

G. O. SQUIER.
MULTIPLEX TELEPHONE AND TELEGRAPHY.
APPLICATION FILED NOV. 5, 1910.

980,356.

Patented Jan. 3, 1911.

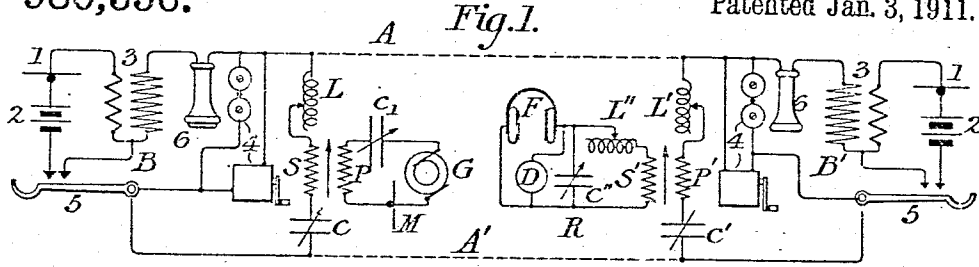


Fig. 2.

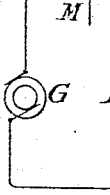


Fig. 3.

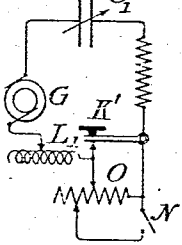


Fig. 4.

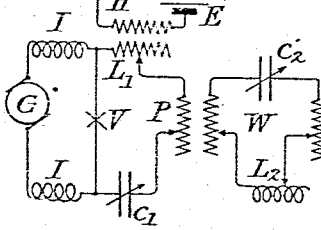


Fig. 5.

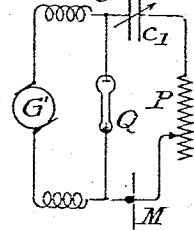


Fig. 6.

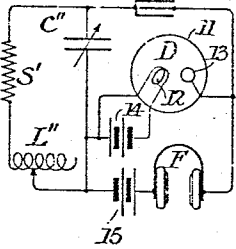


Fig. 7.

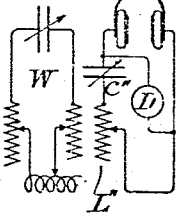


Fig. 8.

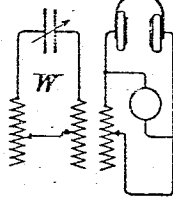
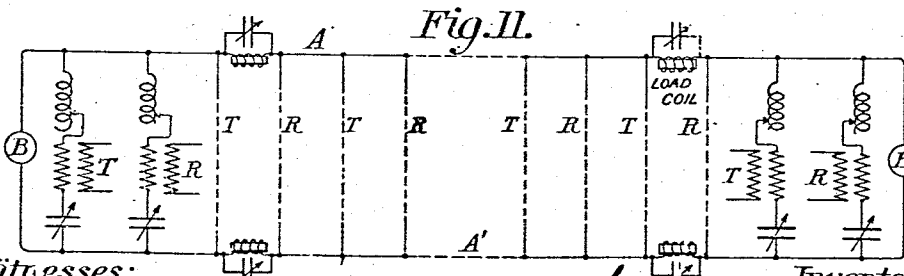
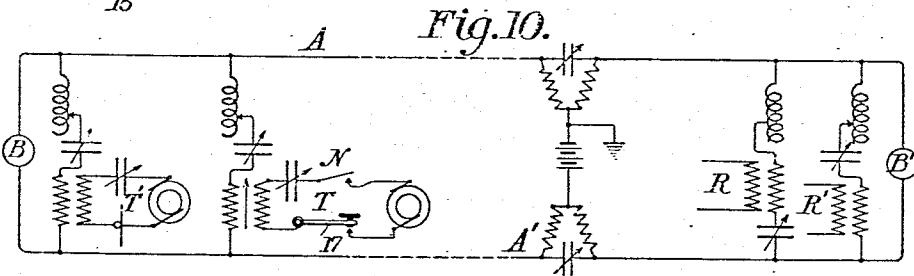
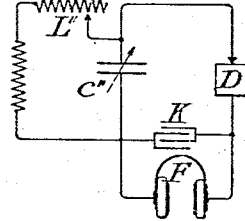


Fig. 9.



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UNITED STATES PATENT OFFICE.

GEORGE OWEN SQUIER, OF THE UNITED STATES ARMY.

MULTIPLEX TELEPHONY AND TELEGRAPHY.

980,576.

Specification of Letters Patent.

Patented Jan. 3, 1911.

Application filed November 5, 1910. Serial No. 590,801.

(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^{10} , 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 view-point, 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 magnitude 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 antennae 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 interferences between neighboring circuits operated by this system is eliminated, so that a plurality of such circuits may be brought to the same switchboard 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 effecting 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 type 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 and 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, and Figure 1 illustrates a form of circuit in which the high frequency oscillatory telephonic messages are impressed on the line by a bridge connection. Figs. 2 to 5 illustrate modifications of various transmitting circuits. Figs. 6 to 9 illustrate various receiving circuits. Figs. 10 and 11 illustrate modifications of the connections shown in Fig. 1.

Referring to these figures in detail, Fig. 1 shows a common metallic circuit for ordinary telephony, across which are 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 its 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.

Bridged across the line wires A and A' at the same terminals or at any convenient distance from the terminals of the common battery telephone there is bridged a circuit containing a variable inductance L, variable capacity C, and the secondary S of a transformer. The primary P of the transformer is in circuit with a generator G of high frequency oscillations, and in circuit with the generator is also included a variable capacity C₁, and a suitable telephone transmitter, such as a microphone transmitter M. The transformer above mentioned is so constructed as to be variable in its coupling, either by sliding one coil within the other, varying the angle between the planes of the coils, or by any other suitable well known arrangement. At the receiving end of the line there is bridged a similar circuit containing a variable inductance L' and variable condenser C' and the primary P' of a transformer. The secondary S' of this transformer is connected in series with a variable inductance L'' and a variable condenser C'', and around the condenser is shunted a detector D of the type commonly used in wireless telegraphy. In circuit with the detector is connected, in the usual way, the telephone receiver, as shown at F.

The operation of the device is as follows:

High frequency oscillations developed by the generator are impressed on the bridge circuit containing the inductance L and capacity C, which oscillations then travel along the line wires A and A' and are received in the receiver R containing the oscillatory circuit L'' C''. If these oscillations are modified in any suitable manner, an effect is immediately produced in the receiver.

While various means may be adopted to give the necessary variations to high frequency currents, I have found it effective and convenient to place in the circuit of the generator, or in the line itself, a microphone transmitter M, which produces on the sustained oscillations of high frequency slight modifications in amplitude of comparatively slow period, but corresponding in every detail with the ordinary voice vibrations. These modified oscillations when received at R and transformed by the detector give a reproduction in the telephone receiver F of speech transmitted from the generator circuit. Since these oscillations are of such high frequency they will produce no effect whatsoever in the battery sets B and B', for the impedance of these sets is so high for these frequencies as to entirely prevent their passage. Furthermore, any telephonic currents transmitted by either of the sets B and B' will travel over the line wires at the same time as the high frequency currents, but they will in no way be influenced by, nor will they exert any sensible influence upon the high frequency currents. It has been found desirable in practice to tune the circuit comprising the line and bridges to the frequency of the generator by means of the variable inductances L and L' and the variable capacities C and C'. The condensers C and C' are also useful in preventing the passage of any telephonic currents from the sets B through the high frequency bridge circuit, for these condensers are of exceedingly small capacity, being measured in thousandths of a microfarad, and thus interpose too large an impedance for currents of ordinary telephonic frequencies. These condensers, however, when taken in connection with the inductances L and L', interpose a low impedance to the oscillations of such high frequencies as lie above 20,000 per second.

Under certain conditions it may be desirable to have in series with the telephone sets B and B' suitable inductance coils, which will be of such dimensions as to prevent the passage of the high frequency oscillations, but which interpose only small impedance to the ordinary telephonic currents. In practice, however, this is found to be unnecessary, for the telephonees themselves contain sufficient impedance for the purpose.

Various forms of generator connections

may be used as shown, for example, in Figs. 2 to 5. In Fig. 2 there is shown the generator G in series with the microphone transmitter M and a variable primary P of a transformer. This circuit, as a whole, may be substituted, if desired, for the transmitter circuit shown in Fig. 1. For more carefully selected tuning, it is sometimes desirable to use the form of transmitter connection shown in Fig. 3, in which there is included a condenser C_1 and the variable inductance L_1 . In case the generator is limited in power, it is desirable to use the circuit shown in Fig. 3, having the same tuned to the frequency of the generator. In Fig. 4 there is shown still another form of generator circuit. In this case the Duddell arc V is supplied with energy from the direct current generator G' through the choke coils I. Around the arc there is shunted an oscillatory circuit containing a variable capacity C_1 and a variable inductance L_1 in series with the primary of a transformer P. This generator circuit may then be connected inductively to the bridge across the line wires, or, if desired, a weeding-out circuit W may be interposed. This weeding-out circuit is well understood in the art, being made up of a variable condenser C_2 in series with a variable inductance L_2 and the necessary transformer coils as shown in Fig. 4. As shown in this figure, the telephonic variations in the oscillations may be introduced by means of a secondary circuit H containing a microphone or other suitable transmitter M and battery E and a primary of a transformer, said primary being inductively connected to the inductance L_1 . This inductive method of modifying the oscillations may be used in the form of circuits shown in Figs. 1, 2, 3 and 5. In Fig. 5 still another form of generator of oscillations is shown, this generator consisting of a mercury vapor lamp connected in series with the D. C. generator G' and suitable choke coils, the lamp being shunted by a capacity and inductance of an oscillatory circuit in the well known manner. Oscillations may then be modified by a microphone transmitter M in any suitable manner as described above.

In Figs. 6 to 9 there are shown modifications of the receiver circuit, and it is to be understood that any one of these circuits may, if desired, be substituted for the one shown in Fig. 1. All of these circuits are such receiving circuits as are well known in the art of wireless telegraphy and telephony and are described here but briefly. Fig. 6 shows the receiving oscillatory circuit consisting of the variable inductance L'' , variable capacity C'' and the secondary S' of the transformer. This circuit is tuned to the frequency of the oscillations developed by the generator G. In shunt to the condenser is placed the detector D, which is of some

high resistance type, such as the Audion or the Perikon detector. Other well known types are equally useful in this relation. In shunt to the detector is shown the telephone receiver F, with or without battery as may be desired. In Fig. 7 there is shown, in connection with the detector circuit, a weeding-out circuit W of a well known type. It is noted that in Fig. 7 the detector is connected directly in series with an oscillatory circuit containing the condenser C'' and inductance L'' , this being a suitable connection only in case the detector is of a low resistance type. As shown in Fig. 8, it may not be necessary to have the detector circuit tuned when use is made of the weeding-out circuit W. Fig. 9 shows still another form of receiver circuit, the oscillations being set up in a circuit containing the inductance L'' and capacity C'' . Around the condenser is shunted a detector D, such as the Perikon detector in series with a capacity K of fairly large electrical dimensions. In shunt to the condenser K is the telephone receiver F.

Although numerous types of detectors have been used, I have found the Audion an exceedingly useful type, for it requires very little attention in the way of adjustments. The connection of this Audion is shown clearly in Fig. 6, in which the exhaust bulb 11 contains the filament 12 and the electrode 13. The filament 12 is heated by the battery 14, and connected to the filament and the electrode 13, as shown in the figure, is the telephone receiver F and the battery 15.

Referring now to Fig. 10: It has been found possible to bridge across the line circuit A and A' a plurality of high frequency circuits, each one similar in every respect to that described in Fig. 1. Preferably, the generators differ from each other in frequency and differ by such an amount as to allow easy selective tuning. It is apparent that these two high frequency oscillation generators, shown in Fig. 10, will be entirely independent of each other in the above properly tuned circuits, so that the oscillations, although existing together on the line, will be properly separated and selected at the receiving stations, that frequency generated at the transmitter T being selected by the receiver R. The local circuit and each pair of bridge circuits with the line are tuned to the same frequency and to the frequency of the generator T. Also the receiver R' is tuned to the same frequency as the generator T'. It is obvious, in connection with this, that telegraphic messages may be transmitted as well as telephonic messages. This is illustrated in the transmitter at T, in which the microphone transmitter is replaced by the interrupter N and the telegraphic key 17, this key being shown in detail in Fig. 3. In said Fig. 3 there is shown the key K', around which is shunted a vari-

able resistance or inductance O. A variable portion of this element O is shunted by the interrupter N. This avoids the necessity of completely breaking the generator current, and the signals are made merely by modifying the oscillations with a definite frequency. Obviously, many modifications of this key may be used. This form of telegraph transmitter may obviously be substituted for any of the telephone transmitters. By means of this system it is possible to transmit simultaneously the ordinary telephonic speech by means of the sets B and B' and high frequency telephonic messages by means of the transmitter T', and also telegraphic messages by means of the transmitter T.

In Fig. 11 there is shown a still further modification, in which a plurality of transmitters and receivers are bridged across the line. In this Fig. 11 the generator circuits T are indicated only diagrammatically by the coil of wire, it being understood that this represents any of the transmitters shown in Figs. 2 to 5. The receivers are shown at R and only diagrammatically, it being understood that any of the receivers shown in Figs. 6 to 9 being useful in this connection. Obviously, it is possible and desirable to have some of these transmitters at one end of the line and the others at the other end, as indicated by the reference letters T and R. The receivers may be placed some at one end and some at the other, and in practice it would ordinarily be convenient to have the same number of transmitters and receivers at each end. It is of course understood that each transmitter has a frequency of its own, and that one receiver and its bridging circuit with the line are tuned to the frequency corresponding to their transmitter. All of these high frequency currents may exist upon the line simultaneously and have no perceptible effect upon each other, nor will they have any sensible effect whatsoever upon the ordinary battery telephonic currents transmitted in the usual way.

In Figs. 10 and 11 the telephone sets B are merely indicated, it being understood that such a set as is shown in Fig. 1 is to be used.

It may be desirable in certain cases to omit the ordinary battery telephonic sets entirely, in which case the multiplex telephony would be carried on entirely by high frequency currents of different periods.

In case a common battery telephone circuit is used, instead of local battery sets as shown, it will be necessary to shunt the repeating coils by variable condensers of such small capacity as to offer a high impedance to ordinary telephone currents but low impedance to the high frequency oscillations. Also, in case of loading coils or other high

inductances, it will be necessary to put in similar shunt condensers.

The generators here described have a single period, but it is obvious that use may be made of multiperiod generators, in which case the individual frequencies from said generators would be used in separate transmitter circuits.

Although several modifications have been described in detail in this specification, it is obvious that many other 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 line wires; means at one end for impressing high frequency oscillations on said line wires; means for modifying said oscillations in accordance with speech; means at the other end for detecting said oscillations the complete circuit for the high frequency oscillations being tuned to the frequency of the oscillations.

2. In a multiplex telephone and telegraph system, the combination of a pair of line wires, battery telephone sets bridged across said line wires; a generator of high frequency electric waves or oscillations inductively connected to said line wires, means for modifying the oscillations; a receiver circuit inductively connected to the line wires and tuned to the frequency of the generator; an integrating detector in said receiver circuit and a telephone operatively connected thereto.

3. In a multiplex telephone and telegraph system, the combination of a pair of line wires, a plurality of generators of high frequency oscillations inductively connected to said line wires, means in each generator circuit for modifying the oscillations; a plurality of receiver circuits inductively connected to the line wires, each receiver circuit being tuned to the frequency of one of the generators, an integrating detector in each receiver circuit and a telephone operatively connected to each detector.

4. In a multiplex telephone and telegraph system, the combination of a pair of line wires, battery telephone sets bridged across said line wires, a generator of high frequency oscillations, a signaling instrument for modifying the high frequency oscillations, said generator being inductively connected to a circuit bridged across the line wires at one end thereof, a similar circuit bridged across the circuit at the other end and a receiver circuit inductively connected thereto said bridges with the line wires being tuned to the frequency of the generator.

5. In a multiplex telephone system, the combination of a pair of line wires, a battery telephone set bridged across said line wires at each end thereof, a generator of oscillations of a frequency above the limit of audibility, a telephone transmitter for modifying the high frequency oscillations, said generator being inductively connected to a circuit bridged across the line wires at one end thereof; a similar circuit bridged across the line at the other end, and a receiver circuit inductively connected to said last named bridge circuit, said bridge circuits with line wires being tuned to the frequency of the generator.

6. In a multiplex telephone system, the combination of a pair of line wires, battery telephone sets bridged across said line wires, a generator of high frequency oscillations, a microphone transmitter for modifying the high frequency oscillations, said generator being inductively connected to a circuit bridged across the line wires at one end thereof, said bridging circuit comprising a condenser and an inductance in series with the secondary of a transformer; a similar circuit bridged across the line at the other end and a receiver circuit inductively connected thereto, said bridge circuits with line wires being tuned to the frequency of the generator.

7. In a multiplex telephone system, the combination of a pair of line wires, a battery telephone set bridged across said line wires at each end thereof, a generator of high frequency oscillations, a microphone transmitter for modifying the high frequency oscillations, said generator being inductively connected to a circuit bridged across the line wires at one end thereof, said bridging circuit comprising a condenser and an inductance in series with the secondary of a transformer; a similar circuit bridged across the line at the other end and a receiver circuit inductively connected thereto, said receiver circuit being tuned by means of a capacity and inductance to the frequency of the generator and said receiver circuit including a detector of high frequency oscillations, and a telephone receiver operatively connected to said detector.

8. 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 circuits bridged across the line wires, each circuit including a variable capacity and inductance; a plurality of sources of high frequency oscillations, one inductively connected to each of the bridge circuits, a signaling instrument in circuit with each source of oscillations to modify the said oscillations, a plurality of similar circuits bridged across the line and a plurality of re-

ceiver circuits, one inductively connected to each of the bridge circuits, each receiver circuit and each pair of bridge circuits with the line wires being tuned to the frequency of the corresponding generator.

9. In a multiplex telephone system, the combination of a pair of line wires, a battery telephone set bridged across said line wires at each end thereof, a plurality of circuits bridged across the line wires, each circuit including a variable capacity and inductance; a plurality of sources of high frequency oscillations, one inductively connected to each of the bridge circuits, a signaling instrument in circuit with each source of oscillations to modify the said oscillations, a plurality of similar circuits bridged across the line and a plurality of receiver circuits, one inductively connected to each of the bridge circuits, each pair of bridge circuits with the line and the corresponding receiver circuit being tuned to the frequency of one of the transmitter circuits, each receiver circuit containing a detector of high frequency oscillations and having a telephone receiver operatively connected thereto.

10. In a multiplex telephone system, the combination of a pair of line wires, a plurality of circuits bridged across the line wires, each circuit including a variable capacity and inductance for tuning, a plurality of sources of high frequency oscillations, one inductively connected to each of the bridge circuits, a signaling instrument in circuit with each source of oscillations to modify the said oscillations, a plurality of similar circuits bridged across the line and a plurality of receiver circuits, one inductively connected to each of the bridge circuits, each pair of bridge circuits with the line and the corresponding receiver circuit being tuned to the frequency of one of the transmitter circuits, each receiver circuit containing a detector of high frequency oscillations and having a telephone receiver operatively connected thereto.

11. In a multiplex telephone system, the combination of a pair of line wires, battery telephone sets bridged across said line wires, a plurality of local transmitter circuits, each circuit including a high frequency dynamo in series with a variable capacity, a variable inductance, a signaling instrument and the primary of a transformer; a plurality of local receiver circuits, comprising a variable condenser in series with a variable inductance and the secondary of a transformer coil; a vacuum detector shunted around said condenser and a telephone head-piece operatively connected to said vacuum detector; a plurality of bridging circuits connected across the line wires, each circuit containing a variable capacity and a variable inductance for tuning; a bridging circuit inductively connected to each of the bridge circuits, each receiver circuit and each pair of bridge circuits with the line wires being tuned to the frequency of the corresponding generator.

tively connected to each transmitter circuit; a bridging circuit inductively connected to each receiver circuit, each pair of bridging circuits with the line and its corresponding receiver circuit being tuned to the frequency of the corresponding transmitter circuit, said plurality of transmitter stations

and receiver stations being distributed along the line wire.

GEORGE OWEN SQUIER.

Witnesses:

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E. R. CRAM.