Building **R**adio frequency **ID**entification for the **G**lobal **E**nvironment

Near field tags based on metamaterials concepts

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Near-field UHF tags based on metamaterials concepts

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Abstract

This paper introduces a new concept for the implementation of near field UHF RFID tags. Near field UHF tags are interesting in front of HF tags, because they can be implemented without via holes and reducing the fabrication cost. Metamaterial concepts are introduced in order to increase the sensitivity of a near field UHF tag to magnetic field.

1. Introduction

Radio Frequency Identification (RFID) is a technology which uses radiofrequency signals for automatic identification. Among the different frequency bands that can be used for RFID, the one that is becoming a standard for supply chain management is the UHF frequency band.

An RFID system is composed basically of two parts: an interrogator, usually known as reader, and a transponder, known as tag. The tag is composed by two parts: an RFID chip and a small antenna. Depending on the antenna structure, it can be optimized to radiate power into the far field, or it can be optimized to produce a strong near field surrounding the antenna (electric or magnetic) but little or no radiation. In the latter case, the structure actually is not a good antenna in the sense of antenna radiation efficiency; however it has other interesting properties.

One interesting property is that by using magnetic near fields, the system becomes more robust to the environment. Dielectric and lossy materials such as water in between the reader and tag antennas may produce strong detuning of the tag and attenuation to radiated waves; however these dielectric materials do not disturb much magnetic near fields. A single coil or loop can be used as an antenna for coupling the magnetic field in the UHF band.

This paper presents a novel approach to increasing the open circuit voltage, and then the sensitivity of a magnetic loop, without needing via holes in the substrate. The paper is organized as follows: section 2 introduces some concepts of metamaterials and the Split-Ring Resonator (SRR), which is a fundamental part of the proposed structure; section 3 compares the proposed structure to a single loop structure in order to assess the advantages of the novel design; finally section 4 presents the main conclusions extracted from the obtained results.

2. Metamaterials and the Split-Ring Resonator

The Split Ring Resonator (SRR), introduced by John Pendry [1], was a great contribution to the field of metamaterials as it was the first particle able to achieve negative values of effective magnetic permeability.

Fig. 1 shows the structure of such a resonator. It is formed by two concentric metallic rings with small gaps in opposite directions. If a variable magnetic field pointed towards the axis of the rings is applied to this structure, the generated currents can only flow by means of the displacement current, due to the high capacitive values originated between the rings. The conductors will introduce an inductive behaviour to the circuit, which combined with the capacity between the rings produce a resonant behaviour. More details about the electromagnetic properties of the SRR have been studied in [2] and [3].

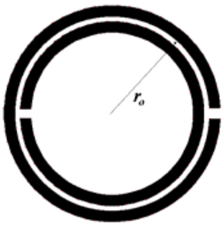

Fig. 1 Structure and relevant dimensions of the SRR.

Fig. 2 shows also the equivalent circuit proposed in [2], where C_0 is the total capacity between the rings and L_s is the total inductance. The resonant frequency of the SRR is given by $f_0=(L_sC_s)^{-1/2}/2\pi$, where C_s is the series connexion of the capacities, i.e. $C_s=C_0/4$. [2].

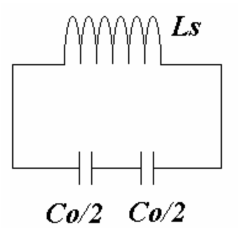

Fig. 2 Equivalent circuit model of the SRR.

A periodic array of these resonators illuminated by a properly polarized incoming wave will not allow the propagation of electromagnetic waves in a specific frequency range, because the array will produce negative values of magnetic permeability, according to the effective medium theory [1]:

$$\mu_{eff}(\omega) = 1 - \frac{F\omega^2}{\omega^2 - \omega_0^2}, \qquad (1)$$

where $\omega=2\pi f$, $\omega_o=2\pi f_o$, $F=\pi(a/p)^2$, a is the inner radius of the SRR and p is the periodicity of the structure. Equation (1) shows the normal behaviour of the effective magnetic permeability as a function of the frequency. This parameter rises dramatically near the resonant frequency and it becomes negative just after it. Then this effective medium will have negative values of μ_{eff} for a limited frequency range.

By constructing each ring of the SRR in a different layer of a common thin substrate, as if it were a parallel plane capacitor, the resonant frequency can be decreased (because the capacity increases). This implementation is known as Broadside Coupled Split Ring Resonator (BC-SRR) [2].

3. Near field tag

A small loop is a loop with conductor length less than $\lambda/3$ [4]. Due to the small dimensions of the loop, the current density along the conductor can be considered to be constant along the conductor. For this reason, the current moment tends to cancel out and it produces a very low radiation resistance.

The small loop is excited by a magnetic field transversal to the loop, and then it can be used for RFID near field operation.

The sensitivity of the small loop to magnetic fields can be increased by introducing a magnetic core (ferrite) within the loop with high magnetic permeability as stated by following equation [5]:

$$V_{oc} = \mu\omega H_z NS, \qquad (2)$$

where V_{oc} is the open-circuit voltage at the terminals of the loop, μ is the magnetic permeability, ω is the angular frequency, H_z is the magnetic field transversal to the loop, N is the number of turns and S is the loop area.

A Split Ring Resonator (SRR) can be used as a magnetic core in order to achieve a relative effective magnetic permeability larger than unity in the core of the loop.

Simulations

A small loop UHF tag antenna is depicted in Fig. 3 (a). It is a single loop with 4.5 mm of external radius and 4 mm of internal radius.

The structure of the small loop with SRR core is depicted in Fig. 3 (b). It has the same dimensions as the small loop, but a BC-SRR has been placed in the middle. Each ring of the BC-SRR is on a different layer of the substrate.

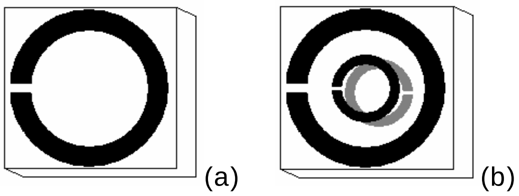

Fig. 3 Structure of the small loop (a) and the small loop with the BC-SRR core (b).

The substrate used in the simulation is a PET substrate with *50* μm thickness. The relative electric permittivity has been assumed to be 3 and no losses have been taken into account.

Both loops have been excited by means of a plane wave propagating with the magnetic field perpendicular to the plane formed by the loop, i.e. the magnetic field is transversal to the loop.

Fig. 4 shows the open circuit voltage versus frequency of the small loop with SRR core, compared to the results of the single small loop. It can be seen that the voltage increases dramatically just below the resonant frequency of the SRR, and decreases beyond it, as expected from (1) and (2).

4. Conclusions

SRR can be used to increase the sensitivity of a small loop as if it were a magnetic core (ferrite) with magnetic permeability that is a function of the frequency.

This characteristic can be used to reduce the overall size of a near field RFID tag keeping the read range constant, or the read range can be increased keeping the size constant.

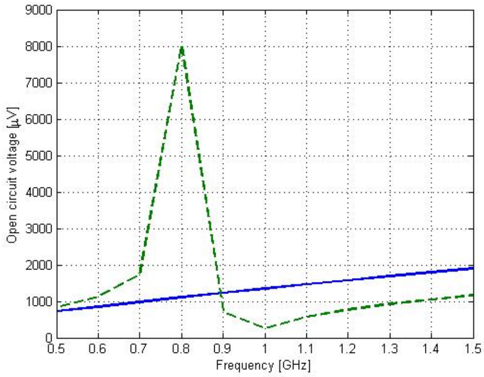

Fig. 4 Comparison between the open circuit voltage of a small loop and a small loop with SRR core.

Acknowledgement

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