# SAR EVALUATION REPORT

**FCC 47 CFR § 2.1093**
**IEEE Std 1528-2013**
**IEC 62232-2017**
**IEC 62209-2:2010**
**IEC TR 62630:2010**

*For*
**Wireless Power Source**

**FCC ID: 2AS57OSSIACOTATX201**
**Model Name: Venus V2**

**Report Number: 12775717-S2V5**
**Issue Date: June 12, 2019**

*Prepared for*
**Ossia Inc.**
**1100 112th Ave NE, Suite 301,**
**Bellevue, WA, 98004**
**U.S.A**


*Prepared by*
**UL VERIFICATION SERVICES INC.**
**47173 BENICIA STREET**
**FREMONT, CA 9438, U.S.A.**
**TEL: (510) 771-1000**
**FAX: (510) 661-0888**



NVLAP LAB CODE 200065-0

**Revision History**

| Rev. | Date | Revisions | Revised By |
|---|---|---|---|
| V1 | 5/23/2019 | Initial Issue | -- |
| V2 | 5/24/2019 | Added Appendix E, F and G plus minor editorial changes. | Dave Weaver |
| V3 | 5/28/2019 | Correction on page 93 , Table 42 Measured Value in unit to 0.0523W/**kg** | Dave Weaver |
| V4 | 5/30/2019 | Section 4.4.2 – Updated system check description | Dave Weaver |
| V5 | 6/12/2019 | Numerous updates based upon FCC feedback. | Dave Weaver |

## Table of Contents

# 1 Attestation of Test Results

| | | | |
|---|---|---|---|
| Applicant Name | Ossia Inc. | | |
| FCC ID | 2AS57OSSIACOTATX201 | | |
| Model Name | Venus V2 | | |
| Applicable Standards | FCC 47 CFR § 1.1307, § 1.1310 and § 2.1093<br>Published RF exposure KDB procedures<br>IEC 62232-2017, IEEE Std 1528-2013, IEC 62209-2:2010, IEC TR 62630:2010 | | |
| Exposure Category | SAR Limits (W/kg) | | |
| | Peak spatial-average(1 g of tissue) | Extremities (hands, wrists, ankles, etc.) (10 g of tissue) | Whole Body |
| General population / Uncontrolled exposure | 1.6 | 4 | 0.08 |
| RF Exposure Conditions | Equipment Class - Highest Reported SAR (W/kg) | | |
| | CW | | |
| 1 g Peak SAR Average | 1.423 W/kg | | |
| Whole Body SAR | 0.0591 W/kg | | |
| Date Tested | 12/5/2018 to 5/13/2019 | | |
| Test Results | Pass | | |

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. This report must not be used by the client to claim product certification, approval, or endorsement by NVLAP, NIST, any agency of the Federal Government, or any agency of the U.S. government.

| Approved & Released By: | Prepared By: |
|---|---|
| Dave Weaver<br>Operations Leader<br>UL Verification Services Inc. | Lance Fleischer<br>Laboratory Engineer<br>UL Verification Services Inc. |

## 2 Test Specification, Methods and Procedures

The tests documented in this report were performed in accordance with FCC 47 CFR § 2.1093 and the relevant sections of the following documents:

**IEEE Std 1528-2013** IEEE Recommended Practice for Determining the Peak Spatial-Average Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices: Measurement Techniques.
**IEC 62232-2017** Determination of RF field strength, power density and SAR in the vicinity of radiocommunication base stations for the purpose of evaluating human exposure.
**IEC 62209-2:2010** Human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices - Human models, instrumentation, and procedures - Part 2: Procedure to determine the specific absorption rate (SAR) for wireless communication devices used in close proximity to the human body (frequency range of 30 MHz to 6 GHz)
**IEC TR 62630:2010** Guidance for evaluating exposure from multiple electromagnetic sources.
**KDB 447498 D01** General RF Exposure Guidance v06
**KDB 865664 D01** SAR measurement 100 MHz to 6 GHz v01r04
**KDB 865664 D02** RF Exposure Reporting v01r02

In addition testing was performed in accordance with guidance provided by the FCC via KDB inquiries

## 3 Facilities and Accreditation

The test sites and measurement facilities used to collect data are located at

| 47173 Benicia Street | 47266 Benicia Street |
|---|---|
| SAR Lab A | SAR Lab 1 |
| SAR Lab B | SAR Lab 2 |
| SAR Lab C | SAR Lab 3 |
| SAR Lab D | SAR Lab 4 |
| SAR Lab E | |
| SAR Lab F | |
| SAR Lab G | |
| SAR Lab H | |

UL Verification Services Inc. is accredited by NVLAP, Laboratory Code 200065-0.

# 4 SAR Measurement System & Test Equipment

## 4.1 SAR Measurement System

**The DASY5 system used for performing compliance tests consists of the items shown in Figure 1:**

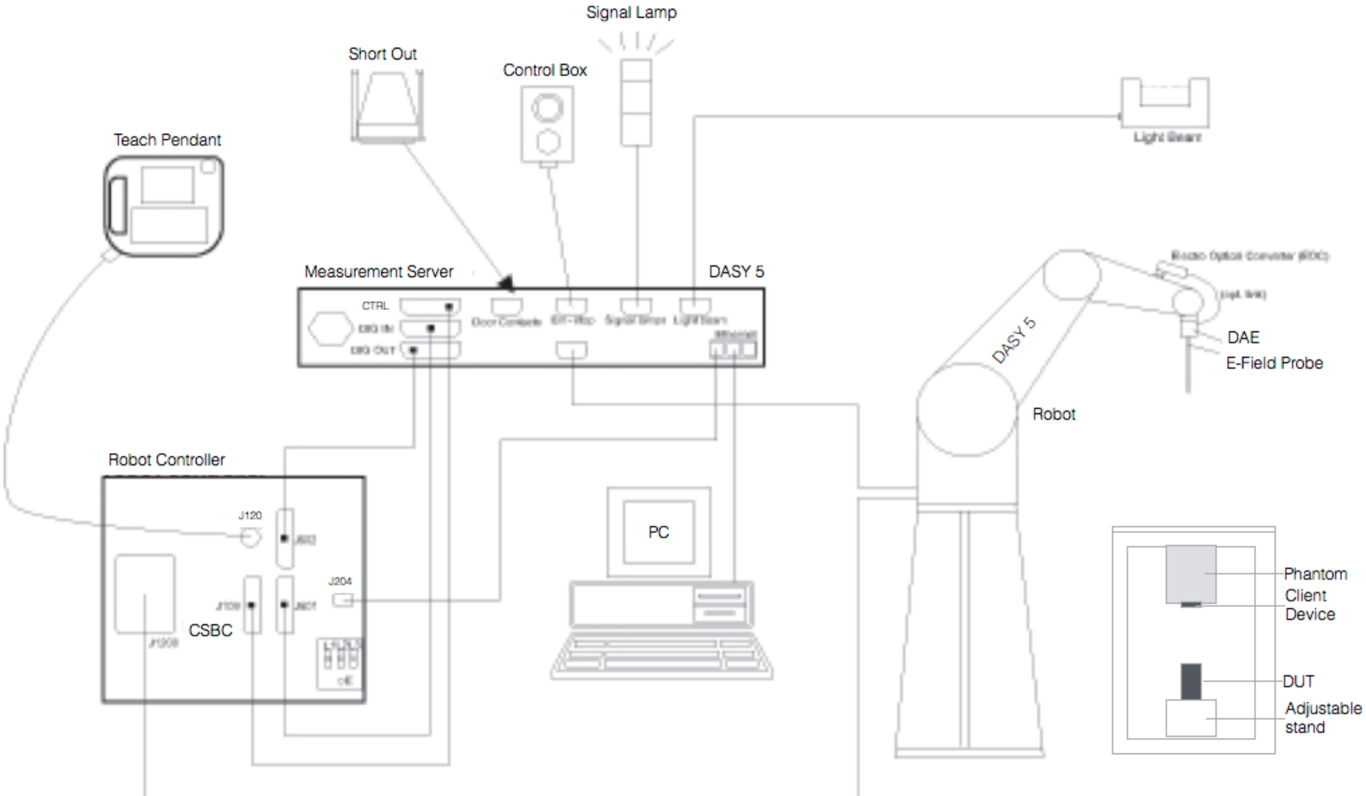



*Figure 1: SAR measurement system*

- A standard high-precision 6-axis robot with controller, teach pendant and software. An arm extension for accommodating the data acquisition electronics (DAE).
- An isotropic field probe optimized and calibrated for the targeted measurement.
- A data acquisition electronics (DAE), which performs the signal amplification, signal multiplexing, AD-conversion, offset measurements, mechanical surface detection, collision detection, etc. The unit is battery powered with standard or rechargeable batteries. The signal is optically transmitted to the EOC.
- The Electro-optical converter (EOC) performs the conversion from optical to electrical signals for the digital communication to the DAE. To use optical surface detection, a special version of the EOC is required. The EOC signal is transmitted to the measurement server.
- The function of the measurement server is to perform the time critical tasks such as signal filtering, control of the robot operation and fast movement interrupts.
- The Light Beam used is for probe alignment. This improves the (absolute) accuracy of the probe positioning.
- A computer running Windows 10 and the DASY5 software.
- Remote control and teach pendant, as well as additional circuitry for robot safety such as warning lamps, etc.
- The phantom, the device holder and other accessories according to the targeted measurement.
- The phantom is a flat box-shaped phantom with lateral dimensions 0,96 m × 0,233 m. The tissue simulating liquid depth (TSL) is >15 cm. The height of the base of the phantom above the floor is 100 cm. This phantom is referred to as the small box-shaped phantom and is specified in IEC 62232 §B3.2.2.2. The small box-shaped phantom was selected as it is the preferred choice for assessing Whole Body SAR for the general public where exposure to children is anticipated.

## 4.2 SAR Scan Procedures

### 4.2.1 1 g SAR

**Step 1: Power Reference Measurement**

The Power Reference Measurement and Power Drift Measurements are for monitoring the power drift of the device under test in the batch process. The minimum distance of probe sensors to surface determines the closest measurement point to phantom surface. The minimum distance of probe sensors to surface is 2.1 mm. This distance cannot be smaller than the distance of sensor calibration points to probe tip as defined in the probe properties.

**Step 2: Area Scan**

The Area Scan is used as a fast scan in two dimensions to find the area of high field values, before doing a fine measurement around the hot spot. The sophisticated interpolation routines implemented in DASY software can find the maximum locations even in relatively coarse grids. When an Area Scan has measured all reachable points, it computes the field maximal found in the scanned area, within a range of the global maximum. The range (in dB) is specified in the standards for compliance testing. For example, a 2 dB range is required in IEEE Standard 1528 and IEC 62209 standards, whereby 3 dB is a requirement when compliance is assessed in accordance with the ARIB standard (Japan). If only one Zoom Scan follows the Area Scan, then only the absolute maximum will be taken as reference. For cases where multiple maximums are detected, the number of Zoom Scans has to be increased accordingly.

Area Scan Parameters extracted from KDB 865664 D01 SAR Measurement 100 MHz to 6 GHz

| | ≤ 3 GHz | > 3 GHz |
|---|---|---|
| Maximum distance from closest measurement point (geometric center of probe sensors) to phantom surface | 5 ± 1 mm | ½·δ·ln(2) ± 0.5 mm |
| Maximum probe angle from probe axis to phantom surface normal at the measurement location | 30° ± 1° | 20° ± 1° |
| Maximum area scan spatial resolution: $\Delta x_{Area}$, $\Delta y_{Area}$ | ≤ 2 GHz: ≤ 15 mm<br>2 – 3 GHz: ≤ 12 mm | 3 – 4 GHz: ≤ 12 mm<br>4 – 6 GHz: ≤ 10 mm |
| | When the x or y dimension of the test device, in the measurement plane orientation, is smaller than the above, the measurement resolution must be ≤ the corresponding x or y dimension of the test device with at least one measurement point on the test device. | |

**Step 3: Zoom Scan**

Zoom Scans are used to assess the peak spatial SAR values within a cubic averaging volume containing 1 g and 10 g of simulated tissue. The Zoom Scan measures points within a cube whose base faces are centered on the maxima found in a preceding area scan job within the same procedure. When the measurement is done, the Zoom Scan evaluates the averaged SAR for 1 g and 10 g and displays these values next to the job's label.

Zoom Scan Parameters extracted from KDB 865664 D01 SAR Measurement 100 MHz to 6 GHz

| | | | ≤ 3 GHz | > 3 GHz |
|---|---|---|---|---|
| Maximum zoom scan spatial resolution: $\Delta x_{Zoom}$, $\Delta y_{Zoom}$ | | | ≤ 2 GHz: ≤ 8 mm<br>2 – 3 GHz: ≤ 5 mm* | 3 – 4 GHz: ≤ 5 mm*<br>4 – 6 GHz: ≤ 4 mm* |
| Maximum zoom scan spatial resolution, normal to phantom surface | uniform grid: $\Delta z_{Zoom}(n)$ | | ≤ 5 mm | 3 – 4 GHz: ≤ 4 mm<br>4 – 5 GHz: ≤ 3 mm<br>5 – 6 GHz: ≤ 2 mm |
| | graded grid | $\Delta z_{Zoom}(1)$: between 1st two points closest to phantom surface | ≤ 4 mm | 3 – 4 GHz: ≤ 3 mm<br>4 – 5 GHz: ≤ 2.5 mm<br>5 – 6 GHz: ≤ 2 mm |
| | | $\Delta z_{Zoom}(n>1)$: between subsequent points | $\le 1.5 \cdot \Delta z_{Zoom}(n-1)$ | |
| Minimum zoom scan volume | x, y, z | | ≥ 30 mm | 3 – 4 GHz: ≥ 28 mm<br>4 – 5 GHz: ≥ 25 mm<br>5 – 6 GHz: ≥ 22 mm |

Note: δ is the penetration depth of a plane-wave at normal incidence to the tissue medium; see draft standard IEEE P1528-2011 for details.

* When zoom scan is required and the *reported* SAR from the *area scan based 1-g SAR estimation* procedures of KDB 447498 is ≤ 1.4 W/kg, ≤ 8 mm, ≤ 7 mm and ≤ 5 mm zoom scan resolution may be applied, respectively, for 2 GHz to 3 GHz, 3 GHz to 4 GHz and 4 GHz to 6 GHz.

The correction factors from IEC62232 B.3.2.3.3 are applied to the 1 g SAR measurements to account for the separation distance of the DUT from the phantom and varying antenna element load conditions.

$$CF_1(d) = \begin{cases} 1 & d < 200\text{ mm} \\ \dfrac{d}{200} & 200\text{ mm} \le d < 400\text{ mm} \\ 2 & 400\text{ mm} \le d \le 1\,000\text{ mm} \end{cases}$$

$$CF_2(d) = \begin{cases} 2 & d \le \dfrac{\lambda}{4} \quad \text{AND } N_e > 1 \\ -\dfrac{4d}{7\lambda} + \dfrac{15}{7} & \dfrac{\lambda}{4} < d < 2\lambda \quad \text{AND } N_e > 1 \\ 1 & d \ge 2\lambda \quad \text{OR } N_e = 1 \end{cases}$$

d is the distance of the sample from the phantom.

λ is the wavelength of the signal.

$N_e$ is the number of elements in the antenna array.

The correction factors are applied to equation B.12 from IEC 66232 to provide the 1 g SAR value ($SAR_{psa}(d)$)

$$SAR_{psa}(d) = SAR_{m}(d)xCF_{1}(d)xCF_{2}(d)$$

**Step 4: Power drift measurement**

The Power Drift Measurement measures the field at the same location as the most recent power reference measurement within the same procedure, and with the same settings. The Power Drift Measurement gives the field difference in dB from the reading conducted within the last Power Reference Measurement. This allows a user to monitor the power drift of the device under test within a batch process. The measurement procedure is the same as Step 1.

**Step 6: Z-Scan**

The Z Scan measures points along a vertical straight line. The line runs along the Z-axis of a one-dimensional grid. In order to get a reasonable extrapolation, the extrapolated distance should not be larger than the step size in Z-direction. The Z-scan is only required if the highest measurement point is less than 2 penetration depths from the top of the tissue simulation liquid in the phantom. Penetration depth is calculated using the equation from Section 3 of IEEE 1528-2013:

$$\delta = \frac{1}{\omega}\left[\left(\frac{\mu_0 \varepsilon_r' \varepsilon_0}{2}\right)\left(\sqrt{1+\left(\frac{\sigma}{\omega \varepsilon_r' \varepsilon_0}\right)^2} - 1\right)\right]^{-1/2}$$

where ω is the angular frequency (radians/s), $\mu_0$ is the free-space permeability ($4\pi \times 10^{-7}$ H/m), $\varepsilon_0$ is the free space permittivity ($8.85 \times 10^{-12}$ F/m), $\varepsilon'_r$ is the relative permittivity, and σ is the conductivity of the medium. Penetration depth is expressed in meters (m).

Using the 2450 MHz body tissue dielectric parameters from KDB 865664 D01 of σ = 1.95 and $\varepsilon'_r$ = 52.7 the penetration depth (δ) is 0.020 m. The tissue simulation liquid depth is >0.15 m. The highest measurement point was at least 0.09 m below the surface of the TSL which is greater than 2δ = 0.040 m. Therefore Z-scans were not required.

### 4.2.2 Whole Body SAR

For the whole body SAR evaluation with the small box-shaped phantom, the measurement grid is setup according to IEC62232. The phantom is filled with a liquid volume of 0.96 m × 0.233 m × ≥0.15 m. Whole body SAR measurements are performed by running a *Volume Scan.* As whole body SAR measurements are time-consuming, a maximized grid spacing according to IEC62232 is recommended, e.g., 20 mm × 20 mm × 5 mm in x,y,z dimension for frequencies below 3 GHz.

The measurement volume specified in IEC62232 for the small box-shaped phantom is 0.96 m × 0.233 m × 0.06 m. Due to mechanical constraints (probe body diameter) and boundary effects, SAR measurements at the location of the sidewalls are physically impossible. The local enhancement occurring due to the boundary effects caused by sharp edges of the phantom can be smoothed to better represent the human exposure. This is supported by DASY52 by extrapolating to the sidewalls (up to 30 mm from the walls, see section Post-processing) and towards the bottom of the phantom in accordance with IEC62209. The actual measurement volume is therefore smaller but the measured values are extrapolated to the base and sides of the phantom. This provides test data for the measurement volume specified in IEC62232.

The actual measurement volume is 0.9 m x 0.18 m x 0.06 m. This is the volume over which the SAR probe scanned. This is formed by a 45 x 9 x 12 grid (x, y, z) with grid spacing of 20 mm, 20 mm and 5 mm respectively. Within the actual measurement volume the interpolated grid spacing is 6.667 mm x 6.667 mm x 1.667 mm.

The extrapolated volume is 0.96 m x 0.233 m x 0.06 m. In the extrapolated regions the interpolated grid spacing is 8.83 mm x 10 mm x 1.667 mm which was determined as follows. The extrapolated SAR data was exported. Each

SAR data point contains the SAR value and its associated x, y and z co-ordinate. The co-ordinates were examined to determine the length of x, y and z. (difference between the min and max values for a given axis). Note that due to capabilities of SAR system version used, the Volume Scan listed on the whole-body SAR plots (i.e., 34x142x40) shows the total number of steps for the interpolated and extrapolated overall volume - not just for the 6.667 mm x 6.667 mm x 1.667 mm interpolated data.

The extrapolated volume is 13.4 liters. (0.96 m x 0.233 m x 0.06 m = 0.0134 $m^3$ = 13.4 liters). This yields a mass of 13.4kg (TSL density is assumed to be 1000 kg/$m^3$).

The calculation of whole body SAR involves dividing by *M* where *M* is the mass of the body specified in kg. For general public exposure the value of *M* is specified in IEC62232 as 12.5 kg. As this is smaller than the extrapolated mass of 13.4 kg this leads to a more conservative value for whole body SAR than if the value of *M* was set to the extrapolated mass.

**Post-processing for General Public whole body SAR**

To determine the whole body SAR the total absorbed power in the phantom is calculated by the DASY52:

1. Computation of the SAR from the raw measurement data (electric field strength) at each *measured* grid point (SAR = $E^2$ x (σ/(ρ x 1000))) where E is the electric field strength, σ is the TSL conductivity and ρ is the tissue density (set to 1).
2. A layer of grid points is created at the sidewalls (within laterally maximum 30 mm from the closest grid point of the volume scan) and the bottom shell of the phantom. Thus extending the evaluation volume to 0.96 m × 0.233 m × 0.06 m. The grid points are used to provide geometric information to the extrapolation algorithm for placement of the extrapolated data. The SAR fields are extrapolated to the bottom and the sidewalls of the phantom using a quadratic SHEPARD interpolator or a constant SAR towards the sidewall.
3. Generation of a high-resolution mesh within the extrapolated volume.
4. Interpolation of the values from the extrapolated grid to the high-resolution grid with a combination of a least-square fitted function method and a weighted average method.
5. Determination of the SAR, volume and mass of each cell in the high resolution grid.
6. Calculation of the absorbed power in each cell by multiplying the cell's SAR with the cell's mass. (Multiplying by the cell's mass gives power in a given volume.)
7. Summation of the absorbed power in each cell over the entire evaluation volume of 0.96 m × 0.233 m × 0.06 m and thus calculation of the total absorbed power.

Calculation of the general public whole body SAR:

The whole body SAR value was calculated using:

$$SAR_{\text{wb}}(d) = \frac{P_{\text{A}}(d) \times CF_3(d) \times CF_4(f)}{M}$$

$P_A(d)$ is the average temporal absorbed power (watts) in the phantom measured at a distance *d*, the EUT distance (mm) measured from the liquid surface;

$$CF_3(d) = \begin{cases} 1 + \frac{0{,}8d}{400} & d < 400\text{ mm} \\ 1{,}8 & d \geq 400\text{ mm} \end{cases};$$

$CF_3(d)$ is a correction factor to account for a possible increase in whole-body *SAR* due to a tissue layering effect defined by:

$CF_4(f)$ is a correction factor to compensate for a possible bias in the obtained general public whole-body *SAR* when assessed using the large box-shaped phantom for child exposure configurations. For frequencies between the data points a linear interpolation shall be used. For other exposure configurations and phantom type combinations, $CF_4(f) = 1$;

$M$ is the mass specified in IEC62232 representing the body. For general public exposure $M = 12.5$ kg.

As the small-boxed shape phantom was used for the SAR measurements $CF_4(f) = 1$.

The whole body SAR procedure was applied to both the whole body SAR system check and the whole body SAR measurement.

## 4.3 Test Equipment

The measuring equipment used to perform the tests documented in this report has been calibrated in accordance with the manufacturers' recommendations and is traceable to recognized national standards.

**Dielectric Property Measurements**

| Name of Equipment | Manufacturer | Type/Model | Serial No. | Cal. Due Date |
|---|---|---|---|---|
| S-Parameter Network Analyzer | Agilent | 8753ES | MY40000980 | 2/12/2020 |
| Dielectric Probe kit | SPEAG | DAK-3.5 | T1058 | 11/6/2019 |
| Shorting Block | SPEAG | DAK-3.5 Short | SM DAK 200 BA | 9/11/2019 |
| Thermometer | Keysight | Traceable | 181649090 | 2/21/2020 |

**System Check**

| Name of Equipment | Manufacturer | Type/Model | Serial No. | Cal. Due Date |
|---|---|---|---|---|
| Signal Generator | Rhode & Schwarz | SMB100A | 180970 | 2/13/2020 |
| Power Sensor | Rhode & Schwarz | NRP18A | 100994 | 2/15/2020 |

**Lab Equipment**

| Name of Equipment | Manufacturer | Type/Model | Serial No. | Cal. Due Date |
|---|---|---|---|---|
| E-Field Probe (SAR Lab 5) | SPEAG | EX3DV4 | 7501 | 5/4/2019* |
| E-Field Probe (SAR Lab 5) | SPEAG | EF3DV3 | 4028 | 7/13/2019 |
| E-Field Probe (SAR Lab 5) | SPEAG | EF3DV3 | 4041 | 3/22/2020 |
| Data Acquisition Electronics (SAR Lab 5) | SPEAG | DAE4 | 1258 | 5/4/2019* |
| Data Acquisition Electronics (SAR Lab 5) | SPEAG | DAE4 | 1472 | 3/21/2020 |
| System Validation Dipole | SPEAG | D2450V2 | 748 | 2/16/2020 |

**Note(s):**

*Equipment not used past calibration due date.

## 4.4 Dielectric Property Measurements & System Check

### 4.4.1 Dielectric Property Measurements

The temperature of the tissue-equivalent medium used during measurement must also be within 18°C to 25°C and within ± 2°C of the temperature when the tissue parameters are characterized.

The dielectric parameters must be measured before the tissue-equivalent medium is used in a series of SAR measurements. The parameters should be re-measured after each 3 – 4 days of use; or earlier if the dielectric parameters can become out of tolerance; for example, when the parameters are marginal at the beginning of the measurement series.

Tissue dielectric parameters were measured at the low, middle and high frequency of each operating frequency range of the test device.

The dielectric constant (εr) and conductivity (σ) of typical tissue-equivalent media recipes are expected to be within ± 5% of the required target values; but for SAR measurement systems that have implemented the SAR error compensation algorithms documented in IEEE Std 1528-2013, to automatically compensate the measured SAR results for deviations between the measured and required tissue dielectric parameters, the tolerance for εr and σ may be relaxed to ± 10%. This is limited to frequencies ≤ 3 GHz.

## Tissue Dielectric Parameters

FCC KDB 865664 D01 SAR Measurement 100 MHz to 6 GHz

| Target Frequency (MHz) | Head | | Body | |
|---|---|---|---|---|
| | $\varepsilon_r$ | σ (S/m) | $\varepsilon_r$ | σ (S/m) |
| 150 | 52.3 | 0.76 | 61.9 | 0.80 |
| 300 | 45.3 | 0.87 | 58.2 | 0.92 |
| 450 | 43.5 | 0.87 | 56.7 | 0.94 |
| 835 | 41.5 | 0.90 | 55.2 | 0.97 |
| 900 | 41.5 | 0.97 | 55.0 | 1.05 |
| 915 | 41.5 | 0.98 | 55.0 | 1.06 |
| 1450 | 40.5 | 1.20 | 54.0 | 1.30 |
| 1610 | 40.3 | 1.29 | 53.8 | 1.40 |
| 1800 – 2000 | 40.0 | 1.40 | 53.3 | 1.52 |
| 2450 | 39.2 | 1.80 | 52.7 | 1.95 |
| 3000 | 38.5 | 2.40 | 52.0 | 2.73 |
| 5000 | 36.2 | 4.45 | 49.3 | 5.07 |
| 5100 | 36.1 | 4.55 | 49.1 | 5.18 |
| 5200 | 36.0 | 4.66 | 49.0 | 5.30 |
| 5300 | 35.9 | 4.76 | 48.9 | 5.42 |
| 5400 | 35.8 | 4.86 | 48.7 | 5.53 |
| 5500 | 35.6 | 4.96 | 48.6 | 5.65 |
| 5600 | 35.5 | 5.07 | 48.5 | 5.77 |
| 5700 | 35.4 | 5.17 | 48.3 | 5.88 |
| 5800 | 35.3 | 5.27 | 48.2 | 6.00 |

## Dielectric Property Measurements Results:

| SAR Lab | Date | Band (MHz) | Tissue Type | Frequency (MHz) | Relative Permittivity (εr) | | | Conductivity (σ) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Measured | Target | Delta (%) | Measured | Target | Delta (%) |
| 5 | 4/5/2019 | 2450 | Body | 2450 | 50.93 | 52.70 | -3.36 | 2.01 | 1.95 | 3.08 |
| | | | | 2400 | 51.10 | 52.77 | -3.17 | 1.94 | 1.90 | 2.42 |
| | | | | 2480 | 50.86 | 52.66 | -3.42 | 2.05 | 1.99 | 2.75 |

### 4.4.2 System Check

SAR system verification is required to confirm measurement accuracy, according to the tissue dielectric media, probe calibration points and other system operating parameters required for measuring the SAR of a test device. The system verification must be performed for each frequency band and within the valid range of each probe calibration point required for testing the device. The same SAR probe(s) and tissue-equivalent media combinations used with each specific SAR system for system verification must be used for device testing. When multiple probe calibration points are required to cover substantially large transmission bands, independent system verifications are required for each probe calibration point. A system verification must be performed before each series of SAR measurements using the same probe calibration point and tissue-equivalent medium. Additional system verification should be considered according to the conditions of the tissue-equivalent medium and measured tissue dielectric parameters, typically every three to four days when the liquid parameters are re-measured or sooner when marginal liquid parameters are used at the beginning of a series of measurements.

**System Performance Check Measurement Conditions:**

- The measurements were performed in the flat section of the phantom, shell thickness: 2.0 ±0.2 mm (bottom plate) filled with Body or Head simulating liquid of the following parameters.
- The depth of tissue-equivalent liquid in a phantom must be ≥ 15.0 cm for SAR measurements ≤ 3 GHz and ≥ 10.0 cm for measurements > 3 GHz.
- The DASY system with an E-Field Probe was used for the measurements.
- The dipole was mounted on the small tripod so that the dipole feed point was positioned below the center marking of the flat phantom section and the dipole was oriented parallel to the body axis (the long side of the phantom). The standard measuring distance was 10 mm (above 1 GHz) and 15 mm (below 1 GHz) from dipole center to the simulating liquid surface.
- The coarse grid with a grid spacing of 15 mm was aligned with the dipole.
  For 5 GHz band - The coarse grid with a grid spacing of 10 mm was aligned with the dipole.
- Special 7x7x7 (below 3 GHz) and/or 8x8x7 (above 3 GHz) fine cube was chosen for the cube.
- Distance between probe sensors and phantom surface was set to 3 mm.
  For 5 GHz band - Distance between probe sensors and phantom surface was set to 2.5 mm
- The dipole input power (forward power) was 100 mW.
- The results are normalized to 1 W input power.

**System Check Results**

The 1-g and 10-g SAR measured with a reference dipole, using the required tissue-equivalent medium at the test frequency, must be within ±10% of the manufacturer calibrated dipole SAR target. Refer to Appendix A for the SAR System Check Plots.

| SAR Lab | Date | Tissue Type | Dipole Type _Serial # | Dipole Cal. Due Data | Measured Results for 1g SAR | | | | Measured Results for 10g SAR | | | | Plot No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Zoom Scan to 100 mW | Normalize to 1 W | Target (Ref. Value) | Delta ±10 % | Zoom Scan to 100 mW | Normalize to 1 W | Target (Ref. Value) | Delta ±10 % | |
| 5 | 4/5/2019 | Body | D2450V2 SN:748 | 2/16/2020 | 5.520 | 55.20 | 53.30 | 3.56 | 2.500 | 25.00 | 23.60 | 5.93 | 1,2 |

## 5 Measurement Uncertainty

Per KDB 865664 D01 SAR Measurement 100 MHz to 6 GHz, when the highest measured 1-g SAR within a frequency band is < 1.5 W/kg and the measured 10-g SAR within a frequency band is < 3.75 W/kg, the extensive SAR measurement uncertainty analysis described in IEEE Std 1528-2013 is not required in SAR reports submitted for equipment approval.

# 6 Device under test (DUT)

## 6.1 General

The Cota wireless power transfer (WPT) system delivers wireless power from a Cota WPT Source to one or many Cota WPT Clients. In order to receive power, the Cota WPT Client must be positioned in the allowed power transfer area. The allowed power transfer area is a 1 m radius from the front and edges of the WPT Source and at an angle of up to 60 degrees from a line extending from the edge of the WPT source and perpendicular to its face. This is also described and illustrated in section 9.1.The WPT Source sends RF energy at 2.450 GHz, which is converted to DC current by the client.

The Cota power system is intended to power sensors, actuators, small displays and other devices in a commercial or industrial environment for which changing batteries and/or connecting wires is impractical. Both the WPT Client and WPT Source may be mounted in a fixed location or placed on a flat surface (for example a table top). In the latter case, the WPT Client needs to be mounted in a fixed position relative to the WPT Source.

## 6.2 DUT Description

### 6.2.1 General

The Cota WPT system delivers wireless power by "retrodirective" functionality, using a two-step process. In the first step, the WPT Client sends a low power (<8mW) continuous wave (CW) "beacon" signal. The beacon signal is received by the WPT Source, and its phase information is used to execute the second step. In the second (powering) step, the WPT Source sends a power signal back to the WPT Client, whereby the power signal from each of its 256 antenna ports is phase-offset with the inverse of the received beacon phase detected in the first step. These phase inverted signals generate a antenna pattern with a focused area of RF energy at the location of the WPT client antenna. This two-step sequence is repeated 50 times per second. For the general theory on such systems, see R. C. Hansen, “Reflectarrays and Retrodirective Arrays” in Kai Chang, Phased Array Antenna (Second Edition, 16 November 2009), Chapter 13.

Any obstruction that enters the direct path between the WPT Source and client will necessarily change the beacon signal as it is received by the WPT Source’s antenna elements, either by enabling receipt of a reflected beacon signal, lowering the strength of the received beacon signal or obstructing it entirely. The corresponding power signal will thus also change, creating an inherent safety feature. In normal operation the WPT Source will never focus power on an obstruction for more than 1/50th of a second (20 ms) between the time of the last beacon preceding an obstruction's appearance and the next beacon following it; as such an obstruction will always block the direct path for the beacon signal between the WPT Source and client.

### 6.2.2 Communication radio modules

The WPT Source and client also exchange information by making use of a separate IEEE 802.15.4 radio contained in each device. They operate at a different frequency from the power signal, also in the 2.4 GHz band. Information exchanged includes client authentication information (client devices that are not properly authenticated will not receive power), system information, and other specialized client information, such as information from the device being powered. These radios operate in a manner consistent with section 15.247 of the FCC’s rules.

### 6.2.3 Regulatory Classification

The Cota WPT Source is properly classified as Industrial, Scientific or Medical equipment as defined in section 18.107(c) of the FCC’s rules, because it is designed to generate and deliver RF energy to power nearby devices in homes, offices, retail facilities and industrial settings (*i.e.* for other than telecommunication applications). The Cota WPT Source generates RF energy on each of its 256 elements and creates a focused area of RF energy at the point of the client Antenna. Per KDB inquiry consultations with FCC staff, this area of focused energy is limited to a specified area within 1 m from the WPT Source where power may be delivered.

## 6.3 Client Device

The Cota WPT Client receives RF power from the WPT Source, converts the RF energy to DC, and provides DC power to a load device. The WPT Client contains two separate radio elements, an IEEE 802.15.4 communications radio, which is authorized under section 15.247 of the Commission's rules, and a "beacon" radio, which qualifies under section 15.249 of the Commission's rules. The WPT Client communicates with the source to set up power delivery, emits the beacon signal at the specified time, and harvests RF energy when the WPT Source creates the focused power signal at the point of its antenna. The Cota WPT Source can provide power to multiple clients, in which case it provides power to each client in a time-division-multiplexing-like manner, resulting in RF exposure in areas proximate to clients in inverse proportion to the number of active clients being powered by the system. The Cota WPT source powers only one client at the time. When there are multiple clients, each client is only powered during its own time slot (i.e., the duty cycle for each client would be a fraction of the duty cycle considered for a single client scenario). Thus, the potential for RF exposure in a multiple client scenario is always a fraction of the potential RF exposure in a single client scenario. Because of this functionality, a single client scenario is always the worst-case RF exposure scenario, and for this reason, RF exposure testing was conducted with a single client.

# 7 Testing rationale

RF exposure testing procedures adapted from IEC 62232 are utilized, as per KDB inquiry consultation with FCC staff.

The Cota WPT Source will only send power to a WPT Client that is in the power delivery area (nominally within 1 m from the source). The extent of the power delivery area was verified, and testing results are set out in section 9.2.

The RF exposure conditions for the Cota System with respect to a specific environment and client position do not change, provided environmental conditions and client location do not change. Moreover, system design and behavior as demonstrated by submitted test results, demonstrate signal coherence only in close proximity to the Client where potential exposure by human bystanders is not possible. The conservative approaches of IEC 62630 for estimating SAR for coherent signals for the range of potential signal variations across the antenna array therefore do not apply.

To determine the appropriate conditions for evaluating SAR, mapping of the RF field was undertaken both within and outside the power delivery area and with and without obstructions. Field scans were undertaken in both horizontal and vertical planes at varying distances and orientations of the WPT Source, WPT Client and obstructions. Specific locations for evaluating SAR results are based on these field scans, and the SAR phantom was positioned in such locations to determine potential location of worst-case RF exposure scenarios.

SAR testing was performed using the "small box-shaped phantom," measuring 0.96 m x 0.233 m, as specified in IEC 62232. This phantom was used for the 1 g peak spatial average SAR measurements and the whole-body SAR measurement. This phantom was chosen as it is the preferred option according to IEC 62232. Whole body SAR testing was assessed using a volume approximating to a mass of 12.5kg. This represents the third percentile body weight data for a four-year old girl. This weight is slightly smaller than the WHO data for a fifth percentile four-year-old child and leads to a conservative whole-body SAR for the general public. See Section 4 for the 1 g peak spatial average SAR and whole-body SAR test methods.

IEC 62232 B.3.2.2.2 specifies for products that may be placed arbitrarily in homes, offices and other places, the small box-shaped phantom shall then be the preferred phantom. The testing should be done with a phantom that circumscribes the EUT per Figure B.12 in the standard.

Additional SAR testing was also performed in a modified version of the human torso simulator phantom described in KDB 617965, as discussed in section 10.8.

Measured SAR values are scaled to compensate for the difference between the measured output power and the maximum specified output power of the DUT.

The test procedures of IEC 62232 include correction factors to account for the test separation distance and other factors. The calculations for these correction factors and their application to the scaled SAR results are shown in sections 11.1 and 11.2.

## 8 Maximum output power

The DUT comprises 256 power output elements. Each has a maximum transmit target power of 13dBm. This results in a maximum power available of 37.1 dBm if all elements are active. SAR power scaling is normally performed by multiplying the measured SAR value by the ratio of the measured conducted power to the maximum specified power of the DUT.

It is impractical to measure the output power of each of the elements. Conducted power was measured for ten of the elements. It was judged that this would provide a representative sample of the power variance. For SAR scaling, the sum of the measured powers was compared to the sum of the target powers as below:

*Table 1: Measured antenna power*

| Antenna # | Measured Power (dBm) |
|---|---|
| 1 | 12.7 |
| 2 | 12.7 |
| 3 | 13.0 |
| 4 | 13.0 |
| 5 | 12.5 |
| 6 | 11.7 |
| 7 | 11.3 |
| 8 | 12.5 |
| 9 | 12.3 |
| 10 | 12.6 |

Sum of the measured power in dBm = 22.46

Sum of the target power = 23dBm (10 ports with the target power of 13 dBm each)

The total target power for ten ports is 0.54 dB higher than the total measured power. The SAR results should be scaled by 1.13 (0.54 dB).

Scaling was only applied to the SAR results in section 11.

# 9 Cota area of operation

## 9.1 General

The Cota system operates in a limited area, which allows powering of devices within a 1 m radius from the front and edges of the WPT Source and at an angle of up to 60 degrees from a line extending from the edge of the WPT source and perpendicular to its face, as shown in Figure 2. These power zone limits are enabled by analysis of the strength of the power received by the WPT Client. The WPT Source will cease sending power when analysis of this signal information indicates that the WPT Client is more than 1 m from the WPT Source.

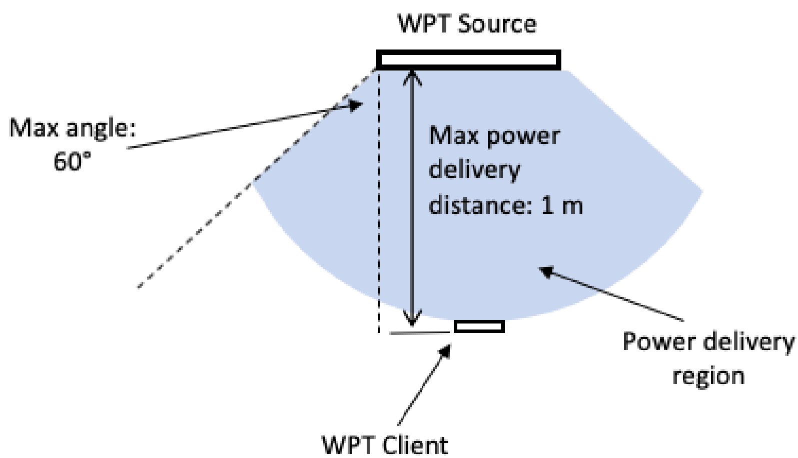



*Figure 2: Power delivery area showing relevant angles and distances between Cota WPT Source and WPT Client devices.*

## 9.2 Verification of power delivery area

### 9.2.1 General

Verification of the power delivery area was performed in accordance with guidance provided via KDB inquiry. The Cota WPT Source will deliver power only if the client is within the power delivery area, as shown in Figure 2.

To test the power delivery area, the Cota WPT Source was placed in an anechoic chamber on a turntable capable of rotating 180̊ (from -90̊ to +90̊, where 0̊ represents the Cota Power Source facing the client). The WPT Client was placed on a non-rotating surface relative to the turntable, as shown in Figure 3. In order to ascertain the presence of a power signal, a spectrum analyzer with a test antenna was placed approximately 2 m away and slightly offset from the front face of the WPT Source. The spectrum analyzer was used solely to indicate the presence of a power signal. This indication was recorded for each step of the testing process.

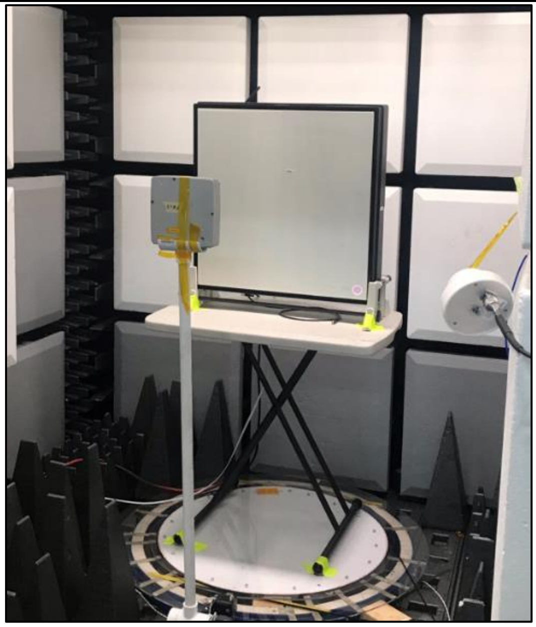


*Figure 3 – power delivery area verification test setup*

Testing was undertaken in an anechoic chamber, because such an environment constitutes the most conservative scenario for verifying power delivery vis-a-vis environments with more reflective and/or scattering characteristics. The range control system delivers power only inside the 1 m range when the power received by the client is higher than the calibrated threshold power. A lower received power will mean a smaller power delivery area. The retro directive functionality of the Cota system is such that maximum power is received when the power signal follows a direct line-of-sight path between the WPT source and client, such as in an anechoic chamber. Reflected and/or scattered power signals result in a lower received power. Thus, because the received power will always be greater, the power delivery area in an anechoic chamber will be larger than in a more reflective environment.

Both the horizontal and vertical axes were evaluated.

### 9.2.2 Horizontal Plane

Verification of power delivery in the horizontal plane was performed in a two-step process. First, the angular limits of the power field were established by rotating the WPT Source in a full 360°. This was undertaken in two 180° sweeps, due to the turntable's limited range of 180°. To perform these sweeps, the client was positioned at a distance of 70 cm from the front of the power source, and the turntable was rotated clockwise from -90̊ to 90̊ at increments of 3°. To achieve a full 360-degree field, the Power Source was rotated by 180̊ manually such that the 0̊ of the turntable represents the case where the back of the Cota Power Source is facing the client and the process is repeated. Figure 4 illustrates this process. At each step of the process, data from the spectrum analyzer is recorded to ascertain the presence of the power signal. The first step demonstrated that a power signal was present from 57° to -51° horizontally. No power was delivered when the WPT Source was faced away from the WPT Client and swept from -90° to 90°.

The second step rotated the WPT Source from 70° to -70° at 10° increments with the WPT Client stepped from 70 cm to 110 cm from the WPT Source and the spectrum analyzer output recorded for each step. This setup is shown in Figure 5. Test results for the horizontal plane are shown in Figure 6 and Table 2 and show the power delivery area extends to 95 cm.

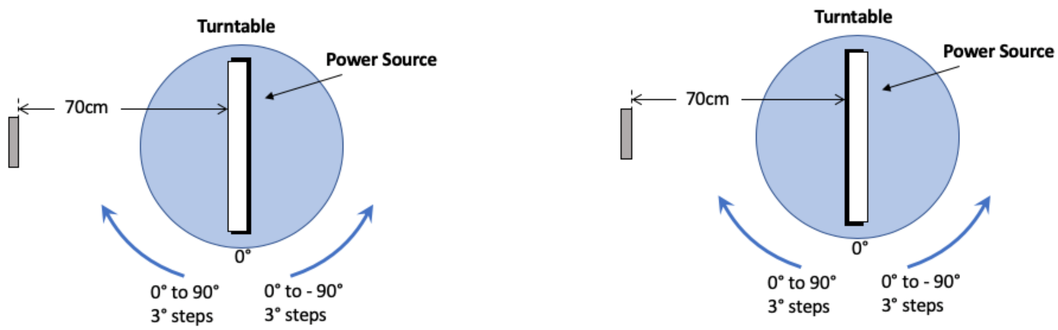



*Figure 4 - power distance verification - step 1*

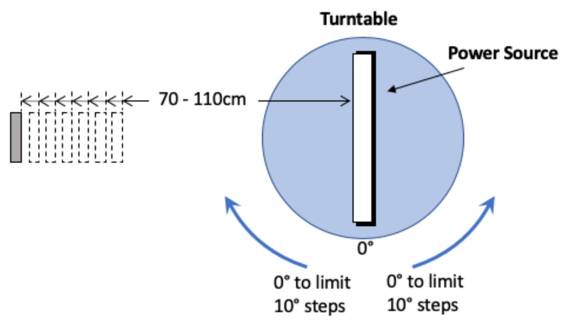



*Figure 5: power distance verification - step 2*

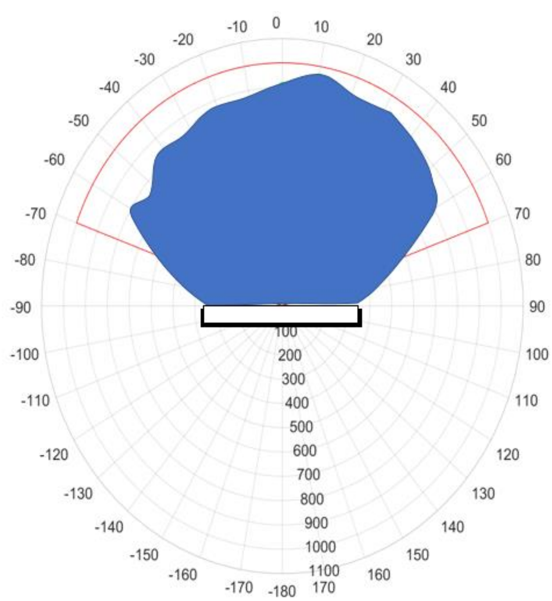



*Figure 6: Power delivery area - horizontal*

*Table 2: Results of horizontal sweep*

| Angle | Horizontal sweep - Distance from WPT Source | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 700 | 750 | 800 | 850 | 900 | 950 | 1000 | 1050 | 1100 |
| -60 | ON | OFF | OFF | OFF | OFF | OFF | OFF | OFF | OFF |
| -50 | ON | ON | ON | OFF | OFF | OFF | OFF | OFF | OFF |
| -40 | ON | ON | ON | ON | OFF | OFF | OFF | OFF | OFF |
| -30 | ON | ON | ON | ON | ON | OFF | OFF | OFF | OFF |
| -20 | ON | ON | ON | ON | ON | OFF | OFF | OFF | OFF |
| -10 | ON | ON | ON | ON | ON | ON | OFF | OFF | OFF |
| 0 | ON | ON | ON | ON | ON | OFF | OFF | OFF | OFF |
| 10 | ON | ON | ON | ON | OFF | OFF | OFF | OFF | OFF |
| 20 | ON | ON | ON | ON | OFF | OFF | OFF | OFF | OFF |
| 30 | ON | ON | ON | OFF | OFF | OFF | OFF | OFF | OFF |
| 40 | ON | ON | ON | OFF | OFF | OFF | OFF | OFF | OFF |
| 50 | ON | OFF | OFF | OFF | OFF | OFF | OFF | OFF | OFF |
| 60 | ON | OFF | OFF | OFF | OFF | OFF | OFF | OFF | OFF |

### 9.2.3 Vertical Plane

The same method described in section 9.2.2 was used to determine the power delivery zone for the vertical orientation. The first step showed power delivery from -57° to 51° vertically. The results of the vertical sweep completed in step 2 are shown in Table 3, and in Figure 7. These tests show, as with the horizontal scan, that the power delivery area extends no further than 95 cm from the front of the WPT Source.

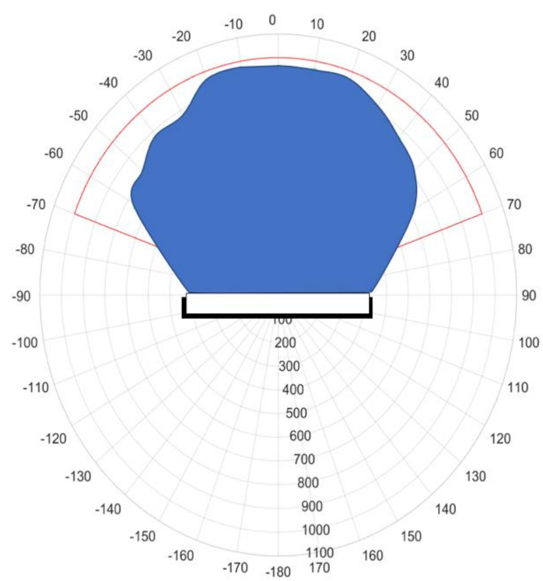



*Figure 7: Power delivery area – vertical*

*Table 3: Results of vertical sweep*

| Angle | Vertical sweep – Distance from WPT Source | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 700 | 750 | 800 | 850 | 900 | 950 | 1000 | 1050 | 1100 |
| -70 | OFF | OFF | OFF | OFF | OFF | OFF | OFF | OFF | OFF |
| -60 | ON | OFF | OFF | OFF | OFF | OFF | OFF | OFF | OFF |
| -50 | ON | ON | ON | OFF | OFF | OFF | OFF | OFF | OFF |
| -40 | ON | ON | ON | ON | OFF | OFF | OFF | OFF | OFF |
| -30 | ON | ON | ON | ON | ON | OFF | OFF | OFF | OFF |
| -20 | ON | ON | ON | ON | ON | ON | OFF | OFF | OFF |
| -10 | ON | ON | ON | ON | ON | ON | OFF | OFF | OFF |
| 0 | ON | ON | ON | ON | ON | ON | OFF | OFF | OFF |
| 10 | ON | ON | ON | ON | ON | ON | OFF | OFF | OFF |
| 20 | ON | ON | ON | ON | ON | ON | OFF | OFF | OFF |
| 30 | ON | ON | ON | ON | OFF | OFF | OFF | OFF | OFF |
| 40 | ON | ON | ON | ON | OFF | OFF | OFF | OFF | OFF |
| 50 | ON | ON | ON | OFF | OFF | OFF | OFF | OFF | OFF |
| 60 | ON | ON | OFF | OFF | OFF | OFF | OFF | OFF | OFF |
| 70 | OFF | OFF | OFF | OFF | OFF | OFF | OFF | OFF | OFF |

# 10 Steps for determining the worst-case scenario

## 10.1 General

The Cota system is a dynamic system that results in changed RF fields due to changes in the relative positionings of power source, power client and any obstructions between the WPT power source and client. Due to the retrodirective features of the Cota technology, the WPT power signal generally avoids such obstructions. Thus, while there may be high field strength in unobstructed space, such fields are not necessarily indicative of potential exposure levels, absent an actual obstruction mimicking the presence of a human body. This aspect of the system requires ascertainment of the worst-case scenario for the potential positioning of power source, client and any obstruction for the potential exposure to RF energy of such an obstruction.

The data in this report demonstrates that there are two potential areas for evaluation of SAR levels of potential for human exposure: (1) a partially obstructed field between the WPT Source and Client and (2) the space immediately behind the WPT Client relative to the WPT Source. In section 10.2.2, Figure 8 shows the unobstructed field between WPT Source and Client, and Figure 10 shows the field behind the WPT Client. Both scans show field strength levels higher than the MPE limit of 1 $mW/cm^2$.

Further field scans detailed in section 10.2 determined that the distance between the WPT Source and WPT Client resulting in the highest field strength in unobstructed space is 1 m and in the space immediately behind the WPT Client is 50 cm. Evaluation of various angular positioning of WPT Source and WPT Client in section 10.3 indicate that the positioning with highest potential exposure level is with the WPT Client directly facing the WPT Source.

In evaluating the potential for exposure between the WPT Source and WPT Client, testing detailed in section 10.5.3.2 shows that a complete obstruction of the path between the WPT Source and WPT Client results in no power being delivered by the WPT Source. Further testing determined that the worst-case for potential exposure is with a partial obstruction with the client positioned 50 cm from the WPT Source and the center of the phantom offset from the boresight line by 22.5 cm.

Based on the testing described above, SAR testing is performed with the WPT Source/Client positioning described in the previous paragraph and with the SAR phantom positioned immediately behind the WPT Client, with a WPT Client/Source positioning of 90 cm. Detailed test results set out in section 11.

Illustrative plots of the RF fields are included in the body of this report. The complete plots are included in Attachment 1. The section numbering within Attachment 1 mirrors that that of the report for ease of cross referencing.

## 10.2 Free-space measurements for various unobstructed distances between WPT Client and WPT Source within the powering zone

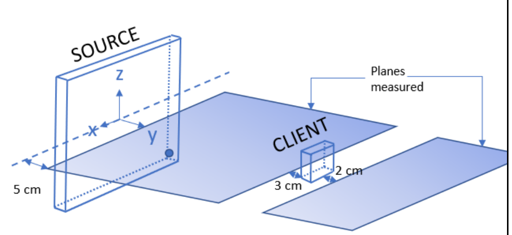
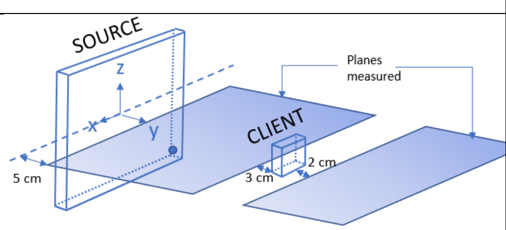
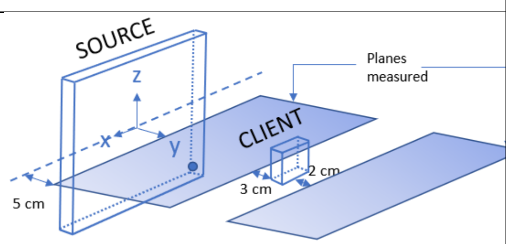
### 10.2.1 General

The following measurements support the determination of the worst case compliance configuration with respect to unobstructed distances between WPT client and WPT source.

To determine the distance between the WPT Source and WPT Client that results in the area of highest relative field strength, we place the WPT Client at various distances (1 m, 0.75 m and 0.5 m) away from the WPT Source and measure the field strength. The WPT Client was not placed any closer than 50 cm from the WPT power source, because there would be little space for obstructions at such distances. The details of this testing and the specific results are set out in Table 4.

Based on these measurements, we have determined that the worst case for RF exposure in the unobstructed field between the WPT Source and WPT Client is test scenario 3 (WPT Source-client distance of 50 cm), and that the worst case for RF exposure behind the WPT Client is scenario 1 (WPT Source-client distance of 1 m) both as set out in Table 4. These conclusions are used to determine the specific location for placement of the phantom(s) for determination of maximum potential RF exposure in obstructed scenarios as discussed in sections 10.5 (field strength) and 11.1 (SAR) and for placement of phantoms behind the WPT Client in sections 10.6 (field strength) and 11.2 (SAR).

*Table 4 measured field strength results for various WPT Source/client distances without any obstruction*

| Test Scenario | Figs. | Source/ Client Dist. (m) | Test Setup | Position of Highest Integrated Field Strength | Max. Field Strength (Horizontal/Vertical) |
|---|---|---|---|---|---|
| 1 | 8 - 11 | 1 |  | X = 0 cm (centered at boresight)<br>Y = 53 cm from Power Source<br>Z = 0 cm (centered on Power Source) | Between Source and Client:<br>H: 188.9 V/m<br>V: 195.4 V/m<br>Average: 191.95 V/m<br>Behind Client:<br>H: 84.86 V/m<br>V: 72.15 V/m<br>Average: 78.51 V/m |
| 2 | 12 - 15 | 0.75 m |  | X = 0 cm (centered at boresight)<br>Y = 50 cm from Power Source<br>Z = 0 cm (centered on Power Source) | Between Source and Client:<br>H: 196.9 V/m<br>V: 202.6 V/m<br>Average: 199.75 V/m<br><br>Behind Client:<br>H: 66.88 V/m<br>V: 68.61 V/m<br>Average: 67.75 V/m |
| 3 | 16 - 19 | 0.5 m |  | X = 0 cm (centered at boresight)<br>Y =47 cm from Power Source<br>Z = 0 cm (centered on Power Source) | Between Source and Client:<br>H: 299.1 V/m<br>V: 307.3 V/m<br>Average: 303.2 V/m<br>Behind Client:<br>H: 52.73 V/m<br>V: 48.19 V/m<br>Average: 50.46 V/m |

## 10.2.2 Unobstructed Case, 1 m

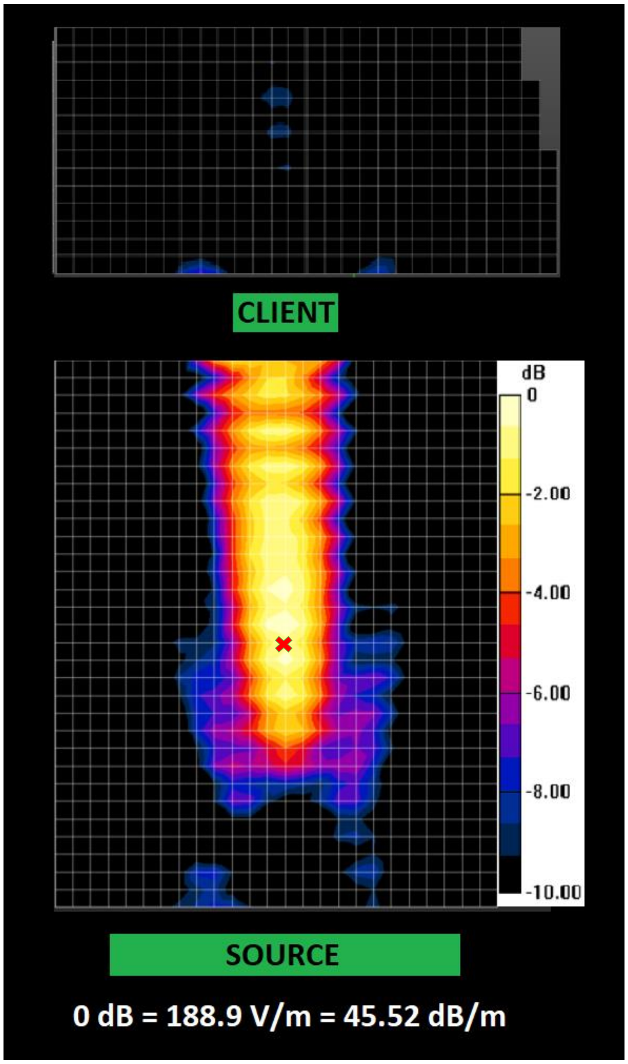



*Figure 8. Unobstructed E-field scan at 1 m between Source and Client - Horizontal Plane*

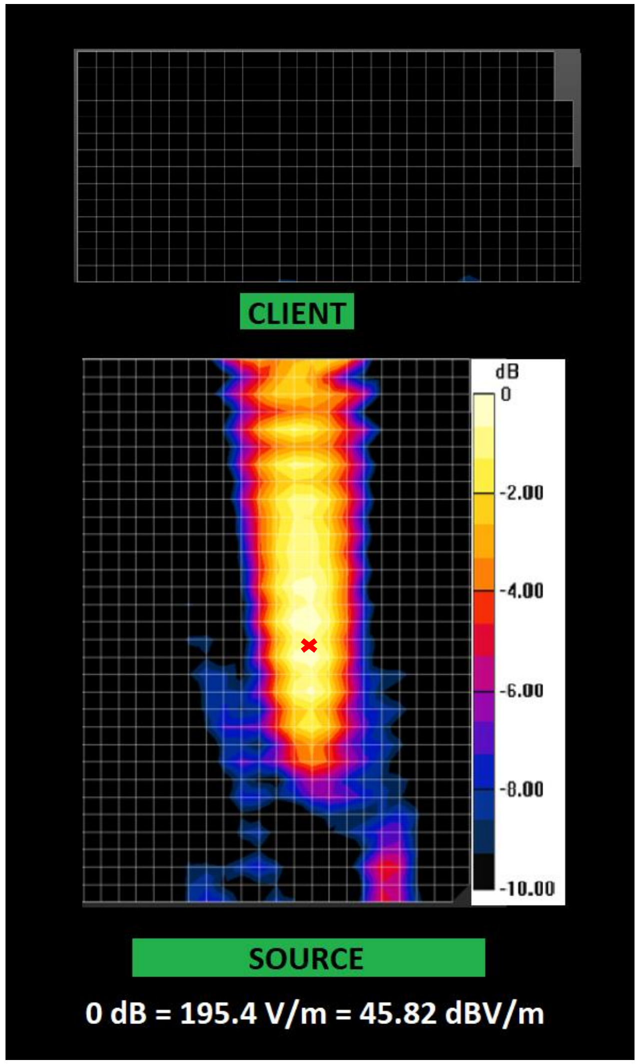



*Figure 9. Unobstructed E-Field Scan at 1 m between Source and Client - Vertical Plane*

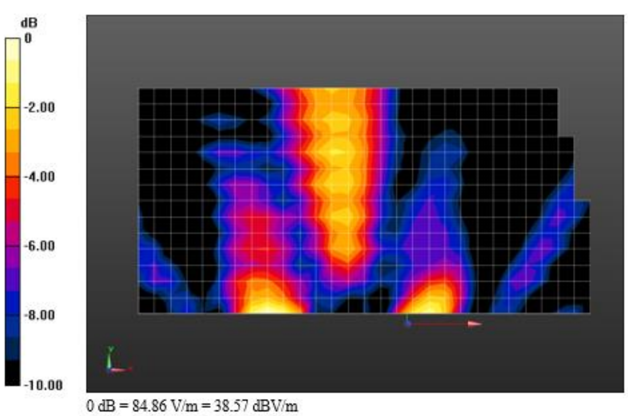



*Figure 10 Unobstructed E-field scan at 1 m behind Client - Horizontal Plane (not Normalized to peak field strength of 188.9 V/m)*

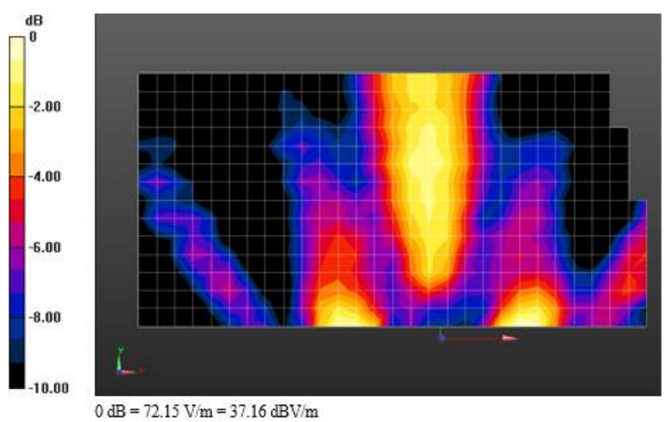



*Figure 11 Unobstructed E-field scan at 1 m behind Client - Vertical Plane (not Normalized to peak field strength of 195.4 V/m)*

### 10.2.3 Unobstructed Case, 75 cm

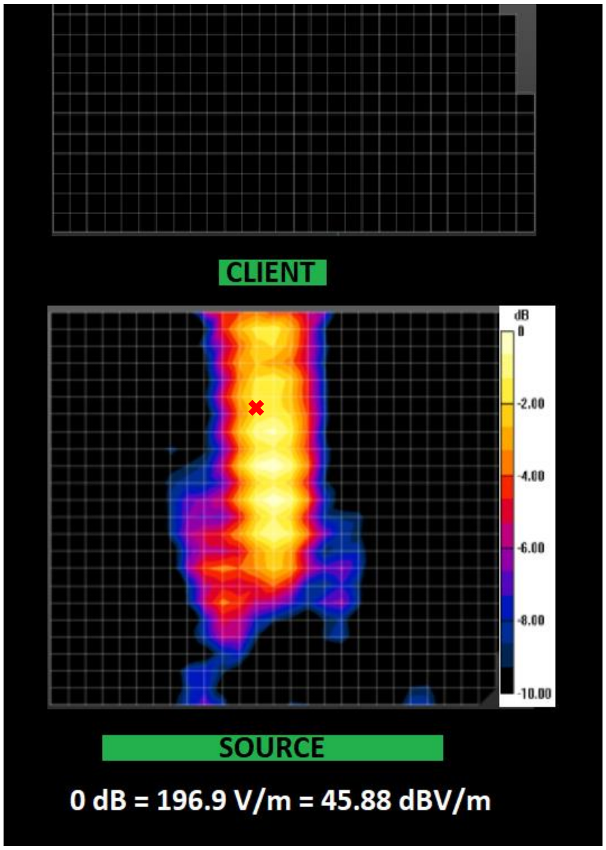



*Figure 12. Unobstructed E-field scan at 0.75 m between Source and Client - Horizontal Plane*

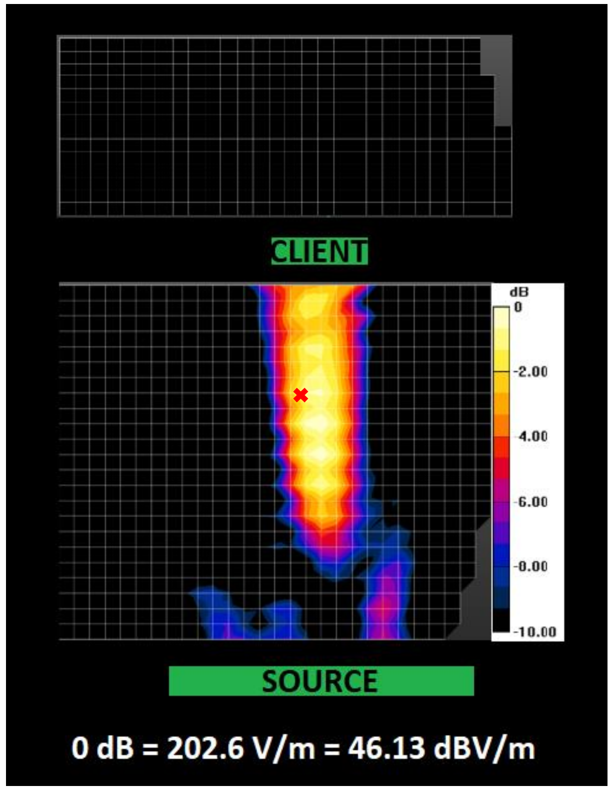



*Figure 13. Unobstructed E-field scan at 0.75 m between Source and Client - Vertical Plane*

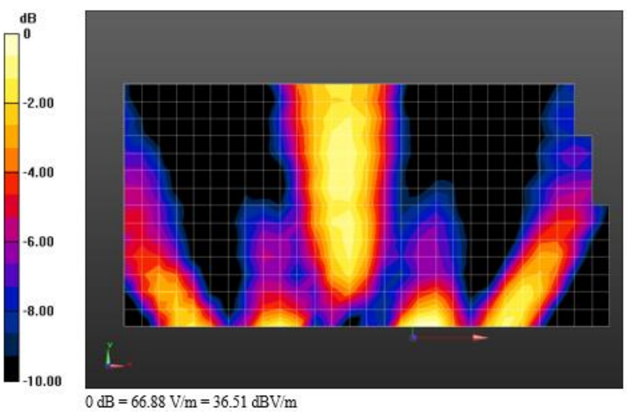



*Figure 14. Unobstructed E-field scan at 0.75 m behind Client - Horizontal Plane (not Normalized to peak field strength of 196.9 V/m)*

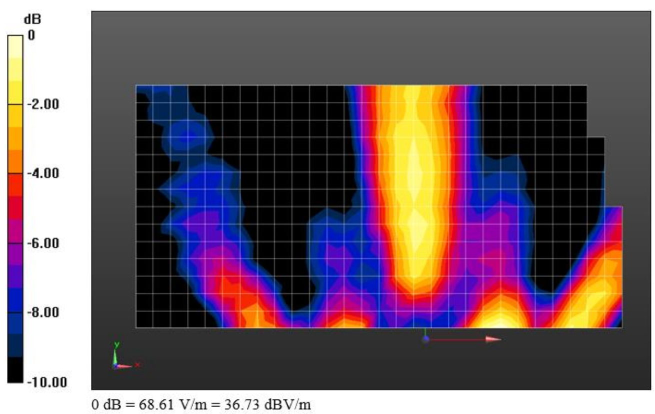



*Figure 15. Unobstructed E-field scan at 0.75 m behind Client - Vertical Plane (not Normalized to peak field strength of 202.6 V/m)*

## 10.2.4 Unobstructed Case, 50 cm

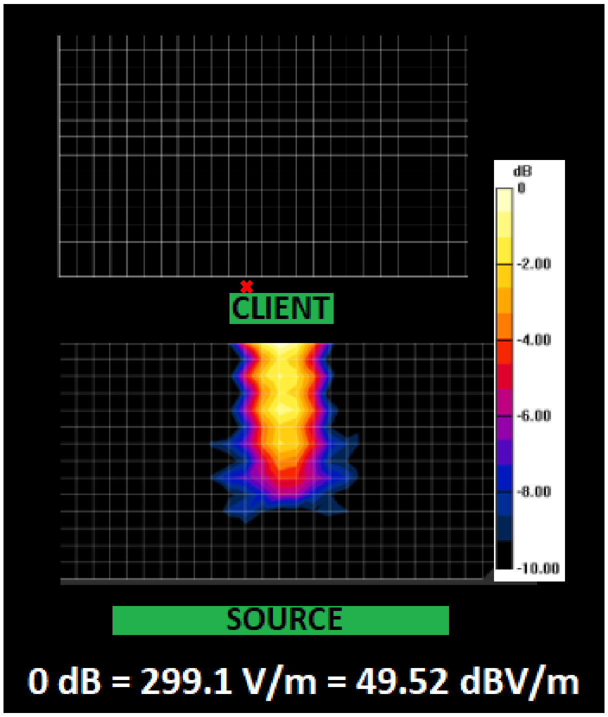



*Figure 16. Unobstructed E-field scan at 0.5 m between Source and Client - Horizontal Plane*

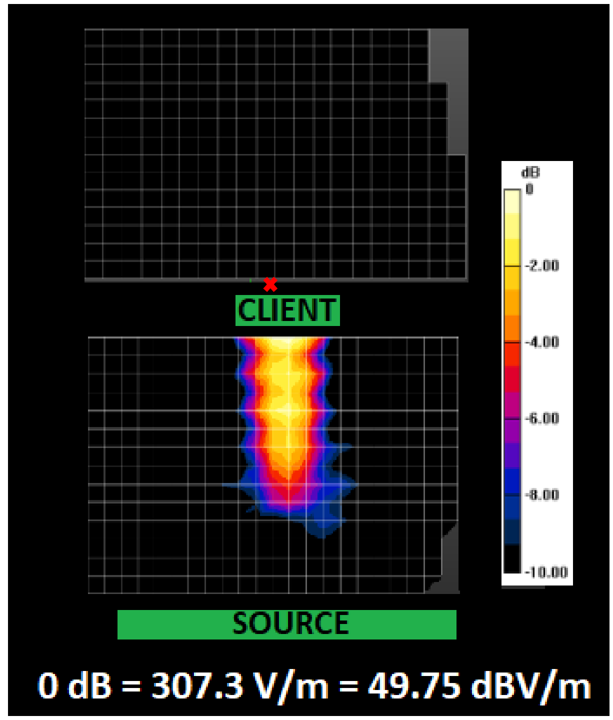



*Figure 17. Unobstructed E-field scan at 0.5 m between Source and Client - Vertical Plane*

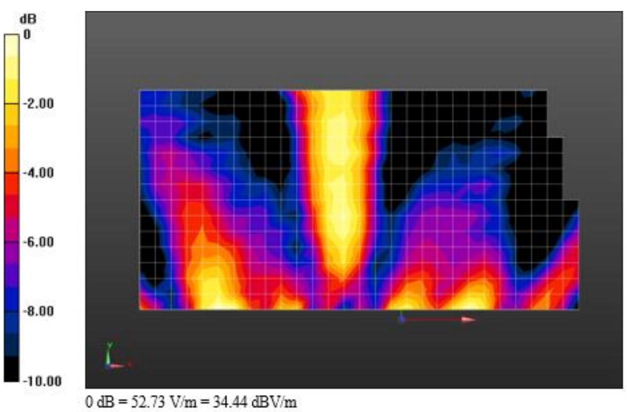



*Figure 18. Unobstructed E-field scan at 0.5 m behind Client - Horizontal Plane (not Normalized to peak field strength of 299.1 V/m)*

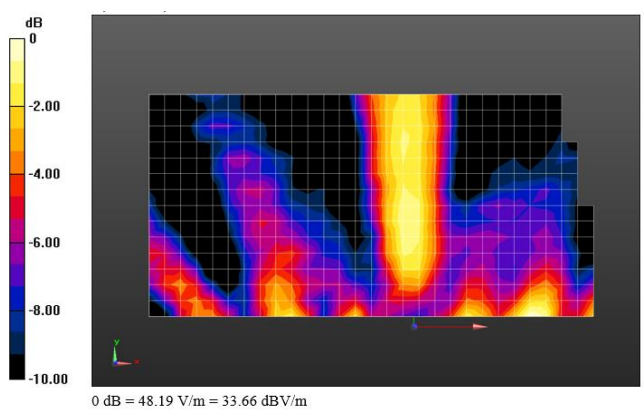



*Figure 19. Unobstructed E-field scan at 0.5 m behind Client - Vertical Plane (not Normalized to peak field strength of 307.3 V/m)*

## 10.3 Identifying the WPT Client angle relative to the WPT Source yielding the highest field strength measured by the probe

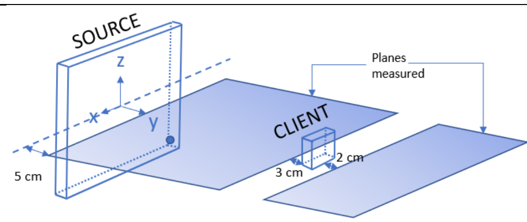
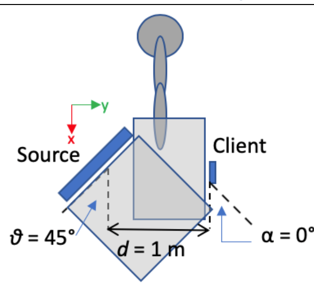
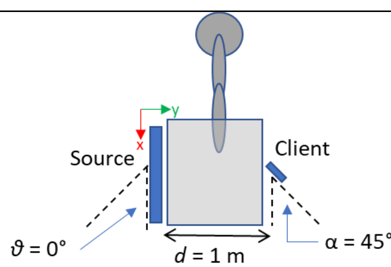
The following measurements support the determination of the worst case compliance configuration with respect to relative angles between WPT client and WPT source.

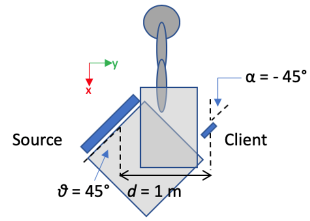
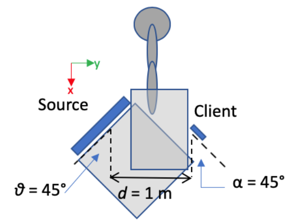
The initial approach is to establish the relative positioning of the power source and client that results in the highest area of relative field strength between power source and client. Testing of several scenarios involving different angles of power source and client establish that there is no positioning that results in RF field strength levels higher than that obtained with the power source directly facing the power client. These tests are detailed below.

Note that the field scans with angled source/client appear similar to the field scans with the directly facing source and client shown in section 10.2. This is expected, as the power beam will always steer toward the location of the WPT client (provided the beacon signal strength is sufficient), irrespective of the orientation of the WPT source relative to the client. One slight difference in these cases worth noting is that where the WPT source is angled with respect to the vertical plane, the width of the power beam in the horizontal plane is larger. When the WPT Source is angled around the vertical plane by 45˚ (i.e., θ=45˚ in Table 5 and as shown in scenarios 4, 6 and 7) the WPT source's antenna aperture towards the client in the horizontal plane is smaller than it would be in the case with the directly facing source/client in section 10.2 (θ=0°=α). These angled source scenarios result in a power beam slightly larger in the horizontal plane than that of the directly facing case. As a result, the maximum field intensity for the angled WPT Source cases is lower than that of the directly facing case.

Table 5, below summarizes these results.

*Table 5 Test results showing relative FS of a variety of Power Source/Client angles*

<table>
<tr><th rowspan="2">Test Scenario</th><th rowspan="2">Source/client angles</th><th rowspan="2">Figs.</th><th rowspan="2">Client angle</th><th colspan="2">Max Power (V/m)</th></tr>
<tr><th>Horiz./Vert.</th><th>Average</th></tr>
<tr><td>3</td><td>0°/0°</td><td>8 and 9</td><td>
</td><td>188.9/195.4</td><td>191.9</td></tr>
<tr><td>4</td><td>45°/0°</td><td>21 - 23</td><td>
</td><td>Field closest to client: 165.6/152.3<br><br>Field closest to source: 177.4</td><td>Field closest to client: 159.0</td></tr>
<tr><td>5</td><td>0°/45°</td><td>25 and 26</td><td>
</td><td>195.4/142.8</td><td>169.1</td></tr>
</table>

| | | | | | |
|---|---|---|---|---|---|
| 6 | 45°/45° | 28 - 30 |   | Field closest to client: 168.4/141.3<br><br>Field closest to source: 161.1 | Field closest to client: 154.9 |
| 7 | 45°/-45° | 32 - 34 |   | Field closest to client: 163.2/122.8<br><br>Field closest to source: 160.3 | Field closest to client: 143.0 |

### 10.3.1 Power source angled 45°

Two sets of field scans are performed with the Power Source angle (ϑ) rotated to 45 degrees as indicated by the grey shaded regions in Figure 20. The distance (d) of the Power Client to the Power Source is 1 m, and (α) is 0 degrees. Scans were repeated to cover horizontal and vertical planes for the field closest to the client. Only the horizontal plane was scanned for the field closest to the WPT Source.

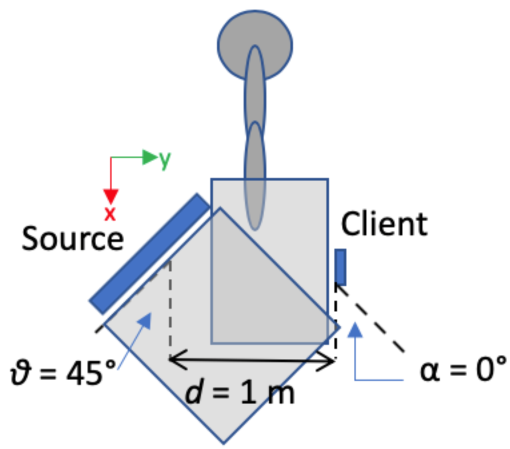
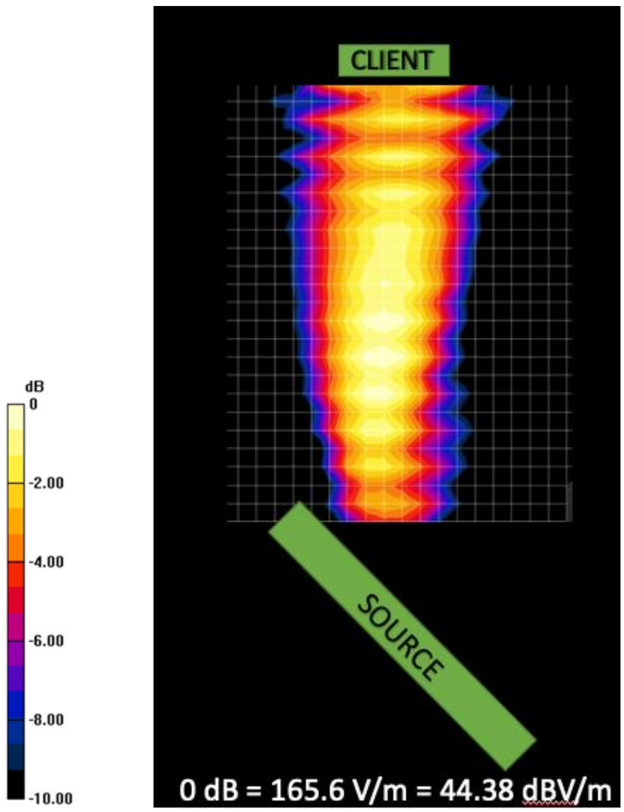



*Figure 20 - Test setup: Scenario 4 Angled Power Source*



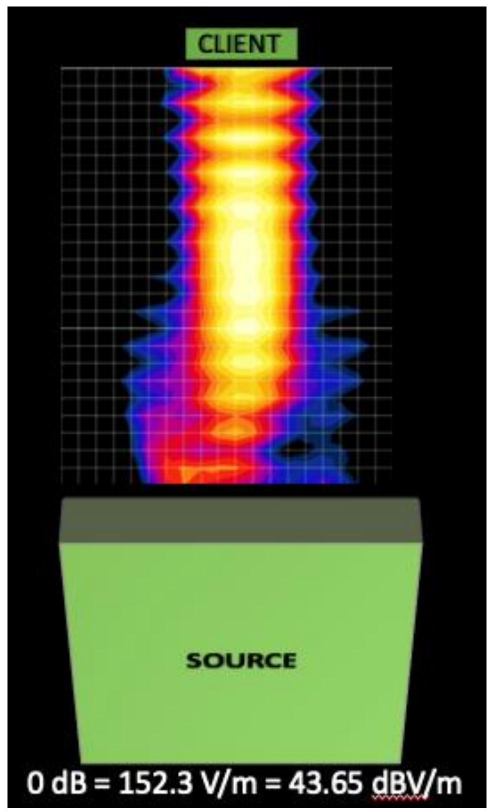




*Figure 21 Power source angle: 45° Client angle: 0° scan closest to WPT Client - Horizontal plane*

*Figure 22 Power source angle: 45° Client angle: 0° scan closest to WPT Client - Vertical plane*

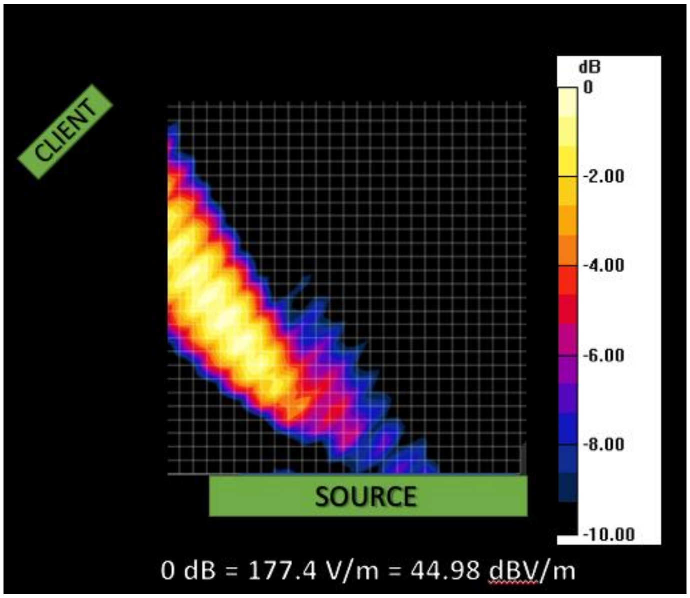



*Figure 23 - Power source angle: 45° Client angle: 0° scan closest to WPT Source - Horizontal plane*

### 10.3.2 Power client angled 45°

Field scans are performed with the Power Client angle (α) rotated to 45 degrees. The distance (d) of the Power Client to the Power Source is 1 m, and (ϑ) is 0 degrees. Scans were repeated to cover horizontal and vertical planes.

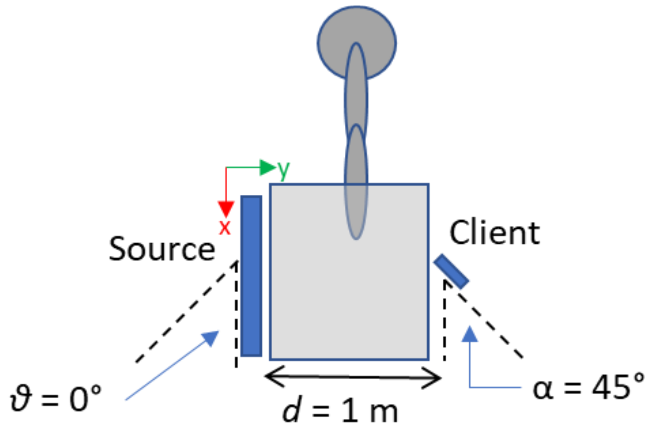



*Figure 24 - Test setup: Scenario 5 Power client angled 45°*

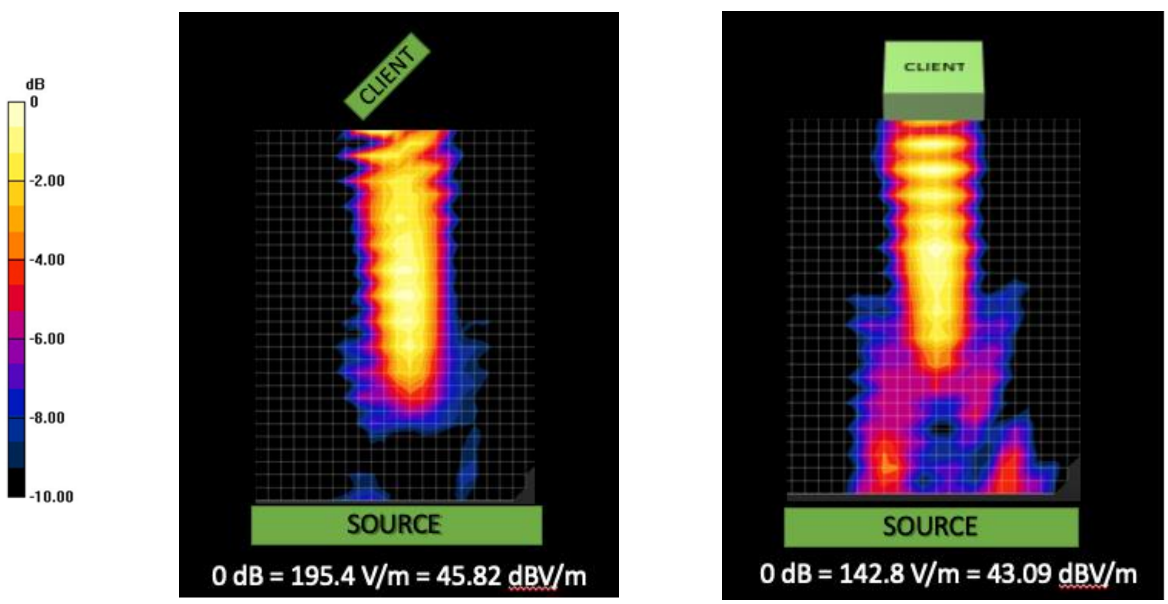



*Figure 25 - Power source angle: 0° Client angle: 45° Horizontal plane*

*Figure 26 Power source angle: 0° Client angle: 45° Vertical plane*

### 10.3.3 Power Source angled 45°, Power Client angled -45°

Two sets of field scans are performed with the center of the Power Client at distance (d) of 1 m from the center of the Power Source, with the angle of the Power Source ($\vartheta$) and Client ($\alpha$) set at 45 degrees, offset and facing each other. The two scan areas are depicted in Figure 27. The distance (d) of the Power Client to the Power Source is 1 m. Scans were repeated to cover horizontal and vertical planes for the field closest to the WPT Client. Only the horizontal plane was scanned for the field closest to the WPT Source.

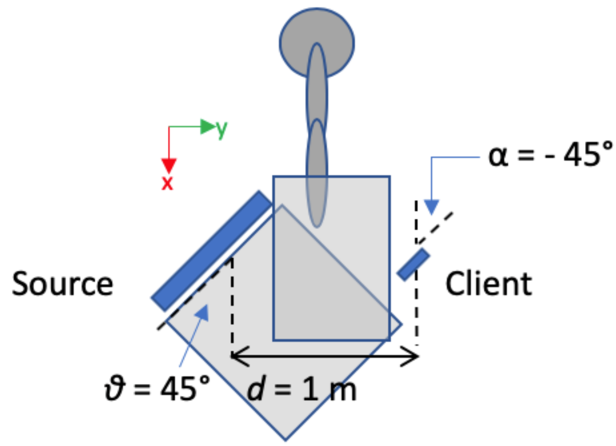
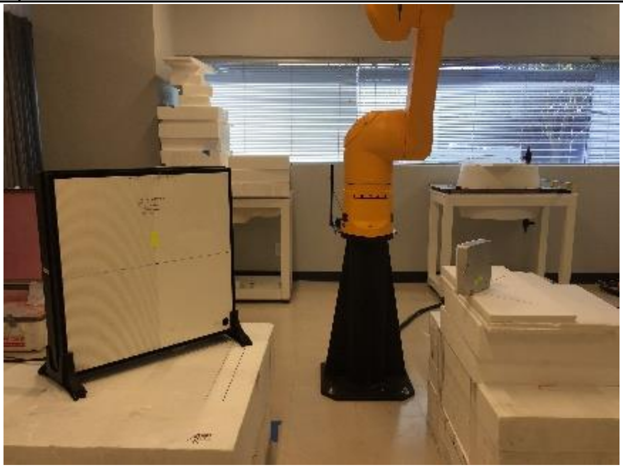
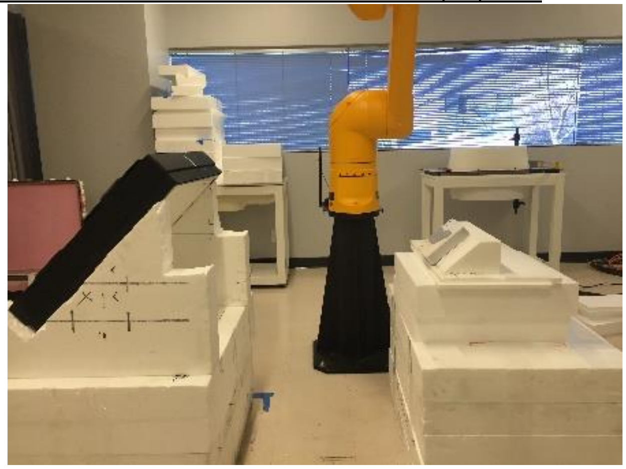



*Figure 27 - Test setup: Scenario 6 Power source angled 45° and client angled -45°*





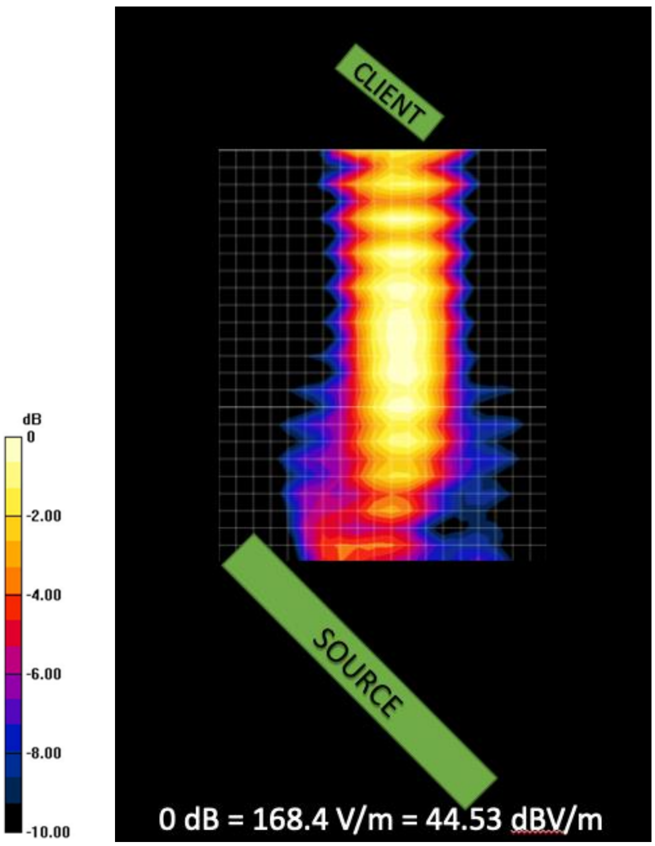



*Figure 28 - Power source angle: 45°*
*Client angle: -45° scan closest to WPT Client - Horizontal plane*

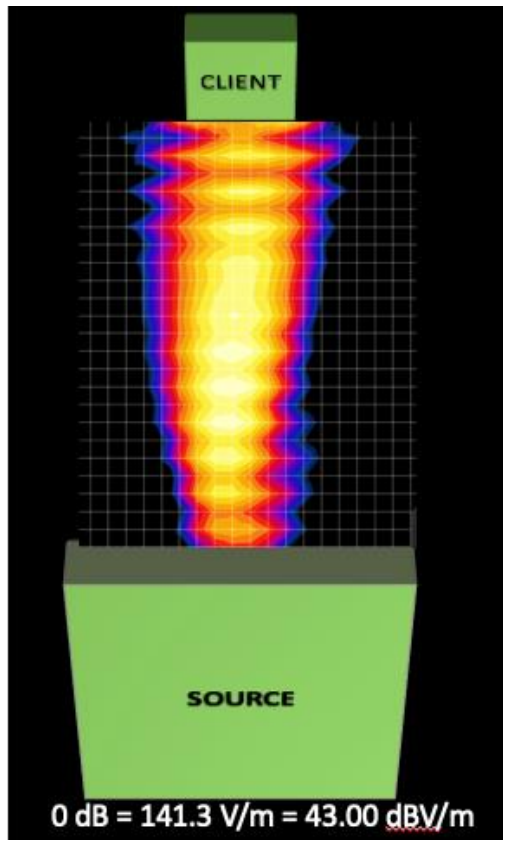



*Figure 29 Power source angle: 45°*
*Client angle: -45° scan closest to WPT Client - Vertical plane*

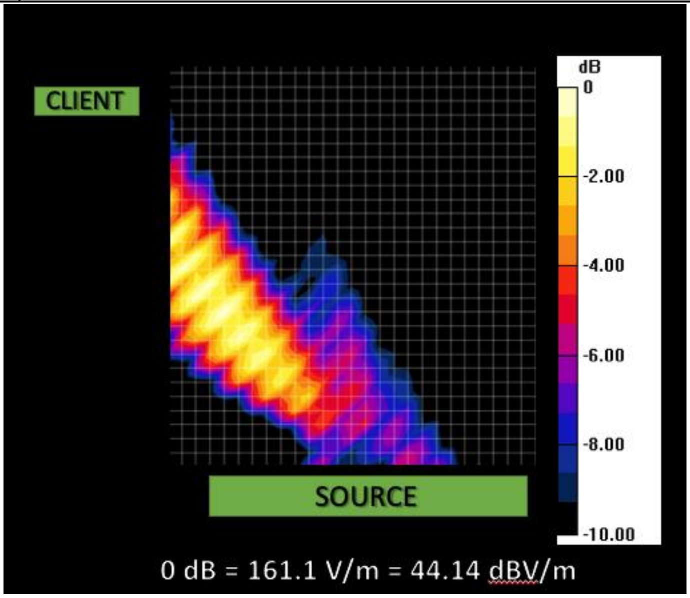



*Figure 30 - Power source angle: 45° Client angle: -45°*
*scan closest to WPT Source - Horizontal plane*

## 10.3.4 Power Source, Client angled 45°

Two sets of field scans are performed with the center of the Power Client at distance (d) of 1 m from the center of the Power Source, with the angle of the Power Source ($\vartheta$) and Client ($\alpha$) set at 45 degrees, offset and angled opposite each other. The two scan areas are depicted in Figure 31. Scans were repeated to cover horizontal and vertical planes for the field closest to the WPT Client. Only the horizontal plane was scanned for the field closest to the WPT Source.

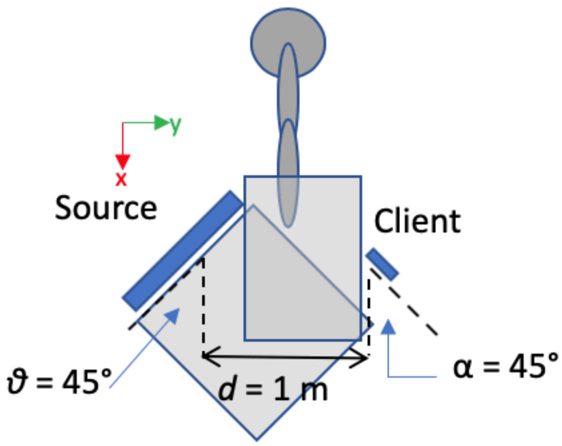
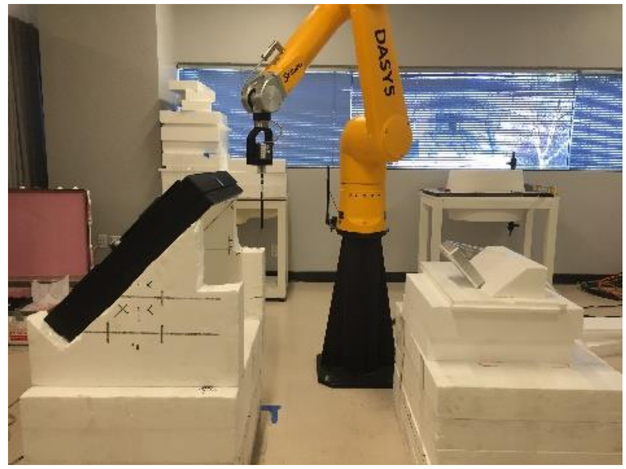
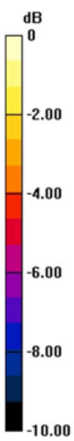



*Figure 31 - Test setup: Scenario 6 Power Source angled 45°, Power Client angled 45°*



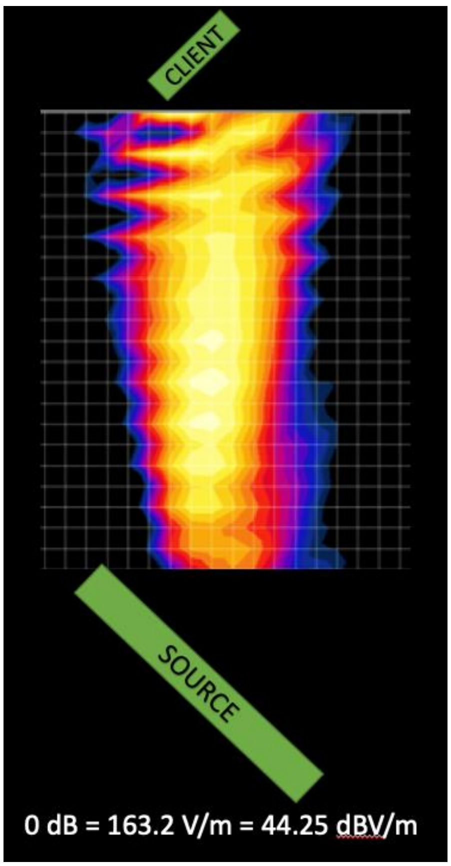




*Figure 32 – Power source angle: 45° Client angle:-45° scan closest to WPT Client - Horizontal plane*

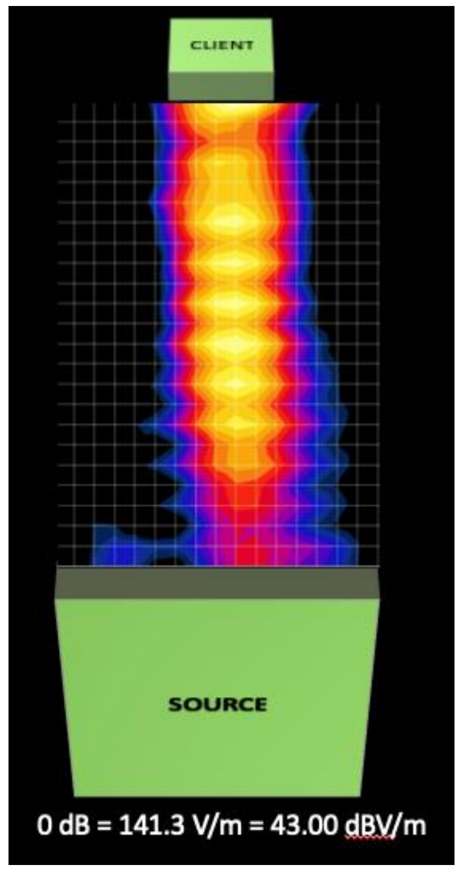
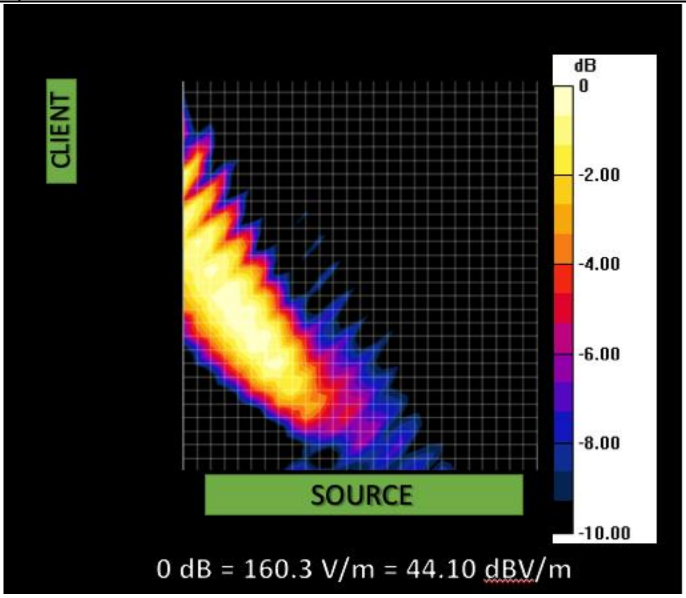



*Figure 33 Power source angle: 45° Client angle:- 45° scan closest to WPT Client - Vertical plane*



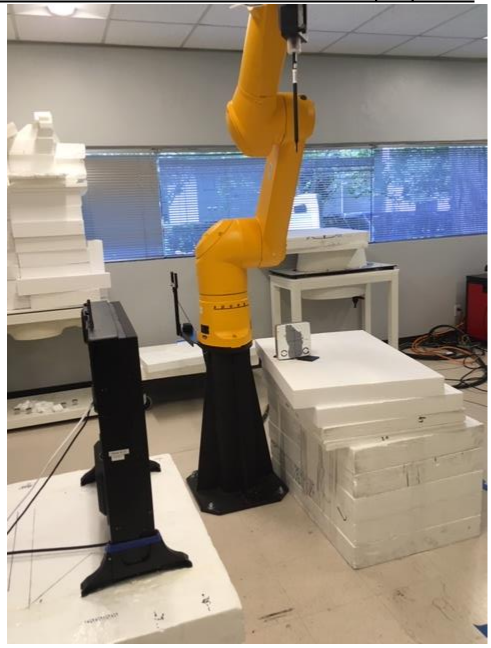



*Figure 34 – Power source angle: 45° Client angle:-45°*
*scan closest to WPT Source - Horizontal plane*

## 10.4 Metallic interactions

The following measurements support the determination of the effects of a metal plate placed behind the WPT client or WPT source.

### 10.4.1 Metal Plate behind WPT Client

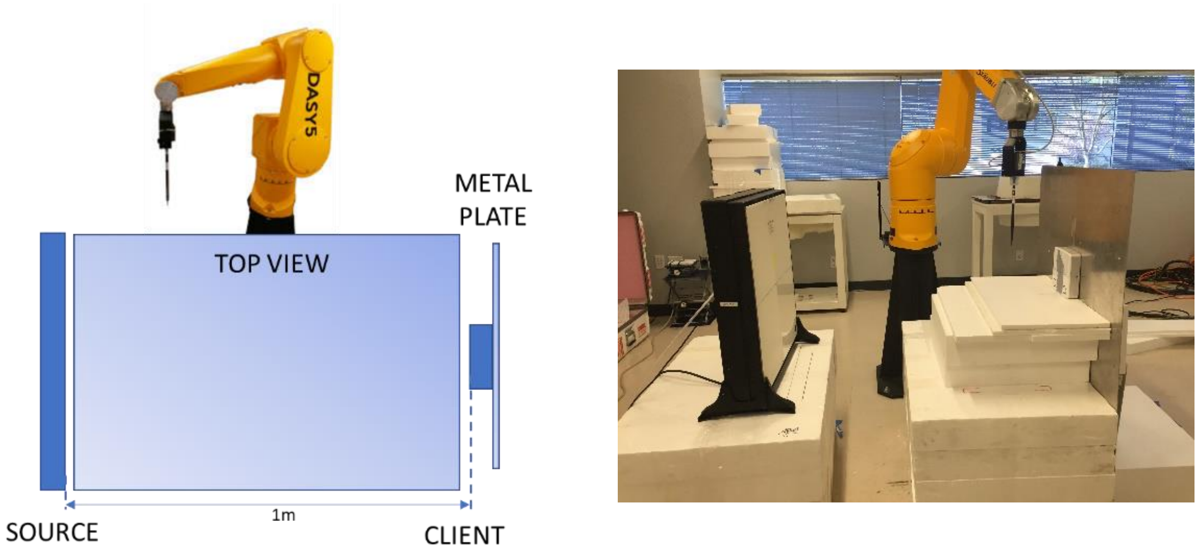



*Figure 35 – Test setup – Scenario 8 Metal plate behind client*

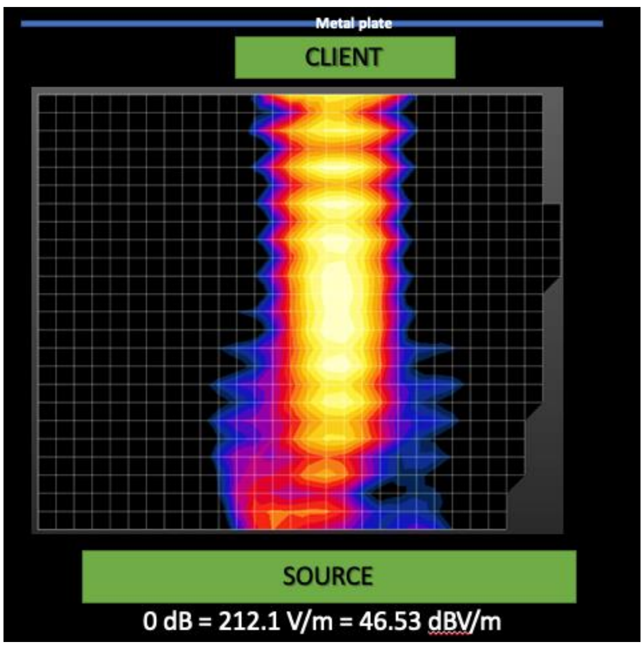



*Figure 36 – Field scan with metal plate behind client*

As per OET response to KDB inquiry, measurement was undertaken of field strength in the unobstructed area between the WPT Source and WPT Client at 1 m separation distance with a metal plate behind the WPT Client. Test setup is shown in Figure 35. We note that the field scan shown in Figure 36 is very similar to the scan shown in Figure 8 and Figure 9, which show the same scenario, but without the metal plate and that the maximum field strength level in this example is within 1 dB of the case without the metal plate.

### 10.4.2 Metal Plate behind WPT Source

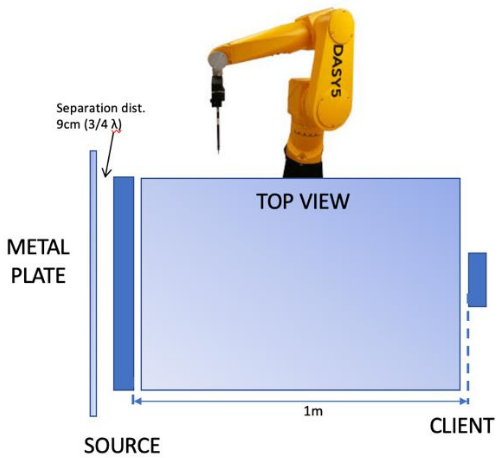



*Figure 37: Test setup - metal plate behind WPT Source*

Per OET communication in response to KDB inquiry, measurement was also undertaken of the unobstructed area between the WPT Source and WPT Client at 1 m separation distance. A metal plate measuring 95 x 85 cm was placed behind the WPT Source at a distance of 9 cm (3/4 λ). Test setup is show in Figure 37. Measurement was concurrently taken of the same setup without the metal plate in place. As indicated in field scans and field strength levels are very similar and indicate little or no difference as a result of the metal plate.

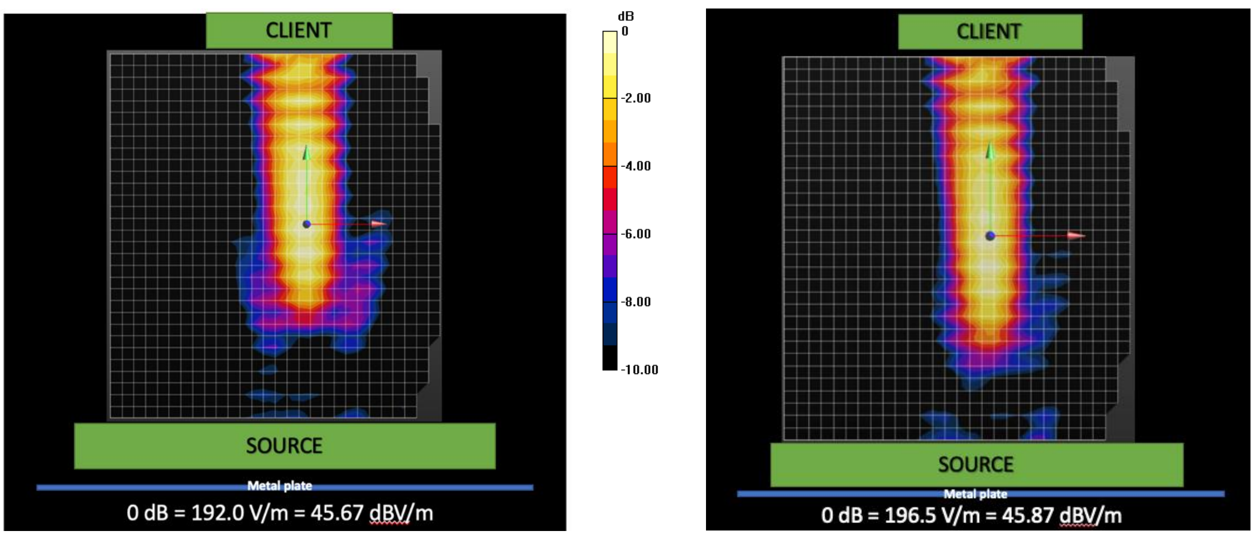



*Figure 38: Field scans of WPT Source with metal plate*

### 10.4.3 Metallic Obstruction

Per OET communication in response to KDB inquiry, measurement was also undertaken of the area between the WPT Source and WPT Client at 1 m separation distance with a metallic obstruction in the power field. Test setup is shown in Figure 39. A galvanized steel duct measuring 8.25 x 25.4 cm (3.25” x 10”) was placed 50 cm from the WPT Source and initially centered on boresight. The obstruction completely blocked the beacon signal, and no power was transmitted with the obstruction in that position. The obstruction was stepped away perpendicular to the boresight line in 6 cm (1/2 λ) increments. The results are shown in Table 6

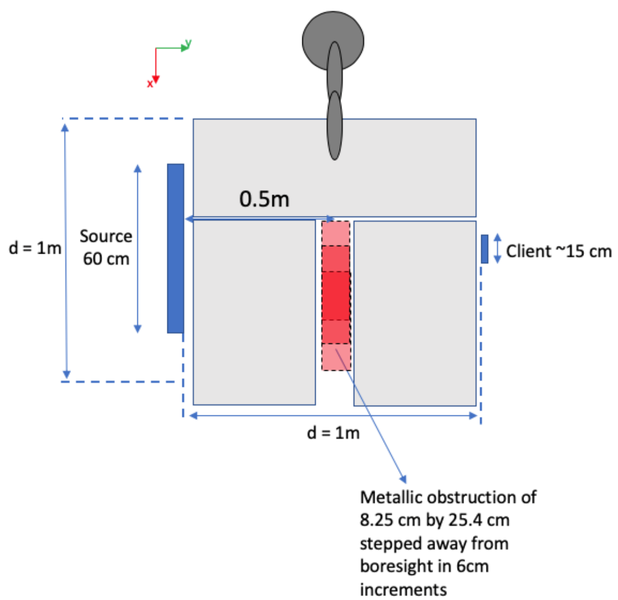
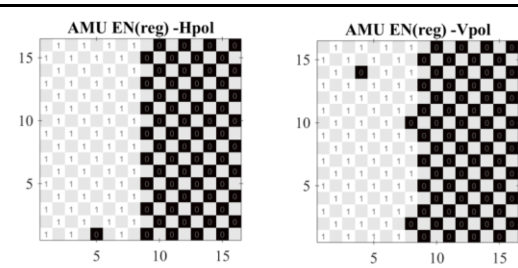
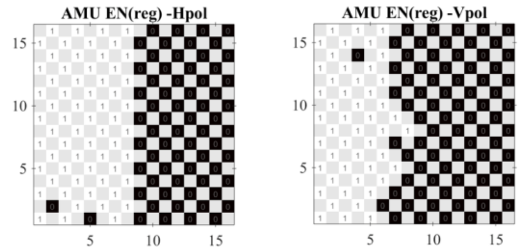




*Figure 39 - Test setup - metallic obstruction*

*Table 6 Test results with metallic obstruction*

| Obstruction Offset (cm) | Max V/m | # Antenna elements (Horiz./Vert.) ON (out of 256 Total) | Antenna map (dark squares = off) |
|---|---|---|---|
| 0 | 0 | 0 | n/a (all antenna off) |
| 6 | 0 | 0 | n/a (all antenna off) |
| 12 | 0 | 0 | n/a (all antenna off) |
| 18 (Horizontal plane) | 119.2 | 63 (H) + 61 (V) = 124 (48% ON) |  |

| Obstruction Offset (cm) | Max V/m | # Antenna elements (Horiz./Vert.) ON (out of 256 Total) | Antenna map (dark squares = off) |
|---|---|---|---|
| 18 (vertical plane) | 91.82 | 62 (H) + 49 (V) = 111 (43% ON) |  |

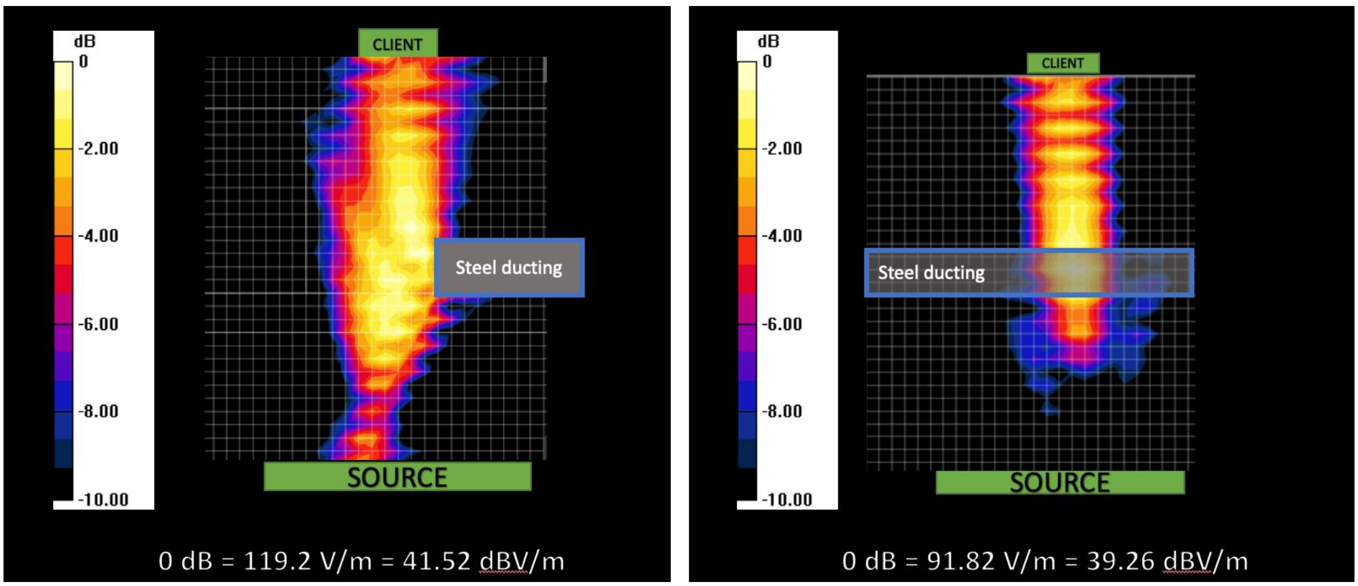



*Figure 40: Field scans with metal obstruction*

## 10.5 Identifying the worst-case scenario with phantom (single phantom cases)

The following measurements support the determination of the worst-case compliance configuration with respect to a single human analog obstruction between WPT client and WPT.

### 10.5.1 General

To determine the worst-case scenario in obstructed cases, we have measured the potential for RF exposure in a range of scenarios with the WPT power source and client at distances 1 m, 75 cm and 50 cm and the phantom(s) at varying offset distances from the boresight line between WPT Source and client. For these scenarios, field scans were performed between the WPT Source and client and single point field strength measurements taken adjacent to (outside) the phantom, close to its edge. Single-point SAR measurements were also taken inside the phantom for the scenarios with the highest field strength around the phantom. Note that the field strength (and thus the single point SAR) decays exponentially inside the phantom as we move toward the center of the phantom. Therefore, the single point SAR data reported here (inside and adjacent to the phantom) is approximately highest single point SAR value inside the phantom. As a result, it is fairly accurate to say that the 1 gram average SAR value for each scenario is much smaller than the single point SAR value reported for that scenario.

*Table 7 RF exposure test results with obstructions*

| **Scenario** | Client to source distance | Phantom to source distance | Phantom offset | Max field strength measured adjacent (outside) to the phantom | Max single point SAR |
|---|---|---|---|---|---|
| 28/29 | 100 cm | 50 cm | 22.5 cm | 73.2 V/m | 0.47 W/kg |
| 30/34 | 75 cm | 25 cm | 15 cm | 79.8 V/m | 0.28 W/kg |
| 31/35 | 75 cm | 25 cm | 22.5 cm | 74.4 V/m | 0.32 W/kg |
| 43/47 | 50 cm | 20 cm | 22.5 cm | 127.7 V/m | 0.57 W/kg |

Detailed results are set out below and summarized in Table 7. Based on the field strength measurements adjacent to (and outside of) the phantom and also the single point SAR measurements inside the phantom, the worst-case scenario is identified as 50 cm distance between WPT Source and client, with 22.5 cm offset. This scenario has the highest single point SAR value (which also corresponds to the highest field strength value adjacent to the phantom).

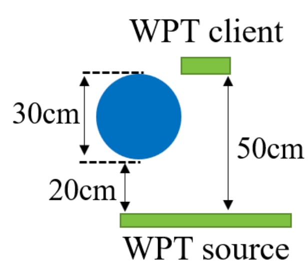



*Figure 41 Worst-case scenario with the cylindrical phantom*

### 10.5.2 Obstructed Case with WPT Source/Client distance of 1 m

#### 10.5.2.1 General

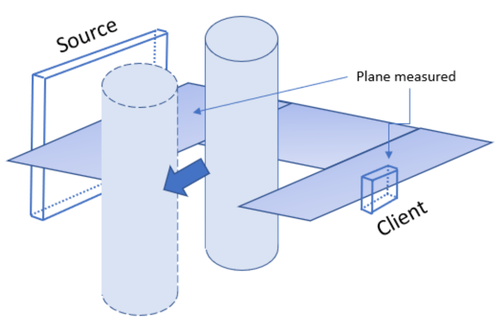
In the following sections, we present the results for a single phantom obstruction using a separation distance of 1 m. For the 1 m case, the phantom edges are placed 50 cm from the WPT source, and 20 cm from the client, (in the region where the field exposure is maximum based on the 1 meter unobstructed scenario reported in section

10.2.2) with varying offsets measured from the boresight line to the center of the phantom. For example, a 0 cm offset is with the center of the phantom aligned with boresight, while a 15 cm offset is with the phantom edge aligned with boresight (due to the 30 cm diameter of the phantom).

Field scans are shown for each test scenario, along with maximum field strength and diagrams showing the antenna that are active, as a result of the RSSI threshold feature (see Operational Description). Note that in the case where there are multiple scans for the same WPT Source/client distance and phantom offset scenarios, the RSSI maps differ slightly between the various scans (*e.g.* transverse and vertical field map, phantom adjacent field scans, etc.) These differences are mainly attributed to (i) slight difference in the shape and size of the vertical phantom compared to the horizontal phantom, and (ii) the identical alignment of the phantom with the client and WPT source among the various scans is difficult to achieve.

### 10.5.2.2 Field Strength with Single Phantom, Stepped off-Axis, Vertical Orientation (1 m)

In this subsection, for the following scenarios, we only measure the field strength in the transverse plane (phantom is vertical). In section 10.5.2.3, we report the field strength for the vertical plane by rotating the phantom, the WPT Source, and the WPT Client by 90˚. Sections 10.5.2.4 and 10.5.2.5 show the horizontal and vertical planes respectively of the scenarios with the phantom in the longitudinal orientation. Also provided in Section 10.5.2.6 are field strength values immediately adjacent to the phantom in the vertical orientation (to account for the limited ability to perform automated scans immediately adjacent to the phantom). Finally, Section 10.5.2.7 shows single-point SAR values for the vertical phantom.



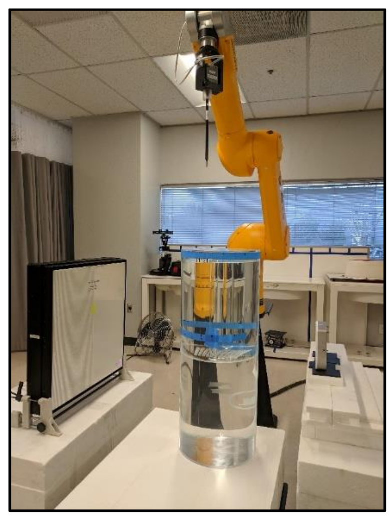
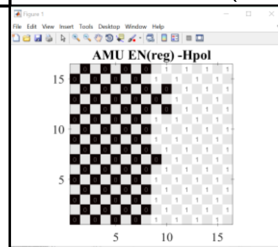
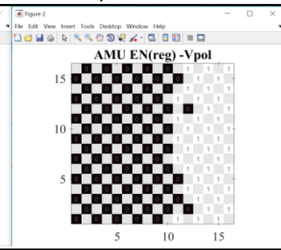
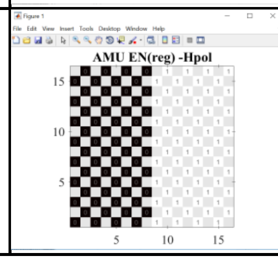
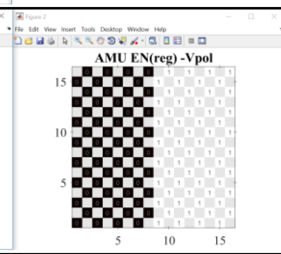



*Figure 42 - Test setup - vertical phantom, transverse plane*

*Table 8 Details: Field Strength, Vertical Orientation (1 m)*

| Test Scenario | Figures | Phantom Offset (cm) | Max V/m | # Antenna elements (Horiz./Vert.) ON (out of 256 Total) | Antenna map (dark squares = off) | |
|---|---|---|---|---|---|---|
| 9 | n/a | 0 | 0 | 0 | n/a (all antenna off) | |
| 10 | n/a | 7.5 | 0 | 0 | n/a (all antenna off) | |
| 11 | Figure 43 | 15 | 86.93 | 60 (H) + 43 (V) = 103 (40% ON) |  |  |
| 12 | Figure 44 | 22.5 | 112.3 | 64 (H) + 64 (V) = 128 (50% ON) |  |  |

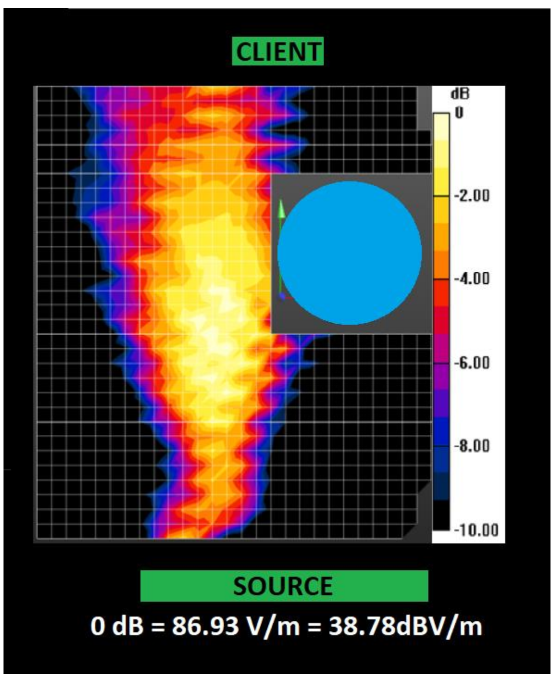



*Figure 43. Obstructed E-field scan at 1 m between Source and Client with 15 cm offset– Vertical Phantom,*

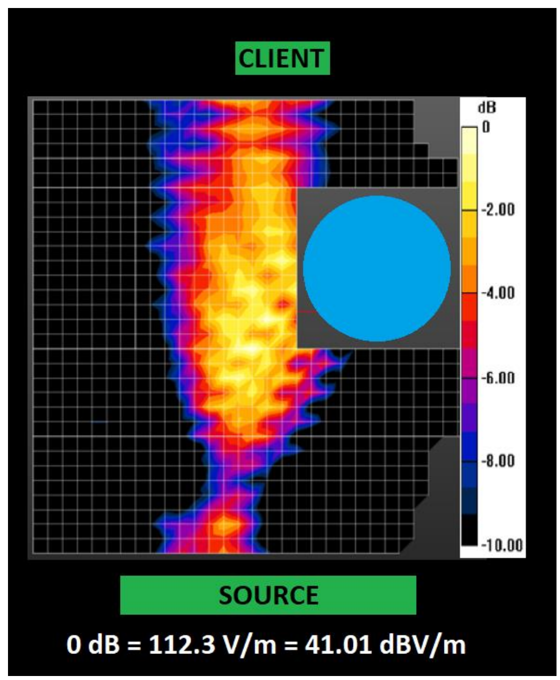
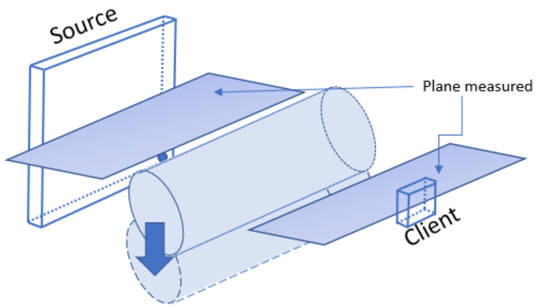



*Figure 44. Obstructed E-field scan at 1 m between Source and Client with 22.5 cm offset– Vertical Phantom*

### 10.5.2.3 Field Strength with Single Phantom, Stepped off-Axis, Transverse Orientation (1 m)

To be able to measure the field strength in the transverse plane for the scenarios explained in Section 10.5.2.2, we rotate the phantom, the WPT Source, the WPT Client counter clockwise by 90˚ in this subsection.



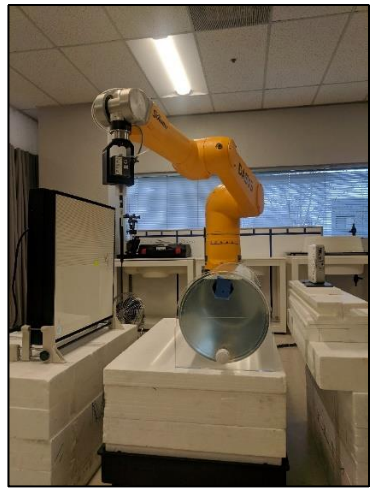
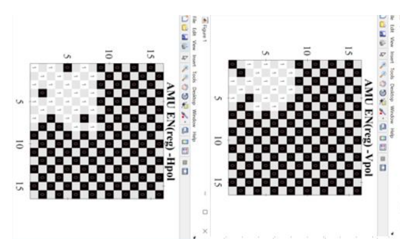
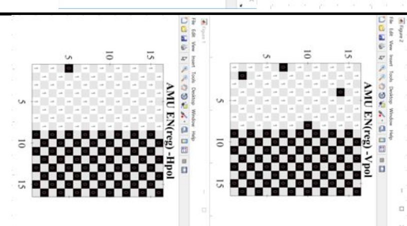



*Figure 45 - Test setup - single phantom transverse plane*

*Table 9 Details: Field Strength, Transverse Orientation (1 m)*

| Test Scenario | Figures | Phantom Offset (cm) | Max V/m | Number of antenna elements (Horiz./ Vert.) ON (out of 256 Total) | Antenna map (dark squares = off) |
|---|---|---|---|---|---|
| 13 | n/a | 0 | 0 | 0 | n/a (all antenna off) |
| 14 | n/a | 7.5 | 0 | 0 | n/a (all antenna off) |
| 15 | Figure 46 | 15 | 59.83 | 26 (H) + 19 (V) = 45 (18% ON) |  |
| 16 | Figure 47 | 22.5 | 94.75 | 63 (H) + 61 (V) = 124 (48% ON) |  |

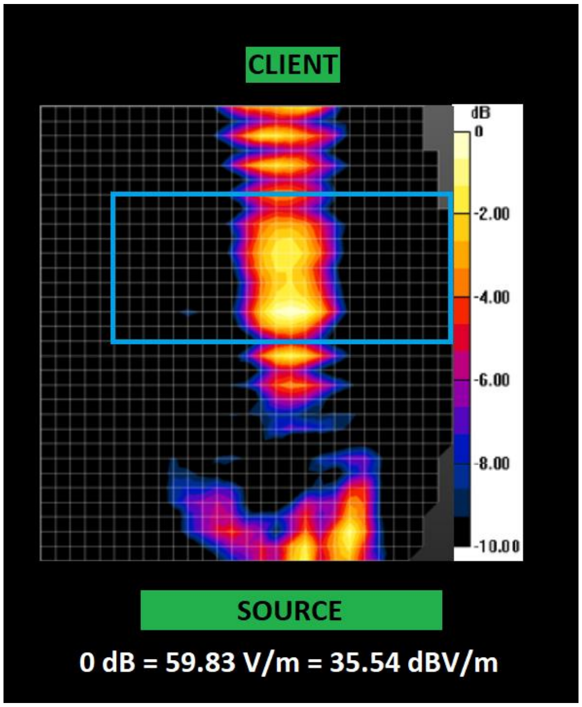



*Figure 46. Obstructed E-field scan at 1 m between Source and Client with 15 cm offset– Transverse Phantom*

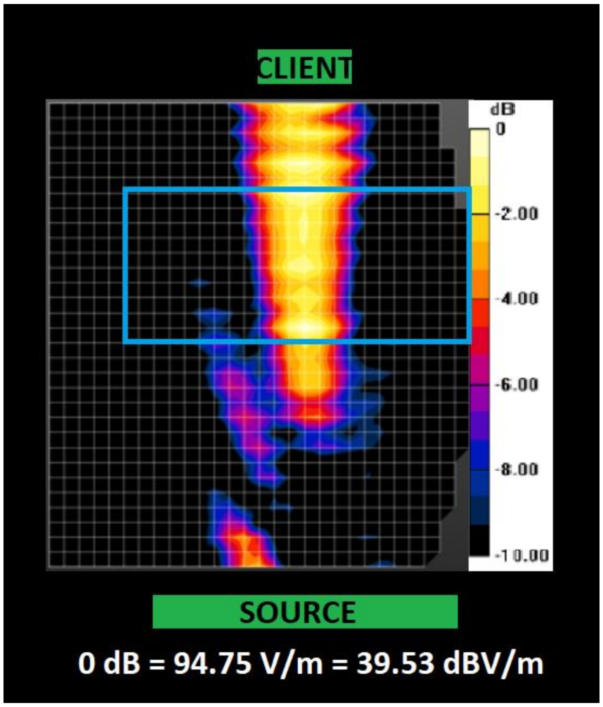



*Figure 47. Obstructed E-field scan at 1 m between Source and Client with 22.5 cm offset– Transverse Phantom*

### 10.5.2.4 Field Strength with Single Phantom, Stepped off-Axis, Longitudinal Orientation, Horizontal Plane (1 m)

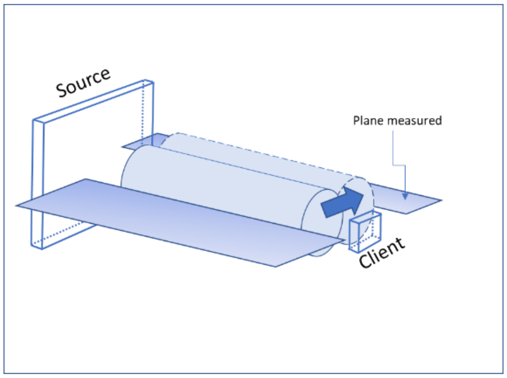
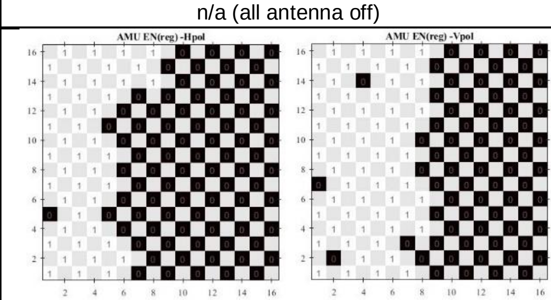



*Figure 48 - Test setup - single longitudinal phantom, horizontal plane*

*Table 10 Details: Field Strength, Longitudinal Orientation, Horizontal Plane (1 m)*

| Test Scenario | Figures | Phantom Offset, Horizontal (cm) | Max V/m | Number of antenna elements (Horiz./ Vert.) ON (out of 256 Total) | Antenna map (dark squares = off) |
|---|---|---|---|---|---|
| 17 | n/a | 0 | 0 | 0 | n/a (all antenna off) |
| 18 | n/a | 7.5 | 0 | 0 | n/a (all antenna off) |
| 19 | n/a | 15 | 0 | 0 | n/a (all antenna off) |
| 20 | Figure 49 | 22.5 | 88.0 | 43 (H) + 57 (V) = 100<br><br>(39.1% ON) |  |

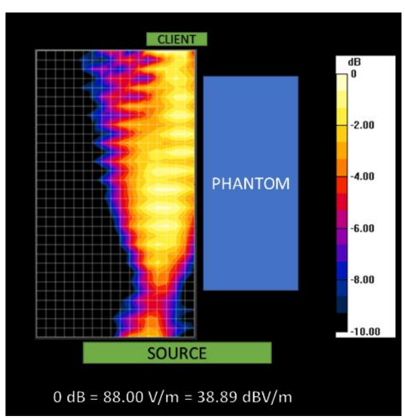



*Figure 49. Obstructed E-field scan at 1 m between Source and Client with 22.5 cm offset– Longitudinal Phantom*

## 10.5.2.5 Field Strength with Single Phantom, Stepped off-Axis Longitudinal Orientation, Vertical Plane (1 m)

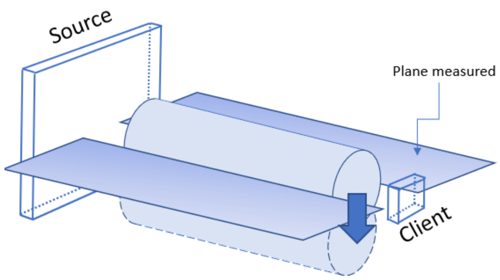
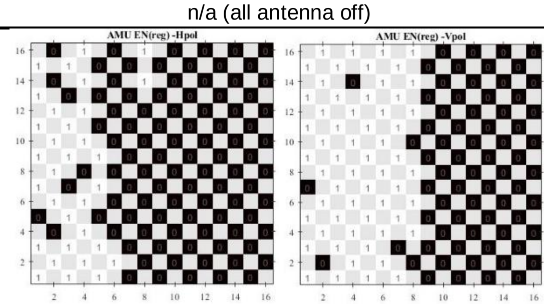



*Table 11 Details: Field Strength, Longitudinal Orientation, Vertical Plane (1 m)*

| Test Scenario | Figures | Phantom Offset, Vertical (cm) | Max V/m | Number of antenna elements (Horiz./ Vert.) ON (out of 256 Total) | Antenna map (dark squares = off) |
|---|---|---|---|---|---|
| 21 | n/a | 0 | 0 | 0 | n/a (all antenna off) |
| 22 | n/a | 7.5 | 0 | 0 | n/a (all antenna off) |
| 23 | n/a | 15 | 0 | 0 | n/a (all antenna off) |
| 24 | Figure 50 | 22.5 | 99.57 | 32 (H) + 58 (V) = 90<br><br>(35.2% ON) |   |

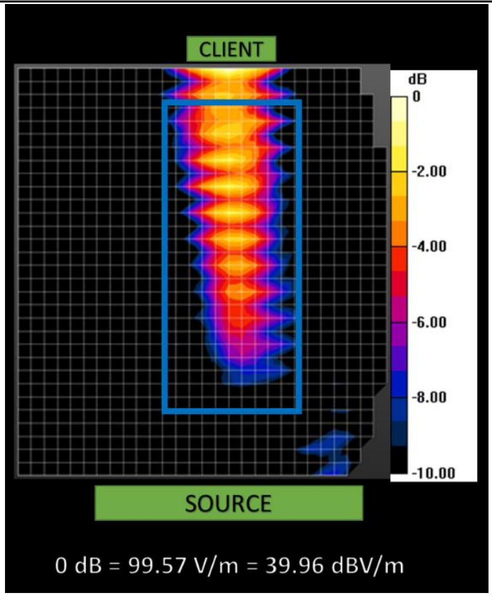



*Figure 50. Obstructed E-field scan at 1 m between Source and Client with 22.5 cm offset– Longitudinal Phantom*

### 10.5.2.6 Field Strength Adjacent to Single Vertical Phantom (1 m)

In addition to E-field mapping for the single phantom obstruction, additional field strength measurements were performed adjacent to the phantom as requested by OET for better resolution of potential exposure near the phantom. These field strength measurements were performed with the WPT Client positioned 1 m away from the WPT Source and at offsets of 15 and 22.5 cm from the centerline. (See test scenarios 11 and 12).

These tests involved manually steering the probe around the perimeter of the phantom at a step size of 1 cm (based on the area scan step size per IEEE 1528-2013). The distance between the probe and the phantom edge was 2 mm. Figure 52 below shows the physical orientation of measurement points around the perimeter of the phantom. Each tick mark comprises a 1 cm step along the circumference of the phantom where each measurement was taken. Figure 52 illustrates how each measurement is converted to an offset in degrees from the point on the phantom that is tangent to the boresight line. Figure 53 illustrates the orientation of the WPT Source, client, phantom, and robot during the measurement.

Table 13 records the field strength next to the phantom at 1 m separation, 22.5 cm offset. The highest field strength measured in this scenario was 73.2 V/m at 3.82 degrees offset from the boresight line.