LAAS-CNRS Laboratoire d'Analyse et d'Architecture des Systèmes

Antenna Design for Inductive Power Charging

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Abstract *— This poster shows design guidelines for a PCB hollow spiral coils employed in an inductive Wireless Power Transfer (WPT) system. Through the link efficiency and with the help of full-wave electromagnetic simulations software, the coils WPT performances are analyzed by geometric parametric analysis. The impact of a ferrite plate positioned behind the coil is also evaluated in order to illustrate its impact on the overall link efficiency.*

The studied (Tx) coil was electromagnetically coupled with a specific (Rx) coil positionned at d=5mm. FEKO allows to directly extract the quality factor of each coil and the coupling factor between them.
The link efficiency η_{Link} is related to the quantity of transmitted power and is defined by Eq. 1.

$$\eta_{Link} = \frac{k^2 Q_{Tx} Q_{Rx}}{\left(1+\sqrt{(1+k^2 Q_{Tx} Q_{Rx})}\right)^2}$$

Eq. 1: Link efficiency

'k': coils' coupling factor
'Q_{Tx}': quality factor of the Tx coil
'Q_{Rx}': quality factor of the Rx coil

❑Validation of electromagnetic modeling methodology:

A PCB reference coil was modeled and prototyped, and its circuital parameters (inductance 'L' and Equivalent Series Resistance 'ESR') were extracted from simulated results and compared with experimental ones for correlation purposes. The modeling was realized using different simulation approaches (MoM-SEP, MoM-VEP, FEM) and different meshing densities.
Analysis was performed at three frequencies (100kHz, 500kHz & 1000kHz).

- ✓ **The simulation time can be excessive but this drawback was overcome by using a cluster**
- ✓ **MoM-SEP :** ***Method of Moment – Surface Equivalent Principle***
- ✓ **MoM-VeP :** ***Method of Moment – Volume Equivalence Principle***
- ✓ **FEM :** ***Finite Element Method***

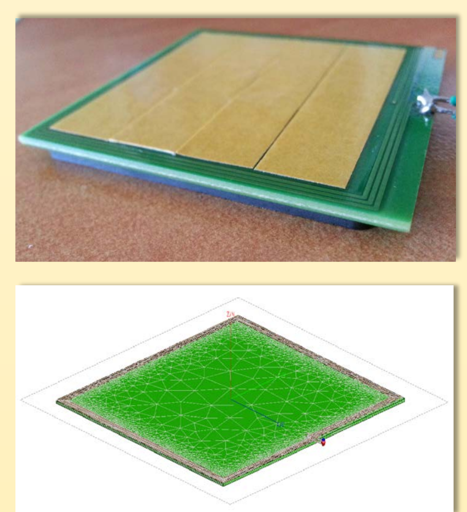


Fig. 1 : Example of prototyped (top, with ferrite) and modeled (bottom, without ferrite) reference coils

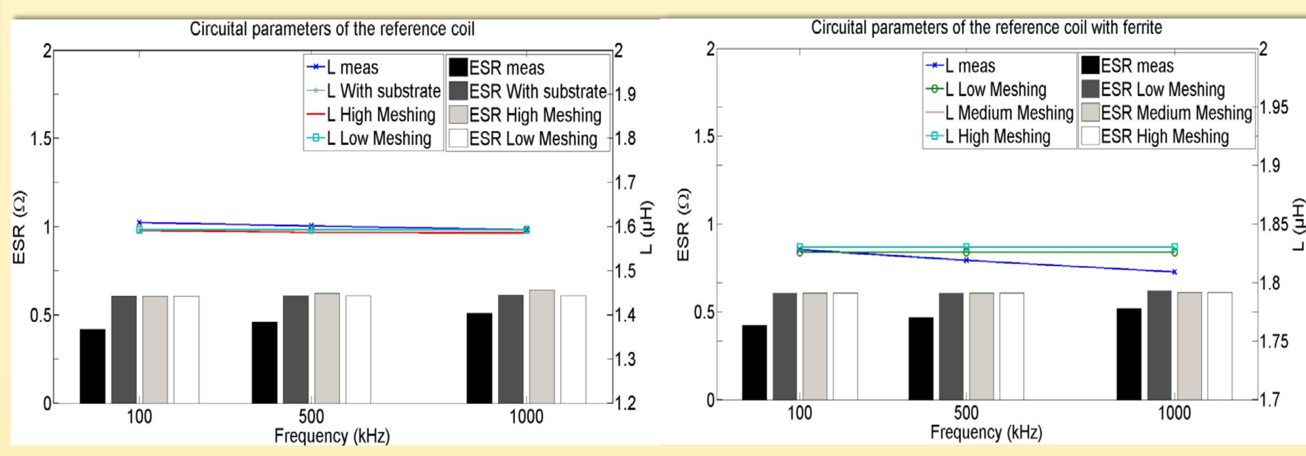


Fig. 2 : Correlation simulation/measurement on coil's circuital parameters with (right) and wihtout (left) ferrite

Fig. 2 shows there is no need to include the FR-4 dielectric in the model or to use high meshing densities at chosen frequencies.

❑Parametric analysis and optimization of PCB coils

A typical hollow spiral coil was chosen for the parametric study, as seen in Fig. 3. The magnetic coupling with the Rx coil, picturing the power transfer between coupled coils is also represented in Fig. 4.
The parameters concerned are: turns number 'N', copper thickness 'Th_Cu', trace width 'wt', gap between traces 'Gap' and inner radius 'Rin'. Their impact on the link efficiency are shown in Fig. 5.

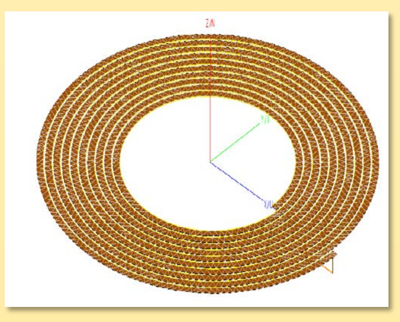


Fig. 3 Basis coil (N=10, Rin=10mm, Th_Cu=35µm, wt=0.8mm & Gap=0.2mm)

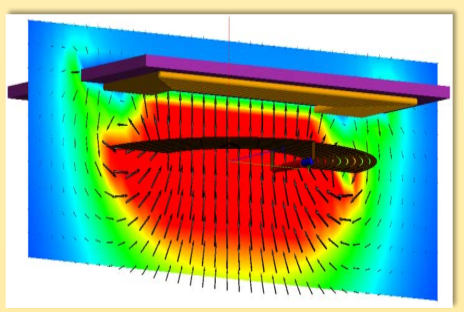


Fig. 4 Magnetic field representation between coupled coils

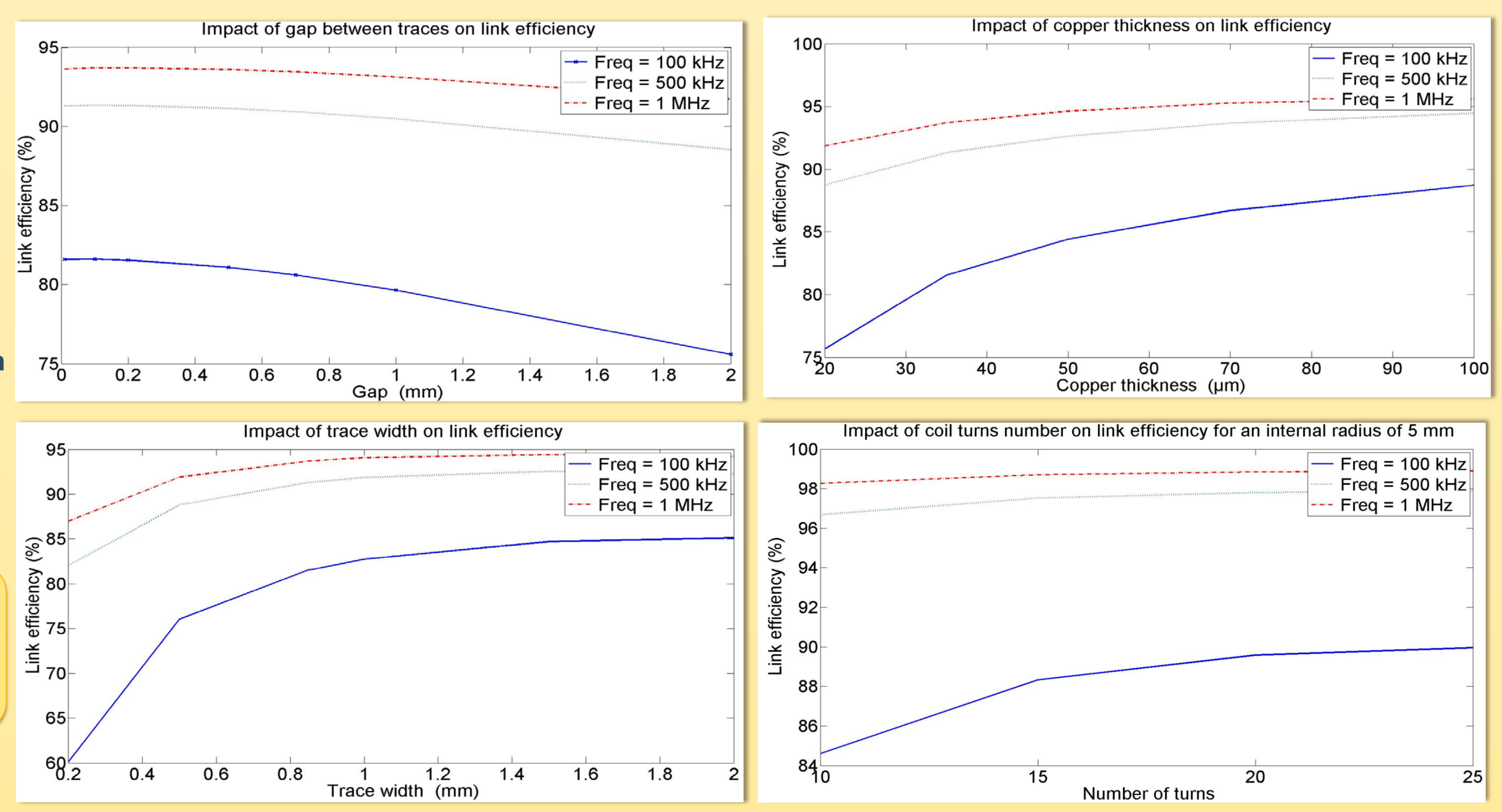


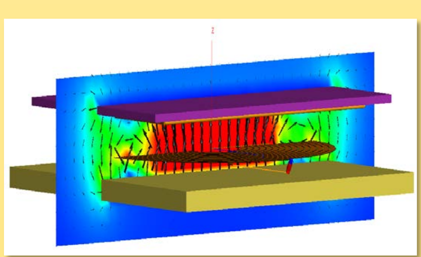
Fig. 5 :Coil parametric study on Gap (top left), copper thickness (top right), trace width (bottom left) & turns number with Rin=5mm (bottom right). All parameters except the analyzed one were constant and identical to basis coil's ones.

Through electromagnetic simulations, we find an optimized Tx PCB coil with:
Rin = 5mm, N = 15, Th_Cu = 70µm, wt = 1mm and Gap = 0.1mm
This coil allows a link efficiency of 88.3% at 100kHz and 98.5% at 1MHz.

❑Impact of ferrite on the link efficiency

A plate ferrite was placed behind the Tx coil, and the link efficiency was evaluated as previously. Geometric (distance to the coil 'd', Relative Area Ratio 'RAR') and magnetic (permeability) parameters were analyzed as shown in Fig. 7.

Fig. 6 Impact of ferrite on the magnetic field between coupled coils



The maximum link efficiency is obtained for d=2mm, μ_r>100 and RAR>1. By using a ferrite the link efficiency was improved with 4% at 100kHz.

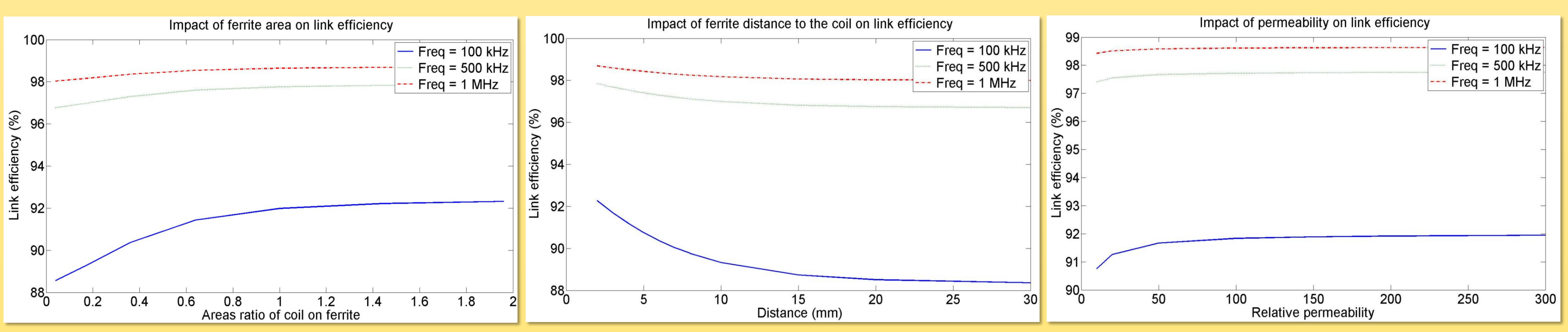


Fig. 7 : Ferrite parametric analysis on RAR (left), distance (middle) and permeability (right).

Conclusion *— Based on a geometric parametric analysis using full wave electromagnetic simulation we derived design guidelines for optimizing the performances of PCB coils. The optimized PCB coil exhibits link efficiencies up to 88.3% at 100 kHz to 98.5% at 1 MHz. By the addition of a ferrite (with μ_r>100, RAR>1) behind the coil (at d=2mm), the link efficiency was improved with 4% at 100kHz.*