

RFID ANTENNA CIRCUIT

DESCRIPTION

The invention concerns an RFID and NFC antenna
5 circuit.

RFID is the abbreviation for Radio Frequency
Identification.

NFC is the abbreviation for Near Field
Communication.

10 This is a technique which allows identification of
objects using a memory chip or an electronic device
which, by means of a radio antenna, is capable of
transmitting information to a specialized reader.

RFID/NFC technology is used in numerous areas, for
15 example in mobile telephones, personal digital
assistants PDAs, computers, contactless card readers,
the cards themselves which are to be read without
contact, but also passports, identification or
description tags, USB keys, SIM and (U)SIM cards called
20 "RFID or NFC SIM card", stickers for Dual or Dual
Interface cards (the sticker itself having an RFID/NFC
antenna), watches.

In RFID/NFC technology, the antenna of a first
RFID circuit (Reader) electromagnetically radiates a
25 radiofrequency signal over a certain distance which

contains data that is to be received by the antenna of a second RFID circuit (transponder) which may optionally reply by data by charge modulation to the first circuit. Each RFID circuit has its antenna
5 operating at its natural resonance frequency.

As a general rule, the problems with RFID antenna circuits relate to the efficiency of the magnetic antenna of the transponder and reader i.e. to the efficiency of coupling by mutual inductance between the
10 two magnetic antennas, to the transmission of energy and information between the electronic part and its antenna, and to the transmission of energy and information between the two antennas of the RFID system.

15 The chief objective is to gain in radio efficiency (emitted or captured magnetic field power, coupling, mutual inductance, etc.) by the antenna without losing any signal quality (data distortion, antenna bandwidth, etc.) whether emitted or received.

20 Antennas with reduced surface areas (30x30 mm) are becoming increasingly more seen, even largely reduced surface areas (5x5 mm) for applications such as cards or μ Cards, stickers, small readers, option or detachable readers in mobile telephony, in USB keys, in
25 SIM cards.

In addition to a reduced ($<16 \text{ cm}^2$) or largely reduced ($<4 \text{ cm}^2$) surface area, very often there are very strong mechanical or electric constraints such as the presence of a battery, a screen or display, a
30 conductor support in the field very close to the antenna.

These various electric and mechanical constraints on the surface lead to reduced efficiency of the antenna, to loss of coupling efficiency, to loss of
35 signal power emitted or received by the antenna, and to

reduced communication distance or reduced transmission of energy or information.

For antennas of reasonable size ($>16 \text{ cm}^2$) as for antennas of reduced ($<16 \text{ cm}^2$) or largely reduced
5 ($<4 \text{ cm}^2$) surface area, increasingly greater needs are being encountered regarding the need for power on the emitted or captured magnetic field, the bandwidth of the radio channel to meet ever increasing data rates and standards in force such as ISO 14443 (e.g. for
10 transport, identity, etc.), ISO 15693 (e.g. for tags) and RFID/NFC specifications for the banking sector (EMVCO).

Document US-A-7,212,124 for example describes an information device for mobile telephone, comprising an
15 antenna coil formed on a substrate, a sheet of magnetic material, an integrated circuit and resonance capacitors connected to the antenna coil. The integrated circuit communicates with an outside apparatus through use by the antenna coil of a magnetic
20 field. A depression serving as a battery receiving section is formed on one part of the surface of the case and covered by the battery cover. The battery, antenna coil and sheet of magnetic material are housed in the depression. A film of vacuum evaporated metal or
25 a conductive material coating is applied to the case, while no film of vacuum evaporated metal or coating of conductive material is applied to the battery cover. The antenna coil is arranged between the battery cover and the battery, whilst the sheet of magnetic material
30 is arranged between the antenna coil and the battery in the depression. The antenna coil has an intermediate tap, the resonance capacitors are connected to both ends of the antenna coil, and the integrated circuit is connected in the centre between one of the ends of the
35 antenna coil and the intermediate tap.

This device has numerous disadvantages.

It only functions in mobile telephones. On account of the presence of a battery, the antenna must have a very high quality factor before its integration.

5 However, a quality factor having such a high value is not suitable for RFID/NFC antenna circuits, readers or transponders (cards, tags, USB keys). In a mobile telephone, the reason this high value quality factor exists is that electric and mechanical constraints

10 overwhelm the original quality factor of the antenna. For conventional applications or without these constraints, this quality coefficient of the antenna would be too high and would generate a much reduced antenna bandwidth at -3 dB, hence very severe filtering

15 of the modulated emitted or received HF signal through charge modulation (subcarrier of 13.56 MHz at ± 847 kHz, ± 424 kHz, ± 212 kHz, etc.) and too high emitted or received power. Also the coupling with said antenna, again for conventional applications or without these

20 constraints, would be such that at a short distance between the 2 antennas (<2 cm for example) the mutual inductance created would be such that it would fully mistune the frequency tuning of the two antennas, would cause the power radiated by the reader to collapse,

25 could saturate the radio stages of the silicon chip and even lead to possible destruction of the transponder silicon, this silicon not having infinite calorific dispersion capacity.

Therefore document US-A1-2008/0450693 for example

30 describes an antenna device essentially for reader mode operation. It has a conventional arrangement of a series inductance, an arrangement of two parallel inductances and finally an arrangement of two series inductances with a third inductance parallel to one of

35 the two series inductances. The embodiments proposed

notably require two different surfaces, one large and one small, either on the same inductance or on two inductances. The objective of the two latter embodiments is to allow amplification of the signal emitted in the centre of the antenna by a small parallel inductance, and in a third embodiment, to eliminate radiation holes over a location lying between the arrangement of the two antenna surfaces.

One of the disadvantages of the antenna device according to document US-A1-2008/0450693 is that it cannot be integrated into an embossed card. Another disadvantage is that the coupling of this device in read mode with another antenna does not meet the ideal conditions to obtain optimum coupling with a transponder.

Documents EP-A-1,031,939 and FR-A-2,777,141 describe an antenna circuit device for transponder mode operation having two electrically independent antenna circuits. In the device described in documents EP-A-1,031,939 and FR-A-2,777,141, a first antenna circuit consists of a conventional inductance and the transponder chip. A second antenna circuit consists of a coil winding forming an inductance associated with a planar capacitance called a "resonator". The objective of the two embodiments is to allow amplification of the electromagnetic signal received by the "resonator" arrangement for the first antenna circuit comprising the transponder.

This device according to EP-1,031,939 and FR-2,777,141 has the disadvantage of coupling that is much too strong, without guaranteeing the efficiency of increased read distance. Worse still, when coupling efficiency is extremely strong, RFID communication between the reader and the transponder does not take place.

Additionally, the same remarks as for document US-A-7,212,124 can be made. With a conventional "resonator" circuit, coupled by mutual inductance with a first antenna circuit comprising the transponder, the relationship is quasi-linear, to make things simple, between, firstly, the efficiency of reading distance or efficiency of electromagnetic field capture and, secondly, the surface of the 2 antenna circuits, their proximity, and their frequency tuning.

10 The advantage of the embodiments described in documents EP-A-1,031,939 and FR-A-2,777,141 is that maximum efficiency is obtained between the 2 antenna circuits, hence the greatest possible quality coefficient. We therefore arrive at the same remarks as
15 for document US-A-7,212,124.

Document EP-A-1,970,840 describes a device comparable with the two preceding devices described in documents EP-A-1,031,939 and FR-A-2,777,141, in that 2 resonators are used to amplify the received
20 electromagnetic field. The same remarks therefore apply as previously made. In addition, the constraints indicated for documents EP-A-1,031,939 and FR-A-2,777,141 are all the higher and more difficult to overcome since the two resonators lie close to one
25 another.

To increase the transmission of emitted or received energy by the antenna, it is possible to add an amplifier in the radio transmission or receiving chain, but this adds to the financial cost and
30 available energy and entails probable distortion on the modulated HF signal.

It is also possible to increase the level of the signal emitted by the silicon, but this is often limited by integration, technological choices, and
35 size.

It is also possible to reduce the internal consumption of the silicon, but current needs for signal cryptography safety, ever increasing memory capacity, and speed of task execution mean that the trend is more in the direction of increased energy consumption.

To increase the emitted or captured magnetic field, coupling, mutual inductance, it is also possible to increase considerably the number of antenna turns. This would increase the inductance of the antenna, the number of turns facing the antenna to be coupled, and hence mutual inductance and coupling. With very close distances between the 2 antennas (<2 cm) this is not an ideal solution either, since the mutual inductance would be very high, and would lead to ill-functioning of the RFID systems by introducing a very high quality coefficient Q and hence a very low bandwidth. For long distance operation (>15 cm) it would be an almost ideal solution, but the modulated HF signal would be filtered for RFID/NFC systems.

Finally, it is possible to act on the size of the antenna, but this is a variable which is rarely debatable and is often a constraint.

The invention generally sets out to obtain an antenna circuit having transmission efficiency and improved transmitting conditions.

For this purpose, a first subject of the invention is an RFID antenna circuit comprising:

- an antenna formed by a number of at least three turns, the antenna having a first end terminal and a second end terminal,
- at least two access terminals to connect a charge,
- at least one tuning capacitance for tuning at a prescribed tuning frequency, having a first

capacitance terminal and a second capacitance terminal,

- an intermediate tap connected to the antenna and distinct from the end terminals,
- 5 - first connection means connecting the intermediate tap to a first of the two access terminals,
- second connection means connecting the second end terminal to the second capacitance terminal, characterized in that it comprises:
- 10 - third connection means connecting the first capacitance terminal and the second of the access terminals respectively to a first point of the antenna and to a second point of the antenna, which is connected to the first point of the antenna by at
- 15 least one turn of the antenna.

According to one embodiment of the invention, said intermediate tap (A) is connected to the first end terminal (D) of the antenna (L) by at least one turn (S) of antenna (L), said intermediate tap (A) being

20 connected to the second end terminal (E) of antenna (L) by at least one turn (S) of antenna (L).

According to one embodiment of the invention (figures 13, 14, 15, 16), the first point (P1) is connected to the intermediate tap (A) by at least one

25 turn of the antenna.

According to one embodiment of the invention (figures 13, 14, 15, 16), the first point (P1) is located at the intermediate tap (A).

According to one embodiment of the invention, the

30 first point (P1) is connected to the first end terminal (D) of the antenna (L) by at least one turn (S) of antenna (L), the first point (P1) being connected to the second end terminal (E) of the antenna (L) by at least one turn (S) of antenna (L).

According to one embodiment of the invention, the first point (P1) is located at the first end terminal (D).

5 According to one embodiment of the invention, the second point (P2) is located at the first end terminal (D) of the antenna.

According to one embodiment of the invention, the second point (P2) is located at the second end terminal (E) of the antenna.

10 According to one embodiment of the invention, the second point (P2) is connected to the intermediate tap (A) by at least one turn of the antenna.

According to one embodiment of the invention, the second point (P2) is connected to the first end terminal (D) of the antenna (L) by at least one turn (S) of the antenna (L), the second point (P2) being connected to the second end terminal (E) of the antenna (L) by at least one turn (S) of the antenna (L).

15 According to one embodiment of the invention, the first point (P1) is located at the intermediate tap (A) of the antenna (L), and the second point (P2) is located at the first end terminal (D) of the antenna (L).

20 According to one embodiment of the invention, said first and second points (P1, P2) are separate from the first intermediate tap (A), the first point (P1) being connected to the first end terminal (D) of the antenna (L) by at least one turn (S) of the antenna (L), the first point (P1) being connected to the second end terminal (E) of the antenna (L) by at least one turn (S) of the antenna (L).

25 According to one embodiment of the invention (figures 13, 14), the second point (P2) is located at the first end terminal (D) of the antenna, the first

point (P1) is connected to the intermediate tap (A) by at least one turn of the antenna.

According to one embodiment of the invention, said intermediate tap (A) forms a first intermediate tap (A), the first intermediate tap (A) being connected to the first end terminal (D) of the antenna (L) by at least one turn (S) of the antenna (L), the first intermediate tap (A) being connected to the second end terminal (E) of the antenna (L) by at least one turn (S) of the antenna (L),

- the second point (P2) is located at a second intermediate tap (P2) of the antenna (L), the second intermediate tap (P2) being connected to the first end terminal (D) of the antenna (L) by at least one turn (S) of the antenna (L), the second intermediate tap (P2) being connected to the second end terminal (E) of the antenna (L) by at least one turn (S) of the antenna (L).

According to one embodiment of the invention, the capacitance comprises a first metal surface forming the first capacitance terminal (C1X), a second metal surface forming the second capacitance terminal (C1E), at least one dielectric layer lying between the first metal surface and the second metal surface.

According to one embodiment of the invention, the capacitance comprises at least one dielectric layer having a first side and a second side distant from the first side,

- a first metal surface forming the first capacitance terminal (C1X) on the first side of the dielectric layer,

- a second metal surface forming the second capacitance terminal (C1E) on the second side of the dielectric layer,

- a third metal surface forming a third capacitance terminal (C1F) lying away from the first metal surface on the first side of the dielectric layer,

5 - the first capacitance terminal (C1X) defining a first capacitance value (C2) with the second capacitance terminal (C1E),

 - the third capacitance terminal (C1F) defining a second capacitance value (C1) with the second
10 capacitance terminal (C1E),

 - the first capacitance terminal (C1X) defining a third coupling capacitance value (C12) with the third capacitance terminal (C1F),

 - connection means connecting the third
15 capacitance terminal (C1F) to one of the access terminals (1, 2).

 According to one embodiment of the invention, the antenna (L) comprises at least one first turn (S1), at least one second turn and at least one third turn,
20 which are consecutive, the first turn (S1) extending from the second end terminal (E) in a first winding direction to a reversal point (PR) connected to the second turn, the second and third turns (S2, S3) extending from said reversal point (PR) to the first
25 end terminal (D) in a second winding direction which is the reverse of the first winding direction,

 - the first point (P1) of the antenna (L) and the second point (P2) of the antenna (L) being located on the second and third turns (S2, S3).

30 According to one embodiment of the invention, the antenna (L) comprises at least one first turn (S1) and at least one second turn (S2, S3) consecutive between two third and fourth points (E; D) of the antenna, the first turn (S1) being connected to the second turn (S2,
35 S3) by a reversal point (PR), the first turn (S1)

extending from the third point (E) to the reversal point (PR) in a first winding direction, the second turn (S2, S3) extending from said reversal point (PR) to the fourth point (D) in a second direction of winding which is the reverse of the first winding direction.

According to one embodiment of the invention (figures 12, 31, 32), the antenna (L) comprises at least one first turn (S1) and at least one second turn (S2, S3) consecutive between two third and fourth points (E; D) of the antenna, the first turn (S1) being connected to the second turn (S2, S3) by a reversal point (PR), the first turn (S1) extending from the third point (E) to the reversal point (PR) in a first direction of winding, the second turn (S2, S3) extending from said reversal point (PR) to the fourth point (D) in a second direction of winding which is the reverse of the first direction of winding,

- the first point (P1) is located at the intermediate tap (A) of the antenna (L) and the second point (P2) is located at the first end terminal (D) of the antenna (L).

According to one embodiment of the invention (figures 15, 17), the antenna (L) comprises at least one first turn (S1) and at least one second turn (S2, S3) consecutive between two third and fourth points (E; D) of the antenna, the first turn (S1) being connected to the second turn (S2, S3) by a reversal point (PR), the first turn (S1) extending from the third point (E) to the reversal point (PR) in a first direction of winding, the second turn (S2, S3) extending from said reversal point (PR) to the fourth point (D) in a second direction of winding which is the reverse of the first direction of winding,

- the first point (P1) is located at the first end terminal (D).

According to one embodiment of the invention, at least one turn (S2) of the antenna comprises in series
 5 a winding (S2') of turns of smaller surrounded surface with respect to the surface surrounded by the remainder (S2'') of said turn (S2) or with respect to the surface surrounded by other turns of the antenna (3).

According to one embodiment of the invention, the
 10 turns (S) of the antenna (3) are distributed over several separate physical planes.

According to one embodiment of the invention, the tuning capacitance (C1) comprises a second capacitance (ZZ) formed by at least one third turn (SC3) comprising
 15 two first and second ends (SC31, SC32) and by at least one fourth turn (SC4) comprising two first and second ends (SC41, SC42), the third turn (SC3) being electrically separated from the fourth turn (SC4) to define at least the tuning capacitance (C1) between the
 20 first end (SC31) of the third turn (SC3) and the second end (SC42) of the fourth turn (SC4),

- the first end (SC31) of the third turn lying further distant from the second end (SC42) of the fourth turn (SC4) than from the first end (SC41) of the
 25 fourth turn (SC4), the second end (SC32) of the third turn (SC3) lying further distant from the first end (SC41) of the fourth turn (SC4) than from the second end (SC42) of the fourth turn (SC4), the second capacitance being defined between the first end (SC31)
 30 of the third turn (SC3) and the second end (SC42) of the fourth turn (SC4).

According to one embodiment of the invention, there is at least one turn (S1) of the antenna between the intermediate tap (A) and the second capacitance.

According to one embodiment of the invention, first coupling means are provided to ensure coupling (COUPL12) by mutual inductance between firstly the at least one turn (S2) of the antenna electrically
5 connected in parallel with the first and second access terminals (1, 2) and secondly the other at least one turn (S1) of the antenna, second coupling means are provided to ensure coupling (COUPLZZ) by mutual inductance between said other at least one turn (S1) of
10 the antenna and the at least one third and fourth turns (SC3, SC4) of the second capacitance (ZZ).

According to one embodiment of the invention, the first coupling means are formed by the proximity between, firstly, the at least one turn (S2) of the
15 antenna electrically connected in parallel with the first and second access terminals (1, 2) and, secondly, the other at least one turn (S1) of the antenna, the second coupling means are formed by the proximity between said other at least one turn (S1) of the
20 antenna and the at least one third and fourth turns (SC3, SC4) of the second capacitance (ZZ).

According to one embodiment of the invention, the third turn (SC3) and the fourth turn (SC4) are interleaved.

25 According to one embodiment of the invention, the third turn (SC3) comprises at least one third section, the fourth turn (SC4) comprises a fourth section, the third section lying adjacent the fourth section.

According to one embodiment of the invention, the
30 sections extend parallel to each other.

According to one embodiment of the invention, the tuning capacitance (C1) comprises a first capacitance (C1) comprising a dielectric between the first
35 capacitance terminal (C1X) and the second capacitance terminal (C1E), the first capacitance (C1) being made

in the form of a wire, etched, discrete, or printed element.

According to one embodiment of the invention (figures 16, 18), another capacitance (C30) is
5 connected between the second end terminal (E) and a point (PC1) of the antenna which is connected to the second point (P2) by at least one turn of the antenna.

According to one embodiment of the invention (figures 20, 22), the tuning capacitance (C1) comprises
10 a first capacitance (C30) in series with said second capacitance (Z).

According to one embodiment of the invention (figure 22), the first capacitance (C30) is connected between the second end terminal (E) of the antenna and
15 the second point (P2) which is connected to the first terminal (SC31) of the third turn (SC3), the intermediate tap (A) being connected to the second terminal (SC42) of the fourth turn (SC4) which forms the first point (P1), the first terminal (SC41) of the
20 fourth turn (SC4) forming the first end terminal (D) of the antenna.

According to one embodiment of the invention (figure 20), the first capacitance (C30) is connected between the second end terminal (E) of the antenna and
25 the second point (P2) which is connected to the first terminal (SC31) of the third turn (SC3) by at least one turn (S10), the intermediate tap (A) being connected to the second terminal (SC42) of the fourth turn (SC4) which forms the first point (P1), the first terminal
30 (SC41) of the fourth turn (SC4) forming the first end terminal (D) of the antenna.

According to one embodiment of the invention (figure 21), the first point (P1) is located at the intermediate tap (A), the second point (P2) is located
35 at the second end terminal (E) of the antenna.

According to one embodiment of the invention (figure 19), the first point (P1) is located at the first end terminal (D) and the second point (P2) is located at the second end terminal (E).

5 According to one embodiment of the invention, the at least one third turn (SC3) and the at least one fourth turn (SC4) define a second sub-circuit having a second natural resonance frequency, the first and second access terminals (1, 2), together with a module
10 (M) connected to them and with at least one turn (S2) connected to said first and second access terminals (1, 2), define a first sub-circuit having a first natural resonance frequency, the turns being arranged so that frequency difference between the first natural
15 resonance frequency and the second natural resonance frequency is equal to or less than 10 MHz.

 According to one embodiment of the invention, the at least one third turn (SC3) and the at least one fourth turn (SC4) define a second sub-circuit having a
20 second natural resonance frequency, the first and second access terminals (1, 2) together with a module (M) connected to them and with at least one turn (S2) connected to said first and second access terminals (1, 2) define a first sub-circuit having a first natural
25 resonance frequency, the turns being arranged so that the frequency difference between the first natural resonance frequency and the second natural resonance frequency is equal to or less than 500 KHz.

 According to one embodiment of the invention, the
30 at least one third turn (SC3) and the at least one fourth turn (SC4) define a second sub-circuit having a second natural resonance frequency, the first and second access terminals (1, 2) together with a module (M) connected to them and with at least one turn (S2)
35 connected to said first and second access terminals (1,

2) define a first sub-circuit having a first natural resonance frequency, the turns being arranged so that the first natural resonance frequency and the second natural resonance frequency are substantially equal.

5 According to one embodiment of the invention (figures 29, 30), the antenna comprises a mid-point (PM) to set a potential at a reference potential, with an equal number of turns on the section extending from the first end terminal (D) to the mid-point (PM) and on
10 the section extending from the mid-point (PM) to the second end terminal (E).

 According to one embodiment of the invention, the antenna lies on a substrate.

 According to one embodiment of the invention, the
15 antenna is a wire.

 According to one embodiment of the invention, said terminals (D, E, 1, 2, C1E, C1X), said tap (A), said points (P1, P2) and the capacitance (C1, ZZ) define a plurality of at least three nodes, the nodes defining
20 at least one first group (S1) of at least one turn between two first nodes (1, C1E) separate from each other, and at least one second group of at least one other turn (S2) between two second nodes (1, 2) separate from each other, at least one of the first
25 nodes being different from at least one of the second nodes, first coupling means are provided to ensure coupling (COUPL12) by mutual inductance between the first group (S1) of at least one turn and the second group of at least one other turn (S2) through the fact
30 that the first group (S1) of at least one turn is positioned in the vicinity of the second group of at least one other turn (S2).

 According to one embodiment of the invention, said terminals (D, E, 1, 2, C1E, C1X), said tap (A), said
35 points (P1, P2), and the capacitance (C1, ZZ) define a

plurality of at least three nodes, the nodes defining at least one first group (S1) of at least one turn between two first nodes (1, C1E) separate from each other, and at least one second group of at least one other turn (S2) between two second nodes (1, 2) separate from each other, and at least one third group of at least one other turn (SC3, SC4) between two third nodes (E, C1X) separate from each other, at least one of the first nodes being different from at least one of the second nodes, at least one of first nodes being different from at least one of the third nodes, at least one of the third nodes being different from at least one of the second nodes,

- first coupling means are provided to ensure coupling (COUPL12) by mutual inductance between, firstly, the first group (S1) of at least one turn and, secondly, the second group of at least one other turn (S2) through the fact that the first group (S1) of at least one turn is positioned in the vicinity of the second group of at least one other turn (S2),

- second coupling means are provided to ensure coupling (COUPLZZ) by mutual inductance between firstly the first group (S1) of at least one turn and secondly the third group of at least one other turn (SC3, SC4) through the fact that the first group (S1) of at least one turn is positioned in the vicinity of the third group of at least one other turn (SC3, SC4).

According to one embodiment of the invention, the first group (S1) of at least one turn is positioned between the second group of at least one other turn (S2) and the third group of at least one other turn (SC3, SC4).

According to one embodiment of the invention, the distance separating the turns (S1, S2, SC3, SC4)

belonging to different groups is equal to or less than 20 millimetres.

According to one embodiment of the invention, the distance separating the turns (S1, S2, SC3, SC4) belonging to different groups is equal to or less than 10 millimetres.

According to one embodiment of the invention, the distance separating the turns (S1, S2, SC3, SC4) belonging to different groups is equal to or less than 1 millimetre.

According to one embodiment of the invention, the distance separating the turns (S1, S2, SC3, SC4) belonging to different groups is equal to or more than 80 micrometres.

This is the distance separating the groups of turns (S1, S2).

According to an embodiment of the invention, at least a reader (LECT) as charge and / or at least a transponder (TRANS) as charge is connected to the access terminals (1, 2).

According to an embodiment of the invention, the circuit comprises several first access terminals (1) which are distinct from each other and / or several second access terminals which are distinct from each other.

According to an embodiment of the invention, said at least one first access terminal (1) and said at least one second access terminal (2) are connected to at least one first charge (Z1) having a first prescribed tuning frequency in a high frequency band and at least one second charge (Z2) having a second prescribed tuning frequency in another ultra high frequency band.

Thanks to the invention, it is managed to maintain a reasonable quality factor or to limit its increase

(the quality factor being equal to the resonance frequency divided by the bandwidth at -3 dB) in order to maintain a reasonable or scarcely increased bandwidth, whilst maintaining or increasing radiated or
5 received power by the antenna and maintaining or reducing the mutual inductance generated during coupling with the second, external RFID antenna circuit.

In particular, this overcomes the need to limit
10 the antenna to one or two turns as in prior art RFID/NFC readers of reasonable size ($>16 \text{ cm}^2$) and to 3 or 4 turns for reduced-size antennas ($<16 \text{ cm}^2$). In prior art RFID/NFC readers provision is made for no more than one or two turns for the antennas of
15 reasonable size ($>16 \text{ cm}^2$) and for no more than three or four turns for antennas of reduced size ($<16 \text{ cm}^2$) to guarantee both radiated and received power that is greater than a minimum power and a bandwidth that is greater than a minimum band. In prior art transponders,
20 the number of turns is imposed by the compromise between the antenna surface and silicon capacity and the desired tuning frequency (around 13.56 Mhz up to 20 MHz). For the transponder there is therefore little freedom regarding the number of turns in the antenna,
25 and hence little freedom regarding the radio efficiency of the antenna, hence little freedom regarding action on the quality factor, the captured magnetic field, coupling and the mutual inductance generated during coupling with the second, external RFID antenna
30 circuit.

The circuit of the invention, whether for transmitting or receiving, makes it possible in particular to reduce mutual inductance with the second, external RFID antenna circuit operating in receiver or
35 transmitting mode, since the current density is

especially concentrated in the active part of the inductance. By simplifying, for the purpose of technical vulgarization, the mutual inductance between two circuits is proportional to the number of opposite facing turns of the circuit. Reducing mutual inductance limits the perturbation on frequency tuning of the antenna circuits at short distances (<2 cm for example). This reduction in mutual inductance does not take place to the detriment of radiated or received power.

Let us consider these 3 rules, governing an HF RFID/NFC antenna system with a coil winding, known to the person skilled in the art:

- The magnetic field (H) is defined by:

$$H = \frac{I \cdot N \cdot R^2}{2\sqrt{(R^2 + x^2)^3}}$$

for circular antennas. N is the number of turns of the antenna, R is the radius of the antenna, and x is the distance from the centre of the antenna in direction x normal to the antenna.

- Mutual inductance (M) is defined by:

$$M_{21} = \frac{\mu_0 \cdot N_1 \cdot R_1^2 \cdot N_2 \cdot R_2^2 \cdot \pi}{2\sqrt{(R_2^2 + x^2)^3}}$$

in which N1 is the number of turns of a first antenna and N2 is the number of turns of a second antenna. Mutual inductance is a quantitative description of the flux coupling two conductor loops.

- The quality coefficient of the antenna (Q) is defined by:

$$Q = L \cdot 2\pi \cdot f_0 / R_a = f_0 / \text{Bandwidth at -3 dB}$$

- The coupling coefficient (K) is defined by:

$$k = \frac{M}{\sqrt{L_1 \cdot L_2}}$$

The coupling coefficient (K) introduces a qualitative prediction for the coupling of the antennas independently of their geometric dimensions. L1 is the
 5 inductance of a first antenna and L2 is the inductance of a second antenna.

The possibilities of increasing the radio efficiency of a magnetic antenna are described below.

To increase the transmitted or received magnetic
 10 field (H), if it is considered that the radius R and the current in the antenna I as imposed, the number N of turns of the antenna must be increased.

To increase the mutual inductance (M) between the 2 antennas, if R1 and R2 are considered to be imposed,
 15 then N1 and/or N2 must be increased.

To reduce the quality coefficient (Q) of the antenna, the inductance (L) of the antenna must be reduced and/or the resistance (Ra) of the antenna increased.

20 To increase coupling (k) between the 2 antennas, the mutual inductance (M) must be increased and/or the inductance L1 and L2 of the 2 antennas must be decreased without decreasing mutual inductance (M).

The problems and parameters related therewith are
 25 the following.

It is difficult to increase the global radio efficiency of the antenna without causing detriment to the emitted or captured magnetic field, to coupling, to mutual inductance, and to the bandwidth. For example,
 30 by increasing the number of turns, a favourable increase is obtained in inductance, in the magnetic field and in mutual inductance, but the bandwidth is reduced through an increase in the quality coefficient.

To summarize the possible choices:

The radiated or captured magnetic field depends on the number of turns in the antenna. Ideally the number of turns must be increased.

5 The coupling coefficient is an inverse function of the inductances of the 2 antennas. By reducing the inductance of the antennas, the coupling coefficient between the 2 antennas is increased. Again, ideally, either mutual inductance must be increased or the loss on mutual inductance must be limited.

10 Mutual inductance is a function of the number of turns of antennas. Therefore, by increasing the number of turns of the antenna, the mutual inductance between the 2 antennas increases. Giving consideration to the coupling coefficient, ideally, the inductances of the
15 antennas must not be increased.

The bandwidth is a function of the inductance of the antenna and the inverse function of the resistance of the antenna. Ideally, therefore, antenna inductance must be reduced and its resistance increased.

20 To conclude on the magnetic field, the number of turns must be the same or more.

To conclude on the coupling coefficient, mutual inductance must be the same or increased and/or the inductance of the antenna must be reduced.

25 To conclude on mutual inductance, the number of turns must be the same or increased.

To conclude on the quality coefficient, the inductance of the antenna must be the same or reduced and/or the resistance of the antenna must be increased.

30 The solution of the invention provides the possibility, using the method of the invention, of parameterizing the distribution of current in the antenna such as, for example, having a different current density in at least 2 turns forming the
35 antenna, therefore not having a uniform current in the

antenna and hence having a different current in at least 2 different turns.

By not having a uniform current in the antenna, it is possible to obtain a variation in the value of inductance and resistance between at least 2 turns forming the antenna. Ideally, therefore, it is possible to promote or limit the general value of the inductance of the antenna relative to the value of the general resistance of the antenna, or conversely.

Through the non-uniform distribution of current and variations in direct parameters, it is ideally possible to promote or limit the indirect parameters such as the generated or received magnetic field, mutual inductance, and coupling and their distributions in the space of the antenna.

Therefore, in some embodiments, the circuit comprises means to make the distribution of current non-uniform between the two ends of the antenna.

The fundamental difference can therefore be appreciated between the prior art technique with "conventional" loop antennas in which the antenna consists of N wound turns. In the conventional loop antenna, current is considered to be highly uniform. There are therefore few means for parameterizing or to cause the direct parameters (inductance, antenna resistance, bandwidth) to cross-vary with indirect parameters (transmitted or captured magnetic field, coupling, mutual inductance).

The solution of the invention and the possible embodiments then introduce the concept of a particular arrangement of inductances and capacitances, connection terminals, so-called "active" inductances, so-called "passive" inductances, so-called "negative inductances" allowing ideal use of the transmitted or captured

magnetic field, coupling, mutual inductance, and bandwidth.

Finally, a particular arrangement of capacitances with charge or with charge plus inductances or with
5 inductances or with a frequency tuning circuit take part in obtaining the proposed objective.

The invention will be better understood on reading the following description, given solely as a non-limiting example with reference to the appended
10 drawings in which:

- Figures 1A, 2A, 3A, 4A illustrate embodiments of the antenna circuit as transponder according to the invention,

- Figures 1B, 2B, 3B, 4B show equivalent electric
15 layouts of the circuits in Figures 1A, 2A, 3A, 4A,

- Figures 5A, 6A, 7A, 8A, 9A, 11A show embodiments of the antenna circuit as reader according to the invention,

- Figures 5B, 6B, 7B, 8B, 9B, 11B show equivalent
20 electric layouts of the circuits in Figures 5A, 6A, 7A, 8A, 9A, 11A,

- Figure 10 is a view of an antenna in one embodiment,

- Figures 12 to 46 show embodiments of the circuit
25 according to the invention.

In what follows, the antenna circuit can either be a circuit emitting electromagnetic radiation via the antenna, or a circuit which receives electromagnetic radiation via the antenna.

30 In a first application, the RFID antenna circuit is of transponder type, to function as a portable card, tag, to be integrated in a paper document such as a document issued by an official authority e.g. a passport, USB keys, SIM cards and (U)SIM cards called
35 "RFID or NFC SIM card", stickers for Dual cards or Dual

Interface cards (the sticker itself having an RFID/NFC antenna), watches.

In a second application, the RFID antenna circuit is of reader type to read i.e. at least receive the
 5 signal radiated by the RFID antenna of a transponder such as defined in the first case, such as mobile phones, PDAs, computers.

Generally, the circuit comprises an antenna 3 formed of at least three turns S of a conductor on an
 10 insulator substrate SUB. The turns S have an arrangement defining an inductance L having a determined value between a first end terminal D of the antenna 3 and a second end terminal E of the antenna 3.

In the embodiment shown Figures 1A and 1B, the
 15 antenna 3 is formed of three consecutive turns S1, S2, S3 from the outer end terminal E to the inner end terminal D.

A first access terminal 1 is connected by a conductor CON1A to an intermediate tap or intermediate
 20 point A of antenna 3 between its end terminals D, E.

A tuning capacitance C at a prescribed tuning frequency i.e. a resonance frequency e.g. of 13.56 MHz up to 20 MHz is provided in combination with the inductance L of the antenna 3.

25 The second end terminal E of antenna 3 is connected via a conductor CON2E to the second terminal C1E of the capacitance C.

The first terminal C1X of the capacitance C is connected via conductor CON31 to the intermediate tap A forming a first point P1 of the antenna 3.
 30

A second access terminal 2 is connected via a conductor CON32 to the first end terminal D forming a second point P2 of the antenna 3. Point P2 is different from point A.

The two access terminals 1, 2 serve to connect a charge.

According to the invention, there is at least one turn S between the first point A, P1 and the second point P2.

The intermediate tap A, P1 is connected to the end terminal D by at least one turn S of the antenna L i.e. a turn S3 in Figure 1. The intermediate tap A, P1 is connected to the second end terminal E of antenna L by at least one turn S of antenna L, i.e. two turns S1 and S2 in Figure 1, in which the intermediate tap A is located between the turns S3 and S2.

Generally, according to the invention, points D, E, 1, 2, A, C1E, C1X, P1, P2 form electric nodes of the circuit. The points directly connected together form the same node, for example when the connection means are electric conductors. Two separate nodes are connected by at least one turn.

In the equivalent schematic shown Figure 1B, the circuit in Figure 1A, the circuit in Figure 1A has a first inductance L1 called an active inductance formed by the third turn S3 between the access terminals 1, 2. Between the intermediate tap A and terminal E, there is a second inductance L2, called passive inductance, formed by the first turn S1 and the second turn S2. The second inductance L2 lies parallel with the capacitance C between the intermediate tap A and terminal E. The sum of the first inductance L1 and second inductance L2 is equal to the total inductance L of the antenna 3. Evidently, the antenna 3 has a resistance in series with its inductance L and inter-turn coupling capacitances which are not shown in all the figures.

The capacitance C may be of any type of technology and using any fabrication method. In the example in

Figure 1A, the capacitance C is of planar type being arranged on the free region of the substrate in the centre of the turns S. In Figure 1A, the capacitance C is formed of a capacitor having a first metal surface S1X forming the first capacitance terminal C1X, a second metal surface S1E carried by the substrate and forming the second capacitance terminal C1E. One or more dielectric layers are located between the first metal surface S1X and the second metal surface S1E.

10 The embodiment shown Figures 1A and 1B makes it possible to increase the efficiency of the antenna 3.

The embodiment shown Figures 2A and 2B is a variant of the embodiment shown Figures 1A and 1B.

15 In Figures 2A and 2B, the intermediate tap A, P1 is located between the turns S1 and S2. The intermediate tap A, P1 is connected to the end terminal D by at least one turn S of the antenna L, i.e. two turns S2 and S3. The intermediate tap A, P1 is connected to the second end terminal E of antenna L by at least one turn S of the antenna L i.e. a turn S1.

20 The capacitance C is formed of a capacitor with one or more dielectric layers having a first side and a second side distant from the first side. The first metal surface S1X forms the first capacitance terminal C1X on the first side of the dielectric layer. A second metal surface S1E forms the second capacitance terminal C1E on the second side of the dielectric layer. The first metal surface S1X, together with the second metal surface S1E, defines a capacitance value C2.

30 A third metal surface S1F forms a third terminal C1F of the capacitance C. The third metal surface S1F is located on the same first side of the dielectric layer as the first metal surface S1X but distanced away from this first metal surface S1X. The

third capacitance terminal C1F is connected by a conductor CON33 to the end terminal D. The third metal surface S1F, together with the second metal surface S1E, defines a capacitance value C1.

5 The third metal surface S1F is coupled to the first metal surface S1X through the fact that they share the same reference terminal C1E formed by surface S1E, to form a coupling capacitance called C12.

10 In the equivalent schematic shown Figure 2B, the circuit in Figure 2A has a first inductance L1 called active inductance, formed by the second turn S2 and the third turn S3, between the access terminals 1, 2. Between the intermediate tap A and terminal E, there is a second inductance L2, called passive inductance,
15 formed by the first turn S1. The sum of the first inductance L1 and the second inductance L2 is equal to the total inductance L of the antenna 3.

20 The second inductance L2 lies parallel with the capacitance C2 between the intermediate tap A and the terminal E.

 The first inductance L1 lies parallel with the coupling capacitance C12.

 Capacitance C1 is connected firstly to terminal D and secondly to terminal E.

25 The embodiment shown Figures 2A and 2B makes it possible to further increase the radio efficiency of the antenna 3, on account of the arrangement of the capacitance C1 and C2 and of the coupling between the capacitances C1 and C2.

30 The embodiment shown Figures 3A and 3B is a variant of the embodiment shown Figures 2A and 2B. In the embodiment shown Figures 3A and 3B, the first point P1 is separate from the first intermediate tap A and is distanced from this first intermediate tap A by
35 at least one turn S. The antenna 3 is formed by four

consecutive turns S1, S2, S3, S4, from outer end terminal E to inner end terminal D. Also, for example, in Figures 3A and 3B the capacitance C is of the type shown in Figures 2A and 2B.

5 The first intermediate tap A is located between turns S2 and S3. The first intermediate tap A is connected to end terminal D by at least one turn S of the antenna L, i.e. the two turns S3 and S4. The intermediate tap A is connected to the second end
10 terminal E of the antenna L by at least one turn S of the antenna L i.e. the two turns S2 and S1.

The access terminal 1 is connected to the first intermediate tap A by the conductor CON1A.

The access terminal 2 is connected to terminal D
15 which is not connected to terminal C1F.

Between the access terminals 1, 2 there is a charge Z. The charge Z may for example be a chip globally designated as "silicon". This chip may also be generally present between the access terminals.

20 The terminal C1X is connected by conductor CON31 to a first point P1 of the antenna 3, separate from its terminals D, E.

The first point P1 is located between turns S3 and S4. The first point P1 is connected to end terminal D
25 by at least one turn S of the antenna L, i.e. turn S4. The first point P1 is connected to the second end terminal E of antenna L by at least one turn S of antenna L i.e. the three turns S3, S2 and S1.

Terminal D forms the second point P2.

30 According to the invention, there is at least one turn S between the first point P1 and the second point P2 i.e. turn S4.

The third capacitance terminal C1F is connected by a conductor CON33 to the access terminal 1.

The terminal C1E is connected by a conductor CON2E to terminal E.

In the equivalent schematic shown Figure 3B, the circuit of Figure 3A has a first inductance L1 called
 5 active inductance formed by turn S4 between terminal 2 and point P1. Between point P1 and tap A, there is a second inductance L11 also said to be active, formed by turn S3.

Between the intermediate tap A and terminal E
 10 there is a third inductance L3, called passive inductance, formed by the two turns S2 and S1. The sum of the first inductance L1 and second inductance L11 and third inductance L3 is equal to the total inductance L of the antenna 3.

15 The third inductance L3 lies parallel with the capacitance C1 between the intermediate tap A and terminal E.

The second inductance L11 lies parallel with the coupling capacitance C12.

20 Capacitance C2 is connected firstly to point P1 and secondly to terminal E.

Evidently, capacitance C could be of the type shown Figure 1A, i.e. instead of having C1 and C12, only having capacitance C between P1 and E in
 25 Figures 3A and 3B.

The embodiment shown Figures 3A and 3B makes it possible to increase the efficiency of antenna 3 on account of the arrangement and combination of the "active" and "passive" inductances and capacitances.

30 The embodiment shown Figures 4A and 4B is a variant of the embodiment shown Figures 1A and 1B. In Figures 4A and 4B, the antenna 3 is formed from the second end terminal E to the first terminal D by a first turn S1, a second turn S2 and a third turn S3
 35 which are consecutive. Turns S1 then S2 extend from the

second end terminal E to a reversal point PR in a first direction of winding, which in Figure 4A corresponds to a clockwise direction. Turn S3 extends from reversal point PR to the first end terminal D in a second direction of winding opposite the first winding direction, and hence in anti-clockwise direction in Figure 4A. For example, inner turn S3 extends in opposite direction compared with outer turns S2 and S3.

The first point P1 forming a first intermediate tap A of the antenna connected to the access terminal 1 is located at the reversal point PR.

According to the invention, there is at least one turn S between the first point P1, A and the second point P2.

It is considered that the positive direction of current in the antenna 3 is the direction extending from reversal point PR to terminal E, coinciding in this example with the largest number of turns extending in the same direction, as indicated by the arrows drawn on the antenna 3. The arrows drawn on turns S1 and S2 correspond to this positive direction of the current.

In the equivalent schematic Figure 4B, the circuit in Figure 4A has a second positive inductance $+L2$ called passive inductance and formed by turns S2 and S1.

On account of the reversal point PR, there is a first negative inductance $-L1$, called active inductance, lying between the intermediate tap A, P1 and terminal D and formed by the third turn S3 between points P1 and P2.

The sum of the first inductance L1 in absolute value and of the second inductance L2 is equal to the total inductance L of the antenna 3.

The negative inductance $-L_1$ makes it possible to further reduce the mutual inductance generated by the antenna 3.

The embodiment shown Figures 5A and 5B is a variant of the embodiment shown Figures 1A and 1B. In Figures 5A and 5B, the antenna 3 is formed by three consecutive turns S_1 , S_2 , S_3 from outer end terminal E to inner end terminal D, forming the first point P1 of the antenna.

10 A first access terminal 1 is connected by connection means CON1A to a first intermediate tap A of antenna 3 between its end terminals D, E. The connection means CON1A is a capacitance C10 for example.

15 The second access terminal is connected by connection means CON32 to a second intermediate tap P2 forming a second point P2 of antenna 3. The connection means CON32 is a capacitance C20 for example.

20 A tuning capacitance C at a prescribed tuning frequency i.e. a resonance frequency of 13.56 MHz for example is provided in combination with the inductance L of the antenna 3.

The second end terminal E of the antenna 3 is connected by a conductor CON2E to the second terminal C1E of capacitance C.

The first terminal C1X of capacitance C is connected by a conductor CON31 to terminal D, P1 of the antenna 3.

30 The two access terminals 1, 2 serve to connect a charge.

According to the invention, there is at least one turn S between the first point P1 and the second point P2 i.e. turn S_3 and turn S_2 in the illustrated embodiment.

The intermediate tap A is located between turns S3 and S2. The intermediate tap P2 is located between turns S1 and S2. The intermediate tap A is connected to end terminal D by at least one turn S of the antenna L, i.e. turn S3 in the illustrated embodiment. The intermediate tap A is connected to the second end terminal E of the antenna L by at least one turn S of the antenna L i.e. two turns S1 and S2 in the illustrated embodiment.

10 The intermediate tap P2 is connected to end terminal D by at least one turn S of the antenna L i.e. turn S2 and turn S3 in the illustrated embodiment. The intermediate tap P2 is connected to the second end terminal E of antenna L by at least one turn S of the antenna L i.e. turn S1 in the illustrated embodiment.

15 In the equivalent schematic shown Figure 5B, the circuit of Figure 5A has a first inductance L1, called active inductance, formed by the second turn S2 between points A and P2. Between the intermediate tap P2 and terminal E there is a second inductance L2, called passive inductance, formed by the first turn S1. Between the intermediate tap A and terminal D, there is a third inductance L3, called passive inductance, formed by the third turn S3.

25 The sum of the first inductance L1, of the second inductance L2 and of the third inductance L3 is equal to the total inductance of antenna 3.

The embodiment shown Figures 5A and 5B makes it possible to increase the efficiency of antenna 3.

30 The embodiment shown Figures 6A and 6B is a variant of the embodiment given Figures 5A and 5B. In Figures 6A and 6B, a fourth additional tuning capacitance C4 is connected between the intermediate tap A and the second point P2, parallel with the first inductance L1. The fourth capacitance C4 takes part in

frequency tuning with C, in particular on the second inductance L2. The embodiment shown Figures 6A and 6B makes it possible to increase the efficiency of the antenna 3.

5 The embodiment shown Figures 7A and 7B is a variant of the embodiment shown Figures 5A and 5B. In Figures 7A and 7B, the antenna 3 is formed by four consecutive turns S1, S21, S22, S3 from outer end terminal E to inner end terminal D.

10 According to the invention, there is at least one turn S between the first point P1 and the second point P2, namely turn S21, turn S22 and turn S3 i.e. three second turns in the illustrated embodiment. The first point P1 is formed by the end terminal D of the
15 antenna.

 The intermediate tap A is located between turns S3 and S22. The intermediate tap P2 is located between turns S1 and S21. The intermediate tap A is connected to the end terminal D by at least one turn S of the
20 antenna L, i.e. turn S3 in the illustrated embodiment. The intermediate tap A is connected to the second end terminal E of antenna L by at least one turn S of the antenna L, i.e. three turns S1, S21 and S22 in the illustrated embodiment. The intermediate tap P2 is
25 connected to end terminal D by at least one turn S of the antenna L, i.e. three turns S21, S22, and S3 in the illustrated embodiment. The intermediate tap P2 is connected to the second end terminal E of the antenna L by at least one turn S of antenna L, i.e. turn S1 in
30 the illustrated embodiment.

 In the equivalent schematic in Figure 7B, the circuit of Figure 5A has a first inductance L1, called active inductance, formed by the three second turns S21, S22, and S3 between points P1 and P2.
35 Between the intermediate tap P2 and terminal E, there

is a second inductance L2, called passive inductance, formed by the first turn S1. Between the intermediate tap A and terminal D, there is a third inductance L3, called passive inductance, formed by the third turn S3.

5 The sum of the first inductance L1, of the second inductance L2, and of the third inductance L3 is equal to the total inductance L of antenna 3.

 The embodiment illustrated Figures 7A and 7B makes it possible to increase the efficiency of antenna 3
10 with a larger number of turns.

 The embodiment shown Figures 8A and 8B is a variant of the embodiment shown Figures 5A and 5B. In Figures 8A and 8B, the antenna 3 is formed by six consecutive turns S1, S2, S31, S32, S33, and S34 from
15 the outer end terminal E to the inner end terminal D. The first point P1 is formed by the end terminal D.

 According to the invention, there is at least one turn S between the first point P1 and the second point P2, namely turns S2, S31, S32, S33, and S34 i.e.
20 five second turns in the illustrated embodiment.

 The intermediate tap A is located between turns S2 and S31. The intermediate tap P2 is located between turns S1 and S2. The intermediate tap A is connected to the end terminal D by at least one turn S of antenna L,
25 i.e. four turns S31, S32, S33, and S34 in the illustrated embodiment. The intermediate tap A is connected to the second end terminal E of antenna L by at least one turn S of antenna L i.e. the two turns S1, S2 in the illustrated embodiment. The intermediate
30 tap P2 is connected to the end terminal D by at least one turn S of antenna L, i.e. the five turns S2, S31, S32, S33, and S34 in the illustrated embodiment. The intermediate tap P2 is connected to the second end terminal E of antenna L by at least one turn S of
35 antenna L, i.e. turn S1 in the illustrated embodiment.

In the equivalent schematic Figure 8B, the circuit of Figure 8A has a first inductance L1, called active inductance, formed by the second turns S2, S31, S32, S33, and S34 between points P1 and P2. Between the intermediate tap P2 and terminal E there is a second inductance L2, called passive inductance, formed by the first turn S1. Between the intermediate tap A and the terminal D, there is a third inductance L3, called passive inductance, formed by the four turns S31, S32, S33, and S34.

The sum of the first inductance L1, of the second inductance L2, and of the third inductance L3 is equal to the total inductance L of the antenna 3.

The embodiment shown Figures 8A and 8B makes it possible to increase the efficiency of the antenna 3 with even more turns.

The capacitance C is formed by example of a capacitor of planar type such as shown Figure 1A.

In transponder applications, the capacitance C, C1, C2 is of the described planar type for example. In reader applications, the capacitance C may be in the form of an added capacitor component, instead of being of planar type.

The embodiment shown Figures 9A and 9B is a variant of the embodiment shown Figures 5A and 5B. In Figures 9A and 9B, the antenna 3 is formed from the second end terminal E to the first end terminal D by a first turn S1, a second turn S2, and a third turn S3 which are consecutive. Turn S1 extends from the second end terminal E to a reversal point PR in a first direction of winding, which in Figure 9A is a clockwise direction. Turns S2 then S3 extend from reversal point PR to the first end terminal D in a second direction of winding opposite the first winding direction, and hence in anti-clockwise direction in

Figure 9A. For example outer turn S1 is in reverse direction compared with inner turns S2 and S3.

The first point P1 is formed by terminal D.

5 The second point P2, forming the second intermediate tap of the antenna connected to the access terminal 2, is located at reversal point PR.

According to the invention, there is at least one turn S between the first point P1 and the second point P2, i.e. turn S2 and turn S3 in the illustrated
10 embodiment.

In the equivalent schematic in Figure 9B, the circuit of Figure 9A has a first positive inductance L1, called active inductance, formed by the second turn S2 between points A and P2.

15 On account of the reversal point PR, there appears a second negative inductance $-L2$, called passive inductance, lying between intermediate tap P2, PR, and terminal E and formed by the first turn S1, considering that the positive direction of the current in the
20 antenna 3 is the direction extending from point PR, P2 to point A, in this example coinciding with the largest number of turns extending in the same direction, as indicated by the arrows drawn on antenna 3. The arrows drawn on the turns S2 and S3 correspond to this
25 positive direction of the current.

Between the intermediate tap A and terminal D, there is a third positive inductance $+L3$, called passive inductance, formed by the third turn S3.

30 The sum of the first inductance L1, of the second inductance L2 in absolute value and of the third inductance L3 is equal to the total inductance L of the antenna 3.

The negative inductance $-L2$ makes it possible to further reduce the mutual inductance generated by the
35 antenna 3.

The embodiment shown Figures 11A and 11B is a variant of the embodiment illustrated Figures 5A and 5B.

5 The connection means CON1A is an electric conductor for example.

The connection means CON32 is an electric conductor for example.

The capacitance C is of the type shown Figure 2A.

10 The second end terminal E of the antenna 3 is connected by a conductor CON2E to the second terminal C1E of the capacitance C.

The first terminal D is connected to the terminal C1F of capacitance C by the conductor CON33.

Point P1 is formed by terminal D.

15 The first terminal C1X of capacitance C is connected by a conductor CON31 to terminal D.

The terminal C1F is connected to the access terminal 2.

20 According to the invention, there is at least one turn S between the first point P1 and the second point P2, i.e. turn S3 and turn S2 in the illustrated embodiment.

25 In the equivalent schematic shown Figure 11B, the capacitance C1 lies parallel with the inductance L2 between terminal E and point P2. The capacitance C2 is connected between terminals D and E. The coupling capacitance C12 is connected between the second point P2 and the terminal D.

30 The embodiment illustrated Figures 11A and 11B makes it possible to further increase the efficiency of the antenna 3, on account of the coupling between the capacitances C1 and C2.

Evidently, one or more of the above embodiments can be combined regarding the arrangement of the

inductances, capacitances, the reversal point(s), the number of turns.

In particular, the connection means such as CON1A, CON32 of the access terminals 1, 2 to the antenna may
5 be via capacitance, via conductor or other, such as active elements for example, in particular of transistor or amplifier type.

Generally, any additional charge or frequency- or power-tuned circuit can be connected to the access
10 terminals 1, 2 such as a chip for example, notably silicon-based, both for the so-called transponder application and the so-called reader application.

In particular, the connection means of the access terminals 1, 2 to the antenna in Figures 5A, 6A, 7A,
15 8A, 9A can also be conductors. It is also possible to add an active or passive element such as a capacitance for example to the access terminals 1, 2 in Figures 1A, 2A, 3A, 4A.

Provision may be made for the number of turns to
20 be one, two, or more between the first point P1 and the second point P2. The number of turns provided between the first tap A and end D may be one, two or more. The number of turns provided between the first tap A and end E may be one, two, or more. The number of turns
25 between the first point P1 and end D may be one, two, or more. The number of turns between the first point P1 and end E may be one, two, or more. The number of turns between the second point P2 and end D may be one, two, or more. The number of turns provided between the
30 second point P2 and end E may be one, two, or more.

The antenna may be made using wire, etched, printed (printed circuit board) technology, in copper, aluminium, with silver or aluminium particles and any other electric conductor and any other non-electric
35 conductor but chemically provided for this purpose.

The turns of the antenna may be multi-layer, whether superimposed or not, either in whole or in part.

As illustrated Figure 10, at least one turn S2 of
 5 the antenna can comprise in series a winding S2' of turns of smaller surface surrounded, with respect to the surface surrounded either by the remainder S2" of turn S2 or by the other turns of the antenna 3, in order to increase the resistance or inductance of
 10 turn S2 without enhancing coupling, mutual inductance, and the general radiation of the antenna 3.

The capacitance(s) may be a discrete element (component) or fabricated using planar technology.

The capacitance(s) can be added to the antenna
 15 during fabrication of the coil windings, as an external element to the printed circuit board and antenna, notably using wire technology.

The capacitance(s) may be integrated into a module, notably the silicon module.

20 The capacitance(s) can be integrated in and fabricated on a printed circuit board.

The turns S of the antenna 3 may be distributed over several separate physical planes, e.g. parallel.

The turns are formed of sections e.g. rectilinear
 25 but may also be of any other shape.

The turns of the antenna may be in the form of a wire, which is then heated to be incorporated on or in an insulator substrate.

The turns of the antenna may be etched onto an
 30 insulator substrate.

The turns of the antenna can lie on opposite faces of an insulator substrate.

The turns are in the form of parallel strips for example.

In the following figures, a charge module M is shown, such as a chip for example, the module M being connected between the first access terminal 1 and the second access terminal 2.

5 In the embodiment shown Figure 12, the antenna L is formed by the turns S1, S2 located between the first end terminal D and the second end terminal E.

The first terminal D is connected to the second access terminal 2 forming the second point P2.

10 The tuning capacitance C1 with a prescribed tuning frequency comprises a first capacitance terminal C1X and a second capacitance terminal C1E.

The first capacitance terminal C1X is connected to the first access terminal 1 by means CON31.

15 The second capacitance terminal C1E is connected to the second end terminal E.

The second point P2 is formed by the second access terminal 2.

20 The first point P1 of the antenna and the intermediate tap A of the antenna are formed by the first access terminal 1.

The second point P2, 2 of the antenna L is connected to the first point P1, 1, A of antenna L by at least one first turn S1 of the antenna L.

25 The antenna L is formed by one or more second turns S1 between E and A, namely by two second turns S1 for example connected by point A to one or more turns S2 extending from point A to terminal D, for example three turns S2.

30 There is a least one turn of the antenna L between the first point P1 and the second point P2, namely the at least one turn S2 between P1 and P2.

35 The tuning capacitance C1 is formed by one or more third turns SC3 (for example five turns SC3) comprising two first and second ends SC31, SC32, and by one or

more fourth turns SC4 (for example five turns SC4) comprising two first and second ends SC41 SC42.

The at least one third turn SC3 is separate from turns S1, S2 forming the antenna L, and is connected to one E of the end terminals of the antenna L. The at
 5 least one fourth turn SC4 is separate from turns S1, S2 forming the antenna L and is separated electrically from the third turns SC3, for example by running alongside the third turns SC3 so that the turns SC3 are
 10 arranged facing turns SC4, for example having parallel sections. End SC31 forms terminal C1E and is connected to terminal E. End SC32 is free and insulated from SC4. End SC41 is free and insulated from SC3. End SC42 forms terminal C1X and is connected to the intermediate
 15 tap A, 1, P1. End SC31 lies distant from end SC42 whilst lying close and being insulated from end SC41. End SC42 lies distant from end SC31, whilst lying close to and being insulated from end SC32.

The sections of the third turns SC3 located facing
 20 fourth turns SC4, which are not electrically connected to the fourth turns SC4, define the capacitance C1. On account of the third turns SC3 and fourth turns SC4 themselves causing inductance due to winding of the turns, the impedance ZZ between the ends SC31, SC42
 25 serving to connect the capacitance C1 to the remainder of the circuit, also brings an inductance. The impedance ZZ between the connecting ends SC31, SC42 can be seen for example as comprising a resonant capacitance - inductance circuit in parallel and/or
 30 series in accordance with Figure 33, comprising two parallel branches with capacitance C1 in one of the branches and a capacitance in series with an inductance in the other branch. As a result, the impedance ZZ seen between the connecting ends SC31, SC42 comprises the
 35 capacitance C1.

The capacitance value C_1 of impedance ZZ depends on the relationship between the turns SC_3 and SC_4 , and in particular on their reciprocal arrangement, for example lying adjacent.

5 In Figure 12, there is at least one turn S_1 between the intermediate tap A connected to the access terminal 1 of the module and the impedance ZZ formed by the at least one third turn SC_3 and the at least one fourth turn SC_4 .

10 The impedance ZZ formed by the at least one third turn SC_3 and by the at least one fourth turn SC_4 is self-resonating, due to the fact that a capacitance and an inductance in series and/or parallel are contained in the impedance ZZ .

15 The equivalent schematic of the circuit illustrated Figure 12 is given in Figure 34. The at least one third turn SC_3 and the at least one fourth turn SC_4 make it possible to equalize the tuning frequency of module M (a chip for example) lying parallel with an inductance (turn(s) S_2) with the tuning frequency of the circuit formed by the at least one third turn SC_3 and the at least one fourth turn SC_4 , for example to have the prescribed tuning frequency 13.56 MHz.

25 In this way, it is possible to obtain extensive coupling between the self-resonating circuit ZZ , SC_3 , SC_4 and the circuit formed by module M lying parallel with the turn(s) S_2 , by reducing the mutual inductance between these two circuits. The inductance formed by the turn(s) S_1 located between module M and turns SC_3 , SC_4 forming the self-resonating circuit ZZ makes it possible to act on this mutual inductance between the self-resonating circuit ZZ , SC_3 , SC_4 and the circuit formed by module M lying parallel with turn(s) S_2 .

Therefore, through an astute arrangement of the values of currents and intrinsic inductances of the turns, it becomes possible to parameterize the mutual inductance values between the two above-mentioned antenna circuits (M, S2) and (ZZ, S1) and to obtain two frequency tunings that are quasi-independent of each other or two tuning frequencies very close to each other, for example with differences in tuning frequencies of < 10 MHz, < 2 MHz or < 500 KHz, or 2 frequency tunings merged in one same frequency range, making it possible to obtain a broad bandwidth relative to the RFID transmission channel, whilst maintaining extensive coupling efficiency and hence energy transmission, even though the integration surface of the antenna circuit may be very small e.g. < 16 cm² or < 8 cm².

It is notably sought to have the greatest possible inductance in the turns S2 lying parallel with the module M, in order to obtain a frequency tuning that is as close as possible to the useful frequency, for example 13.56 MHz.

It is sought in particular to have the smallest possible inductance contained in the self-resonating circuit ZZ, SC3, SC4 to allow integration of the antenna circuit on a small surface < 16 cm² such as a tag for example or a sticker.

In addition, it can be seen that one of the advantages of the invention is the possibility to parameterize the mutual inductance between the antenna circuits, for example between, firstly, the antenna circuit comprising the transponder or reader chip and, secondly, a first and a second antenna part, so as to parameterize the final mutual inductance of the transponder or reader system. Also, contrary to the prior art documents indicated above, it becomes

possible to produce two frequency tunings quasi-independent of each other, or two frequency tunings very close to each other for example < 10 MHz, < 2 MHz or < 500 KHz or 2 frequency tunings merged over one same frequency range.

Depending on the embodiment of the invention, there is at least one electric connection between a first antenna circuit comprising the chip and at least one second (or more) antenna circuit(s) comprising at least one capacitive element.

In particular, the devices according to documents EP-A-1,031,939 and FR-A-2,777,141 do not allow two quasi-independent frequency tunings to be produced, or two frequency tunings very close to each other e.g. < 10 MHz, < 2 MHz or < 500 KHz, or 2 frequency tunings merged over one same frequency range. The greater the mutual inductance between the 2 antenna circuits, the greater the increase in the 2 so-called "natural" tunings of the 2 antenna circuits. If it is desired that these 2 frequency tunings should be close, mutual inductance must be reduced, for example by strongly decreasing one of the surfaces of the antenna circuit relative to the other, which induces a considerable loss in the efficiency of the transponder.

Means are provided to ensure coupling COUPL12 by mutual inductance between the neighbouring turns S1 and S2. Means are provided to ensure coupling COUPLZZ by mutual inductance between the neighbouring turns S1 and SC3, and SC4 of impedance ZZ. This coupling by mutual inductance is due for example to the arrangement of S1 close to S2 and to the arrangement of S1 close to SC3, SC4. For example in Figure 12 we successively have from the periphery towards the centre: S2, S1, SC3, SC4.

The antenna circuit has at least two natural intrinsic mutual inductances coupled together: between S1 and S2, between S1 and ZZ.

This makes it possible to increase the reading
5 distance of the circuit in Figure 12.

Other embodiments of the invention are described in the table below with reference to the figures mentioned below. This table indicates the points electrically connected together in the four
10 corresponding columns (1, A), (C1E, E), (C1X, P1), and (2, P2) and the number of turns. In Figures 12 *et seq* mentioned below, the connection means CON1A of the intermediate tap A with the first access terminal 1, the connection means CON2E between the second end
15 terminal E and the second capacitance terminal C1E, the connection means CON31 between the first capacitance terminal C1X and the first point P1 of the antenna L, and connection means CON32 between the second access terminal 2 and the second point P2 are implemented via
20 electric conductors, these not necessarily being indicated either in the figures or in the table below. Column A-E indicates the number of turns S1 between A and E. Column A-D indicates the number of turns S2 between A and D. Column P1-P2 indicates the number N12 equal to at least one turn S of the antenna L between
25 points P1 and P2. The last column on the right indicates either the presence of the impedance ZZ formed by the turns SC3 and SC4, in this case giving the number of turns of ZZ in brackets, or the presence
30 of an additional capacitance C30 called first capacitance formed by a capacitive component with a dielectric between its terminals.

By dielectric capacitive component is meant any embodiment allowing the arrangement of a capacitance.

This capacitive component may optionally be formed by another circuit ZZ.

Fig N°	1, A	C1E, E	C1X, P1	2, P2	A-E	A-D	P1-P2	Z and/or C1
1A	P1, C1X	C1E, E	1, A	D	≥ 1	≥ 1	≥ 1	C1
2A	P1, C1X	C1E, E	1, A	D, C1F	≥ 1	≥ 1	≥ 1	C1
3A	C1F	C1E, E	C1X, P1	D	≥ 1	≥ 1	≥ 1	C1
4A	P1, C1X, PR	C1E, E	1, A, PR	D	≥ 1	≥ 1	≥ 1	C1
5A	1, A	C1E, E	D	2, P2	≥ 1	≥ 1	≥ 1	C1
6A	1, A	C1E, E	D	2, P2	≥ 1	≥ 1	≥ 1	C1
7A	1, A	C1E, E	D	2, P2	≥ 1	≥ 1	≥ 1	C1
8A	1, A	C1E, E	D	2, P2	≥ 1	≥ 1	≥ 1	C1
9A	1, A	C1E, E	D	2, P2, PR	≥ 1	≥ 1	≥ 1	C1
11A	P1	C1E, E	1, A	2, P2, C1F	≥ 1	≥ 1	≥ 1	C1
12	P1, C1X, SC42	SC31	1, A, SC42	D	2	3	3	Z(5)
13	1, A	C1E, E	P1≠A	D	5	3	4	C1
14	1, A	C1E, E	P1≠A	D	6	3	5	C1
15	1, A	SC42	D	2, P2	1	4	3	Z(4)
16	1, A	SC42	D, C1XZ	2, P2	1	4	3	Z and C30
17	1, A	SC42	D	2, P2	1	2	1	Z(4)
18	1, A	SC42	D, C1XZ	2, P2	1	2	1	Z(4) and C30

Fig N°	1, A	C1E, E	C1X, P1	2, P2	A-E	A-D	P1- P2	Z and/or C1
19	1, A	SC42	D, SC31	E	3	2	5	Z(4)
20	C1X, P1 SC42	C1E, E (with D=SC41)	1, A, SC42	PC1	3	4	3	Z(5) and C30
21	C1X, SC31, P1	2, P2, SC42	SC31, 1, A	E (with D=SC32)	3	4	3	Z(4)
22	C1X, P1, SC42	C1E, E (with D=SC41)	1, A, SC42	PC1, SC31	3	4	3	Z(4) and C30
23	1, A	C1E, E	D	2, P2	4	1	4	C1
24	1, A	C1E, E	D	PR2	4	1	3	C1
25	C1X, P1, PR1	C1E, E	1, A	D	4	1	1	C1
26	C1X, P1, PR1	C1E, E	1, A	D	3	2	2	C1
27	C1X, P1	C1E, E	1, A	D	2	3	3	C1
28	1, A	C1E, E	C1X, P1≠A	D	2	2	1	C1
29	1, A	C1E, E	D	2, P2	5	1	5	C1
30	1, A	C1E, E	D	2, P2	2	1	2	C1
31	C1X, P1, SC42	C1E, E, SC31	1, A, SC42	D	2.5	4	4	Z(17)
32	C1X,	C1E, E,	1, A,	D	5.5	3	4	Z (17)

Fig N°	1, A	C1E, E	C1X, P1	2, P2	A-E	A-D	P1- P2	Z and/or C1
	P1, SC42	SC31	SC42					

In Figures 16 and 18, two capacitances C30 and ZZ are provided. Capacitance ZZ is formed by turns SC3, SC4 between SC42 and SC31 (4 turns for example) with SC31 forming C1XZ. In addition to Z, another capacitance C30 formed by a capacitive component is provided between E and C1XC1. The terminal C1XC1 is connected to a point PC1 of the antenna L, which lies distant from P2 by at least one turn, for example one turn in this figure. In Figures 16 and 18, ZZ lies between C1XZ and C1E, and C30 is a capacitive component between E and C1XC1.

In Figure 22, two capacitances C30 and ZZ are provided in series between the terminal C1E, E and the terminal C1X, P1 formed by end SC42. The capacitance ZZ is formed by turns SC3, SC4 between SC42 and SC31 (for example 4 turns) with SC31 forming PC1. In addition to Z, another capacitance C30 formed by a capacitive component is provided between E and PC1. Terminal PC1 is connected to point 2, P2 of the antenna L. Terminal C1E, E is formed by the end of the turn or turns S1, distant from terminal 2.

In Figure 20, two capacitances C30 and ZZ are provided in series between the terminal C1E, E and the terminal C1X, P1 formed by end SC42. The capacitance ZZ is formed by the turns SC3, SC4 between SC42 and SC31 (4 turns for example) with SC31 connected in series with point PC1 by one or more turns S10 (for example two turns S10). In addition to Z, another capacitance C30 formed by a capacitive component is

provided between E and PC1. Terminal PC1 is connected to point 2, P2 of the antenna L. Terminal C1E, E is formed by the end of the turn or turns S1 lying distant from terminal 2.

5 In Figures 23, 24 two reversal points PR1 and PR2 are provided in the turns S1 between A and E. Point PR1 lies distant from A by at least one turn and from E by at least one turn (for example two turns between A and PR1 and two turns between PR1 and E). Point PR2 lies
10 distant from A by at least one turn and from E by at least one turn (for example one turn between A and PR2 and three turns between PR2 and E).

 In Figure 23, PR2 lies distant from P2 by at least one turn.

15 In Figure 25, two reversal points PR1 and PR2 are provided in the turns S1 between A and E. Point PR1 is located at A. Point PR2 lies distant from A by at least one turn and from E by at least one turn (for example one turn between A and PR2 and three turns between PR2
20 and E).

 In Figure 26, two reversal points PR1 and PR2 are provided in the turns S1 between A and E. Point PR1 is located at A. PR2 lies distant from A by at least one turn and from E by at least one turn (for example one
25 turn between A and PR2 and four turns between PR2 and E).

 In Figure 27, two reversal points PR1 and PR2 are provided in the turns S1 between A and D. Point PR1 lies distant from A by at least one turn and from D by
30 at least one turn (for example one turn between A and PR1 and two turns between PR1 and D). Point PR2 lies distant from A by at least one turn and from D by at least one turn (for example two turns between A and PR2 and one turn between PR2 and D).

In Figures 29 and 30, a mid-point PM to set a potential at a reference potential is provided on the antenna midway between the two end terminals D and E of the antenna. In Figure 29, in which the number of turns of the antenna between D and E is an even number, the mid-point PM lies distant from the other points 1, A, 2, P2, C1E, E, C1X, P1, D by at least one turn of the antenna. In Figure 30 in which the number of turns of the antenna between D and E is an uneven number, the mid-point PM lies distant from the other points 1, A, 2, P2, C1E, E, C1X, P1, D by at least one half-turn of the antenna and lies, for example, on the other side relative to the side having these points 1, A, 2, P2, C1E, E, C1X, P1, D.

Evidently, in the foregoing, the number of turns between the above-mentioned points on the antenna (1, A, 2, P2, C1E, E, C1X, P1, D and the reversal point or points) may be any number, for example one or more. This number of turns may be an integer for example as shown in the figures, or non-integers such as in Figures 31 and 32.

In Figures 12, 13, 14, 19, 21, 25, 26, a reversal point PR3 is provided at point 1, A i.e. a reversed direction of winding of the turns of the antenna at point 1, A, when going from D towards E. In Figures 15, 16, 17, 18, 22, 23, 24, 27, 28, 29, 30, 31, and 32, point 1, A is passed in the direction from D towards E maintaining the same winding direction of the antenna turns. However, one or more changes in direction of winding of the turns is made at a point PR2, PR1 other than 1, A in Figures 23, 24, 26, 27.

The first access terminal is distinct from the second access terminal. The first access terminal is distant from the second access terminal by one or several turns.

One single first access terminal 1 and one single second access terminal 2 are for example provided.

In an embodiment, a transponder TRANS as charge Z is connected to the first access terminal 1 and to the second access terminal 2, as for example on figure 35.

The figures 35 to 46 correspond to any one of the embodiments described above, in which the capacitances C10, C20 which may be present were not shown.

In another embodiment, a reader LECT as charge Z is connected to the first access terminal 1 and to the second access terminal 2, as for example on figure 36.

Several charges may be provided.

In another embodiment, several distinct charges may be connected to the same first access terminal 1 and to the same second access terminal 2.

For example, a transponder TRANS as first charge Z1 and a reader LECT as second charge Z2 may be connected to the same first access terminal 1 and to the same second access terminal 2, as shown for example on figures 37 and 38, wherein the transponder TRANS and the reader LECT are electrically in parallel on figure 38.

In another embodiment, the antenna may comprise several first access terminals 1 distinct from each other and / or several second access terminals 2 distinct from each other for the connexion of several distinct charges. The first access terminals 1 distinct from each other are distant from each other by at least one turn of the antenna. The second access terminals 2 distinct from each other are distant from each other by at least one turn of the antenna.

For example, on figure 39, a transponder TRANS as first charge Z1 is connected between the first access terminal 1 and the second access terminal 2, whereas a reader LECT as second charge Z2 is connected between

another first access terminal 1 and another second access terminal 2.

For example, on figure 40, a transponder TRANS as first charge Z1 is connected between the first access terminal 1 and the second access terminal 2, whereas a reader LECT as second charge Z2 is connected between another second access terminal 12 and the second access terminal 2 (successive access terminals).

In another embodiment, several RFID applications and / or RFID reader and / or RFID transponder may be connected between the first and second identical access terminals 1, 2 or between distinct first and second access terminals 1, 2, as for example applications APPL1, APPL3 on figure 41 between the distinct successive first and second access terminals 1, 2, 12, 13.

Of course above, the role of the first access terminal 1 and of the second access terminal 2 may be reversed.

Above, the charge Z connected to access terminals 1, 2 has for example a prescribed tuning frequency, as shown on figure 42. This tuning frequency is fixed.

This tuning frequency is for example in a high frequency band (HF), wherein the high frequency band covers the frequencies higher than or equal to 30 kHz and lower than 80 MHz. This tuning frequency is for example 13.56 MHz.

The tuning frequency may also be in an ultra high frequency band (UHF), wherein the ultra high frequency band covers the frequencies higher than or equal to 80 MHz and lower than or equal to 5800 MHz. The tuning frequency is for example in this case 868 MHz or 915 MHz.

In an embodiment, said at least one first access terminal 1 and said at least one second access terminal

2 are connected to at least a first charge Z1 having a first prescribed tuning frequency and at least a second Z2 having a second prescribed tuning frequency different from the first prescribed tuning frequency.

5 In an embodiment, a first charge Z1 having the first prescribed tuning frequency in the high frequency band and a second charge Z2 having the second prescribed tuning frequency in the ultra high frequency band are connected to the access terminals 1, 2.

10 In the embodiment of figure 43, the first charge Z1 having the first prescribed tuning frequency in the high frequency band and a second charge Z2 having the second prescribed tuning frequency in the ultra high frequency band are connected to the same first access
15 terminal 1 and to the same second access terminal 2.

In the embodiment of figure 44, the first charge Z1 having the first prescribed tuning frequency in the high frequency band is connected between the first access terminal 1 and the second access terminal 2, whereas the second charge Z2 having the second
20 prescribed tuning frequency in the ultra high frequency band is connected between another first access terminal 11 and another second access terminal 12.

In the embodiment of figures 45 and 46, the first
25 charge Z1 having the first prescribed tuning frequency in the high frequency band is connected between the first access terminal 1 and the second access terminal 2, whereas the second charge Z2 having the second prescribed tuning frequency in the ultra high frequency
30 band is connected between another second access terminal 12 and the second access terminal 2 (successive access terminals), the number of turns between the terminals of figure 45 being different from the number of turns between the terminals of figure 46.

35

CLAIMS

1. RFID antenna circuit comprising:

- 5 - an antenna (L) formed by a number of at least three turns (S), the antenna having a first end terminal (D) and a second end terminal (E),
 - at least two access terminals (1, 2) to connect a charge,
 - at least one tuning capacitance (C1, ZZ) for tuning
10 at a prescribed tuning frequency, having a first capacitance terminal (C1X) and a second capacitance terminal (C1E),
 - an intermediate tap (A) connected to the antenna (L) and distinct from the end terminals,
 - 15 - first connection means (CON1A) connecting the intermediate tap (A) to a first (1) of the two access terminals,
 - second connection means (CON2E) connecting the second end terminal (E) to the second capacitance terminal
20 (C1E),
- characterized in that it comprises:
- third connection means (CON31, CON32) connecting the first capacitance terminal (C1X) and the second
25 (2) of the access terminals respectively to a first point (P1) of the antenna (L) and to a second point (P2) of the antenna (L), which is connected to the first point of the antenna (L) by at least one turn (S) of the antenna (L).

30 2. Circuit according to claim 1, characterized in that said intermediate tap (A) is connected to the first end terminal (D) of the antenna (L) by at least one turn (S) of antenna (L), said intermediate tap (A) being connected to the second end terminal (E) of
35 antenna (L) by at least one turn (S) of antenna (L).

3. Circuit according to either of claims 1 and 2, characterized in that the first point (P1) is connected to the intermediate tap (A) by at least one turn of the antenna.

5

4. Circuit according to either of claims 1 and 2, characterized in that the first point (P1) is located at the intermediate tap (A).

10 5. Circuit according to any of claims 1 to 4, characterized in that the first point (P1) is connected to the first end terminal (D) of the antenna (L) by at least one turn (S) of antenna (L), the first point (P1) being connected to the second end terminal (E) of the
15 antenna (L) by at least one turn (S) of antenna (L).

6. Circuit according to either of claims 1 and 2, characterized in that the first point (P1) is located at the first end terminal (D).

20

7. Circuit according to any of claims 1 to 5, characterized in that the second point (P2) is located at the first end terminal (D) of the antenna.

25 8. Circuit according to any of claims 1 to 5, characterized in that the second point (P2) is located at the second end terminal (E) of the antenna.

30 9. Circuit according to any of claims 1 to 6, characterized in that the second point (P2) is connected to the intermediate tap (A) by at least one turn of the antenna.

10. Circuit according to any of claims 1 to 6,
characterized in that the second point (P2) is
connected to the first end terminal (D) of the antenna
(L) by at least one turn (S) of the antenna (L), the
5 second point (P2) being connected to the second end
terminal (E) of the antenna (L) by at least one turn
(S) of the antenna (L).

11. Circuit according to claim 2, characterized
10 in that the first point (P1) is located at the
intermediate tap (A) of the antenna (L), and the second
point (P2) is located at the first end terminal (D) of
the antenna (L).

12. Circuit according to claim 1, characterized
15 in that said first and second points (P1, P2) are
separate from the first intermediate tap (A), the first
point (P1) being connected to the first end terminal
(D) of the antenna (L) by at least one turn (S) of the
20 antenna (L), the first point (P1) being connected to
the second end terminal (E) of the antenna (L) by at
least one turn (S) of the antenna (L).

13. Circuit according to claim 1, characterized
25 in that the second point (P2) is located at the first
end terminal (D) of the antenna, the first point (P1)
is connected to the intermediate tap (A) by at least
one turn of the antenna.

14. Circuit according to claim 1, characterized
30 in that said intermediate tap (A) forms a first
intermediate tap (A), the first intermediate tap (A)
being connected to the first end terminal (D) of the
antenna (L) by at least one turn (S) of the antenna
35 (L), the first intermediate tap (A) being connected to

the second end terminal (E) of the antenna (L) by at least one turn (S) of the antenna (L),

- the second point (P2) is located at a second intermediate tap (P2) of the antenna (L), the second
5 intermediate tap (P2) being connected to the first end terminal (D) of the antenna (L) by at least one turn (S) of the antenna (L), the second intermediate tap (P2) being connected to the second end terminal (E) of the antenna (L) by at least one turn (S) of the antenna
10 (L).

15 15. Circuit according to any of the preceding claims, characterized in that the capacitance comprises a first metal surface forming the first capacitance terminal (C1X), a second metal surface forming the second capacitance terminal (C1E), at least one dielectric layer lying between the first metal surface and the second metal surface.

20 16. Circuit according to any of claims 1 to 14, characterized in that the capacitance comprises at least one dielectric layer having a first side and a second side distant from the first side,

- a first metal surface forming the first
25 capacitance terminal (C1X) on the first side of the dielectric layer,

- a second metal surface forming the second capacitance terminal (C1E) on the second side of the dielectric layer,

30 - a third metal surface forming a third capacitance terminal (C1F) lying away from the first metal surface on the first side of the dielectric layer,

- the first capacitance terminal (C1X) defining a first capacitance value (C2) with the second capacitance terminal (C1E),
- the third capacitance terminal (C1F) defining a second capacitance value (C1) with the second capacitance terminal (C1E),
- the first capacitance terminal (C1X) defining a third coupling capacitance value (C12) with the third capacitance terminal (C1F),
- connection means connecting the third capacitance terminal (C1F) to one of the access terminals (1, 2).

17. Circuit according to any of the preceding claims, characterized in that the antenna (L) comprises at least one first turn (S1), at least one second turn and at least one third turn, which are consecutive, the first turn (S1) extending from the second end terminal (E) in a first winding direction to a reversal point (PR) connected to the second turn, the second and third turns (S2, S3) extending from said reversal point (PR) to the first end terminal (D) in a second winding direction which is the reverse of the first winding direction,

- the first point (P1) of the antenna (L) and the second point (P2) of the antenna (L) being located on the second and third turns (S2, S3).

18. Circuit according to any of the preceding claims, characterized in that the antenna (L) comprises at least one first turn (S1) and at least one second turn (S2, S3) consecutive between two third and fourth points (E; D) of the antenna, the first turn (S1) being connected to the second turn (S2, S3) by a reversal point (PR), the first turn (S1) extending from the

third point (E) to the reversal point (PR) in a first winding direction, the second turn (S2, S3) extending from said reversal point (PR) to the fourth point (D) in a second direction of winding which is the reverse of the first winding direction.

19. Circuit according to claim 1, characterized in that the antenna (L) comprises at least one first turn (S1) and at least one second turn (S2, S3) consecutive between two third and fourth points (E; D) of the antenna, the first turn (S1) being connected to the second turn (S2, S3) by a reversal point (PR), the first turn (S1) extending from the third point (E) to the reversal point (PR) in a first direction of winding, the second turn (S2, S3) extending from said reversal point (PR) to the fourth point (D) in a second direction of winding which is the reverse of the first direction of winding,

- the first point (P1) is located at the intermediate tap (A) of the antenna (L) and the second point (P2) is located at the first end terminal (D) of the antenna (L).

20. Circuit according to claim 1, characterized in that the antenna (L) comprises at least one first turn (S1) and at least one second turn (S2, S3) consecutive between two third and fourth points (E; D) of the antenna, the first turn (S1) being connected to the second turn (S2, S3) by a reversal point (PR), the first turn (S1) extending from the third point (E) to the reversal point (PR) in a first direction of winding, the second turn (S2, S3) extending from said reversal point (PR) to the fourth point (D) in a second direction of winding which is the reverse of the first direction of winding,

- the first point (P1) is located at the first end terminal (D).

21. Circuit according to any of the preceding
 5 claims, characterized in that at least one turn (S2) of
 the antenna comprises in series a winding (S2') of
 turns of smaller surrounded surface with respect to the
 surface surrounded by the remainder (S2'') of said turn
 (S2) or with respect to the surface surrounded by other
 10 turns of the antenna (3).

22. Circuit according to any of the preceding
 claims, characterized in that the turns (S) of the
 antenna (3) are distributed over several separate
 15 physical planes.

23. Circuit according to any of the preceding
 claims, characterized in that the tuning capacitance
 (C1) comprises a second capacitance (ZZ) formed by at
 20 least one third turn (SC3) comprising two first and
 second ends (SC31, SC32) and by at least one fourth
 turn (SC4) comprising two first and second ends (SC41,
 SC42), the third turn (SC3) being electrically
 separated from the fourth turn (SC4) to define at least
 25 the tuning capacitance (C1) between the first end
 (SC31) of the third turn (SC3) and the second end
 (SC42) of the fourth turn (SC4),

- the first end (SC31) of the third turn lying
 further distant from the second end (SC42) of the
 30 fourth turn (SC4) than from the first end (SC41) of the
 fourth turn (SC4), the second end (SC32) of the third
 turn (SC3) lying further distant from the first end
 (SC41) of the fourth turn (SC4) than from the second
 end (SC42) of the fourth turn (SC4), the second
 35 capacitance being defined between the first end (SC31)

of the third turn (SC3) and the second end (SC42) of the fourth turn (SC4).

24. Circuit according to the preceding claim,
5 characterized in that there is at least one turn (S1) of the antenna between the intermediate tap (A) and the second capacitance.

25. Circuit according to either of claims 23 and
10 24, characterized in that first coupling means are provided to ensure coupling (COUPL12) by mutual inductance between firstly the at least one turn (S2) of the antenna electrically connected in parallel with the first and second access terminals (1, 2) and
15 secondly the other at least one turn (S1) of the antenna, second coupling means are provided to ensure coupling (COUPLZZ) by mutual inductance between said other at least one turn (S1) of the antenna and the at least one third and fourth turns (SC3, SC4) of the
20 second capacitance (ZZ).

26. Circuit according to the preceding claim,
characterized in that the first coupling means are formed by the proximity between, firstly, the at least
25 one turn (S2) of the antenna electrically connected in parallel with the first and second access terminals (1, 2) and, secondly, the other at least one turn (S1) of the antenna, the second coupling means are formed by the proximity between said other at least one turn (S1)
30 of the antenna and the at least one third and fourth turns (SC3, SC4) of the second capacitance (ZZ).

27. Circuit according to any of claims 23 to 26,
characterized in that the third turn (SC3) and the
35 fourth turn (SC4) are interleaved.

28. Circuit according to any of claims 23 to 27, characterized in that the third turn (SC3) comprises at least one third section, the fourth turn (SC4) comprises a fourth section, the third section lying adjacent the fourth section.

29. Circuit according to claim 28, characterized in that the sections extend parallel to each other.

30. Circuit according to any of claims 23 to 29, characterized in that the tuning capacitance (C1) comprises a first capacitance (C1) comprising a dielectric between the first capacitance terminal (C1X) and the second capacitance terminal (C1E), the first capacitance (C1) being made in the form of a wire, etched, discrete, or printed element.

31. Circuit according to any of claims 23 to 30, characterized in that another capacitance (C30) is connected between the second end terminal (E) and a point (PC1) of the antenna which is connected to the second point (P2) by at least one turn of the antenna.

32. Circuit according to any of claims 23 to 30, characterized in that the tuning capacitance (C1) comprises a first capacitance (C30) in series with said second capacitance (Z).

33. Circuit according to the preceding claim, characterized in that the first capacitance (C30) is connected between the second end terminal (E) of the antenna and the second point (P2) which is connected to the first terminal (SC31) of the third turn (SC3), the intermediate tap (A) being connected to the second

terminal (SC42) of the fourth turn (SC4) which forms the first point (P1), the first terminal (SC41) of the fourth turn (SC4) forming the first end terminal (D) of the antenna.

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34. Circuit according to claim 32, characterized in that the first capacitance (C30) is connected between the second end terminal (E) of the antenna and the second point (P2) which is connected to the first
10 terminal (SC31) of the third turn (SC3) by at least one turn (S10), the intermediate tap (A) being connected to the second terminal (SC42) of the fourth turn (SC4) which forms the first point (P1), the first terminal (SC41) of the fourth turn (SC4) forming the first end
15 terminal (D) of the antenna.

35. Circuit according to any of claims 23 to 30, characterized in that the first point (P1) is located at the intermediate tap (A), the second point (P2) is
20 located at the second end terminal (E) of the antenna.

36. Circuit according to any of claims 23 to 30, characterized in that the first point (P1) is located at the first end terminal (D) and the second point (P2)
25 is located at the second end terminal (E).

37. Circuit according to any of claims 23 to 26, characterized in that the at least one third turn (SC3) and the at least one fourth turn (SC4) define a second
30 sub-circuit having a second natural resonance frequency, the first and second access terminals (1, 2), together with a module (M) connected to them and with at least one turn (S2) connected to said first and second access terminals (1, 2), define a first sub-
35 circuit having a first natural resonance frequency, the

turns being arranged so that frequency difference between the first natural resonance frequency and the second natural resonance frequency is equal to or less than 10 MHz.

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38. Circuit according to any of claims 23 to 26, characterized in that the at least one third turn (SC3) and the at least one fourth turn (SC4) define a second sub-circuit having a second natural resonance
10 frequency, the first and second access terminals (1, 2) together with a module (M) connected to them and with at least one turn (S2) connected to said first and second access terminals (1, 2) define a first sub-circuit having a first natural resonance frequency, the
15 turns being arranged so that the frequency difference between the first natural resonance frequency and the second natural resonance frequency is equal to or less than 500 KHz.

20 39. Circuit according to any of claims 23 to 38, characterized in that the at least one third turn (SC3) and the at least one fourth turn (SC4) define a second sub-circuit having a second natural resonance frequency, the first and second access terminals (1, 2)
25 together with a module (M) connected to them and with at least one turn (S2) connected to said first and second access terminals (1, 2) define a first sub-circuit having a first natural resonance frequency, the turns being arranged so that the first natural
30 resonance frequency and the second natural resonance frequency are substantially equal.

40. Circuit according to any of the preceding claims, characterized in that the antenna comprises a
35 mid-point (PM) to set a potential at a reference

potential, with an equal number of turns on the section extending from the first end terminal (D) to the mid-point (PM) and on the section extending from the mid-point (PM) to the second end terminal (E).

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41. Circuit according to any of the preceding claims, characterized in that the antenna lies on a substrate.

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42. Circuit according to any of the preceding claims, characterized in that the antenna is a wire.

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43. Circuit according to any of the preceding claims, characterized in that said terminals (D, E, 1, 2, C1E, C1X), said tap (A), said points (P1, P2) and the capacitance (C1, ZZ) define a plurality of at least three nodes, the nodes defining at least one first group (S1) of at least one turn between two first nodes (1, C1E) separate from each other, and at least one second group of at least one other turn (S2) between two second nodes (1, 2) separate from each other, at least one of the first nodes being different from at least one of the second nodes, first coupling means are provided to ensure coupling (COUPL12) by mutual inductance between the first group (S1) of at least one turn and the second group of at least one other turn (S2) through the fact that the first group (S1) of at least one turn is positioned in the vicinity of the second group of at least one other turn (S2).

30

44. Circuit according to any of the preceding claims, characterized in that said terminals (D, E, 1, 2, C1E, C1X), said tap (A), said points (P1, P2), and the capacitance (C1, ZZ) define a plurality of at least three nodes, the nodes defining at least one first

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group (S1) of at least one turn between two first nodes (1, C1E) separate from each other, and at least one second group of at least one other turn (S2) between two second nodes (1, 2) separate from each other, and
 5 at least one third group of at least one other turn (SC3, SC4) between two third nodes (E, C1X) separate from each other, at least one of the first nodes being different from at least one of the second nodes, at least one of first nodes being different from at least
 10 one of the third nodes, at least one of the third nodes being different from at least one of the second nodes,
 - first coupling means are provided to ensure coupling (COUPL12) by mutual inductance between, firstly, the first group (S1) of at least one turn and,
 15 secondly, the second group of at least one other turn (S2) through the fact that the first group (S1) of at least one turn is positioned in the vicinity of the second group of at least one other turn (S2),
 - second coupling means are provided to ensure
 20 coupling (COUPLZZ) by mutual inductance between firstly the first group (S1) of at least one turn and secondly the third group of at least one other turn (SC3, SC4) through the fact that the first group (S1) of at least one turn is positioned in the vicinity of the third
 25 group of at least one other turn (SC3, SC4).

45. Circuit according to the preceding claim, characterized in that the first group (S1) of at least one turn is positioned between the second group of at
 30 least one other turn (S2) and the third group of at least one other turn (SC3, SC4).

46. Circuit according to any of claims 43 to 45, characterized in that the distance separating the turns

(S1, S2, SC3, SC4) belonging to different groups is equal to or less than 20 millimetres.

47. Circuit according to any of claims 43 to 45,
5 characterized in that the distance separating the turns (S1, S2, SC3, SC4) belonging to different groups is equal to or less than 10 millimetres.

48. Circuit according to any of claims 43 to 45,
10 characterized in that the distance separating the turns (S1, S2, SC3, SC4) belonging to different groups is equal to or less than 1 millimetre.

49. Circuit according to any of claims 43 to 48,
15 characterized in that the distance separating the turns (S1, S2, SC3, SC4) belonging to different groups is equal to or more than 80 micrometres.

50. Circuit according to any of the preceding
20 claims, characterized in that at least a reader (LECT) as charge and / or at least a transponder (TRANS) as charge is connected to the access terminals (1, 2).

51. Circuit according to any of the preceding
25 claims, characterized in that it comprises several first access terminals (1) which are distinct from each other and / or several second access terminals which are distinct from each other.

30 52. Circuit according to any of the preceding claims, characterized in that said at least one first access terminal (1) and said at least one second access terminal (2) are connected to at least one first charge (Z1) having a first prescribed tuning frequency in a
35 high frequency band and at least one second charge (Z2)

having a second prescribed tuning frequency in another ultra high frequency band.