Oct. 7, 1958 J. P. KLEESPIES 2,855,571

INDUCTANCE DEVICE

Filed Nov. 22, 1955 3 Sheets-Sheet 1

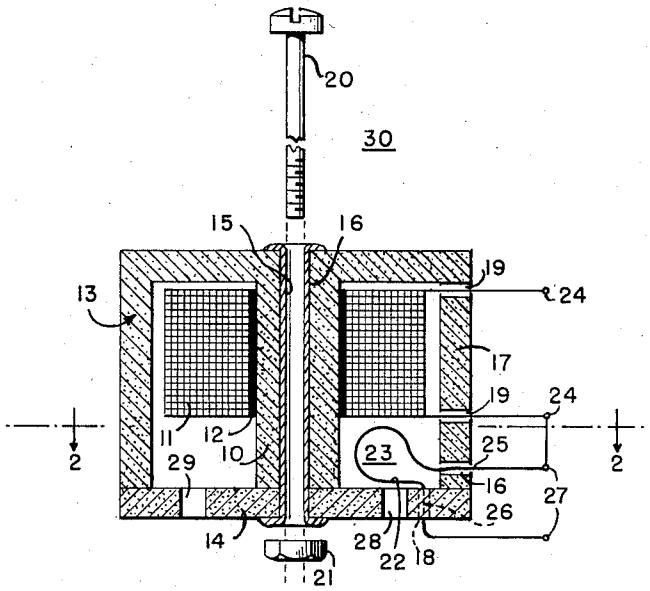


FIG.1

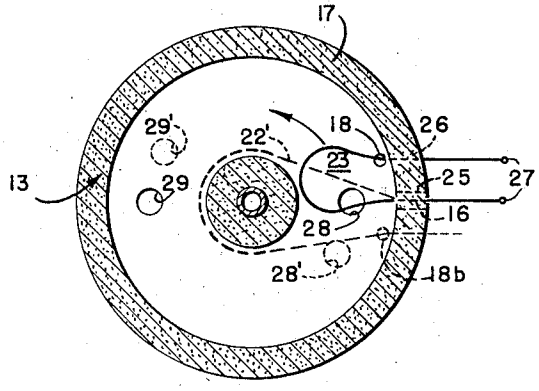


FIG.2

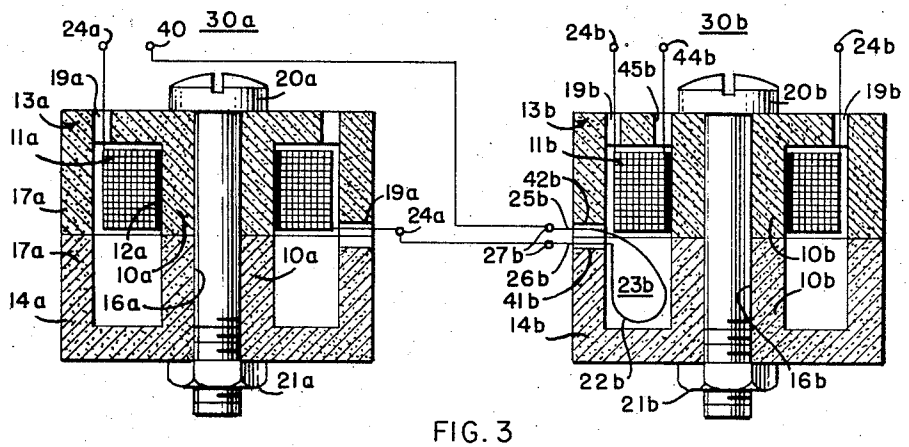

24a
40
30a
19a
20a
13a
11a
17a
12a
10a
16a
14a
21a
24b
30b
45b
44b
19b
20b
13b
11b
42b
25b
27b
26b
41b
14b
23b
22b
21b
16b
10b

FIG. 3

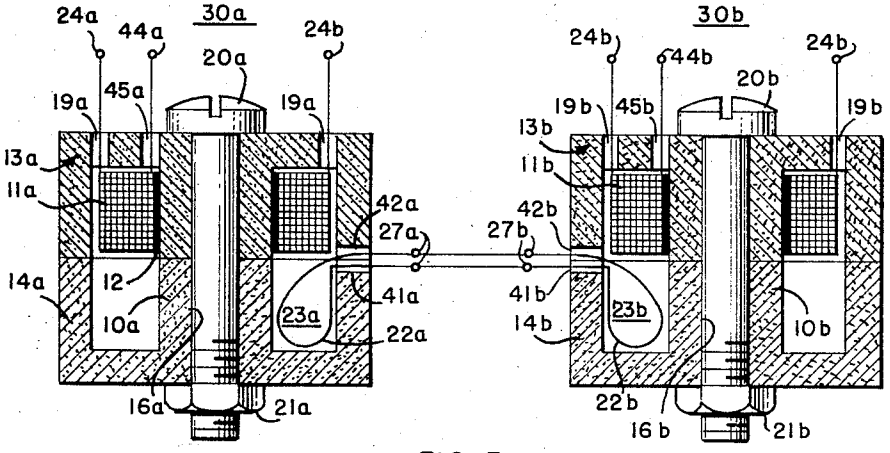

24a
44a
30a
24b
20a
19a
45a
13a
11a
42a
27a
14a
12
10a
23a
41a
22a
16a
21a
30b
44b
20b
19b
45b
13b
11b
42b
27b
41b
14b
23b
22b
16b
21b
10b

FIG. 5

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INDUCTANCE DEVICE

Filed Nov. 22, 1955 3 Sheets-Sheet 3

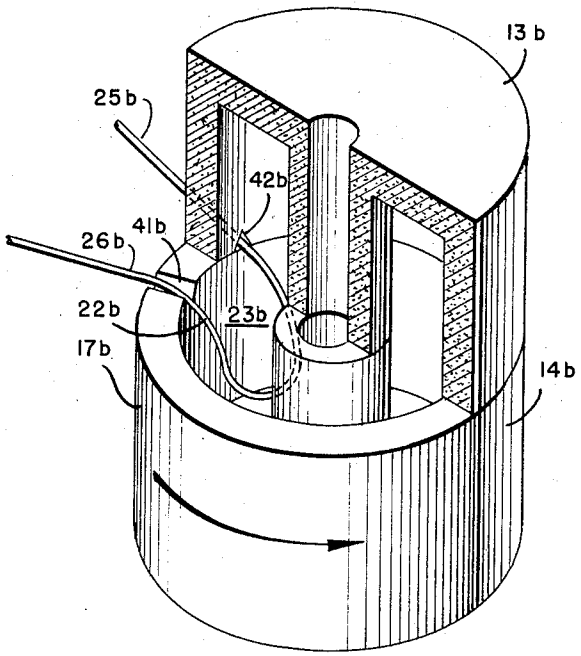


FIG.4

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2,855,571

INDUCTANCE DEVICE

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11 Claims. (Cl. 333—24)

General

The present invention is directed to adjustable inductance devices and, more particularly, to inductance devices such as high-frequency transformers wherein the inductive coupling between the winding portions thereof may be readily adjusted. While the invention is of general application, it has particular utility in connection with tunable high-frequency band-pass selector systems such as those employed in the intermediate-frequency amplifier stages of superheterodyne radio receivers.

The advent of transistorized radio receivers has made it desirable to employ therein electrical components such as intermediate-frequency transformers of a size which is in keeping with the small size of the transistors, thereby permitting an over-all reduction in the size of those receivers. Miniature intermediate-frequency transformers have made their appearance and, in general, have proved to be quite satisfactory. One prior such transformer employs a pair of similar cup-shaped members of magnetic material, the walls or skirts of the members enclosing re-entrant portions which serve as central core legs. The rims of the skirts are disposed in abutting relation as are also the free ends of the core legs. Primary and secondary windings are disposed about the core legs and are shielded by the skirts of the cup-shaped members from external electrical circuits. The ends of the core legs are tapered or beveled so that relative rotation of the cup-shaped members produces a wedge-like or spreading action between the core legs which changes the lengths of the air gaps and, hence, the effective spacings between the core legs and between the skirts of the members. This, in turn, alters the coupling inductance between the transformer windings and controls the tuning of the resonant circuits which include those windings. Another prior transformer is similar to the one described above but, instead of employing tapered ends on the contiguous core legs, it has a 120° segment at the rims of the skirts which is cut out to a depth of a small fraction of an inch. Relative rotation of the cup-shaped members alters the effective area of the air gap between the rims of the skirts and, in turn, adjusts the tuning of the circuit including the transformer.

Altering the inductance of such a transformer by varying the effective length of an air gap or air gaps in the transformer core structure presents a rather serious disadvantage in that as the saturation of the closed magnetic path of the transformer is changed, the figure of merit or Q of the transformer is likewise changed. Reductions as much as 35 percent in the Q of a transformer have been experienced in the minimum inductance position of the cup-shaped core members due to leakage from the air gaps. In transformers employing beveled ends on the contiguous core legs, special interlocking rims for the skirt portions of the closed magnetic path have been employed to reduce leakage and to increase the Q over the entire tuning range. Unfortunately, however, the cost of manufacturing cup-shaped core members with

the special interlocking portions is more costly because of the difficulty in fabricating the interlocking portions.

It is recognized that it is desirable from an operational standpoint to maintain the Q of an intermediate-frequency transformer substantially constant as the tuning of the transformer is adjusted by way of a change in inductance.

It is an object of the invention, therefore, to provide a new and improved adjustable inductance device or transformer which avoids one or more of the above-mentioned disadvantages and limitations of prior such transformers.

It is another object of the invention to provide a new and improved high-frequency transformer which is relatively simple in construction, easy to fabricate, and inexpensive to manufacture.

It is a further object of the invention to provide a new and improved high-frequency transformer which has a high degree of accuracy and readily reproducible performance characteristics.

It is an additional object of the invention to provide a new and improved high-frequency transformer, the inductance of which may be adjusted without greatly modifying the Q of the transformer.

In accordance with a particular form of the invention, an adjustable inductance device comprises a core of magnetic material and a winding disposed around that core. The device also includes a pair of cooperating members substantially completely enclosing the core and the winding, one of the members and at least one of the core and the other of the members having wire-confining means. The adjustable inductance device also includes a wire coupled in an electrical relation to the winding and having a loop portion between the cooperating members adjacent the core and having the other portions disposed within the wire-confining means. The adjustable inductance device additionally includes means for permitting relative movement between the aforesaid one of the members and the aforesaid at least one of the core and the other of the members about the axis of the core so that the wire-confining means shift the positions of the other portions of the wire and modify the geometry of the loop portion, thereby adjusting the inductance of the loop portion and the coupling between the winding and that loop portion.

For a better understanding of the present invention, together with other and further objects thereof, reference is had to the following description taken in connection with the accompanying drawings, and its scope will be pointed out in the appended claims.

Referring to the drawings:

Fig. 1 is a longitudinal sectional view of an adjustable inductance device embodying a particular form of the present invention;

Fig. 2 is a sectional view taken on the line 2—2 of Fig. 1;

Fig. 3 is a longitudinal sectional view of a high-frequency transformer in accordance with another form of the invention;

Fig. 4 is a perspective view, with portions broken away, of a portion of the transformer of Fig. 3, and

Fig. 5 is a longitudinal sectional view of a modified form of a high-frequency transformer.

Description of inductance device of Fig. 1

Referring now more particularly to Fig. 1, the adjustable inductance device 30 there represented comprises a core 10 of magnetic material such as a ferrite which has a very high permeability. A winding 11 is wound on an insulating form 12 which is disposed around the core 10 and ordinarily has an inductance approximately equal to a desired value. The pair of cooperating members 13

and 14 enclose the core 10 and shield it from the influence of external electrical circuits. Member 13 is cup shaped and may be of the same material as the core 10. The latter may be an integral re-entrant portion of the member 13. The member 14 may be a disc of suitable material which serves as a cover for the member 13 and its core. A suitable clamping means such as a hollow rivet 15 axially disposed in a central bore 16 in the core 10 maintains the members 13 and 14 in contiguous relationship as represented in Fig. 1. A bolt and nut assembly 20, 21 may be employed, if desired, to mount the Fig. 1 device on a suitable support such as a chassis. When the members 13 and 14 are of magnetic material like the core 10, the elements just mentioned form a closed magnetic path for flux developed by the winding 11.

One of the members 13 and 14 and at least one of the core 10 and the other of the members just mentioned has a wire-confining means. The wire-confining means in the member 13 is a passage or aperture 16 in the skirt portion 17 of the member while the corresponding means in the member 14 is an aperture 18. Apertures 19, 19 permit leads from the winding 11 to be connected to external circuits by way of terminals 24, 24.

The adjustable inductance device also includes a wire 22, preferably of a resilient material such as beryllium copper, coupled in electrical relation to the winding 11 and having a loop portion 23 in the space between the members 13 and 14 adjacent the core 10 and having two other portions 25 and 26 constituting the free ends of the loop 23 for coupling the latter to an external circuit by way of terminals 27, 27. By the term "coupled in electrical relation," as employed in the text and claims with reference to the wire 22, is meant that the wire is conductively or otherwise coupled to external circuits and is inductively or magnetically coupled to the core 10, or that one terminal of the wire is coupled to an external circuit while the other terminal thereof is coupled to one of the terminals 24, 24 of the winding 11. Such connections or couplings are of the type represented in Figs. 3 and 5 and the details thereof need not be considered at this time.

The adjustable inductance device further includes means for permitting relative movement, in particular rotation, between one of the members 13 and 14 and at least one of the core 10 and the other of the aforesaid members about the axis of the core so that the confiining means or apertures 16 and 18 serve to shift the relative positions of the other portions 25 and 26 of the wire 22 and modify the geometery of the loop portion 23, thereby adjusting the inductance of the loop portion and the coupling between the winding 11 and the loop portion. This means comprises the hollow rivet 15 and may also comprise a pair of tool-receiving apertures 28 and 29 in the cover 14.

Explanation of operation of inductance device of Fig. 1

In considering the operation of the device of Fig. 1, it will initially be assumed that the two adjacent terminals 24 and 27 are interconnected by a conductor and that the remote terminals 24, 27 are connected to an external electrical circuit. It will also be assumed that the winding 11 has an inductance approximately equal to a desired value and that it is desirable to adjust this inductance to that value. To this end, the cover 14 is rotated with reference to the cup-shaped member 13 by applying the fingers to the periphery of the member or by inserting a suitable tool in the apertures 28 and 29 and effecting a rotational displacement of the cover. In circuits operating at radio frequencies, it is not practicable to alter the flux density in the core 10 and the inductance of the device 30 because of the relatively small current flowing in the winding 11. However, the inductance of the device may be changed by modifying the geometry of the loop portion 23 by the rotation of the cover 14 in the manner mentioned above.

Referring now to Fig. 2, the initial position of the loop portion 23 is represented by the solid line loop associated with the confining means or apertures 16 and 18. When the cover 14 is rotated in the direction indicated by the arrow and the cup-shaped member 13 remains fixed, the wire-confining aperture 18 carries the end portion 26 of wire 22' in a counterclockwise direction. When the disc is rotated nearly 360°, the wire-confining aperture is shifted to the position represented by the dotted aperture 18*b*. It will be seen from the drawings that the loop portion 23 has been wrapped about the core 10 for about one turn. This operation takes up some of the slack in the wire 22' and is effective to couple the loop portion 23 more closely to the ferrite core 10. Since the loop portion 23 is now linked by a greater magnetic flux, the inductance of the loop portion is increased and this, in turn, increases the combined inductance of the inductance device including the winding 11 and that loop portion. Rotation of the cover 14 may be made in either direction until the combined inductance of the device has reached the desired value.

It will now be assumed that the adjacent terminals 24 and 27 are not interconnected as previously mentioned and that the terminals 24, 24 of winding 11 are connected to one electrical circuit and that the terminals 27, 27 of the coupling loop portion 23 are connected to another electrical circuit. It will also be assumed that it is desired to control the extent of the coupling between these two electrical circuits by way of modifying the geometry of the loop portion. To accomplish this, the disc is rotated from its last-mentioned position in either a clockwise or a counterclockwise direction until the desired coupling between the two external circuits is achieved by virtue of adjustment of the inductance of thte loop portion. Such adjustment does not significantly alter the inductance of the winding 11.

It will be apparent from the foregoing description and explanation that, since the winding 11 is substantially enclosed in a magnetic shield, that winding may be small and any tuned circuit in which the winding is connected will have relatively low losses and hence a high Q. Consequently, a high gain and a stable bandpass frequency characteristic may be procured from the receiver stages employing such an inductance device.

Description of Fig. 3 transformer

Referring now to Fig. 3 of the drawings, there is represented a high-frequency transformer comprising a pair of inductance devices 30*a*, 30*b* which are generally similar to the device 30 represented in Fig. 1. Accordingly, corresponding elements of the devices 30*a*, 30*b* are designated by the same reference numerals represented in Fig. 1 but with the respective suffixes "*a*" and "*b*." In lieu of a single cup-shaped member of magnetic material as in the Fig. 1 embodiment, the device 30*a* employs a pair of cup-shaped members 13*a* and 14*a* having their skirt portions 17*a*, 17*a* and their cores 10*a*, 10*a* in abutting relationship as represented. The inductance device 30*b* has similar cup-shaped members 13*b* and 14*b*. The device 30*a* does not include a coupling loop. However, one terminal 24*a* of the winding 11*a* is connected to a terminal 27*b* associated with the coupling loop portion 23*b* while the other terminal of the latter is adapted to be connected to an external circuit by way of a terminal 40. Portions 25*b* and 26*b* of the wire 22*b* which serves to form the coupling loop portion 23*b* pass through a pair of notches 41*b* and 42*b* which are cut in the skirt portions 17*b*, 17*b* of the magnetic shield members 13*b*, 14*b* as more clearly represented in Fig. 4. For some purposes, it may be desirable that the winding 11*b* include a center tap and this is represented by the terminal 44*b* connected to a suitable lead passing through an aperture 45*b* in the core member 13*b*.

Explanation of operation of Fig. 3 transformer

In considering the operation of the transformer of Fig. 3, it will be assumed that the pair of adjacent terminals **24***a* and **40** are coupled to a suitable circuit such as the output terminals of an intermediate-frequency amplifier tube and that the terminals **24***b*, **24***b*, and **44***b* are connected to the input terminals of a suitable succeeding intermediate-frequency amplifier stage. It will further be assumed that in order to transfer energy in the desired manner from the primary winding **11***a* to the secondary winding **11***b* of the transformer, it is desirable to adjust the coupling between the primary winding and the secondary winding to a desired value. This is quickly and conveniently accomplished by rotating the cup-shaped member **14***b* relative to the corresponding member **13***b* (in the manner which will be more easily understood by reference to Fig. 4) so that the notch or passage **41***b* angularly displaces the wire portion **26***b* with relation to the corresponding wire portion **25***b* associated with the loop portion **23***b*. In the manner explained in connection with the Fig. 1 embodiment of the invention, the geometry of the loop portion **23***b* is modified so that it is coupled with a greater portion of the closed magnetic path, thereby adjusting the inductance of the loop portion **23***b* and the coupling between the winding **11***b* and that loop portion. This, in turn, alters the extent of the coupling between the inductance device **30***a* or primary portion of the transformer and the secondary portion comprising device **30***b*. The closed magnetic paths of the transformer not only serve magnetically to shield the primary and secondary windings of the transformer from each other but also are effective to shield the windings from the influence of external electrical circuits. While the adjustment of the geometry of the loop portion **23***b* is effective to modify its inductance and the coupling between the winding **11***b* and that loop portion, this is not accomplished by a significant change in the inductance of winding **11***b*. This is particularly important where the winding **11***b* has a center tap since it is usually desirable to maintain an electrical balance in the two halves of that winding. As in the Fig. 1 embodiment of the invention, the air gap between the portions of the closed magnetic circuits is maintained substantially constant and no changes in the cross section of the magnetic path take place, thus permitting the circuits coupling the transformer of Fig. 3 to maintain a high Q.

Description and explanation of operation of transformer of Fig. 5

The transformer of the Fig. 5 embodiment of the invention is essentially the same as that represented in Fig. 3 and corresponding elements are designated by the same reference characters. The transformer of Fig. 5 differs from that of Fig. 3 in that a coupling loop portion is employed in each of the chambers formed by the pairs of cup-shaped members. The terminals **27***a*, **27***a* and **27***b*, **27***b* associated with the coupling loop portions **23***a*, **23***b* are interconnected so that link coupling exists between the devices **30***a* and **30***b*. If desired, both of the windings **11***a* and **11***b* may be center tapped as indicated, thus permitting the terminals **44***a* and **44***b* associated with the center taps to be connected to ground, if desired. The extent of the coupling between the primary winding **11***a* and the secondary winding **11***b* of the transformer may be varied in the manner explained above in connection with Fig. 3 by modifying the geometry of one or more of the loop portions **23***a* and **23***b*.

From the foregoing description, it will be apparent that the high-frequency transformer in accordance with the invention has an inductance which should be adjusted without greatly modifying the Q of the transformer. It will also be clear that a high-frequency transformer embodying the invention is simple in construction, easy to fabricate and to assemble, relatively inexpensive to manufacture, and has readily reproducible performance characteristics.

While there have been described what are at present considered to be the preferred embodiments of this invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and it is, therefore, aimed to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. An adjustable inductance device comprising: a core of magnetic material; a winding disposed around said core; a pair of cooperating members substantially completely enclosing said core and winding, one of said members and at least one of said core and the other of said members having wire-confining means; a wire coupled in an electrical relation to said winding and having a loop portion between said members adjacent said core and having two other portions disposed within said confining means; and means for holding while permitting relative movement between said one of said members and said at least one of said core and said other of said members about the axis of said core so that said confining means shift the positions of said other portions of said wire and modify the geometry of said loop portion, thereby adjusting the inductance of said loop portion and the coupling between said winding and said loop portion.

2. An adjustable inductanve device comprising: a core of magnetic material; a winding disposed around said core and having an inductance approximately equal to a desired value; a pair of cooperating members substantially completely enclosing said core and winding, one of said members and at least one of said core and the other of said members having wire-confining means; a wire electrically connected to said winding and having a loop portion between said members adjacent said core and having two other portions disposed within said confining means; and means for holding while permitting relative movement between said one of said members and said at least one of said core and said other of said members about the axis of said core so that said confining means shift the positions of said other portions of said wire and modify the geometry of said loop portion, thereby adjusting the combined inductance of said winding and said loop portion to said desired value.

3. An adjustable inductance device comprising: a core of magnetic material; a winding disposed around said core; a pair of cooperating members substantially completely enclosing said core and winding, one of said members and at least one of said core and the other of said members having wire-confining passages therethrough; a wire coupled in an electrical relation to said winding and having a loop portion between said members adjacent said core and having two other portions disposed within said confining passages; and means for holding while permitting relative movement between said one of said members and said at least one of said core and said other of said members about the axis of said core so that said confining passages shift the positions of said other portions of said wire and modify the geometry of said loop portion, thereby adjusting the inductance of said loop portion and the coupling between said winding and said loop portion.

4. An adjustable inductance device comprising: first and second members of magnetic material in contiguous relation and forming a closed magnetic path including a core; a winding disposed around said core; one of said members and at least one of said core and the other of said members having wire-confining means; a wire coupled in electrical relation to said winding and having a loop portion between said members adjacent said core and having two other portions disposed within said confining means; and means for holding while permitting relative

movement between one of said members and said at least one of said core and said other of said members about the axis of said core so that said confining means shift the positions of said other portions of said wire and modify the geometry of said loop portion, thereby adjusting the inductance of said loop portion and the coupling between said winding and said loop portion.

5. An adjustable inductance device comprising: a cup-shaped member of magnetic material including a re-entrant core and a cover for said member in contiguous relation therewith and forming a closed magnetic path; said member and said cover having wire-confining means; a winding disposed around said core; a wire coupled in electrical relation to said winding and having a loop portion in said member adjacent said core and having two other portions disposed within said confining means; and means for holding while permitting relative movement between said member and said cover about the axis of said core so that said confining means shift the positions of said other portions of said wire and modify the geometry of said loop portion, thereby adjusting the inductance of said loop portion and the coupling between said winding and said loop portion.

6. An adjustable inductance device comprising: first and second members of magnetic material in contiguous relation and forming a closed magnetic path including a core, said members having wire-confining means; a winding disposed around said core; a wire coupled in electrical relation to said winding and having a loop portion between said members adjacent said core and having two other portions disposed within said confining means; and means for clamping said members in said relation while permitting rotation therebetween about the axis of said core so that said confining means shift the positions of said other portions of said wire and modify the geometry of said loop portion, thereby adjusting the inductance of said loop portion and the coupling between said winding and said loop portion.

7. An adjustable inductance device comprising: first and second members of magnetic material in contiguous relation and forming a closed magnetic path including hollow cores, said members having wire-confining means; a winding disposed around at least one of said cores; a wire coupled in electrical relation to said winding and having a loop portion between said members adjacent said core thereof and having two other portions disposed within said confining means; and means extending through said hollow cores for clamping said members in said relation while permitting rotation therebetween about the axis of said core thereof so that said confining means shift the positions of said other portions of said wire and modify the geometry of said loop portion, thereby adjusting the inductance of said loop portion and the coupling between said winding and said loop portion.

8. A high-frequency transformer comprising: shielding means of magnetic material having a first chamber and including a first core of said material disposed in said chamber, and having a second chamber and including a second core of said material disposed in said second chamber; first and second covers of said material for corresponding ones of said chambers which with said shielding means and said cores form closed magnetic paths; a first winding in said first chamber disposed around said first core; a second winding in said second chamber disposed around said second core; wire-confining means in said second cover and said shielding means; a wire in said second chamber coupled in electrical relation to said second winding and having a loop portion adjacent said second core and having two other portions within said confining means; means for coupling said first winding to said other portions of said wire; and means for holding while permitting relative movement between said shielding means and said second cover about the axis of said second core so that said confining means shift the positions of said other portions of said wire and modify the geometry of said loop portion, thereby adjusting the inductance of said loop portion and the coupling between said first and second windings.

9. A high-frequency transformer comprising: shielding means of magnetic material having a first chamber and including a first core of said material disposed in said chamber, and having a second chamber and including a second core of said material disposed in said second chamber; first and second covers of said material for corresponding ones of said chambers which with said shielding means and said cores form closed magnetic paths; a first winding in said first chamber disposed around said first core; a second winding in said second chamber disposed around said second core; wire-confining means in said second cover and said shielding means; a wire in said second chamber coupled in electrical relation to said second winding and having a loop portion adjacent said second core and having two other portions within said confining means; means including a coupling loop in said first chamber adjacent said first core for coupling said first winding to said other portions of said wire; and means for holding while permitting relative movement between said shielding means and said second cover about the axis of said second core so that said confining means shift the positions of said other portions of said wire and modify the geometry of said loop portion, thereby adjusting the inductance of said loop portion and the coupling between said first and second windings.

10. A high-frequency transformer comprising: a first shielding means of magnetic material having a first chamber and including a first core of said material disposed in said chamber; a second shielding means of said material having a second chamber and including a second core of said material disposed in said second chamber; a first winding in said first chamber disposed around said first core; a second winding in said second chamber disposed around said second core; first and second covers of said material for corresponding ones of said chambers which with said shielding means and said cores form closed magnetic paths; wire-confining means in said second cover and said second shielding means; a wire in said second chamber coupled in electrical relation to said second winding and having a loop portion adjacent said second core and having two other portions within said confining means; means for coupling said first winding to said other portions of said wire; and means for holding while permitting relative movement between said second shielding means and said second cover about the axis of said second core so that said confining means shift the position of said wire and modify the geometry of said loop portion, thereby adjusting the inductance of said loop portion and the coupling between said first and second windings.

11. A high-frequency transformer comprising: a first cup-shaped shielding means of magnetic material including a first core of said material disposed in the chamber of said means; a second cup-shaped shielding means of said material including a second core of said material disposed in the chamber of said second means; a first winding in said first-mentioned chamber disposed around said first core; a second winding in said second-mentioned chamber disposed around said second core; first and second covers of said material for corresponding ones of said chambers which with said shielding means and said cores form closed magnetic paths; wire-confining means in said second cover and said second shielding means; a wire in said second chamber coupled in electrical relation to said second winding and having a loop portion adjacent said second core and having two other portions within said confining means; means for coupling said first winding to said other portions of said wire; and means for holding while permitting relative movement between said second shielding means and said second cover about the axis of said second core so that said confining means shift the position of said wire and modify the geometry of said loop portion, thereby adjusting the inductance of said loop

portion and the coupling between said first and second windings.

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