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J. A. STRATTON.

MEANS FOR TRANSMITTING ELECTRIC CURRENTS WITH INCREASED ENERGY.

APPLICATION FILED JULY 13, 1906.

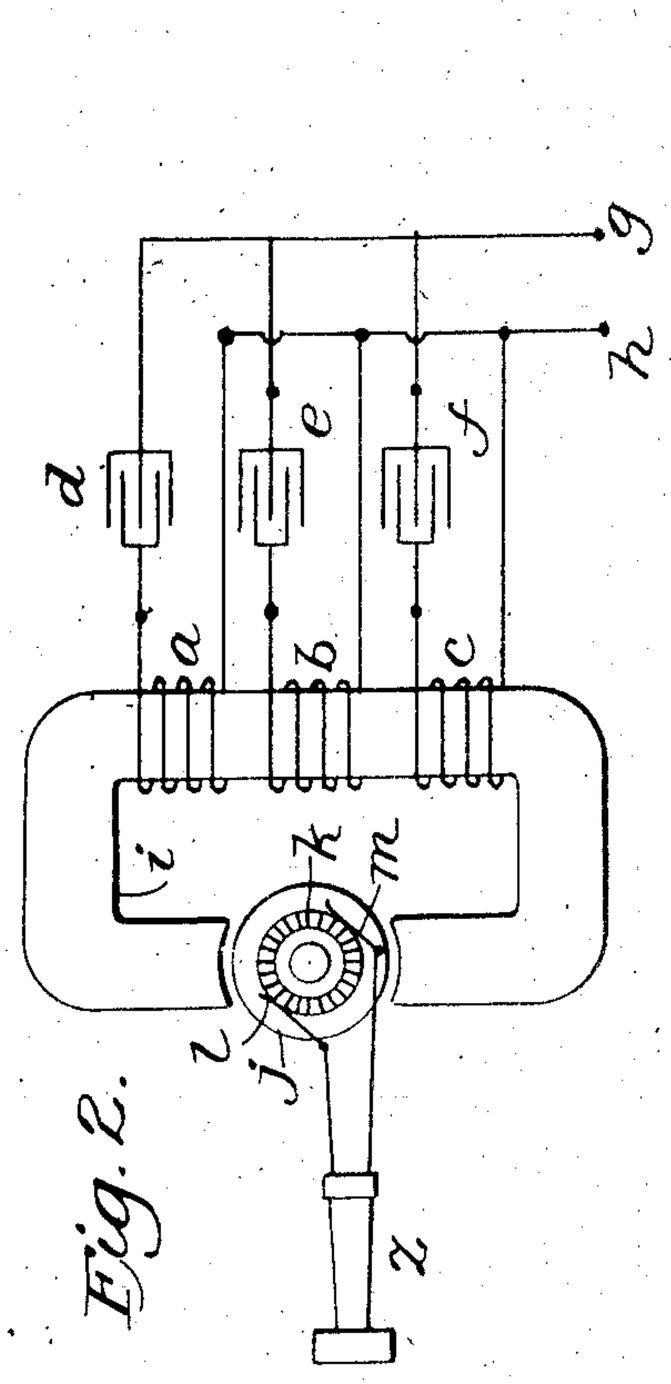

Fig. 2.

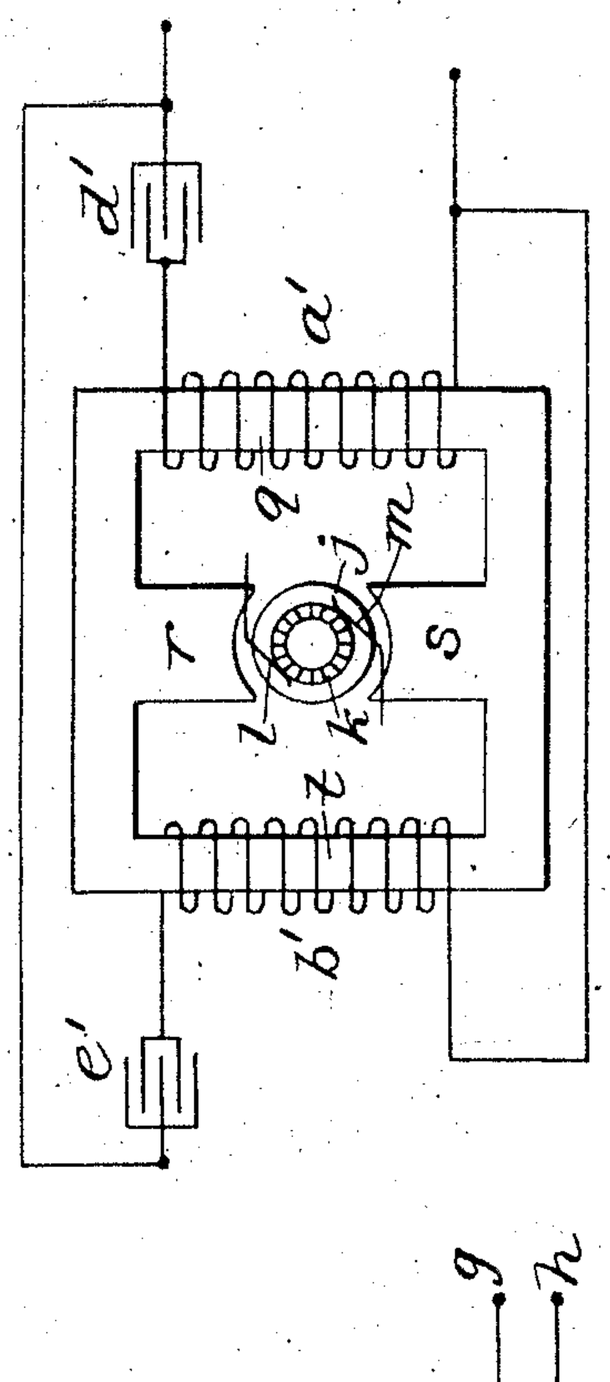

Fig. 4.

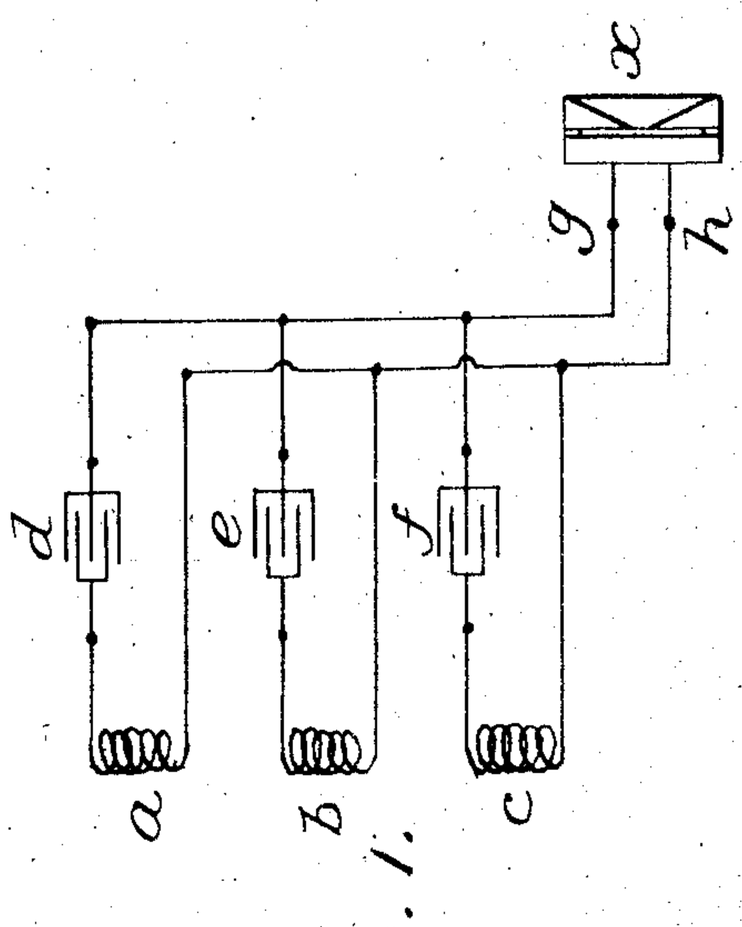

Fig. 1.

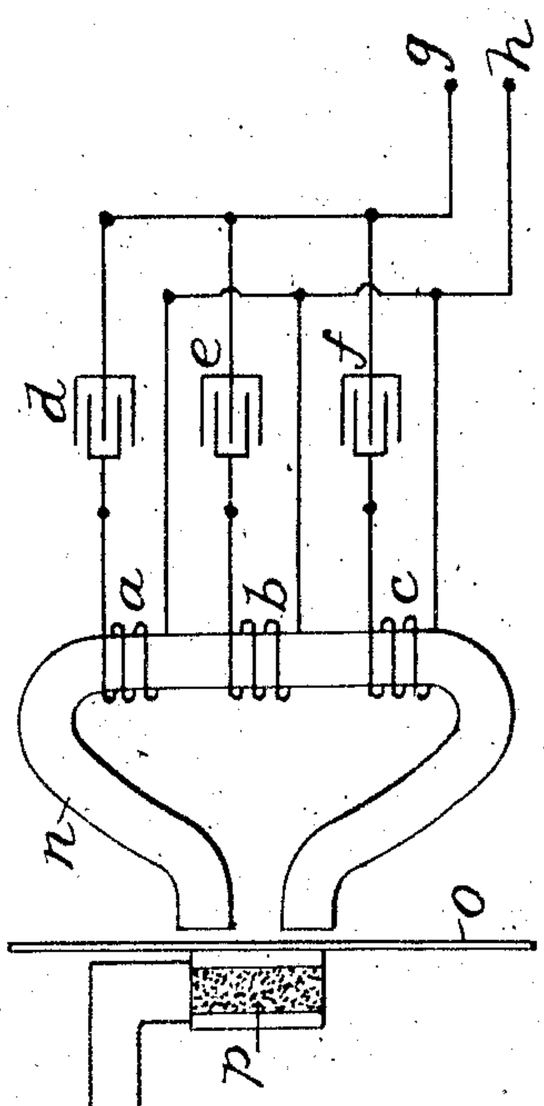

Fig. 3.

WITNESSES

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UNITED STATES PATENT OFFICE.

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MEANS FOR TRANSMITTING ELECTRIC CURRENTS WITH INCREASED ENERGY.

No. 882,026. Specification of Letters Patent. Patented March 17, 1908.

Application filed July 13, 1906. Serial No. 326,135.

To all whom it may concern:

Be it known that I, JULIAN A. STRATTON, a citizen of the United States, residing at Chicago, in the county of Cook and State of Illinois, have invented certain new and useful Improvements in Means for Transmitting Electric Currents with Increased Energy, of which the following is a specification, reference being had to the accompanying drawings.

My invention relates to improvements in means for transmitting electric waves or undulations, giving to them increased energy in their propagation; and as hereinafter set forth, my invention is shown and described as embodied in what are called telephone repeaters. It will, however, be obvious to all skilled in this art that the particular use to which the invention is put may be varied through a wide range.

In the following description and claims, the terms, "primary" and "secondary" refer, respectively, to the parts of the device which receive and which transmit the currents, whether such parts be connected directly to the lines or indirectly thereto through intermediate devices. It is my intention to cover in the following description only the essential features of my new device and certain modifications thereof, but to omit description of parts which are dependent upon the mode of connection of my new device in the circuit, such as induction coils and the like used in two-way transmission.

In the electrodynamic or "dynamo" type of telephone repeaters, the essential features may be described as follows: The voice currents (which are the currents to be reproduced or transmitted with an increase of energy or intensity) pass through suitable primary windings, which correspond to the field windings of a generator, and by their passage there is set up a varying magnetic field the variations of which correspond to the variations of the currents which produce it. Through the varying magnetic field so established, there is moved a conductor or combination of conductors from which the currents generated by such motion are led to the secondary or transmitting circuit. By virtue of the motion of the said conductors through the varying magnetic field, electromotive forces are set up in them which vary as the field they are cutting varies from instant to instant, the speed of the conductors remaining constant. Therefore, the currents generated in the secondary or transmitting section of the device correspond in wave form to the currents which flow in the primary section or element. While thus preserving the same wave form in the electrical vibrations transmitted, it is sought to give such vibrations increased energy; and this increase in energy is obtained by a transformation of the energy used in driving the conductors through the magnetic field. Various forms of this type of repeater have been devised, using the homopolar type and the commutator type of electric motors or generators, of which those designed particularly for electrical smoothness of operation are selected in order to prevent disturbances due to irregularities in the generation of the secondary electro motive forces.

An increase of energy of the electrical vibrations is theoretically obtainable by this means alone; but it is found in practice that it is difficult to obtain any substantial increase of such energy without resorting to the use of excessive speeds for the moving conductors. For example, using a repeater of this (dynamo) type, running at high speed, it has been found by me that the electrical energy delivered from the moving conductors of the secondary was approximately eight times that supplied to the primary windings, when a constant direct current was used as the exciting current. Using the same repeater and running it at the same speed but with telephonic voice currents as the field exciting current, I found that the energy of the electrical vibrations delivered from the secondary or transmitting circuit was even less than that available in the primary side, the comparison being made by a telephone receiver. This result is due to the fact that the telephonic voice currents are pulsating or alternating in character and of high frequency and are, therefore, opposed in their passage through the primary windings by the inductive impedance of those windings; and this inductive impedance is of such a high value that the strength of the magnetic fields established by the voice currents in the primary circuit or windings is small in comparison with the field which would result, were a constant electromotive force of the same effective value applied to the terminals of the primary windings. Consequently, in order to generate any considerable energy, the secondary conductors must move through this weak mag-

netic field at an extremely high speed, or must be of very great length. In the latter case the increase of resistance consumes a large part of the energy generated. Furthermore, the higher harmonics of the voice currents are more effectually suppressed than those of low frequency, which is a disadvantage as the higher harmonics naturally suffer the greatest loss in transmission.

The object of my invention is to provide a repeater in which the effects of the inductive impedance above referred to will be reduced to a minimum and in which the higher harmonics will not only be allowed to pass but will also be repeated, reproduced or transmitted with greatly increased energy. A further object of my invention is to provide a repeater in which a wide range of selection of the parts of the telephonic scale to be transmitted (or of waves of widely different length) may be made.

Another object of my invention is to provide a repeater in which a maximum efficiency of transmission will be attained.

In carrying out my invention, I use a primary or field winding having in series with it a condenser suitably proportioned as described below, the combined parts being connected to the line in the ordinary manner. The values of the capacity of the condenser and the coefficient of self-induction of the primary winding are so chosen that a condition of resonance exists for currents of a certain frequency, which may be termed the critical frequency and which has a definite relation to the frequency of the voice currents composing the telephonic scale. Currents, alternating or pulsating, of the chosen frequency, pass through the primary windings practically as freely as would direct current through a similar winding without the condenser, and they establish a field of such strength that a large increase of energy for currents of the critical frequency is obtained in the moving secondary conductors cutting that field. From this it follows that the function of the resonant circuit is to allow the passage through the winding of sufficient current to establish the proper strength of variable magnetic field.

For currents above and below the critical frequency, the nature of the effect is the same, although in a lesser degree, and decreases as the difference in frequency becomes greater. The critical frequency is chosen with regard to the frequencies of the voice currents of the telephonic scale, depending upon the results which it is desired to obtain. It may be taken in the upper part of the scale, thus causing the repeater to reinforce most strongly the vibrations of high pitch which lend distinctness to telephonic conversation; or it may be taken in the lower part of the scale to magnify the fundamental vibrations, which determine the loudness of the speech reproduction; or it may be taken at any point intermediate these extremes.

To make clear the principle of my invention, I have described a single resonant primary circuit; but in its application I prefer to use a plurality of such resonant windings or circuits, the different circuits being tuned to frequencies taken at suitable intervals along the telephonic scale. By these means the voice currents are greatly magnified throughout the whole scale by increasing the strength of the variable magnetic field which acts upon the secondary element, the effect of the different primary windings merging into each other at intermediate points. Any part of the scale may, nevertheless, be more strongly reinforced than the rest, if desired. For example, if it is desired that the frequencies of a certain order should predominate, the resonant windings corresponding to that part of the scale may be tuned to frequencies at relatively closer intervals, or may be arranged to have a relatively larger number of turns. While the individual primary resonant circuits are preferably connected to the line in parallel, the essential feature of the arrangement of parts is that a resonant path be provided for each chosen frequency. In some cases it may be desirable to provide for frequencies above or below the telephonic scale. Such a provision may be made in the same manner as for frequencies within the scale. The frequency intervals may be taken equally, or in any other desired way, the number of possible intervals depending upon the mechanical construction chiefly. The closer the intervals are taken, the more uniform is the reinforcement; but a large number of intervals is not required to give satisfactory results. This system of resonant primary windings may be applied to any telephonic repeater employing a variable magnetic field established or controlled by the currents which it is desired to reinforce. The function of such windings remains the same as just described in connection with the electrodynamic or "dynamo" type of repeater; namely, the increasing in intensity of the variations of field strength obtainable from a given available amount of electrical energy, although the function which such a variable field serves in the operation of the repeater may be different in the different types. Thus, in a repeater using a variable magnetic field to actuate a magnetic diaphragm, or armature, which operates a variable resistance device, the resonant primary windings may be advantageously used for establishing or controlling that field. Similarly, the system may be employed in any other type of repeater in which one of the steps incident to the operation of the device is the establishing of a variable magnetic field by the telephonic currents, whether

such field exists alone or in connection with other magnetic fields. However, I prefer to use the "dynamo" type of repeater, because of the positive nature of its operation and the absence of microphonic contacts and diaphragms. In the "dynamo" type of repeater, either the commutator type or the unipolar type of machine may be used; and either the field structure or the secondary conductors, or both of them, may be made the moving element or elements. The energy used to provide for the relative motion of the secondary conductors with regard to the variable magnetic field may be supplied mechanically, as through a shaft, or electrically by means of auxiliary windings and magnetic fields. Further, the motion of the conductors relatively to the magnetic field may be one of translation, or of oscillation, instead of one of rotation. It will, therefore, be understood that I am not limited to any particular arrangement or form of construction in these respects. However, to obtain the best results, the following considerations should be observed, in order to obtain the best results: The parts of the magnetic circuit subjected to alternating or to fluctuating magnetic fields should be laminated or stranded. Further, it is desirable to use a small amount of iron in that part of the circuit composing the path of the variable magnetic field set up by the voice currents. Any periodically recurring irregularity in the generation of the secondary currents will cause objectionable disturbances in the secondary circuit. These disturbances are more liable to occur, when the armature is of the commutating type, than when the unipolar form is used. To avoid this, smooth core armatures should be used carrying a large number of armature coils and provided with a large number of commutator segments, in those cases in which the commutating type of armature is used; the brushes should be wide with respect to the commutator segments, or a plurality of brushes should be used; and the pole pieces should be formed in such a way that the conductors enter and leave the variable magnetic field gradually.

Although there is an increase in the electrical energy delivered from the secondary of the repeater over that received in the primary, this increase in the energy will not be available for transmission, if the voltage variations are too small. Consequently, it is found desirable in some cases to step up these voltage variations before re-transmission and this is done by means of an induction coil, the use of which is particularly desirable where the unipolar form of generator is employed in the repeater. Even in the case of the commutator type of repeater, I consider it more desirable to obtain a high value of voltage variation by means of step-up devices, than to make the armature conductors of great length. An induction coil with a suitable ratio of transformation may be used, its primary being connected to the repeater and its secondary to the line.

It will be understood that my invention is not limited in its application to the reinforcement of currents transmitting speech, the particular use to which the currents reinforced are put, or the particular mode of generation of the primary pulsating or alternating currents, not having any bearing upon the scope of my invention.

My invention may be embodied in a repeater in any electrical system in which the frequency of the currents employed are of the order of those used in transmitting speech; or are such as to render the inductive impedance of ordinary primary windings objectionable, as, for example, in the electrical transmission of music.

In the drawings illustrating the principle of my invention and the best mode now known to me of applying that principle, Figure 1 is a diagrammatic representation of a series of resonant circuits tuned to given frequencies; Fig. 2 shows diagrammatically a repeater of the dynamo type the variable field of which is generated by currents flowing in such resonant circuits; Fig. 3 is a view similar to that of Fig. 2 but showing a repeater of the variable resistance type instead of one of the dynamo type; and Fig. 4 illustrates the mode of arranging the primary windings to link different magnetic circuits.

In series with the primary windings *a*, *b* and *c* are, respectively, the condensers *d*, *e* and *f* each of which condensers is so proportioned with regard to its associated winding that a condition of resonance exists in each of the three circuits for currents of a given frequency traversing that circuit, each chosen frequency being properly related to the scale of frequencies of the currents which the repeater is intended to reinforce in the manner heretofore described. Under the action of the pulsating or alternating currents from a transmitter *x* in a circuit of which the terminals are the common terminals *g*, *h* of the three resonant circuits, the primary windings *a*, *b* and *c* establish variable magnetic fields which serve in the operation of the repeater in the manner above described. The object of the resonant primary circuits is to provide certain paths free from inductive impedance for currents of certain frequencies to one of which each circuit is tuned, as before stated, and to eliminate to a less (or partial) degree the effect of such impedance on currents of frequencies intermediate or between those selected (the critical frequencies of the respective circuits). In this way more powerful magnetic fields are obtained than could be obtained without the use of

such resonant circuits, the number of which may be greater or less than the number shown in the drawings depending upon the closeness with which it is desired to cover the range of frequencies in question. The windings *a*, *b* and *c* may link the same magnetic circuit or they may link circuits wholly or partially distinct. In the first case the magnetic fields produced by the several windings are combined throughout the entire magnetic circuit, while in the second case the magnetic field set up by each individual winding is established in a magnetic circuit which, if not wholly, is at least partially separate from the magnetic fields set up by the others.

The magnetic fields established through the different magnetic circuits are combined at the point where they are utilized, as at the armature of the secondary in Fig. 2, where the repeater is of the dynamo type, or at the diaphragm where the repeater is of the variable resistance type, as shown in Fig. 3. The object of this latter arrangement is to minimize, if not to eliminate, the inductive effect upon one another of the windings devoted to the different critical frequencies of the several tuned circuits, in order to increase the total number of effective ampere-turns producing the variable magnetic field, the strength of which is thereby increased. In explanation of this result it may be stated that, although the primary circuit resonant to a particular frequency receives the greater part of the available primary energy of that frequency, it is still desirable to utilize as much as possible of the remainder of such energy by means of the other windings, although they are not resonant to that particular frequency. When all the windings link the same magnetic circuit in series, the relatively powerful magnetic field established by a current of a certain frequency passing through its own particular winding acts inductively upon the other windings setting up counter-electromotive forces in them which tend to prevent the passage of currents of that same frequency. By arranging the primary windings to link separate magnetic circuits or separate parts of the same magnetic circuit, this mutual inductive effect is reduced, since the counter-electromotive force opposing the passage of current through any winding is dependent upon only the magnetic field established by that winding itself, while in the case in which the windings all link the same magnetic circuit, the counter-electromotive force opposing the passage of current is dependent upon the sum of the magnetic fields established by all the windings. The counter-electromotive force generated by the varying magnetic field is neutralized in the latter case by the condenser in the circuit tuned to that particular frequency; but in the other circuits it is only partly neutralized and its value should be, therefore, kept as low as possible. This arrangement of resonant circuits, by increasing the flow of current set up through a given set of windings by a given available primary electromotive force increases the total variable field strength and provides for more efficient operation, since the magnetic fields are combined at the point of application,—the movable armature, or the diaphragm. It is usually sufficient to separate the parts of the magnetic circuit which bear the primary windings, although more complete separation may be provided in order to prevent mutual inductive action due to the leakage between the various magnetic circuits. This arrangement of the magnetic circuits may be applied to any type of repeater employing a variable magnetic field; but it is more especially advantageous in the case of the dynamo type, where it is not necessary to concentrate the magnetic field over a small area at the place of application, as for example, on a diaphragm. The mechanical arrangement of the windings will vary with the type and the form of the repeater, as will be understood by all skilled in this art.

In Fig. 2 the windings of the several resonant circuits are linked around the yoke of the field magnet *i* between the pole-pieces of which is rotatably mounted the armature *j* provided with a commutator *k* upon which press the brushes *l*, *m*, connected in any suitable way with the receiver *z*, as by the secondary lines. It will be understood by all skilled in this art that the arrangement shown in Fig. 2 of the drawing is merely diagrammatic and is intended merely to illustrate the application of the resonant circuits of Fig. 1 to a repeater of the commutating dynamo type; and that the magnetic circuit or the secondary elements of the repeater may be modified in any way desired, provided such modification does not interfere with the essential features of operation hereinbefore described. For instance, the field structure and the armature may be of the unipolar type, the commutator and brushes being replaced by sliding contacts, in the usual way. Further, auxiliary magnetic fields or other modifications may be employed for various purposes. This drawing shows the primary windings linking the same magnetic circuit (the circuit of which the field magnet *i* is a part), but the arrangement may be varied, however, as will be hereinafter shown. Similarly, Fig. 3 is intended simply to show the application of the system of resonant primary circuits to a repeater of the variable resistance type; and here, as in Fig. 2, the primary windings link a common magnetic circuit. In this type of repeater the variable magnetic field acts (directly or indirectly, it may be) to vary the resistance of the

secondary circuit containing a source of current. The field structure *n* concentrates the magnetic fields due to the primary windings *a*, *b* and *c* in series with their respective condensers *d*, *e* and *f* in the resonant circuits each of which is, as before, tuned to a certain critical frequency. A variable resistance device *p*, such as a microphonic transmitter, is mechanically connected with the diaphragm *o* of the secondary element of the repeater and is electrically connected in a local circuit (not shown).

In Fig. 4 there is shown an arrangement comprising primary windings which link separate magnetic circuits for the purpose hereinbefore described. The primary windings *a'*, *b'* are in circuit, respectively with the condensers *d'*, *e'*, the elements of each circuit being so proportioned that each circuit is tuned to a certain frequency, as hereinbefore set forth. The winding *a'* links the magnetic circuit *q*, *r*, *s*, while the winding *b'* links the magnetic circuit *t*, *r*, *s*. While the field structure is shown as designed for the "dynamo" type of repeater, it will be understood that its form may be varied for use with the variable resistance type of repeater, an example of which is shown in Fig. 3. In the arrangement shown in Fig. 4, the current passing through either winding is not opposed by the counter-electromotive forces generated by the variable fields established by the other windings, except for the magnetic leakage which may exist between the circuits. The variable magnetic fields established by the various windings are cumulative in their effect upon the secondary element.

It will be understood that I am not limited to the use of two separate magnetic circuits but may employ any number of such circuits in either the dynamo or variable resistance type of repeater.

In a resonant circuit, the impedance of the windings dominates in opposing currents above the critical frequency. Below the critical frequency, the impedance of the condenser dominates. As the separation of the magnetic circuits described reduces the effect of the inductive impedance of the windings, it will be seen that the arrangement serves to emphasize the higher harmonics in transmission, which is desirable for the reason before stated.

It will be understood that where a current-reinforcing device is herein referred to, a device which relays or reinforces the electrical vibrations is meant rather than one which merely transforms or transmits the energy which it receives. The resonant electric circuits hereinbefore described as linking the same or separate magnetic circuits increase the strength of the variable magnetic field brought to bear upon a dynamo armature, transmitter diaphragm or similar device.

What I claim is:

1. The combination with a source of current having diverse frequencies, of a plurality of inductive windings in circuit therewith; a condenser for each of said windings, each condenser and its coöperating winding being proportioned for resonance to a given frequency from said source; separate magnetic circuits each of which is linked by one of said windings and a current-reinforcing device controlled by the variable magnetic field established through said magnetic circuits.

2. The combination with a source of current having diverse frequencies, of a plurality of primary circuits connected therewith, each circuit being resonant to a given frequency from said source; a magnetic field energized by said current; and an armature which rotates in said field.

3. The combination with a source of current having diverse frequencies, of a plurality of primary circuits connected therewith, each circuit being resonant to a given frequency from said source; a plurality of separate magnetic circuits each of which is linked by one of said primary circuits; and a secondary circuit in inductive relation to said circuits.

4. The combination with a source of current having diverse frequencies, of a plurality of primary circuits connected therewith, each circuit being resonant to a given frequency from said source; and a movable secondary element in inductive relation to said primary circuits.

5. The combination with a source of current having diverse frequencies, of a plurality of primary circuits connected therewith, each circuit being resonant to a given frequency from said source; a plurality of separate magnetic circuits each of which is linked by one of said primary circuits; and a movable secondary element in inductive relation to said primary circuits.

6. The combination with a source of current having diverse frequencies, of a plurality of inductive windings connected therewith and in parallel with each other; a condenser mounted in series with each of said windings, each condenser and its coöperating winding being proportioned for resonance to a given frequency from said source; a plurality of separate magnetic circuits each of which is linked by one of said windings and a current-reinforcing device controlled by the variable magnetic field established through said magnetic circuits.

7. In combination, a plurality of circuits each containing an inductive winding and a condenser, said winding and condenser being

proportioned for resonance to a given frequency; a source of current having diverse frequencies connected with said circuits; a magnetic field energized by said current; an armature in said field; and a secondary circuit the current in which is controlled by said armature.

In testimony whereof I hereunto set my hand this sixth day of July, 1906, at said Chicago, in the presence of two witnesses.

JULIAN A. STRATTON.

Witnesses:
HERMAN E. BAIR,
HARRY T. REYNOLDS.