



WPT SAR Compliance Simulation Report for WCJ05ZM

Model Name: WCJ05ZM

FCC ID: 2AMIN-WCJ05ZM

Date of Simulation: 2023-4-10

Note:

The test results in this test report relate only to the devices specified in this report. This report shall not be reproduced except in full without the written approval of CTTL.

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1 Introduction

This report demonstrates RF exposure compliance using SAR simulation for WPT of WCJ05ZM (FCC ID: 2AMIN-WCJ05ZM)

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 115-148 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 modeling to obtain SAR values.

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

2 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

ANS: The wireless charging operating frequency range of the DUT is 115 kHz-148 kHz.

B. Wireless charging maximum output power

ANS: When the DUT is used as the wireless charging Tx device, the maximum power of the wireless charging is 50 W.

C. Wireless charging usage scenarios

ANS: The device is a transmitter wireless charging device. The DUT can provide wireless charging for a mobile phone. The DUT is used as a wireless charging transmitter device (Tx) in this usage scenario like Figure 1. The transfer system includes only single primary coil. The device only supports one to one pairing with the client device. The wireless charging coil is located at the back side of the DUT.

It is automatically turn on the wireless charging TX function when a client device placed directly in contact with the front side charging area of TX device. This is a car charger that uses a clamp to place the DUT on the vehicle's central console. Once the DUT detects a phone, it will automatically open the clamp and hold the phone in place for wireless charging.



Figure 1. DUT Used as a wireless charging transmitter device

D. Wireless charging standard and operating diagram

ANS: The operating diagram of the wireless charging DUT is as below picture:

The adapter supplies power to the transmitter side and converts AC to DC (5-20V) by protocol. The transmitter converts DC to AC by using the LC charge/discharge circuit, which provides the transmitter coil to generate a magnetic field. The receiving coil couples AC power within the magnetic field, and provides it to the RX chip. The RX uses the rectifier output DC to charge the mobile phone.

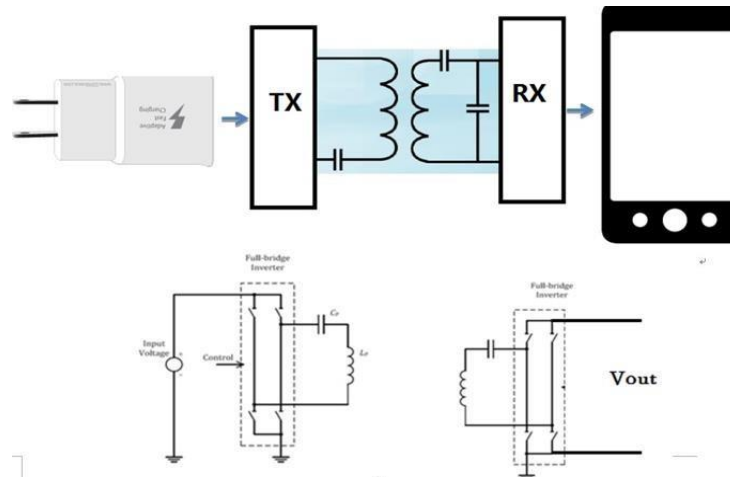


Figure 2. The wireless charging operating diagram

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

ANS: The device has only one coil and the number of turns for the primary coil is 12 turns. The coil in DUT has 3.24 A current while the DUT is operating in maximum output power.

F. Details on how charging is initiated and managed.

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

1. The wireless charging IC is powered on, and identifying the adapter type.
2. Then the PING frequency, the PING duration and the PING interval time are set.
3. The OCP (over current protection) and OVP (over voltage protection) parameters are set, the PING signal is sent, and the transmission is continued.
4. 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.
5. Once RX is removed, TX re-enters the PING phase.

G. Detail information of the RF exposure analysis the coil design to simulate the actual coil.

ANS: 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.

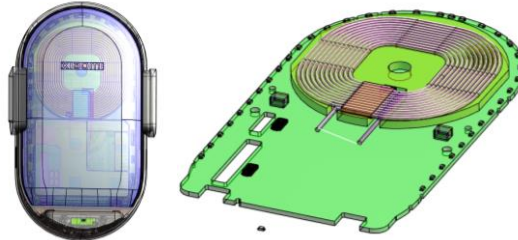


Figure 3. Coil Schematic

H. 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 physical channels are wireless signals transmitted by Tx. Rx-Tx is AM (Amplitude Modulation) communication, and Tx-Rx is FM (Frequency Modulation) communication. 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.

3 Simulation Tool and Model

3.1 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 SEMCAD 19.2. SEMCAD 19.2 is one of several commercial tools for 3D electromagnetic simulation of wireless charging. The low frequency domain solver in SEMCAD 19.2 is based on Scalar-Potential Finite Difference (SPFD) solution.

3.2 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 SEMCAD 19.2 adaptive meshing technique was used. SEMCAD 19.2 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 SEMCAD 19.2 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 SEMCAD 19.2, the accuracy of the convergence results depends on the tolerance. Figure 4 is an example of computing an object adaptive mesh.

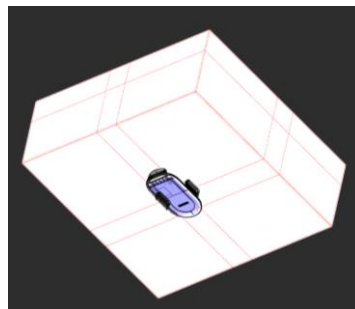


Figure 4. an example of computing an object adaptive mesh.

3.3 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 (\vec{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 (\vec{S}) as follows:

$$\vec{S} = \frac{1}{2} \text{Re}(\vec{E} \times \vec{H})$$

\vec{S} is the power density at the node is calculated for each mesh, which can be obtained directly from SEMCAD.

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

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

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.

3.4 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.

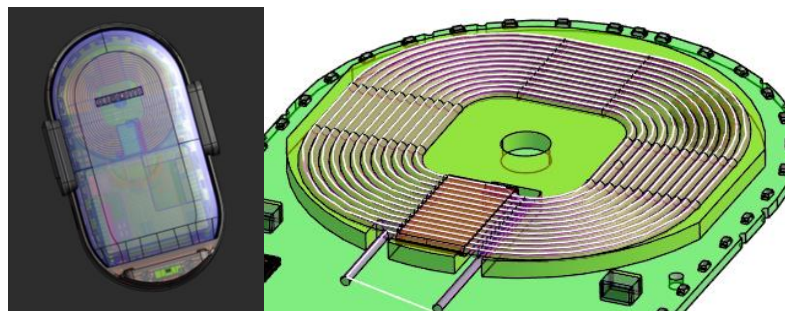


Figure 5. The 3D simulation model of wireless charging device and wireless charging coil

4 SAR Simulation Step

4.1 SAR Simulations Methodology

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

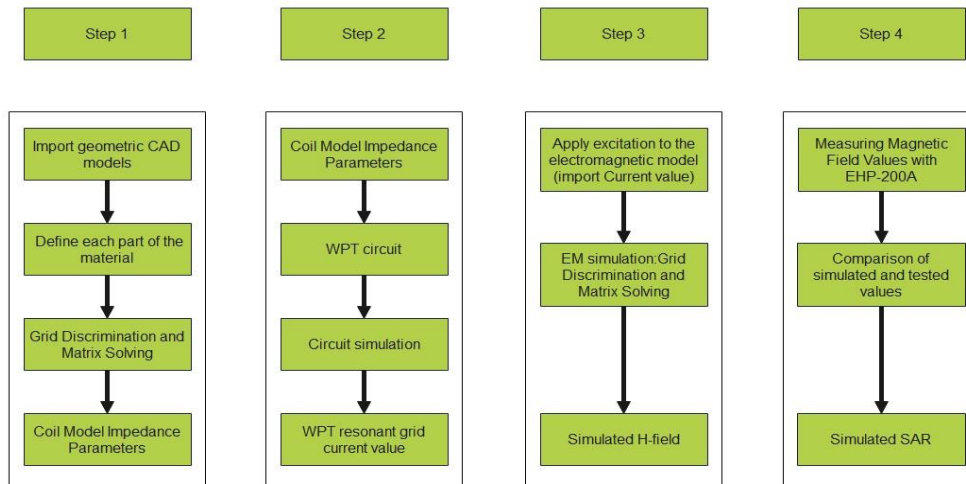


Figure 6. The steps of SAR simulation

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.

4.1.1 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). SEMCAD 19.2 supports the direct application of Dirichlet boundary conditions.

4.1.2 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 modeled structure, the current to the coil can be loaded using the SEMCAD 19.2 "low frequency source" function. Since SEMCAD 19.2 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.

4.1.3 Simulation Completion Conditions

The simulation completion condition in SEMCAD 19.2 is defined as a tolerance smaller than the desired value. The simulation result for this report is to set the tolerance to 1e-8.

4.2 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 analyzer has been designed for accurate measurements of both electric (0.02 to 1000 V/m) and magnetic (3 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-3 MHz
Measurement range @10 kHz RBW	30 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 below 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 center 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)

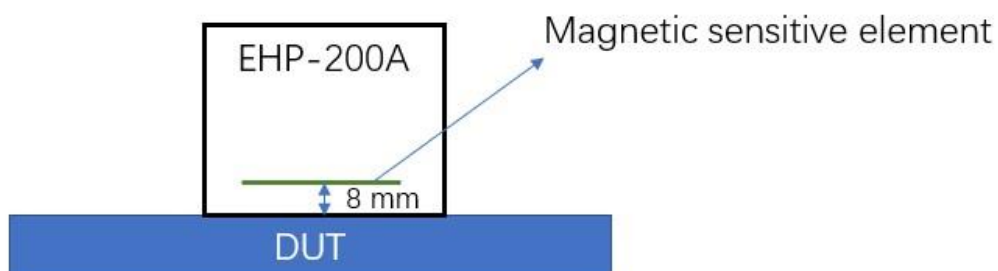


Figure 7. The located of sensitive element

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 12V and the input current is 4.17A. The front, back, left, right, top and bottom sides of the test are defined as shown in Figure 8.

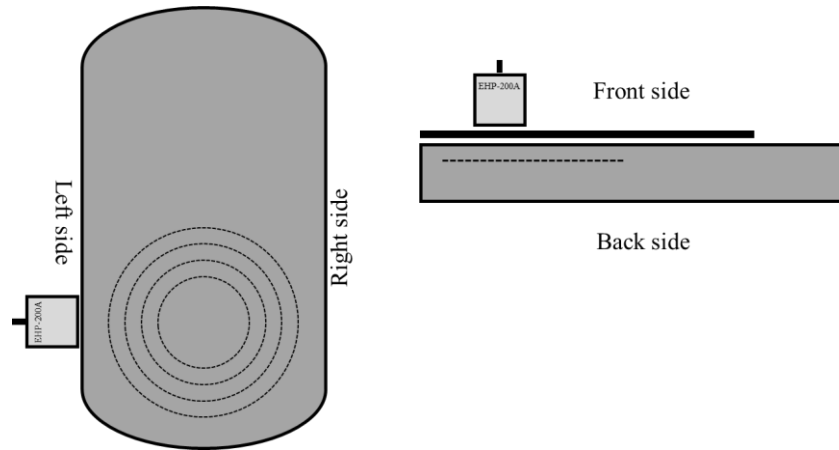


Figure 8. DUT test diagram

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, Back, 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 SEMCAD. 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 50 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 gap between simulation and test is only 25.74%, which is far below the requirement of 30% (per April 27, 2022, TCB Workshop). In this case the H-field strength values of the four sides are in good agreement with the simulated values. So, this mode can be used to calculate SAR values.

Test/simulation Side	Text	Text Tx Power (W)	Horizontal offset (mm)	Text Result (A/m)	Simulation Result (A/m)	Gap (%)
	Channel/Freq (kHz)					
Front Side	131.5	50	0	59.19	63.43	7.17
Back Side	131.5	50	0	7.92	8.75	10.49
Left Side	131.5	50	0	9.38	10.08	7.42
Right Side	131.5	50	0	7.15	8.03	12.29
Top Side	131.5	50	0	0.99	1.24	25.74
Bottom Side	131.5	50	0	13.39	14.58	8.88

Table 2. The Test and simulation result of H-field at 50W

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/Freq (kHz)	Tx Power(W)	Horizontal offset(mm)	Simulation Result(A/m)
Front Side	131.5	50	8	55.64
Back Side	131.5	50	8	7.31
Left Side	131.5	50	8	9.12
Right Side	131.5	50	8	7.87
Top Side	131.5	50	8	1.17
Bottom Side	131.5	50	8	13.72

Table 3. The simulation result of H-field at 50W with 8 mm horizontal offset

Per TCB Workshop April 2022, If the center 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 frontside surface of 50 W. The results are shown in the following figure. The figure shows good correlation between the measurements and simulations.

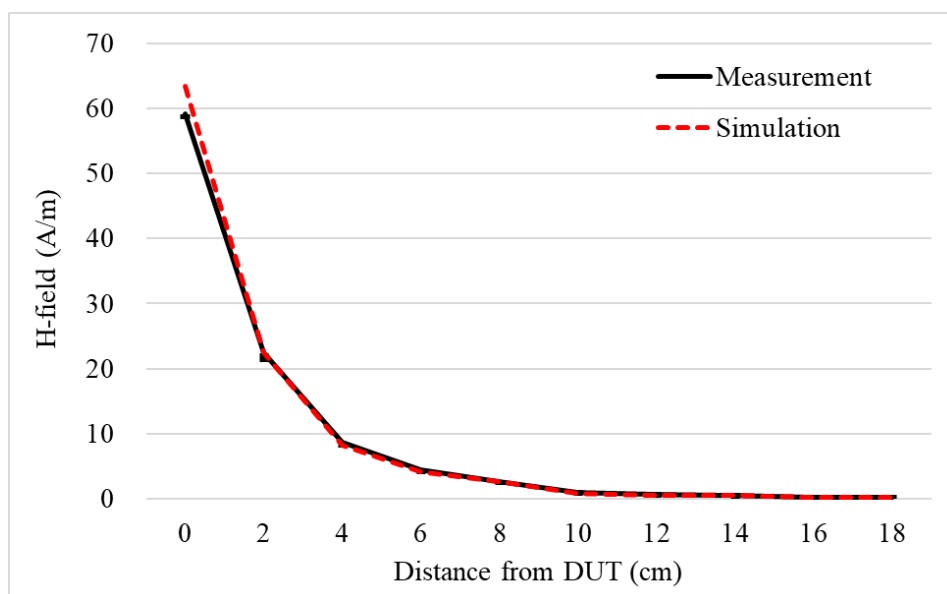


Figure 9. Comparison of test and simulation at different distances at 50 W

4.3 SAR simulation

The SAR simulations are conducted using commercially available software SEMCAD 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:

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

where P is the Power loss density, and ρ 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 131.5 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

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 worst use case is at 50 W, we made SAR simulations for the 50 W case with and without horizontal offset. The results are shown below:

Simulation Side	Tx Power (W)	Peak Spatial Average SAR over 1-g (W/kg)	99th Simulated Efield (V/m)
Top Side	50	4.91E-03	0.86125
Bottom Side	50	2.23E-04	0.42997
Left Side	50	1.33E-04	0.18937
Right Side	50	1.68E-04	0.21931
Top Side	50	1.39E-06	0.01805
Bottom Side	50	2.47E-04	0.21404

Table 5. The Peak spatial average SAR result calculated by simulation

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

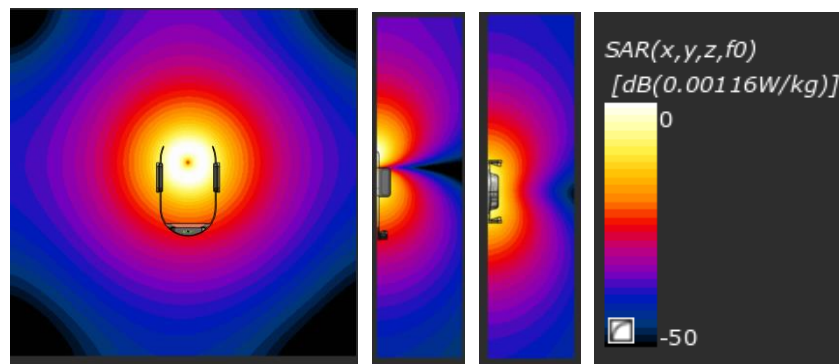


Figure 10. SAR distribution for different slice view, front side without offset.

4.4 Calculation

The accuracy of the SAR simulations is demonstrated by correlating H-field measurements to simulations in Figure 9, Figure 10, Table 2 and Table 5. For the case where the phones have no Horizontal offset, the highest peak spatial 1-g average SAR is 4.91E-03 W/kg, well below FCC SAR limit 1.6 W/kg.