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 charger

FCC ID: 2ADNG-MS300
Model Name: MS-300

Report Number: 12023867-S1V3
Issue Date: 12/19/2017

Prepared for

ENERGOUS CORPORATION

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NVLAP LAB CODE 200065-0

Revision History

Rev.	Date	Revisions	Revised By
V1	12/4/2017	Initial Issue	--
V2	12/13/2017	Updated Section 6.1 – Operational Description Changed Charging Area to Charging Zone in multiple sections	Dave Weaver
V3	12/19/2017	Numerous updates based upon FCC feedback	Dave Weaver

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1. Attestation of Test Results

Applicant Name	Energous Corporation		
FCC ID	2ADNG-MS300		
Model Name	MS-300		
Applicable Standards	FCC 47 CFR § 2.1093 Published RF exposure KDB procedures 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	0.966		
Whole Body SAR	0.043		
Date Tested	7/4/2017 to 11/28/2017		
Test Results	Pass		

UL Verification Services Inc. tested the above equipment in accordance with the requirements set forth in the above standards. All indications of Pass/Fail in this report are opinions expressed by UL Verification Services Inc. based on interpretations and/or observations of test results. Measurement Uncertainties were not taken into account and are published for informational purposes only. The test results show that the equipment tested is capable of demonstrating compliance with the requirements as documented in this report.

Note: The results documented in this report apply only to the tested sample, under the conditions and modes of operation as described herein. 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 any government (NIST Handbook 150, Annex A). This report is written to support regulatory compliance of the applicable standards stated above.

Approved & Released By:	Prepared By:
	
Dave Weaver Operations Leader UL Verification Services Inc.	Lance Fleischer Laboratory Engineer 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**:**

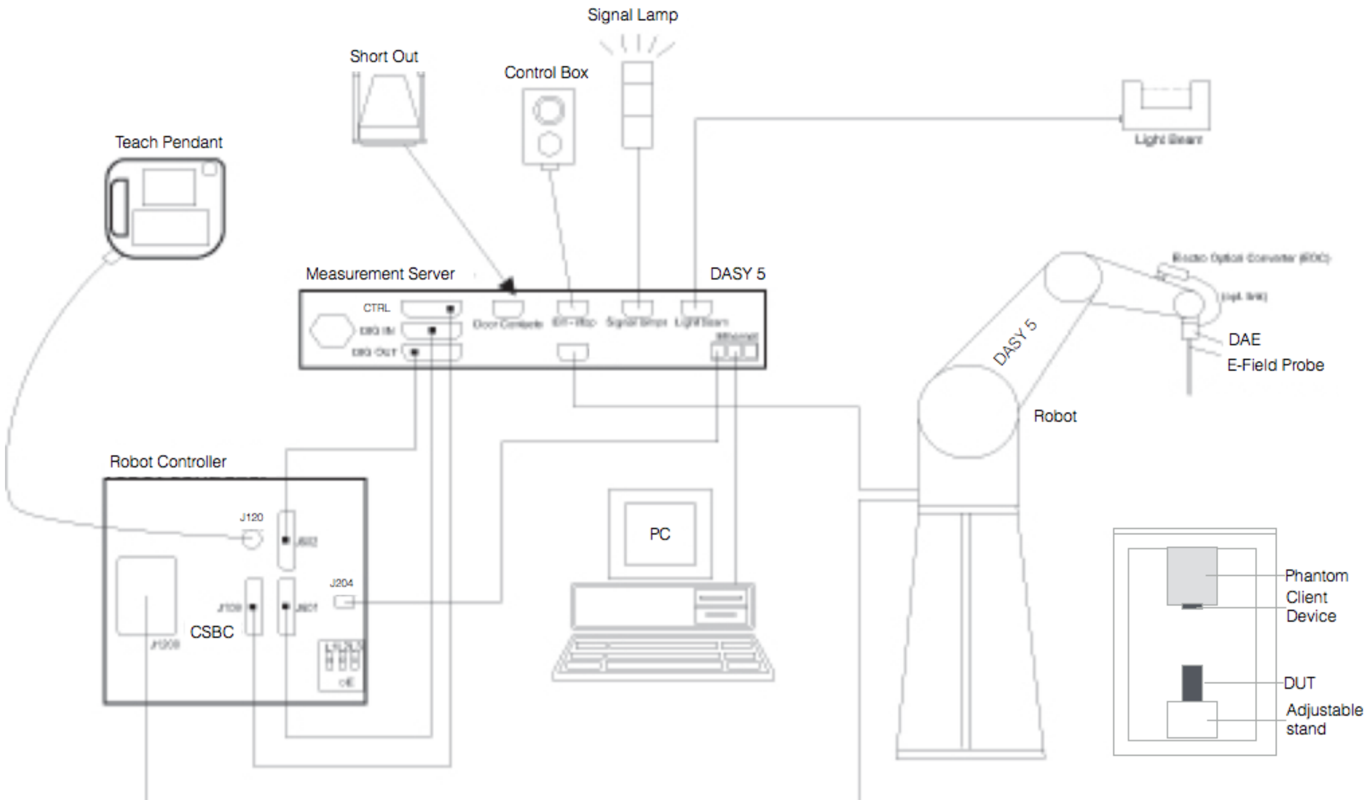


Figure 1: SAR measurement system

- 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 WinXP or Win7 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. Additionally, the broadside of the EUT can be circumscribed by the lateral dimensions of the phantom as required by IEC 62232.

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: Δx_{Area}, Δy_{Area}	≤ 2 GHz: ≤ 15 mm 2 – 3 GHz: ≤ 12 mm	3 – 4 GHz: ≤ 12 mm 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: Δx_{Zoom}, Δy_{Zoom}			≤ 2 GHz: ≤ 8 mm 2 – 3 GHz: ≤ 5 mm*	3 – 4 GHz: ≤ 5 mm* 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 4 – 5 GHz: ≤ 3 mm 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 4 – 5 GHz: ≤ 2.5 mm 5 – 6 GHz: ≤ 2 mm
		$\Delta z_{Zoom}(n>1)$: between subsequent points	≤ $1.5 \cdot \Delta z_{Zoom}(n-1)$	
Minimum zoom scan volume	x, y, z		≥ 30 mm	3 – 4 GHz: ≥ 28 mm 4 – 5 GHz: ≥ 25 mm 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 (*$SAR_{psa}(d)$*)

$$SAR_{psa}(d) = SAR_m(d) \text{x} CF_1(d) \text{x} CF_2(d)$$

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), μ_0 is the free-space permeability ($4\pi \times 10^{-7}$ H/m), ε_0 is the free space permittivity (8.85×10^{-12} F/m), ε'_r is the relative permittivity, and σ is the conductivity of the medium. Penetration depth is expressed in meters (m).

Using the 915 MHz body tissue dielectric parameters from KDB 865664 D01 of σ = 1.06 and ε'_r = 55 the penetration depth (δ) is 0.038m. The tissue simulation liquid depth is >0.15m. The highest measurement point was at least 0.09m below the surface of the TSL which is greater than 2δ = 0.074m. 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 30mm 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 30mm 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:

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

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

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

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

$CF_4(f)$ 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 of the MS-300.

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.

Name of Equipment	Manufacturer	Type/Model	Serial No.	Cal. Due Date
S-Parameter Network Analyzer	Agilent	8753ES	MY40000980	5/10/2018
Dielectric Probe kit	SPEAG	DAK-3.5	1103	2/17/2018
Thermometer	Control Company	Traceable 4242	122529162	11/11/2017*
Thermometer (Liquid Check)	Traceable	15557603	160643192	7/25/2018

Note: * Equipment not used past calibration due date.

System Check

Name of Equipment	Manufacturer	Type/Model	Serial No.	Cal. Due Date
Synthesized Signal Generator	Agilent	N5181A	MY50140810	5/31/2018
Power Meter	Agilent	N1912A	MY55196008	5/12/2018
Power Meter	HP	437B	3125U11347	8/15/2018
Power Sensor	Agilent	N1921A	MY52260009	1/5/2018
Power Sensor	Agilent	N1921A	MY52270022	12/17/2017
Amplifier	MITEQ	AMF-4D-00400600-50-30P	1795093	N/A
Directional coupler	Werlatone	C8060-102	2148	N/A
DC Power Supply	BK PRECISION	1611	215-02292	N/A

Lab Equipment

Name of Equipment	Manufacturer	Type/Model	Serial No.	Cal. Due Date
E-Field Probe (SAR Lab D)	SPEAG	EF3DV3	4041	3/14/2018
E-Field Probe (SAR Lab D)	SPEAG	EX3DV4	7356	4/21/2018
Data Acquisition Electronics (SAR Lab D)	SPEAG	DAE4	1359	2/10/2018
System Validation Dipole	SPEAG	D900V2	1d118	5/10/2018
Thermometer (SAR Lab D)	EXTECH	445703	PRE0126871	4/4/2018

Other

Name of Equipment	Manufacturer	Type/Model	Serial No.	Cal. Due Date
Power Meter	Agilent	N1912A	MY55196004	7/14/2018
Power Sensor	Agilent	N1921A	MY52260009	1/5/2018

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) Information

6.1. Operational Description

The MS-300 is a wireless power charging system that delivers RF energy to a Client Device seeking to be charged when positioned within the Charging Zone. The Charging Zone of the MS-300 is up to 90 cm for Client Devices placed in front of the MS-300, i.e. Client Devices within 90 cm of the front of the MS-300 may be charged; Client Devices further than 90 cm or outside an angle of ±35° from a centerline projecting from the front of the MS-300 will not be charged.

The MS-300 transfers RF energy using the a Frequency of 913 MHz. The MS-300 does not transmit information at this frequency. Data communication, for example for the authentication of Client Devices, is performed through standard 2.4 GHz BLE protocols. The MS-300 will only charge Client Devices that can authenticate.

The MS-300 falls under FCC Part 18.107(c) because it is designed to generate and use RF energy locally to charge domestic consumer electronic devices. The MS-300 transfers RF energy from the front of the transmitter and creates a pocket around the authenticated Client Device that will be charged. The Client Device uses this energy to power itself or charge internal batteries. The MS-300 is intended to be used by the general public in a residential or office environment.

Figure 2 illustrates the RF pocket formed around a Client Device.

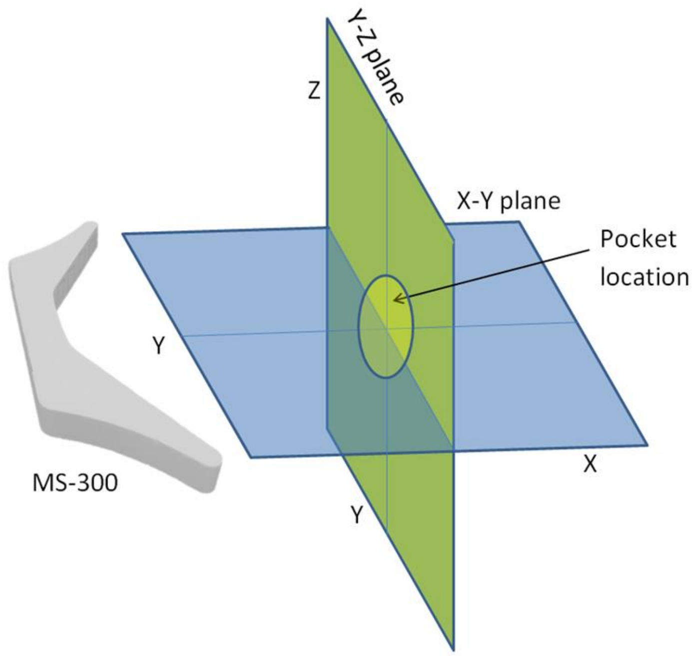


Figure 2: Depiction of Pocket Location

The MS-300 has an internal communication system to ensure it is working as designed. Once the MS-300 begins transferring RF energy to an authenticated Client Device, the communication system continues to monitor and track through proprietary fail-safes to ensure proper operation. If any single fail-safe is triggered, the RF transmission from the MS-300 is immediately shut down.

The MS-300 has five fail-safe features:

1) Self-check procedure to ensure proper operation of the motion detection sensors.
2) Self-check procedure to ensure no motion is detected in the Keep-Out Zone.
3) Self-check procedure to ensure proper operation of the BLE.
4) Self-check procedure to ensure proper operation of the MS-300 system.
5) Self-check procedure to determine if the Client Device is in the Charging Zone.

The Keep-Out Zone, is a zone within 50cm of the front of the transmitter where charging is suspended when motion is detected. This zone is established to provide an additional margin of RF safety. The MS-300 motion detection sensors are designed to detect all types of motion including breathing. The sensors are not designed to detect an inanimate object. Once motion is detected in the Keep-Out Zone, a timer in the MS-300 system will hold the transmitter in an off-state for 30 seconds. Any subsequent motion detected will hold the transmitter in an off-state and restart the timer.

The MS-300 will determine if the Client Device is located in the Charging Zone and oriented adequately to receive power. This determination is made by comparing the power received by the Client Device as reported via the BLE link between the Client Device and the MS-300. The reported power must be 30mW or more before the MS-300 will enable energy transfer to the Client Device. The optimum orientation for maximum power transfer is with the Client Device's antenna facing directly towards the MS-300. The receive power decreases as the Client Device orientates toward the edges or back. If the MS-300 determines that the Client Device is not oriented adequately, then power transfer will not occur. Edge and back orientations are below the 30mW threshold and the MS-300 will not enable energy transfer in these configurations. Therefore, these orientations are not applicable for compliance testing.

Ultimately, the Client Device can be charged at any point within the Charging Zone if three conditions are met; all self-checks passed, the device is determined to be positioned in the Charging Zone, and the device is receiving sufficient power to charge. The determination of the location of the Client Device within the Charging Zone is determined by proprietary means and is described in the confidential operational description exhibit.

6.2. DUT Description

MS-300 (FCC ID: 2ADNG-MS300) is a wireless power charging mechanism that delivers RF energy to a Client Device seeking to be charged.

The MS-300 has 6 antenna elements on each arm in a single row along the front of transmitter in a horizontal polarization that projects RF energy to the front of the device. RF energy will not charge the Client Device if it is placed to the rear or to the adjacent sides of the MS-300.

The operational Charging Zone is further explained in Section 10 of this report.

Device Dimension	Overall (Length x Width x Height): 790 mm x 65 mm x 235 mm	
Test sample information	**S/N**	**Notes**
	MS300-WN005	-
Hardware Version	MS-300 r1.0	
Software Version	3.0.17.57	

6.3. Client Device

The Client Device is an RF receiver with a singularly polarized antenna along the front of its long axis that is able to charge USB devices or its internal onboard battery when in the Charging Zone of the MS-300 transmitter. Once the Client Device is authenticated, it will receive energy from the transmitter to charge a USB device or the internal onboard battery. The Client Device consists of the RF receive antenna, battery, and a BLE and USB interface control board. The major component drawings and photos are shown in Appendix A, The Client Device (FCC ID: 2ADNG-MS300a) referenced in this report is the only device considered for certification at this time. At the time of issue FCC ID: 2ADNG-MS300a was still undergoing certification.

Unless otherwise stated, the front of the Client Device is facing the MS-300 for all RF field and SAR tests as this demonstrates worst case measurements as described in the Theory of Operation. Different Client Device orientations were tested per the Table 7.

7. Test Rationale

As the MS-300 is designed not to charge a Client Device when the user is closer than 50 cm from the middle of the MS-300 center section (between the two sensor windows. See Figure 3), the test procedures from IEC 62232 were deemed appropriate. IEC 62232 provides SAR test methods and correction factors to compensate for SAR measurements when the sample is not close to the phantom.

Unless otherwise specified the reference point for distances relative to the MS-300 are measured from the middle of the MS-300 center section (between the two sensor windows) as denoted by the yellow dot shown in figure 3.

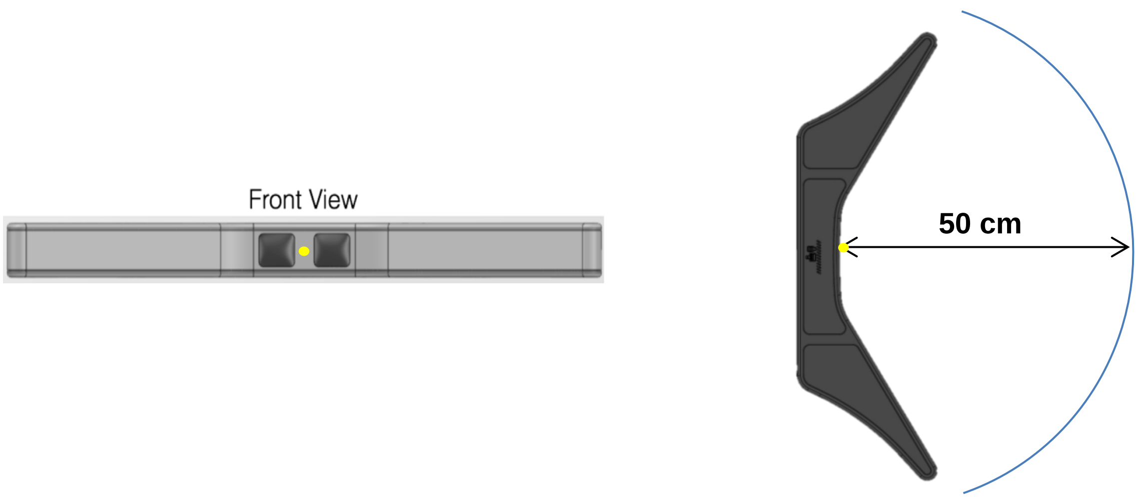


Figure 3: Location of reference point and Keep-Out Zone

The MS-300 will only charge a Client Device if it is placed within a pre-defined Charging Zone. The extent of the Charging Zone was verified and the results are reported in Section 10.

The MS-300 features a Keep-Out Zone that will disable charging if movement is detected within a predefined zone in front of the MS-300. SAR testing is not required within the Keep-Out Zone. The extent of the Keep-Out Zone was verified and the results are reported in Section 11.

The field conditions established by the MS-300 for a Client Device in a specific location and condition are fixed and do not change provided the Client Device conditions remain the same. Therefore, the testing considerations of IEC 62630 regarding coherent signals for various combinations of signal variations (amplitude, phase etc.) would not apply.

To determine the appropriate SAR test conditions, RF field mapping of the MS-300 was performed with the pocket at various distances and angles from the center of the sample. Testing was performed in the X-Y plane and the Y-Z plane. The worst-case field strengths from the X-Y plane testing determined the operating condition (pocket distance and angle) for SAR testing. The RF field mapping results are reported in Section 12 with plots reported in Appendices D and E.

SAR testing was performed using the small box-shaped phantom 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 4.2. 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.

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 15.3 and 15.4 of this report.

SAR results are reported in Section 15.

8. Maximum Output Power

The MS-300 has 6 antenna elements on each arm in a single row along the front of transmitter in a horizontal polarization that projects RF energy to the front of the DUT at the location of the Client Device. Each element has a maximum specified transmit power of 29.4 dBm. The output power to each element is fixed. Refer to Appendix A for the antenna locations. The measured output power is reported in Section 14.

9. RF Exposure Conditions (Test Configurations)

The Charging Zone of the MS-300 is up to 90 cm for Client Devices placed in front of the MS-300. I.E. devices within r = 90 cm of the front of the device may be charged; devices further than 90 cm or outside an angle, ϕ, of ±35° from a centerline projecting from the front of the MS-300 will not be charged. The MS-300 energy transfer is also precluded for vertical angles, Ө, greater than +/- 90 degrees where r increases to a maximum of 90 cm as Ө approaches zero degrees (See Figures 4 and 5).

To mitigate RF exposure, the MS-300 uses motion sensors that switch off the RF power whenever movement is detected within an arc approximately 50 cm from the reference point at the front of the MS-300.

SAR testing was performed at 50 cm radially from the reference point in front of the MS-300 and at various angles within ±30° of the centerline of the MS-300 (See Section 12.5 of this report).

10. Verification of the Charging Zone

To verify the correct operation for range and position of the client, testing was performed based upon guidance from the FCC via a KDB inquiry. The MS-300 will not enable the charging signal if the Client Device is outside of the nominal Charging Zone shown in Figures 4 and 5.

10.1. X - Y Plane:

The MS-300 was centered upon a turntable in a fully anechoic room. A Client Device was mounted level with and facing the MS-300 at a distance of 85 cm (r=85) from its center. The client was fixed relative to the turntable. The turntable was initially oriented with the rear of the MS-300 facing the Client Device (client at 180°). With the client in this position the charging signal is disabled. This was verified by observing a spectrum analyzer for the charging signal from the MS-300 via a test antenna in the room. The turntable was rotated clockwise in 3° steps. After each step the spectrum analyzer was checked to see if charging signal was present. The process was repeated until the entire circumference of the envelope had been evaluated. If the Client Device was in range, then the charging signal was observed to remain on.

The Client Device was positioned with the horizontal and vertical edges toward the MS-300 and charging was not observed.

During the r=85 cm test run charging signal was only observed between angles -30° to +33° from the front of the MS-300. Additional tests at 5 cm intervals along the arc were performed for greater precision between ±45°.

Testing was subsequently performed between r=95 cm and r=75 cm at 5 cm intervals within the ±40° area to determine the charging distance at a given angle. The results are plotted in Figure 4. The MS-300 did not establish charging signal at any angle when r= 95 cm.

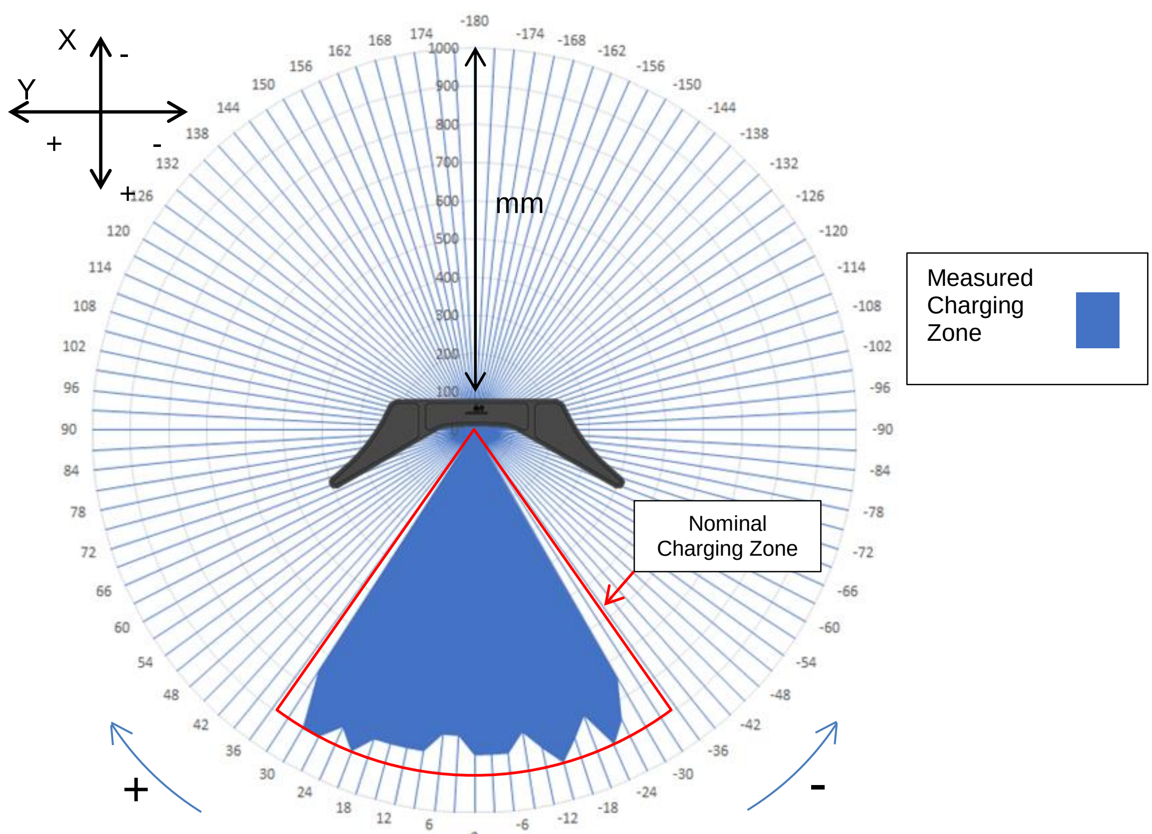


Figure 4: Charging Zone Test Result – X-Y plane

NOTE: The Charging Zone (region where WPT signal is active) extends as a sector volume out to a 90 cm radial distance from the center of the front surface of the MS300. Even though the Charging Zone overlaps and encompasses the so-called Keep-Out Zone, a Client Device within the Keep-Out Zone can still be charged when persons are absent.

Additional testing to verify the Charging Zone at closer distances was performed and is summarized in Table 1

Table 1: Charging Zone results at closer distances

Distance (cm)	Angle						
	-40	-35	-30	0	30	35	40
40	0	0	1	1	1	0	0
50	0	0	1	1	1	0	0
60	0	0	1	1	1	0	0
75	0	0	1	1	1	0	0
85	0	0	0	1	1	0	0
90	0	0	0	0	1	0	0

0 = no charging signal observed, 1 = charging signal observed

10.2. X - Z Plane:

To verify the Charging Zone in the vertical plane, the MS-300 was assessed in a similar manner as the X-Y plane but the MS-300 was mounted in the vertical direction. Figure 5 illustrates an example of the angle versus distance of the Charging Zone with the Client Device placed directly in front of the MS-300.

The charging range tends to diminish as the angle gets further away from 0°. Testing with the Client Device at different angles in the X-Y plane revealed the same pattern.

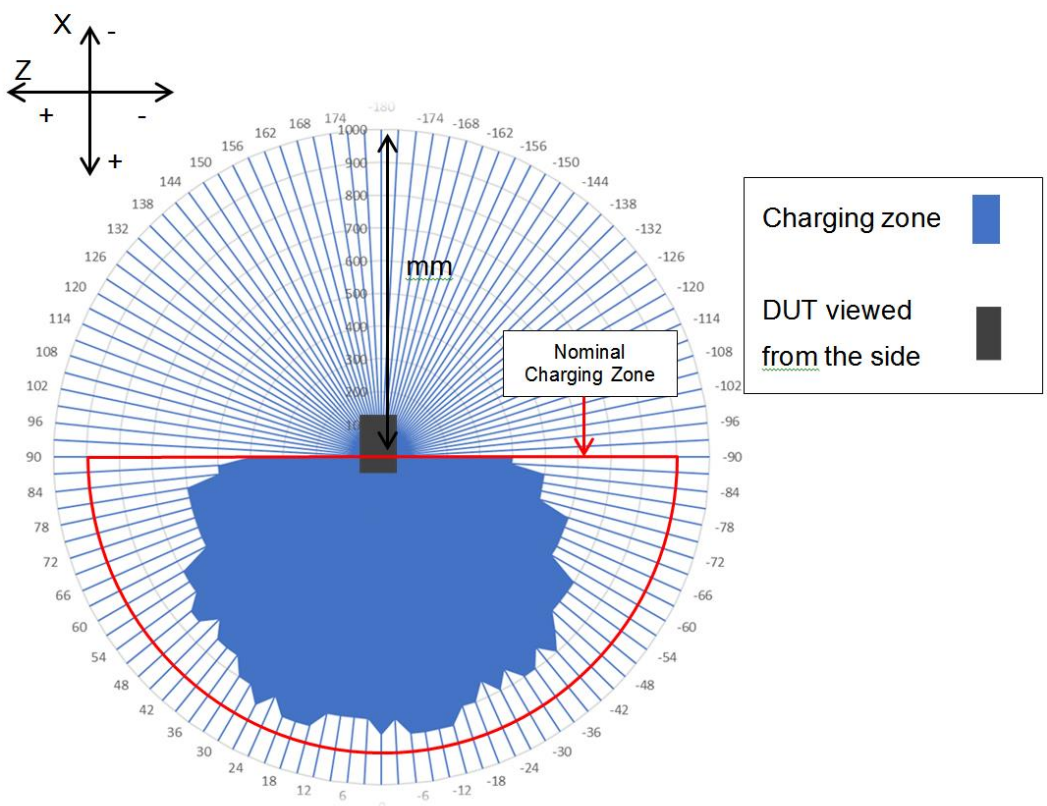


Figure 5: Charging Zone Test Result – X-Z plane

10.3. Charging Zone Conclusions

The data show that the Charging Zone is well defined within the stated boundaries. See the operational description for details.

11. Keep-Out Zone.

11.1. Description

To mitigate RF exposure, the MS-300 uses motion sensors that switch off the RF power whenever movement is detected within an arc approximately 50 cm from the reference point at the front of the device (See Figure 6). The Keep-Out Zone is set such that objects moving toward the MS-300 and crossing the arc will cause the RF power to turn off.

The sensor's sensitivity is such that it can detect small motions, such as those induced by breathing (which are greater than 4mm). Once motion is detected, a timer in the system will hold the transmitter in an off-state for 30 seconds. Any subsequent motion restarts the timer. Once motion has been detected the sensitivity level of motion detection is enhanced to be twice as sensitive. The detected object must remain motionless for the duration of the timer for the sensitivity level to be restored to the normal level and for the object to be regarded as inanimate.

The Charging Zone and the Keep-Out Zone are independent. If motion is detected within the Keep-Out Zone, the transmitter will be commanded off if previously on, and kept off if previously off.

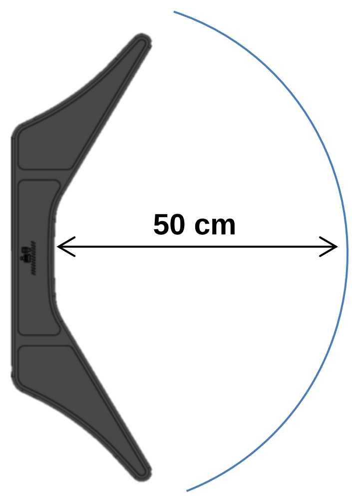


Figure 6: Depiction of Keep-Out Zone

To verify the operation of the sensors, the tests in section 11.2 were performed based upon guidance from the FCC via a KDB inquiry.

11.2. Verification of the Keep-Out Zone.

11.2.1. Verification of the Keep-Out Zone for movement along the arc

With a Client Device located at approximately 10 cm outside the Keep-Out Zone, along the center of the array structure, and being charged, a hand model was moved along two separate arcs that are each 2 cm on either side of the arc of the Keep-Out Zone, at ~ 5 cm increments along the arc. The test was repeated with the Client Device located inside the Keep-Out Zone.

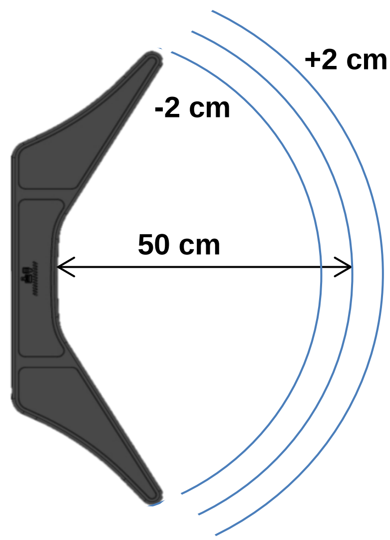


Figure 7: Location of test arcs.

It was verified that the RF power remained on when the hand was moved along the +2 cm arc. When the hand was moved along the -2 cm arc the RF power remained off.

The results show that the MS-300 Keep-Out Zone distance is greater than the specified distance of 50 cm for movement in the same horizontal plane. SAR testing therefore does not need to be performed at distances closer than 50 cm radially from the reference point at the front of the MS-300.

Figure 8: Test setup for Keep-Out Zone Verification.

The hand is a wooden posable artistic model (manufacturer Xin Ran, model number XRT-001).

11.2.2. Verification of the Sensitivity of the Detector to Approaching and Receding Objects.

With the Client Device located at approximately 10 cm outside the Keep-Out Zone, and charging signal present, the hand model was moved from outside the Keep-Out Zone to confirm that RF power is switched off promptly. The approximate location from the Keep-Out Zone where RF power is switched off and remains off was noted and is shown in tables 2 and 3. This procedure was performed at five locations along the Keep-Out Zone arc at the center, near the left/right boundaries of the antenna structure and at the corresponding mid-points on the left and right sides. A hand model attached to a linear actuator was used to ensure the speed was consistent at about 0.75m/s, in order to simulate human motion. The procedure was repeated with the Client Device located inside the Keep-Out Zone.

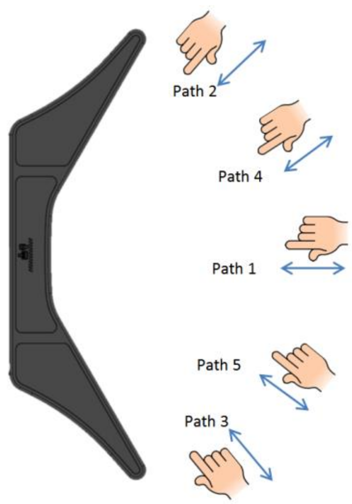


Figure 9: Trajectories of the Hand Model

Table 2: Keep-Out Zone Sensitivity Test Results – hand at tabletop height

Client Device within Keep-Out Zone	Trigger distance from center of DUT (cm)				
	Path 1	Path 2	Path 3	Path 4	Path 5
Hand approaching (Charging signal off)	54	54	55	53	55
Hand receding (Charging signal restored)	56	56	56	54	55
Client Device outside Keep-Out Zone	Trigger distance from center of DUT (cm)				
	Path 1	Path 2	Path 3	Path 4	Path 5
Hand approaching (Charging signal off)	52	55	53	53	55
Hand receding (Charging signal restored)	54	56	54	53	56

The closest distance that the charging signal was switched off while the hand was approaching was 52 cm. The closest distance that the charging signal was restored while the hand was receding was 53 cm.

Additional testing was performed with the hand moving in at different heights above the sample to determine the charging-off boundary above the DUT. The hand was moved along the same paths shown in Figure 9

Table 3: Keep-Out Zone Sensitivity Test Results – Hand Above Tabletop

Hand Height above DUT center (cm)	Trigger distance from center of DUT (cm)				
	Path 1	Path 2	Path 3	Path 4	Path 5
15	55	55	55	56	53
20	54	54	52	54	54
25	50	46	50	49	51

Most data points lie outside the 50 cm Keep-Out Zone. There was one data point at 46 cm and one path at 49 cm, however, review of the RF field plots at minus fifteen and minus thirty degrees (equivalent location of Path 2 and Path 4 from Table 3) in Appendix E shows this position is more than 2 dB lower than peak power therefore additional investigation was deemed unnecessary.

11.2.3. Sensitivity to Small Movements

To confirm the sensitivity of the sensors to detect small movement like a breathing pattern, the artificial hand was placed inside the Keep-Out Zone boundary and kept stationary until the transmitter turned on. The hand was then moved slowly until the transmitter turned off. The amount of motion required to trigger the sensor was recorded in Table 4. The test was performed at 5 locations just within the Keep-Out Zone (See Figure 10). The worst-case measurement was 3mm detected motion, which is less than the motion of a breathing pattern.

Table 4: Small Movement Detection Results

Hand position	Minimum Detected Motion (mm)
Location 2	2
Location 4	3
Location 1	2
Location 5	2
Location 3	3

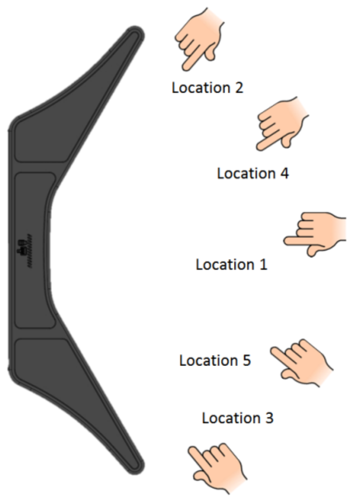


Figure 10: Hand Model locations

12. RF Field Mapping

12.1. General

The Client Device can be charged at any point within the Charging Zone if two conditions are met; the device is determined to be positioned in the Charging Zone and the device is receiving sufficient power to charge. Since the antenna in the Client Device is along the front, sufficient power will not be received with the back or the edges of the client facing the MS-300.

These possible locations and orientations result in a large number of potential charging pocket configurations. In order to identify the set of SAR measurements to be performed the RF Field distributions were investigated for a variety of charging pocket configurations. Those configurations with the highest field strengths were considered for SAR testing. The Client Device was tested in different orientations to determine the highest RF field conditions. The data demonstrates that client orientation does not have a significant impact on field measurements. For this report, all RF field measurements were made with client orientation at 0 degrees (see Figure 11) facing the transmitter, since that is the configuration where the highest field values occur. The Client Device was positioned with the horizontal and vertical edges toward the MS-300. Test mode software determined the reported receive power was below the threshold that would enable energy transfer.

The RF field strength was assessed with the Client Device placed vertically and horizontally (90 and 0 degrees - see Figures 11 and 12) facing the MS-300 to determine which orientation provided the highest (worst case) values. Once this was determined, all RF field tests were conducted with the Client Device at this position. For RF-Field mapping, the front of the Client Device faces the front of the MS-300. The Client Device is oriented with the long axis parallel or in line with the long axis of the MS-300. This orientation is termed zero (0) degrees. The distance of this testing is along the Keep-Out Zone boundary of 50 cm.

Table 5: Field strength versus Client Device Orientation

Client Device Orientation	Pocket Distance	Pocket Angle	Field Value (V/m)
0°	40 cm	0°	79.42
90°	40 cm	0°	77.49
0°	50 cm	0°	82.22
90°	50 cm	0°	71.91

The results show that the measured field strength is higher with the Client Device orientation at 0°.

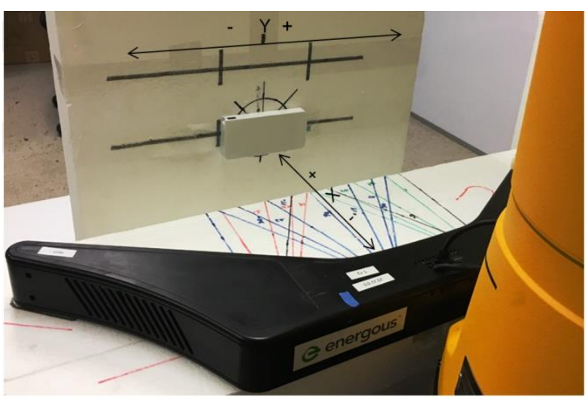


Figure 11: Client Device Orientation at 0°

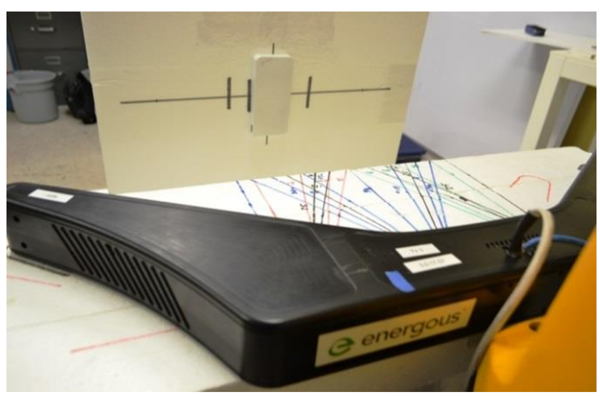


Figure 12: Client Device Orientation at 90°

RF Field testing was performed using a DASY5 and EF3DV3 probe. Testing was performed in air. The EUT was configured to project ‘pockets’ at various locations. The pocket locations were set by placing a Client Device at the desired position, allowing the MS-300 to lock-on to its location. The MS-300 internal settings were recorded. These settings could then be used again in Test Mode to project the pocket without the Client Device present.

Table 6 shows the location of the pockets with respect to the MS-300. The pocket numbers reflect the file name that was recalled to set the pocket and are used on the plots for identification. For example, pocket 1 was projected at 400 mm radially from the center of the MS-300 and offset by 15° to the right when looking toward the sample from the front. The locations were established via a KDB inquiry.

Table 6: Pocket locations

Distance (cm)	Pocket Angle (degrees)	Pocket Number
40	0	2
40	-15	1
40	+15	3
40	-30	0
40	+30	4
50	0	15
50	-15	14
50	+15	16
50	-30	13
50	+30	17
60	0	6
60	-25	5
60	+25	7
85	0	9
85	-25	8
85	+25	10
40[†]	0, 20 cm above	11
40[†]	0, 20 cm below	12

† - Pocket location is 0°, X=40 cm, Y=0 cm, Z= 20 cm (above) / Z= -20 cm (below)

12.2. X-Y Plane

12.2.1. Test Setup

The MS-300 was initially assessed in the X-Y plane.

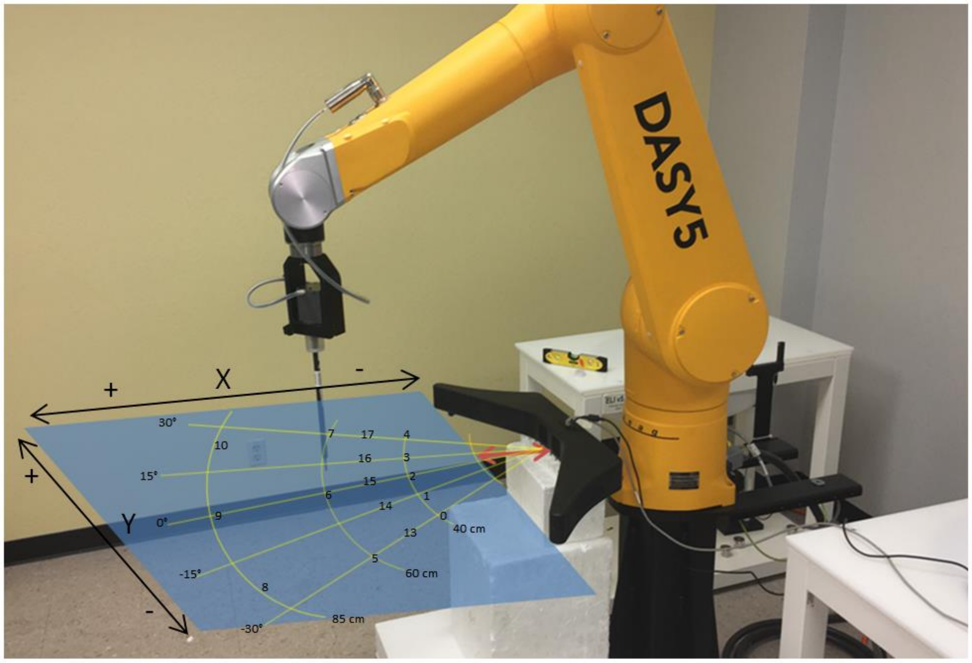


Figure 13: X-Y Plane Field Measurements Test Setup

Refer to Appendix A for the location of the Client Device and accessories during setup of the pocket.

The pocket numbers shown in Figure 13 and Table 6 are used consistently throughout this report with the exception of Section 12.4.

Figure 14 is provided to help with the visualization of the coarse resolution scan dimensions and MS-300 location:

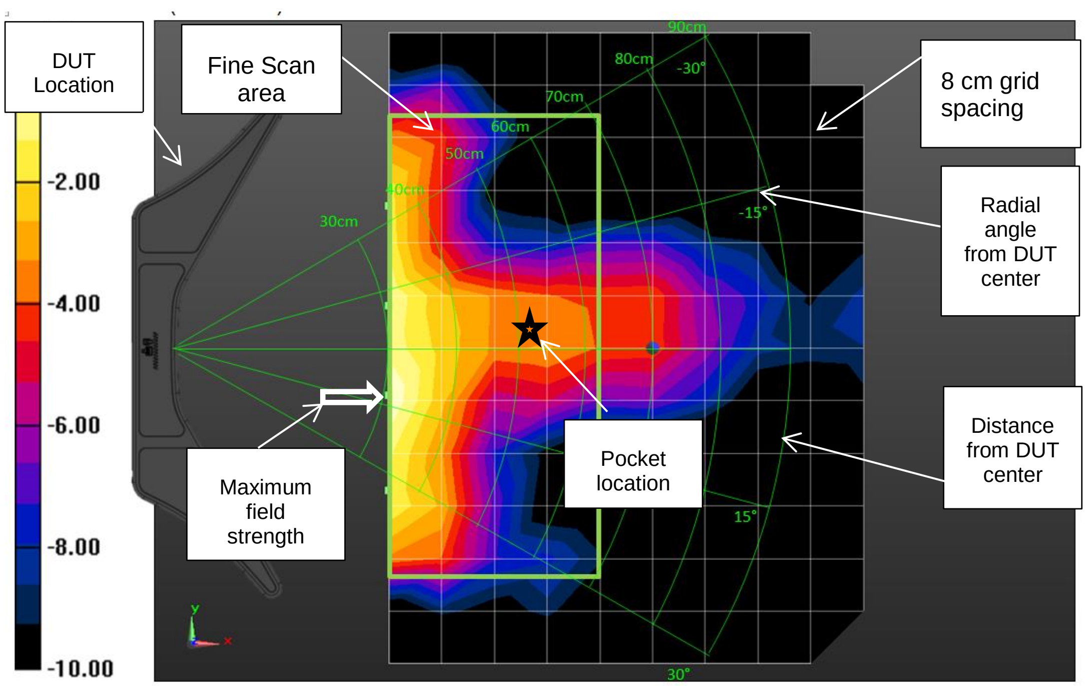


Figure 14: Explanatory Diagram of the X-Y Plane Field Plots

The plots show a coarse scan followed by the corresponding fine resolution scan highlighted by the green box. The fine resolution scan area and location were determined by the distribution of the peaks found in the coarse resolution scans. A third plot shows the fine scan superimposed upon the coarse scan.

Each coarse scan plot uses a star to demonstrate the pocket location and an arrow to demonstrate the peak field value measured during that scan.

The step size used was 80 mm for the coarse resolution scan. The measurement grid was set to 13 x 13 in the X and Y directions. The robot did not have the reach to measure all the points in the X direction. The plots show the number of points in the X direction is truncated at 9 or 10 accordingly. The interpolated data is similarly truncated as the interpolated data is generated from the coarse scan data.

The fine resolution scan step size was 15 mm.

Additional testing, with pockets created with a smartwatch and a cellphone attached to the charging port of the Client Device, was performed at 50 cm and a pocket angle of 0°. Once the pocket was established for these devices, the physical devices were removed to avoid damaging the measurement probe. The pockets were recalled using test mode software and measured. These pockets with product under charge measured a reduction in the RF field strength so testing at other distances and angles was deemed unnecessary.

An additional Client Device was also assessed (Client Device B). Client Device B is identical to Client Device A. Comparison of the results for each device show that variation of the RF field is negligible.

The X-Y plots are in Appendix D. The Maximum recorded field strengths are shown in Table 7

12.2.2. Key to X-Y RF Field Plots

The SAR plots use abbreviated notation to identify the test configurations:

1	2	3	4	5	6	7	8	9	10
913MHz CW/	**Start 300mm/**	**TX5**	**x mm/**	**x mm**	**x Degrees**	**CD x**	**RX 0 Degrees**	**Pocket xx/**	**x scan**

Lower case **x** represents a variable value

Definitions:

1. 913MHz CW – Frequency and modulation (MS-300 only supports 913 MHz CW).
2. Start 300mm – distance of the measurement plane from the front of the MS-300
3. TX5 – Shorthand serial number of the MS-300
4. x mm – translation along the Y axis of the MS-300 in mm (see 12.2.3)
5. xxx mm – the radial pocket distance from the center of the MS-300
6. x Degrees - indicates the angle of the pocket from the center of the MS-300. Pocket angles are indicated by 0, ±30, ±25 and ±15
7. CD x – Client Device A (Primary Client Device under test) or Client Device B.
8. RX 0 Degrees – Relative orientation of the Client Device to the MS-300 (See 12.1)
9. Pocket x – Number assigned to the pocket location. This is consistent across the SAR and RF field plots per Figure 13.
10. x scan – indicates the type of scan performed, Pre-Area indicates coarse scan. Area scan indicates fine scan.

Plots 55 and 56 include either +watch or +phone to indicate the presence of accessories attached to the Client Device.
Plots 49-54 include either 20 cm above or 20 cm below to indicate the height of the Client Device above or below the MS-300

12.2.3. Maximum Field Strength From the X-Y E- field Measurements

Table 7: X-Y Field Strength Summary **Pocket Distance (cm)**	Pocket Number	Pocket angle (degrees)	Client Device	Maximum Field Strength (V/m)	Plot Numbers
40	2	0	A	79.42	1-3
40	4	30	A	87.96	4-6
40	0	-30	A	88.58	7-9
40	3	15	A	86.80	10-12
40	1	-15	A	80.00	13-15
50	15	0	A	82.22	16-18
50	16	15	A	86.21	19-21
50	14	-15	A	82.95	22-24
50	17	30	A	84.94	25-27
50	13	-30	A	83.60	28-30
60	6	0	A	74.89	31-33
60	7	25	A	83.13	34-36
60	5	-25	A	82.80	37-39
85	9	0	A	75.88	40-42
85*	10	25	A	81.80	43-45
85*	8	-25	A	74.77	46-48
40†	11	0 (20 cm above)	A	64.98	49-51
40†	12	0 (20 cm below)	A	68.79	52-54
50	15	0	A+watch	72.35	55**
50	15	0	A+phone	76.77	56**
40	2	0	B	77.68	57-59
60	6	0	B	76.45	60-62
85	9	0	B	72.87	63-65

*The measurements at pocket distances of 85 cm at ±25° were performed with the MS-300 translated along the Y axis. This was done to ensure that the pocket location was projected at the boundary of the test system. This is shown in the RF Field X-Y Plots of Appendix D by the relative location of the MS-300 to the measurement plane and indicated in the header with the text '+160mm Offset' or '-160mm Offset'

**Only coarse scans were performed. The maximum field strength was reduced with accessories attached to the Client Device.

† - Pocket angle = 0 degrees. X=40 cm, Y=0 cm, Z= 20 cm (above) / Z= -20 cm (below). The MS-300 was tilted so that the measurement plane was parallel to the ground (See Figure 15).

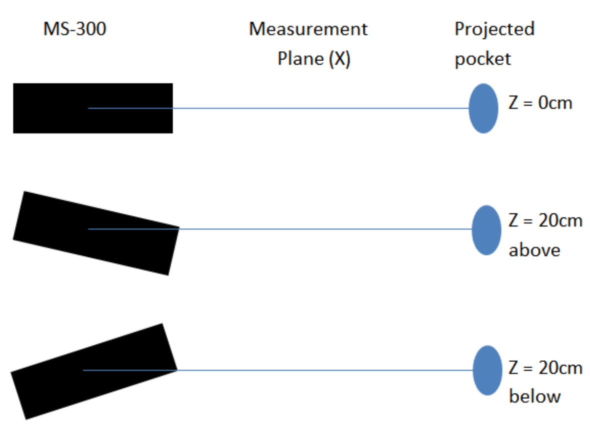


Figure 15: Diagram depicting the measurement planes

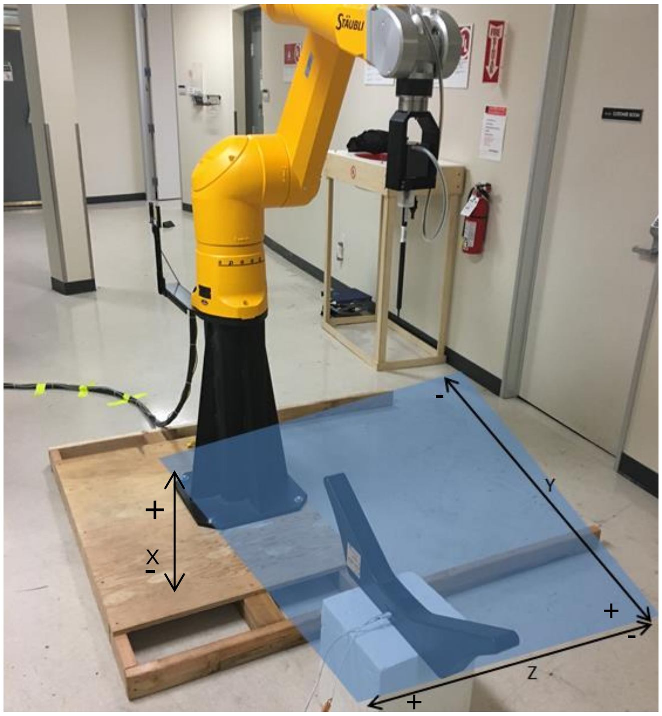
12.2.4. X-Y RF Field Conclusions

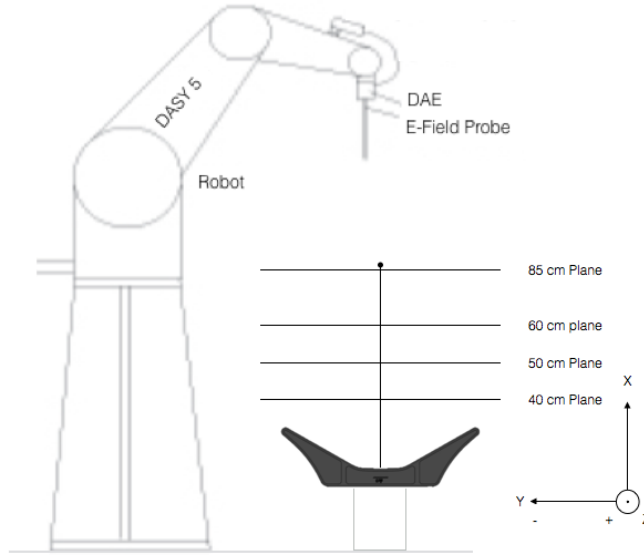
The X-Y field plots show that the maximum field strengths that a user would encounter are located at the Keep-Out Zone. The higher levels within the Keep-Out Zone will not be encountered by the user as the charging signal will be disabled once the user crosses the Keep-Out Zone boundary.

12.3. Y-Z Plane

12.3.1. Test setup

The MS-300 was tested in the Y-Z plane to assess the characteristics of the pocket in the Z direction. The MS-300 was positioned so that the robot arm was above the Y-Z plane of the MS-300 (See Figure 16).





Side View Diagram for RF Field Measurements in Y-Z Plane

Figure 16: Test set up for measuring RF Fields in the Y-Z Plane

12.3.2. Key to Y-Z RF Field Plots

The SAR plots use abbreviated notation to identify the test configurations:

1	2	3	4	5	6	7	8	9	10
913MHz CW/	**Start x mm/**	**TX5**	**x Degrees**	**x mm Offset**	**x mm**	**x Degrees**	**RX 0 Degrees**	**Pocket x/**	**x scan**

Lower case **x** represents a variable value

Definitions:

1. 913MHz CW – Frequency and modulation (MS-300 only supports 913MHz CW).
2. Start x mm – distance of the measurement plane above the MS-300 (See 12.3.3)
3. TX5 – Shorthand serial number of the MS-300
4. x Degrees – Rotation of the MS-300 (See 12.3.5).
5. x mm Offset – Distance the MS-300 was translated along the Y-axis to ensure the pocket was projected onto the measurement plane.
6. x mm - indicates the pocket distance.
7. x Degrees – indicates the angle of the pocket from the center of the MS-300. Pocket angles are indicated by 0, ±30, ±25, and ±15
8. RX 0 Degrees – Relative orientation of the Client Device to the MS-300 (See 12.1)
9. Pocket x – Number assigned to the pocket location.
10. x scan – indicates the type of scan performed.

12.3.3. Location of the measurement planes

The measurement height (X axis) was coincident with the pocket distance adjusted for the angle of the pocket. For example, a pocket distance of 50cm from the center of the MS-300 at an angle of 30° would result in a measurement height of 50 x cos30° = 43.3 cm (See Figure 17). This is indicated on the plots as ‘Start xxx mm’.

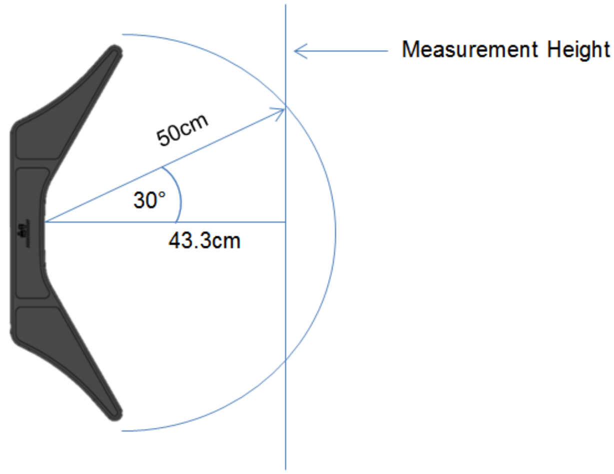


Figure 17: Radial distance versus measurement height

The Y-Z measurements are positioned to intercept the X-Y plane at the pocket location. I.E. the ‘Start’ distances indicated on the Y-Z plots

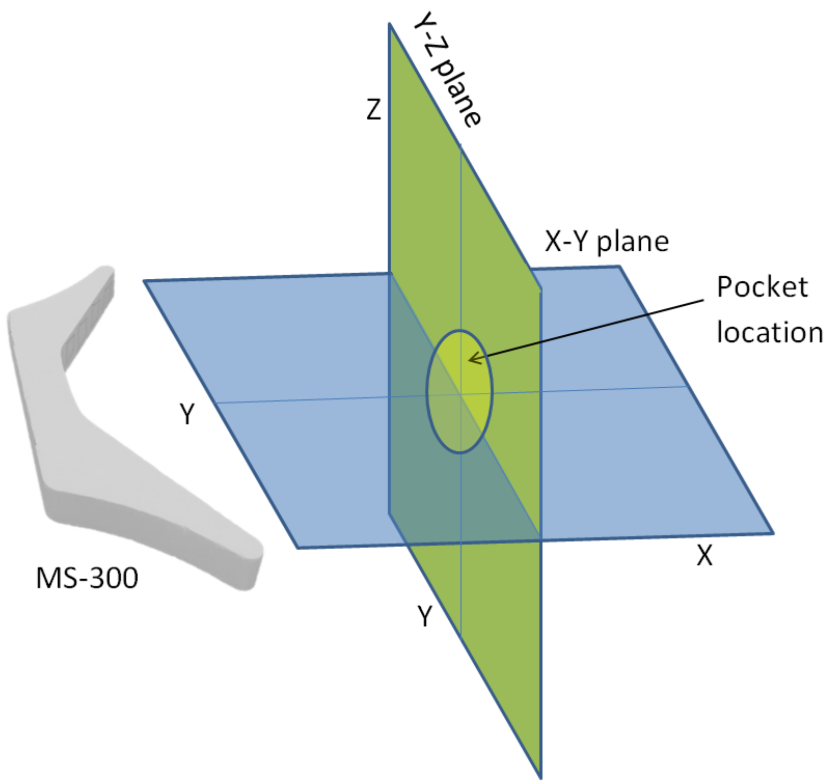


Figure 18: Depiction of a Pocket Location Showing both the X-Y and Y-Z Planes

12.3.4. Y-Z Field Plot Description

Figure 19 shows the relative size of the MS-300 to the scan area, the location of the robot with respect to the sample and the location of the Y and Z axes. The grid size is 8 cm.

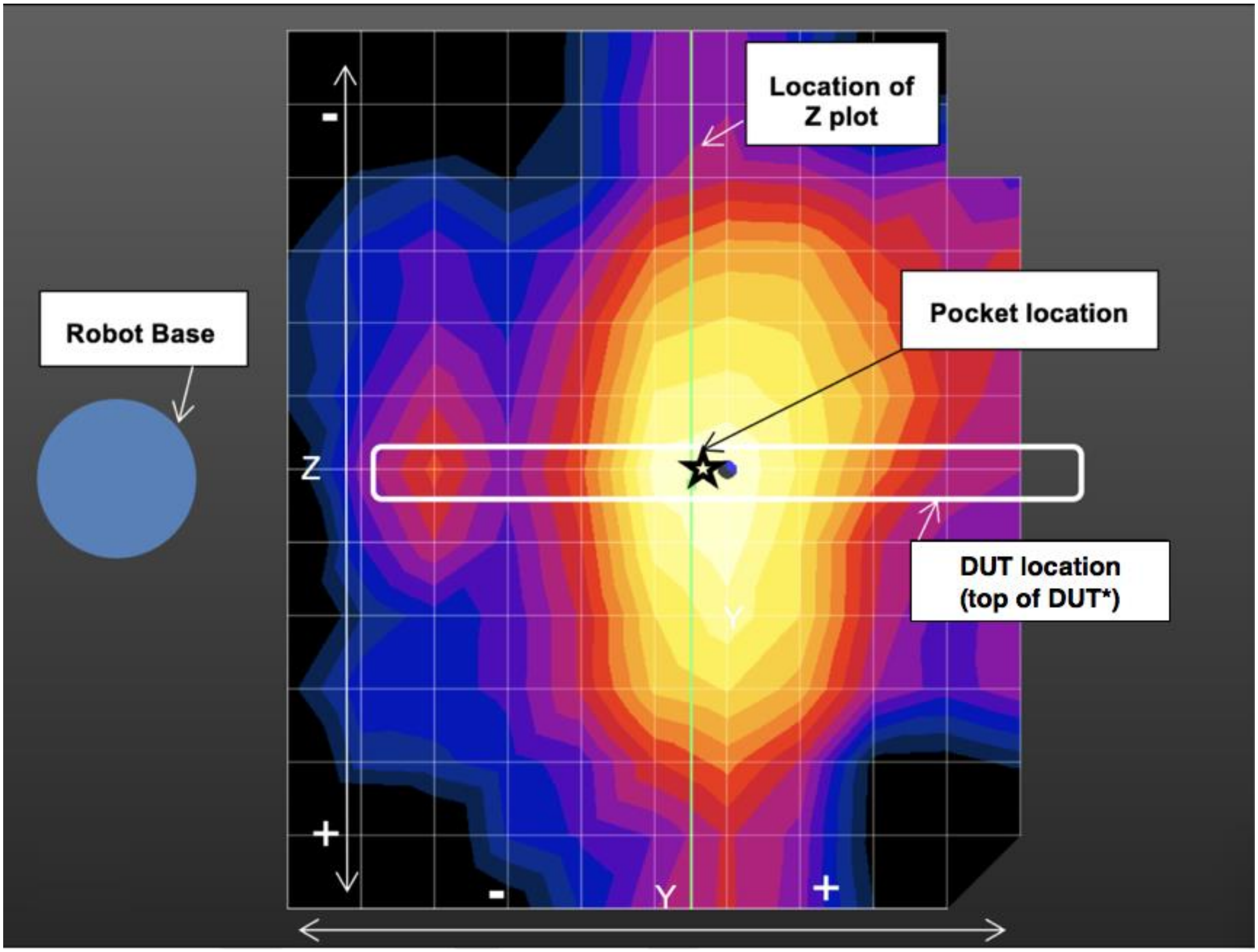


Figure 19: Explanatory Diagram of the Y-Z Plane Field Plots

The measurement grid was set to 13 x 13 in the Y and Z directions. The robot did not have the reach to measure all of the points in the Y direction. The plots show the number of points in the Y direction is truncated at 10 or 11 accordingly. The interpolated data is similarly truncated as the interpolated data is generated from the 13 x 13 scan data.

*Please see Note in Table 7 demonstrating results where the DUT is rotated 180 degrees.

12.3.5. Maximum Field Strength From the Y-Z E-field Measurements

The Y-Z RF field plots are in Appendix E.

Table 8: Y-Z Field Strength Summary Pocket Distance (cm)	Measurement Height (cm)	Pocket Number	Pocket angle (degrees)	Maximum Field Strength (V/m)	Plot Numbers
40	40	2	0	75.42	1-2
40	34.6	4	30	77.74	3-4
40	34.6	0	-30	77.46	5-6
40	38.6	3	15	71.33	7-8
40	38.6	1	-15	69.96	9-10
50	50	15	0	66.75	11-12
50	43.3	17	30	67.57	13-14
50	43.3	13	-30	70.87	15-16
50	48.3	16	15	62.48	17-18
50	48.3	14	-15	63.45	19-20
60	60	6	0	56.00	21-22
60*	54.4	7	25	54.60	23-24
60	54.4	5	-25	57.78	25-26
85	85	9	0	37.99	27-28
85*	77	10	25	41.55	29-30
85	77	8	-25	41.86	31-32

*Note – The MS-300 was rotated 180° so that the pocket was projected within the measurement range of the robot. For asterisk positions, the top of the MS-300 (surface with the cable ports) is facing towards the top of the Y-Z plots.

12.3.6. Y-Z RF Field Conclusions

The Y-Z field mappings demonstrate that the energy projected by the MS-300 is located at the anticipated pocket locations.

12.4. Y-Z Pocket Evaluation

Testing was performed with the pocket initially set for a distance of 50 cm at a pocket angle of 0°. The pocket was formed by placing the center of Client Device 50 cm in front of the reference point of the MS-300 as shown in Figure 20. The MS-300 formed a pocket at this Client Device location. The internal settings of the MS-300 for this pocket were recorded and designated pocket 8. The Client Device was then relocated so that the center of the Client Device was 2.5 cm above its original position. The MS-300 formed a pocket at this Client Device location. The internal settings of the MS-300 for this pocket were recorded and designated pocket 0. The center of the Client Device was relocated to each of the positions shown in Figure 21 and the subsequent pocket settings were recorded.

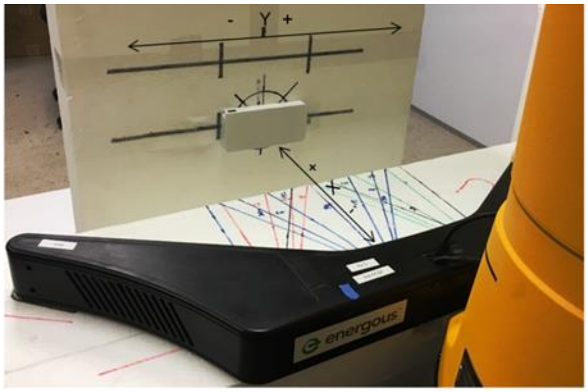


Figure 20: Y-Z Pocket Evaluation Test Setup

The Client Device and its support were then removed and pocket 8 was projected into free space using the previously recorded settings. A scan in the Y-Z plane was performed to determine the location of the maximum field strength. The probe tip was placed at the location of the maximum measured field strength within the projected pocket (pocket 8) and a point field strength measurement was performed. Pocket 0 was then projected and a point field strength measurement was performed with the probe at the same location of the previous point field strength measurement. This was repeated for the rest of the pocket locations with the probe tip remaining in the same location for all tests. The results are shown in Table 9.

Table 9: Y-Z Pocket Evaluation test data

Pocket #	Result (V/m)	dBV/m
0	58.39	35.32
1	58.03	35.27
2	57.97	35.26
3	54.97	34.80
4	57.00	35.11
5	57.88	35.25
6	57.75	35.23
7	57.44	35.18
8	58.01	35.27

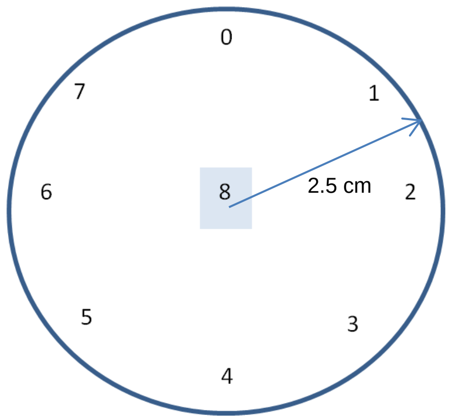


Figure 21: pocket number versus radial location

The pocket numbering for the Y-Z pocket evaluation differs from the numbering used in other sections of this report.

12.4.1. Y-Z Pocket Conclusions

The data above show there is very little difference between the values at these different angles, and therefore the maximum reading we are using for maximum field from the X-Y plots is valid.

12.5. RF Field Mapping Conclusions.

The RF field mapping results show that the maximum RF field strengths that the user will experience are located at the Keep-Out Zone boundary. The highest levels were typically for pockets projected 50 cm from the reference point at the front of the MS-300 at the Keep-Out Zone. SAR testing was performed at a distance of 50 cm from the reference point from the front of MS-300 with pockets projected at the same distance. Testing at 50 cm with other pocket distances is not feasible as the Client Device would either be in the SAR tissue simulation liquid or masked by the SAR phantom. For example, placing the reference point of the MS-300 50 cm below the base of the phantom and setting up a pocket at 60 cm would result in the Client Device being 10 cm above the base of the phantom and therefore in the tissue simulation liquid. Testing using preset pockets was deemed unnecessary as it was observed that SAR values were higher for a given pocket if the Client Device was in place against the phantom during testing. The SAR results in section 15.3.3 show that the 50 cm 0° result with the client removed is lower than the result with the client in place.

Additionally, the value of $CF_2(d)$ (see 15.3.1) decreases as *d* (*i.e.,* the distance of the DUT from the phantom) increases. This results in lower reported SAR values, for the same measured SAR, at larger distances. SAR testing at distances further than the Keep-Out Zone was judged unnecessary as a result.

13. Dielectric Property Measurements & System Check

13.1. 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 (ε_r) 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 ε_r and σ may be relaxed to ± 10%. This is limited to frequencies ≤ 3 GHz.

Table 10: Tissue Dielectric Parameters

FCC KDB 865664 D01 SAR Measurement 100 MHz to 6 GHz

Target Frequency (MHz)	Head		Body	
	ε_r	σ (S/m)	ε_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

IEEE Std 1528-2013

Refer to Table 3 within the IEEE Std 1528-2013

Table 11: Dielectric Property Measurements Results

SAR Lab	Date	Band (MHz)	Tissue Type	Frequency (MHz)	Relative Permittivity (εr)			Conductivity (σ)		
					Measured	Target	Delta (%)	Measured	Target	Delta (%)
1	10/28/2017	900	Body	900	53.40	55.00	-2.91	1.07	1.05	2.19
				880	53.57	55.07	-2.73	1.06	1.02	3.38
				915	53.27	55.00	-3.15	1.09	1.06	2.45
1	11/1/2017	900	Body	900	53.48	55.00	-2.76	1.01	1.05	-3.90
				910	53.41	55.00	-2.89	1.02	1.06	-3.41
				915	53.35	55.00	-3.00	1.02	1.06	-3.58

13.2. 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.

13.3. System Performance Check Measurement Conditions:

- The measurements were performed in the flat section of the TWIN SAM or Small box-shaped phantom, shell thickness: 2.0 ±0.2 mm (bottom plate) filled with Body or Head simulating liquid of the specified 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 2.5 mm.
- The dipole input power (forward power) was 100 mW.
- The results are normalized to 1 W input power.

13.4. System Check Results

13.4.1. 1 g peak spatial average SAR

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.

Table 12: 1 g System Check Results

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 %	
D	10/28/2017	Body	D900V2 SN:1d118	5/10/2018	1.010	10.10	10.47	-3.53	0.660	6.60	6.76	-2.37	1,2
D	11/1/2017	Body	D900V2 SN:1d118	5/10/2018	1.040	10.40	10.47	-0.67	0.679	6.79	6.76	0.44	

13.4.2. Whole Body SAR

The Whole Body SAR measured with a reference dipole as the signal source, using the required tissue-equivalent medium at the test frequency, must be within 10% of the reference SAR values given in Table B.11 of IEC 62232.

The whole body SAR procedure described in section 4.2.2 was followed.

The specified separation distance 15 mm for the dipole was used. Whole body SAR was calculated using:

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

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

For d =15mm $CF_3(d)$ = 1.03

$CF_4(f)$ depends on the phantom used for testing. For the small box-shaped phantom $CF_4(f)$ = 1

M=12.5kg.

The power into the reference dipole was set to 100mW. All results are normalized to 1W by multiplying the measured values by 10.

The total absorbed power, $P_A(d)$, is 0.863 W (normalized to 1W).

This results in a whole body SAR of (0.863 x 1.03 x 1)/12.5 = 0.0711

Table 13: Whole Body SAR System Check Results

SAR Lab	Date	Tissue Type	Dipole	Dipole Cal. due date.	Frequency		1 g SAR	10 g SAR	Local SAR at Surface (above feedpoint)	Whole body SAR (small box-shaped phantom)	Plot No.
					MHz		W/kg	W/kg	W/kg	W/kg	
D	11/28/2017	Body	D900V2 SN 1d118	5/10/2018	900	Target Values	10.9	6.99	16.4	0.068	3
						Measured Values (normalized to 1W)	11.1	7.22	16.5	0.0711	
						Δ ± 10%	1.8%	3.3%	0.6%	4.6%	

14. Conducted Power Measurements

Table 14: Conducted Power Test Results

Freq. (MHz)	Mode	Chain Number	Avg Pwr (dBm)	
			Measured	Target
913	CW	0	29.4	29.4/chain
		1	29.3	
		2	29.4	
		3	29.3	
		4	29.4	
		5	29.3	
		6	29.3	
		7	29.3	
		8	29.3	
		9	29.1	
		10	29.4	
		11	29.4	

For SAR scaling, the sum of the measured powers for each chain was compared to the sum of the target powers:

Sum of the measured power = 40.11 dBm

Sum of the target power = 40.19 dBm

The total target power is 0.09 dB higher than the total measured power. The SAR results were scaled by +0.09 dB.

15. Measured and Reported (Scaled) SAR Results

15.1. Overview

1 g SAR testing was performed in accordance with IEC 62232. The small box-shaped phantom specified in clause B.3.2.2.2 was used for the testing as the MS-300 can be used in the vicinity of members of the general public, including children.

Extensive pre-testing was performed to determine the worst-case conditions for SAR testing.
The receive antenna is located at the front of the Client Device. Several placement orientations were tested to determine which orientation provided the highest (worst-case) values. Once this was determined, all tests were conducted with the Client Device at this position. For SAR testing, the front of the Client Device faces the front of the MS-300. The Client Device is oriented with the long axis perpendicular to the long axis of the MS-300. This orientation is termed ninety (90) degrees and is different than the worst case for field mapping which was found to be 0 Degrees. The distance of this testing is along the Keep-Out Zone boundary at 50 cm radially from the reference point at the front of the MS-300.

The pocket locations were set by taping the Client Device against the small box-shaped phantom and allowing the MS-300 to lock-on to its location. The MS-300 internal settings were recorded. These settings could then be used to project the pocket with or without the Client Device present. Unless otherwise indicated in the test results the Client Device was attached to the phantom during SAR testing.

The front of the Client Device faced away from the phantom towards the face of the transmitter.

The pocket location was set at the start of each SAR test.

During pre-testing, it was observed that the orientation of the MS-300 to the Client Device affected the SAR distributions. When the Client Device was placed on its edge against the phantom, the MS-300 could not create a pocket as the reported receive power was below the threshold required for charging and therefore not tested for compliance.

As a result of these observations, final SAR testing was performed with the long axis of the Client Device perpendicular to the long axis of the phantom (Client Device rotation = 90°). This orientation provided the highest SAR values as shown in Table 15.

Table 15: Comparison SAR Data for Client Device at 0 and 90 degrees

RF Exposure Conditions	Mode	Dist. (cm)	Pocket location	Client Rotation	Power (dBm)		1-g SAR (W/kg)			Plot No.
					Tune-up limit	Meas.	Meas.	Power scaling	With CFs	
Body	CW 913MHz	50	0°	90°	40.2	40.1	**0.372**	**0.379**	**0.966**	1
		50	0°	0°	40.2	40.1	0.183	0.186	0.475	2

The SAR plots are provided in Appendix C.

15.1.1. MS-300 and Client Device positioning

In the SAR test result tables, the MS-300 and client rotations with respect to the Small box-shaped phantom are shown in Figure 22

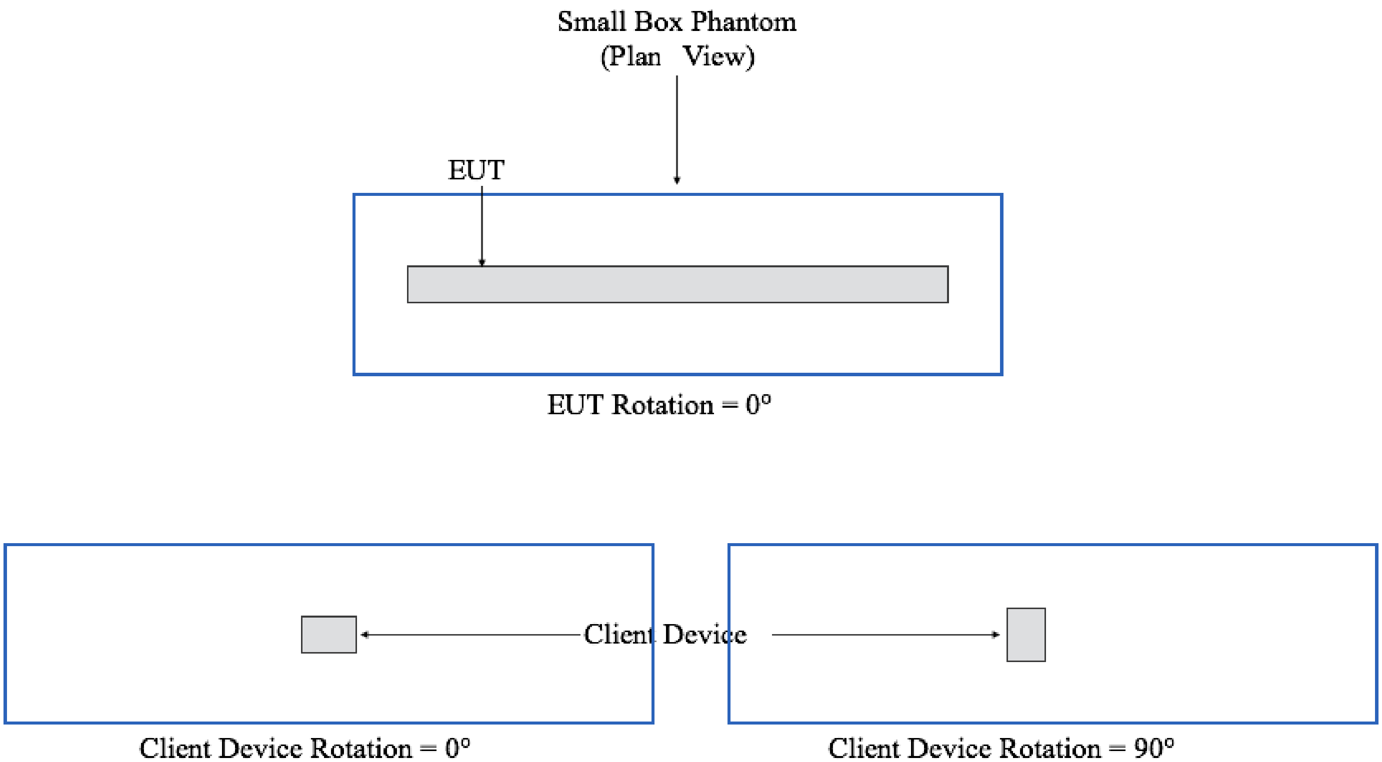


Figure 22: Orientation of DUT and Client Device with Respect to the Phantom

The pocket location indicates the angle of the pocket with respect to a perpendicular line projecting from the reference point at the front of the MS-300. For all pocket angles the MS-300 was placed directly under the center of the small box-shaped phantom. For angles ≠ 0° the vertical height of the MS-300 was adjusted so the distance of the pocket from the reference point at front of the MS-300 to the base of the phantom was 50 cm when adjusted for the pocket angle. For example, a pocket distance of 50cm from the center of the MS-300 at an angle of 30° would result in a measurement height of 50 x cos30° = 43.3 cm (See Figure 23) . This is indicated on the SAR plots as 'Start xxx mm'.

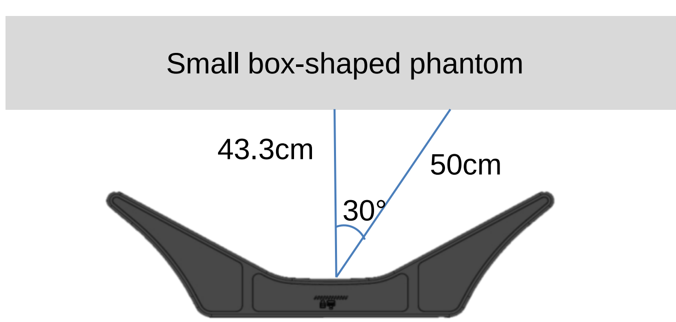


Figure 23: Example of DUT distance from the Phantom

15.2. Key to SAR Plots

The SAR plots use abbreviated notation to identify the test configurations:

1	2	3	4	5	6	7	8
913MHz CW/	**Start xxx mm/**	**CD A_**	**RX xx Degrees/**	**x Degrees**	**xxx mm/**	**Pocket xx/**	**x scan**

Lower case **x** represents a variable value

Definitions:

1. 913MHz CW – Frequency and modulation (MS-300 only supports 913 MHz CW).
2. Start xxx mm – Vertical distance of the DUT from the phantom. xxx is the distance in mm (See 15.1.1)
3. CD A_ – Client Device A (Primary Client Device under test) Only one Client Device was used for SAR testing.
4. RX xx Degrees – Relative orientation of the Client Device to the phantom (See 15.1.1)
5. x degrees – indicates the angle of the pocket from the center of the MS-300. Pocket angles are indicated by 0, -30, -25, -15, 15, 25, & 30.
6. xxx mm – the radial pocket distance from the center of the MS-300
7. Pocket xx – Number assigned to the pocket location. This is consistent across the SAR and RF field plots.
8. x scan – indicates the type of scan performed, area or zoom scan

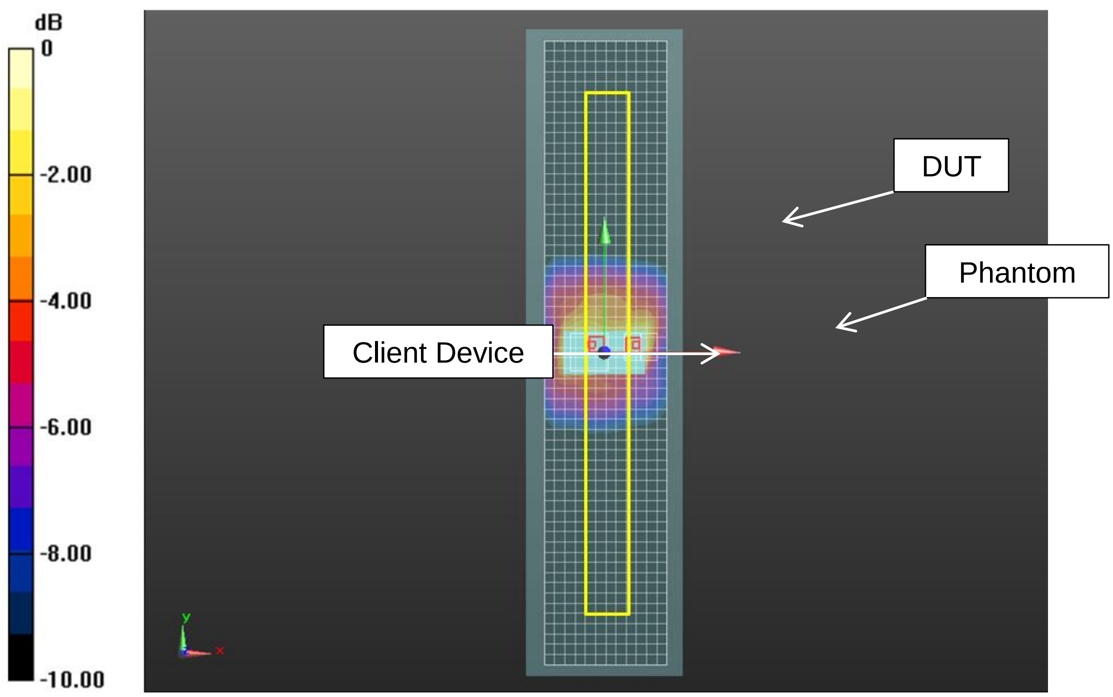


Figure 24: Explanatory Diagram of the SAR plots

In all the SAR plots the top of the MS-300 is facing right.

15.3. SAR Test Results

15.3.1. SAR Test Methodology

Per IEC 62232 B.3.2.3.3, correction factors apply to 1 g peak SAR average measurements.

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

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

where d is the distance of the sample from the phantom – 500mm.

The correction factors are applied to equation B.12 from IEC 62232 to provide the 1 g SAR value ($SAR_{psa}(d)$)

$$SAR_{psa}(d) = SAR_m(d) \text{ x } CF_1(d) \text{ x } CF_2(d)$$

At 500mm $CF_1(d)$ = 2

For λ = 328 mm, d = 500 mm $CF_2(d)$ =1.273.

The total correction factor [($CF_1(d)$ x CF2(d)] is 2.55.

15.3.2. SAR Tests Performed

Testing was performed with the MS-300 500 mm directly below the center of the phantom. Initial testing was performed with the Client Device placed directly above the MS-300 against the phantom (0°) and at ±15°and ±30° offsets relative to the MS-300. Refer to appendix A for test setup photographs. The worst-case SAR test condition was then repeated with a smartwatch connected to the Client Device and again with a cellphone connected to the Client Device to simulate actual use conditions. A final test was performed with the Client Device removed from the phantom. The worst-case test position was with the Client Device at pocket location 0°.

15.3.3. SAR Results

Table 16: 1 g SAR Test Result Summary

RF Exposure Conditions	Mode	Radial Dist. (cm)	Vertical Dist. (cm)	Pocket location	DUT Rotation	Client Rotation	Power (dBm)		1-g SAR (W/kg)		
							Tune-up limit	Meas.	Meas.	Power scaling	With CFs
Body	CW 913MHz	50	50	0°	0°	90°	40.19	40.11	**0.372**	**0.379**	**0.966**
		50	48.3	minus 15°	0°	90°	40.19	40.11	0.336	0.342	0.873
		50	48.3	plus 15°	0°	90°	40.19	40.11	0.352	0.359	0.914
		50	43.3	minus 30°	0°	90°	40.19	40.11	0.290	0.295	0.753
		50	43.3	plus 30°	0°	90°	40.19	40.11	0.343	0.349	0.891
		50	50	0° with watch	0°	90°	40.19	40.11	0.294	0.299	0.764
		50	50	0°with phone	0°	90°	40.19	40.11	0.320	0.326	0.831
		50	50	0° client removed	0°	90°	40.19	40.11	0.242	0.246	0.629

The Client Device and attached USB devices (where appropriate) were in place on the phantom during the SAR tests except where indicated in the pocket location column (client removed).

The 1 g final reported SAR values, including power scaling and correction factors, are shown in Table 16 in the column labelled 'with CFs'. The maximum 1 g SAR is 0.379 W/kg with power scaling. When combined with the recommended additional correction factor of 2.55 from IEC 62232, the reported maximum value is 0.966 W/kg. Therefore, the MS-300 meets the 1 g peak SAR average requirement.

15.4. Whole Body SAR Evaluation

15.4.1. Whole Body SAR Methodology

Whole body SAR testing was performed using the test configuration that yielded the worst case 1 g SAR value in the previous section. This was considered to be the worst-case scenario.

The whole body SAR procedure described in section 4.2.2 was followed.

The test separation distance was 500 mm. Whole body SAR was calculated using:

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

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

For d = 500mm $CF_3(d)$ = 1.8

$CF_4(f)$ depends on the phantom used for testing. For the small box-shaped phantom $CF_4(f)$ = 1

M=12.5kg.

The total absorbed power is 0.293 W.

This results in a whole body SAR of (0.293 x 1.8 x 1)/12.5 = 0.0422 W/kg before power scaling.

15.4.2. Whole body SAR Test Result

Table 17: Whole Body SAR test result Summary

RF Exposure Conditions	Mode	Dist. (cm)	Pocket location	DUT Rotation	Client Rotation	Power (dBm)		wbSAR (W/kg)		Plot No.
						Tune-up limit	Meas.	Meas.	Power scaling	
Body	CW 913MHz	50	0°	0°	90°	40.19	40.11	**0.0422**	**0.0430**	10,11

The whole body SAR result, including correction factors, is 0.0430 W/kg. As this is less than 0.08 W/kg the MS-300 meets the whole body SAR requirements.

15.5. SAR Testing Conclusion.

The reported 1 g average and Whole body SAR values do not exceed their respective limits. Therefore, the MS-300 meets the SAR requirements.

Appendixes

Refer to separated files for the appendixes.

12023867-S1V1 SAR_App A Setup Photos

12023867-S1V1 SAR_App B System Check Plots

12023867-S1V1 SAR_App C Highest SAR Test Plots

12023867-S1V1 SAR_App D RF Field X-Y Plots

12023867-S1V1 SAR_App E RF Field Y-Z Plots

12023867-S1V1 SAR_App F Tissue Ingredients

12023867-S1V1 SAR_App G Probe Cal. Certificates

12023867-S1V1 SAR_App H Dipole Cal. Certificates

END OF REPORT