WiseHarbor Spotlight Report

By Keith Mallinson, 24th August 2015

WEVC Requires Many Technologies with Well-Integrated Systems and Supply

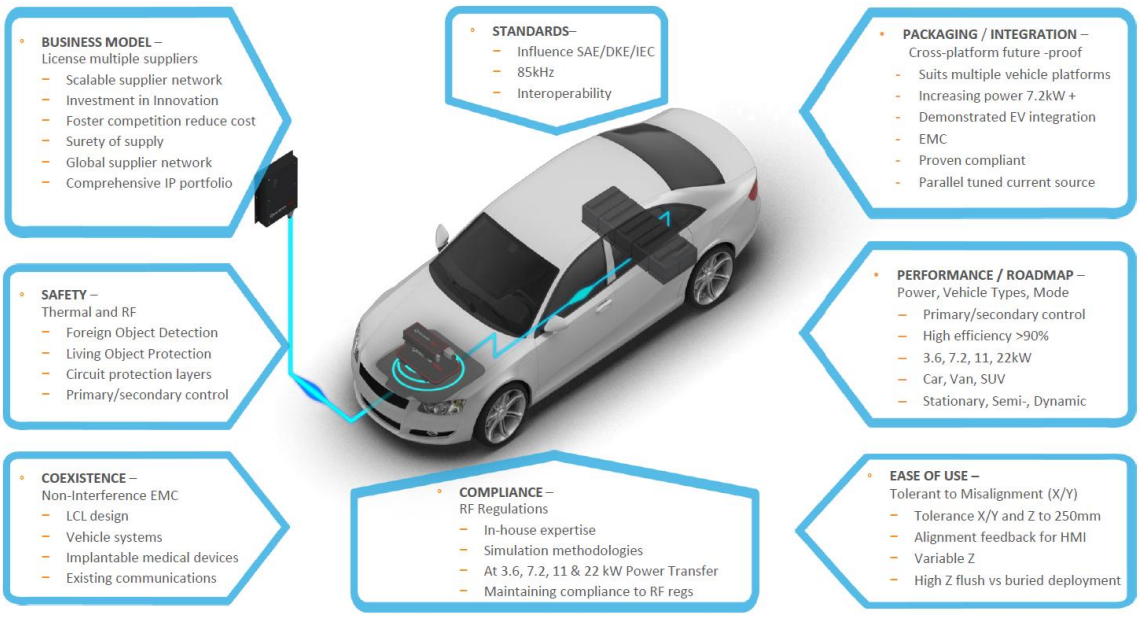
Bottom Line:	Effective and economic wireless charging systems entail much more than coil and pad technologies
Report Focus:	Systems and supply aspects of WEVC including the need for various complementary and well-integrated technologies
Target Readers:	Product and engineering managers in automotive Tier 1 suppliers and OEMs including standard setting participants

Executive Summary

State-of-the art coil and pad technologies including Double-D and BiPolar are highly desirable in Wireless Electric Vehicle Charging; but there is much more to building the effective, economic and safe systems required by Tier 1 suppliers, OEMs and consumers. Many complementary and compliant elements must be developed, integrated and optimized. Technology transfer from a WEVC expert is best for all with highest-performance and homologated systems at lowest cost.

Exhibit 1

WEVC Elements, Integration, Commercial and Compliance Requirements



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I. Introduction

This is the second in a series of WiseHarbor Spotlight Reports on WEVC commissioned by Qualcomm. This report focuses on systems aspects of wireless charging including development and integration of various complementary technologies, the optimal division of labor and business models among suppliers including technology transfer to Tier 1s and OEMs. The first report discussed developments in coil, pad and associated technologies employed in inductive power transfer, including DD and BiPolar coil topologies which have been proven most-effective. The next report will focus on crucial ancillary safety technologies for foreign object detection and living object protection.

II. What is in a WEVC system and its supply?

Tier 1 suppliers need to source much more than just the most effective coil and pad technologies in development and manufacture of high-performance and standards-compliant WEVC products for their OEM customers. State-of-the–art coil and pad technologies including DD and BiPolar are indeed crucial enablers for IPT; but these need to be integrated and optimized with other, complementary technologies including power electronics and system control. Tier 1 suppliers need to be not merely providers of components; but also of complete WEVC systems. These must comply with various regulations internationally, including those for safety and electromagnetic interference. Technologies need to be standardized to ensure highest performance, interoperability, and backward-compatibility where possible.

The entire package of high-performance, compliant and certified technologies must be readily available with technical support for implementation as systems by Tier 1 suppliers in OEM production model designs. Ongoing R&D, providing the most competitive technology improvement roadmap including various functional elements in an overall system is also required. Planned developments should include higher-power ratings, advances from static to dynamic charging which can be used while vehicles advance in-line slowly (e.g. taxis waiting at train stations and airports) or at regular driving speeds. Systems must also comply with any new safety requirements.

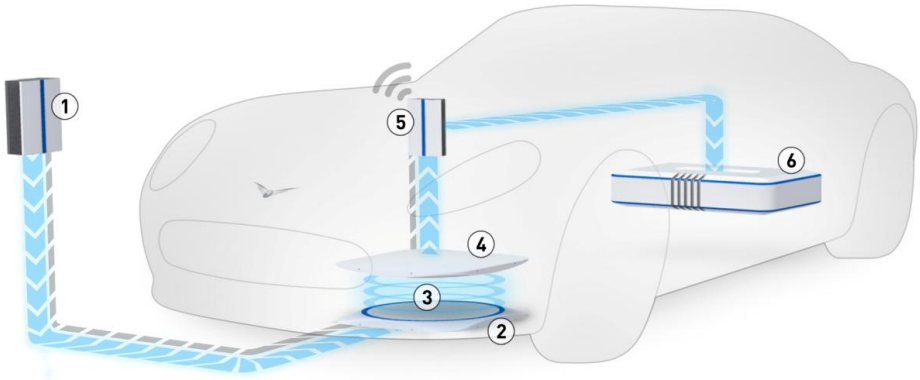
III. WEVC system components, integration and compliance

There are several fundamental components in any WEVC system as illustrated in the following overview exhibit. The power supply (1) accesses the mains supply and generates the high-frequency electrical waveforms required for IPT with one or more transmitter pad (2), also referred to as base pad, coils. The power supply unit also includes electronics and software for primary-side power-transfer optimization over the air (3) with Z-gaps varying by vehicle make and model due to differing vehicle ride heights and laden weights as well

as by mount of base pad including buried, flush and surface, and with X/Y positioning variations each time a vehicle is parked for charging. The electronics also include the communications controller and antenna for the WiFi data link to the in-vehicle systems.

Exhibit 2

WEVC System Components



1 Power Supply 2 Transmitter Pad 3 Wireless Electricity & Data Transfer
4 Receiver Pad 5 System Controller 6 Battery

The receiver pad (4), also referred to as the vehicle pad, collects electrical power by inductive coupling with the transmitter pad. The systems controller unit (5) includes the vehicle's power electronics, WiFi communications and secondary-side power transfer optimization software. The communications capabilities and optimization software also enable secondary-side control, coordination of primary-side and secondary-side controllers, and regulation of voltage and power flow to the battery (6), including the battery management system.

The following system schematic provides more detail on the electrical and electronic functions in WEVC. Many technologies have been developed including coil and pad technologies such as DD and BiPolar, and with extensive developments in associated power electronics, impedance matching, signaling and control. In fact, there are significant innovative technologies in all eleven of the functional categories listed in the table.

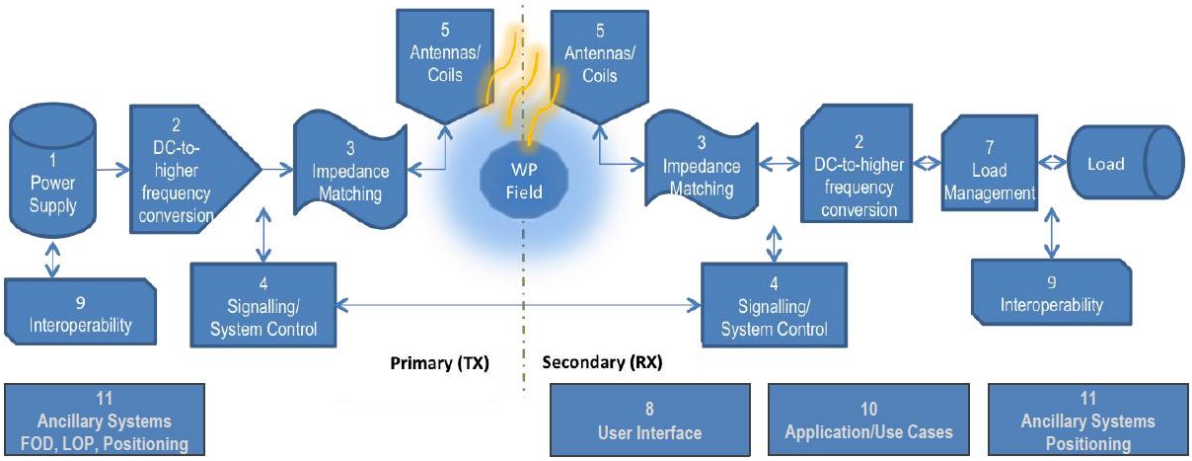
This has all taken a couple of decades to develop; in academia with dozens of PhD and post-doctorate students, with extensive pre-commercial work and a few commercial implementations in recent years. Every functional element is subject to extensive technology developments to maximize its performance and that of the entire system working in concert. This includes theoretical work in inductive power transfer, software simulations, lab testing, development of prototypes and product reference designs. Technologies in all eleven categories are also subject to hundreds of patents in the US, Europe, Japan, Korea and China. There is extensive additional intellectual property in hardware design, software models and in know-how.

Following some small commercial implementations with buses; fully-working prototypes and reference designs including hardware and software models have been completed. Reference designs are well-proven implementations of components and systems which can be readily and rapidly adapted by Tier 1 suppliers with additional development work for mass-market product design and manufacture. Specific product implementations will

reflect differing hardware and software platform preferences (e.g. for processor architectures and programming languages) among manufacturers, the desires of these to differentiate themselves and the rigorous performance, quality and reliability requirements for automotive products.

Exhibit 3

WEVC System Electrical and Electronic Functional Schematic



1	Power Supply	Power Supply
2	DC-to-higher frequency conversion	Amplification and voltage conversion
3	Impedance Matching	Tuning, switching in and out elements
4	Signaling/system control	In-band and out-of-band
5	Antennas/ Coils	Repeaters
6	Wireless Power Field	Evenness; interference mitigation; emissions; safety
7	Load Management	Conveying or disconnecting WP to the load/ battery
8	User Interface	User Interface
9	Interoperability	Connectivity to other solutions e.g. wired
10	Application/Use case	E.g. charging in public places
11	Ancillary systems	Foreign object detection; living object protection, positioning

Technologies are developed to conform to various regulations and drive formulation of common international standards. This includes making WEVC safe, minimizing electromagnetic interference, maximizing technical performance and ensuring interoperability among different types of pad including circular vehicle pads working with bipolar base pads. Relevant standards organizations include ICNIRP, SAE, ISO and IEC.

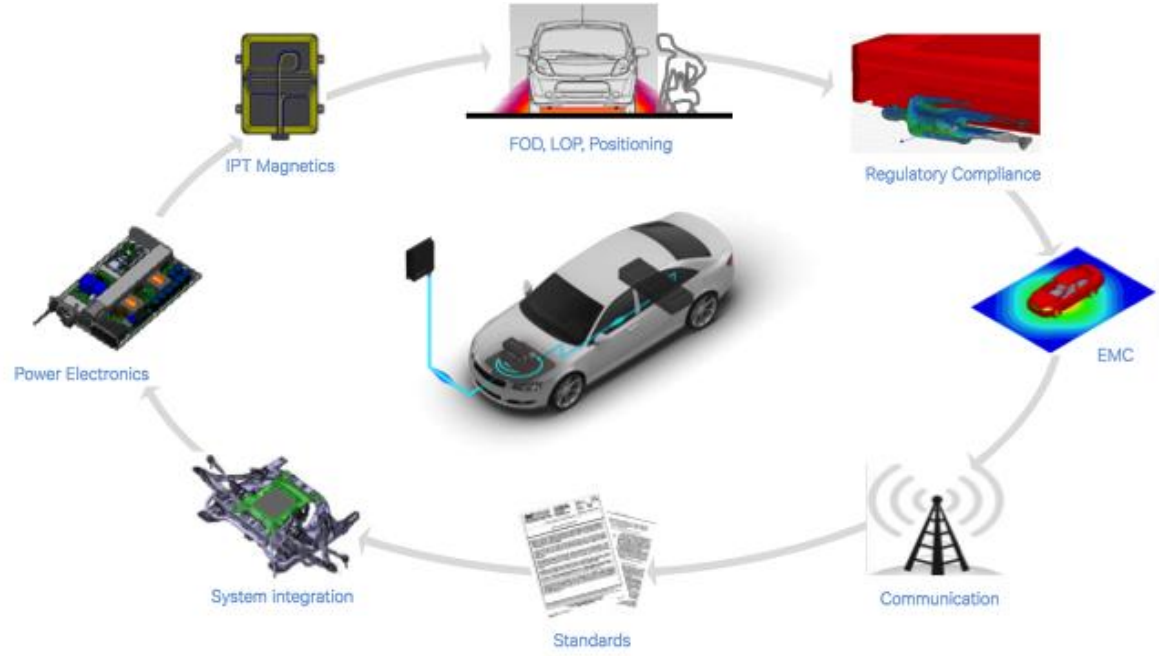
IV. Third-party experts specialize in supply of WEVC technologies and systems

The enormous progress in WEVC has largely been achieved by specialists with the necessary competences and economies of scale in technology development, standards development and in complying with applicable regulations for safety and electromagnetic interference. In addition to the core capabilities detailed above, a complete WEVC system needs various complementary and ancillary capabilities together with support, including technical and non-technical aspects in compliance and standardization. For example,

signaling and systems control across the wireless charging air gap also requires wireless data communications. Open-standard WiFi technology is very suitable for this. Electromagnetic compatibility among various different systems within the car must be ensured despite the generation of IPT magnetic fields. Safe and commercially viable WEVC must also include ancillary FOD and LOP systems which shut down charging and alert car owners when safety hazards are detected. FOD systems detect when stray metal or magnetic objects present between the charging pads might get hot. LOP systems primarily ensure that no harm can come to humans—including children playing nearby— while also affording protection to pets by complying with ICINRP requirements on maximum bodily exposure to electromagnetic emissions. I will examine FOD and LOP systems, and the safety requirements for these, in detail in the next Spotlight report in this series.

Exhibit 4

Technologies, Systems Integration, Standardization and Compliance in WEVC



Ensuring that compliance to safety including electrical emission regulations is achieved and maintained on an international basis is also a substantial endeavor, as is contributing to interoperability standards with selection of best technologies for these. It would be very inefficient for every WEVC equipment supplier to be doing everything for themselves.

It is highly efficient that these technology developments and supporting activities have been pursued by specialists. WEVC is a relatively new field which primarily demands expertise in electrical engineering and electronics, as well as in the automotive industry. It therefore makes great sense that base technologies, hardware and software models, as well as certain expertise, can be significantly shared between technology developers and various Tier 1 suppliers and OEMs producing mass-market products. It is one thing getting WEVC to work in the lab, and quite another to integrate it with a vehicle to charge a battery. Few have the ability or experience in this. A lot of downstream electrical and mechanical integration including software-based optimization is required. These specialists also shoulder a significant share of costs and commercial risks on behalf of the entire emerging WEVC market.

V. One-stop-shop for technology and commercial support

It makes best sense for a complete package of WEVC technologies to be provided to Tier 1 manufacturers on a pre-integrated and regulations-compliant basis from an expert one-stop-shop. This provides confidence that everything will work well together when implemented in commercial products for production. This is most cost-effective versus more vertically-integrated supply. WEVC capabilities including technologies, reference designs and expertise with capabilities in regulatory compliance and standardization can be shared most widely as common platforms across Tier 1s and OEMs. Rather than every Tier 1 "reinventing the wheel," technologies and reference designs can readily be adopted and adapted in development on commercial products. Know-how including staff training and associated documentation can also be provided.

The automotive industry recognizes it is often necessary to adopt technologies including entire systems from outside its sector and to share them among several Tier 1s and OEM suppliers. This is currently illustrated by a consortium of Audi, BMW and Daimler acquiring Nokia's HERE mapping division.[1] HERE's capabilities, and those of its competitors Google and Apple who have broad strategic ambitions in information and entertainment in cars as well as everywhere else, are becoming increasingly important in the automotive industry.

Systems developers can best conceptualise and develop world-leading technologies and WEVC solutions. They can plan and execute delivery of class-leading IPT systems with economies of scale in serving several or many customers while providing customized-design support where required for Tier 1 and OEM product implementation and differentiation. Their expertise in the manufacture and test of small runs of pre-production prototypes is the ideal precursor to the mass-market product development and production work by Tier 1s and OEMs.

Developments in WEVC and ancillary technologies have generated a lot of different kinds of intellectual property. As explained above, much of it among the eleven functional elements described above is patented. There is also significant patented and other intellectual property in the methods and processes required to manufacture WEVC systems. Considerable amounts of copyright-protected material also arise from developments including reference designs in hardware and software for system operation and optimization. Substantial technological and other know-how has also been developed. Manufacturers need to access this to avoid illegal infringement and wasteful duplication of effort.

Trademarks and branding are also important in development of demand for WEVC as they are with other in-car systems. For example, Bose in entertainment, TomTom and HERE in navigation bring additional value to OEM brands with the specialized complementary nature of the technologies and capabilities provided. With many OEMs on the market, it is economically efficient that primary demand for WEVC, with consumer purchases from OEMs, be developed in conjunction with trademarks, brands and marketing initiatives including advertising and sports sponsorship which span the entire potential market. OEM product demand is thus significantly stimulated by the marketing programs of expert WEVC technology suppliers.

VI. Security in supply through licensing from a weighty specialist

A highly-effective way of exploiting technologies and mitigating risks, while securing fruits of R&D on an ongoing basis, is through technology licensing on fair, reasonable and non-discriminatory terms. This enables all comers to employ technologies which have proven best in development and prototype testing. The most effective WEVC capabilities can be

[1] http://fortune.com/2015/07/21/nokia-maps-here-german-cars/

obtained for exploitation by Tier 1 suppliers and OEMs with the lowest technological and commercial risks by licensing from a substantial technology provider with extensive R&D and experience in technology transfer. The latter's ability to use its intellectual property both defensively and offensively is also important. An expert developer and licensor of WEVC technologies is best placed to ensure that solutions have "freedom to operate" with access to all technologies required, while protecting against infringement with unlicensed use of technologies by competitors.

Security of supply is essential in vehicle manufacture. This can be achieved by selecting an expert technology supplier with sufficient scale, diversity of resources and financial strength to work alongside customers over OEMs' several-year design cycles for integration of Tier 1 supplier WEVC systems in new vehicles.

This approach is highly effective for all. It enables Tier 1 suppliers and OEMS to focus on what they do best while acquiring the highest-performance and most compliant technologies as rapidly as possible and at low cost. It provides R&D and associated commercial support in compliance, standards and marketing on an outsourced basis. It does not preclude differentiation of the WEVC products and solutions offered by Tier 1 suppliers and OEMs. To the contrary, they can engage in as much differentiation as they wish by modifying and improving upon reference designs. A licensed approach also provides an ideal means of enabling second-source and third-source Tier 1 supply when diversity of supply is demanded by the OEMs.

Further Reading

Wireless Charging Ready for Burgeoning Mass Market in EVs. WiseHarbor Spotlight report, by Keith Mallinson, 18th August 2015
http://www.wiseharbor.com/pdfs/WiseHarbor%20Spotlight%20Report%201%20Efficacy%202015Aug18.pdf

The Inductive Power Transfer Story at the University of Auckland. By John T. Boys and Grant A. Covic. IEEE Circuits and Systems Magazine, Second Quarter 2015
http://ieeexplore.ieee.org/xpl/login.jsp?tp=&arnumber=7110451&url=http%3A%2F%2Fieeexplore.ieee.org%2Fiel7%2F7384%2F7110439%2F07110451.pdf%3Farnumber%3D7110451

About WiseHarbor

Founded in 2006, WiseHarbor is an industry analyst and expert consultant in wireless and communications technology markets. WiseHarbor has many large and global companies among its clients. It frequently publishes articles in the trade press and for industry associations on various technical, commercial and regulatory issues. Engagements include commercial and financial analysis and expert witness testimony.