April 28, 1931. W. VAN B. ROBERTS 1,802,738

ELECTRICAL NETWORK

Filed Oct. 8, 1928

Fig. 1

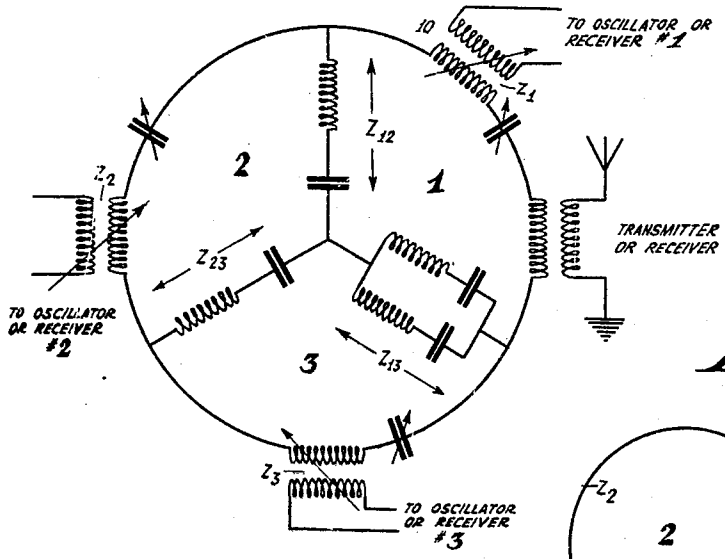


Fig. 2

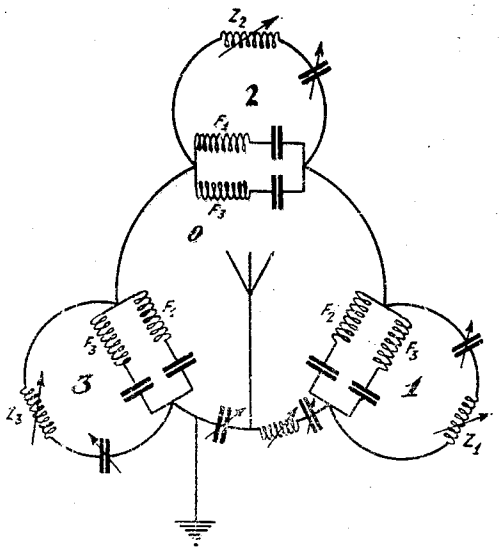


Fig. 3

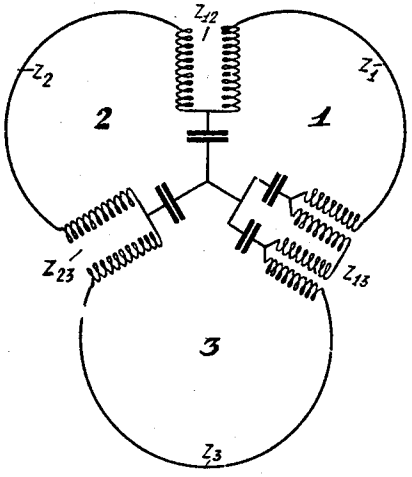
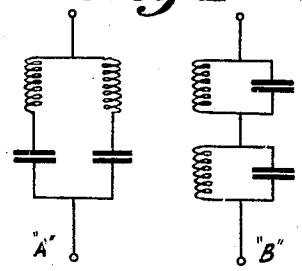


Fig. 4



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UNITED STATES PATENT OFFICE

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ELECTRICAL NETWORK

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The present invention relates to electrical networks and particularly to electrical networks composed of a plurality of individual meshes in which a plurality of different natural frequencies exists.

It is well known that an electrical network having a number of periods of vibration can not be adjusted conveniently to make these various periods assume desired values because any change in the values of the constants in the network will, in general, effect all the various periods of vibration. Thus in the prior art, even in a simple case, for example, where three oscillatory circuits are coupled to each other it would be in practice extremely tedious to adjust the various constants so that the three periods of vibration would take on or assume three desired values.

It is, therefore, an object of my present invention to provide, in a manner to be hereinafter set forth in detail when reading the following specification and claims in connection with the drawings, a system and method for constructing electrical networks possessing several periods of vibration in such a manner that one element or individual mesh forming a part of the network can be adjusted to one of the vibration periods and after being adjusted to this particular period or desired value may remain unaltered by subsequent changes in the rest of the network, and also that the constants of a second element or mesh may be adjusted to adjust a second period of vibration without effecting the first chosen period of vibration in the first mesh and in like manner subsequent changes in the remaining meshes will have no effect upon frequencies previously adjusted to their desired values. Therefore, there will be no necessity of making any readjustments on meshes which have previously been set to make natural frequencies of the system coincide with predetermined chosen frequencies.

Still another object of my invention is to provide, in a manner to be hereinafter set forth, a system wherein an electrical network is formed by a plurality of individual meshes and so arranged that various individual meshes may resonate at various different desired frequencies so that several different frequencies may be impressed upon the complete network for the purpose of transmission or reception of energy and, at the same time, provide a system wherein, various individual meshes are responsive respectively only to various chosen frequencies.

Other objects and advantages will at once be apparent from a consideration of the following specification when read in connection with the accompanying drawings by which the invention has been illustrated in several of the preferred forms, wherein:

Fig. 1 represents the network composed of three individual meshes with an intermesh coupling between each mesh and every other mesh in the net work;

Fig. 2 represents a modification of Fig. 1 wherein four individual meshes comprise a network and in which one mesh is mutually coupled to each and every other mesh of the network;

Fig. 3 represents a modification of Fig. 1 wherein the mutual impedance between the individual meshes is of a modified form from that shown by Fig. 1; and

Fig. 4 represents two types of couplings which might be used for mutual impedances between meshes wherein "A" represents a form for parallel connection of series connected inductance and capacity elements and "B" represents a modification which is electrically equivalent to "A".

The conditions which must be complied with in building up a network to meet the above named requirements will now be described in detail by making reference to the drawings and particularly to Fig. 1 thereof. Let it be assumed that the network includes and is composed of a plurality of meshes 1, 2 and 3, for example, although any number, e. g. "n", may be used. The mutual impedance between meshes 1 and 2, for example, will be designated as Z_{12} that between meshes 2 and 3 as Z_{23} and between meshes 1 and 3 as Z_{13} etc. Suppose that mesh 1 is to be adjusted first and the adjustment is to make one of the frequencies of vibration

equal to a frequency F_1. In accordance with this supposition, then the condition necessary, in order to insure that at the frequency F_1 the mesh 1 is unaffected by adjustments in any of the other meshes, is that

$$Z_{12}=Z_{13}=Z_{14}=\text{----}=Z_{1n}=0$$

at the frequency F_1 chosen. When this is established mesh 1 is adjusted by altering its constants until the natural frequency in the mesh takes on the value F_1, which is the frequency desired. This adjustment may be made by variation of the coupling inductance 10 between the mesh 1 and either a receiver or oscillator "A" connected to the mesh, (dependent, of course, whether the system is used for transmitting or receiving, whether the connection is from an oscillator to the mesh or from the mesh to a receiver), or by variation of the capacity shown in series with the coupling inductance.

After this adjustment has been made it is necessary to make the impedance between mesh 1 and 3, between mesh 1 and 4, up to and including the mutual impedance between mesh 1 and mesh n equal zero at a second frequency F_2 and to make the mutual impedance between mesh 2 and mesh 3 and mesh 2 and mesh 4, etc. up to and including the impedance between mesh 2 and mesh n also equal to zero at F_2. To restate this problem mathematically,

$Z_{13}=Z_{14}=Z_{15}=\text{----}=Z_{1n}=0$ at frequency F_2 and

$Z_{23}=Z_{24}=Z_{25}=\text{----}=Z_{2n}=0$ at frequency F_2

which insures that the mesh 2 at a frequency F_2 will be unffected by any adjustments of meshes 3, 4, 5 ---- n. Mesh 2 will be unaffected by changes in mesh 1 for the simple reason that mesh 1 had already been adjusted and will have no further changes made in it. These conditions being complied with, the constants of mesh 2 are adjusted in a similar manner to that described in connection with mesh 1 except that the frequency F_2 is produced which, of course, depends partly upon the now fixed values of the constants of mesh 1.

In general, to state the conditions necessary to accomplish the results which have been provided, I may tabulate them as follows:

At F_1, $0=Z$ (1)	(2, 3, 4,----n)
At F_2, $0=Z$ (1, 2)	(3, 4, 5,----n)
At F_3, $0=Z$ (1, 2, 3)	(4, 5, 6,----n)

and so forth, where the terminology becomes self-explanatory by reference to the conditions given previously for the first two frequencies.

The foregoing may also be explained as follows: Oscillations at the frequency F_1 exist only in mesh 1 and mesh 1 has no coupling with any other mesh at the particular frequency F_1, since the impedances Z_{12} and Z_{13} have been made equal to zero at the frequency F_1 and form a complete by-pass for this frequency. Oscillations at F_2 exist only at meshes 1 and 2, and meshes 1 and 2 have no coupling with any other meshes at frequency F_2, since impedances Z_{23} and so forth have been made equal to zero at F_2. At frequency F_3 oscillations exist only in meshes 1, 2 and 3 since these meshes likewise have no other coupling with other meshes at frequency F_3, and so forth, as has been described in the above named table for any chosen number of meshes. Having fulfilled these general conditions the various frequencies may be adjusted to coincide with the desired frequencies by choosing the constants of the various meshes 1, 2, 3,----n in order.

Now referring to the drawings in more particular I will endeavor to further describe the method which I have followed from the illustration. Considering first Fig. 1, suppose it is desired to tune mesh 1 to frequency F_1, the combination consisting of meshes 1 and 2 to frequency F_2, and the combination consisting of meshes 1, 2 and 3 to frequency F_3, then, by making impedances Z_{12} and Z_{13} series combinations of inductances and capacity so chosen that their impedance completely vanishes at a frequency F_1 the first general condition is specified. Similarly the second condition expressed by the formula is specified by the construction indicated. Impedance Z_1 which includes the coupling between the mesh 1 and the receiver or oscillator "A" may be adjusted to make the mesh 1 resonant to a frequency F_1 without the value of Z_1 required for this purpose being dependent upon the constants of the other meshes. After this, impedance Z_2 may be varied in a similar manner to the variation of Z_1 until resonance occurs in mesh 2 at the frequency F_2. The adjustment of Z_2 for this purpose is independent of the constants of mesh 3 but does depend upon the constants of mesh 1. However, the fact that Z_2 is dependent upon the constants of mesh 1 forms no objection, as to the constants of mesh 1, assuming that the adjustments to the various frequencies which may be maintained in the network have already been made, will not be changed. Finally, the impedance of mesh 3 is adjusted until mesh 3 is brought to resonance at the frequency F_3. The value of Z_3 required to achieve this result depends upon all the circuit constants of the entire network referring, of course, to Fig. 1 where the network is composed of three meshes where all the constants of the entire network except impedance Z_3 have previously been adjusted and will not subsequently be altered, thus making no difference in the system.

The network including the separate meshes 1, 2 and 3 may now be assumed to be adjusted to give resonant effects at any one of the frequencies F_1, F_2, or F_3, if voltages are inserted in Z_1, for, if the voltage is inserted in mesh 1 and is of a frequency F_1, resonance current will circulate in mesh 1; if the voltage is of a frequency F_2 resonance current is excited in mesh 2; and, if the voltage is of a frequency F_3 resonance occurs in mesh 3.

At this point it is important to emphasize the advantage obtained by complying only with the necessary general conditions, for example, if $Z_{13}=0$ at all frequencies the same results may be obtained, but the current in mesh 3 at frequency F_3 caused by voltage at Z_1 will be very much weaker in this case because mesh 2 must act as an untuned link circuit to transfer energy at frequency F_3 from the first to the third mesh. As the number of meshes in the network increases it is increasingly disadvantageous to transfer the energy from the first mesh to the last mesh through intermediate meshes and hence it is increasingly important that the various mutual impedances do not vanish except at the frequencies required by the general conditions.

Now referring to Fig. 2 of the case it is shown where there is one more mesh than is required for transmitting or receiving the required three frequencies assumed by the description of Fig. 1. Hence, in this case the antenna mesh 0 can be tuned to any desired frequency or left alone. The other three meshes 1, 2 and 3 in this network may then be tuned to their respective frequencies in any desired order because in this case $Z_{12}=Z_{23}=Z_{13}=0$ at all frequencies. However, if the antenna mesh 0 is coupled directly to each of the other meshes so that energy may be transferred directly between the antenna and any mesh without passing through any intervening meshes, the three receivers or sources of oscillatory energy according to whether the arrangement is to be used for reception or transmission may be coupled to Z_1, Z_2, and Z_3, as has been illustrated by Fig. 1.

The above described Figs. 1 and 2, of course, must be regarded as illustrative only of my invention and it will be recognized that there are many well known equivalent couplings which might be used for practicing the method shown for specifying the general conditions. By Fig. 3 I have illustrated one of these possible modifications in the coupling between meshes. The disclosure of Fig. 3 is substantially the same as that of Fig. 1 but is based upon a type of intermesh coupling which has been shown and illustrated by Patent No. 1,481,945, issued to Julius Weinberger on January 29, 1924 relating to a system of coupling which allows a mutual impedance to vanish at a certain frequency, namely, the frequency at which the mutual inductive reactance between the two coils in the two meshes balances the reaction of a single condenser common to the two meshes even in a case where the inductance used is of a high resistance value. It should be regarded that the disclosure of Fig. 3 is equivalent to that of Fig. 1 the only difference being in the use of the Weinberger method for obtaining mutual impedance between the various meshes.

Other equivalents are also easily devised by means of the application of well known transformation formulæ such as that which states that a parallel arrangement of series circuits may be replaced by series arrangements of parallel circuits. These two systems have become well recognized in the art to which this invention relates as being the equivalent of one another and I have illustrated by Fig. 4— "A" a parallel arrangement of series circuits and by Fig. 4— "B" a series arrangement of parallel circuits. It is to be recognized that either of the systems shown by Fig. 4— "A" or 4— "B" may be used to form the impedence Z_{13} between the meshes 1 and 3 of Fig. 1, for example.

I have, therefore, provided by this invention a system whereby it is possible in the case of the most general type of network composed of a plurality of individual meshes to adjust in sequence the constants of the individual meshes so as to produce a resonance at various desired frequencies without subsequent adjustments altering the resonance frequencies established by previous adjustments which method, as I have illustrated and described, consists in adjusting mesh 1, then mesh 2, and so forth until the network resonates at each of the desired frequencies.

Having now described my invention what I claim and desire to secure by Letters Patent is:

1. An electrical network system having n meshes and more than $(n-1)$ intermesh couplings, means for adjusting in a predetermined order the n natural frequencies of vibration of the complete network to coincide with n desired frequencies, and means for preventing any adjustment of the individual meshes made in accordance with a predetermined chosen order from effecting the natural frequencies of the system previously established, where n is greater than two.

2. The method of bringing into coincidence with n desired frequencies the n natural frequencies of a network comprising n individual meshes and provided with more than $(n-1)$ intermesh couplings, which consists in, adjusting the impedance between the first of the n meshes and all other meshes to equal zero at a first predetermined fre-

quency, adjusting the total impedance in the first mesh to a value such that the natural frequency of the said mesh is brought into coincidence with the first predetermined frequency, adjusting the impedence between each of the first two meshes and all following meshes to equal zero at the second predetermined frequency, adjusting the impedance in the second mesh to such a value that a second natural frequency of the network is brought into coincidence with the second predetermined frequency, and continuing the adjustments in like manner to the *n*th mesh and adjusting the impedance of the *n*th mesh to a value such that the remaining natural frequency of the system is brought into coincidence with the *n*th desired frequency.

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