SAR Compliance Simulation Report for WPT Watch Charger

Model: WIZ022,
FCC ID: K7SWIZ022

Vendor Name:
Belkin International, Inc.

Simulation Performed By:
ANSYS, Inc.

Date of Simulation:
01/15/2024-01/15/2024

Location:
California, USA

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1 A Brief Summary of Assessment Results

The Watch Charger wireless power transfer (WPT) module is designed to charge Apple Watch through closely coupled inductive field at 326.5 kHz and 1.778 MHz. The evaluation of the SAR and E-field induced inside the phantom is the main purpose of this report. The results for different scenarios are summarized in Table 1 below.

	Exposure Case	Phantom Orientation	I_{tx} (A_{rms})	I_{rx} (A_{rms})	Frequency	Peak Spatial Average SAR (W/Kg) (Averaged over 1 gram)	SAR Limit (W/Kg)	Peak Spatial Average E (V/m) Averaged over 2x2x2 mm^3
1	Low-Frequency (LF) Charging case (a)	Watch side	0.21	0.11	326.5 kHz	1.94e-8	1.6	1.24e-2
2	Low-Frequency (LF) Charging case (b)	Charger side	0.21	0.11	326.5 kHz	1.36e-8	1.6	9.79e-3
3	High-Frequency (HF) Charging case (a)	Watch side	0.25	0.20	1.778 MHz	4.71e-8	1.6	0.0193
4	High-Frequency (HF) Charging case (b)	Charger side	0.25	0.20	1.778 MHz	4.44e-7	1.6	0.0564
5	LF Unrealistic (theoretical) case (a) (No RX)	Charger side towards Tx coil	0.21	N/A	326.5 kHz	1.50e-4	1.6	1.68
6	LF Unrealistic (theoretical) case (b) (No RX)	Charger side away from Tx Coil	0.21	N/A	326.5 kHz	5.88e-8	1.6	1.91e-2
7	HF Unrealistic (theoretical) case (a) (No RX)	Charger side towards Tx coil	0.25	N/A	1.778 MHz	4.39e-3	1.6	9.17
8	HF Unrealistic (theoretical) case (b) (No RX)	Charger side away from Tx Coil	0.25	N/A	1.778 MHz	1.15e-6	1.6	0.0839

Table 1. Summary of evaluated cases for SAR and E field compliance.

Cells marked in "GREEN" values are within limit

Cells marked in "RED" are out of limit

For the normal use cases (cases 1-4 in Table 1), the highest 1g averaged SAR of **4.44e-7 W/kg** occurs for **case 4**, and the highest peak spatial average E-field of **0.0564 V/m** occurs for **case 4**. For the unrealistic (theoretical) cases (cases 5-8 in Table 1), the highest 1g averaged SAR of **4.39e-4 W/kg** occurs for **case 7** and the highest peak spatial average E-field of **9.17 V/m** occurs **case 7**.

The SAR values in Table 1 do **not** exceed the SAR limit of 1.6 W/Kg.

More details of the simulation setup and results are provided in the following sections.

2 Introduction

This report demonstrates RF exposure compliance, using SAR simulations, for the Watch Charger WPT (Wireless Power Transfer) module introduced by Apple. The WPT Watch Charger module operates at 326.5 kHz and 1.778 MHz supporting both low- and high-frequency charging. This WPT module is being integrated in a housing that was designed by **Belkin International, Inc.** Apple's Watch Charger WPT model is combined with **Belkin's** housing design to show compliance for SAR using EM simulations.

For simultaneous transmission analysis, a more accurate estimated SAR value for the WPT transmitter is needed. This report uses computational modeling to arrive at an estimate of the maximum SAR value.

To demonstrate RF exposure compliance for the WPT Watch Charger module operating at 326.5 kHz (Low-Frequency) and at 1.778 MHz (High-Frequency), as permitted by §2.1093 (certification for portable devices below 4 MHz), SAR numerical simulations are performed to demonstrate compliance to the 1.6 W/kg localized 1-g SAR limit.

The following sections describe the modeling, and simulated SAR for the proposed WPT device.

3 EUT Description

The EUT, BoostCharge Portable USB-C Apple Watch Charger, is a single coil wireless charger capable of charging one client device at a time. It is used to charge an Apple Watch at 326.5kHz or 1.778MHz (5W Max). The EUT is powered through a USB-C port that can output at least 5V/1A (5W). The maximum input current the EUT will draw is 1A.

4 Wireless Power Transfer System

The wireless power transfer system consists of a transmitting coil with 9 turns and measures 2.35 uH nominally in free air. The receiver coil on the client side consists of 6 turns and measures 7.55 uH nominally in free air. Both coils are wound spirally and made of stranded wire.

Below are key design parameters:

Item	**Description**
Max Power Delivered	2.8 W (delivered to battery)
Full Charge Time	1 hour 9 minutes (from empty)
Operating Frequency	326.5 kHz, 1.778 MHz
Communications/Modulation Method	ASK from Watch to Charger FSK from Charger to Watch
Object Detection Mode	Low Power Efficiency test

Table 2. Key design parameters

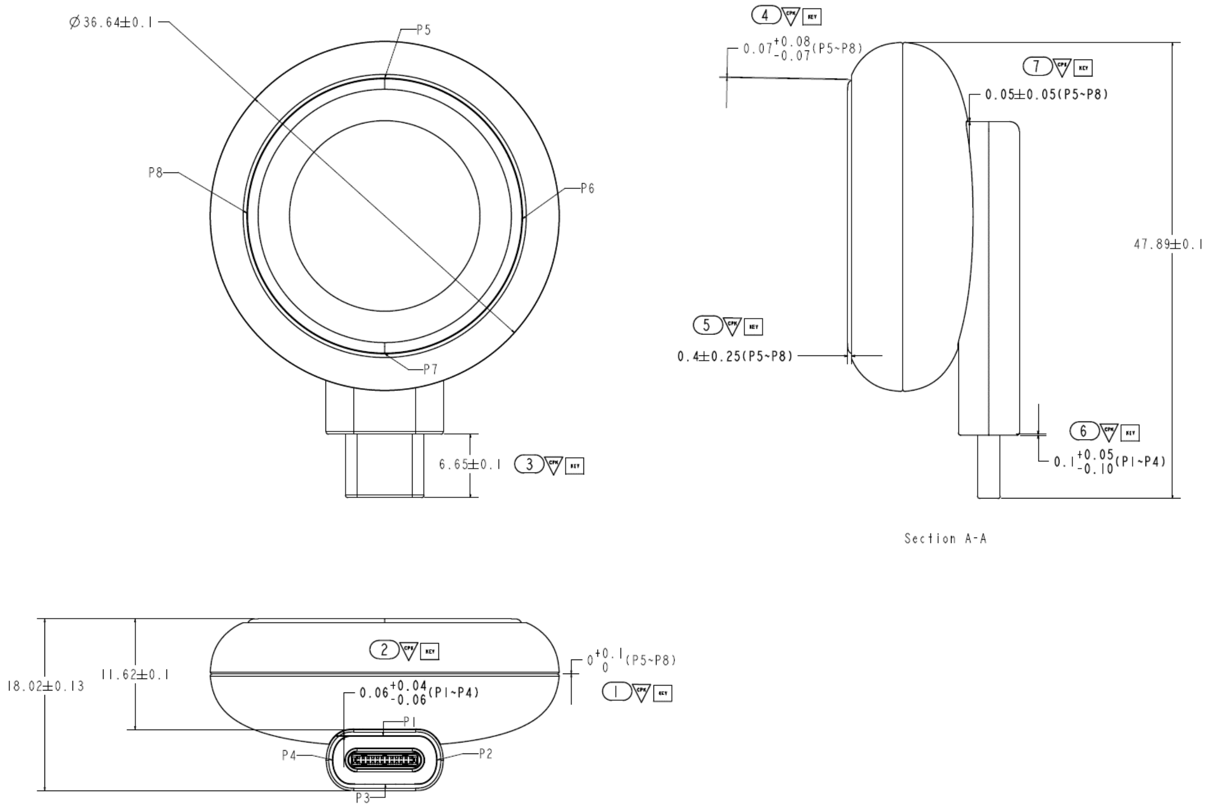

Figure 1: EUT Mechanical Dimensions and Tolerances

5 SAR Simulations Methodology

The simulation methodology is based on the guidance provided by Apple. Please refer to the confidential report “Simulation Tool for Third-Party Vendors using Apple’s Watch Charger WPT module” submitted by Apple for detailed description.

6 Model Validation Methodology

As an initial step, we need to validate the simulation model provided by Apple to make sure that the simulation setup with the Watch Charger WPT model is consistent with Apple’s simulation model. Please refer to Annex C: Simulation Model Validation for detailed analysis on validation of Watch Charger WPT simulation model.

Good correlation is observed between the simulation results for the two simulation model setups. Therefore, the Watch Charger WPT simulation model will be used for performing SAR calculations.

7 SAR Simulations

The Watch Charger WPT simulation model is combined with the tissue Phantom and the following additional **Belkin** geometries and electrical material properties. Specific absorption rate (SAR) and internal E-field calculations within the Phantom are calculated.

	Material	**Relative Permittivity (er)**	**Loss tangent**	**Relative Permeability(ur)**	**Magnetic Loss tangent**	**Conductivity (S/m)**
1	Copper	1	0	1	0	5.96e7
2	PC	3	0.011	1	0	0
3	PSA	3	0.011	1	0	0
4	SUS304	1	0	1	0	1.45e6

Table 3. Material Properties of the additional housing geometries

	Object Name	Material Name
1	B0000165346	Copper
2	B0000165347	Copper
3	B0000165350	PC
4	B0000165355	PC
5	B0000165356	PC
6	B0000165360	PC
7	B0000165354	PSA
8	B0000165348	SUS304
9	B0000165358_1	SUS304
10	B0000165358_2	SUS304

Table 4. Material Assignments for the additional housing geometries

The following steps are used for accurate SAR calculations:

1) Elliptical phantom used in body exposure measurements is commercially available from SPEAG: Outer dimensions of 600mm x 400mm x 150mm.
2) Homogeneous tissue material is used as liquid for desired frequency.
3) Power loss in phantom is calculated.
4) Divide power loss by mass density to calculate SAR.

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

$$P_l = \text{Power loss density}$$

$$\rho = \text{Mass density}$$

5) Point SAR is averaged over 1g or 10g tissue.

6) A mass density of 1000 Kg/m^3 is used for the modeling and the simulation of the phantom.

Human Tissue Material Properties at 326.5 kHz and 1.778 MHz:
The worst-case scenario has been identified to be when a user is holding the device in hand or holding the watch on their body while charging. The electrical properties for body and hand layers are shown in Appendix: Annex B. Since the SAR phantom is homogenous, using the layers' properties, the worst-case scenario is selected and applied for the phantom properties. Therefore, for the SAR simulations, the phantom that has conductivity of 0.5 and permittivity of 5016 is used. Frequency-dependent properties of Human Tissue materials are included in Appendix: Annex B.

SAR Results:
Two exposure cases were selected for SAR investigation. Considering that the phantom can be in contact with the Watch or Charger, there is a total of four scenarios.

Low-Frequency (LF) Charging Exposure Case (a): Nominal configuration with charging at 326.5 kHz with phantom placed above the receiving unit.
Low-Frequency (LF) Charging Exposure Case (b): Nominal configuration with charging at 326.5 kHz with phantom placed below the transmitting unit.
High-Frequency (HF) Charging Exposure Case (a): Nominal configuration with charging at 1.778 MHz with phantom placed above the receiving unit.
High-Frequency (HF) Charging Exposure Case (b): Nominal configuration with charging at 1.778 MHz with phantom placed below the transmitting unit.

In addition, four unrealistic cases where only the charger is present, and phantom is placed towards and away from Tx charging coil are investigated. It is worth mentioning that these cases do not happen in real-life applications.

Low-Frequency Charging Unrealistic (Theoretical) Exposure Case (a): Unrealistic worst-case with charging at 326.5 kHz with receiving unit absent and phantom placed above the transmitting unit.
Low-Frequency Charging Unrealistic (Theoretical) Exposure Case (b): Unrealistic worst-case with charging at 326.5 kHz with receiving unit absent and phantom placed below the transmitting unit.
High-Frequency Charging Unrealistic (Theoretical) Exposure Case (a): Unrealistic worst-case with charging at 1.778 MHz with receiving unit absent and phantom placed above the transmitting unit.
High-Frequency Charging Unrealistic (Theoretical) Exposure Case (b): Unrealistic worst-case with charging at 1.778 MHz with receiving unit absent and phantom placed below the transmitting unit.

For all the exposure cases, dielectric properties (conductivity and permittivity) used for the phantoms are fixed as (permittivity: 5016, conductivity: 0.5). The coil properties are also fixed. The transmitting coil has 9 turns and measures 2.35 uH nominally in free air. The receiver coil on the client side consists of 6 turns and measures 7.55 uH nominally in free air. Both coils are wound spirally and made of stranded wire.

The following outputs are calculated and reported in the Table:

a. 1g average SAR at maximum electric field location in tissue.
b. Peak sense electric field inside tissue at maximum electric field location, spatially averaged over 2 mm x 2 mm x 2 mm tissue volume

The simulation results for the four realistic exposure cases are listed in table 5 and the unrealistic cases in table 6 below.

	Exposure Case	**Phantom Orientation**	**I_{tx} (A_{rms})**	**I_{rx} (A_{rms})**	**Frequency**	**Peak Spatial Average SAR (W/Kg) (Averaged over 1 gram)**	**SAR Limit (W/Kg)**	**Peak Spatial Average E (V/m) Averaged over 2x2x2 mm^3**
1	Low-Frequency (LF) Charging case (a)	Watch side	0.21	0.11	326.5 kHz	1.94e-8	1.6	1.24e-2
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4	High-Frequency (HF) Charging case (b)	Charger side	0.25	0.20	1.778 MHz	4.44e-7	1.6	0.0564

Table 5. Simulation results for evaluated normal use cases for 1-gram averaged SAR and maximum averaged internal E-field.

Cells marked in "GREEN" values are within limit
Cells marked in "RED" are out of limit

	Exposure Case	Phantom Orientation	I_{tx} (A_{rms})	I_{rx} (A_{rms})	Frequency	Peak Spatial Average SAR (W/Kg) (Averaged over 1 gram)	SAR Limit (W/Kg)	Peak Spatial Average E (V/m) Averaged over 2x2x2 mm^3
5	LF Unrealistic (theoretical) case (a) (No RX)	Charger side towards Tx coil	0.21	N/A	326.5 kHz	1.50e-4	1.6	1.68
6	LF Unrealistic (theoretical) case (b) (No RX)	Charger side away from Tx Coil	0.21	N/A	326.5 kHz	5.88e-8	1.6	1.91e-2
7	HF Unrealistic (theoretical) case (a) (No RX)	Charger side towards Tx coil	0.25	N/A	1.778 MHz	4.39e-3	1.6	9.17
8	HF Unrealistic (theoretical) case (b) (No RX)	Charger side away from Tx Coil	0.25	N/A	1.778 MHz	1.15e-6	1.6	0.0839

Table 6. Simulation results for unrealistic direct exposure cases for 1-gram averaged SAR and maximum averaged internal E-field in tissue.

Cells marked in "GREEN" values are within limit
Cells marked in "RED" are out of limit

SAR plot for the worst-case normal use **case 4** is shown in the figure below. The peak spatial 1-gram average SAR is **4.44e-7 W/kg**.

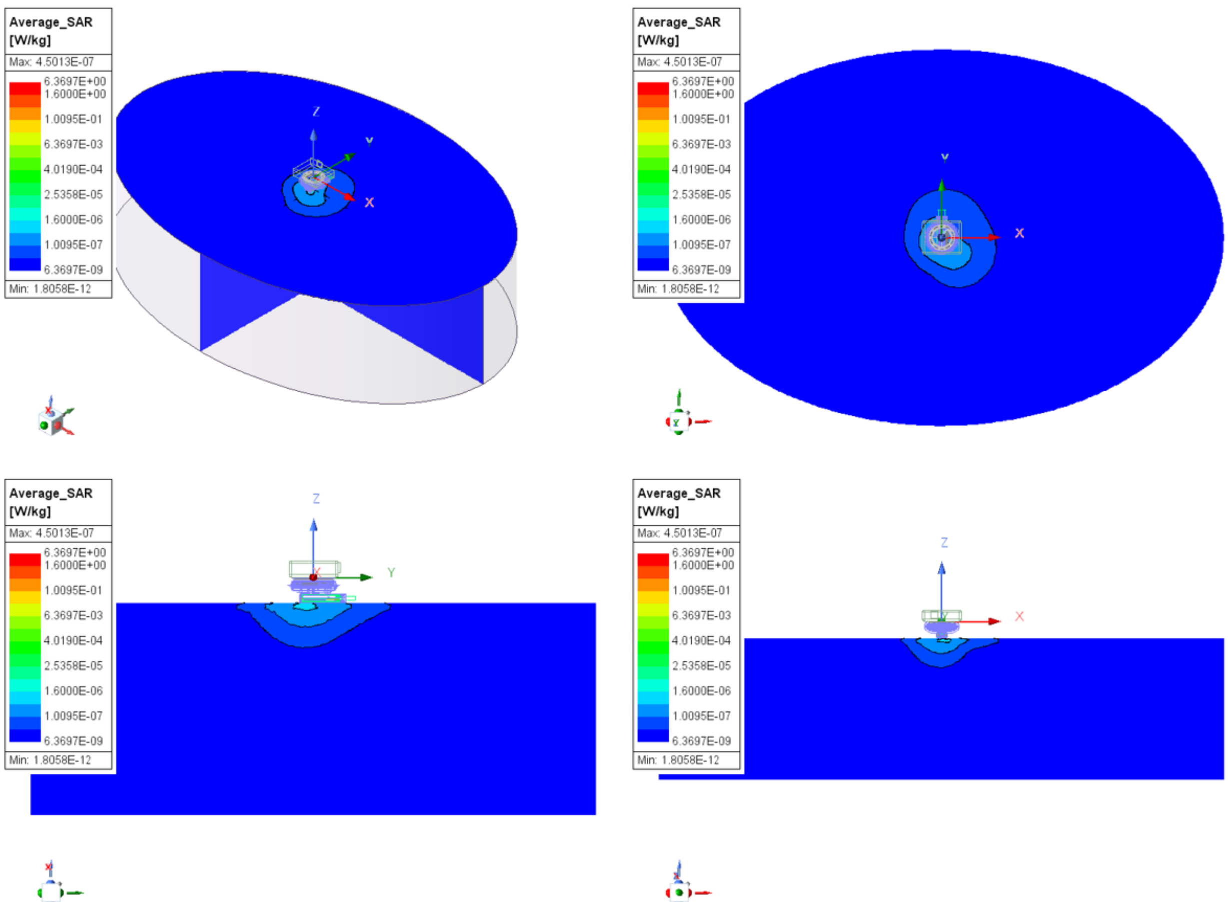


Figure 2: Spatial 1-gram average SAR for worst-case normal use **case 4**. The second number from the top of the plot legend, 1.6 W/Kg, is the maximum threshold value. If red coloration exists, it denotes areas where the threshold has been exceeded.

SAR plot for the worst-case unrealistic **case 7** is shown in the figure below. The peak spatial 1-gram average SAR is **4.39e-3 W/kg**.

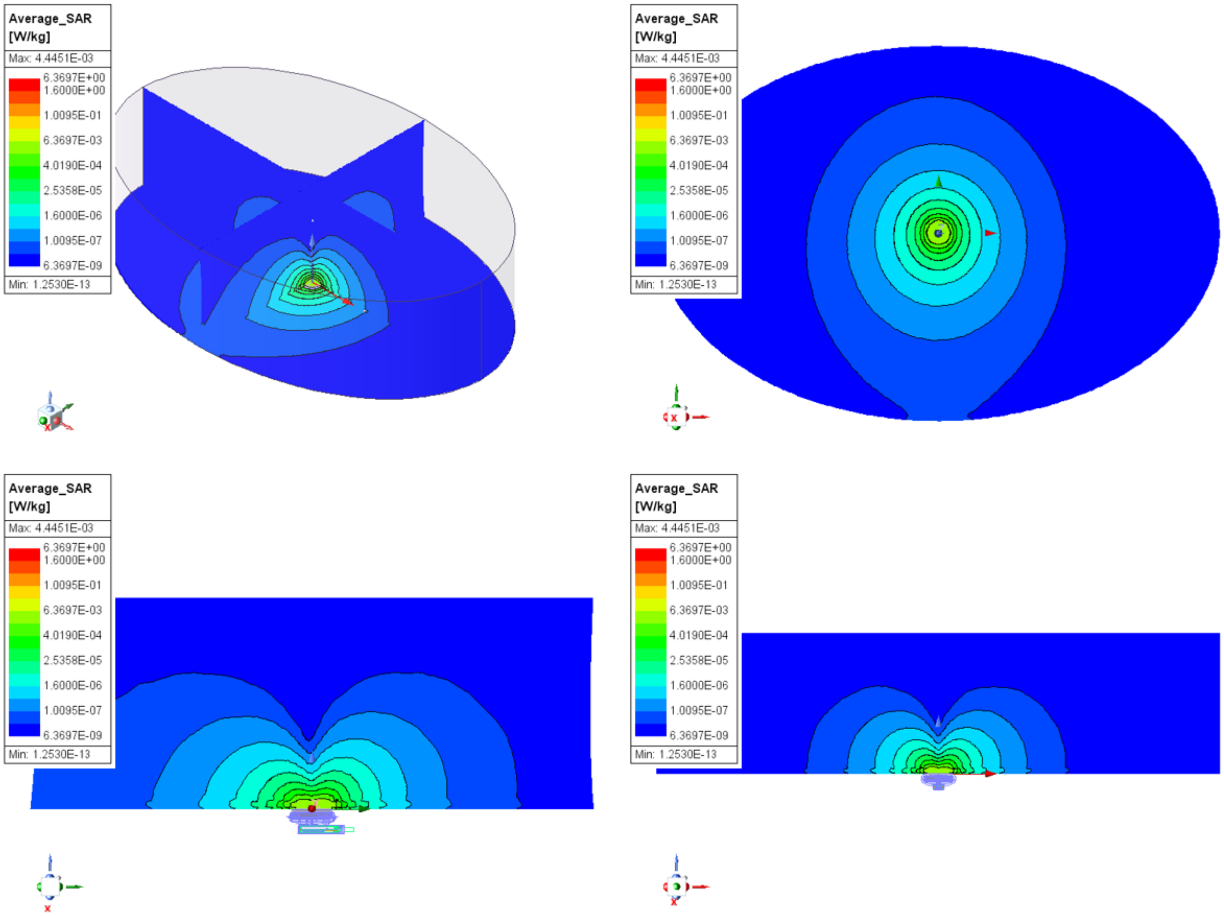


Figure 3: Spatial 1-gram average SAR for the worst-case unrealistic **case 7**. The second number from the top of the plot legend, 1.6 W/Kg, is the maximum threshold value. If red coloration exists, it denotes areas where the threshold has been exceeded.

Moreover, the E-field distribution inside the phantom for the worst-case unrealistic **case 7** is shown in the figure below. Please note that the value reported in the table above was averaged over a cube of 2mm x 2mm x 2mm. The E-field values in Figure 3 are higher

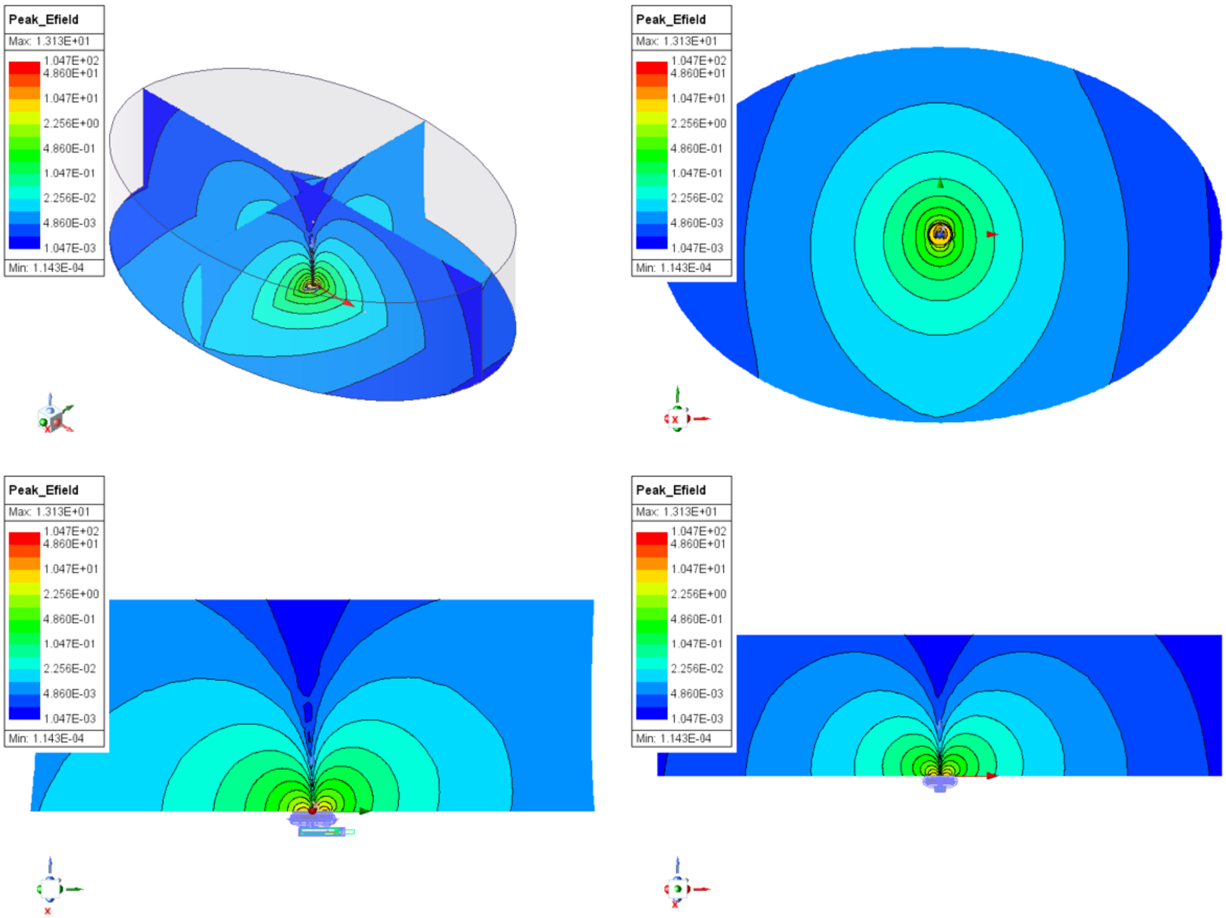


Figure 4: E-field [V/m] (peak sense) inside phantom for the worst-case unrealistic **case 7**.

8 Summary

The accuracy of the SAR simulations is demonstrated by correlating H-field measurements to simulations. The validity of using this modeling and SAR computational method is established. Overall, the SAR is significantly lower than the SAR limit of 1.6 W/Kg (below 0.01% of the actual SAR limit). Also, this low level of SAR value indicates that any contribution of the WPT operation to the overall RF exposure budget for this device when operating close to the body is negligible and does not need to be considered in the SAR / Power Density calculations for assessing simultaneous transmissions. Therefore, we respectfully request that the allowance to use of this model to demonstrate RF Exposure compliance for Apple's proposed WPT products and exclusion of SAR contribution due to WPT from the overall SAR simultaneous transmissions.

9 Annex A: SAR Computational Modelling

1) Computation Resources

The models were simulated using 5 cores each on a server with an available RAM of 768GB. Each model variation took approximately 2-3 hours to complete, each using 70GB-140GB RAM.

2) Algorithm Implementation and Validation

Please refer to the simulation methodology report from Apple for the below two sections:
i) Code performance validation of finite-element algorithm in HFSS.
ii) Comparison of finite-element algorithm used by HFSS with canonical benchmarks.

3) Computational Peak SAR from Peak Components & 1-g Averaged SAR Procedure

The calculation method for SAR follows IEEE P1528.4. Once the solver calculated the S-Parameter results, different coils can be driven and the result from the S-Parameter calculation is automatically scaled to the driving current of the coils. This result combination provides the correctly scaled power loss density in the phantom. The SAR calculation computes the local SAR first using electric field and conducting current:

$$SAR = \vec{E} \bullet \vec{J}_{conj}/(2\rho)$$

Afterwards the local SAR is averaged over a specific mass, usually 1g or 10g. As described in [IEEE P1528.4] the mass averaging is done by mapping the results to a structured hexahedral grid and afterwards the averaging scheme for FDTD per [IEEE P1528.4] is applied. The SAR calculation on the hexahedral grid is compliant with IEC 62704-1.

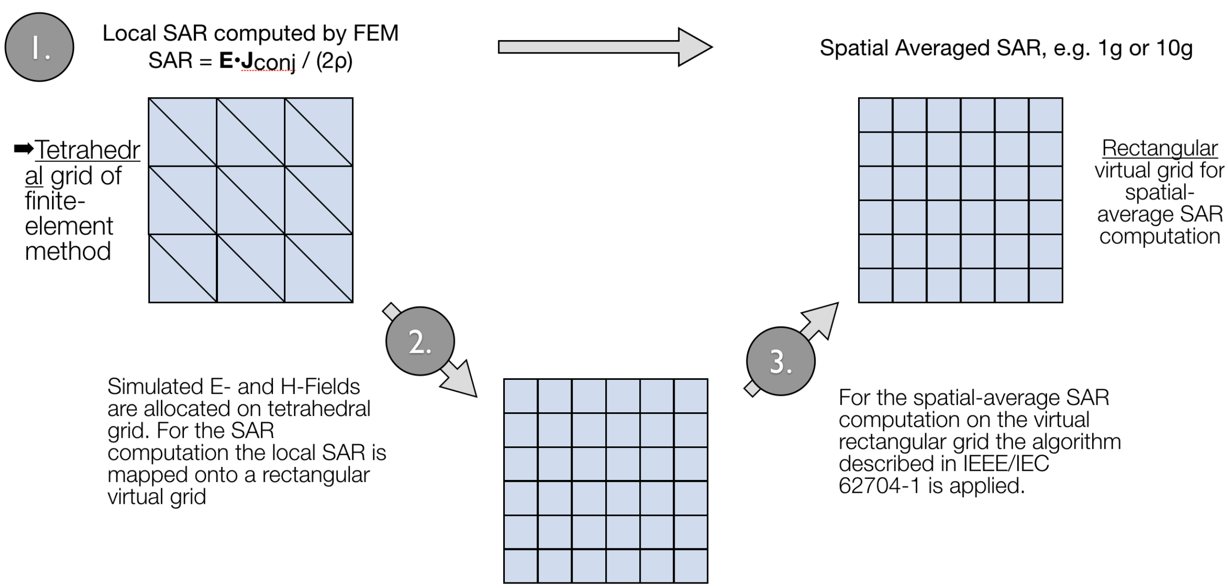


Figure 5:IEEE P1528.4 SAR Computation

4) Total Computational Uncertainty

The expanded ($k = 2$) uncertainty result as per the IEC/IEEE 62704-1/-4 is 20.4, which is lower than the limit of 30. This number is provided by Apple based on their studies on the Watch Charger WPT model simulation vs. measurements. For detailed analysis, please refer to the simulation methodology report from Apple.

10 Annex B: Human Tissue Modeling

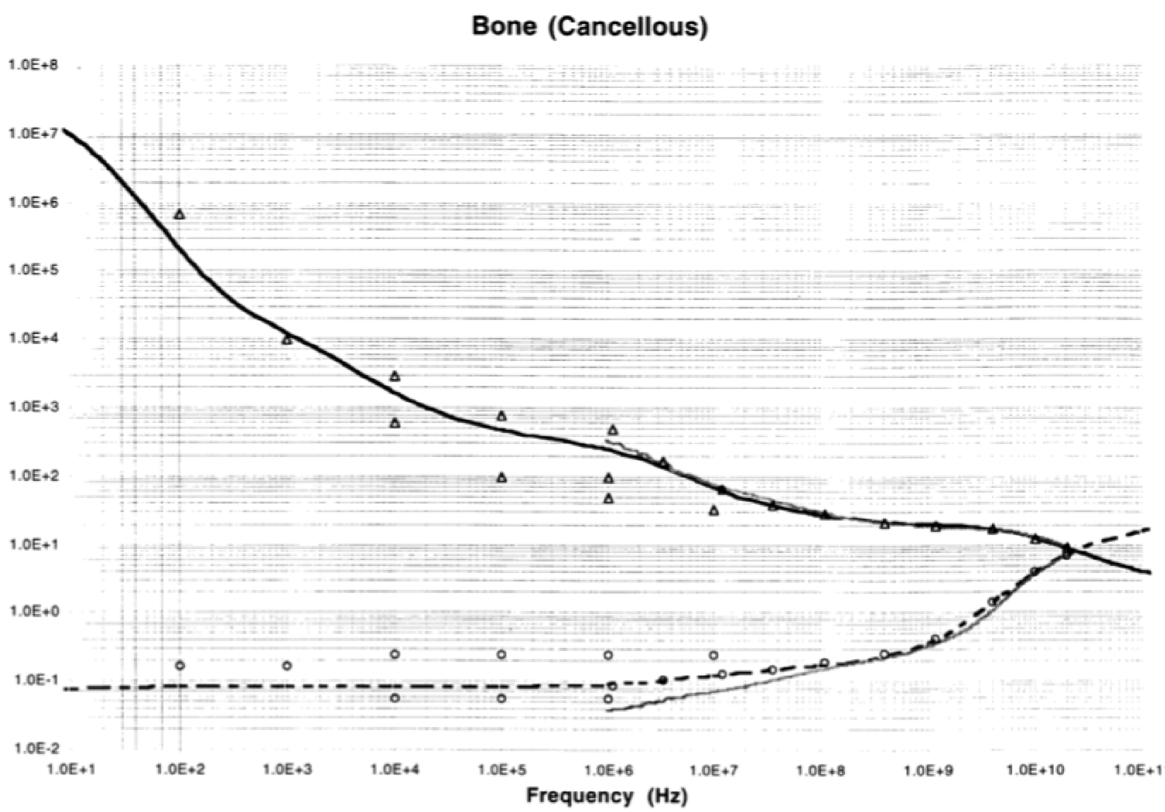
Human Tissue Material Properties at 326.5 kHz and 1.778 MHz:
The worst-case scenario has been identified to be when a user is holding the device in hand or holding the charger on their body while charging. The electrical properties for body and hand layers are shown below. Since the SAR phantom is homogenous, using the layers' properties, the worst-case scenario is selected and applied for the phantom properties. Therefore, for the SAR simulations, the phantom that has conductivity of 0.5 and permittivity of 5016 at the 360 kHz operating frequency is used. In addition, mass density of 1000 Kg/m^3 was used.

Electrical Properties:

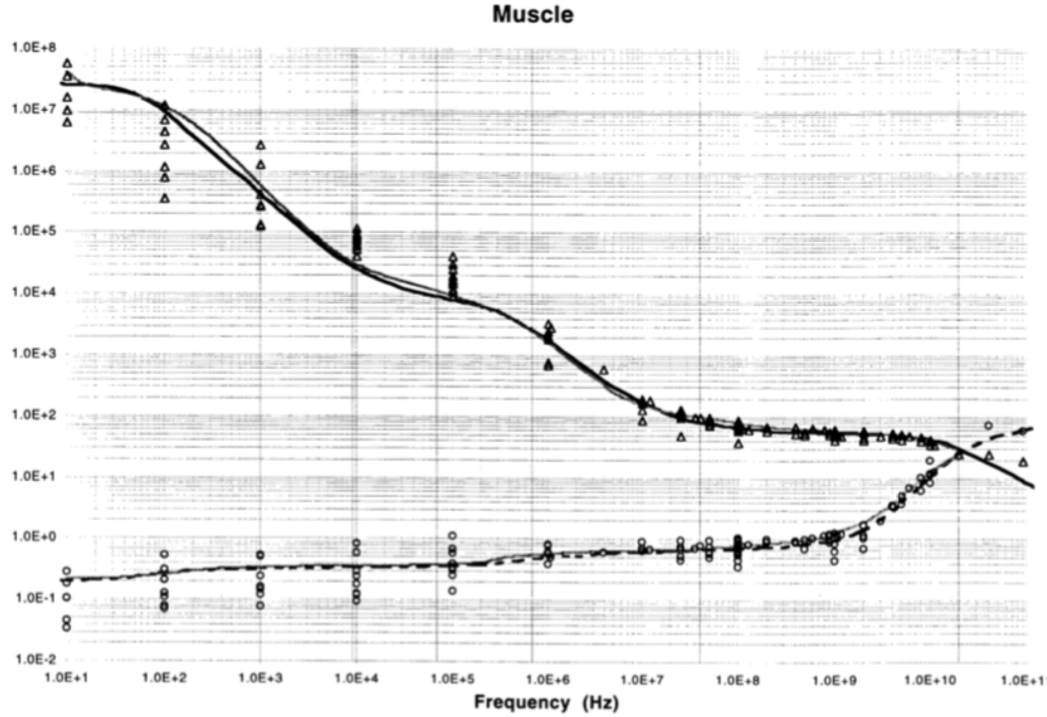
Based on our research below are ε_r and σ values shown in Table 5 are used for body & hand layers [2-5]:

	Tissue	Thickness in Hand (mm)	Thickness in Body (mm)	Permittivity	Conductivity (S/m)
1	Skin	2	3	5016	0.16
2	Muscle	2	9	4666	0.5
3	Bone	15	20	1414	0.165
4	Worst case	100	100	5016	0.5

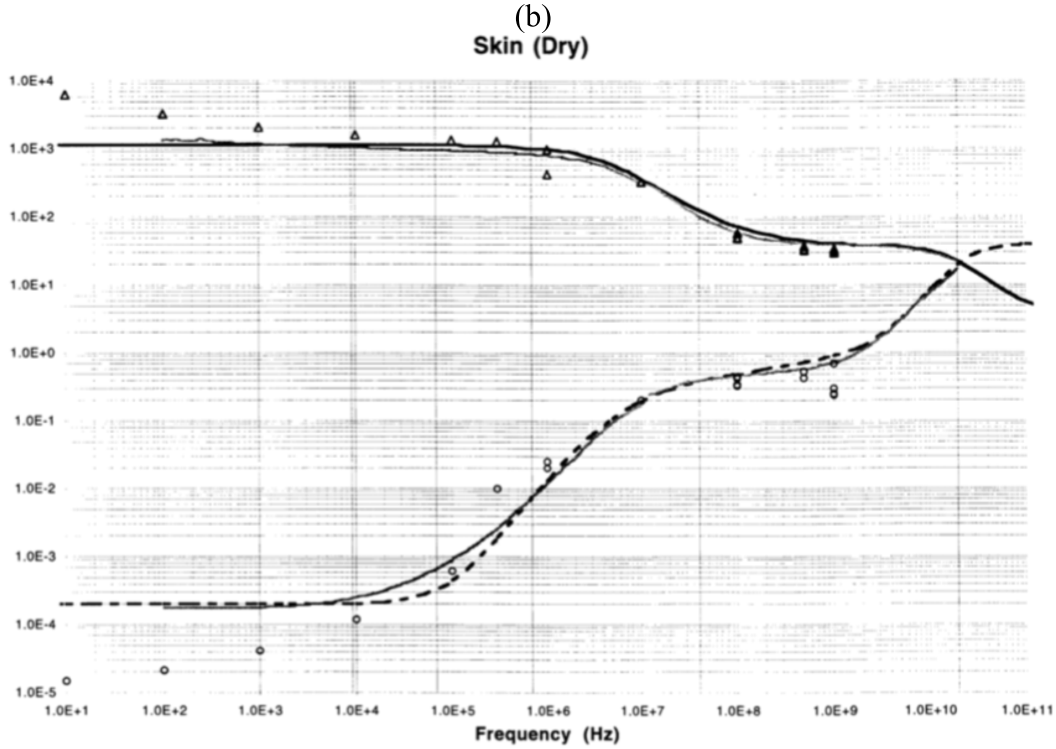
Table 7.Electrical properties for body & hand layers.



(a)



(b)



(c)

Figure 6: Electrical properties (over a frequency range) of (a) Bone, (b) Muscle, and (c) Dry Skin.

11 Annex C: Simulation Model Validation

Introduction

This report describes the procedure used to validate the simulation model provided by Apple to make sure that the simulation setup with the Watch Charger WPT model is consistent with Apple's simulation model. To perform this, we compare the Electric (E) and Magnetic (H) field simulation results on two planes 2 mm away from Tx and Rx with the E and H field results provided by Apple. Workflow is described in the figure below

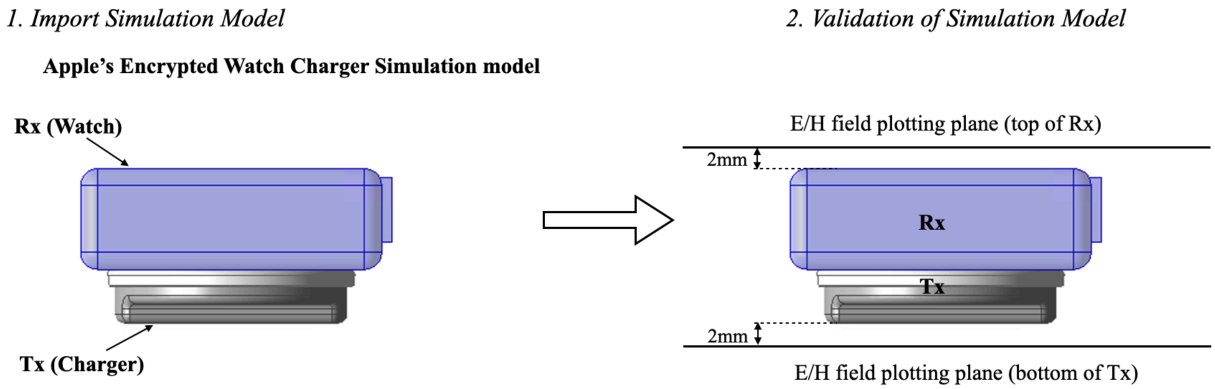


Figure 7: Steps to verify Apple simulation model

Model Validation Methodology for Computational Exposure Assessment

In this section, before performing any SAR/E-field simulations we verify the Apple Watch Charger WPT simulation model setup. For this study, comparison between E and H fields for a baseline setup will be performed to compare the Watch Charger WPT model vs. Apple's simulation model setup.

Electromagnetics simulations are conducted using commercially available software ANSYS HFSS. In order to validate the Watch Charger WPT simulation model setup, E and H field for the two exposure cases are compared to the E and H field simulation results from Apple's simulation setup. These two cases are associated with (i) Low-Frequency Charging case and, (ii) High-Frequency Charging case. Initial verification step is to make sure that the simulation setup with the Watch Charger WPT model is consistent with Apple's simulation model. After validation is performed, the encrypted simulation model will be used for SAR simulations.

Comparison between the Apple's simulation model and Watch Charger WPT simulation model are shown in the following figures.

H-field Comparison for Low Frequency Charging case at 326.5 kHz

Comparison of the H-field plots for low frequency charging case at 326.5 kHz between Apple's simulation model and Watch Charger WPT simulation mode are shown below.

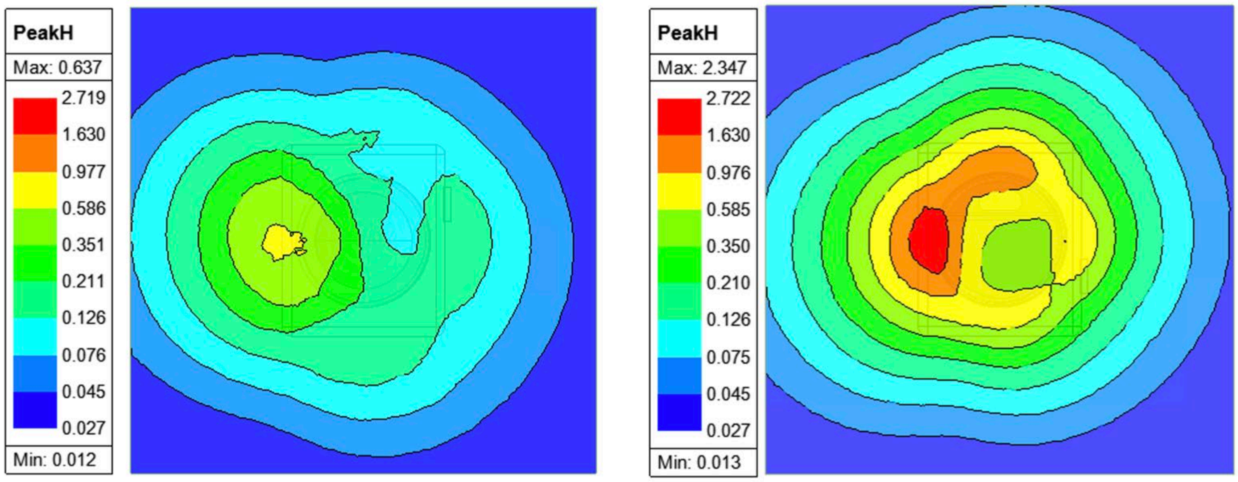


Figure 8: H-field on the two planes from Apple's simulation model at 326.5 kHz

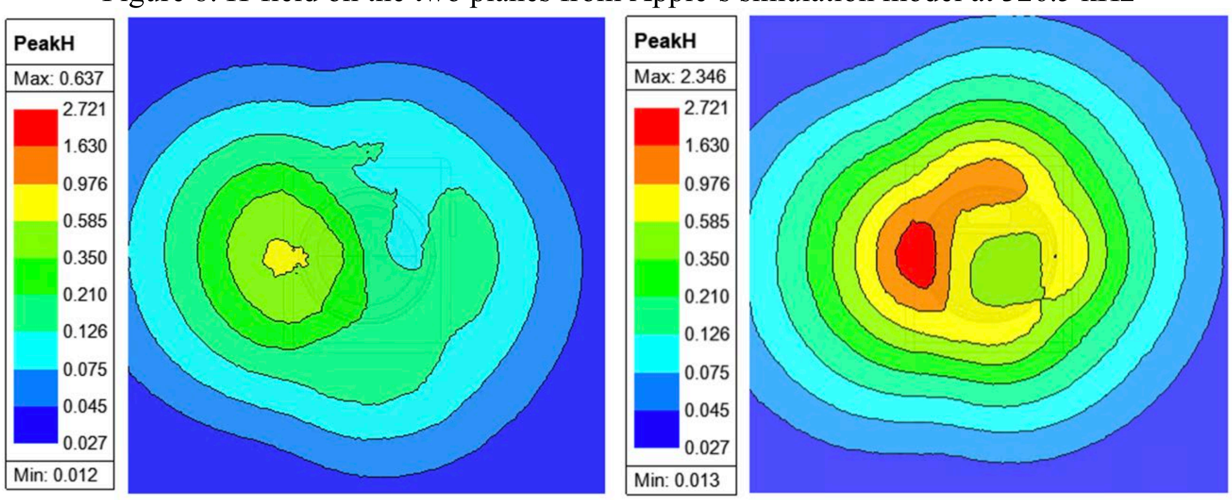


Figure 9: H-field on the two planes from WPT Charger WPT simulation model at 326.5 kHz

From the above Peak H-field plots legend, the second number from the top of the plot legend, 1.63 A/m, is the maximum threshold value. Red coloration denotes areas where the threshold has been exceeded.

Comparison of the field plots is also done by computing the delta between the field plot values exported along the plotting planes on a point-by-point basis. The maximum difference for all locations is 1.7 %.

E-field Comparison for Low Frequency Charging case at 326.5 kHz

Comparison of the E-field plots for low frequency charging case at 326.5 kHz between Apple's simulation model and Watch Charger WPT simulation mode are shown below.

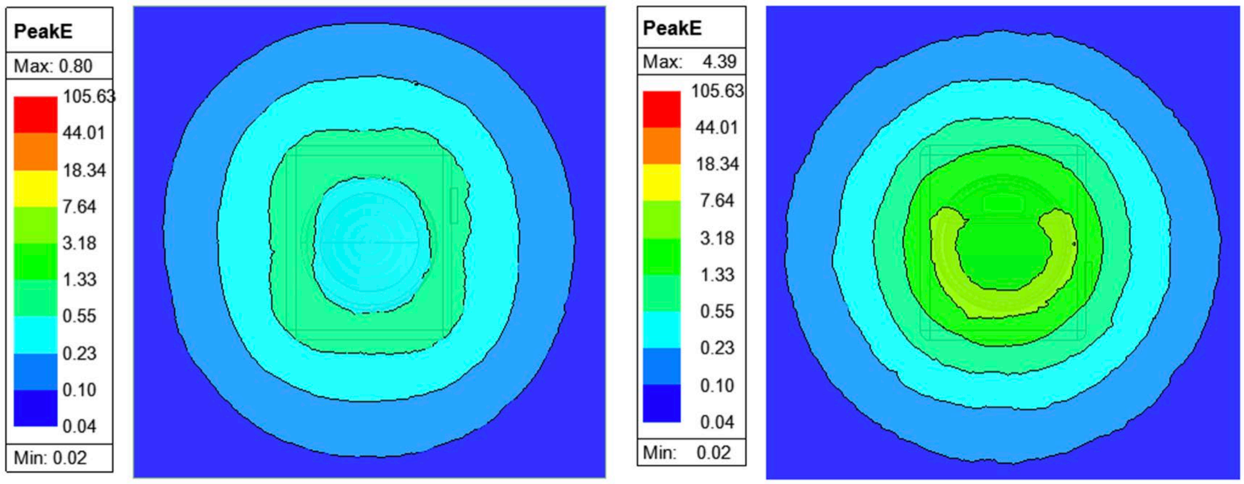


Figure 10: E-field on the two planes from Apple's simulation model at 326.5 kHz

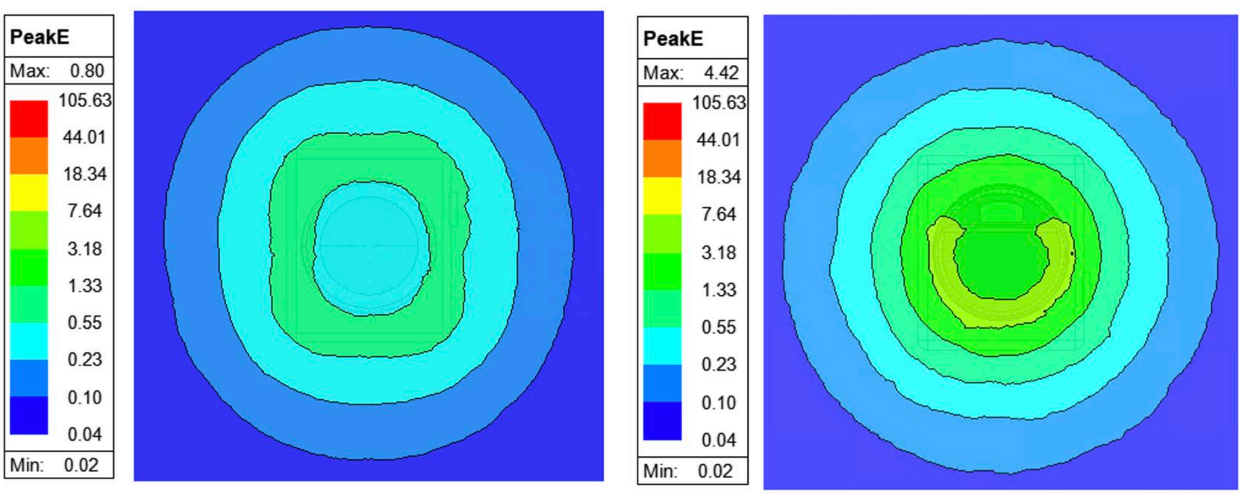


Figure 11: E-field on the two planes from WPT Charger WPT simulation model at 326.5 kHz

Comparison of the field plots is also done by computing the delta between the field plot values exported along the plotting planes on a point-by-point basis. The maximum difference for all locations is 2.6%.

H-field Comparison for High Frequency Charging case at 1.778 MHz

Comparison of the H-field plots for high frequency charging case at 1.778 MHz between Apple's simulation model and Watch Charger WPT simulation mode are shown below.

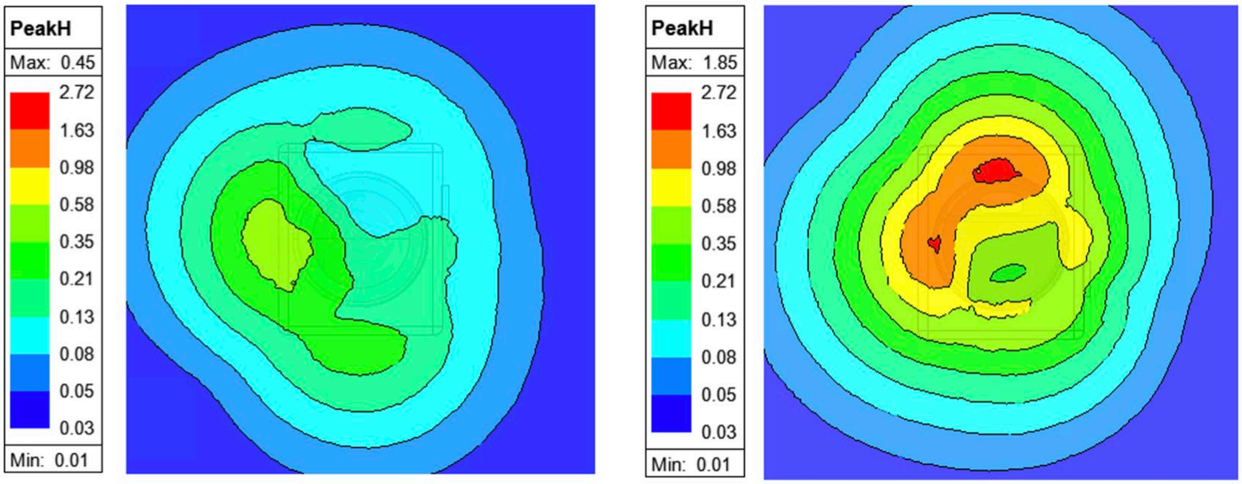


Figure 12: H-field on the two planes from Apple's simulation model at 1.778 MHz

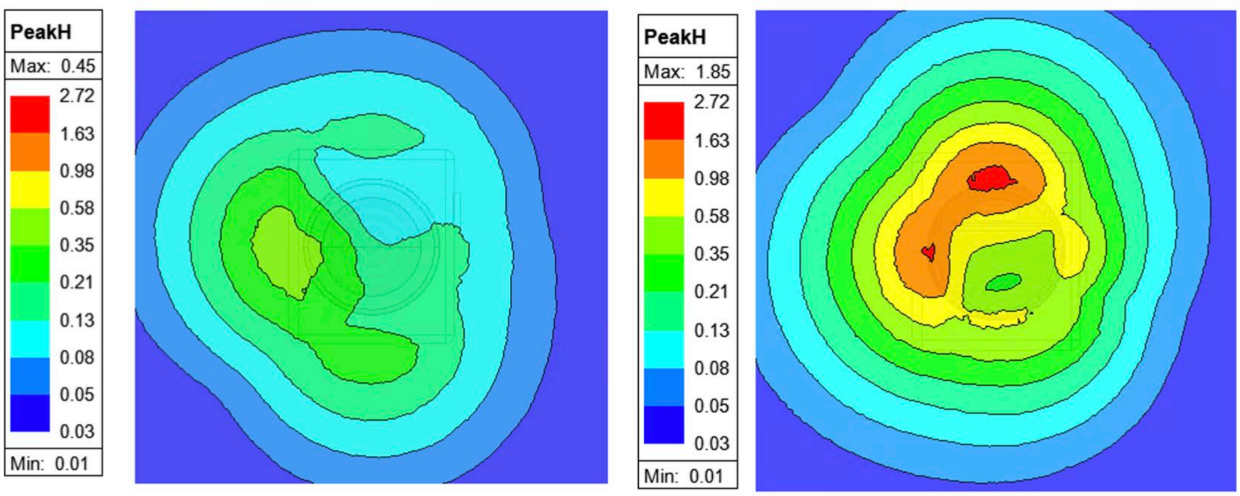


Figure 13: H-field on the two planes from WPT Charger WPT simulation model at 1.778 MHz

From the above Peak H-field plots legend, the second number from the top of the plot legend, 1.63 A/m, is the maximum threshold value. Red coloration denotes areas where the threshold has been exceeded.

Comparison of the field plots is also done by computing the delta between the field plot values exported along the plotting planes on a point-by-point basis. The maximum difference for all locations is 1.9%.

E-field Comparison for High Frequency Charging case at 1.778 MHz

Comparison of the E-field plots for high frequency charging case at 1.778 MHz between Apple's simulation model and Watch Charger WPT simulation mode are shown below.

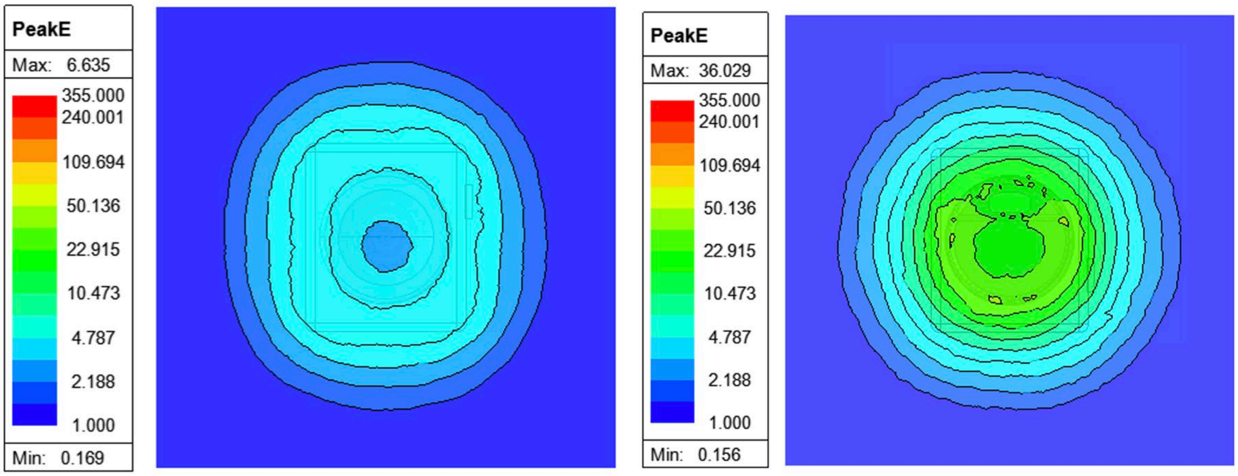


Figure 14: E-field on the two planes from Apple's simulation model at 1.778 MHz

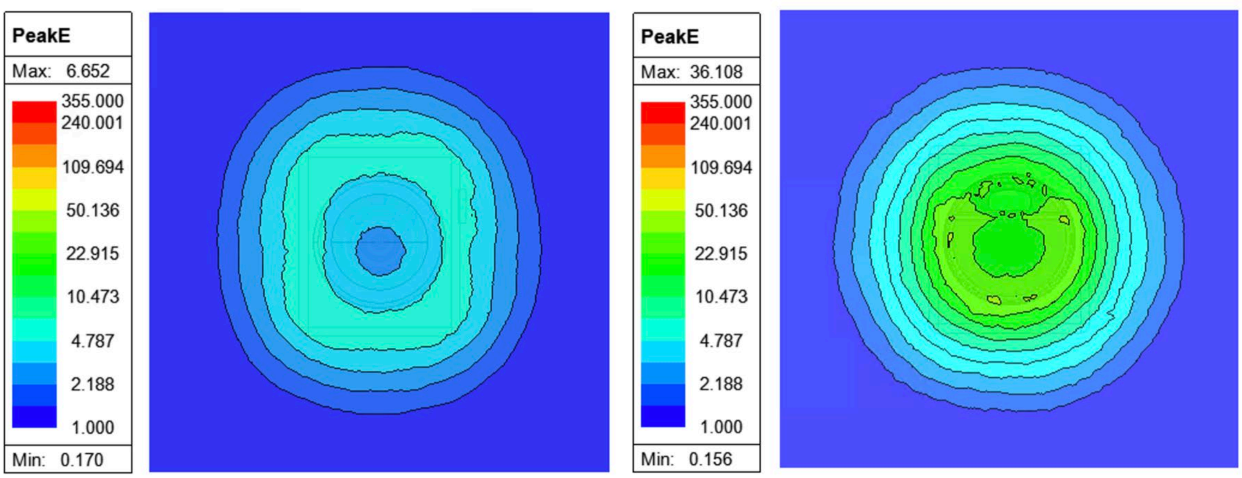


Figure 15: E-field on the two planes from WPT Charger WPT simulation model at 1.778 MHz

Comparison of the field plots is also done by computing the delta between the field plot values exported along the plotting planes on a point-by-point basis. The maximum difference for all locations is 2.7%.

Simulation Model Validation Conclusion

The maximum difference for all fields, cases, and locations is 2.7 %. Good agreement is seen between Apple's simulation model and the Watch Charger WPT model, and the Watch Charger WPT simulation model can be used for performing SAR calculations.

References:

1) The electrical conductivity of human cerebrospinal fluid at body temperature, S.B. Baumann ; D.R. Wozny ; S.K. Kelly ; F.M. Meno, IEEE Transactions on Biomedical Engineering (Volume: 44 , Issue: 3 , March 1997)
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