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H. NYQUIST
ELECTRICAL TRANSFORMER
Filed June 29, 1921

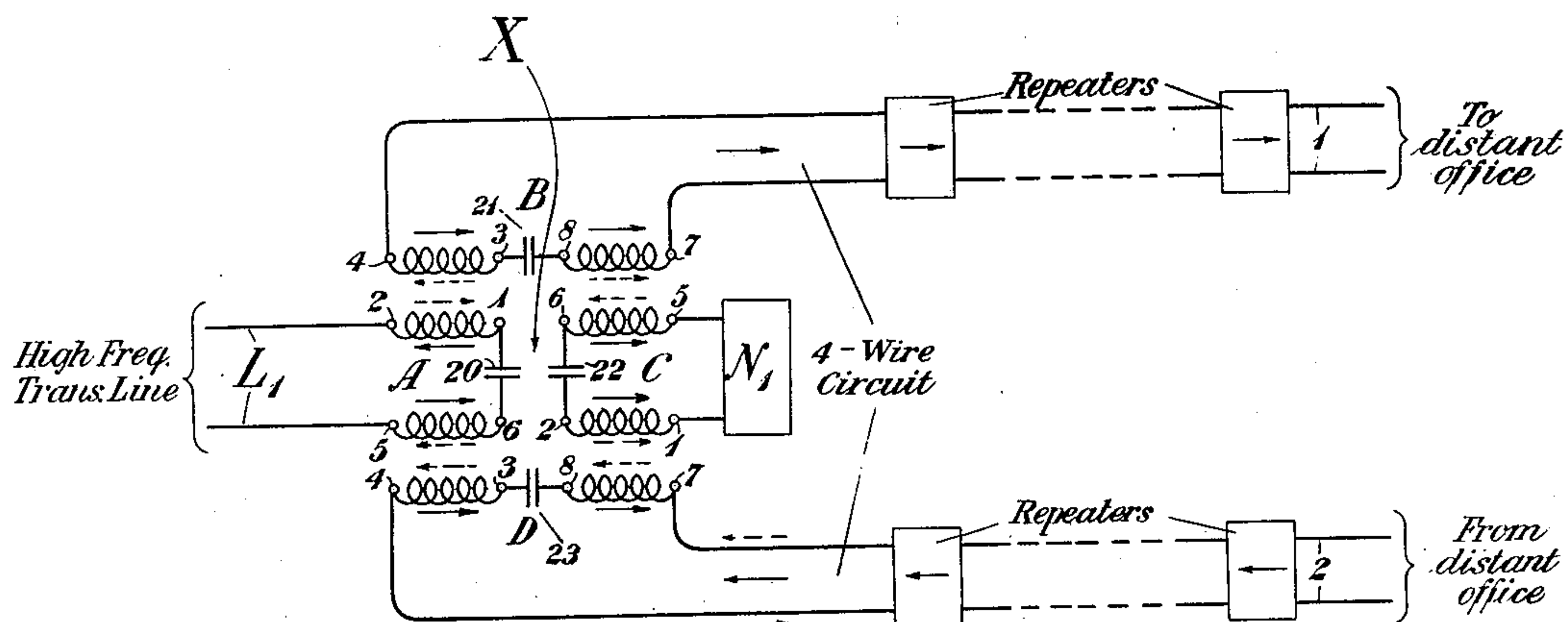


Fig. 1

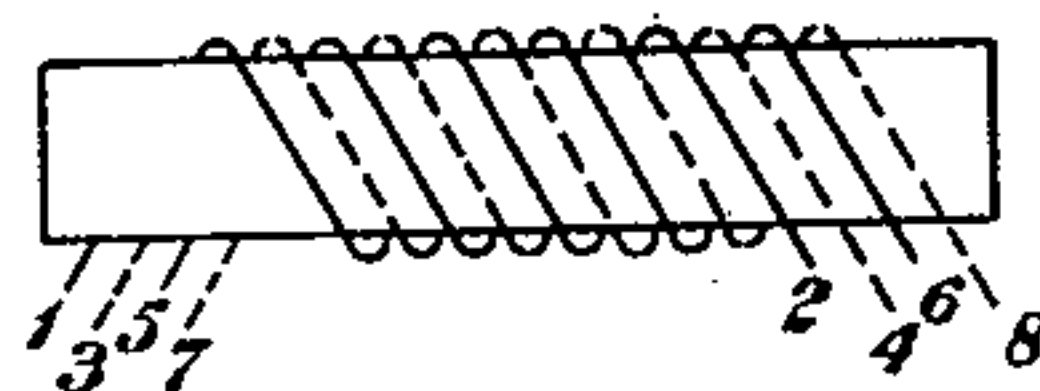


Fig. 2

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By his Attorney

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UNITED STATES PATENT OFFICE.

HARRY NYQUIST, OF ELMHURST, NEW YORK, ASSIGNOR TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK.

ELECTRICAL TRANSFORMER.

Application filed June 29, 1921. Serial No. 481,319.

To all whom it may concern:

Be it known that I, HARRY NYQUIST, residing at Elmhurst, in the county of Queens and State of New York, have invented certain Improvements in Electrical Transformers, of which the following is a specification.

This invention relates to electrical transformers and especially to a transformer arrangement used in signaling circuits for the purpose of connecting a two-wire circuit with a four-wire circuit.

Heretofore it has been customary to connect a two-wire signaling circuit with a four-wire signaling circuit by means of a transformer arrangement commonly known as a hybrid coil. The terminals of the windings of the hybrid coils are arranged in groups, one group being connected with the two-wire circuit, another group being connected with the input side of the four-wire circuit, a third group being connected with the output side of the four-wire circuit and the fourth group being connected with a balancing network adapted to simulate the electrical characteristics of the two-wire circuit. If the two-wire circuit is absolutely balanced by its network and likewise each two-wire branch of the four-wire circuit balances the other, the application of a difference of potential across the group of terminals connected with the output branch of the four-wire circuit, will cause current to flow in the two-wire circuit and also in the circuit of the balancing network, but there will be no resultant current in the two-wire branch of the four-wire circuit which constitutes the input side of the four-wire circuit. Furthermore if a difference of potential is established across the two-wire circuit, current will be transmitted into each of the two-wire branches of the four-wire circuit, but it will not be transmitted to the circuit containing the balancing network.

In connection with such transformer arrangements it has frequently been found desirable to use filters in order to limit the range of frequencies transmitted from the

four-wire circuit to the two-wire circuit and vice versa. Thus, for example, such a filter might be connected in the two-wire circuit between the terminus of the two-wire line and the group of windings of the transformer arrangement normally connected with the said two-wire line. A similar filter would be included in the circuit of the balancing network in order to balance its corresponding filter in the two-wire line circuit. Such an arrangement of coils and filters is undesirable for many reasons, and it is the object of this invention to so arrange the apparatus for connecting the two-wire with the four-wire circuits that it will perform simultaneously the functions of a filter and a transformer.

This invention will be better understood from the following description when read in connection with the attached drawing of which Figure 1 shows schematically an arrangement for carrying out the principle of this invention, and Fig. 2 shows the arrangement of the windings of the coils shown in Fig. 1, which will serve to make clear the invention.

In Fig. 1, L_1 represents a high frequency two-wire transmission line which is to be connected with the four-wire circuit by means of the transformer arrangement indicated by X. The form of arrangement represented in the figure comprises two transformers each of which has upon its core four windings which are wound in the same direction, as shown in Fig. 2. One terminal of each winding has been given an odd number and the other the next higher even number. The windings have been wound in such a direction that when current flows from an odd to an even terminal the flux set up in the core is in a given direction irrespective of which winding is taken. The same would be true if current were to flow from an even numbered to an odd numbered terminal, but in this case the flux would of course be in the opposite direction.

As stated, the transformer arrangement X consists of two transformers, each compris-

ing four windings. The windings of these coils are connected in groups of two each, which groups are associated with the various circuits connected to the transformer arrangement. Thus the group A is connected with the line L_1 , the group B with the input circuit of the four-wire circuit, group C with the circuit containing the balancing network N_1 and group D with the output circuit of the four-wire circuit. The winding 1—2 of group A, together with the windings 3—4, 7—8 of group B and winding 5—6 of group C constitute one of the transformers of the transformer arrangement X, and in like manner winding 5—6 of group A, windings 3—4, 7—8 of group D and winding 1—2 of group C constitute the other transformer of the transformer arrangement.

Furthermore it will be seen that there has been connected a condenser between the inner terminals of the windings of each group. Thus condenser 20 is connected between the inner terminals of the windings of group A; condenser 21 is similarly connected in group B; condenser 22 in group C and condenser 23 in group D. Since all of the groups are symmetrical, and the corresponding elements of each group have the same values, a balanced condition exists between the four circuits related to each other by the said transformer arrangement. It will furthermore be apparent that the combination of the various groups constitutes in effect a high-pass filter which is adapted to transmit readily frequencies above a certain limit or to offer high impedance to the transmission of frequencies below the said limit.

Having in mind the foregoing description of the circuit in which the invention is embodied, the invention will be understood from the following description of the mode of transmitting signals over the said circuit. Let it be assumed that energy is being transmitted over line L_1 from left to right, viz, in such direction as to impress its energy upon the four-wire circuit, and furthermore let the direction of flow of current at any instant in line L_1 be as indicated by the solid arrows. The current flowing in winding 1—2 of group A will induce a potential in the windings of group B that will cause flow of current from 4 to 7 and will also induce a potential in winding 6—5 of group C that will tend to cause a flow of current from 6 to 5. Similarly, the flow of current through winding 5—6 of group A, as indicated by the solid arrow, will induce a potential in the windings of group D that will cause flow of current from 4 to 7, and there will also be induced in winding 2—1 of group C a potential that will tend to cause current to flow in the direction indicated by the solid arrow. If the impedance of the output circuit of the four-

wire circuit equals that of the input circuit, equal currents will exist in these circuits and as a result the potentials induced in the two windings of group C are equal in magnitude. It will be seen, therefore, that no resultant effect takes place in the circuit of network N_1 . The current set up in group B will be transmitted in the direction of the arrows and will be amplified by the repeaters. The current set up in group D will not be transmitted beyond the first repeater in this two-wire branch of the four-wire circuit since the repeaters associated therewith are adapted to transmit in only one direction, which direction is represented from right to left.

If, on the other hand, it is assumed that a signaling wave is being transmitted from a distant station at the right over the two-wire branch 2 of the four-wire circuit and is being impressed upon group D of the transformer arrangement, the distribution of energy in the said arrangement is as follows: The direction of flow of current of the transmitted wave in the group D is represented, for example, by the dotted arrows, viz, the current will flow through the windings of the said group in the direction from 7 to 4. This flow of current will induce potentials in groups A and C, which are related to group D by having one of their windings upon the same core. The potentials induced in windings 6—5 and 2—1 of groups A and C respectively will cause current to flow in the directions indicated by the dotted arrows. Since the circuits of groups A and C are closed, current will flow in winding 2—1 and winding 5—6 of groups A and C respectively in the directions indicated by the dotted arrows. If the impedance of N_1 equals that of L_1 these currents will be of equal magnitude. In view of the fact that windings 2—1 and 5—6 of groups A and C respectively are upon the same magnetic core, and since the flow of current in winding 2—1 of group A is in opposite direction to the flow of current in winding 5—6 of group C (as may be clearly seen by considering the distribution of windings shown in Fig. 2), no resultant flux occurs in the core, and consequently no induced potential results in the windings of group B. Consequently the energy of the transmitted signaling wave, which is impressed upon group D by the repeaters associated with the two-wire branch 2, is in turn impressed upon the two-wire line L_1 and upon the circuit of network N_1 , but is not impressed upon group B associated with the other two-wire branch of the four-wire circuit. Consequently singing of the four-wire circuit is prevented.

Furthermore, since the groups which comprise the transformer arrangement are de-

signed to transmit frequencies above a certain limit, other frequencies will be practically excluded. It is therefore unnecessary to insert in the line L_1 and also in the circuit of the network N_1 a filter to perform the function of excluding the undesired frequencies. The symmetrical groups, each containing two windings and a condenser, constitute, when combined, not only means for transferring energy from one circuit to another but also act as a filter to exclude undesired frequencies. The invention is not, however, limited to the particular arrangement shown since it will be apparent to those skilled in the art that a different rearrangement of the elements constituting the groups will produce a combined transformer arrangement and a filter adapted to transmit, for example, low frequencies and to suppress high frequencies. Or the groups might be so designed as to transmit only a band of frequencies. The invention, therefore, is not limited to the particular elements constituting a group, or to a particular arrangement in the group, but covers broadly a transformer arrangement which, by the arrangement of its windings and by the connection of condensers thereto, is adapted to function as a filter as well as a transformer. Although this invention has been described as embodied in a certain form of circuit and arrangement of parts, it is to be understood that it is capable of embodiment in other and different forms and arrangements without departing from the spirit and scope of the appended claims.

What is claimed is:

1. In a signaling system, the combination with a line circuit of a balancing network circuit, an input circuit, an output circuit and a transformer arrangement adapted to electrically connect all of said circuits and to transmit readily currents of frequencies above a certain limit.
2. In a signaling system, the combination with a line circuit of a balancing network, a four-wire circuit comprising an input circuit and an output circuit, and a transformer arrangement comprising a plurality of impedance groups, each containing a plurality of windings, and a condenser individual to each group adapted to transmit currents of frequencies above a certain limit between certain of said circuits.
3. In a transformer system the combination with a plurality of transformers each having a plurality of windings, one of the said windings of one transformer being connected with one winding of said other transformer, and similarly another winding of the said first transformer being connected with another winding of the said second transformer, thereby constituting four groups of windings, each group being con-

ductively separated from the others and all groups being inductively related, and a condenser individual to and connected with each group of said windings.

4. In a signaling system, the combination with a line circuit of a balancing network circuit, an input circuit, an output circuit, a plurality of transformers each having a plurality of windings, certain of said windings being arranged in combination with a condenser to form an impedance group, there being one group for each of said circuits, and the groups being so related as to transmit readily currents of frequencies above a certain limit and to suppress those of other frequencies.

5. In a signaling system, the combination with four circuits arranged in pairs of approximately equal impedance, of a plurality of transformers each having the same number of windings, the said windings being arranged in groups each containing a condenser, each group being connected with one of said circuits, and the magnitude of the inductance of the windings and the capacity of the condenser being so chosen that only those current of frequencies lying above a certain limit flowing through one group of windings will be transmitted to the windings connected with said other pair of circuits.

6. In an electrical transforming and filtering system, the combination with a plurality of transformers, each comprising a plurality of windings of a plurality of condensers, one condenser being connected serially with two of the windings of the first transformer, the second condenser being connected serially with two windings of the second transformer, the third being connected serially with the third windings of the first transformer and of the second transformer, respectively, and the fourth condenser being serially connected with the fourth windings of the first transformer and of the second transformer, respectively, the magnitude of the inductance of the windings and the capacity of the condensers being so chosen as to limit the range of frequencies transformed by the said system.

7. In an electrical repeating system, the combination with two transformers each comprising four windings arranged upon a magnetic core of a line circuit connected with one winding of each transformer, a network circuit connected with another winding of each transformer, a repeater input circuit connected with two windings of one transformer and a repeater output circuit connected with two windings of the other transformer, each of the groups of windings connected with the said circuits having a condenser in series therewith, and the said groups being so arranged as to

transmit readily currents of frequencies lying above a certain limit and to suppress all other frequencies.

8. In a signalling system the combination
5 with a hybrid coil comprising four symmetrical impedance groups electro-magnetically related, each group containing a plurality of inductance coils and a condenser, of a plurality of circuits individual to and
10 connected with the said impedance groups,

the constants of the said groups being so chosen as to transmit from one of said circuits to certain of the other circuits a particular frequency or band of frequencies and to suppress other frequencies or bands thereof.

In testimony whereof, I have signed my name to this specification this 25th day of June, 1921.

HARRY NYQUIST.