transmitter and the primary of a transformer the secondary of said transformer being in series in the line, a receiver circuit comprising a variable condenser, a variable inductance and the secondary of a transformer, the primary of said transformer being connected in series in the line; an integrating detector in shunt to the condenser and a telephone operatively connected thereto.

6. In a multiplex telephone system, the combination of a pair of line wires, a variable condenser of small capacity bridged across each end of said line wires, battery telephone sets bridged across said line wires, a plurality of transmitter circuits, each consisting of a high frequency dynamo with a circuit adapted to be tuned, each circuit including a microphone transmitter for modifying the oscillations and the primary of a transformer, the secondaries being connected in series in said line, a plurality of receiver circuits, one for each transmitter circuit, containing a condenser, an inductance for tuning the same to its transmitter circuit and the secondary of the transformer, the primary of said transformer being in series in the line, an audion detector in shunt to the condenser and a telephone operatively connected to the audion.

7. In a multiplex telephone and telegraph system, the combination of a pair of line wires, battery telephone sets bridged across said line wires, a plurality of transmitter circuits, each consisting of a high frequency generator with a circuit adapted to be tuned, each circuit including a signaling instrument for modifying the oscillations and the primary of a transformer, the secondaries being connected in series in said line, a plurality of similar transmitter circuits, the secondaries of the transformers being connected in circuits bridged across said lines, said bridges including a variable capacity and inductance for tuning; a plurality of receiver circuits, one for each transmitter circuit, containing a condenser, and an inductance for tuning the same to its transmitter circuit and the secondary of a transformer; the primaries of a portion of said transformers being in series with the line, and the primaries of the others being in circuits bridged across the line, each bridge circuit being similar to the transmitter bridge circuits, a vacuum detector in shunt to the condenser in each receiver circuit and a telephone operatively connected to the detector.

8. In a multiplex telephone and telegraph system, the combination of a pair of line wires, a plurality of transmitter circuits, each consisting of a high frequency generator with a circuit adapted to be tuned, each circuit including a signaling instrument for modifying the oscillations and the primary of a transformer, the secondaries being connected in series in said line, a plurality of similar transmitter circuits, the secondaries of the transformers being connected in circuits bridged across said line, said bridges including a variable capacity and inductance for tuning, a plurality of receiver circuits, one for each transmitter circuit, containing a condenser, and an inductance for tuning the same to its transmitter circuit and the secondary of a transformer, the primaries of a portion of said transformers being in series with the line, and the primaries of the others being in circuits bridged across the line, each bridge circuit being similar to the transmitter bridge circuits; a vacuum detector in shunt to the condenser in each receiver and a telephone operatively connected to the detector.

GEORGE OWEN SQUIER.

Witnesses:
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Correction in Letters Patent No. 980,357.

Letters Patent No. 980,357, granted January 3, 1911, upon the application of George Owen Squier, of the United States Army, for an improvement in "Multiplex Telephony and Telegraphy," it is hereby certified that an error appears in the printed matter at the head of the specification of this patent in that it includes "Dedicated to the Public." These words should have been omitted and the words *Filed under the act of March 3, 1883*, printed in lieu thereof, and the patent should be read as so corrected.

Signed and sealed this 20th day of April, A. D., 1920.

[SEAL.]

M. H. COULSTON,

Acting Commissioner of Patents.