Dec. 15, 1936. H. VOGT 2,064,771

HIGH FREQUENCY COIL

Filed June 8, 1933

Fig. 1.

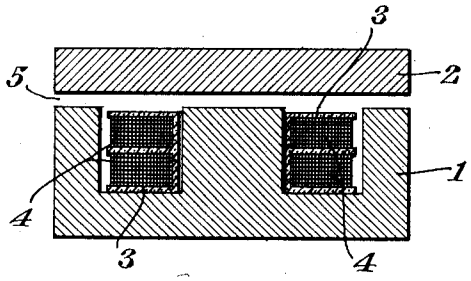


Fig. 2.

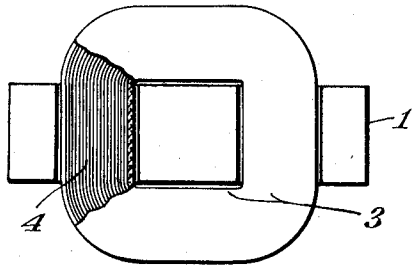


Fig. 3.

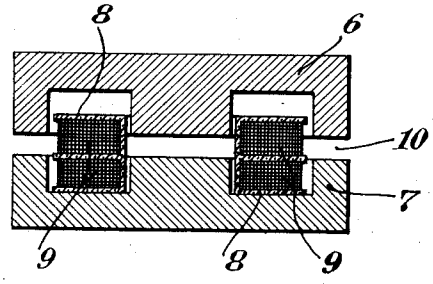
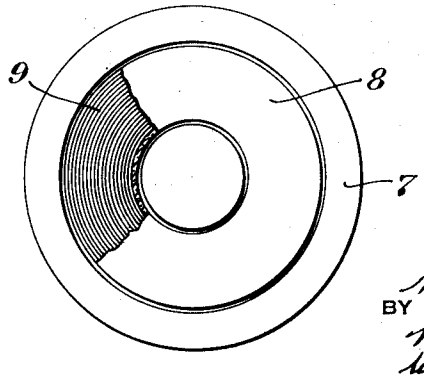


Fig. 4.



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UNITED STATES PATENT OFFICE

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HIGH FREQUENCY COIL

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Application June 8, 1933, Serial No. 674,847
In Germany February 6, 1933

16 Claims. (Cl. 175—356)

This invention relates to inductance coils for high frequency use, more particularly to high frequency coils for oscillatory circuits in broadcast receivers. The main object of the invention is, to enable the construction of an iron cored high frequency coil of minimum size, small stray field, minimum losses, and minimum price.

Other objects of the invention are, to facilitate the manufacture and fitting of iron cored tuning coils and to reduce the core weight of iron cores in tuning coils of broadcast receivers which, due to the precious core materials required for high frequency use, will mean an enormous reduction in the cost of production of such coils.

The invention relates to an iron cored high frequency coil for broadcast receivers, the windings of which are arranged in form of a compact very small cylindrical multi-layer bobbin. The total thickness of the several superposed layers is approximately equal to the length of the bobbin, so that a compact coil of minimum size is formed. The bobbin is separated from the core on which it is wound by an intermediate layer of insulating material of low high frequency losses.

In one embodiment of the invention the insulating material forms a coil former having several chambers in which the windings are fitted and evenly distributed.

It is known to use an iron core composed of small insulated particles for a high frequency coil. The iron cored high frequency coils hitherto in use, however, still are rather bulky and consist of toroid coils, same as used in the Pupin coil technique, of a diameter of about 5 cm. and a core of 60 g. weight on which the windings are fitted in a single layer and wound with considerable distance between the turns.

Apart from the advantage of smaller size and from constructional arrangement of a high frequency coil according to the invention, it offers the advantage that the length of the magnetic path due to the small size of the bobbin can be reduced to a minimum and in addition the magnetic cross section can be enormously reduced, whereby the size and weight of the core are reduced again. It has been possible to reduce the weight of the core from 60 g. as the known toroid coils to about 15 g. without detrimentally affecting the losses of the coil. On the contrary, the losses are reduced simultaneously with the weight. This enormous reduction of the core weight and size has been possible by reducing the length of the magnetic path as mentioned above and in addition is based on the observation that the magnetic load in broadcast receiver coils is extremely low, so that saturation effects, which may cause distortion, will not occur although the magnetic cross section is so enormously reduced. In fact, the limit of the reduction in size of the coil is determined by manufacturing considerations only (too small coils are difficult to make) and by the necessary minimum winding space.

Due to the reduction of the core cross section, the length of the copper path (average length of one winding around the core) is likewise reduced, whereby the copper losses are reduced also.

An embodiment of the invention is illustrated by way of example in the accompanying drawing in which:—

Fig. 1 shows in section a high frequency coil with rectangular core.

Fig. 2 is a top plan view of Fig. 1, partly in section.

Fig. 3 shows in cross section a high frequency coil with cylindrical core.

Fig. 4 is a top plan view of the Fig. 3, partly in section.

The coil in Fig. 1 consists of a divided magnet core 1, 2, windings 4 and a coil former 3 of insulating material, comprising two chambers and separating the windings 4 from the core 1, 2. The distance between core and winding should be about 1 mm. to prevent detrimental electrostatic effects.

The magnetic core parts 1, 2 consist of pure iron, carbonyl iron, silicon iron or nickel iron alloys, i. e., preferably alloys having low hysteresis and low eddy current losses at weak high frequency fields, in powder form. The particle size should be 0.5×10^{-7} to 0.6×10^{-4} mm^3 and the particles should preferably have spherical shape or rounded corners as obtained by mechanical disintegration and rounding (for instance in a ball mill), by a chemical process (by precipitation), by separation from the gas phase (carbonyl iron), or by reduction from the oxides. The particles are coated with an insulating skin which is produced by oxidizing, other chemical treatment or by coating with a varnish-like or glass-like insulating skin. Very often the particles already possess a tenuous natural insulating skin, which may be sufficient, otherwise the oxidizing may be effected by gradually heating the powder to a temperature of 300° to 400° C., for example in a rotary tube furnace.

The magnetic particles are solidified to form a core by means of an insulating binder which is chemically neutral with respect to the other components of the mixed core material. Varnish-like substances of high viscosity may be used which

are solidifying by evaporating of the solvent (for instance solutions of nitrocellulose, colophonium, resin and the like) or binding agents may be employed which are liquid in hot state, such as paraffin, ceresin and the like, the melting point of which should amount to 50 to 100° C. or more.

The cores are produced by mixing the magnet powder with the insulating binder and filling the mixture into molds in which it is dried or cooled down and thus solidified. In this way, a core is obtained having a permeability of from 5 to 18 which is best suited for the frequency range used in broadcasting. The permeability is calculated in the conventional manner for a standard core of L=200 microhenrys in toroid shape, having 42 mm. outer and 19 mm. inner diameter and 12 mm. height, with evenly distributed wire winding, using the well-known formula

$$L=4\pi\mu.n^2.\frac{g}{l_e}$$

(L=inductance in cm., μ=permeability, n=number of turns, g=magnetic cross-section, l_e=length of magnetic path).

In order to prevent subsequent change of permeability it is advisable to subject the cores produced as described to a subsequent heat treatment, for example in case of a core which is solidified by means of a drying binder, to heat said core to about 70 to 80° C. for about 48 hours. It is also possible to gently press the core, however, so much only that the insulating skin is not injured and the permeability remains within said range from 5 to 18.

The bobbin **4** is made of finely divided wire (stranded wire) the single filaments of which are insulated from each other and twisted. A stranded wire having 20 to 40 insulated filaments of 0.04 to 0.07 mms. diameter each effects an exceedingly high reduction of the copper losses in the frequency range of 500 to 1,500 kilocycles.

The bobbin is wound turn close to turn in several superposed layers, a compact coil being thus formed, the length of which is approximately equal to the total thickness of the superposed layers, the cross section of the turns approximating a square shape.

The windings are separated from the core by an intermediate layer of insulating material which is represented by the coil former **3**. The coil former is subdivided into two chambers in which the windings are evenly distributed. The material of the coil former should have a low dielectric constant below 3 and a loss angle indicating the dielectric losses of tg δ lower than 0.001; for instance a hydrocarbon product known under the name of "Trolitul" may be used, which is easy to mold by spraying and has a dielectric constant of 2.5 and a loss angle of tg δ=0.0002.

The winding is arranged on the medium limb of the core and is situated between the exterior limbs of the core so that a core of the shell type is formed. In order to obtain a magnetic path of minimum length, the cross section of the bobbin is approximately a square and surrounded by the core on the shortest possible path.

In order to facilitate the fitting of the winding **4** which is automatically wound on the coil former **3**, the core is composed of two parts **1** and **2** between which a variable air gap **5** remains by variation of which the inductance of the coil may be matched during manufacture or subsequently, for instance in the manner disclosed and claimed in my copending application Serial No. 674,848, filed June 8, 1933.

The core in Figs. 3 and 4 consists of two cylindrical core parts **6**, **7** of symmetrical shape. In the adjacent surfaces of these parts an annular groove is formed in which the winding **9** of stranded wire fitted on the coil former **8** is accommodated. The air gap **10** between the core parts serves for matching the inductance. A coil of this kind has an even smaller stray field than that shown in Figs. 1 and 2.

It should be noted that the coil shown in Figs. 1 to 4 is shown on enlarged scale compared with the real dimensions. The bobbin diameter of a normal tuning coil for broadcast receivers, having an inductance of about 200 microhenrys (for 500 to 1,500 kilocycles frequency range) is less than 2 cms. and the bobbin is 0.5 to 1.5 cms. high and consists of 60 to 70 turns of stranded wire of 20 to 40 insulated filaments of 0.04 to 0.07 mm. diameter, each fitted in several layers and in several chambers on the coil former. The magnet core having a permeability of about 12 has a cross section of about 1.5 cm.^{2} and a magnetic path about 5 cms. long and it weighs 15 gs. In spite of its miniature size, this coil has a low logarithmic damping decrement of δ=0.024 at 1000 kilocycles.

I claim:

1. A highly selective radio frequency inductance element, having a high ratio of reactance to effective resistance, for use in tuned radio receiver circuits, resonant at frequencies above 150 k. c. including a ferro-magnetic core comprising magnetic powder having a particle volume smaller than $.6\times10^{-4}$ mm.^{3}, said magnetic particles being substantially insulated from one another and distributed throughout an insulating binder to provide a permeability higher than air but lower than 18, and a multi-turn multi-layer winding having a low capacity arrangement of turns and closely surrounding said core, and having an average length of turn not greater than 6 cm., the magnetic cross-section of the portion of said core within said winding not substantially exceeding 1.5 cm.^{2}, said winding being concentrated and having a radial depth sufficiently approximating its axial length, to accommodate the winding within a substantially minimum attainable length of magnetic flux produced by and encircling said winding.

2. A highly selective radio frequency inductance element, having a high ratio of reactance to effective resistance for use in tuned radio receiver circuits, resonant at frequencies above 150 k. c., including a ferro-magnetic core comprising substantially round magnetic particles having a volume smaller than $.6\times10^{-4}$ mm.^{3}, said magnetic particles being substantially insulated from one another and distributed throughout an insulating binder to provide a permeability higher than air but lower than 18, and a multi-turn multi-layer winding having a low capacity arrangement of turns and closely surrounding said core, and having an average length of turn not greater than 6 cm., the magnetic cross-section of the portion of said core within said winding not substantially exceeding 1.5 cm.^{2}, said winding being concentrated and having a radial depth sufficiently approximating its axial length, to accommodate the winding within a substantially minimum attainable length of magnetic flux produced by and encircling said winding.

3. A highly selective radio frequency inductance element, having a high ratio of reactance to effective resistance, for use in tuned radio receiver circuits, resonant at frequencies above

150 k. c. including a ferro-magnetic core comprising magnetic particles having a volume smaller than $.6\times10^{-4}$ mm.^{3}, said magnetic particles being substantially insulated from one another and distributed throughout an insulating binder to provide a permeability of the order of 12, and a multi-turn multi-layer winding having a low capacity arrangement of turns and closely surrounding said core, and having an average length of turn not greater than 6 cm., the magnetic cross-section of the portion of said core within said winding not substantially exceeding 1.5 cm.^{2}, said winding being concentrated and having a radial depth sufficiently approximating its axial length, to accommodate the winding within a substantially minimum attainable length of magnetic flux produced by and encircling said winding.

4. A highly selective radio frequency inductance element, having a high ratio of reactance to effective resistance, for use in tuned radio receiver circuits, resonant at frequencies above 150 k. c. including a ferro-magnetic core comprising magnetic particles having a volume smaller than $.6\times10^{-4}$ mm.^{3}, said magnetic particles being substantially insulated from one another and compacted with an insulating binder under pressure to provide a permeability higher than air but lower than 18, and a multi-turn multi-layer winding having a low capacity arrangement of turns and closely surrounding said core, and having an average length of turn not greater than 6 cm., the magnetic cross-section of the portion of said core within said winding not substantially exceeding 1.5 cm.^{2}, said winding being concentrated and having a radial depth sufficiently approximating its axial length, to accommodate the winding within a substantially minimum attainable length of magnetic flux produced by and encircling said winding.

5. A highly selective radio frequency inductance element, having a high ratio of reactance to effective resistance, for use in tuned radio receiver circuits, resonant at frequencies above 150 k. c. including a ferro-magnetic core comprising small magnetic particles, said magnetic particles being substantially insulated from one another and distributed throughout an insulating binder to provide a permeability higher than air but lower than 18, and a multi-turn multi-layer winding having a low capacity arrangement of turns and closely surrounding said core, and having an average length of turn not greater than 6 cm., the magnetic cross-section of the portion of said core within said winding not substantially exceeding 1.5 cm.^{2}, said winding being concentrated and having a radial depth sufficiently approximating its axial length, to accommodate the winding within a substantially minimum attainable length of magnetic flux produced by and encircling said winding, said flux having an average length of not more than 5 cm.

6. A highly selective radio frequency inductance element, having a high ratio of reactance to effective resistance, for use in tuned radio receiver circuits, resonant at frequencies above 150 k. c. including a ferro-magnetic core comprising magnetic particles, having a volume smaller than $.6\times10^{-4}$ mm.^{3}, said magnetic particles being substantially insulated from one another and distributed throughout an insulating binder to provide a permeability higher than air but lower than 18, and a multi-layer multi-turn winding of stranded wire having a low capacity arrangement of turns and closely surrounding said core, and having an average length of turn not greater than 6 cm., the magnetic cross-section of the portion of said core within said winding not substantially exceeding 1.5 cm.^{2}, said winding being concentrated and having a radial depth sufficiently approximating its axial length, to accommodate the winding within a substantially minimum attainable length of magnetic flux produced by and encircling said winding.

7. A highly selective radio frequency inductance element, having a high ratio of reactance to effective resistance, for use in tuned radio receiver circuits, resonant at frequencies above 150 k. c. including a ferro-magnetic core having a cylindrical center portion and comprising magnetic particles, having a volume smaller than $.6\times10^{-4}$ mm.^{3}, said magnetic particles being substantially insulated from one another and distributed throughout an insulating binder to provide a permeability higher than air but lower than 18, a thin insulating layer around the center portion of said core and a multi-layer multi-turn winding of stranded wire consisting of twenty to forty strands of .04 to .07 mm. thickness, said winding having a low capacity arrangement of turns and closely surrounding said core, and having an average length of turn not greater than 6 cm., the magnetic cross-section of the portion of said core within said winding not substantially exceeding 1.5 cm.^{2}, said winding being insulated by insulating substances of low dielectric loss and being concentrated and having a radial depth sufficiently approximating its axial length, to accommodate the winding within a substantially minimum attainable length of magnetic flux produced by and encircling said winding.

8. A highly selective radio frequency inductance element, having a high ratio of reactance to effective resistance, for use in tuned radio receiver circuits, resonant at frequencies above 150 k. c. including a ferro-magnetic core comprising magnetic particles having a volume smaller than $.6\times10^{-4}$ mm.^{3}, said magnetic particles being substantially insulated from one another and distributed throughout an insulating binder to provide a permeability higher than air but lower than 18, a sectionalized coil former on the center portion of said core, and a multi-turn multi-layer winding accommodated in said coil former, and having an average length of turn not greater than 6 cm., the magnetic cross-section of the portion of said core within said winding not substantially exceeding 1.5 cm.^{2}, said winding being concentrated and having a radial depth sufficiently approximating its axial length, to accommodate the winding within a substantially minimum attainable length of magnetic flux produced by and encircling said winding.

9. A highly selective radio frequency inductance element, having a high ratio of reactance to effective resistance, for use in tuned radio receiver circuits, resonant at frequencies above 150 k. c. including a ferro-magnetic core comprising magnetic particles having a volume smaller than $.6\times10^{-4}$ mm.^{3}, said magnetic particles being substantially insulated from one another and distributed throughout an insulating binder to provide a permeability higher than air but lower than 18, and a multi-turn multi-layer winding having a low capacity arrangement of turns and closely surrounding said core, and having an average length of turn not greater than 6 cm., the magnetic cross-section of the portion of said core within said winding not sub-

stantially exceeding 1.5 cm.², said winding being concentrated within a winding cross-section of less than .5 cm.², and having a radial depth sufficiently approximating its axial length, to accommodate the winding within a substantially minimum attainable length of magnetic flux produced by and encircling said winding.

10. A highly selective radio frequency inductance element, having a high ratio of reactance to effective resistance, for use in tuned radio receiver circuits, resonant at frequencies above 150 k. c. including a ferro-magnetic core having a cylindrical center portion and comprising magnetic particles having a volume smaller than $.6\times10^{-4}$ mm.³, said magnetic particles being substantially insulated from one another and distributed throughout an insulating binder to provide a permeability higher than air but lower than 18, and a multi-turn multi-layer winding having a low capacity arrangement of turns and closely surrounding said core, and having an average length of turn not greater than 6 cm., the magnetic cross-section of the portion of said core within said winding not substantially exceeding 1.5 cm.², said winding being concentrated and having a radial depth substantially equal to its axial length.

11. A highly selective radio frequency inductance element, having a high ratio of reactance to effective resistance, for use in tuned radio receiver circuits, resonant at frequencies above 150 k. c. including a ferro–magnetic core composed of a plurality of parts forming together a substantially ferro-magnetically closed circuit, said ferro-magnetic core comprising magnetic particles having a volume smaller than $.6\times10^{-4}$ mm.³, said magnetic particles being substantially insulated from one another and distributed throughout an insulating binder to provide a permeability higher than air but lower than 18, and a multi-turn multi-layer winding having a low capacity arrangement of turns and closely surrounding said core, and having an average length of turn not greater than 6 cm., the magnetic cross-section of the portion of said core within said winding not substantially exceeding 1.5 cm.², said winding being concentrated and having a radial depth sufficiently approximating its axial length, to accommodate the winding within a substantially minimum attainable length of ferro-magnetic material enclosing said winding.

12. A highly selective radio frequency inductance element, having a high ratio of reactance to effective resistance, for use in tuned radio receiver circuits, resonant at frequencies above 150 k. c. including a ferro-magnetic core comprising magnetic particles having a volume smaller than $.6\times10^{-4}$ mm.³, said magnetic particles being substantially insulated from one another and distributed throughout an insulating binder to provide a permeability higher than air but lower than 18, and a multi-turn multi-layer winding having a low capacity arrangement of turns and closely surrounding said core, and having an average length of turn not greater than 6 cm., the magnetic cross-section of the portion of said core within said winding not substantially exceeding 1.5 cm.², said winding being concentrated and having a radial depth sufficiently approximating its axial length, to accommodate the winding within a substantially minimum attainable length of magnetic flux produced by and encircling said winding, said core having portions extending outside said winding and being shaped to direct the magnetic flux around said winding.

13. A highly selective radio frequency inductance element, having an inductance value of the order employed in tuned circuits of broadcast receivers and having a low effective resistance, and being resonant at frequencies above 150 k. c. including a ferro-magnetic core comprising magnetic particles having a volume smaller than $.6\times10^{-4}$ mm.³, said magnetic particles being substantially insulated from one another and distributed throughout an insulating binder to provide a permeability higher than air but lower than 18, and a multi-turn multi-layer winding having a low capacity arrangement of turns and closely surrounding said core, and having an average length of turn not greater than 6 cm., the magnetic cross-section of the portion of said core within said winding not substantially exceeding 1.5 cm.², said winding being concentrated and having a radial depth sufficiently approximating its axial length, to accommodate the winding within a substantially minimum attainable length of magnetic flux produced by and encircling said winding.

14. A radio frequency inductance element, including a ferro-magnetic core comprising magnetic particles having a volume smaller than $.6\times10^{-4}$ mm.³, said magnetic particles being substantially insulated from one another and distributed throughout an insulating binder to provide a permeability higher than air but lower than 18, and a multi-turn multi-layer winding having a low capacity arrangement of turns and closely surrounding said core, and having an average length of turn not greater than 6 cm., the magnetic cross-section of the portion of said core within said winding not substantially exceeding 1.5 cm.², said winding being concentrated and having a radial depth sufficiently approximating its axial length, to accommodate the winding within a substantially minimum attainable length of magnetic flux produced by and encircling said winding, the damping decrement of said inductance element being not more than .024 at frequencies above 150 k. c.

15. A radio frequency inductance element, including a ferro-magnetic core comprising magnetic particles having a volume smaller than $.6\times10^{-4}$ mm.³, said magnetic particles being substantially insulated from one another and distributed throughout an insulating binder to provide a permeability higher than air but lower than 18, and a multi-turn multi-layer winding having a low capacity arrangement of turns and closely surrounding said core, and having an average length of turn not greater than 6 cm., the magnetic cross-section of the portion of said core within said winding not substantially exceeding 1.5 cm.², said winding being concentrated and having a radial depth sufficiently approximating its axial length, to accommodate the winding within a substantially minimum attainable length of magnetic flux produced by and encircling said winding, and damping decrement of said inductance element being not more than .024 at frequencies of the order of 1000 k. c.

16. A highly selective radio frequency inductance element, having a high ratio of reactance to effective resistance, for use in tuned radio receiver circuits, resonant at frequencies above 150 k. c., including a ferro-magnetic core comprising magnetic powder having a particle volume of the order of $.5\times10^{-7}$ mm.³, said magnetic particles being substantially insulated from one another and compacted with an insulating binder under

pressure to provide a permeability higher than air but lower than 18, and a multi-turn multi-layer winding having a low capacity arrangement of turns and closely surrounding said core, and having an average length of turn not greater than 6 cm., the magnetic cross-section of the portion of said core within said winding not substantially exceeding 1.5 cm.^{2}, said winding being concentrated and having a radial depth sufficiently approximating its axial length, to accommodate the winding within a substantially minimum attainable length of magnetic flux produced by and encircling said winding.

HANS VOGT.