No. 707,008. Patented Aug. 12, 1902.

M. I. PUPIN.

MULTIPLE TELEGRAPHY.

(Application filed Dec. 29, 1897.)

(No Model.)

Fig. 1.

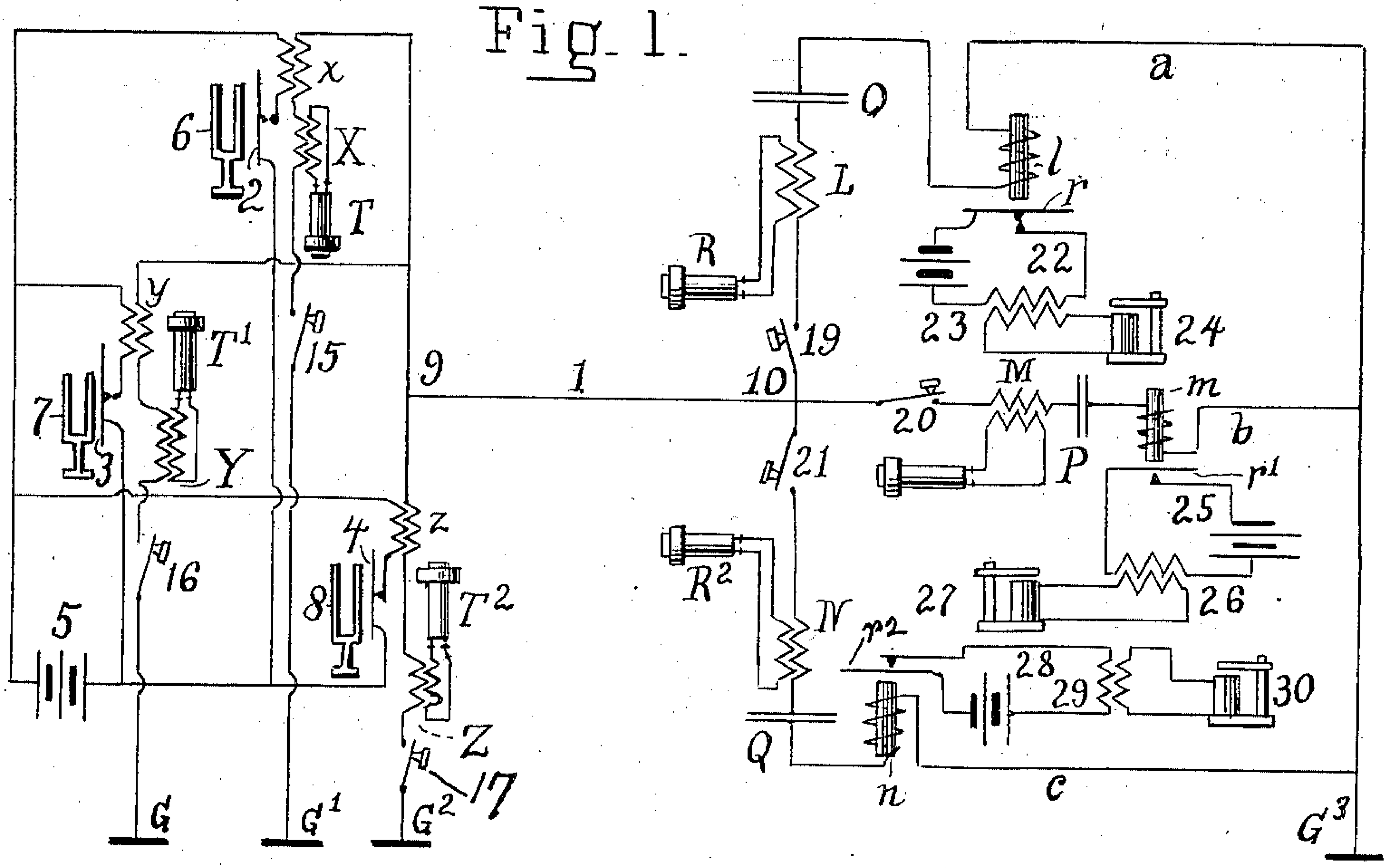


Fig. 2.

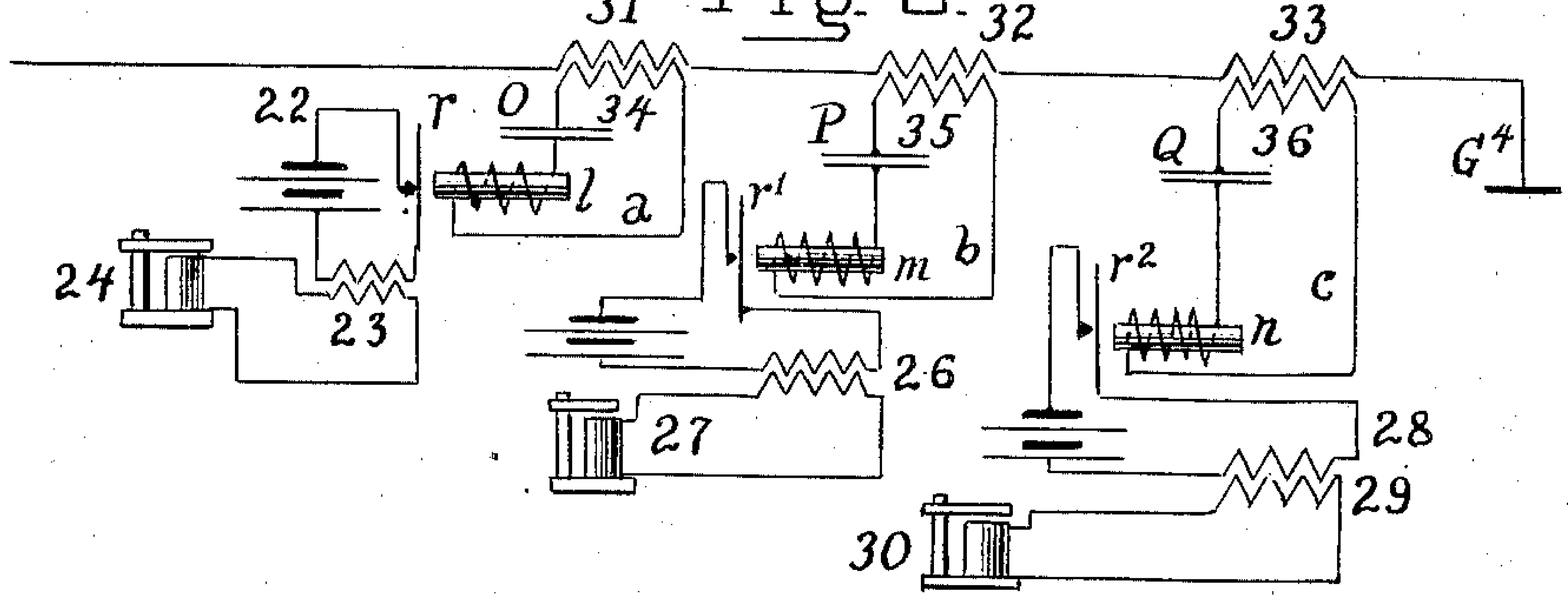
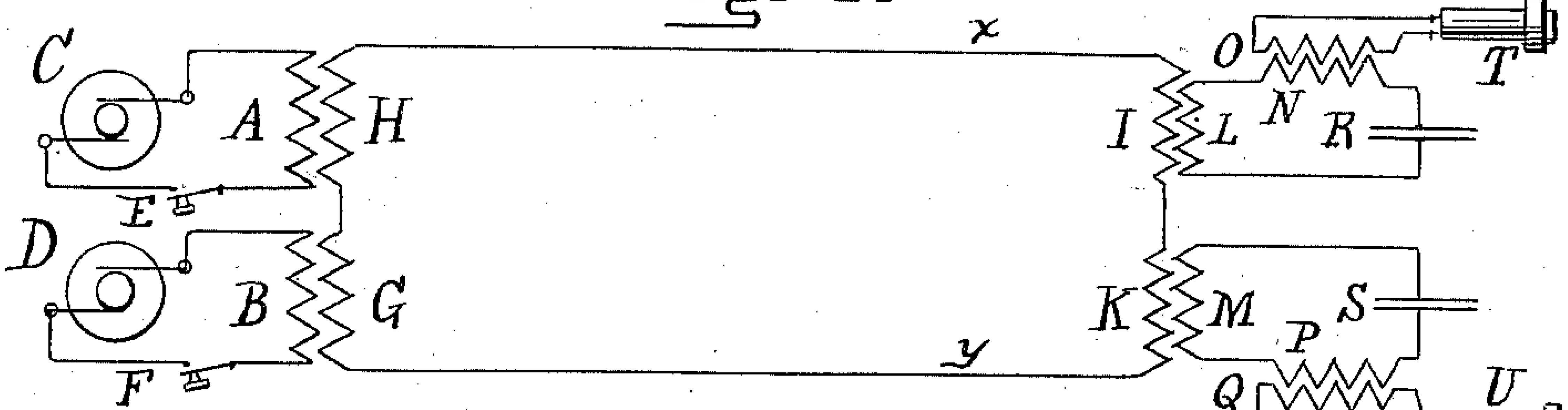


Fig. 3.



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UNITED STATES PATENT OFFICE.

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MULTIPLE TELEGRAPHY.

SPECIFICATION forming part of Letters Patent No. 707,008, dated August 12, 1902.

Application filed December 29, 1897. Serial No. 664,357. (No model.)

To all whom it may concern:

Be it known that I, MICHAEL I. PUPIN, a citizen of the United States of America, and a resident of Yonkers, county of Westchester, State of New York, have invented a new and useful Improvement in Apparatus for Multiple Telegraphy, of which the following is a specification.

The object of my invention is to send a large number of messages simultaneously over a single conductor by means of periodic currents of different periodicities.

My invention is based on the following physical fact: When a periodic electromotive force acts upon a conductor of adjustable electromagnetic constants—that is, of adjustable capacity, self-induction, and resistance—then by varying the capacity or self-induction, or both, these electromagnetic constants can be proportioned with respect to each other in such a way as to make the natural period of the conductor equal to the period of the impressed electromotive force. The conductor and the electromotive force are then in electrical resonance. The process of adjusting the natural period of the conductor, so as to render it resonant, is called "electrical" tuning. The laws which underlie electrical tuning and electrical resonance are analogous to those which underlie acoustical tuning and acoustical resonance. This physical fact has been investigated by me, and a reference is made here to my publications, *The American Journal of Science* for March, April, May, 1893, and November, 1894; *Transactions of the American Institute of Electrical Engineers* for May 17, 1893.

Having described the fundamental physical fact on which my invention is based, I shall now state the broad features of my invention.

A resonant conductor offers under all conditions a smaller impedance to the electromotive force with which it is in resonance than to any other electromotive force. Hence a resonant conductor can act as a current-selector—that is to say, if such a conductor forms part of a directly or inductively connected system of conductors upon which a number of electromotive forces of various periodicities or pitch are impressed then its impedance will be smaller to that one among these electromotive forces with which it is in resonance than to any other. If in a system of conductors consisting of parts which are either directly or inductively connected to each other there are in each part adjustable self-induction coils and electrostatic condensers, then these coils and condensers can be adjusted in such a way that each separate conductor will have a different predetermined natural period, and therefore each part will resonate to a periodic electromotive force of its own pitch, and this independently of the presence of other electromotive forces. Such a system of interrelated tuned conductors of different periodicities or pitches acts, therefore, in consequence of its resonating properties, as a set of current-selectors. This discovery originated with me, and I made it known and discussed it in an article published in the *Transactions of the American Institute of Electrical Engineers*, Vol. X, May 17, 1893. This selective system of conductors, in which various selective parts are connected to each other either directly or by induction and in which each separate selective part is tuned to a different natural period from the periods of the other selective parts by means of self-induction coils and condensers, forms the broad feature of my invention. The applicability of such a selective system of interrelated conductors to multiple telegraphy is now evident.

In my application filed February 23, 1894, Serial No. 501,092, I have claimed the broad method herein disclosed of distributing electrical energy, no matter for what purpose it may be used, which method consists in throwing upon a common conductor a number of alternate currents of different frequencies and distributing the several energies of these currents each selectively to a separate electrical translating device, and in my said original application I have also claimed the method herein disclosed of tuning the various selective parts to different periodicities. In this application I have claimed the apparatus shown in my aforesaid application, and the claims herein made thereon have been removed therefrom in compliance with a requirement of the Patent Office.

In the accompanying drawings, which form a part of this specification, Figure 1 is an electrical diagram showing an arrangement of devices for carrying said application to multiple telegraphy into effect. Fig. 2 shows a modification. Fig. 3 shows a system in which a plurality of generators at the transmitting end are connected to the main line through induction-coils.

Referring now to Fig. 1, the common conductor shown in the form of a main line 1 is connected at two points with, say, three telephone-transmitters 2, 3, and 4, which are connected in circuit with the battery 5. The secondary coils of the transformers *x y z* of these transmitters are connected in parallel on one side to the common conductor at 9 and on the other side to the ground at G G′ G^2. Let there be placed in front of each transmitter any device for throwing its diaphragm into periodic vibration—say a tuning-fork—and let each tuning-fork, as 6 7 8, be tuned to a different note. Thus let the fork 6 be tuned (to illustrate) to the note A, the fork 7 to B, and the fork 8 to C. Consequently three periodic electromotive forces, each of a different periodicity, will be impressed upon the common conductor at the point 9 simultaneously. The function of the keys 15 16 17 in the circuits *x y z* and of the three telephone-receivers T T′ T^2 will be explained presently. Suffice it to state here that of the instruments inserted in the transmitting branch conductors, the transmitter with its induction-coil and an auxiliary coil, as X Y or Z, in each secondary circuit, are the primary parts, and the key and the telephone are the auxiliary parts in the operation. At the receiving end of the line, starting from point 10, I arrange any number—say three—of branch circuits *a b c*, consisting, essentially, of coils L M N for furnishing the auxiliary self-induction and condensers O P Q for furnishing the auxiliary capacity by the proportioning of which self-induction and capacity the receiving-conductors are tuned. All of these receiving-conductors are connected to the ground G^3. The auxiliary parts of these three branch conductors are the telephone-receivers R, R′, and R^2, which are placed in inductive relation with coils L M N and the small coils surrounding permanent magnets or soft-iron cores *l m n* and also three keys 19 20 21.

I proceed to explain the operation of the instruments in any branch at the receiving end by the instruments in the corresponding branch at the transmitting end. Say it is required to send a message from transmitter 4 to branch *a*. It is to be understood that what follows is also true of any other branch, as *b* or *c*. The coil L has a predetermined self-induction, and the condenser O has a predetermined capacity, and their values have been predetermined in such a way as to render branch *a* resonant to a frequency C. Hence the operator at 4 will use a fork of frequency C. The telephone T^2 is acted upon inductively by coil Z or any other convenient part of the circuit of the transmitting end. The sound of the telephone R calls the attention of the operator in the branch circuit *a*. This telephone is connected and operated similarly to T^2. He answers the call by means of breaking the circuit several times in quick succession with the key 19, which breaks are heard in the telephone T^2. He then closes the battery-circuit which works the receiving-transmitter *r*, and the receiving-instrument 24 is then ready to receive the electrical impulses from the line. These impulses are given in the following way: Whenever the operator at 4 closes key 17, an alternating current of frequency C passes to the branch *a* and by its action upon the magnet *l* sets the diaphragm of the receiving-transmitter *r* in vibration, thus producing a strong induced current of the same frequency in the secondary coil of the transformer 23 of this transmitter, which current passing through the coil of the sounder 24 repeats the signals sent by the key 17. This communication of signals will in no way be interfered with by the simultaneous transmission of signals between the circuits *b* and *c* and the transmitters 2 and 3 as long as these transmissions employ frequencies different from the frequency employed in the branch *a*. It should also be observed that each receiving-instrument, as 24, may have an adjustable condenser in series with it in order to reduce its electromagnetic impedance to a minimum for the frequency to be used in the branch. It is also clear that we may have any number of branches both at the receiving and at the transmitting end; also, that each branch can operate simultaneously as receiver and transmitter, provided that it has both the receiving and the transmitting apparatus. In Fig. 1 the receiving apparatus only in the branches *a b c* is described. Thus in branch *b* at the receiving end is a key 20, coil M, condenser P, and iron core or permanent magnet *m*. The core *m* operates the transmitter-diaphragm at *r′* and local circuit 25 and through the transformer 26 the sounder 27. Similarly in branch *c* is a key 21, coil N, condenser Q, and iron core *n*. The core *n* operates the transmitter-diaphragm at r^2 and local circuit 28 and through the transformer 29 the sounder 30; but I wish it to be clearly understood that in each branch, like *a*, we may have any number of receiving and transmitting apparatus all connected in multiple with this branch and working with the same frequency.

Referring now to Fig. 2, here the common conductor 1, instead of being connected directly with the local circuits *a b c*, is inductively connected with them by means of transformers. The primaries 31 32 33 are in series in the common conductor, while the secondaries 34 35 36 are included in the local circuits. It will be noted, therefore, that in Fig. 1 the branch circuits *a b c* are in parallel with the common conductor, while in Fig. 2 the pri-

[redacted]

maries, including the branch circuits a b c, are in series with the main line. They might also be in multiple.

I desire to direct especial attention to the fact that I use no synchronically-moving mechanism of any sort at opposite ends of the line, and need no apparatus which interferes with the selection effected. All that is required is that the various receiving branch conductors of the system shall be tuned in electrical resonance with the several periodic currents of previously-selected periodicity by properly proportioning the electromagnetic constants of said branch conductor and that the tuning may be done once for all.

It is of course to be understood that in the local circuits a b c will be disposed the means here shown to effect the tuning of each by varying the self-induction or the capacity, or both, and also that in place of telephone-transmitters I may use oscillators or vibrators or any other contrivances adapted to produce and transmit to line currents of different predetermined periodicities; also, that both at the transmitting and receiving ends the telegraph keys and sounders, here introduced merely for the sake of their simplicity, may be replaced by any suitable telegraphic transmitting and receiving apparatus.

In Fig. 3 is shown a system which at the receiving end is substantially like that of Fig. 2, but shows an arrangement at the transmitting end preferable to that of Fig. 1. A plurality of generators, as C and D, suitably constructed and operated to generate currents of desired periodicities, are inductively connected to the main line x y through induction-coils, as A H, B G. Keys E and F are also provided. At the receiving end selective circuits are connected inductively to the line through coils, as I L, K M. Adjustable condensers, as R S, and coils of adjustable self-induction, as N and P, are also provided, as shown. Telephones T and U or other suitable receivers are also provided, preferably constructed with secondary coils O and Q, all as shown. Circuit L N R is tuned to respond to the current generated by C, and circuit M S P is tuned to respond to the current generated by D.

It is not possible to calculate mathematically the values of the self-induction and the capacity in the selective branches or circuits which will satisfy the conditions of selectivity to predetermined frequencies in the different selective parts of a complex system. At most the mathematical theory only suggests in a general way how the tuning should be done. It may be stated generally that the use of iron should be avoided in the coils in the selective parts, and when the selective circuits are connected inductively to the main line iron should be omitted from the induction-coils through which these circuits are inductively connected. The ohmic resistance of secondary circuits should be as small as possible, and where the selective parts are branches in parallel from the main line the ohmic resistances in the system should be as small as possible. Each selective part should be provided with an adjustable coil, the self-induction of which should be as large as conveniently may be. The condensers should be adjustable in small steps. With these general cautions it may be stated that the way to proceed to tune the selective parts of the system is to choose convenient periodicities for the currents to be transmitted and then by varying one or both of the electromagnetic constants of each selective part in succession tune each selective part to one of the periodic currents until the maximum effect is obtained. It is usually necessary in a complicated system to make a preliminary tuning of all of the selective parts and then make a final and more accurate tuning. When the selective parts are once tuned to the appropriate frequencies, they are left unchanged. The final tuning is performed by adjusting the frequency to be employed to suit the electromagnetic constants of the circuits, for it should be observed here that it is impossible to reach in each selective circuit the point of true maximum selectivity by varying only the electromagnetic constants of these circuits. Having, therefore, adjusted approximately the circuits to respond to the periodicities previously selected, the final step to be made is then to vary the frequencies. This last act is easy to perform in any case, and especially easy where the alternating electromotive forces are impressed upon the main line by means of electromagnetic oscillators—that is, circuits which, like the Hertzian exciters, maintain a current of definite periodicity in the form of electrical oscillations when their electrical equilibrium is disturbed. In such cases the periodicity of the impressed electromotive force can be varied by varying gradually the electromagnetic constants of the exciting-oscillators. Such a system is set forth in my Patent No. 640,515, dated January 2, 1900.

It will be clear that the systems herein described are applicable either to selective signaling or multiplex telegraphy. The difference in the arrangement for practicing the two lies at the transmitting and not at the receiving end and is that in selective signaling it is not necessary that the provision be made for throwing upon the line at the transmitting instruments currents of different frequencies independently of each other, since the operator signaling may never want to call more than one receiving-station at a time; but for multiplex telegraphy each transmitting operator must be able to send his message whether other transmitting instruments are in use or not, so that there must be provided at the transmitting end means for throwing upon the line currents of different frequencies independently of each other and simultaneously, if necessary.

It has been proposed to maintain currents of different frequencies upon a main line and modify their intensity by means located at the transmitting-stations, and thus operate receiving instruments at the receiving-stations. This method is in a general sense an equivalent of generating at or throwing from the transmitting-stations upon the main line alternating-current energies of different frequencies and might perhaps be operative and desirable in certain specific arrangements of selective resonance systems. It is, however, in most cases decidedly inferior to it.

Where I specify "throwing" currents of different frequencies upon the line, I mean to designate specifically the systems described by me in this specification and which I consider the best method and arrangement.

What I claim, and desire to secure by Letters Patent of the United States, is—

1. A set of electrical conductors consisting of selective parts connected to each other, each such part containing a condenser and a self-induction coil, whereby it can be made resonant to an electromotive force of predetermined periodicity by properly proportioning its electromagnetic constants, and means for impressing upon the system electromotive forces of different predetermined periodicities, substantially as described.

2. A system of multiple telegraphy consisting of transmitting and receiving instruments and a set of electrical conductors made up of selective parts connected to each other, each selective part which controls a receiving instrument containing a condenser and a self-induction coil, whereby it can be made resonant to an electromotive force of predetermined periodicity by properly proportioning its electromagnetic constants, and means controlled by the transmitting instruments for impressing upon the system electromotive forces of predetermined periodicities, substantially as described.

3. A system of a set of conductors consisting of a common conductor and selective parts all directly connected to the common conductor, each part having directly connected therein a condenser and a self-induction coil whereby it can be made resonant to an electromotive force of predetermined periodicity by properly proportioning its electromagnetic constants, and means for impressing upon the system electromotive forces of predetermined periodicities, substantially as described.

4. A system of multiple telegraphy consisting of transmitting and receiving instruments, a common conductor, one or more conductors containing transmitting instruments, and two or more conductors containing receiving instruments, all connected directly to the common conductor, each selective conductor which controls a receiving instrument containing directly connected therein a condenser and self-induction coil, whereby it can be made resonant to an electromotive force of predetermined periodicity by properly proportioning its electromagnetic constants, and means controlled by the transmitting instruments for impressing upon the system from the transmitting conductor or conductors electromotive forces of predetermined periodicity, substantially as described.

Signed by me in New York city this 23d day of December, 1897.

MICHAEL I. PUPIN.

Witnesses:
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