

Radio Frequency Signal Modulation by Impedance Variation

Field of the invention

[0001] The present invention concerns a RFID tag, notably a chipless RFID tag, and a RFID reader.

[0002] The invention also concerns a method for transmitting a message
5 from a device to a reader as a RF backscattered radiation in response to an impinging RF signal of the reader.

Description of related art

[0003] There an increasing interest in devices providing tracking of products, notably in critical domains such as nutrition, aviation and medical
10 domains.

[0004] Radio-frequency identification (RFID) tags efficiently provide tracking of objects. In particular, unlike barcodes that require a human operator for interrogation, the identification of RFID tags relies on electromagnetic field (notably in Radio Frequency - RF), providing an
15 automatization of the tracking of objects on which the tags are attached.

[0005] The main challenge to their adoption is the cost of RFIDs. The main costs is related to the design and fabrication of integrated circuit, notably of application-specific integrated circuit (ASIC) providing the electromagnetic field coding the identification. Today's, there is thus an
20 increasing interest in providing RFID tags devoid of integrated circuit (also called chipless RFID tag) for reduce the unitary manufacturing cost.

[0006] The major challenges in designing chipless RFID (i.e. RFID tags that do not require a microchip in the transponder) is how to efficacy encoding and transmitting data.

[0007] Chipless RFID tags relying on time-domain reflectometry are already known. In response to an impinging RF signal, notably in form of an interrogator pulse, these Chipless RFID tags generate echoes, wherein the timing of the pulse generation (i.e. arrival) encodes the data.

- 5 **[0008]** Chipless RFID tags relying on frequency signature techniques are already known. These RFID tags are configured to attenuate up to absorb selected frequency components of an interrogator pulse, wherein the presence or absence of certain frequency components encodes the data. They may use chemicals, magnetic materials or resonant circuits to
10 attenuate or absorb radiation of a particular frequency.

- [0009]** However, Chipless RFID tags relying on time-domain reflectometry or on frequency signature techniques are suitable to provide a uniquely small amount of data as a coding of each bit of the data requires a dedicated echo or frequency. Moreover, a multiplication of echoes and
15 signatures frequencies leads not only to an increase of the dimension of the tag but also to intra-echoes or -frequencies interferences decreasing data discrimination.

Brief summary of the invention

- [0010]** An aim of the invention is to provide a more efficient
20 transmission of a message from a (chipless) device to a reader as a RF backscattered radiation in response to an impinging RF signal of the reader, with respect to known transmissions.

- [0011]** An aim of the invention is to provide a RFID tag, notably a passive or chipless RFID tag, that is except of, or at least mitigates, the
25 drawbacks of known RFID tags. Dependent claims relate to particular advantageous embodiments of the invention.

- [0012]** According to the invention, these aims are achieved by means of the RFID Tag of claim 1, a RFID reader of claim 10, the kit of claim 11, and the method of claim 12.

[0013] The proposed solution provides a more efficient transmission of a message from a (chipless) device to a reader as a RF backscattered radiation in response to an impinging RF signal of the reader, as each backscattered signal is suitable to provide a symbol digitally represented by more than a
5 single digital bit. The number of required coding frequencies can thus be reduced with respect to the number of digital bit of the data to be transmitted. Moreover, the reduction of the number of coding frequencies leads to a reduction of the dimension of the RFID tag.

[0014] In one embodiment, the code is defined by the electrical
10 impedance of portions of antennas or electrically connected to one or more antennas. In particular these portions are portions of dipole antennas and/or resonator transmission lines and/or meander line loaded antennas and/or of any other-shaped antenna of the RFID tag. This embodiment provides an efficient encoding and transmission of data.

15 **[0015]** In one embodiment, these portions are printed on a support of the RFID tag. In a particular embodiment, the code is defined by modifying a shape, a dimension and/or a material of these printed portions.

[0016] In one embodiment, each amplitude of the coding backscattered signals relative to the amplitude of the reference backscattered signal
20 defines a symbol of the code.

[0017] In one embodiment, the code and/or the symbol correspond and/or is represented by: one or more alphabetical symbols, one or more alphanumeric symbols, one or more numerical symbol, one or more
25 binary digits, one or more typographical symbols, and/or one or more graphical symbols.

[0018] In one embodiment, The RFID tag is a passive RFID tag, preferably the RFID tag is a chipless RFID tag.

[0019] In one embodiment, the code is a unique identifier, preferably being assigned to the RFID tag.

[0020] The invention further concerns a method for transmitting a code from a device to a reader as a RF backscattered radiation in response to an impinging RF signal generated by the reader.

[0021] In a particular embodiment of the method, the code is a unique
5 identifier or a digital message collected by the device.

[0022] In an embodiment of the method, the device is a RFID tag, preferably a passive RFID tag or a chipless RFID tag.

[0023] These particular embodiments furthermore provide not only an efficient encoding and transmission of data, but also a cost-effective
10 manufacturing of the RFID tag.

Brief Description of the Drawings

[0024] The invention will be better understood with the aid of the description of an embodiment given by way of example and illustrated by the figures, in which:

15 Figure 1 shows an exemplary view of a communication system comprising an RFID tag and a RFID reader, according to the invention.

Figure 2a-c show a view of embodiments of RFID tags relying on dipole antennas, according to the invention;

20 Figure 3 shows an exemplary view of backscattered signals generated by the RFID tags of Figures 1a-c;

Figure 4a-c show a view of others embodiments of RFID tags relying on dipole antennas, according to the invention;

25 Figure 5a-b show a view of embodiments of RFID tags relying on resonating units, according to the invention;

Figure 6 shows a view of an embodiment of a RFID tag relying on meander line loaded antennas, according to the invention.

Detailed Description of possible embodiments of the Invention

- 5 **[0025]** The invention relates to a cost-effective system and an efficient method for transmitting a message from a device to a reader as a backscattered radiation in response to an impinging signal generated by the reader.
- 10 **[0026]** In particular, the invention relates to a Radio-frequency identification (RFID) tag, notably a passive or chipless RFID tag, capable to transmit a message to a RFID reader as a RF backscattered radiation in response to a Radio Frequency (RF) impinging signal. In particular, the invention relates to a chipless RFID tag.
- 15 **[0027]** A RFID tag is any device attachable to an object and configured to provide a code, preferably being assigned to or collected by the device, using electromagnetic field in the Radio frequency in response of an interrogating radio wave. The code is preferably a unique identifier for identification and tracking purposes.
- 20 **[0028]** A passive RFID tag refers to a RFID tag configured to generate the backscattered radiation uniquely from (energy provided by) the interrogating radio wave, i.e. devoid of energy source for storing and/or transmitting the given code.
- [0029]** A Chipless RFID tag refers to a RFID tag devoid of integrated circuit, e.g. devoid of transistors, for storing and/or transmitting a given code.
- 25 **[0030]** Radio Frequency refers to an oscillation rate (frequency) of an electromagnetic field in the frequency range from 20 kHz to 300 GHz.

[0031] Figure 1 shows an exemplary view of a method and a system for transmitting a code 3_K from a device 1 to a reader 4. In particular, the device 1 is configured to provide a radio-frequency (RF) backscattered radiation 2 (i.e. a backscattered radiation having frequencies in the range of radio frequency) in response of an impinging RF signal 41 (i.e. an
5 interrogating signal having frequencies in the range of radio frequency) generated by the reader 4.

[0032] As illustrated in Figure 1, the device 1 is configured to :
provide a (reference) backscattered signal 2_R in reaction to an
10 impinging signal at a predetermined reference frequency 23; and
provide at least a (coding) backscattered signal $2_F, 2_G$ in reaction to an impinging signal at least a transmission frequency 21, 22,
wherein the code 3_K is defined by comparing the amplitude $20_A, 20_B$ of each coding backscattered signals 2_F with the amplitude 20_R of the reference
15 backscattered signal (i.e. the backscattered signal at the predetermined reference frequency 23).

[0033] As illustrated Figure 1, the device 1 can be configured to, in reaction to an impinging signal at whichever transmission frequency of a group of predefined distinct (i.e. different) transmission frequencies 21, 22,
20 to provide a distinct backscattered signal $2_F, 2_G$ at the interrogated transmission frequency. The code 3_K can thus be defined by the relative amplitude of each of the coding backscattered signals relative to the amplitude of the reference backscattered signal.

[0034] The code can comprise (e.g. being represented by) a series of
25 juxtaposed symbols 31, 32, preferably the symbols being selected within a predefined list of symbols, notably comprising alphabetical symbols, alphanumerical symbols, numerical symbols, binary digits, typographical symbols, and/or graphical symbols.

[0035] The relative amplitude of each coding backscattered signal can
30 thus (relatively to the amplitude 20_R of the reference backscattered signal) define a symbol 31, 32 (e.g. a single symbol up to a groups of symbols) of

the code 3_K . The provided symbol can be: one or more alphabetical symbols, one or more alphanumerical symbols, one or more numerical symbols, one or more binary digits, one or more typographical symbols, and/or one or more graphical symbols.

- 5 **[0036]** The position of the provided symbols in the code (juxtaposition of symbols) can be defined in relationship with (e.g. function of) their transmission frequencies (e.g. from the lower to the highest frequencies). The relationship can be determined according to a given (amplitude) unit providing a measure of the amplitude of a backscattered signal and/or with
10 respect to a given (ratio) unit (e.g. dB) providing a ratio between two amplitudes of electromagnetic waves.

- [0037]** The code 3_K and/or a symbol thereof can be defined by providing a coding backscattered signal (at a given coding frequency) whose amplitude is greater, (substantially) equal, or smaller than the amplitude of
15 the reference backscattered signal, the relationship (greater/ equal / smaller) defining the code 3_K and/or a symbol.

- [0038]** The code 3_K and/or a symbol thereof can be defined by providing a coding backscattered signal (at a given coding frequency) whose amplitude is a multiple of the amplitude of the reference backscattered
20 signal, the multiple defining the code 3_K and/or a symbol.

[0039] Depending on the code 3_K , the amplitude 20_R of the reference backscattered signal 20_R is thus either the smallest or identical to smallest amplitude of the coding backscattered signals.

- [0040]** The code 3_K and/or a symbol thereof can be defined by providing
25 a coding backscattered signal (at a given coding frequency) whose amplitude is a divisor of the amplitude of the reference backscattered signal, the divisor defining the code 3_K and/or a symbol. Depending on the code 3_K , the amplitude 20_R of the reference backscattered signal 20_R is thus either the largest or identical to largest amplitude of the coding
30 backscattered signals.

[0041] The code 3_K and/or a symbol thereof can be defined by providing a coding backscattered signal (at a given coding frequency) whose amplitude is a ratio of the amplitude of the reference backscattered signal, the ratio defining the code 3_K and/or a symbol. The amplitude 20_R of the
5 reference backscattered signal 20_R can be advantageously defined as being either the smaller or larger amplitude the device 1 can provide.

[0042] Advantageously, the applicant found that a modification of the amplitude 20_A , 20_B , 20_R of each of said coding backscattered signals (2_{A-E}) relative to the amplitude 20_R of the reference backscattered signal can be
10 pursued (obtained) by modifying the electrical impedance of an electrical conductive portion of the device 1, this electrical conductive portion being involved in the generation of the coding backscattered signal. In particular, these portions can be portions of antennas or are portions electrically connected to one or more antennas.

[0043] Moreover, the applicant found that a manufacturing of these electrical conductive portions by a printing process can provide a cost-efficient device. In fact, a code (e.g. a unique identifier) can be assigned to the device by printing these electrical conductive portions so as they have the desired electrical impedance, notably by dimensioning these portions
20 and/or selecting an adequate (electrical conductive) printed material.

[0044] These portions can be printed on a (common) support, notably by serigraphy, by semiconductor lithography, by electrical conductive-inkjet printing, by 3D printing of electrical conductive material, or by a combination thereof.

[0045] The support can be a printed circuit board, or any other non conductive material such as PET (Polyethylene Terephthalate), PS (Polystyrene), PC (Polycarbonate), ABS (Acrylonitrile Butadiene Styrene), PLA (Polylactic acid), paper, cardboard or many others. The support can be a part of an existing package of an object or a part of the object itself.

[0046] The reader 4 is thus arranged to emit an interrogation RF signal 41, to receive backscattered signals 2 from the device 1, and to reconstruct a code 3_K encoded in the backscattered signals. In particular, the reader 4 is further arranged to:

- 5 measure the reference amplitude 20_R of the reference backscattered signal 2_R at the reference frequency 23,
 measure the coding amplitude 20_{A-B} of the coding backscattered signal 2_{F-G} at each transmission frequency of the group of transmission frequencies 21, 22, and
- 10 determine the code 3_K of the device 1 based on the coding amplitude 20_{A-B} relative to the reference amplitude 20_R .

[0047] The impinging signal (interrogation RF signal) 41 can be broad-frequency impinging signal that (simultaneously) interrogating all the transmission frequencies of the group of transmission frequencies.

- 15 **[0048]** Advantageously, the device 1 can be a RFID tag 1, in particular a passive RFID, notably a chipless RFID tag. The code can be advantageously a unique identifier assigned to the RFID tag for identification and/or tracking purposes, notably of an object on which the RFID tag is attached. The reader can be thus a RFID reader 4.

- 20 **[0049]** As illustrated in Figure 1, the RFID tag 1 is thus configured to transmit a code 3_K as a RF backscattered radiation 2 in response to an impinging RF signal 41. In particular, the RFID tag 1 is configured to:
 react to an impinging signal at the (predetermined) reference frequency 23 with a reference backscattered signal 2_R , and to
- 25 react to an impinging signal 41 at any of the group of transmission frequencies 21, 22 with coding backscattered signals 2_G , 2_F whose amplitudes 20_A , 20_B relative to the amplitude 20_R of the reference backscattered signal define the code 3_K .

- 30 **[0050]** The reference frequency 23 and the transmission frequencies of the group being within the Radio Frequency (RF) range.

[0051] The group of transmission frequencies comprises at least a transmission frequency, preferably a plurality of transmission frequencies 21, 22, notably the number of transmission frequencies being a power of 2.

[0052] Figures 2a-c and 4a-c show a view of embodiments of RFID tags
5 relying on dipole antennas, while Figure 3 shows the related backscattered signals. In particular, these embodiments relying on dipole antennas printed on a (common) support 10 of the RFID 1.

[0053] In these embodiments, the reference backscattered signal 2_R at the reference frequency 23 (cf. Figure 3) is provided by a reference dipole
10 antenna 24_R .

[0054] The dimensions (in particular the length 290 of their conductive strip 29_A-29_F) and the electrical impedance (of the conductive strip 29_A-29_F) of each dipole antenna 24_A-24_E , 24_R determine the frequency at which the dipole antenna reacts (i.e. the reference frequency) as well as with what
15 intensity (i.e. amplitude attenuation).

[0055] As illustrated in Figure 2a, the reference dipole antenna 24_K , notably the length of his conductive strip 29_C , can thus be dimensioned so as to react to a (predefined) reference frequency, while his electrical conductivity can be selected so as to provide a given reference amplitude
20 attenuation. The width and the electrical conductivity of the conductive strip 29_C determine the electrical conductivity of the reference dipole antenna 24_R .

[0056] The RFID of Figure 2a is configured to provide a plurality of backscattered signals 2_A , 2_D at given (transmission) frequencies 22, 23 (cf
25 Figure 3), each backscattered signal being generated by a (coding) dipole antenna 24_A , 24_B so as to define a given code 3_A .

[0057] In this exemplary embodiment, the code 3_A is represented by a juxtaposition of (a same) symbol S_1 , the symbol S_1 being (in this example) defined by a backscattered signal having (substantially) the same amplitude

as the amplitude of the reference backscattered signal 2_R . By the term substantially the same amplitude, it is meant an identical amplitude or a similar amplitude (e.g. a difference less than variations in the backscattered signal due to components manufacturing errors, notably antenna
5 manufacturing errors, thermal errors, reader uncertainty or ambient noise).

[0058] The RFID tag of Figure 2a can thus transmit the code 3_A (in response of an impinging signal) by means of a first and a second backscattered signal 2_A , 2_D having (substantially) the same amplitude as the reference amplitude 20_R of the reference backscattered signal 2_R provided
10 by the reference dipole antenna 24_R . (cf. Figure 3).

[0059] In the exemplary embodiments of Figure 2b and 3b, the code 3_B , 3_C assigned to the RFID tag 1 comprises at least a symbol S_2 , S_3 , S_4 being defined by an amplitude 20_A , 20_B being different (i.e. larger or smaller) than the reference amplitude 20_R (cf. Figure 3).

15 **[0060]** A modification of amplitude of the backscattered signal can be provided by modifying the electrical impedance of the related coding dipole antenna 24_C , notably by modifying the dimensions of the conductive strip 29_D , 29_E , 29_F of (related) the dipole antenna.

20 **[0061]** As illustrated in Figure 2b and 2c, in particular, an increase of the amplitude can be obtained by enlarging the width 29_3 , 29_4 of the conductive strip 29_D , 29_E of the dipole antenna that leads to a decrease of the electrical impedance of the dipole antenna.

25 **[0062]** Similarly, as illustrated in Figure 2c, in particular, a decrease of the amplitude can be obtained by reducing the width of the conductive strip 29_E (even up to a complete elimination the strip) of the dipole antenna that leads to an increase of the electrical impedance of the dipole antenna.

[0063] Alternatively or complementarily, as illustrated in the exemplary embodiments of Figures 4a-4c, an increase or a decrease of the amplitude

can be obtained using another material for manufacturing (e.g. printing the conductive strip 29_G-29_J of) the dipole antenna, the material having another electrical resistivity (also called specific electrical resistance).

5 **[0064]** The printable material can be a conductive metal, a conductive ceramic and/or a conductive polymer, such as heated to liquid state metals (e.g. copper or aluminium), any metal or carbon doped inks (e.g. silver and silver chloride inks or epoxies) or melted polymers (e.g. carbon doped polylactic acid - PLA).

10 **[0065]** These particular embodiments furthermore provide not only an efficient encoding and transmission of data, but also a cost-effective manufacturing of the RFID tag as a given code can be assigned to the RFID by printing particular shaped and/or dimensioned dipoles antenna with one or more printable materials having different electrical resistivity.

15 **[0066]** Alternatively, or complementarily, backscattered signals can be provided by a group of resonating units 25_A-25_D and 25_R, as illustrated in Figures 5a and 5b.

[0067] The RFID tag 1 can thus comprises a group of resonating units comprising:
 a reference resonating unit 25_R with a resonator transmission line
20 29_J electrically connected between two antennas, the reference resonating unit 25_R providing the reference backscattered signal 2_R; and
 one or more coding resonating units 25_{A-D}, each comprising a resonator transmission line 251_A, 251_C electrically connected between two antennas 253_A, 253_C; each coding resonating unit providing one coding
25 backscattered signal at one transmission frequency of the group of transmission frequencies 22, 23.

[0068] In particular, at least a portion (preferably the entire) resonator transmission line of each resonating unit is advantageously printed on a (same) support 10 of the RFID tag.

[0069] Each antenna of each resonating unit is advantageously a monopole antenna.

[0070] A code 3_{G-H} can be assigned to the RFID tag 1 by means of one or more resonator transmission lines whose electrical inductivities provide, in response of an impinging signal, coding backscattered signals with predefined amplitudes with respect to the reference amplitude (of the reference backscattered signal). As previously described, desired electrical inductivity can be obtained (notably during the printing process) by dimensioning each resonator transmission line, notably the length and/or the width thereof (e.g. lines 29_L and 29_M) and/or by selecting an adequate material having a particular electrical resistivity (e.g. lines 29_M and 29_N).

[0071] Alternatively or complementarily, backscattered signals can be provided by a group of meander line loaded antennas 26_{A-B} , 26_R , as illustrated in Figure 6.

[0072] The RFID tag 1 can thus comprise a group of meander line loaded antennas 26_{A-B} , 26_R comprising:
a reference meander line loaded antenna 26_R providing the reference backscattered signal 2_R , and
one or more coding meander line loaded antennas 26_{A-B} , each coding meander line loaded antenna providing one coding backscattered signal at one transmission frequency of the group of transmission frequencies 22, 23.

[0073] In particular, at least a portion 29_O , 29_P , 29_Q of meander line loaded antennas, the portion being located between the antennas, is advantageously printed on a (same) support 10 of the RFID tag. Preferably, the entire meander line loaded antenna is printed on the support.

[0074] A code 3_{G-H} can be thus assigned to the RFID tag 1 by means of one or more meander line loaded antennas whose electrical inductivities provide, in response of an impinging signal, coding backscattered signals

with predefined amplitudes with respect to the reference amplitude (of the reference backscattered signal).

[0075] The desired electrical inductivity can be obtained (notably during the printing process) by:

- 5 - selecting a shape of the meander line loaded antenna, notably the number of meanders; and/or by
- dimensioning the (selected) shape, notably the length and/or the width of the meander (e.g. meander lines 29_o) and/or by
- using a material with a particular electrical resistivity (e.g. meander line
- 10 29_p).

[0076] Alternatively or complementarily, backscattered signals can be provided by other antennas having other geometrical shape, such as spiral-shaped antennas, notably having geometrical shape being entirely or at least partially printable on a support.

- 15 **[0077]** A code 3 can be thus assigned to the RFID tag by means of one or more of such antennas whose electrical inductivities provide, in response of an impinging signal, coding backscattered signals with predefined amplitudes with respect to the reference amplitude (of the reference backscattered signal).

- 20 **[0078]** The desired electrical inductivity can thus be obtained (notably during the printing process) by:
 - selecting a particular shape of the antenna, notably between a catalogue of different shapes; and/or by
 - dimensioning the (selected) shape, notably the length and/or the width of
 - 25 the printable portion of the antenna, and/or by
 - using a material with a particular electrical resistivity, notably selected within a catalogue of printable materials.

Numerical references used in the drawings

1 _{A-I}	RFID tag
10	Support
2	RF backscattered radiation
2 _{A-G}	Backscattered signal
2 _R	Reference Backscattered signal
20 _{A-B}	Amplitude
20 _R	Reference amplitude
21	1 st Radio Frequency
22	2 nd Radio Frequency
23	Reference Radio Frequency
24 _{A-K}	Dipole antenna
24 _R	Reference dipole antenna
25 _{A-D}	Resonating unit
251 _A , 251 _C	Resonator transmission line
252 _A , 252 _C	Antenna
253 _A , 253 _C	Antenna
25 _R	Reference resonating unit
26 _{A-B}	Meander line loaded antenna
26 _R	Reference Meander line loaded antenna
29 _{A-Q}	Printed electrical conductive portion
290	Length
291-294	Width
3 _{A-K}	Code
31, 32	Symbol
4	RFID reader
41	RF signal
5	Kit
S1-11	Symbol