



Recent advancements in wireless power transfer in terms of technology and standards

April 2025



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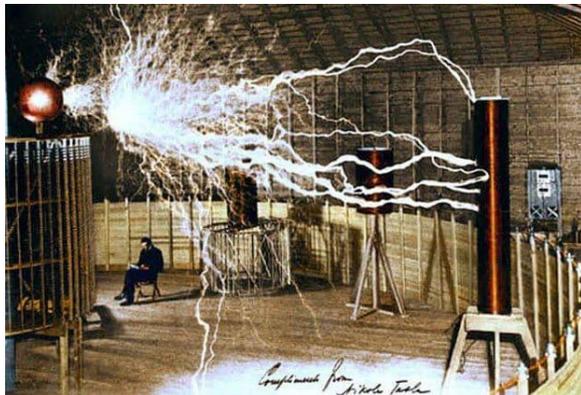
1. Introduction on Wireless Power Transfer
2. Wireless Power Transfer: Category
3. Applications of (Near-Field) WPT
4. Standards and Regulations
5. Challenges

Wireless Power Transfer: Background



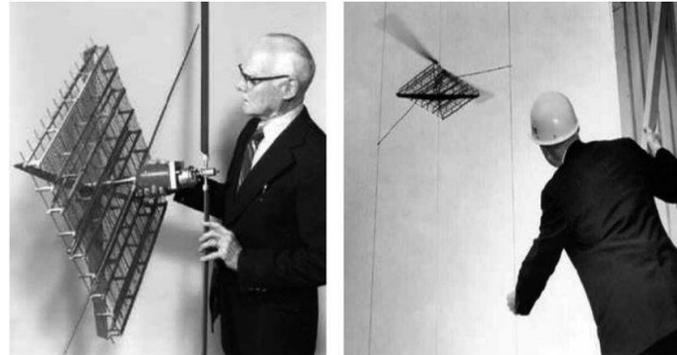
1890s

Nikola Tesla:



1964

Brown:



2007

MIT's WiTricity:



- Industrial Adoption and Applications:

Automotive Industry

Medical Devices

Kitchen Appliances

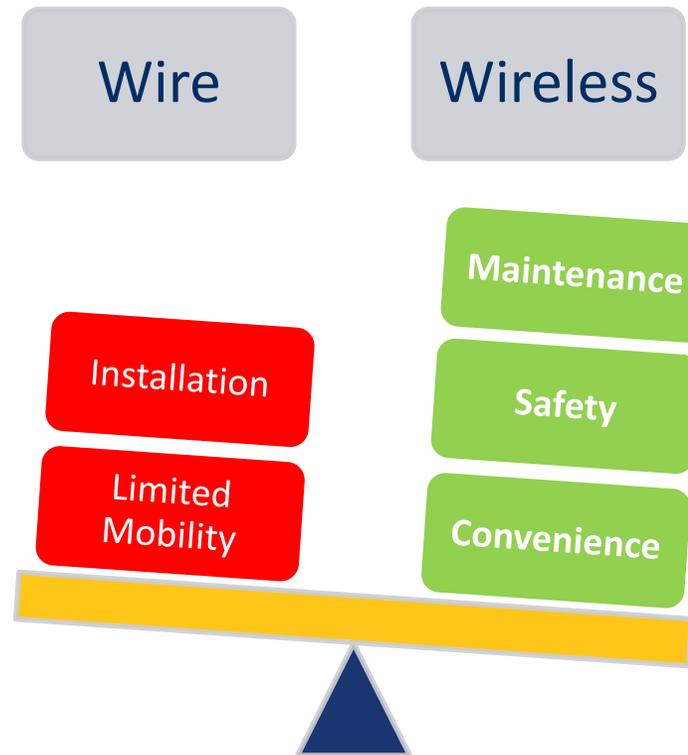
Wireless Power Transfer: Market Growth

- **Market Size:**

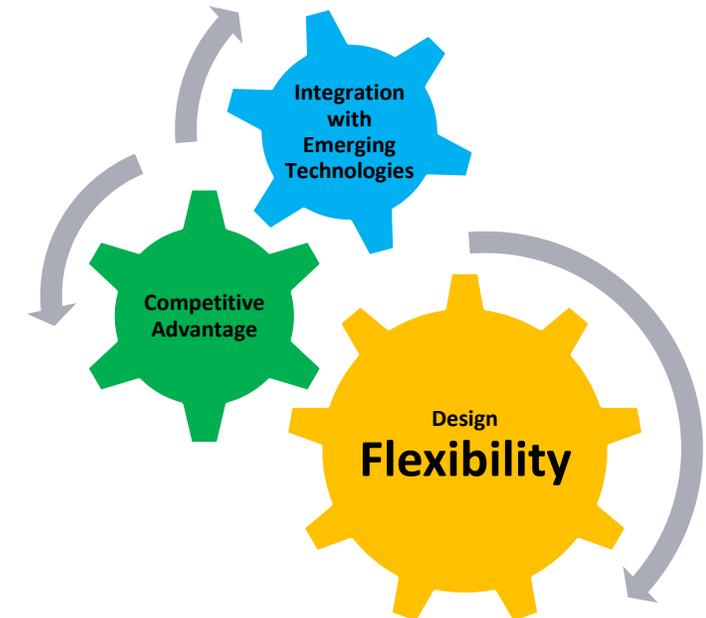
- USD 35.13 billion in 2021
- USD 170.19 billion by 2029



- **Comparison with Wired Power Transfer:**



- **Attractiveness to Companies:**

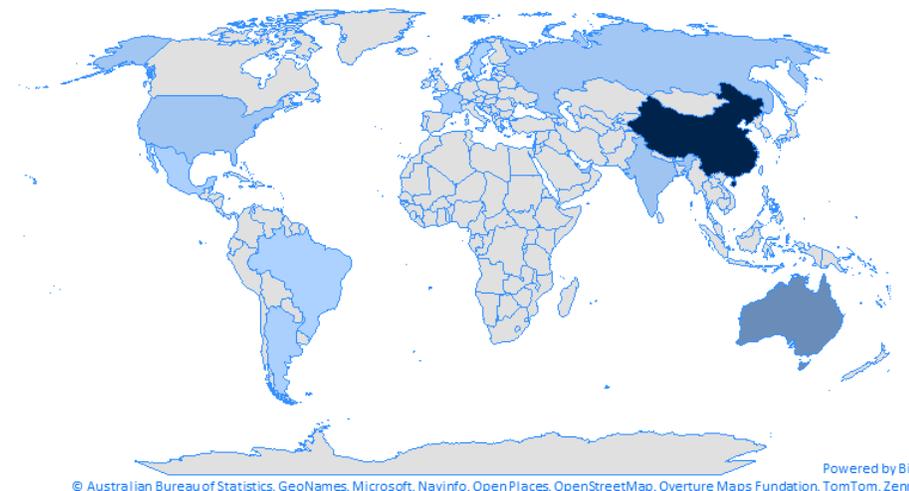


Wireless Power Transfer: Market Growth

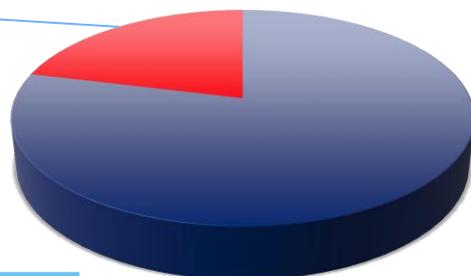
- Electric Vehicle Charger market Size:



- WPT Market Analysis:



Power Transmission Market
20.3%
WPT



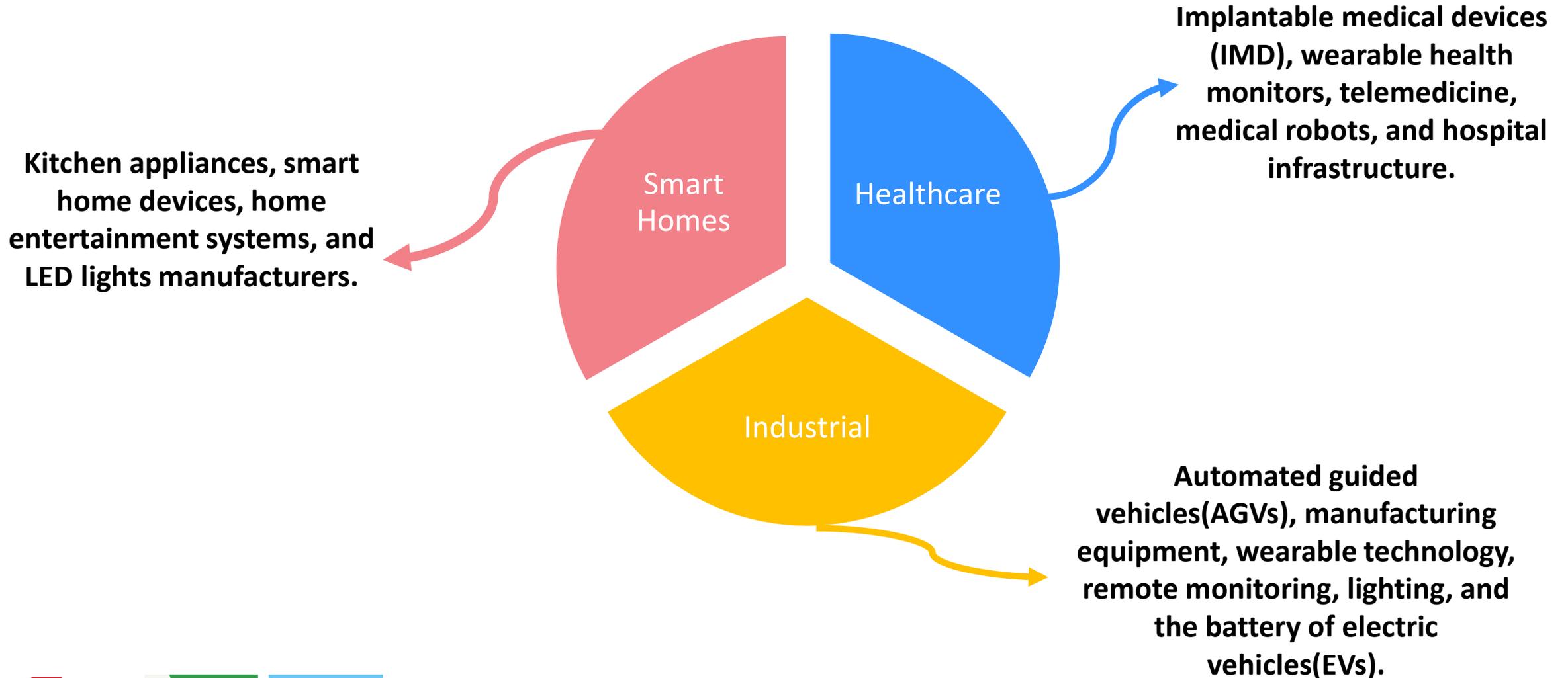
Dominating Region

Asia Pacific

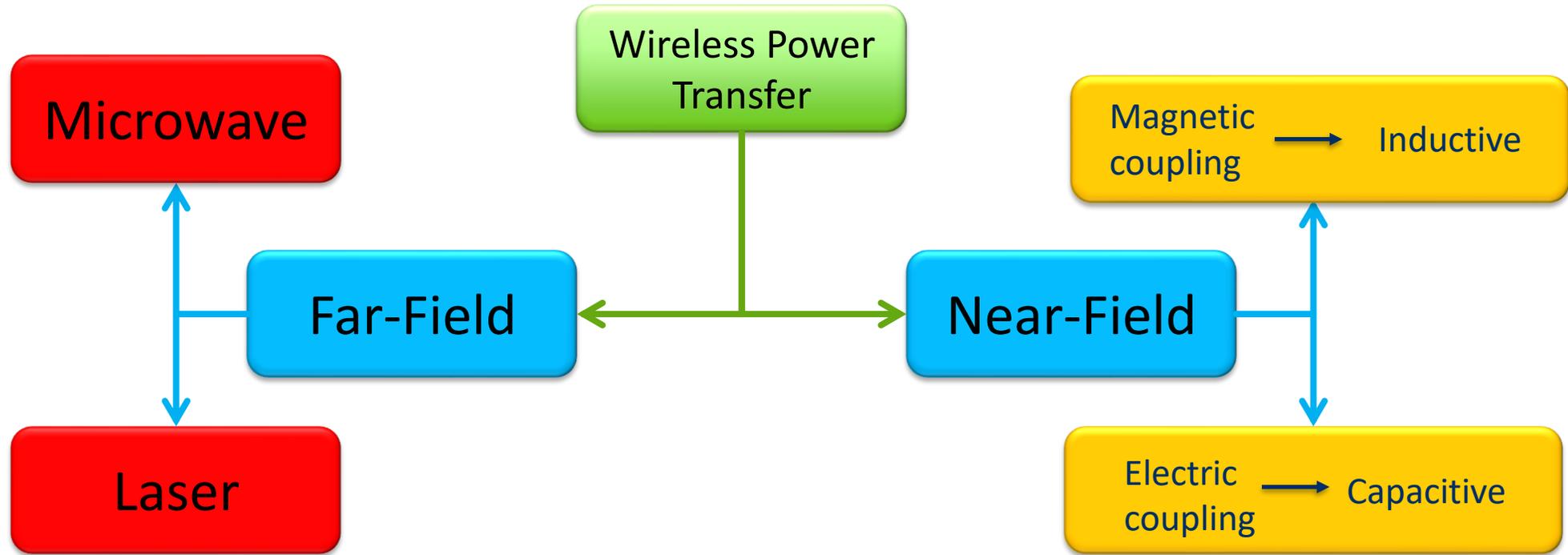
45%



Application of Wireless Power Transfer

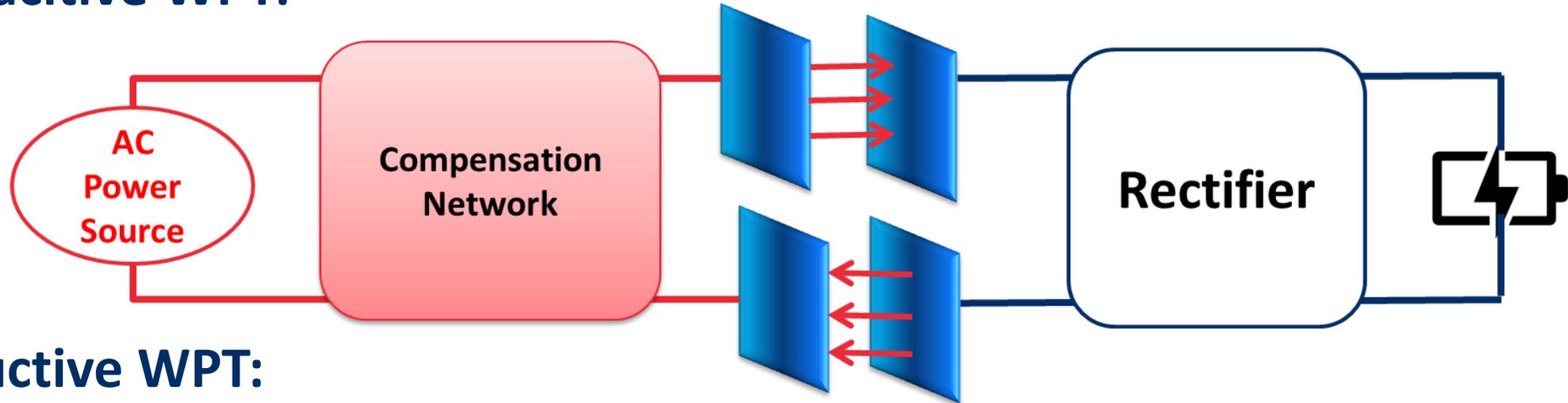


Wireless Power Transfer: Category

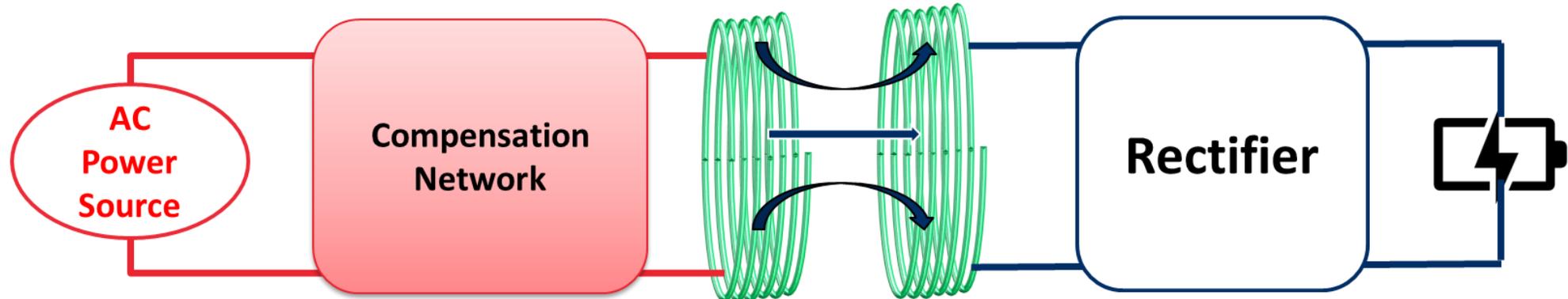


IPT and CPT in Simple Word

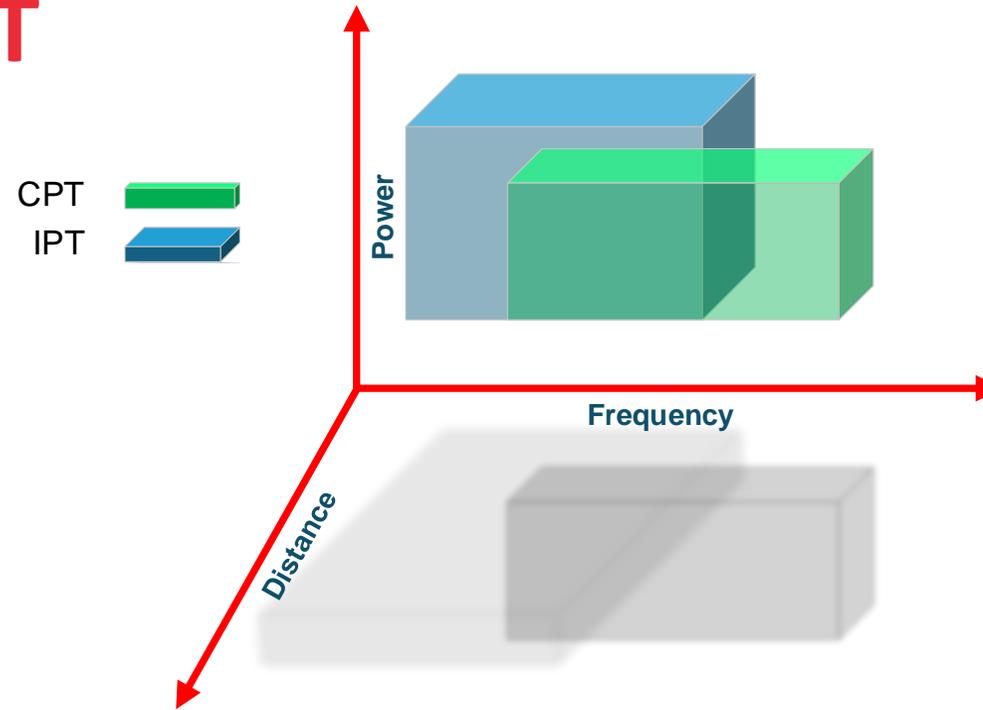
- **Capacitive WPT:**



- **Inductive WPT:**



Near-Field WPT



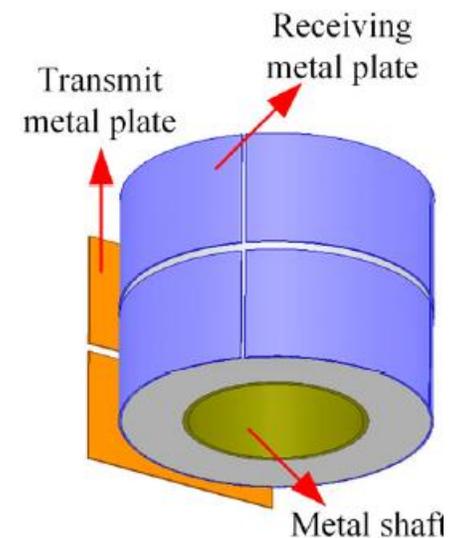
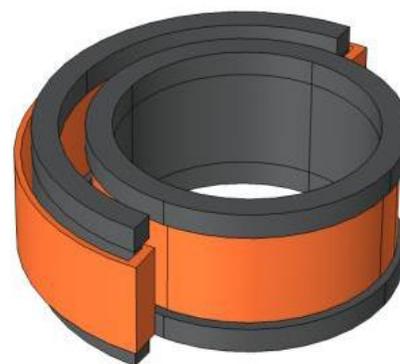
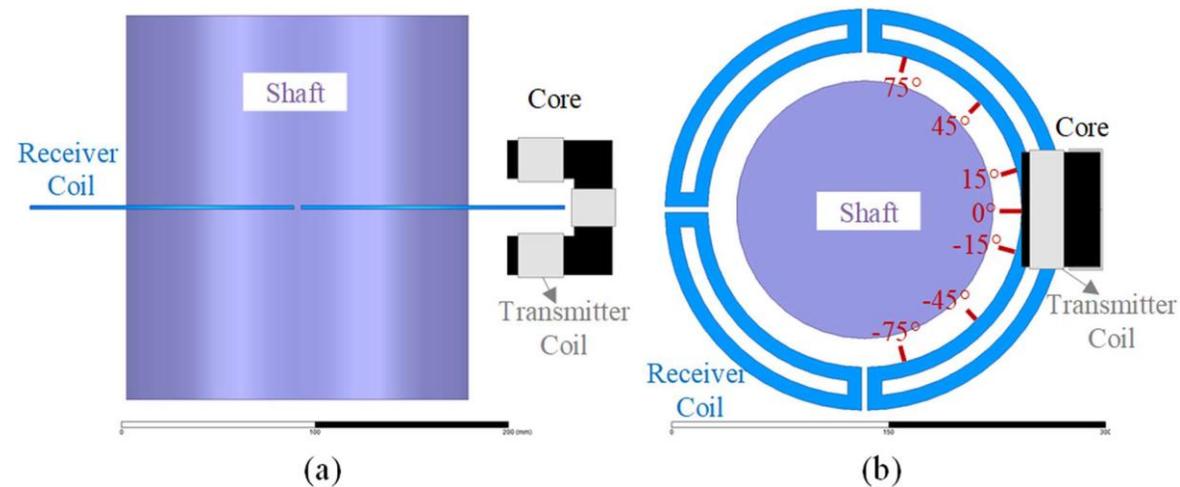
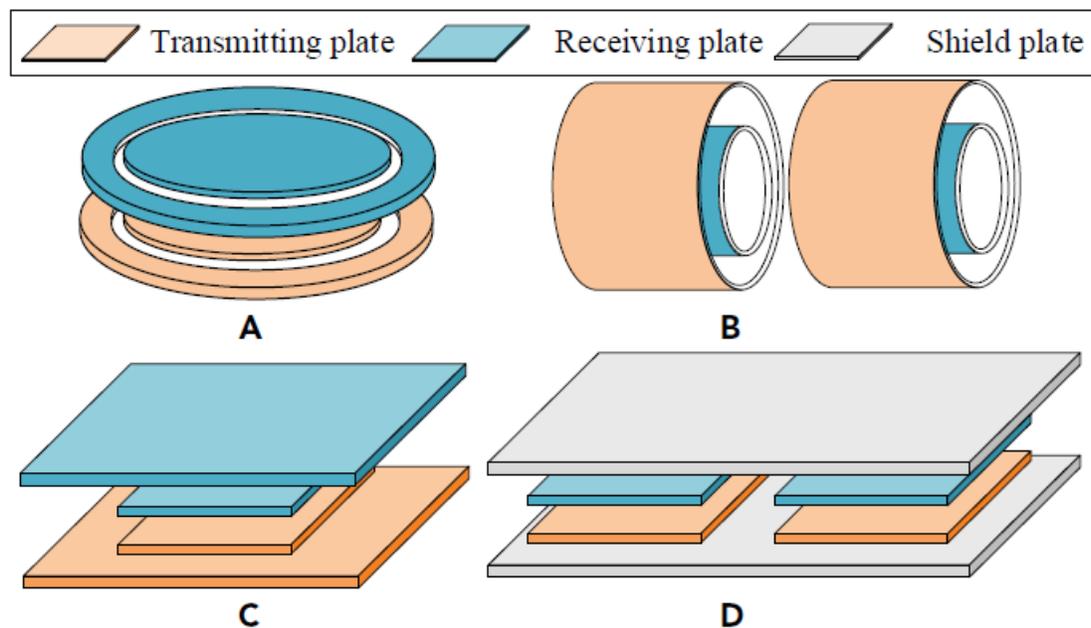
WPT Metrics	Inductive	Capacitive
Frequency	up to 200 kHz	up to 15 MHz
Output Power (W)	up to 27000	up to 5000
Distance (cm)	up to 30	up to 20
Efficiency (%)	up to 98	up to 96.3

Applications

Near-Field applications in Medical, Logistic and other industries

Different Plate Structures of WPT

- Ring and Flat type:

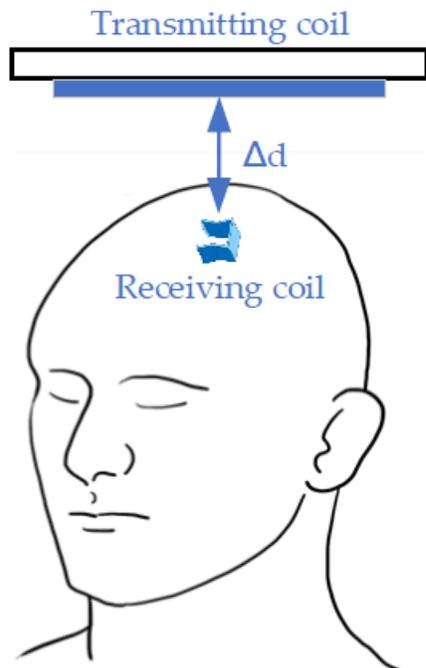


Near-Field WPT: Medical Application

- **Deep Brain Stimulation:**

Power gain of 0.1%

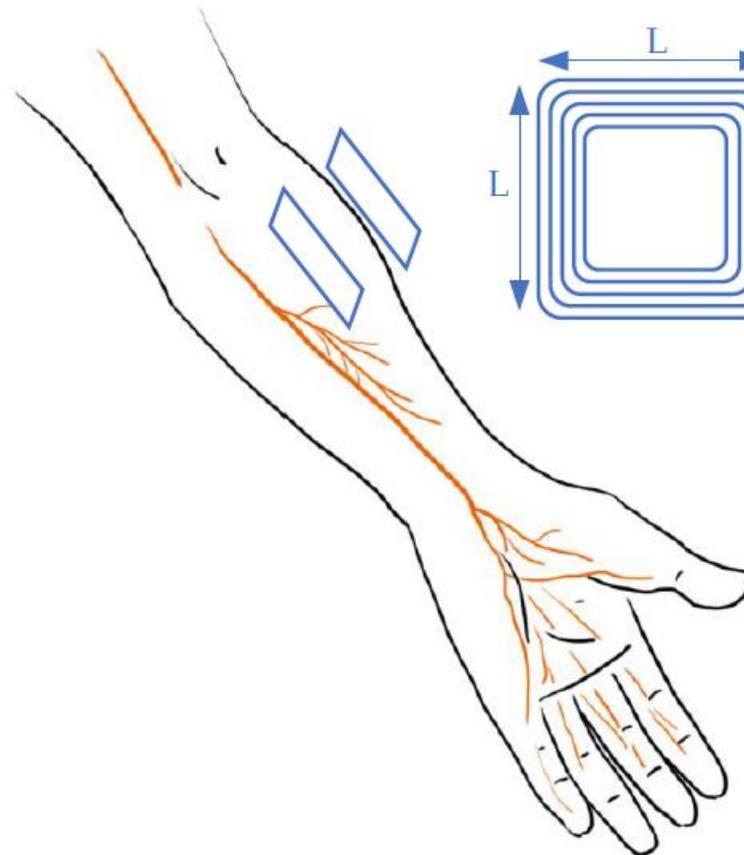
Transmitting distance of 15 mm



- **Tissue Implant:**

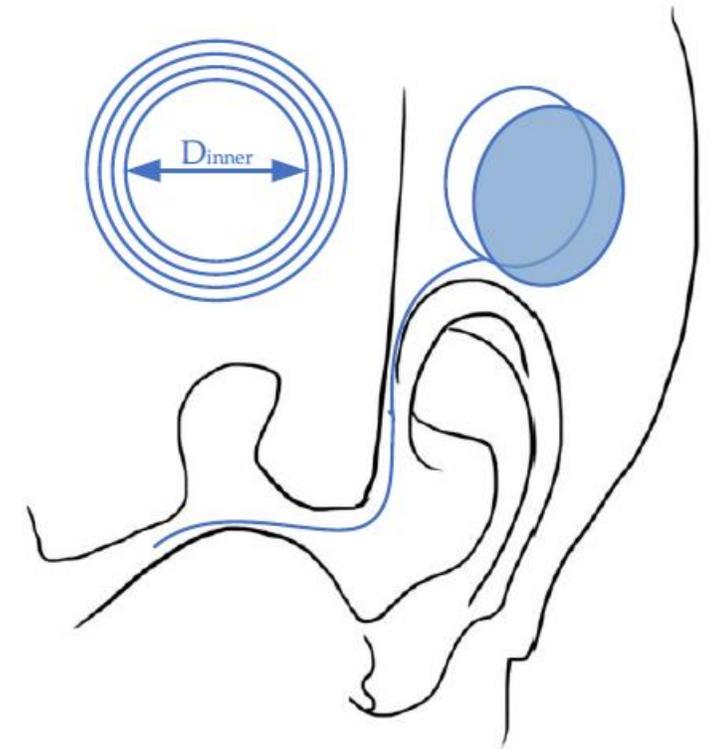
Frequency: 13.56 MHz

Provide 5V



- **Cochlear Nerve Stimulation:**

Power: 20mW to 40mW



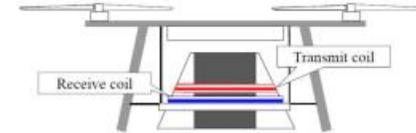
Comparison of WPT in different medical applications

Category	Frequency	Output Power	Efficiency	Media
deep brain stimulation.	120 kHz-907.5 MHz	118 μ W-100 mW	~0.04%-3.16%	Head equivalent Phantom, Porcine tissue, Man's Head Model, Air
retinal prosthesis	125kHz-160MHz	320 μ W-60mW	30%- 60%	Air & phosphate buered saline
pacemakers	20kHz-198MHz	200 μ W-5W	6.0%- 88%	Mannequin/por k fat/air

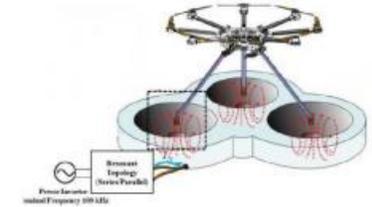
Near-Field WPT: UAV

Charger Design:

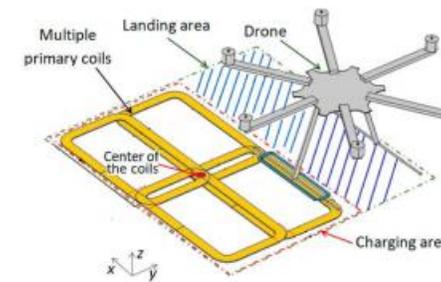
- Flat shape
- Helical coils
- Square coil
- Magnetic coupler
- Circular coils
- PCB circular coil



(a)



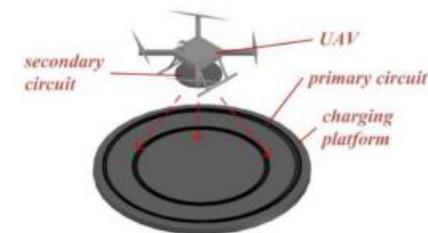
(b)



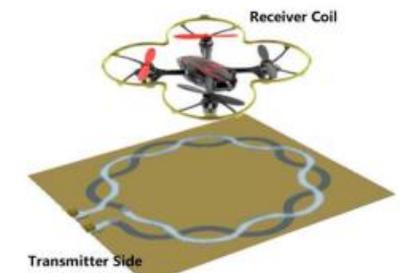
(c)



(d)



(e)



(f)

Comparison summary for UAV application

Name	IPT Technology	CPT Technology
Frequency range	10's kHz to MHz	1 MHz to 10 MHz
Air Gap Distance	<500mm	<30mm
Compensation Topology	SS-SP	Series L- LC compensation
Power Level	10's to 500W	10's W to 70W
Max Power Efficiency	93%	90%
Technical Analysis	Advantages: Mature Tech. Disadvantage: EMI	Advantages: less EMI Disadvantage: Power level, Distance

Applications: High power → Logistic industry

Automotive industry

- Wireless charging of vehicles: stationary or dynamically
- Low duty vehicles: Passenger electrical vehicles (EV's)
- High duty vehicles: trucks, buses
- Technology: IPT, CPT*



Stationary (up to 270kW*)



Dynamically (up to 190kW*)

Automated guided vehicles (AGV's)

- Automated transportation of packages in warehouses
- Stationary or dynamical charging
- Technology: IPT or CPT



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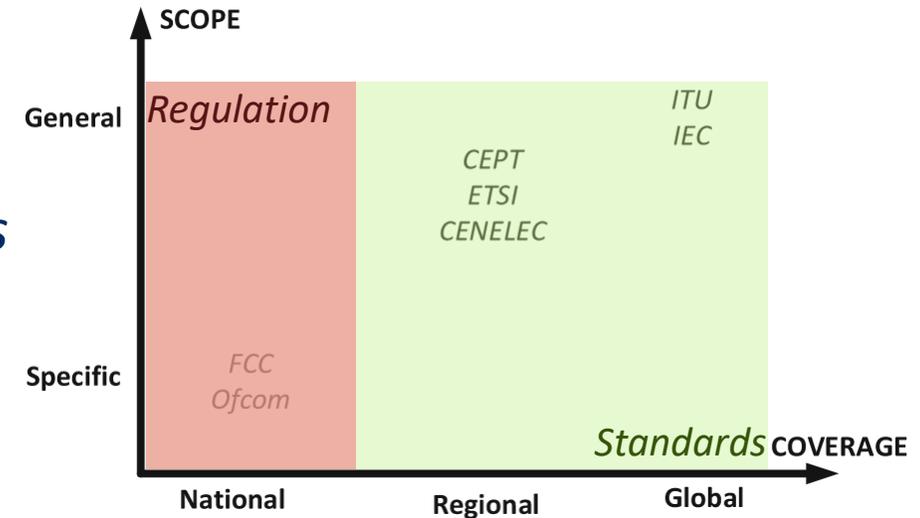
Standards and Regulations

Finding the right standards for the right application

Standardization and regulation procedure

■ Relation Standard-Regulation:

- Standard: Focus on *how to comply*
- Regulation: Focus on generic *requirements*
→ Reason to use standards!



■ Wireless Power Transfer devices → Interdisciplinary nature:

- Telecommunication → datalink between Tx-Rx, frequency bands, emitted power
- Electrical → Electromagnetic compatibility/immunity (EMC/EMI)
- Health & Safety → Radiation exposure

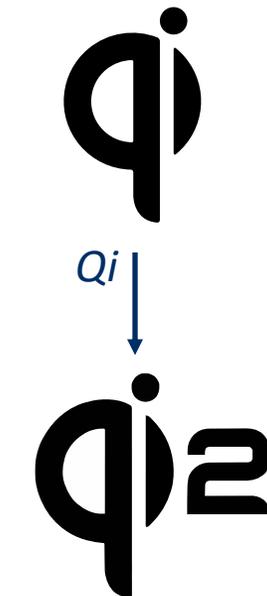
Standards for WPT applications: low power

NFC Forum

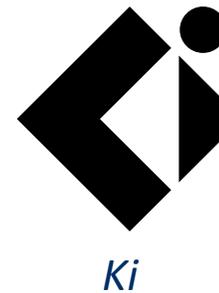


WireLess Charging Specification (WLC)

WPC



LEV



AirFuel Alliance

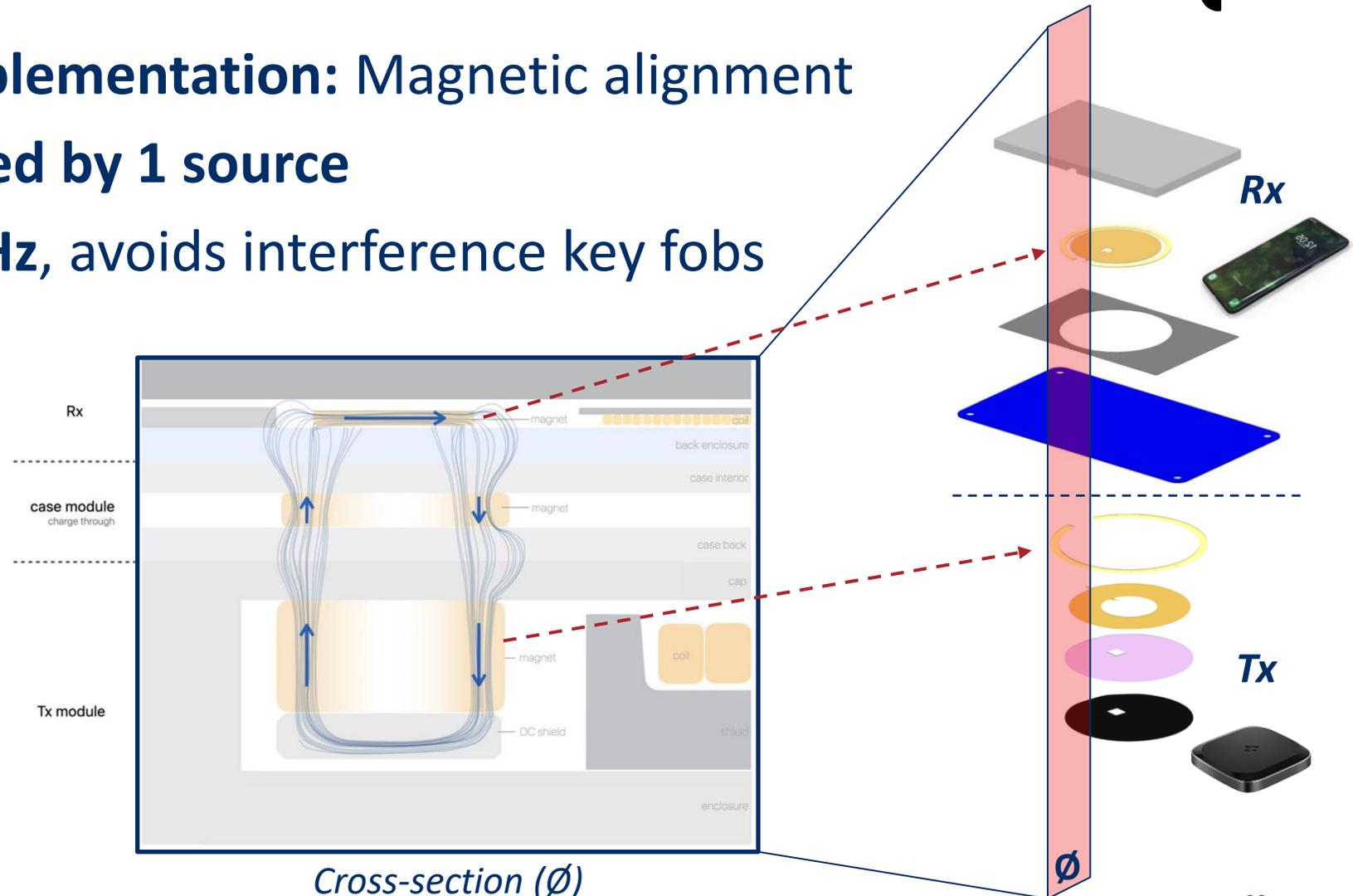
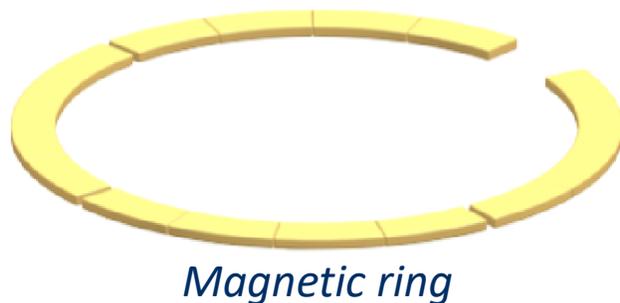


AirFuel™
Wireless Power



Zoomed-in: WPC's Qi2 new standard

- **MagSafe-principle implementation: Magnetic alignment**
- **Multiple device charged by 1 source**
- **New frequency: 360kHz, avoids interference key fobs**



Standards for WPT applications: low power

Standard (organization)	Qi2 (WPC)	WLC (NFC)	AirFuel Resonant
Applications	Wearables, phones	Small wearables, IoT	Headsets, phones, laptops
Power	5 (BPP) – 15W (MPP)	0 – 1W	1.5W – 50W
Distance	4cm	2cm	Few cm's
Power frequency	87-205kHz, 360kHz	13.56MHz	6.78MHz
Data transmission	In-band (2 kbit/s)	RF-link (424 kbit/s)	BLE (2Mbit/s)
Multiple device	Yes	Yes	Yes (max 8 Rx's)



Standards for WPT applications: high power

SAE



J2954:“WPT for Light-Duty P(H)EV and Alignment Methodology”.

- Power Classes: 3.7, 7.7, 11.1kW
- Frequency: 79-90 kHz
- Distance: 10-25cm

Future:

- Heavy-duty EV's (J2954/2)
- In-motion charging (J2954/3)
- Bidirectional charging

UL



UL2750:“WPT Equipment for EV's”.

- ~J2954
- Interoperability with J2954

IEC



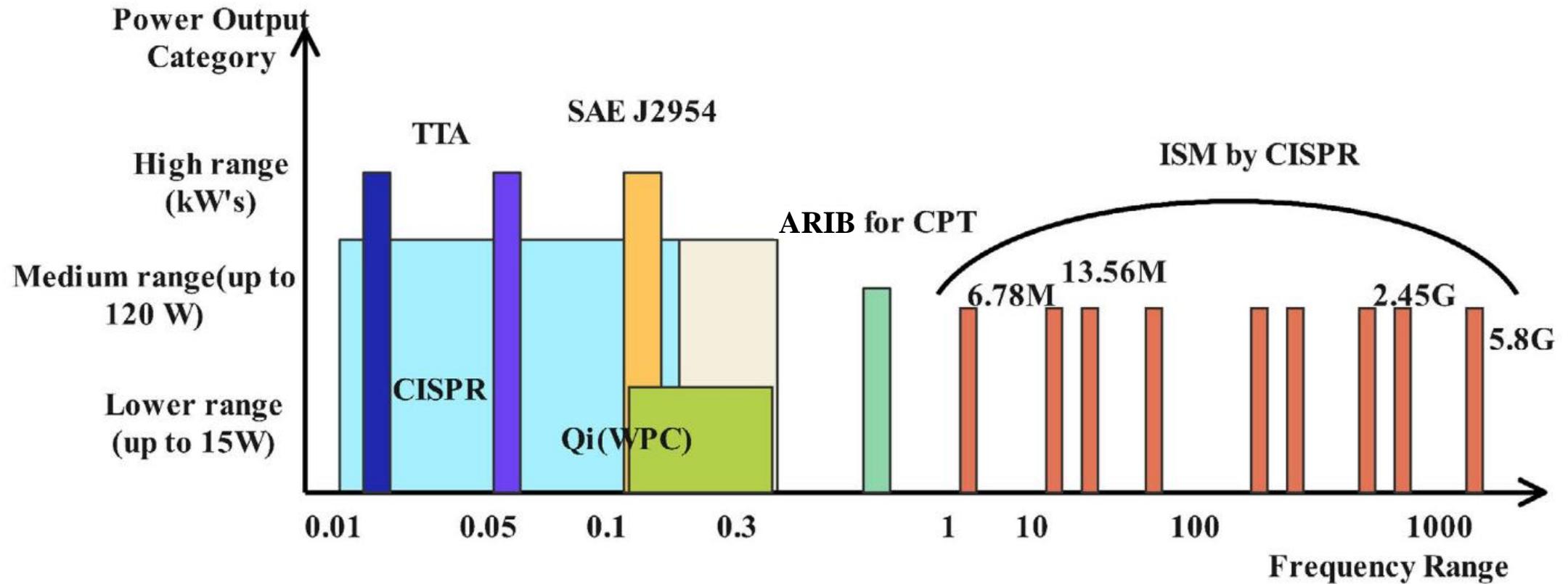
IEC61980:“Electric vehicle WPT systems”.

- Power Classes: 3.7, 7.7, 11.1, 22.2kW, 50* → 500kW*
- Frequency: 19-21kHz and 79-90kHz

Future:

- Heavy-duty EV's
- 2/3-wheel vehicles
- In-motion charging
- Bidirectional charging

Standards: Frequency bands

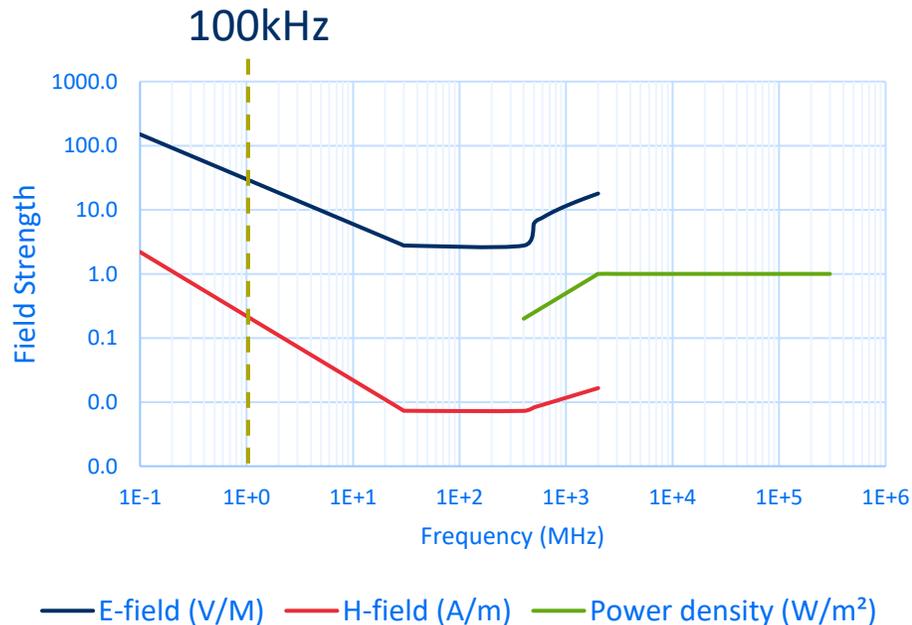


Standards: Health (radiation)

ICNIRP 2010, 2020



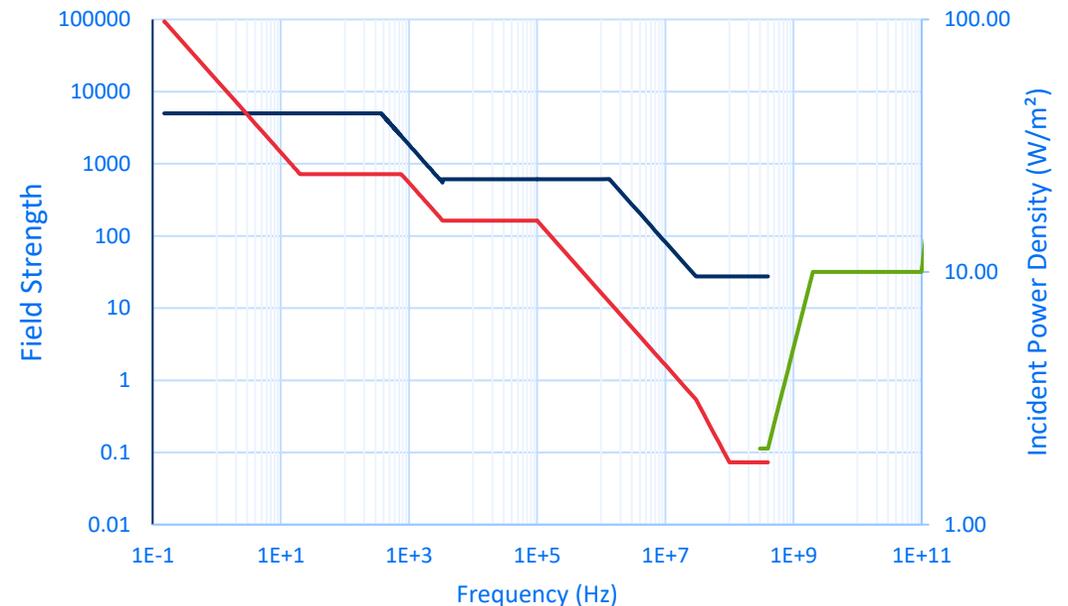
- 2010: 0 to 100kHz (nerve stimulation)
- 2020: 100 to 300 GHz (heating)



IEEE C95.1-2345-2014



- Exposure to MF, EF, EMF
- Frequency: 0 to 300 GHz
- Specific Absorption Rate (SAR)*

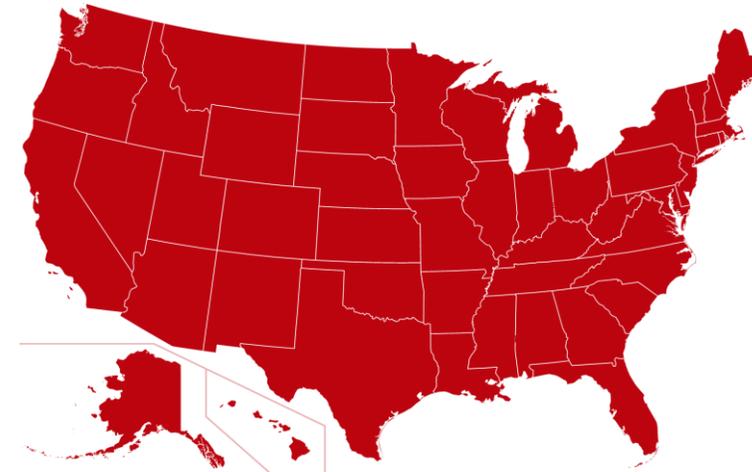


Regulations and needed standards

1. European Union



2. United States of America



Regulations and needed standards: Europe



- A WPT-device can be charged:

without
Tx-Rx-communication



Ex.: Electrical toothbrush

Case 1

with Tx-Rx-communication at
 $f_{\text{power}} = f_{\text{communication}}$



Ex.: Qi-smartphone charger

Case 2

with Tx-Rx-communication at
 $f_{\text{power}} \ll f_{\text{communication}}$



Ex.: J2954 certified EV charger

Case 3

Regulations and needed standards: Europe



▪ Depending on the case → different Directives:

- Low Voltage Directive (LVD), 2014/35/EU
- Radio Equipment Directive (RED), 2014/53/EU
- EMC Directive (EMC), 2014/30/EU

RED

- Human Safety
- No interference
- Frequency bands

LVD

- Human Safety
- Interoperability
- Efficiency

EMC

- Compatibility
- Health & Safety
- Frequency bands

Regulations and needed standards: Europe



Case	Low voltage Directive	Radio Equipment Directive	EMC
1  	Safety: IEC 60335	/	EMF: EN 62311 or 62479 EMC: EN 55011
2  	Safety: IEC 60335	*EMF: EN 62311 *EMC: EN 301 489-1/3 *Radio: ~frequency EN 300 330, - 220, -440	EMF: EN 62311 or 62479 EMC: EN 55011
3 	Dependent of the power rating and application	*EMF: EN 62311 *EMC: EN 301 489-1/3 *Radio: ~frequency EN 300 330, -220, -440	EMF: EN 62311 or 62479 EMC: EN 55011

- *EN 303 417: harmonized standard for WPT devices (covers Art. 3.2 RED)

Regulations and needed standards: Europe



- **Frequency bands (EN 303 417):**

- @6.78MHz: 42dB μ A/m

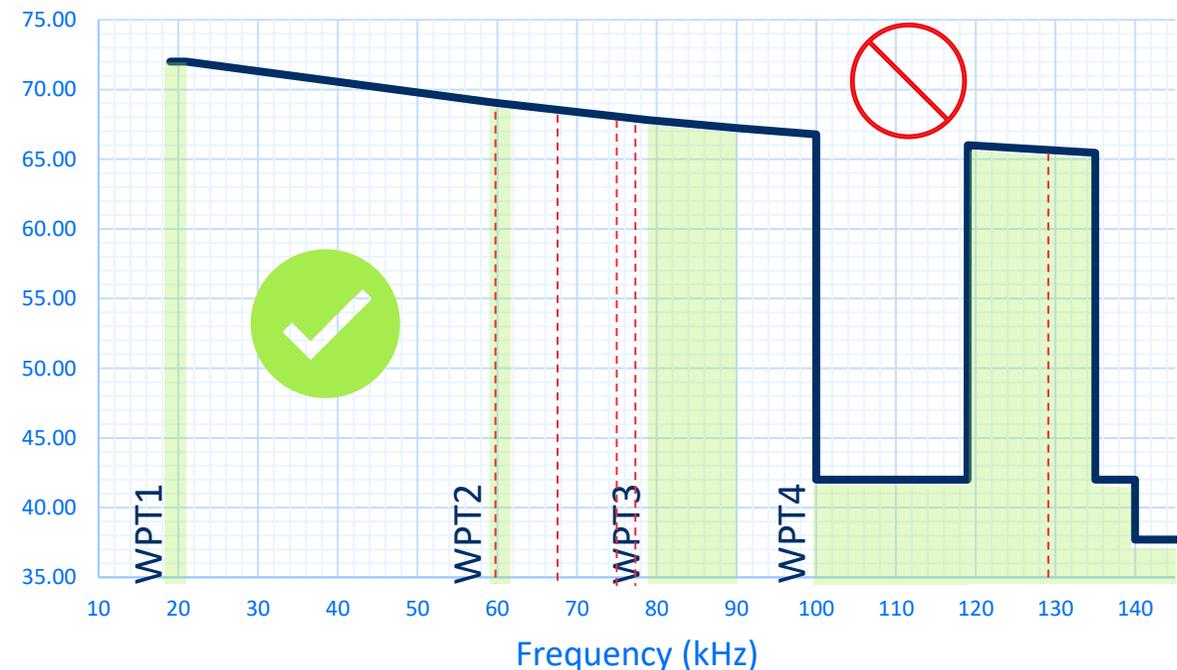
- **Specific frequency bands**

- WPT1: 19-21kHz
- WPT2: 59-61kHz
- WPT3: 79-90kHz
- WPT4: 100-300 kHz
- WPT5: 6.765-6.795MHz

- **Remark: Protected frequencies!**

- (red dashed line) Radio, military, emergency...

H-field strength limit (dB μ A/m) at 10m



Regulations and needed standards: USA



Regulation organization: Federal Communications Commission (FCC)

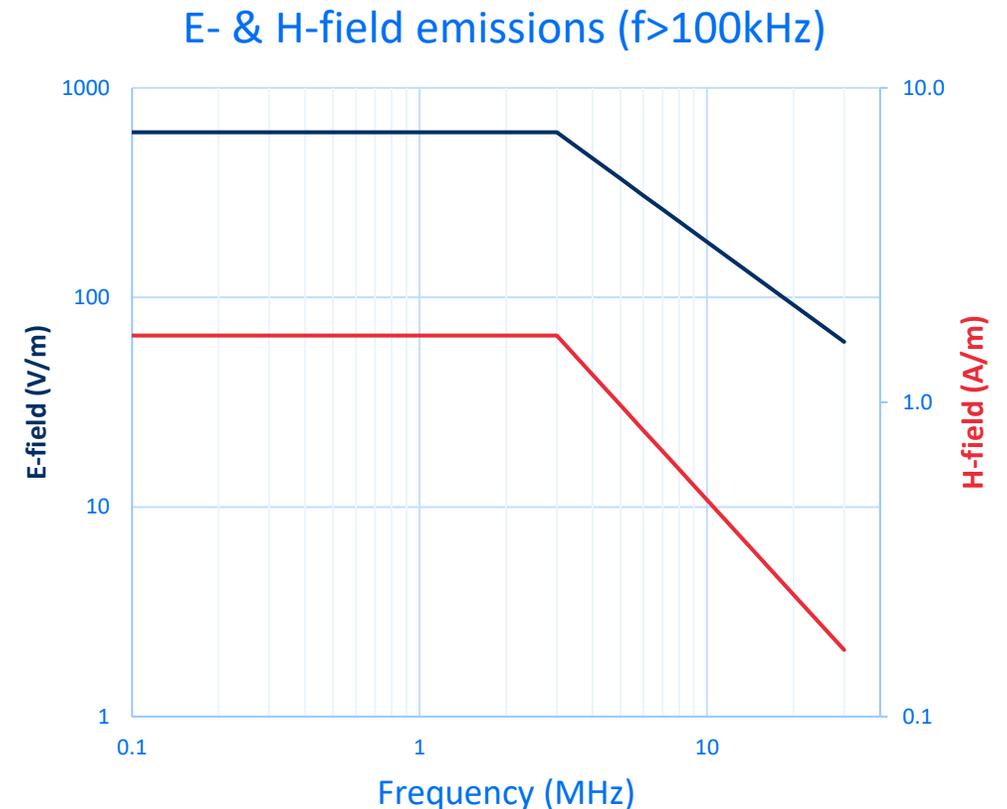
- **WPT-device: Intentional Radiator → FCC Part 15 C**
 - Certification is necessary by a *Telecommunication Certification Body* (ex.: UL)
 - Bounded to proposed f -bands: from 90kHz → 4,4GHz)
- **WPT-device: working in an ISM-band → FCC Part 18**
 - Some frequencies with unlimited radiation limit
 - Otherwise: low exposure
- **Both: RF exposure assessment per KDB 680106**

Regulations and needed standards: USA



Radiofrequency exposure (KDB 680106)

- $f > 100\text{kHz}$:
 - See graph
 - Reference time: 6min
- $f < 100\text{ kHz}$:
 - External (peak) temporal field strength:
 - E-field: 83V/m
 - H-field: 90A/m



Challenges

Near-Field Application Challenges in terms of sustainability and technology

Sustainable Development Goals (SDGs): WPT



Capacitive WPT: Challenges

- **Efficiency and Performance Issues**

- Low Power Transfer Efficiency
- Limited Transfer Distance

- **Interference and Safety Concerns**

- Electromagnetic Interference (EMI)

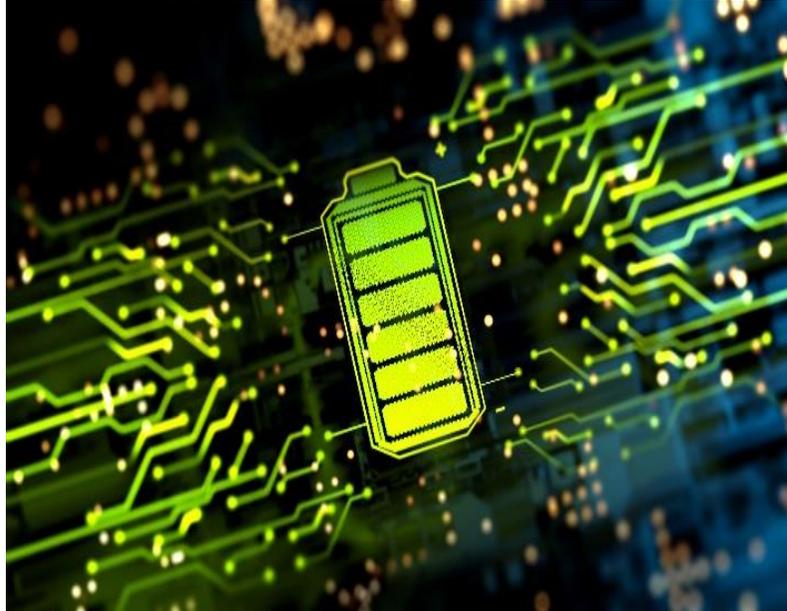


- **Technical and Design Constraints**

- Misalignment Sensitivity
- Parasitic Effects
- Multiple Receiver Design

Inductive WPT: Challenges

- **More 'mature' technology than CPT**
- **Challenges:**
 - Transfer Distance & Efficiency
 - Electromagnetic Safety
 - Energy Security
 - Improvement of WPT guidelines



Thank you for your attention!

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