THE DESIGN OF A HF RFID TAG ANTENNA FOR WAREHOUSE MANAGEMENT

FINIȘ Ilie*
LAVRIC Alexandru*

ABSTRACT
THIS PAPER PRESENTS THE DESIGN OF TWO TAG ANTENNA MODELS THAT CAN BE INTEGRATED INTO A 13.56 MHZ HF RFID SYSTEM. IN ORDER TO VERIFY, THE PERFORMANCE OF THE TWO TAG ANTENNA MODELS PROPOSED A SERIES OF SIMULATIONS USING THE ANSOFT HFSS APPLICATION WERE PERFORMED. THE ADVANTAGES OF USING THESE NEW MODELS DETERMINE THE INCREASE OF THE INTERROGATION AREA ENSURING A HIGH LEVEL OF PERFORMANCE

KEYWORDS: TAG ANTENNA, ANSOFT HFSS, COUPLING FACTOR

1. Introduction

An important element in each RFID system, irrespective of the frequency range are represented by the tags integrated in the system. It is needed to get a much lower cost, store a sufficient amount of information about a certain product and function in the presence of any environmental. Some of these tags characteristics have been achieved, but others are still looking for solutions.

An antenna suitable for these tags must have a low cost, easy to designed and developed, and the size should be minimized in order to be attached to objects of different sizes, providing the highest performance level. Another important element is regards to the operation performance in the vicinity of different environments such as liquids or metal.

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* PhD Student, Stefan cel Mare University of Suceava, Faculty of Electrical Engineering and Computer Science, email: ifinis@eed.usv.ro;
* PhD Student, Stefan cel Mare University of Suceava, Faculty of Electrical Engineering and Computer Science, email: alavric@eed.usv.ro;

This fact is important because is intended to achieve the highest possible communication distance no matter what environments are in their proximity.

Many of the RFID system that work on 13.56 MHz use inductive coupling between[1] the tag and the reader antenna[2]. Because these tags are passive, the energy needed to activate the HF chip is taken out of the magnetic field generated by the reader antenna. To achieve inductive coupling between the antenna and the tag, chip used by tag must be capacitive, and the antenna must have a certain inductance. For this reason, multi loop coils are used in tags that operating at 13.56 MHz frequency.

One solution is to connect several antennas to a single reader with different orientations between them. Therefore, using a multiplexer each antenna can be activated separately, leading to a major reduction of errors, in the tags identification. This method can be helpful in cases we have to carry out a smaller scale inventory, but when we inventory in a warehouse or a store this approach is no longer viable.

A problem with HF tags is the fact that the reading distance between the reader antenna and tags changes, according to the tag orientation. Any change in the orientation angle between the reader antenna and tag leads to the reduction of energy received by the tag antenna from the magnetic field generated by the reader antenna. In figure 1 is presented how the communication distance decreases when the tag orientation is changed.

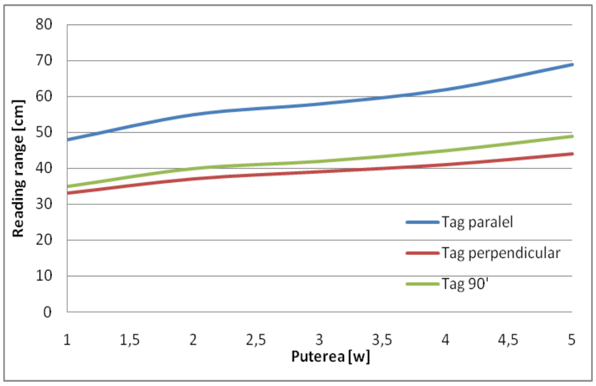

Fig. 1 Changing the reading distance according to tag position in relation to reader antenna

Also, was determinated the distance of identification in case the tag is applied on two adjacent sides of a product (Figure 2). From the data obtained, we can see an increase

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[1] S. C. Q. Chen and V. Thomas, Optimization of inductive RFID technology, in Proc. IEEE International Symposium on Electronics and the Environment, pp. 82-87, Jul. 2001.

[2] S. S. Basat, K. Lim, J. Laskar, and M. M. Tentzeris, Design and modeling of embedded 13.56 MHz RFID antennas, in Antennas and Propagation Society International Symposium, 2005 IEEE, vol. 4B, 2005, pp. 64–67 vol. 4B.

of interrogation distance up to 5 cm, compared with the case when the tag is positioned perpendicular to the readers antenna.

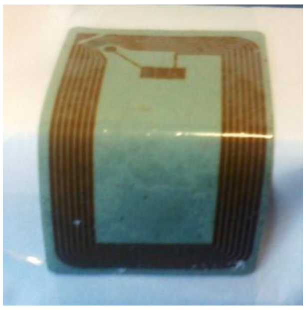

Fig. 2 The attachment of a HF tag on both sides of a product

2. The design of the tag antenna

When designing a HF RFID tag the most important components are antenna and minimum energy required to activate the chip. If in the chip case changes cannot be make, for antennas solutions are still looking. The most important issue, when designing a tag antenna, is given by the coil inductance that should be between some values in order the tag to operate at the desired frequency. In the specialized literature, there are a number of papers[3,4,5,6] which presents numerous calculation methods, through which can determine the inductance of HF antenna. Also, can be used a software application which can model and optimize the parameters and the performance of tag antenna.

Choosing the desired chip is important because depending on the internal capacity, the inductance can be determined. It is needed, for the new formed circuit to resonate at the desired frequency format, taking into account the relation (1).

$$f_{Tag} = \frac{1}{2\pi\sqrt{L_{ant}C_{chip}}} \tag{1}$$

From equation (1) may be determined the antenna inductance value L_{ant} using equation (2) after the chip type has been chosen for the design of new antennas shape.

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[3] http://www.st.com/internet/com/TECHNICAL_RESOURCES/TECHNICAL_LITERATURE/APPLICATION_NOTE/CD00221490.pdf

[4] R. Escovar, S. Ortiz, and R. Suaya, Mutual inductance between intentional inductors: closed form expressions, in Proc. Circuits and Systems, pp. 2448-2452, Sep. 2006.

[5] R. Escovar, S. Ortiz, and R. Suaya, An improved long distance treatment for mutual inductance, IEEE Trans. Computer-Aided Design, vol. 24, no. 5, pp. 783-793, May 2005.

[6] S. Hackl, C. Lanschutzer, P. Raggam, and W. L. Randeu, A novel method for determining the mutual inductance for 13.56MHz RFID systems, in Communication Systems, Networks and Digital Signal Processing, pp. 297-300, Aug. 2008.

$$L_{ant} = \frac{1}{\left(2\pi f_{tag}\right)^2 C_{chip}}$$

(2)

The designed antennas took into consideration the ISO/IEC 15693-2, -3 standards, concerning the maximum dimensions of the tag and the activation energy. The first and the second antenna design use two, respectively four coils that must be connected together so that when the tag is attached to a product, careless of its orientation, it can obtain a maximum identification distance.

To reach the obtained dimensions, concerning the three antenna models used in HF tags, the next steps were followed: the first was determining the antenna's external dimensions. For this first step, the limitations of the standards in force must be taken into consideration, but also the physical limitations resulted after the designing stage. After setting the dimensions of the antenna, the next step is the concern of knowing the chip specifications, and implicitly the internal capacity (C_{chip}).

After determining the variables (length and width of the antenna), the next step, is finding the maxim turns number of the coil for that specific antenna. The maxim number of turns is obtained after calculating the maximum inductance for the antenna to obtain the desired resonance frequency. In figure 3 is presented the influence of the inductance of the antenna by the number of turns and the maximum dimensions of the coil.

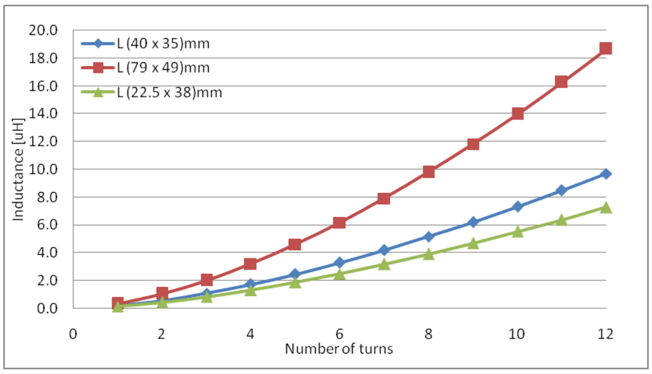


Fig. 3 Changing the inductance of an antenna for HF tag according to the number of turns

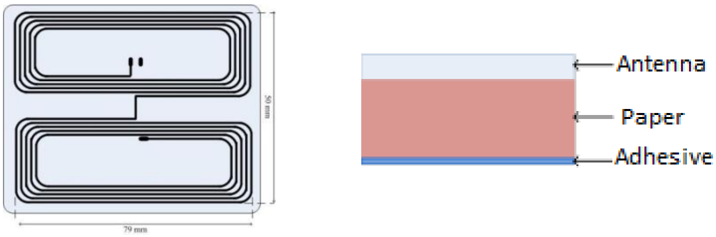
Another parameter that influences the number of turns of an antenna is the area that can be occupied by that specific antenna. In case of using small lengths and widths of the antenna, a large number of turns cannot be used in order to obtain the desired inductance, it is recommending using a double layer antenna. This method requires the two antennas being located on both sides of the layer used, obtaining an equivalent circuit made of two coils connected in series. Another element influencing the inductance is the material used as sub layer. It has a certain permeability, which must be taken into consideration for the design. In addition, the thickness of the material gives small variations to the frequency of the tag.

The first antenna model was designed so that it can be attached on small goods. It consists of two coils of 22x79 mm. Table1 presents the physical dimensions obtained after following the previous steps and the electrical parameters of the antenna resulted after the simulation. This model was designed on one layer and the sub layer used is paper with a thickness of 50 µm. A sub layer of 5 µm made up of an adhesive was used for the simulations, giving us easy positioning.

Table – 1 Parametrical values of the firs antenna

The parameters of the antenna	
Number of turns	5
Wire width	0,48 mm
Space between wires	0,1 mm
Wire thickness	35 um
Exterior dimensions	2*(79 x 22 mm)
Inductance	2*2,94 µH

In figure 4, is presented the first model of the antenna and a section of the plane (x-z) in order to observe all the component layers of the tag. In the design, the HF chip from Texas Instruments is used, which has an internal capacity of 23.5 pF[7]. In order to validate the antenna tag performance, some simulations were done using the Ansoft HFSS software package. First, the coupling factor (k) was determined between the proposed antenna model and another antenna 31x31 cm.



a) b)

Fig. 4 The first antenna model for a RFID tag, a) front side, b) section in x-z plane

In figure 5, is presented the case of the tag being parallel to the reader's antenna, in this case the best coupling factor is achieved. The situation differs when the tag is oriented

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[7] http://www.ti.com/lit/ds/symlink/rf-hdt-ajls.pdf.

by 90 degrees from the reader’s antenna. In this situation, the coupling factor gets close to 0%, as the distance between rises. In the second case, the simulations had the tag positioned in the center of the antenna, and on a side of it, the coupling factor is also reduced.

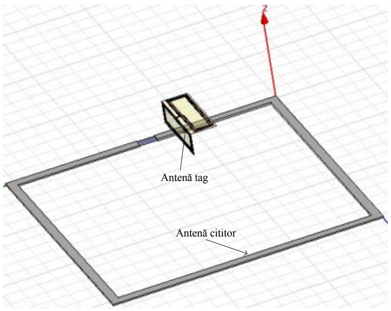


Fig. 5 Tag antenna positioning at 90^0

The situation changes when the tag is bent (figure 6), coupling factor gets to 1.6% when it is centred in the middle of the antenna, and may get to 2.5% when it is placed on a side. These values are valid for a distance of 1 cm. If the distance increases, the coupling factor drops.

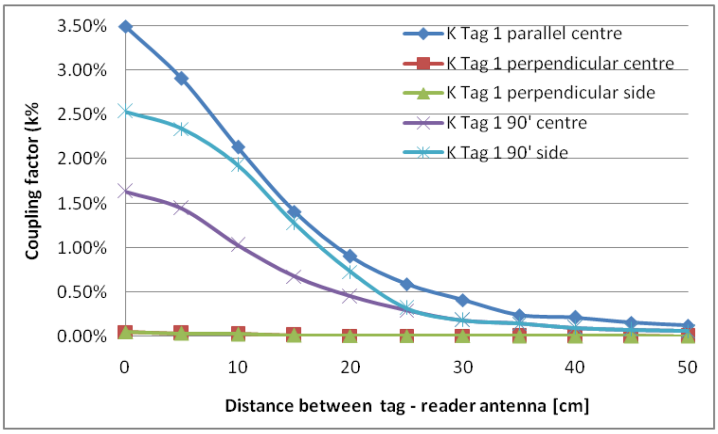


Fig. 6 Coupling factor variation depending on the distance between model one and the reader’s antenna

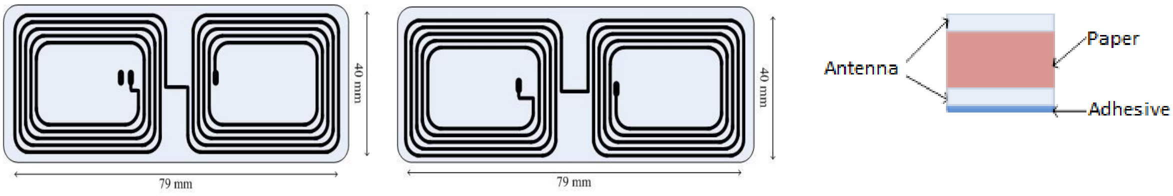
When the tag is not bent, the inductance simulation of the antenna gets to 5.865 μH and system (antenna + chip) will resonate at the frequency of 13.56 MHz. When the tag antenna is bent at 90^0, the inductance of the antenna gets to 5.406 μH this fact gets the tag to resonate at the frequency of 14.23 MHz. The antenna should be redesigned in order to obtain the needed inductance or an external capacitor connected parallel to the chip can be used. If not, the capacitor in the projection phase of the tag antenna can be designed. This is possible by inserting two metal plane parallel of finite size, and the dielectric – the material used as the sub layer for the tag. No matter what the used method is the resonance frequency tolerance should not be above 450 kHz so that an optimum functioning of the whole RFID system is met.

In the second case, the tag dimension are 40x79 cm and the tag antenna size is 40x34 cm. This tag model has four antennas connected in a series, being double, two antennas on one side of the tag. In table 2 are presented the physical dimensions and electrical parameters for the proposed antenna model.

Table – 2 Parametrical values of the second antenna model.

The parameters of the antenna	
Number of turns	4
Wire width	0,51 mm
Space between wires	0,122 mm
Wire thickness	18 um
Exterior dimensions	4*(40 x 34 mm)
Inductance	4*1,475 µH

In figure 7 is presented the shape of the antenna and.



a) b) c)

Fig. 7 The second antenna model for a RFID tag a) front side, b) back side, c) section in x-z plane

Fig. 9 shows the variation of the coupling factor when the tag is parallel and perpendicular to the reader's antenna.

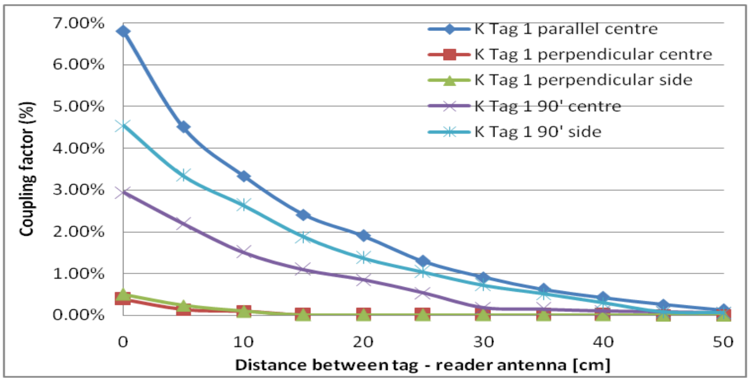


Fig. 8 Coupling factor variation depending on the distance between tag and the reader's antenna

In case the tag is making a 90^0 angle with the reader's antenna the coupling factor gets close to 0%, just like in the first case – the separation distance increases. If the tag is bent and centred in the middle of the antenna, maximum k reaches 3.9%. When the tag is positioned to a side of the antenna, the maximum coupling factor gets as high as 4.6%. These values were obtained at a 1 cm distance between the two antennas if the distance increase, the coupling factor drops.

3. Conclusion

The proposed models present superior performances from the existed solutions. So an increase of the tag identification distance is achieved, regardless of their orientation.

For the first antenna case, the coupling factor (k) reduces significantly if the tag is positioned perpendicular to the reader's antenna. In the situation when the antenna bents at 90^0, the value of the coupling factor increases up to 2.6%. This determines an increase of the interrogation area. In the second antenna, modeling case are used four coils connected in series. In this case, the coupling factor rises up to 4%. The advantages of using these new models determine the increase of the interrogation area and that makes them usable for warehouse management.

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