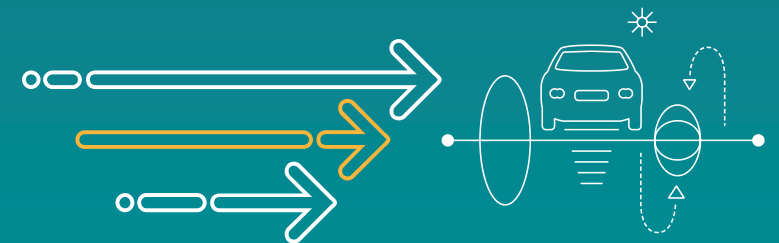


Dr. Daniel Kuerschner, Sen Staff Engineer / Manager
QUALCOMM CDMA Technologies GmbH
June 21st 2016, EVS29

DD Vehicle Coil as Interoperable Solution for Stationary Wireless Electric Vehicle Charging (WEVC)



1

Introduction

2

Test Setup

3

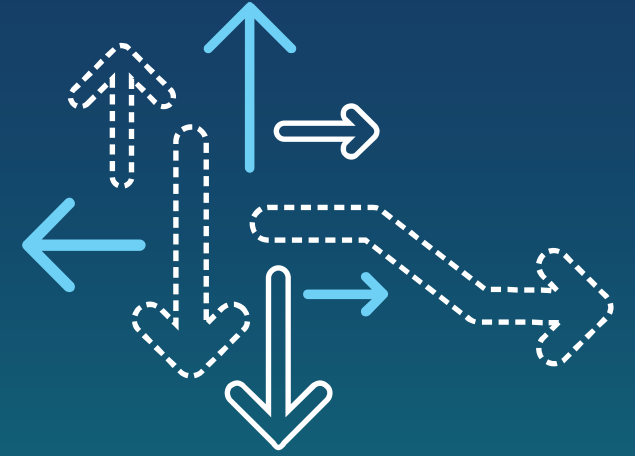
Simulations

4

Measurements

5

Conclusion



Introduction

QUALCOMM HALO™

- **WEVC for a better driver experience**

- Simple, effortless & convenient
- Automatic hands-free charging
- No cord to unplug, or steal
- Unaffected by water, ice & snow
- Simple to package on electric vehicles

- **Multiplicity of charging opportunities**

- Charge little, often and everywhere
- Simple to deploy, no street clutter
- Encourages intensive charging infrastructure
- Reduce battery size and electric vehicle cost

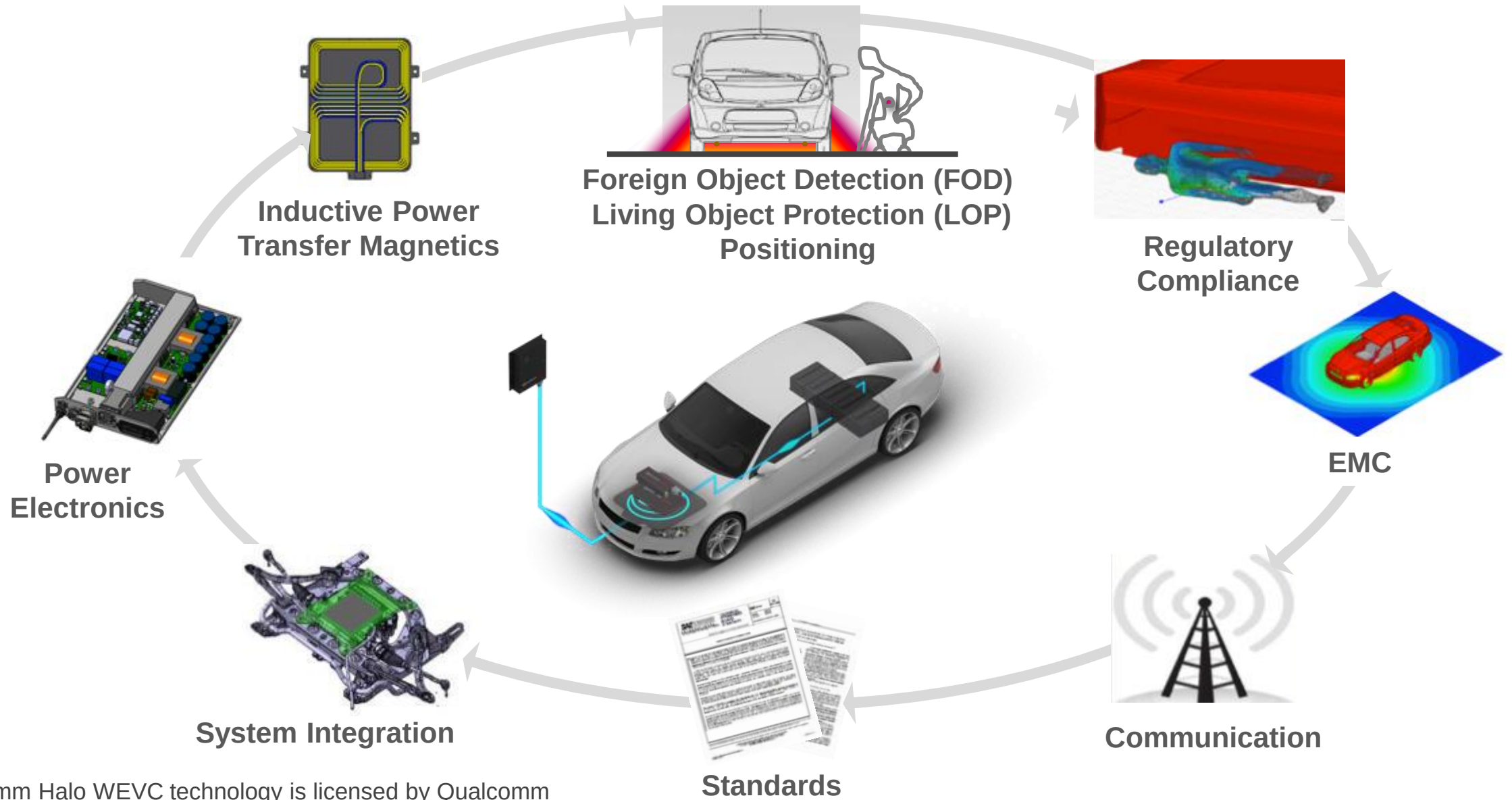
Interoperability is Key to Adoption and Electric Vehicle Growth

Static
Charging

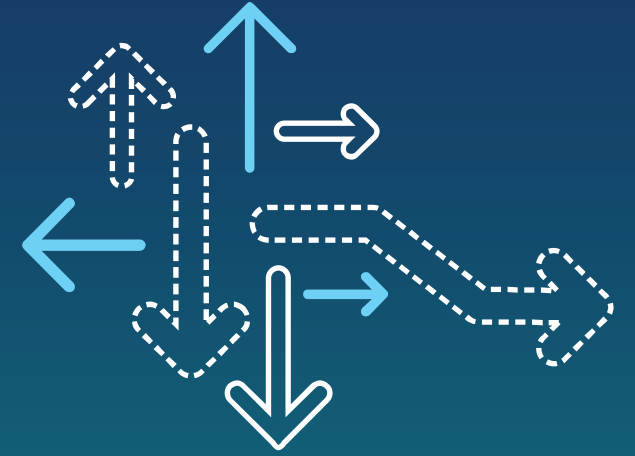
Semi-Dynamic
Charging

Dynamic
Charging

Qualcomm Halo – Delivering End-to-End WEVC Technology



Qualcomm Halo WEVC technology is licensed by Qualcomm Incorporated. Prototype charging systems, functional prototypes and reference designs are products of Qualcomm Technologies, Inc.

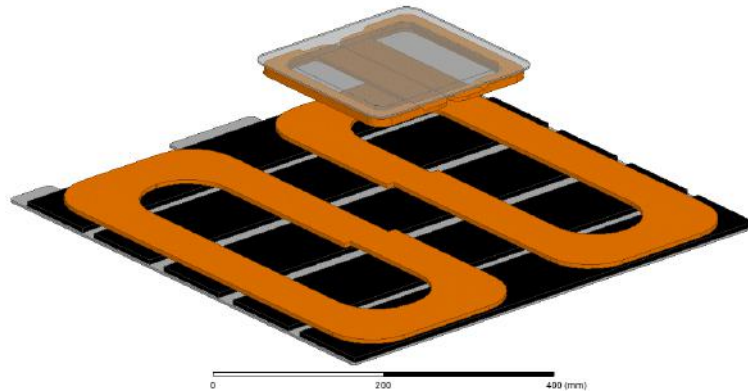


Test Setup

QUALCOMM HALO™

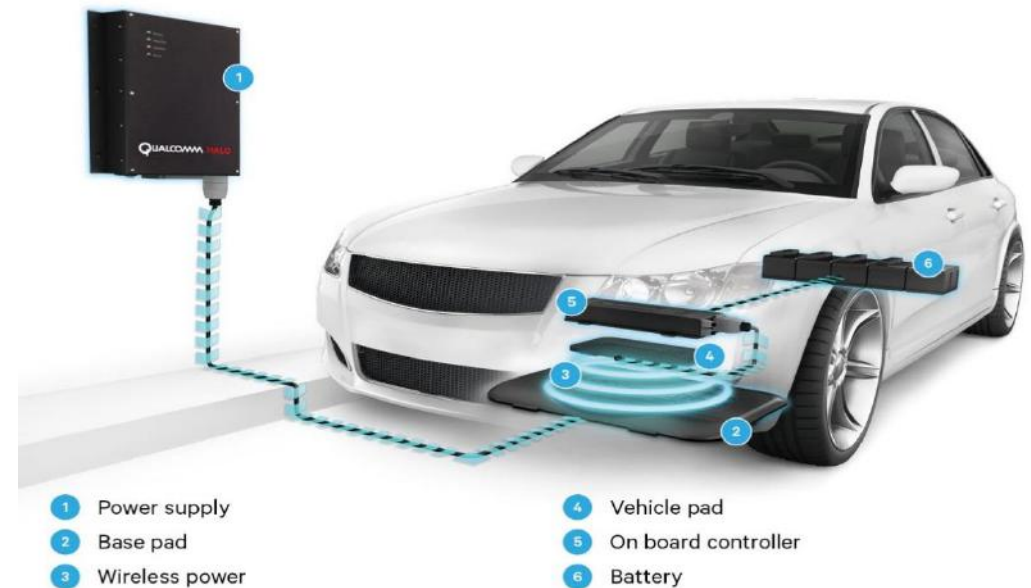
WEVC System Under Consideration

- Offset range: $x = \pm 75$ mm (driving direction) and $y = \pm 100$ mm (lateral direction).
- Z gap range: $Z1 = 100 \dots 160$ mm (sedan vehicle) and $Z2 = 160 \dots 220$ mm (SUV).
- $V_{\text{bat}} = 280 \dots 420$ V.
- Nominal charging power (input power, P_{in}): 3.7 kW (WPT1) and 7.7 kW (WPT2).



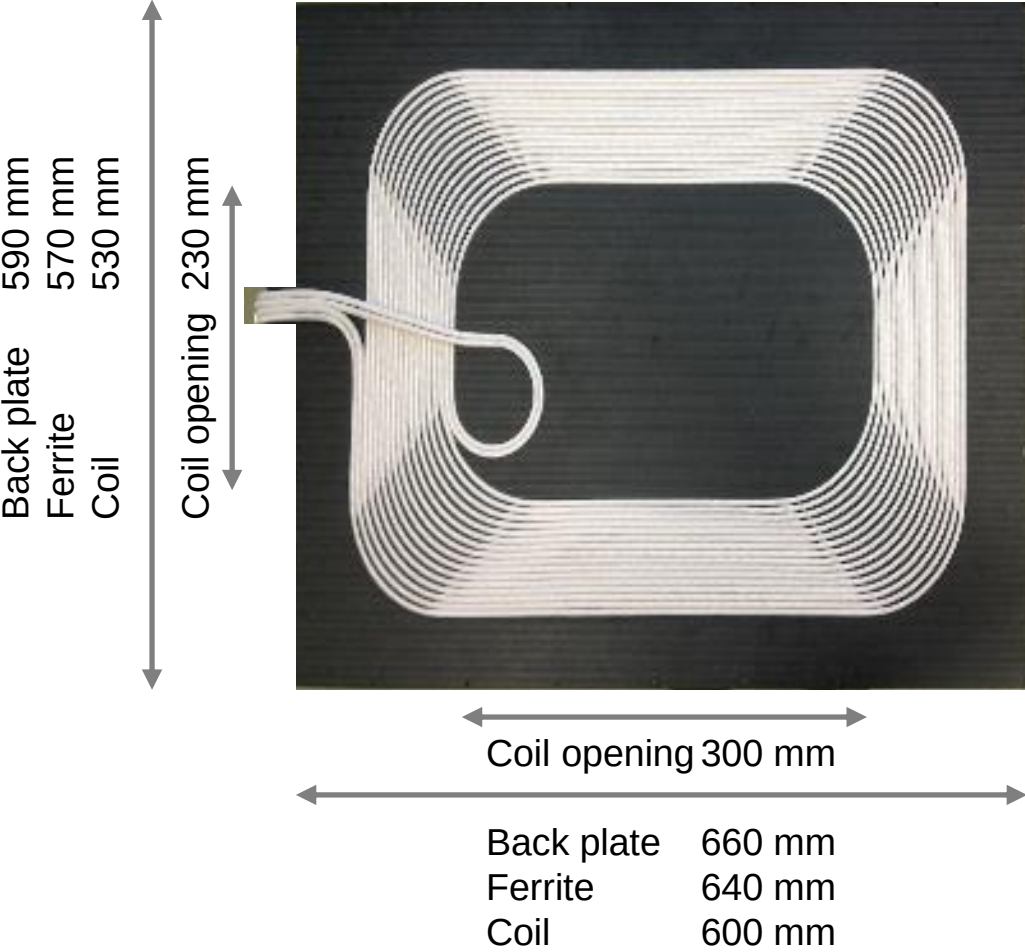
Base Pad (BP): (650 x 650 x 50) mm³

Vehicle Pad (VP): (250 x 260 x 20) mm³

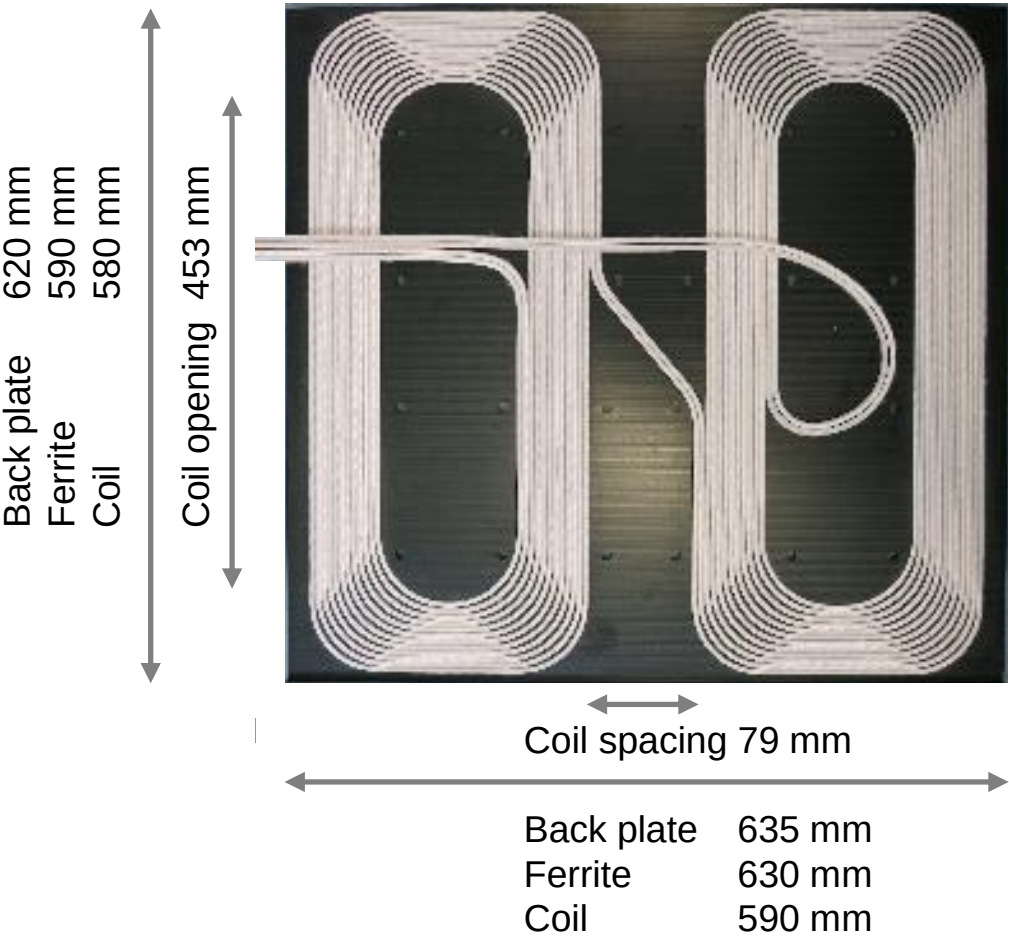


BP Topologies Under Consideration

Circular (CR) type



Polarized double-D (DD) type



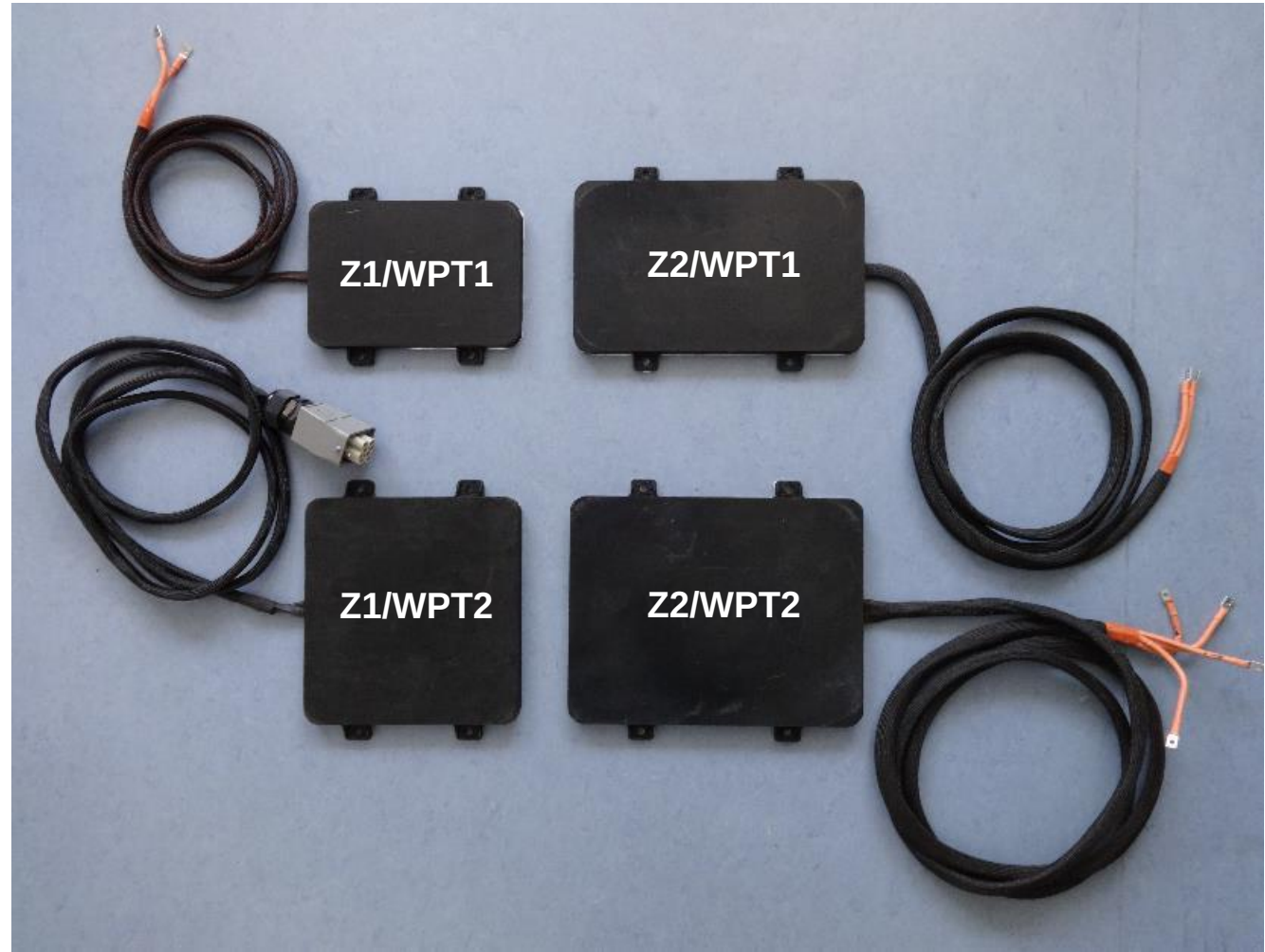
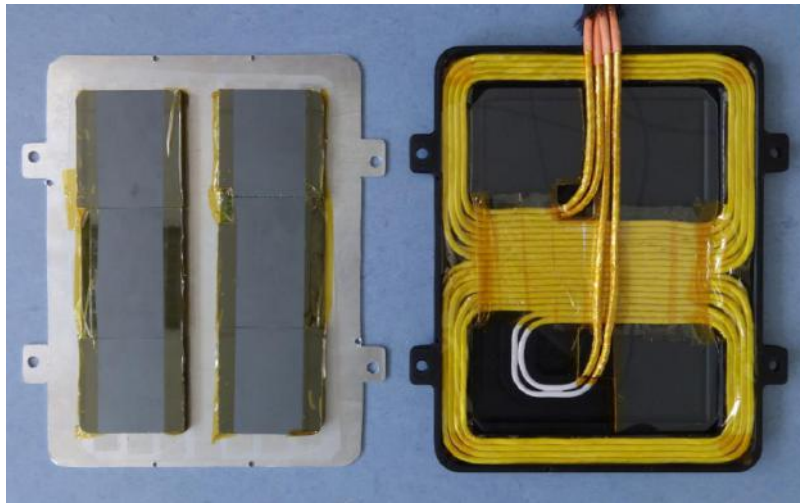
- DD VP coils designed to optimize coupling and performance with the DD BP.
- Minimum VP size determined by FEM simulation (pattern search algorithm).
- Design criteria and restrictions:
 1. Magnetic coupling factor $k \geq 0.8$.
 2. Maximum pad power loss density: $p_L < 60 \text{ W/L}$ (includes litz, ferrite and back plate).
 - > Goal: Meet the maximum allowed temperature of touchable parts (limits according to SAE J2954, UL2750).
 - > Limit of $p_L < 60 \text{ W/L}$ results in maximum BP ampere-turns (AT): $N_{BP} * I_{BP} = 450 \text{ A}$.
 3. Magnetics efficiency $\eta_{mag} \geq 96 \%$ (to reach overall system efficiency of $\eta_{tot} \geq 90 \%$).
 4. Nominal transferred power $P_{nom} = P_{in} * \eta_{tot}$.
 5. Magnetic flux density in ferrite $B_{fer} < 200 \text{ mT}$.
 6. Magnetic flux density above BP $B_{BP} < 3 \text{ mT}$.

VP Topologies Under Consideration

VP dimensions as a result of the design process

	Z1	Z2
WPT1	(250x170x20) mm ³	(340x200x20) mm ³
WPT2	(250x260x20) mm ³	(340x260x20) mm ³

Example: DD VP designed for WPT1/Z1



Assessment Method and Considered Configurations

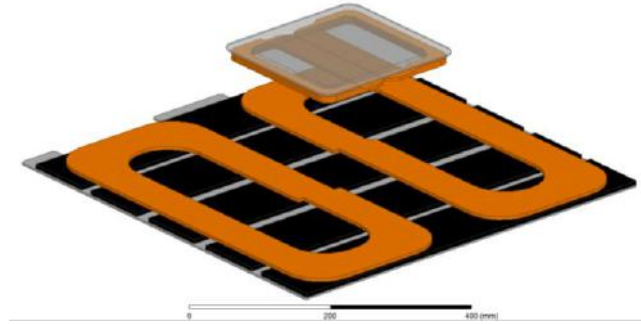
Simulation

- Couplings
- Inductances
- Ampere-turns
- Magnetics efficiency

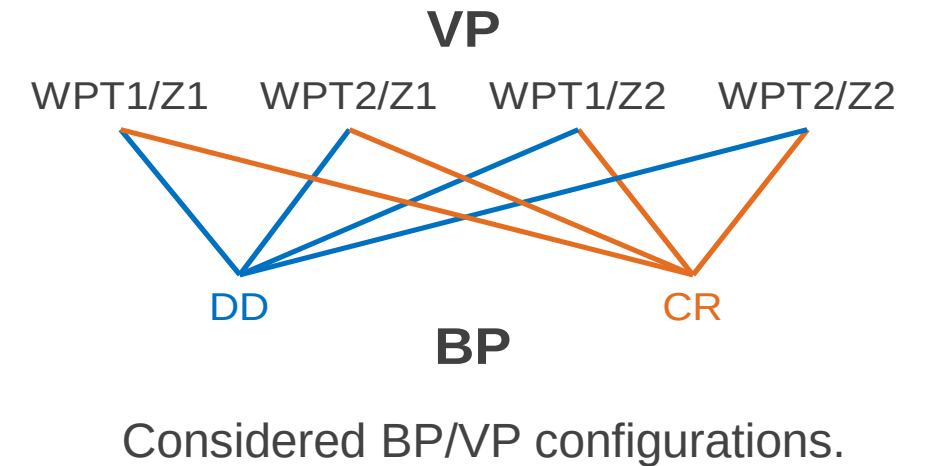


Performance measurement

- Ampere-turns
- Electrical power
- System efficiency

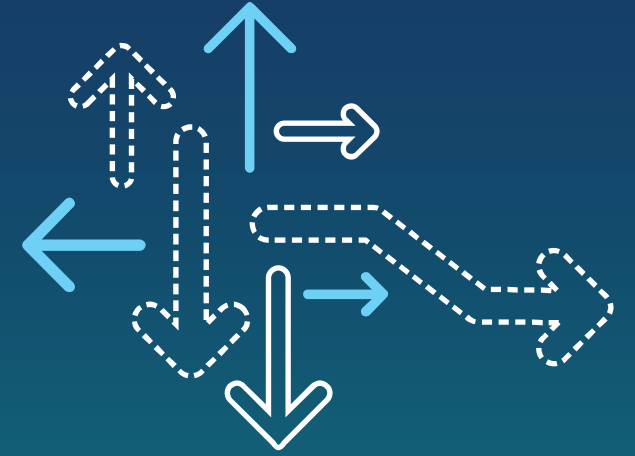


Assessment method

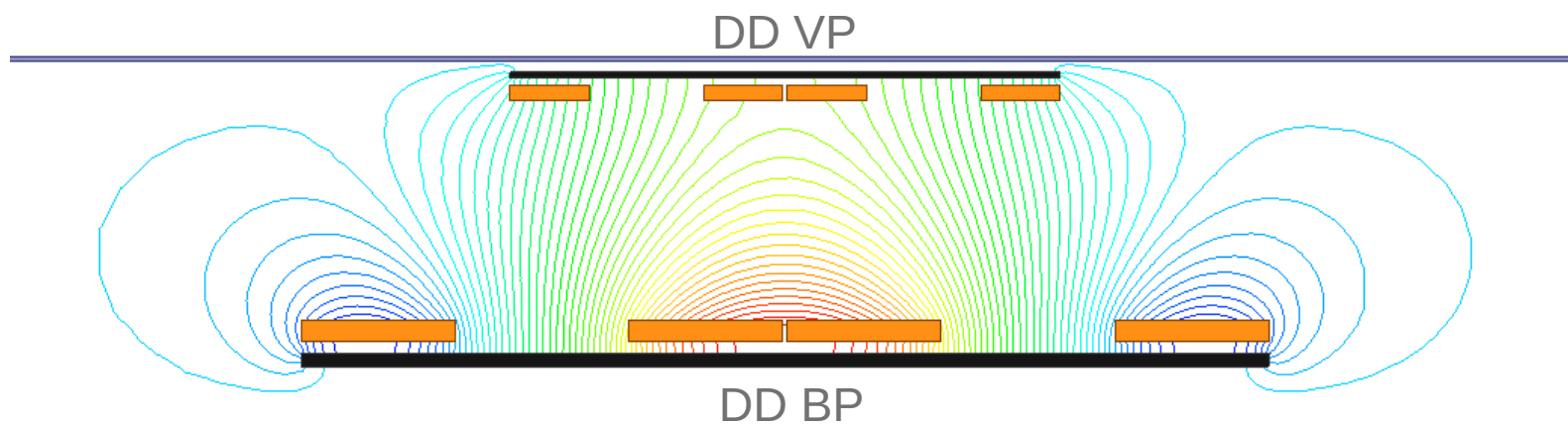
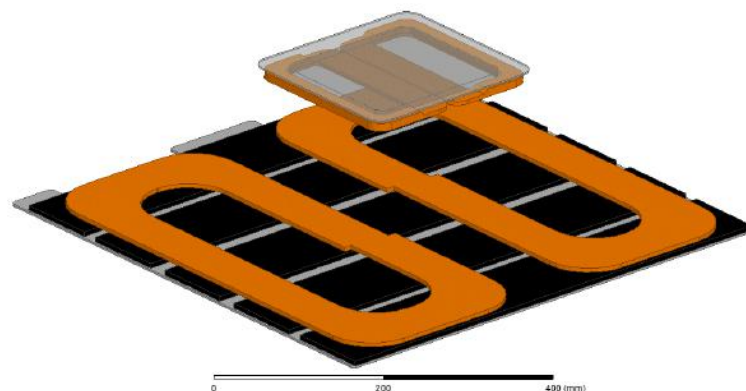
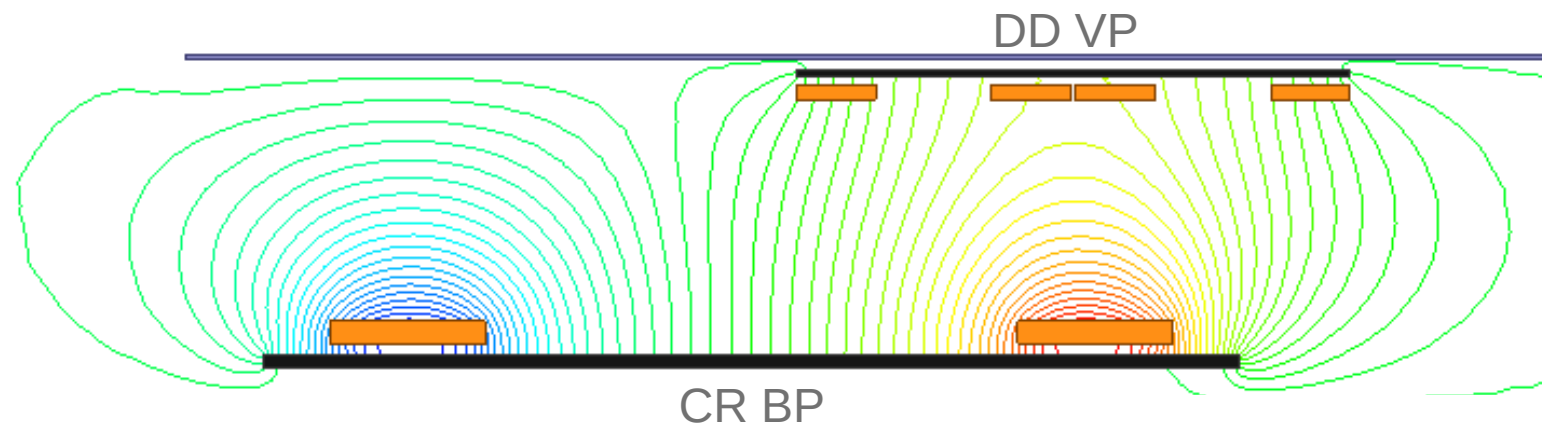
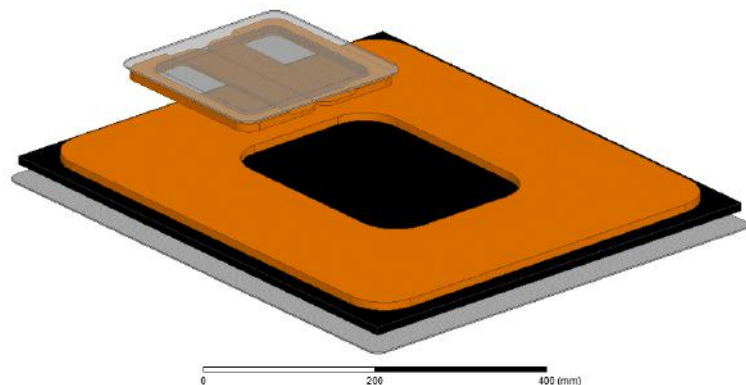


Simulations

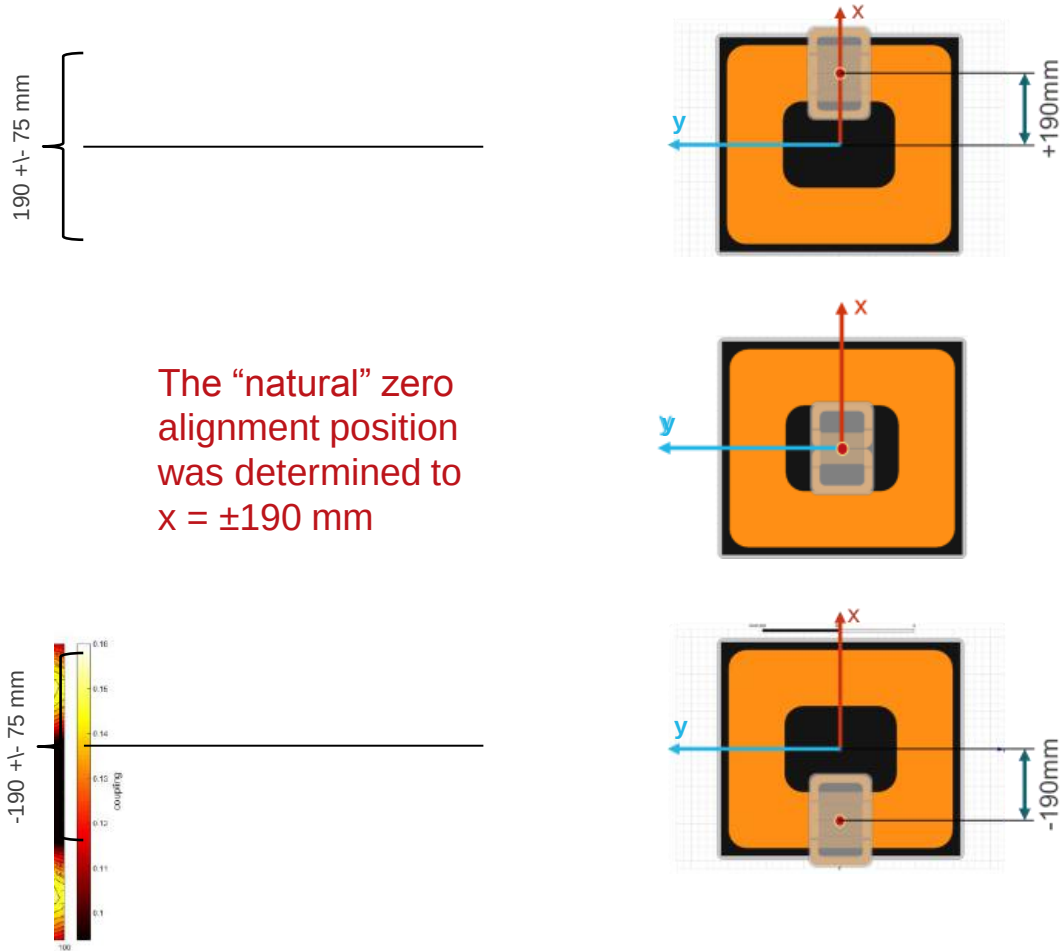
QUALCOMM HALO™



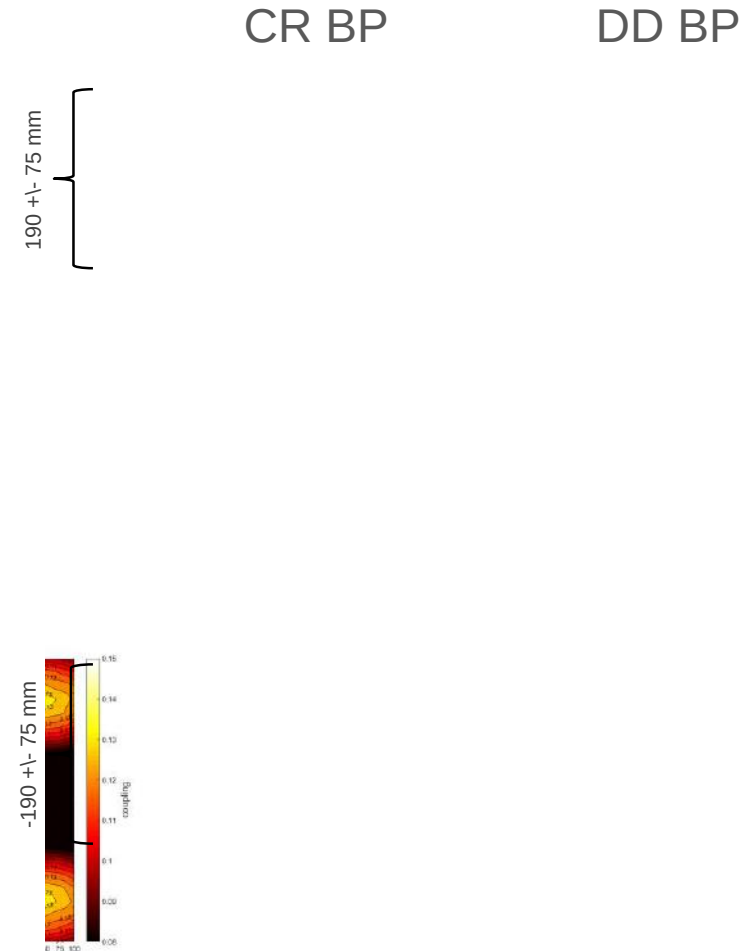
H Field Distribution of Different BP Topologies



Examples of Magnetic Coupling Maps



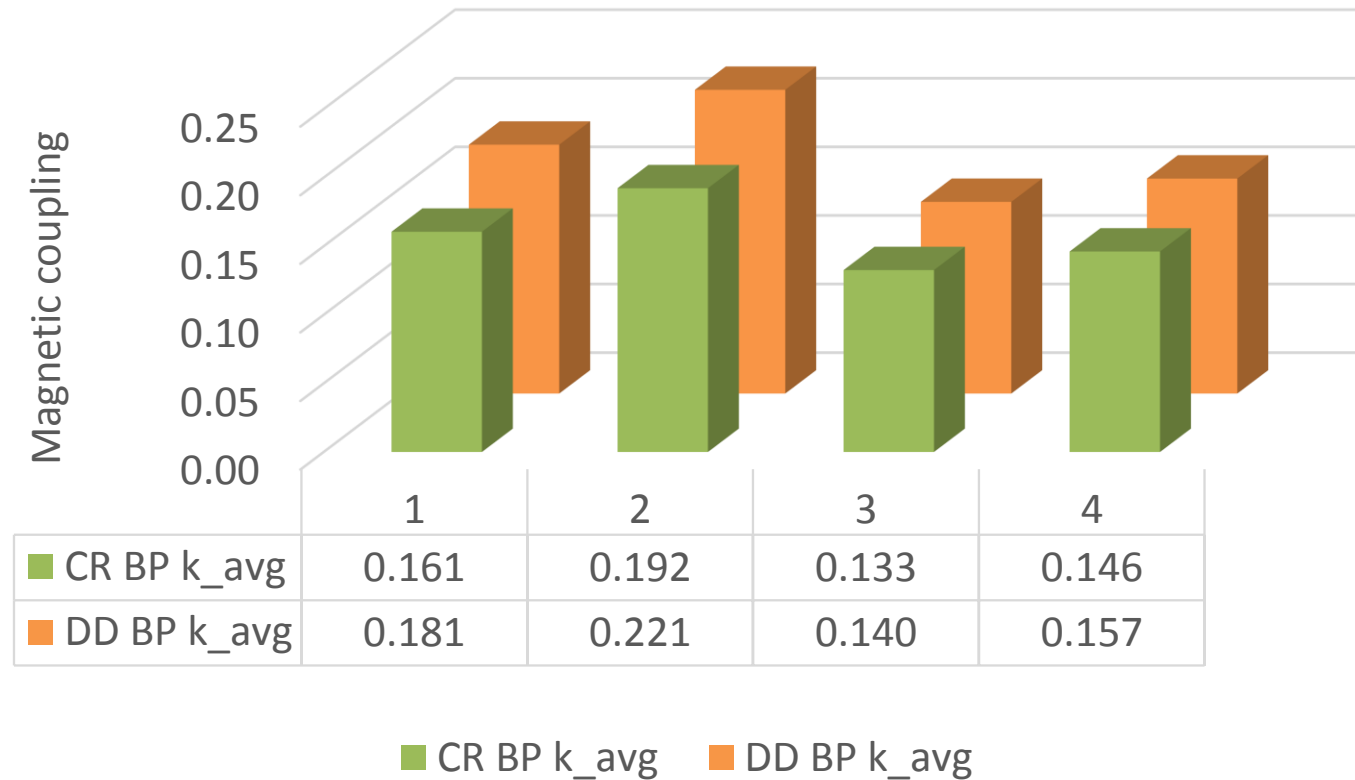
WPT2/Z1 DD VP over CR BP at $Z_{1\max} = 160$ mm.



WPT1/Z1 DD VP over both DD and CR BP at $Z_{1\max}$.

Magnetic Couplings for All Configurations

- Magnetic coupling factors (simulation) for all VP and BP combinations and for the full Z gap range:
 $k_{\max}(Z_{1\min})$ and $k_{\min}(Z_{1\max})$ or $k_{\max}(Z_{2\min})$ and $k_{\min}(Z_{2\max})$.
- Using the DD BP results in higher average couplings and in lower coupling ranges.
- Using the DD BP enables better reliability and potentially lower component costs.

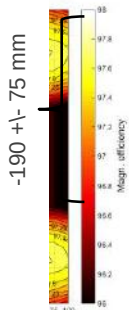


Magnetics Efficiency

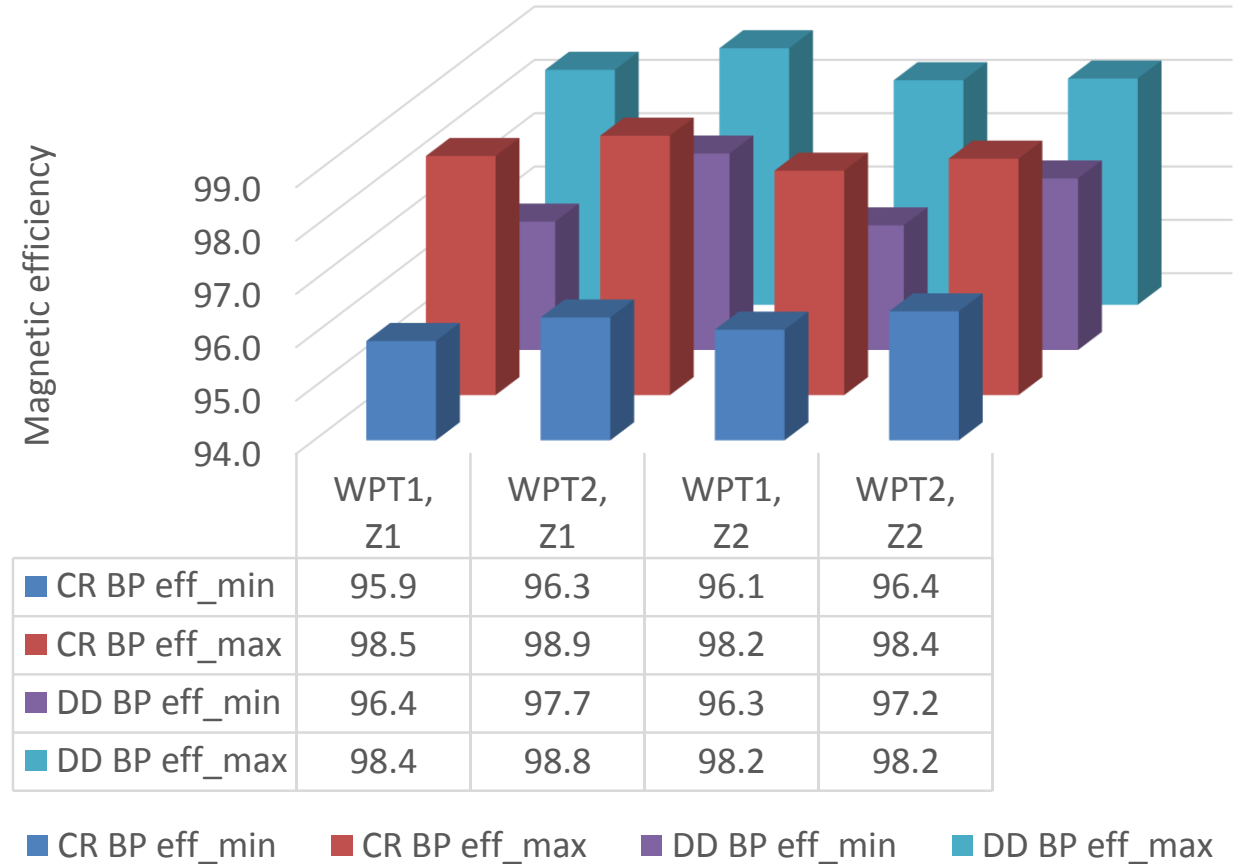
CR BP

DD BP

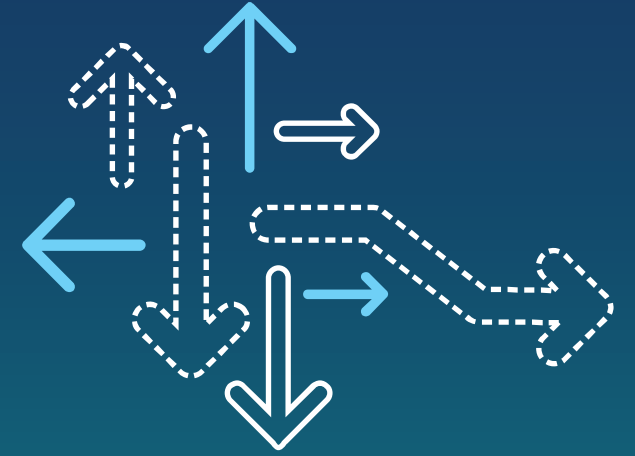
190 +\/- 75 mm



Magnetics efficiency distribution for example for the WPT1/Z1 DD VP over DD/CR BP at $Z_{1max} = 160$ mm.



All pads meet the design criterion of $\eta_{mag} > 96$ %.

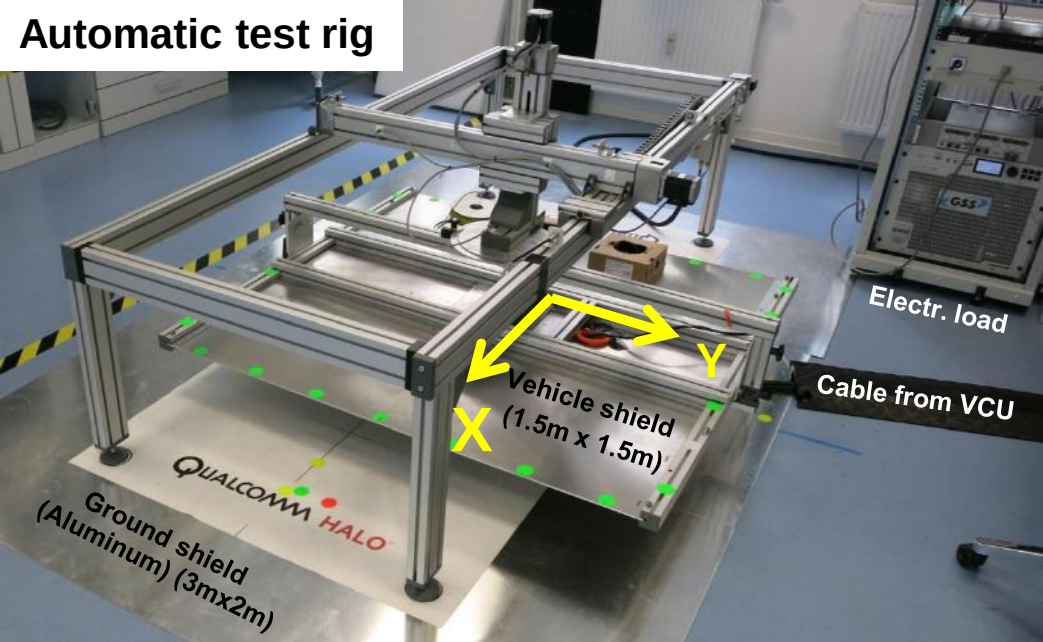


Measurements

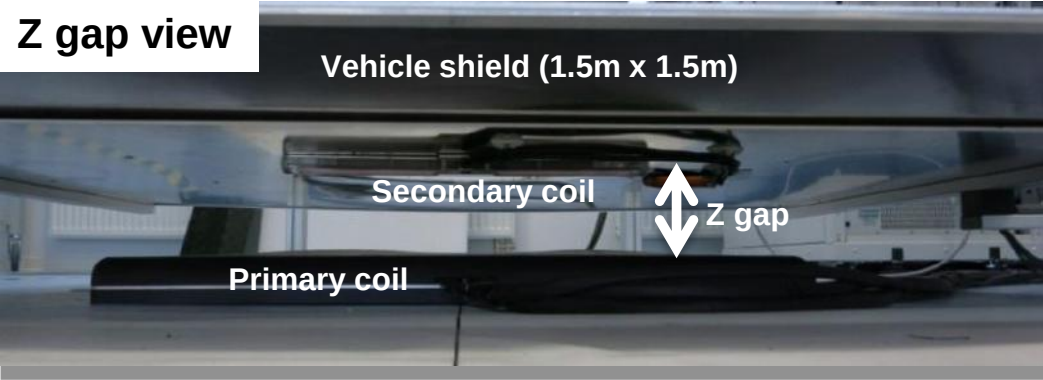
QUALCOMM HALO™

System Performance Test of All VP and BP Combinations Using a Test Rig

Automatic test rig



Z gap view



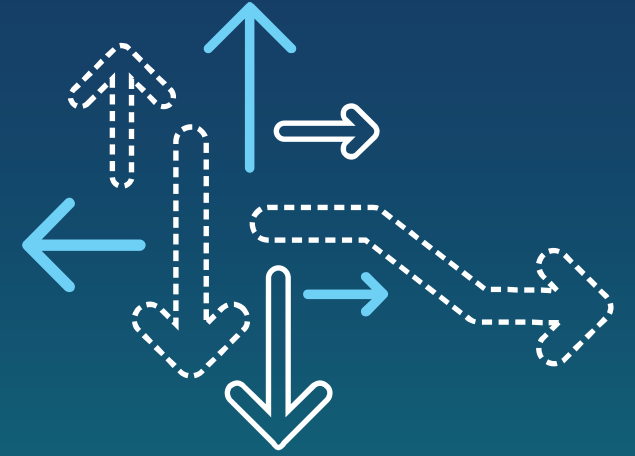
Z gap / mm	x offset / mm	y offset / mm	k (sim)	k (meas)
160	190 (=0)	0	0.136	0.135
160	190 (=0)	100	0.124	0.123
160	265 (=75)	0	0.105	0.103
160	265 (=75)	100	0.095	0.096
160	115 (= -75)	0	0.107	0.106
160	115 (= -75)	100	0.097	0.095
100	190 (=0)	0	0.261	0.260
100	190 (=0)	100	0.244	0.245
100	265 (=75)	0	0.172	0.171
100	265 (=75)	100	0.161	0.168
100	115 (= -75)	0	0.190	0.187
100	115 (= -75)	100	0.178	0.171

- Example: Magnetic coupling factor validation for WPT1/Z1 DD VP over CR BP.
- Difference between measurement and simulation below 3 %.

System Performance Test of all VP and BP Combinations by Using a Test Rig

- Performance measurements of all pad combinations at max Z gap, full offset and full V_{bat} range.
- Determination of needed AT for zero and max. offset, for $Z(1/2)_{max}$ and for $V_{bat} = 350$ V.
- All combinations are feasible.**
- Benefits when using the DD BP ($N_{BP} * I_{BP} < 360$ A).
- Drawbacks of CR BP due to natural lower coupling:
 - Up to 47 % higher BP AT needed.
 - Up to 178 % of $N_{BP} * I_{BP} * N_{VP} * I_{VP}$ needed compared to the configuration with the DD BP (e. g. at WPT2/Z2, zero offset).
 - Higher AT can result in increased EMF/EMC challenges and in thermal challenges.
 - Reduced power operation as one possible solution.?

	WPT1, Z1	WPT2, Z1	WPT1, Z2	WPT2, Z2
CC BP				
P_out(0,0) / W	3300	6600	3300	6600
P_out(75,100) / W	3300	6600	3300	6600
I_BP(0,0) / A	45.2	43.3	43.0	50.0
I_VP(0,0) / A	20.3	54.1	27.6	67.1
I_BP(75,100) / A	63.5	61.6	53.9	65.5
I_VP(75,100) / A	20.2	54.0	27.7	66.5
$N1I1 * N2I2$ (0,0) / A^2	73405	93701	66461	107360
$N1I1 * N2I2$ (75,100) / A^2	102616	133056	83610	139384
DD BP				
P_out(0,0) / W	3300	6600	3300	6600
P_out(75,100) / W	3300	6600	3300	6600
I_BP(0,0) / A	30.2	29.1	30.5	32.6
I_VP(0,0) / A	20.0	52.0	26.6	66.2
I_BP(75,100) / A	50.4	51.1	49.5	46.0
I_VP(75,100) / A	20.1	51.0	26.8	66.0
$N1I1 * N2I2$ (0,0) / A^2	42210	52871	39689	60427
$N1I1 * N2I2$ (75,100) / A^2	70913	91214	65003	85008



Conclusion

QUALCOMM HALO™

- Interoperable operation of a DD VP and either a CR or a DD BP was demonstrated while maintaining the complete positioning tolerance (offset) range of +/- 75/100 mm and power transfer (including 3.7 kW and 7.7 kW input power classes).
- Different power and Z gap levels could be provided using the designed and considered DD VPs without changes needed to the CR and DD BP hardware.
- Magnetic coupling factors and magnetics efficiencies of all pad combinations were determined by simulations and successfully validated by measurements.
- When the DD BP was used, all considered DD VPs were able to operate at full power and over the entire offset range.
- When the CR BP was used, there were drawbacks which can be explained by the natural lower magnetic coupling and therefore the higher AT needed to drive the nominal electric power on the vehicle side.
- Since the coil AT are limited due to thermal and EMC/EMF reasons, a WEVC system based on CR coils might need to be operated in reduced power operation.



Official Founding & Technology Partner

Driving adoption
of new technologies
for EVs:
Qualcomm Halo
WEVC

Enhancing
the connected
fan experience



Thank you

Follow us on:  

For more information on Qualcomm, visit us at:
www.qualcomm.com & www.qualcommhalo.com

Nothing in these materials is an offer to sell any of the components or devices referenced herein.

© 2016 Qualcomm Technologies, Inc. All Rights Reserved.

Qualcomm is a trademark of Qualcomm Incorporated, registered in the United States and other countries. Qualcomm Halo is a trademark of Qualcomm Incorporated. All Qualcomm Incorporated trademarks are used with permission. Other product and brand names may be trademarks or registered trademarks of their respective owners.

References in this presentation to “Qualcomm” may mean Qualcomm Incorporated, Qualcomm Technologies, Inc., and/or other subsidiaries or business units within the Qualcomm corporate structure, as applicable.

Qualcomm Incorporated includes Qualcomm’s licensing business, QTL, and the vast majority of its patent portfolio. Qualcomm Technologies, Inc., a wholly-owned subsidiary of Qualcomm Incorporated, operates, along with its subsidiaries, substantially all of Qualcomm’s engineering, research and development functions, and substantially all of its product and services businesses, including its semiconductor business, QCT.

Qualcomm Halo WEVC technology is licensed by Qualcomm Incorporated. Prototype charging systems, functional prototypes and reference designs are products of Qualcomm Technologies, Inc.

