Oct. 20, 1931. K. LUTOMIRSKI 1,828,503

MEANS FOR REDUCING INTERFERENCE IN ELECTRICAL CIRCUITS

Filed April 26, 1928 2 Sheets-Sheet 1

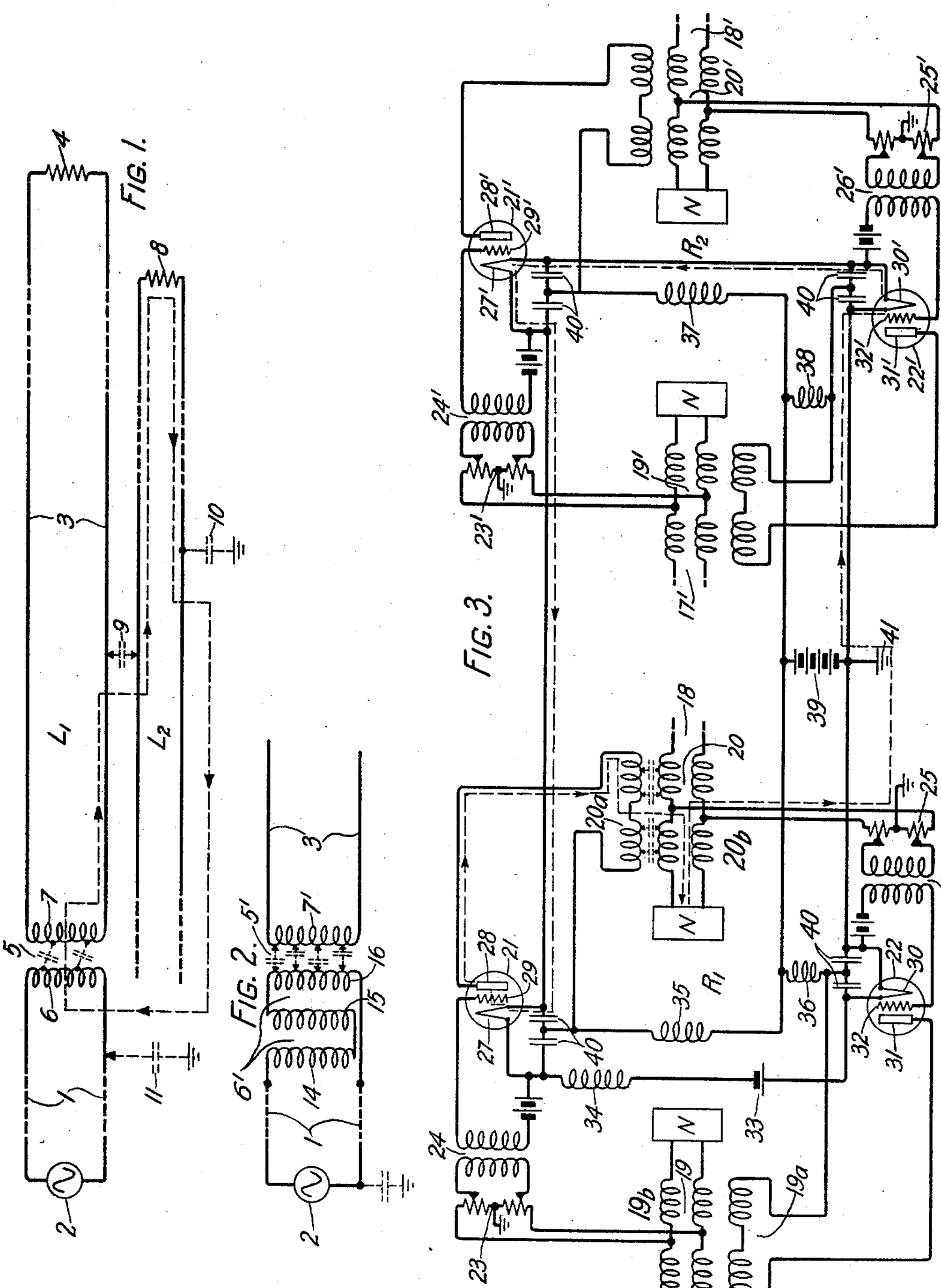

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FIG. 4.

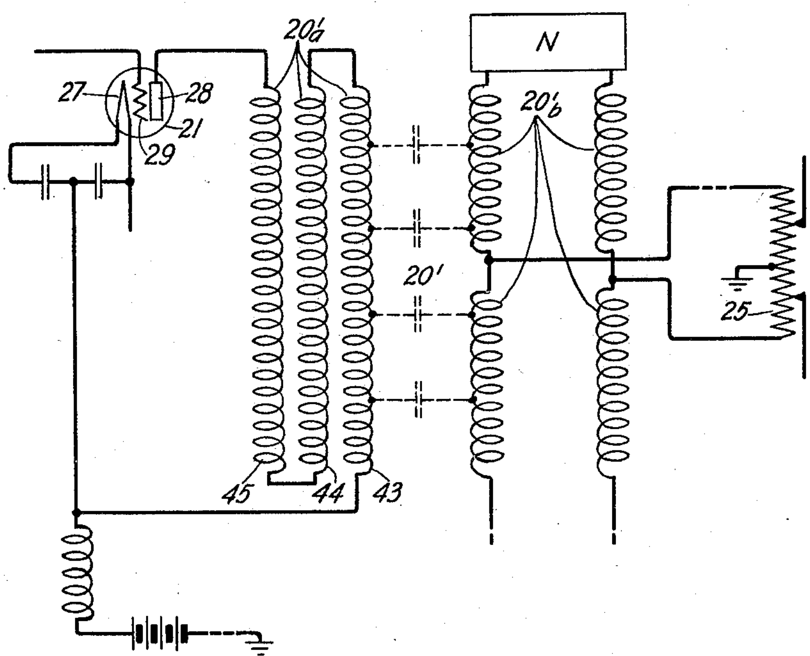
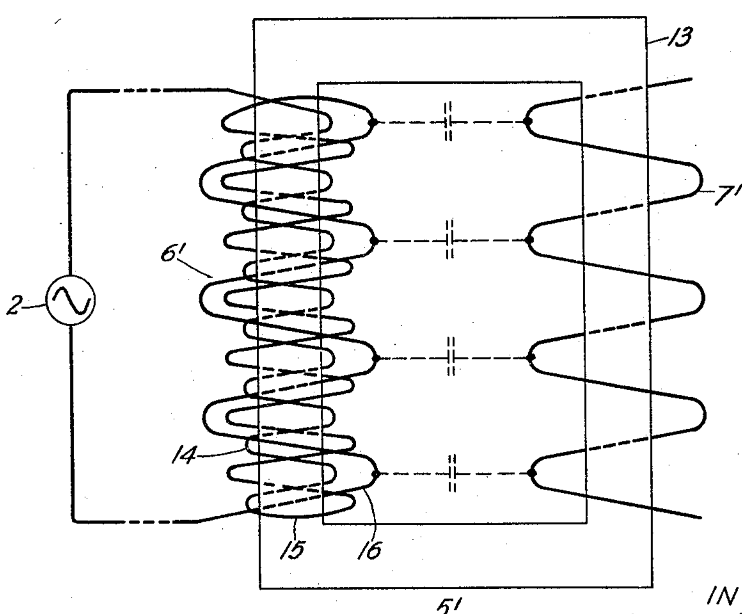


FIG. 5.



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UNITED STATES PATENT OFFICE

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MEANS FOR REDUCING INTERFERENCE IN ELECTRICAL CIRCUITS

Application filed April 26, 1928. Serial No. 273,078.

This invention relates to electrical transmission circuits and particularly to means for preventing disturbances in the operation of such circuits.

An object of the invention is to reduce interference between neighboring transmission circuits or apparatus due to undesired transfer of electrical energy between them.

Another object is to reduce interference between transmission apparatus, such as space discharge devices, by preventing or reducing the transfer of stray currents between their circuits.

Another and a more specific object is to prevent interference between the operation of space discharge devices, the filaments of which are electrically connected or are energized from a common current source, by reducing or preventing potential disturbance in the circuit of one device due to stray or leakage currents from the circuit of another of the space discharge devices.

It is frequently desirable to energize the filaments of a plurality of electron tubes in the same telephone repeater or in separate telephone repeaters from a single potential source as by connecting the filaments of the tubes with a source of energizing potential, such as a grounded direct current battery. In such cases, it has been found that the portion of the output currents, such as speech currents, of each tube which is fed back through ground to the common filament circuit will cause objectionable disturbances, commonly known as cross-talk, in the output of the other tubes. Means have been adopted in the prior art to minimize this cross-talk by effectively neutralizing the effects of the fed-back currents. Applicant has discovered that the principal source of cross-talk trouble in certain typical systems is stray current transmitted from the output of one electron tube through the output transformer therefor to the filament circuits of the other electron tubes through leakage paths such as ground or other connections.

In one embodiment of the invention, this latter type of interference is minimized by reducing the amount of stray current transmitted from the output of one electron tube through the output transformer therefor and leakage or other paths to the filament circuits of the other tubes. In a preferred embodiment of the invention this reduction in the feed-back currents is obtained by using an output transformer for a tube or repeater having such a structure that the capacities between the windings of the transformer and between the windings and ground are very low, and such that these capacities are located at points where alternating current potential differences between the windings and between the windings and ground are low. By this means it has been found that the cross-talk interference between repeater tubes may be substantially eliminated.

The invention itself and its objects and advantages will be best understood by reference to the following detailed description taken in connection with the accompanying drawings in which:

Fig. 1 shows diagrammatically one way in which cross-talk interference occurs between neighboring transmission circuits;

Fig. 2 shows how a transformer of the system of Fig. 1 may be modified in accordance with the invention to minimize the cross-talk interference therein;

Fig. 3 shows diagrammatically one way in which cross-talk interference occurs between electron tubes energized from a common source, in the same or different telephone repeaters;

Fig. 4 shows how the hybrid coil transformers in the repeater circuits of Fig. 3 may be modified to minimize the cross-talk interference therein; and

Fig. 5 shows in more detail the construction of the modified transmission devices of Figs. 2 and 4.

Referring to Fig. 1 two neighboring electrical circuits L_1 and L_2 which may be, for example, telephone lines, are shown. The circuit L_1 comprises a primary portion 1 connected to a source of alternating current waves such as a subscriber's signaling circuit, indicated by the alternating current generator 2, and a secondary portion 3 connected to a load circuit indicated by the resistance 4. The primary and secondary portions 1 and 3 of circuit L_1 are coupled to each other so as to obtain efficient transmission therebetween by a transmission device having inherent capacity effects or leakage between its elements which are at different potential, such as the transformer 5 having a primary winding 6 and a secondary winding 7 with mutual capacity therebetween, connected to the portions 1 and 3 of circuit L_1, respectively. The circuit L_2 may also be utilized for transmitting electrical waves from a source (not shown) to a load circuit indicated by the resistance 8.

It is assumed that the two circuits L_1 and L_2 are relatively located, as is often the case, so that the circuit L_2 is coupled to the secondary portion 3 of circuit L_1 through a leakage or capacitive path, as indicated by the dotted condenser 9, and so that the primary portion 1 of circuit L_1 is connected directly to circuit L_2 as by an electrical conductor or a common ground (such as might be obtained if these circuits comprise grounded transmission apparatus), or indirectly through leakage or capacitive paths for alternating currents from the respective circuits to ground, as indicated by the dotted condenser 10 between circuit L_2 and ground and the dotted condenser 11 between the primary portion 1 of circuit L_1 and ground.

In the system of Fig. 1 described above there will be a stray path, as indicated by a dash line, for alternating currents between the circuits L_1 and L_2, which path may be traced from the primary winding 6 of transformer 5, through the capacitive path between windings 6 and 7 to secondary winding 7, the lower wire of the secondary portion 3 of line L_1, capacitive path 9, the upper wire of circuit L_2, load resistance 8, lower wire of circuit L_2, capacitive path 10 to ground, capacitive path 11 and primary portion 1 of circuit L_1 to primary winding 6 of transformer 5.

Applicant has discovered that prior art repeating coils or transformers, such as transformer 5, inserted in a system such as illustrated in Fig. 1 have such mutual capacity between the windings thereof and between the windings and ground as to allow leakage alternating current of considerable magnitude to be transmitted through the capacitive paths, which leakage will be transmitted over the leakage or capacitive paths between circuits L_1 and L_2 and cause objectionable interference or cross-talk.

This interference or cross-talk may be reduced or substantially eliminated in accordance with the invention by utilizing in the system of Fig. 1 repeating coils or transformers constructed so as to have low mutual capacity between windings and between the windings and ground, such as for example, the specially designed transformer 5′ illustrated in Figs. 2 and 5.

Referring to Figs. 2 and 5, it will be seen that transformer 5′ comprises a multi-layer primary winding 6′ and a secondary winding 7′ respectively wound on different legs of the shell-type core 13. The secondary winding 7′ may comprise a single layer only, but the primary winding 6′ has two or more layers superposed on the core comprising in the case illustrated an inner layer 14 nearest the core and farthest from the secondary winding 7′, an intermediate layer 15, and an outer layer 16 farthest from the core and nearest the secondary winding 7′.

By winding the primary 6′ on the core in superposed layers as illustrated in Figs. 2 and 5 so that only a portion of its turns are adjacent the secondary winding 7′, the effective mutual capacities between these windings are reduced. This effectively reduces the amount of leakage alternating current which will be transmitted over the capacitive path from the primary portion 1 to the secondary portion 3 of circuit L_1 and thus the amount of stray alternating current transmitted from circuit L_1 to circuit L_2 over the capacitive path 9.

The effective leakage of alternating current from the high potential layer 14 of primary winding 6′ to ground may be also minimized by increasing the distance between that layer and the core 13, by inserting the core 13 in a metal case (not shown) and spacing it or insulating it from the case so that the effective capacity between core and case is low, or by locating a part of the lower potential layer 16, between the higher potential layer 14 and the core to effectively shield the latter layer from the core.

The effective difference of alternating current potential between windings 6′ and 7′, and thus the transfer of stray alternating currents from circuit L_1 to circuit L_2 over the path described above may be also reduced in accordance with the invention, as shown in Figs. 2 and 5 by connecting the layer 14 of primary winding 6′, which is farthest from the secondary winding 7′, to the terminal of the source of alternating current 2 which has the highest alternating current potential with respect to secondary winding 7′, and the layer 16 of primary winding 6′, which is nearest the secondary winding 7′, to the terminal of source 2 which is at a lower alternating current potential with respect to secondary winding 7′. By this means, the secondary winding 7′ is shielded from the high potential layer 14 of primary winding 6′ by layers 15 and 16 of primary winding 6′, which layers are of lower potential than layer 14. The effective transfer of energy over the capacity path between windings 6′ and 7′ and between the portions 1 and 3 of circuit L_1 is thus minimized.

Any one of the above described methods or any desired combination of them or any other suitable construction, may be used for designing the transformers in the system of Fig. 1 to reduce the leakage of alternating currents between the circuits L_1 and L_2 to such a low value that it will not cause objectionable interference in the operation of these circuits.

In Fig. 3 are shown two neighboring telephone repeaters R_1 and R_2, which are of the well known two-way, two-element or 22-type. Repeater R_1 comprises two two-way transmission line sections 17 and 18 which are terminated in the usual balancing networks N which simulate the impedance of the line. The line sections 17 and 18 are associated by means of hybrid coil transformers 19 and 20 in a manner well known in the art with an amplifying device 21 for impressing on line section 18 in amplified form signals from line section 17 and with an amplifying device 22 for impressing on line section 17 in amplified form signals from line section 18. The hybrid coil transformer 19 comprises the usual series winding 19_a and the line windings 19_b, and the hybrid coil transformer 20 a series winding 20_a and line windings 20_b. The input circuit of amplifier 21 is connected across bridge points in line section 17 between line windings 19_b through the gain adjusting potentiometer 23, which has its mid-point grounded, and input transformer 24, and the output circuit of amplifier 23 is connected to the series winding 20_a of hybrid coil transformer 20. Similarly, the input circuit of amplifier 22 is connected across bridge points in line section 18 between line windings 20_b through the gain adjusting potentiometer 25, which has its mid-point grounded, and input transformer 26, and the output circuit of amplifier 22 is connected to the series winding 19_a of hybrid coil 19.

The amplifiers 21 and 22 may be of any desired type, but three electrode-vacuum tube amplifiers are illustrated, amplifier 21 including a cathode or filament 27, an anode or plate 28 and a control electrode or grid 29 and amplifier 22 similar electrodes designated, respectively 30, 31 and 32.

The repeater R_2 as illustrated has elements which are identical with those of repeater R_1 which has been described, these elements being designated with similar characters, but with the addition of a prime (′) mark.

The filaments 27, 30 of amplifiers 21 and 22 respectively, of repeater R_1, and the filaments 27′, 30′ of amplifiers 21′ and 22′, respectively, of repeater R_2 are connected in series in a circuit supplied with heating current from a common battery 33 through a retardation coil 34. The anodes 28, 31, 28′, 31′ of amplifiers 21, 22, 21′ and 22′, respectively, are connected through retardation coils 35, 36, 37 and 38, respectively, to a common plate current supply battery 39.

The balancing condensers in the individual filament leads of the amplifier tubes are utilized to prevent unsymmetrical distribution of the plate current, causing a voltage to be set up across the filament circuits of these tubes, which in turn would cause cross-talk disturbances in the other tubes having filament circuits in common with the disturbing tube, in the manner disclosed in Crisson Patent 1,431,219, issued October 10, 1922.

The grid electrodes 29, 32, 29′ and 32′ of the amplifier tubes 21, 22, 21′ and 22′, respectively, are maintained at negative potential with respect to the filaments of the tubes by means of individual C batteries inserted between the filaments and the grids. As usual in such circuits the common filament circuit of the amplifier tubes is connected to ground at some convenient point, such as point 41.

To show how cross-talk interference may arise in the repeater system just described, it will be assumed that signal variations are being received over transmission line 17. These variations will be transmitted through the bridged connections of hybrid coil 19 and impressed through gain adjusting potentiometer 23 and input transformer 24 on the input circuit of amplifier tube 21. The amplified variations in the output circuit of amplifier tube 22 will be impressed on line section 18 through the inductive coupling between the series winding 20_a and the line windings 20_b of the hybrid coil 20.

It has been found that in such a repeater circuit, because of the mutual capacity effect present between the series winding 20_a and the line windings 20_b of hybrid coil 20, all portions of the circuit connected to the series winding 20_a will have a certain alternating current potential with respect to ground. Because of this capacity effect between the series winding 20_a and line windings 20_b of the hybrid coil 20, as indicated by the dotted condensers between the windings, there will be a stray path for alternating currents between the output circuit of tube 21 and the common filament circuit for tubes 21, 22, 21′ and 22′, this path being traced from the series winding 20_a of hybrid coil 20, through the capacitive path between that winding and the line windings 20_b and over the bridge connections of hybrid coil 20 to potentiometer 25, the ground connection thereto, ground connection 41 to the common filament circuit for tubes 21, 22, 21′ and 22′, as indicated by the dotted lines, to cathode 27 of tube 21, space path of tube 21 to series winding 20_a of hybrid coil 20.

It has been found that in repeater systems in which hybrid coil transformers of the prior art are used, such as those illustrated in the circuit of Fig. 3, when talking currents are being transmitted through one repeating path, the mutual capacities between the windings of the hybrid coil in the output of that path and between the windings and ground are of appreciable value. Because of this mutual capacity effect, leakage alternating current will be transmitted from the output of the amplifier tube in one repeating path over the path traced above to the common filament circuit for the several amplifier tubes. This leakage current may be sufficient to cause appreciable cross-talk disturbance in the circuits of the amplifier tubes in the oppositely directed repeating path of the same repeater or in the circuits of the amplifier tubes in the repeating paths of the neighboring repeater.

This cross-talk disturbance may be reduced or substantially eliminated in accordance with the invention by employing in the system of Fig. 3 hybrid coil transformers constructed to have low mutual capacities between windings and between windings and ground, such as, for example, the specially designed hybrid coil 20′ illustrated in Fig. 4.

Referring to Fig. 4, it will be seen that hybrid coil 20′ comprises a multi-layer series winding $20_a'$ and line windings $20_b'$, each of which may comprise a single layer. The series winding $20_a'$ may have any desired number of superposed layers which may be wound in the manner similar to that illustrated for the multi-layer primary winding 6′ of transformer 5′ in Figs. 2 and 5, on one leg of a shell type core, the line windings $20_b'$ being wound on the other legs of the core. As illustrated in Fig. 4, the multi-layer series winding $20_a'$ of coil 20′ may be wound on the core so as to comprise an outer layer 43 which is nearest to the line windings $20_b'$, an intermediate layer 44, and an inner layer 45 farthest from the line windings $20_b'$. By constructing the hybrid coil transformer 20′ in this way, the number of turns of the series winding $20_a'$ adjacent to the lower potential line winding $20_b'$ is reduced, thus reducing the mutual capacity between the windings of the hybrid coil and therefore the stray alternating current transmitted over the capacitive path. The leakage alternating current transmitted from the output of tube 21 to the common filament circuit for the several amplifier tubes over the path traced above in connection with the system of Fig. 3, will be correspondingly reduced, thus decreasing the variations in the output currents of the several amplifier tubes due to this cause.

The stray alternating currents transmitted from the output of amplifier 21 to the circuits of the other amplifier tubes 22, 21′ and 22′ over the path traced above may be further reduced by concentrating the mutual capacity between series winding $20_a'$ and line windings $20_b'$ between points of minimum difference of alternating current potential. This is accomplished as indicated in Fig. 4 by connecting the terminal of the inner layer 45 of series winding $20_a'$ which is farthest from the line windings $20_b'$, to a high alternating current potential point in the output circuit of tube 21, for example, directly to the plate 28 of that tube, and by connecting the terminal of the outer layer 43 of series winding $20_a'$, which is nearest to the line windings $20_b'$, to a point of lower alternating current potential in the output circuit of tube 21, for example, to the midpoint of the filament 27 of tube 23. By this means low potential line winding $20_b'$ is effectively shielded from the high potential layer 45 of the series winding $20_a'$ by layers 44 and 45 of winding $20_a'$, which are of lower alternating current potential. This substantially reduces the effective difference of alternating current potential between the adjacent portions of the high and low windings of the hybrid coil and, therefore, the amount of stray current transmitted over the capacitive path therebetween.

The above methods, as well as the additional methods described in connection with transformer 5′, combinations of these methods, or any other suitable construction, may be utilized in designing the hybrid coils 19, 20, 19′ and 20′ so as to substantially eliminate the effect of the mutual capacity between the windings of the hybrid coils and between the windings and ground, and thus to reduce the stray alternating current passing from the output circuit of one tube through the associated hybrid coil transformer and ground connections to the common filament circuit to an amount which will be too small to cause serious cross-talk interference in the circuits of the other amplifier tubes.

While the invention has been described as embodied in special transmission and repeating systems, and in connection with output transformers therein, it is apparent that it is not limited to the systems described or to output transformers, but may be employed in other systems comprising circuits employing transmission apparatus having a capacitive effect between its elements at different potentials and between its elements and ground, and having leakage paths for alternating currents between the circuits, without departing from the spirit and scope of the invention as defined in the appended claims.

What is claimed is:

1. In combination, a source of alternating current waves, a circuit having a primary portion connected to said source, and a secondary portion, a transmission device comprising elements respectively connected to and coupling said primary portion and said secondary portion of said circuit for a desired transmission of said waves therebetween, said device providing a leakage path for alternating currents between said primary portion and said secondary portion of said circuit, a second circuit for transmitting electrical waves and coupled respectively to said primary portion and said secondary por-

tion of the first mentioned circuit through leakage paths for alternating currents, and means inherent in said device for reducing the amount of leakage alternating current transmitted between the first mentioned circuit and said second circuit over said leakage path including means for substantially reducing the amount of alternating current transmitted between said primary portion and said secondary portion of said first-mentioned circuit due to the capacitive coupling therebetween.

2. A combination in accordance with that of claim 1, and in which one element of said transmission device connected to the primary portion of said first-mentioned circuit comprises several sections only one of which is in close proximity to an element of said device connected to the secondary portion of said first-mentioned circuit.

3. A combination in accordance with that of claim 1 and in which an element of said transmission device of low alternating current potential is shielded from the portions of another element of said device of higher potential by portions of said other element of intermediate potential.

4. A combination in accordance with that of claim 1 and in which said transmission device comprises a transformer having a primary winding connected to the primary portion of said first-mentioned circuit and a secondary winding connected to the secondary portion thereof, and said means included in said transformer for substantially reducing the amount of alternating current transmitted between said primary portion and said secondary portion of said first mentioned circuit comprises means for reducing the mutual capacities between said primary and secondary portions to a negligible value.

5. In combination, a circuit for transmitting alternating electrical currents and having a primary portion and a secondary portion, a transformer comprising windings respectively connected to and inductively coupling said primary and said secondary portions of said circuit, a second circuit for transmitting electrical currents, coupled to the secondary portion of the first-mentioned circuit through a leakage path, and a path for alternating currents between said second circuit and the primary portion of said first-mentioned circuit, said transformer including means for reducing the transfer through said leakage path of alternating currents between said first-mentioned circuit and said second circuit due to the capacitive coupling therebetween.

6. A combination in accordance with that of claim 1, and in which said transmission device comprises a transformer having a primary winding connected to said primary portion of said first-mentioned circuit and a secondary winding connected to the secondary portion of said first-mentioned circuit, said transformer including means for reducing the mutual capacities between its windings and between said primary winding and said second circuit, and for locating said capacities at points where the difference of alternating current potential between the windings and between the windings and said second circuit are substantially lowest.

7. A combination in accordance with that of claim 1 and in which said transmission device comprises a transformer having a core and windings mounted thereon including a primary winding connected to the primary portion of said first-mentioned circuit and a secondary winding connected to the secondary portion of said first-mentioned circuit, said primary winding comprising a plurality of layers superposed on said core, said secondary winding being shielded from the layer of said primary winding of highest alternating current potential with respect to said secondary winding by a layer of said primary winding at an alternating current potential intermediate that of said secondary winding and that of the high potential layer of said primary winding.

8. In combination, a plurality of space discharge devices each having a plate or anode and a cathode or filament and an independent direct current output circuit connected between its plate and filament, the filament of said devices being fed in series from a common heating source, a path for alternating currents between the output circuit of one of said devices and the common heating circuit, and means for rendering the output circuit current of said one device substantially ineffective to cause variations in the circuit of another of said devices over said path.

9. In combination, a plurality of space discharge devices each having a filament and a plate, the filaments of said devices being energized in series from a common source, an output transformer comprising primary and secondary windings connected between the plate and filament of one of said devices, a path for alternating currents between said primary winding and the common filament circuit, and means inherent in said transformer for preventing leakage due to the capacitive coupling between said alternating current path and the output of said one device to the filament of another of said devices of sufficient current to cause appreciable disturbance in the circuit of said other device.

10. In combination, a plurality of space discharge devices each having a filament and a plate, the filaments of said devices being energized in series from a common current source, an output transformer comprising a core and primary and secondary windings wound thereon, said primary winding being

connected in the output circuit of one of said devices between the plate and filament thereof, a path for alternating currents between one of the winding of said transformer and the common filament circuit, said transformer including means for reducing the capacity couplings between said output circuit and said path for alternating currents sufficiently to prevent substantially any transfer of leakage alternating current through the output transformer of said one device to the filament of another of said devices.

11. In a transmission system, a pair of transmission lines, a repeater circuit interconnecting said lines and including one-way paths for transmitting in opposite directions between said lines, each of said paths including a space discharge amplifying device having a cathode or filament and an anode or plate, the filaments of the space discharge devices in said paths being supplied with energizing current in series from a common source, a transformer comprising a core and primary and secondary windings wound thereon, said primary winding being connected in the output circuit of one of said devices between the plate and filament thereof, and a path for alternating currents between said secondary winding and the common filament circuit for said devices, said transformer including means for reducing the effective mutual capacities between said output circuit and said path for alternating currents to value sufficiently low as to prevent the leakage of sufficient alternating current from the output of said one amplifying device through the capacitive path to cause disturbance in the circuit of the other amplifying device.

12. In a transmission system, a repeater circuit including a space discharge device having a cathode or filament and an anode or plate, and a transformer comprising a core and a primary winding and a secondary winding mounted thereon, said primary winding being connected in the output circuit of said device between the plate and filament thereof, a second repeater circuit including a second space discharge device having a cathode-filament and a plate or anode, the filaments of the first-mentioned space discharge device and said second space discharge device being supplied with heating current in series from a common source, a path for alternating currents between the secondary winding of said transformer and the common heating circuit for said filaments, said transformer including means for preventing the leakage of sufficient alternating current from the output circuit of said first-mentioned space discharge device over the capacitive path between said output circuit and said path for alternating currents and over said path to said common heating circuit for said filaments to cause disturbance in the circuit of said second space discharge device.

In witness whereof, I hereunto subscribe my name this 24th day of April, 1928.

KAREL LUTOMIRSKI.