

March 14, 1939.

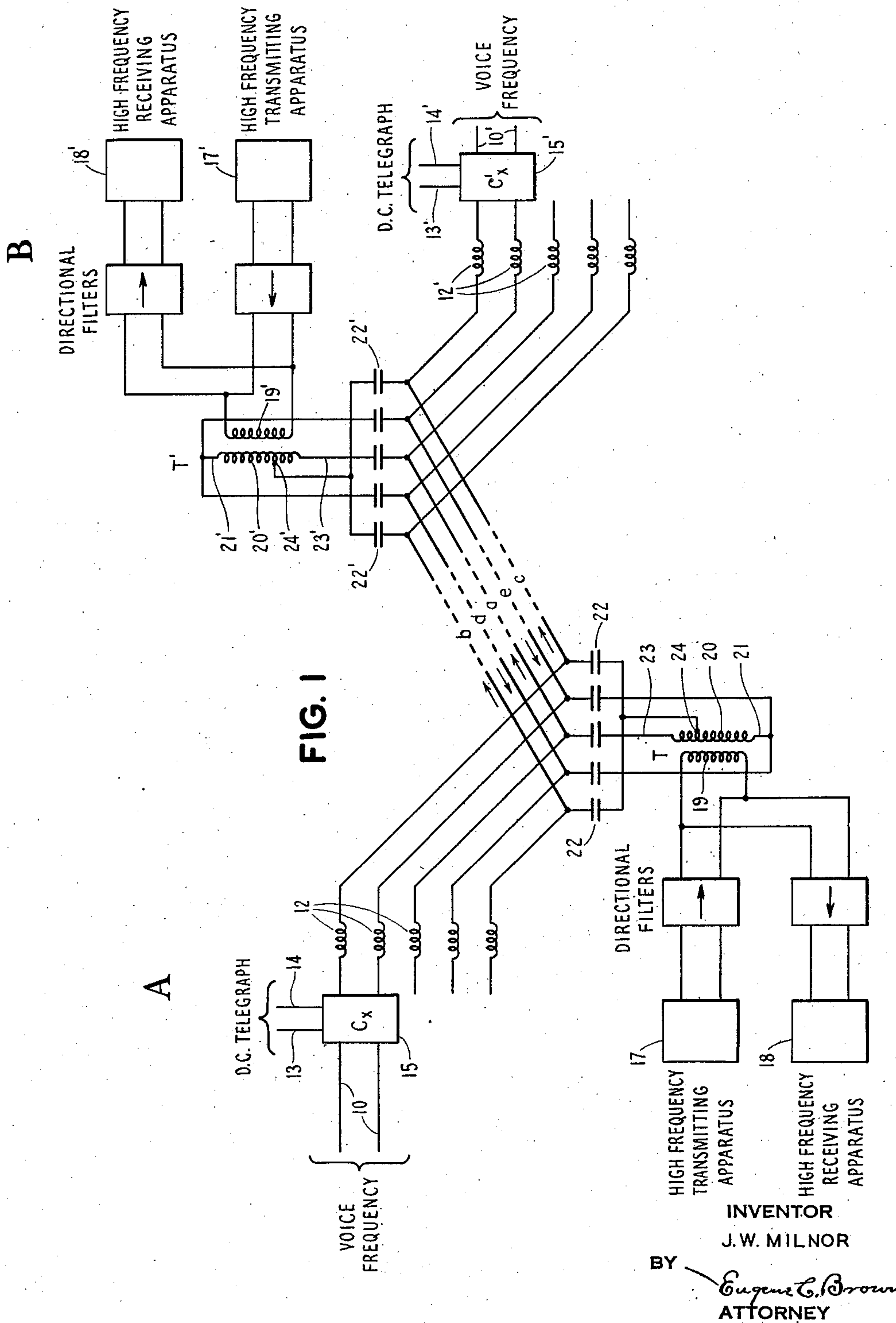
J. W. MILNOR

2,150,451

HIGH FREQUENCY CONDUCTOR SYSTEM

Filed Oct. 16, 1936

4 Sheets-Sheet 1



March 14, 1939.

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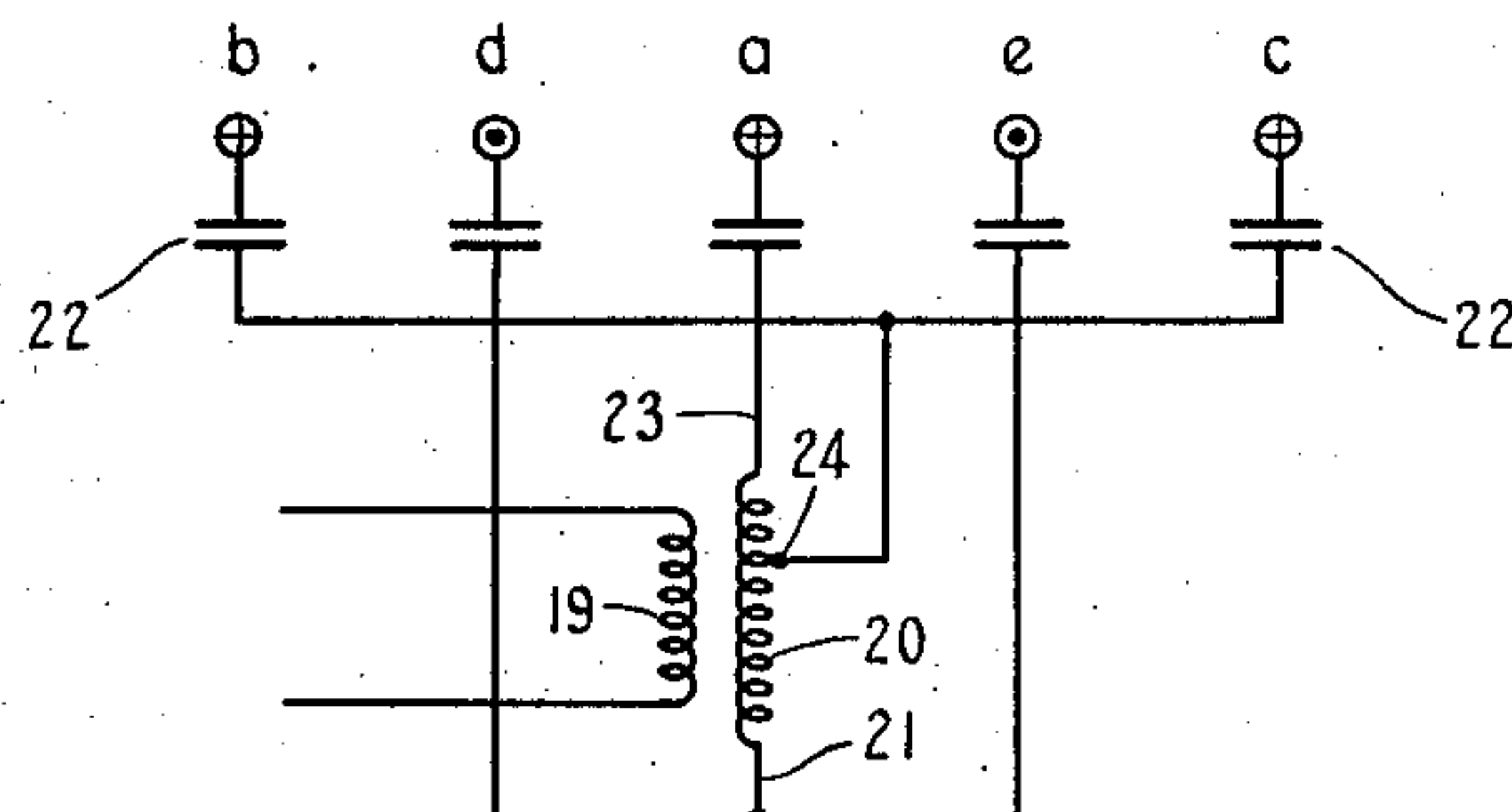
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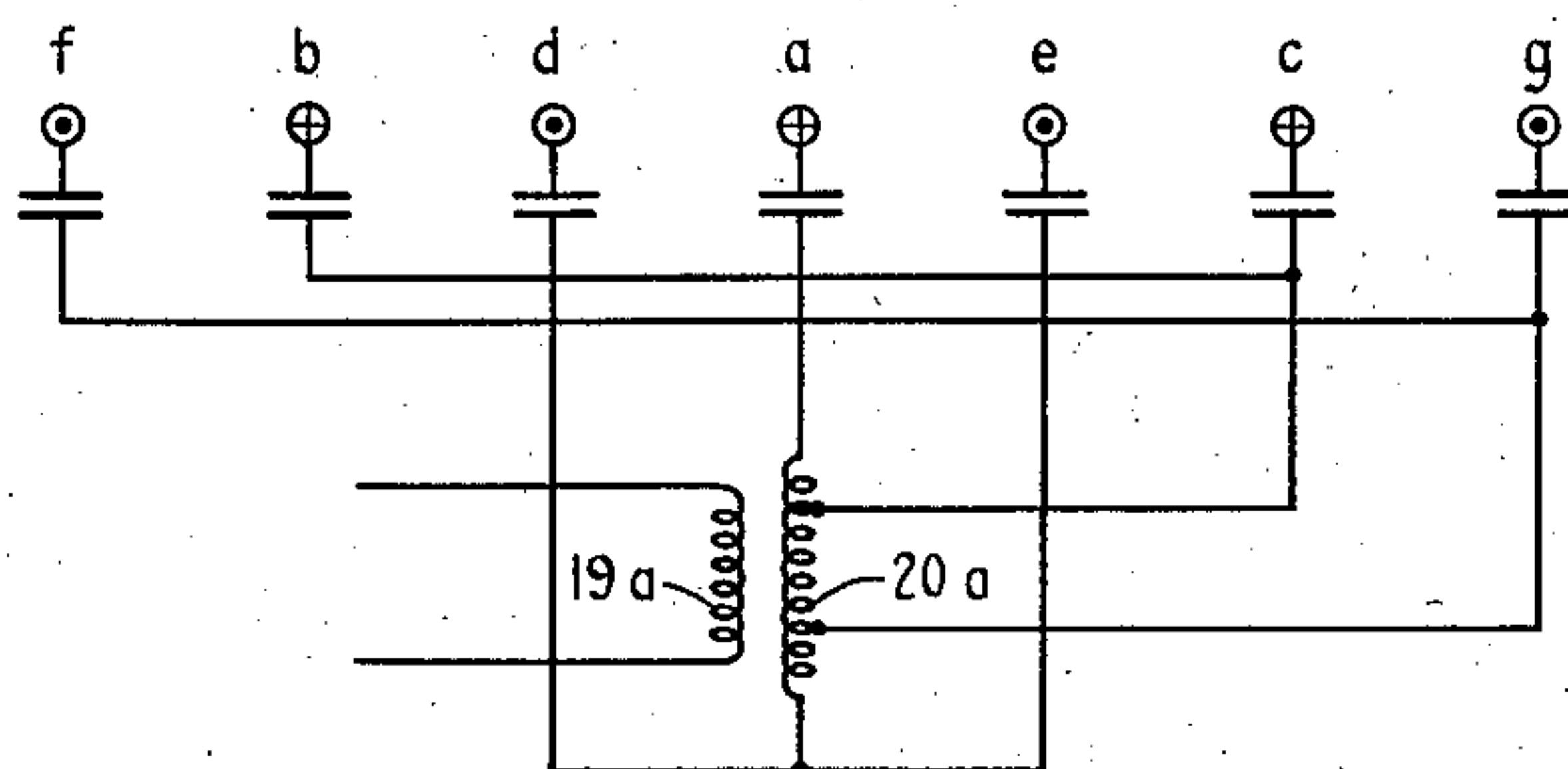
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FIG. 2



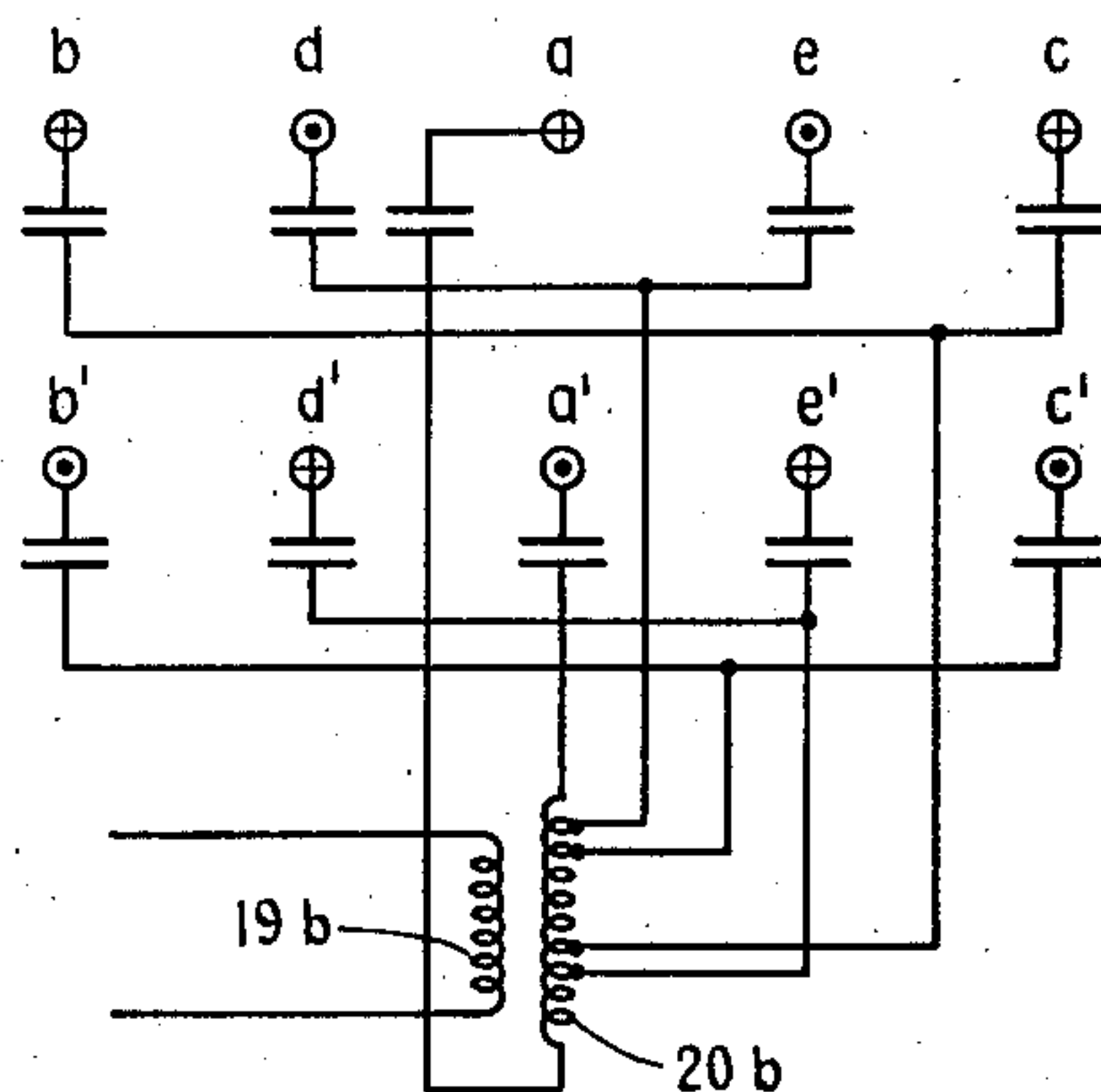
$$\begin{aligned} I_b \quad I_c &= .2 I_a \\ I_d \quad I_e &= .7 I_a \end{aligned}$$

FIG. 3



$$\begin{aligned} I_d = I_e \quad I_b = I_c \quad I_f = I_g \\ I_a > I_d > I_b > I_f \end{aligned}$$

FIG. 4



$$\begin{aligned} I_d = I_e \quad I_b = I_c \\ I_a > I_d > I_b \end{aligned}$$

CURRENT IN ADJACENT
WIRES IN VERTICAL
AND HORIZONTAL ROWS
EQUAL AND OPPOSITE
IN DIRECTION

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FIG. 5

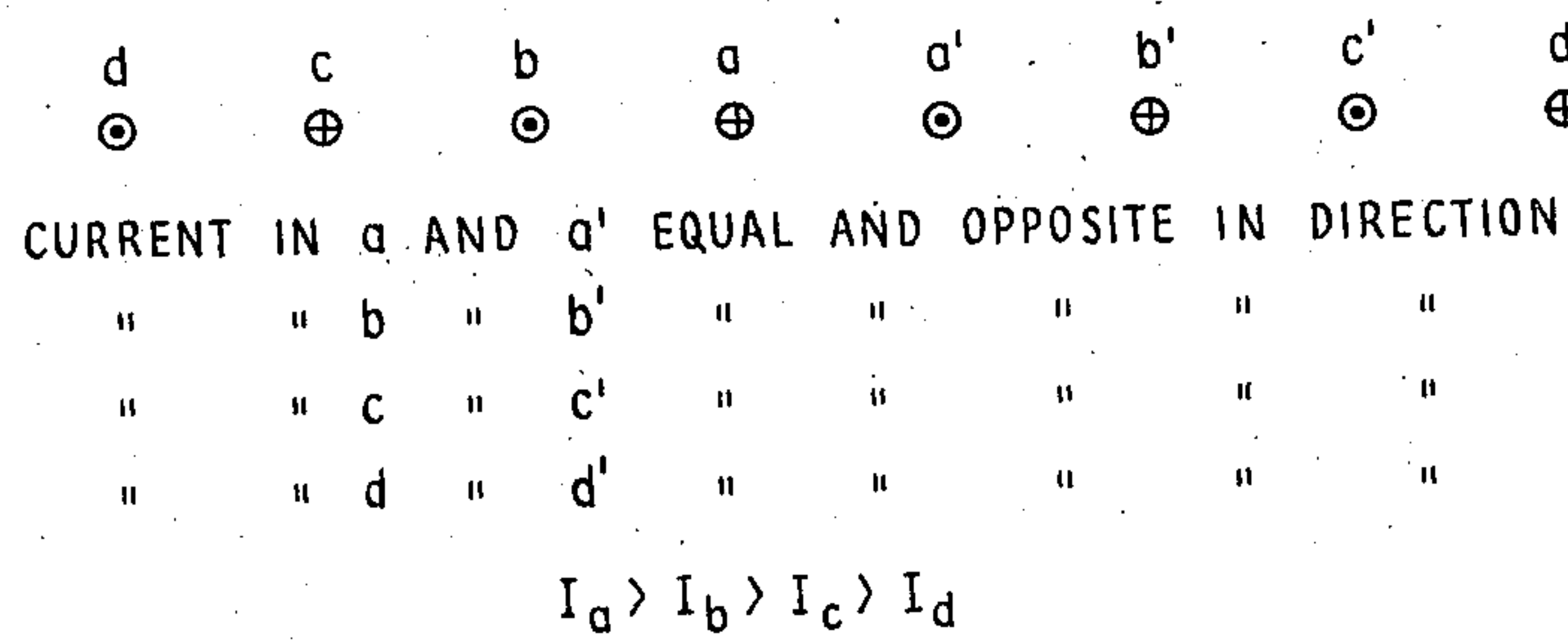


FIG. 6

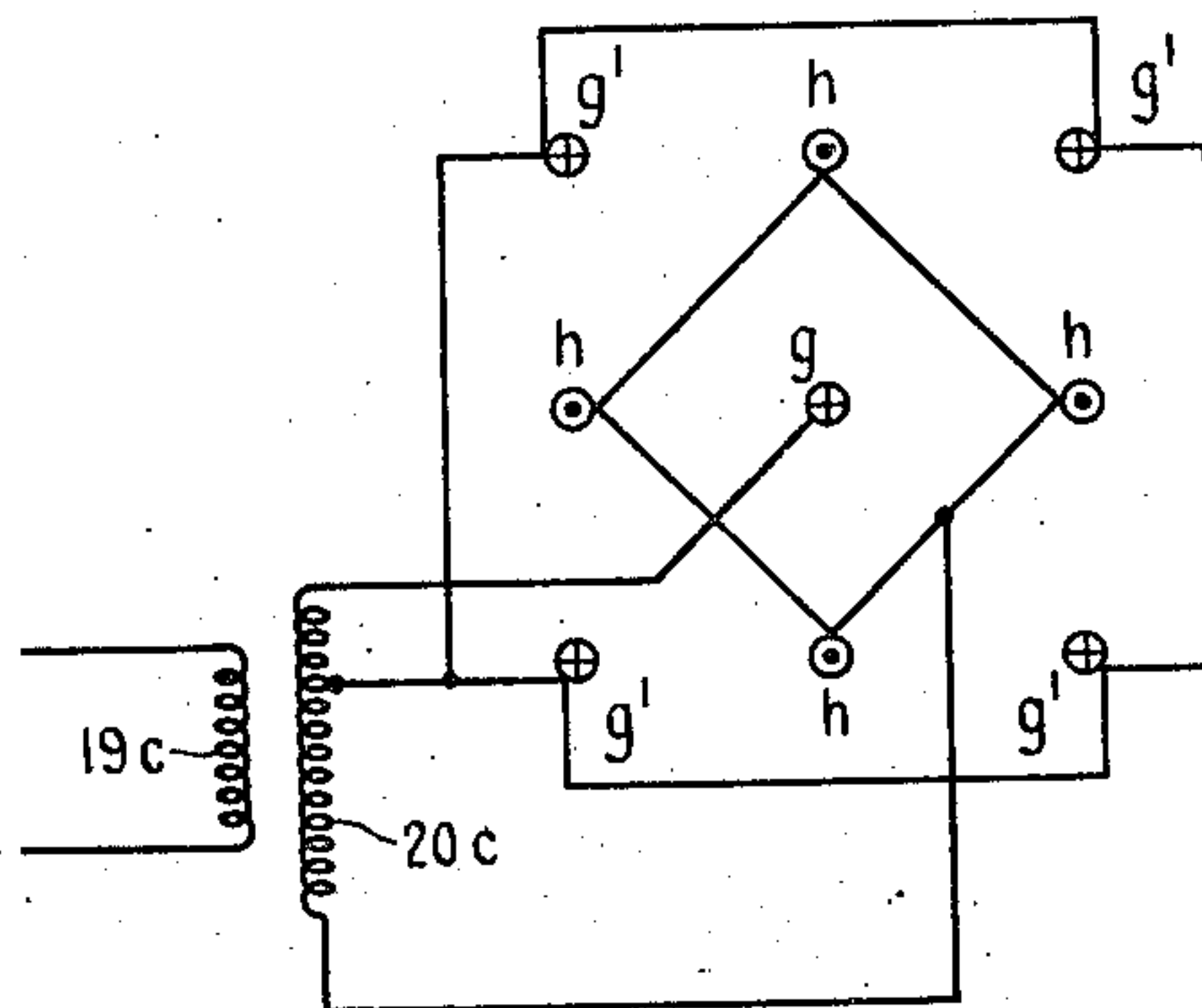
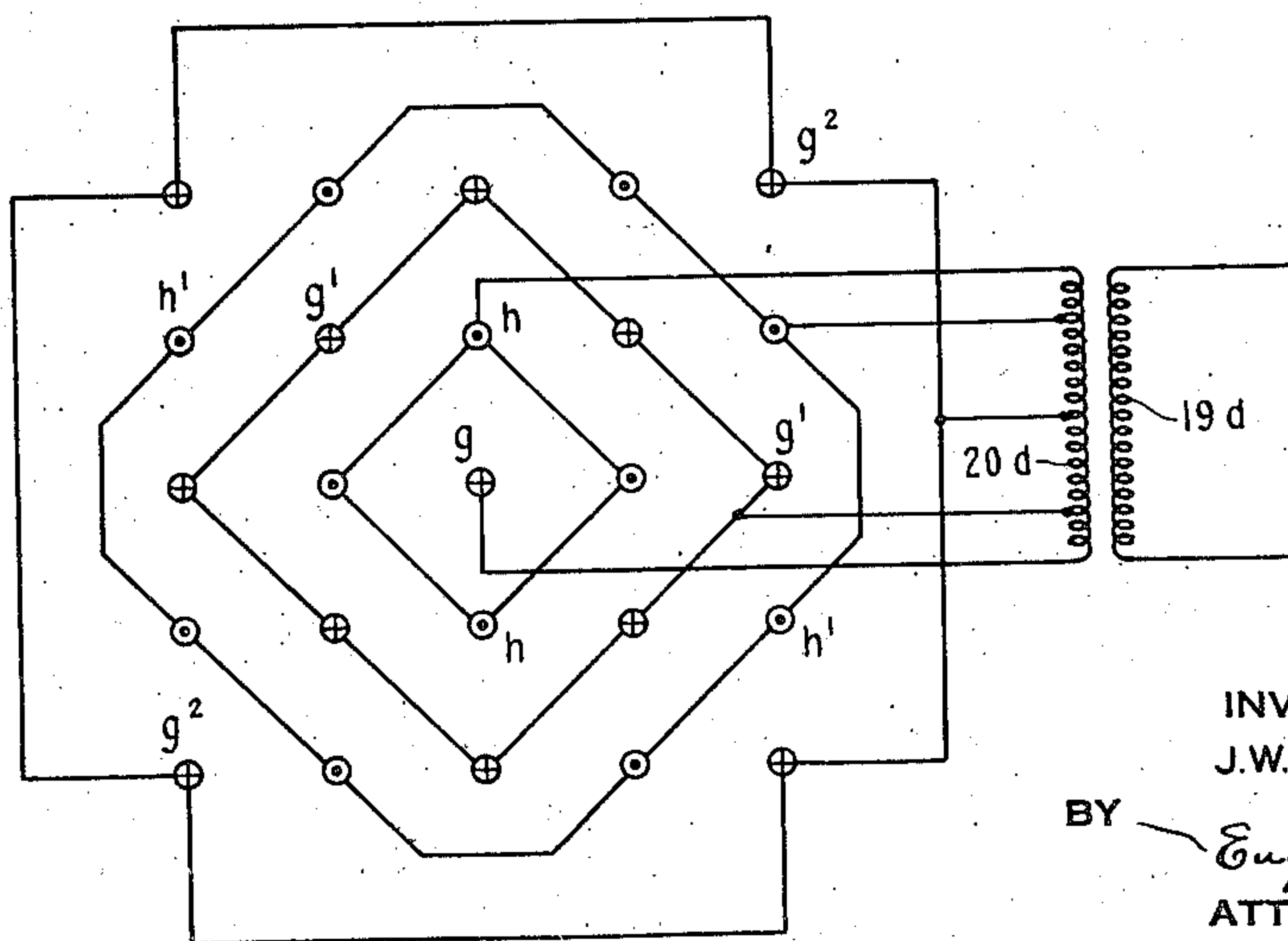


FIG. 7



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2,150,451

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FIG. 8

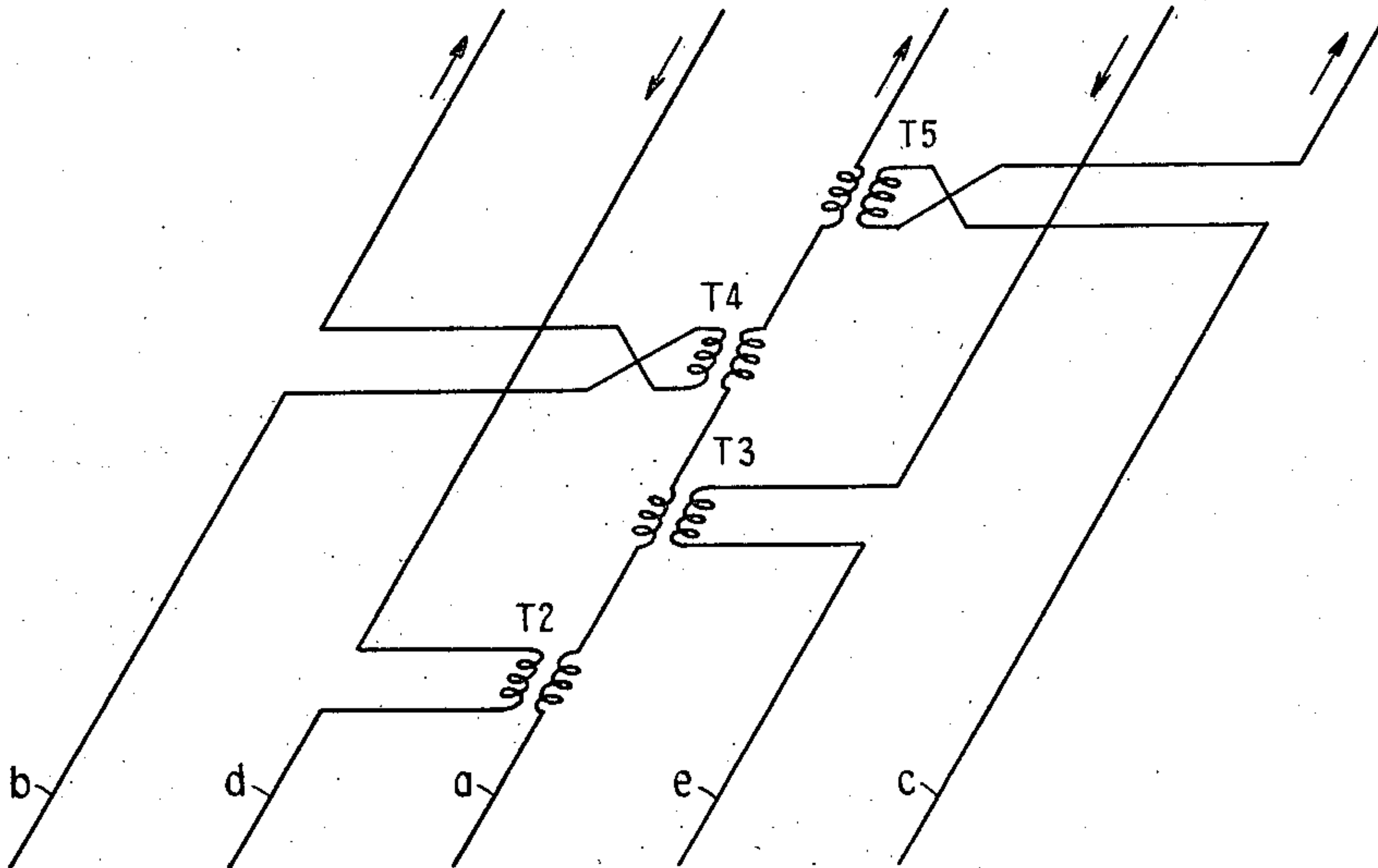
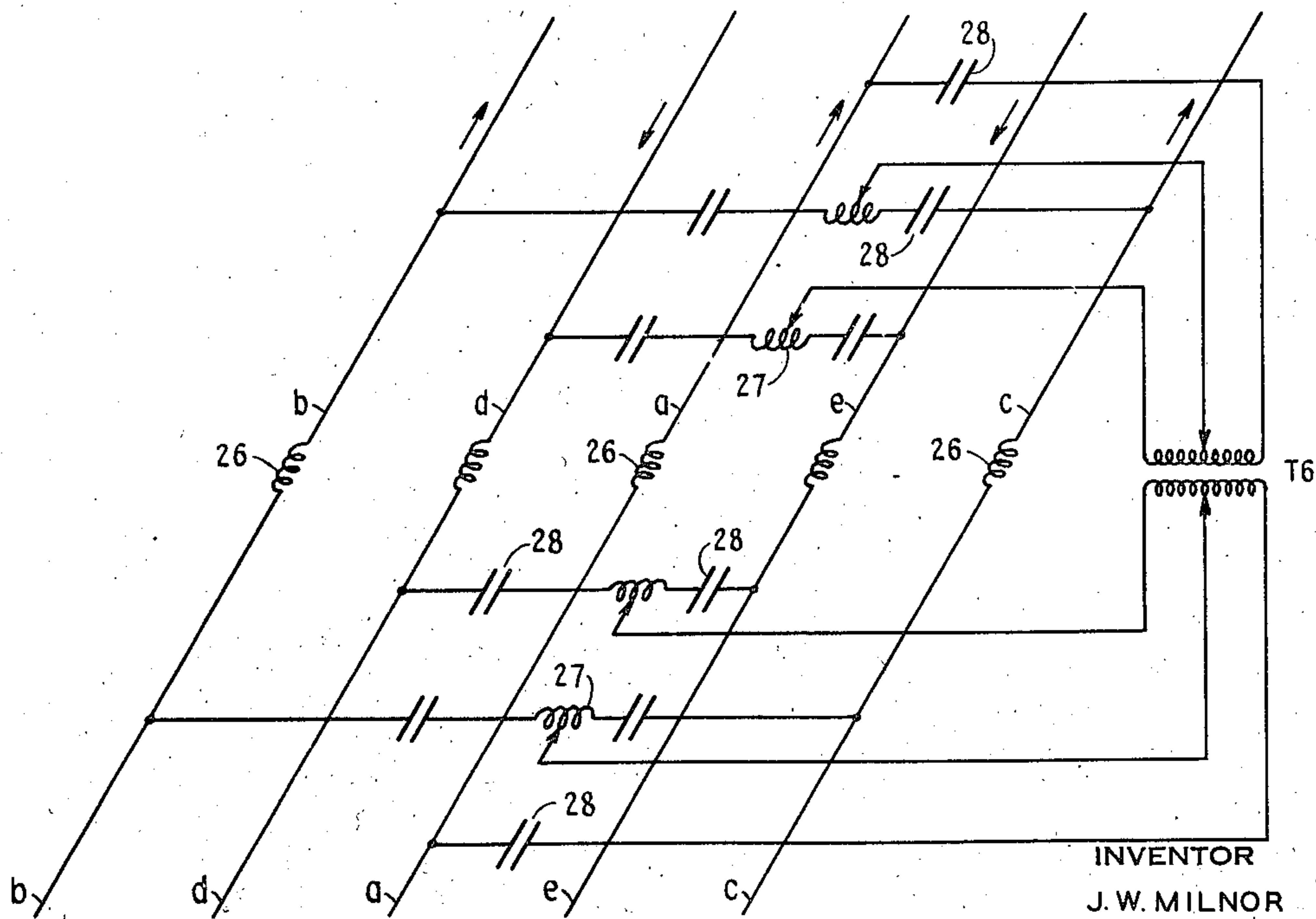


FIG. 9



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HIGH FREQUENCY CONDUCTOR SYSTEM

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Application October 16, 1936, Serial No. 106,036

20 Claims. (Cl. 179—78)

My invention relates to a high frequency conductor system, and particularly to a high frequency communication system especially applicable to open wire conductors.

Ordinarily, open wire communication lines, even though carefully paired and transposed in the usual way, may not be used for the transmission of frequencies above the order of 20,000 cycles, and to extend the range to include frequencies as high as 50,000 cycles or more requires the employment of special arrangements of the conductors. These special arrangements may require more frequent transpositions, special spacing of the conductors, special low loss insulators, bonding of the insulator pins, soldering of the wire joints, and in general necessitate a very high degree of care in construction, resulting in undesirably high installation and maintenance costs. For higher frequency ranges, even these precautions are inadequate to prevent inductive effects and radiation of energy, thus causing losses and also interference with other transmission systems or with radio receivers and, in turn, causing the circuit to be highly susceptible to interference from external electric and magnetic fields.

One of the objects of the invention is to provide a novel and improved high frequency system in which radiation losses and inductive effects of the system on other circuits are minimized, and which has low susceptibility to interference from external fields.

Another object is a suitable system for high frequency transmission applicable to ordinary open wire communication conductors without requiring special rearrangements of the conductors.

An additional object is to increase the carrying capacity and provide new uses for existing standard lines.

The invention further resides in a transmission system having the novel features hereinafter disclosed and claimed.

In order to describe the invention, and for illustration of some of the various forms it may take, reference is had to the accompanying drawings, in which:

Fig. 1 is a schematic circuit diagram of a composite telephone and telegraph system embodying the invention;

Fig. 2 illustrates the relative direction of flow and relative values of the high frequency currents flowing in adjacent ones of the five line wires of the system of Fig. 1;

Fig. 3 shows the invention applied to seven

conductors, such as may be carried by one cross-arm of a pole line;

Fig. 4 shows the invention applied to two adjacent rows of five conductors each, such as may be carried by two adjacent cross-arms of a pole line;

Fig. 5 is a further application of the invention to an even number of conductors;

Fig. 6 illustrates one form of a two dimensional symmetrical arrangement;

Fig. 7 shows another form of a two dimensional symmetrical arrangement;

Fig. 8 illustrates a system of interconnected transformers arranged to maintain the desired current relations between adjacent conductors; and

Fig. 9 shows a choke coil and transformer arrangement for maintaining the desired current relations between the conductors of the system.

Referring now to Fig. 1 of the drawings, there is shown a composite telephone and telegraph system having two stations A and B interconnected by a line comprising five open wire conductors *a*, *b*, *c*, *d*, and *e* disposed substantially in the same plane, such as the five adjacent wires on a cross-arm of a telegraph route. At station A means are provided for transmitting and receiving voice frequencies, for example, telephone messages, over a circuit 10 connected to a pair of the conductors *a* to *e*, such as conductors *c* and *e*, the circuit continuing to station B where conductors 10' complete the circuit to a second voice frequency receiving and transmitting station. Choke coils 12 and 12' are inserted in the lines 10 and 10' at the respective stations to prevent the admission to the voice frequency transmitter and receiver of the high frequency currents hereinafter referred to. Direct current telegraph circuits 13 and 14 at the respective stations may also be connected, through suitable composite apparatus *C_x* diagrammatically indicated at 15, 15', to the circuits 10 and 10'. Various methods and types of apparatus for thus compositing a circuit are well known in the art and for this reason are not here described in detail. Other telephone and telegraph circuits may be connected, through choke coils, to the other three conductors *a*, *b* and *d* to form other paired or single conductor circuits, as is indicated by the terminating conductors connected thereto.

Stations A and B also comprise high frequency transmitting and receiving apparatus 17 and 18 for superimposing any desired number of high frequency channels on the existing line wires *a* to *e*, the frequencies of which channels may be

and frequently are of the order of 50,000 cycles or more. The high frequency connections may be extended to any of a number of well known types of terminal or repeater apparatus where the high frequency currents may be repeated directly into other line sections or may be converted into signals of another character by means of the proper modulating and demodulating apparatus for connection to terminal apparatus or for extension over ordinary lines to more distant points. The high frequency system may be used entirely for transmission in one direction or portions of the frequency range may be allotted for transmission in opposite directions.

The high frequency currents are impressed on, and are received from, the conductors *a* to *e* preferably by means of coupling devices such as the transformers *T* and *T'* each comprising primary and secondary windings 19 and 20. The winding 19 of each transformer is connected to the high frequency apparatus, and the other winding 20 has one end 21 thereof connected through two of the blocking condensers 22 to the conductors *d* and *e*, and the other end 23 of the winding 20 is connected through another of the blocking condensers 22 to the centrally disposed line conductor *a*. A tap taken from the winding 20 at the point 24 is connected through two other blocking condensers 22 to the two outside conductors *b* and *c*. The arrows adjacent to the conductors *a* to *e* indicate the relative direction of flow of the high frequency signaling current in the respective conductors.

In general, the greater portion of the transmitted high frequency energy is carried over a small number of conductors, for example, from one to four, and smaller portions of the high frequency energy are carried over the remaining conductors, the direction of flow of the high frequency current at any instant being in opposite directions in adjacent conductors, the instantaneous values of the high frequency current flowing in the respective conductors at any instant being progressively less in magnitude from a centrally disposed conductor or conductors of the group towards the outer conductors of the group. When the high frequency current values are properly adjusted as between the various conductors, the foregoing arrangement minimizes the radiation losses and inductive effects of the system on other circuits, and also causes the system to have low susceptibility to interference from external electric and magnetic fields. The relative high frequency current values in the various conductors of the system may be determined empirically or may be computed from known engineering formulae for expressing the electromagnetic and electrostatic relation between the conductors of a circuit, the current values also being adjusted, if necessary, to compensate for the individual electrical characteristics of the circuit.

In the specific arrangement disclosed in Fig. 2, the transformer connections are such that the high frequency current values are as follows: The current flowing in conductor *b* is approximately equal to the current in conductor *c* but is only 0.2 of the current in conductor *a*, and the current in conductor *d* is equal to the current in conductor *e* and is approximately 0.7 of the current in conductor *a*, although it will be understood that these values are for the purpose of illustration only, and that they may vary within considerable limits depending upon the particular characteristics of the system, the purpose for which it is intended, and the desired degree of

freedom from interference. The relative current values in the respective conductors *a* to *e* may be modified or changed by varying the point or points at which the transformer winding 20 is tapped, or by the addition of impedance networks in circuit with the individual conductors, or in any other suitable manner. The transformer may be provided with a number of taps extending from the winding 20 and coacting with an adjustable arm or connector, whereby the relative current values in the conductors may readily be changed in service to meet temporary disturbing conditions. Also, separate transformer windings may be employed to maintain the desired relative current values in the conductors *a* to *e*. That the flow of current at any instant is in opposite directions in adjacent conductors is indicated by the two different markings in the small circles which represent the conductors, the instantaneous flow of current being in one direction in the conductors marked with a cross and in the opposite direction in the conductors marked with a dot.

Where the open wire conductors must be carried through entrance cable or other sections of cable, a similar choice of conductors in the cable may be employed; that is, a number of conductors may serve for transmission in one direction while an intermingling group of conductors may comprise the return circuit. If desired, special cables of types suitable for the transmission of such frequencies may be installed. This system of conductors in which heavier currents are carried by a symmetrically surrounded series of conductors, the surrounding conductors carrying lower currents, can be installed in numbers on a single pole line with materially reduced interference over that ordinarily encountered in two conductor systems. At the same time the considerable expense of providing special transpositions and modifications that would otherwise be required is avoided.

Fig. 3 shows a system in which seven conductors in a plane are employed, the connections to the conductors being made by means of a suitably connected tapped transformer winding 20*a* generally in the manner hereinbefore set forth in regard to the five conductor system. In this figure the high frequency current in conductor *d* equals the current in conductor *e*; the current in conductor *b* equals the current in conductor *c*; and the current in conductor *f* equals the current in conductor *g*. The current in conductor *a* is greater in magnitude than the current in conductor *d*; the current in *d* is greater than the current in *b*; and the current in *b* is greater than the current in *f*. The current values in the conductors therefore progressively diminish from the centrally disposed conductor *a* towards the outer conductors *f* and *g*. The flow of current at any instant is in opposite directions in adjacent conductors, as will be noted from the different markings in the small circles which represent the conductors.

In Fig. 4 the method of minimizing interference is extended to two similar groups of conductors located in parallel horizontal rows or planes, one above the other, such as the wires carried by two adjacent cross-arms of an open-wire route. In this arrangement the current flowing in the adjacent conductors in both vertical and horizontal rows is equal and opposite in direction. In each horizontal row, due to the manner of connecting the taps from the transformer winding 20*b*, the current in conductor

d is equal to the current in conductor e ; and the current in conductor b is equal to the current in conductor c . The current in a is greater than the current in d , and the current in d is greater than the current in b .

In the conductor system illustrated in Fig. 5, the system is built up on conductors in pairs, the high frequency current flowing in the system being progressively less in magnitude from the centrally disposed or innermost pair of the group to the outermost pair. The currents are equal and opposite in direction in conductors a and a' , b and b' , c and c' , and d and d' , respectively. The manner in which the transformer connections may be made to give this arrangement will be apparent from a consideration of Figs. 3 and 4.

Figs. 6 and 7 are further illustrations of different forms of two dimensional symmetrical arrangements of conductors. In these systems, due to the connections from the transformer windings 20c and 20d, the instantaneous current flow is in one direction in the central conductor g and in one or more external groups of conductors g^1 , g^2 , and is in the opposite direction in an intermediate group or groups h , h^1 . Groups of conductors, such as shown in these figures, particularly if individual groups be segregated from each other, as on the two sides of a pole, provide systems which are free from interference troubles with all external fields to a relatively high degree. To simplify the drawings, the blocking condensers, such as condensers 22 of Figs. 1 to 4, are not shown in Figs. 6 and 7, although it will be understood that such condensers ordinarily will be used.

Systems in accordance with the invention will, of course, operate most satisfactorily if all the conductors are identical and symmetrically disposed with respect to each other. Various irregularities, however, may be compensated by adjustments of the relative terminal voltages. While a number of conductors are employed for a single system which may accommodate a large number of channels, thus making the system susceptible to a considerable failure hazard, it is possible by means of simple switching arrangements to reduce the number of conductors in the system by a proper number of wires in the case of failure of any wire so that the system can continue in operation at somewhat reduced efficiency.

When high frequency currents are transmitted along conductors in accordance with the systems hereinbefore disclosed, they may undergo non-uniform attenuation due to nonuniformities in the nature of the conductors, spacing, etc. In case it is desirable at locations other than the terminal or repeater points to secure a more nearly perfect neutralization of the external fields, the current proportions in the various conductors of the system may be readjusted by various methods such, for example, as shown in Figs. 8 and 9. In Fig. 8 the method is applied to the five wire conductor system of Fig. 1, and comprises a system of interconnecting transformers T^2 to T^5 having turn ratios so proportioned as to tend to maintain the required current relations between the different conductors.

In Fig. 9 the high frequency circuit is effectively terminated or divided into line sections, by the insertion of high frequency choke coils 26 in the several conductors a to e , and the currents are then retransmitted by the transformer T^6 into the following line section in the correct rela-

tions as determined by the transformer and the adjustable impedances 27 interposed between pairs of blocking condensers 28.

For brevity in the specification and claims, the expressions "centrally disposed" and "central portion" where employed to define the location of a conductor or conductors, refer to a conductor or conductors which either relate to, or are situated in or near, or contain or constitute the central portion of a group of conductors; and where reference is made to the flow of high frequency current in or over a conductor or conductors, this includes the flow of such current either through such conductors, or on or along the surfaces thereof.

It will be appreciated that the foregoing illustrative embodiments of the invention will suggest various other specifically different embodiments and arrangements to those skilled in the art without departing from the spirit of the invention, and the invention intended to be covered hereby is therefore not limited except as indicated by the scope of the appended claims.

I claim:

1. In a transmission system in which a group of adjacent conductors are substantially parallel to each other, with at least one of said conductors being disposed intermediate other conductors of the group, the method which comprises transmitting a high frequency current over each of a plurality of said conductors, causing the flow of said high frequency current at any instant to be in opposite directions in adjacent conductors of the group, and causing the instantaneous values of said high frequency current flowing in said conductors at any instant to differ in amplitude from an intermediate conductor of said group towards said other conductors of the group.

2. In a transmission system in which a group of adjacent conductors parallel each other, said group comprising at least one centrally disposed conductor, the method which comprises transmitting a high frequency current over each of a plurality of said conductors, causing the flow of said high frequency current at any instant to be in opposite directions in adjacent conductors of the group, and causing the instantaneous values of said high frequency current flowing in said conductors at any instant to differ in amplitude from a centrally disposed conductor of said group towards the outer conductors of the group.

3. In a transmission system in which a group of adjacent conductors parallel each other, said group comprising centrally disposed conductors, the method which comprises transmitting a high frequency signalling current over each of a plurality of said conductors, causing the flow of said signalling current at any instant to be in the same direction in alternate ones of the conductors and in the opposite direction in the remainder of the conductors, and causing the instantaneous values of said signalling current flowing in said conductors at any instant to be progressively less in amplitude from the centrally disposed conductors of said group towards the outer conductors of the group.

4. In a transmission system in which a high frequency channel transmits a signalling current over each of a plurality of adjacent conductors substantially paralleling each other and forming a group, said group comprising at least one centrally disposed conductor, the method which comprises maintaining the instantaneous direction of flow of said signalling current the same in alternate conductors and opposite to the di-

rection of flow of said current in the remainder of the conductors, and maintaining the relative current values of said signalling current in said group of conductors so as to be progressively less in magnitude in accordance with the radial distance of said conductors from a centrally disposed conductor of said group.

5. In a transmission system in which a plurality of pairs of adjacent conductors parallel each other to form a group, said group comprising at least one centrally disposed pair of conductors, the method which comprises transmitting a high frequency signalling current over each of a plurality of said conductors, causing the instantaneous signalling current in the two conductors of each of said pairs to be equal in magnitude and opposite in direction and to be progressively less in magnitude in said pairs of conductors from a centrally disposed pair of said group towards an outer pair thereof.

6. A high frequency transmission system comprising a group of adjacent conductors substantially parallel to each other, at least one of said conductors being disposed intermediate other conductors of the group, means for transmitting a high frequency current over each of a plurality of said conductors, means for causing the flow of said high frequency current at any instant to be in opposite directions in adjacent conductors of the group, and means for causing the instantaneous values of said high frequency current flowing in said conductors at any instant to differ in amplitude from an intermediate conductor of said group towards said other conductors of the group.

7. A high frequency transmission system comprising a group of adjacent conductors substantially parallel to each other, said group comprising centrally disposed conductors, means for transmitting a high frequency signalling current over each of a plurality of said conductors, means for causing the flow of said signalling current at any instant to be in the same direction in alternate ones of the conductors and in the opposite direction in the remainder of the conductors, and means for causing the instantaneous values of said signalling current flowing in said conductors at any instant to be progressively less in amplitude from the centrally disposed conductors of said group towards the outer conductors of the group.

8. A high frequency transmission system comprising a group of adjacent conductors substantially parallel to each other, said group comprising at least one centrally disposed conductor, means for transmitting a high frequency signalling current over each of a plurality of said conductors, means for maintaining the instantaneous direction of flow of said signalling current the same in alternate conductors of the group and opposite to the direction of flow of said current in the remainder of the conductors of the group, and means for maintaining the relative current values of said signalling current in said group of conductors so as to be progressively less in magnitude in accordance with the radial distance of said conductors from a centrally disposed conductor of said group.

9. A high frequency transmission system comprising a group of adjacent conductors substantially parallel to each other, said group comprising at least one centrally disposed conductor, means for transmitting a high frequency current over each of a plurality of said conductors, means for maintaining the instantaneous direc-

tion of flow of said current in opposite directions in each two adjacent ones of said conductors, and means for maintaining the relative values of said current in said group of conductors so as to be progressively less in magnitude in each two adjacent ones of the conductors from a centrally disposed one of the conductors of the group towards the outer ones of the conductors.

10. A high frequency transmission system comprising a group of pairs of adjacent conductors substantially parallel to each other, said group comprising at least one centrally disposed pair of conductors, means for transmitting a high frequency signalling current over each of a plurality of said conductors, means for causing the instantaneous signalling current in the two conductors of each of said pairs to be equal in magnitude and opposite in direction, and means for causing said current to be progressively less in magnitude in said pairs of conductors from a centrally disposed pair of the group towards an outer pair of the group.

11. A high frequency transmission system comprising a group of adjacent conductors substantially parallel to each other, certain of said conductors comprising a central portion of the group, means for transmitting a high frequency signalling current over each of a plurality of said conductors in such manner that the instantaneous direction of flow of said signalling current is opposite in adjacent conductors of the group, and means for maintaining the instantaneous value of said signalling current in any of said conductors less than that of the value of said current in any of the other of said conductors nearer the central portion of the group.

12. A high frequency transmission system comprising a plurality of groups of adjacent conductors substantially parallel to each other, each of said groups comprising at least one centrally disposed conductor, said groups being disposed in adjacent planes respectively, means for transmitting a high frequency current over said conductors, means for causing the flow of said high frequency current at any instant to be in opposite directions in adjacent conductors of each of the groups and in opposite directions in adjacent conductors in different planes, and means for causing the instantaneous values of the high frequency current flowing in the conductors of each of said groups at any instant to differ in amplitude from a centrally disposed conductor of the group towards the outer conductors of the group.

13. A high frequency transmission system comprising at least one centrally disposed conductor and surrounding groups of conductors substantially parallel to each other, means for transmitting a high frequency current over said conductors, means for causing the flow of said high frequency current at any instant to be in opposite directions in conductors of adjacent groups, and means for causing the instantaneous values of said high frequency current flowing in said conductors at any instant to be progressively less in amplitude from a centrally disposed conductor towards the outer conductors of the respective groups.

14. A high frequency transmission system comprising a group of adjacent conductors substantially parallel to each other, said group comprising at least one centrally disposed conductor, a source of high frequency current, a high frequency coupling device connected to said source

of high frequency current, said coupling device having different portions thereof connected in circuit with different ones of said conductors, respectively, said portions being connected in such manner that the flow of said high frequency current at any instant is in opposite directions in adjacent conductors of the group, said portions of the coupling device causing the instantaneous values of said high frequency current flowing in said conductors any instant to be progressively less in amplitude from a centrally disposed conductor of the group towards the outer conductors of the group.

15. A high frequency transmission system comprising a group of adjacent conductors substantially parallel to each other, said group comprising at least one centrally disposed conductor, a source of high frequency current, a transformer having a primary winding connected to said source of high frequency current and a secondary winding having different portions thereof connected in circuit with different ones of said conductors, respectively, the instantaneous polarities of said portions of the secondary winding being such that the flow of said high frequency current at any instant is in opposite directions in adjacent conductors of the group, said portions of the secondary winding differing in ampere turns in such ratios as to cause the instantaneous values of said high frequency current flowing in said conductors at any instant to be progressively less in amplitude from a centrally disposed conductor of the group towards the outer conductors of the group.

16. A high frequency transmission system comprising a group of adjacent conductors substantially parallel to each other, a source of high frequency current, at least one of said conductors being disposed intermediate other conductors of the group, a transformer having a primary winding connected to said source of high frequency current and a secondary winding having the opposite ends thereof connected to different ones of said conductors and an intermediate portion of the secondary winding connected to the remainder of said conductors in such manner that the flow of said high frequency current at any instant is in opposite directions in adjacent conductors of the group and the instantaneous values of said high frequency current flowing in said conductors at any instant are progressively less in amplitude from an intermediate one of said conductors of the group towards other conductors of the group.

17. A high frequency transmission system comprising a group of adjacent conductors substantially parallel to each other, said group comprising at least one centrally disposed conductor, a source of high frequency current, a transformer having a primary winding connected to said source of high frequency current and a secondary winding having the opposite ends thereof connected to different ones of said conductors and an intermediate portion of the secondary winding connected to the remainder of said conductors in such manner that the flow of said high frequency current at any instant is in opposite directions in adjacent conductors of the group and the instantaneous values of said high frequency current flowing in said conductors at any

instant are progressively less in amplitude from a centrally disposed one of said conductors of the group towards the outer conductors of the group.

18. A high frequency transmission system comprising a group of adjacent conductors substantially parallel to each other, at least one of said conductors being disposed intermediate other conductors of the group, a source of high frequency current, a transformer having a primary winding connected to said source of high frequency current and a secondary winding having one end thereof connected to a centrally disposed conductor of the group and the other end thereof connected to other conductors of the group, the remainder of said conductors being connected at intermediate points of said secondary winding in such manner that the flow of said high frequency current at any instant is in opposite directions in adjacent conductors of the group and the instantaneous values of said high frequency current flowing in said conductors at any instant are progressively less in amplitude from an intermediate one of said conductors of the group towards other conductors of the group.

19. A composite transmission system comprising a group of adjacent conductors substantially parallel to each other, said group comprising at least one centrally disposed conductor, means connected to said conductors for transmitting a high frequency current over each of a plurality of said conductors, other means for simultaneously transmitting a low frequency current over certain of said conductors, receiving means connected to said conductors responsive to said high frequency current, other means connected to said certain of the conductors for receiving said low frequency current, means associated with said high frequency transmitting means for causing the flow of said high frequency current at any instant to be in opposite directions in adjacent conductors of the group, and means for causing the instantaneous values of said high frequency current flowing in said conductors at any instant to be progressively less in amplitude from a centrally disposed conductor of said group towards the outer conductors of the group.

20. A high frequency transmission system comprising a group of adjacent conductors substantially parallel to each other, said group comprising at least one centrally disposed conductor, transmitting means connected to said conductors for transmitting a high frequency current over each of a plurality of said conductors, receiving means connected to said conductors responsive to said high frequency current, means associated with said transmitting means for causing the flow of said high frequency current at any instant to be in opposite directions in adjacent conductors of the group, means for causing the instantaneous values of said high frequency current flowing in said conductors at any instant to be progressively less in amplitude from a centrally disposed conductor of said group towards the outer conductors of the group, and means disposed intermediate said transmitting and receiving means for readjusting the said relatively instantaneous values of the high frequency current flowing in the respective conductors.