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Project Details

Project request id : 2022-10-17_12_55_Belkin

Project Name : BoostCharge™ Pro Wireless Car Charger With MagSafe 15W

Project Creation Date : 18 Oct 2022

Name of the customer : Belkin International, Inc.

Executive Summary

Project Name:	BoostCharge™ Pro Wireless Car Charger With MagSafe 15W
Name of the customer:	Belkin International, Inc.
Equipment Under Test (EUT)	
Model Name:	WIC008
Puck type:	MFI618-00021
Receipt Date:	18 Oct 2022
Test Date:	19 Oct 2022
Issue Date:	19 Oct 2022
FCC ID:	K7SWIC008
Conclusions:	**PASS** The sample of the above-mentioned product in accordance with the provisions of the relevant specific standards and directives.

Description:

The EUT, BoostCharge™ Pro Wireless Car Charger With MagSafe 15W, is a single charging coil capable of charging one client device at a time. The coil is used for charging a MagSafe iPhone at 360kHz (15W). The EUT is intended to be mounted to a vehicle's air conditioning vent and intended to only be used hands-free. When installed and mounted in the vehicle, it will never be used near any portion of the head or body

This report details the results of the simulation carried out on mentioned EUT. The results contained in this report do not relate to other other models/designs of the same product.

SAR Compliance Simulation Report for WPT Charger

Model:WIC008
FCC ID: K7SWIC008

Vendor Name:
Belkin International, Inc.

Date of Simulation:
19 Oct 2022 - 20 Oct 2022
Location:
California, USA

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1. A Brief Summary of Assessment Results

The wireless power transfer (WPT) device is designed to charge Apple phone through closely coupled inductive field at 360 kHz. The evaluation of the SAR and E-field induced inside the phantom is the main purpose of this report. The results for different scenarios where the charger and the phone are held in different positions relative to each other and relative to the phantom, is summarized in the Table, below.

	Exposure Case	Phantom Orientation	Frequency (kHz)	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	Optimal Placement (Max Coupling)	Phone side	360	**9.99e-07**	1.6	0.0986
2	Optimal Placement (Max Coupling)	Charger side	360	**1.82e-07**	1.6	0.0276
3	Maximum Offset x = z = 5mm	Phone side	360	**8.83e-06**	1.6	0.399
4	Maximum Offset x = z = 5mm	Charger side	360	**1.1e-05**	1.6	0.143
5	Unrealistic (theoretical) Case (a) (No RX)	Charger side towards Tx coil	360	**0.167**	1.6	25.1
6	Unrealistic (theoretical) Case (b) (No RX)	Charger side away from Tx coil	360	**1.37e-05**	1.6	0.153

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

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

For the normal use cases (cases 1-4 in Table 1), the highest 1g averaged SAR of 1.1e-05 W/kg occurs when there is maximum offset with phantom on the charger side, and the highest peak spatial average E-field of 0.399 V/m occurs for maximum offset with phantom on the phone side. For the unrealistic (theoretical) cases (cases 5-6 in Table 1), the highest 1g averaged SAR of 0.167 W/kg occurs for Unrealistic Case (a), and the highest peak spatial average E-field of 25.108 V/m occurs for Unrealistic Case (a).

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 is provided in the following sections.

2. Introduction

This report demonstrates RF exposure compliance, using SAR and internal E-field simulations, for the new WPT (Wireless Power Transfer) MagSafe Charger module introduced by Apple. The new WPT MagSafe Charger module operates at 360 kHz. The new module is being integrated in a housing that was designed by Belkin International, Inc.. The Apple MagSafe model is combined with Belkin's housing design to show compliance for SAR using EM simulations.

Apple introduced an ecosystem of wireless charging products, including several usable in portable applications. The initial product is a WPT transmitter installed in a small charging pod with magnets to secure the charger to the client. The charging session only occurs with the host (i.e., WPT source) connected to an AC power outlet. However, due to the charger being held in place by magnets, it is expected that customers may use the charging function in portable use conditions; charging the phone while making a call, or texting. Additional products will support true portable use, with the host-client pair able to be placed in a pocket or backpack.

At 360 kHz operating frequency, Apple has found that in portable exposure conditions the near-field H-field strength may exceed the 1.63 A/m limit defined in §1.1310. Therefore, as permitted by §2.1093(d)(3) and Paragraph 3.d) of KDB 680106 D01, we use SAR numerical modeling to demonstrate compliance to the 1.6 W/kg localized 1-g SAR limit, due to the unavailability of SAR measurement tools and procedures.

Applying the SAR limit is also justified because:

1. The §1.1310 limits are intended for mobile whole-body exposure condition, and are therefore far too stringent for local exposure conditions. In contrast, the §2.1093 local exposure limit is 20 times the whole-body SAR limit, and extremity exposure (held-in-hand) limit is 50 times higher.
2. The current H-filed limits specified in international standards (IEEE and ICNIRP) are much higher than 1.63 A/m at 360 kHz.

Apple's MagSafe simulation model includes a single primary source coil (Tx) and a secondary client coil (Rx), which allows for wireless power transfer between one source and one client at any given time. This simulation model can only be used to demonstrate SAR compliance for iPhone wireless charger modules at 360 kHz. Maximum output power supported is up to 15W. The MagSafe simulation model supports only Portable case SAR simulations: 0 mm spacing between DUT and phantom in all scenarios mimicking on-body use case, therefore the worst case is being considered compared to other SAR scenarios such as head, extremities, and desktop case which will have lower SAR values.

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

3. EUT Description

The EUT, BoostCharge™ Pro Wireless Car Charger With MagSafe 15W, is a single charging coil capable of charging one client device at a time. The coil is used for charging a MagSafe iPhone at 360kHz (15W). The EUT is intended to be mounted to a vehicle’s air conditioning vent and intended to only be used hands-free. When installed and mounted in the vehicle, it will never be used near any portion of the head or body

4. Wireless Power Transfer System

The wireless power transfer system consists of a transmitting coil with 11 turns and measures 7.5 uH nominally in free air. The receiver coil consists of 13 turns and measures 9.06 uH nominally in free air. Both coils are wound spirally.

Below are key parameters of the design that will be helpful in determining worst-case use for exposure:

Item	Description
Max Power Delivered	15 W (delivered at rectifier)
Full Charge Time	3 hours 10 minutes (from empty)
Operating Frequency	f_0 = 360 kHz
Communications/Modulation Method	ASK for Phone to Charger (load modulation) FSK for Charger to Phone

Table 2. Key design parameters.

5. SAR Simulations Methodology

The simulation methodology is based on the guidance provided by Apple. Please refer to the confidential report "SAR Simulation Tool for Developers Using Apple WPT MagSafe Charger 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 MagSafe model is consistent with Apple's simulation model. Please refer to Annex C: Simulation Model Validation for detailed analysis on validation of MagSafe simulation model.

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

7. SAR Simulations

The verified simulation model is then used for SAR calculations with a phantom added in contact with the DUT along with accessories integrating the MagSafe Charger module.

As a next step, additional geometries were added to the MagSafe simulation model along with the Phantom to perform the SAR computational assessment. The below tables list the material properties and their assignments.

	Material	Relative Permittivity (ε_r)	Loss Tangent	Relative Permeability (μ_r)	Magnetic Loss Tangent	Conductivity (S/m)
1	lexan141r	2.96	0.01	1	0	0
2	TPE75A	4.42	0.035	1	0	0
3	PSAFoam	3.3	0.212	1	0	0
4	PCgf10	3.2	0.009	1	0	0
5	si50	2.83	0.0011	1	0	0
6	steel	1	0	1	0	2000000
7	magnet	1	0	1	0	667000

Table 3.Material Properties of the additional housing geometries.

	Object Name	Material Name
1	b0000133971	steel
2	b0000133972	magnet
3	b0000140584	lexan141r
4	b0000142681	TPE75A
5	b0000143264	lexan141r
6	b0000143347	PSAFoam
7	b00001339341	PCgf10
8	b00001339342	si50
9	hw00000304	steel
10	hw00000304_1	steel
11	hw00005000	steel
12	hw00005000_1	steel
13	hw00005000_2	steel
14	hw00005000_3	steel
15	hw00005000_4	steel

	Object Name	Material Name
16	hw00005000_5	steel
17	hw00006000	steel

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 tissue.
Here, a mass density of 1000 Kg/m^3 is used for the modeling and the simulation of the phantom.

Human Tissue Material Properties at 360 kHz:
The worst-case scenario has been identified to be when a user is holding the device in hand and taking a call or holding the phone 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 at the 360 kHz operating frequency 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 phone or charger, there is a total of four scenarios.

Exposure Case 000 (a): Nominal configuration with perfect alignment and phantom placed above the receiving unit.
Exposure Case 000(b): Nominal configuration with perfect alignment and phantom placed below the transmitting unit.
Exposure Case 505 (a): Misaligned configuration with the worst-case alignment and phantom placed above the receiving unit.
Exposure Case 505 (b): Misaligned configuration with the worst-case alignment and phantom placed below the transmitting unit.

In addition, two unrealistic cases where the charger is in direct contact with the phantom are investigated. Worth mentioning that these cases do not happen in real-life applications.

Unrealistic (Theoretical) Exposure Case 1(a): Unrealistic worst-case configuration with receiving unit absent and phantom placed above the transmitting unit.
Unrealistic (Theoretical) Exposure Case 1(b): Unrealistic worst-case configuration 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, transmitting coil with 11 turns and measures 7.5 uH nominally in free air. The receiver coil consists of 13 turns and measures 9.06 uH nominally in free air. Both coils are wound spirally. The following outputs are calculated and reported in the Table:
a. Peak spatial 1-g average SAR in tissue.
b. Peak spatially averaged electric field in tissue. Electric field is spatially averaged in a contiguous tissue volume of 2 mm x 2 mm x 2 mm.

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

	Exposure Case	Description	Phantom Orientation	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	Case 000 (a)	Optimal Placement (Max Coupling)	Phone side	**9.99e-07**	1.6	0.0986
2	Case 000 (b)	Optimal Placement (Max Coupling)	Charger side	**1.82e-07**	1.6	0.0276
3	Case 505 (a)	Maximum Offset x = z = 5mm	Phone side	**8.83e-06**	1.6	0.399
4	Case 505 (b)	Maximum Offset x = z = 5mm	Charger side	**1.1e-05**	1.6	0.143

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" values are out of limit.

	Description	Phantom Orientation	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	Unrealistic (theoretical) Case (a) (No RX)	Charger side towards Tx coil	**0.167**	1.6	25.1
2	Unrealistic (theoretical) Case (b) (No RX)	Charger side away from Tx coil	**1.37e-05**	1.6	0.153

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

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

SAR plot for the worst-case normal use case (maximum offset with phantom on the charger side) is shown in the figure below. The peak spatial 1-gram average SAR is 1.1e-05 W/kg

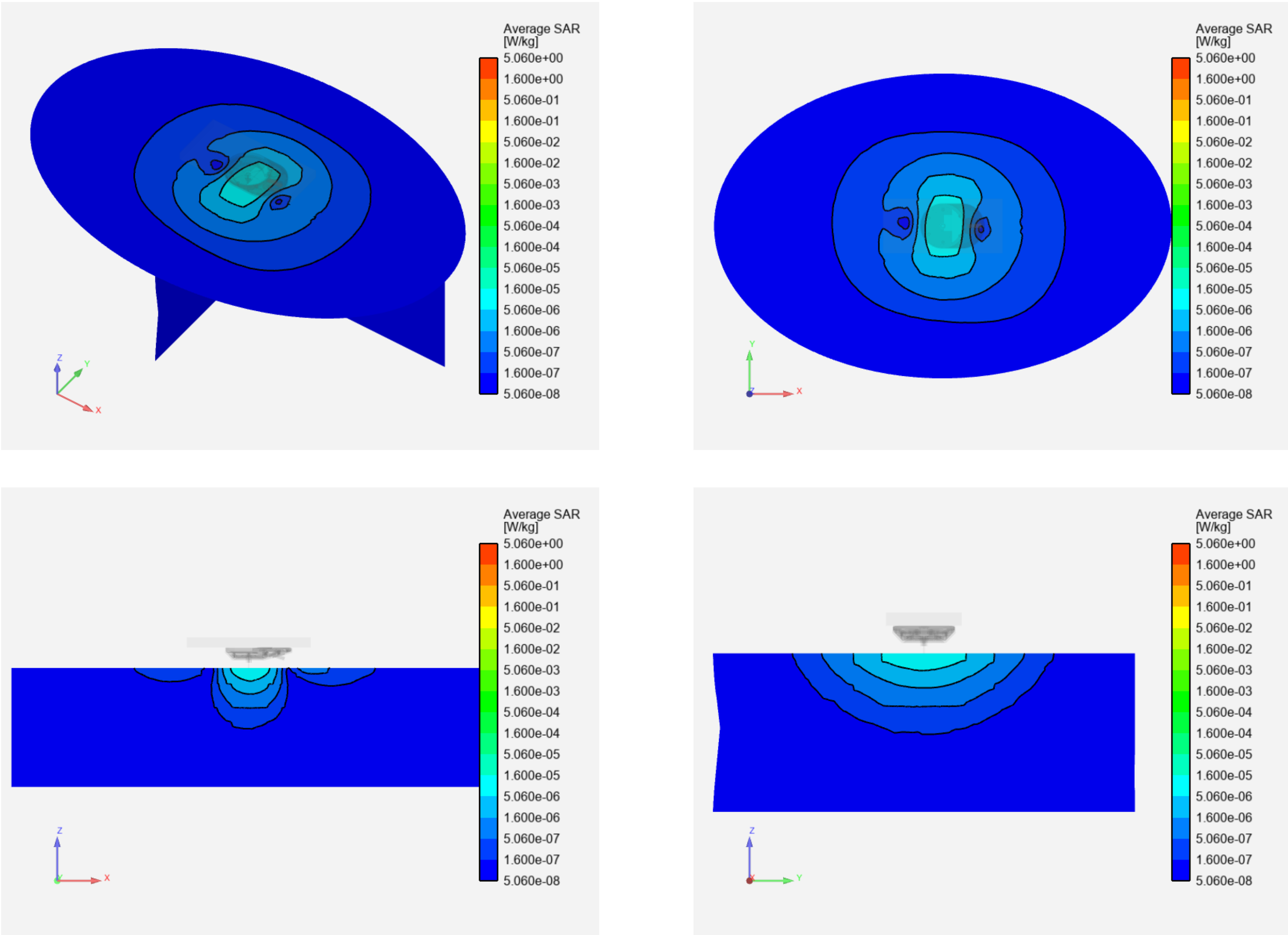

Figure 1: Spatial 1-gram average SAR for worst-case normal use case. The second number from the top of the plot legend, 1.6 W/kg, is the maximum threshold value. Red coloration denotes areas where the threshold has been exceeded.

SAR plot for the worst-case unrealistic case (Unrealistic Case (a)) is shown in the figure below. The peak spatial 1-gram average SAR is 0.167 W/kg:

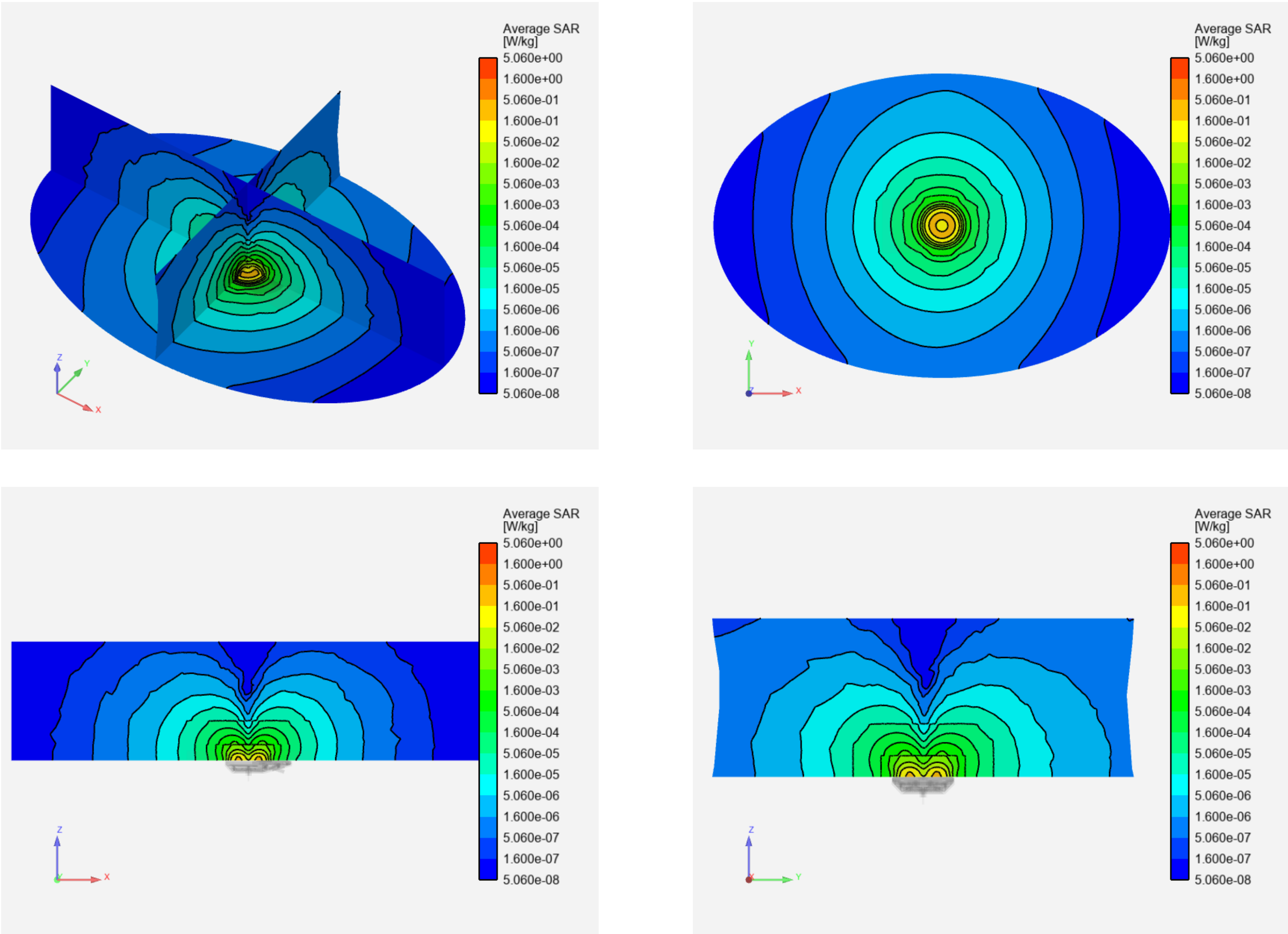

Figure 2: Spatial 1-gram average SAR for the worst-case unrealistic case. The second number from the top of the plot legend, 1.6 W/kg, is the maximum threshold value. Red coloration denotes areas where the threshold has been exceeded.

Moreover, the E-field distribution inside the phantom for the worst-case unrealistic case (Unrealistic Case (a)) is shown below. Please note that the value reported in the table above was averaged over a cube of 2mmx2mmx2mm and that explains why the value is lower than the peak E-field in this plot.

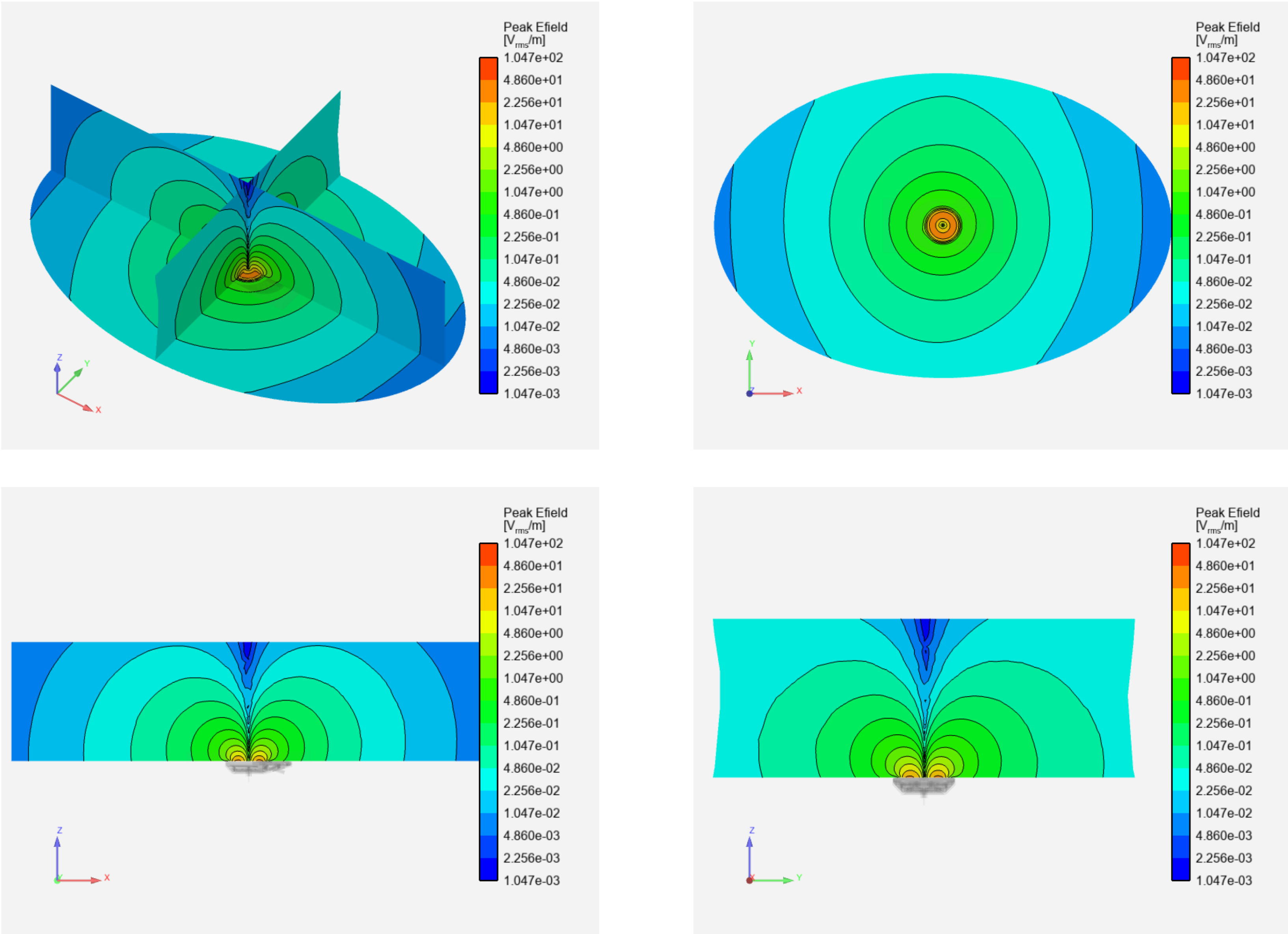

Figure 3: Peak values for E-field spatial distribution inside phantom for the worst-case unrealistic case

8. Summary

Based upon the above results, the accuracy of the MagSafe simulation model is demonstrated by correlating the H-field simulation results with Apple's simulation model. Please refer to Appendix: Annex C for detailed analysis. The validity of using this modeling and SAR computational method hence is established.

For the normal use cases, the highest 1g averaged SAR of 1.1e-05 W/kg occurs for maximum offset with phantom on the charger side, and the highest peak spatial average E-field of 0.399 V/m occurs for maximum offset with phantom on the phone side. For the unrealistic (theoretical) cases, the highest 1g averaged SAR of 0.167 W/kg occurs for Unrealistic Case (a), and the highest peak spatial average E-field of 25.108 V/m occurs for Unrealistic Case (a).

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

9. Annex A: SAR Computational Modelling

1) Computation Resources

The models were simulated using 32 cores on a server with an available RAM of 325 GB. Each model variation took approximately 1 hours to complete.

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.

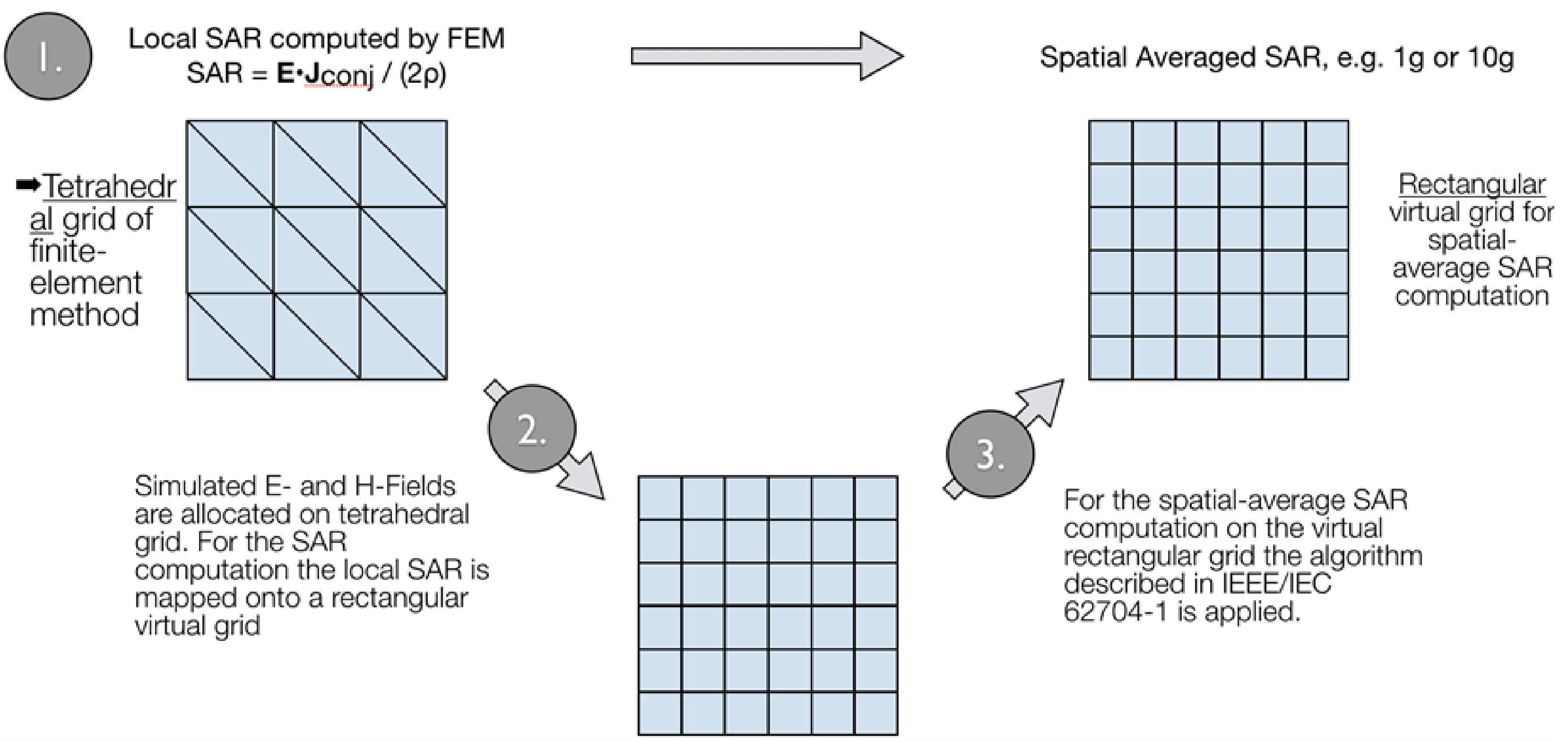

Figure 4: IEEE P1528.4 SAR Computation.

4) Total Computational Uncertainty

The expanded (k = 2) uncertainty result as per the IEC/IEEE 62704-1/-4 is 12.44, which is lower than the limit of 30. This number is provided by Apple based on their studies on the MagSafe 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 360 kHz:
The worst-case scenario has been identified to be when a user is holding the device in hand and taking a call or holding the phone 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 and σ values shown in Table 7 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	0.160
2	Muscle	2	9	4666	0.500
3	Bone	15	20	1414	0.165
4	Worst case	100	100	5016	0.500

Table 7. Electrical properties for body & hand layers

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 MagSafe 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 16mm away from Tx and Rx with the H and E field results provided by Apple. Workflow is described in the figure below.

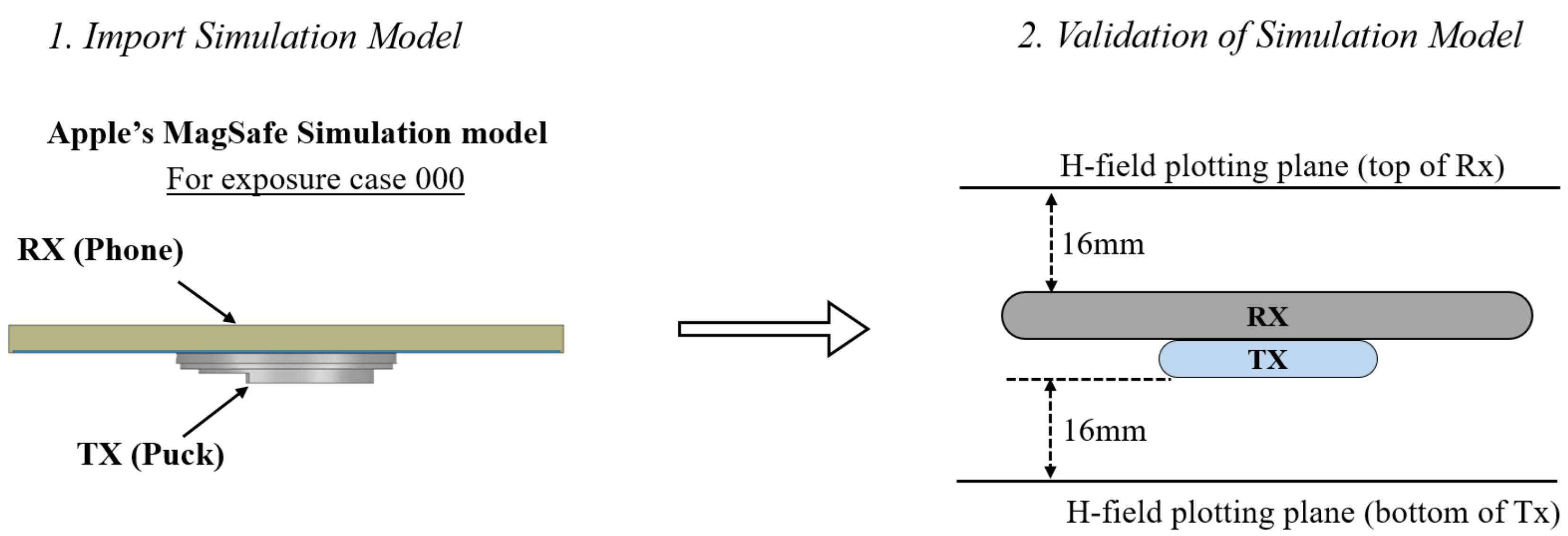

Figure 5: Steps to verify Apple Simulation Model

Model Validation Methodology for Computational Exposure Assessment

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

Electromagnetics simulations are conducted using commercially available software ANSYS HFSS. In order to validate the MagSafe model simulation setup, E and H fields 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 the aligned case (Case 000) and misaligned case (Case 505), and both are shown in the figure below. After validation is performed, the MagSafe simulation model will be used for SAR simulations.

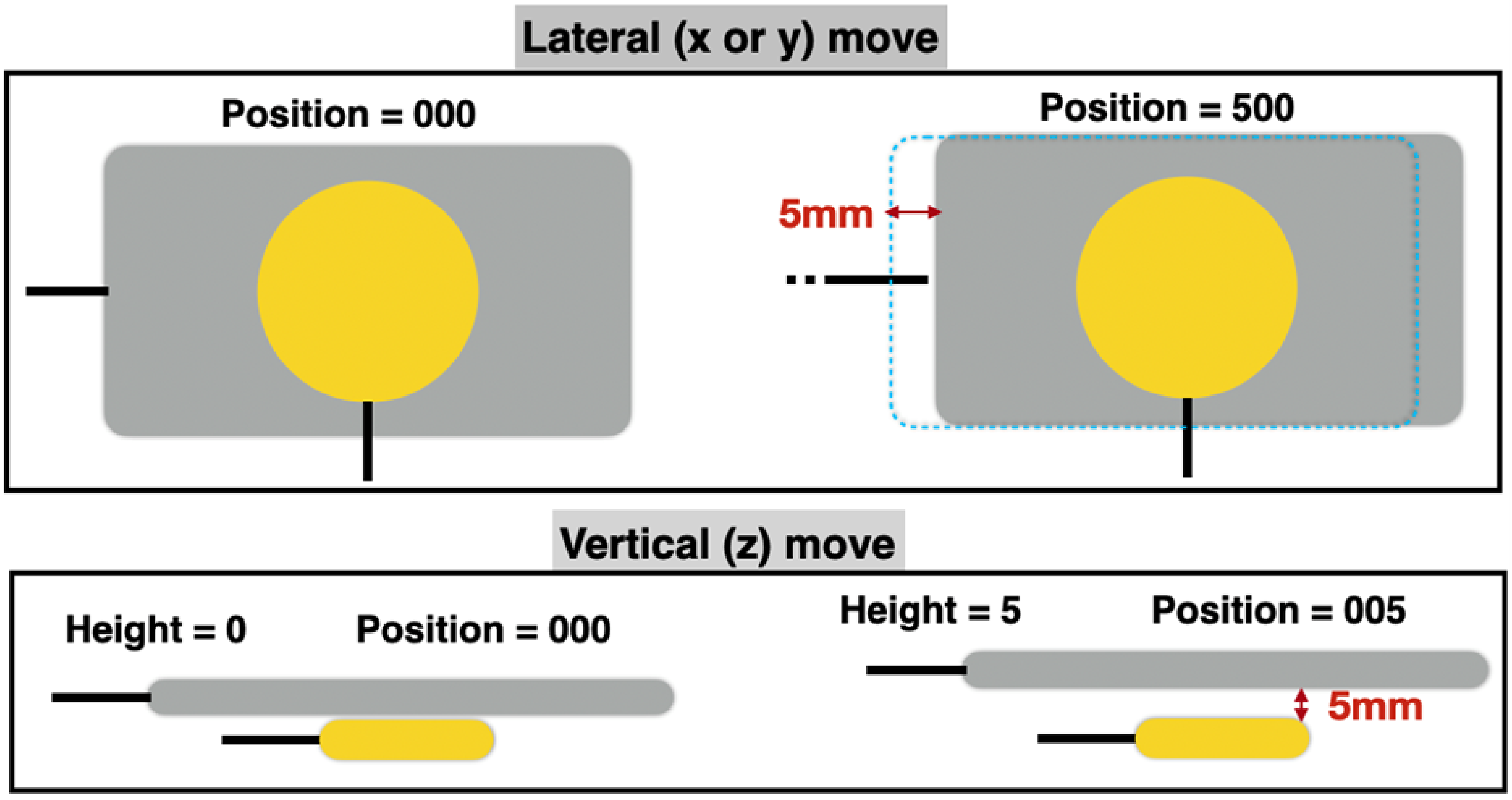

Figure 6: Baseline setup for exposure cases 000 and 505

Initial verification setup is to make sure that the simulation setup with the MagSafe model is consistent with Apple's simulation model. To verify the simulation setup, E/H-field on two planes 16mm away from Tx and Rx, as shown in the figure below, is used for comparison for the following two baseline setups:

1. Case 000: Nominal configuration with perfect alignment between Tx and Rx
2. Case 505: Misaligned configuration with worst-case alignment between Tx and Rx

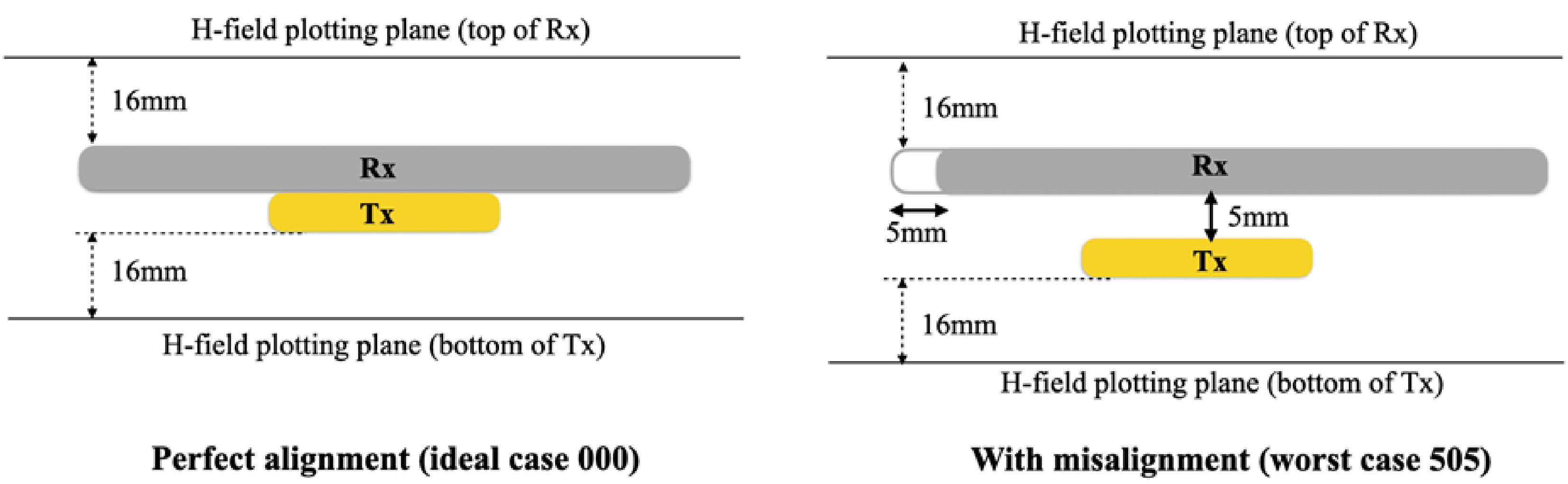

Figure 7: E/H-field plotting planes for two baseline simulation models.

Comparisons between Apple's simulation model and the MagSafe simulation model are shown in the following Figures.

Case 000 H-Field Comparison

Comparison of the H-field plots for case 000 between Apple's simulation model and the MagSafe simulation model are shown below.

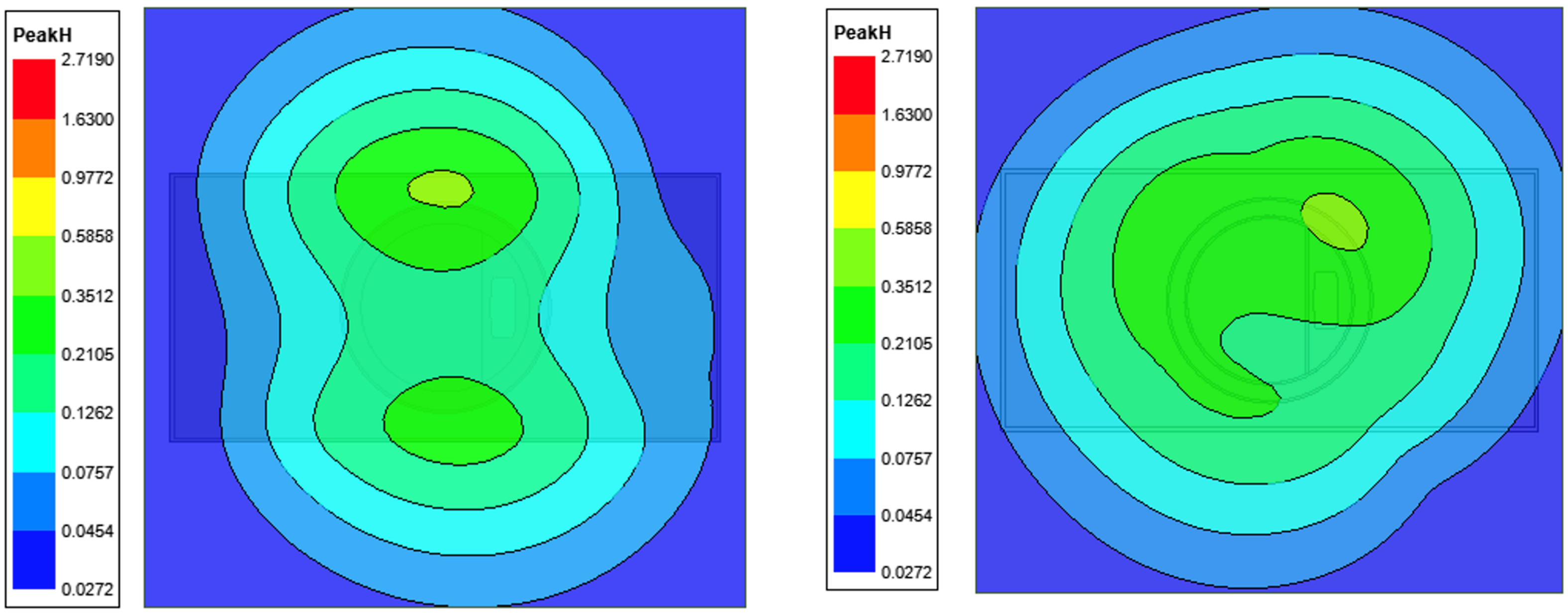

Figure 8: H-field on the two planes for case 000 from Apple's simulation model

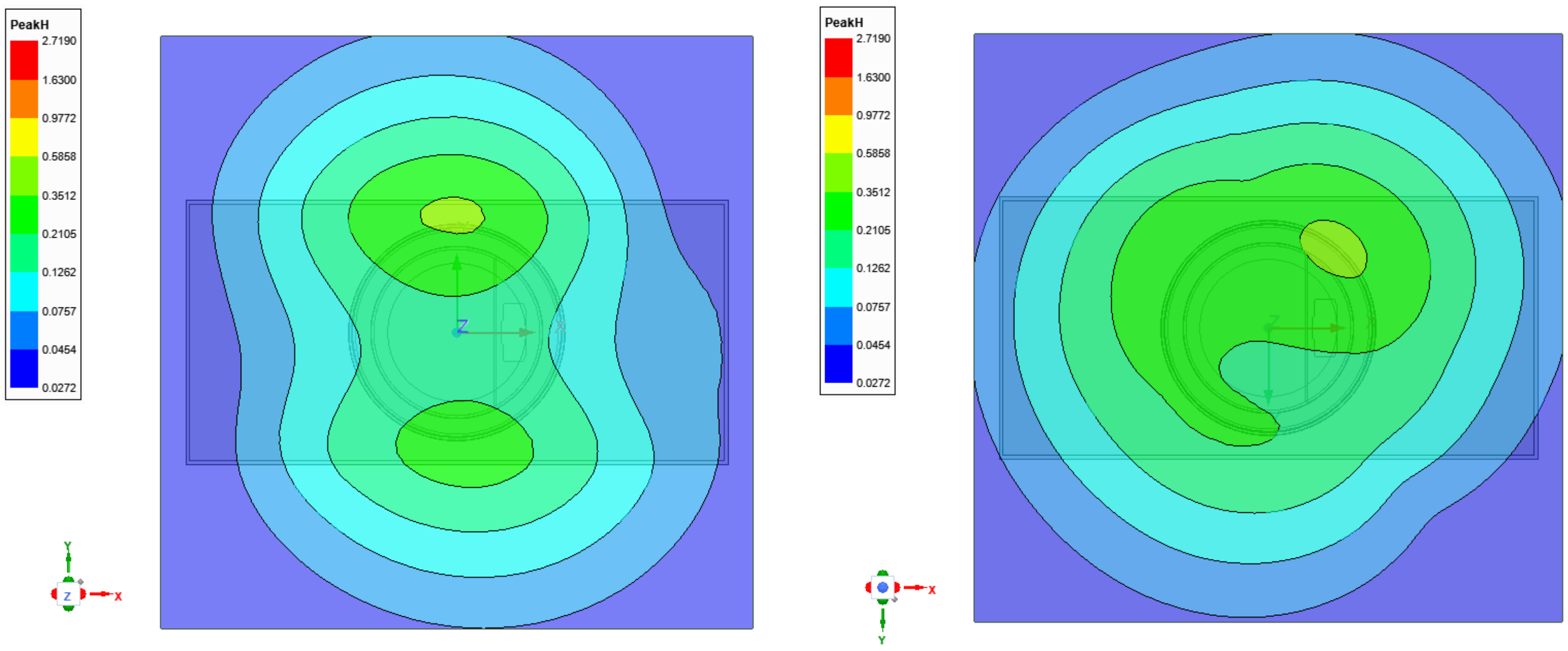

Figure 9: H-field on the two planes for case 000 from MagSafe simulation model.

For 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 0.15%. The average difference on the top and bottom plotting planes is 0.01% and 0.02%, respectively.

Case 000 E-Field Comparison

Comparison of the E-field plots for case 000 between Apple's simulation model and the MagSafe simulation model are shown below.

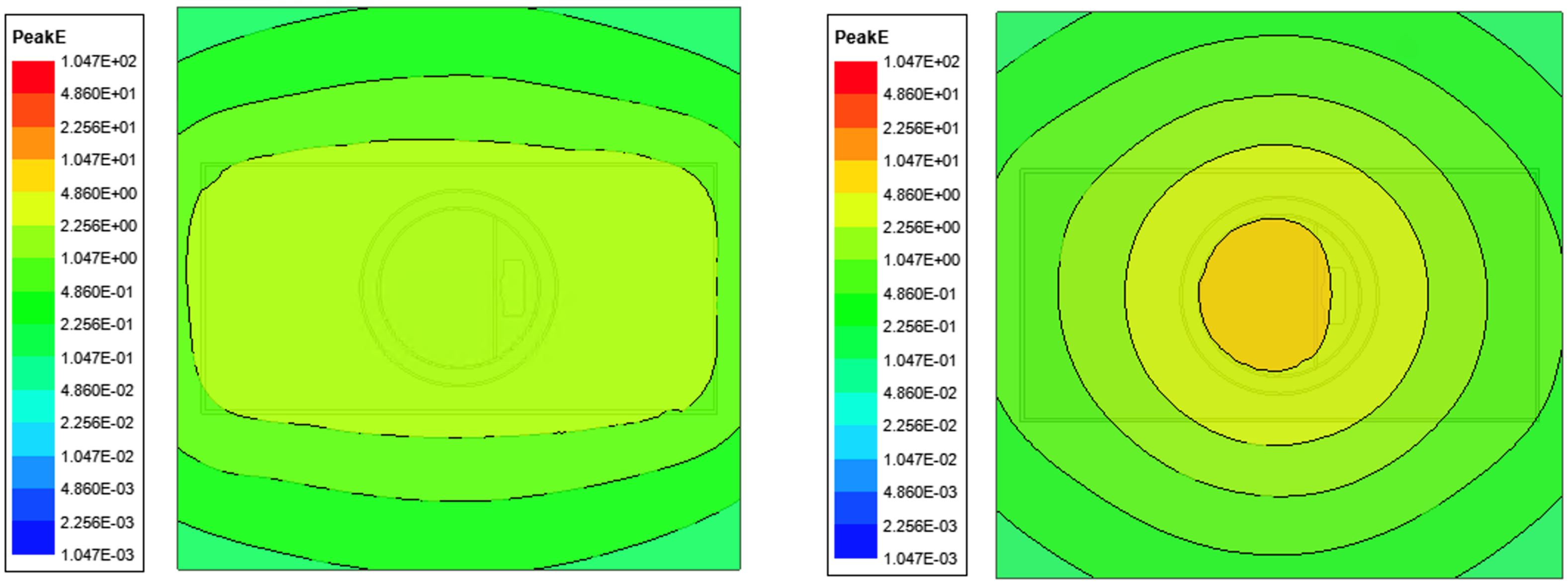

Figure 10: E-field on the two planes for case 000 from Apple's simulation model

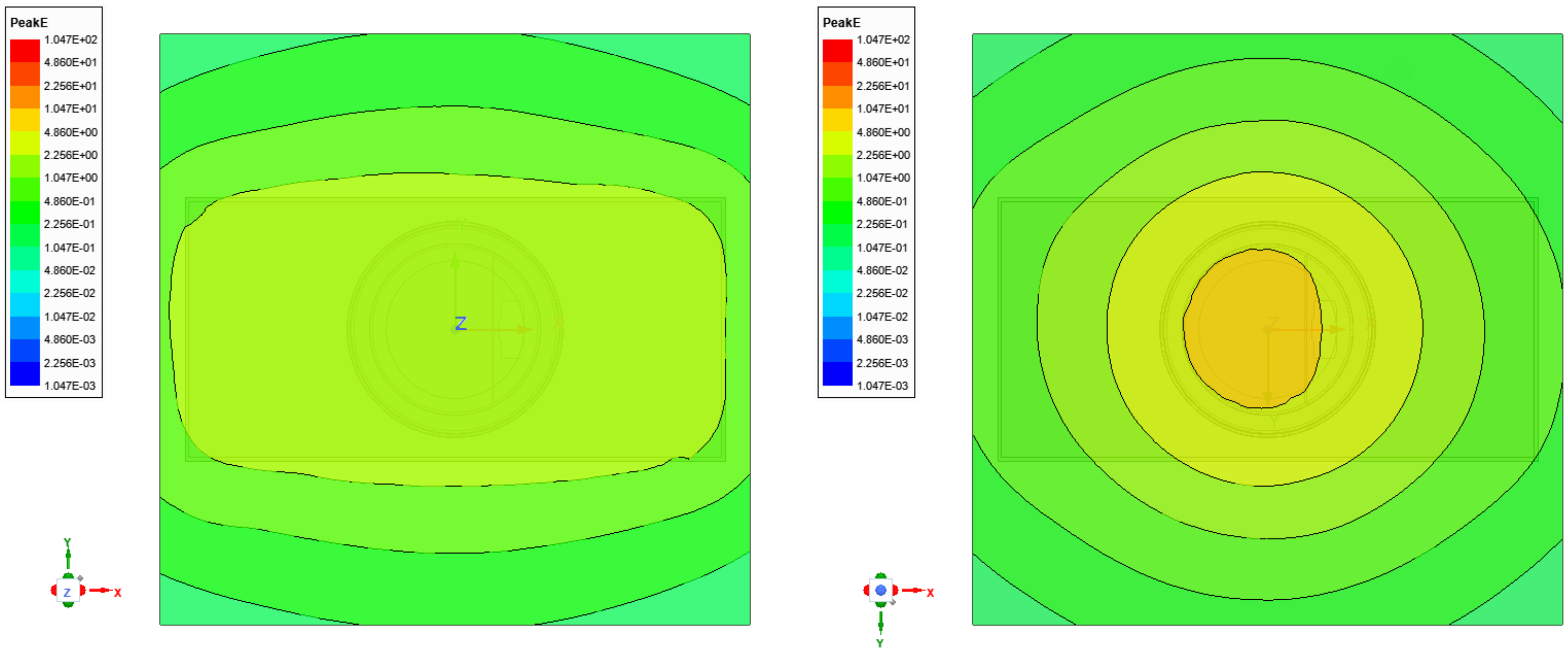

Figure 11: E-field on the two planes for case 000 from MagSafe simulation model.

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 0.32%. The average difference on the top and bottom plotting planes is 0.01% and 0.02%, respectively.

Case 505 H-Field Comparison

Comparison of the H-field plots for case 505 between Apple's simulation model and the MagSafe simulation model are shown below.

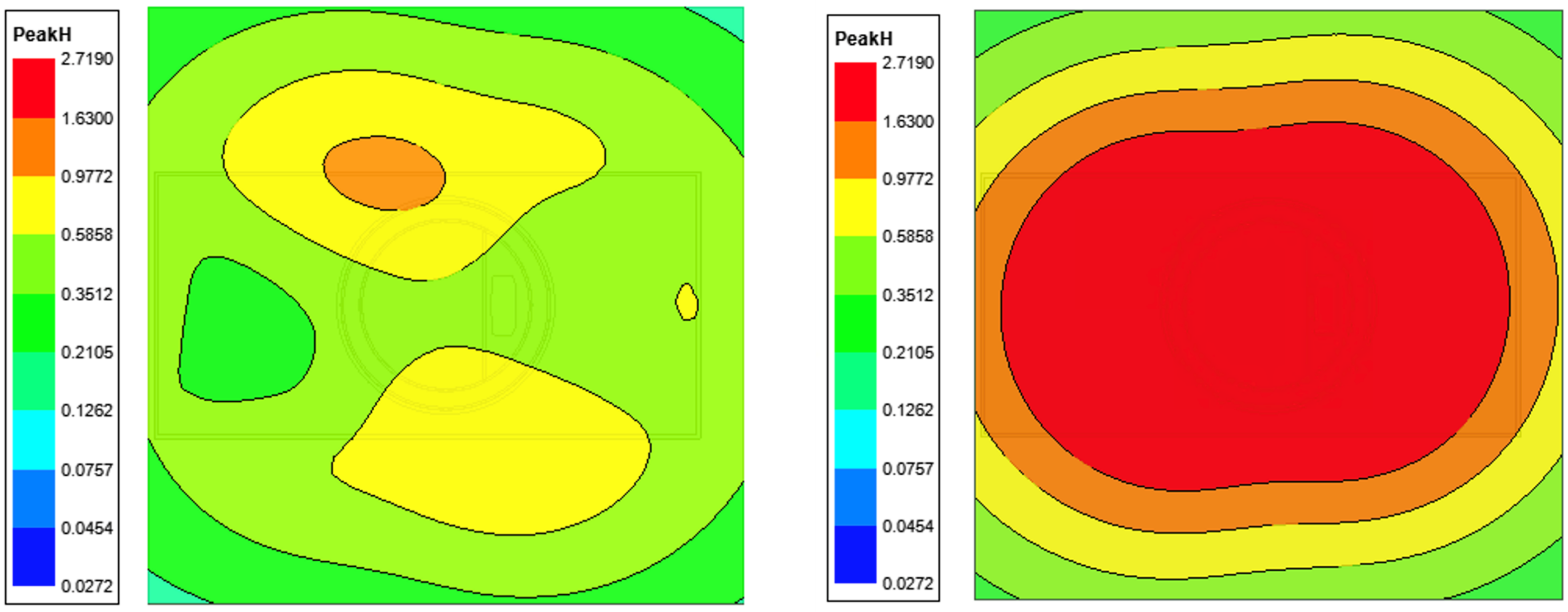

Figure 12: H-field on the two planes for case 505 from Apple's simulation model

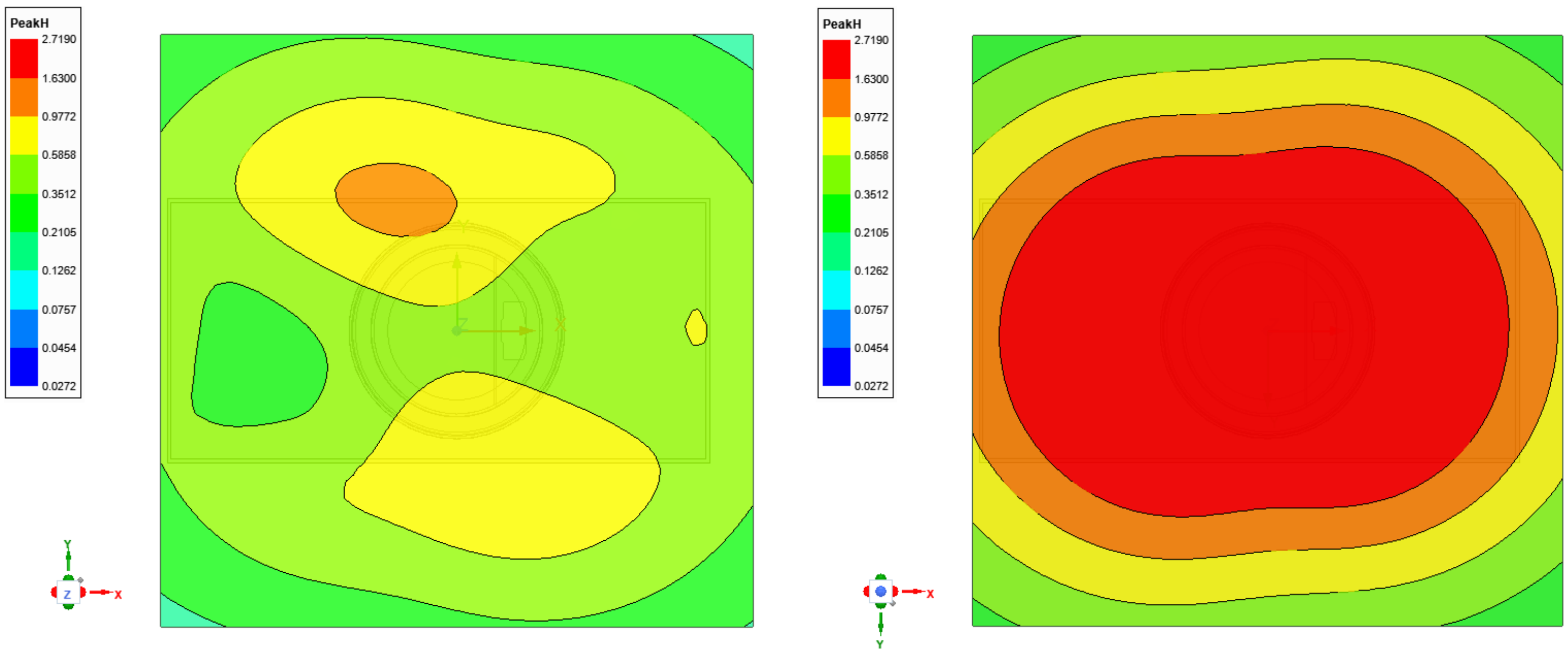

Figure 13: H-field on the two planes for case 505 from MagSafe simulation model.

For 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 less than 0.01%. The average difference on the top and bottom plotting planes is <0.01% and <0.01%, respectively.

Case 505 E-Field Comparison

Comparison of the E-field plots for case 505 between Apple's simulation model and the MagSafe simulation model are shown below.

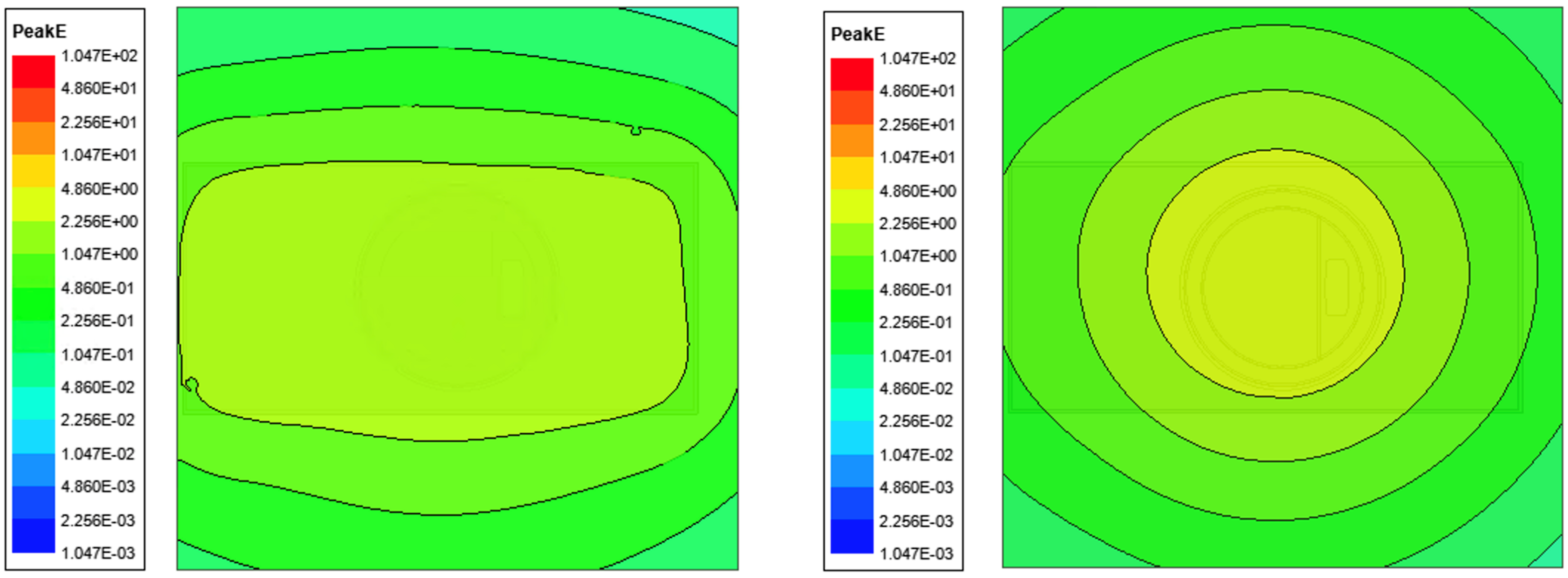

Figure 14: E-field on the two planes for case 505 from Apple's simulation model

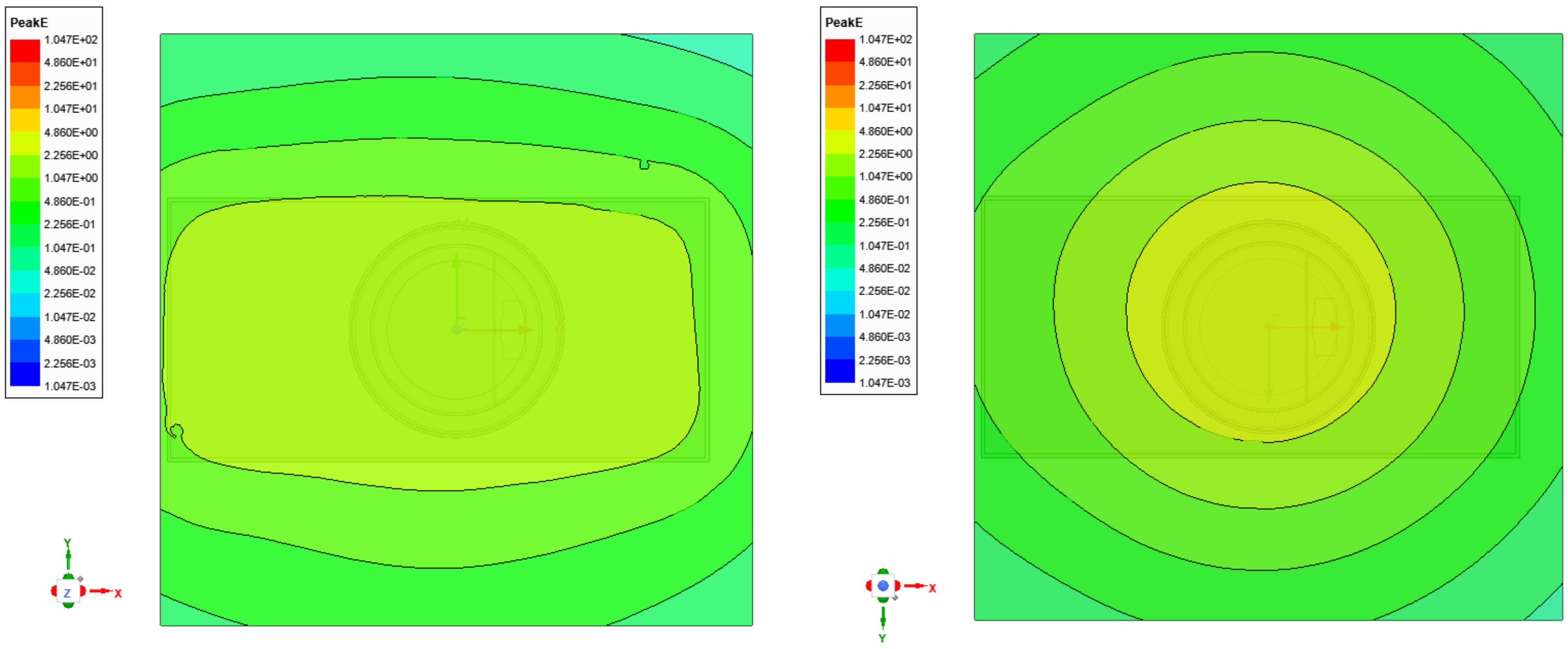

Figure 15: E-field on the two planes for case 505 from MagSafe simulation model.

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 0.22%. The average difference on the top and bottom plotting planes is 0.04% and 0.10%, respectively.

Simulation Model Validation Conclusion

The accuracy and validity of the SAR simulations is demonstrated by correlating Apple's MagSafe simulation model to our simulation model. The SAR is significantly lower than the SAR limit of 1.6 W/Kg (below 0.01% of the actual SAR limit). This low SAR value indicates that the contribution of any additional RF exposure 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 allowance to use this model to demonstrate RF Exposure compliance for Apple MagSafe WPT accessories and for the exclusion of any SAR contribution due to the WPT from any SAR simultaneous transmissions. This product is intended to be mounted to a vehicle's air conditioning vent and intended to only be used hands-free. When installed and mounted in the vehicle, it will never be used near any portion of the head or body. The maximum difference for all fields, cases, and locations is 0.32% which is in good agreement with Apple's simulation model. Because of all this, we conclude that this simulation model is valid and can be used for performing SAR calculations.

12. References

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