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HIGH-FREQUENCY COIL

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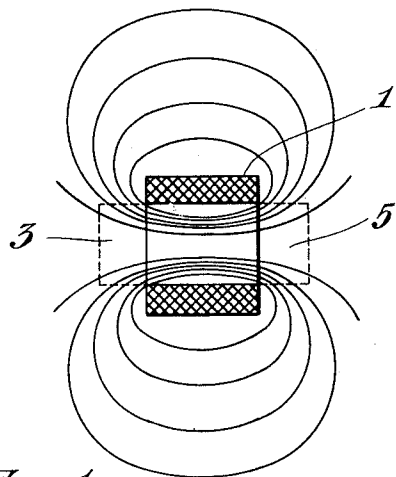


Fig. 1.

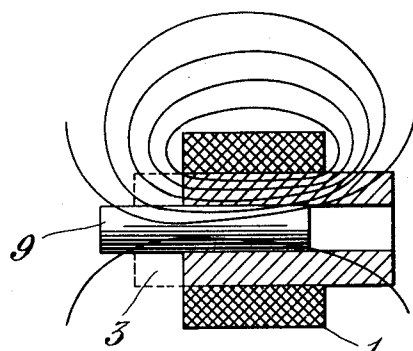


Fig. 2.

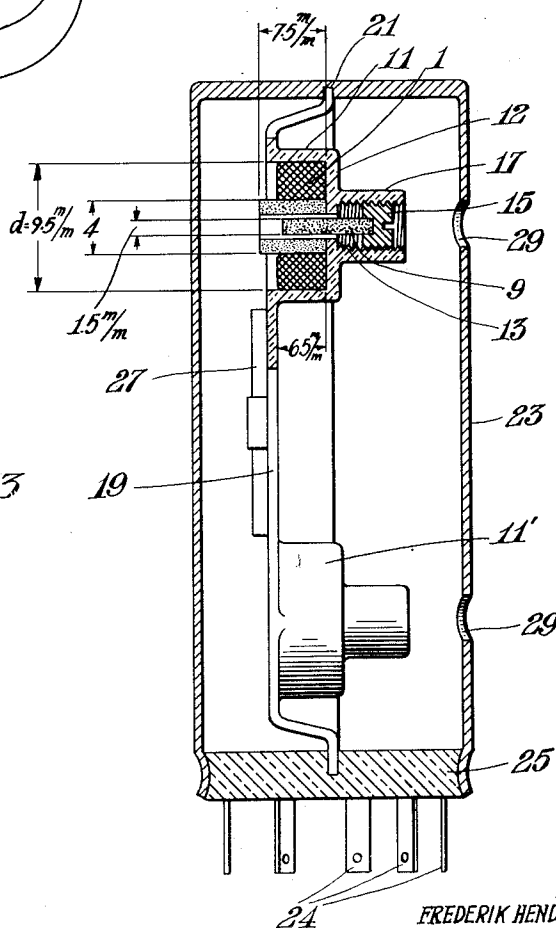


Fig. 3

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HIGH-FREQUENCY COIL

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The invention relates to a high-frequency coil having arranged in its central aperture an axially perforated bar-shaped core of high-frequency iron in which a plunger of high frequency iron serving for the variation of the inductance is slidably arranged.

The term "high-frequency iron" is to be understood to include any ferromagnetic material which, even at high frequencies, exhibits low losses.

Such a coil is known from British specification 433,366, both the core and the plunger being made of moulded iron powder (mutually insulated iron particles).

According to the invention it has been found that if the flanges of the coil described in this specification were made of insulating material the coil would not be effective, since the inductance variation liable to be achieved by moving the plunger is only very slight.

According to the invention it has been found that, as will be explained more fully hereinafter, this is due to the comparatively low permeability (10 to 20) of the high-frequency iron used. According to the invention satisfactory results are obtainable if at least the core and preferably also the plunger are made of high-frequency iron having a permeability (μ) of at least 100, whilst the end of the core from which the plunger can be moved out projects from the coil winding for not more than a length equal to half the diameter of the core. Sintered ceramic ferromagnetic material, for example, certain kinds of ferrite, particularly suits the purpose. Such materials have a μ of approximately 400.

In order that the invention may be more clearly understood and readily carried into effect, it will now be described more fully with reference to the accompanying drawing, in which:

Figs. 1 and 2 illustrates the effect obtained by the invention;

Fig. 3 shows, by way of example, one form of coil according to the invention as used in a coil system.

The inductance L of a coil may be represented by the formula:

$$L = \frac{Kn^2}{R_m}$$

in which K is a constant, n the number of turns and R_m the reluctance of the circuit of lines of force of the coil. This reluctance is known to depend on the length and the section of the circuit of lines-of-force and on the permeability μ of the material contained therein.

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Fig. 1 shows the field of the lines of force of a coil winding 1 without core, in which a current flows. As is well-known the lines of force are greatly concentrated in the central aperture of the winding and the greater part of the reluctance is concentrated in this aperture and in the two immediately adjoining zones 3 and 5 shown in dotted lines in Fig. 1 on either side of the winding 1. The part of the magnetic circuit embraced by the winding 1 and the outer dotted lines comprise from 80 to 90% of the total reluctance. Provision of ferromagnetic material (material of low reluctance, for example moulded iron powder) in this part of the field permits of the total reluctance R_m of the circuit being reduced to a fraction and the inductance of the coil being materially increased.

Assuming 90% of the reluctance concentrated in the coil aperture and the total reluctance to be 100 arbitrarily chosen units, the reluctance in the coil aperture may be denoted 90 and the reluctance external to the coil 10 units. If a dust core (μ about 15) is arranged in the coil, the reluctance in situ becomes $90/15=6$ and the total reluctance $10+6=16$ units. The inductance is thus increased by a factor

$$\frac{100}{16} = 6$$

If the core comprises a tubular core portion and a plunger fitting it, as described in the British specification 433,366, the core section may be reduced, for example by 20%, by pulling out the plunger and hence the reluctance of the core may be increased from 6 to 7.5. The total reluctance of the magnetic circuit is thus increased from 16 to 17.5, so that in this case the inductance would be expected to decrease by more than 8.5%

However, measurement reveals that the variation is substantially smaller. This will be explained more fully with reference to Fig. 2.

Referring to Fig. 2, the central aperture of the coil winding 1 receives a perforated core 7 of high-frequency iron in which a fitting plunger 9 of the same material is adapted to move. At one of its ends the core 7 does not project from the coil winding 1, but the plunger 9 may be pulled out from the same core end.

Since the core 7 does not fill the zone 3 of high concentration of lines of force, the inductance of the coil with entirely introduced plunger 9 is materially smaller than in the case of the zone 3 being filled completely by the core iron. Moving out the plunger 9 permits of the inductance being

increased, since part of the lines of force, as is shown, tends to make their way through the plunger, whereas the remaining part is concentrated to a less marked extent. The greater the extent to which the plunger is moved out, the more is decreased the concentration of the lines of force in the zone 3 and the reluctance thus decreases.

From the foregoing it will be understood that the arrangement according to British specification 433,366, gives rise to two adverse effects which largely balance one another and hence this arrangement does not permit of satisfactory results being achieved.

This is permitted by an arrangement in which the effect aimed at in the British specification is achieved alone. Such arrangements are known, for example, from the British specifications 449,450 and 450,286 and from Swiss specification 182,818, the ends of the core being provided with flanges of high-frequency iron. It is immediately apparent from the foregoing that with these arrangements concentration of the lines of force issuing from the core is out of the question. Consequently, on the core being moved out the inductance will be decreased owing to the decrease in diameter of the core.

The present invention takes another course, that is to say making use of the concentration of the issuing lines of force adjacent one of the core ends (or both), whilst at the same time avoiding decrease in inductance due to reduction in cross-sectional area of the core. The latter purpose is attained by using core material having a μ of at least 100, preferably sintered ceramic high-frequency iron, such as ferrite, which has a μ of approximately 400. If in this case conditions are such that the reluctance (without core) in the coil aperture and in the adjoining zones 3 and 5 is 90 units and outside 10 units, provision of a core having a μ of 100 will have the effect of reducing the reluctance in the area occupied to $90/100=0.9$ and the total reluctance to $10+0.9=10.9$. Reduction of the iron section by 20% will cause the total reluctance to assume a value of $10+5/4 \times 0.9=11.12$, a variation of only 2%, whereas with a μ of about 400 this variation is approximately 0.5 only. This increase in reluctance is negligible as compared with a decrease of, for example, 30% owing to the moving out of the plunger into a zone of concentrated lines of force.

According to the invention, it has been found that the increase in inductance thus obtainable continues until the plunger 9 is moved out beyond the zone 3, so that gradual and smooth control of the inductance is possible up to, say, 15% above the minimum value with completely inserted plunger. An even larger variation, but a lower maximum inductance is obtained if the front surface of the core is arranged at some depth within the coil aperture. It has, however, also been found that, if the core already projects for a length of more than half the core diameter from the coil winding 1 no substantial variation of the inductance is obtained by moving out the plunger, the zone 3 being already "filled" by the core, so that appreciable concentration of the lines of force outside the core 7 no longer occurs. It is evident that in this case moving out of the plunger is very little effective.

A practically serviceable control range also is not obtained if the core is made of material having a low μ , for example pulverulent iron, but reduction of the iron sectional area on the

plunger being moved out is obviated, for example, by the use of a long plunger, the core being proportioned in accordance with the invention. In this case the effect described occurs, it is true, but it does not occur to a sufficient extent to be appreciable in practice.

A tubular ferrite core and a plunger arranged therein have been suggested before per se for the purpose of correcting the divergences from the μ -value occurring in manufacture, the plunger being set tightly in the core prior to arrangement of the core in the coil.

Based on a further principle is the coil according to French specification 921,324, which is provided with an open ferromagnetic sheath, the core also being perforated and receiving a plunger. In this case the lines of force emanating from the core ends each extend in a radial direction to the opposite point on the inside of the sheath and are, consequently all of the same length, among them those emanating from the moved-out plunger. It is here practically not material how far the core extends beyond the coil, so long as the moved-out plunger is internal or substantially internal to the sheath. Owing to the presence of the ferromagnetic sheath this coil is considerably more costly than the coil according to the invention and occupies more space.

Fig. 3 shows a particularly expedient, structural form of a coil system comprising two relatively coupled coils according to the invention, said coils corresponding, as far as the shape of their active parts is concerned, to the coil shown in Fig. 2. In the construction shown in Fig. 3, the winding 1 is fixed in position, for example by cement, within a fitting cylindrical housing 11, which may be made of moulding material. The head surface of the winding 1 and the end of the core 7 the head surface of which coincides with the head surface of the winding 1 engage the bottom wall 12 of the housing 11. Recessed in this bottom is a central aperture 13 for the passage of the plunger 9. The end of this plunger is fixed in a short screw bolt 15 of non-magnetic moulding material which is adapted to be screwed into an external tubular extension 17 of the bottom wall 12. The cylindrical housing 11 together with the housing 11' of the second coil is moulded to be integral with an elongated plate 19 comprising a trough-like recess and serving to support the two coils, the coil axes being at right angles to the carrier plate. One of the ends of the plate 19 enters a fitting recess 21 in the top surface of a metal screening box 23, whereas the other end of the plate 19 is received in a similar recess in the insulating foot 25 of the coil system, which foot is provided with connecting tags 24. The box 23 is provided with apertures, which permit of the cores 9 being adjusted by a screw driver.

The plate 19 also serves to keep the supply wires from the connecting tags 24 to the two coils separated one from another. This is desirable, since in many cases, for example if the coils are used as intermediate-frequency band-pass filter in a superheterodyne receiver, the coils have different direct-voltage potentials. The plate 19, which divides the box 23 in two parts, ensures that connecting wires conveying different voltages cannot contact one another and keep them sufficiently spaced apart, so that the capacity between the wires is maintained within permissible limits.

The coils are magnetically coupled with one

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another by means of a thin rod 27, preferably also of ferrite, which conveys part of the lines of force from one coil to the other. The rod 27 is secured to the plate 19, for example by means of a piece of gummed tape. A choice of the length or the position of this rod permits of the coupling of the coils being adjusted to the proper values.

The dimensions of the winding and of the core are indicated in Fig. 3 in mms.

The core and the plunger are preferably made of sintered (ceramic) ferromagnetic high-frequency iron, for example ferrite of the kind described in French specification 887,083. This material has a very high permeability (approximately 400). This ensures that in spite of its small iron section the thin plunger has a low reluctance. This is desirable, since otherwise the moved-out plunger would be traversed by a small flux of lines of force only and the inductance could be enhanced only slightly by the displacement. Furthermore, ferrite is a comparatively rigid material which lends itself readily to use in the manufacture of cores and plungers of the very small size indicated.

When using ferrite—which is of high conductive resistance—as the core material it is possible to wind the coils directly on the core without any particularly intermediate insulating layer, preferably in meander fashion, it being thus not necessary for the coil to have stay flanges. This has several advantages; there is no need for a coil former and this furthermore enables the coil winding to be of a minimum size and hence the loss resistance to be of minimum value. During the winding operation the two core ends must, however, project by at least 1 mm. from the coil in order to prevent the wire from running off the core. According to the invention it has, however, been found that, subsequent to impregnation of the coil, the aggregate of coil and core being immersed in an impregnating agent, for example wax, it is directly possible to push the core into the coil until one of the core ends is located in a front surface of the coil.

What we claim is:

1. A high-frequency inductance coil comprising a fixed generally bar-shaped substantially flangeless core having an axial bore therein and having a given diameter, a generally cylindrical coil winding on said core and so positioned thereon that one end of said core projects a distance beyond one end of the coil which is less than one-half said given diameter, and a plunger of high-frequency iron material inserted into the bore in said core in the said one end thereof and movable therein to increase the inductance of the coil when the plunger is moved out of the core, said core consisting of a high-frequency iron material having a magnetic permeability of at least 100.

2. A high-frequency inductance coil comprising a fixed generally bar-shaped substantially flangeless core having an axial bore therein, a generally cylindrical coil winding on said core and so positioned thereon that one end of the core is disposed within one end of the coil and the other end of the core extends beyond the other end of the coil, and a plunger of high-frequency iron material inserted into the bore in said core at the said one end thereof and movable therein to increase the inductance of the coil when the plunger is moved out of the core, said core consisting of a high-frequency iron material having a magnetic permeability of at least 100.

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3. A high-frequency inductance coil comprising a fixed generally bar-shaped substantially flangeless core having an axial bore therein, a generally cylindrical coil winding on said core and so positioned thereon that one end of the core is disposed within one end of the coil and the other end of the core extends beyond the end of the coil, and a plunger of high-frequency iron material inserted into the bore in said core at the said one end thereof and movable therein to increase the inductance of the coil when the plunger is moved out of the core, said core consisting of a sintered ceramic ferromagnetic material having a magnetic permeability of approximately 400.

4. A high-frequency inductance coil comprising a fixed generally bar-shaped substantially flangeless core having an axial bore therein, a generally cylindrical coil winding on said core and so positioned thereon that one end of the core is disposed within one end of the coil and the other end of the core extends beyond the other end of the coil, and a plunger inserted into the bore in said core at the said one end thereof and movable therein to increase the inductance of the coil when the plunger is moved out of the core, said core and said plunger consisting of a sintered ceramic ferromagnetic material having a magnetic permeability of approximately 400.

5. A high-frequency inductance coil comprising a fixed generally bar-shaped substantially flangeless core having an axial bore therein, a generally cylindrical coil winding directly on said core without an intermediate insulating layer between the coil winding and the core, and so positioned thereon that one end of the core is disposed within one end of the coil and the other end of the core extends beyond the other end of the coil, and a plunger inserted into the bore in said core at the said one end thereof and movable therein to increase the inductance of the coil when the plunger is moved out of the core, said core and said plunger consisting of a sintered ceramic ferromagnetic material having a magnetic permeability of approximately 400.

6. A high-frequency coil system comprising two coils mounted spaced apart on a plate of insulating material, each of said coils comprising a fixed generally bar-shaped substantially flangeless core having an axial bore therein, a coil winding directly on said core without an intermediate insulating layer between the winding and the core and so positioned thereon that one end of the core is disposed within one end of the coil and the other end of the core extends beyond the other end of the coil, a plunger inserted into the bore in the core at the said one end thereof, said core and said plunger consisting of a sintered ceramic ferromagnetic core material having a magnetic permeability of approximately 400, said coils being mounted perpendicular to the mounting plate and parallel to one another.

7. A high-frequency coil system comprising two coils mounted spaced apart on a plate of insulating material, each of said coils comprising a fixed generally bar-shaped substantially flangeless core having an axial bore therein, a coil winding directly on said core without an intermediate insulating layer between the winding and the core and so positioned thereon that one end of the core is disposed within one end of the coil and the other end of the core extends beyond the other end of the coil, a plunger inserted into the bore in the core at the said one

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end thereof, said core consisting of a sintered ceramic ferromagnetic core material having a magnetic permeability of approximately 400, said coils being mounted perpendicular to the mounting plate on the same side thereof and parallel to one another, and a metal screening envelope surrounding the coil system having a base support in one end thereof, the insulating mounting plate fitting into recesses in the envelope and the base support for dividing the screening envelope into two portions.

8. A high-frequency coil system as claimed in claim 7 including connecting lead wires for the coils, the mounting plate for the coils serving to separate the connecting leads for the coils.

9. A high-frequency coil system as claimed in claim 7 including a rod of sintered ceramic ferromagnetic core material for magnetically coupling the cores of the two coils.

10. A high-frequency coil system as claimed in claim 7 including means to position the plunger in the core of each coil, said means comprising a tubular projection of said mounting plate provided with a threaded recess for receiving a threaded head of the plunger.

11. A high-frequency coil system as claimed in

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claim 7 in which the mounting plate is indented to receive the coils.

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