TEST REPORT

Report Number. : 14932130-E2V3

Applicant	**:**	WiTricity Corporation 57 Water Street Watertown, MA, 02472 US
Model	**:**	GWA1100
FCC ID	**:**	2BFEF-WWA1101
EUT Description	**:**	Charging Pad
Test Standard(s)	**:**	KDB 680106 D01 Wireless Power Transfer v04

Date Of Issue:
2025-05-21

Prepared by:
UL Verification Services Inc.
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CERT #0751.05

Revision History

Rev.	Issue Date	Revisions	Revised By
V1	2025-02-18	Initial Issue	---
V2	2025-05-07	Section 6, 8 Updated	Henry Lau
V3	2025-05-21	Section 5.1 & 5.2 Updated	Henry Lau

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1. ATTESTATION OF TEST RESULTS

COMPANY NAME:	WiTricity Corporation 57 Water Street Watertown, MA, 02472 US
EUT DESCRIPTION:	Charging Pad
MODEL NUMBER:	GWA1100
BRAND:	WiTricity
SERIAL NUMBER:	GWA11001023252000300
SAMPLE RECEIPT DATE:	2023-10-20
DATE TESTED:	2023-12-12

APPLICABLE STANDARDS	
STANDARD	**TEST RESULTS**
KDB 680106 D01 Wireless Power Transfer v04	Complies

UL Verification Services Inc. tested the above equipment in accordance with the requirements set forth in the above standards. The test results show that the equipment tested is capable of demonstrating compliance with the requirements as documented in this report.

The results documented in this report apply only to the tested sample, under the conditions and modes of operation as described herein. It is the manufacturer's responsibility to assure that additional production units of this model are manufactured with identical electrical and mechanical components. All samples tested were in good operating condition throughout the entire test program. Measurement Uncertainties are published for informational purposes only and were not taken into account unless noted otherwise.

This document may not be altered or revised in any way unless done so by UL Verification Services Inc. and all revisions are duly noted in the revisions section. Any alteration of this document not carried out by UL Verification Services Inc. will constitute fraud and shall nullify the document.

Approved & Released For
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2. TEST METHODOLOGY

This report contains data provided by the customer which can impact the validity of results. UL Verification Services Inc. is only responsible for correctly integrating customer-provided data with measurements performed by UL Verification Services Inc.

All testing / calculations were made in accordance with

- FCC KDB 680106 D01 RF Exposure Wireless Charging Apps v04

3. FACILITIES AND ACCREDITATION

UL Verification Services Inc. is accredited by A2LA, certification #0751.05, for all testing performed within the scope of this report. Testing was performed at the locations noted below.

	Address	ISED CABID	ISED Company Number	FCC Registration
☐	Building 1: 47173 Benicia Street, Fremont, CA 94538, USA	US0104	2324A	550739
☐	Building 2: 47266 Benicia Street, Fremont, CA 94538, USA			
☐	Building 3: 843 Auburn Court, Fremont, CA 94538, USA			
☒	Building 4: 47658 Kato Rd, Fremont, CA 94538, USA			
☐	Building 5: 47670 Kato Rd, Fremont, CA 94538, USA			

4. DECISION RULES AND MEASUREMENT UNCERTAINTY

4.1. METROLOGICAL TRACEABILITY

All test and measuring equipment utilized to perform the tests documented in this report are calibrated on a regular basis, with a maximum time between calibrations of one year or the manufacturers' recommendation, whichever is less, and where applicable is traceable to recognized national standards.

4.2. DECISION RULES

The Decision Rule is based on Simple Acceptance in accordance with ISO Guide 98-4:2012 Clause 8.2. (Measurement uncertainty is not taken into account when stating conformity with a specified requirement.)

4.3. MEASUREMENT UNCERTAINTY

Where relevant, the following measurement uncertainty levels have been estimated for tests performed on the apparatus:

PARAMETER	U_{Lab}
Magnetic Field Reading (A/m)	+/-0.04284 (A/m)
Electric Field Reading (V/m)	+/-0.03682 (V/m)

Uncertainty figures are valid to a confidence level of 95.45%.

5. EQUIPMENT UNDER TEST

5.1. DESCRIPTION OF EUT, OPERATING FREQUENCY AND POWER

The EUT is a charging pad using a coil that produces a magnetic field in the reactive near-field that is only coupled to a receiving magnetic coil designed to be interoperable at a frequency of 85 kHz. The coupled coil does not produce intentional far-field RF energy (i.e., the far-field energy of the charging pad is well below one billionth of the transferred energy); however, the charging pad is capable of transferring up to ~10.5 kW of power to a coupled Receiver. The device is powered via a Wall Box (240 V / 46 Amps). The EUT also contains a FOD / LOD (Foreign Object Detection / Living Object Detection) System Short Range Device (SRD) operating at 3 MHz & 4.4 MHz.
Each FOD/LOD Sensor can dissipate up to ~2.8mW (4.47 dBm) of peak RMS power but each sensor is only active for 3ms within a 100ms window (10Log(3/100) = -15.23 dB) therefore the average power dissipation each sensor is equal to -10.76 dbm or 84 uW.

5.2. DESCRIPTION OF AVAILABLE ANTENNAS/COILS

The antenna gain(s) and type, as provided by the manufacturer, are as follows:

The EUT includes a charging pad that contains a coil that produces a magnetic field that is used to couple energy in the reactive near-field. The frequency of operation of that coil is fixed to 85 kHz.

The EUT includes an array of near-field coils / electrically very small loop antennas that are fixed in the EUT and operate at 3 MHz & 4.4 MHz. These electrically small loop antennas do not have appreciable far-field gain due to their near-field nature.

5.3. SOFTWARE AND FIRMWARE

The firmware installed in the EUT during testing was

WEVSE: 677
PPC: 0.8.8
MODS: 3.5.2

5.4. WORST-CASE CONFIGURATION AND MODE

A Mimic plate connected to a load is placed over the charging pad. Measurements are made to the following regions

Region 0 (Area between mimic plate and charging pad)
Region 1 (20 cm from mimic plate in the back)
Region 2 (20 cm from mimic plate in the right)
Region 3 (20 cm from mimic plate in the front closer to wall box)
Region 4 (20 cm from mimic plate in the left)
Region Top (20 cm from the top of the mimic plate)

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The EUT was tested in the following configurations:

Config	Descriptions	Frequency	Remarks
1	EUT is powered by Wall box and charging mimic plate	85 kHz (11 kW input)	Tested at 0cm
2	EUT is powered by Wall box and charging mimic plate	85 kHz (11 kW input)	Tested at 20cm

6. TEST MEASUREMENT EQUIPMENT AND METHODS

The following test and measurement equipment was used for the tests documented in this report:

Test Equipment List					
Description	Manufacturer	Model	Label ID	Cal Due	Cal Date
Electric and Magnetic Field Probe	Narda	EHP-400	23682	2024-06-30	2023-06-30
Thermometer - Digital	Control Company	14-650-118	175731	2024-02-29	2023-02-08

UL Verification Services Inc. utilized a calibrated Narda ELT-400 Field Meter for all Electromagnetic Field (EMF) measurements performed. The field meter is capable of reading up to 400 kHz. The frequency of operation of the WPT system under test was verified to be a fixed frequency of 85 kHz, which falls easily within the capabilities of the Narda ELT-400 meter.

6.1. Magnetic Field Measurement Units

The Narda ELT-400 gives field strength values in micro-Tesla. Given that all measurements were performed with the open-air probe in open air, the field levels are converted from B Field to H Field using the following formula: $H = \frac{B}{\mu_0}$, where $\mu_0 = 4\pi \times 10^{-7}$.

6.2. Operation of Narda ELT-400 Instrument

The field meter contains an attachable probe. The probe consists of 3 internal loops each orthogonal to each other to measure the total magnitude of the B-Field ($|B| = \sqrt{{B_x}^2 + {B_y}^2 + {B_z}^2}$). The attachable probe that was used for testing has internal loop areas of 100 cm^2 (internal loop radius, $r = \sqrt{\frac{100}{\pi}} \cong 5.64\ cm$). The outer protective shell of the 100 cm^2 probe has a diameter of 12.5 cm (radius = 6.25 cm).
The following settings were used on the Narda ELT-400 meter:

- Mode = 320 µT
- Range = High
- Detection = RMS
- Display mode = Both Instantaneous & Max Hold values measured
- Cutoff = 30 Hz

6.3. Data Visualization

Prior to testing, the setup distances described in WiTricity's test procedure were validated to ensure that the center of the probe was always used as the reference location. Additionally, it was validated that the distance from the probe center any part of the WPT system was always ≤ 20 cm. In many cases, the distance was much less than 20 cm for conservancy.
The raw field data can be found in Section 9. All measurements were taken by hand using markings to help position the probe.

7. MAXIMUM PERMISSIBLE RF EXPOSURE

7.1. FCC LIMITS AND SUMMARY

KDB 680106

3.2 Equipment Authorization Procedures for Devices Operating at Frequencies Below 4 MHz

The RF exposure limits, as set forth in § 1.1310, do not cover the frequency range below 100 kHz for Specific Absorption Rate (SAR) and below 300 kHz for Maximum Permitted Exposure (MPE). In addition, present limitations of RF exposure evaluation systems prevent an accurate evaluation of SAR below 4 MHz. For these reasons, a specific MPE-based RF Exposure compliance procedure for devices operating in the aforementioned low-frequency ranges has been set in place. This procedure is applicable to Equipment Authorization of all RF devices, thus including, but not limited to, Part 18 and WPT devices.

Accordingly, for § 2.1091-Mobile devices, the MPE limits between 100 kHz to 300 kHz are to be considered the same as those at 300 kHz in Table 1 of § 1.1310, that is, 614 V/m and 1.63 A/m, for the electric field and magnetic field, respectively. For § 2.1093-Portable devices below 4 MHz and down to 100 kHz, the MPE limits in § 1.1310 (with the 300 kHz limit applicable all the way down to 100 kHz) can be used for the purpose of equipment authorization in lieu of SAR evaluations.
Furthermore, consistent with FCC's equipment authorization RF exposure guidance, any device (both portable and mobile) operating at frequencies below 100 kHz is considered compliant for the purpose of equipment authorization when the external (unperturbed) temporal peak field strengths do not exceed the following reference levels:

83 V/m for the electric field strength (E)
and
90 A/m for the magnetic field strength (H).

These data may be provided through measurements and/or numerical simulations, and for all the positions in space relevant for any possible body exposure.

For all the cases mentioned above, E and H measurements should be made from all sides of the transmitter along all the principal axes defined with respect to the orientation of the transmitting element (e.g., coil or antenna). When clearly demonstrated, symmetry considerations may be used to reduce the amount of testing. Furthermore, for "low-frequency" loop/coil emitting structions that lead to dominant H-field near-field emissions (i.e., with E/H ratio less than 1/10 of the 377-ohm free space wave impedance, typically frequencies less than 1 MHz), only H-field measurements are sufficient for demonstrating MPE limit compliance.

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RESULT

Test Engineer:	45256 JB 23422 SI	Test Date:	2023-12-12

7.1.1. MAXIMUM RESULT SUMMARY

Ambient check before test 0.027 A/m.

Procedure

Measurements were taken at all 4 sides of the mimic plate and the top & bottom (area between EUT and Vehicle assembly.
For the top, it was verified that the area around the vehicle assembly exhibited worst case field strength.
For the bottom Region 0, it was verified that charging plate would stop charging when a foreign object is detected.

EUT was tested with the Narda ELT-400 meter at both 0 cm and 20 cm.

CONFIGURATION 1: OPERATING MODE WITH mimic plate (85kHz) at 0cm

360V Output

Limit	Max Value	Location	PASS / FAIL
90 A/m (113.10 µT)	11.248 A/m (14.06 µT)	Top above Vehicle Assembly	**PASS**

480V Output

Limit	Max Value	Location	PASS / FAIL
90 A/m (113.10 µT)	16.472 A/m (20.59 µT)	Top above Vehicle Assembly	**PASS**

CONFIGURATION 2: OPERATING MODE WITH mimic plate (85kHz) at 20cm

360V Output

Limit	Max Value	Location	PASS / FAIL
90 A/m (113.10 µT)	3.75 A/m (4.688 µT)	Top above Vehicle Assembly	**PASS**

480V Output

Limit	Max Value	Location	PASS / FAIL
90 A/m (113.10 µT)	3.76 A/m (4.7 µT)	Top above Vehicle Assembly	**PASS**

7.1.2. H- FIELD MEASUREMENTS

Note: Avg measurements were performed.

CONFIGURATION 1: OPERATING MODE WITH mimic plate (85kHz) at 0cm

Configuration	Test Mode	Measuring Distance (cm)	Magnetic Field Limit (A/m)	Magnetic Field Reading (A/m)				
			FCC	Location	RMS (uT)	A/m conversion	Duty Cycle %	FCC Average
1	360 V Charge Level (Greatest current)	0 cm surrounding the device (1 - 4) and 0 cm above the top surface of the mimic plate.	90	Ambient	0.034	0.027	100	0.027
				1	6.718	5.374		5.374
				2	5.517	4.414		4.414
				3	3.718	2.974		2.974
				4	9.558	7.646		7.646
				Top	14.060	11.248		11.248
				Max	14.060	11.248		11.248
	480 V Charge Level			Ambient	0.034	0.027	100	0.027
				1	9.049	7.239		7.239
				2	4.871	3.897		3.897
				3	3.348	2.678		2.678
				4	7.605	6.084		6.084
				Top	20.590	16.472		**16.472**
				Max	20.590	16.472		**16.472**

CONFIGURATION 2: OPERATING MODE WITH mimic plate (85kHz) at 20cm

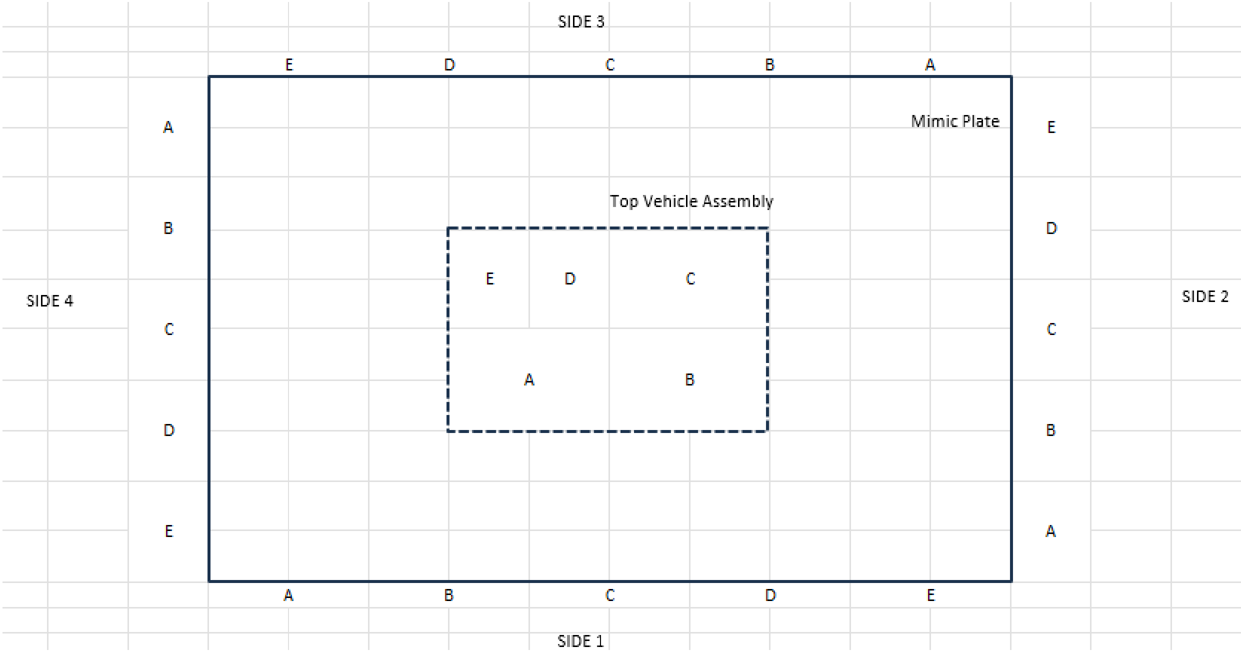
Configuration	Test Mode	Measuring Distance (cm)	Magnetic Field Limit (A/m)	Magnetic Field Reading (A/m)				
			FCC	Location	RMS (uT)	A/m conversion	Duty Cycle %	FCC Average
2	360 V Charge Level (Greatest current)	20 cm surrounding the device (1 - 4) and 20 cm above the top surface of the mimic plate.	90	Ambient	0.034	0.027	100	0.027
				1	2.622	2.098		2.098
				2	1.994	1.595		1.595
				3	1.538	1.230		1.230
				4	1.338	1.070		1.070
				Top	4.688	3.750		3.750
				Max	4.688	3.750		3.750
	480 V Charge Level			Ambient	0.034	0.027	100	0.027
				1	2.740	2.192		2.192
				2	1.301	1.041		1.041
				3	1.352	1.082		1.082
				4	1.267	1.014		1.014
				Top	4.700	3.760		**3.760**
				Max	4.700	3.760		**3.760**

8. RF EXPOSURE TEST SETUP AND SETUP PHOTO

Refer to 14932130 EP1 for setup photos.

9. Appendix of Raw Data

RMS and Max Hold readings were performed.



0 cm distance at 360V output

		Side				
	uT	1	2	3	4	5 (top)
RMS	A	1.156	3.135	1.666	2.629	13.72
MH		1.193	2.46	1.619	2.643	20.26
RMS	B	5.411	3.756	3.718	6.595	10.03
MH		4.282	5.003	3.792	5.952	6.55
RMS	C	6.718	5.517	3.571	9.558	11.53
MH		9.837	4.222	3.139	8.246	5.658
RMS	D	7.152	2.586	2.761	3.373	4.726
MH		4.869	2.327	3.129	2.47	3.478
RMS	E	2.546	1.512	2.196	1.272	14.06
MH		3.113	1.408	2.159	1.22	19.47

	1	2	3	4	5
Max hold Sweep	9.758	5.639	3.79	10.28	20.17

0 cm distance at 480V output

		Side				
	uT	1	2	3	4	5 (top)
RMS	A	1.628	2.601	1.359	2.589	3.463
MH		1.755	3.297	1.423	2.603	8.273
RMS	B	4.75	4.871	3.348	5.118	9.164
MH		3.852	3.734	3.576	4.916	1.069
RMS	C	7.048	4.023	2.846	7.605	6.224
MH		9.318	5.227	2.769	6.861	4.191
RMS	D	9.049	2.264	2.351	3.173	1.604
MH		6.317	2.235	3.219	2.674	16.67
RMS	E	2.044	1.266	2.384	1.117	20.59
MH		2.558	1.398	2.467	1.306	6.505

	1	2	3	4	5
Max hold Sweep	9.934	5.292	3.576	7.942	26.47

20 cm distance at 360V output

		Side				
	uT	1	2	3	4	5 (top)
RMS	A	0.572	1.994	0.741	1.338	1.526
MH		0.58	1.258	0.846	1.097	1.557
RMS	B	1.459	1.437	1.538	1.277	3.982
MH		1.501	1.897	1.254	1.643	4.583
RMS	C	2.622	1.536	1.139	1.29	4.688
MH		2.39	1.325	1.198	0.884	3.229
RMS	D	2.1	0.848	1.321	0.632	1.651
MH		1.954	1.108	1.077	1.015	2.537
RMS	E	1.58	0.953	0.986	0.564	2.107
MH		1.422	0.601	1.262	0.445	2.764

	1	2	3	4	5
Max hold Sweep	2.569	1.549	1.34	1.643	4.574

20 cm distance at 480V output

		Side				
	uT	1	2	3	4	5 (top)
RMS	A	0.57	1.118	0.628	1.028	2.158
MH		0.624	1.65	0.777	1.282	2.549
RMS	B	1.63	1.301	1.352	1.267	4.7
MH		1.4	1.558	1.081	1.271	4.232
RMS	C	2.74	1.292	1.041	1.175	3.801
MH		2.197	1.148	1.282	1.717	1.683
RMS	D	1.208	0.984	1.297	1.345	1.627
MH		1.901	0.74	1.068	0.815	2.898
RMS	E	1.385	0.522	0.881	0.47	2.09
MH		1.997	0.821	1.153	0.549	1.783

	1	2	3	4	5
Max hold Sweep	2.74	1.9	1.352	1.778	4.807

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10. Appendix: Witricity Exposure Test Plan

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RF Exposure Testing of WiTricity Halo™ Wireless Power System for Electric Vehicles

Electromagnetic Field (EMF) Testing of Reference Levels in accordance with FCC's KDB 680106, attachment v04

Version 2.0

1. Contents

2. Document Version History

Version	Date	Editor(s)	Changes
v1.0	12-Sept-2024	Ky Sealy	Original
V2.0	05-Feb-2025	Morris Kesler	Added operational information

3. Applicable documents

Reference	Document
FCC WPT KDB	FCC KDB 680106 - 680106 Wireless Power Transfer (WPT) (fcc.gov)
FCC WPT KDB Attachment	FCC KDB 680106 attachment v04 - GetAttachment.html (fcc.gov)
IEEE C95.1-2019	IEEE Standard for Safety Levels with Respect to Human Exposure to Electric, Magnetic, and Electromagnetic Fields, 0 Hz to 300 GHz

4. Glossary

CFR	Code of Federal Regulations (U.S.)
CW	Continuous Wave
DRL	Dosimetric Reference Limit
EHC	Environmental Health Criteria
ELF	Extremely Low Frequency
EMC	Electromagnetic Compatibility
ERL	Exposure Reference Level
FCC	Federal Communications Commission
IEEE	Institute of Electrical and Electronics Engineers
ISED	Canada's Innovation, Science and Economic Development department
KDB	Knowledge Data Base
EV	Electric Vehicle
OEM	Original Equipment Manufacturer
RF	Radio Frequency
WPT	Wireless Power Transfer

5. Introduction

The WiTricity Halo™ 11 kW wireless charging transmitter allows light-duty electric vehicles (EVs) equipped with a standard SAE J2954 wireless receiver to be charged wirelessly when parked appropriately over the ground pad. Wireless power transfer occurs via a near-field magnetic field at a fixed operating frequency using the principles of magnetic resonance. The charging pad contains additional sensors that continuously scan for unwanted objects on the charging pad and disables itself if an unwanted object is detected.

A rendering of the WiTricity Halo™ 11 kW wireless charging transmitter, including both a wall box and a charging pad, is shown in Figure 1, and a top view of the ground pad with dimensions is shown in Figure 2.

Figure 1: WiTricity Halo™ wireless power system

Figure 2. Top View of the Ground Pad with the coordinate axes defined.

Operating instructions and installation details are provided in the WiTricity Halo ™ Wireless EV Charger User Manual. An excerpt of the specific RF Exposure warnings in the manual are provided below:

- The WiTricity Halo™ EV Charger meets the requirements of IEEE C94.1-2019, Safety Levels for Human Exposure of Electromagnetic Fields when used in accordance with instructions.
- Do not position any cardiac implantable electronic devices, including pacemakers, underneath a vehicle when charging. Do not lay on or next to the Wireless EV Charger at any time. Medical devices such as pacemakers, defibrillators, and other implantable devices may contain sensors that respond to fields in close proximity. Consult with your physician and device manufacturer for more specific guidance.
- The WiTricity Halo™ EV Charger utilizes near-field radio frequencies at 85 kHz for wireless power transfer. The exposure reference level is tested at the edge of the vehicle underbody. Never place any body part underneath the vehicle while charging.
- Do not crawl or reach underneath the vehicle during charging.

- Do not attempt to move or adjust the WiTricity Halo™ EV Charger or any of its accessories while powered on.

6. Executive Summary

This report discusses the detailed test procedures utilized in evaluating the RF exposure testing of the WiTricity Halo™ Wireless Power System for Electric Vehicles. Additionally, it provides information about RF exposure effects to magnetic fields below 100 kHz, discusses the rationale for the distance criteria used for testing, and provides insights into the reference levels used as a basis for exposure evaluation. For additional reference, the report also provides insights into the magnetic design and operation of the wireless power system.

The test procedures, measurement distances, measurement equipment, and reference levels utilized for testing of the WiTricity Halo™ Wireless Power System are all consistent with the requirements outlined in the *FCC's Wireless Power Transfer v04 attachment* to *KDB 680106 issued on October 24, 2023* [1].

7. Effects of Human Exposure to Magnetic Fields < 100 kHz

In 2007, the World Health Organization, with joint sponsorship by multiple other organizations, created the *Environmental Health Criteria 238* report on *Extremely Low Frequency Fields (EHC 238)* [2] addressing frequencies ranging from 0 Hz to 100 kHz. Regarding the interaction of the body with magnetic fields in this frequency range, it states in Section 1.1.2, "For magnetic fields, the permeability of tissue is the same as that of air, so the field in tissue is the same as the external field. The bodies of humans and animals do not significantly perturb the field. The main interaction of magnetic fields is the Faraday induction of electric fields and associated current densities in the conductive tissues."

EHC 238 (section 1.1.12) further indicates in its summary that no causal chronic health effects have been shown but rather, "Only the acute effects have been established…"; where an "acute effect" (Glossary) is defined as, "Effect of short duration and occurring rapidly…following a single dose or short exposure to a substance or radiation." Regarding these acute effects, EHC 238, in section 12.2.2, establishes that in the extremely low frequency (ELF) range, "…magnetic fields can affect the nervous system of people exposed to them, resulting in … nerve stimulation, at very high exposure levels. …These acute effects on the nervous system form the basis of international guidelines. However, they are unlikely to occur at the low exposure levels in the general environment and most working environments."

IEEE C95.1-2019 [3], in section 1.3.3.2, also provides clearer and more direct language as to the known effects of exposure below 100 kHz: "Below 100 kHz, this standard protects against aversive or painful effects associated with electrostimulation, which has a characteristic response time that is much less than 1 s and exposures are thus assessed in terms of instantaneous fields or currents. … **Electrostimulation that might occur at the upper tier limit has no lasting adverse health effect.**"

(bold emphasis added). In IEEE C95.1-2019, the upper tier refers to occupational limits which include a reduction factor of 3 over what 99% of the population would not even perceive. For general public exposure, an additional reduction factor of 3 (total 9 times) is applied for limbs and an additional factor of 9 (total 27 times) is applied for other tissues. The limits in IEEE C95.1-2019 include significant margins for both general public and occupational use cases.

The only known exposure risk for very strong magnetic fields below 100 kHz is electrostimulation (or nerve stimulation), which could result in a nerve tingling sensation when extremely high fields are present. However, standards that address this type of exposure provide extremely large safety margins to ensure this temporary causal effect does not occur whatsoever.

There are two general methodologies for ensuring compliance with RF Exposure standards: The first is a *Fundamental Requirement* and the second is a *Conservative Level Check*. The *Fundamental Requirement* method checks actual magnetic field impact to human tissue by means of tissue mimics (SAR for frequencies above 4 MHz) or by simulation (particularly for electrostimulation conditions < 100 kHz). The *Conservative Level Check* is based on assumptions that uniform whole body exposure occurs at a maximum magnetic field level and is therefore ultra-conservative since this practically never occurs for WPT (i.e., higher fields are very localized). The *Conservative Level Check* is easier to measure because standard free-space field instruments can be used to determine the field levels.

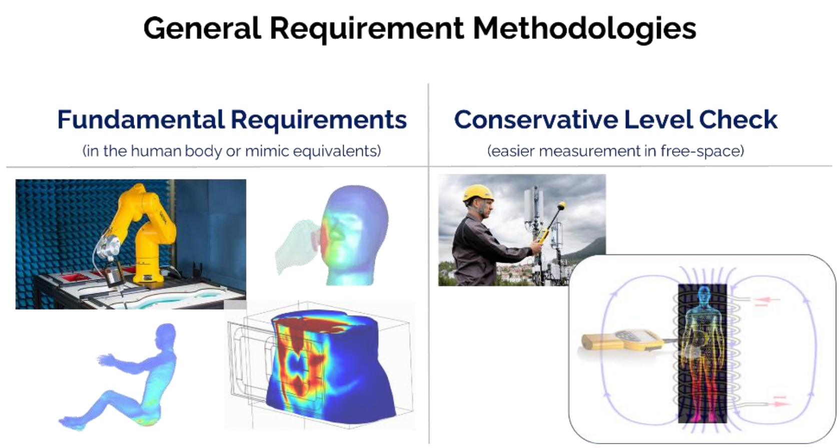

Figure 1: General RF Exposure Measurement Methods

Different RF Exposure guideline, standards, and texts refer to these methodologies differently. For example, the IEEE C.95.1-2019 standard refers to the fundamental requirement as a "Dosimetric Reference Limit (DRL)"; whereas it refers to the conservative levels as "Exposure Reference Level (ERL)". However, the FCC's regulations refer to a conservative level as "Maximum Permissible Exposure (MPE)" as discussed in Title 47 CFR §1.1310 [4].

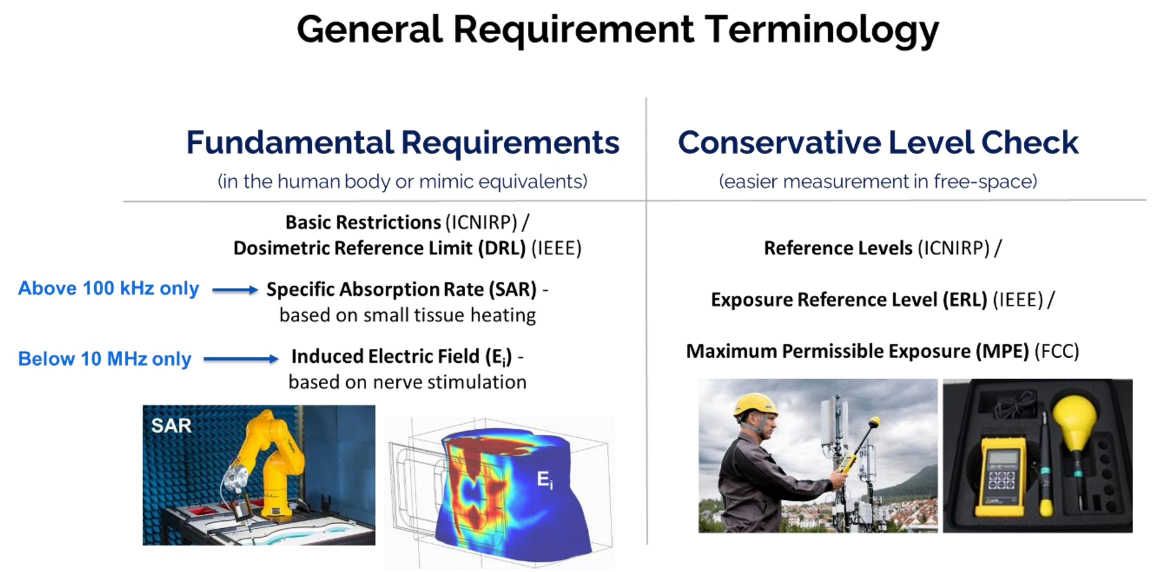

Figure 2: General RF Exposure Terminology

When considering the very conservative reference levels (based on whole-body uniform exposure), such as the ERLs in IEEE C95.1-2019, section 4.2.2.1 indicates, "Note that the ERLs … protect against adverse reactions associated with electrostimulation. … lack of compliance with [ERLs] does not necessarily indicate lack of compliance with the DRLs" [3].

The test procedures outlined in this document are intended to show conservative compliance with the reference levels indicated in the FCC KDB 680106 and IEEE's C95.1-2019 ERLs.

8. Background on Related RF Exposure Requirements

The U.S. Title 47 Code of Federal Regulations (CFR) provides related requirements for human RF exposure outlined in Parts §1.1307(b) [5], §1.1310 [4], §2.1091 [6], and §2.1093 [7] and these are also referenced by Part §18.313 [8]. However, within the CFR, there are no specific limit criteria provided for frequencies below 100 kHz and the MPE listings only cover from 300 kHz to 6 GHz. Despite this, it is clear the RF exposure should be considered in order to mitigate the temporary effects of nerve stimulation potential below 100 kHz (albeit they are non-chronic and sensational effects only). IEEE C95.1-2019 [3] provides appropriate details for this frequency range including DRLs and ERLs as previously discussed. Using Table 2 and Table 3 to calculate the conservative ERLs in IEEE C95.1, it is possible to determine the appropriate reference level at a frequency of 85 kHz (the WiTricity Halo™ WPT Charger Operating Frequency) as follows:

IEEE C95.1-2019 ERLs, 3.35 kHz to 5 MHz		
Type and Body Part	**B-Field**	**H-Field**
Unrestricted Head / Torso	205 µT	163 A/m
Unrestricted Limbs	1.13 mT	900 A/m
Restricted Head / Torso	615 µT	490 A/m
Restricted Limbs	1.13 mT	900 A/m

Table 1: IEEE C95.1-2019 Conservative ERLs from 3.35 kHz to 5 MHz

It should be noted that these field magnitude values are provided for both the B-Field and H-Field. In free-space (e.g., open air) conditions, which is how these are measured, these values are related through the free-space magnetic permeability constant, μ_0, where $\mu_0 = 4\pi \times 10^{-7}$ and $B = \mu_0 H$ for these conditions.

The unrestricted levels consider the general public who may be entirely unaware of an emission source or potential exposure in an open area. The restricted levels consider areas that are not in the general public environment. For example, it could be considered that the space underneath the vehicle is a restricted environment; whereas the space in and around the vehicle would be considered an unrestricted environment.

Interestingly, ISED Canada issued an updated *Supplementary Procedure for Assessing Compliance of Equipment Operating from 3 kHz to 10 MHz with RSS-102, SPR-002, Issue 2*, in October of 2022 [9] that considered wireless power transfer in this range of frequencies. In SPR-002, Issue 2, ISED provides their own set of conservative reference levels by which exposure can be evaluated as shown below:

Canda's SPR-002, Issue 2, Reference Levels 3 kHz to 10 MHz (RMS)			
Body Part	**B-Field (translated from H-Field)**	**H-Field**	**Relaxation Factor**
Head / Torso	113 µT	90 A/m	1.0
Leg	170 µT	135 A/m	1.5
Arm	283 µT	225 A/m	2.5
Hand/foot	565 µT	450 A/m	5.0

Table 2: Canda's SPR-002, Issue 2, H-Field Reference Level Relaxation for Local Exposure

While the U.S. Code of Federal Regulations doesn't provide MPE / reference level value below 300 kHz, it does distinguish between three different types of devices for radiation exposure evaluation; namely "fixed devices", "mobile devices", and "portable devices". The table below is derived in concept from the text found in 47 CFR §2.1091 [6], and §2.1093 [7]:

U.S. CFR, Title 47 §2.1091(b) and §2.1093(b) RF Exposure Device Types		
Device Type	**Description**	**Evaluation Distance**
Portable	Device not fixed and generally used in such a way that the RF source is within 20 cm of the user's body.	0 cm
Mobile	Device is not fixed and generally used in such a way that the RF source has a separation of at least 20 cm from the user's body or nearby persons.	20 cm
Fixed	Physically secured device not easily moved while transmitting.	Application Dependent
Other	Per §2.1091(b), other cases such as modular or desktop that are not easily classified.	Application Dependent

Table 3: U.S. CFR Title 47, §2.1091(b) and §2.1093(b) RF Exposure Device Types

Furthermore, the FCC has provided guidance in their attachment v04 to KDB 680106 [1] to indicate that a value of **90 A/m** is appropriate for assessment of any device operating below 100 kHz. Based on the aforementioned standards and reports, it is clear this value is extremely conservative and also incorporates consideration only for full body exposure (i.e., including head and torso) without separating restrictions or expectations that may be present and could allow relaxation for arms, legs, hands, and feet.

For the WiTricity Halo™ Wireless Power System for EVs, the Charger meets the **Fixed Device** definition per the CFR requirements. Users are instructed to avoid encroaching the area beneath the vehicle during charging and an appropriate label is applied to the product with this instruction. That being said, WiTricity also employs a Living Object Detection system that will disable the magnetic field and charging if any part of the body is positioned too closely. WiTricity utilizes industry standards for the wireless power system and the living object detection system such as SAE J2954 and UL 2750. For the purposes of FCC compliance, however, the WPT system can be treated as a Fixed Device wherein a user is instructed not to place any body part underneath the vehicle in the restricted area; the test procedures have been designed in accordance with this concept.

8.1. FCC KDB 680106 RF Exposure Test Guidelines

For the purposes of compliance to the U.S. CFR and per the FCC's guidance in the v04 attachment to KDB 680106 [1], this section focuses on listing specific requirements indicated in Section 3, "RF Exposure Requirements" of the KDB. A bulleted summary list of these requirements that relate to the WiTricity Halo™ PV WPT System is provided below:

- WPT devices must comply with RF exposure requirements for all design configurations in which they can operate. At a minimum, they must be evaluated for the worst-case scenario (typically maximum output power).
- RF exposure compliance for equipment authorization must follow guidance of KDB 447498 [10] [11].
    - Refers back to KDB 680106 for RF Exposure Limits below 100 kHz and related requirements.
    - Transmitters operating in consumer products must comply with general population exposure limits as applicable.
    - Device operating instructions and installation requirements must be consistent with chosen test configurations presented for compliance purposes.
    - User instructions for installation, OEM integration, or assembly by a third-party must be sufficiently clear and consistent for the target audience. The manufacturer is responsible for ensuring installers and integrators have a clear understanding of the compliance requirements.
    - For mobile devices operating in mostly stationary configurations and when a sufficiently large separation distance is inherent in the installation conditions, a simplified procedure may be used for assessing compliance following approval obtained via KDB.
- Any device operating at frequencies below 100 kHz is considered compliant when the external (unperturbed) temporal peak field strengths do not exceed the following reference

- levels: 83 V/m for the electric field strength (E) and **90 A/m** for the magnetic field strength (H).
    - HOWEVER, for "low-frequency" loop/coil emitting structures that lead to dominant H-field near-field emissions (E/H ratio less than 1/10 of the 377-ohm free space wave impedance, typically frequencies less than 1 MHz), **only H-field measurements are sufficient for demonstrating MPE limit compliance**. (Where E-Field refers to the electric field strength and H-field refers to the magnetic field strength).
- Field measurements should be made from all sides of the transmitter, along the principal axes defined with respect to the orientation of the transmitting element (e.g., coil). Symmetry considerations may be used to reduce the amount of testing.
- If the probe sensing element is more than 5 mm from the probe outer surface AND the positions are not reachable then estimated modeling is needed to determine the positions that are not reachable.
    - (Note: For the WiTricity Halo™ WPT System Test Procedures, all positions are reachable.)
- Manufacturers shall use the KDB Inquiry process to obtain FCC concurrence for the WPT device testing under "Equipment Compliance Review "(ECR) and "Wireless Power Transfer". Information on the WPT operating frequency, conducted power for the radiating structure, mobile vs portable demonstrated scenarios of operation, including RF exposure compliance information, and maximum distance from the WPT transmitter to which a load can be charged.

9. Test Plan Details for RF Exposure Compliance with FCC KDB 680106

9.1. Test Equipment for Measuring Magnetic Field

A Narda ELT-400 Field Probe [12] that is designed specifically for the purpose of exposure level testing is used to evaluate the magnetic field present at a given location. The field probe consists of a meter that provides B-Field readings up to 400 kHz and a detachable probe. The probe used for the measurements consists of 3 internal loops each orthogonal to each other and each having an area of 100 cm^2 (internal loop radius, $r = \sqrt{\frac{100}{\pi}} \cong 5.64\ cm$). The outer protective shell of the 100 cm^2 probe has a diameter of 12.5 cm (radius = 6.25 cm). The meter value (when set in the appropriate mode) provides the magnitude of the B-Field computed across all three orthogonal axes, $|B| = \sqrt{{B_x}^2 + {B_y}^2 + {B_z}^2}$ in micro-Tesla.

For purposes of testing the WiTricity Halo™ WPT System, the probe is used to capture a grid of points on each side of the WPT system and above the system. Whenever the WPT system is measured with a specific distance, the distance is adjusted by ~6.25 cm less to account for the large shell of the probe and ensuring that all measurements occur based on the center of the probe.

The settings used on the Narda ELT-400 for testing the WiTricity Halo™ PV WPT system are as follows:

- Mode = 320 µT
- Range = High
- Detection = RMS
- Display mode = Both Instantaneous & Max Hold values measured
- Cutoff = 30 Hz

These settings account for the dynamic range of the fields expected (to ensure no overload), maximize resolution, and are consistent with KDB 680106 [1] and IEC C95.1-2019 [3] requirements when considering that the magnetic field emission is a continuous wave (CW) sinusoidal emission.

The value on the meter read-out can be translated to the equivalent H-Field with the following formula $H = \frac{B}{\mu_0}$, where $\mu_0 = 4\pi \times 10^{-7}$, considering that the field measurements occur in open air (i.e., $\mu_r \cong 1$). Pursuant to the guidance in KDB 680106, a measurement of only the magnetic-field is sufficient on the basis that the transducer is a near-field magnetic source operating at a low-frequency (i.e., 85 kHz), and therefore, the magnetic field component is by far dominant in the region of measurement.

9.2. Test Procedure

9.2.1. Receiver Installation on Vehicle

The WiTricity Halo™ Receiver is mounted to the underside of the vehicle and always centered from side-to-side. Each vehicle is customized specifically with an appropriate mounting system and mechanical, electrical, communication interfacing, thermal, EMC, and RF exposure considerations are accounted for by coordinating between the vehicle OEM and WiTricity's engineering staff. For RF exposure considerations (and for thermal reasons), the Receiver is mounted underneath the vehicle wherein the vehicle has adequate mechanical metallic underbody protection. Additionally, an aluminum plate is typically added when required behind the Receiver for improved performance. The WiTricity Halo™ utilizes a positioning detection system also to ensure that the vehicle is within appropriate tolerances before power transfer is attempted (see also the SAE J2954 standard).

For testing, the Receiver is mounted to a 1.5 m x 1.5 m steel mimic plate (pursuant to SAE J2954) representing a very small vehicle. The WPT system is positioned at the highest operating height and the worst-case offset to maximize the transmitter coil current. Measurements are made at minimum and maximum battery voltages to ensure the worst-case condition for EMF is measured.

9.2.2. Test Procedure

With the mimic plate and receiver in place, measurements are performed in the following regions (see test report for photos):

Region 0 (Area between the mimic plate and the charging pad)
Region 1 (20 cm from mimic plate in the back)

Region 2 (20 cm from mimic plate in the right)
Region 3 (20 cm from mimic plate in the front closer to the wall box)
Region 4 (20 cm from mimic plate in the left)
Region Top (20 cm from the top of the mimic plate)

Additional details of the test procedure and the test results are contained in the test report prepared by the testing laboratory (UL Solutions) [14] included with this document.

10. ANNEX – Supplemental System Information

10.1. WiTricity Halo™ WPT General System Operation

The WiTricity Halo EV wireless EV charging system consists of three main components: a wall box that connects to the AC grid, a ground pad connected to the wall box that is mounted to the floor and a power receiver that mounts to the underbody of the vehicle. The wall box contains filtering and power electronics to convert the low frequency grid voltage to a high frequency voltage at 85 kHz that is used for power transfer. The output of the wall box is connected though a low-loss cable (3 – 10 m in length) to the ground pad mounted on the floor underneath where the vehicle will park. The ground pad contains a resonant coil structure that creates a localized magnetic field above the pad for power transfer to the vehicle receiver. This receiver consists of resonant receiving coil and power electronics to convert the 85 kHz energy to a DC voltage used to charge the vehicle battery. Messages transmitted over an out-of-band communication channel, operating over an IEEE 8.02.11 compliant Wi-Fi link between the ground side and the vehicle receiver, is used to control the system operation. The system provides up to 10.2 kW of charging power to the vehicle battery.

A picture of the system components is contained in Figure 7.

Figure 7: WiTricity Halo™ wireless power system

The wall box is available in two functionally equivalent variants: a single-phase version that operates with a 240 V single phase AC input (50/60 Hz), and a three-phase version that operates with a 380V three phase AC input (50/60 Hz). The output of both is an 85 kHz voltage signal with a variable amplitude of up to 720 V rms used to excite the resonant ground coil. The current in the ground coil has a maximum value of 65 A rms and is controlled by the amplitude of the wall box output voltage. The magnetic field created by the ground coil is a fixed CW sinusoid at a frequency of 85 kHz and is directly proportional to the amplitude of the current in the coil. Details of the ground coil structure are contained in section 10.2.

The vehicle receiver coil is sized to be used on vehicles with a ground clearance from 14.0 – 21.0 cm, defined as the distance from the bottom surface of the receiver housing to the ground, within a parking alignment range of +/- 10 cm in the side-to-side direction and +/- 7.5 cm in the front-to-back direction. It is mounted on the lateral centerline of the vehicle in a location generally near the front axle. In all cases, the distance from edge of the receiver package to any edge of the vehicle is greater than 50 cm. The output of the vehicle receiver is a DC voltage used to charge the battery. The voltage range depends on the vehicle battery pack voltage, typically in the 320 -450 V DC range.

The WiTricity Halo EV wireless EV charging system also includes systems to ensure safe operation. The ground coil is only energized when a vehicle with an authorized receiver is parked within the allowed alignment tolerance of the system and the vehicle receiver initiates charging through the out-of-band communications channel. An integrated alignment system provides position information to aid the driver in parking in the allowed zone and ensuring that the charging can only be initiated when properly aligned. Other sensing systems in the ground pad prevent charging if there are metallic objects or living objects present on the pad.

Typical system operation follows this procedure:

- The ground side is in standby mode, with no current in the ground coil and only Wi-Fi and some safety sensing systems active.
- A Wi-Fi communications link between the vehicle receiver and the wall box is established as the vehicle approaches. The vehicle must be pre-authorized with the ground side to make this connection.
- Positioning information is provided to the driver when the vehicle is over the ground pad.
- Once the vehicle is positioned within the alignment tolerance zone and the driver puts the vehicle into park, the vehicle signals to the wireless charging receiver over the vehicle CAN bus that charging can begin.
- The vehicle receiver sends a message to the wall box over the Wi-Fi link that indicates charging can begin and includes a desired target power.
- The wall box then ramps up the current in the ground pad while monitoring the input power being drawn from the grid. The vehicle receiver begins to send power to the vehicle battery.
- The vehicle receiver and ground side remain in constant communication over the Wi-Fi link, with the vehicle providing updated power request commands. If communications is interrupted, the power transfer is stopped until communications is re-established.
- Charging continues until the vehicle indicates charging is complete, the vehicle is turned on, or a safety alert requiring shut-down occurs.

A key feature of the wireless charging system is the ground pad is never energized unless an authorized vehicle is parked properly over it. This means the only time a magnetic field is generated is during the charging process.

10.1.1. Summary of information requested in KDB 680106 for the WPT System

- **WPT Operating Frequency:** 85 kHz (fixed frequency)
- **Conducted Power for Each Radiating Structure:** The operation of the WPT system is in the near field therefore, technically the field level is proportional only to Wireless Charger's coil current and independent of the power level. However, for purposes of operation, the field level is only ever at maximum condition when the maximum distance and offset of operation are applied and maximum power output is required. The **maximum power output is ~10,000 W from the Receiver**. However, when considering localized losses in the Receiver (e.g., rectification, DC-DC conversion, quiescent power, etc.), and also losses in both the Power Hub and Receiver coils, the amount of power provided from the local inverter inside the Power Hub to the Power Hub coil can reach up to ~11000 W.
- **Mobile or Portable Scenarios of Operation and RF Compliance Information:** The WiTricity Power Hub™ WPT System is considered a fixed device given the distance in which the user interacts with the system are inhibited by the vehicle generally. There are two primary operating conditions namely Standby and WPT Operation. In Standby no field is emitted from the Wireless Charger whatsoever. A vehicle containing a wireless Receiver must be detected by the Wireless Charger (using its positioning system) and be over the Wireless Charger before any field is presented. The Wireless Charger is typically bolted or affixed to a concrete or asphalt floor where the vehicle will be parked regularly. For WPT Operation, a corresponding WiTricity Halo™ Receiver must be present and mounted to the underside of a vehicle in accordance with the manufacturer's instructions (i.e., centered left-to-right on the vehicle and well beneath the vehicle underbody). During WPT Operation, the area near the Wireless Charger is always restricted by the vehicle itself. Instructions are provided in the WiTricity Halo™ Wireless Charger User Manual further confirm that users are not to encroach beneath the vehicle; however, in the event they do so anyway, WiTricity's living object detection system will force the charging to stop and the magnetic field will be terminated until there is no more detection.
- **Maximum Distance from the WPT transmitter at which, by design a load can be charged (including slow-charging operations):** The maximum distance between the ground and the Wireless Receiver is 210 mm (the height of the Wireless Charger's Ground Pad with the coil is 61 mm) the maximum offset conditions are per SAE J2954 in that there is an allowance of ± 100 mm side-to-side and ± 75 mm front-to-back or in the direction of vehicle travel.

10.2. WiTricity Halo PV WPT Magnetic Field Transducer Details

10.2.1. WiTricity Halo Ground Pad Coil

The magnetic field used for power transfer is created by driving current at 85 kHz through a coil in the ground pad, which sits flat on the ground surface. A top view of the ground pad is shown in Figure 2.

The coil is constructed out of Litz wire and is an 8-turn, bi-filar coil with outer dimensions of 650 mm x 500 mm, with a maximum current rating of 65 A rms. Underneath the coil is a layer of 5 mm thick ferrite tiles that serve to guide the magnetic flux and shield the region below it. An aluminum base plate sits at the bottom of the ground pad and is electrically connected to ground through the ground wire from the wall box. A top view of the coil is contained in Figure 8 and a side view is in Figure 9.

Between the base plate and the ferrite layer, there are two printed circuit boards. One contains the resonant capacitors and the other contains electronics needed for the metallic object detection and living object detection systems.

Figure 8. Top view of the ground pad showing the bi-filar coil and ferrite tiles.

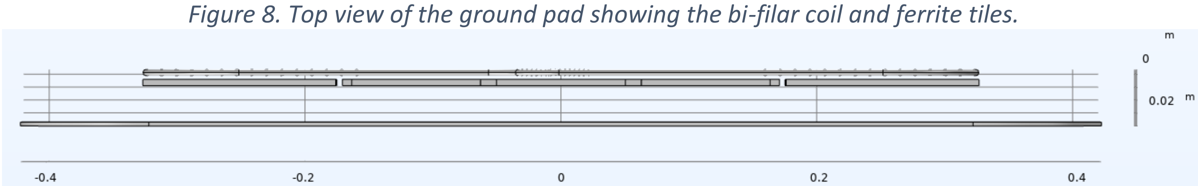

Figure 9. Side view of the ground pad showing the aluminum backplate at the bottom, the ferrite times with the coil above it. Electronic circuit boards for the detections sensors and resonant capacitors reside in the space between the backplate and the ferrite (not shown).

10.2.2. WiTricity Halo PV Receiver Coil

The WiTricity Halo 11 kW wireless charger requires a SAE J2954 compliant receiver in order to operate and transfer power. One such compatible receiver is the WiTricity Halo 11 kW Receiver, which is shown in Figure 10.

Figure 10. WiTricity Halo Receiver including coil and electronics.

11. References

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END OF TEST REPORT