

AGENDA

- Basics of wireless power transfer (WPT)
- WE WPT portfolio
- Customer WPT applications
- WE WPT solutions and services
- WE WPT paper work



Basics of Wireless Power Transfer

WIRELESS POWER TRANSFER HISTORY

1893 first wireless powered lightbulb N. Tesla



Source: <https://savvyleo.com/science/famous-scientists/nikola-tesla/>

1990's electrical toothbrush



2008 founding of Wireless Power Consortium (WPC) Qi Standard



WIRELESS POWER
CONSORTIUM

2012 first smart phones with integrated Qi receiver



2017 Apple joins WPC



2018 Wireless charging of EVs

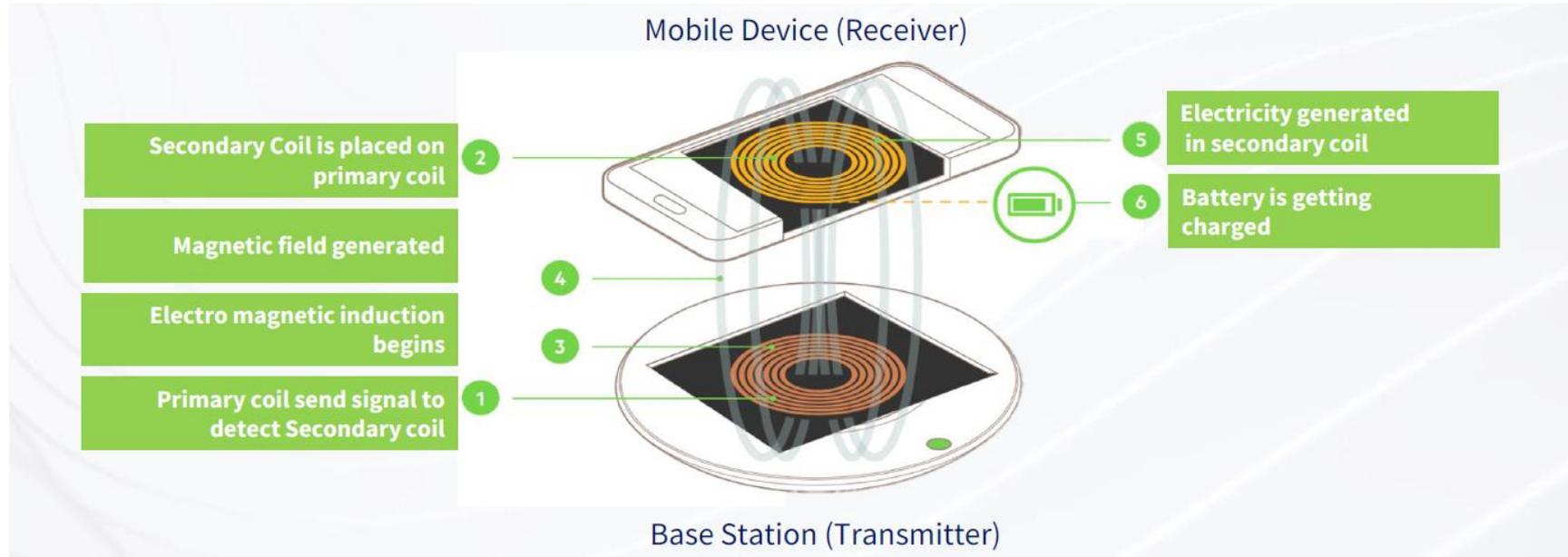
2023 Apple Magsafe => Qi 2.0



2024 Release of the Ki Cordless Kitchen Standard



HOW DOES WIRELESS POWER TRANSFER (WPT) WORK?



- ❖ Typical frequency range: 100 kHz – 200 kHz.
- ❖ Powers capable up to kW range depending on application.
- ❖ Low in-band communication possible with data rates up to 1kbit/s.

Image source- Graniteriverlabs.com

WIRELESS POWER STANDARDS SUPPORTED BY WE

Qi and Qi2

- The Qi standard is for mobile devices and handheld devices operating upto 15W.
- Qi Frequency range : 87kHz to 205kHz
- Qi2 Frequency range : 360kHz



Ki

The Ki standard is for Tx kitchen appliances operating upto 2.2kW.



Airfuel alliance

- Power transfer based over longer distances (40mm)
- Ability to charge multiple devices at same time
- Resonant tank at 6.78MHz. (ISM Band)
- Capability up to *30W systems
- Under 50 products certified



Image source-Wireless Power Consortium

CURRENT WIRELESS POWER TECHNOLOGY LANDSCAPE

Frequency band	Low frequency		High frequency		Ultra High-Frequency
Technology type	Magnetic Induction	Magnetic Resonance	Magnetic Resonance	NFC Charging	'Distance' Charging (RF, Ultrasound, Infrared, 5G, etc.)
Coupling	"Tightly coupled"	'Loosely coupled'	"Loosely coupled"	"Loosely coupled"	'Uncoupled'
Frequency band	100 kHz-200 kHz (~330 kHz)	79-90 kHz (85 kHz)	6.78 MHz	13.56 MHz	<ul style="list-style-type: none"> RF: 900 MHz, 2.4GHz-5.8GHz US: 45 kHz-75 kHz/145-155 dB
Regulatory Body/ Standard	WIRELESS POWER CONSORTIUM	SAE INTERNATIONAL, ISO IEC, CEVIAE	AirFuel Alliance	NFC FORUM	AirFuel Alliance
Standard name/type	Qi & Ki + Proprietary	SAE specification for EVs	AirFuel Resonance + Other Proprietary	NFC Charging	AirFuel RF + Other Proprietary
Power Classes	Very Low, Low, Medium & High	Very High and Ultra High	Low, Medium and High	Very Low and Low	Ultra Low, Very Low and Low

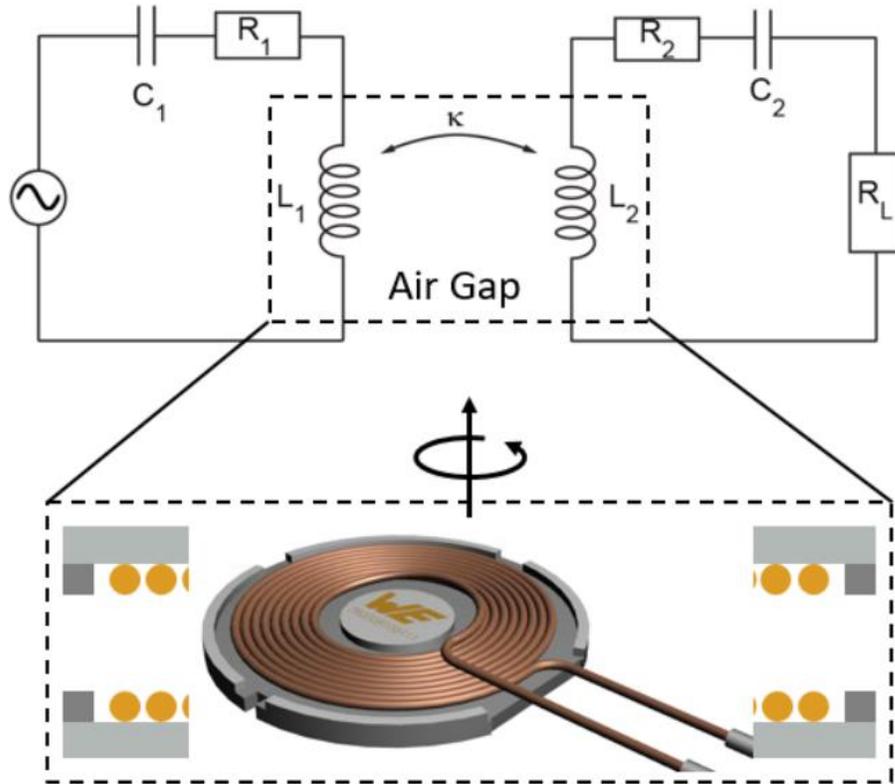
Source: WAWT

Source: WAWT's Wireless Power Intelligence Service

© 2023 WAWT

HOW DOES WIRELESS POWER TRANSFER WORK?

Inductively coupled magnetic resonant system



- Frequency: kHz regime
- Distance: short range regime (e.g. 1-10mm)

Maximum Transmission Efficiency

$$\eta_{\max} = \frac{\kappa^2 Q^2}{(1 + \sqrt{1 + \kappa^2 Q^2})^2} \approx 1 - \frac{2}{\kappa Q}$$

↑
high Q

κ
coupling factor

Q
quality factor

$$Q_L = \frac{2\pi f L}{R}$$

Coil quality factor

[1] R. Bosshard, PhD thesis 2015, "Multi-Objective Optimization of Inductive Power Transfer Systems for EV Charging"

COUPLING FACTOR (K) AND TX/RX SIZE RATIO IMPACT

Tx/Rx coil size impacts coupling factor k



Coil A- 760 308 100 111 (A11)

Coupling factor between Coils A&B (k)= 0.29

$$A_{Rx}/A_{Tx} = 1:6$$



Coil B- 760 308 101 214



Coil C-760 308 101 104

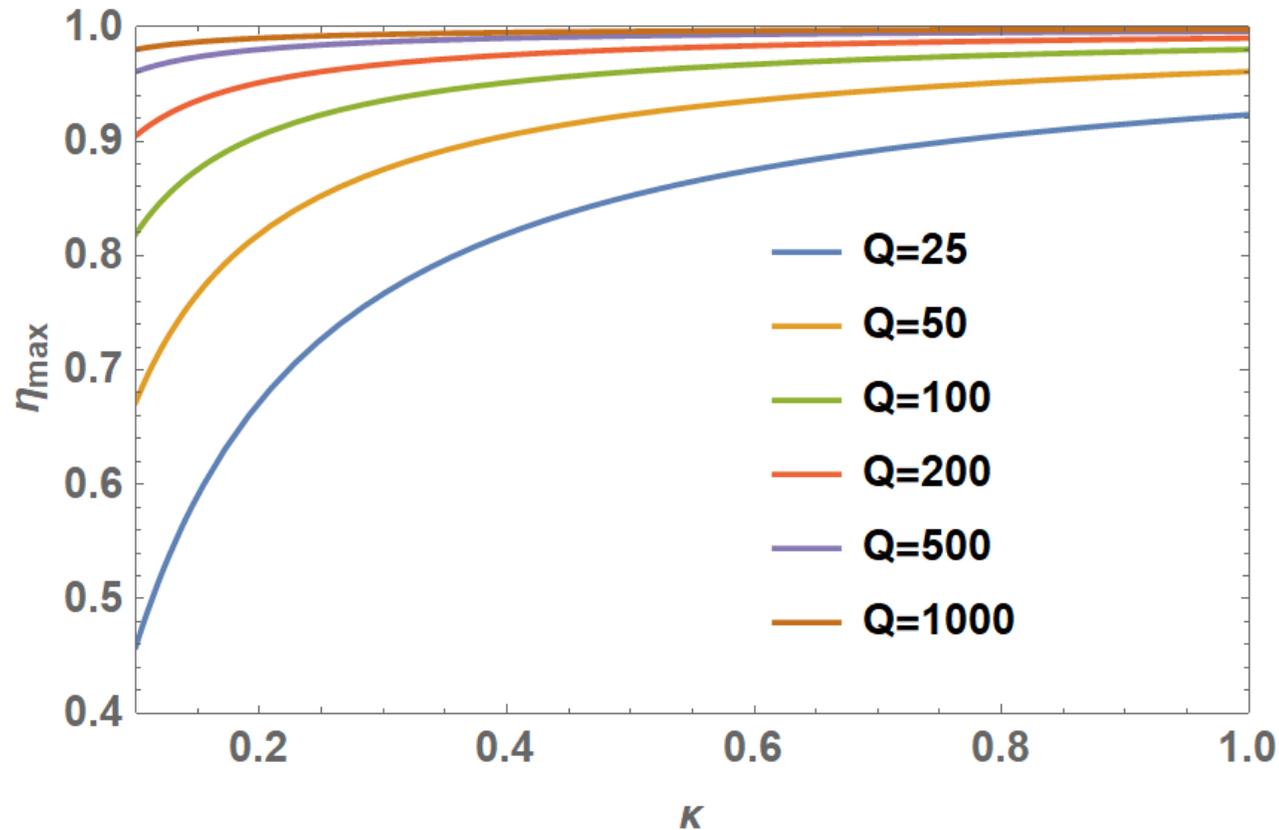
Coupling factor between Coils C&D (k)= 0.60

$$A_{Rx}/A_{Tx} = 1:1$$



Coil D- 760 308 101 214

FIGURE OF MERIT FOR EFFICIENT POWER TRANSFER



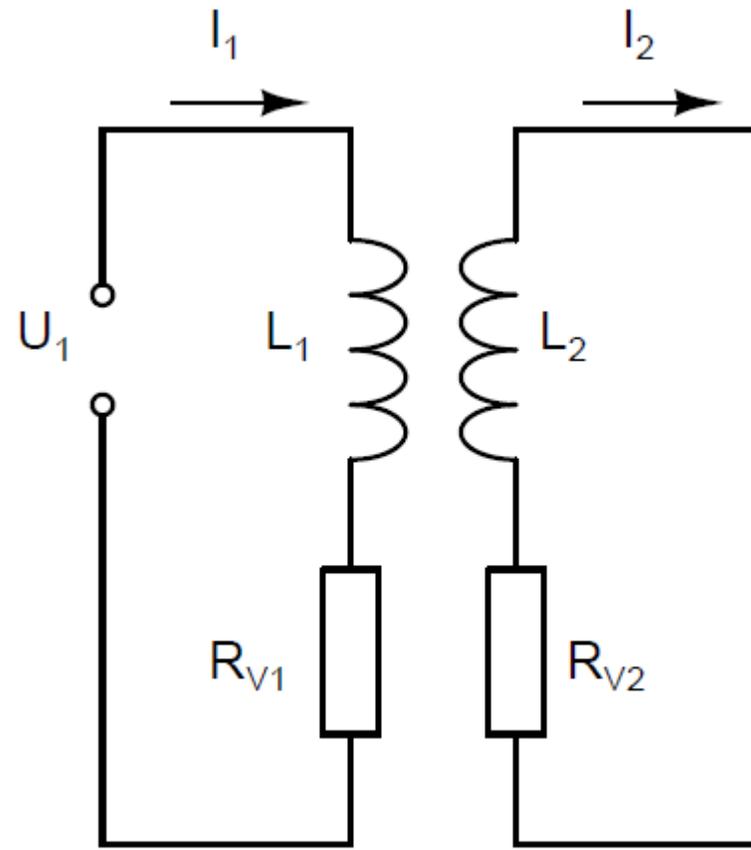
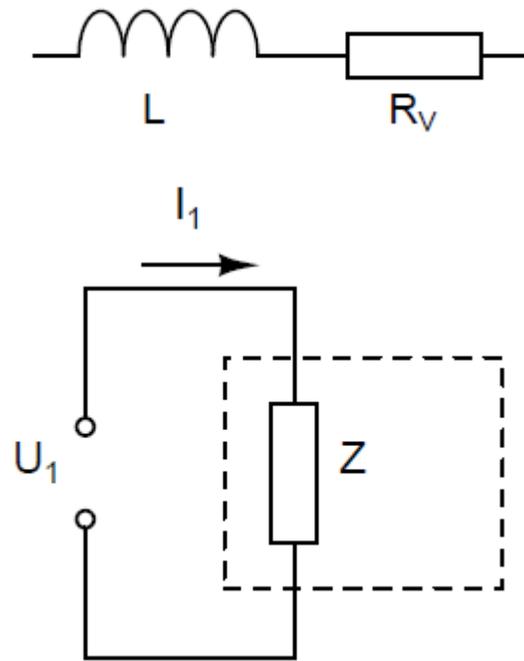
coupling κ is often limited by boundary conditions of the application

High Q coils allow

- long transfer distance
- higher freedom of positioning

$$\eta_{\max} = \frac{\kappa^2 Q^2}{(1 + \sqrt{1 + \kappa^2 Q^2})^2} \approx 1 - \frac{2}{\kappa Q}$$

COUPLING FACTOR

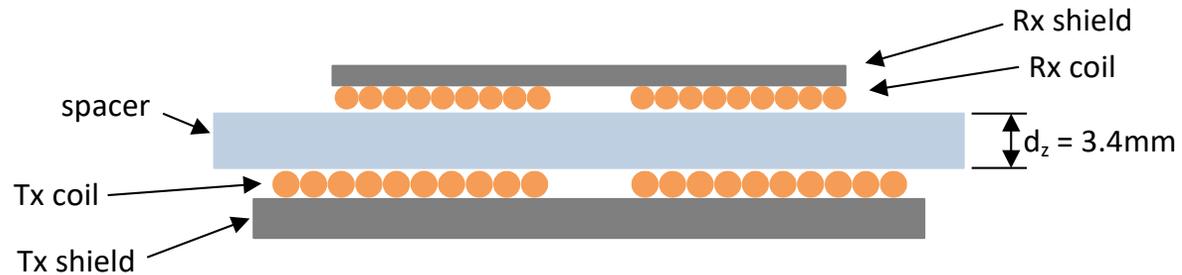


Faradays law of induction and Kirchhoffs law:

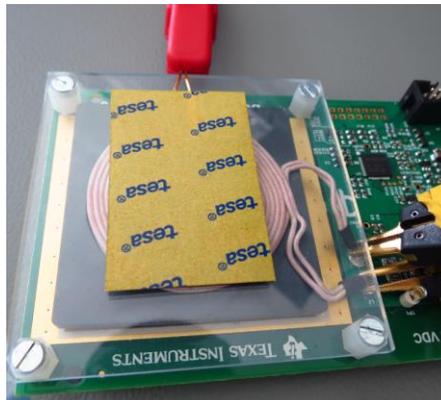
$$Z = R_{V1} + R_{V2} \frac{L_1}{L_2} k^2 + j (1 - k^2) \omega L_1 \xrightarrow[\text{side is shorted}]{\text{If secondary}} L'_1 = (1 - k^2) L_1 \xrightarrow{\text{solve for k}} k = \sqrt{1 - \frac{L'_1}{L_1}}$$

HOW CAN THE COUPLING FACTOR BE DETERMINED BY MEASUREMENT?

1. Determine the transfer distance and the transfer frequency (e.g. 3.4 mm and 100 kHz)

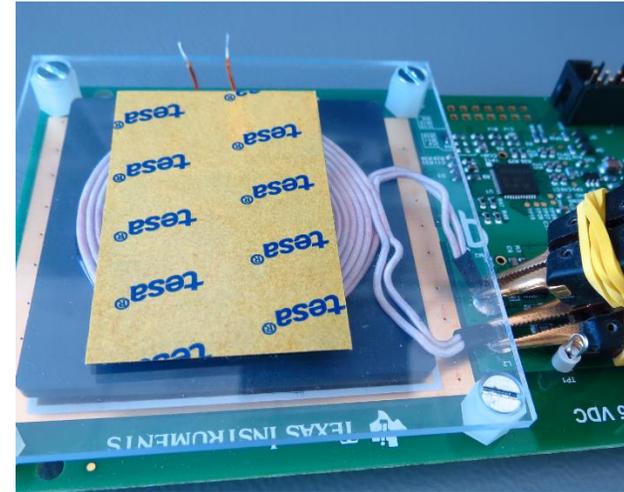


2. Measure $L1'$



HOW CAN THE COUPLING FACTOR BE DETERMINED BY MEASUREMENT?

3. Measure L1



4. Determine coupling factor for the certain distance

$$k = \sqrt{1 - \frac{L'_1}{L_1}}$$

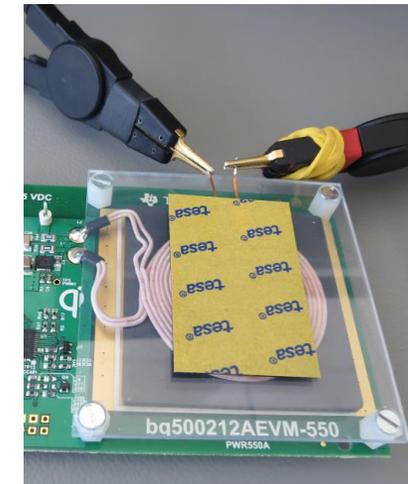
HOW CAN THE RESONANT TANK CAPS BE DETERMINED BY MEASUREMENT?

1. C1 can be calculated using L1 with (f = 100 kHz):

$$C1 = \frac{1}{(2\pi f)^2 L1}$$

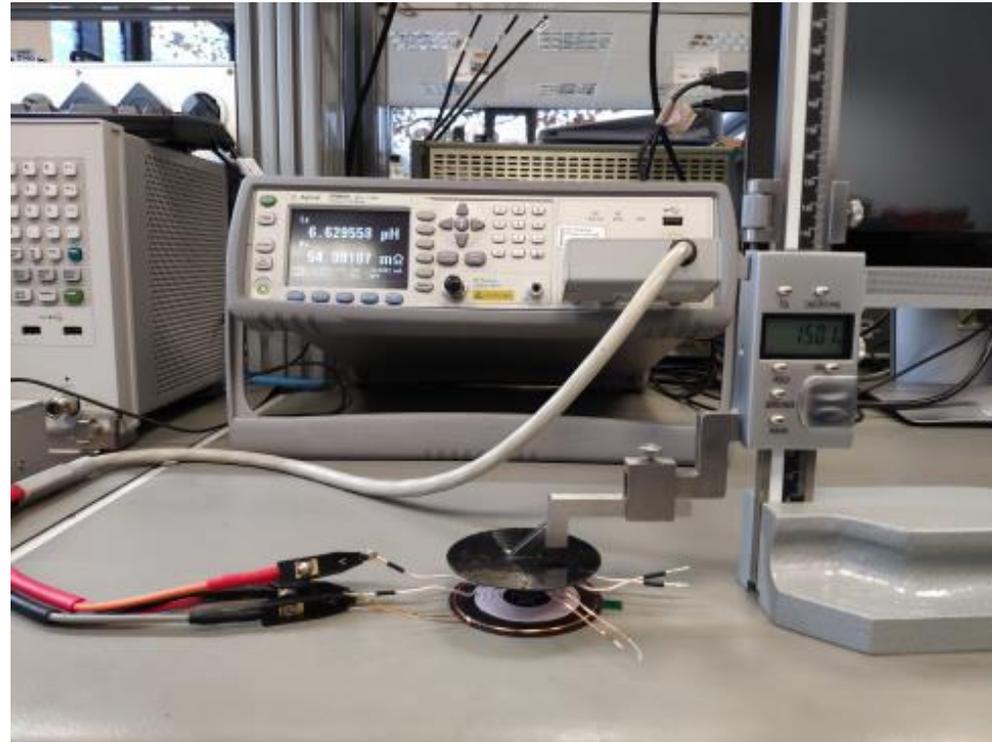
2. Measure L2' and calculate C2:

$$C2 = \frac{1}{(2\pi f)^2 L2'}$$

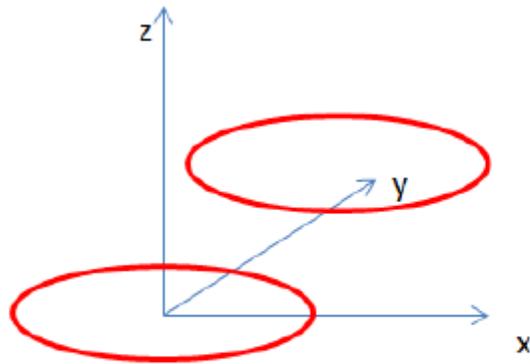


DIFFERENT DISTANCES?

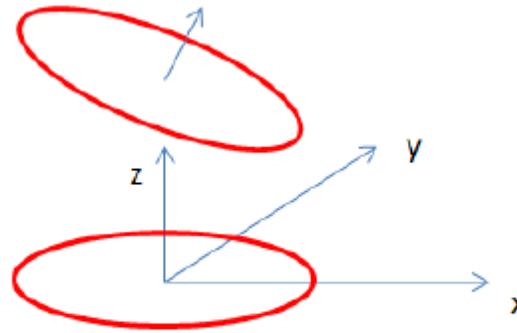
- If the coupling factor and the resonant tank caps have to be determined for different distances, a variable spacer can be used.



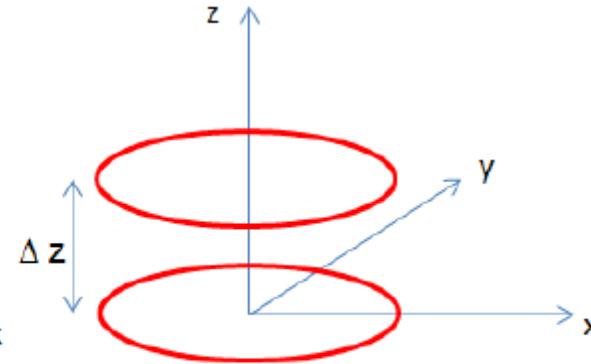
COIL MISALIGNMENT



lateral misalignment



angular misalignment

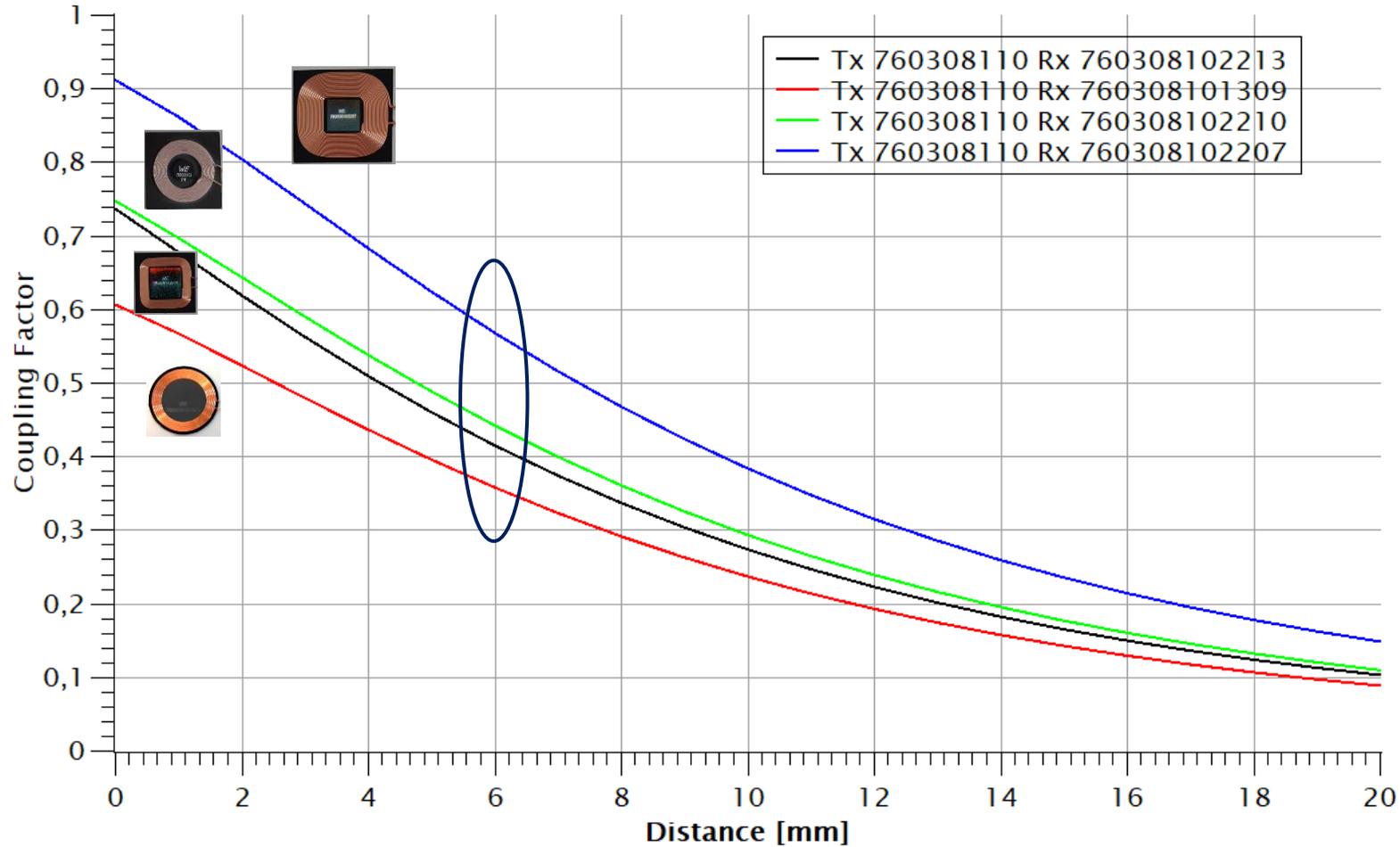


vertical misalignment

Good coupling and maximum energy transmission depends on

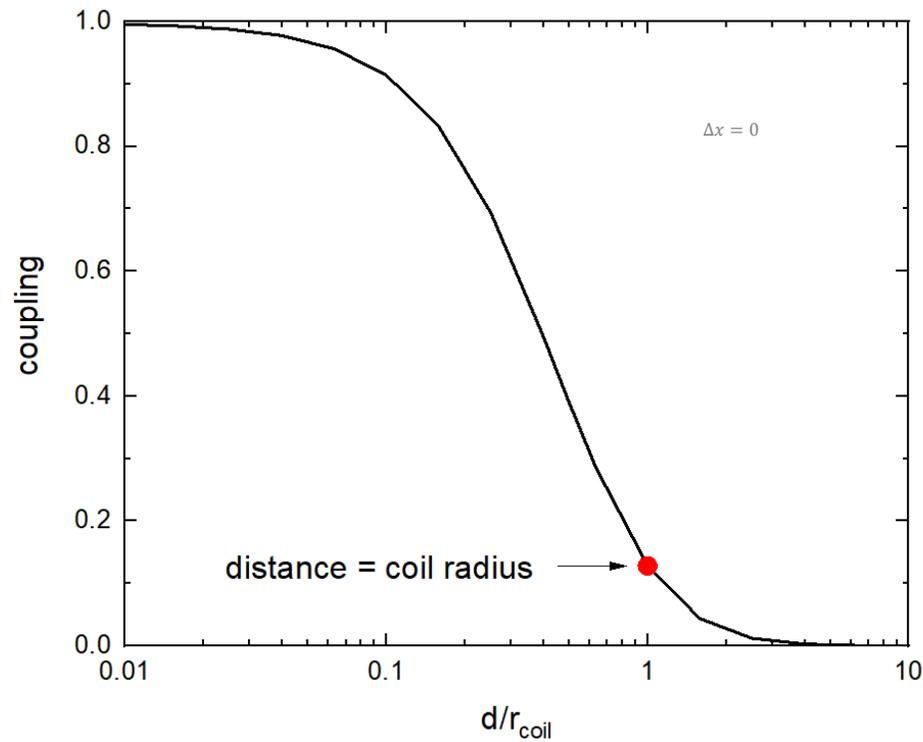
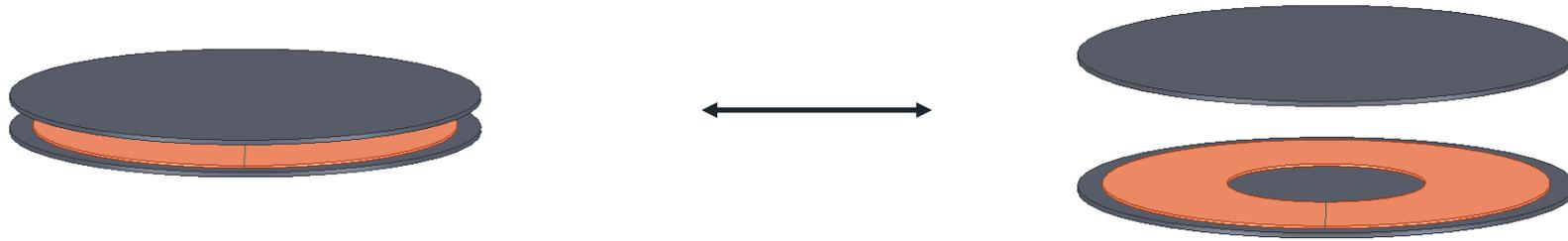
- Relation between the effective area of the receiver and transmitter coil in the magnetic field
- Lateral, angular or vertical misalignment

COUPLING VERSUS TX AND RX COIL COMBINATION



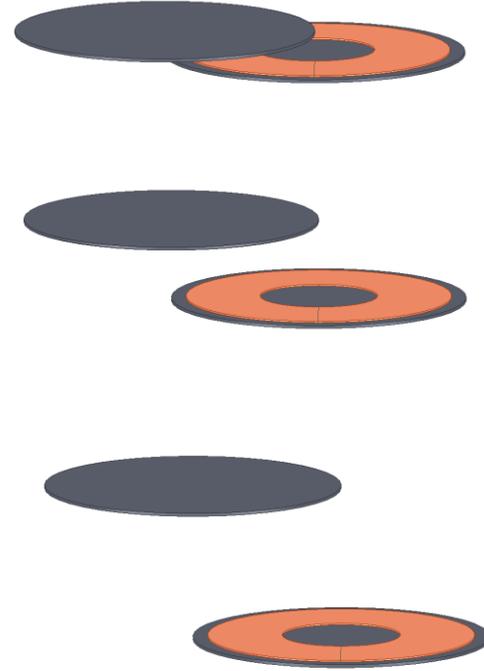
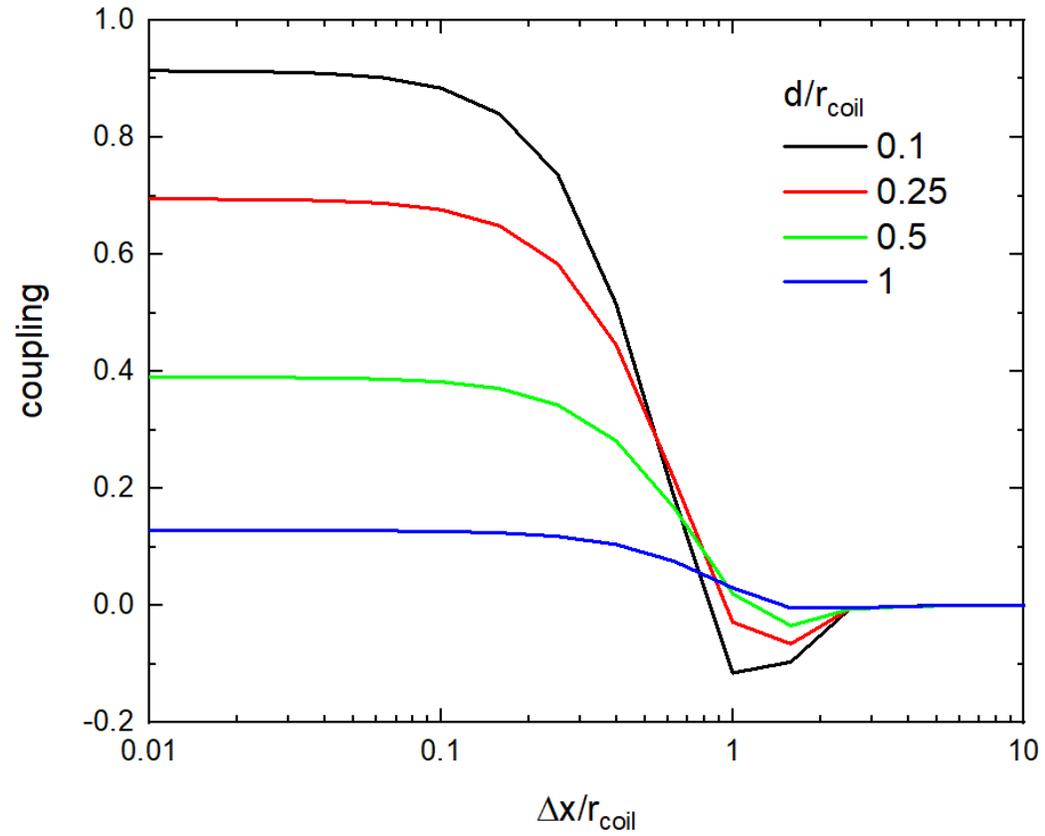
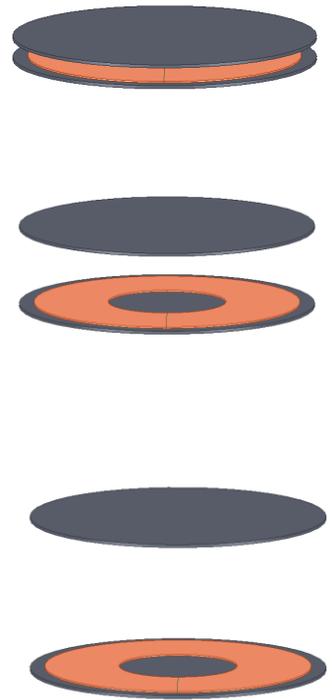
	Q Factor	k Factor at z=6mm	FoM $(Q_{Tx} + Q_{Rx}) * k$	
760308110	180			
760308102207	30	0,56	118	
760308102210	45	0,44	99	-16%
760308101309	19	0,36	72	-39%
760308102213	18	0,41	81	-31%

COUPLING VERSUS AIR GAP

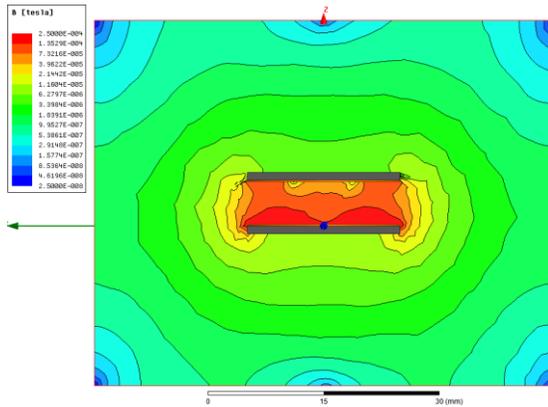


- The coupling factor drops already below 0,4 at a distance of half of the coil radius!

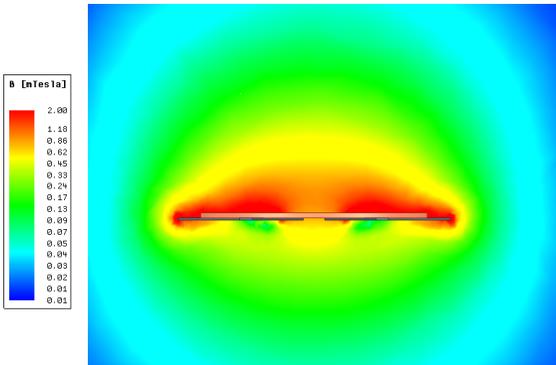
COUPLING VERSUS COIL DISPLACEMENT



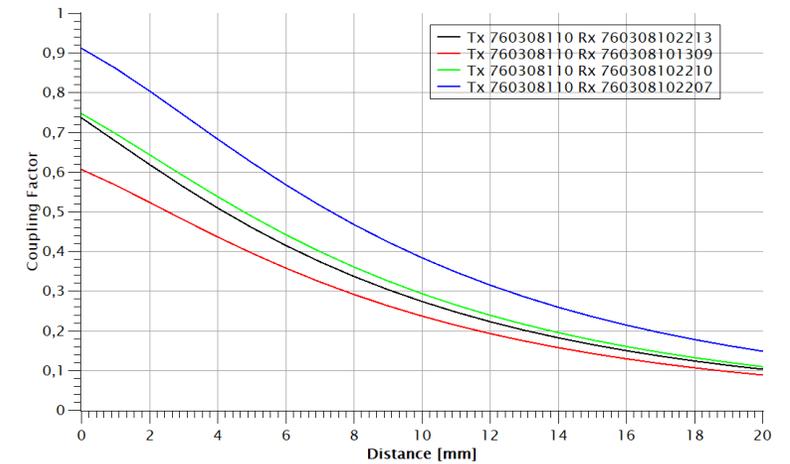
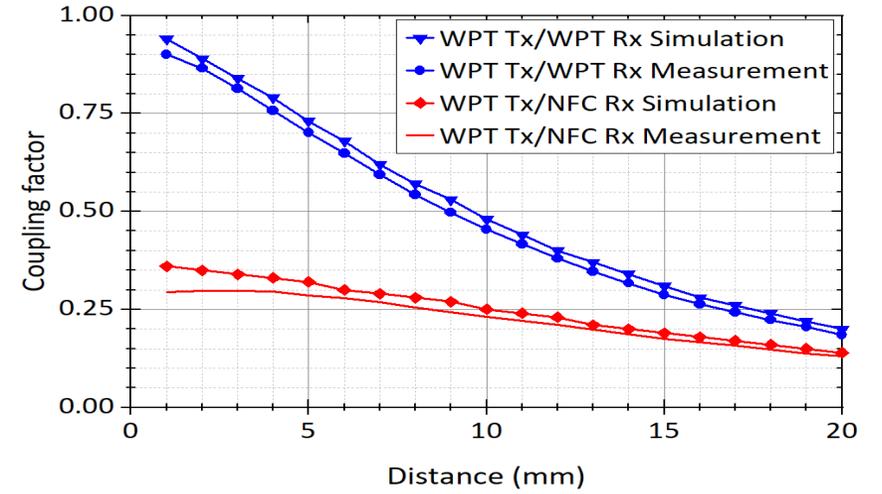
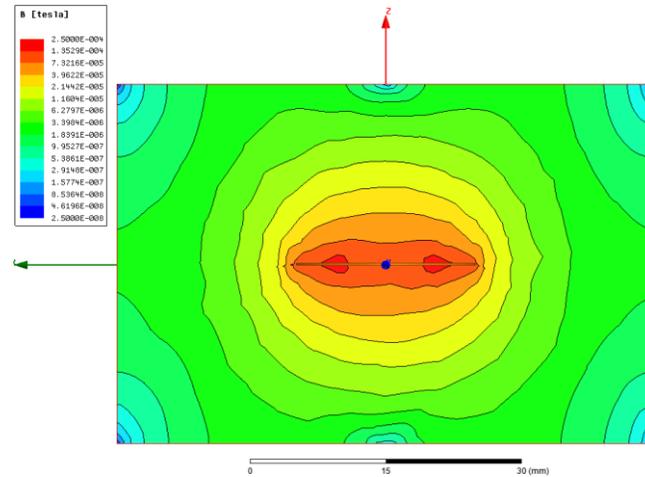
SIMULATIONS



2D simulations of the coupling of different coil combinations

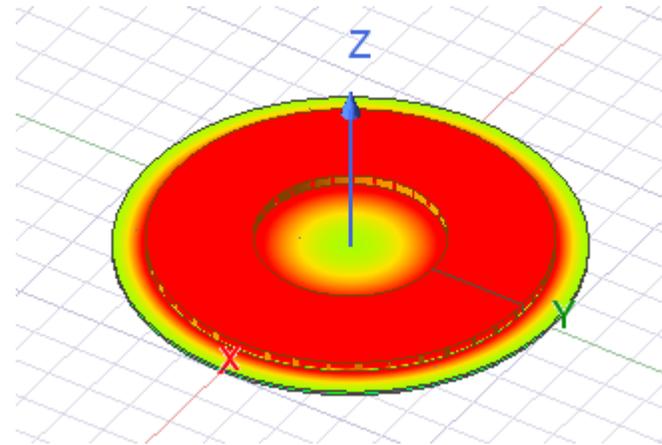
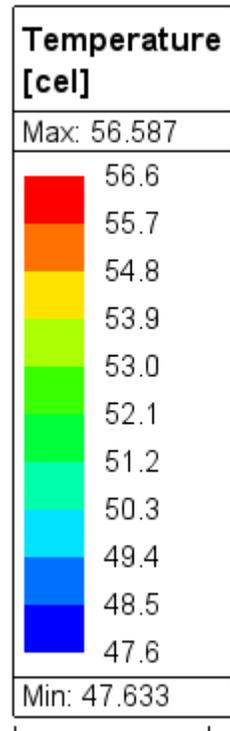


Field Simulations



SIMULATIONS

Thermal simulations of WPT coils with Ansys ICEPAK



A11 coil at 5 A RMS @125 kHz

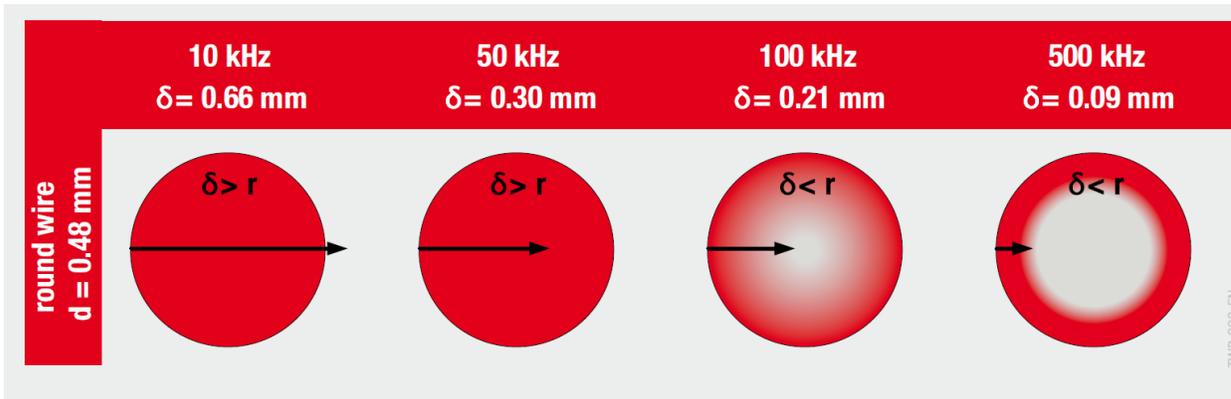


760308101411

Deviation Simulation (5A) and measurement (4.7 A) : 6%

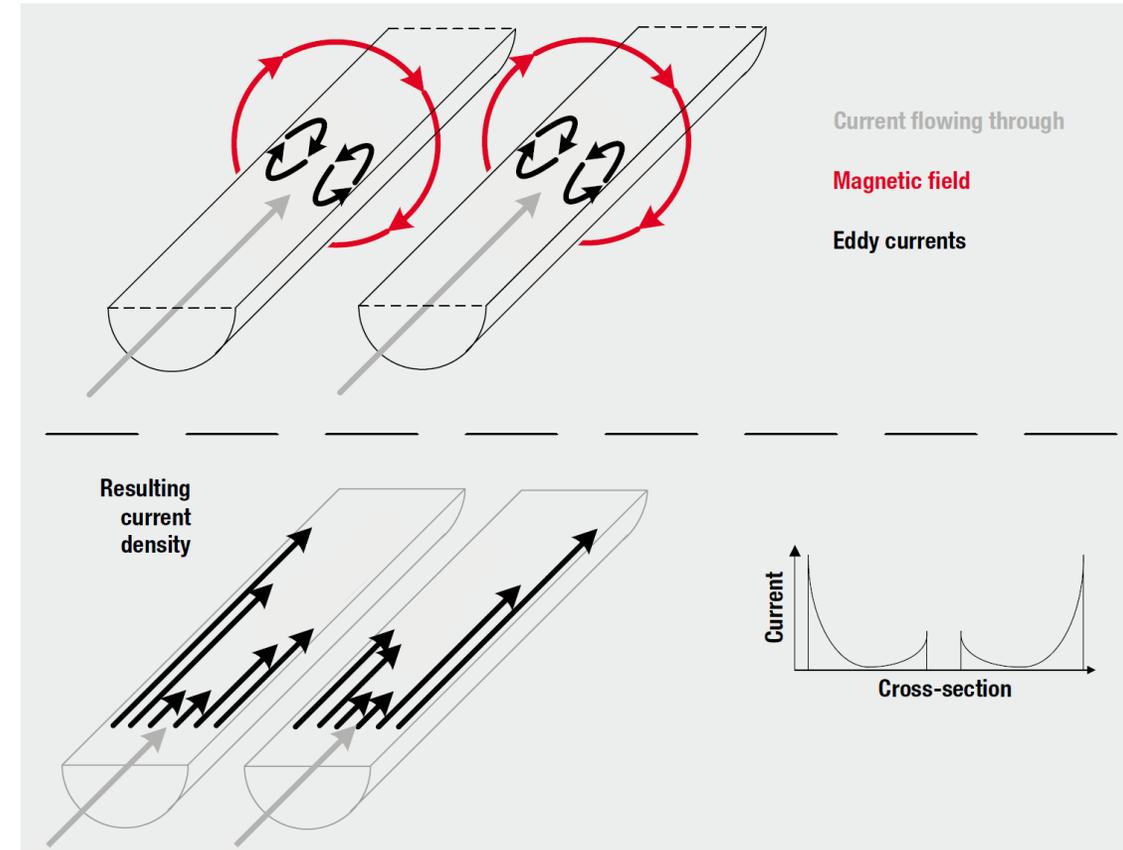
Deviation Simulation (5A) and calculation (5.3 A): 5,6 %

PROXIMITY EFFECT & SKIN EFFECT



$$Q_L = \frac{2\pi f L}{R}$$

Coil quality factor



Skin effect: the penetration depth δ is related to frequency

$$\delta = \sqrt{\frac{2 \cdot \rho}{\omega \cdot \mu}}$$

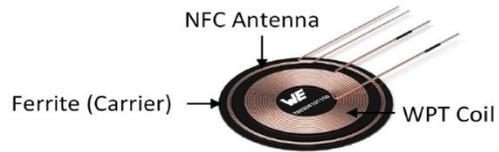
➤ Skin effect can be avoided by using a litz wire

The proximity effect causes current constriction or current displacement in closely spaced conductors.

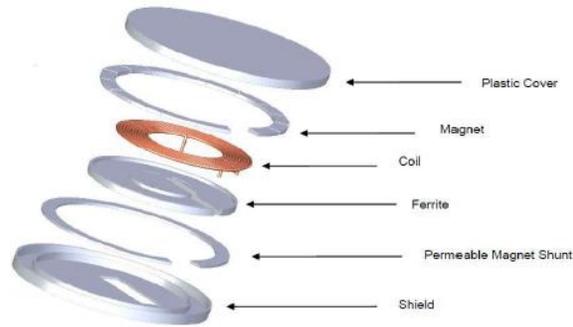
WE wireless power portfolio

WE PRODUCT OFFERS

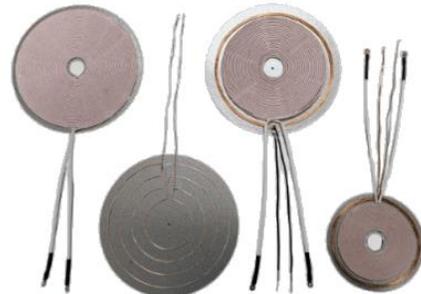
**Standard coils
(if on stock,
shipped in less
than 48 h)**



**Customized
WPT coils**



Power Transmitter Coil (PTx)
(Concealed) Power Transmitter Coil (PRx)
OD : 180mm with NFC Antenna

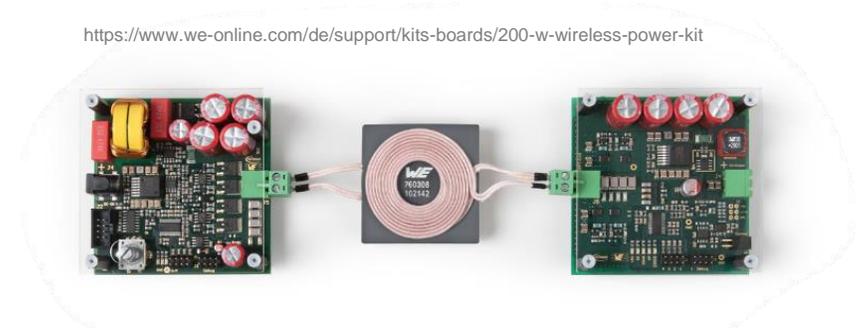


Power Transmitter (PTx)
NFC Antenna Power Transmitter Coil (PRx)
OD : 120mm with NFC Antenna

Design solutions

200 Watt design

<https://www.we-online.com/de/support/kits-boards/200-w-wireless-power-kit>



<https://www.we-online.com/en/products/components/applications/wireless-power-15w>

Qi 15 W Kit

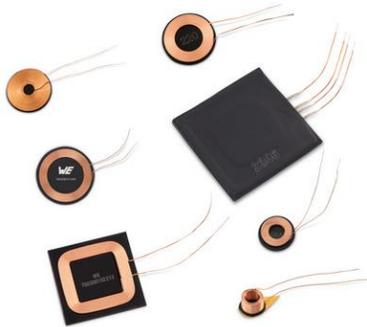


WE WIRELESS POWER COILS

Broadest portfolio of wireless power coils: in total 65 coils

https://www.we-online.com/en/components/products/pbs/power_magnetics/wireless_power_transmission

Receiver coils



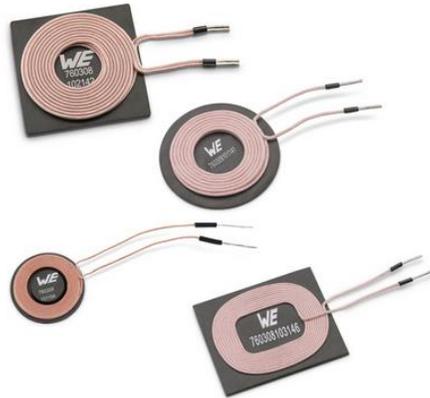
24 coils

Size: 6 – 48 mm

Power: 5 – 80 W

Magnet wire

Transmitter coils



28 coils

Size: 20 – 75 mm

Power: 40 – 400 W

Litz wire

Array coils



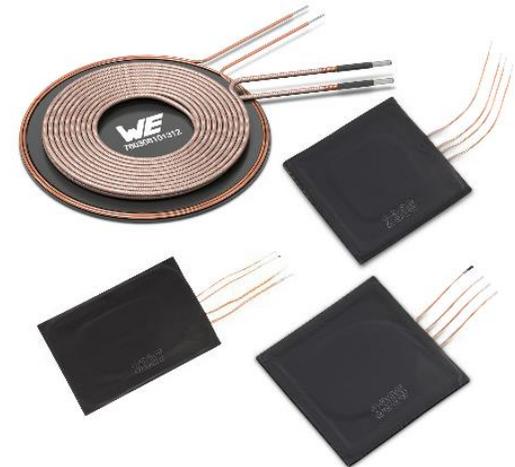
8 coils

Size: 71 – 130 mm

Power: 150 W

Litz wire

WPT / NFC coils



5 coils

Size: 40 – 65 mm

Power: 20 – 100 W

Magnet / Litz wire

200W WPT SOLUTION WITH DATA TRANSFER

<https://www.we-online.com/de/support/kits-boards/200-w-wireless-power-kit>

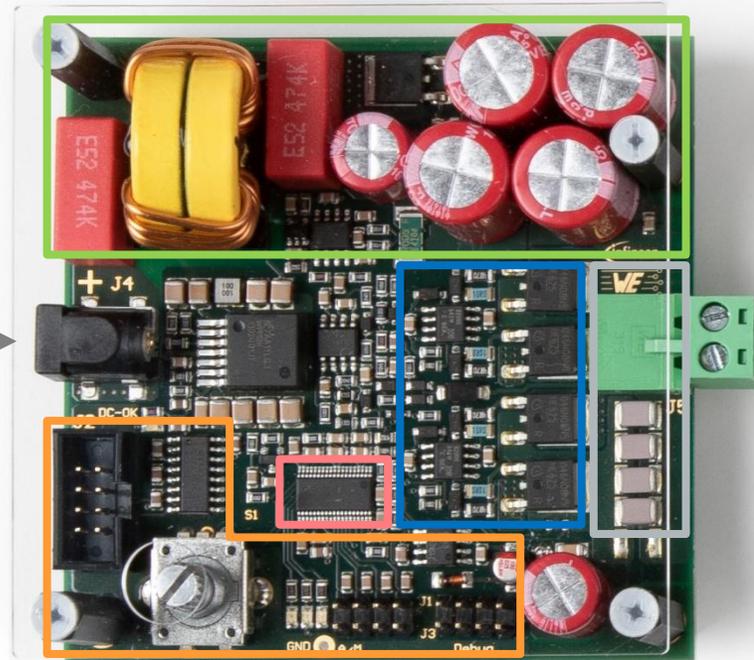
- By changing the switching frequency the output voltage can be regulated
- It is scalable from low to high power (10 W – 10 kW)
- The MOSFETs switch close to the zero crossover point (ZVS)
 - efficiency > 90 %
- It is scalable for many different voltages/currents
- Data transfer from receiver to transmitter possible



NEW 200W WPT SOLUTION WITH DATA TRANSFER

Input power 200 W:

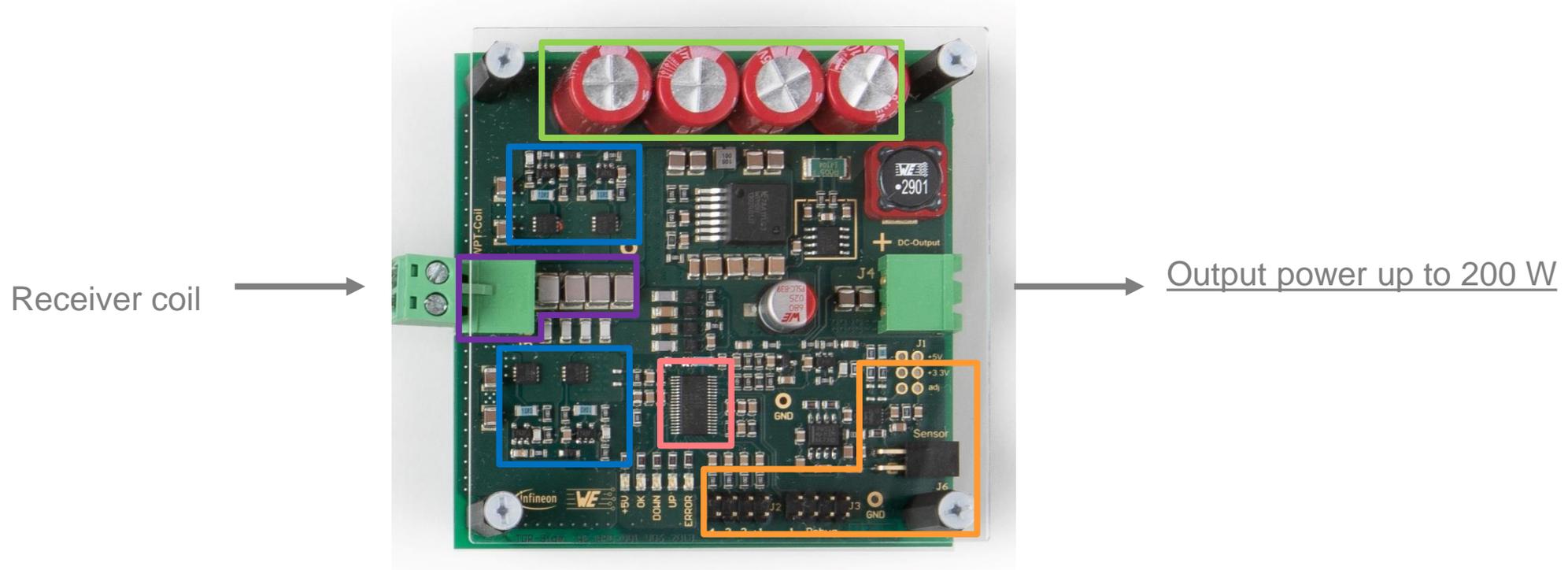
- Input voltage 19...24 V
- Input current 10 A max.



Transmitter coil

- Structures for EMC protection, signal filtering
- Resonant tank: series resonant circuit
- XMC controller to control all signals (PWM, LEDs, RS232, Debug, Encoder, operating mode and other internal signals)
- Full Bridge circuit and bridge control: transformation of DC current to AC current
- Interfaces: RS232 (e.g. display board), debug, operating mode (man./auto.), incremental encoder

NEW 200W WPT SOLUTION WITH DATA TRANSFER

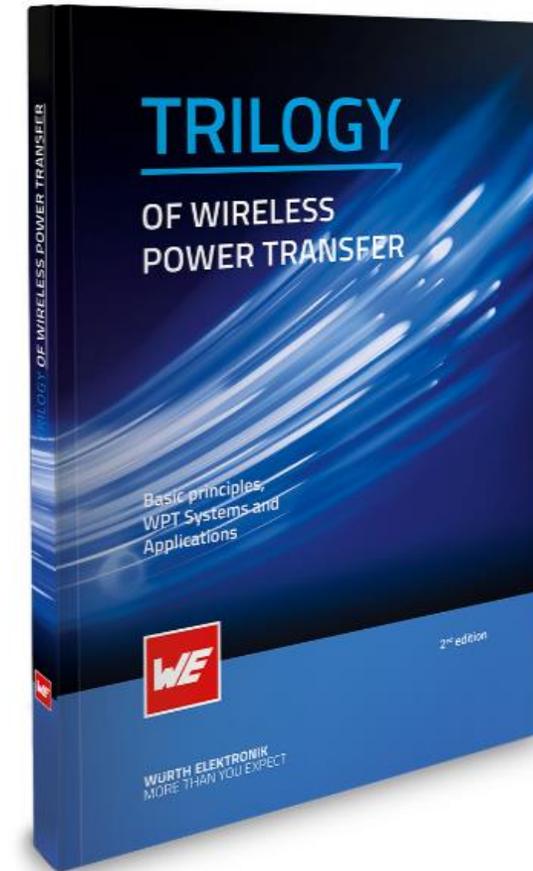


- Smoothing capacitors for a stable output voltage
- Resonant tank: series resonant circuit
- XMC controller to control all signals (PWM, LEDs, I²C, Debug and other internal signals)
- Active rectifier: transformation of AC current to DC current
- Interfaces: I²C (e.g. temperature sensor), debug, interface to define

TRILOGIE OF WIRELESS POWER TRANSFER

https://www.we-online.com/de/components/products/TRILOGY_WIRELESSPOWER

- 2nd edition: now available as ebook or printed book
- Chapter 1: basic principles of WPT
- Chapter 2: WPT Systems
- Chapter 3: Applications (now with NFC part)

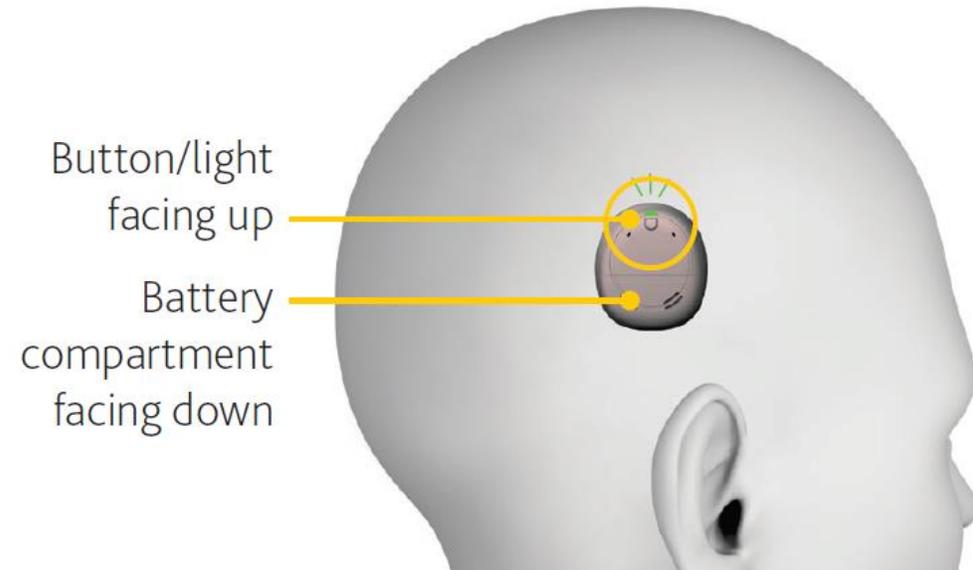


WE customer wireless power applications

APPLICATIONS OF WE CUSTOMERS



Attach your processor



APPLICATIONS OF WE CUSTOMERS

Heinrichs Weikamp gmbh
Charge diving computer



Power < 5W

APPLICATIONS OF WE CUSTOMERS

Schmitz & Söhne Germany
Remote control operating table



Power < 5W

WE WPT solutions and services

SERVICES

- Customization of standard coil parts to customer specific design.
- Fast delivery of samples available for standard parts.
- Downloadable EDA models and CAD files available for all standard parts on the website.
- RED Expert ([Wireless Power Transmission - REDEXPERT \(we-online.com\)](http://we-online.com))
- Mix and Match Table ([Mix and Match for Wireless Power Coils \(we-online.com\)](http://we-online.com))
- Resonant tank calculation and support with designing the Resonant tank calculation according customer specific application.
- Application Notes on a broad range of interesting topics.
- 15W development kit and 200W design to get a better hands on experience of wireless power transfer. ([Wireless Power Development Kit from Würth Elektronik \(we-online.com\)](http://we-online.com))
- EMC preliminary tests on a system level for the Wireless power end application
- FEM simulations of coils during the design phase of customer projects

ARGUMENTS FOR WPT PROMOTION

USP – Our selling points:

- *WE* have the broadest publicly available portfolio of wireless power coils
- *WE* do customer specific coils
- *WE* offers Ansys FEM simulations for free
- *WE* have a high volume product line
- *WE* guarantee lifelong availability of all WE-WPCC coils from stock
- *WE* support our customers with our local sales (face-to-face/on-call) and expert team
- *WE* have expert Webinars, customer training and supporting tools (Mix&Match, Red Expert)



WE WPT Paper Work

PUBLICATIONS

WE offers a broad range of application notes and publications about WPT and NFC

Application notes:

[High Power Wireless Power Transfer for the Industrial Environment](#)

[Proprietary wireless power transfer solution for high performance including data transmission](#)

[Impedance Matching for Near Field Communication Applications](#)

[Wireless Energy Transmission – Coil as Key Element](#)

[Wireless Power Charging Coil Changing Considerations](#)

PUBLICATIONS

WE offers a broad range of application notes and publications about WPT and NFC

Industrial papers (EWC):

[Analysis, Design and Optimization of a Combined Wireless Power Transfer and Near Field Communication System](#)

[Circuit and Antenna Design of a Simultaneous Wireless Power Transfer and Near Field Communication System](#)

Design of a Surface-Mounted Qi-Compliant Wireless Power Coil



PUBLICATIONS

WE offers a broad range of application notes and publications about WPT and NFC

Scientific papers (IEEE):

[AC Loss Behavior of Wireless Power Transfer Coils](#)

[Design and Optimization of Simultaneous Wireless Power Transfer and Near Field Communication Systems](#)

[Mathematical Model of the Temperature Rise of a Wireless Power Transfer Coil in DC Operation](#)

Current research projects:

Development of a GaNFET based WPT system for the MHz range (master thesis, start March 2025)

THANKS FOR YOUR ATTENTION

Contact: wirelesspower@we-online.com