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TRANSFORMER AND COIL SYSTEM

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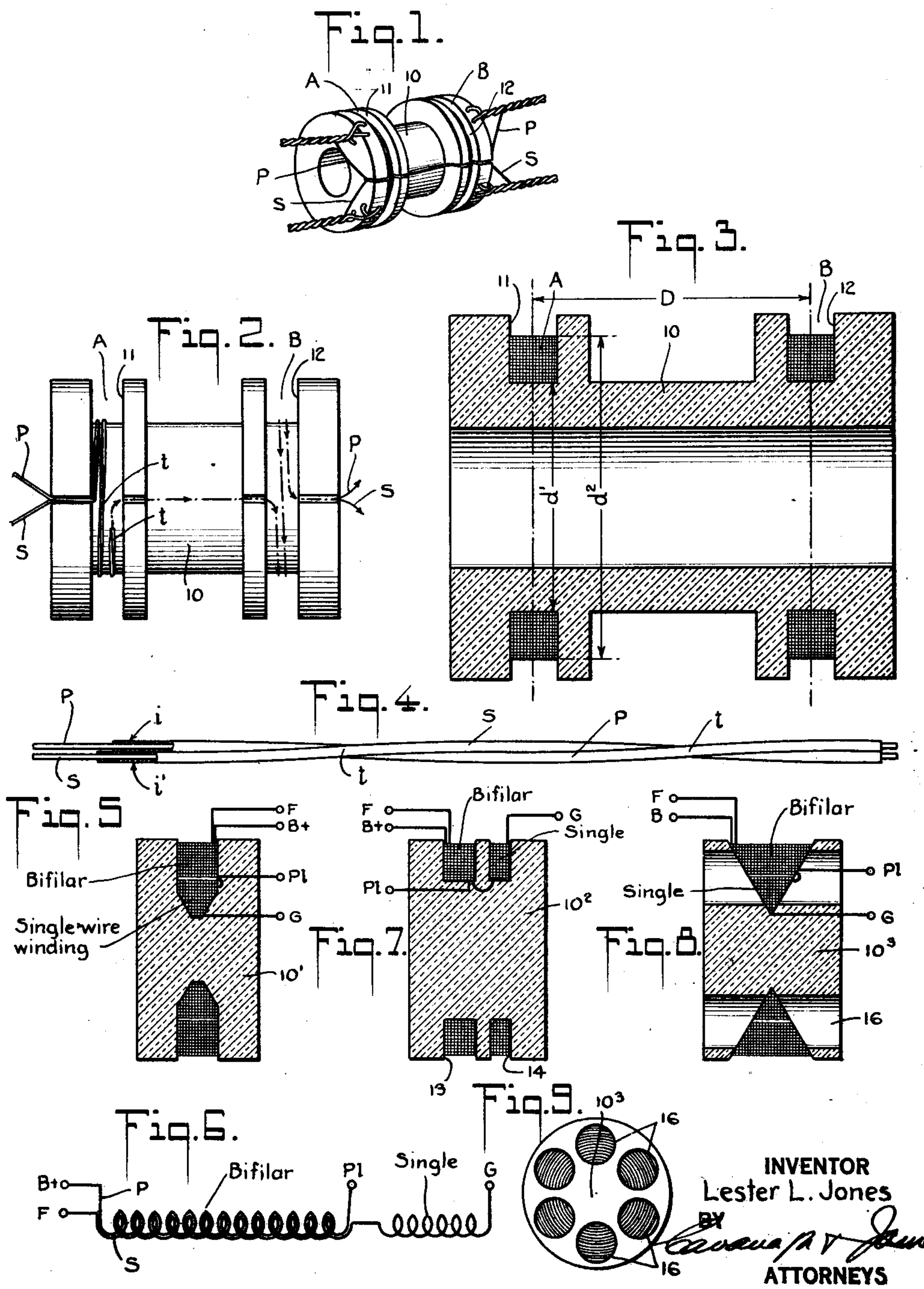

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TRANSFORMER AND COIL SYSTEM

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This invention relates to transformer and coil systems, and has special reference to the provision of improved transformers and coil systems adapted for use with electron discharge devices or relays such as are employed in radio circuits or systems.

A prime object of my present invention centers about the provision of a transformer specially adapted for use with three element electron discharge devices or relays, especially for the securing of amplification of alternating currents having a wide range of frequency without adjustment, such transformers being of the socalled untuned or broad band type.

It has been found that such transformers of the untuned type do not have a constant amplification over the whole frequency band for which they are intended. This undesirable characteristic is noticeable in audio frequency transformers and is especially objectionable in radio frequency transformers. In transformers for the amplification of the frequency band of 500,000 to 2,000,000 cycles per second the variation in amplification is most pronounced, and to such an extent as to render the application of this method to this frequency range distinctly non-commercial.

I have found that a primary factor in the production of a high rate of variation of amplification with frequency in amplifying transformers of prior types is the occurrence of a second mode of oscillation in the windings which I designate or call a short wave oscillation. All prior types of transformers are subject to this mode of short wave oscillation in a frequency band closely adjacent to the frequency band for which the transformer is designed. In the prior art, attempts have been made to utilize this second mode of oscillation by modifying the design so as to include it in the frequency band for which the transformer is designed.

I have found that this short wave mode of oscillation is primarily due to the leakage of magnetic flux between the primary and secondary windings. In transformers which are wound in opposite directions the short wave mode of oscillation may be predetermined from the leakage inductance of the transformer and the distributed capacities of the coils. In a general way, in this type of transformer, the frequency of the short wave oscillation is determined by a capacity which is mainly the sum of the distributed capacities of the primary and secondary windings and an inductance which is approximately the parallel inductance of the primary and secondary windings, which parallel inductance may be defined as

$$\frac{L_p \quad L_s - M^2}{L_p + L_s + 2M}$$

In transformers wound in the same direction the short wave oscillation is again determined by a capacity, which, however in this case, is mainly the capacity between the primary and secondary windings and an inductance which is approximately the series inductance of the primary and secondary windings which may be defined as $L_p + L_s - 2M$

In these formulas

L_p = self-inductance of primary

L_s = self-inductance of secondary

M = mutual inductance between primary and secondary

I have discovered that it is feasible to completely suppress this objectionable short wave mode of oscillation by eliminating completely or substantially completely the leakage inductance between the windings of the transformer. This I have found can be accomplished by winding the primary and secondary of the transformer bifilarly, with the filaments of said windings arranged in such close juxtaposition that the leakage inductance between the windings is substantially completely eliminated. I have discovered, in order to completely suppress this objectionable short wave mode of oscillation, that great care must be taken in winding the primary and secondary filaments of the transformer so as to produce a substantially unity coupling between the primary and secondary transformer windings; and by this I mean that the primary and secondary windings should nowhere be separated by a space greater than the space occupied by the insulation coverings of the wires or filaments.

It is a prime desideratum, therefore, of my present invention to provide a transformer having a bifilar construction so designed as to effect the elimination of the leakage inductance between the windings, all to the end of obviating or completely suppressing the short wave mode of oscillation.

A further prime object of my present invention centers about the provision of a transformer, preferably of the bifilar type, which is astatic. As is well known, it is a desideratum of certain types of selective and sensitive radio receiving apparatus and in apparatus employable near transmitting stations, to construct the coils or windings of the receiving apparatus so that they are uncoupled magnetically to other coils and apparatus in the receiving circuit or to the transmitting apparatus. To accomplish the magnetic uncoupling of the coils to other apparatus, various types of coil windings have hitherto been designed, such as double D windings, toroid windings and binocular coils. These prior types of coil windings have, however, been found insufficient to produce the desired results on account of their relatively large external fields near the coil which produce considerable coupling to other parts, and even between similar coils when placed at a moderate distance apart. To reduce the inter-magnetic couplings between similar coils in the radio receiving set with the use of such prior structures, it has been found necessary to so relatively arrange the coils one with respect to the other in the radio receiving set as to minimize the reacting fields. Other structural difficulties, such as the large volume of winding required and the difficulty of winding methods have also hindered the use of these prior and known types of winding coils.

It is therefore a prime desideratum of my present invention to provide a transformer or an inductance coil system designed and constructed so that the external magnetic field is reduced to such a minimum that the coil is substantially de-coupled magnetically from surrounding apparatus and may be placed in close proximity to other similar coils of a radio receiving system without inter-magnetically reacting with the same.

To the accomplishment of the foregoing and such other objects as will hereinafter appear, my invention consists in the elements and their relation one to the other, as hereinafter more particularly described and sought to be defined in the claims; reference being had to the accompanying drawings which show the preferred embodiment of my invention, and in which

Fig. 1 is a perspective view showing a preferred form of construction of the bifilar astatic transformer of my invention,

Fig. 2 is an enlarged front elevational view thereof depicting the manner of winding the sections of the transformer and portraying the bifilar character of the construction,

Fig. 3 is a cross-sectional view thereof drawn to an enlarged scale showing the preferred mathematical relation between the dimensions thereof to secure astaticism,

Fig. 4 is a view showing a preferred manner of producing close juxtaposition of the filaments of the transformer,

Fig. 5 is a cross-sectional view of a modified form of the transformer showing either a step-down or step-up ratio of transformation,

Fig. 6 is a wiring diagrammatic view of Fig. 5,

Figs. 7 and 8 are two other modifications of step-up or step-down transformations embodying the invention, and

Fig. 9 is a side face view of the structure shown in Fig. 8 drawn to a reduced scale.

To accomplish the result of suppressing the objectionable short wave mode of oscillation, the transformer of my invention comprises primary and secondary windings P and S wound bifilarly, that is to say, wound so that the filaments of the windings are arranged in close juxtaposition substantially throughout their entire lengths, as clearly shown in Figs. 1, 2 and 4 of the drawings, and as diagrammatically illustrated in part of Fig. 6 of the drawings. The juxtaposition or contiguous arrangement of the primary and secondary filaments P and S is such as to produce substantial unity coupling between the windings, that is to say, the primary and secondary filaments are separated by a space no greater than the space occupied by the insulating covering of the wires or filaments. This is depicted in Fig. 4 of the drawings where *i* and *i′* designate the insulating coverings of the primary and secondary filaments P and S respectively. To assist in producing this close juxtaposition over substantially the whole length of the filaments, the filaments P and S are twisted during the winding operation with a relatively large pitch, that is to say, with a pitch which is relatively large compared to the diameters of the filaments. This is shown particularly in Figs. 2 and 4 of the drawings where the windings are shown transposed by twists in regions designated as *t*, *t*. This frequent transposition of the windings materially aids in holding the wires or filaments close together throughout their entire length, this so as to produce the intended results. While I prefer, for ease and economy of operation, to effect the close juxtaposition by twisting, it will be apparent that the same result may be accomplished in other ways, as for example, by securing the filaments together at points along their lengths.

I have found that a transformer constructed and wound in this manner exhibits extremely desirable characteristics. By exercising care to prevent a separation between the filaments greater than the separation produced by the insulation, I am enabled to eliminate the undesired leakage inductance between the windings substantially completely. I have found the transformer suitable for automatic tuning and when so used I have found the same to give higher average amplification with a more constant value over the wave length band than any other type of transformer thus far developed. The transformer of my invention may be used without automatic tuning in any way whatsoever without developing disturbing interstage oscillations which have been the bugbear of prior types of transformers and which give rise to the necessity of iron cores to overdamp the transformers and stop oscillation, or the use of grid biasing potentiometers to reduce the tube amplification and increase the secondary losses of the transformer by reason of passage of excessive grid current. The efficiency of this transformer construction is in some measure due to the high capacity between the windings which accompanies the close spacing of the primary and secondary filaments throughout their entire lengths. The twisting of the filament pair in effectively preventing any primary turn from developing appreciable capacity at a different potential with respect to a secondary turn also contributes to the efficiency of the transformer. Another effect which is contributory to the successful result produced is the obtaining of relatively large air spaces in the winding due to the fact that the twisted pair may be wound at random; and these air spaces tend to reduce the distributed capacity of the coil which should be a minimum for the purpose of untuned amplification.

To produce the magnetically astatic results hereinbefore described, the transformer of my invention is made to comprise two coil sections A and B shown particularly in Figs. 1 to 3 of the drawings, each coil section being composed of a plurality of windings, the windings of the sections A and B being wound in opposite directions, as clearly shown by the arrows in Fig. 2 of the drawings. To produce these coil sections I provide a spool 10 forming the transformer core. This spool may be made of wood or other insulation material, said spool being provided with grooves 11 and 12 in which the coil sections are wound.

To produce a magnetic field at a distance which is substantially equal to zero, I have found that the coil sections A and B should desirably be arranged co-axially with the windings of the coil section A equal in number to the windings of the coil section B. Optimum results are obtained when the coil sections A and B are separated by a distance equal to the average diameter of a coil section, and this is depicted in Fig. 3 of the drawings where the separation between the coil sections A and B, that is to say, the separation between their centers is represented by "D" and where the average diameter of the coil section is one-half the sum of the minimum diameter d' and the maximum diameter d^2. The distance D is thus preferably made equal to one-half the sum of the diameters d' and d^2. I have found that where the coil sections are farther apart than the distance D, the coil system loses astaticism very rapidly, and on the other hand, where the coil sections are closer together than the distance D, the useful inductance decreases rapidly on account of the growth of the bucking or reverse mutual.

It will be apparent that the astatic characteristic of the transformer may be used without the leakage eliminating characteristic and vice versa, it being understood that the preferred transformer construction shown in Figs. 1 to 4 embodies both characteristics in the preferred manner. It will be also appreciated that the astatic characteristic is generic to inductance coil systems whether or not such systems are made in the form of a transformer.

In Figs. 1 to 3 of the drawings, the transformer is made with a one to one ratio of transformation. The bifilar transformer of my present invention, however, may be made with either step-up or step-down ratios of transformation, and this is depicted in Figs. 5 to 9 of the drawings.

In the modification shown in Figs. 5 and 6 of the drawings, the transformer is shown to comprise primary and secondary windings P and S having portions wound bifilarly with the filaments arranged in close juxtaposition and forming one transformer section with one of said windings having a portion forming a single wire wound section. Thus the primary and secondary windings P, S are wound bifilarly in a section designated "bifilar", the secondary winding having a portion designated "single wire winding" which represents the single wire wound section. As shown in Fig. 5, the single wire wound section is preferably first wound on the core 10′ on which the bifilar section is wound. The terminals of the primary and secondary windings are connected to audion circuits as indicated by the reference characters at such terminals shown in Figs. 5 and 6 of the drawings, the reference characters being "F" for filament, "Pl" for plate, "G" for grid, and B+ for the positive side of the B battery.

With a construction such as shown in Figs. 5 and 6 it becomes possible to use a transformer of other than a one to one ratio having a very high mutual inductance or a very low leakage and yet secure small dielectric and capacity losses. In amplifying at very high frequencies, one of the chief difficulties lies in the elimination of capacity across the secondary winding. The arrangement shown in these Figs. 5 and 6 permits of a step-up transformer having minimum distributed capacity and maximum mutual inductance without the use of iron cores.

In Fig. 7 of the drawings I show an alternative form of construction in which the bifilar coil is wound in a groove 13 of the spool or core 10^2, and the single wire winding is wound in a groove 14 in said spool. The terminals of the composite windings are designated in Fig. 7 with the same reference characters as those in Fig. 5.

Another alternative construction of this composite winding is shown in Figs. 8 and 9 of the drawings wherein the bifilar coil is wound superposed over the single coil in a V-shaped channel 15 provided in the core or spool 10^3. Preferably this spool is provided with orifices 16, 16 produced by drilling out the insulation for the purpose of further minimizing the capacity. The terminals of the windings in Fig. 8 are designated by reference characters similar to those of Figs. 5 to 7.

The use and operation, the method of winding and the advantages of the transformer and coil system of my present invention will in the main be apparent from the above detailed description thereof. While I have shown and described my invention in the preferred form it will also be apparent that many changes and modifications may be made in the structure disclosed without departing from the spirit of the invention, defined in the following claims.

I claim:

1. An astatic bifilar transformer comprising primary and secondary windings wound bifilarly, similar parts of the filaments of said windings being arranged in close juxtaposition throughout their lengths, said windings comprising two axially spaced sections substantially equal in size and oppositely wound.

2. An astatic bifilar transformer comprising primary and secondary windings wound bifilarly, similar parts of the filaments of said windings being arranged in close juxtaposition throughout their lengths, said windings comprising two co-axially arranged sections equal in size and oppositely wound.

3. An astatic bifilar transformer comprising primary and secondary windings wound bifilarly, similar parts of the filaments of said windings being arranged in close juxtaposition throughout their lengths, said windings comprising two sections substantially equal in size and oppositely wound, said sections being arranged co-axially with the separation between their centers substantially equal to the average diameter of a coil section.

4. An astatic bifilar transformer comprising primary and secondary windings wound bifilarly, similar parts of the filaments of said windings being arranged in close juxtaposition throughout their lengths with a substantial unity coupling, said windings comprising two sections equal in size and oppositely wound, said sections being separated a distance substantially equal to the average diameter of a coil section.

5. An astatic transformer comprising primary and secondary windings wound in the same form, said windings together comprising two axially spaced sections substantially equal in size and oppositely wound.

6. An astatic transformer comprising primary and secondary windings wound together in the same form, said windings together comprising two co-axially arranged sections, the said sections having windings equal in number and oppositely wound.

7. An astatic transformer comprising primary and secondary windings coupled together with a substantially unity coupling, said windings comprising two coil sections substantially equal in size and oppositely wound, said sections being arranged co-axially with the separation between their centers substantially equal to the average diameter of a coil section.

8. An astatic transformer comprising primary and secondary windings divided into two coil sections, said sections having windings substantially equal in number and oppositely wound and said sections being arranged co-axially with the separation between their centers substantially equal to the average diameter of a coil section.

9. An astatic coil comprising two coil sections arranged co-axially, the said coil sections having windings equal in number and oppositely wound, the separation between the centers of said windings being substantially equal to the average diameter of a coil section, the said coil sections having windings in size, number and arrangement to produce a high resulting inductance with a small distributed capacity.

10. An astatic bifilar transformer comprising primary and secondary windings wound bifilarly, similar parts of the filaments of said windings being arranged in close juxtaposition throughout their lengths, said windings comprising a plurality of axially spaced coil sections connected in circuit, said coil sections being wound in opposite directions to produce oppositely directed fluxes and being spaced a distance apart to produce a result-

ing self-inductance of substantial magnitude, the spacing between and the product of the number of turns and area of each of said oppositely wound coil sections being such as to produce substantially neutralizing magnetic fields at a distance.

11. An astatic bifilar transformer comprising primary and secondary windings wound bifilarly, similar parts of the filaments of said windings being arranged in close juxtaposition throughout their lengths, each of said windings comprising a plurality of coil sections connected in circuit, said coil sections being wound and connected to produce oppositely directed fluxes of substantially equal magnitude and being spaced axially a distance apart to produce a resulting self-inductance of the coil of substantial magnitude and to produce substantially neutralizing magnetic fields at a distance.

12. An astatic bifilar transformer comprising primary and secondary windings wound bifilarly, similar parts of the filaments of said windings being arranged in close juxtaposition throughout their lengths, said windings comprising a plurality of coil sections wound on the same coil and connected in circuit, said coil sections being wound in opposite directions to produce oppositely directed fluxes and being spaced a distance apart to produce a resulting self-inductance of substantial magnitude, the product of the number of turns and area of one coil section being substantially equal to the product of the number of turns and area of the other coil section, and the distance between said coil sections being substantially small, whereby neutralizing magnetic fields are produced at a distance.

13. An astatic transformer comprising two windings, similar parts of the filaments of said windings being wound with a substantially unity coupling therebetween, said windings comprising a plurality of coil sections wound in opposite directions to produce oppositely directed fluxes and being spaced apart a distance to produce a resulting self-inductance of substantial magnitude, the said coil sections being spaced apart and the product of the number of turns and area of one coil section being related to the product of the number of turns and area of the other coil section so as to produce neutralizing magnetic fields at a distance.

14. An astatic transformer comprising two windings, similar parts of the filaments of said windings being wound with a substantially unity coupling therebetween, said windings comprising a plurality of coil sections wound in opposite directions to produce oppositely directed fluxes and being spaced apart a distance to produce a resulting self-inductance of substantial magnitude, the product of the number of turns and area of one coil section being related to the product of the number of turns and area of the other coil section so as to produce neutralizing magnetic fields at a distance, the said coil sections having windings of a size, number and arrangement to produce said resulting self-inductance of substantial magnitude combined with a small distributed capacity.

15. An astatic transformer comprising two windings, similar parts of the filaments of said windings being wound bifilarly, similar parts of the filaments of said windings being arranged in close juxtaposition throughout their lengths, said windings comprising a plurality of coil sections wound in opposite directions to produce oppositely directed fluxes and being spaced apart a distance to produce a resulting self-inductance of substantial magnitude, the said coil sections being spaced apart and the product of the number of turns and area of one coil section being related to the product of the number of turns and area of the other coil section so as to produce neutralizing magnetic fields at a distance.

Signed at New York, in the county of New York and State of New York, this 28th day of May, A. D. 1927.

LESTER L. JONES.