Size-Reduction of Magnetic Radiators for RFID-Based Technology

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Abstract

Innovative compact geometries suitable for the realization of loop antennas for RFID applications are proposed in this paper. The radiators have been simulated using common commercial tools and measurements have been performed to validate their usability. All the design procedures and the choice in the manufacturing phase are discussed in details through the paper.

The antennas characteristics have been analyzed focusing on important characteristics, such us the return loss value, the radiation pattern and the antenna efficiency.

1. Introduction

Radio frequency identification (RFID) represent a key point of application and research in the next future 0. RFIDs are applied in many technological areas, including industrial control, habitat monitoring, healthcare applications, manufacturing automation, traffic control, packaging development, industrial production management, logistics 0000. Many researchers are developing studies to analyze the use of RFIDs for an increasing number of applications, looking for optimized solutions in terms of power consumption, available bandwidth, antenna dimensions, security, realization costs.

Most of the RIFD applications are set at UHF frequencies. The RFID band is allocated on different frequency bands from Country to Country. For example in the US the frequency allocation is set between 902 MHz and 928 MHZ, while in Europe is set between 865.6 MHz and 867.6 MHz. The aim of this work is to define a new antenna design for the European's RFID frequency range focused on the lossy media radiation characteristics.

Compared to analogous solutions, RFIDs are particularly interesting, since a cabled connection among the TAG and the reader is not needed. For this reason, RFIDs are absolutely promising, if applied to the analysis of objects embedded in lossy media 0 - 0.

When the TAG is embedded (or even moving) in a dissipative medium, several RF design constraints must be considered and the antenna should be:

- magnetic, to favor the radiation through the conductive medium;
- small in size, to favor the TAG insertion within objects (or pipes) of narrow dimensions;
- working at the lower identifiable frequency, to minimize attenuations caused by losses;
- efficient, to optimize the transmission of the power generated by the transmitter, which is typically low;
- omnidirectional in the plane containing the antenna, to guarantee stability to the transmission link, independently from the antenna rotations (in case of mobility, e.g. in a bottle of water, in a pipe or in an aquarium) .

Among all possible solutions, the antenna that better matches the whole set of the listed properties, is the elementary magnetic dipole, and its practical implementation, the electrically small loop. In the following it will be referred as micro-magnetic radiator.

2. Designing Technique

The antenna design has been based on two major constraints: the minimization of the space occupation and an extreme simplification of the radiofrequency circuits. For this reason, more complex antenna configurations have been discarded and a planar solution that implements the whole set of matching circuits inside the loop, has been identified.

The design of the antenna has been carried out by choosing the dimension for which the real part of the impedance is equal to 50 Ohm. The imaginary part has been subsequently modified by inserting a series of one or more stubs whose input reactance cancels the antenna one. The insertion of the stubs introduces an electromagnetic coupling that slightly

978-1-4244-6051-9/11/$26.00 ©2011 IEEE

modifies the overall impedance of the antenna, and consequently the stubs position and dimension must be re-adapted, following an iterative algorithm similar to a one that these authors have recently published and which will be referenced in the final version of the paper. The procedure is very efficient, converges in no more than three steps, and avoids any need for optimization algorithms.

The presence of the stubs must introduce a minimal electromagnetic coupling that should not (or slightly) modify the radiative characteristics of the antenna. Among all possible solutions that have been investigated, a series of two curvilinear stubs parallel to the loop wire has been chosen, as shown in Fig.1. As an auxiliary result, the input impedance of curvilinear transmission lines grows more slowly, compared to straight ones; hence, the matching bandwidth is increased. Furthermore, varying position and thickness of the lines, it is possible to improve the bandwidth increment. The form and shape of the resulting antenna are very similar to a smiling face; hence, we have added two small metallizations, and baptized the antenna "Smiley Antenna".

Finally, to reduce the radius of the antenna, allowing an extended minimization of space occupation, more complex loop geometries have been investigated. In this way, it has been possible to synthesize small antennas, having radiuses down to 60% of a standard circular loop with the same behavior. To this purpose, a geometrical shape similar to a flower, with a variable number of petals, has been defined. Fig.2 shows an example, with its matching circuit. With this shape, the smiley has grown his hairs, and we have baptized the antenna "Hair Antenna".

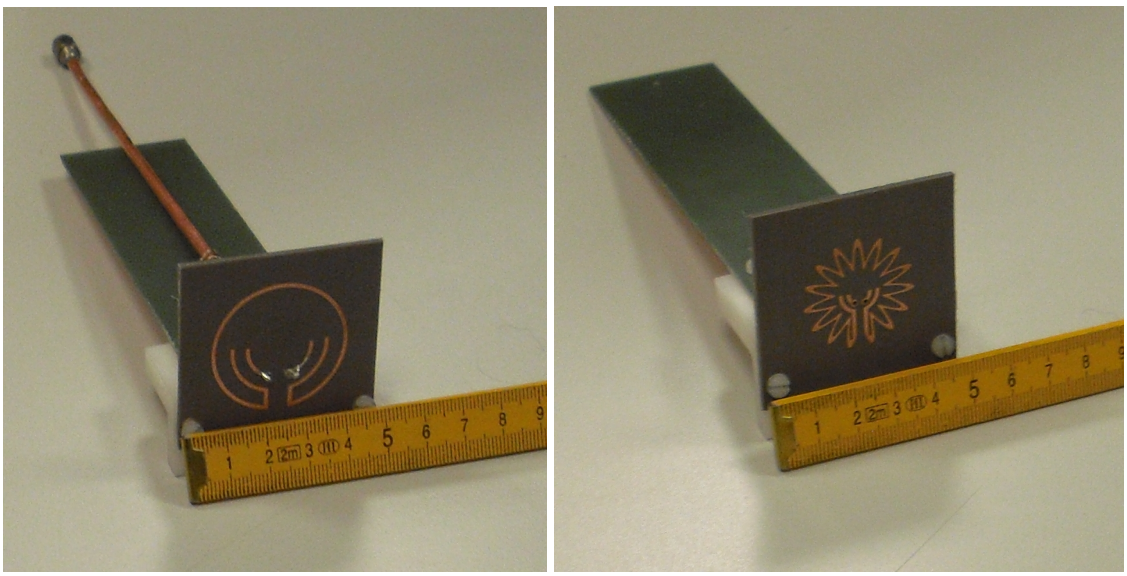

Figure 1: Prototypes of the Smailey and Hair Antennas

3. Antenna Realization

Two prototypes, one Smiley and one Hair Antenna both working at 900 MHz, have been designed, realized and measured. The described antenna is intended to work in a wireless TAG that uses an RF board operating in the 900 MHz band. At the mentioned working frequency, the wavelength is equal to 33.3 cm, and the radius of the loop is approximately $0.36\ \lambda / (2\ \pi)$, i.e. 1.9 cm. A full-wavelength loop would have a radius equal to 5.3 cm.

To strengthen the antenna and simplify its realization, it has been decided to construct it on a substrate, by etching techniques. The characteristics of the chosen material are Dielectric Constant (over the band of interest) 2.9 ± 0.05, Surface Resistivity 2.5 MΩ, Thickness 0.18 cm.

The Smiley Antenna shown in Fig. 1, has been designed with radius 1.6 cm, thickness of the ring 2 mm, lines thickness 2 mm. The results reported in Fig.2a show the return loss (RL) of the whole antenna, simulated by means of commercial software (HFSS), compared to measurements. As it can be observed, the antenna exhibits a -10 dB bandwidth equal to 4 MHz (0.3 %). The result is aligned to what reported in the technical literature 0.

Results about the Hair Antenna are reported in Fig. 3. The geometrical configuration allows a reduction of the external loop radius, down to 1.35 cm, with a 40% reduction of the dimensions, maintaining the same frequency

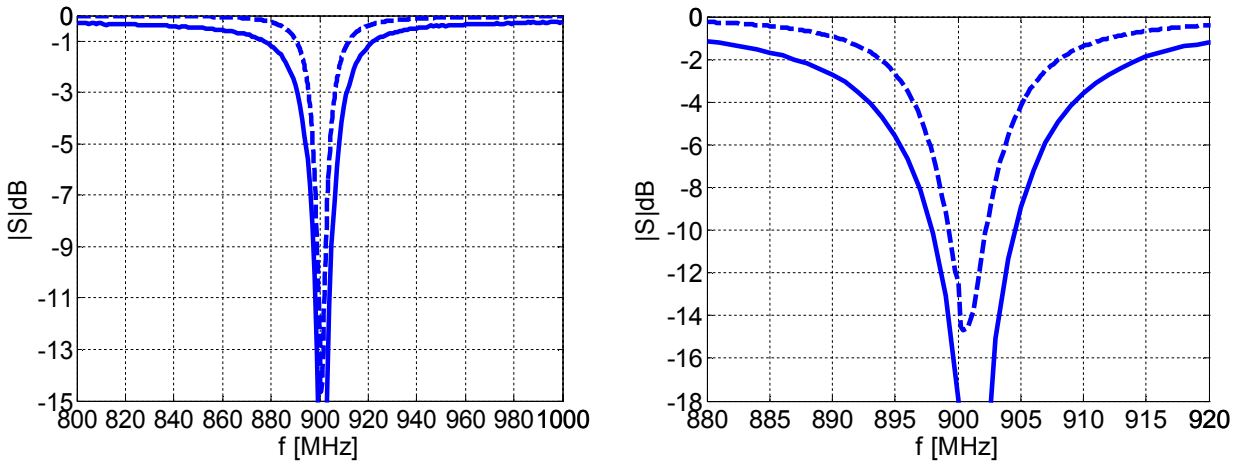

Figure 2: Reflection Loss of the Smiley Antenna (left) and Hair Antenna (right). Simulation (dotted line) versus measurements (solid line)

behaviour and a 74.52% reduction, compared to the full wavelength solution. Fig. 2b shows the antenna RL simulations vs measurements. In this case the bandwidth is 0.22%, with a performance decrement, compared to the Smiley Antenna.

The matching technique does not affect the radiation pattern, which remains sufficiently omnidirectional in the plane containing the antenna (Fig.3 shows a comparison between measurements and simulations).

Measurements were carried out in our anechoic chamber. The comparison between simulated and measured results shows a good agreement (see Fig. 2), where measured results (continuous line) evidence an improved bandwidth, compared to the predicted ones, thanks to a variation of the matching stubs thickness that allowed the realization of an antenna with 0.6% bandwidth. Under the design constraints, this represents a result in line with the technical literature 0 where single resonator antennas with 0.3% to 0.4 bandwidths can be found.

The antenna efficiency is under evaluation now. First results are good, thanks to the simple design that has been introduced, ranging between 75% and 82%, depending on the type of antenna.

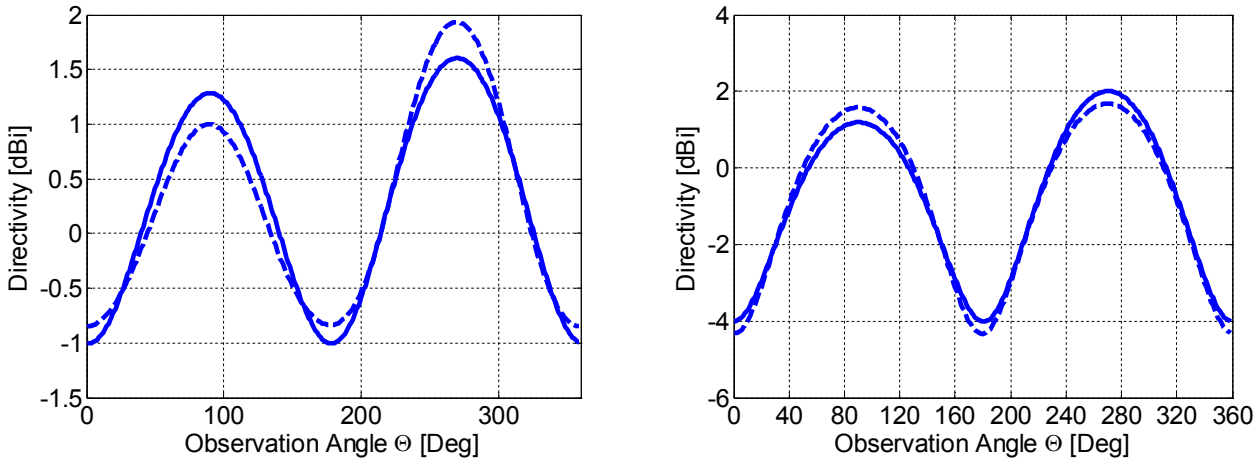

Figure 3: Radiation Pattern in the plane containing the antenna: Smailey (Left) and Hair (right)

4. Conclusion

Two new geometries for the implementation of compact magnetic antennas have been presented. In particular, it has been evaluated the possibility to use these radiators for RFID applications.

The antenna characteristics have been analyzed focusing on return loss, radiation pattern and antenna efficiency. Those results are satisfactory and show excellent agreement between measurements and results

The goal of an omnidirectional radiation patter has been achieved and the resonant frequency belongs to the European RFID band. Similar design techniques can be followed in order to design an antenna suitable for the US specifications.

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