Institute of Information and Communication Technologies, Electronics and Applied Mathematics

High-Efficiency Wireless Power Transfer for mm-Size Biomedical Implants

T.P. Delhaye, N. André, S. Gilet, C. Gimeno,

L. A. Francis, D. Flandre

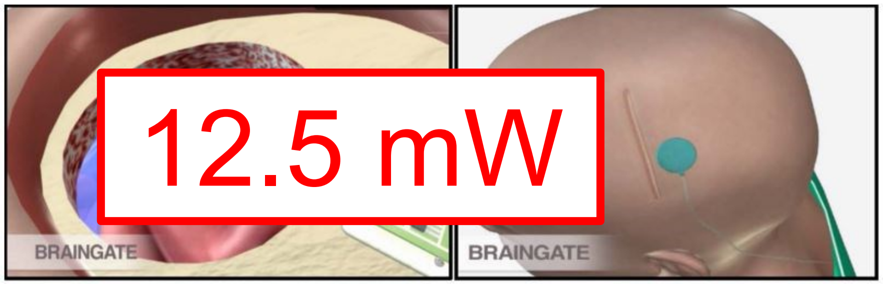
Institute of Information and Communication Technologies, Electronics and Applied Mathematics (ICTEAM),
Université catholique de Louvain (UCL), Louvain-la-Neuve, Belgium

IEEE SENSORS 2017, GLASGOW, SCOTLAND, UK, October 30 – November 01, 2017

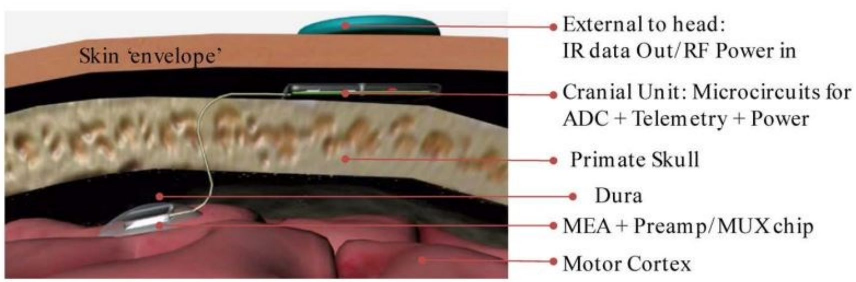
Introduction
&
state-of-the-art

The biomedical implants world: a lot of needs

Neural signals



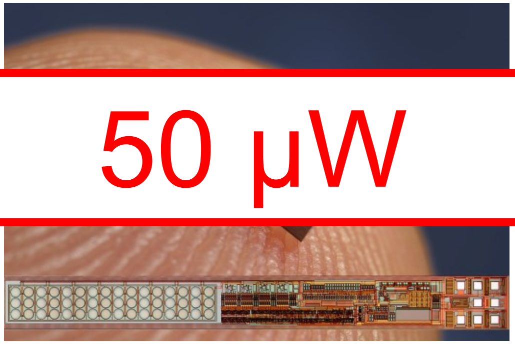
12.5 mW



Nurmikko, Proc. IEEE 2010

Power needed ?

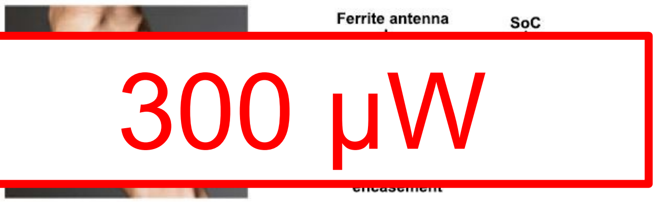
Blood pressure



50 µW

Cleven, IEEE Tr. Biomed. Eng. 2012

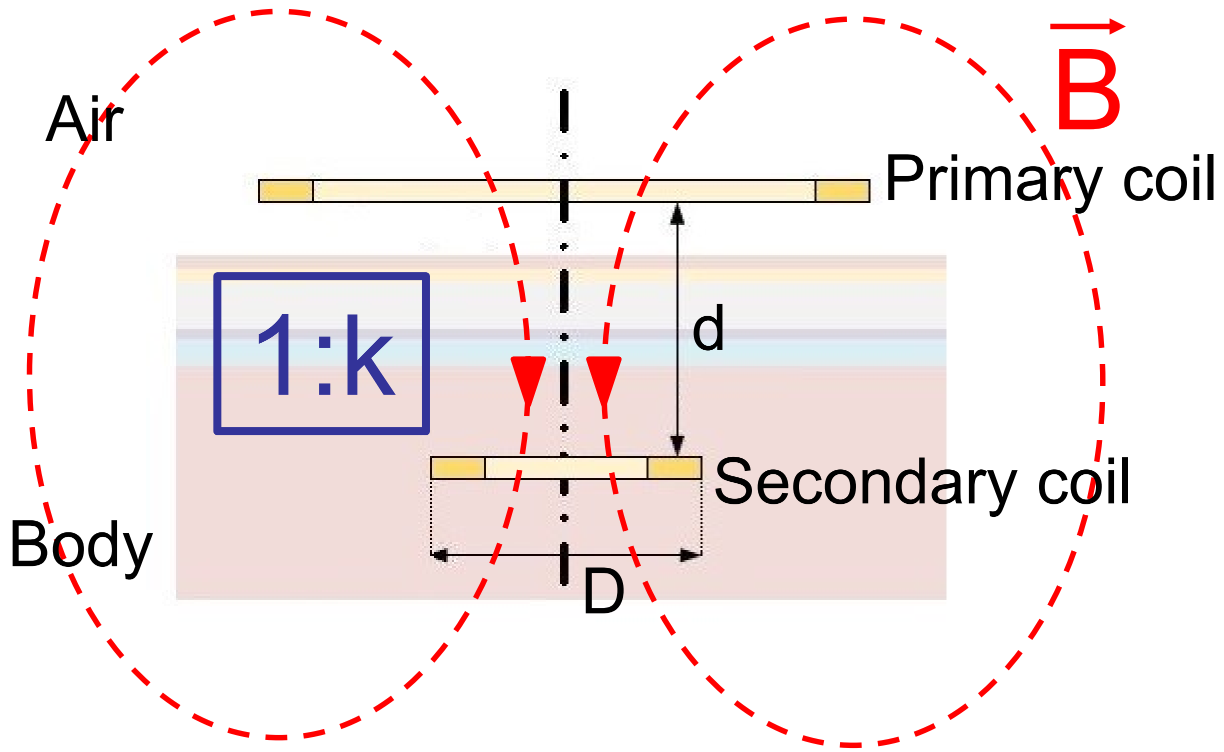
Glucose level



300 µW

Xiao, IEEE J. Biomed. Health Inform. 2012

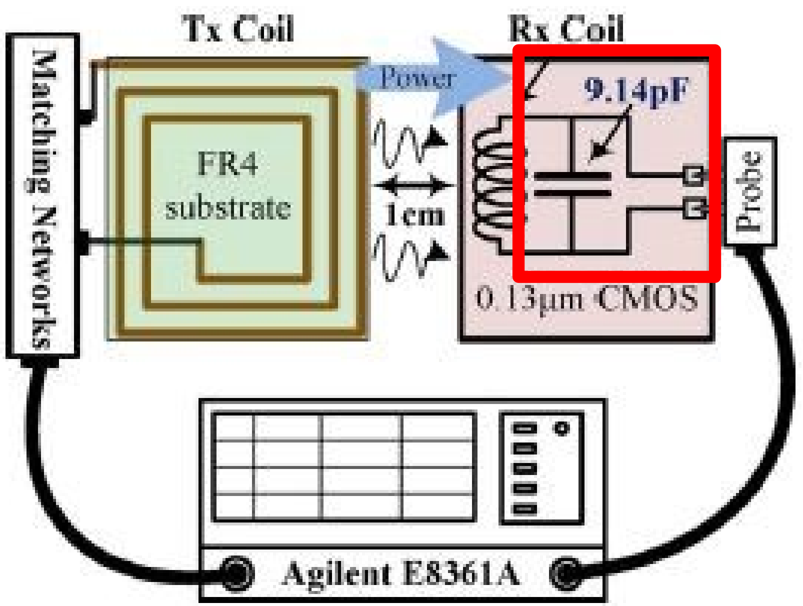
Inductive power transmission: Classical implementation



Requirements

- Size of the implants: maximum 1-2 cm
- Working distance: up to 5 cm
- Power received: from ~10 µW to ~10 mW
- Low SAR for respecting health standard: high efficiency to limit the emitted power needed 2 W/kg

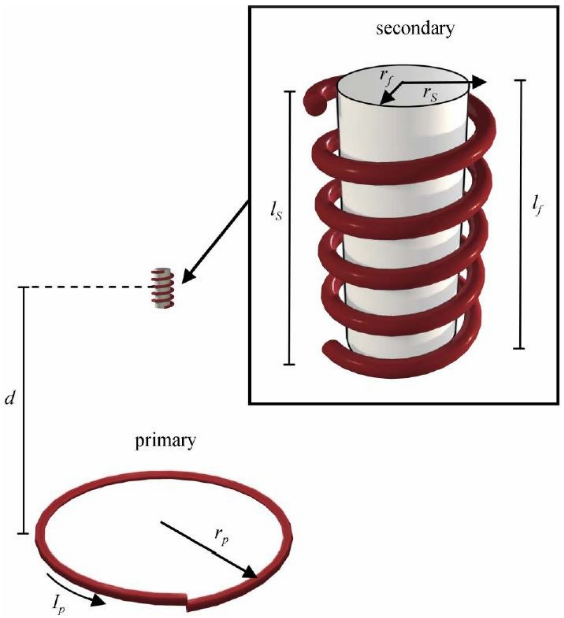
How to meet the requirements: Impedance matching (1)



Zargham, IEEE Trans. Biomed. Circuits Syst. 2015

<u>Goal :</u>
To reduce the reactive power of the system

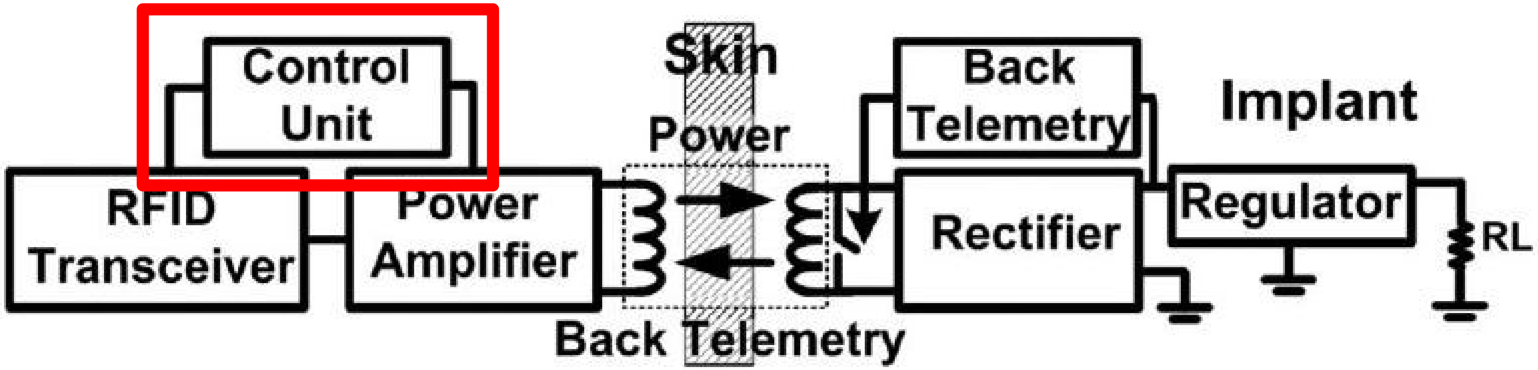
How to meet the requirements: Ferrite core (2)



Theilmann, IEEE Trans. Biomed. Circuits Syst. 2009

<u>Goal :</u>
To improve the coupling factor between the two coils

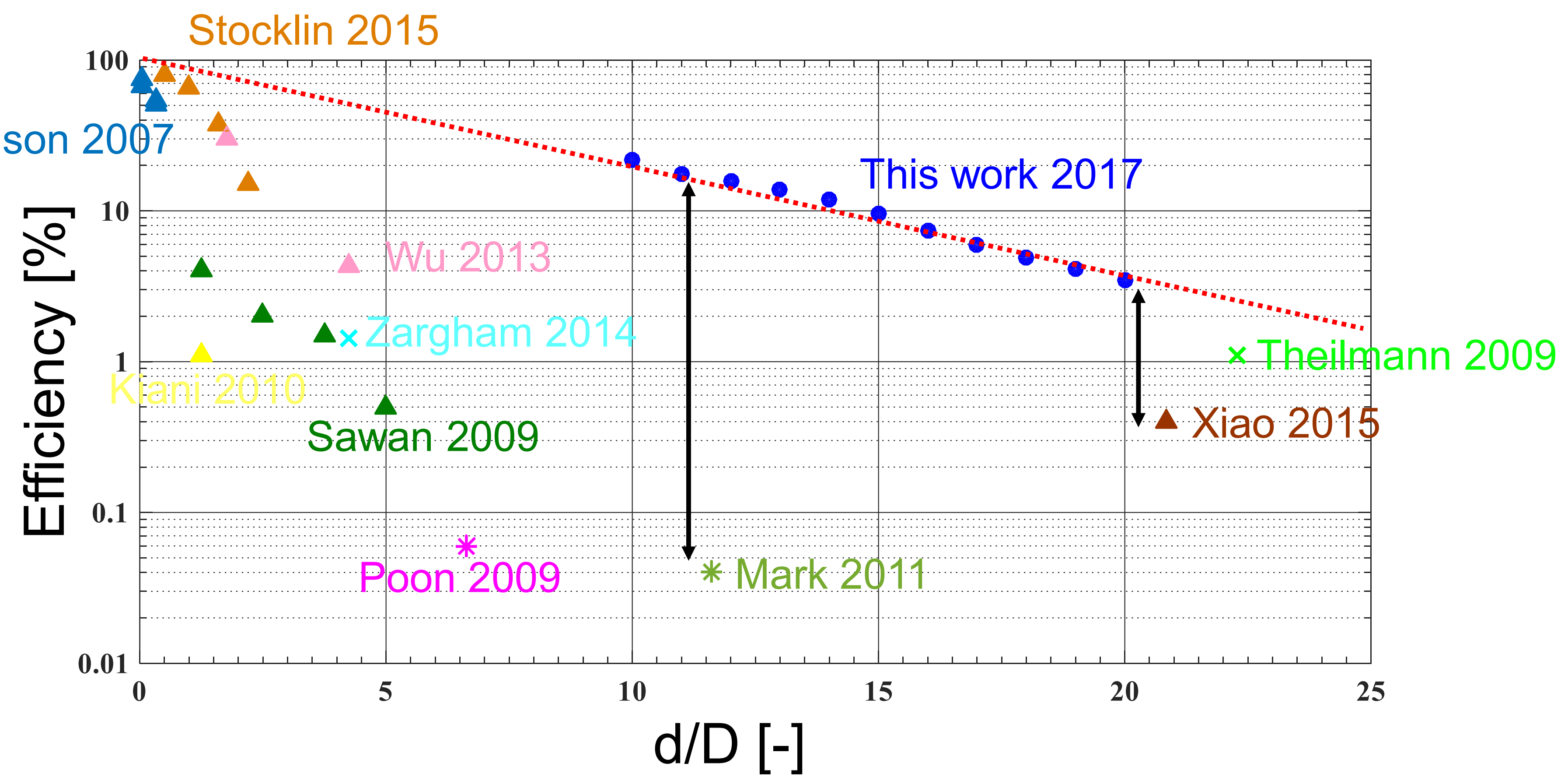
How to meet the requirements: Phase-locked loop (3)



Kiani, IEEE Trans. Circuits Syst. II.
2010

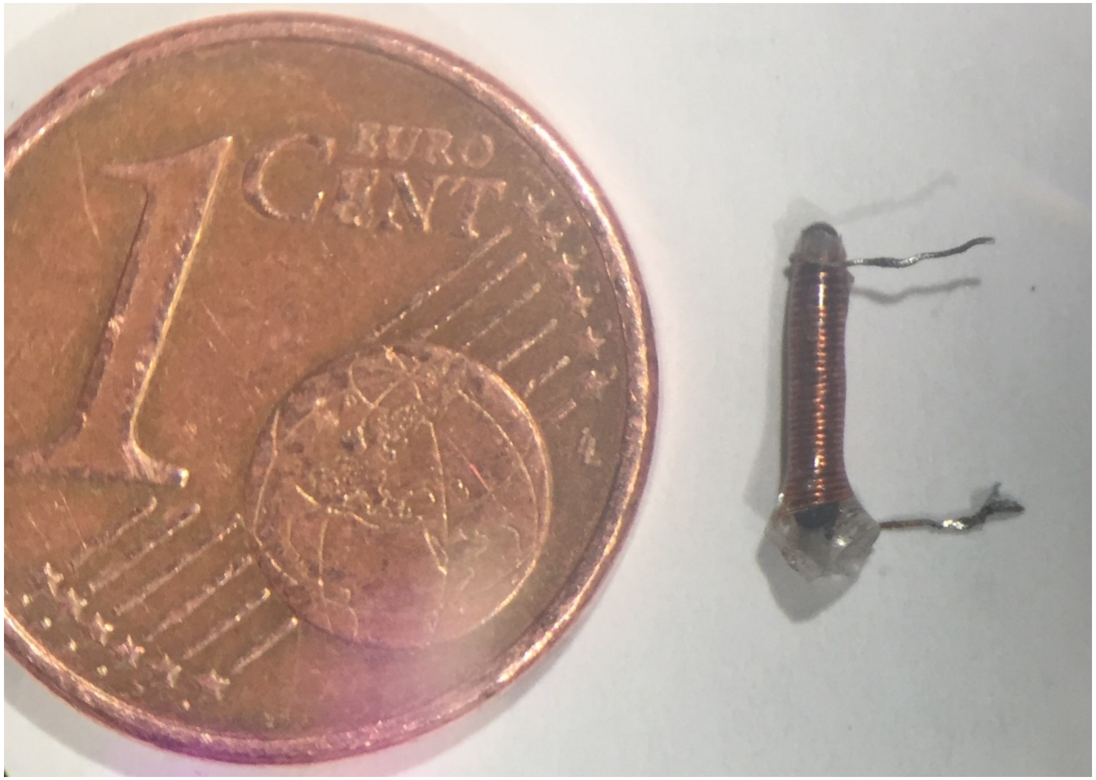
<u>Goal :</u>
To track the frequency that allows the higher power transmission

SoA : Wireless power transfer



Description of our high-efficiency wireless power transfer

Tiny-coil around NiZn ferrite core

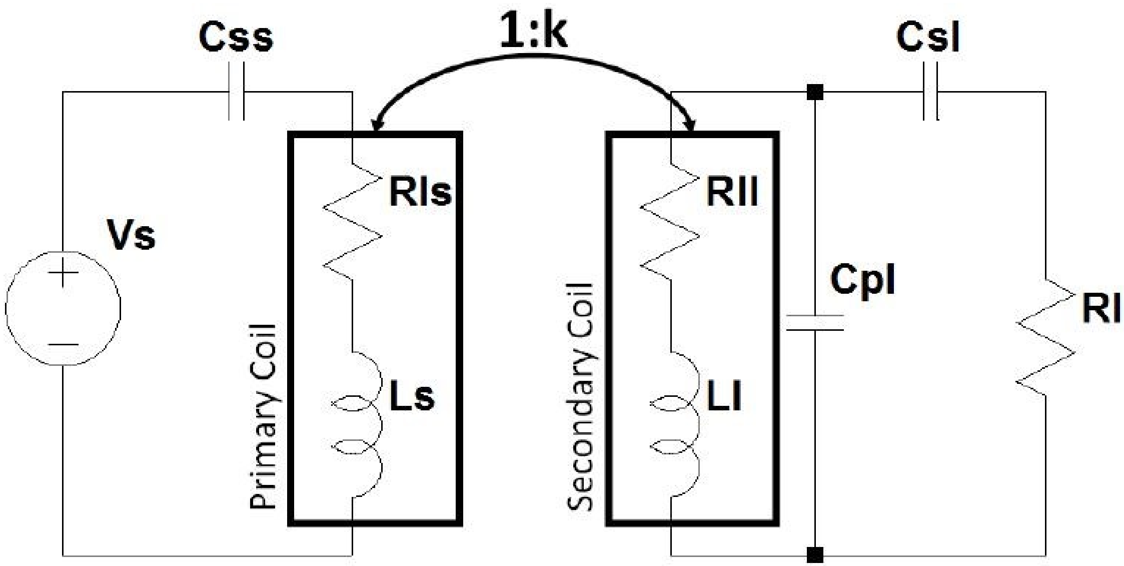


Ferrite core :
- 7.5 mm long
- 1 mm diameter
- $\mu_r = 35$

Wire :
- 100 µm diameter
- 31 turns (hand-made)

Coil :
- 3.65 µH inductance
- 200 mΩ DC – 8.45 Ω at 14MHz

Power transmission circuit

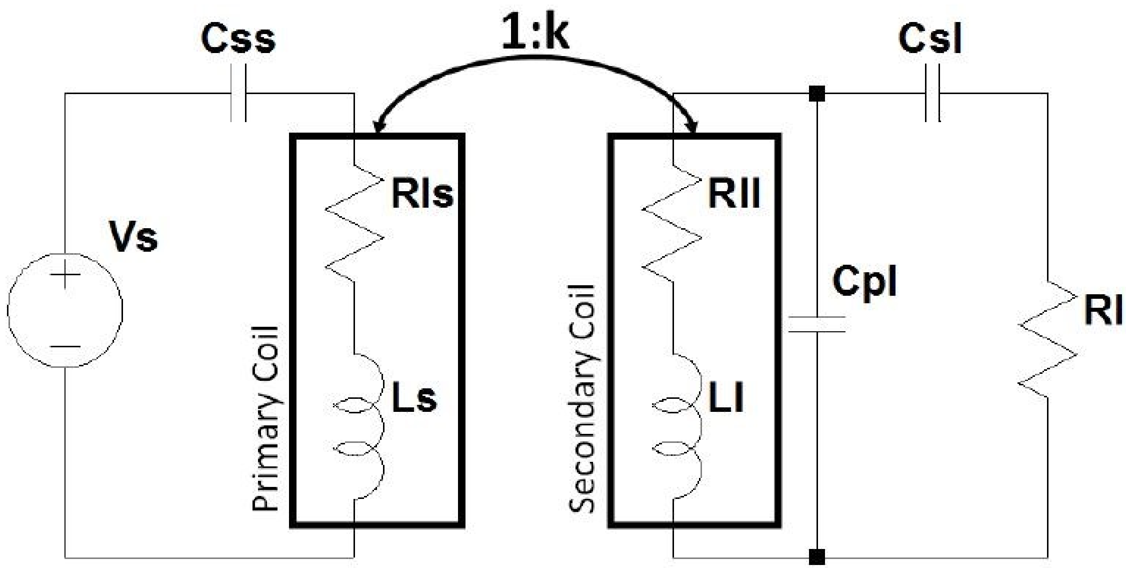


$$k = \frac{V_{Ls}}{V_{Ll}}\sqrt{\frac{L_l}{L_s}}$$

Resonant impedance matching

$$\rightarrow \quad C_{ss}.Ls \approx (C_{pl} + Csl).Ll$$

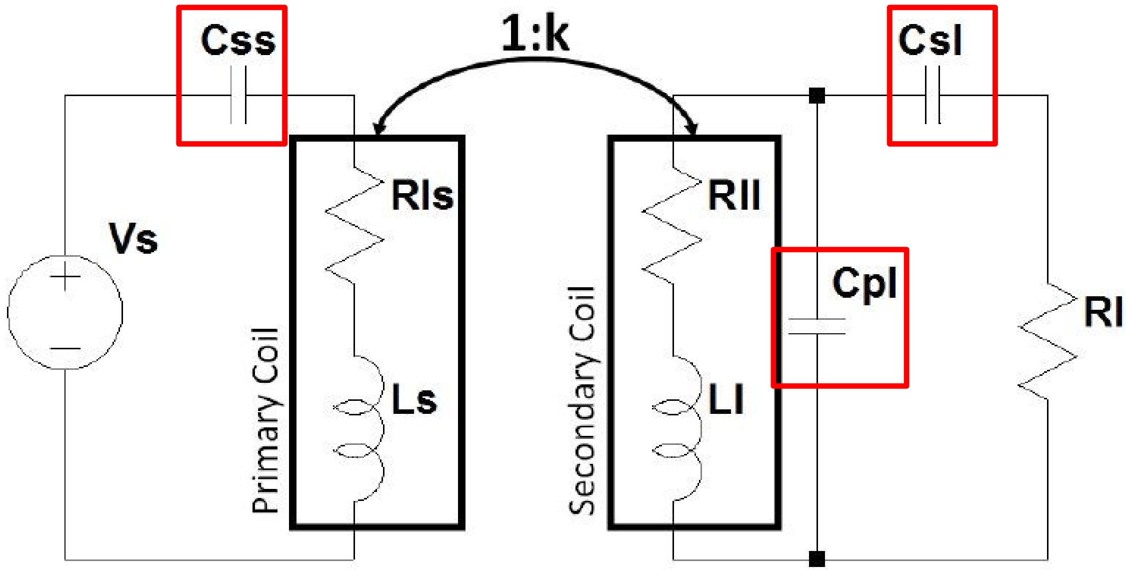
Power transmission circuit



To be optimized:
- Capacitors values
- Primary coil
- Working frequency

To have the highest power transfer efficiency (η), and a low input voltage for a given power needed by the load

Power transmission circuit

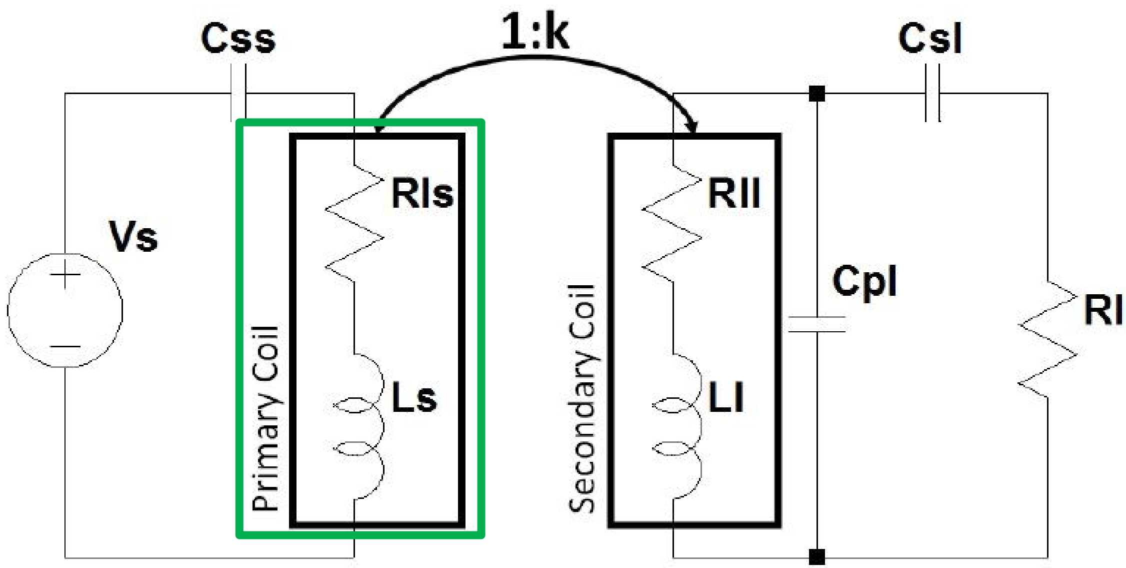


To be optimized:

- Capacitors values
- Primary coil
- Working frequency

To have the highest power transfer efficiency (η), and a low input voltage for a given power needed by the load

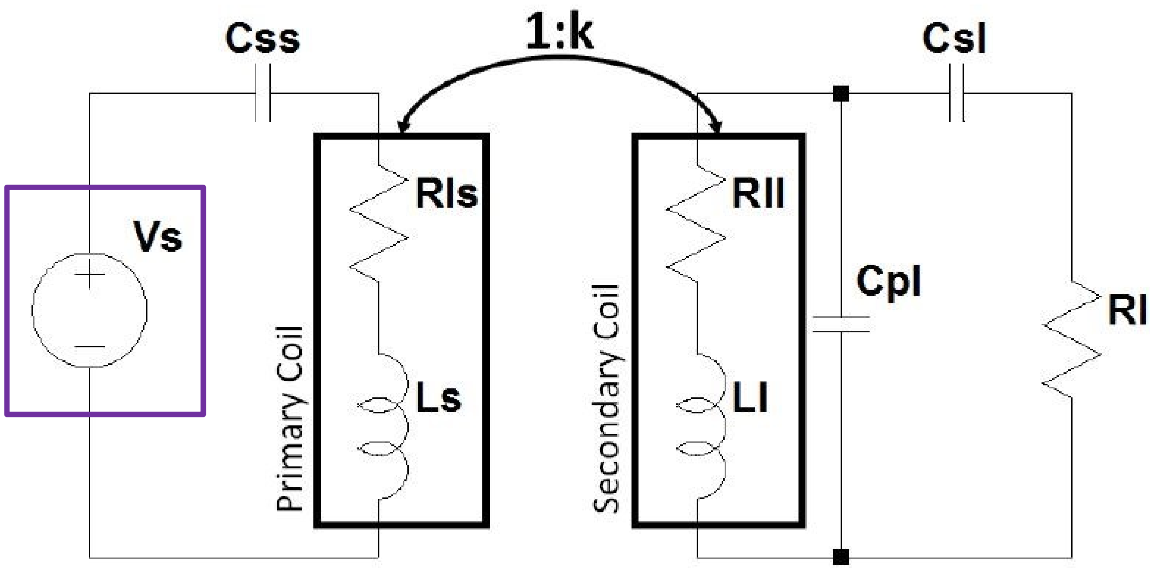
Power transmission circuit



To be optimized:
- Capacitors values
- Primary coil
- Working frequency

To have the highest power transfer efficiency (η), and a low input voltage for a given power needed by the load

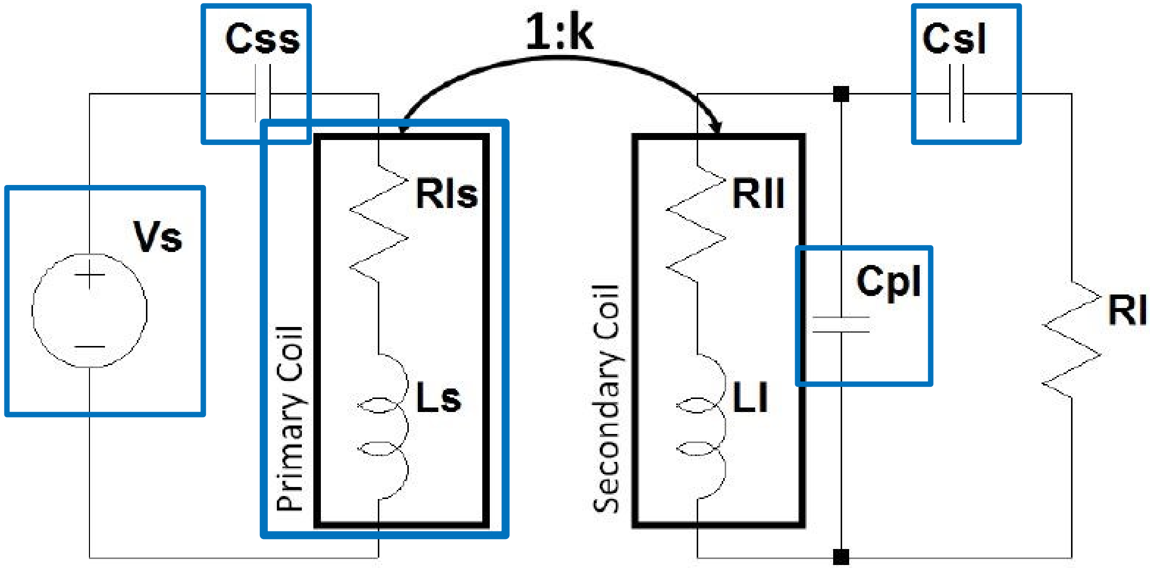
Power transmission circuit



To be optimized:
- Capacitors values
- Primary coil
- Working frequency

To have the highest power transfer efficiency (η), and a low input voltage for a given power needed by the load

Power transmission circuit

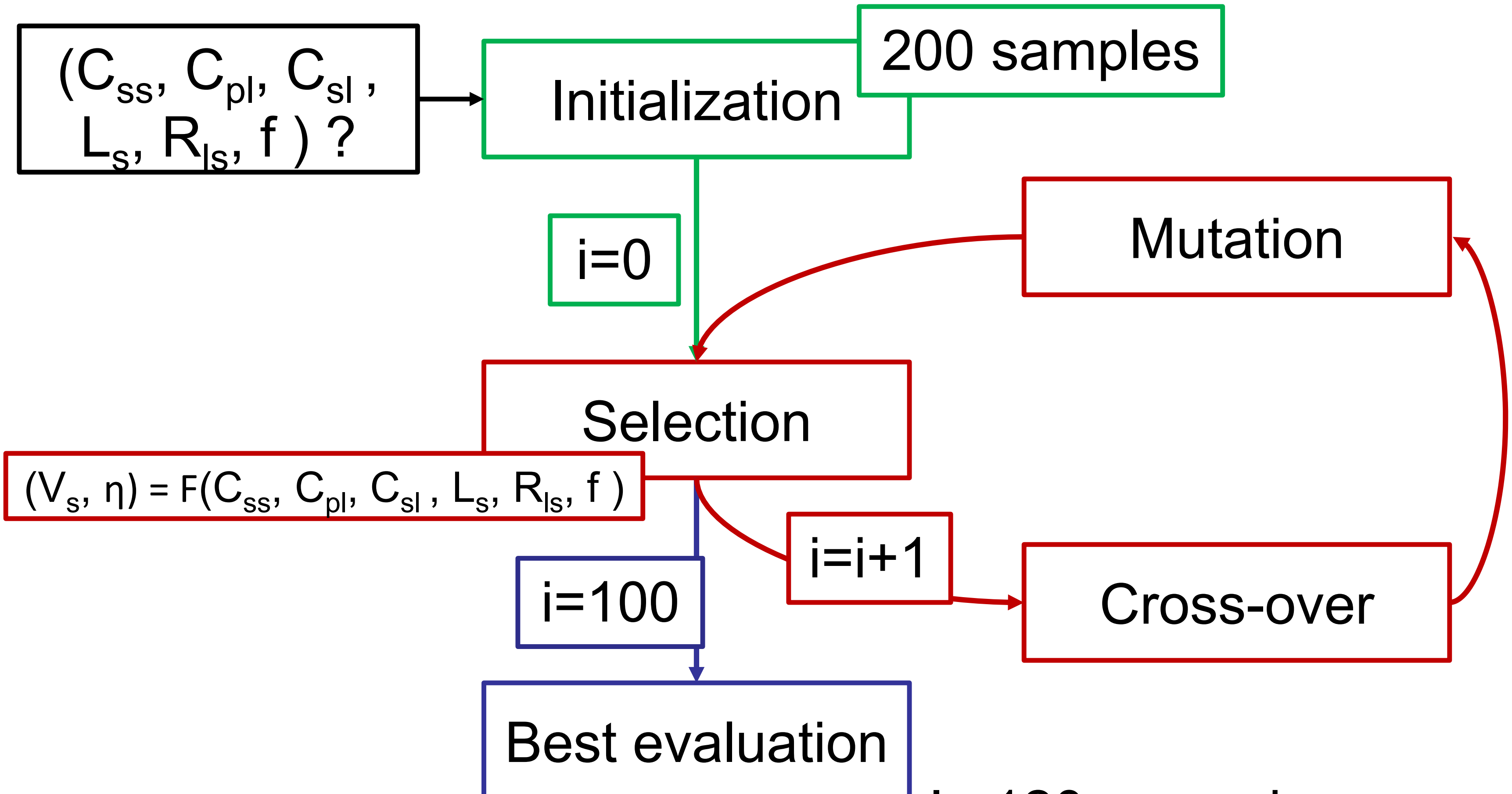


To be optimized:
- Capacitors values
- Primary coil
- Working frequency

- 5 degrees of freedom

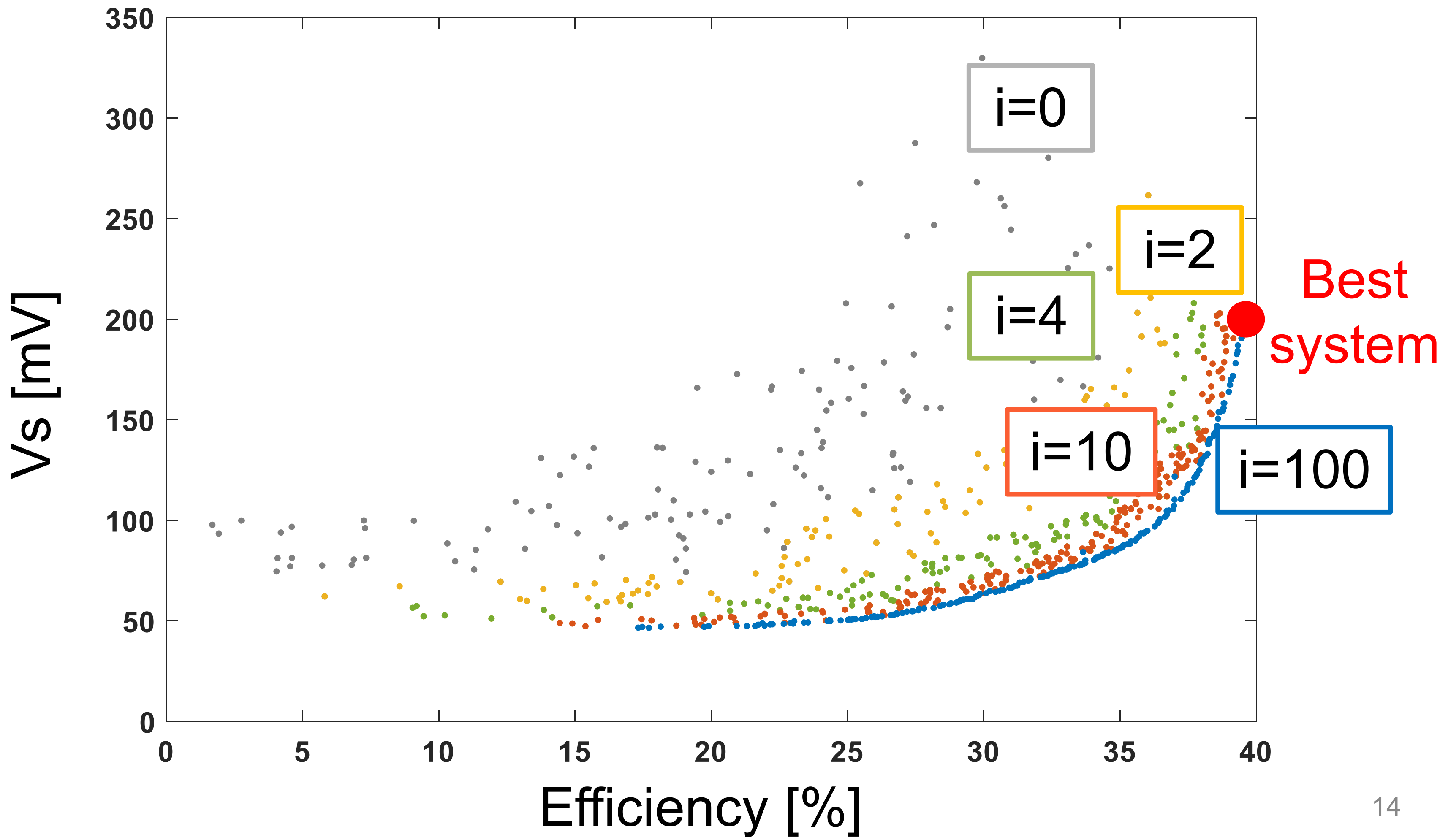
To have the highest power transfer efficiency (η), and a low input voltage for a given power needed by the load

Optimization: Genetic algorithm



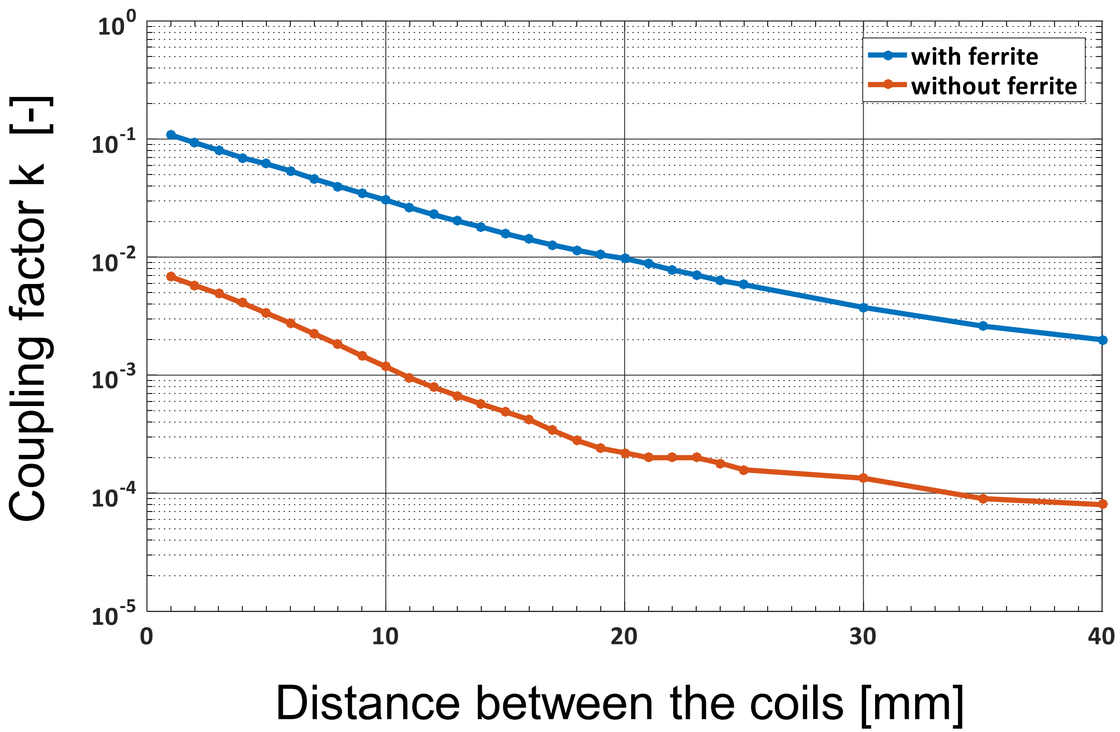
In 120 seconds

Optimization: Genetic algorithm



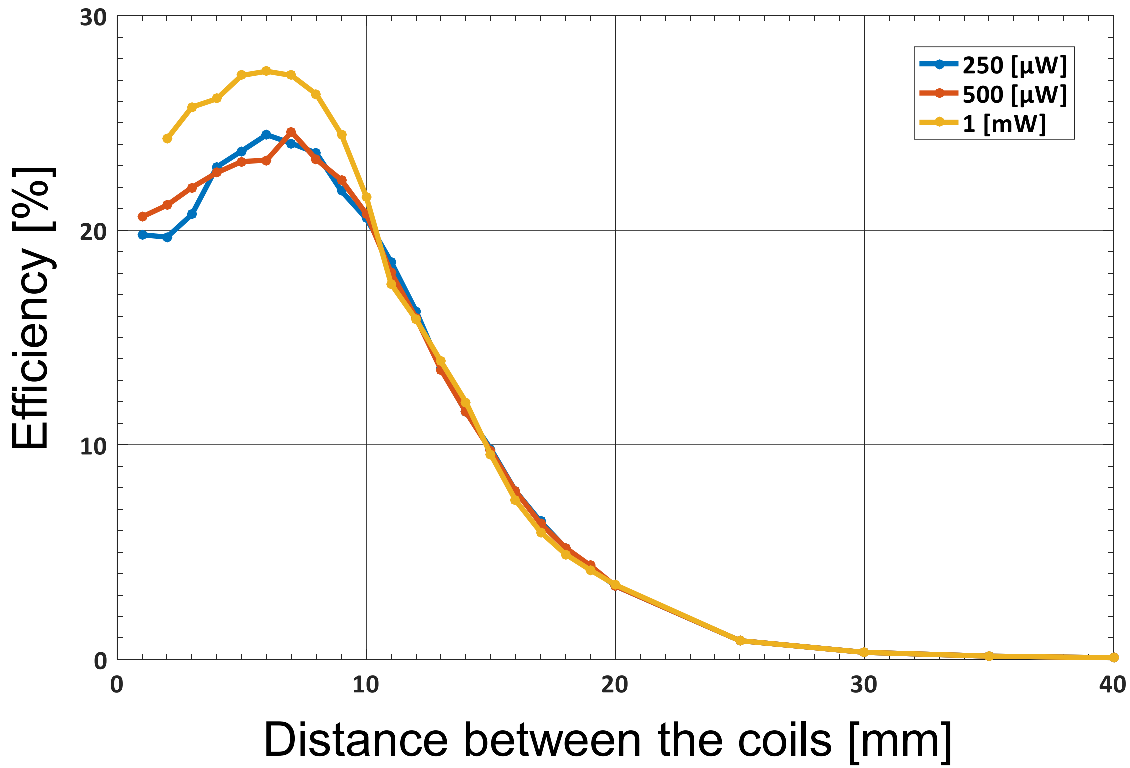
Measurements

Coupling factor measurement



$k_1 = 10 \times k_0$!

Power transfer efficiency measurement results



- Efficiencies around 21%
- Power transmissions from 250 μW to 1 mW with 1 cm of distance between the two coils at 1MHz
- Negligible attenuations in tissues

Conclusion

- Demonstration of an high-efficiency mm-size wireless power transfer:
  - Hand-made tiny-coil with a inductance of 3.65 µH and a optimized resonant impedance matching system
  - Maximum efficiency of 21% at 1 cm: the best of litterature for the size of the implant
  - Delevering 1 mW to a 560 Ω load at 1MHz
  - Negligible attenuations in tissues

Acknowledgements

- **Many thanks to funding**
  - BioCloud 4.0 project, funded by the Walloon region

BioWin THE HEALTH CLUSTER OF WALLONIA
Wallonia Clusters