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

Miniaturized UHF tags based on metamaterials geometries

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Miniaturized UHF tags based on metamaterials geometries

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Abstract

This paper introduces a new radiating structure inspired by the Split-Ring resonator (SRR) used in some metamaterials structures. It has the advantage of being easily miniaturized and fabricated in planar substrates.

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. This transponder or tag is composed by two parts: an RFID chip and an antenna. The antenna has to be efficient and well matched to the RFID chip, in order to deliver enough power to power it up. In addition it has to be small enough to be easily attached to small objects, mainly for item-level tagging.

Electrically small antennas (e.g. meanders, fractals, etc.) tend to have small efficiencies because the currents on the surface of the antenna have opposite directions [1].

This paper presents a novel antenna design which can be manufactured in planar substrates and small sizes. This design tends to maximize the net current in order to increase the radiation efficiency.

The paper is organized as follows: section 2 presents some concepts about metamaterials and the Split Ring resonator that is the structure on which the proposed design is based; section 3 describes the behaviour of the SRR antenna; section 4 presents the results of a prototype of the novel antenna; finally section 5 presents the main conclusions of this work.

2. Metamaterials and the Split-Ring Resonator

The Split Ring Resonator (SRR), introduced by John Pendry [2], 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.

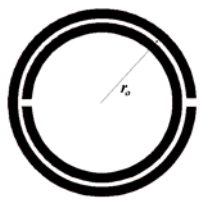

Fig. 1 Structure and relevant dimensions of the SRR.

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 currents, 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 provide a resonant behaviour. More details about the electromagnetic properties of the SRR have been studied in [3] and [4].

The behaviour of the SRR in its first resonance can be approximated by a resonant dipole [2] and [5], and it can be modelled by a resonant series LC circuit Fig. 2.

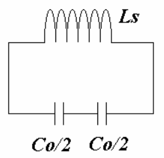

Fig. 2 Equivalent circuit model of the SRR.

The SRR at the self-resonant frequency behaves as a uniform current loop [3]. It is well known that small loops, because of the low current moment, have small radiation resistance, and thus low efficiency.

3. SRR as a tag antenna

The SRR can be excited by a small gap in the middle of one of the two rings of the SRR (Fig. 3).

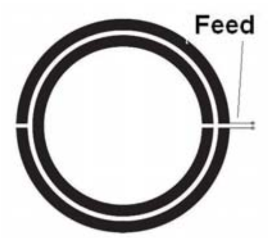

Fig. 3 SRR feed through a small gap in one of the two rings.

In order to use the SRR as an antenna the efficiency has to be increased and this is done by using the SRR outside the self-resonant frequency.

Out of the resonant frequency, the current distribution in the external ring is not equal to that of the internal ring. Then, the SRR cannot be compared to a uniform current loop. This increases the net current. For frequencies below the resonant frequency the current is mainly concentrated in the feed ring while for frequencies beyond it the current it is concentrated in the other. Then, the radiation resistance increases dramatically for frequencies beyond the resonant frequency, as it is proportional to the radiated power over the current at the feed point square. Fig. 4 shows the behaviour of the current distribution on the SRR.

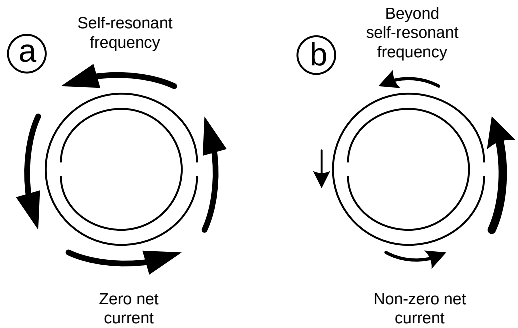

Fig. 4 Comparison between the current distribution on the SRR at the resonant frequency (a) and beyond the resonant frequency (b).

The behaviour of the input impedance beyond the self-resonant frequency becomes inductive, even more than the predicted by the series LC circuit model (it is only valid near the resonant frequency). Fig. 5 shows the comparison of the simulated input impedance of a specific SRR feed as in Fig. 3 with the input impedance resulting of applying the LC model. Only the imaginary part of the input impedance has been represented, because no losses or radiation resistance have been taken into account in the model.

Because of the inductive behaviour of the SRR beyond the self-resonant frequency it can be designed to cancel out the capacitive behaviour of common RFID chips, simplifying the matching between the antenna and the chip.

4. Prototype of the SRR tag antenna

In order to assess the capabilities of the SRR, an antenna for an RFID tag has been fabricated.

Fig. 6 shows the prototype of the antenna with the RFID chip soldered in the external ring. The radius of the external ring of the prototype is 15 mm, while the substrate, which has dielectric constant 10.2 and thickness 1.27 mm, is 40 x 40 mm^2.

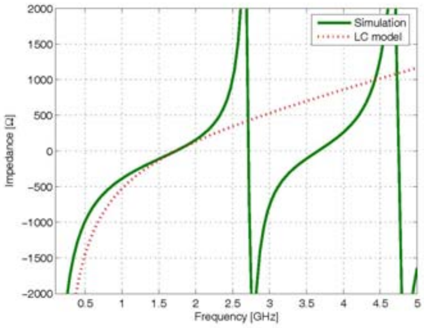

Fig. 5 Comparison between LC model and simulation. SRR has parameters: r_o=8.75 *mm*, *c*=1 *mm* and *d*=0.5 *mm*. LC model has parameters: *L*=42.11 *nH* and *C*=0.201 *pF*.

Fig. 6 Prototype of the SRR tag antenna.

The tag antenna has been tested using a Gen2 RFID chip (Fig. 6). The read range has been measured by using a standard Gen2 reader with the maximum allowed power in the European regulations (ERP = 2 W). The measurement setup is depicted in Fig. 7 and the read range achieved was about 6.5 m.

5. Conclusions

The current distribution of the SRR for frequencies above the first resonant frequency is no longer comparable to that of a small loop. The radiation resistance and efficiency of the SRR, used as an antenna, increase because of the current moment increases. The input impedance above the first resonance is inductive and it facilitates the matching of the antenna to the capacitive input impedance of the RFID chip.

The SRR structure makes possible to construct planar, electrically small antennas which can be used for RFID tags.

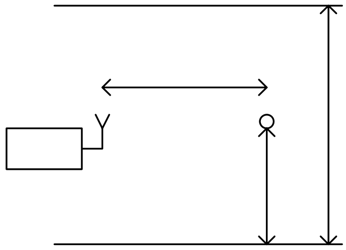

Fig. 7 Read range measurement setup.

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References

[1] S. R. Best, "A comparison of the resonant properties of small space-filling fractal antennas", *IEEE Antennas and Wireless Propagation Letters*, vol. 2, pp. 197-200, 2003

[2] J. B. Pendry, A. J. Holden, D. J. Robbins, and W. J. Stewart, "Magnetism from conductors and enhanced non linear phenomena", *IEEE Transactions on Microwave Theory and Techniques*, vol. 47, pp. 2075-2084, Nov 1988.

[3] R. Marqués, F. Mesa, J. Martel and F. Medina "Comparative analysis of edge and broadside coupled split ring resonators for metamaterial design. Theory and experiments", *IEEE Transactions on Antennas and Propagation,* vol. 51 (10), pp. 2572-2581, October 2003.

[4] R. Marqués, F. Medina, and R. Rafii-El-Idrissi, "Role of bianisotropy in negative permeability and left-handed metamaterials," *Phys. Rev. B*, vol. 65, pp. 144440(1-6), 2002.

[5] F. Falcone, T. Lopetegi, M. A. G. Laso, J. D. Baena, J. Bonache, M. Beruete, R. Marqués, F. Martín and M. Sorolla, "Babinet principle applied to the design of metasurfaces and metamaterials", *Phys. Rev Lett.*, vol. 93, pp. 197401-4, Nov. 2004.