MAGNETIC FIELD SENSITIVE ANTENNA DESIGN FOR HF BAND RFID SYSTEM

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Abstract: Antenna designs are influenced by a range of matters, such as the region of label operation (near or far), the coupling field (electric field or magnetic field), the regulatory constraints and the environment in which they operate. Typically antennas used in the high frequency (HF) band RFID operate at 13.56 MHz whose frequency has an electromagnetic wavelength of around 22 m giving a near-field far-field boundary of around 3.5 m. A common practice of using a magnetic field-sensitive HF antenna suitable for operation in the HF ISM band (13.56 MHz).The label is designed to have a sufficient number of turns to provide the resonating inductance for the microcircuit input capacitance, as well as a flux collecting area in the interior, which is as large as practicable and consistent with the size requirement for the label. This paper presents a design method to optimize the RFID magnetic field sensitive antenna design with an EM simulation program Sonnet Lite manufactured by Sonnet Software Inc. The Sonnet Lite simulator program is very well known program for antenna design. A well designed RFID antenna can effectively reduce the system cost and improve the radio wave broadcast. Apart from that, communication range between tag and reader can be improved. In this project we have designed an antenna, where design has been done and verified its performance by simulation.

Načrtovanje antene občutljive na magnetno polje za RFID sisteme, ki delujejo na HF pasu

Kjučne besede: RFID, ISM frekvenčni pas, na magnetno polje občutljiva antena

Izvleček: Na načrtovanje anten za RFID sisteme vpliva veliko stvari, kot so zahtevana čitalna daljava (bližnje ali oddaljeno), sklopitveno polje (električno ali magnetno področje), zakonske omejitve in okolje, v katerem deluje. Antene, ki se uporabljajo v HF frekvenčnem pasu delujejo pri 13.56 MHz, oz. valovna dolžina je okoli 22m, kar omeji področje čitanja na okoli 3.5 m. Kartica je narejena tako, da ima zadostno število navojev, da omogoči resonanco z obstoječo vhodno kapacitivnostjo, kakor tudi, da omogoči zadosten pretok skozi navoj.

V prispevku predstavimo načrtovalsko metodo in programsko opremo, s katero optimiziramo geometrijo RFID antene. Dobro načrtana RFID antena lahko močno zniža stroške celega sistema in izboljša oddajno-sprejemni signal, oz. komunikacijo med kartico in oddajnikom.

1. Introduction

The history of Radio Frequency Identification (RFID) is old as far back as the 1920s with the birth of radar systems /1/. The development of the technology, a combination of radar and radio broadcast technology, is messy and convoluted but there is consensus that it developed from the work carried out during WW-II to identify enemy aircraft, known as 'Identification: Friend or Foe' (IFF) systems.

The RFID systems use radio frequency waves to identify, locate, and track people, assets and animals when RFID tag is attached to them /2/. RFID systems composed of mainly two components a reader (or interrogator) and tag as shown if Figure 1.

Antennas used in the HF region operate at 13.56 MHz. Thus, given reading distance requirements of <3 m and using the regulated radiation power at the HF ISM band, reader antennas are almost always near-field creation structures that aim to create large energy density fields with the minimum amount of radiation. However, at UHF frequencies the scenario is different. At UHF frequencies, the near-field far-field boundary is around 50 mm. Thus the region of operation in the UHF spectrum is almost always in the far field, and therefore reader antenna designs are far-field creation structures that aim to operate at the highest possible efficiency.

The base station or reader continuously transmits an RF signal through its antenna while always watching for modulated backscattering signal. Once the tag has received sufficient energy to operate correctly, it begins clocking out its stored data that make to tuned and de-tuned the antenna circuit. As a result it causes amplitude fluctuation of antenna voltage across the antenna circuit. The reader detects the amplitude variation of the tag and uses a peak-detector to extract the modulation data. The most popular medium frequency band RFID system used 13.56 MHz frequency as carrier. Now the largest component of an RFID tag is obviously the antenna. However, the practical tag

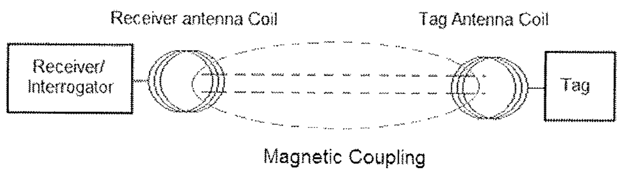

Fig. 1: Basic Block Diagram of RFID systems (near field)

has dimensions of only a few centimeters. These dimensions are very small compared to the wavelength and the radiation resistance is only few milliohms /3/.

Thus a 13.56 MHz RFID system cannot possibly radiate very well. It is essentially not an antenna. Some people refer to RFID reader as "couplers" /2//4/. This terminology is certainly quite appropriate in this case. We have indeed to consider the RFID system antenna plus tag, as a loosely coupled transformer, with reader antenna coil acting as a primary and the tag coil acting as the secondary of this transformer respectively.

2. Materials and Method

Designs are carried out in this project by used EM analysis software called Sonnet Lite version 11.55. Design method and calculations ware made by following the standard loop antenna design theory.

2.1 Designing of 13.56 MHz Antenna

The first step is to create an RFID inductor. Figure 2 (a) shows a typical RFID inductor.

a

b

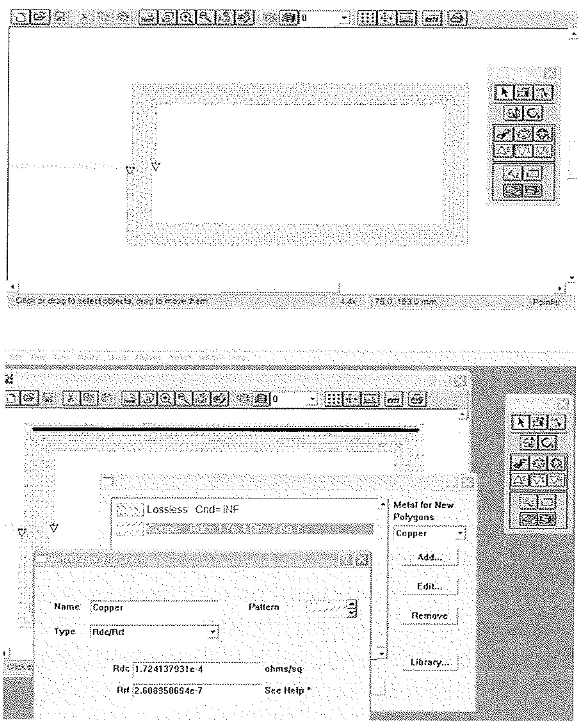

Fig. 2: (a) Designed RFID Planar Inductor (b) Metal Properties

It is a planar inductor with 6 turns, each 0.5 mm wide and separated by 0.5 mm. The coil has the dimensions are 78 mm × 41mm. Metal losses are taken into consideration during the design process. Since this analysis uses the Sonnet ABS interpolation, accurate data at 300 frequencies is calculated from electromagnetic analysis at only four frequencies.

By using the Sonnet Option Analysis, a lumped equivalent PI-model sub-circuit is generated. The output, shown here, is in PSPICE codes.

```
* Analysis frequencies: 12.1, 13.3 MHz
.subckt SON9_2 1 GND
C_C1 1 GND 1.185049pf
L_L1 1 2 4495.387nh

* Analysis frequencies: 13.3, 14.65 MHz
.subckt SON9_3 1 GND
C_C1 1 GND 1.198058pf
L_L1 1 2 4493.561nh
R_RL1 2 GND 1.859145
.ends SON9_3
R_RL1 2 GND 1.770104
.ends SON9_2
```

It shows that models are generated between two frequency bands. The first SPICE netlist is generated from data at 12.1 and 13.3MHz. The second SPICE netlist is generated from data at 13.3 and 14.65MHz. These PSPICE models are used to design the RFID antenna circuit.

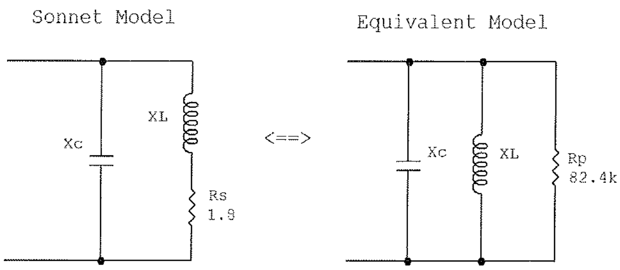

Fig. 4: (a) Sonnet Mode (b) Equivalent Model

Figure 4(a) is the direct Sonnet SPICE model and Figure 4(b) is its equivalent model. The generated lumped equivalent component for PI-model at 13.56 MHz frequency, the value of the capacitance is 1.2 pF and the inductance is 4523 nH. The series resistance of Rs =1.8 Ω is equivalent to parallel resistance /5/ Rp = 82.4 kΩ as shown Figure 4.

In this design we assumed that a typical 13.56 MHz RFID integrated circuit has capacitance 23.5 pF and internal resistance 25 kΩ. The simulated equivalent circuit is shown in Figure 5.

The RFID IC that has been used in this design has a total internal capacitance 23.5 pF. The distributed capacitance of the inductor is calculated by the Sonnet SPICE model is 1.2 pF. To make resonate an antenna coil of inductance 4523 nH with a frequency 13.56 MHz, total capacitance must be 30.6 pF /6/. So for the best matching between the tag (or reader) coil and the RF IC, an external capacitor 5.9 pF is calculated to tune the inductor at the frequency 13.56 MHz. The total impedance of the resonant circuit at resonance is the parallel combination of the internal resistance of the IC and the equivalent parallel resistance of the coil is 19.2 KΩ. This is the impedance that the RFID

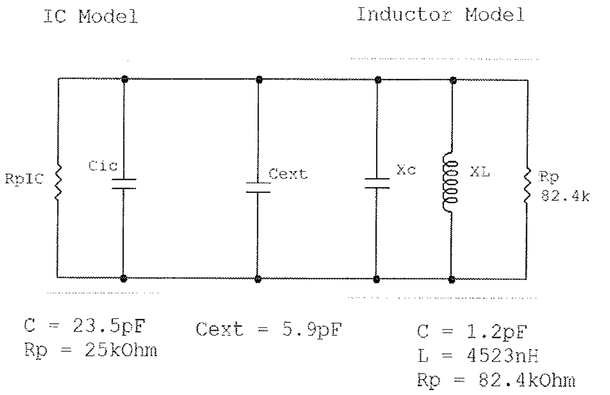

Fig. 5: Equivalent Model for IC and External Capacitor to Tune the Circuit

tag/reader IC will "see" at resonance. The nodal circuit analysis is accomplished for the complete RFID design by using Sonnet software.

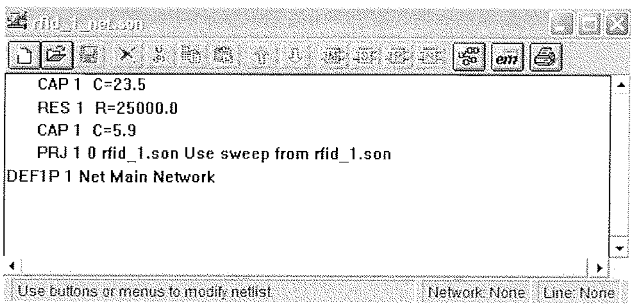

Fig. 6: Nodal Analysis for Complete RFID Circuit

In the Figure 6 the first two lines are showing the internal capacitance and resistance of the RFID chip respectively. The external capacitance is included in the third line. The fourth line begins with "PRJ". This includes the Sonnet project file for this inductor.

3. Simulated Result

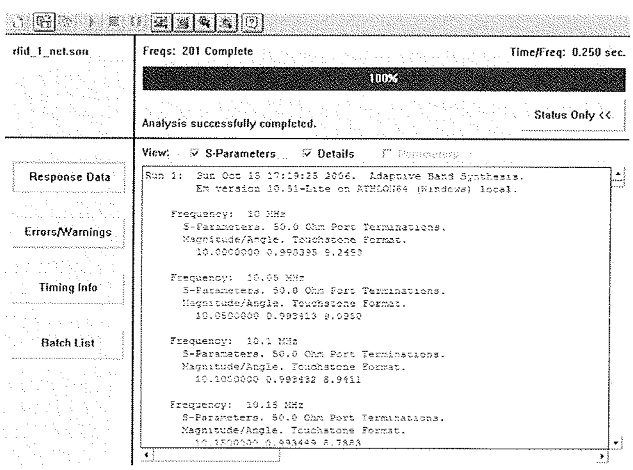

Fig. 7: Frequency Analysis Starts at 10 MHz

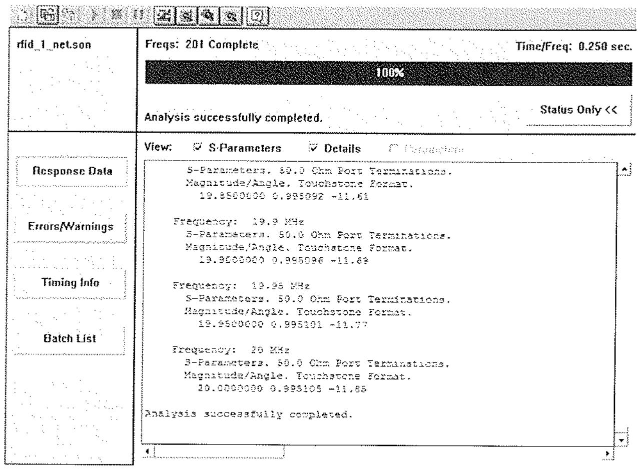

Fig. 8: Frequency Analysis Ends at 20 MHz

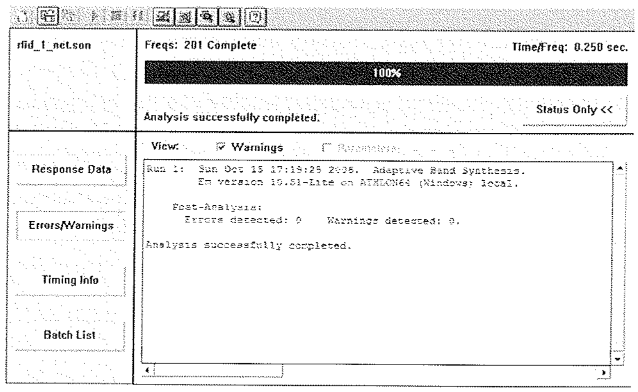

Fig. 9: Analysis Using 'Adaptive Band Synthesis' at a Rate of 0.25 Second

4. Result and Discussion

Figure 10 shows the graphical representation of the simulated result for the nodal analysis of RFID tag/reader. From this graph, it is clearly seen that the magnitude Z_{in} is maximum at the resonance frequency 13.56 MHz and same as the calculated value i.e. 19.2 kΩ. It is also seen from the graph that the imaginary part of the impedance at resonance frequency is close to zero.

For matching the antenna circuit with the RFID chip an external capacitor, *Cext*=5.9 pF is calculated and its position is shown in the Figure 5.

5. Conclusions

To verify the PSPICE results, lumped components value between two netlists near the frequency band of interest are compared and found the same result. In other words, the PSPICE model generated by Sonnet is working well for this circuit. Ones the data in the Sonnet project file is ready, it just reads the data and proceeds with the nodal analysis. If the layout has been changed the old data is no

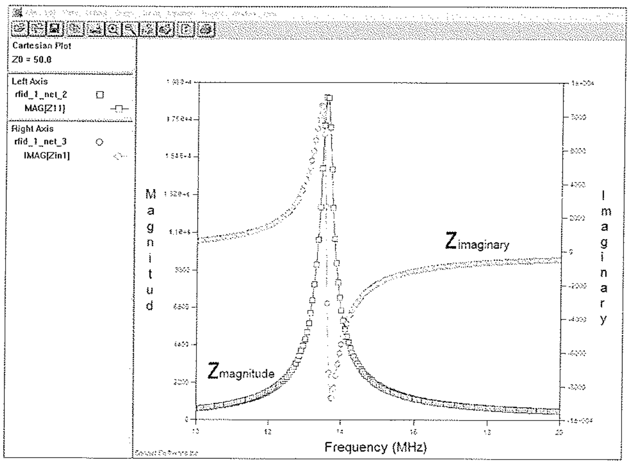

Fig. 10: Frequency Analysis Plotted in both Real and Imaginary

longer valid, in this case Sonnet calculates a new electromagnetic data automatically.To find the optimized parameter values of the RFID antenna matched to the conjugate of the RFID chip impedance, a design automation tool is very useful. The one of RFID antenna is successively optimized with this design optimization process. This method can be applied to any other applications with different simulation tools.

6. References

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