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2,287,170

INDUCTANCE DEVICE

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FIG. 1

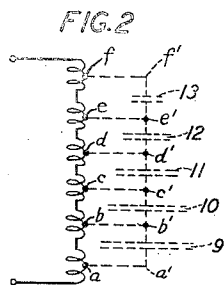
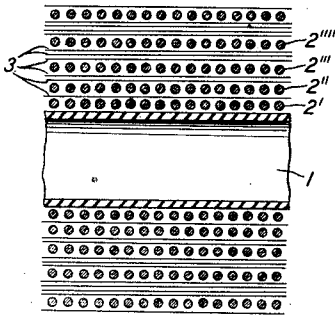


FIG. 3

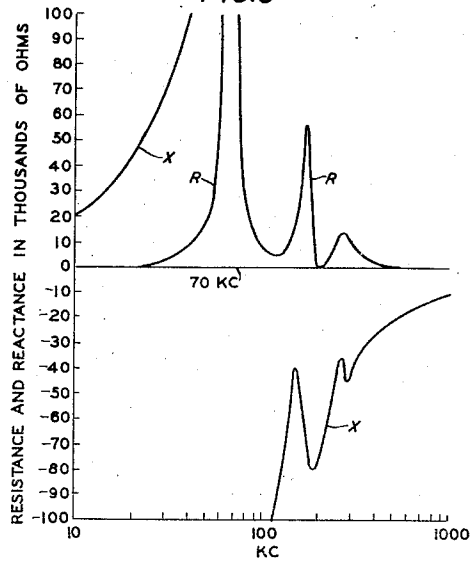
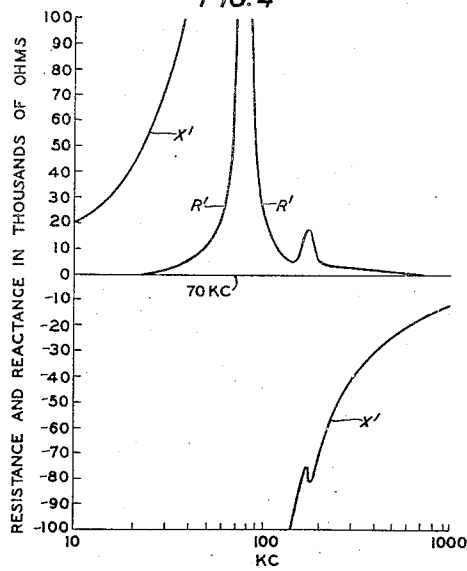


FIG. 4



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INDUCTANCE DEVICE

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This invention relates to inductance devices and more particularly to devices subject to impedance irregularities at frequencies above the resonant frequency of the device.

The term "inductance devices" as herein used includes single winding coils such as choke coils, reactors, etc., and multiwinding coils such as transformers of various types.

It is well known that all inductance devices have inherent capacitances and that the inherent capacitance of any device coacting with the inductance thereof usually causes the device to resonate at a certain frequency. In designing inductance devices it is sometimes possible to so arrange the characteristics of the device that this resonant frequency occurs outside the band of frequencies which will be impressed on the device. In some cases the resonant frequency is below the impressed band.

When frequencies of the order of 10 kilocycles and higher are involved, secondary resonances may occur in the band which is impressed on the device, thereby giving rise to impedance irregularities which are detrimental to high quality transmission. For example, if the device is used in a feedback type amplifier such impedance irregularities result in phase variations at very high frequencies, which may cause the amplifier to sing at these high frequencies and to be inoperative at all frequencies.

Inductance devices are most frequently wound in layers. The effective distributed capacitance of a layer winding is the result of several contributions. The contributions due to the turn to turn capacitances and the capacitances between parts of the winding other than the adjacent layers are comparatively very small and may be neglected. The contribution due to capacitances from the winding to a surrounding metallic shield or case need not be considered in the following description, since these capacitances which ordinarily exist from the outermost layer of the winding to shield, act as if connected across the entire winding and therefore do not give rise to impedance irregularities. The main contribution, however, is that due to the capacitances between adjacent layers and such capacitances do give rise to secondary resonances and impedance irregularities.

The present invention is directed to the solution of the problem outlined above and has as its main object an inductance device in which secondary resonance effects are greatly reduced if not entirely eliminated.

Another object is an inductance device having

an impedance characteristic which is substantially smooth over the frequency range of interest.

A further object is an inductance device in which the inherent capacitances thereof act as a single capacitance effectively in parallel with the inductance whereby only one resonant frequency of the device occurs.

In accordance with this invention the above objects and others that will appear hereinafter are attained by so designing the inductance device that the potential gradient from winding layer to winding layer due to the natural capacitance between adjacent layers is substantially the same as the potential gradient from layer to layer due to magnetic flux linkages. This may be accomplished by progressively increasing the thickness of insulation between layers, by using insulation of progressively decreasing dielectric constant or by progressively decreasing the number of turns per layer.

In windings of unusual conformation it may be found that the desired potential distribution would be accomplished by some other rate of change of insulation, than progressively increasing, the actual rate being determined by methods described hereinafter.

The invention will be better understood from the following description together with the attached drawing forming a part thereof and in which:

Fig. 1 is a partial cross-section of one embodiment of the invention;

Fig. 2 is a schematic diagram of a device illustrating the capacitance variation;

Fig. 3 is a graph showing the impedance characteristic of an inductance device to which the invention has not been applied; and

Fig. 4 is a graph showing the impedance characteristic of an inductance device wound in accordance with the invention.

Referring now particularly to Fig. 1, an insulating material core tube 1 has a multilayer winding thereon comprising winding layers 2', 2'', 2''' Between layers 2' and 2'' there is a single layer of insulation 3 which may be paper or any other satisfactory dielectric. Between layers 2'' and 2''' there are two layers of insulation. Between layers 2''' and 2'''' there are three layers of insulation, and so on between succeeding layers of windings there are increasing layers of insulation.

In this structure, if desired, insulation of decreasing dielectric constant may be used instead of an increasing number of layers of insulation

of the same dielectric constant. In the structure of Fig. 1 since the distance between winding layers or the effective insulation progressively increases the capacitance between layers progressively decreases. It is also to be understood that whereas Fig. 1 shows a structure in which the layers of insulation progress arithmetically this is not controlling, and the number of layers of insulation may progress in some other fashion as determined by methods described hereinafter. It is also to be understood that whereas the device of Fig. 1 is illustrated as being an air core device the invention is equally applicable to devices having magnetic material cores of any shape or composition and is also applicable to devices such as transformers having multiple windings.

Fig. 2 diagrammatically illustrates the distribution of the capacitances in a device constructed in accordance with the invention. As is well known, when a voltage is impressed on an inductance device the magnetic flux linkage is such that the voltage between any layer and the innermost layer increases from the innermost to the outermost layer of the winding, but the rate of increase may not be constant since the rate depends on the relative couplings between the individual layers and the entire winding. It is also well known that each winding layer may be considered as acting like the plate of a condenser. Therefore, a series of capacitances 9, 10, 11, 12, 13 exists as shown in Fig. 2. These capacitances may be assumed to be effectively connected to the mid-points of the layers as at a, b, c, d, e, f , where points a', b', c', d', e', f' indicate connections between the individual capacitances corresponding to the mid-points of the layers.

Consider first an ordinary winding not in accordance with the present invention. Now, let it be assumed for the moment that in such a winding the connections $b-b', c-c', d-d'$ and $e-e'$ are opened but that the connections $a-a'$ and $f-f'$ remain closed as shown. Points a and a' and points f and f' must necessarily be at the same potential, respectively, by virtue of the connections. However, points b and b', c and c', d and d' and e and e' are not ordinarily at the same potentials respectively. Therefore, when the connections assumed to be opened are closed, currents must flow in them and a complex current condition for the entire winding results. Hence, the capacitances 9, 10, 11, 12, 13 cannot be considered as being in series and equivalent to a single capacitance between a and f . The currents in the connections cause resonances between parts of the windings and the capacitances, and pronounced irregularities in transmission and impedance result.

If, on the other hand, the coil is constructed in accordance with the present invention, that is, so that the potential gradient from layer to layer due to capacitance is substantially the same as the potential gradient from layer to layer due to magnetic flux linkages, the potential at b will be equal to that at b' , the potential at c equal to that at c' , that at d equal to d' , etc., regardless of whether the connections are made or not. Therefore, no current flows in connections $b-b', c-c',$ etc., and the series of capacitances 9, 10, 11, 12, 13, can be considered as lumped into a single capacitance in parallel with points a and f . To a very close approximation with a large number of layers this single capacitance is equivalent to a slightly smaller capaci-

tance across the entire winding and in such a structure no secondary resonances exist.

Although it is possible by mathematical analysis to determine the required insulation it is often more expedient to determine it by experimental procedure of which the following is a simple example. First, a model of the inductance device is constructed of the proportions desired, bringing out taps at the mid-points of each layer (as, for example, points a to f of Fig. 2). The ratio of the voltages between successive layers to that between points a and f are then measured, that is to say, the ratios

$$\frac{E_{ab}}{E_{af}}, \frac{E_{bc}}{E_{af}}, \frac{E_{cd}}{E_{af}}, \text{etc.}$$

A frequency should be chosen for this measurement sufficiently below the resonant frequency of the device that the voltages due to flux linkages dominate and capacitance effects are small. Next, the value of capacitors 9—13, which will give the same voltage ratios as were measured for the inductance, should be computed. Use may be made of the formulae

$$\frac{E_{ab}}{E_{af}} = \frac{C_9}{C_9 + C_{10}}, \frac{E_{bc}}{E_{af}} = \frac{C_{10}}{C_{10} + C_{11}}, \text{etc.}$$

where

$$C_0 = \frac{1}{\frac{1}{C_9} + \frac{1}{C_{10}} + \dots + \frac{1}{C_{13}}}$$

A compromise between circuit and practical design considerations usually dictates a value for C_0 from which $C_9, C_{10},$ etc. may be found. The thickness of the insulation required to give capacitances $C_9, C_{10},$ etc., may be determined from the formula

$$C = .225 \times \frac{KS}{t} \text{ mmf.},$$

where K is the dielectric constant, S is the area of the insulation between the two layers in question, and t is the insulation thickness. Some allowance for the insulation on the wire may be found necessary, which allowance may be made by methods well known in the art.

The addition of varying insulation as found by this procedure may change the distribution of voltages due to flux linkages somewhat. If such is the case the procedure may be repeated using the previously determined insulation in the winding when making the inductive voltage determinations. The ideal proportions may thus be approached to any desired degree by repeating the procedure.

In multiwinding inductance devices account must be taken of the terminations on the additional windings when measuring or computing the ratios

$$\frac{E_{ab}}{E_{af}}, \frac{E_{bc}}{E_{af}}, \text{etc.}$$

The effect of the improved winding arrangement on the impedance characteristic of a typical coil may be readily seen by comparing the graphs of Figs. 3 and 4. Fig. 3 shows the impedance characteristic of a device not wound in accordance with the invention. The inductive reactance curve X and the effective resistance curve R show that the resonant frequency in this case is about 66 kilocycles. Above the resonant frequency two other pronounced irregularities occur, one at about 140 kilocycles and the second at about 280 kilocycles.

Fig. 4 shows the impedance characteristic of a

device constructed in accordance with the invention but otherwise approximating the characteristics of the device of Fig. 3. In this case the resonant frequency occurs at about 78 kilocycles as shown by curves X' and R', only one minor irregularity occurs above the resonant frequency and this occurs at about 180 kilocycles. A minor readjustment of inductance or capacity may be made if desired to shift the resonance from 78 to 66 kilocycles as in Fig. 3.

The actual coil whose characteristic is shown in Fig. 4 comprised approximately 1540 turns of thirty No. 40 enamel-stranded double silk covered copper wire. The insulation was paper .001 inch thick and was arranged as follows:

	Layers of paper
Over winding layer 1	1
Over winding layers 2, 3, 4	2
Over winding layers 5, 6	3
Over winding layer 7	4
Over winding layers 8, 9	5
Over winding layers 10, 11	6
Over winding layers 12, 13	7
Over winding layers 14, 15	8
Over winding layers 16, 17, 18	9
Over winding layers 19, 20, 21	10
Over winding layers 22, 23	11
Over winding layers 24, 25	12
Over winding layers 26, 27, 28	13
Over winding layers 29, 30	14
Over winding layers 31, 32, 33, 34, 35, 46	15

The curves of Figs. 3 and 4 are drawn to the same scale and the improvement of the structure of Fig. 4 over that of Fig. 3 is readily seen. The remaining slight irregularities shown in Fig. 4 are not of a serious nature and were tolerable in the practical application of the design. If desired, these irregularities may be substantially eliminated by slight readjustments of the insulation thickness to approximate more closely the ideal potential conditions.

The invention may be carried out in other specific ways than those herein set forth without departing from the spirit and essential characteristics of the invention and the present embodiments are, therefore, to be considered in all respects as illustrative and not restrictive, and

all changes coming within the meaning and equivalency range of the appended claims are intended to be embraced therein.

What is claimed is:

1. A high frequency inductance device for the transmission of frequencies of the order of 10 kilocycles or higher comprising a multilayer winding, each layer having a plurality of turns and insulation between adjacent layers, characterized in this that said layers and said insulation are adjusted to give between adjacent layers an inherent capacitance which varies progressively from the innermost layer to the outermost layer by such relative values that the potential gradient from layer to layer due to capacitances is substantially the same as the potential gradient from layer to layer due to magnetic flux linkages.

2. The combination in a high frequency electrical apparatus for the transmission of frequencies of the order of 10 kilocycles or higher of a multilayer winding, each layer comprising a plurality of turns, and means for making the potential gradient from layer to layer of said winding due to the inherent capacitance between adjacent layers substantially the same as the potential gradient from layer to layer due to magnetic flux linkages.

3. The combination in accordance with claim 2 in which insulating material is inserted between adjacent layers of said winding and the thickness of the insulation is varied progressively from the innermost layer to the outermost layer.

4. The combination in accordance with claim 2 in which insulating material is inserted between adjacent layers of said winding and the dielectric constant of said insulating material is varied progressively as one proceeds from the innermost layer to the outermost layer.

5. A high frequency electrical transformer for the transmission of currents of a frequency of 10 kilocycles or higher comprising a plurality of windings at least one of which windings comprises a plurality of layers, said layers being so related that the potential gradient due to inter-layer capacitance is substantially equal to the potential gradient due to magnetic flux linkages.

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