

DD vehicle coil as interoperable solution for stationary wireless EV charging

D. Kuerschner¹ Member IEEE, G. Ombach² Senior Member IEEE,
S. Mathar³ Member IEEE
QUALCOMM CDMA Technologies GmbH, Hollerithstraße 7a, 81829 Munich, Germany
¹ *dkuersch@qti.qualcomm.com*, ² *g.ombach@ieee.org*, ³ *smathar@qti.qualcomm.com*

Summary

Wireless electric vehicle charging (WEVC) for stationary applications has entered the commercialization stage. Electric vehicles with automaker installed WEVC are expected to be available in the next few years. Parallel to commercialization also standardization efforts for interoperable operation of base pads and vehicle pads are currently ongoing. In this paper the interoperability performance between polarized vehicle pads and different base pad coil topologies (circular and polarized) are investigated. Theoretical and practical studies have been conducted based on magnetic field simulations and on measurements which demonstrate that the interoperability between the investigated magnetics topologies is possible.

Keywords: inductive charger, wireless charging, electric vehicle (EV), simulation, standardization

1. Introduction

A WEVC system utilizes complex technology which includes both primary side (infrastructure) and secondary side (vehicle) components. The primary side consists of a high frequency power supply unit (PSU) and a base pad (BP). The secondary side consists of a vehicle pad (VP) and a vehicle control unit (VCU or on board controller) (See Fig. 1) [1-12]. When ancillary systems are included in the WEVC system, foreign object detection (FOD) and living object protection (LOP) are typically on the primary side, and positioning is typically on both sides.



Fig. 1: Wireless electric vehicle charging (WEVC) system components.

Interoperability between VPs and BPs from different systems is a key factor for successful deployment and consumer adoption of WEVC. Therefore, it is important to specify a set of VPs and BPs with coil topologies that are capable of interoperating. Interoperability is a general term and as such must be analyzed from a component to a system level. This paper focusses on the magnetic coil topology only. For the purposes of this paper, interoperability is defined as a basic requirement to transfer an electrical power with a given magnetic efficiency at a given maximum coil current. The analysis discussed in this paper concludes that a polarized double-D (DD) VP coil topology has magnetic interoperability with a circular rectangular (CR) and a DD BP coil topology. Four different DD VP coil configurations were designed to accommodate two different Z gap classes (vehicle ground clearance) and two different power classes. The two Z gap classes included in this study were for a sedan vehicle: ($Z_1 = 100..160$ mm) and SUV ($Z_2 = 160..220$ mm). The two electrical input power (P_{in}) classes used were 3.7 kW (WPT1) and 7.7 kW (WPT2) [20].

2. Considered coil topologies

This study considered two BP topologies: a DD coil and a CR coil (Fig. 2). These BPs were used to enable testing the system performance of various DD VPs. Both BPs were designed to support an offset range of $x = \pm 75$ mm (driving direction) and $y = \pm 100$ mm (lateral direction). Based on these requirements, the size of the DD and CR BPs were selected based on current standardization requirements [20]. Also factored into the selection was the objective of having comparable volumes of copper (Litz) and ferrite layer.

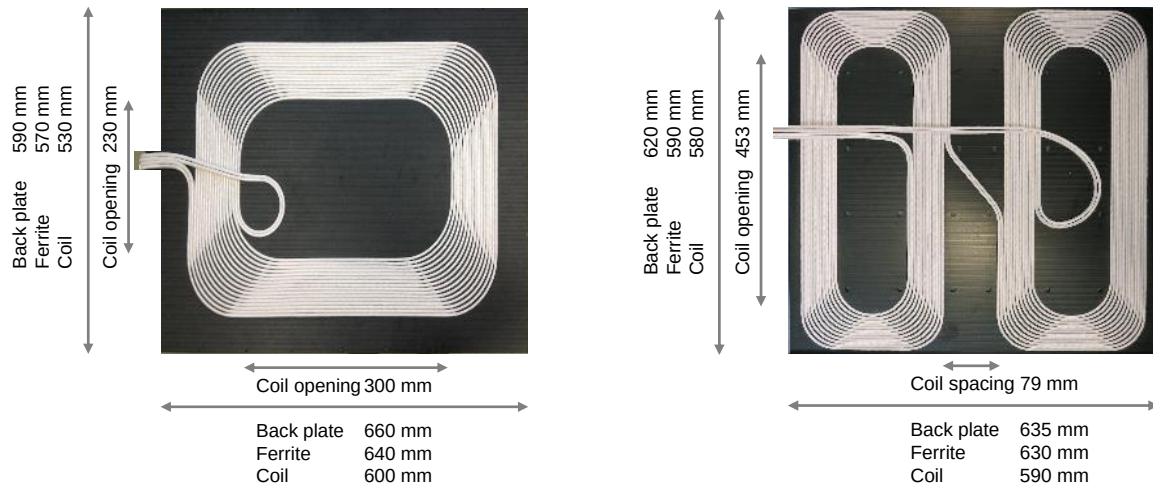


Fig. 2: Circular rectangular (CR) base pad (BP) design (left) and polarized double-D (DD) BP design (right) which support Z1 and Z2 Z gap classes and WPT1 and WPT2 power classes.

The DD VP coils used in this study were designed to optimize magnetic coupling and performance when used in combination with the DD BP. The CR BP was not considered in the DD VP design. The minimum VP size needed was determined by numerical simulation (ANSYS Maxwell) and by applying a pattern-search algorithm, which provided an iterative sweep of pads sizes and length-width aspect ratios of the magnetics. For this iterative simulation, the following design criteria and restrictions were used:

- 1) Magnetic coupling factor $k \geq 0.8$,
- 2) Maximum pad power loss density $p_L < 60$ W/L (includes Litz, ferrite and back plate) in order to meet the maximum allowed temperature rise of touchable parts (e. g. pad housing surface). Limits for surface temperatures are defined in [19] and are also currently being discussed in SAE J2954 and UL2750 task forces. The maximum power loss density and temperature limits result in a maximum BP ampere-turns (AT) of about $N_{BP} \cdot I_{BP} = 450$ A,
- 3) Magnetics efficiency $\eta_{mag} \geq 96$ % (in order to reach overall system efficiency of $\eta_{tot} \geq 90$ %),
- 4) Nominal transferred power $P_{nom} = P_{in} \cdot \eta_{tot}$,
- 5) Magnetic flux density in ferrite $B_{fer} < 200$ mT,
- 6) Magnetic flux density above $B_{BP} < 3$ mT.

As shown in Fig. 2, one DD BP and one CR BP were designed and used in this in this study. Different VPs were developed and used to accommodate the different Z gap and power classes. Requirements for higher Z gap and increased power transfer resulted in the need for larger VP dimensions. Tab. 1 and Fig. 3 show the sizes and the pictures of the four VP coils built and used in the study.

Tab. 1: Vehicle pad (VP) coil dimensions for different Z gap and power classes (all dimensions in mm).

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

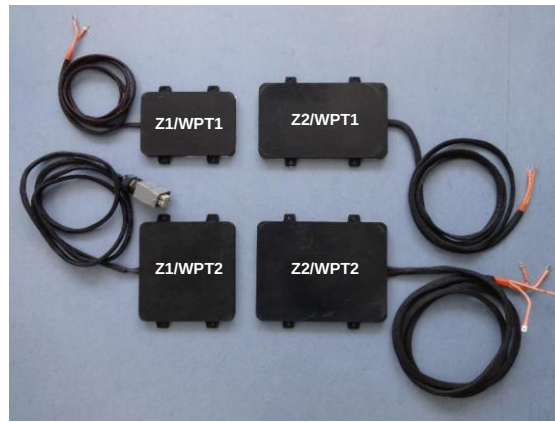


Fig. 3: Polarized double-D (DD) vehicle pads (VP) built and considered for different Z gap classes and power classes.

All VPs (WPT1/Z1, WPT2/Z1, WPT1/Z2, WPT2/Z2) were built following general “sandwich” design rules (coil, ferrite, back plate, plastic housing); but, were scaled based on power level and Z gap requirements. Fig. 4 shows the WPT/Z1 VP in detail as an example. For the magnetic layer, soft ferrite material (Tridelta MF95) was used. For the copper layer Litz wire with multiple turns was used. The ferrite was placed on a back plate made of aluminum.

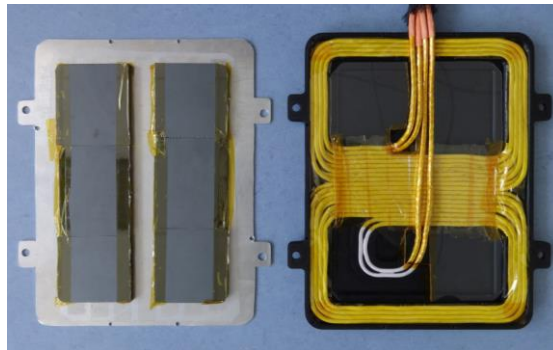


Fig. 4: The polarized double-D (DD) vehicle pad (VP) built for WPT1/Z1, Size: (250x170x20)mm³.

Using the BPs and VPs discussed in this section, simulations were conducted in order to analyze the general distribution of the magnetic main and leakage field of the DD and CR BP topologies in principle. In Fig. 5, the simulated magnetic field distribution is shown for operation of the BP (only the BP was powered, the

VP coil was at open circuit). In order to analyze the magnetic field distribution in main magnetization direction in principle, a 2D FEM simulation model can be used. It was determined that for an optimum operating condition, a DD VP needed be placed over the DD BP at zero offset position (optimum alignment). In this position, the horizontal component of the magnetic field (H field vector lines) reached its maximum (Fig. 5, top). When a CR BP was used, all DD VPs needed to be placed at some offset so that the VP was able to “collect” the major portion of the horizontal magnetic field (Fig. 5, bottom).

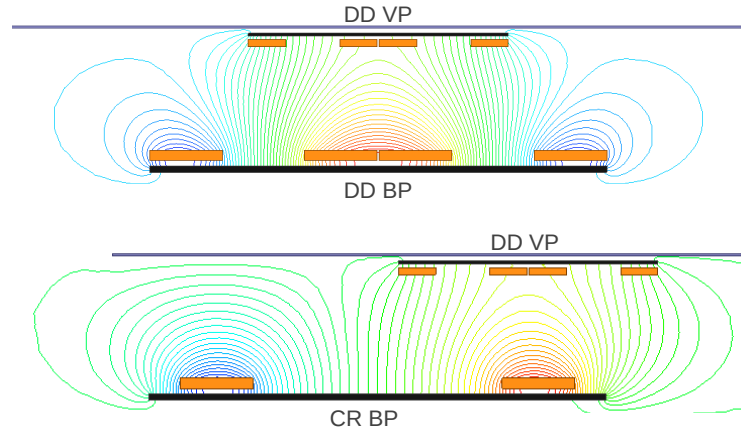


Fig. 5: Simulated magnetic field distribution of a polarized double-D (DD) vehicle pad (VP) and a DD base pad (BP) combination (top) and for a DD VP and circular rectangular (CR) BP combination (bottom).

3. Assessment methodology

The performance of all VP and BP combinations was determined and compared by simulation and then the results were validated by measurements. The combinations shown in Fig. 6 and the workflow shown in Fig. 7 were used. In the first step, the magnetic mutual and self-inductances – and therefore the magnetic coupling factors – of the considered VP and BP topologies were determined using FEM simulation (ANSYS Maxwell). The coils of the WEVC system were modeled as solid blocks (one turn) conducting a homogeneous current density to emulate using Litz wire with multiple turns. The ferrite layer was modeled as a block region at a permeability of $\mu_r = 2000$. All electrically conductive regions, such as coil back plates or vehicle shields (both assumed to be aluminum) were modeled using the ANSYS Maxwell surface impedance boundary condition ($\sigma = 24 \text{ MS/m}$, $\mu_r = 1$) in order to reflect the real magnetic field distribution. Use of this boundary condition allows metallic surfaces and bodies to be considered, but avoids the need for a real meshing of these regions. The latter option would result in a very small needed finite element sizes (due to small skin-depth) and therefore result in a very high number of needed finite elements.

The AT in the BP and in the VP needed for a specific transferred power (e. g. 3.7 kW, 7.7 kW) can be determined based on simulated mutual and self-inductances (which are specific for each VP and BP combination and for each offset and Z gap case) and with the assumption of an ideally tuned transformer [13]. The phase shift between the BP and VP currents was set to $\phi_{(IBP_IVP)} = 90^\circ$ to provide realistic WEVC system resonance operating conditions [13, 14]. Using the AT determined by simulation, the power loss of the magnetic parts of the WEVC system was determined for each individual configuration and for each offset and Z gap case. The ferrite power loss was calculated by ANSYS Maxwell based on the B field distribution inside the ferrite layer and by applying the material and frequency specific parameter of the STEINMETZ model. The eddy current power loss in the back plates and vehicle shield was calculated by ANSYS Maxwell using the surface impedance boundary condition. The copper (Litz wire) power loss was calculated based on specific coil currents and by applying coil specific current displacement factors which were determined by measurements.

The turns counts used for the BP and VP assemblies were determined by an electrical circuit model of the resonance transformer for a specific tuning topology and for a frequency of 85 kHz [13]. The tuning topology was selected to provide the optimum performance in terms of magnetics efficiency and resonance detuning sensitivity [14].

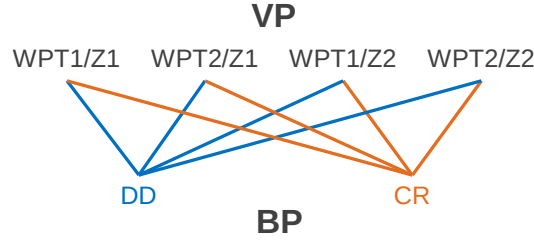


Fig. 6: The eight investigated combinations for the polarized double-D (DD) vehicle pad (VP) and circular rectangular (CR) and DD base pads (BPs).

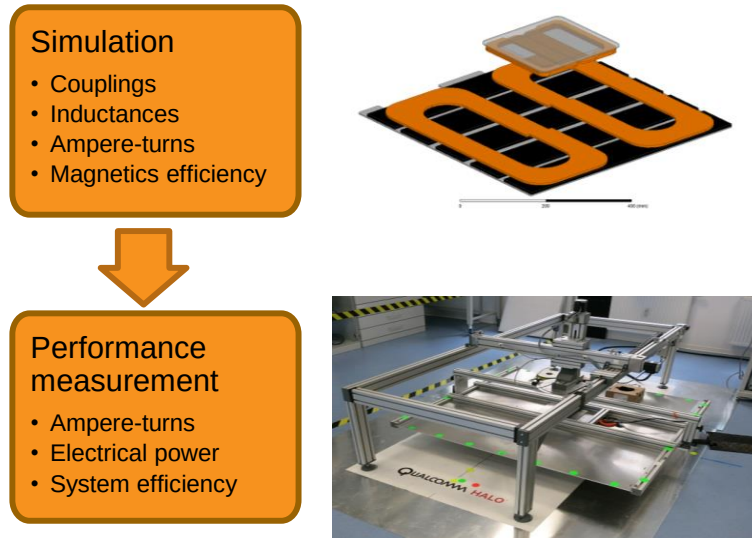


Fig. 7: Workflow for simulation and measurement of the considered wireless electric vehicle charging (WEVC) vehicle pad (VP) and base pad (BP) combinations.

4. Simulations

Fig. 8 shows a map of the magnetic coupling factors as a function of coil offset for a DD VP and CR BP combination as an example for WPT2/Z1. Based on the design criteria and restrictions in Section 2, the operational offset map is divided into two areas which are symmetrical (mirrored) by the mechanical zero ($x = 0$) alignment position. This means, the use of this combination “doubles” the possible offset operation area compared to when combinations of the same VP and BP coil topologies are used (e. g. CR BP with CR VP or DD BP with DD VP). For the DD VP and CR BP combinations, the new “natural” zero alignment position was determined to $x = \pm 190$ mm, respectively. For other DD VP and CR BP combinations, the natural zero alignment position might be different and depends on the design of the used BP and also on the considered Z gap range. From a practical viewpoint, it is expected that this new shifted zero alignment position has no real impact on the use case of parking a car in a parking lot, noting that any “natural scatter” of vehicles by different car sizes (e. g. a compact class car vs. a large sedan) is large compared to 190 mm.

Fig. 9 shows the comparison of the magnetic coupling map for a DD VP operated over both the CR BP and the DD BP for WPT1/Z1 as an example. For both BP/VP combinations, the operational offset range met the required offset range. It was also shown that the maximum couplings were higher when the DD BP was used than when the CR BP was used.

The coupling map in y-direction was very similar for both of the CR and DD BPs. However, the coupling gradient in y-direction, was a bit smaller, indicating better coupling, when the DD BP was used. When the DD BP was used, there was no “mirrored” coupling map in x-direction but in this case the zero (ideal) alignment position met the mechanical center ($x = 0$) of both the BP and VP.

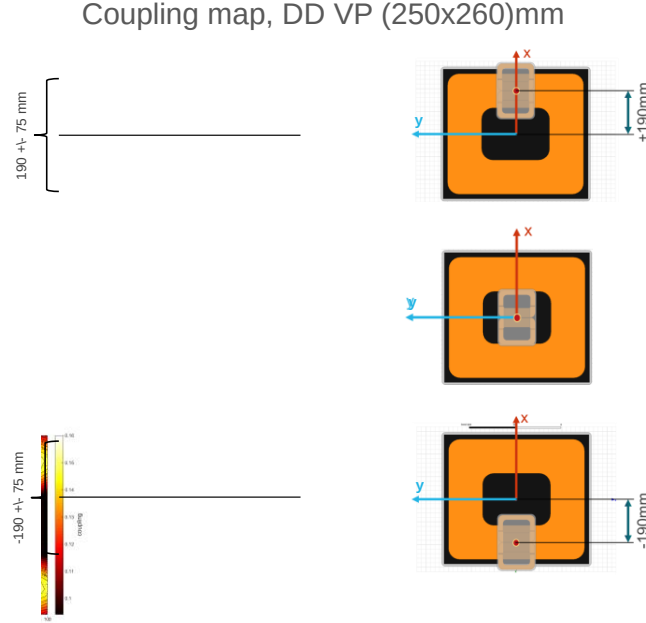


Fig. 8: Magnetic coupling map (simulation) of the WPT2/Z1 polarized double-D (DD) vehicle pad (VP) in combination with the circular rectangular (CR) base pad (BP) (at $Z1_{\max} = 160$ mm).

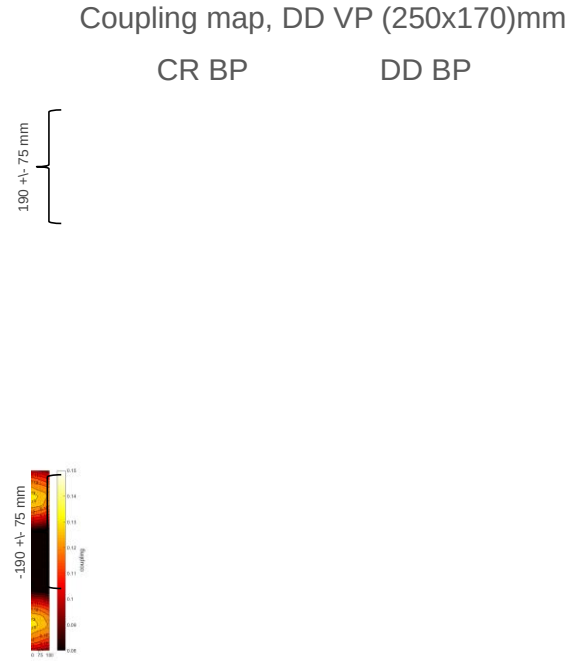


Fig. 9: Magnetic coupling map (simulation) of the WPT1/Z1 polarized double-D (DD) vehicle pad (VP) in combination with the circular rectangular (CR) base pad (BP) and the DD BP (at $Z1_{\max} = 160$ mm).

Fig. 8 and 9 show the coupling data for the $Z1_{\max}$ Z gap only. Fig. 10 shows the simulated minimum and maximum magnetic coupling factors for all eight investigated VP and BP combinations and for both minimum and maximum Z gap, $Z(1/2)_{\min}$ and $Z(1/2)_{\max}$. When the DD BP was used, the coupling values were slightly higher for all VP coils compared to when the CR BP was used. In addition, the CR BP was found to have a higher coupling variation. This may result in higher effort, complexity and costs for control and power electronics components.

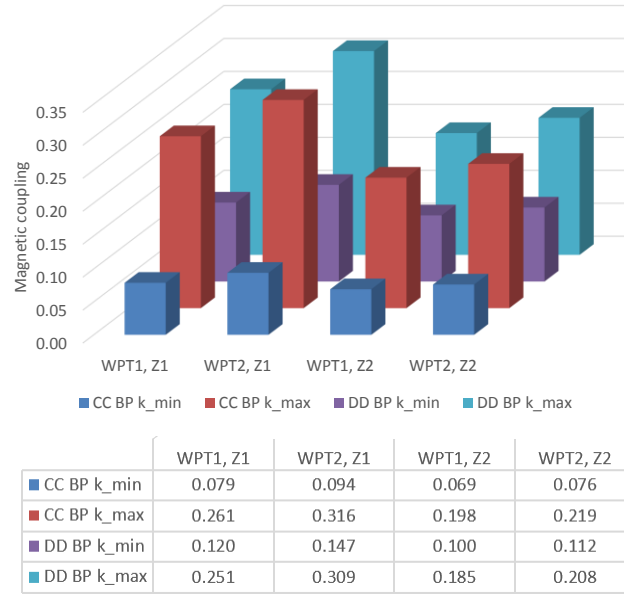


Fig. 10: Magnetic coupling factors (simulation) for all vehicle pad (VP) and base pad (BP) combinations and for the full Z gap range: $k_{max}(Z1_{min})$ and $k_{min}(Z1_{max})$ or $k_{max}(Z2_{min})$ and $k_{min}(Z2_{max})$, respectively.

Fig. 11 shows the simulated magnetics efficiency map for WPT1/Z1 using the DD VP in combination with DD BP and the CR BP. The efficiency/offset map shows a qualitatively similar numerical distribution compared to the magnetic coupling factors of Fig. 9. The minimum and maximum magnetic efficiencies for all VP and BP combinations at $Z(1/2)_{min}$ and $Z(1/2)_{max}$, respectively are shown in Fig. 12. All were found to meet the design criterion $\eta_{mag} > 96\%$.

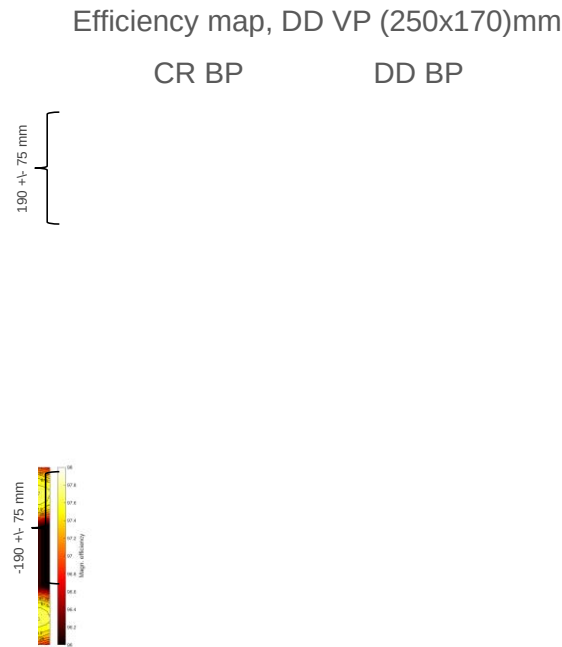


Fig. 11: Magnetic efficiency map (simulation) of the WPT1/Z1 polarized double-D (DD) vehicle pad (VP) in combination with the circular rectangular (CR) base pad (BP) and the DD BP (at $Z1_{max} = 160$ mm).

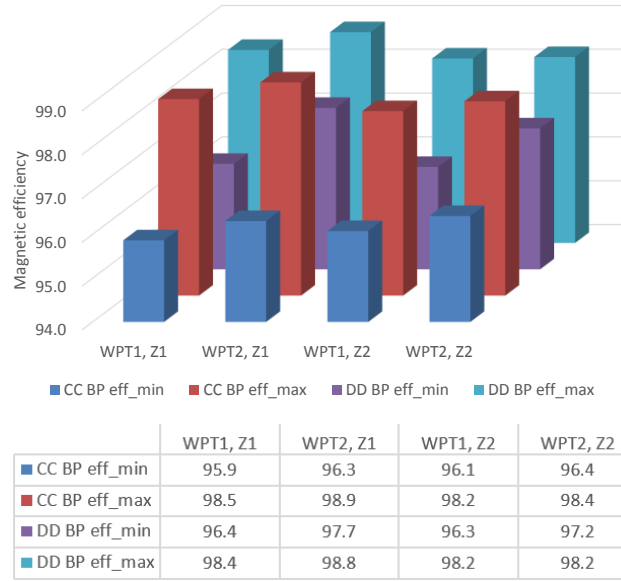


Fig. 12: Magnetic efficiencies (simulation) for all vehicle pad (VP) and base pad (BP) combinations and for the full Z gap range: $\eta_{\max}(Z1_{\min})$ and $\eta_{\min}(Z1_{\max})$ or $\eta_{\max}(Z2_{\min})$ and $\eta_{\min}(Z2_{\max})$, respectively.

5. Measurements

An automatic test rig was used to conduct a system performance test of all VP and BP combinations (Fig. 13). The performance test included the measurement of the mutual and self-inductances as well as of the transferred power. A modular high frequency inverter fed the BP. On the vehicle side, an electronic load was used to emulate the typical battery and its voltage range of $V_{\text{bat}} = 280 - 420 \text{ V}$.

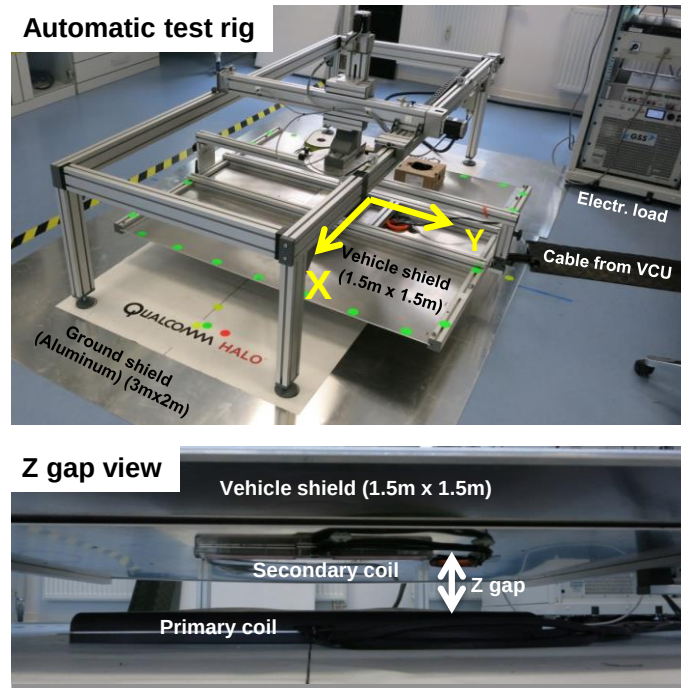


Fig. 13: Test rig setup (top), Z-gap view a base pad (BP) and a vehicle pad (VP) mounted on a $(1.5 \times 1.5) \text{ m}^2$ aluminum vehicle shield (bottom).

Tab. 2: Magnetic coupling validation for selected offset points using the WPT1/Z1 polarized double-D (DD) vehicle pad (VP) in combination with the circular rectangular (CR) base pad (BP).

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

The simulation-measurement agreement of the inductances and magnetic coupling factors for a DD VP and DD BP combination was demonstrated in a previous study [17]. Tab. 2 shows the simulated and measured coupling factors for the WPT1/Z1 DD VP in combination with the CR BP. For all Z gap and offset conditions, the difference between measurement and simulation was below 3%.

The performance measurements of all eight BP and VP combinations were conducted for minimum and maximum Z gap, for the full offset range, and for the full battery voltage range. Tab. 3 summarizes the needed AT for the combinations in zero and maximum offset operating conditions and for $Z(1/2)_{\max}$ and for $V_{\text{bat}} = 350$ V. It was shown that all combinations at all power levels, Z gap heights and offset conditions are generally feasible and all combinations were able to operate at full power and over the entire offset range. When the DD BP was used, the maximum AT required to transfer the nominal power was below $N_{\text{BP}} \cdot I_{\text{BP}} = 358$ A for all offset and Z gap cases and therefore met the defined thermal limitation described in Section 2. In some cases of high Z gap or high offset, the AT needed by the CR BP were up to 47% higher than what the DD BP needed to achieve full nominal power transfer.

The transferable electric power of loosely coupled inductive power transfer systems is defined by the product of the VP and BP AT rather than by the BP AT only. The AT distribution between primary (BP) and secondary (VP) coils can be adjusted by the coils turns counts selection or controlled by power electronics converters [14]. For the coil topology used in this study, the BP currents were set to be variable and the VP currents were set to be constant. Considering the freedom of flexible AT in the BP and the VP, the CR configuration was found to need up to 178 % (e. g. at WPT2/Z2, zero offset) of the value $N_{\text{BP}} \cdot I_{\text{BP}} \cdot N_{\text{VP}} \cdot I_{\text{VP}}$ compared to the configuration with the DD BP (Tab. 3).

The higher amount of AT needed by the CR BP compared to the DD BP is a general drawback of CR coil topology which can be mainly explained by its naturally lower magnetic coupling. The higher amount of AT result in increased EMF/EMC (low frequency leakage field emission) challenges and also in thermal challenges produced by the increased VP and BP operational temperature. These disadvantages of the CR BP have already been reported in the previous studies [17, 18]. Reduced power operation in certain offset and/or Z gap conditions can be used to compensate for the disadvantages of the CR BP.

Tab. 3: Needed ampere-turns (AT) for the vehicle (VP) and base pad (BP) combinations at $Z(1/2)_{\max}$ and $U_{\text{bat}} = 350$ V to enable nominal power transfer.

	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
N111*N212 (0,0) / A ²	73405	93701	66461	107360
N111*N212 (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
N111*N212 (0,0) / A ²	42210	52871	39689	60427
N111*N212 (75,100) / A ²	70913	91214	65003	85008

6. Conclusion

This study demonstrated that interoperable operation of a polarized double-D (DD) vehicle pad and either a circular (CR) or a DD base pad (BP) is possible. In particular, it was shown that a DD vehicle pad (VP) can be operated over both a CR and a DD BP while maintaining the complete positioning tolerance (offset) range of $\pm 75/100$ mm and with no ramifications on the parking lot design. The power transfer was supported over various Z gap distances and over different power levels, including 3.7 kW and 7.7 kW. No changes to the hardware of the CR BP was required for interoperability with the DD VP.

Magnetic coupling factors and magnetics efficiencies of the different vehicle and base 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 ampere-turns (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 mode at some operating conditions. The best performing combination was determined to be the DD VP used in combination with the DD BP.

References

- [1] G. A. Covic and J. T. Boys: *Inductive Power Transfer*. Proc. IEEE, pp. 1-11, 2013
- [2] T. Boys, G. A. Covic: *IPT Fact Sheet Series: No. 1 – Basic Concepts*. 2012 <http://www.qualcomm.com>
- [3] M. Budhia, G.A. Covic, T. Boys: *Design and Optimization of Circular Magnetic Structures for Lumped Inductive Power Transfer Systems*. Power Electronics, IEEE Transactions on Volume: 26 , Issue: 11 Digital Object Identifier: 10.1109/TPEL.2011.2143730 Publication Year: 2011 , Page(s): 3096 - 3108
- [4] M. Budhia, G.A. Covic, J.T. Boys, and C.Y. Huang: *Development and evaluation of single sided flux couplers for contactless electric vehicle charging*. Proc. IEEE Energy Conv. Cong., 2011, pp. 614-621
- [5] O. H. Stielau and G. A. Covic: *Design of loosely coupled inductive power transfer systems*. Proc. IEEE POWERCON, 2000, pp. 85–90
- [6] M. Yilmaz, P. Krein: *Review of charging power levels and infrastructure for plug-in electric and hybrid vehicles*. Electric Vehicle Conference (IEVC), 2012 IEEE International Digital Object Identifier: 10.1109/IEVC.2012.6183208 Publication Year: 2012 , Page(s): 1 – 8
- [7] H. H. Wu, Hunter, A. Gilchrist, D. K. Sealy, P. Israelsen, J. Muhs: *A review on inductive charging for electric vehicles*. Electric Machines & Drives Conference (IEMDC), 2011 IEEE International Digital Object Identifier: IEMDC.2011.5994820 Publication Year: 2011 , Page(s): 143 – 147
- [8] Hiroya Takanashi, Yukiya Sato, Yasuyoshi Kaneko, Shigeru Abe, and T. Yasuda: *A Large Air Gap 3 kW Wireless Power Transfer System for Electric Vehicles*. IEEE Energy Conversion Congr. Exposition (ECCE), 2012

- [9] I. Fujita, T. Yamanaka, Y. Kaneko, S. Abe, and T. Yasuda: *A 10kW transformer with a novel cooling structure of a contactless powertransfer system for electric vehicles*. IEEE Energy Conversion Congr. Exposition (ECCE), 2013, pp. 3643-3650
- [10] M. Budhia, G. A. Covic, and J. T. Boys: *Design and Optimization of Circular Magnetic Structures for Lumped Inductive Power Transfer Systems*. IEEE Trans. Power Electron., vol. 26, pp. 3096-3108, 2011
- [11] Y. Nagatsuka, N. Ehara, Y. Kaneko, S. Abe, and T. Yasuda: *Compact contactless power transfer system for electric vehicles*. IEEE Power Electron. Conf. (IPEC), 2010, pp. 807-813
- [12] F. Y. Lin, A. Zaheer, M. Budhia, Grant A Covic: *Reducing Leakage Flux in IPT Systems by Modifying Pad Ferrite Structures*. IEEE Energy Conversion Congr. Exposition (ECCE), 2014, pp. 1770-1777
- [13] Kürschner, D. ; Rathge, C. ; Jumar, U.: *Design methodology for high efficient inductive power transfer systems with high coil positioning flexibility*. IEEE Transactions on Industrial Electronics, Vol. 60, Issue: 1, 2013, p.372-381
- [14] Kürschner, D. ; Rathge, C. ; Schulze, E.: *Optimization of contactless inductive transmission systems for high power applications*. Power Electronics Intelligent Motion Power Quality - PCIM, Nürnberg, 22.-24.05.2007, Proceedings on CD-ROM
- [15] <http://www.draysonstracingtechnologies.com/product.html?Wireless-Power-Transfer-Systems-6>, 9/17/2014
- [16] <http://www.ipt-technology.com/index.php/en/about-us>, 9/17/2014
- [17] Ombach, G.; Kuerschner, D.; Mathar, S.: *Universal base coil solution for interoperable system for stationary wireless EV charging*. International Conference on Sustainable Mobility Applications – SMART, 23.-25.11.2015, Kuwait
- [18] Ombach, G.; Kuerschner, D.; Mathar, S.; Chlebosz, W.: *Optimum magnetic solution for interoperable system for stationary wireless charging*. International Conference on Ecological Vehicles and Renewable Energies - EVER, 31.03.2015 - 02.04.2015, Monte-Carlo (Monaco)
- [19] INTERNATIONAL ELECTROTECHNICAL COMMISSION: *IEC guide 117 - Electrotechnical equipment – Temperatures of touchable hot surfaces*. Edition 1.0, 2010-10, ISBN 978-2-88912-219-6
- [20] IEC 61980-1:2015 *Electric vehicle wireless power transfer (WPT) systems - Part 1: General requirements*. IEC Webstore: <https://webstore.iec.ch/publication/22951>

Authors



Daniel Kuerschner received Diploma and Ph.D degrees in electrical engineering from the Otto-von-Guericke-University of Magdeburg in 2005 and 2009, respectively. He worked on wireless power transfer at the Institut f. Automation und Kommunikation (Magdeburg) from 2004-2011 and at Paul Vahle (Kamen) from 2011-2013. In 2013, he joined QUALCOMM CDMA Technologies GmbH and is responsible for simulation, design and EMC/EMF of wireless electric vehicle charging systems (WEVC). Daniel Kuerschner has more than 12 years' experience with inductive power transfer technology, particularly with magnetics, power electronics, electromagnetic compatibility and simulation methods. In these fields he has published more than 30 scientific papers. He is member of IEEE, SAE international and several German standardization committees, including VDE and DKE.



Grzegorz Ombach is the Vice President of Engineering at QUALCOMM CDMA Technologies GmbH and is responsible for global research and development of Qualcomm Incorporated's wireless electric vehicle charging (WEVC) technology. He joined Qualcomm in April 2012 from Brose Fahrzeugteile, where he managed the design of automotive electric drive systems as Director of Advanced Development Drives. Prior to Brose Fahrzeugteile, he was Principal Expert for Electromagnetic Simulation and Motor Design at Siemens VDO Automotive AG. His responsibilities included management of a panel of experts in charge of electric drive systems for automotive. Grzegorz Ombach holds a MSc. in electrical engineering from the Technical University of Lodz, Poland, and a Ph.D. in electrical engineering from the Silesian University of Technology, Poland. He has published over 70 papers and holds more than 25 patents (awarded and pending) on automotive electrical systems.



Sebastian Mathar studied electrical engineering at RWTH Aachen University. He has a Ph.D in mechanical engineering, also from RWTH Aachen University. Sebastian Mathar is an expert for standardization of wireless electric vehicles charging (WEVC) systems. He has more than 10 years of experience in standardization work, and is a founding member of all major working groups in IEC, ISO and SAE which deal with WEVC standards. He joined QUALCOMM CDMA Technologies GmbH in 2013. Before that, he worked for an engineering services provider in the automotive industry in various leadership positions.

