

March 30, 1954

R. J. WILLIAMSON
INDUCTANCE COIL

2,673,961

Filed Dec. 16, 1950

3 Sheets-Sheet 1

FIG. 1

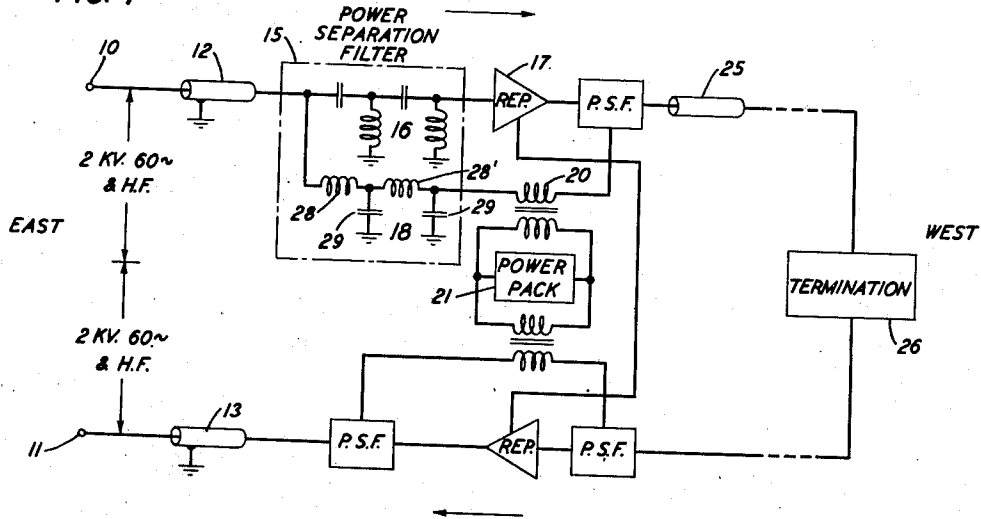
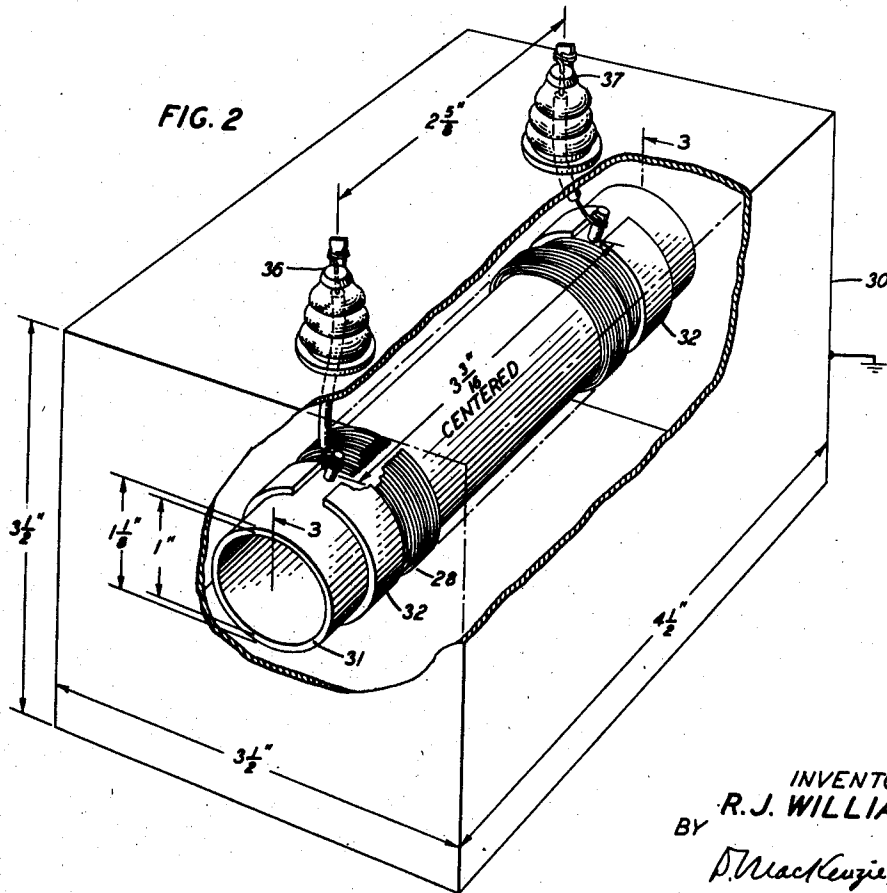


FIG. 2



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FIG. 3

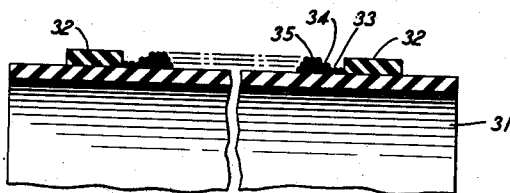


FIG. 4A

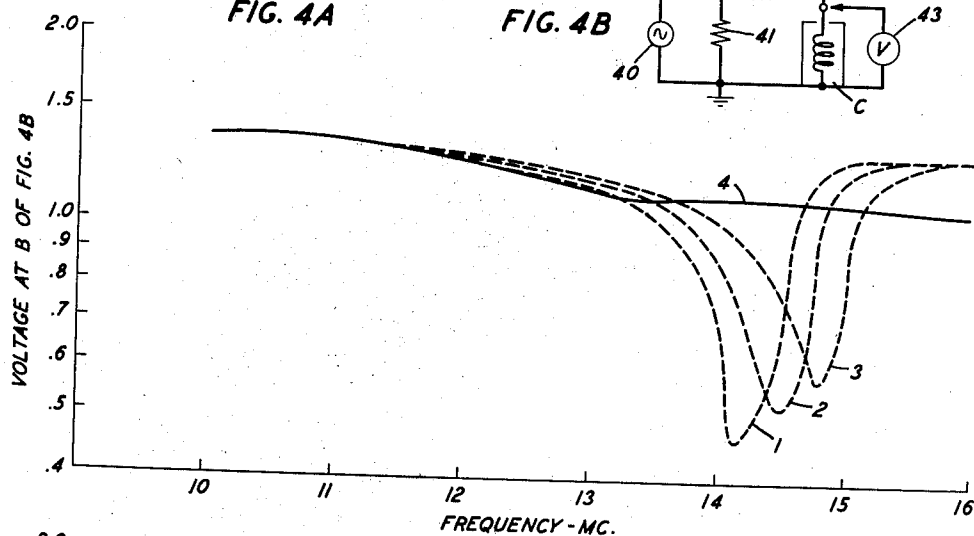


FIG. 4B

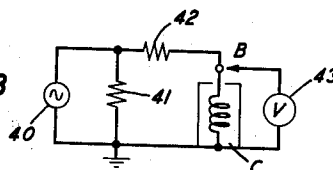
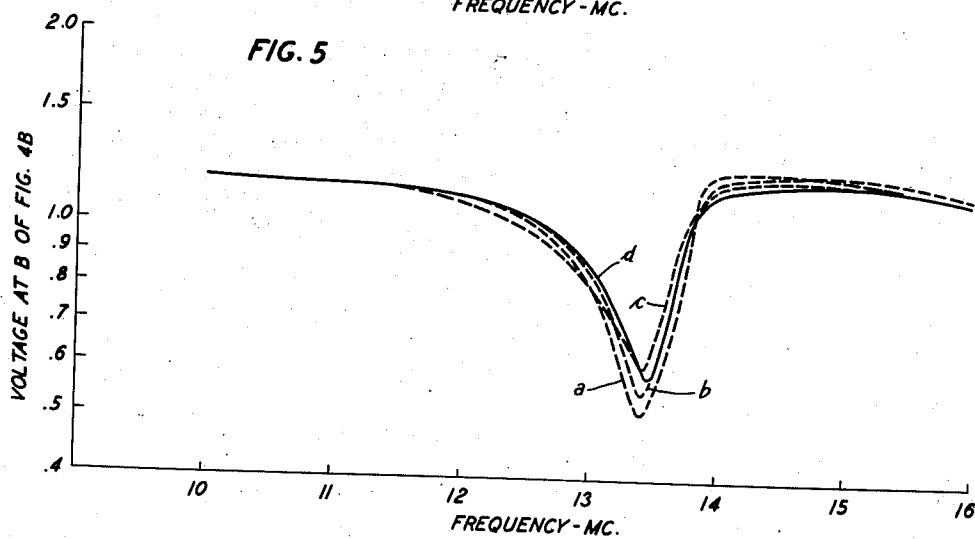


FIG. 5



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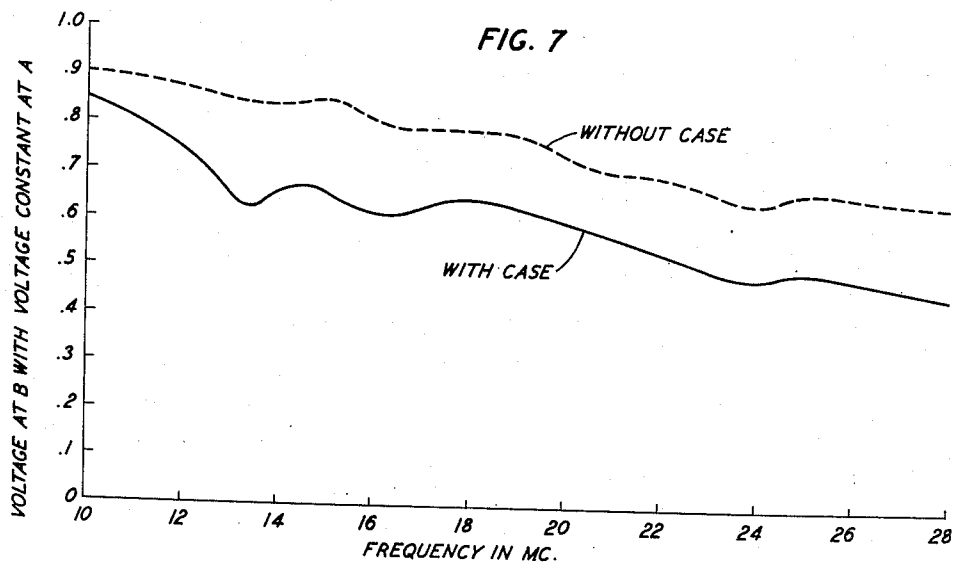
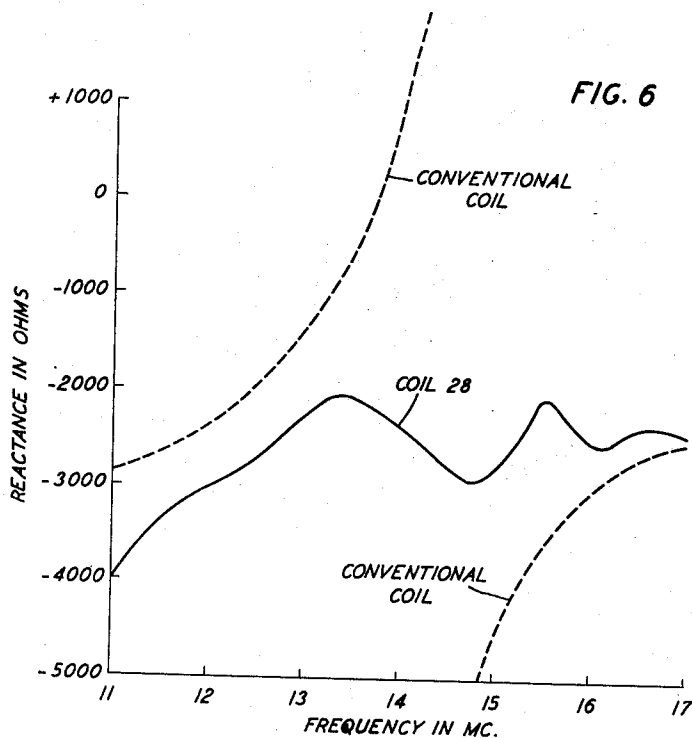
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3 Sheets-Sheet 3



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UNITED STATES PATENT OFFICE

2,673,961

INDUCTANCE COIL

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5 Claims. (Cl. 333-70)

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This invention relates to inductance coils and more particularly to such coils particularly suitable for use in filter networks and intended to exclude or block currents within a prescribed range of frequencies.

The invention finds utilization to particular advantage in coils intended to pass currents of low frequencies, say of the order of 60 cycles, and to exclude currents within a wide band of much higher frequencies, say a band extending from 200 kilocycles to 8 megacycles or higher.

One general object of this invention is to provide an inductance coil having a low impedance at frequencies within a first prescribed band of low frequencies and a very high impedance at frequencies within a second prescribed band of much higher frequencies.

A more specific object of this invention is to provide a coil having a low inductive reactance at frequencies of the order of 60 cycles and a high and substantially uniform capacitive reactance over a wide band of frequencies in the kilocycle and megacycle range.

The coil of the invention exhibits, when appropriate measurements are made, no sharp minimum of impedance within, or near the limits of, the selected bands. To provide such a coil is another object of the invention.

The coil, in one embodiment, comprises a plurality of coaxial parallel-connected windings of round wire on a common core (non-ferrous), the successive windings being layers of diminishing numbers of turns from nearest to the core outwards. The several windings have approximately the same low frequency inductance and the same direct-current resistance when separately measured. Although no quantitative explanation has been worked out, the improved impedance characteristic of the coil is believed to be due to alteration of the self inductances of the individual windings and redistribution of the couplings and parasitic capacitances within and between the windings of the coil with unequal numbers of turns as compared with one of equal numbers of turns. Thus, it comes about that the measured high frequency reactance is capacitive.

The coil may be used in one illustrative case in a power-separation filter which comprises two branches. A coaxial cable, of low impedance, transmits to the filter 1.7 amperes of 60 cycle current for power supply to a repeater, superposed on a band of high frequencies in the megacycle range. One branch of the filter excludes the low frequency current, transmitting the high frequency band to be amplified in the repeater. The

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other branch, in which the invention provides a series element, transmits the 60 cycle current for the repeater power supply, while excluding the high frequencies. It is, therefore, required that the inductance coil have a large current carrying capacity and be mounted within a grounded shield. Under these circumstances, parasitic capacities of a conventionally wound coil are likely to result in a low impedance resonance path shunting the high frequency branch and so attenuating the high frequency signal.

Another object of the invention, therefore, is to provide an inductance coil of high carrying capacity for currents of low frequency and of uniformly high impedance for currents in a band of frequencies of the order of megacycles.

The invention will be understood from the following description of an illustrative embodiment thereof, referring to the accompanying drawings in which:

Fig. 1 is a schematic of a two-way transmission line including a coil employing the invention;

Fig. 2 is a perspective view of an inductance coil illustrative of the invention as mounted in a shielding case, partly broken away;

Fig. 3 is a longitudinal section of the coil of Fig. 2 taken along the lines 3-3 thereof;

Figs. 4A and 4B show, respectively, curves, representative of the impedance-frequency characteristic of a typical coil constructed in accordance with the invention and a schematic of the circuit for measuring that characteristic;

Fig. 5 shows curves similarly measured as those of Fig. 4A when the several coaxial windings have equal numbers of turns;

Fig. 6 shows curves of the measured reactances, as functions of frequency, of the coaxial windings, respectively, of equal and of unequal numbers of turns; and

Fig. 7 shows curves representative of the impedance-frequency characteristic of the parallel windings having unequal numbers of turns, with and without the enclosing case.

Referring now to Fig. 1, terminals 10 and 11 indicate respectively the control conductors of coaxial cables 12 and 13, of which cable 12 is the East-West transmission line and cable 13 transmits from West to East. Between central conductor 12 and the sheath of cable 12 (grounded) there is impressed the 60 cycle power current in conjunction with the high frequency communication current, the conductor to ground potential being about 2,000 volts.

Power separation filter 15 includes within the dashed rectangle a high pass branch 16 through

which the communication current is fed to the input of repeater 17, and a low pass branch 18 which supplies the 60 cycle power through transformer 20 to power pack 21. The power pack supplies cathode heating power and anode power for repeater 17. The output of repeater 17, which is the amplified communication current received through filter branch 16, joins the 60 cycle current flowing through the primary of transformer 20 and the high and low frequency currents are supplied together to the central conductor of another length 25 of coaxial cable similar to cable 12.

Cable 25 then furnishes the composite current to a subsequent power separation filter in which the phenomena already described repeat themselves, and so on through a succession of repeaters and filters indicated by dashed lines to termination 26.

It will be seen that filter 15 is of the class of line filter sets, such as shown in Fig. 6, page 23, of "Transmission Networks and Wave Filters," T. E. Shea, D. Van Nostrand Company, New York 1929. The two branches of filter 15 are schematically the same as shown in Fig. 1 of United States Patent 2,076,248, April 6, 1937, to E. L. Norton.

The West-East line, indicated below in Fig. 1, operates in the same fashion as the East-West line just described, power pack 21 serving both lines for power supply to the respective repeaters.

It will be noted that the low frequency branch 18 of filter 15 is a two (or more) section low-pass filter, each section comprising a series inductance 28 and shunt capacitance 29. This filter branch shunts the output of cable 12 and must present a high impedance at the frequencies within or near the limits of the communication band. Otherwise this band will be attenuated and the purpose of filter 15 will be defeated.

Coils 28 and 28' are alike embodiments of the present invention but not of the same inductance. Referring to Figs. 2 and 3, one of coils 28 is shown encased in grounded metallic case 30. A cylindrical plastic core 31, extending axially between end walls of case 30, is fitted with stop rings 32 of like material to the core. Between these rings and coaxial with the core are three windings 33, 34 and 35. The ends of these windings are electrically joined together and to terminals 36, 37 in conventional manner.

As shown best in Fig. 3, winding 33 includes more turns than winding 34, and the latter includes more turns than winding 35. It has been previously mentioned that, measured separately, resistances and inductances of the individual windings are approximately the same, the increase in cross-sectional area of the outer coils offsetting the decrease in the number of turns to preserve the balance in inductance, while the increase in length of each turn offsets the decrease in turn number to preserve the balance in resistance.

The inductance of each winding (of round wire) is suitably computed from the formula

$$L = L_s - 0.01257 na (A + B) \text{ microhenry} \quad (1)$$

the resistance, from the formula

$$R = 2 \pi n r \quad (2)$$

where

$$L_s = 0.03948 n^2 a \frac{2K}{b}$$

a = radius (inches) of each turn,

n = number of turns,

r = resistance per inch of the wire used,

b = axial length of coil, inches

while K, A and B are taken from Tables 10, 11 and 12, respectively, on pages 283 and 284 of Bureau of Standards Circular C74, "Radio Instruments and Measurements," Washington, 1937.

It is noted that, approximately for the inductance and strictly for the resistance, the number of turns varies inversely as the radius of each turn to provide equality of these quantities for the several coaxial windings.

In the particular illustration of Fig. 2, the inductance of the paralleled windings was 202 microhenries, the direct-current resistance being 0.5 ohm. For each of the coaxial windings to have approximately 1.5 ohms resistance and 202 microhenries inductance, the application of the above formulae led to the choice of No. 25E wire of which the inner, middle and outer windings had respectively 156, 152 and 148 turns, the axial length of the inner winding and the outer diameter of the common core being $3\frac{3}{4}$ inches and $1\frac{1}{8}$ inches, respectively. Fig. 2 shows these and other linear dimensions of both coil and enclosing case.

It is a matter of simple computation to apply Formulae 1 and 2 to derive the nearest whole numbers of turns, the wire size and dimensions of core, etc., suitable for a larger number of coaxial windings to be connected in parallel and provide a desired value of inductance, the separate windings having approximately the same inductance and resistance when separately measured. In inductance and resistance, a 2 per cent and 1 per cent respectively, variations in the measured values are reasonably tolerable.

It is, of course, appropriate to check by actual measurement the inductances and resistances of the successive winding layers in comparison with that of the innermost layer and, by adding or removing one or more turns, to make the separate inductances and resistances nearly equal. This is usually not an indispensable precaution.

To exhibit the superiority of the coil 28, Fig. 1, made in accordance with the present invention, reference is made now to Figs. 4A and 5.

Fig. 4A shows in curves 1, 2 and 3, the voltage across the inner, middle and outer windings, with the other windings present and floating, of the improved coil when separately measured in the circuit of Fig. 4B, while curve 4 shows the like voltage across the parallel connected coils 1, 2 and 3. Allowance is made for the factor of about 3 (ratio of voltage drop across a single coil to that across three coils in parallel) by so adjusting the voltage across the 100 ohm resistor of Fig. 4A to be the same in all four measurements. The smoothing out of the voltage (i. e., impedance) versus frequency curve of the three windings in parallel is practically complete, at least to 16 megacycles. The resonances of the curves 1, 2 and 3 are the first series self-resonances of the separate windings with the other windings present and floating.

Fig. 4B is a schematic of the measuring circuit. Variable frequency oscillator 40 supplies a voltage of desired frequency and controllable magnitude across 100 ohm resistor 41. In shunt with resistor 41 is resistor 42, 1060 ohms, in series with coil C. The voltage across resistor 41 is kept constant at all frequencies used, and the voltage across coil C is measured by vacuum tube voltmeter 42. Such voltage is of course proportional to the impedance of coil C.

Fig. 5 shows similar curves obtained for an inductance coil, nominally of the same inductance

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as coil 28 but wound conventionally with three windings having equal numbers of turns. Curves *a*, *b*, *c*, and *d* are indicative of the impedance-frequency characteristics of the three separate windings and of the three in parallel.

The series self-resonance of the four conditions occur at nearly the same frequency, somewhat lower than that of the inner winding of coil 28 shown in Fig. 4A. In a coil for use in the low frequency branch of filter 15, Fig. 1, the presence of such resonance would give rise to damaging attenuation of the high frequencies in the communication branch of filter 15.

Measurements of the reactance of a conventional coil wound in three parallel layers of the same number of turns give radically different results from the like measurements of coil 28, Figs. 1 and 2.

Fig. 6 shows in dotted lines the reactance of the conventional coil, and in full line the reactance of coil 28, as a function of frequency. The effect of redistribution of distributed capacities by variation in number of turns is to make the reactance of coil 28 capacitive over the megacycle range it is designed to exclude, although, of course, being inductive at the low frequencies.

Fig. 7 shows curves representative of the impedance frequency characteristics of the coil of the invention, over the range 10 to 28 megacycles, with and without the shield 30 Fig. 2.

While the invention has been described with reference to a particular coil, it is obvious that the description implies a method applicable to the design of coils of any number (greater than one) of coaxial windings, for any desired nominal

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value of impedance and for use over any prescribed band of high frequency current. The specific coil selected for description is illustrative only.

5 What is claimed is:

1. An inductance coil comprising a core of insulating material and a plurality of superposed coils of wire, each consisting of a single layer, on the core; the individual coils being conductively connected in parallel and having progressively fewer turns from the innermost to the outermost.
2. An inductance coil as in claim 1 in which the individual coils have approximately the same direct-current resistance.
- 15 3. An inductance coil as in claim 1 in which the individual coils have approximately the same inductance.
4. An inductance coil as in claim 1 in which the individual coils have approximately the same direct-current resistance and inductance.
- 20 5. An inductance coil as in claim 1 in which the first series self-resonances of the individual coils occur at spaced frequencies.

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References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
1,896,993	Arland	Feb. 7, 1933
1,996,729	Rigandi	Apr. 2, 1935
2,102,410	Fyler	Dec. 14, 1937
2,120,973	Dietze et al.	June 21, 1938

FOREIGN PATENTS

Number	Country	Date
606,551	Great Britain	Aug. 16, 1948