

July 15, 1924.

1,501,649

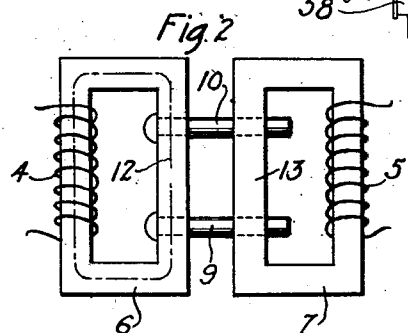
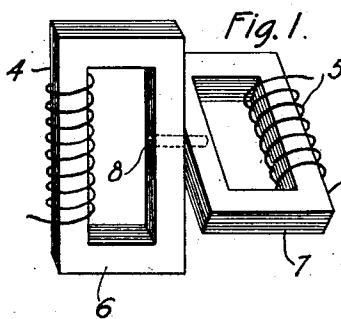
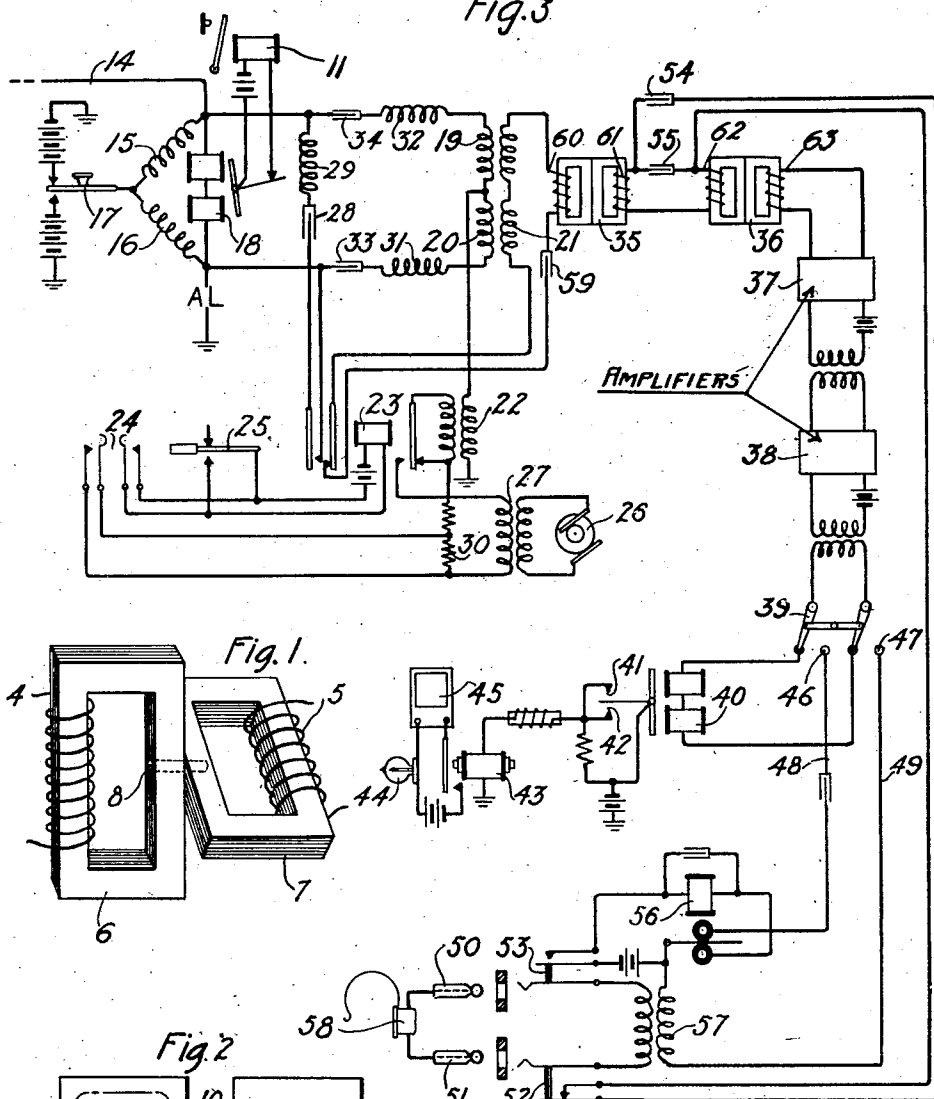
G. C. CUMMINGS

TRANSFORMER

Filed Dec. 26, 1919

2 Sheets-Sheet 1

Fig. 3



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Fig. 4

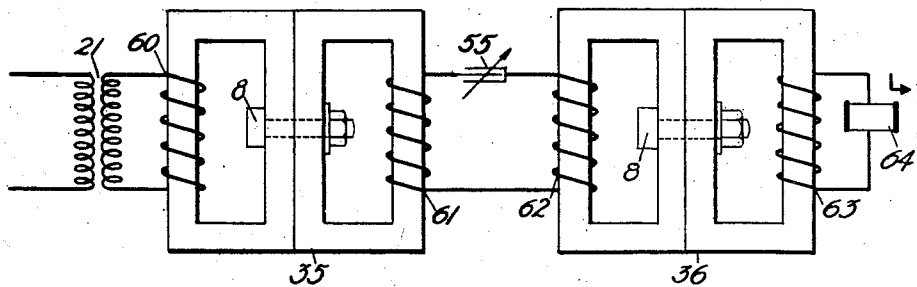
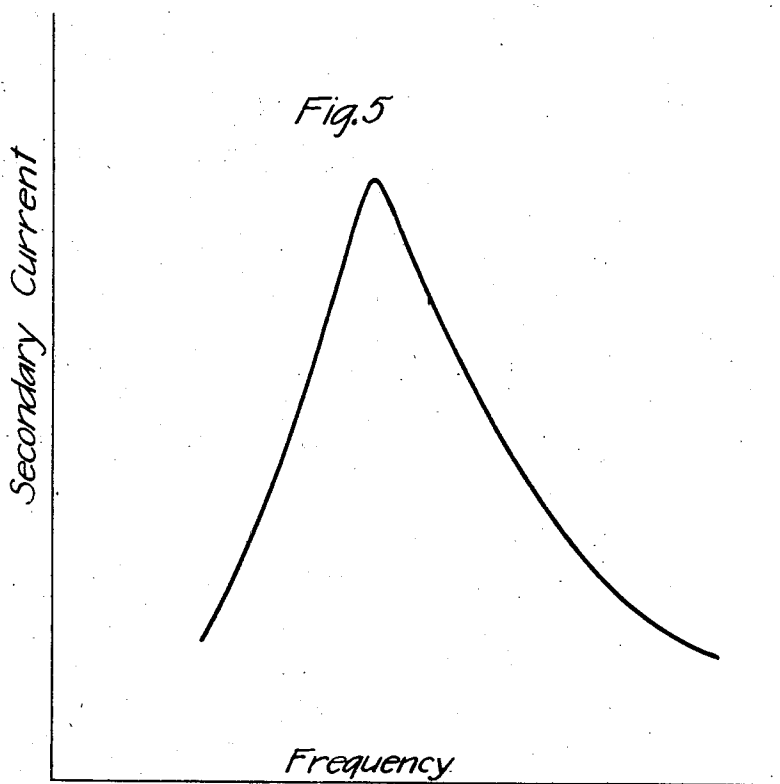


Fig. 5



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UNITED STATES PATENT OFFICE.

GEORGE C. CUMMINGS, OF EAST ORANGE, NEW JERSEY, ASSIGNOR TO WESTERN ELECTRIC COMPANY, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK.

TRANSFORMER.

Application filed December 26, 1919. Serial No. 347,511.

To all whom it may concern:

Be it known that I, GEORGE C. CUMMINGS, a subject to the King of Great Britain, residing at East Orange, in the county of Essex, State of New Jersey, have invented certain new and useful Improvements in Transformers, of which the following is a full, clear, concise, and exact description.

This invention relates to transformers, and particularly to an improved type of transformer for coupling apparatus for receiving alternating current signals of relatively low frequency with the line.

One object of this invention is to provide a loosely coupled transformer particularly applicable to low frequency signaling circuits.

Another object is to provide a loosely coupled transformer adapted for use in electric filters capable of selectively transmitting certain frequencies, particularly audio or lower frequencies, such as the frequencies of importance in telegraphy.

In constructing a filter for a telegraph system, for example, which will pass frequencies of the order of 45 cycles for example, it is essential that the inductive factor be large compared with the capacity factor, that the ohmic resistance be as low as possible and the coupling relatively loose. Such requirements necessarily preclude the use of air-core transformers such as are used for high frequency work.

This invention provides a highly inductive loose coupling transformer having its primary and secondary windings on separate branches of a core of magnetic material, there being a magnetic shunt between these branches which can be varied to alter the degree of magnetic short circuit and thereby change the magnetic coupling between the primary and secondary windings. This feature is of particular importance where the transformer is used as the inductive element of a filtering network in that the range of frequencies to be passed can be controlled by the adjustable shunt.

A better understanding of the invention may be had from the following description taken in conjunction with the accompanying drawing, in which Figure 1 shows a perspective of a transformer arrangement in which the two cores are suitably connected together

so as to be movable with respect to one another. Figure 2 shows an alternative coupling arrangement. Figure 3 shows one end of a telegraph system in which transformers of the character as shown in either Figs. 1 or 2 are adapted to be employed. Figure 4 shows more in detail the application of a transformer of the construction as shown in Fig. 1 and as employed in Fig. 3, while Figure 5 shows a performance curve of a transformer such as shown in Fig. 1.

Referring now to the drawing and especially to Fig. 1, there is shown a transformer having a primary winding 4 and a secondary winding 5. These windings are wound upon separate and distinct cores such as 6 and 7 respectively, which are built of laminations such as are employed in the construction of standard closed transformers. The two cores 6 and 7 are suitably connected by means of a bolt 8. This thereby permits the cores to be moved out of the plane of each other, that is, the angle which the one core makes with the other may be varied. This amounts to taking two standard closed transformers, removing one of the windings, and suitably connecting the two cores thereof so as to be movable. A transformer of this construction thereby forms a magnetic short circuit for the flux as set up by the current in the primary winding when the core upon which the secondary winding is wound is revolved so as to be positioned at right angles with respect to the primary winding. The flux emanating from the primary winding will thus circulate around through its own core and will induce but a small amount of current in the turns of the secondary winding for producing an effect in the circuit which is connected therewith. This flux can be termed as "stray" magnetic flux in that it does not produce an appreciable effect in the secondary winding. When the two cores 6 and 7 together with their windings are positioned so that they lie in the same plane, the flux as emanating from the primary winding 4 passes through the outer legs of the cores and cuts the turns of the secondary winding, thereby producing a transformation effect. A portion of the flux will, however, pass through the central portion of the core 6 when the two are positioned in the same plane, so that the device

is in effect a loose coupling transformer with variable coupling.

In Fig. 2 there is shown an alternative construction in which the primary and secondary windings as before are wound upon separate and distinct cores 6 and 7 respectively. In this case, however, the cores are adapted to be moved longitudinally with respect to one another in place of being revolved as was the case in the construction as shown in Fig. 1. The two cores are secured together by means of the bolts 9 and 10. The apertures in the cores 6 and 7 through which these bolts pass are bored slightly larger than the diameter of the bolts for permitting the cores 6 and 7 to be readily moved from one position to another. In this case, the amount of primary flux which finds its way into the secondary core will depend upon the separation between the two cores rather than upon their angular displacement as in Fig. 1. The portions 12 and 13 of the cores 6 and 7 may be made of a material of higher reluctance than the other portions of the cores so as to reduce the shunting effect and aid the transfer of flux from one core to the other.

Referring now to Fig. 3 and the particular embodiment illustrated therein, in which there are employed transformers of the construction previously described in connections with Figs. 1 and 2, there is shown one end of a telegraph line 14, to which is connected suitable apparatus for transmitting and receiving both direct current and alternating current signals. There may also be connected with this line suitable composite equipment for use in connection with telephonic communication. The line 14 is connected with a direct current duplex set comprising ratio arms 15 and 16 which are inserted between the main line 14 and the artificial line A. L. The sending key 17 is connected to the apex of the ratio arms for sending direct current telegraphic signals. A polarized relay 18 is connected across the extremities of these ratio arms at the point of connection thereof with the main line and artificial line. To this receiving relay is suitably connected a sounder 11 for the purpose of receiving direct current signals.

In order to provide an additional signaling channel, a second pair of ratio arms 19 and 20 are likewise suitably connected with the main line and the artificial line. If as in many cases, it is desired to employ this additional channel for the transmission of alternating current impulses, the receiving circuit therefor may be conveniently connected with the ratio arms 19 and 20 by means of a transformer 21 having a primary winding thereof in each of these ratio arms. To the transformer 21 there is con-

nected the alternating current receiving apparatus through suitable transformers and amplifiers, the application of which will be more clearly understood from the description which is to follow. In the existing circuits the apex of the ratio arms 19 and 20 leads to ground through the secondary winding of transformer 22 which serves to connect the alternating current transmitting apparatus with the line.

The primary winding of transformer 22 is normally short circuited through the contact and armature of relay 23, the energizing circuit of which is controlled through the contacts of an actuating key 24 and a transmitting key 25. The alternating current generator 26 is connected with the transformer 22 through the contacts of either of these keys and the windings of an additional transformer 27. The generator 26 preferably generates current of about 45 cycles, which differs sufficiently from the ringing current frequency used in connection with telephone service to cause no interference with the telephone signaling apparatus and low enough to have but little effect on the telephone instruments which may be connected with the line. If the generated current is of sinusoidal form there will be but little difficulty from interference but in many cases it has been found desirable to employ filters for the purpose of excluding from the receiving apparatus current of a frequency other than those which are desired to be manifested therein.

If the main and artificial lines are perfectly balanced for the frequency used, the alternating current signals in the ratio arms 19 and 20 will present equal potentials to the opposite sides of the direct current receiving relay 18 and thus cause no disturbances. It is, however, very difficult to have the main line and artificial line perfectly balanced and it is, therefore, necessary to provide means for preventing the alternating current signals from disturbing the direct current receiving relay. In order to eliminate any disturbances which may occur from this source, the condenser 28 together with the inductance 29 is connected in shunt with the direct current receiving relay 18 upon the energization of relay 23. This condenser and inductance are so chosen as to be substantially opaque to direct current signals intended for the receiving relay 18 but will, however, readily conduct signals of the frequency as generated by the generator 26. This is due to the fact that the capacity of the condenser 28 is small, while the inductance 29 is of a comparatively high value. It is also advisable, during the transmission of alternating current signals, that the receiving portion of the circuits at the transmitting station be disconnected for preventing the unbalancing of the main line.

This is accomplished by the provision of an additional contact on the relay 23 which, upon being energized, opens the alternating current receiving circuit upon the actuation of either of the keys 24 or 25.

Let us now consider that it is desired to transmit over the main line 14 alternating current impulses to a distant station at which is located the same apparatus and circuit arrangement as that shown in this figure. The operator, in desiring to transmit to a distant operator actuates key 24 which closes through its contacts the energizing circuit for relay 23 and short circuits a portion of the resistance 30. The short circuiting of a portion of this resistance thereby sends to the line the full volume of the alternating current signal. Relay 23 in operating opens at its normal contact the shunt around the primary winding of the transformer 22 and connects the same in series with the secondary winding of the transformer 27. The secondary winding of the transformer 21, the circuit of which is normally connected through the contacts of relay 23, is thereby severed upon the energization of this relay, while the condenser 28 and the inductance 29 are connected in bridge of the direct current receiving relay. The actuation of key 24 connects through the transformer 27 the source of alternating current with the transformer 22. The impulses, as transmitted from the generator 26, will, therefore, pass through the transformer 22 to the apex of the ratio arms 19 and 20 where they are equally divided between the main line and the artificial line, those going to the latter pass through inductance 31 and the condenser 33, while those to the former pass through the inductance 32 and the condenser 34 to the main line. The impulses will thus be received at the distant station over the line 14, and pass through the condenser 34, inductance 32, the ratio arms 19 and 20 to ground. The impulses in passing through the coils in the ratio arms 19 and 20 induce a current into the secondary coils of the transformer 21, the terminals of which are connected to the primary winding of the transformer 35. The current in the secondary winding of the transformer thus circulates through the primary winding 60 of the transformer 35. This transformer is of the same construction as the one described in connection with Fig. 1 and has its windings so adjusted with respect to one another as to give a performance curve similar to that shown in Fig. 5. This curve is derived by plotting secondary current values on the vertical axis against frequency on the horizontal axis. Thus by having such a curve one can at once determine the degree of coupling, as the width of the band is controlled by the amount of magnetic leakage which, as was

seen from the previous description, depends upon the amount which the one coil is displaced from the other. In this way the inductive element of the filtering network consisting of the windings of the transformer 35 and the condenser 55 is adapted to be varied. The current in the primary winding 60 having been induced into the secondary winding 61 causes a like current to flow through the primary winding 62 of the transformer 36 and the condenser 55. It is, of course, understood that the transformer 36 is of the same construction as that of 35 and that the condenser 55 is so chosen as to render the series circuit of windings 61 and 62 and condenser 55 in resonance for current of the frequency as generated at the alternating current source. This is especially true when the circuit containing windings 61 and 62 and condenser 55 is loosely coupled to the circuit containing windings 60 and 63 for permitting the circuit to be free to oscillate when excited by the proper frequency.

The current in the primary winding 62 is thus induced into the secondary winding 63 which is adjusted in the same manner as described in connection with the transformer 35. The current in the secondary winding 63 traverses the winding of relay 64 shown in Fig. 4 for effecting its operation, which is the equivalent of that represented by the numeral 40 in Fig. 3. It is thus seen that by providing a filtering network of this character, current of a frequency not desired to be manifested in the receiving circuit may be readily excluded. The current in the secondary winding 63 as shown in Fig. 3 thus passes through suitable amplifiers as represented by the numerals 37 and 38, switch 39 and the windings of relay 40. The current in passing through the winding of this relay causes the armature thereof to vibrate between the contacts 41 and 42 for connecting with the winding of the relay 43 a source of battery for causing the operation thereof. Relay 43 in operating closes at its contacts the operating circuit for the lamp 44 and the buzzer 45 which are thereupon operated. The operator upon receiving a signal of this character is thereby informed that the distant operator is desirous of conversing telegraphically.

The switch 39 would thereupon be thrown to the right, making contact with contacts 46 and 47 and transferring the receiving circuit to the leads 48 and 49. The receiving operator also inserts the plugs 50 and 51 into the jacks 52 and 53. The insertion of the plug 51 into the jack 52 opens through its contacts a circuit including the condenser 54 which normally shunts the condenser 55. The removing of the shunt from around the condenser, thereby changes the natural

period of oscillation of the oscillating circuit. The insertion of the plug 53 closes at its contacts a circuit including the winding of the chopper or microphonic relay 56, the armature of which immediately begins to vibrate at the rate of about 1500 cycles per second. This relay, as is well known to those skilled in the art, is for the purpose of rendering the signals as transmitted from the distant station audible in the telephone receiver 58 which is connected with the induction coil 57 through contacts of the plugs 50 and 51, and the jacks 52 and 53. Inasmuch as this is well known to those skilled in the art, a detailed description thereof is considered to be unnecessary.

The operator at the distant station, having communicated this signal may now converse telegraphically by means of the key 25. The relay 23 will be actuated in accordance with the operation of the key 25 for connecting with the ratio arms 19 and 20 the source of alternating current as generated by the generator 26. The telegraphic signals will thereby, as before, pass over the line 14 to the distant station, through the condenser 34, inductance 32 and the ratio arms 19 and 20 thereat to ground. The signals are thereby transformed through the coils of the transformer 21 to the primary winding of the transformer 35 and subsequently to that of transformer 36. These transformers have their windings, as before described, so adjusted with respect to one another that signals other than those which are desired to be manifested in the alternating current receiving circuits are prevented from traversing this portion of the circuit. The condensers 33 and 34 in the ratio arms 19 and 20 as well as the condenser 59 in circuit with the secondary of the transformer 21 and the primary winding of transformer 35 serve to materially reduce the interference between the alternating current signals and the other signaling current. It is, of course, understood that the value of these condensers will depend upon the frequency of the alternating current used. These condensers in conjunction with the transformers 35 and 36, the reluctance path of which may be varied, render the alternating current receiving circuit almost opaque to current of a frequency other than that of the current as generated by the alternating current generator 26. This amounts to a tuning process and by merely adjusting the windings of the transformers 35 and 36 with respect to one another the selectivity of the circuits can be varied. The signals thus pass through the amplifiers 37 and 38, where the current is amplified, to the transformers associated therewith and are acted upon by the relay 56. The frequency of the signals is thus increased for rendering them audible

in the receiver 58 which is connected with the plugs 50 and 51. In this way the operator can readily communicate with a distant operator and the frequency of current which is employed at the transmitting station is not required to be of as high a value as would be necessary if a relay of the type the same as 56 were not employed.

When the telegraphic conversation is completed the key 39 is thrown to the left so as to connect in circuit with the receiving circuit the winding of relay 43.

Referring now more in detail to Figure 5, in which there is shown a performance curve of a transformer of the construction as shown in Fig. 1, the curve is a graphical representation for a particular degree of coupling, in which current in milliamperes in the secondary winding is plotted along the vertical axis, while frequency in cycles per second is plotted along the horizontal axis. The percentage of coupling in this case was found to be thirty-three per cent. If the percentage of coupling were less than the one here chosen, the width of the band would be considerably less, that is giving a sharper curve, while if it were of a higher percentage the opposite would be true. It is thus seen that a transformer of this construction gives very desirable results and is especially applicable to currents of low frequency.

The circuit arrangement in which the transformers of the construction covered by this invention are shown is to be regarded as merely illustrative, as it is obvious that modifications may be made thereof without departing from the spirit and scope of the invention.

What is claimed is:

1. A transformer comprising a primary and a secondary winding, a separate and complete magnetic core for each of said windings, and means for connecting said cores together whereby the reluctance path between said windings may be varied for providing a loose coupling.
2. A transformer comprising a primary and a secondary winding, a separate and complete magnetic core for each of said windings, and means for connecting said cores together whereby one may be moved with respect to the other for varying the reluctance path between said windings.
3. A transformer comprising a primary and a secondary winding, a separate and complete magnetic core for each of said windings, and means for connecting said cores together whereby one of said cores may be revolved for varying the reluctance path between said windings.
4. A transformer comprising a primary and a secondary winding, a separate and complete magnetic core for each of said windings, and a bolt passing through a por-

tion of each of said cores whereby said cores may be revolved for varying the reluctance path between said windings.

5 A transformer for telegraph systems employing low frequency currents comprising a primary and a secondary winding, a rectangular-shaped core for each of said windings, each of said cores forming a separate and complete magnetic circuit, and connecting means for said cores for permitting the one to be rotated out of the plane of the other whereby the reluctance path between said windings may be varied.

6. A transformer for telegraph systems 15 employing low frequency currents comprising a primary and a secondary winding, a rectangular-shaped core for each of said windings, each of said cores forming a separate and complete magnetic circuit, and a 20 bolt passing through the central portion of each of said cores for permitting the one to

be rotated out of the plane of the other whereby the reluctance path between said windings may be varied.

7. A transformer comprising a primary 25 winding, a secondary winding, a rectangular-shaped core for each of said windings; each of said cores forming a separate and complete magnetic circuit, and connecting means for said cores to permit the one to be 30 moved with respect to the other whereby the reluctance of the magnetic path between said windings may be varied.

8. A transformer comprising a primary winding, a secondary winding, a substan- 35 tially circumferentially magnetic core for each of said windings, and an adjustable connecting means for said cores.

In witness whereof I hereunto subscribe my name this 23rd day of December, A. D. 1919.

GEORGE C. CUMMINGS.