Oct. 7, 1941. H. O. ROOSENSTEIN 2,258,261

COIL WITH LINE PROPERTIES

Filed March 7, 1940

Fig. 1

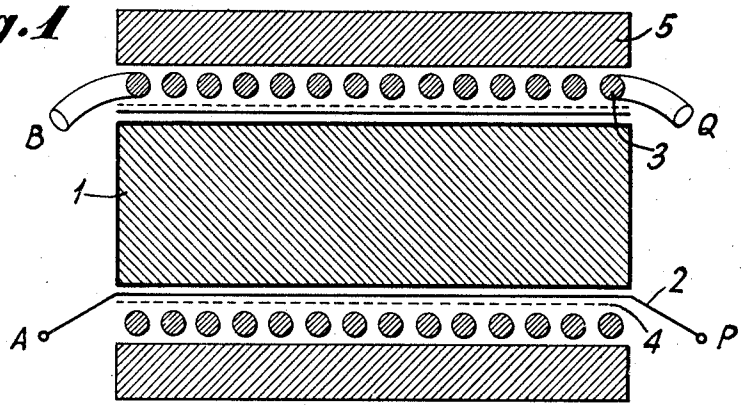


Fig. 2

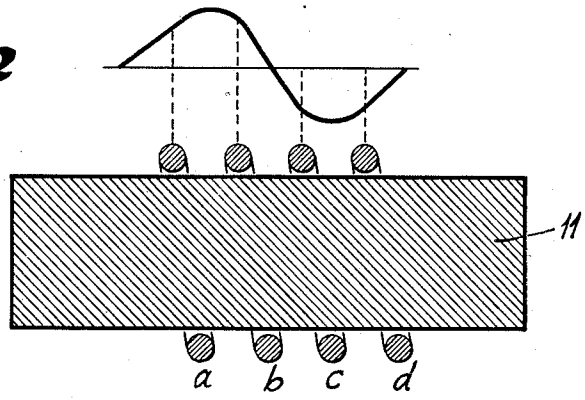
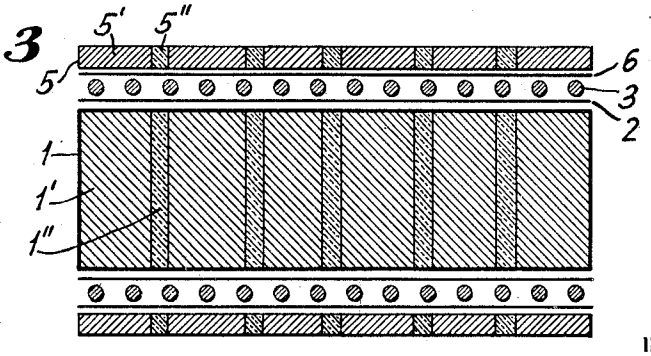


Fig. 3



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Patented Oct. 7, 1941 2,258,261

UNITED STATES PATENT OFFICE

2,258,261

COIL WITH LINE PROPERTIES

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Application March 7, 1940, Serial No. 322,656
In Germany January 18, 1939

5 Claims. (Cl. 178—44)

This invention is concerned with a coil possessing transmission line properties, that is to say, a coil of a kind involving a certain transit time for electromagnetic waves. In the communication arts it is quite frequently necessary to retard or delay a signal a certain length of time. In most cases the demand is that the form of the electromagnetic phenomenon or action, say, the signal, should be preserved; more particularly, the steepness of a (wave) front should not be rounded. This demand implies that both the transit time of the line as well as the surge impedance for all frequencies comprised in the signal should be of the same value. This demand of fixed transit time or phase (time of phase transmission) for a wide frequency band arises not only in connection with the problem hereinbefore outlined, but also in a great many other communication systems where switchings are necessary, and also in such cases the requirement mostly is that in spite of that the transit time relations should stay unaltered for the entire waveband. In this case it is necessary to substitute artificial lines for disconnected line portions, and these must present the same transit time for all frequencies. The invention will be found useful and valuable in all cases of the said sort.

According to the invention a coil is endowed with line properties or characteristics by providing means whereby the dielectric and/or the magnetic permeabilities of the space or ambient around the coil turns in axial direction are diminished in comparison with the values thereof in a direction at right angles thereto. This means that the space in which the coil is located involves a certain amount of anisotropy both as a dielectric as well as, and particularly so, a ferro-magnetic material. This anisotropic feature of the dielectric and/or the ferro-magnetic properties may be chosen in such a way that a desired frequency dependence of the surge impedance and/or the transit time of the coil results. More particularly speaking, a constant surge impedance or a constant transit or transmission time may be secured for a wide frequency band.

It has been suggested in the prior art to design an artificial line for RF by mounting a metallic cylinder split in longitudinal direction and in co-axial relationship with a cylindrical coil, the said split metallic cylinder forming a capacity conjointly with the spires of the coil. However, artificial lines of this kind do not yet offer the required fidelity in transmission whenever very broad wavebands or ultra-short waves are concerned.

In the drawing accompanying the specification, Figure 1 illustrates a retarding network arrangement using a ferro-magnetic core and a ferro-magnetic sheath; Figure 2 is a diagrammatic illustration of a core and coil used to explain certain features of the present invention; and, Figure 3 illustrates a preferred embodiment of the invention using a sectionalized core and sheath.

A coil as known in the earlier art is shown, for instance, in Fig. 1. Referring to Fig. 1 it will be seen that the coil comprises a ferro-magnetic core 1 preferably made of high frequency iron and which has the purpose of imparting to the coil a high propagation or transit time. Over this core is placed a copper cylinder 2 which has a split extending in axial direction thereof and which has the two terminals A and P of the line, the assembly being here conceived as a quadripole or four-terminal network. The second pair of terminals indicated at B and Q are formed by the beginning and the end of the winding 3, the latter being placed upon the copper cylinder 2 with the interposition of an insulation layer 4. In such an arrangement, by action of the current flowing through the winding, a magnetic field is set up in the ferro-magnetic core 1, the intensity of the said magnetic field being independent of the shielding 2. Because of the relatively small distance between winding 3 and the shielding 2 the cable 2 has a well-defined capacitance per unit of length. This capacitance will be present up to frequencies for which neighboring turns of the coil show already potential differences. However, where such high frequencies are dealt with for which potential differences arise across adjacent coil turns, there arise mutual capacitances between the turns which play an essential part in addition to the capacitance between winding 3 and the shielding. As a result the apparent capacitance experiences a change, and thus also the transit time as well as the surge impedance of the entire arrangement. Hence, it is necessary, if the transit or propagation time shall be constant and independent of the frequency, that the said inter-turn capacitance should be minimized as much as possible in order that the effect thereof may be diminished. This end is attainable, for instance, by spacing the various turns or spires far apart from one another, care having to be taken in addition that the capac-

itance between each turn and the shielding cylinder should be as high as feasible.

Particularly favorable results are obtained by making the dielectric constant of the dielectric anisotropic in nature, say by building the same of alternate layers possessing a high dielectric constant and a low dielectric constant so that in a direction at right angles to the layers there results a relatively low dielectric constant, but in the direction parallel to the layers a high dielectric constant. In other words, for the present case it would be advantageous to stratify the dielectric at right angles to the axis. This, for instance, is accomplishable by supporting the various coil turns upon strips of insulation material having a high dielectric constant, while being in direct contact with the shielding cylinder. In the interstices or gaps between the various spires of the coil is preferably air, for this assures a great disparity in the dielectric constants in axial sense and in radial sense. This step by itself insures an appreciable improvement in the transit time constancy as well as the constancy of the surge impedance.

However, the marked frequency dependence of the propagation time where higher frequencies are dealt with resides essentially in the dependence upon the frequency of the inductance per centimeter length (inductivity) of such an artificial line. This is caused by the existence of mutual inductance between individual turns. This mutual inductance which is necessary to obtain the high transit times to be attained by the coil, is the cause and source for the coupling relation of line portions being remote from one another and thus also the reason why the inductance is a function of the frequency.

The situation shall be explained in more detail and basically by reference to Fig. 2. Referring to Fig. 2, 11 denotes the iron core, while *a*, *b*, *c*, *d*, are four turns or spires. Suppose that a half wave ($\frac{1}{2}\lambda$) of the oscillations just happens to be on these turns as indicated schematically by the current diagram shown over the turns. In other words, turns *a* and *b* carry positive current and turns *c* and *d* negative current. Accordingly, the magnetic fields in the iron core 11 are of opposite direction and they mutually destroy each other almost completely because of the close coupling relation. The inductance of the coil for such frequencies, therefore, is practically equal to zero. Although the extreme case pictured in Fig. 2 where there is a reversal in the sense or sign of the current after two turns may hardly ever be expected to occur in actual practice, it will nevertheless be seen that, if there is a divergence in the current flowing at the beginning of the coil and at the end thereof, in other words, if the coil can no longer be regarded as quasi-stationary, there must happen a reduction of inductance with rising frequency. As a result the transit or propagation time and the surge impedance must be affected, indeed, this influence must be in the same sense as that occasioned by the mutual capacitance of the turns as above explained.

Now, in order to avoid the fault introduced by the circumstance that the coil inductance decreases with rise of the frequency, the coil must be embedded in a material of high permeability in such a way that the leakage will assume high values so that each line of force will always embrace only a few turns and not embrace the entire coil. In the extreme instance illustrated in Fig. 2, this, as will be noted, would mean that the demand is made that the magnetic line of force of turn *a* will embrace only turn *b*, whereas turn *c* will be hardly affected by the field. And, inversely, this should apply also to the turn *d*.

An extremely high leakage as required according to the invention may be preferably obtained by providing the coil not only by a ferro-magnetic core, but also by a ferro-magnetic sheath so that the flux lines emerging from the core will preferably cut across through the diamagnetic gap which is of but small dimensions and which contains the coil spires, into the ferro-magnetic cylinder surrounding the coil. Extremely high leakage according to the invention is obtained by endowing the ferro-magnetic material with a special anisotropic nature, the anisotropy being so chosen that the permeability in axial direction will be low and as high as possible in radial sense.

In Fig. 1 the ferro-magnetic cylinder surrounding the coil has been denoted by 5. Fig. 3 shows an arrangement predicated upon the use of subdivided ferro-magnetic material, for in this embodiment both the core as well as the cylinder 5 consists of a plurality of ferro-magnetic disks or rings 1' and 5' being subdivided or separated by non-magnetic disks or rings 1'' and 5'', respectively. Thus, the magnetic lines of force are compelled to flow preferably in radial direction with the consequence that the field of force of a given coil turn will embrace only a limited number of neighboring coil turns. The subdivision such as shown in Fig. 3, is intended to be merely schematic and does not imply any definite instructions as regards the arrangement to be chosen in practice. In fact, the subdivision preferably will have to be chosen far smaller than the inter-turn distance. In addition to the shielding cylinder 2 disposed between the core 1 and the turns 3, there could be provided another shielding cylinder 6 between the ferro-magnetic cylinder 5 and the turns, with the result that the propagation times will be raised another factor

$$\sqrt{2}$$

I claim:

1. In a retarding network, a pair of input terminals and a pair of output terminals, a coil connected between one of said input terminals and one of said output terminals, a core for said coil composed of a plurality of stacked ferro-magnetic discs insulated from one another, a split shielding sheath of electrical conducting material mounted between the core and the coil, means for connecting the other input terminal and the other output terminal to said sheath, and an outer sheath for said coil composed of a plurality of stacked rings of ferro-magnetic material insulated from one another.

2. In a retarding network, a core composed of a plurality of stacked discs of ferro-magnetic material separated by insulating means, a sleeve within which said core is mounted, said sleeve having a slit which extends in an axial direction for its entire length, a coil wound around the outer surface of said sleeve, a second sleeve mounted co-axially with the sleeve and so as to form a sheath for said coil, and a third sleeve composed of a plurality of stacked rings of ferro-magnetic material separated by insulating means, said last named sleeve forming a sheath for said second sleeve.

3. In an inductance device a cylindrical member composed of a plurality of stacked ferro-

magnetic rings insulated from one another, a coil mounted within said cylindrical member and in co-axial relation thereto, a core for said coil composed of a plurality of stacked ferromagnetic discs insulated from one another, said core being mounted within said coil and in coaxial relationship thereto, and a cylindrical electrical shielding sleeve interposed between the coil and the core, said sleeve being slitted in an axial direction along its entire length.

4. The arrangement described in the next preceding claim wherein said coil is made up of a plurality of spaced turns and wherein ferromagnetic discs of said core have a thickness which is considerably less than the distance between adjacent turns of the coil.

5. The arrangement described in claim 1 wherein the coil is composed of a plurality of spaced turns of wire and wherein the ferromagnetic discs making up the core and the ferromagnetic rings making up the cylindrical member are of the same thickness which thickness is considerably less than the distance between adjacent turns of the coil.

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