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(54) SELF-RESONANT ELECTRICALLY SMALL ANTENNA

EIGENRESONANTE ELEKTRISCHE KLEINE ANTENNE

PETITE ANTENNE ÉLECTRIQUEMENT AUTO-RÉSONANTE

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Description

OBJECT OF THE INVENTION

[0001] The present invention is applicable to the antenna miniaturization design, for example, in the technical field of Radiofrequency Identification (RFID) by a micro-antenna coupled to a chip conforming an electronic label, commonly termed RFID tag, and attached to an object, animal or a person for its/his/her automatic identification.

[0002] More particularly, the invention that is disclosed herein relates to an antenna that achieves self-resonance without needing any external matching network between the antenna and the source (for example an RFID chip) and can be reduced in size arbitrarily, just adjusting different parameters of the resonant structure (at the expense of a reduced read range). This tiny antenna is especially suitable for RFID applications because it can be fabricated in a single layer substrate, with small dimensions as the antennas used in RFID tags require.

BACKGROUND OF THE INVENTION

[0003] The size reduction of antennas is a fundamental issue for different communications applications. Antennas should be integrated in different electronic products as mobile phones, laptops, personal digital assistant (PDA), etc..., and they require a small antenna capable of being integrated with different products.

[0004] Another common application for small antennas is Radio Frequency Identification (RIFD). This technology allows the identification of any object with the aid of an electronic tag attached to it. This electronic tag is composed by a small antenna and a micro-chip. In the technological development of Radiofrequency Identification, the tiny antennae of the RFID electronic tag can operate in a low-frequency band (LF), around 125 kHz, others in the high-frequency band (HF) at 13.56 MHz and some last ones are developed to work in the 900 MHz range, in the ultra-high-frequency (UHF) band. Different implementations of the RFID tags carrying in the interior thereof the microchip connected to the printed circuit antenna are known, for example, implemented in self-adhesive labels, capsules, coins, cards, badges, etc.

[0005] Normally, the size of a given antenna is in the order of the wavelength. This restriction means that antennas for low frequencies will be larger than antennas for high frequencies. In contrast, small antennas herein are commonly defined as antennas that fit in a sphere of radius $\lambda/(2\text{-}\pi)$, being λ the wavelength.

[0006] One of the most usual antennas is the resonant dipole as known in literature. A resonant dipole is a balanced antenna formed by a wire with length slightly shorter than half a wavelength fed at the centre.

[0007] A self-resonant antenna, as the resonant dipole, is an antenna whose input impedance is purely real. The maximum power transfer theorem states that, for a linear network with fixed source impedance, the maximum power is delivered from the source (antenna) to the load (chip) when the load impedance is the complex conjugate of the source impedance.

[0008] For a self-resonant antenna, as the impedance is real, the maximum power will be delivered when the antenna and source impedance are equal.

[0009] Based on the maximum power transfer theorem, if the antenna is not self-resonant, usually a matching network is needed in order to achieve the maximum power transfer between antenna and load.

[0010] As the resonant dipole, the self-resonant antennas known so far have a size in the order of the wavelength, which for some applications is very large. If the size of the antenna is required to be reduced, the input impedance becomes reactive (inductive or capacitive, depending of the structure of the antenna).

[0011] Therefore, the common solution for small antenna design and in order to achieve resonance is the introduction of a matching network, inevitably increasing the overall size and the cost.

[0012] Among the well-known self-resonant structures, besides the aforementioned resonant dipole, the Split Ring Resonator (SRR), introduced by Pendry (see "Magnetism from conductors and enhanced non linear phenomena" by J. B. Pendry et al., IEEE Transactions on Microwave Theory and Techniques, vol. 47, pp. 2075-2084, November 1988) is a great contribution to the field of metamaterials since it is the first particle able to achieve negative values of effective magnetic permeability. The structure of such resonator consists of two concentric metallic rings. Both rings have a certain thickness (c) and small gaps etched on opposite sides, as shown in Figure 1A. The SRR has a mean radius (r_0) measured just in between the two concentric rings. Also, Figure 1B shows the equivalent circuit of a SRR (proposed in "Comparative analysis of edge and broadside coupled split ring resonators for metamaterial design. Theory and experiments" by R. Marqués et al., IEEE Transactions on Antennas and Propagation, vol. 51, pp. 2572-2581, October 2003), where the total capacity (C_0) between the rings is $C_0=2\pi r_0 C_{pul}$, where C_{pul} is the capacity between rings per unit length. The resonant frequency of the SRR is given by $f_0=(L_s C_s)^{-1/2}/2\pi$, where C_s is the series connexion of the capacities corresponding to the upper and lower parts, i.e. $C_s=C_0/4$. The induction (L_s) can be approximated by the induction of a single ring with a radius equal to the mean radius (r_0) of the SRR and width (c) of each concentric ring.

[0013] The behaviour of the SRR in its first resonance can be approximated by a resonant dipole (stated in "Magnetism from conductors and enhanced non linear phenomena" by J. B. Pendry et al., IEEE Transactions on Microwave Theory and Techniques, vol. 47, pp. 2075-2084, November 1988) and then its magnetic polarization is expressed by:

$$m_z = \alpha_0 \left(\frac{1}{\frac{\omega_0^2}{\omega} - 1} \right) B_z$$

wherein B_z is the axial magnetic component of the electromagnetic field, α_0 is a geometric factor and ω_0 is the resonant frequency of the SRR.

[0014] According to the previous expression, the polarizability will have extreme values near the resonant frequency. Since the current in the SRR is uniform, it can be approximated by a plane loop and so the following expression applies:

$$m_z = IS$$

wherein I is the current through the SRR and S is the total area. Hence, the current I through the SRR is:

$$I = \frac{\alpha_0}{S} \left(\frac{1}{\frac{\omega_0^2}{\omega} - 1} \right) B_z = \alpha_0{}' \left(\frac{1}{\frac{\omega_0^2}{\omega} - 1} \right) B_z$$

[0015] From this expression it can be seen that the current in the SRR (I) is very large near the resonant frequency, even for a small structure. Figure 2 shows the current density distribution in a SRR at the resonant frequency.

[0016] Due to the resonant behaviour of the SRRs, a periodic array of these resonators, such as the one shown in Figure 3, illuminated by a properly polarized incoming field does not allow the propagation of electromagnetic waves for a specific frequency range. Thanks to such an effect due to the effective medium theory, a periodic array of SRRs can be used as a filter for millimetre waves and microwaves. An example of this use is EP 1675212 A1, wherein a planar transmission element, such as a microstrip line or a central metallic plane with dielectric substrate on both sides and a conducting strip formed on it, is mounted in magnetic coupling with an in-series insertion of several SRRs. Besides, EP 1675212 A1 provides an antenna or a battery of antennae which incorporates the described filter comprising said array of SRRs for emission and reception of electromagnetic waves, because the behaviour of the array of SRRs as an effective medium allows the propagation of fast waves for a given frequency, and then it behaves as a leaky wave antenna.

[0017] Other variations of SRRs are depicted in Figures 4-7 (see "Equivalent-circuit models for split-ring resonators and complementary split-ring resonators coupled to planar transmission lines" by J.D. Baena et al., IEEE Trans. on Microwave Theory and Techniques, vol. 53 (4), pp. 1451-1461, April 2005), showing structures and equivalent circuits respectively of:

Non-bianisotropic SRR (NBSRR), shown in Figure 4: it presents a 180° rotation symmetry in the plane of the SRR; as a consequence of this symmetry the NBSRR avoids cross-polarization effects while keeping the single-plane geometry.

Double-Slit SRR (D-SRR) or Distorted/Dual Split Ring Resonator, shown in Figure 5: it also presents the aforementioned symmetry, thus avoiding cross polarization; however, the D-SSR equivalent circuit differs from that of the SRR, being the frequency of resonance twice than that of a SRR of identical size.

Spiral resonator (SR), shown in Figure 6, and Double spiral resonator (DSR), shown in Figure 7: The SR presents a structure composed by a spiral element with two radii. The DSR has two coupled spiral elements In both cases, the resonant frequency does not only depend on the overall size. As can be seen from their equivalent circuits, the SR as well as the DSR allow for a reduction of the resonant frequency with respect to the SRR.

[0018] Following the Babinet principle, the SRR has a dual counterpart which is so-called Complementary SRR (CSRR).

Metal parts of the SRR are changed by slots in a conducting plane in the CSRR. In this way, electric currents in the rings are changed by magnetic currents in the slots and electric and magnetic fields surrounding the SRR are swapped by each other in the CSRR. Magnetic currents in the slots do no physically exist; actually they are a mathematical model for modelling the electric currents on the conducting plane. The currents are not confined to the edges of the slot but rather spread out over the conducting plane. In the SRR, the currents are more confined, and a higher current density flows through the rings. Because of this, power loss in SRR due to metal losses can be higher (lower efficiency) than in CSRR.

[0019] Returning to resonant simple structures like the dipole, when it is used in antennas, a solution to overcome the reduction of the radiation resistance due to the miniaturization of the antenna is using a folded structure, which allows a x4 increment of the radiation resistance. At the resonant frequency using a folded dipole allows to increase the real component of the input impedance (radiation resistance and loss resistance) without varying the resonant frequency. A dipole antenna and a single folded-dipole antenna are shown in Figure 8A and 8B respectively.

[0020] Another example of resonant antenna is the one disclosed in US 2005/0088342 which comprises a magnetically coupled feed ring within an electrically conductive ring which is a resonant and radiant element built in a planar dielectric. In this approach, the resonant structure is a split ring resonator used as an antenna and the internal ring has a gap to define feed points in diametrical opposition to a gap in the external conductive ring. This latter gap provides a desired capacitance and establishes a desired resonant frequency.

DESCRIPTION OF THE INVENTION

[0021] The present invention is intended to resolve the problem outlined above on miniaturized antenna design without needing to introduce a matching network in the antenna and satisfying both of two antenna design requirements: small size and matching to the source. Thus, one aspect of this invention deals with an antenna which comprises a self-resonant radiating structure that is perfectly adaptable to manufacture of micro-antennas for Radiofrequency Identification (RFID). And hence, another aspect of the invention refers to an RFID tag which comprises an antenna configured with this self-resonant radiating structure as described as follows.

[0022] The antenna proposed in this invention comprises at least a radiant element consisting of a resonant structure, built in a planar substrate and excited at a feed point, which produces an electric current through the feed point when said resonant structure is excited by a magnetic field (or an electric field in case the complementary resonant structure, applying the Babinet principle, is used) pointed in a direction transversal to the planar substrate. The resonant structure, which can be modelled by an equivalent electric circuit with inductance and capacitance that determine its resonant frequency, is a folded structure used as a split ring resonator (SSR) antenna.

[0023] More over, such self- resonant structure can be used as a near field UHF tag antenna, because it can be excited by the magnetic near (or evanescent) field from a reader antenna.

[0024] Contrary to the radiated fields, which decouple from the antenna and travel at the speed of light in waveforms, near fields exist only coupled to the antenna, and confined to a region in its vicinity. This property can be used in RFID to gain control and resolution over the space in which tags will be detected.

[0025] If a variable magnetic field pointed towards the axis of both rings (internal and external rings) conforming a split ring resonator structure is applied, due to the gaps built in these rings, the generated currents only can flow by means of the displacement current, because of the high capacitive values originated between the internal and external rings. The conductors introduce an inductive behaviour to the circuit and combined to the capacity between the rings, the SRR has a resonant behaviour when excited by an axial magnetic flux, showing a high diamagnetism over the first resonance.

[0026] Since the split ring resonator structure can resonate at a frequency not only dependent on its overall size, this means that the size of the resonator can be reduced arbitrarily for a given frequency and so, when the structure is fed to produce electromagnetic radiation, the SRR is a self-resonating and radiating element which becomes an antenna as small as required.

[0027] In order to feed the antenna, a small slit or gap can be done in the middle of the SRR, without modifying significantly the resonance frequency, because the equivalent circuit of this SRR behaves as a RLC series circuit at the resonant frequency and said resonant frequency is not affected by introducing a series resistor in the feeding point or feeding port etched in the external or internal ring.

[0028] An advantage of the antenna based on the SRR configuration is that the resonant antenna overall size can be reduced as much as needed just by increasing the overall inductance and capacitance between rings of the SRR.

[0029] A main difference of the present invention from the antennae described in EP 1675212 A1 lies in the electromagnetic radiation originated by the rings of the SRR. The radiation pattern of the SRR antenna described here is almost omni-directional with maximum gain in the plane containing the rings. If these rings have a radius much smaller than the wavelength, the SRR can be modelled, at the resonant frequency, as a loop antenna with an equivalent radius equal to the mean radius (r_0) of the SRR and an equivalent width equal to the width (c) of the rings. Thus, the radiation pattern of the SRR is similar to the one generated by a loop antenna. However, the SRR radiating structure is self-resonant, whilst the loop is purely inductive and requires a matching network to maximize transferring of power to the load of the antenna. For a loop antenna, the load must be the complex conjugated of the antenna impedance and the inductive component must be cancelled. On the contrary, the SRR does not need any matching network to the load and, at the same time, the resonant frequency can be kept independent from the SRR size, being an optimal configuration to be applied in miniature antennae. That is not applicable in EP 1675212 A1, wherein the radiant element of the antenna is a transmission line, not the SRR, but the SRR array structure behaves as a metamaterial or effective medium allowing the propagation of fast waves through the transmission line and then radiating power as a leaky wave antenna, constituted by the combination of all rings, and where each individual ring does not radiate by itself.

[0030] When the physical dimension of the SRR is reduced keeping the resonant frequency constant, i.e., not dependent on the ring size (because of the reduction in size is compensated by changing other parameters of the structure), one of the consequences is decreasing of the radiation resistance, and in turn, the reduction of the radiation efficiency of the antenna. Similarly as the increment of radiation resistance is achieved in a resonant dipole by the technique of the folded structure, a folded SRR antenna can be used to increase more than four times the radiation resistance for a given (constant) resonant frequency with respect to the SRR antenna for matching purposes.

[0031] Another way to increase the radiation resistance is to shift the feed port along the ring. Because of the current density in each ring decreases as it gets close to the gap of the ring, the feed point displacement along the external or internal ring achieves higher radiation resistance without modifying the resonant frequency. Moving the feed port results in an unbalanced antenna, so it is not suitable for applications which require a balanced transmission line, but it is perfectly valid for RFID applications.

[0032] An aspect of the invention deals with a self-resonant electrically small antenna comprising at least a radiant element which is a resonant structure built in a planar substrate and excited at a feed point, being said resonant structure modelled by an equivalent electric circuit with inductance and capacitance that determine a resonant frequency, and said resonant structure producing an electric current through the feed point when said resonant structure is excited by a magnetic field pointed in a direction transversal to the planar substrate, and being said resonant structure a folded split ring resonator which comprises:

- an internal ring with a gap
- and a folded ring with an external slit for the feed point.

[0033] In said resonant structure, the folded ring configures another gap in diametrical opposition to the gap of the internal ring and the feed point.

[0034] Another aspect of the invention deals with a self-resonant electrically small antenna comprising at least a radiant element which is a resonant structure built in a planar substrate and excited at a feed point, being said resonant structure modelled by an equivalent electric circuit with inductance and capacitance that determine a resonant frequency, and said resonant structure producing an electric current through the feed point (1) when said resonant structure is excited by a magnetic field pointed in a direction transversal to the planar substrate, and being said resonant structure a folded split ring resonator which comprises:

- an external ring with a gap
- and a folded internal ring with an internal slit for the feed point.

[0035] In said folded internal ring, another gap is configured in diametrical opposition to the gap of the external ring and said feed point.

[0036] Most RFID tags have their maximum radiation direction perpendicular to the plane containing the tag itself, but with the antenna based on the SRR in any of the proposed configurations the maximum direction of radiation is situated in the plane containing the antenna. This is advantageous for diverse applications, for example, an RFID tag with an SRR-based antenna can be placed inside a cap on a bottle so that the RFID reader can interrogate the SRR-based antenna when the reader antenna reaches the cap, being the optimum read direction the natural one defined by the major surface of the cap.

[0037] A main benefit of the present invention, in any of the diverse implementation ways disclosed here, is that the antenna can be fabricated very easily using a planar, rigid or flexible, substrate. This means that the fabrication process involves lower costs and also the fabricated antenna can be easily integrated for numerous applications that demand strictly reduced dimensions.

DESCRIPTION OF THE DRAWINGS

[0038] To complete the description being made and to assist in a better understanding of the characteristics of the invention, in accordance with a preferred example of practical embodiment, this description is accompanied, as an integral part of the same, with a set of drawings which illustrates but does not restrict, in which the following has been represented:

Figure 1. - It shows the structure (A) with relevant dimensions and the equivalent circuit model (B) of a split ring resonator, according to prior art.

Figure 2. - It shows the uniform and high current density distribution in a SRR at the resonant frequency, according to the behaviour at magnetic polarization of the SRR studied in prior art.

Figure 3. - It shows an effective medium composed by a plurality of split ring resonators, according to the normal behaviour studied in prior art of the effective magnetic permeability with negative values near the resonant frequency.

Figure 4. - It shows the structure (A) and the equivalent circuit model (B) of a non-bianisotropic split ring resonator, according to prior art.

Figure 5. - It shows the structure (A) and the equivalent circuit model (B) of a double-slit split ring resonator, according to prior art.

Figure 6. - It shows the structure (A) and the equivalent circuit model (B) of a spiral resonator, according to prior art.

Figure 7. - It shows the structure (A) and the equivalent circuit model (B) of a double spiral resonator, according to prior art.

Figure 8. - It shows a dipole (A) and a folded-dipole (B) antennae, according to prior art.

Figure 9. - It shows an antenna based on a folded SRR structure, configured with two arms, according to a possible embodiment of this invention.

Figure 10. - It shows an antenna based on a folded SRR structure configured with three arms, according to another possible embodiment of this invention.

PREFERRED EMBODIMENT OF THE INVENTION

[0039] Several options of implementations of an antenna comprising a radiant element that is a self-resonant structure as defined before are here described, being based on the possible folded split ring resonator configurations.

[0040] A possible embodiment of this invention deals with folding one or both rings of the SRR in order to achieve a larger radiation resistance. An example of a folded split ring resonator (11) structure is drawn in Figure 9. This folded split ring resonator (11) is composed by an internal ring (R1) and a folded ring (R2') with an external slit for the feed point (1).

[0041] For comparison, Table 1 shows the self-resonant frequency and real part of the input impedance of different resonant structures known in the prior art and the folded SRR implementation of the invention. All the structures have been simulated with a full wave MoM *[Method of Moments]* simulator assuming they are in free space, made of copper and have the same size with a maximum value about 20 millimetres.

Table 1.- Characteristics of different radiating structures.

Structure	Single loop	Single split ring	Split Ring Resonator	Folded SRR (Figure 9)
Resonant frequency (f_r)	5.5 GHz	2.36 GHz	1.72 GHz	1.72 GHz
Re(Z_a) at f_r.	150 Ω	10 Ω	3 Ω	14 Ω

[0042] The single split ring resonates at 2.36 GHz. At this frequency the length of the ring is approximately half a wavelength. This means that it is equivalent to the resonant frequency of a dipole of the same length (however, a dipole would have a larger overall size because it is straight).

[0043] Looking at Table 1, it can be seen that the higher input resistance is for a single loop antenna; however the resonant frequency is 5.5 GHz. The input impedance of the single loop at 1.72 GHz is 15.2 + j979 Ω, which is highly inductive. If we cancel out the reactive part by means of a series capacitor, the input resistance would be 15.2 Ω, which is very close to the folded split ring resonator, but the folded SRR does not need any matching network or external lumped components.

[0044] Moreover, the folded structure used in the folded split ring resonator has two arms. In order to increase more the input resistance, more arms can be used. As instance, a three-arms folded SRR, drawn in Figure 10, with identical overall size, would have a resonant frequency of 1.72 GHz and input impedance of 27 Ω. The input resistance is about N^2 times the input resistance of the non-folded structure, where N is the number of arms.

Claims

1. Self-resonant electrically small antenna comprising at least a radiant element which is a resonant structure built in a planar substrate and excited at a feed point (1), being said resonant structure modelled by an equivalent electric circuit with inductance and capacitance that determine a resonant frequency, and said resonant structure producing an electric current through the feed point (1) when said resonant structure is excited by a magnetic field pointed in a direction transversal to the planar substrate, **characterized in that** the resonant structure is a folded split ring resonator (11) which comprises an internal ring (R1) with a gap and a folded ring (R2') with an external slit for the feed point (1), said folded ring (R2') configuring another gap in diametrical opposition to the gap of the internal ring (R1) and said feed point (1).

2. Self-resonant electrically small antenna comprising at least a radiant element which is a resonant structure built in a planar substrate and excited at a feed point, being said resonant structure modelled by an equivalent electric circuit with inductance and capacitance that determine a resonant frequency, and said resonant structure producing an electric current through the feed point when said resonant structure is excited by a magnetic field pointed in a direction transversal to the planar substrate, **characterized in that** the resonant structure is a folded split ring resonator which comprises an external ring with a gap and a folded internal ring with an internal slit for the feed point, said folded internal ring configuring another gap in diametrical opposition to the gap of the external ring and said feed point.

3. An RFID tag comprising the self-resonant electrically small antenna defined according to any preceding claim.

4. The RFID tag according to claim 3, wherein the self-resonant electrically small antenna is built inside a cap of a bottle.

5. The RFID tag according to claim 3, wherein the self-resonant electrically small antenna is built out of a blister package metal sheet.

Patentansprüche

1. Eigenresonante, elektrisch kleine Antenne mit mindestens einem Strahlungselement in Form einer Resonanzstruktur, die in ein planares Substrat eingebaut ist und an einem Einspeisepunkt (1) angeregt wird, wobei die Resonanzstruktur durch eine äquivalente elektrische Schaltung mit einer Induktivität und Kapazität modelliert ist, die eine Resonanzfrequenz bestimmen, und die Resonanzstruktur einen durch den Einspeisepunkt (1) geleiteten elektrischen Strom erzeugt, wenn die Resonanzstruktur mittels eines Magnetfelds erregt wird, das in einer quer zu dem planaren Substrat verlaufenden Richtung ausgerichtet ist, **dadurch gekennzeichnet, dass** die Resonanzstruktur ein gefalteter Split-Ring-Resonator (11) ist, der einen Innenring (R1) mit einem Spalt und einen gefalteten Ring (R2') mit einem äußeren Schlitz für den Einspeisepunkt (1) aufweist, wobei der gefaltete Ring (R2') einen weiteren Spalt bildet, der dem Spalt des Innenrings (R1) und dem Einspeisepunkt (1) diametral gegenüberliegt.

2. Eigenresonante, elektrisch kleine Antenne mit mindestens einem Strahlungselement in Form einer Resonanzstruktur, die in ein planares Substrat eingebaut ist und an einem Einspeisepunkt angeregt wird, wobei die Resonanzstruktur durch eine äquivalente elektrische Schaltung mit einer Induktivität und Kapazität modelliert ist, die eine Resonanzfrequenz bestimmen, und die Resonanzstruktur einen durch den Einspeisepunkt geleiteten elektrischen Strom erzeugt, wenn die Resonanzstruktur mittels eines Magnetfelds erregt wird, das in einer quer zu dem planaren Substrat verlaufenden Richtung ausgerichtet ist, **dadurch gekennzeichnet, dass** die Resonanzstruktur ein gefalteter Split-Ring-Resonator ist, der einen Außenring mit einem Spalt und einen gefalteten Innenring mit einem inneren Schlitz für den Einspeisepunkt aufweist, wobei der gefaltete Innenring einen weiteren Spalt bildet, der dem Spalt des Außenrings und dem Einspeisepunkt diametral gegenüberliegt.

3. RFID-Tag mit der eigenresonanten, für kleine Ströme ausgelegten Antenne gemäß einem der vorhergehenden

Ansprüche.

4. RFID-Tag nach Anspruch 3, bei dem die eigenresonante, für kleine Ströme ausgelegte Antenne innerhalb der Kappe einer Flasche angeordnet ist.

5. RFID-Tag nach Anspruch 3, bei dem die eigenresonante, für kleine Ströme ausgelegte Antenne aus einer Blister-Packungs-Metallfläche ausgebildet ist.

Revendications

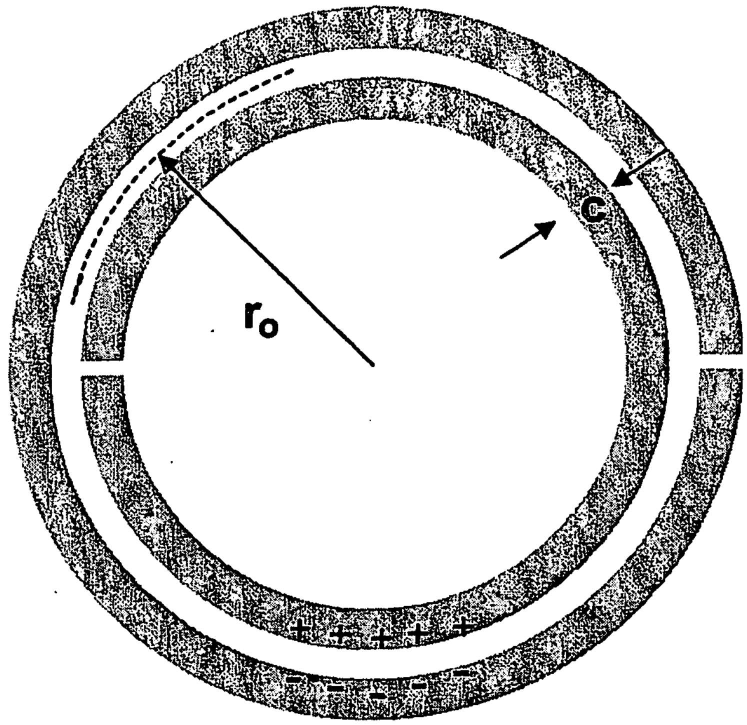
1. Petite antenne électrique auto-résonnant comprenant au moins un élément de rayonnement qui est une structure de résonance construite dans un substrat plan et excitée à un point d'alimentation (1), étant ladite structure résonnante modelée par un circuit électrique équivalent avec une inductance et capacité qui déterminent une fréquence de résonance, et ladite structure résonnante produisant un courant électrique à travers le point d'alimentation (1) lorsque ladite structure résonnante est excitée par un champ magnétique pointé dans une direction transversale au substrat plan, **caractérisée en ce que** la structure résonnante est un résonateur en anneau plié, divisé (11) qui comprend un anneau interne (R1) avec un espace et un anneau plié (R2') avec une fente externe pour le point d'alimentation (1), ledit anneau plié (R2') configurant un autre espace diamétralement opposé à l'espace de l'anneau interne (R1) et audit point d'alimentation (1).

2. Petite antenne électrique auto-résonnante comprenant au moins un élément de rayonnement qui est une structure résonnante construite dans un substrat plan et excitée à un point d'alimentation, étant ladite structure résonnante modelée par un circuit électrique équivalent avec une inductance et capacité qui déterminent une fréquence de résonance, et ladite structure résonnante produisant un courant électrique à travers le point d'alimentation lorsque ladite structure résonnante est excitée par un champ magnétique pointé dans une direction transversale au substrat plan, **caractérisée en ce que** la structure résonnante est un résonateur en anneau plié, divisé qui comprend un anneau externe avec un espace et un anneau interne plié avec une fente interne pour le point d'alimentation, ledit anneau interne plié configurant un autre espace diamétralement opposé à l'espace de l'anneau externe et audit point d'alimentation.

3. Etiquette d'identification par radiofréquence comprenant une petite antenne électrique auto-résonnante définie selon l'une quelconque des revendications précédentes.

4. Etiquette d'identification par radiofréquence selon la revendication 3, dans laquelle la petite antenne électrique auto-résonnante est installée à l'intérieur d'un capuchon d'une bouteille.

5. Etiquette d'identification par radiofréquence selon la revendication 3, dans laquelle la petite antenne électrique auto-résonnante est réalisée à partir d'une tôle en feuille d'emballage sous coque.



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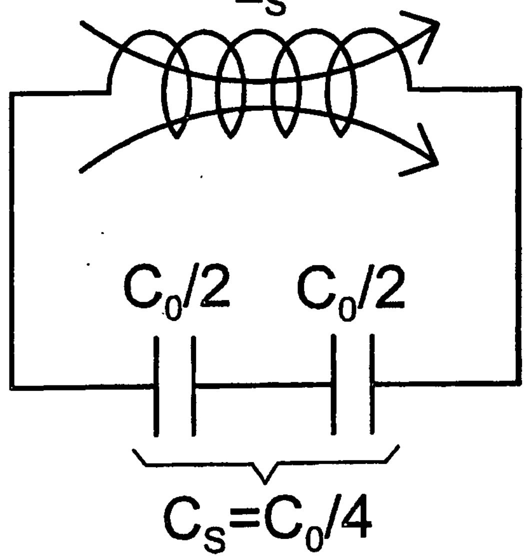

(B)

FIG. 1

prior art

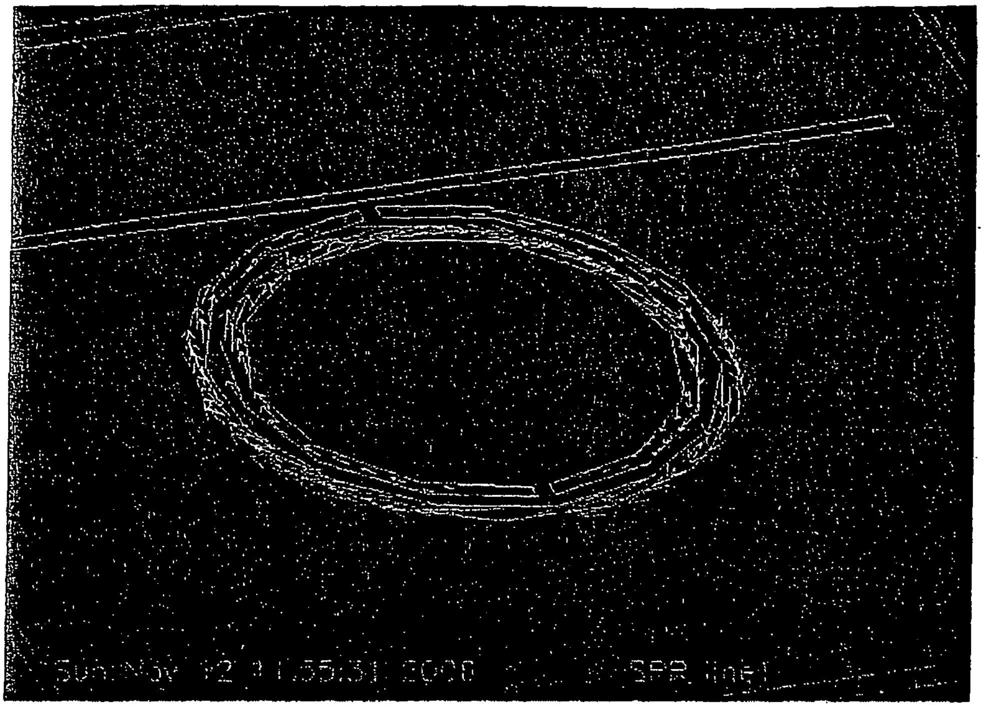

FIG. 2
prior art

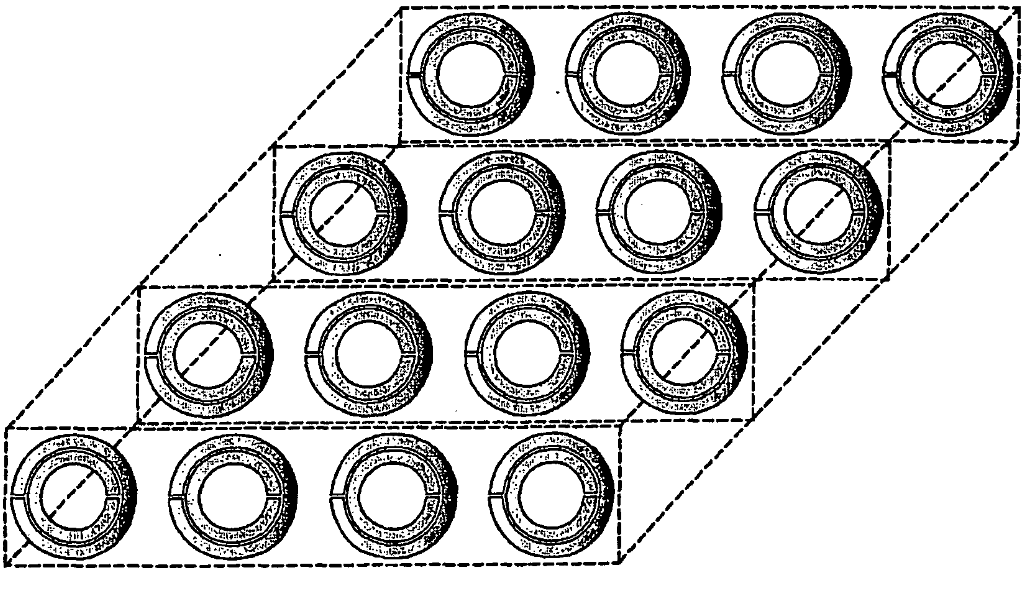

FIG. 3
prior art

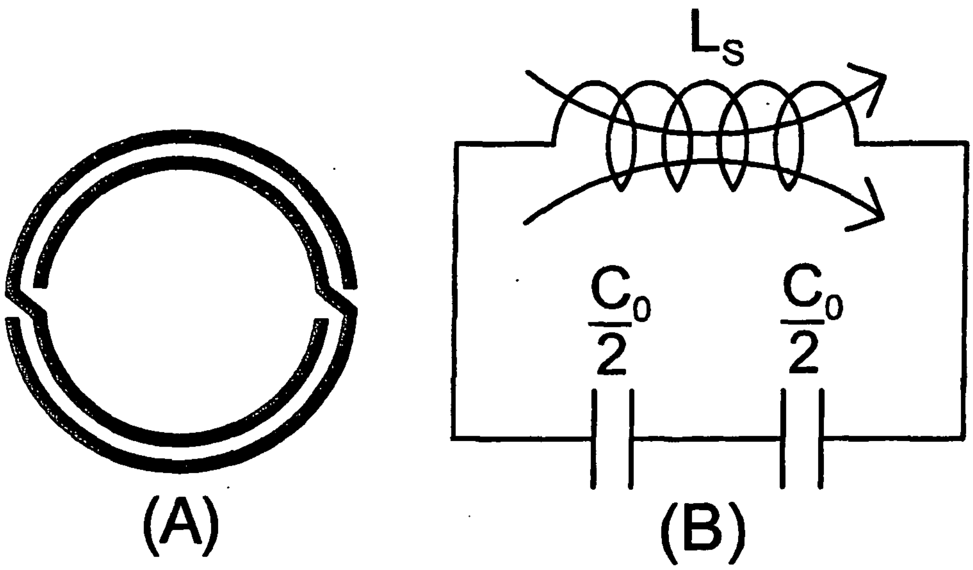

FIG. 4
prior art

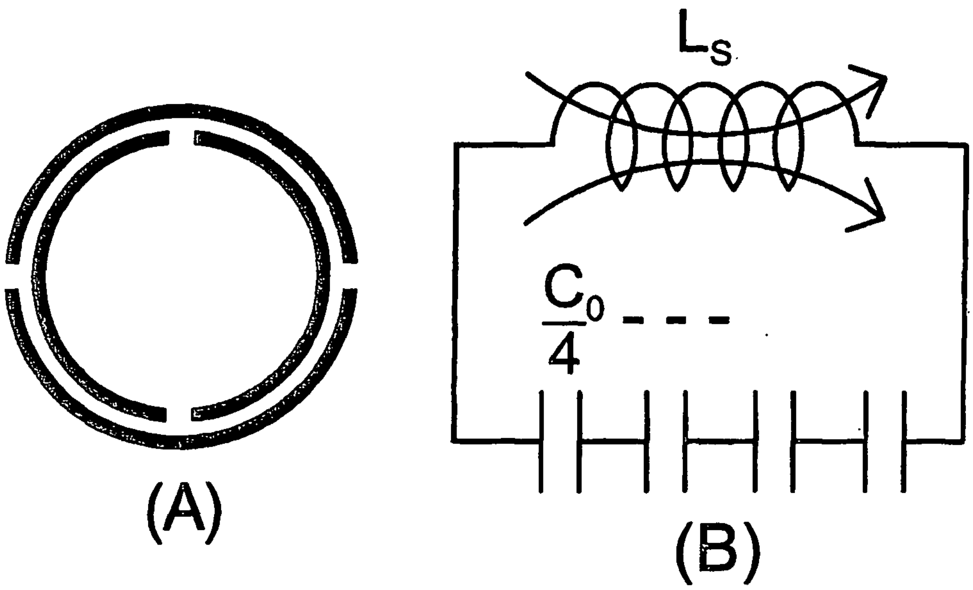

FIG. 5
prior art

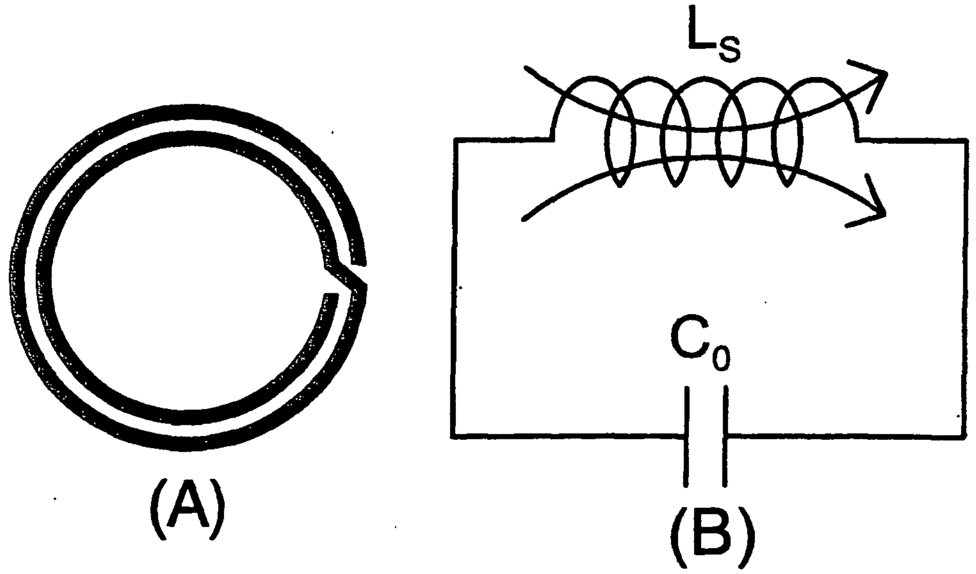

FIG. 6
prior art

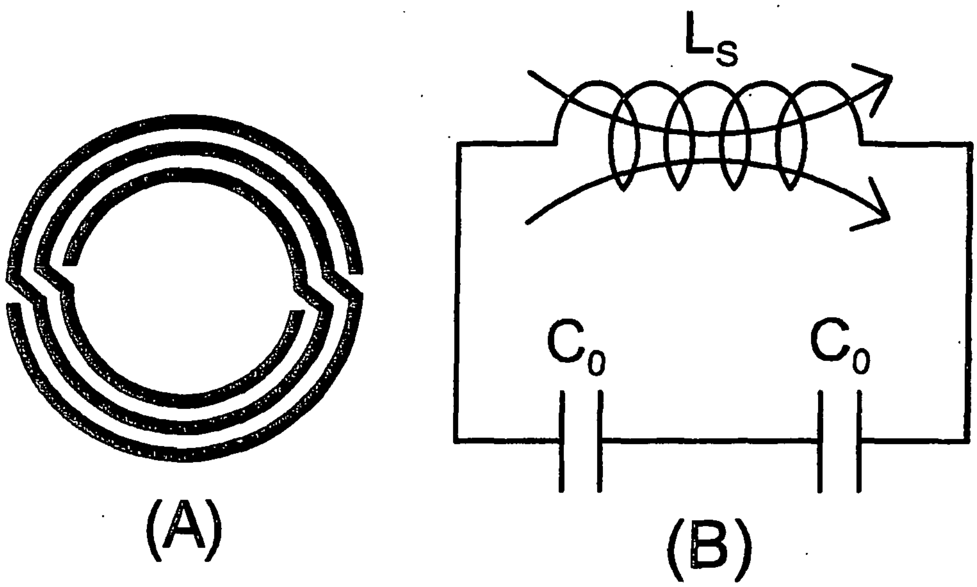

FIG. 7
prior art

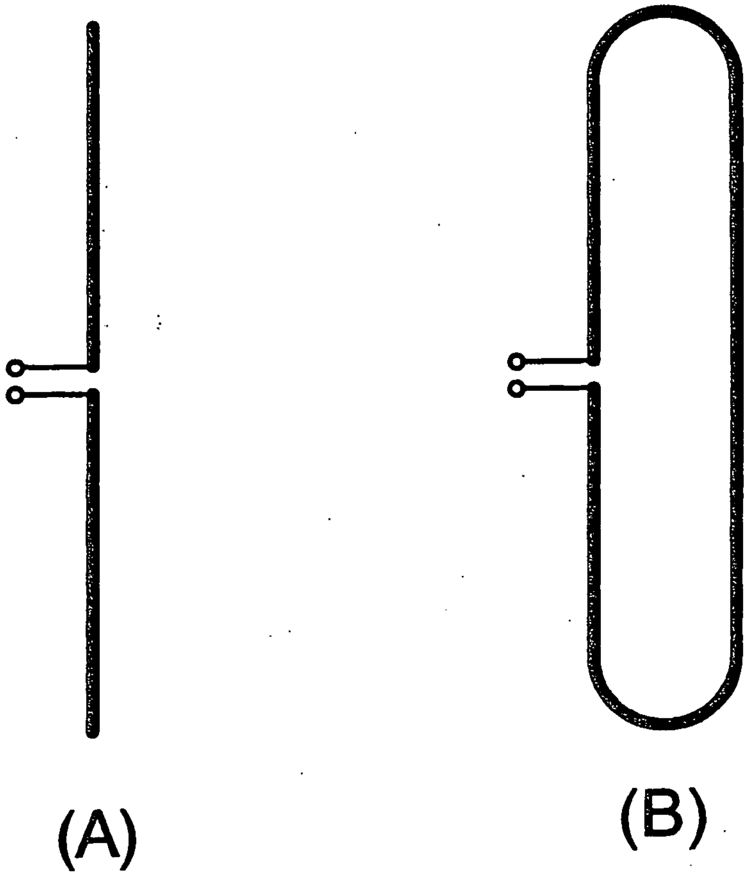

FIG. 8
prior art

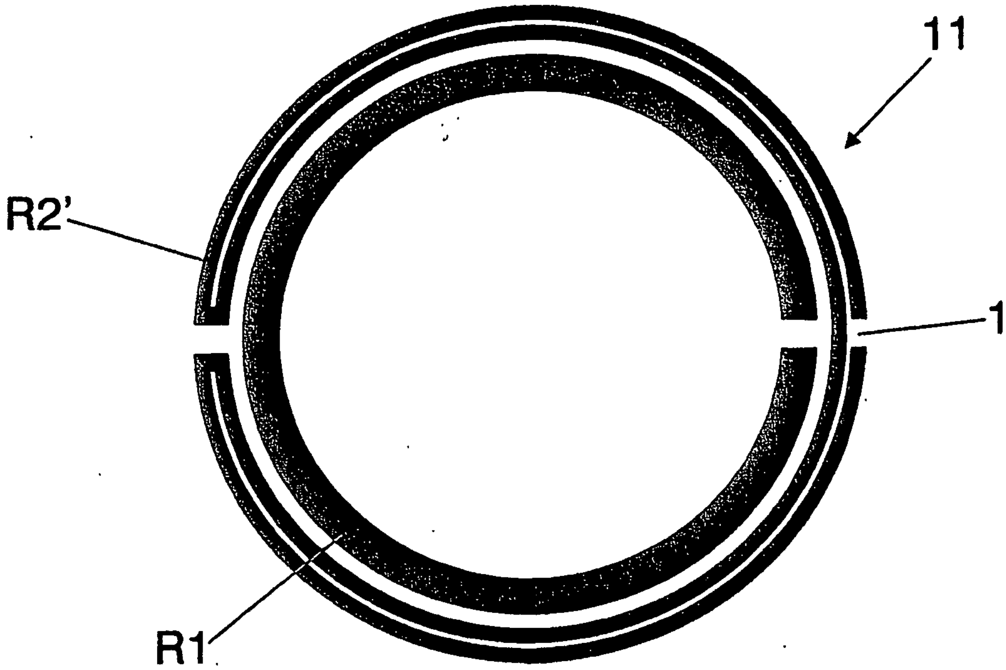

FIG. 9

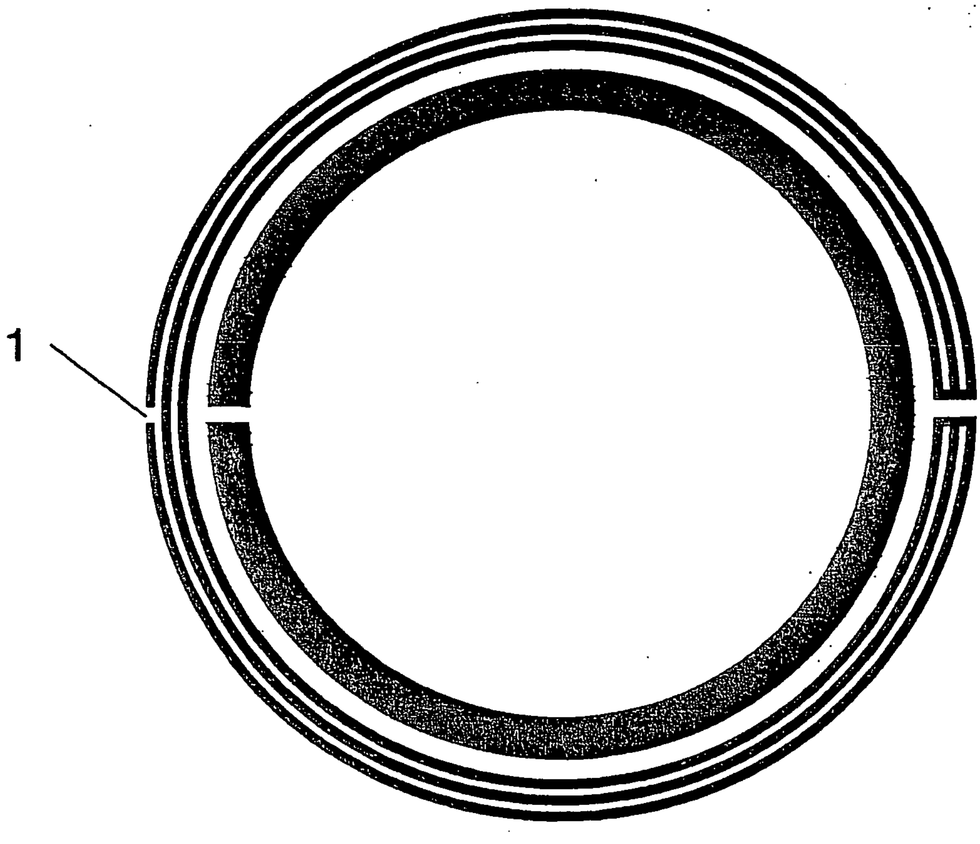

FIG. 10

REFERENCES CITED IN THE DESCRIPTION

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