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(54) Antenna device and electromagnetic detection device comprising such antenna device

(57) Antenna device for use in an electromagnetic detection system, comprising two loop antenna coils for generating a detection field for detecting responders provided with a loop antenna coil in a detection zone, the loop antenna coils in operation forming part of an antenna circuit connected to an excitation circuit, which antenna circuit comprises a series resonance circuit and a parallel resonance circuit with the same resonance frequency as the series resonance circuit. The antenna circuit comprises a single damping resistance (R); one of the loop antenna coils (L) is constructed as a transformer (T) with two very strongly coupled windings (T1, T2) and a central branch, which loop antenna coil (L3) is connected in parallel with a first tuning capacitor (C3); and the damping resistance (R) is connected in series with the first tuning capacitor (C3) and is connected in parallel with a series connection of a second tuning capacitor (C4) and a second loop antenna coil (L4), while the end of the second loop antenna coil (L4) that is not connected with the second tuning capacitor (C4) is connected with the central branch of the loop antenna coil (L3) constructed as a transformer.

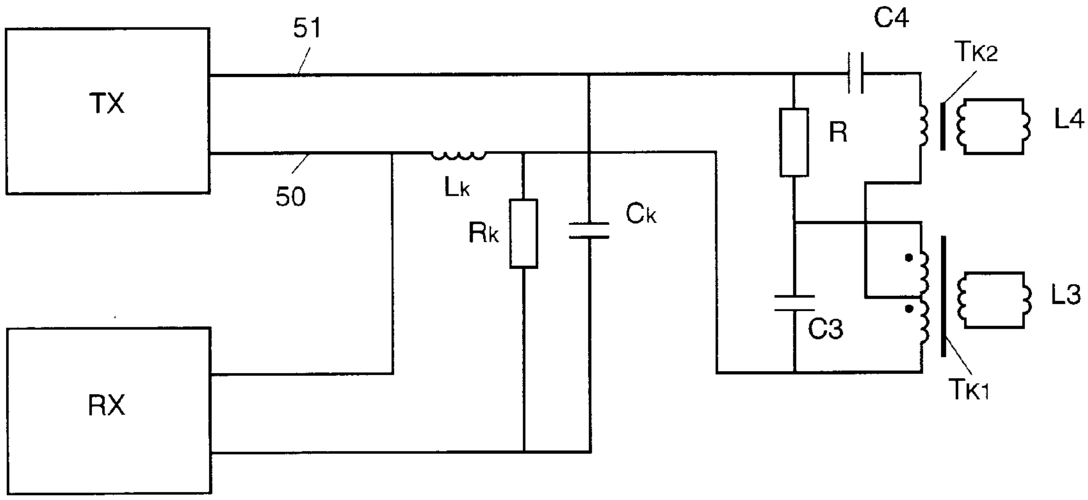

FIG. 5

EP 0 762 355 A1

Description

The invention relates to a circuit for connecting two antenna coils to a source, whereby the coupling of the power available at the source to the energy in the two antenna coils is maximal at a given bandwidth. More particularly, the invention relates to an antenna device for use in an electromagnetic detection system, comprising two loop antenna coils for generating a detection field for detecting responders provided with a loop antenna coil in a detection zone, the loop antenna coils in operation forming part of an antenna circuit connected to an exciting circuit, which antenna circuit comprises a series resonance circuit and a parallel resonance circuit with the same resonance frequency as the series resonance circuit. Further, the invention relates to an electromagnetic detection system.

In applicant's European patent application EP-A-0 579 332, concerning an anti-shoplifting antenna with rotary field, a circuit is described by which a HF signal source can provide two antenna coils with current, while the antenna network exhibits a constant and real impedance (R) and the currents in the two coils are 90° out of phase.

In this rotary field network, in both coils the same energy is available, which is as large as the energy in the single coil in the classic method whereby a tuning capacitor and a damping resistance are connected in parallel to the coil, and whereby this parallel circuit is excited with a source of current.
In it, $2\pi fo\ I^2L = PQ$
with

fo:	the resonance frequency
I^2L: energy in the coil,	I = effective coil current
	L = self-inductance of the coil

P: the available power
Q: the Q factor, 1/Q = 3dB-bandwidth/fo

In the known rotary field network, the Q factor of the circuit, and hence the bandwidth fo/Q, is equal to the situation with one current-controlled parallel circuit. The available power is therefore utilized twice, in two coils instead of in one coil.

However, the energy available in the two coils has been found not to be optimal yet in proportion to the available power and the Q factor. The object of the present invention is to increase the energy available in the antenna coils. With the circuit according to the invention, a doubling of the available antenna energy is possible, with otherwise the same properties, that is, an increase of the antenna efficiency by 3dB. To that end, according to the invention, a circuit of the above-described type is characterized in that the antenna circuit comprises a single damping resistance (R); that one of the loop antenna coils (L) is constructed as a transformer (T) with two very strongly coupled windings (T1, T2) and a central branch, which loop antenna coil (L3) is connected in parallel to a first tuning capacitor (C3); and that the damping resistance (R) is connected in series to the first tuning capacitor (C3) and is connected in parallel to a series connection of a second tuning capacitor (C4) and a second loop antenna coil (L4), while the end of the second loop antenna coil (L4) that is not connected to the second tuning capacitor (C4) is connected to the central branch of the loop antenna coil (L3) constructed as a transformer.

Hereinafter, the invention will be further described with reference to the appended drawings.

Fig. 1 schematically shows a rotary field network according to EP-A-0 579 332, in which the two antenna coils are designated as L1 en L2 and the associated tuning capacitors as C1 and C2.

Fig. 2 shows an equivalent-circuit diagram of two series-connected resistors R.

Fig. 3 schematically shows the modified rotary field network of Fig. 1 after replacement of the two resistors and the elimination of the parallel resistor 2R.

Fig. 4 schematically shows an example of a network that emerges after the conversion to an input impedance of R and the shift of the transformer T of Fig. 3 to the coil L1.

Fig. 5 schematically shows an example of an application of a rotary field network according to the invention in combination with a directional coupling to distinguish the signal to the receiver RX from the signal of the transmitter TX.

In the existing rotary field network described in applicant's patent application EP-A-0 579 332 (see Fig. 1), two resistors R are mutually connected in series and each resistor is connected in parallel to the series circuit and the parallel circuit that are formed with the two antenna coils L1 and L2 and with capacitors C1 and C2. This network thus has a constant frequency-independent impedance R.

The series connection of two resistors is electrically identical to a resistor with the value 2R parallel to an ideal transformer T with a resistor 2R in series, the central branch of the transformer T replacing the nodal point of the series connection (see Fig. 2). The transformer consists of two series-connected windings T1, T2, which are coupled 100%.

If in the rotary field network of Fig. 1 the two resistors R are replaced by the transformer T with the resistor of 2R in series, that is, the equivalent-circuit diagram of Fig. 2 with omission of the parallel resistor 2R, as shown in Fig. 3, it is found that all properties of the network remain the same with the exception of the input impedance, which doubles to 2R. This means that, given the same input voltage, and hence with the same coil currents, only half of the nominal input is needed. So this energy saving is possible through the conversion of two damping resistors of the two circuits to a different pair, one of which is capable of damping both circuits, while the other stands across a constant impedance and hence is superfluous for damping, but still absorbs half of the power. This last resistor can be omitted, as shown in Fig. 3.

If, with the methods known for the purpose, this network is converted to an input impedance R and the transformer T is moved to the parallel circuit, a network emerges consisting of a parallel circuit with coil L3 and capacitor C3 and a series circuit with coil L4 and capacitor C4 on the central branch of coil L3, as shown in Fig. 4.

This network comprises a single shared damping resistor R instead of the two resistors R of Fig. 1.

Coil L3 now forms one whole with the transformer T and so consists of two 100% coupled coils with a value of one quarter of the self-inductance L3 in series.

In it, the following applies:

$$2\pi fo\ L3 = 2R/Q \quad \text{or} \quad L3/C3 = 4R^2Q^2$$

and

$$2\pi fo\ L4 = QR/2 \quad \text{or} \quad L4/C4 = R^2/4Q^2$$

Therefore it holds here that $2\pi fo\ I^2L = 2PQ$

For the conversion:

$$L4 = 1/2\ L2 \quad C4 = 2\ C2$$

$$L3 = 2\ L1 \quad C3 = 1/2\ C1$$

where:

$$L1 = Q^2 * L4$$

and

$$L3 = Q^2 * L4$$

In those situations where the two antenna coils are not connected directly but via two matching transformers, this network is simpler than the preceding one. The two strongly coupled coils of L3 can then be realized with an additional winding on the matching transformer in question. In that case, in addition to the two matching transformers, only two tuning capacitors and one resistor are needed.

In the filter technique this network is also known as a passive second-order allpass-filter. The input voltage is transmitted unchanged to the only resistor R at the output of the filter. A frequency-dependent group running time, however, makes it impossible to utilize the power dissipated in the resistor in the same manner for still more coils in which the current changes with respect to the input voltage according to a second-order transfer function.

The circuit according to the invention is useful not only for adjusting coils to a constant impedance or generating a rotary field, but also for increasing the efficiency or the bandwidth of a single antenna coil. In that case, one of the antennas, for instance L4, can be replaced by a fixed coil.

In absorption systems in which a system of antennas is connected to both the transmitter and the receiver, the signal-to-noise ratio of the transmitter generally constitutes a limitation of the detection sensitivity. The sensitivity is then determined directly by the antenna efficiency and the Q factor of the antenna. By using the above-described circuit for the antenna of an absorption system, the received signal, and hence the detection sensitivity, will increase by 6 dB, given the same Q factor or bandwidth.

In a classic absorption system, whereby the transmitter is varied in frequency over the frequency band under inquiry and with which electronic labels (responders) are detected as small changes in the antenna impedance, the frequency dependence of the antenna impedance constitutes an additional limitation for the permitted Q factor. Fast changes of the impedance as a result of too high a Q factor cannot be distinguished from the labels to be detected. In the antenna network according to the invention the Q factor does not have any direct influence on the impedance of the antenna system and it can therefore be increased to a value which the desired bandwidth and tuning accuracy still permit. The detection sensitivity can thereby be further improved.

Accordingly, the rotary field network according to the invention is eminently suitable for absorption systems because the gain in sensitivity can be greater than the 6 dB already expected.

Because the impedance of the network is accurately known and constant, the rotary field network according to the invention provides the possibility in an absorption system to further improve the sensitivity by the use of a directional coupling. By comparing the voltage and current in the feeder cable to the antenna system, using the antenna impedance, a directional coupling can distinguish between the power going one way and the other. An absorption system comprising an antenna system according to the invention and a directional coupling is schematically shown in Fig. 5.

In its simplest form, a directional coupling consists of a small coil Lk in series in the transmitter line 50, 51 and a series connection of a small capacitor Ck and a resistor Rk parallel to the transmitter line 50, 51.

If these three components have a value such that: $R * Rk = Lk/Ck$, the voltage across Lk as a result of the current to the antenna network is equal to the voltage across Rk as a result of the voltage across the antenna network.

In that case, the signal of the transmitter TX does not reach the receiver RX directly, but only via disturbances of the impedance of the antenna network caused by responders. The receiver signal is here attenuated by the slight coupling factor of the directional coupling, determined by

$$(2\pi f)^2 * L * C << 1,$$

but because the receiver sensitivity is mostly not determined by its own noise, this attenuation is not of importance. The limitation of the receiver sensitivity by noise and other undesired signals derived from the transmitter can be reduced in this manner. With a directional coupling, small changes of the antenna impedance, and hence the label signals to be detected, can be amplified with respect to the transmitter signal.

Claims

1. An antenna device for use in an electromagnetic detection system, comprising two loop antenna coils for generating a detection field for detecting responders provided with a loop antenna coil in a detection zone, the loop antenna coils in operation forming part of an antenna circuit connected to an exciting circuit, which antenna circuit comprises a series resonance circuit and a parallel resonance circuit with the same resonance frequency as the series resonance circuit, characterized in that the antenna circuit comprises a single damping resistance (R); that one of the loop antenna coils (L) is constructed as a transformer (T) with two very strongly coupled windings (T1, T2) and a central branch, which loop antenna coil (L3) is connected in parallel to a first tuning capacitor (C3); and that the damping resistance (R) is connected in series to the first tuning capacitor (C3) and is connected in parallel to a series connection of a second tuning capacitor (C4) and a second loop antenna coil (L4), while the end of the second loop antenna coil (L4) that is not connected to the second tuning capacitor (C4) is connected to the central branch of the loop antenna coil (L3) constructed as a transformer.

2. An antenna device according to claim 1, characterized in that one of the loop antenna coils is replaced by an ordinary coil, not functioning as a loop antenna coil.

3. An antenna device according to claim 1 or 2, characterized in that at least one of the loop antenna coils (L3, L4) of the antenna device is coupled to the rest of the antenna circuit via a matching transformer (Tk1, Tk2).

4. An antenna device according to claim 3, wherein the coil constructed as a transformer is provided with an additional winding, which is connected to the corresponding loop antenna coil (L3).

5. An electromagnetic detection system comprising an antenna device according to any one of claims 1-4.

6. An electromagnetic detection system according to claim 5, comprising a transmitter (Tx) and a receiver (Rx), characterized in that the transmitter (Tx) and the receiver (Rx) are connected to the antenna circuit through a directional coupling.

7. An electromagnetic detection system according to claim 6, characterized in that the directional coupling comprises a coil (Lk) arranged in a connecting line (50) between the transmitter (Tx) and the antenna circuit, as well as a series connection, connected in parallel to the antenna circuit, of a resistor (Rk) and a capacitor (Ck), the nodal point between the resistor (Rk) and the capacitor (Ck) being connected to the receiver (Rx).

8. An electromagnetic detection system according to claim 5, characterized in that the detection system is a system of the absorption type.

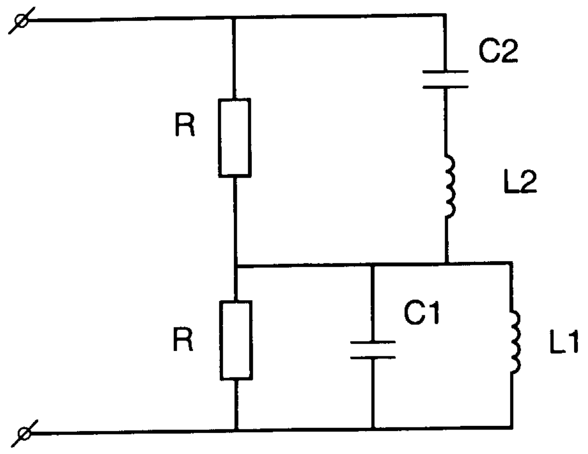

FIG. 1

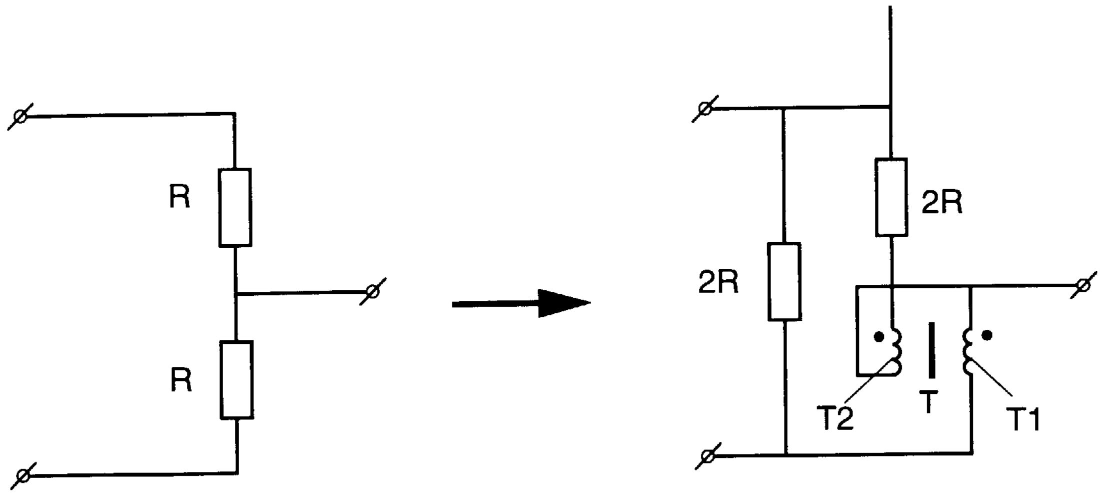

FIG. 2

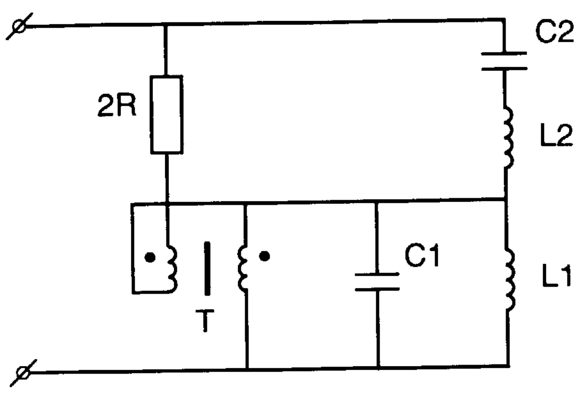

FIG. 3

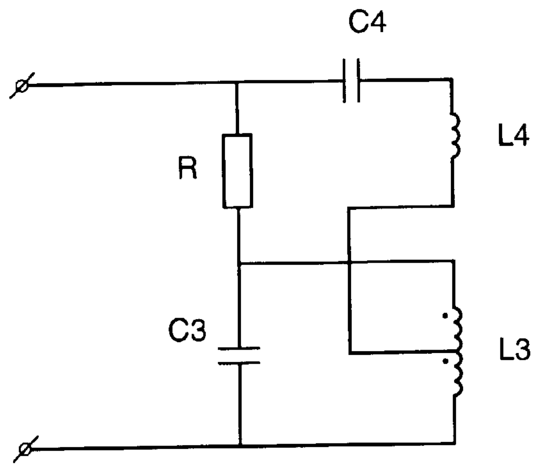

FIG. 4

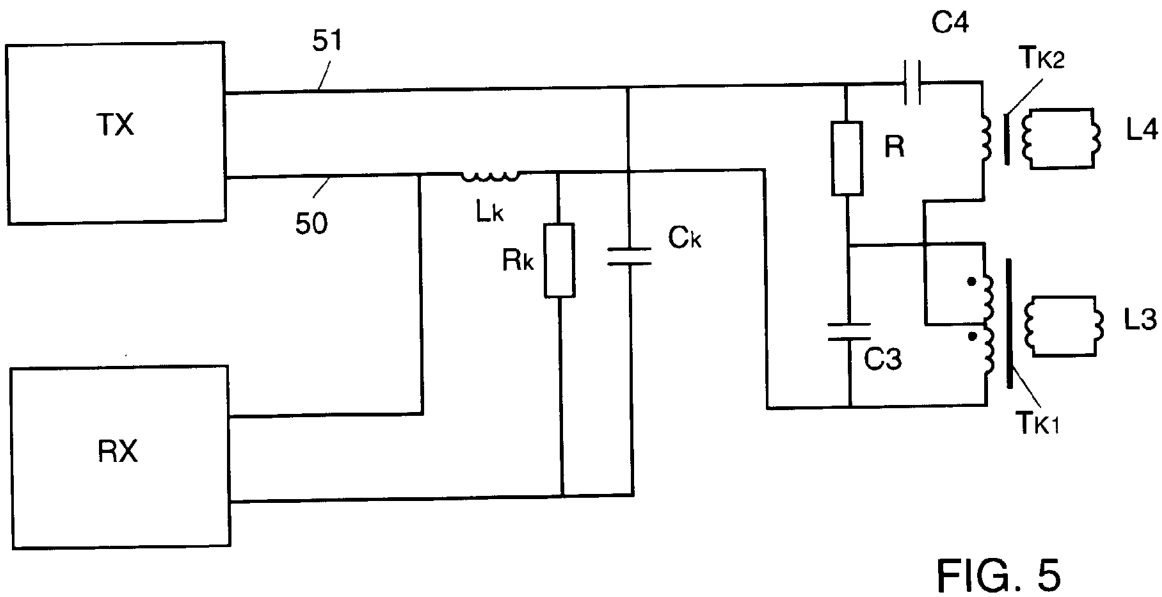

FIG. 5

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EUROPEAN SEARCH REPORT

Application Number
EP 96 20 2459

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A,D	EP-A-0 579 332 (NEDAP) * the whole document * -----	1	G08B13/24
			TECHNICAL FIELDS SEARCHED (Int.Cl.6)
			G08B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	6 December 1996	Sgura, S

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