

July 23, 1935.

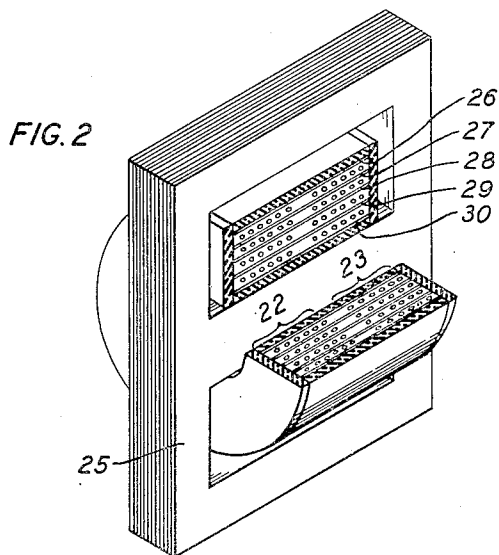
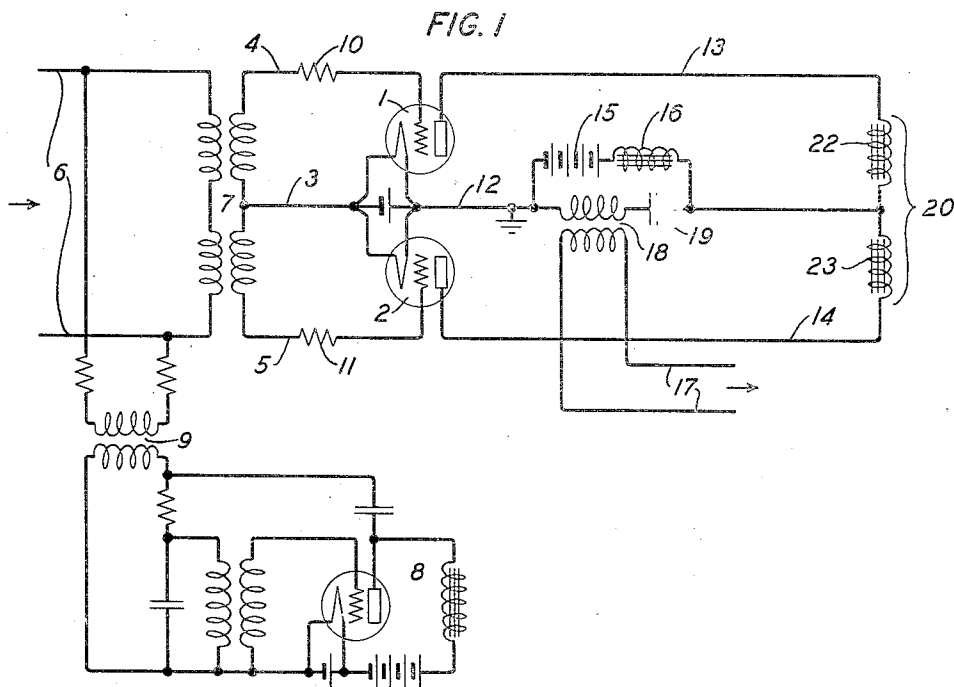
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2,008,859

INDUCTANCE DEVICE

Filed Dec. 7, 1933

3 Sheets-Sheet 1



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FIG. 3

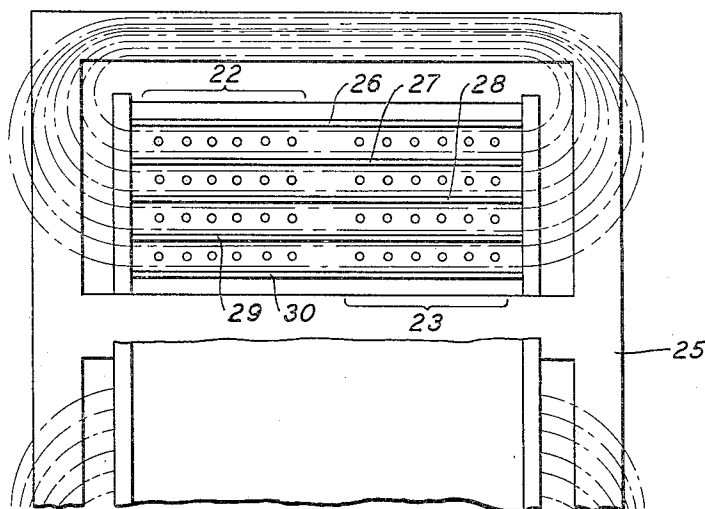
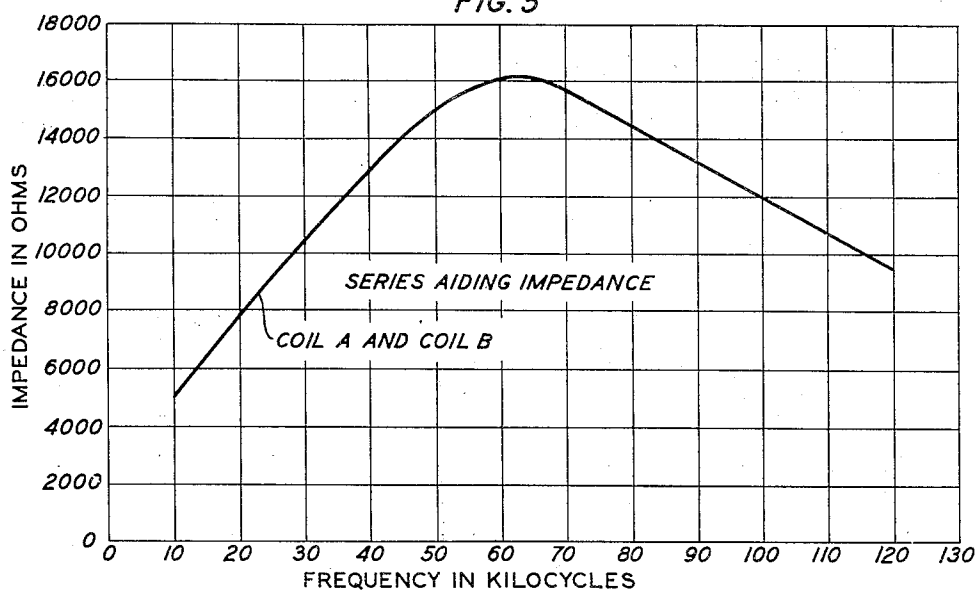


FIG. 5



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FIG. 4

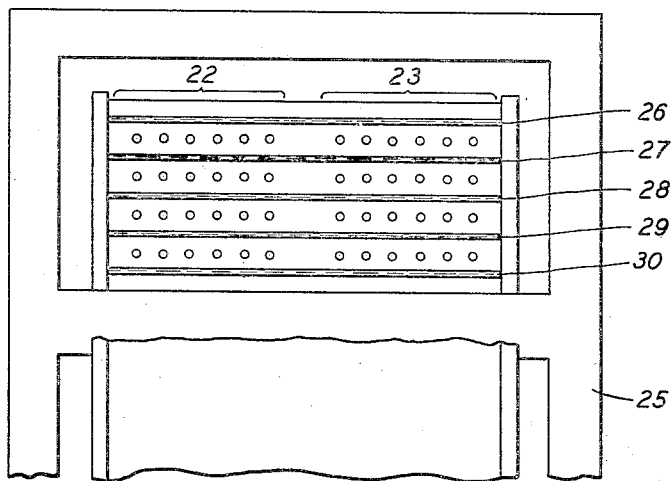
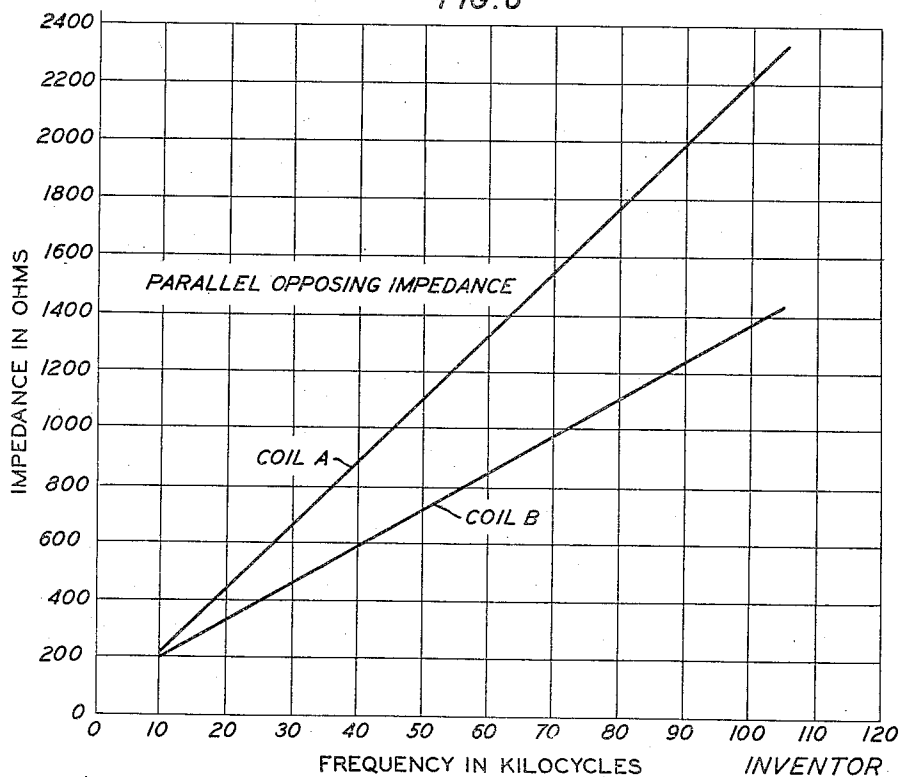


FIG. 6



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UNITED STATES PATENT OFFICE

2,008,859

INDUCTANCE DEVICE

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Application December 7, 1933, Serial No. 701,330

19 Claims. (Cl. 179—171)

This invention relates to inductance devices.

It is desirable with respect to certain types of inductance devices that a high impedance be obtained with one distribution of current in the windings and a low impedance be obtained with another distribution. It is particularly desirable, for example, in the instance of the inductance device associated with the output circuit of push-pull vacuum tube modulators, that the ratio of the series aiding impedance of the windings to the parallel opposing impedance be large.

An object of the invention is to increase the ratio of the series aiding impedance to the parallel opposing impedance of the windings of inductance devices.

Another object of the invention is to improve the transmission efficiency of inductance devices used to inductively connect two electrical circuits.

According to a feature of the invention, thin sheets of conductive material such as copper foil are disposed between each two adjacent layers of winding of an inductance device being so arranged, in a manner to be later described in detail, that they tend to further decrease the impedance corresponding to the low impedance distribution of current in the windings and yet have little or no effect on the impedance corresponding to the high impedance distribution in the windings.

A full understanding of the invention may be gained from a consideration of the following detailed description when read in connection with the appended drawings in which:

Fig. 1 shows a modulator circuit of a type with which the invention may advantageously be used;

Fig. 2 shows in partial section the application of the invention to an inductance device;

Figs. 3 and 4 are enlarged schematic views of the inductance device shown in Fig. 2; and

Figs. 5 and 6 are graphs showing the results of tests performed upon two inductance devices, one of which was provided with the arrangement contemplated by this invention.

Referring now to Fig. 1, the circuit of a push-pull modulator is schematically illustrated which may be of the type described in Patent No. 1,675,876, issued July 3, 1928 to H. S. Black. Included are a pair of three-electrode electron discharge tubes 1 and 2. An input circuit comprising two parallel branches, one branch including common path 3 and individual path 4 and the other branch including common path 3 and in-

dividual path 5 is connected between the filaments and grids of the two tubes.

An incoming line 6 is associated with the modulator input circuit through a transformer 7. The other terminal of the line 6 may be associated with a source of signaling variations, not shown. A source of sustained high frequency waves 8 is also connected to the input circuit of the modulator across the incoming line 6 by means of a coupling coil 9.

The circuit illustrated is of the type in which modulation is produced in the input circuit of the modulator by the action of an impedance included therein. Such an impedance may be represented by high resistance elements 10 and 11 included in the input paths 4 and 5, respectively. This method of producing grid current modulation is disclosed in U. S. Patent 1,699,711, issued January 22, 1929 to E. Peterson, and need not be here described in detail.

The modulator output circuit which comprises two parallel branches, one branch including common path 12 and individual path 13 and the other branch including common path 12 and individual path 14 is connected between the filaments and plates of the tubes 1 and 2. A battery 15 and choke coil 16 are connected in the common path 12 to supply a constant space current to the two tubes. An outgoing line 17 is associated with the modulator by means of a transformer 18, the primary of which is included in the common output path 12. The condenser 19 may be included in series with the primary winding of transformer 18 to prevent the flow of direct current through it.

It will be seen from the above that carrier waves from the source 8 are differentially impressed upon the respective control elements of the tubes 1 and 2, and that at the same time speech currents or other modulating waves from the line 6 are similarly impressed upon the said control elements. According to the well known action of grid current modulators, these waves are combined in the tube input circuit, and the combination frequencies, together with the unmodified components, appear in the tube output circuit.

The arrangement of this modulator is such that the unmodified wave components are balanced out in the output circuit of the modulator, and only the side bands produced by modulation are transmitted. To assure an effective balance inductance coil 20 is included in the plate circuit of the modulator.

The inductance coil 20 included in the output circuit of the balanced modulator comprises two

windings 22 and 23 connected between the common path 12 and the individual path 13, and between the common path 12 and the individual path 14, respectively. The windings of this coil are connected in the circuit in such a way that they act in series aiding as to the wave components which are differentially impressed upon the tube input circuit, and hence offer a high impedance to the passage of these waves. The windings 22 and 23 of coil 20, however, are connected in parallel opposing relation as to the sidebands produced by modulation, since the sideband components flow between the plate and the filament in the same direction in each branch of the divided circuit, and these components alone appear in the common path 12 of the plate circuit. Since the outgoing line 17 is coupled to the common path 12 in which only the sideband components are flowing, it is evident that the sideband energy alone is transmitted to the line.

It is desirable therefore that the impedance of the windings of inductance 20 be as small as possible with respect to the parallel-opposing distribution of currents, i. e., the paths provided for the sidebands produced by modulation, and yet a high impedance should be presented for the series-aiding distribution of current, i. e., the path provided for the wave components differentially impressed upon the tube input circuit. In order to increase the ratio of these impedances the inductance 20 is constructed as shown in Fig. 2.

Referring to Fig. 2, inductance 20 comprises two windings 22 and 23 wound on shell type core 25. Strips of conductive material, such as copper foil, 26, 27, 28, 29 and 30, are disposed between adjacent layers of the windings while paper strips may also be placed between the layers in the usual manner if desirable. The ends of each conductive strip are either insulated or spaced from one another in order to prevent formation of short-circuited turns.

The conductive strips are so disposed that they are, so far as practical, parallel to the flux lines set up by currents passing through the series-aiding path of the windings, i. e., the path provided for the wave components differentially impressed upon the tube input circuit shown in Fig. 1. Fig. 3 shows, in a schematic manner, the relationship of the strips 26, 27, 28, 29 and 30 to the lines of flux set up by the series-aiding current distribution in the windings. As shown, the flux lines do not tend to cross the conductive strips due to their parallel relationship therewith and are not therefore affected to any appreciable extent by the presence of the conductive strips. In other words, so far as the series-aiding path is concerned, the characteristics of inductance 20 are not appreciably changed by the provision of the strips of conductive material between the layers of windings.

Now, in general, the positions of the flux lines in space change when the current distribution in the windings changes so that the direction of the flux lines set up by the currents passing through the parallel-opposing path of the windings, i. e., the path provided for the sideband produced by modulation, is, in general, perpendicular to the direction of the series-aiding flux shown in Fig. 3. The parallel opposing flux lines are therefore set up in such a direction that they tend to cross the conductive strips 26, 27, 28, 29 and 30. As shown in Fig. 4 eddy currents (represented by the dotted lines) are set up in the conductive strips as a result of

the action of the flux lines. The flux lines are largely suppressed by these eddy currents.

As a result of the cumulative effect of the eddy currents set up in the conductive strips disposed between the layers of winding, the field set up by the currents of the parallel-opposing path is largely suppressed. This suppression of flux results, in turn, in a substantial reduction of the impedance of the parallel-opposing path.

It is apparent, therefore, that the provision of the means contemplated by this invention results in a material reduction in the impedance of inductance 20 with respect to the parallel-opposing path through the windings and yet has no appreciable effect on the impedance of the series-aiding path.

The effect, as determined by actual observation, of the provision of conductive layers, in accordance with this invention, upon the impedances of the series-aiding and the parallel-opposing paths of an inductance device is represented by the curves of Figs. 5 and 6.

The data from which these curves were computed was obtained by measuring the impedances, at various frequencies, of two coils, one, hereafter referred to as "Coil A", having only interleaving paper between the layers of windings while the other, hereafter referred to as "Coil B", was provided with strips of copper foil disposed between the layers in accordance with the method described above.

By referring to Fig. 5, it is apparent that the conductive strips had no effect on the series-aiding impedance, the curve for the series-aiding impedance of the coil provided with conductive strips (Coil B) coinciding throughout with the series-aiding impedance curve of the coil provided with interleaving paper only (Coil A).

It is apparent from an examination of Fig. 6, however, that the parallel-opposing impedance has been reduced materially by provision of the conductive strips. For example, it is shown that at a frequency of 80 kilocycles the parallel opposing impedance of Coil B is approximately 680 ohms less than that of Coil A. It is apparent also from Fig. 6 that the relative decrease in the parallel-opposing impedance becomes greater as the frequency increases. The invention is more effective at carrier and higher frequencies because of the greater shielding efficiency of the conductive strips at these higher frequencies. It has been observed, further, that the effectiveness may be increased somewhat by increasing the number of layers of windings or by increasing the thickness of the conductive strips.

While one particular application has been selected for detailed description, the invention is not of course limited to the particular embodiment described, it being intended to limit the scope of the invention only as indicated by the claims annexed hereto. It has been found, for example, that in the instance of inductance devices used for coupling electrical circuits, particularly output transformers used with push-pull modulator and demodulator circuits, the transmission efficiency is materially improved by the provision of conductive strips disposed between the layers of windings in accordance with the invention.

It will be apparent, further, that the invention provides a means for improving the effective high frequency coupling of windings. For example, an improvement in the ratio of series-opposing to series-aiding inductance may be obtained by the use of conductive strips in a manner similar to that described.

This method of improving the effective coupling is believed to be superior to the usual methods of coupling windings closely as it has been found that the provision of the conductive strips does not increase the capacity effects of the coil materially since the surfaces, to a rough approximation, usually connect points of equal electrostatic potential. The close association of the turns of the windings necessarily involved in the usual methods of close coupling, however, often results in increasing the distributed capacities of the windings beyond permissible limits.

What is claimed is:

1. In an electric circuit including an energy transferring device, an input circuit and an output circuit for said device, said output circuit comprising two parallel branches each branch including a common path and an individual path, an inductance device having two windings, each of said windings having an individual terminal and a common terminal, each individual terminal being connected to an individual path and the common terminal being connected to the common path, means for so energizing the device that current is produced in the output circuit, layers of conductive material so disposed between the individual layers of each winding of the inductance device that they are in general parallel to the flux set up in the windings by the currents passing from one individual terminal through the two windings in series to the other individual terminal.

2. In an electric circuit including an energy transferring device, an input circuit and an output circuit for said device, said output circuit comprising two parallel branches each branch including a common path and an individual path, an inductance device having two windings, each of said windings having an individual terminal and a common terminal, each individual terminal being connected to an individual path and the common terminal being connected to the common path, means for so energizing the device that current is produced in the output circuit, layers of conductive material so disposed between the individual layers of each winding of the inductance device that they are in general parallel to the flux set up in the windings by the currents passing from one individual terminal through the two windings in series to the other individual terminal and at an angle to the flux which the currents passing from the common terminal through the windings in parallel to the individual terminals tend to set up.

3. In an electric circuit including an energy transferring device, an input circuit and an output circuit for said device, said output circuit comprising two parallel branches each branch including a common path and an individual path, an inductance device having two windings, each of said windings having an individual terminal and a common terminal, each individual terminal being connected to an individual path and the common terminal being connected to the common path, means for so energizing the device that current is produced in the output circuit, means disposed between the individual layers of each winding for decreasing the impedance thereof with respect to currents in the output circuit passing from the common terminal through the two windings in parallel to the respective individual terminals.

4. In an electric circuit including an energy transferring device, an input circuit and an output circuit for said device, said output circuit comprising two parallel branches each branch

including a common path and an individual path, an inductance device having two windings, each of said windings having an individual terminal and a common terminal, each individual terminal being connected to an individual path and the common terminal being connected to the common path, means for so energizing the device that current is produced in the output circuit, means disposed between the individual layers of each winding for decreasing the impedance thereof with respect to currents in the output circuit passing from the common terminal through the two windings in parallel to the respective individual terminals, said means having no appreciable effect on the high-frequency impedance of the windings with respect to currents in the output circuit passing from one individual terminal through the two windings in series to the other individual terminal.

5. In an electric circuit, an inductance device having two windings, each winding having an individual terminal and a common terminal, an energy transferring device having an input circuit and an output circuit, said output circuit comprising two parallel branches each branch including a common path and an individual path, each individual path being connected to one of said individual terminals and said common path being connected to said common terminal, means for so energizing the energy transferring device that currents flow in the output circuit, means for improving the effective coupling between the windings comprising layers of conductive material so disposed between the individual layers of windings that the impedance of said windings with respect to currents in the output circuit passing from the common terminal through the two windings in parallel is reduced, said means having no appreciable effect on the high frequency impedance of said windings with respect to currents in the output passing from one individual terminal through the two windings in series to the other individual terminal.

6. An inductance device of the type having two windings each winding having an individual terminal and a common terminal, a "push-pull" circuit comprising two electron discharge devices, an output circuit for said electron discharge devices comprising a common path connecting the common cathode connection of the two discharge devices to the common terminal of said inductance device and two individual paths each connecting the anode of one discharge device to one individual terminal, means for so energizing said discharge devices that currents flow in the output circuit, means disposed between the individual layers of the two windings for reducing the impedance thereof with respect to the currents in the output circuit passing from the common cathode connection to the common terminal and through the windings in parallel to the respective individual terminals.

7. An inductance device of the type having two windings each winding having an individual terminal and a common terminal, a "push-pull" circuit comprising two electron discharge devices, an output circuit for said electron discharge devices comprising a common path connecting the common cathode connection of the two discharge devices to the common terminal of said inductance device and two individual paths each connecting the anode of one discharge device to one individual terminal, means for so energizing said discharge devices that currents flow in the output circuit, layers of conductive material so disposed

between the individual layers of each winding that they are in general parallel to the flux set up in the windings by the currents in the output circuit passing from the anode of one discharge device through one individual path to one individual terminal, through the two windings in series to the other individual terminal and through the other individual path to the anode of the other discharge device.

8. An inductance device of the type having two windings each winding having an individual terminal and a common terminal, a "push-pull" circuit comprising two electron discharge devices, an output circuit for said electron discharge devices comprising a common path connecting the common cathode connection of the two discharge devices to the common terminal of said inductance device and two individual paths each connecting the anode of one discharge device to one individual terminal, means for so energizing said discharge devices that currents flow in the output circuit, layers of conductive material so disposed between the individual layers of each winding that they are in general parallel to the flux set up in the windings by the currents in the output circuit passing from the anode of one discharge device through one individual path to one individual terminal, through the two windings in series to the other individual terminal and through the other individual path to the anode of the other discharge device and at an angle to the flux which the currents passing from the common cathode connection through the individual path to the individual terminal and through the two windings in parallel tend to set up.

9. An electric system comprising divided input and output circuits, means for supplying different waves to said input circuit, means in said input circuit for combining said waves to produce combination frequency components of the supplied waves, an inductance device having a plurality of windings in said output circuit offering a high impedance to the unmodified wave components flowing therein and offering low impedance to the combination frequency components flowing in said output circuit, and means disposed between the individual layers of windings for reducing the impedance offered to the combination frequency components, said means having no appreciable effect on the impedance offered to the unmodified wave components.

10. An electric system comprising divided input and output circuits, means for supplying waves having different characteristics to said input circuit, means in the input circuit for modulating one of said waves in accordance with the other, and an inductance device connected in said output circuit in series-aiding as to the unmodified wave components and in parallel opposing relation as to the sideband produced by modulation, means disposed between the individual layers of windings of the inductance for increasing the ratio of the series-aiding impedance to the parallel-opposing impedance.

11. A wave translating system comprising input and output circuits, means for supplying waves of different frequencies to said input circuit, means included in said input circuit for combining said waves to produce combination frequency components of the supplied waves, means comprising an inductance device having a plurality of windings in the output circuit offering high impedance to the unmodified wave components flowing therein of the frequency of each of the supplied waves and offering low impedance

to the combination frequency components and layers of conductive material so disposed between individual layers of the windings of the inductance device that they are in general parallel to the flux set up in the windings by the unmodified wave components flowing therein.

12. A wave translating system comprising input and output circuits, means for supplying waves of different frequencies to said input circuit, means included in said input circuit for combining said waves to produce combination frequency components of the supplied waves, means comprising an inductance device having a plurality of windings in the output circuit offering high impedance to the unmodified wave components flowing therein of the frequency of each of the supplied waves and offering low impedance to the combination frequency components and layers of conductive material so disposed between individual layers of the windings of the inductance device that they are in general parallel to the flux set up in the windings by the unmodified wave components flowing therein and at an angle to the flux which the combination frequency components flowing therein tend to set up.

13. In a wave translating system, sources of waves of different frequency, a space discharge device having an input and an output or anode circuit, said sources of waves being coupled to the input circuit, means in the input circuit producing current components therein representing modulation components of the waves from said sources, a retard coil having a winding in said anode circuit, a second circuit, means to produce therein modulated current components similar to those produced in said anode circuit and unmodulated components similar but opposed to those produced in said anode circuit, said retard coil having a winding in said second circuit, said windings being mutually aiding as to their impedance effects in said anode circuit for unmodulated components and mutually opposing as to their impedance effects in said anode circuit for the modulated components, means disposed between the individual layers of windings of the retard coil for reducing the impedance effects thereof in said anode circuit for the modulated components.

14. In a wave translating system, sources of waves of different frequency, a space discharge device having an input and an output or anode circuit, said sources of waves being coupled to the input circuit, means in the input circuit producing current components therein representing modulation components of the waves from said sources, a retard coil having a winding in said anode circuit, a second circuit, means to produce therein modulated current components similar to those produced in said anode circuit and unmodulated components similar but opposed to those produced in said anode circuit, said retard coil having a winding in said second circuit, said windings being mutually aiding as to their impedance effects in said anode circuit for unmodulated components and mutually opposing as to their impedance effects in said anode circuit for the modulated components, means disposed between the individual layers of windings of the retard coil for reducing the impedance effects thereof in said anode circuit for the modulated components, said means having no appreciable effect on the impedance effects thereof in said anode circuit for the unmodulated components.

15. In an electric circuit, an energy trans-

ferring device having an output circuit comprising two parallel branches each branch including a common path and an individual path, an inductance device having a plurality of windings, one winding connected between the common path and one individual path and the other winding connected between the common path and the other individual path, the windings being so connected and arranged that they act in series aiding with respect to currents flowing from one individual path through the windings to the other individual path and in parallel opposing to currents flowing from the common path through the respective windings to the individual paths, means for so energizing said transferring device that currents flow in the output circuit, means, comprising layers of conductive material disposed between the individual layers of said windings, for reducing the impedance thereof with respect to their parallel opposing action.

16. In an electric circuit, an energy transferring device having an output circuit comprising two parallel branches each branch including a common path and an individual path, an inductance device having a plurality of windings, one winding connected between the common path and one individual path and the other winding connected between the common path and the other individual path, the windings being so connected and arranged that they act in series aiding with respect to currents flowing from one individual path through the windings to the other individual path and in parallel opposing to currents flowing from the common path through the respective windings to the individual paths, means for so energizing said transferring device that currents flow in the output circuit, means, comprising layers of conductive material disposed between the individual layers of said windings, for reducing the impedance thereof with respect to their parallel opposing action, said means having no appreciable effect on the high frequency impedance thereof with respect to their series aiding action.

17. In an electric circuit, an energy transferring device having an output circuit comprising two parallel branches each branch including a common path and an individual path, an inductance device having a plurality of windings, one winding connected between the common path and one individual path and the other winding connected between the common path and the other individual path, the windings being so connected and arranged that they act in series aid-

ing with respect to currents flowing from one individual path through the windings to the other individual path and in parallel opposing to currents flowing from the common path through the respective windings to the individual paths, means for so energizing said transferring device that currents flow in the output circuit, layers of conductive material so disposed between the individual layers of the windings that they are in general parallel to the flux set up in the windings by the currents passing from one individual path through the windings in series to the other individual path.

18. In an electric circuit, an energy transferring device having an output circuit comprising two parallel branches each branch including a common path and an individual path, an inductance device having a plurality of windings, one winding connected between the common path and one individual path and the other winding connected between the common path and the other individual path, the windings being so connected and arranged that they act in series aiding with respect to currents flowing from one individual path through the windings to the other individual path and in parallel opposing to currents flowing from the common path through the respective windings to the individual paths, means for so energizing said transferring device that currents flow in the output circuit, layers of conductive material so disposed between the individual layers of the windings that they are in general parallel to the flux set up in the windings by the currents passing from one individual path through the windings in series to the other individual path, and at an angle to the flux which the currents passing from the common path through the respective windings in parallel to the individual paths tend to set up.

19. An inductance device having a plurality of windings, sources of current associated with the windings, means for so connecting the windings with respect to the sources of current and with respect to each other that currents passing through the windings from said sources set up two distinctive groups of flux lines, the longer axis of one group being at right angles to the longer axis of the other group, and layers of conductive material so disposed between the individual layers of each winding that they are in general parallel to one of said longer axes.

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