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(54) **ANTENNA GENERATING AN ELECTROMAGNETIC FIELD FOR TRANSPONDER**

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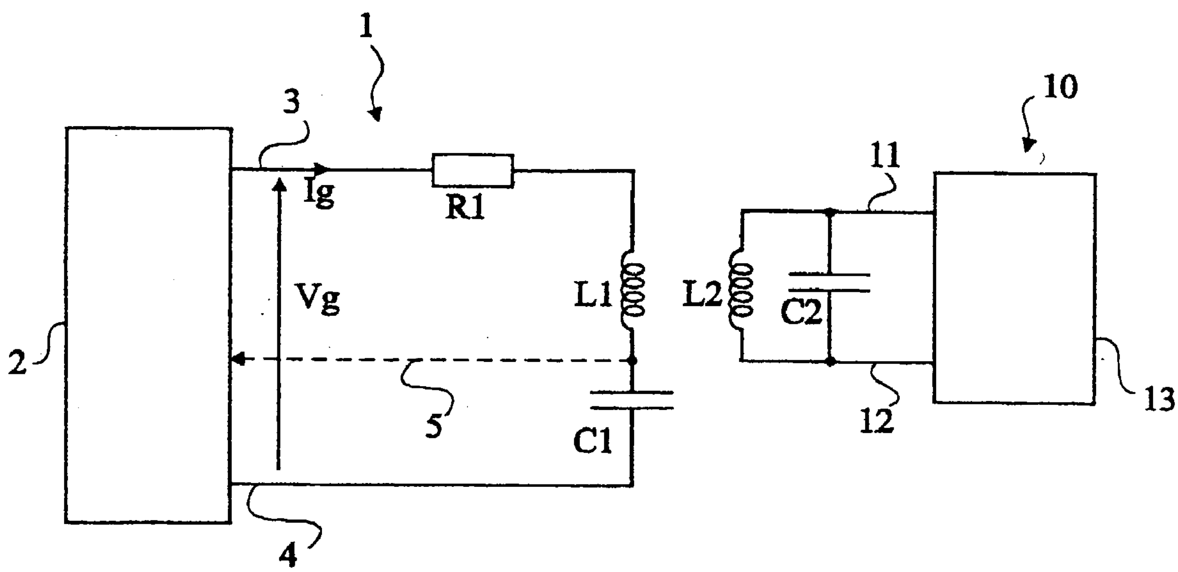
(57) **ABSTRACT**

The invention concerns an antenna generating an electromagnetic field for an electromagnetic transponder. and a terminal provided with such an antenna, comprising a first inductive element (Lp) designed to be connected to two terminals **(3, 4)** applying an energizing voltage (Vg), and a parallel resonant circuit **(21)** coupled with the first inductive element.



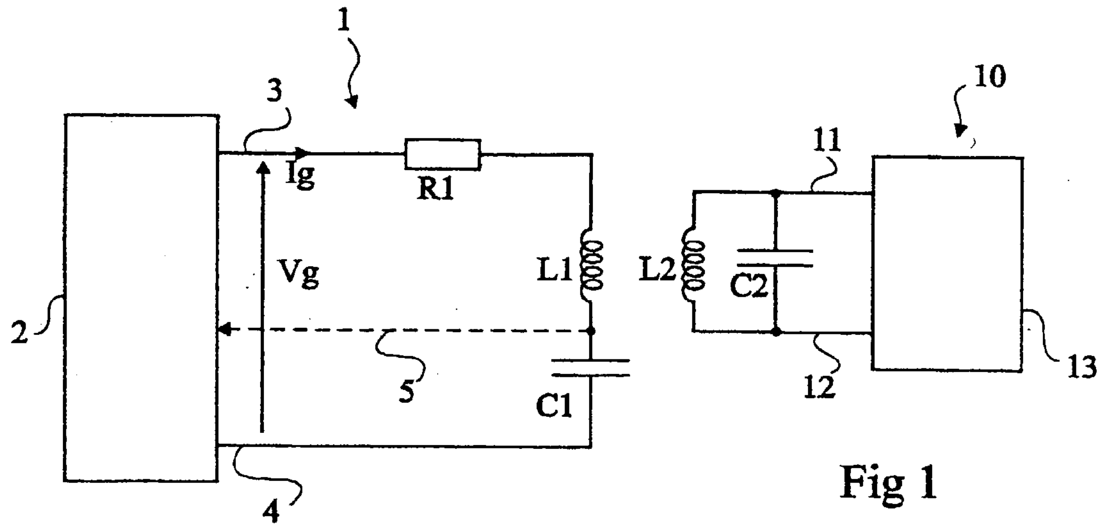


Fig 1

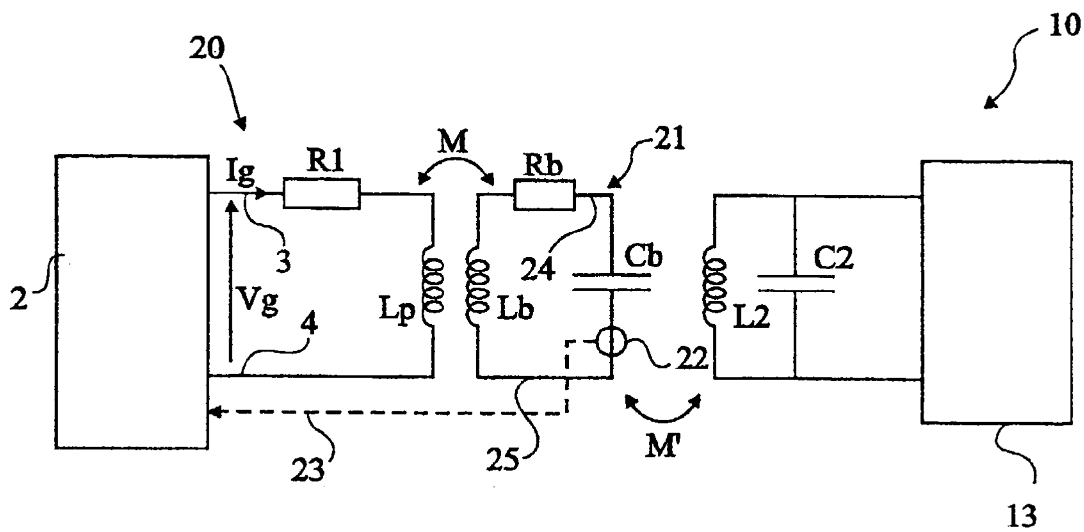


Fig 2

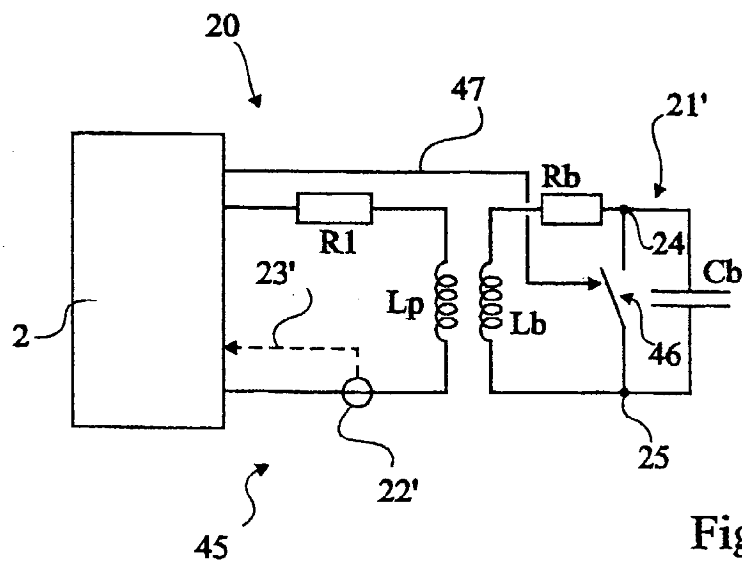


Fig 4

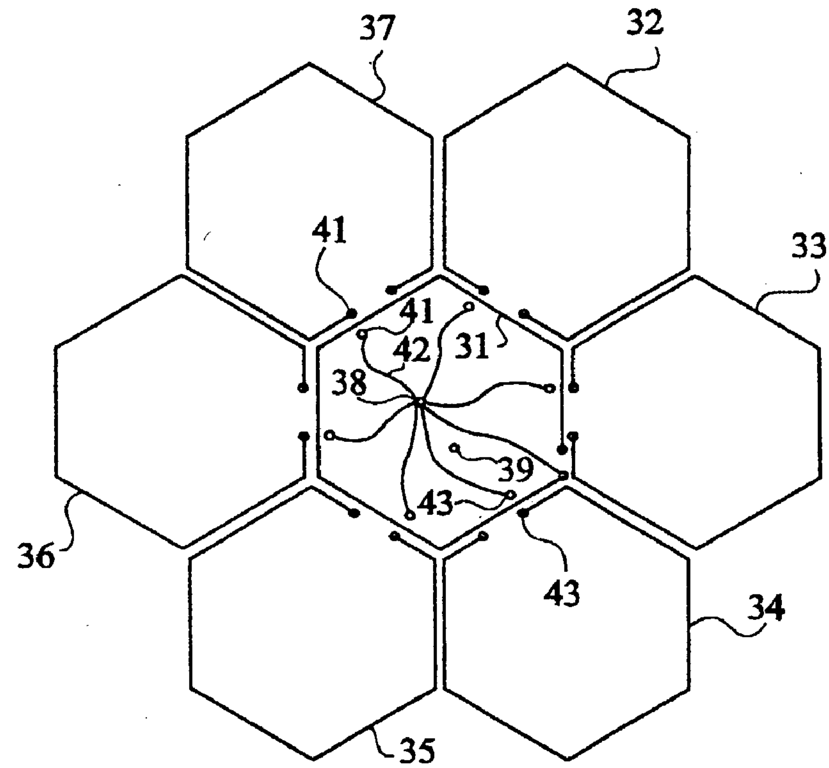


Fig 3A

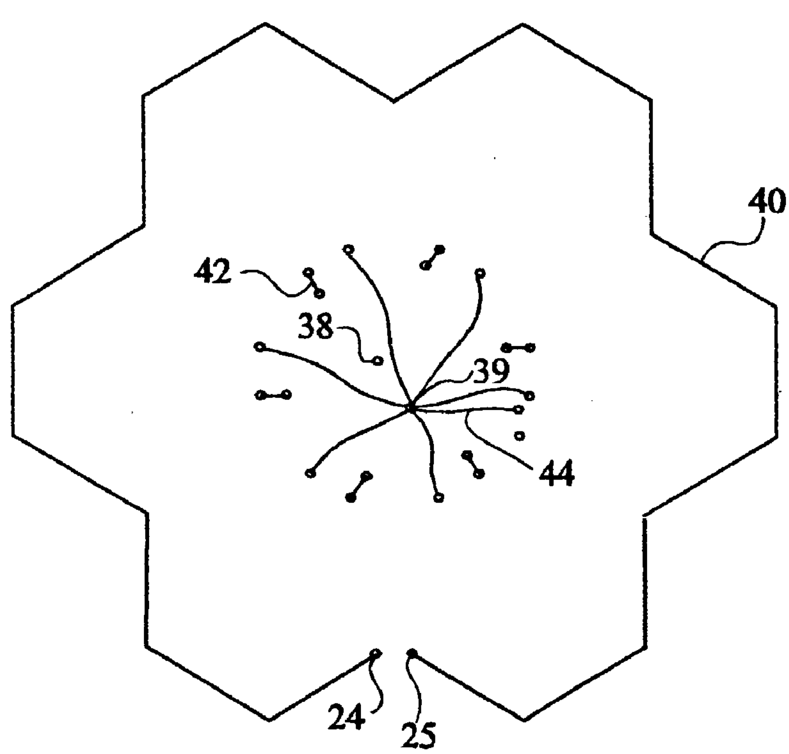


Fig 3B

ANTENNA GENERATING AN ELECTROMAGNETIC FIELD FOR TRANSPONDER

[0001] The present invention relates to systems using electromagnetic transponders, that is, transmitters and/or receivers (generally mobile) capable of being interrogated in a contactless and wireless manner by a unit (generally fixed), called a read and/or write terminal. Generally, transponders extract the power supply required by the electronic circuits included therein from the high-frequency field radiated by an antenna of the read-write terminal. The present invention more specifically relates to a read and/or write terminal for electromagnetic transponders as well as to the antenna that it includes.

[0002] **FIG. 1** very schematically shows a conventional example of a read/write terminal **1** associated with a transponder **10**.

[0003] Generally, terminal **1** is essentially formed of a series oscillating circuit formed of an inductance L1 in series with a capacitor C1 and a resistor R1. This oscillating circuit is controlled by a device **2** including, among others, an amplifier or antenna coupler and a control circuit exploiting the received data provided, in particular, with a modulator/demodulator and a microprocessor for processing the control signals and the data. The oscillating circuit is excited by a voltage Vg provided by device **2** between terminals **3** and **4**. Circuit **2** generally communicates with different input/output circuits (keyboard, screen, means of exchange with a server, etc.) and/or processing circuits, not shown. The circuits of the read/write terminal draw the power necessary to their operation from a supply circuit (not shown) connected, for example, to the electric supply system.

[0004] A transponder **10**, intended for cooperating with a terminal **1**, essentially includes a parallel oscillating circuit. This circuit is formed of an inductance L2 in parallel with a capacitor C2 between two input terminals **11**, **12** of a control and processing circuit **13**. Terminals **11**, **12** are in practice connected to the input of a rectifying means (not shown), the outputs of which form D.C. supply terminals of the circuits internal to transponder **10**. These circuits generally include, essentially, a microprocessor, a memory, a demodulator of the signals that may be received from terminal **1**, and a modulator for transmitting information to the terminal.

[0005] The oscillating circuits of the terminal and of the transponder are generally tuned on a same frequency corresponding to the frequency of excitation signal Vg of the terminal's oscillating circuit. This high-frequency signal (for example, at 13.56 MHz) is not only used as a carrier of data transmission from the terminal to the transponder, but also as a remote supply carrier for the transponders located in the terminal's field. When a transponder **10** is located in the field of a terminal **1**, a high-frequency voltage is generated across terminals **11** and **12** of the transponder's resonant circuit. This voltage, after being rectified and possibly clipped, provides the supply voltage of electronic circuits **13** of the transponder.

[0006] The high-frequency carrier transmitted by the terminal is generally modulated in amplitude by said terminal according to different coding techniques to transmit data and/or control signals to one or several transponders in the field. In return, the data transmission from the transponder to a terminal is generally performed by modulating the load formed by resonant circuit L2, C2. The load variation is performed at the rate of a sub-carrier having a frequency (for example, 847.5 kHz) smaller than that of the carrier. This load variation can then be detected by the terminal as an amplitude variation or as a phase variation by means, for example, of a measurement of the voltage across capacitor C1 or of current Ig in the oscillating circuit. In **FIG. 1**, the measurement signal has been symbolized by a connection **5** in dotted lines connecting the midpoint of the series connection of inductance L1 and capacitor C1 to circuit **2**.

[0007] A problem which arises in conventional transponder systems is that they generally have a limited range. The system range corresponds to the limiting distance beyond which the field sensed by a transponder is too small to enable extraction of the power necessary for its operation therefrom. The limited range is essentially due to the maximum admissible magnetic field, which is set by standards. Conventionally, to increase the range, the diameter of the antenna is desired to be increased, to avoid exceeding this maximum allowed magnetic field. Now, increasing the diameter amounts to increasing excitation current Ig in proportions that are not desirable, among others, for power consumption reasons.

[0008] An object of the present invention is to improve the range of electromagnetic transponder read/write terminals.

[0009] The present invention more specifically aims at providing a novel long-range electromagnetic field generation antenna.

[0010] The present invention also aims at requiring no modification of the transponders and, accordingly, at being able to operate with any conventional transponder.

[0011] The present invention also aims at reducing or minimizing the power consumption of the terminal.

[0012] To achieve these objects, the present invention provides an antenna for generating an electromagnetic field for an electromagnetic transponder, including a first inductive element intended for being connected to two terminals of application of an excitation voltage, and a parallel resonant circuit coupled with the first inductive element.

[0013] According to an embodiment of the present invention, said resonant circuit includes a second inductive element, the value of which is chosen to be greater than the value of the first inductive element with a ratio depending on a desired field amplification.

[0014] According to an embodiment of the present invention, the first inductive element is formed of several inductances associated in a network.

[0015] According to an embodiment of the present invention, the inductive element(s) are formed of planar windings.

[0016] According to an embodiment of the present invention, the two inductive elements are in parallel planes.

[0017] According to an embodiment of the present invention, the distance that separates the respective planes of the inductive elements is chosen according to the power consumption of the transponders for which the antenna is intended and to the desired range.

[0018] The present invention also provides a terminal for generating a high-frequency electromagnetic field for at least one transponder entering this field, the terminal including a resonant circuit, magnetically coupled to an excitation circuit including a first inductive element and having no capacitive element.

[0019] According to an embodiment of the present invention, the resonant circuit is formed of a second inductive element and of a capacitive element in parallel, and is tuned to the frequency of an excitation signal of the first inductive element.

[0020] According to an embodiment of the present invention, said resonant circuit includes a control switch.

[0021] The foregoing objects, features and advantages of the present invention, will be discussed in detail in the following non-limiting description of specific embodiments in connection with the accompanying drawings.

[0022] **FIG. 1**, previously described, shows a conventional example of a transponder system of the type to which the present invention applies;

[0023] **FIG. 2**, schematically shows a first embodiment of a read and/or write terminal, provided with an antenna according to the present invention, and associated with a conventional transponder;

[0024] **FIGS. 3A and 3B** show an antenna according to a second embodiment of the present invention; and

[0025] **FIG. 4** shows an alternative embodiment of a terminal according to the present invention.

[0026] The same elements have been referred to with the same references in the different drawings. For clarity, only those elements which are necessary to the understanding of the present invention have been illustrated in the drawings and will be described hereafter. In particular, the internal structures of the electronic circuits of a transponder and of a read and/or write terminal have not been detailed.

[0027] A feature of the present invention is to provide the antenna of a read and/or write terminal in the form of an LR circuit coupled to a resonant LC circuit. According to the present invention, the LR circuit is excited by the high-frequency generator of the terminal. The excitation frequency is, conventionally, that of the remote supply carrier and of the possible data to be transmitted. The resonant circuit forms a rejector circuit formed of an inductance and of a capacitor. It is in practice an RLC circuit with as small a resistance as possible corresponding to the series resistances of the inductance and of the capacitor.

[0028] Another feature of the present invention is to provide a value of the inductance of the rejector circuit greater than that of the LR excitation circuit. Thus, the voltage developed across the capacitor of the rejector circuit is greater than the excitation voltage of the LR circuit. According to the present invention, the quality factor of the rejector circuit is desired to be maximized to favor the amplification created by its coupling with the LR excitation circuit. The quality factor is inversely proportional to the sum of the series resistances and to the square root of the capacitance of the rejector circuit, and directly proportional to the square root of its inductance. Accordingly, the inductance is desired to be maximized and the series resistances and the capacitance are desired to be minimized.

[0029] **FIG. 2** very schematically shows a first embodiment of a read and/or write terminal according to the present invention.

[0030] Conventionally, a terminal **20** according to the present invention includes circuits **2** for processing, controlling, and analyzing data to be exchanged with a transponder **10**, also conventional. A high-frequency voltage Vg used as a remote power supply carrier and/or as a modulation carrier for a transponder is provided across output terminals **3** and **4** of circuit **2**. According to the present invention, terminals **3** and **4** are connected to a series LR circuit formed of a resistor R1 in series with an inductance Lp. Inductance Lp is intended to be coupled with an inductance Lb of a rejector circuit **21** associated with the LR circuit. Circuit **21** also includes a capacitor Cb, the two electrodes of which are respectively connected to the two terminals **24** and **25** of inductance Lb. According to the present invention, the inductive LR circuit, connected across terminals **3** and **4** of circuit **2**, includes no capacitor. Thus, there is no tuning of the excitation circuit on the remote supply carrier frequency. According to the present invention, this tuning is transferred to rejector circuit **21**. For the latter, the respective values of inductance Lb and of capacitance Cb are selected so that the resonance frequency of this circuit corresponds to the remote supply carrier of the system (for example, 13.56 MHz).

[0031] According to the present invention, inductances Lp and Lb are, preferably, made in the form of planar inductances having one or several spirals. The inductances are placed in parallel planes to increase or maximize the magnetic coupling between them. This coupling is symbolized in **FIG. 2** by mutual inductance M between the LR and LC circuits. Transponder **10** is a conventional transponder, the present invention requiring no modification of the transponder for its implementation. When transponder **10** is present in the terminal's field, it is in magnetic coupling (mutual inductance M') with the rejector circuit, from which it draws the power necessary to its operation.

[0032] The fact of placing a transponder in the antenna's field amounts to increasing the series resistance of rejector circuit **21**, and thus reduces its quality factor and the current flow therethrough. This causes power consumption on the side of excitation circuit R1-Lp. However, the terminal's generator can just provide an energizing current to the rejector circuit where the current and the voltage are naturally high.

[0033] Inductance Lp is chosen to be as small as possible to optimize the system efficiency and maximize the use of the installed power of the generator providing voltage Vg. The value of inductance Lb of rejector circuit **21** is chosen to be as high as possible to maximize the system range. Indeed, the higher ratio Lb/Lp, the greater the ratio between the voltage developed across capacitor Cb and voltage Vg.

[0034] According to a preferred embodiment of the present invention, the interval between the planar inductances, arranged in parallel planes, is adapted to the transponders for which the terminal is intended. According to the charge level represented by different transponders (in particular, according to whether they include or not a microprocessor) and according to the desired range, the coupling between the excitation and rejector circuits can be optimized. In the case of low-power consumption transponders and where a large range is desired, the antenna's inductances will be drawn away from each other to maximize the overvoltage generated across the rejector circuit. For example, an interval ranging between approximately 0.5 cm and a few centimeters will be selected. Conversely, for transponders having a higher power consumption, the coupling between inductances must be maximized so that the load represented by the transponders does not alter too much the quality factor of the rejector circuit. The antenna's inductances are then placed as close as possible to each other. The interval of course depends, among others, on the diameter of the inductances and on the quality coefficient of the rejector circuit.

[0035] An advantage of the present invention is that it enables increasing the range of a read and/or write terminal for a given voltage Vg and excitation current Ig.

[0036] Another advantage of the present invention is that it requires no modification of existing transponders.

[0037] The detection of a back modulation coming from a transponder can be performed either on the LR circuit or in LC circuit **21**. In the embodiment of **FIG. 2, a** current transformer **22** having the function of measuring the current in rejector circuit **21** has been symbolized. A connection **23** provides the result of this measurement to circuit **2**. As an alternative, the measurement may be performed in the LR circuit. However, it is easier to detect variations in the rejector circuit where the signal levels are higher. It will however be ascertained that this measurement disturbs as little as possible the quality factor of the rejector circuit. For example, if a voltage measurement is performed across capacitor Cb, it will be ascertained to use a measurement element with a high input impedance.

[0038] The present invention enables increasing the transmitted magnetic field without increasing either the current provided by the generator or voltage Vg, and thus without increasing the installed terminal power. For a same terminal with a given installed power, the present invention enables easy use of antennas of large dimensions, which is difficult with conventional terminals without increasing the generator voltage to provide the sufficient current.

[0039] Another advantage of the present invention is that it eases the impedance matching of the antenna with respect to control circuit **2**. Indeed, the impedance Zpeq seen by the generator (circuit **2**) providing the high-frequency excitation voltage can be generally written as:

$$Zpeq=Rp+j.Xp,$$

[0040] where Rp represents the following real part:

$$Rp = \frac{\omega^2 \cdot k_{pb}^2 \cdot Lp \cdot Lb}{Rb}, \text{ and}$$

[0041] where Xp represents the following imaginary part:

$$Xp=\omega.\times Lp,$$

[0042] with k_{pb} representing the magnetic coupling coefficient between the excitation and rejector circuits, and Rb representing the equivalent resistance of circuit **21** (sum of the parasitic resistances of capacitor Cb and of inductance Lb). In real part Rp, no account has been taken of resistance R1, which corresponds in practice to the output resistance of the excitation generator. The series resistance of inductance Lp has further been neglected. The taking into account of these resistive elements merely amounts to adding their respective values to resistance Rb indicated hereabove.

[0043] To adapt the antenna's impedance, the ratio between inductances Lb and Lp may, for example, be modified, or a resistor may be introduced in parallel in circuit **21**.

[0044] Further, imaginary part Xp of impedance Zpeq is a function of inductance Lp, which is minimized. Accordingly, the impedance may, as a first approximation, be considered as being purely resistive. It is thus particularly easy to obtain an off-load impedance matching (for example, at 50 Ω). An advantage then is that the antenna of the read/write terminal can be easily moved aside from its control circuits. A 50-Ω matched impedance cable is sufficient. Of course, when a transponder is present in the field, it has an influence upon the impedance seen by the generator (at the denominator of the real part).

[0045] **FIGS. 3A and 3B** show the two sides of an antenna according to a preferred embodiment of the present invention. According to this preferred embodiment, inductive excitation element Lp is formed of several inductances **31**, **32**, **33**, **34**, **35**, **36**, and **37** in a network, that is, electrically in parallel. Inductances **31**, **32**, **33**, **34**, **35**, **36**, and **37** are coplanar. The inductances are, preferably, distributed in a honeycomb. Each inductance **31**, **32**, **33**, **34**, **35**, **36**, and **37** includes, for example, a single hexagonal spiral. The number of spirals of these inductances may be adapted to the value desired for the resulting inductive element Lp. Terminals **38** and **39** of interconnection of the respective terminals of inductances **31** to **37** form the terminals of element Lp. The inductances are for example formed by depositions of conductive tracks on a printed circuit wafer. A first end of each inductance is connected to terminal **38**. This connection is performed by means of vias **41** and of conductive tracks **42** of the two wafer surfaces (**FIGS. 3A and 3B**). The second end of each inductance is connected to terminal **39** by means of vias **43** and of tracks **44**.

[0046] The network association of the inductances must be such that all inductances in the network generate fields, the lines of which add (all are in the same direction).

[0047] Inductance Lb is formed on the second wafer surface. In this preferred embodiment, this inductance is formed of a single spiral **40** approximately delimiting a surface equivalent to that of all the network-connected spirals of inductive element Lp. It thus follows the external contour of the honeycomb. The end terminals of spiral **40** define terminals **24** and **25** of inductance Lb intended for being connected to capacitor Cb (not shown).

[0048] An advantage of using a network inductive element on the side of the LR circuit is that the voltage and current ratio is maximized between the rejector circuit and the excitation circuit. Indeed, the ratio between the inductances of the rejector circuit and of the excitation circuit is increased.

[0049] Another advantage of using network inductive elements in the excitation circuit is that this further eases the impedance matching. Indeed, the value of inductance Lp, which intervenes in the imaginary part of the impedance of the excitation circuit, is minimized.

[0050] **FIG. 4** shows another embodiment of a read and/or write terminal **45** according to the present invention. This embodiment more specifically applies to a terminal intended for operating either in relatively remote coupling with a transponder, or in very close coupling therewith. Indeed, in some applications, it is desired to only exchange information between a transponder and the terminal when said transponder is very close to the terminal. This, to avoid that a pirate device intercepts the data exchanges. In such a case, to use a single terminal, the data exchange sequences must conventionally be adapted and software controls must be performed for an operation in very close coupling allowed to a single transponder.

[0051] **FIG. 4** illustrates that the implementation of the present invention greatly eases an operation in extreme closeness of a read and/or write terminal. For this purpose, a switch **46** is provided in rejector circuit **21**'. This switch is placed in parallel with inductance Lb and is intended for short-circuiting the rejector circuit and, accordingly, eliminating the coupling with excitation circuit LR. Switch **46** is controlled by circuit **2**, via a connection **47**.

[0052] For example, when the terminal is desired to be dedicated to an operation in extreme closeness, switch **46** is closed. In this case, a transponder that wants to exchange data with the terminal must be placed almost on the terminal's antenna to obtain a magnetic coupling with inductive element Lp. The smaller the value of this inductance, the more it will be necessary for the transponder to be close to the terminal. The operation will here be close to an operation as a transformer. When switch **46** is open, the rejector circuit performs its function and the range of the read and/or write terminal is maximum.

[0053] As an alternative, the switch is placed in series in the rejector circuit. The operation is then inverted and the opening of the switch turns off the rejector circuit. In this alternative, it will be ascertained that the series resistance of the switch is minimum.

[0054] The embodiment of **FIG. 4** shows a current transformer **22**' in series with inductive element Lp, and measurement signal **23**' of which is sent to circuit **2**. This current transformer provides a measurement of the current in the excitation circuit. Such an arrangement is here necessary at least for the operation in extreme closeness since a detection can no longer be performed by the rejector circuit. It is however possible to maintain the use of a measurement system, on the rejector circuit side, when the terminal operates in remote range.

[0055] Of course, the present invention is likely to have various alterations, modifications, and improvements which will readily occur to those skilled in the art. In particular, the sizing of the different components of a read and/or write terminal according to the present invention is within the abilities of those skilled in the art based on the functional indications given hereabove.

1. An antenna for generating an electromagnetic field for an electromagnetic transponder, including:

a first inductive element (Lp) intended for being connected to two terminals (**3**, **4**) of application of an excitation voltage (Vg); and

a parallel resonant circuit (**21**, **21**') coupled with the first inductive element.

2. The antenna of claim 1, characterized in that the first inductive element (Lp) is formed of several inductances (**31**, **32**, **33**, **34**, **35**, **36**, **37**) organized in a network.

3. The antenna of claim 1 or **2**, characterized in that the inductive element(s) (Lp), Lb) are formed of planar windings.

4. The antenna of claim 3 characterized in that the two inductive elements (Lp, Lb) are in parallel planes.

5. The antenna of claim 4, characterized in that the distance that separates the respective planes of the inductive elements (Lp, Lb) is chosen according to the power consumption of the transponders for which the antenna is intended and to the desired range.

6. A terminal (**20**, **45**) for generating a high-frequency electromagnetic field for at least one transponder (**10**) entering this field, characterized in that it includes a resonant circuit (**21**, **21**'), magnetically coupled to an excitation circuit including a first inductive element (Lp) and having no capacitive element, said resonant circuit including a second inductive element (Lb), the value of which is chosen to be greater than the value of the first inductive element with a ratio depending on a desired field amplification.

7. The terminal of claim 1, characterized in that the resonant circuit (**21**, **21**') is formed of a second inductive element (Lb) and of a capacitive element (Cb) in parallel, and is tuned to the frequency of an excitation signal (Vg) of the first inductive element (Lp).

8. The terminal of claim 6 or **7**, characterized in that said inductive elements (Lp, Lb) form the antenna of any of claims 1 to 6.

9. The terminal of any of claims 6 to 8, characterized in that said resonant circuit (**21**') includes a control switch (**46**).

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