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Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA
MOST CENTRO NAZIONALE PER LA MOBILITÀ SOSTENIBILE

Experimental Evaluation of Wireless Charging Systems: the DEXTER Project

Giulia Di Capua

Department of Electrical and Information Engineering "Maurizio Scarano"
University of Cassino and Southern Lazio

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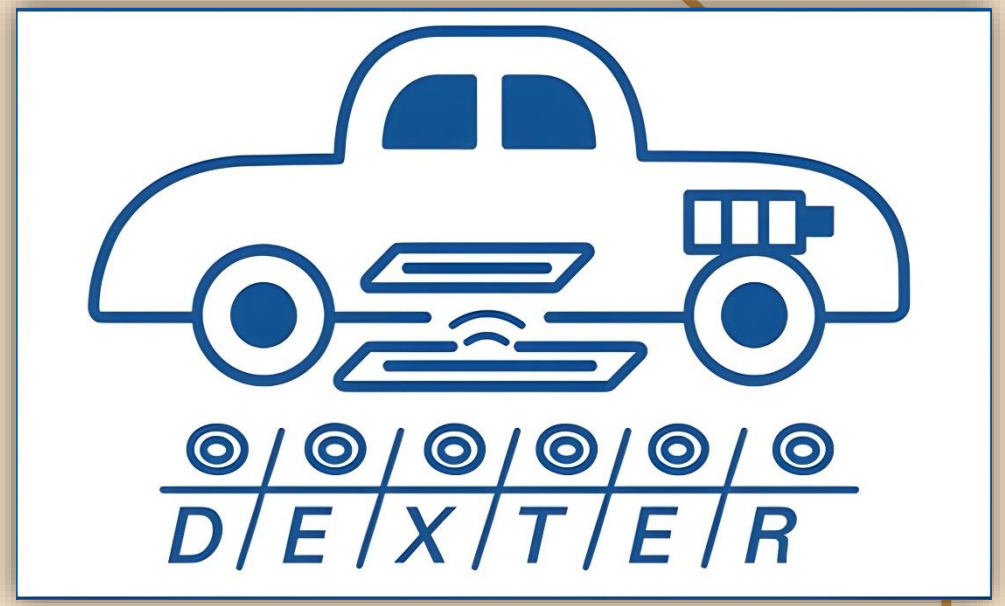
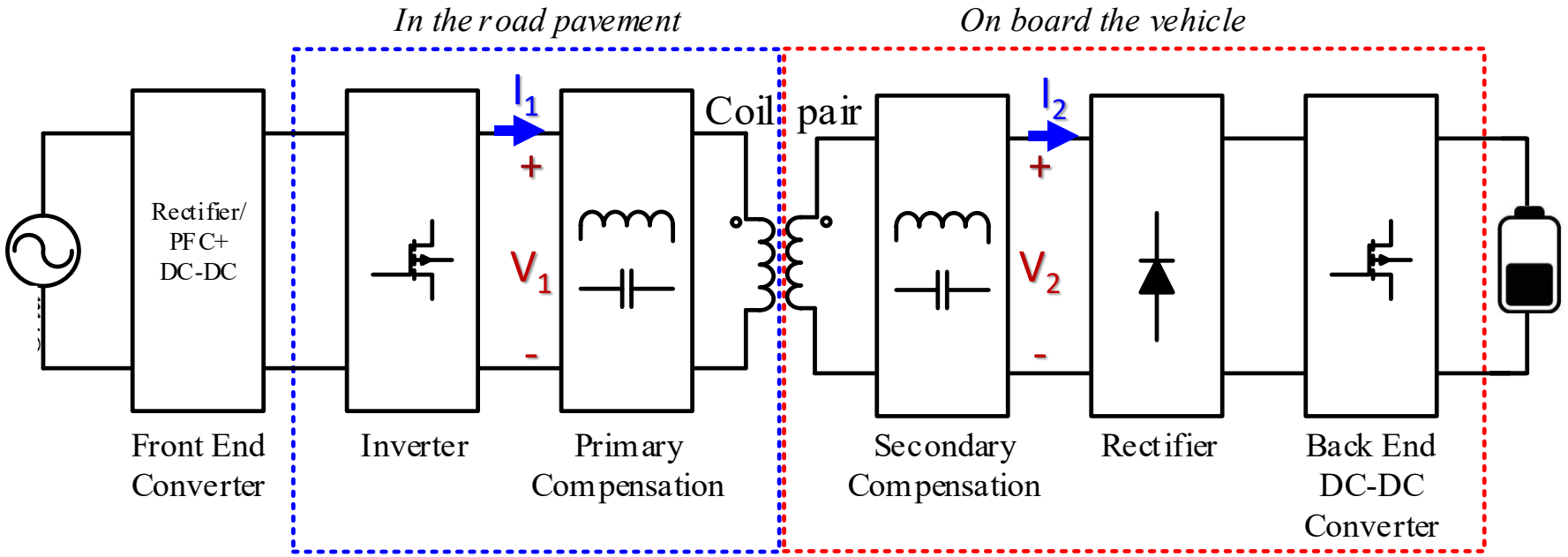
Progetto DEXTER

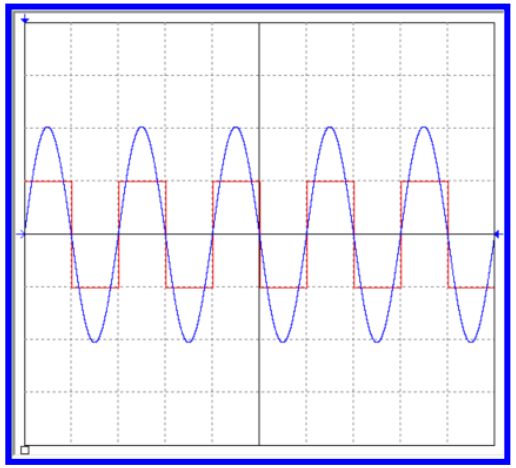
finanziato dall'Unione europea – NextGenerationEU – Piano Nazionale Resistenza e Resilienza (PNRR) – Missione 4 Componente 2 Investimento 1.4 – Progetto CN_00000023 denominato Sustainable Mobility Center (MOST)

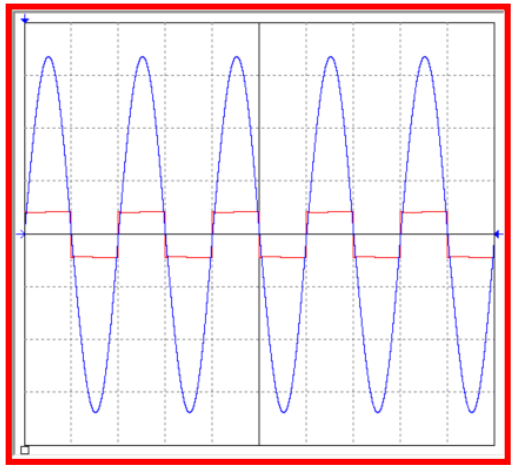


Development of an **E**nhanced e**X**perimental pro**T**otype of wir**E**less charge**R**

Wireless Power Transfer Systems: powertrain architecture







red = voltage

blue = current

Wireless Power Transfer Systems Challenges

- Coils design and performance characterization (*mutual inductance*)
- Compensation topologies (*series/parallel/hybrid*)
- Power electronics design and system's performance management (*power/efficiency trade-off, energy/charge transfer rating*)
- EM field analysis and limitations (*coils geometries, ferrites-based shielding, weight trade-off*)
- EM shields design and arrangement (*resonant coils' arrays*)
- Battery Architecture and Management (*charge/discharge patterns, SoC, SoH*)
- Behavioral Modeling (*design-oriented/performance-oriented modeling*)

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DEXTER Project

GOAL: Developing a Dynamic Wireless Power Transfer (DWPT) prototyping platform for Electric Vehicle Dynamic Battery Chargers (EV-DBCs).

SYSTEM ARCHITECTURE: The platform integrates a **3D movement system** of the coils, two digitally-controlled **power electronics units**, a **battery emulator**, a set of **shielding coils**, a **field measurement probe**, and a **control panel**.

FEATURES: Hardware-in-the-Loop (HiL) design process, integration of simulations and measurements for multi-objective characterization and optimization, testing of different solutions in terms of coil pairs, shielding coils, power electronics control settings, device-level and system-level behavioral modeling.

DEXTER team

WP.#	WP.NAME		UNICAS	UNIPI	UNISA
1	Prototype and power electronics		contributor	contributor	leader
2	Coils and field modeling		leader	contributor	contributor
3	Electromagnetic Shields Modeling and Design		contributor	leader	contributor
4	Prototype assembly and validation		contributor	contributor	leader

DEXTER schedule:

July 1st, 2024 – February 28th, 2025 (extended to June 30th 2025)

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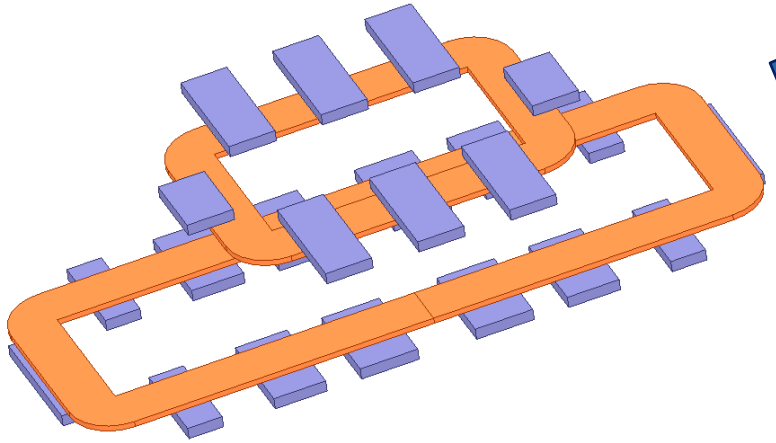
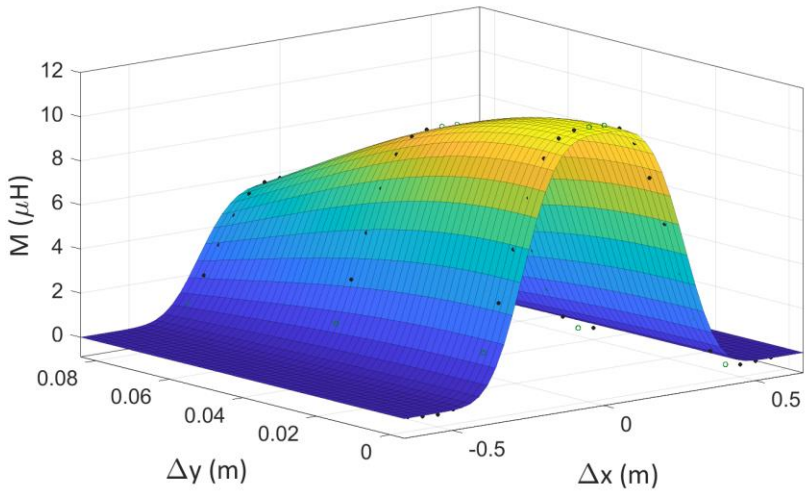
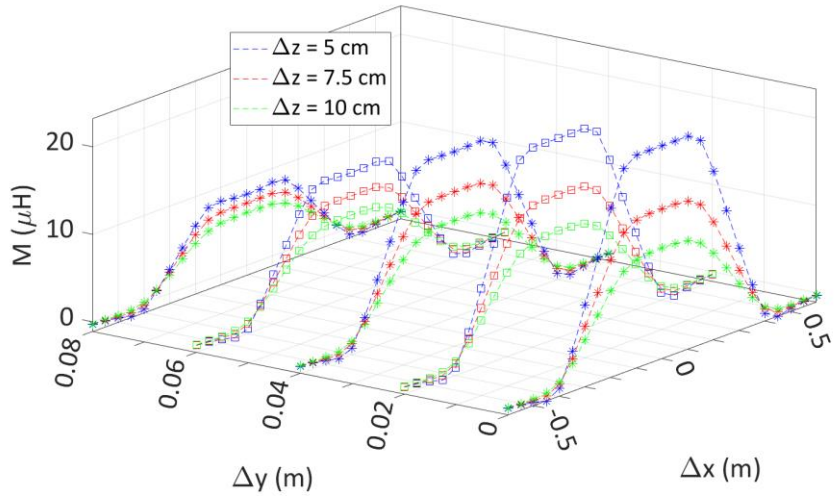
UNICAS: coils analysis and design







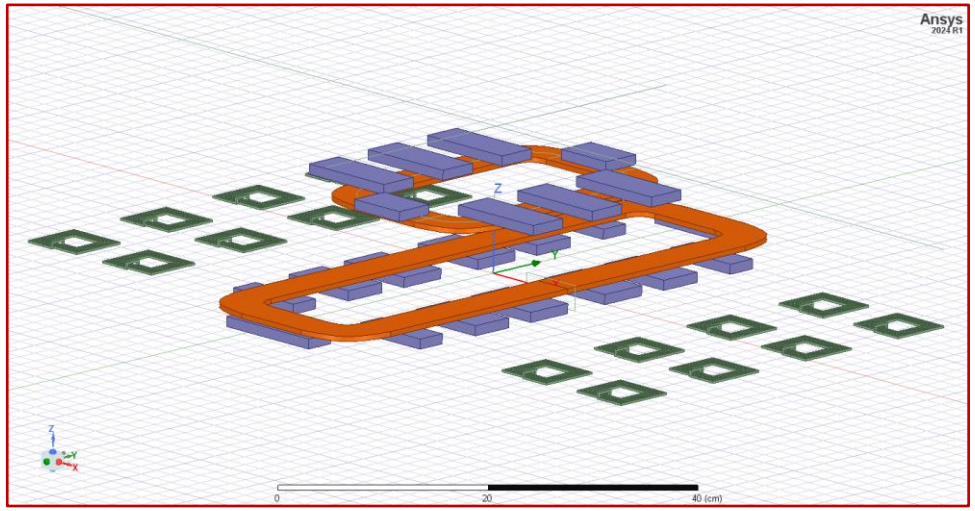
$$M(\Delta x;\ \Delta y;\ \Delta z) = a_0 \cdot e^{(a_1 \cdot |\Delta x|^{a_2} + a_3 \cdot |\Delta y|^{a_4})}$$

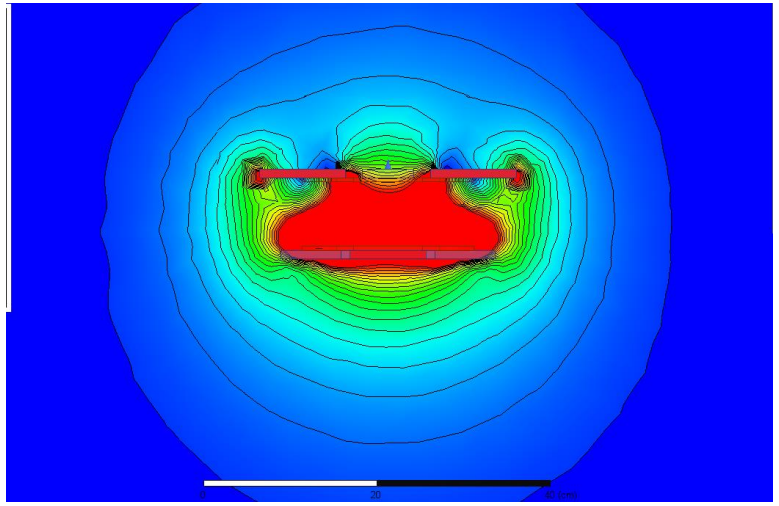
$$a_i = p_{i0} + p_{i1} \cdot \Delta z + p_{i2} \cdot \Delta z^2$$

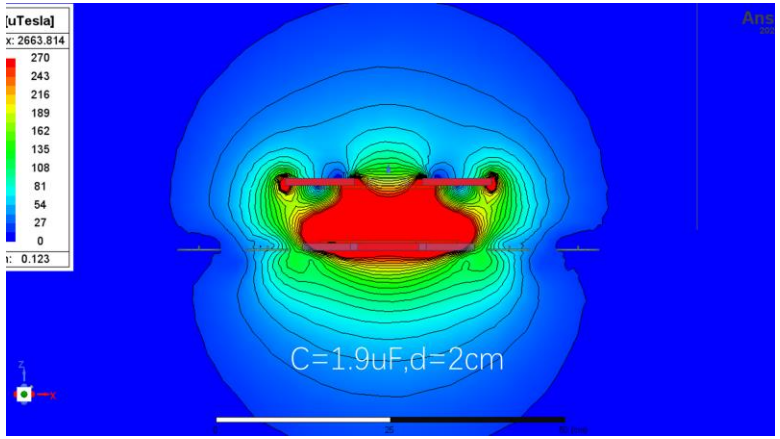
coils and ferrites optimization → **Ansys Maxwell 3D simulations** → **mutual inductance modeling** → **model validation**

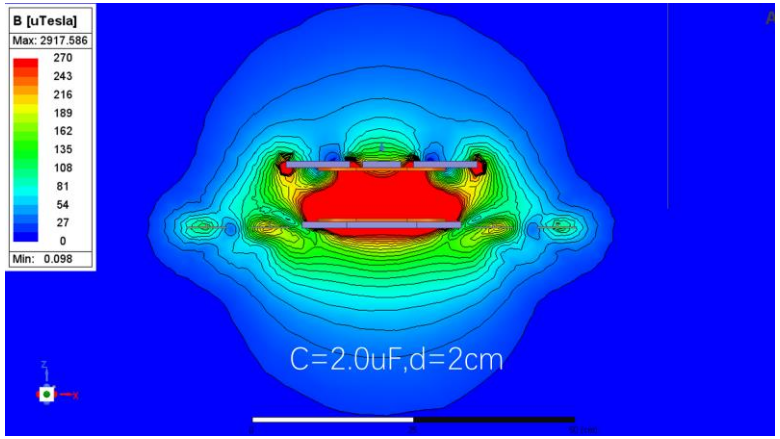
G. Di Capua et al., "Mutual Inductance Modeling for the Analysis of the Impact on Wireless Power Transfer Systems", 2024 IEEE International Symposium on Measurements & Networking (M&N), Rome, Italy, 2024

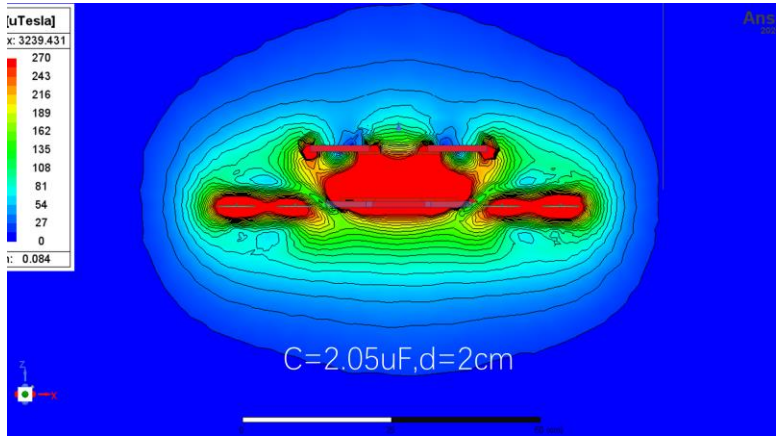
UNIPI: shielding analysis and design











N. Fontana et al., "Design and Optimization of Passive Coil Array Shielding for Reducing Magnetic Flux Leakage in Dynamic Wireless Power Transfer“, 2025 IEEE Wireless Power Technology Conference and Expo (WPTCE), Rome, Italy, 2025

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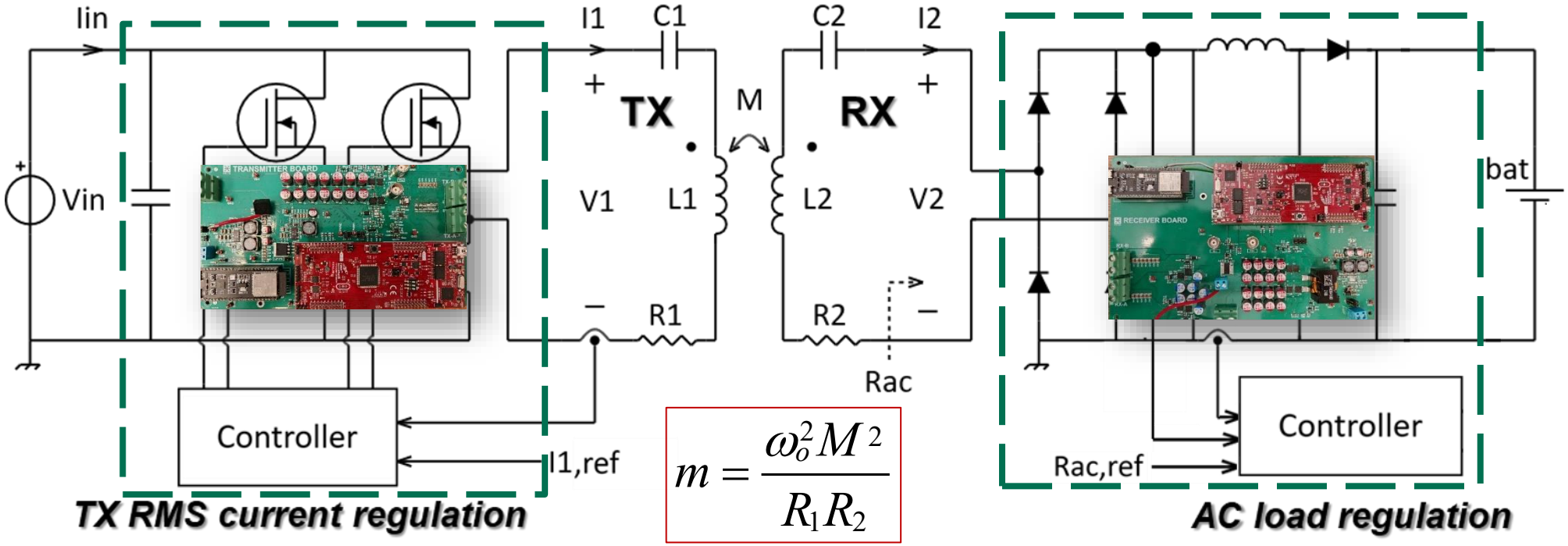
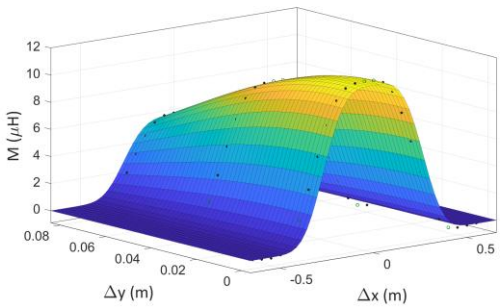
UNISA: power electronics and system-level analysis and design



$$m = \frac{\omega_o^2 M^2}{R_1 R_2}$$

$$I_{1,ref} = \frac{4V_{in}}{\pi R_1} \frac{n_{i\max}\left(1+\sqrt{1+m_{av}}\right)}{\left(1+m_{pk}+\sqrt{1+m_{av}}\right)} = I_{1,opt}$$



$$r_{ac,ref} = \sqrt{1+m_{av}} = r_{ac,opt}$$

N. Femia et al., "Comparative Analysis of High-Performance Wireless Battery Charging Systems," 2025 IEEE Wireless Power Technology Conference and Expo (WPTCE), Rome, Italy, 2025

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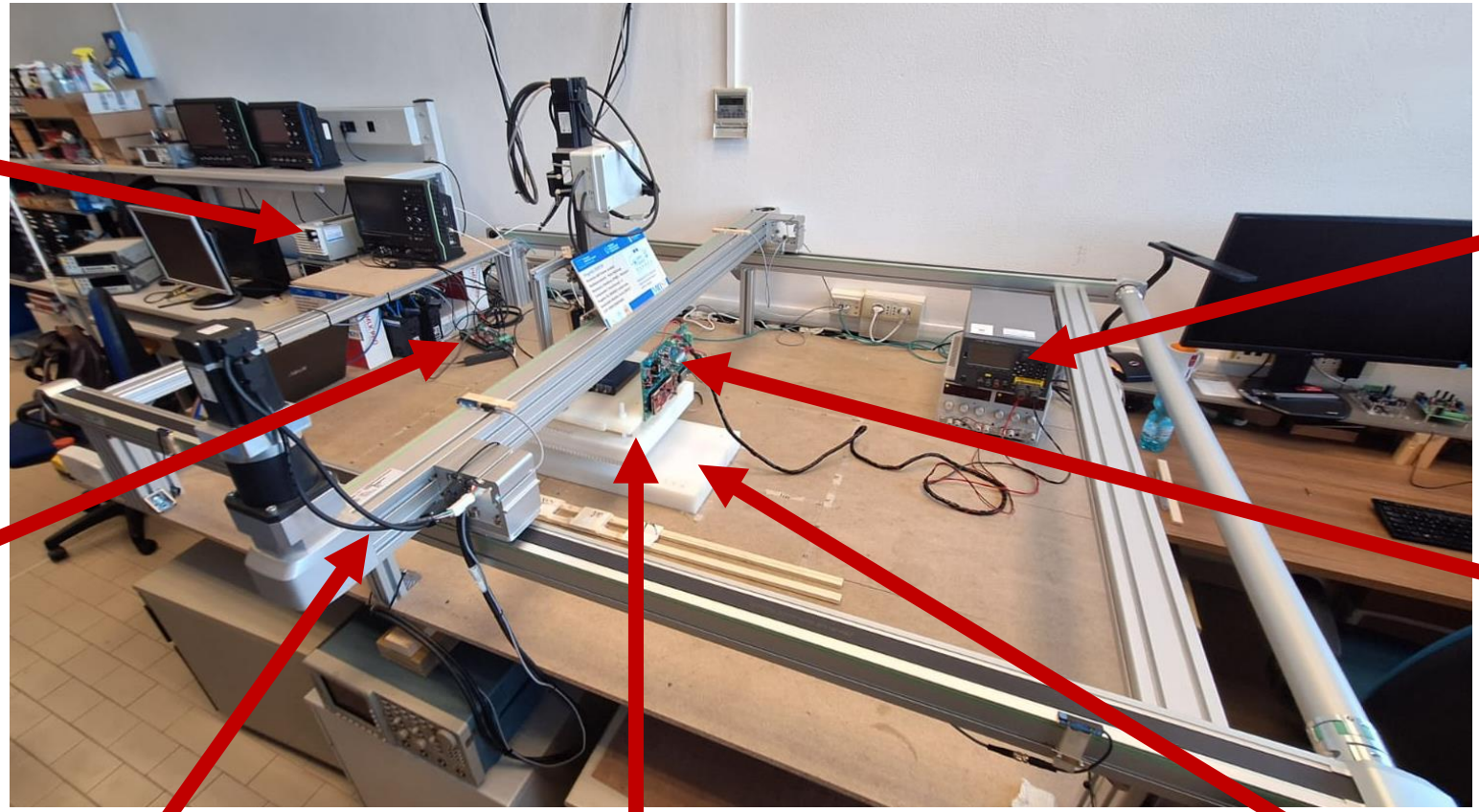
DEXTER prototype @ the UNISA Power Electronics Laboratory



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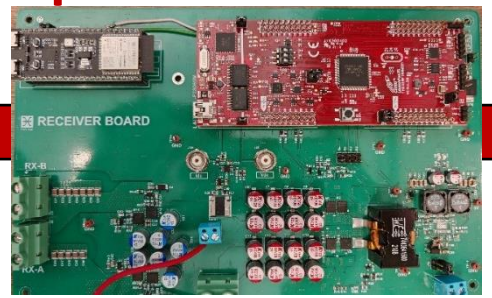
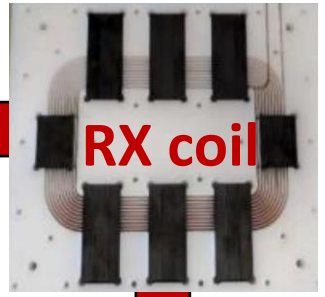
DEXTER prototype: power train

battery emulator

RX power electronics

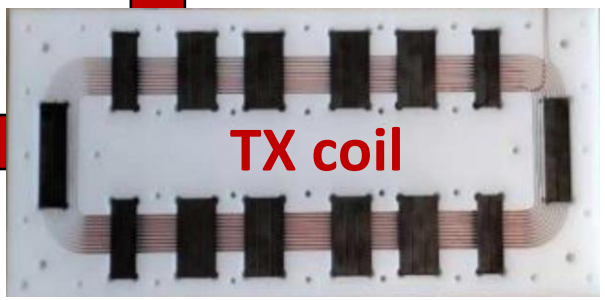




3D RX mover

DC power supply

TX power electronics



shielding coils

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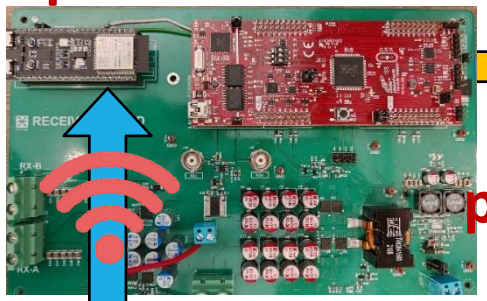
DEXTER prototype: control and system management

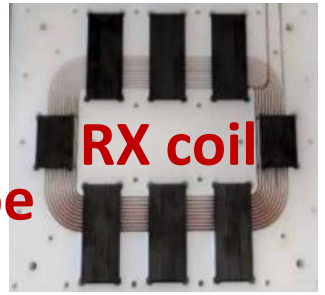
battery emulator

RX power electronics

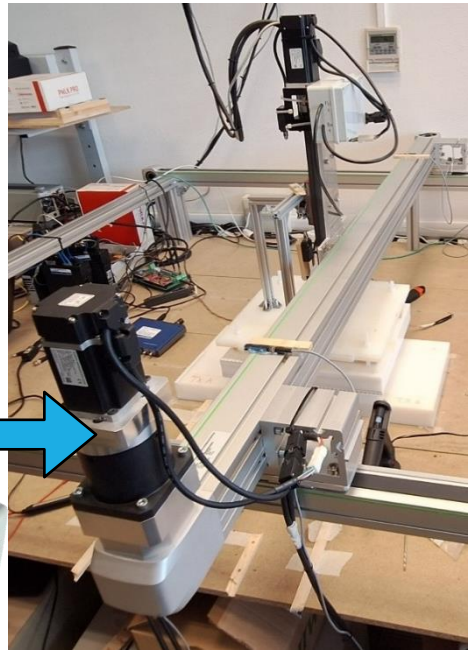


picoscope

RX coil



3D mover

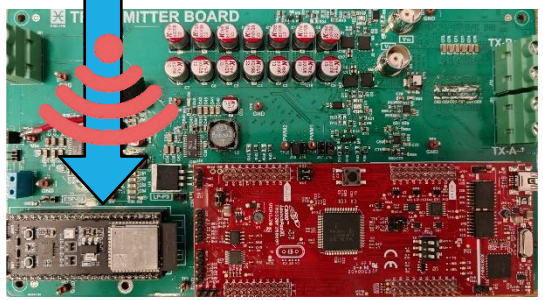


scope

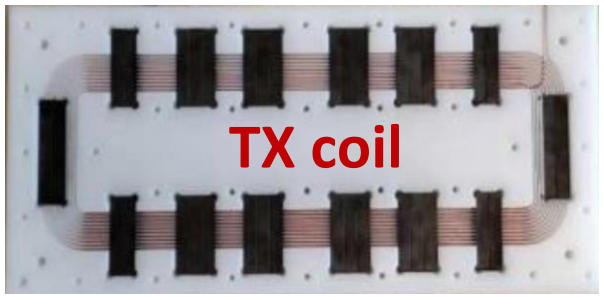
3D field probe

DC power supply

TX power electronics



TX coil



shielding coils

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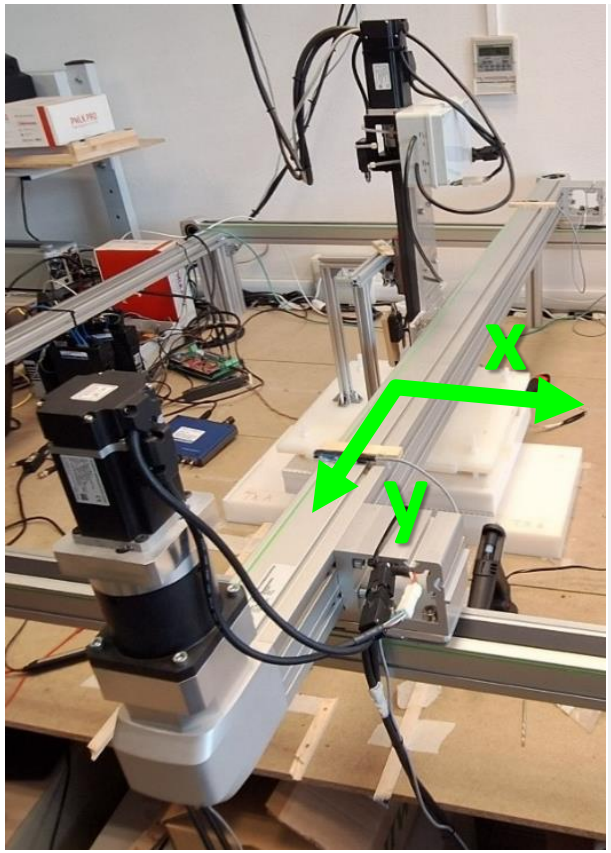
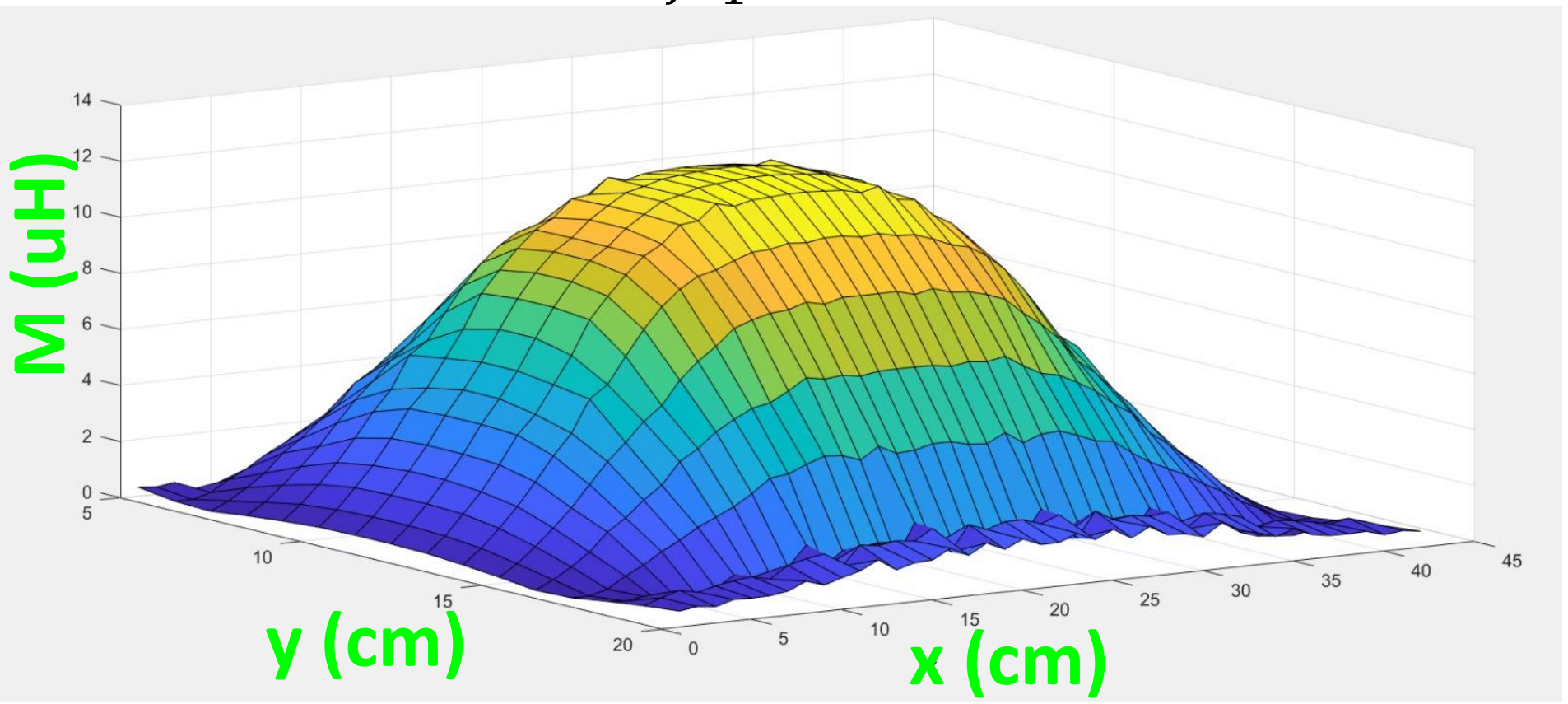
DEXTER experiments: automatized mutual inductance mapping

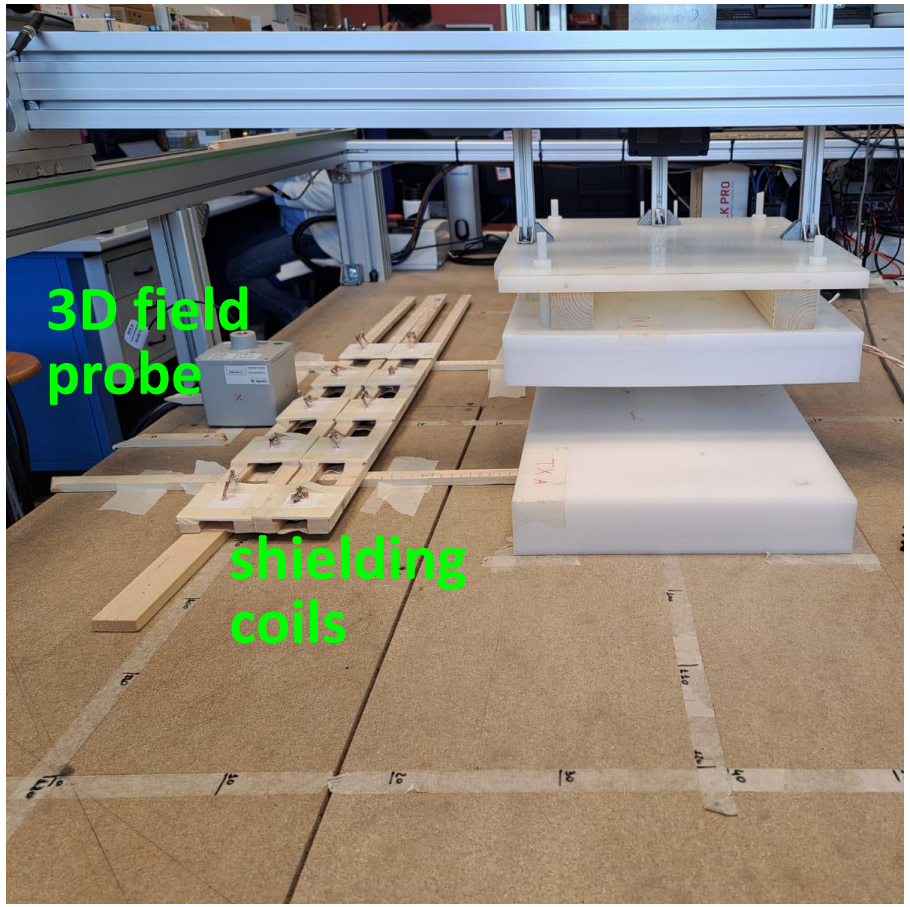
$$M(x,y) = \frac{\left|\bar{V}_{2,open}(x,y)\right|}{2\pi f I_1}$$

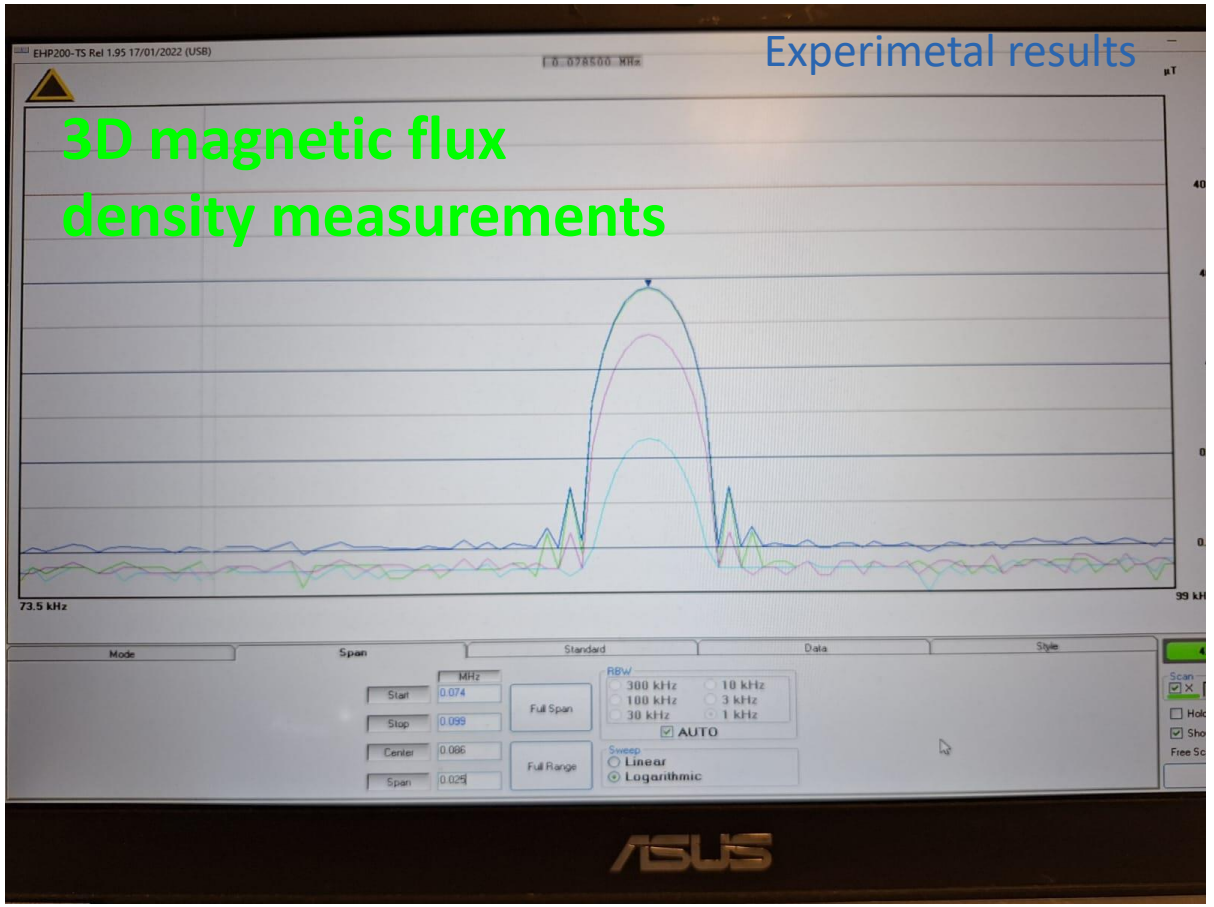
Experimetal results





DEXTER experiments: field measurements





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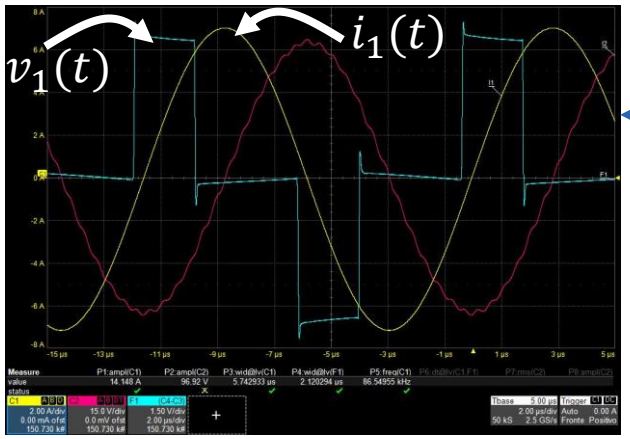
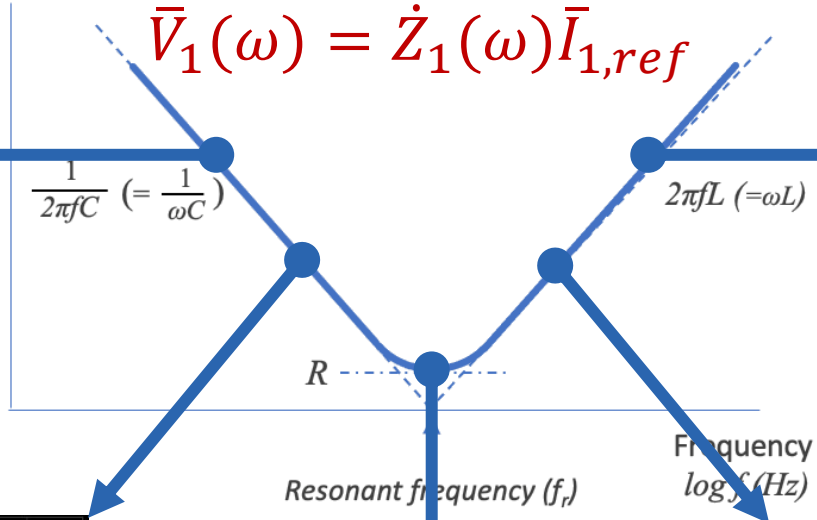
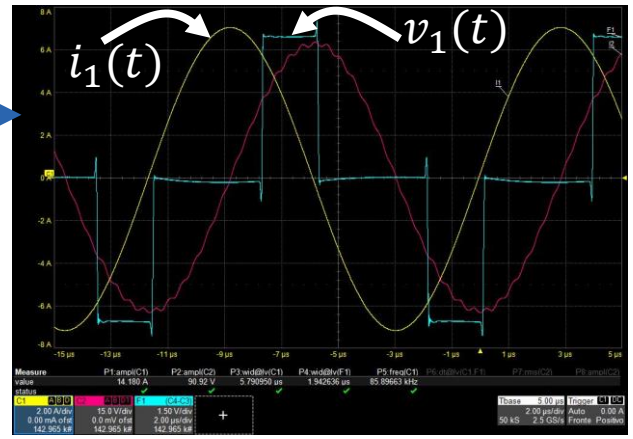
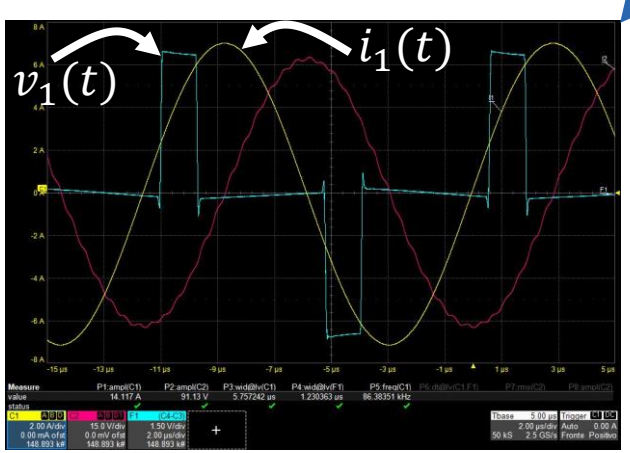
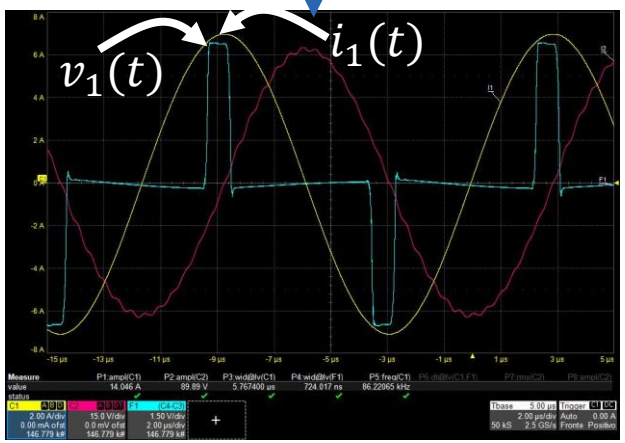
DEXTER experiments: automatized resonance frequency detection

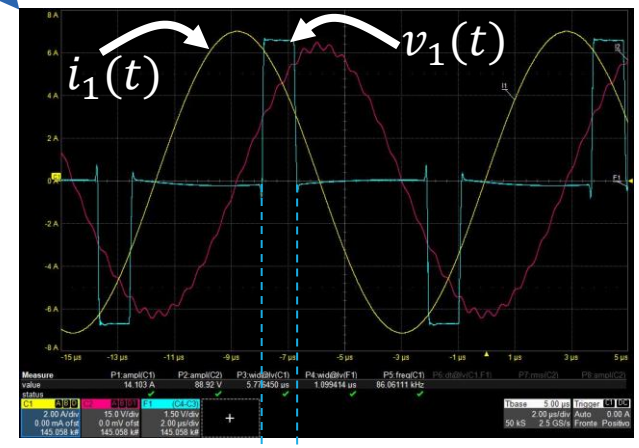


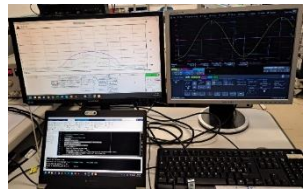




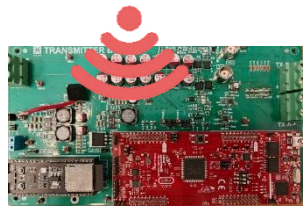








$[f_{min}, f_{max}]$
$I_{1,ref}$



t_{ON}

TX power electronics

$$\bar{V}_1(\omega) = \frac{4}{\pi} V_{in} sin\left(\frac{\omega t_{ON}}{2}\right)$$

Collaborative research and education opportunities

RESEARCH:

- coils, shielding, power electronics, control modeling and design validation
- battery modeling and validation in static and dynamic WPT charging
- device-level to system-level performance characterization and optimization

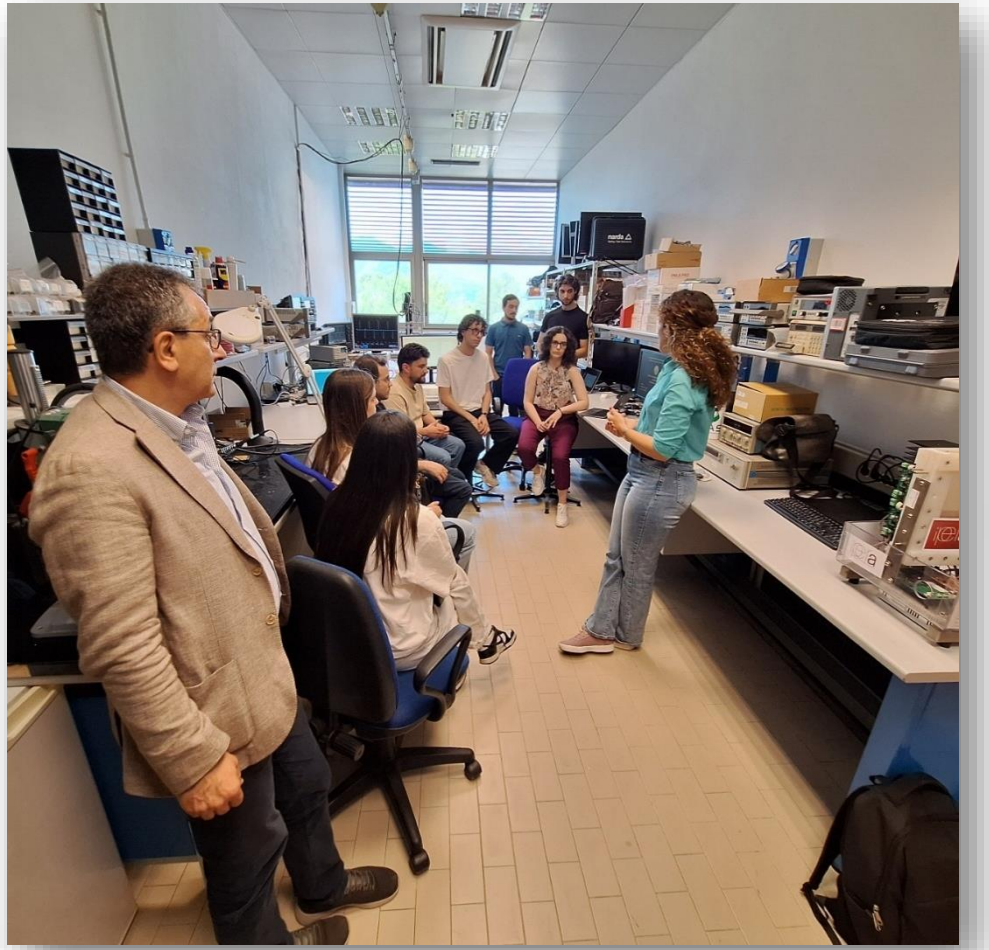
EDUCATION:

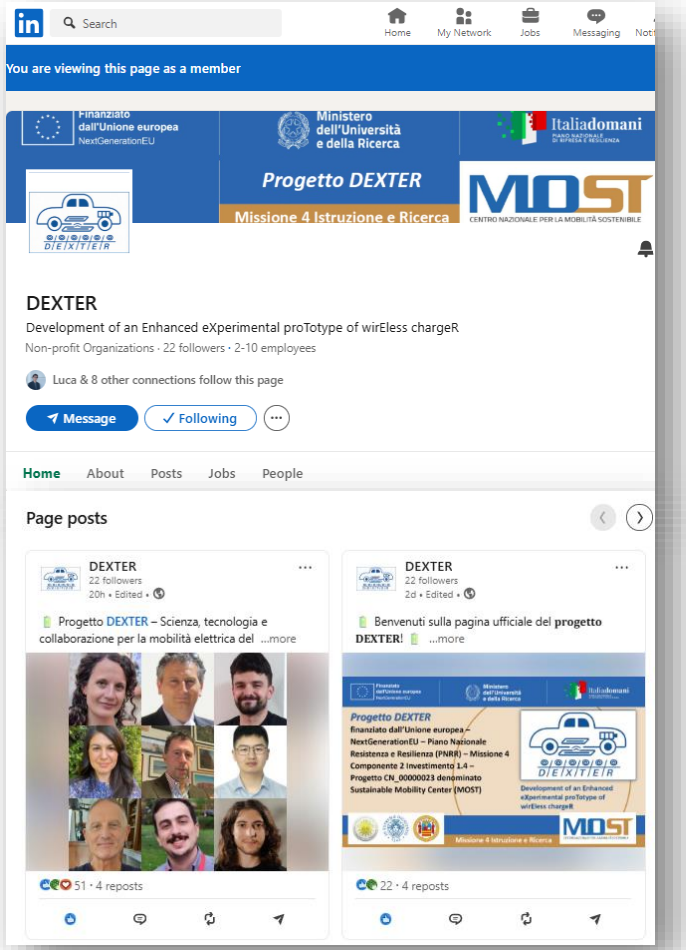
- seminars/classes
- training-on-the-job
- master/PhD thesis

DEXTER deadline:
June 30th 2025

DEXTER

DEXTER: dissemination initiatives





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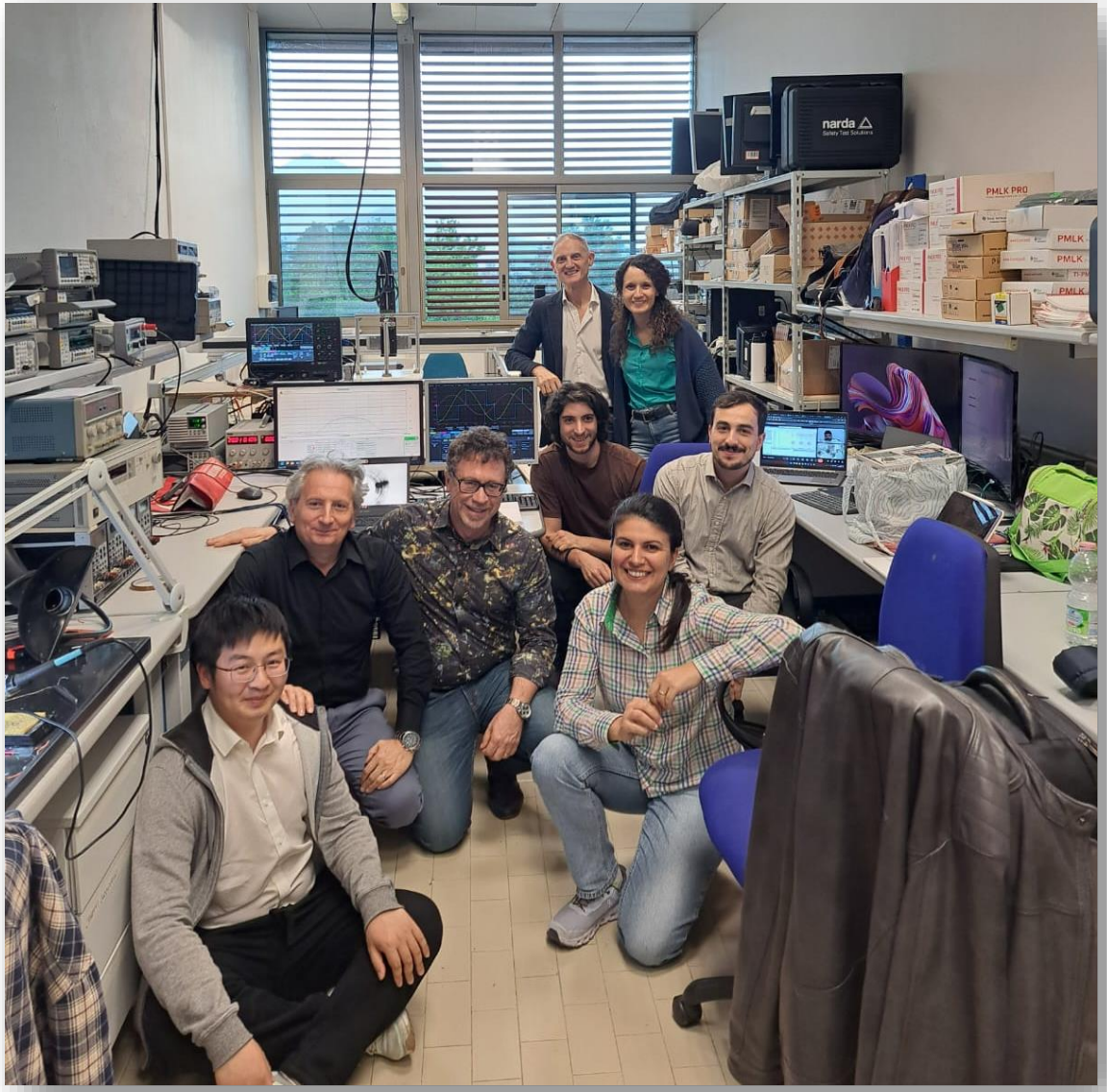
The DEXTER Team



- UNICAS
  - Giulia Di Capua (PI)
  - Antonio Maffucci
  - Gennaro Di Mambro
- UNISA
  - Nicola Femia
  - Luca De Guglielmo – partnership EXELING s.r.l.
  - Nunzio Oliva – partnership EXELING s.r.l.
- UNIPI
  - Nunzia Fontana
  - Sami Barmada
  - Junda Zhu

DEXTER

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Thank you for your attention

giulia.dicapua@unicas.it

Giulia Di Capua

Department of Electrical and Information Engineering “Maurizio Scarano”
University of Cassino and Southern Lazio