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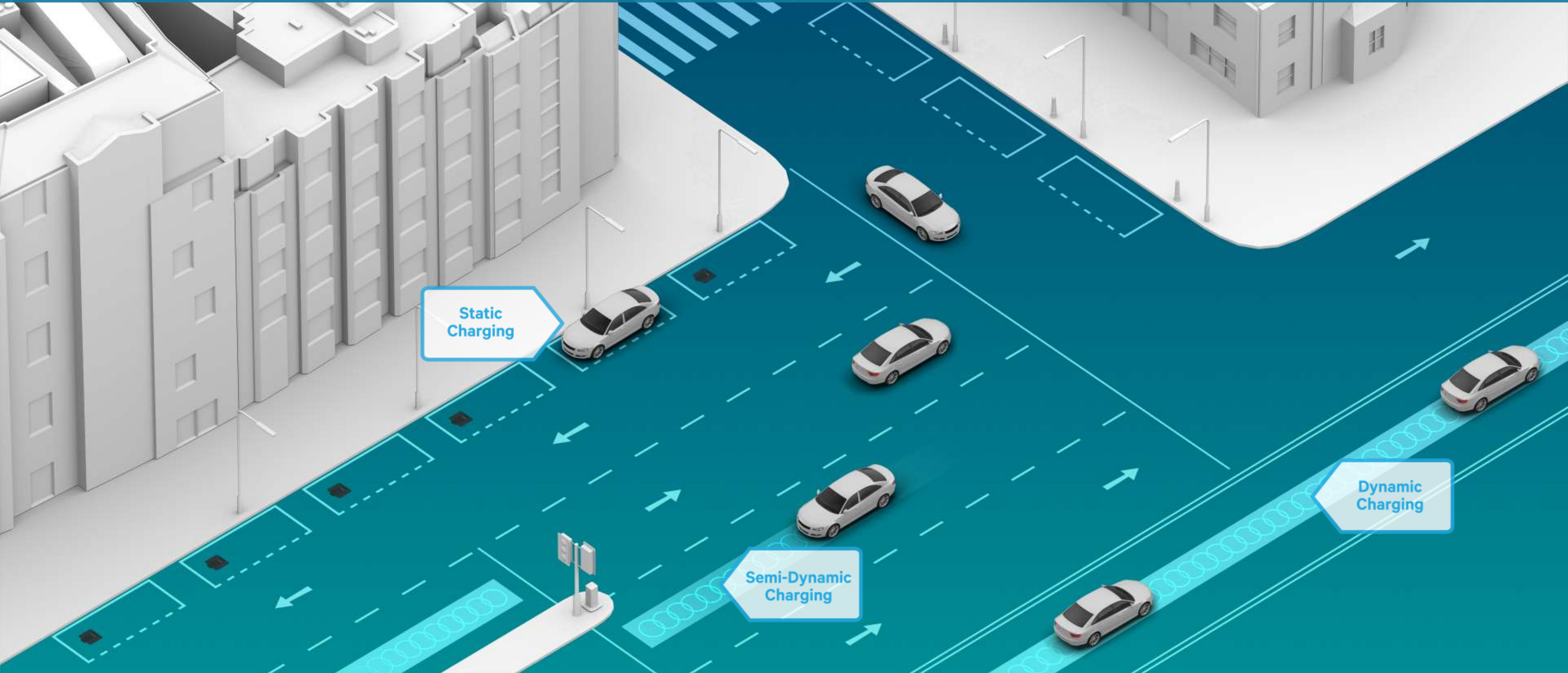
Magnetic solutions towards interoperability for stationary, semi-dynamic and dynamic charging

QUALCOMM HALO™

Factors for EV Market Growth – Ease of use

- **Wireless EV Charging meets our needs**
  - Simple, effortless & convenient
- **Multiplicity of charging opportunities**
  - Charge little, often and everywhere

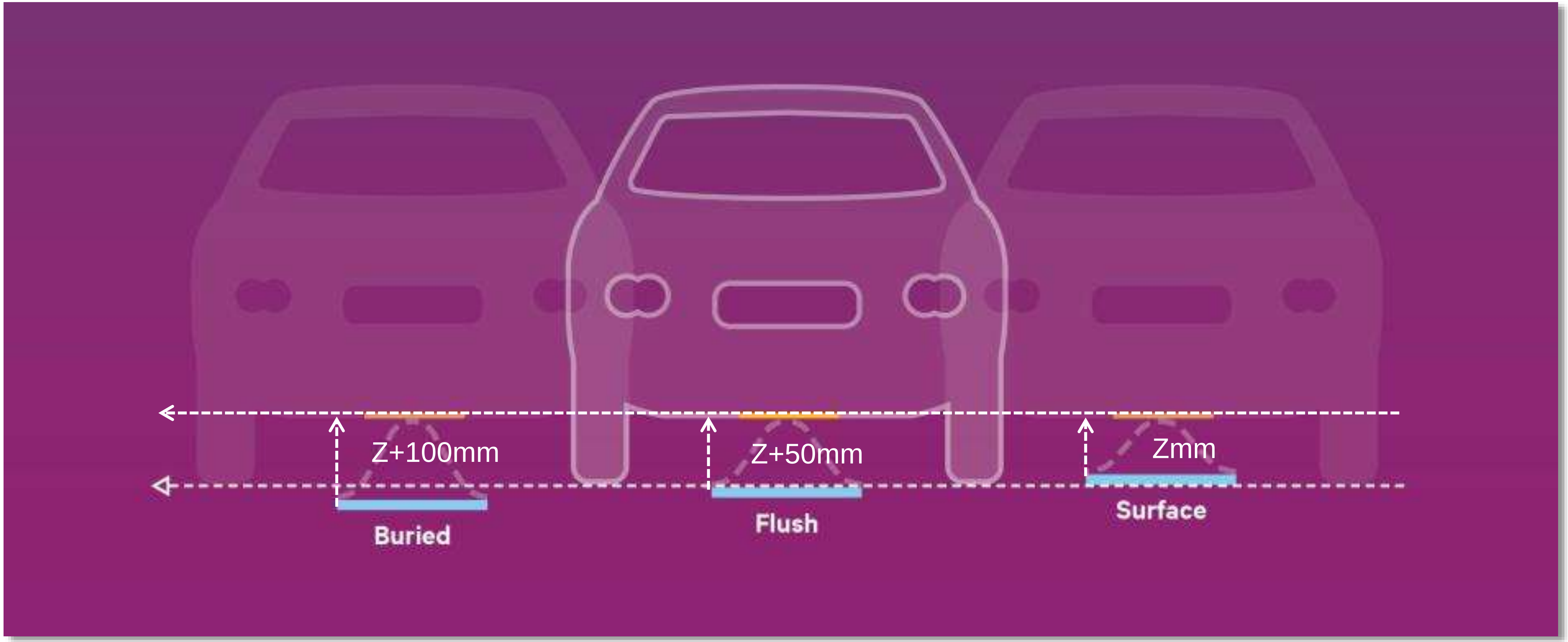


Interoperability Parameters

- Operating Frequency
- Magnetic Compatibility
- Power levels
- Lateral and Longitudinal Tolerance
- Nominal air-gap, vehicle classes
- Various mounting requirements for base pad (surface, flush, buried)
- Pad positions on vehicle and parking slot
- Efficiency Levels
- EMC and EMF Regulatory Compliance
  - Leads to the requirement to limit leakage of electromagnetic energy and potential requirement for FOD and LOP
- Support of an alignment mechanism
- Communications between EV and EVSE

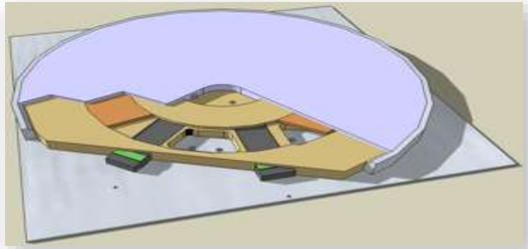
Critical to support different vehicle platforms

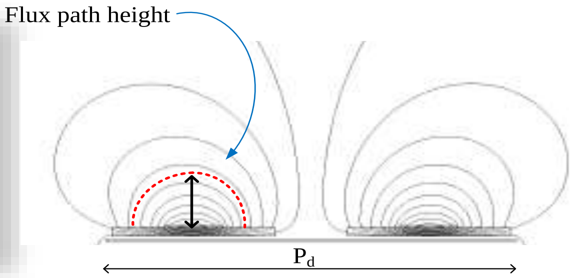
Standards must ensure that different Z Gaps are supported, circular coils may not meet future requirements

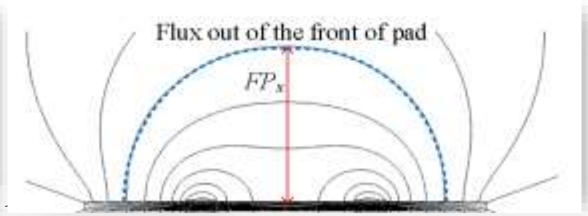


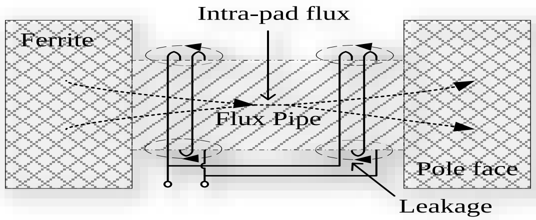
Comparison of Pad Magnetic Architecture

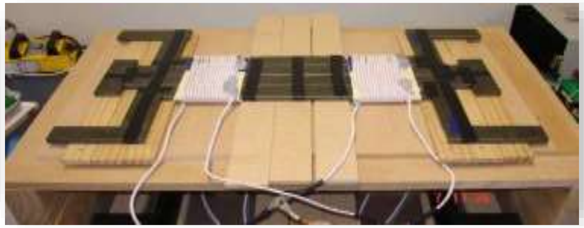
- Circular
  - \+ Low field emissions
  - – Large diameter for z-gap
  - – Low Coupling
  - – Low x/y tolerance
- Solenoid
  - – High emissions
  - – Shielding required
- Solenoid Multi-Coil
  - \+ Good coupling
  - – High emissions
  - – Shielding required
- Double D / DDQ
  - \+ Low field emissions
  - \+ High Coupling
  - \+ Superior z- gap
  - \+ Superior x/y tolerance

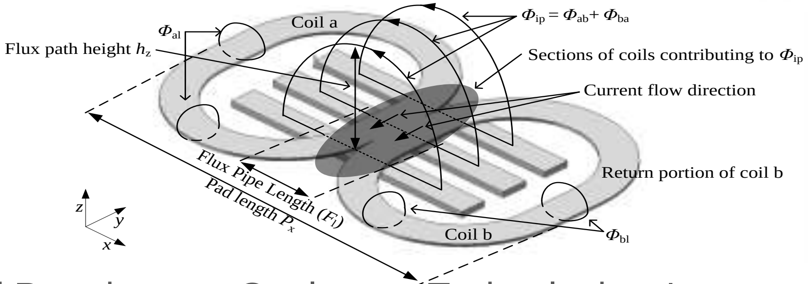


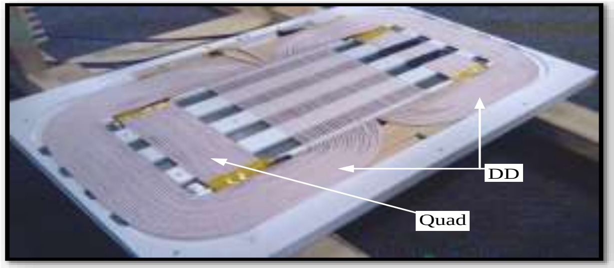








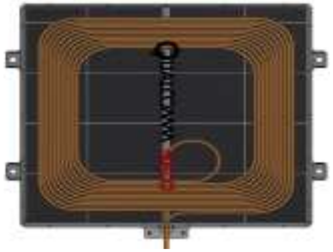




Test conditions – 7.7 kW pad topologies

Vehicle Pad

CR



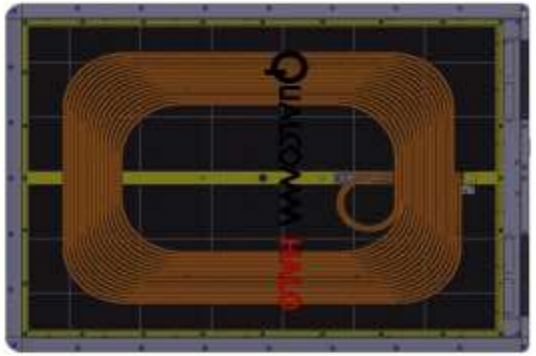

400x400mm

DD


400x400mm

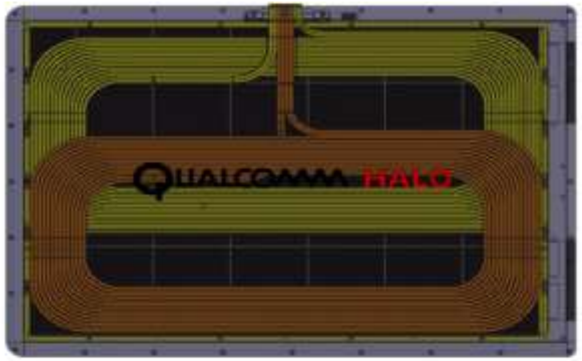
Base Pad

CR

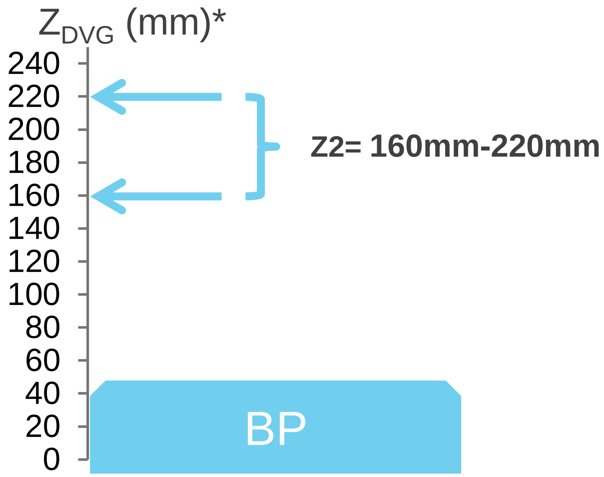


765x575mm

BP



765x575mm



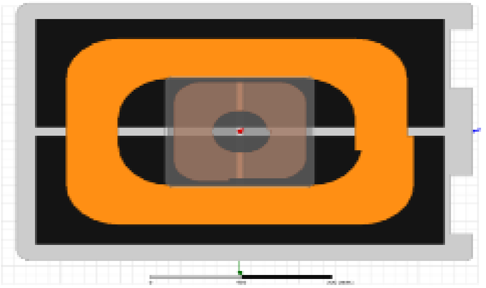
**DVG = vehicle to ground distance*

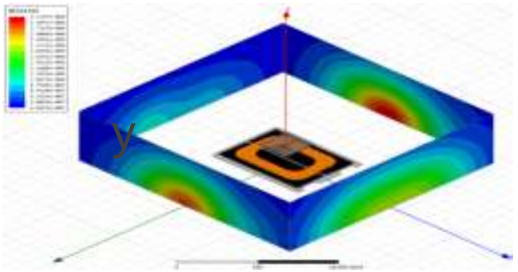
X \ Y	0	50	100	150
0				
50				
75				
100				
150				

Test procedure

Coupling simulation → **Emissions simulation** → **Performance measurement** → **B-Field measurement**

- **Coupling simulation**
- **Emissions simulation**
  - Determine worst case positions
- **Performance measurement**
- **B-Field measurement**
  - @ worst case pos.





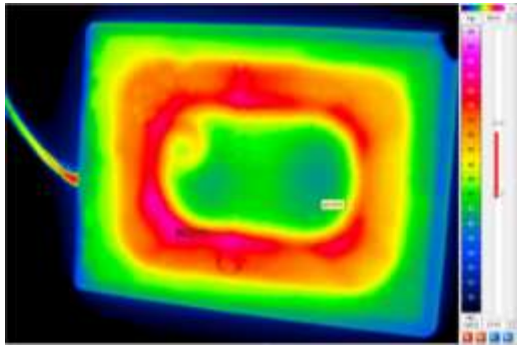
Magnetic Coupling (Simulation)

BP	VP		x = 0 y = 0	x = 50 y = 50	x = 75 y = 100	x = 100 y = 100	x = 100 y = 150	x = 150 y = 150
				Z2min = 160 mm				
CR 575 x 765	CR 400 x 400	k	0.230	0.204	0.164	0.136	0.107	0.054
BP 575 x 765	DD 400 x 400	k	0.273	0.230	0.225	0.209	0.194	0.177
				Z2max = 220 mm				
CR 575 x 765	CR 400 x 400	k	0.133	0.120	0.098	0.084	0.067	0.039
BP 575 x 765	DD 400 x 400	k	0.153	0.133	0.130	0.125	0.116	0.100

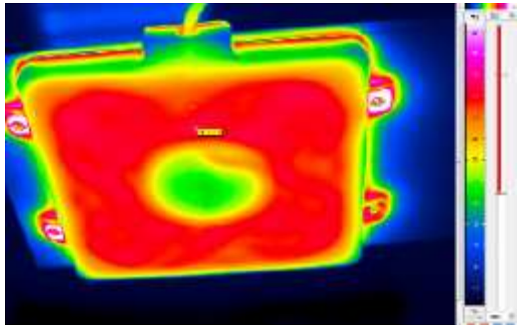
The CR VP has much lower coupling than the DD VP!

Thermal investigations – Maximum operating limits

- Conditions for base pad:
  - Size: 756x575x45 (Volume: 19,8l)
  - Ambient temp. base pad: 35°C
  - Max. allowed primary pad surface temp: **95°C** (according to UL 2750)
    - ΔT_{max}=35K to have 25K margin for pad with integrated power electronics
- Conditions for vehicle pad:
  - Size: 250x250x20 (Volume: 1,25l)
  - Ambient temp. vehicle pad (under hybrid car): 60°C
  - Max. allowed vehicle pad surface temp: 110°C
    - ΔT_{max}=50K to meet 110°C max. vehicle pad surface temp. and **120°C max**. vehicle pad core temp.)



Temperature measurement with 456 AT



Temperature measurement with **360** AT.

- Results for Base pad:
  - **Max. surface temperature of 70°C is reached at 456 Ampturns (AT) (optimized thermal design of base pad)**

System Performance at max. BP 456AT (maximum operating limit due to thermal constraints)

BP	VP		x = 0 y = 0	x = 50 y = 50	x = 75 y = 100	x = 100 y = 100	x = 100 y = 150	x = 150 y = 150
Z2min = 160 mm								
CR 575 x 765 (Turn count 8)	CR 400 x 400 (Turn count 10)	P (W)	6600	6600	6600	6600	6280	2730
		I (A)	29	32,4	39,4	47,5	57	57
BP 575 x 765 (Turn count 7)	DD 400 x 400 (Turn count 8)	P (W)	6600	6600	6600	6600	6600	6600
		I (A)	31,1	30	32	33	36,5	37
Z2max = 220 mm								
CR 575 x 765 (Turn count 8)	CR 400 x 400 (Turn count 10)	P (W)	6600	6600	5560	4630	3430	550
		I (A)	46,9	52,8	57	57	57	57
		BP AT	375	422	456	456	456	456
		VP AT	300	300	300	300	300	300
BP 575 x 765 (Turn count 7)	DD 400 x 400 (Turn count 8)	P (W)	6600	6600	6600	6600	6600	6600
		I (A)	29	31,6	48,3	50,3	53,8	43,5
		BP AT	203	221	338	352	376	304
		VP AT	304	304	304	304	304	304

The CR VP performs significantly worse than the DD VP!

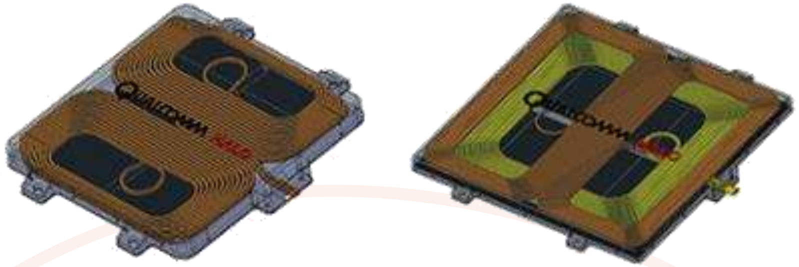
Summary

Reduced-size DD (for 3.3 kW and 6.6 kW)

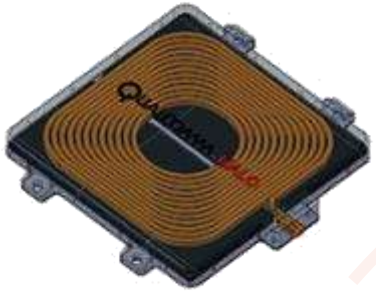
3.3 kW: 250mm x 190mm

6.6 kW: 340mm x 270mm

Different Magnetic Pad Designs Must be Supported



Double D & DD Quadrature
Secondary Vehicle Pads

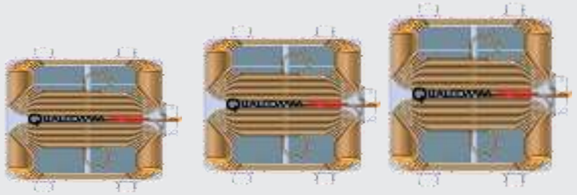


Circular/Square Coil
Secondary Vehicle Pad

Single Coil Solenoid
Secondary Vehicle Pad

Bi-Polar Primary Base Pad

Evolution from Stationary to Dynamic

	Stationary (*)	Semi&Dynamic (**)
Frequency	85 kHz	85 kHz
Power Classes	**3.7 / 7.7 / 20 kW**	**10/ 20 / 40 / 200 kW**
Offset Tolerance (x/y)	±75 / ±100 mm	Not relevant / ±200 mm
Magnetics (vehicle side)		

(*): Based on worldwide standardization

(**): Proposal for FABRIC project (currently, there are no standards specifying requirements for dynamic charging)

Thank you

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