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The Role of Impedance Matching for Power Transfer Efficiency in HF RFID Systems

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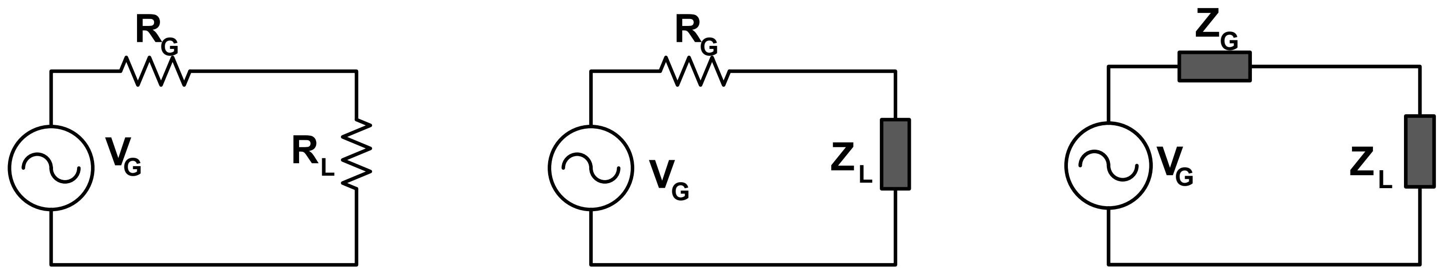
The 9th International Symposium on
ADVANCED TOPICS IN ELECTRICAL ENGINEERING
07th – 09th May 2015, Bucharest

ATEE

Introduction

- RFID (**R**adio **F**requency **ID**entification) systems are increasingly found in a relatively high number in various applications and fields due to the advantages offered
- The performances of the RFID systems are given especially by the identification range of the tags
- Even if the systems works in LF, HF, UHF or MW frequency band, achieving the maximum reading range implies transferring enough power from the reader antenna to the area where tags must be identified
- If the tag isn't matched in impedance and the resonance frequency is different from the reader's frequency, a power loss will occur and the power transfer efficiency will drop significantly
- When the antenna is mismatched, the reader's output power will be reflected back and into the identification field will be only a part of the total transmitted power. This will cause a small identification rate of the tags located in the identification field

IMPEDANCE MATCHING – THEORETICAL APPROACH

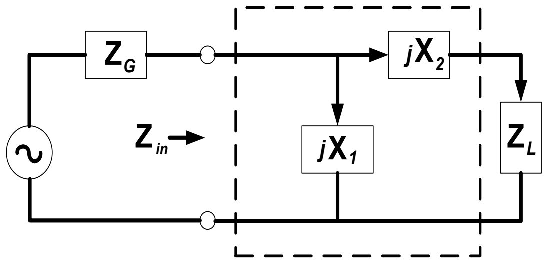


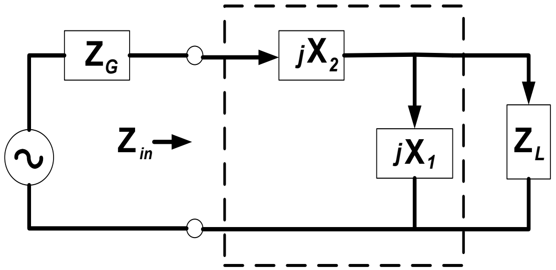
- **Case A** – the simplest situation and the most easy for matching in impedance
- **Case B** – the most commonly used for RFID reader antenna
  - The source resistance must be equal with the complex value of the antenna impedance (in this case the reactance must be 0)
- **Case C** – used in special for RFID tags where the IC chip impedance (that has a complex value) must be equal with the antenna impedance (that also has a complex value)

IMPEDANCE MATCHING – THEORETICAL APPROACH

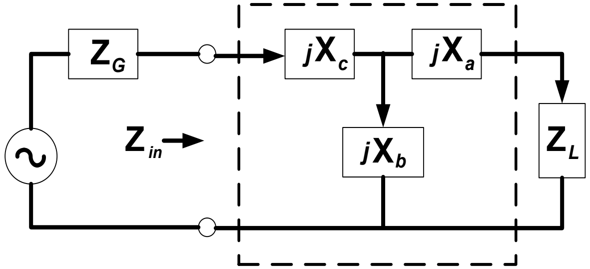
❖ We can meet, depending on the complexity, two types of impedance matching circuits:

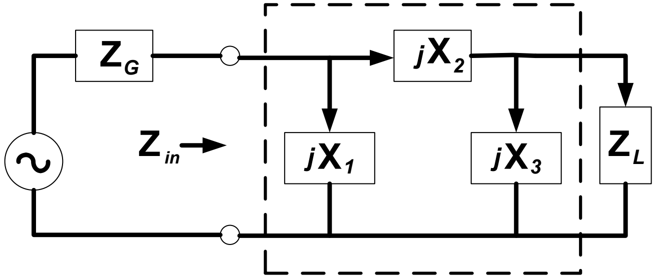
- ✓ Matching circuits with two elements – L type network





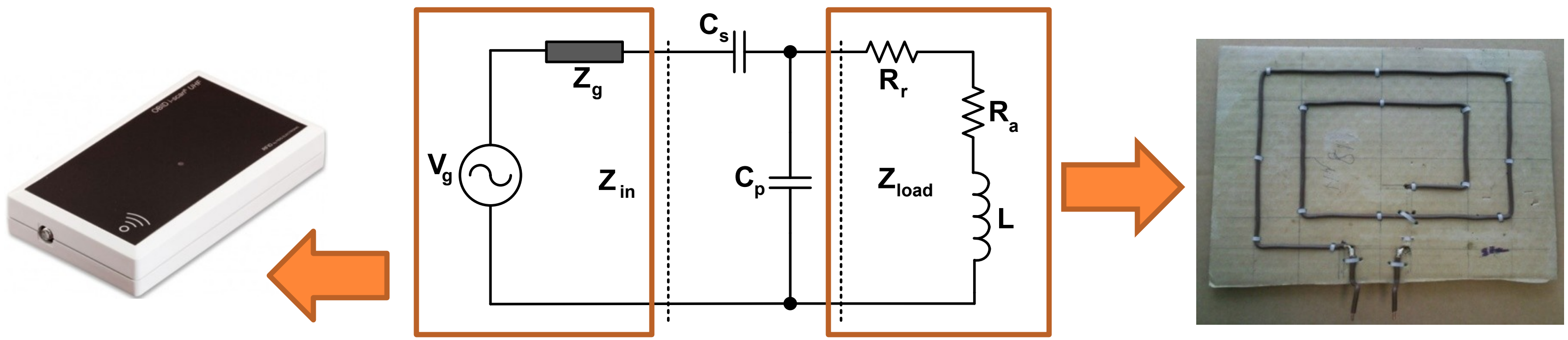
- ✓ Matching circuits with three elements – T or π network





IMPEDANCE MATCHING – EXPERIMENTAL SETUP

❖ In order to test the importance of impedance matching is used a standard RFID reader antenna and a simple two elements matching circuit



❖The antenna impedance must have 50Ω (must be equal with the RFID reader output impedance). This can be achieved in several ways:

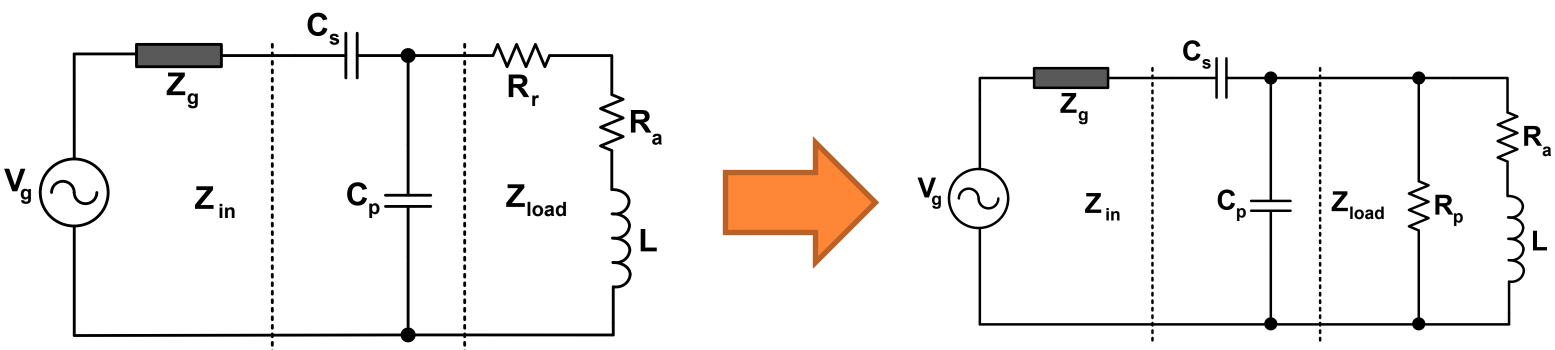
❖ Analytical determination using mathematical approach

❖Experimental determination using specialized measurement equipment (Vector Network Analyzer)

❖ Simulations with specialized EM simulator software

IMPEDANCE MATCHING – EXPERIMENTAL SETUP

❖ To ensure enough bandwidth (approx. 450kHz) for the HF RFID system in order to identify tags that have technological dispersion (3-5%) we need to have a proper value for the circuit quality factor.



$$Q = \frac{2\pi f_0 L}{R}$$

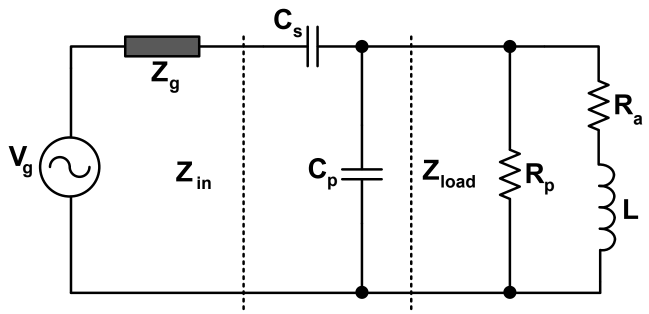
Small changes for R will have big changes in Q factor value

$$Q = \frac{R}{2\pi f_0 L}.$$

Small changes for R will have insignificant changes in Q factor value

IMPEDANCE MATCHING – ANALYTICAL APPROACH

❖ Optimal structure for the impedance matching circuit with two elements

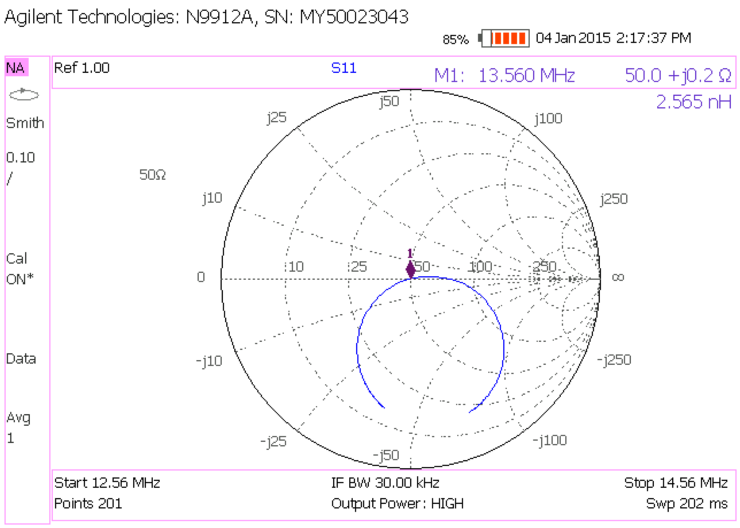


Parameter	Value
L	**1.8µH**
R_a	**1.84Ω**
R_p	**1.3kΩ**
C_p	**372pF**
C_s	**118pF**

$$Z_{in} = \frac{1}{j\omega C_s} + \frac{1}{j\omega C_p + \frac{1}{R_a + j\omega L} + \frac{1}{R_p}}.$$

$$\frac{R_p\left(\omega^2 L^2 + R_p R_a + R_a^{\ 2}\right)}{\left(R_p + R_a - \omega^2 C_p L R_p\right)^2 + \left(\omega C_p R_p R_a + \omega L\right)^2} = 50$$

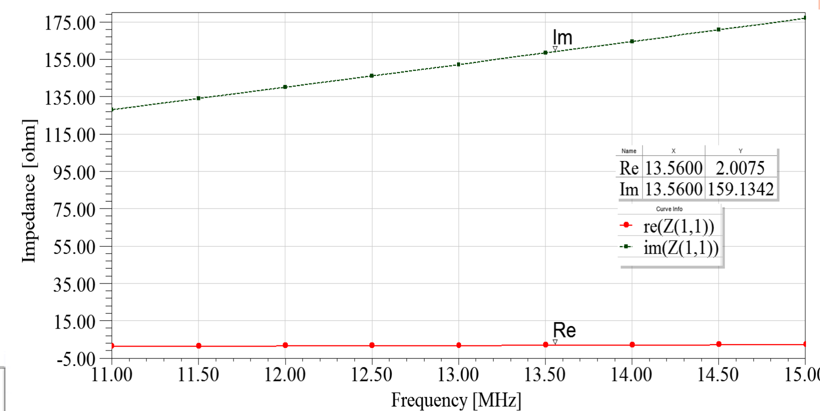
$$\frac{R_p\left(\omega^2 C_s L^2 + 2C_p R_p R_a + 2L + C_s R_p R_a + C_s R_a^{\ 2}\right)}{C_s\left(R_p + R_a - \omega^2 C_p L R_p\right)^2 + \left(\omega C_p R_p R_a + \omega L\right)^2} = 0$$

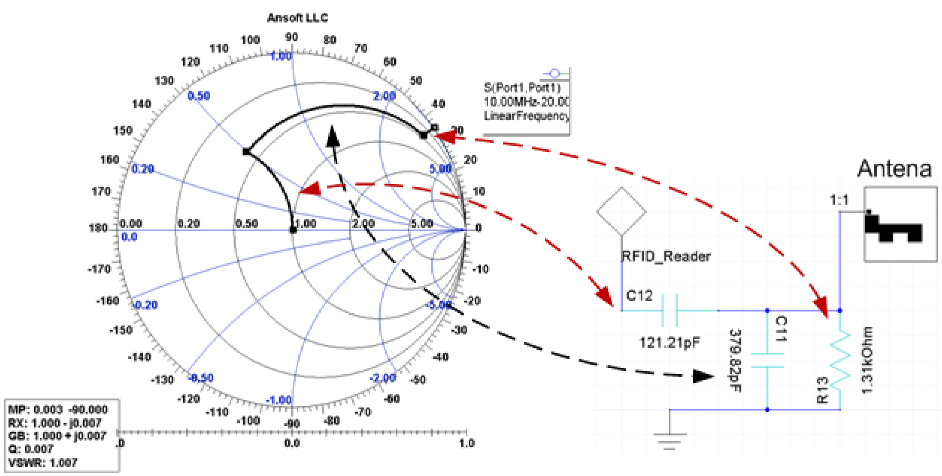


IMPEDANCE MATCHING – SIMULATION APPROACH

- For simulation approach is used an EM simulation software.
- First is simulated the antenna for knowing the exact impedance (Z_L=(2+j159)Ω).
- Using $X_L = 2\pi f_0 L$

the antenna inductance is 1.86uH.





Parameter	Value
L	**1.86μH**
R_a	**2Ω**
R_p	**1.31kΩ**
C_p	**379pF**
C_s	**121pF**

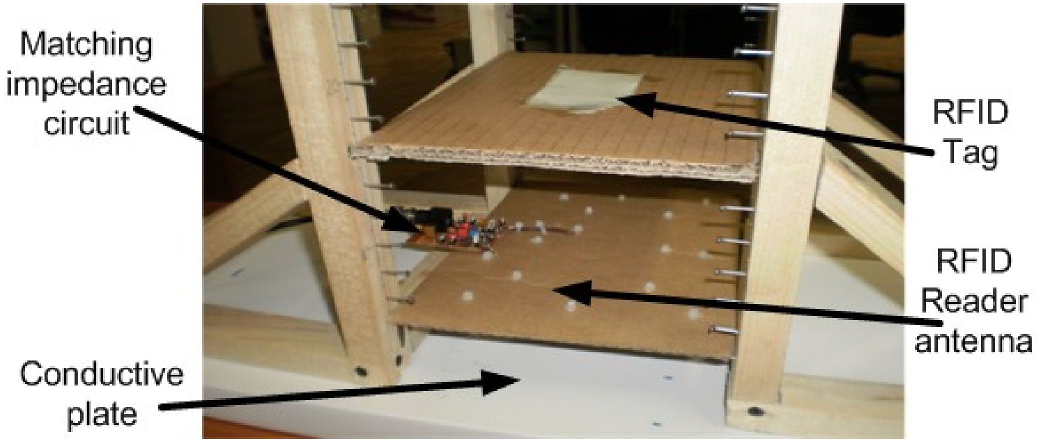
Knowing the antenna inductance we can calculate the impedance matching circuit using the Smith Chart

Impedance matching - results

❖ In order to verify the importance of the antenna impedance matching, is used a standard HF RFID reader with an output power of 1W.

❖ First the antenna is tuned and matched at 50Ω. The maximum reading distance is **50cm**.

❖ To achieve the mismatch is used a 2mm thickness conductive plate placed under the RFID antenna. This plate will detune the antenna because of the effects caused by a metallic plate in the close proximity of an antenna.



Impedance matching - results

❖ The distance between the antenna and the conductive plate is changed from 2mm to 35mm, causing the changing of the antenna inductance. In this way for changing the antenna impedance only one circuit component is changed.

Distance between the antenna and the conductive plate [mm]	Antenna impedance [Ω]	Reading distance [cm]
2	28.1-j18.3	16
4	32.4-j15.1	24
6	36.3-j10.4	30
10	39.7-j8.3	40
15	42.8-j6.7	44
25	48.3-j3.2	47
35	50.3+j0.1	50

Conclusion

- The impedance matching of an antenna used for RFID systems is very important and has a powerful impact over the entire system.
- If between the antenna and the reader will be an impedance mismatch, then the power transfer efficiency will decrease, affecting directly the identification range of the tags.
- In this paper are related some methods of matching the impedance of a standard antenna and the results obtained will conclude that when the RFID reader antenna is mismatched in impedance the reading distance can decrease up to 60% towards when is well matched.

THANK YOU !

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Acknowledgements

This paper was supported by the project "Sustainable performance in doctoral and post-doctoral research" PERFORM - Contract no. POSDRU/159/1.5/S/138963, project co-funded from European Social Fund through Sectorial Operational Program Human Resources 2007-2013.