SAR Compliance Numerical Simulation Report

Application No:	SZCR2312004222AU
Applicant:	Primax Electronics LTD
Manufacturer:	Dongguan Primax Electronic &Telecommunication Products Ltd.
Factory:	Dongguan Primax Electronic &Telecommunication Products Ltd.
Product Name:	Wireless Charger
Model No.(EUT):	P00001122
Add Model No.(EUT):	N/A
Trade Mark:	ZOOX
FCC ID:	EMJWP00001122
Standards:	FCC 47CFR §1.1310, §2.1093 KDB 447498 D01 v06
Date of Receipt:	2023-10-8
Date of Test:	2023-10-11 to 2024-07-16
Date of Issue:	2024-07-20
Test conclusion:	**PASS ***

* In the configuration tested, the EUT detailed in this report complied with the standards specified above.

Keny Xu

EMC Laboratory Manager

检验检测专用章
Inspection & Testing Services

SGS-CSTC Standards Technical Services Co., Ltd.
Shenzhen Branch Testing Center EEC Laboratory.

Revision Record				
Version	**Chapter**	**Date**	**Modifier**	**Remark**
01		2023-12-19		Original
02		2024-07-20		Updated H-fielded and simulation result on page 18-25

Authorized for issue by:				
		Martin Li/ Test Engineer		
		Eric Fu/Reviewer		

TEST SUMMARY

Frequency Band	Test position	The highest peak spatial 1-g average SAR (SAR simulation) (W/kg)	SAR limit (W/kg)	Verdict
127.76KHz	Front(Z-axis)	**0.83**	1.6	PASS

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4 General Information

4.1 Details of Client

Applicant:	Primax Electronics LTD
Address:	669, Ruey Kuang Road, Neihu 114 Taipei, Taiwan
Manufacturer:	Dongguan Primax Electronic &Telecommunication Products Ltd.
Address:	No#135, Keji East Road, Shijie Town, Dongguan City, Guangdong Province, 523290, China
Factory:	Dongguan Primax Electronic &Telecommunication Products Ltd.
Address:	No#135, Keji East Road, Shijie Town, Dongguan City, Guangdong Province, 523290, China

4.2 Test Location

All tests were performed at:

SGS-CSTC Standards Technical Services Co., Ltd., Shenzhen Branch
No. 1 Workshop, M-10, Middle Section, Science & Technology Park, Nanshan District, Shenzhen, Guangdong, China. 518057.
Tel: +86 755 2601 2053 Fax: +86 755 2671 0594

No tests were sub-contracted.

4.3 Test Facility

The test facility is recognized, certified, or accredited by the following organizations:

• A2LA (Certificate No. 3816.01)

SGS-CSTC Standards Technical Services Co., Ltd., Shenzhen EMC Laboratory is accredited by the American Association for Laboratory Accreditation(A2LA). Certificate No. 3816.01.

• VCCI (Member No. 1937)

The 3m Fully-anechoic chamber for above 1GHz, 10m Semi-anechoic chamber for below 1GHz, Shielded Room for Mains Port Conducted Interference Measurement and Telecommunication Port Conducted Interference Measurement of SGS-CSTC Standards Technical Services Co., Ltd. Shenzhen EMC laboratory have been registered in accordance with the Regulations for Voluntary Control Measures with Registration No.: G-20026, R-14188, C-12383 and T-11153 respectively.

• FCC –Designation Number: CN1336

SGS-CSTC Standards Technical Services Co., Ltd., Shenzhen EMC Laboratory has been recognized as an accredited testing laboratory.

Designation Number: CN1336. Test Firm Registration Number: 787754.

• Innovation, Science and Economic Development Canada

SGS-CSTC Standards Technical Services Co., Ltd., Shenzhen EMC Laboratory has been recognized by ISED as an accredited testing laboratory.

CAB identifier: CN0006.

IC#: 4620C.

4.4 General Description of EUT

Product Name:	Wireless Charger
Model No.(EUT):	P00001122
Trade Mark:	ZOOX
Product Phase:	production unit(or Variant)
Device Type :	Vehicle device
Exposure Category:	uncontrolled environment / general population
FCC ID:	EMJWP00001122
IMEI/SN:	21004-00063
Hardware Version:	V10
Software Version:	V9.1
Antenna Type:	Coil Antenna
Device Operating Configurations :	
Modulation Mode:	FSK
Frequency Bands:	127.72-132.72kHz
Power transfer method	Multiple primary coils and clients that be able to detect and allow coupling only between individual pairs of coils
Output power from each primary coil	<15W
Input/output power:	13.5V, 3.5A
	12.0V, 15W*2
Turns of the coil:	L3 Coil: 12 L1, L2 Coil: 11

4.5 Test Specification

Identity	Document Title
FCC 47CFR §2.1093	Radiofrequency Radiation Exposure Evaluation: Portable Devices
FCC 47CFR §1.1310	Radiofrequency radiation exposure limits
KDB 447498 D01 v06	General RF Exposure Guidance
KDB 680106 D01v04	RF Exposure considerations Low Power Consumer Wireless Power Transfer Applications

5 Introduction

This report demonstrates RF exposure compliance using SAR simulation for WPT of P00001122 (FCC ID: EMJWP00001122)

The device is a transmitter wireless charging device. The DUT can provide wireless charging for a mobile phone. According to §2.1093 (certification for portable devices below 4 MHz), the device operating at 127.72-132.72kHz kHz should demonstrate RF exposure compliance to the 1.6 W/kg localized 1-g SAR limit. Therefore, to be conservative, we consider the device to be a portable device as a wireless charger. For portable devices, an accurate SAR value for the WPT transmitter is required. Since SAR test tools is not suitable for use below 100 MHz, we apply SAR numerical modelling to obtain SAR values.

The following sections describe the modelling, measured H-field, simulated H-field, and simulated SAR

6 Detailed Product Information

This is a device supporting wireless charging function. It can provide charging for other mobile phone through wireless charging. The Wireless power transfer application details are as below:

A. Wireless charging operating frequency

Answer: The wireless charging operating frequency range of the DUT is 127.72 kHz-132.72 kHz.

B. Wireless charging maximum output power

Answer: When the DUT is used as the wireless charging Tx device, the maximum power of the wireless charging is <15 W.

C. Wireless charging usage scenarios

Answer: The DUT is used as a wireless charging device (Tx) in this usage scenario like Figure 1. The transfer system includes 6 primary coils, the device has two charging pads, each pads has 3 primary coils connected to it. The device only supports one by one pairing with the client device, the two pads support simultaneous transmitting, but each pad which connected 3 coils couldn't be simultaneous transmitting. The wireless charging coil is located at the top side of the DUT.

It is automatically turn on the wireless charging TX function when a client device placed directly in contact with the top side of charging area of DUT.

Figure 1. DUT Used as a wireless charging device

D. The number of turns for the primary coils, the amperes into the coil, and primary and secondary coil alignment and separation requirements.

Answer: The device has 6 primary coils, each pad connects to 3 different primary coils, the number of turns of each primary coil are 11 turns for L1, 11 turns for L2 and 12 turns for L3. The coil in DUT has 1.25 A current while the DUT is operating in maximum output power.

E. Details on how charging is initiated and managed.

Answer: When the charging function (Tx mode) is enabled：

a) The wireless charging IC is powered by the Vehicle battery.

b) The PING duration and the PING interval time are set.

c) The OCP (over current protection) and OVP (over voltage protection) parameters are set, the PING signal is sent, and the transmission is continued.

d) Once the PING is successful, the transmitting adjusts the transmission frequency according to the CEP (Control Error Packet) packet sent by the RX to establish a wireless power transmission.

e) Once RX is removed, TX re-enters the PING phase.

F. Detail information of the RF exposure analysis for the coil design to simulate the actual coil.
Answer: The coil module is composed of an FPC coil and a ferrite shielding material, and the magnetic shielding material blocks the magnetic field in the direction behind the coil.

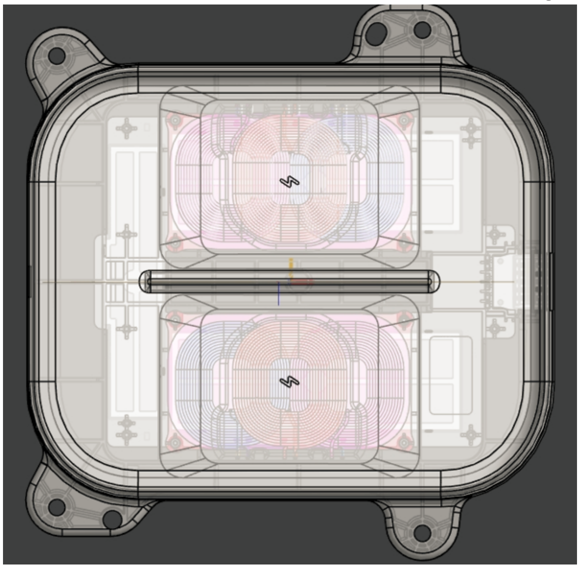


Figure 3. Coil Schematic

G. Description on the message exchanges between the transmitter and the receiver

ANS: Tx and Rx communicate using a single channel, and all Rx-Tx and Tx-Rx communication by physical channels. During the handshake, Rx sends a Signal Strength Packet, ID Packet, and Config Packet to the Tx. After the handshake is successful, Rx sends RPP (Received Power Packet) and CEP (Control Error Packet) to adjust the power.

7 Simulation Tool and Model

7.1 Simulation Tool

For the calculation of the magnetic field value and SAR simulation method of the DUT with the function of wireless charging, this article uses the electromagnetic module in SIM4LIFE. SIM4LIFE is one of several commercial tools for 3D electromagnetic simulation of wireless charging. The low frequency domain solver in SIM4LIFE is based on Scalar-Potential Finite Difference (SPFD) solution.

7.2 Mesh and Convergence Criteria

To use SPFD to calculate the magnetic field value and SAR value of wireless charging, it is necessary to divide the charging device, human tissue, and surrounding environment into multiple small units. The physical quantities on the nodes and edges of each small unit can be used as the calculated magnetic field value and the process of dividing the unknown SAR value into small cells is called meshing. In order to calculate the objective of the solution, the SIM4LIFE adaptive meshing technique was used. SIM4LIFE generates an initial mesh based on the minimum value of the wavelength of the electromagnetic field and the size of the target body, calculates the energy error during each iteration, and performs adaptive refinement and refinement for the regions with large errors. The determination of the number of calculation iterations in SIM4LIFE and the completion of the final iterative calculation process are called the convergence process. The convergence criterion tolerance is used to judge whether the convergence process is over. During the calculation process, the iterative adaptive grid process is performed until the convergence criterion tolerance is met. In SIM4LIFE, the accuracy of the convergence results depends on the tolerance. Figure 4 is an example of computing an object adaptive mesh.

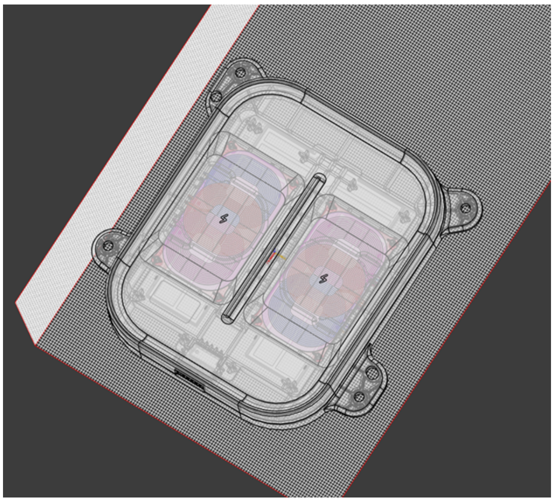


Figure 4. an example of computing an object adaptive mesh.

7.3 Power Loss Density Calculation

By solving the three-dimensional wireless charging reverse charging simulation model, the numerical values of the electric field and magnetic field physical quantities at each position in the space can be obtained. In order to calculate the power density, two physical quantities need to be extracted: the electric field ($\vec{E}$) and the magnetic field ($\bar{H}$). The actual power density dissipated as the complex conjugate product of the electric field E and the magnetic field H yields the real part of the vector (S) as follows:

$$S = \frac{1}{2} \mathrm{Re} \left(\vec{E} \times \bar{H} \right)$$

S is the power density at the node is calculated for each mesh, which can be obtained directly from SIM4LIFE.

From the point power density S, the calculation formula of the average power density of the space volume V is as follows:

$$P = \frac{1}{V} \iiint S \cdot dV$$

Here, the spatial average power density P is the total power density value of the X, y, and z components of the point power density, and the estimated volume is 1 cm3.

7.4 3D Model

Figure 5 shows the 3D simulation model of wireless charging device. The simulation model includes most of the finishing structure of the device: PCB, plastic frame, metal structure, wireless charging coil and magnetic conductive material, etc.

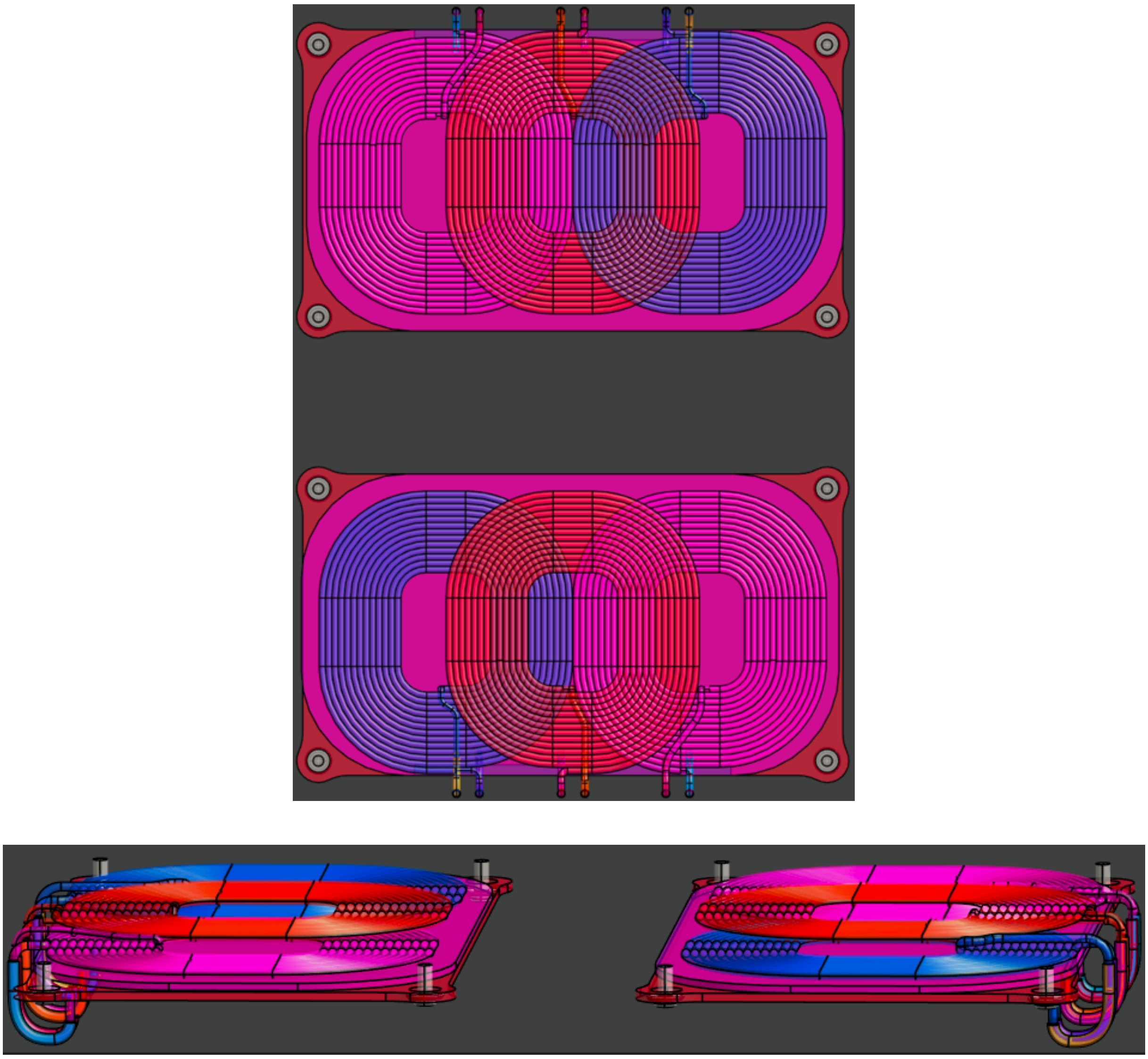


Figure 5. The 3D simulation model of wireless charging device and wireless charging coil

8 SAR Simulation Step

8.1 SAR Simulations Methodology

The following Figure are taken to show the validity of the model used for SAR simulations：

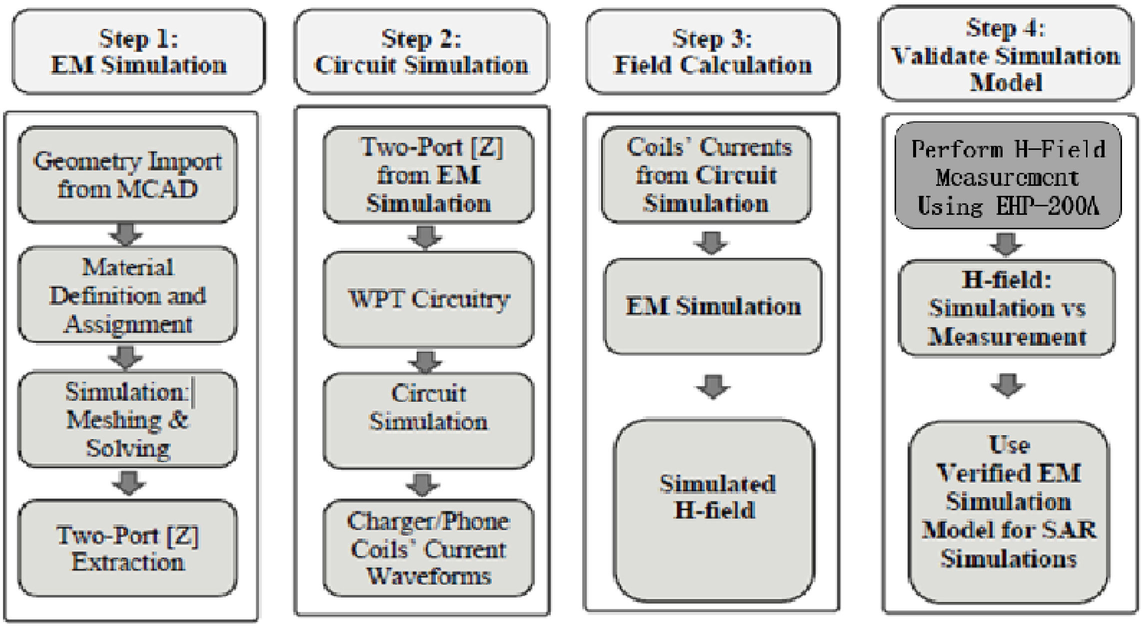


Figure 6. The steps of SAR simulation

First, the CAD model of the wireless charging device is imported into the software for material definition and mesh division to calculate the impedance of the coil. Then import the coil impedance into the WPT circuit to calculate the current value of the WPT circuit. And then, the electromagnetic model is excited by the current, and the simulated value of the field strength can be obtained. The accuracy of the wild goose array simulation is compared by the simulation and the actual measurement, and finally the SAR value is simulated.

8.1.1 Boundary Conditions

SPFD-based electromagnetic simulation tools need to impose boundary conditions on the simulation model, and the boundary conditions imposed are the first type of boundary conditions (Dirichlet boundary conditions). SIM4LIFE supports the direct application of Dirichlet boundary conditions.

8.1.2 Source Excitation Condition

The excitation conditions for wireless charging calculation are obtained by the circuit as shown in Figure 6. Calculated current excitation results of the circuit can be applied directly at the coil port. After completing a 3D full-wave electromagnetic simulation of the modelled structure, the current to the coil can be loaded using the SIM4LIFE "low frequency source" function. Since SIM4LIFE uses a SPFD solver based on the frequency domain analysis method, the input source of the coil excitation is calculated using a sinusoidal waveform for the operating frequency.

8.1.3 Simulation Completion Conditions

The simulation completion condition in SIM4LIFE is defined as a tolerance smaller than the desired value. The simulation result for this report is to set the tolerance to 1e-8

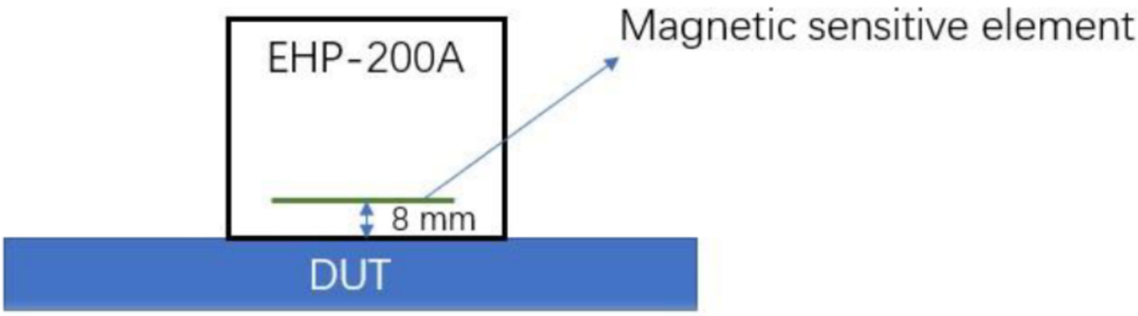
8.2 H-field Strength Measurement and Simulations

We use the Narda EHP-200A to measure the actual H-field strength of the DUT. EHP-200A E-H fields analyser has been designed for accurate measurements of both electric (0.02 to 1000 V/m) and magnetic (0.6 mA/m to 300 A/m) fields in the frequency range 9 kHz to 30 MHz. Both the field sensors and the electronic measuring circuitry are accommodated in a robust housing. Measurements are given total value (peak and average), with exceptional flatness and linearity. The probe specifications of H- field mode are giving below:

Test Mode	Magnetic Field Mode A
Frequency range	9 kHz-30 MHz
Measurement range @10 kHz RBW	0.6 mA/m – 300 A/m
Dynamic range	> 80 dB
Resolution	1 mA/m
Sensitive @10 kHz RBW	30 mA/m
Flatness	0.8 dB
Span	0 to Full Span

Table 1 The information of EHP-200A for H-field measurement

For the EHP-200A the sensitive element is located approximately 8 mm bellow the external surface like Figure 7, therefore, when comparing the simulated values, the simulated field strength should be obtained at 8 mm from the surface of the DUT. Per TCB Workshop April 2022, If the centre of the probe sensing element is more than 5 mm from the probe outer edge, the field strengths need to be estimated for the positions that are not reachable (from the surface, in 2 cm increments)



When the charging device is close to the DUT device, the DUT is activated. In order to make the DUT operate at maximum transmitting power, the test is performed with an electronic load that is adjusted to start the test when the DUT input voltage is 13.5V and the input current is 3.5A. The front(Z-axis), back, left, right, top and bottom sides of the test are defined as shown in Figure 8.

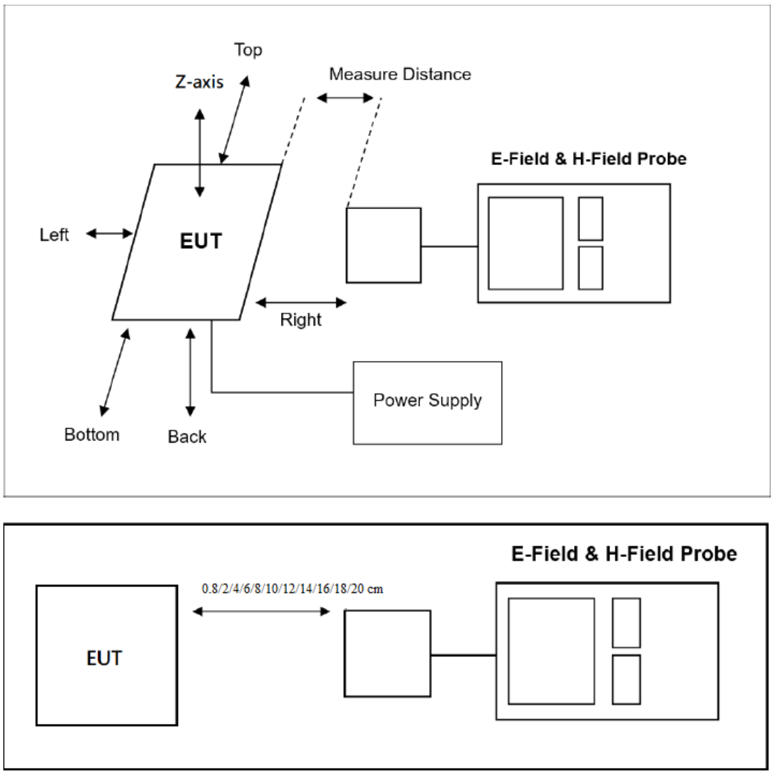


Figure 8. DUT test diagram

To accurately measure the value of the magnetic field strength, we set the measurement step to 2 mm, and the test surface is the Front(Z-axis), Top, Bottom, Right and Left sides that conform to the Portable device. Each point is repeat measured three times.

The H-field simulations are conducted using commercially available software ANSYS. To validate the simulation model, H-field measurements are made on the DUT and compared to the simulated results (as shown in Figure 9). The validated model is then used for SAR simulations.

For wireless charging, the maximum transmit power of Tx is 15 W. Although the conditions for this scenario are very harsh, considering the worst case, it needs to be simulated. The measured result and simulation result are shown below. It can be seen that the biggest deviation between simulation and test is 16%, which is far below the requirement of 30% (per April 27, 2022, TCB Workshop). In this case the H-field strength values of the five sides are in good agreement with the simulated values. So, this mode can be used to calculate SAR values.

Test / Simulation Side	Channel Frequency (kHz)	Tx Power(W)	Horizontal Offset (mm) Remark: The sensor of the probe close to EUT	Measured Result (A/m)	Simulation Result (A/m)	Deviation (%)
Front Side (Z-axis)	127.76	15	0.8	22.366	26.710	16
Left Side	127.76	15	0.8	1.536	1.781	14
Right Side	127.76	15	0.8	1.461	1.667	12
Top Side	127.76	15	0.8	0.537	0.598	10
Bottom Side	127.76	15	0.8	0.449	0.521	13

Table 2. The Test and simulation result of H-field of DUT with transmitted power of 15 W (the two coils are transmitting at same time)

When in use, the coil has a certain offset in the horizontal plane, so we also take the offset into account. The simulation results are shown in the table below.

Test / Simulation Side	Channel Frequency (kHz)	Tx Power(W)	Horizontal Offset (mm) Remark: the distance between the simulated human body and EUT	Simulation Result (A/m)
Front Side (Z-axis)	127.76	15	0	28.670
Left Side	127.76	15	0	1.987
Right Side	127.76	15	0	1.876
Top Side	127.76	15	0	0.673
Bottom Side	127.76	15	0	0.595

Table 3. The simulation result of H-field of DUT with transmitted power of 15W (the two coils are transmitting at same time) at 0 mm (distance between the simulated human body and EUT)

Per TCB Workshop April 2022, If the centre of the probe sensing element is more than 5 mm from the probe outer edge, the field strengths need to be estimated for the positions that are not reachable (from the surface, in 2 cm increments). Therefore, we did a simulation test comparison from 8 mm (the distance between the magnetic induction unit from the DUT surface) to 18 cm on the front side(Z-axis) surface. The results are shown in the following figure. The figure shows good correlation between the measurements and simulations.

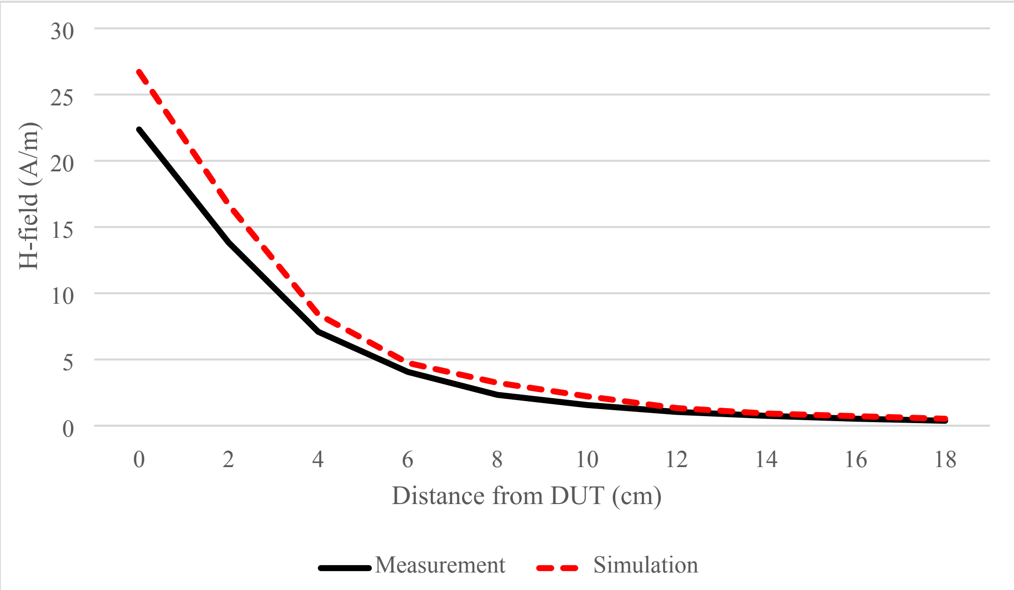


Figure 9. Comparison of test and simulation at different distances

8.3 SAR simulation

The SAR simulations are conducted using commercially available software SIM4LIFE by same model. For this simulation, a phantom is added in contact with the DUT.

The following steps are used for accurate SAR simulation:

1) Homogenous tissue material is used as liquid for desired frequency.

2) Power loss in phantom is calculated.

3) SAR can be calculated by the Equation:

$$\text{SAR} = \frac{P}{\rho}$$

where P is the Power loss density, and p is the tissue density.

4) SAR is averaged over 1 g at 0 mm (FCC).

The portable scene during charging appears when holding a mobile phone to make a call or placing it on the body to use the mobile phone. Therefore, it is necessary to determine the electrical properties of phantom. As mentioned earlier, the frequency of wireless charging is 127.76 kHz, so the electrical characteristics of the body and hand at this frequency are summarized as follows:

Tissue	Thickness (mm)	Permittivity	Conductivity(S/m)
Skin	3	1114.62	0.17
Muscle	9	7428.41	0.355
Bone	20	433.88	0.082
Worst case	/	7428.41	0.355

Table 4. The electrical characteristics for body layers

Frequency (MHz)	Real part of the complex relative Permittivity	Conductivity(S/m)
0.1 to 30	55	0.75

Table 5. The electrical characteristics from IEC 63184 using homogeneous flat phantom

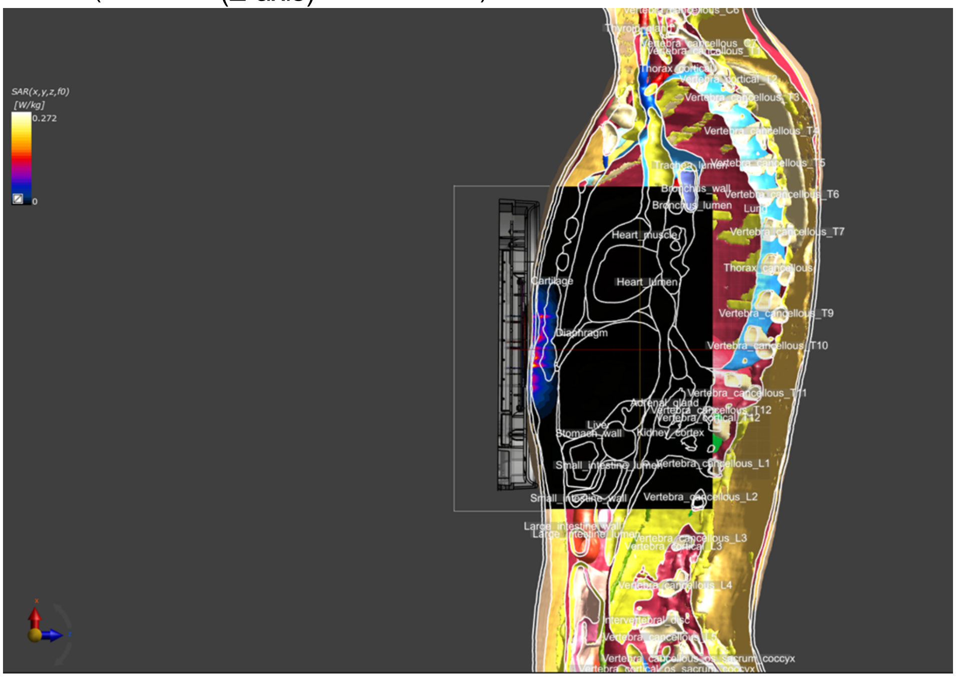
For hand phantom, compared with body layers, the thickness of each layer is different, but the electrical characteristics are the same at the same frequency, so the same worst case can be used. For all exposure cases, conductivity and permittivity used for the phantoms are fixed as the worst case (0.355 S/m and 7428.41), and the phantom thickness is 100 mm. And the SAR results are peak spatial 1-gram average SAR.

The two clients were placed on the EUT and the two coils are transmitting at same time, we made SAR simulations for the 15 W*2 scenarios without horizontal offset. The results are shown below:

Simulation Side	Tx Power (W)	Peak Spatial Average SAR over 1-g(W/kg)	99th Simulated E field (V/m)
Front Side (Z-axis)	15	0.2718	37.6
Left Side	15	2.417E-03	6.1
Right Side	15	1.918E-03	6.3
Top Side	15	1.428E-04	1.6
Bottom Side	15	8.763E-05	1.5

Table 6. The Peak spatial average SAR result simulated by SIM4LIFE using torso front.

SAR plot is show below (Front side(Z-axis) without offset).



	Max Loss Power Density	Min. local SAR	Mass-Averaged SAR	Max. local SAR	Total Loss	Total Mass	Total Volume	Peak Spatial-Average SAR[IEEE/IEC62704-1] (1g)
	W/m^3	W/kg	W/kg	W/kg	W	kg	m^3	W/kg
All Regions	296.3494	0	1.624e-03	0.2718	1.162e-02	7.1556	1.200e-02	0.1051

Figure 10. SAR distribution for different slice view, front side without offset.

Simulation Side	Tx Power (W)	Peak Spatial Average SAR over 1-g(W/kg)	99th Simulated E field (V/m)
Front Side (Z-axis)	15	0.8263	37.6

Table 7. The Peak spatial average SAR result simulated by SIM4LIFE using homogeneous flat phantom with Permittivity and conductivity showed in Table 5.

SAR plot is show below (Front side(Z-axis) without offset).

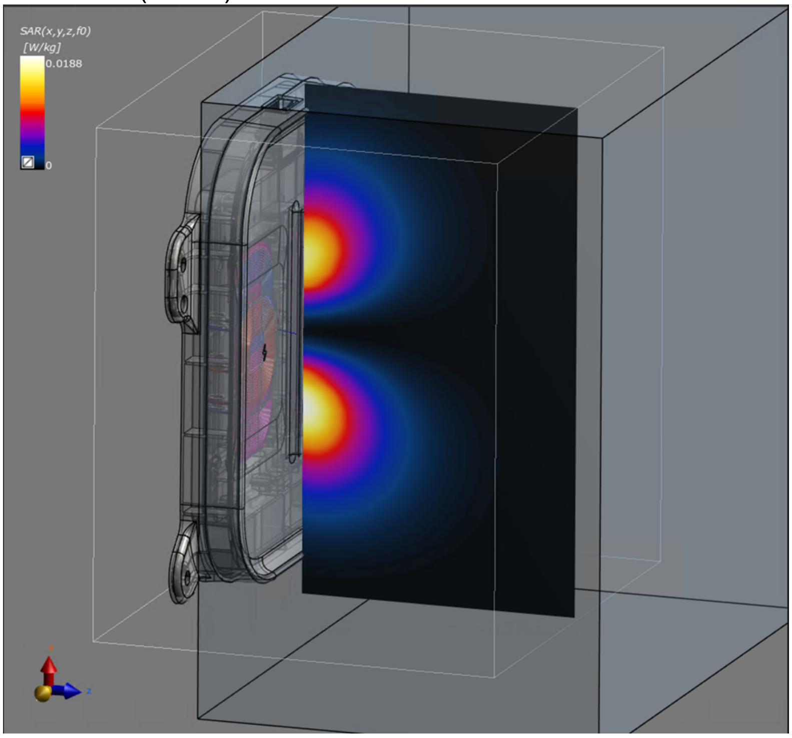


Table view

SAR Statistics

Show 25 entries Filter:

	Max Loss Power Density	Min. local SAR	Mass-Averaged SAR	Max. local SAR	Total Loss	Total Mass	Total Volume	Peak Spatial-Average SAR[IEEE/IEC62704-1] (1g)
	W/m^3	W/kg	W/kg	W/kg	W	kg	m^3	W/kg
Background	0	0	0	0	0	0	3.720e-03	0
Phantom	826.3147	3.276e-11	4.124e-03	0.8263	3.414e-02	8.2800	8.280e-03	0.2782
All Regions	826.3147	0	4.124e-03	0.8263	3.414e-02	8.2800	1.200e-02	0.2782

Showing 1 to 3 of 3 entries Previous 1 Next

Figure 11. SAR distribution using homogeneous flat phantom for different slice view, front side without offset.

8.4 Calculation

The accuracy of the SAR simulations is demonstrated by correlating H-field measurements to simulations in Figure 9, Figure 10, Table 2, Table 6 and Table 7. For the case where the phones have no Horizontal offset, the highest peak spatial 1-g average SAR is 0.8263 W/kg, well below FCC SAR limit 1.6 W/kg.

- End of the Report -

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