RF Exposure Simulation Report

For

Humane, Inc.

969 Folsom Street,

San Francisco, CA 94107, USA

FCC ID: 2BAFM-HU223

Product Type: Wireless Charger

Model Name: HU0223

Rule Part: FCC § 1.1310 and § 2.1093

Date of Simulation: 01/25/2023 - 05/02/2023

Report Date: 06/07/2023

Report Number: HU0223-06072023-12VL

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Senior Regulatory Engineer

Summary of Test Results

Rule Parts:	FCC § 1.1310 and § 2.1093	
Test Procedures:	KDB 680106 D01	
Device Category:	Portable Device	
Exposure Category:	General Population/Uncontrolled Exposure	
Modulation Type:	ASK	
Tx Frequency Range:	112-290 kHz	
Maximum Output Power:	5 W	
Power Transfer Method:	Magnetic Induction on Single Primary Coil	
Maximum Simulated E-Field:	Level (V/m)	Position
	624.22	Body Side
Maximum Simulated H-Field:	Level (A/m)	Position
	76.45	Body Side
Maximum Simulated SAR:	Level (W/kg)	Position
	0.000026	Body Side
Test Result	Pass	

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1. Introduction

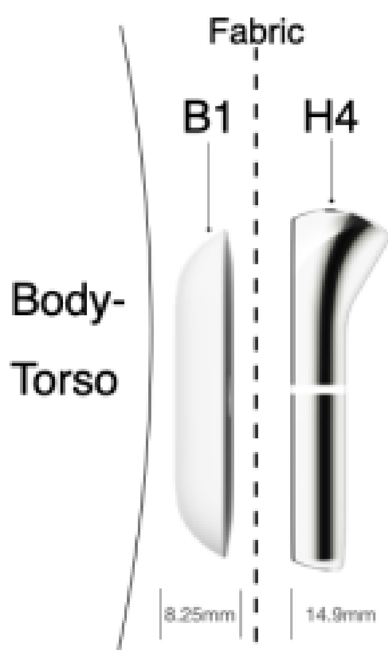
The purpose of this report is to demonstrate compliance for RF Exposure according to FCC rule parts § 1.1310 and § 2.1093 against the 1.6 W/kg localized 1g SAR limit. KDB 680106 D01 allows the use of SAR numerical modeling to demonstrate compliance due to SAR tools and procedures being unavailable for the frequency range that the HU0223 operates at. HU0223 operates in the frequency range of 112-290 kHz and can operate at a maximum power of 5 W.

The HU0123[1], is designed to be worn on the torso over clothing and contains the Humane Device's user interfaces and its radiofrequency ("RF") transmitters. The HU0223, is worn under clothing and uses magnets to attach to the HU0123 through the user's shirt or jacket.

When HU0123 and HU0223 are paired and in use, HU0223 supplements the HU0123 battery by charging it wirelessly when needed[2]. In order to maximize efficiency, HU0123 will only request charge from HU0223 under certain conditions to limit wasted energy during charging.

HU0223 can be used either as a portable or mobile device depending on if it is mounted to the end user or placed inside of the charge pad. This report will only cover the portable condition as this will be the worst case scenario. Worst case scenario is defined as HU0223 in contact with the end user's torso while transmitting 5 W of power to HU0123 through fabric that is approximately 2 mm thick. This worst case scenario as seen in Figure 1 below will be the condition that is evaluated in this report for RF Exposure to demonstrate compliance.

Figure 1: The Humane Device's HU0123(H4) and HU0223(B1) Components



[1] Model Number HU0123 will be certified according to the FCC regulations under its own FCC ID: 2BAFM-HU123.
[2] Simultaneous Transmission SAR will be assessed in FCC ID: 2BAFM-HU123.

2. Wireless Charger Description

With respect to HU0123 and HU0223 wireless charging subsystems, HU0223 serves as the main power source for the HU0123 device. HU0223 consists of a transmit coil with 12 turns and measures 6.9uH nominally in free air. The HU0123 receiver coil consists of 14 turns and measures 9.6uH nominally in free air. Both HU0223 and HU0123's coils are wound in a spiral made of wire with 3 strands.

3. Simulation Methodology for Exposure Assessment

The methodology for exposure assessment was done in a phased approach as described below. All following simulations were performed under the assumption of 1 A input current and 5 V input voltage to achieve the maximum rated power of 5 W.

Phase 1:

- Electromagnetic Simulation Model Creation
    - System model setup:
        - Charger/Receiver System
        - Primary Coil
        - Secondary Coil
        - Simulation implant volume
    - Implant modeling and excitation assignment
    - Implant placement parameterization
    - Relevant boundary condition assignment

- Initial Baseline Simulation
    - Fields shall be evaluated at distances of 0 cm, 2 cm, 4 cm, 6 cm, 8cm and 10cm away from the system
    - Simulation outputs include:
        - E-Fields in V/m
        - H-Fields in A/m
    - Correlation with measured results
    - Refine model until good enough correlation is established and use this model for the SAR simulations.

Phase 2:

- Correlated SAR Simulation
    - Fields shall be evaluated at a distance of 0 mm away from the Phantom
    - Simulation outputs to include:
        - SAR in W/kg

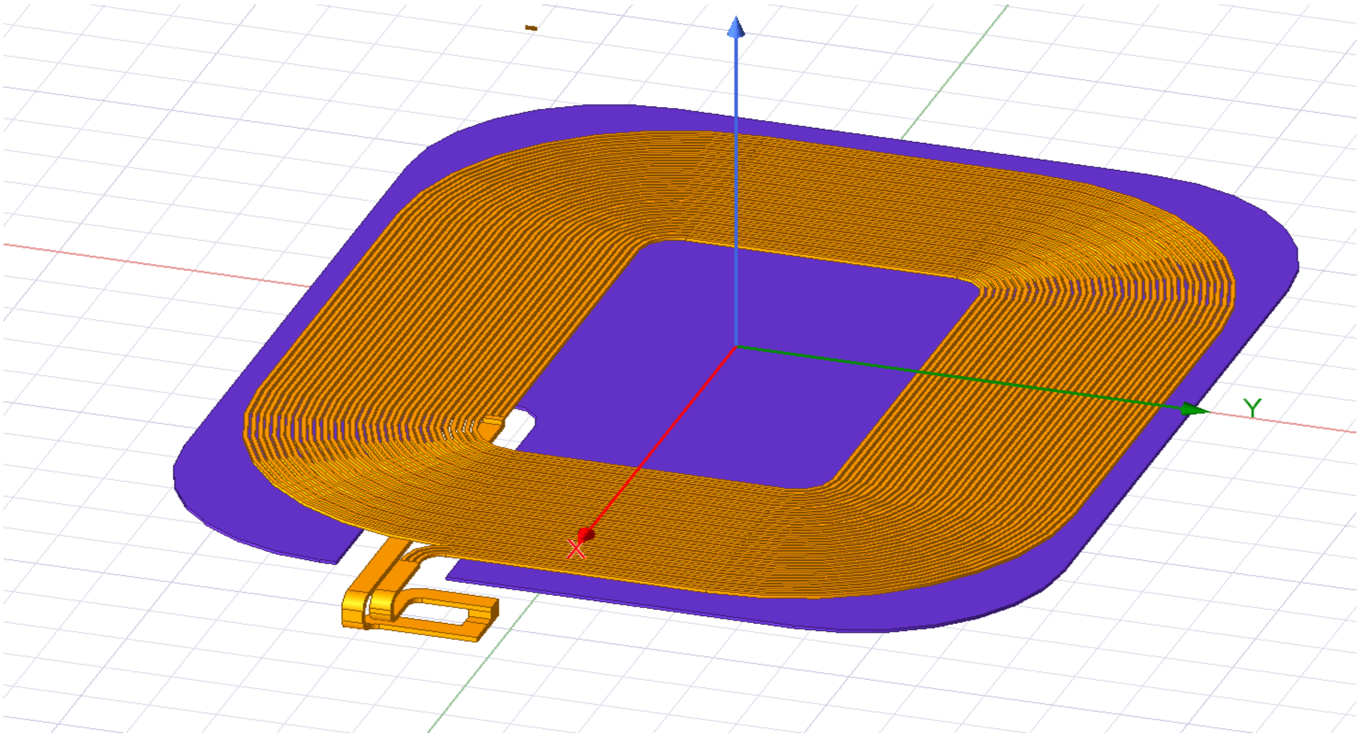
4. Phase 1 Electromagnetic Simulation Model Creation

The electromagnetic simulations are done using ANSYS HFSS and ANSYS Maxwell software. According to test report R14722187-S3 the maximum E/H-Fields were measured on the frequency 182.5 kHz. This frequency is what was used in the simulations.

4.1. Tx Coil Validation

For Tx coil validation the first step was to define the Tx coil. A CAD model that represents the DUT Tx coil was imported as seen in Figure 2. Then the material properties that represent the DUT were assigned at the operating frequency of 182.5 kHz.

Figure 2: Tx Coil Inside the Model



Tx coil inductance and resistance were then calculated using a 1 A current applied through the coil using Ansys Maxwell.

Frequency (kHz)	Inductance (µH)	Resistance (mOhm)
182.500	6.899	334.331

With this information being used as inputs the Tx coil E/H-Fields were able to be simulated in Ansys HFSS as seen in Figures 3 and 4.

Figure 3: Tx Coil E-Field

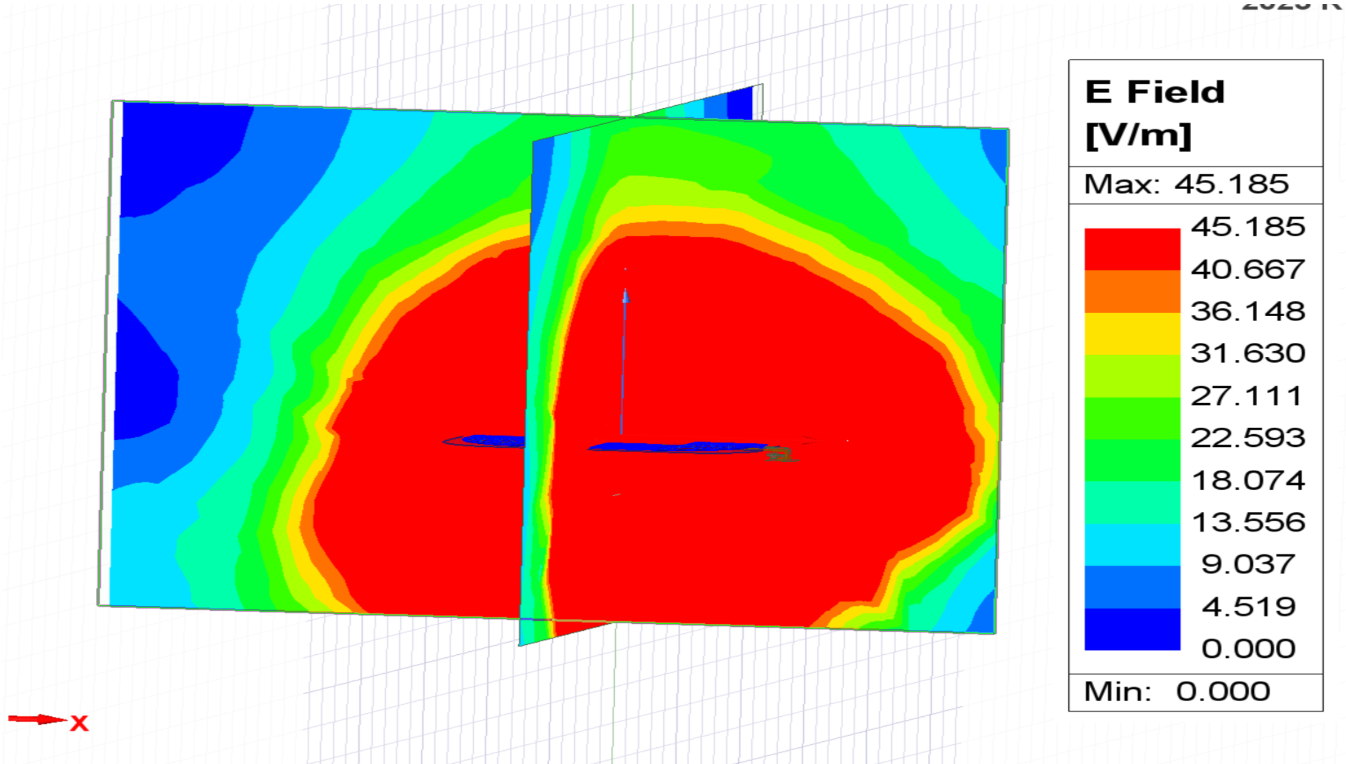
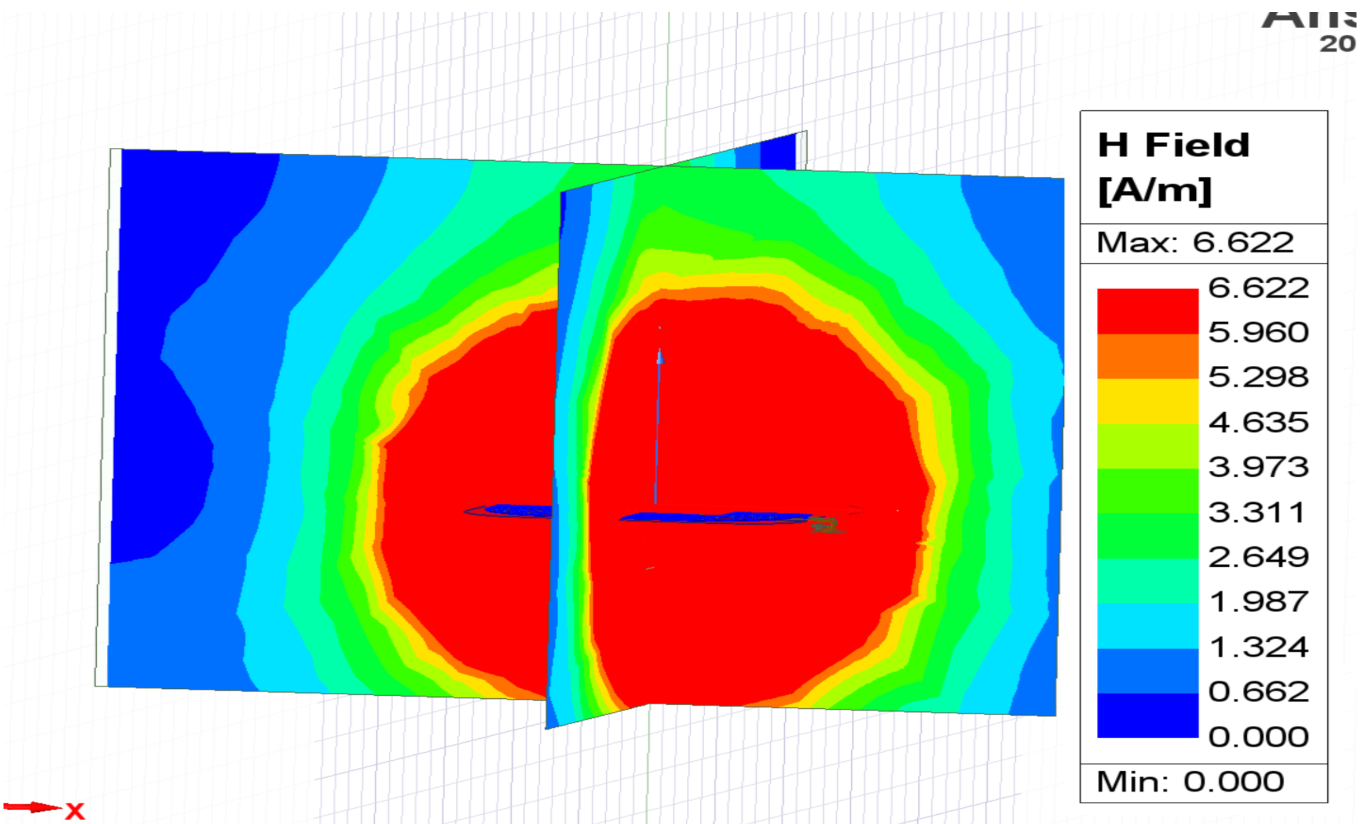


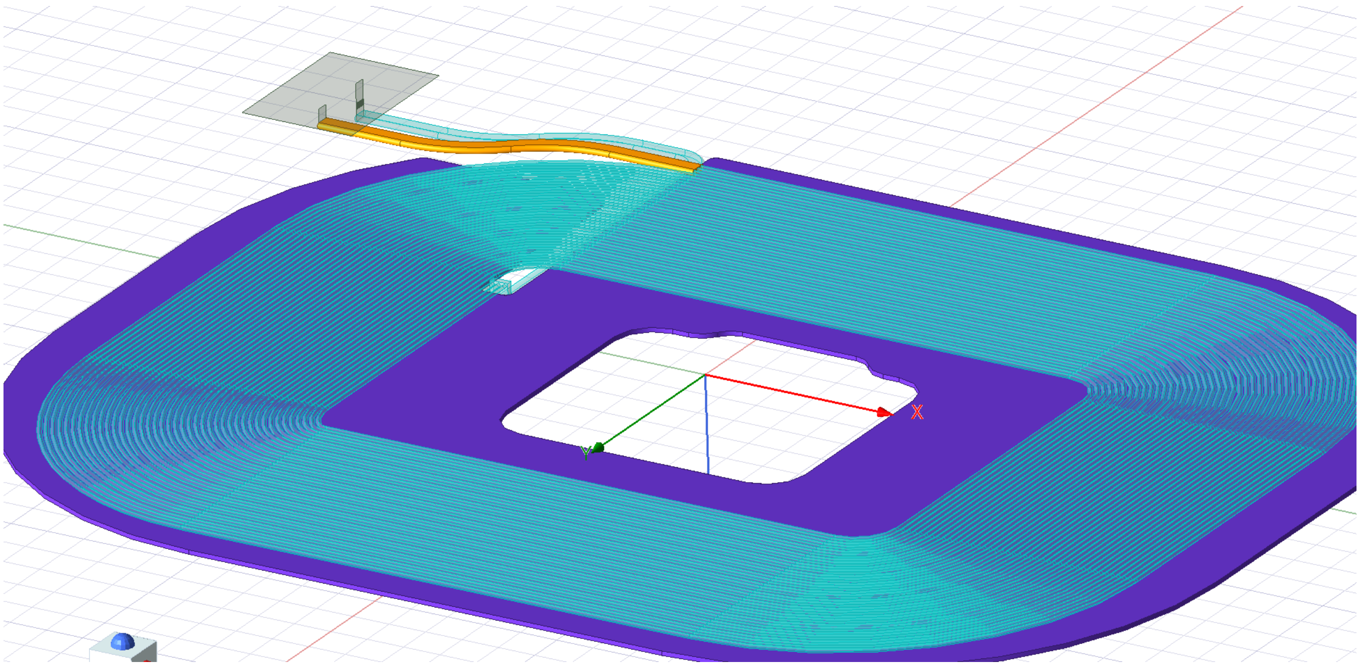
Figure 4: Tx Coil H-Field



4.2. Rx Coil Validation

For Rx coil validation the first step was to define the Rx coil. A CAD model that represents the DUT Rx coil was imported as seen in Figure 5. Then the material properties that represent the DUT were assigned at the operating frequency of 182.5 kHz.

Figure 5: Rx Coil Inside the Model



Rx coil inductance and resistance were then calculated using a 1 A current applied through the coil using Ansys Maxwell.

Frequency (kHz)	Inductance (µH)	Resistance (mOhm)
182.500	9.628	397.888

With this information being used as inputs the Rx coil E/H-Fields were able to be simulated in Ansys HFSS as seen in Figures 6 and 7.

Figure 6: Rx Coil E-Field

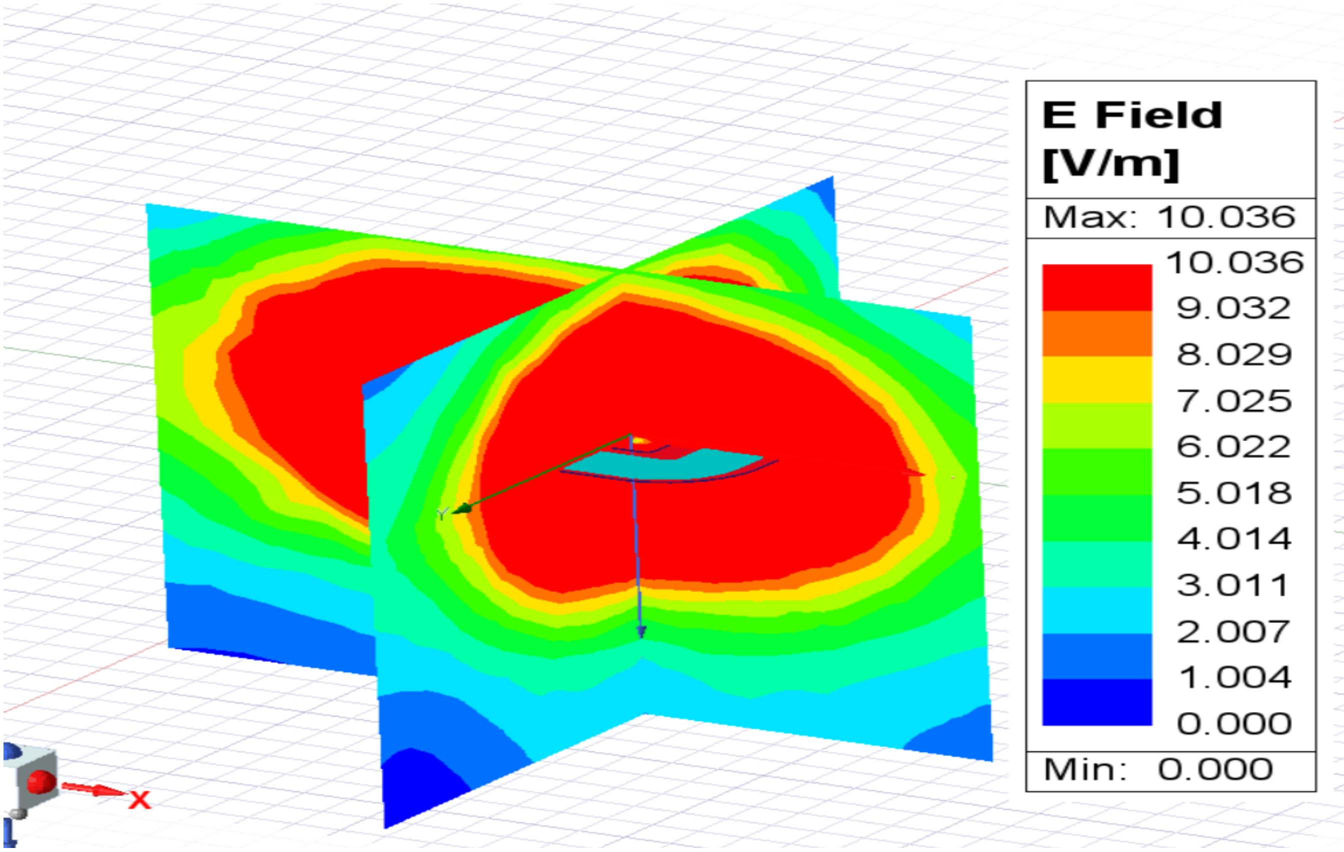
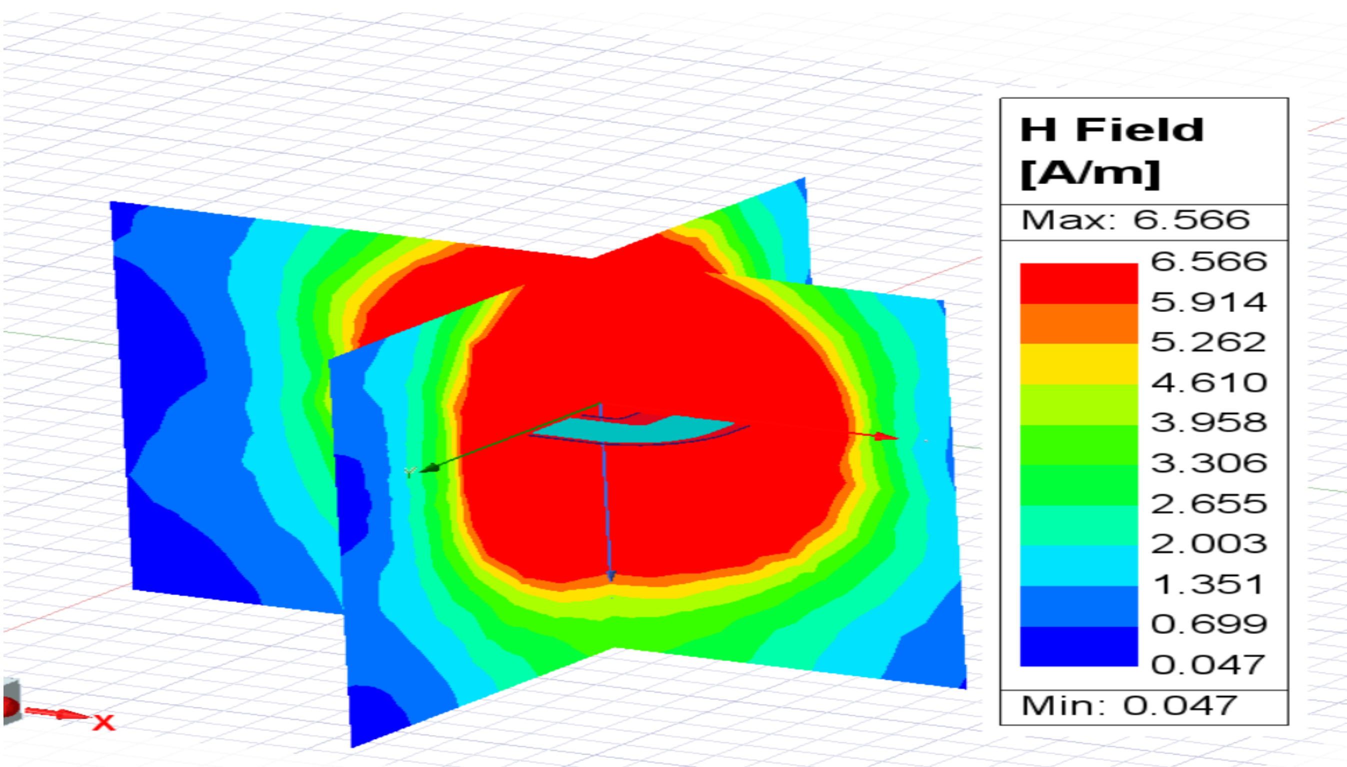


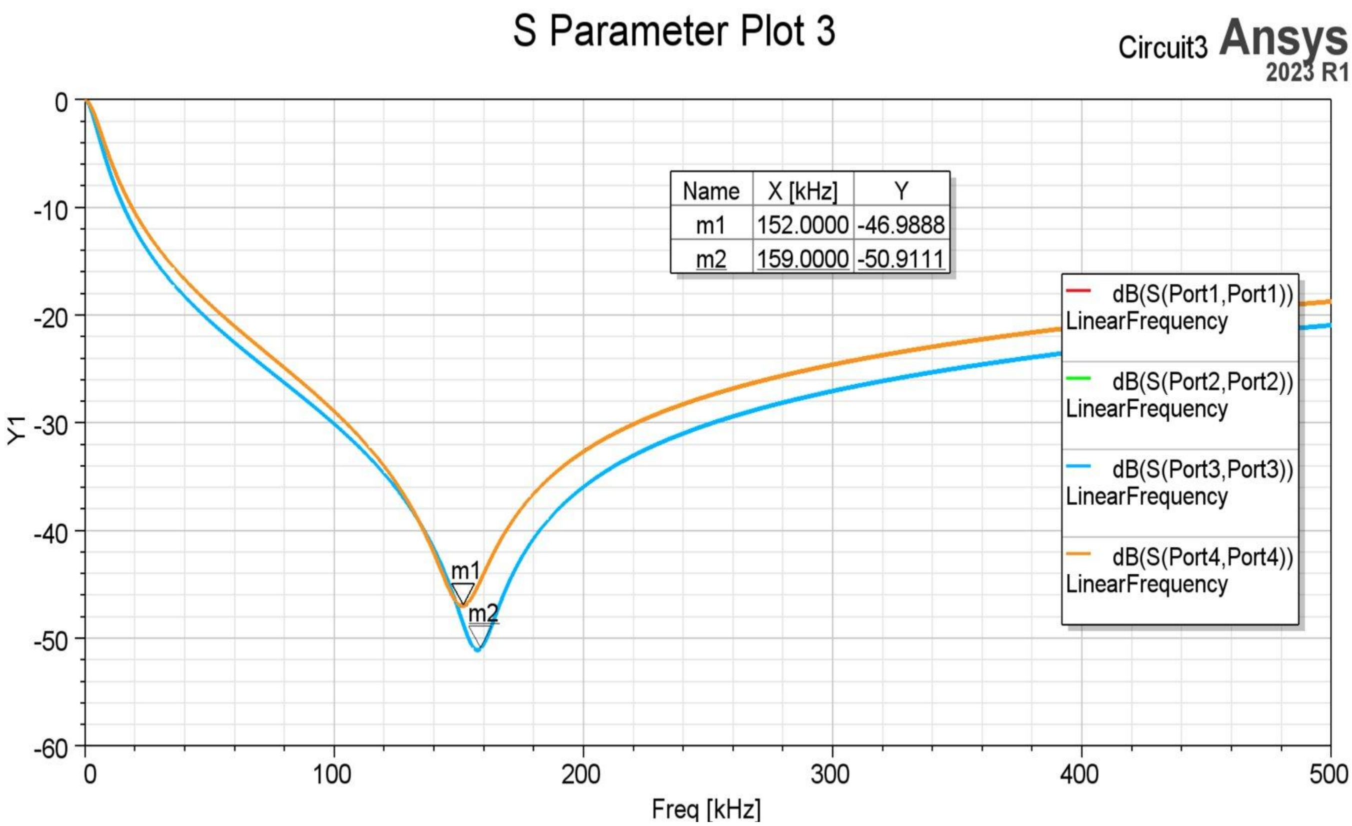
Figure 7: Rx Coil H-Field



4.3. Coil Coupling

Since the Tx and Rx coils have been validated the next step is to implement them in the model together and consider the coupling between the Tx and Rx coils. First step in determining the coupling is to consider the Reflections coefficients as seen in Figure 8.

Figure 8: Reflections Coefficients



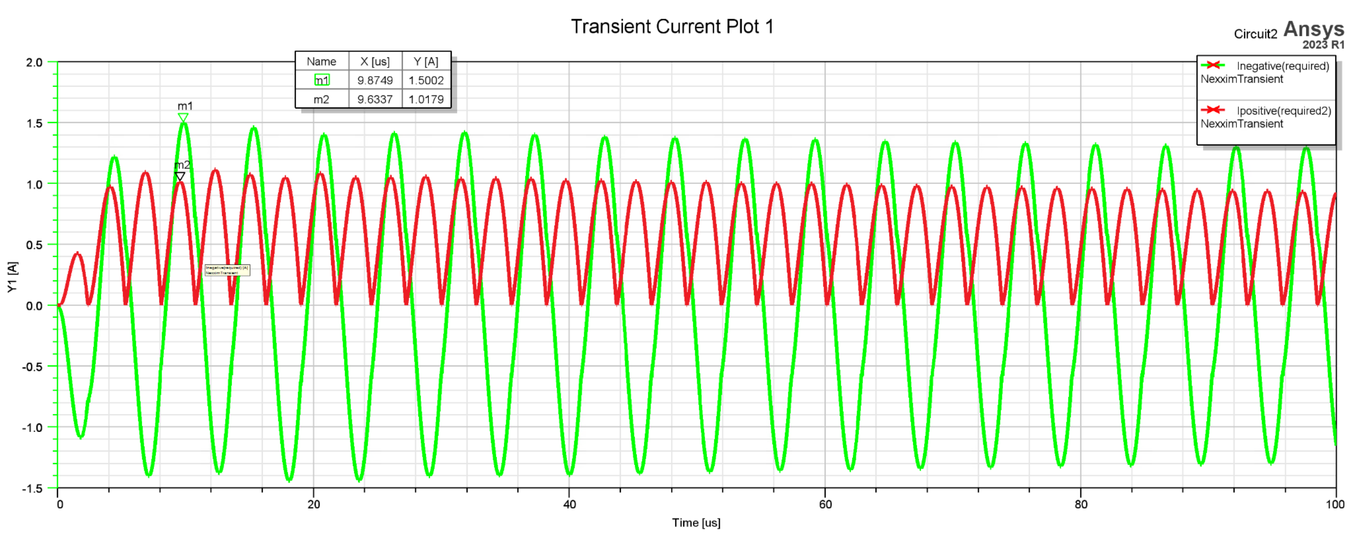
The reflections coefficients are then used to determine the coupling between the Tx and Rx coils as seen in Figure 9.

Figure 9: Coil Coupling

4.4. Transient Analysis

The next step is to consider the transient current for the system. First the CAD model of the HU0123 and HU0223 were imported into the model. To save time for the simulations in the model plastic components, gaskets, and adhesives were ignored as these will not impact the result. Then A 5V sinusoidal voltage was applied to the input of the Tx coil, a bridge rectifier model was implemented alongside the Rx side tuning capacitor and current probes were applied on the input and output. This yielded the transient result as seen in Figure 10.

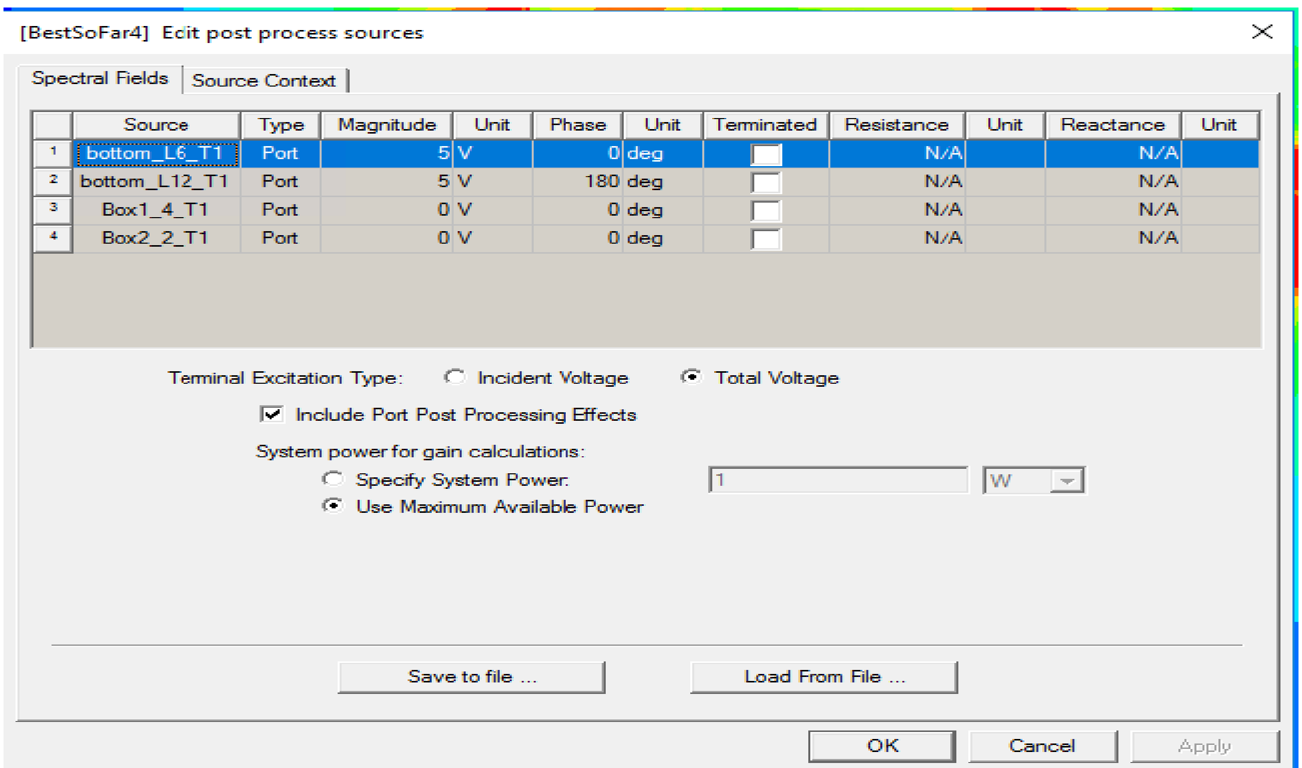
Figure 9: Transient Analysis



4.5. Simulated System E-Field and H-Field Results

The final step is to take all of this information that was gathered from the model and to use it to simulate the E/H Fields of the system. A 5 V source was applied to both Tx ports with 180 degrees phase offset was applied to represent the 5 V sinusoidal output from the Tx IC's inverter circuit. Simulations were performed under the assumption of 1 A input current and 5 V input voltage to achieve the maximum rated power of 5 W.The HFSS excitation sources were used as seen in Figure 10.

Figure 10: HFSS Excitation Sources



With all the parameters set HFSS was able to simulate the E/H Fields as seen in Figures 11-14.

Figure 11: E-Field Visualization

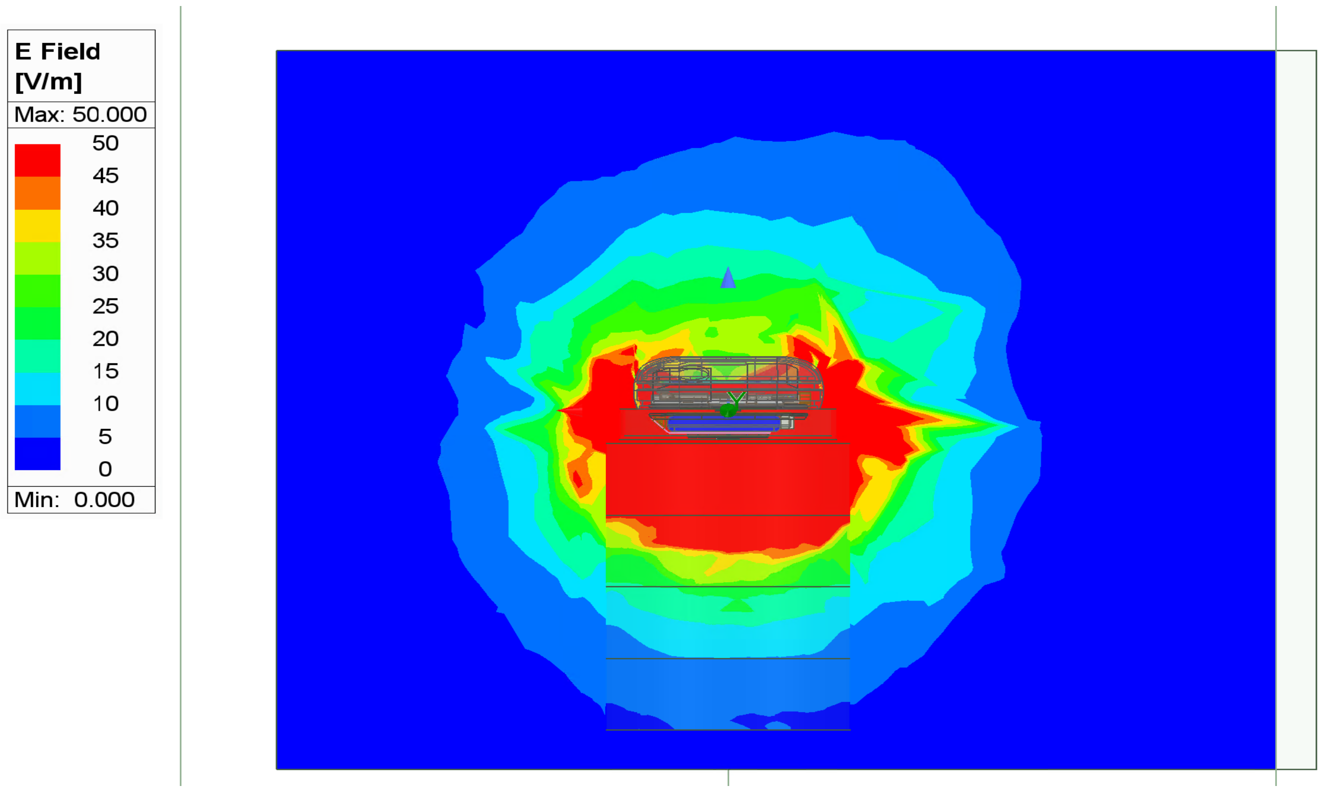


Figure 12: E-Field Roll Off Plot

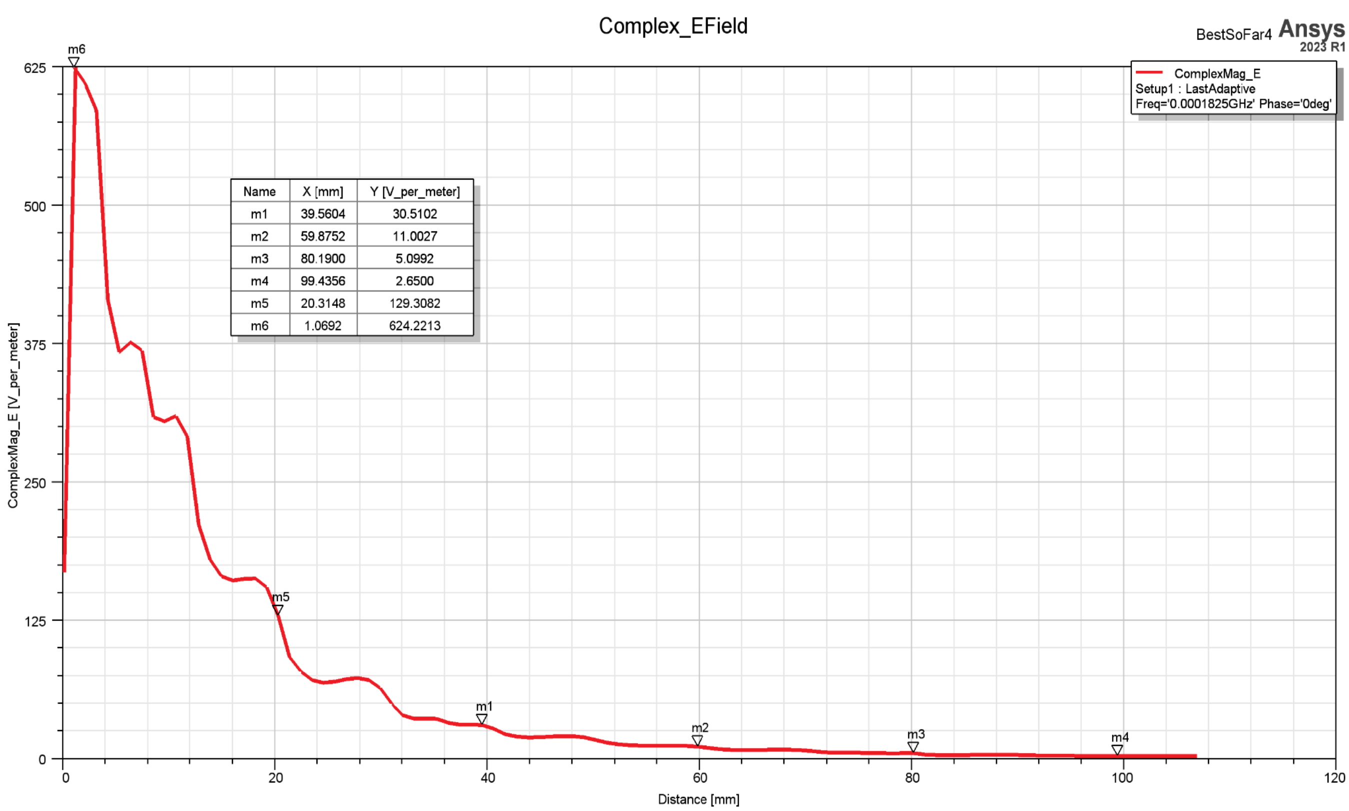


Figure 13: H-Field Visualization

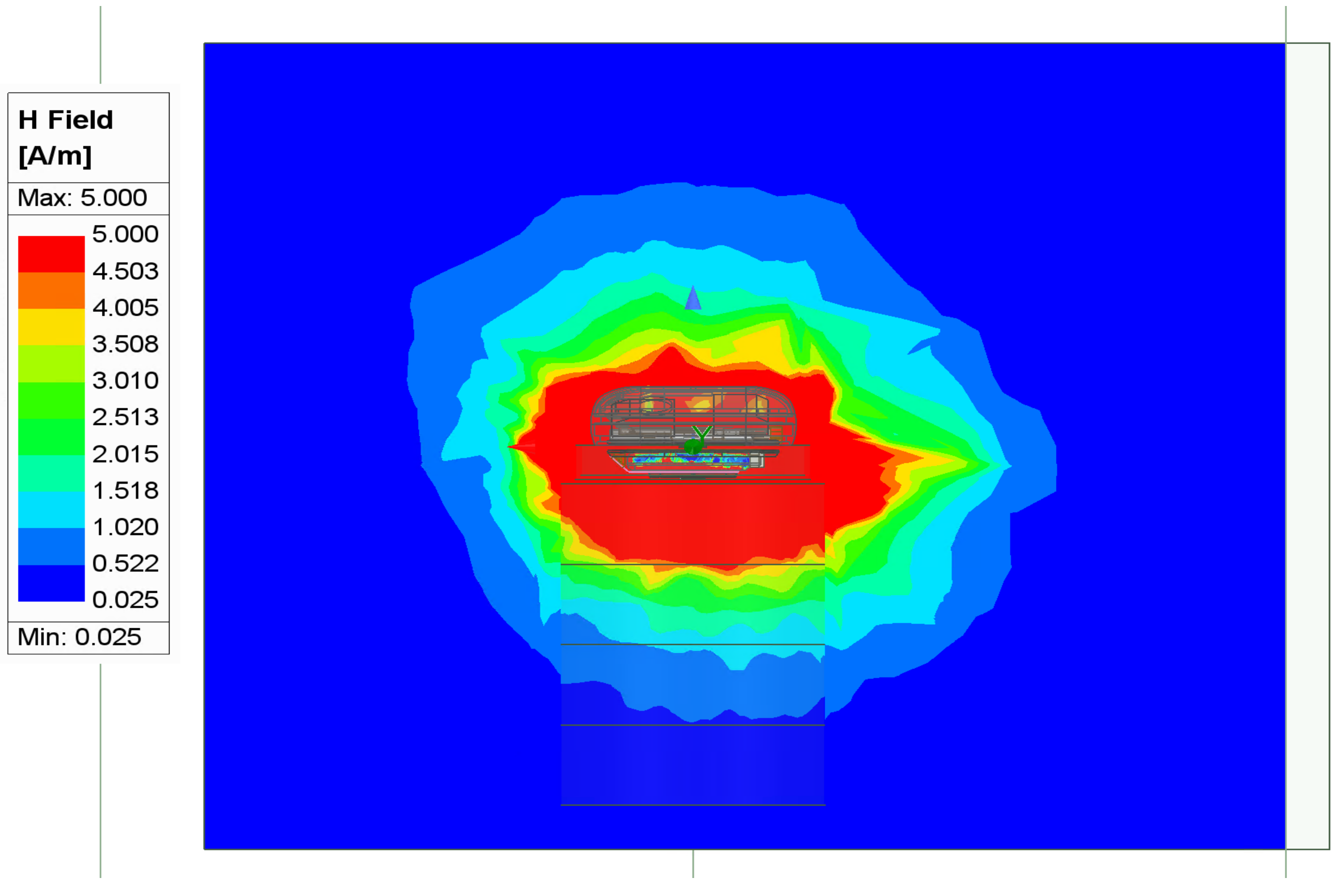
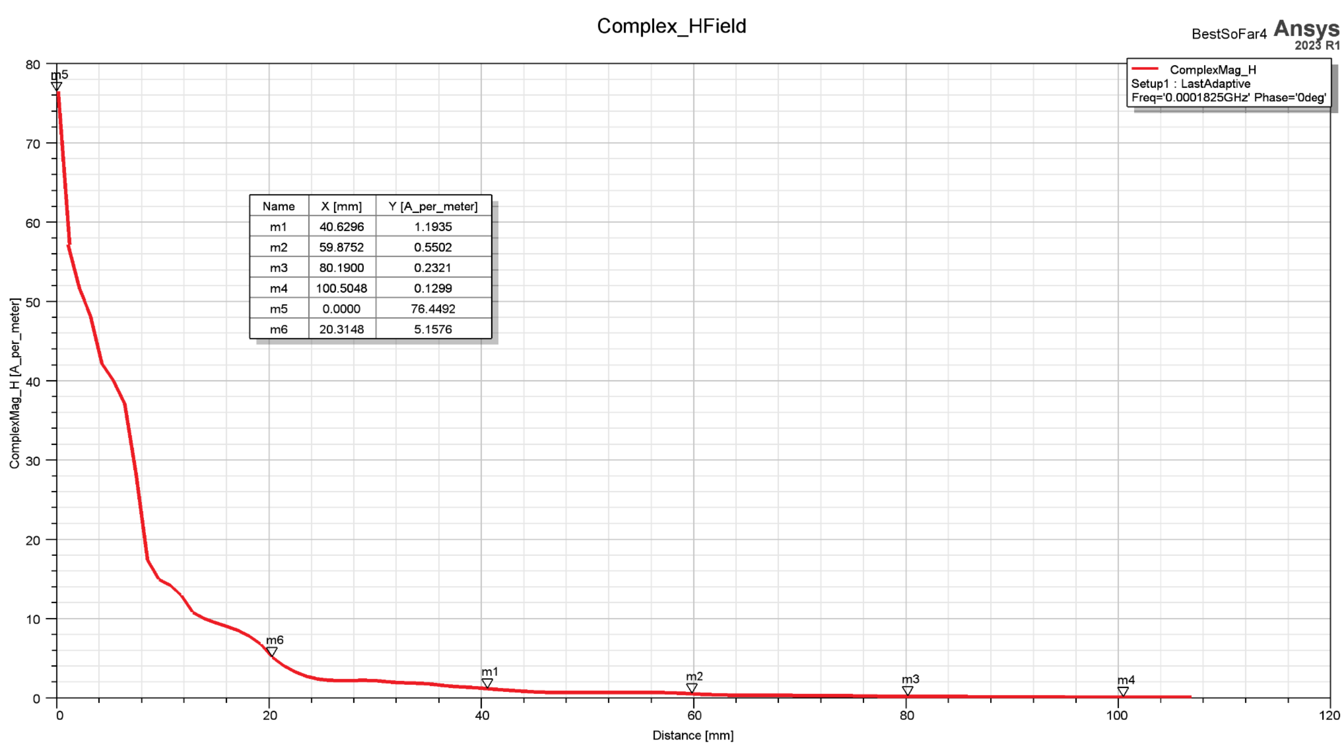


Figure 14: H-Field Roll Off Plot



Name	X [mm]	Y [A_per_meter]
m1	40.6296	1.1935
m2	59.8752	0.5502
m3	80.1900	0.2321
m4	100.5048	0.1299
m5	0.0000	76.4492
m6	20.3148	5.1576

5. Phase 1 Correlation to Measured Results

This section of the report will cover the correlation between the simulated results and the measured results.

5.1. E-Field Correlation

Table 1: E-Field Results

Distance (cm)	E-Field Measured[3] (V/m)	E-Field Simulated (V/m)
0	N/T[4]	624.22
2	N/T	129.31
4	39.7	30.51
6	7.03	11.00
8	3.06	5.01
10	1.45	2.65

Table 1 shows good correlation between measured and simulated results and therefore verifies the accuracy of the simulation model.

[3] Please refer to report R14722187-S3 for the measured E-Field results.
[4] N/T = Not tested, measurement probe dimensions do not allow for the center of the probe to be positioned closer than 4 cm from the device.

5.2. H-Field Correlation

Table 2: H-Field Results

Distance (cm)	H-Field Measured[5] (A/m)	H-Field Simulated (A/m)
0	N/T[6]	76.45
2	N/T	5.16
4	1.40	1.19
6	0.50	0.55
8	0.29	0.23
10	0.12	0.13

Table 2 shows good correlation between measured and simulated results and therefore verifies the accuracy of the simulation model.

6. Phase 2 SAR Simulations and Results

This section of the report will cover the SAR analysis configuration as well as the SAR simulation and results.

6.1. SAR Analysis Configuration

Since there was good correlation between measured and simulated results the same model is then used for SAR simulations. SAR was only assessed for the worst case condition which was determined through KDB Inquiry process to be Body Side at 0 mm distance from DUT while having a separation distance of 2 mm in between HU0223 and HU0123. The following simulations were performed under the assumption of 1 A input current and 5 V input voltage to achieve the maximum rated power of 5 W. The SAR value is averaged over 1 g of tissue and is calculated by dividing the power loss density by the mass density as seen in Figure 15. The phantom and material properties used can be seen in Figures 16 and 17.

[5] Please refer to report R14722187-S3 for the measured H-Field results.

[6] N/T = Not tested, measurement probe dimensions do not allow for the center of the probe to be positioned closer than 4 cm from the device.

Figure 15: SAR Equation

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

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

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

Figure 16: SAR Phantom Settings

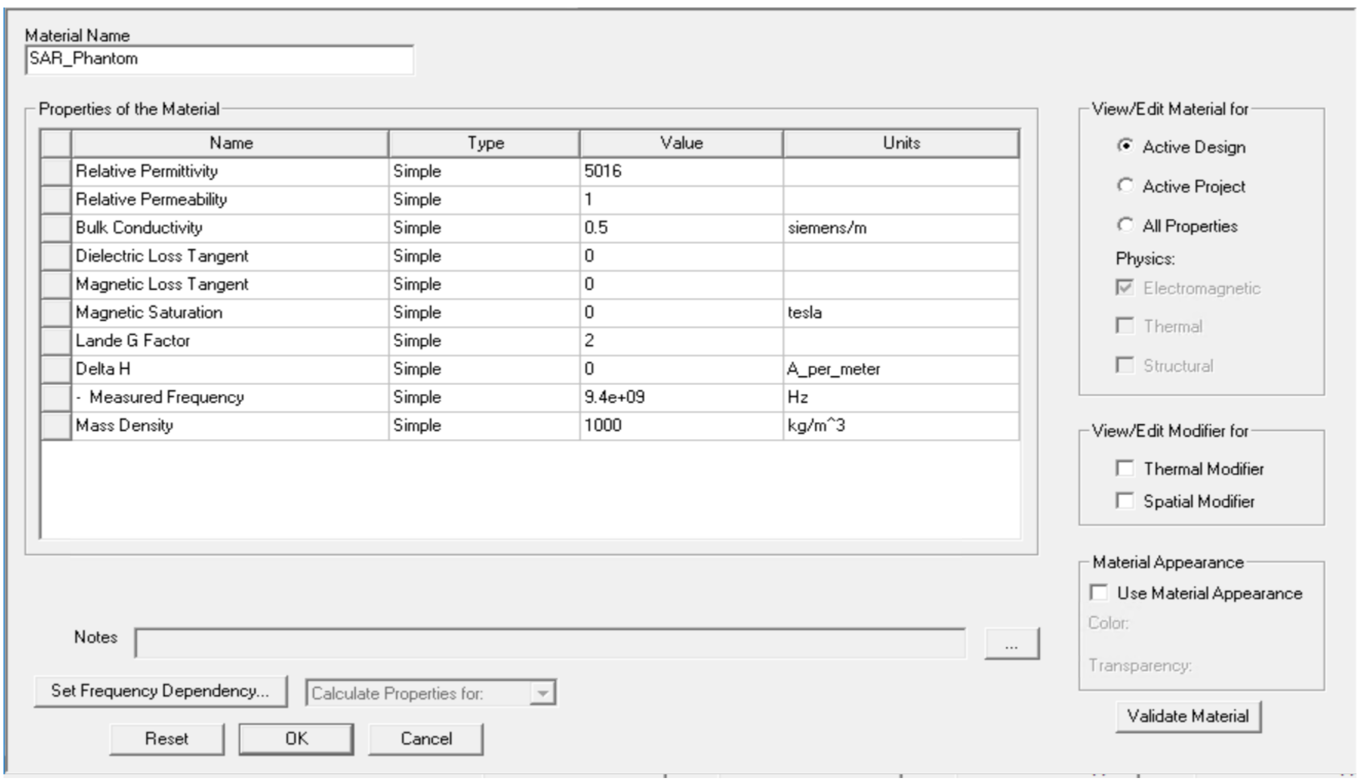
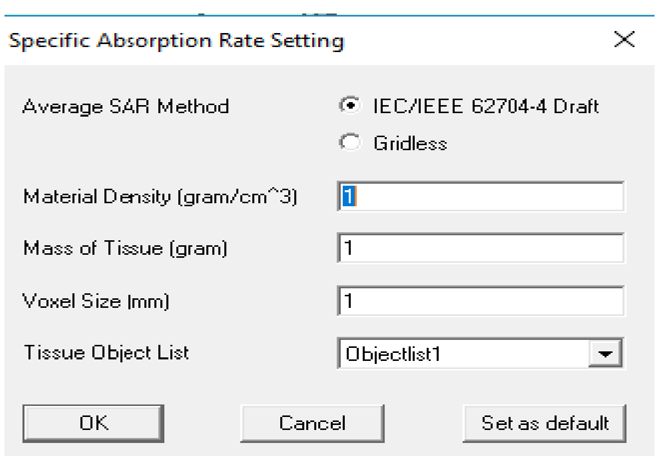
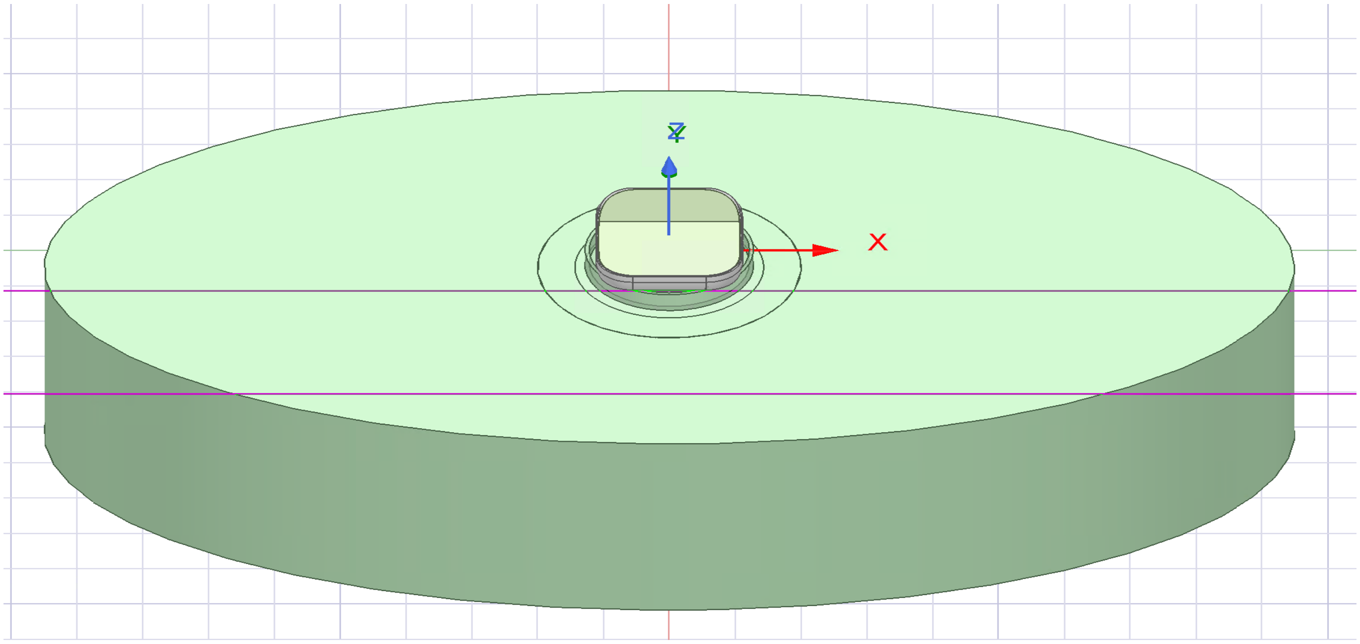


Figure 17: SAR Settings



The model generated from using these settings can be seen in Figure 18.

Figure 18: SAR Model View



6.2. SAR Simulation and Results

With the SAR model established the remaining item was to run the SAR simulation in HFSS and determine the SAR value. The result for the worst case position established during the KDB Inquiry process was 0.000026 W/kg for peak spatial 1-g average SAR in tissue. The visual of the SAR simulation results can be seen in Figure 19 through Figure 21.

Figure 19: SAR Simulation Result Side View

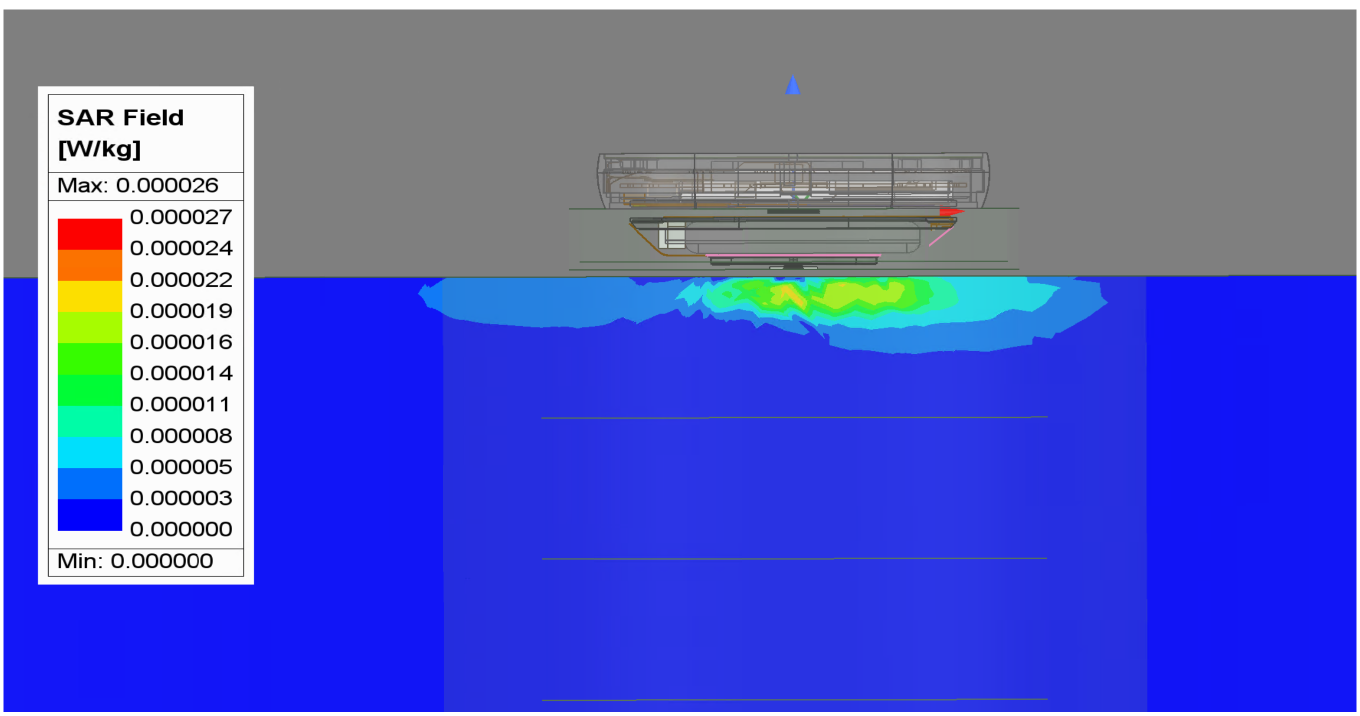


Figure 20: SAR Simulation Result Top View

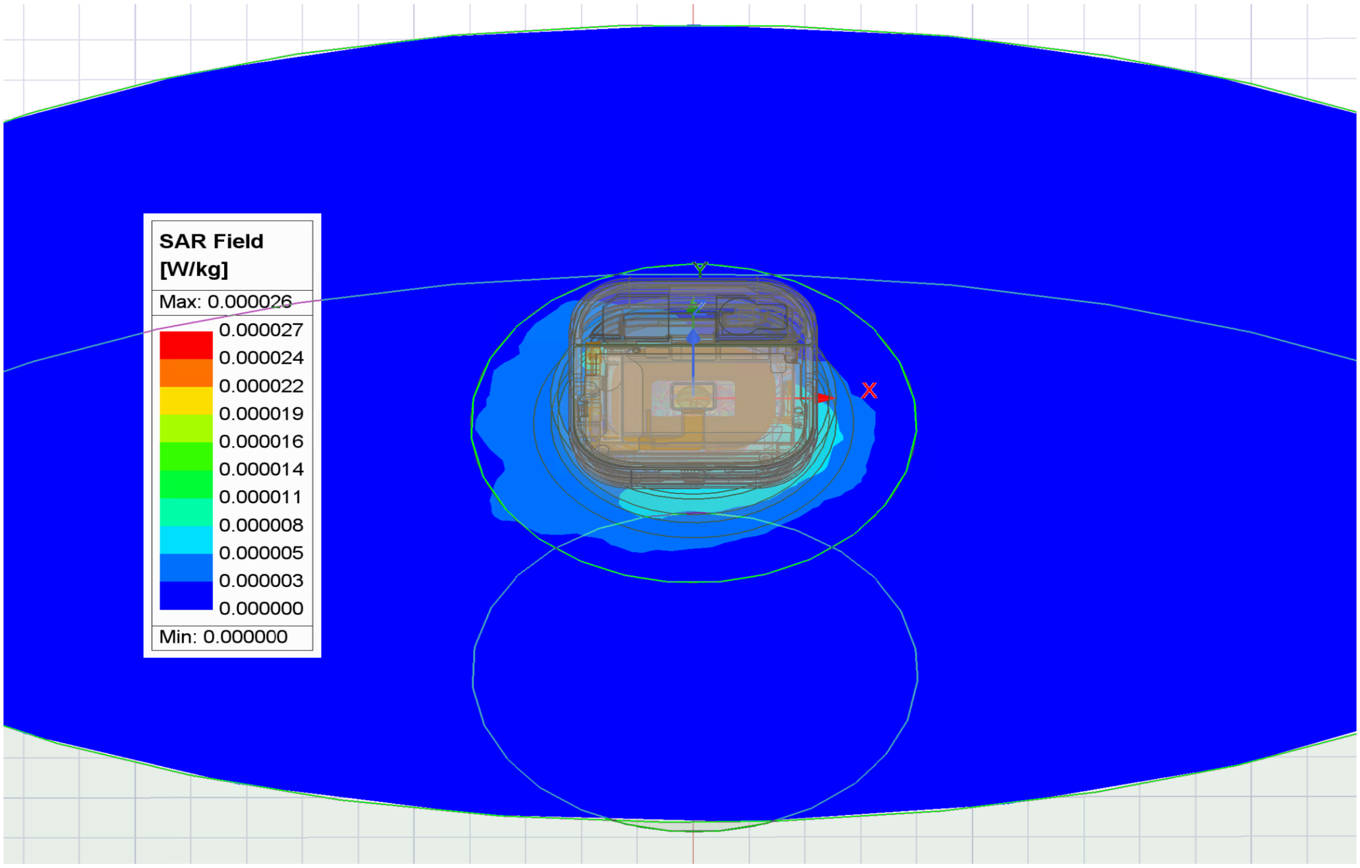
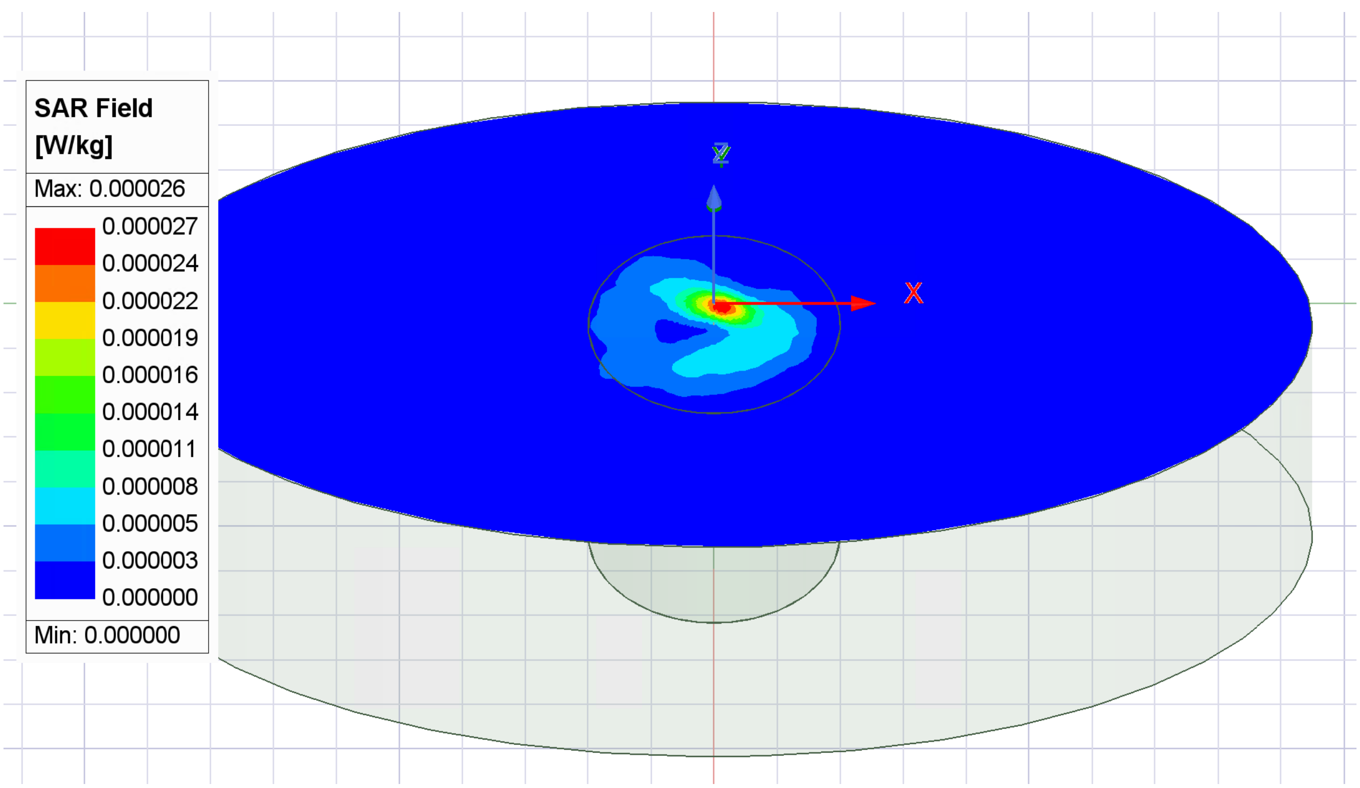


Figure 21: SAR Simulation Phantom View



7. Conclusions

Based on the results in this report by correlating the E/H Fields measured and simulated results the accuracy of the SAR model has been demonstrated. SAR was only assessed for the worst case condition which was determined through KDB Inquiry process to be Body Side at 0 mm distance from DUT while having a separation distance of 2 mm in between HU0223 and HU0123. The SAR peak spatial-average value averaged over 1-g of tissue was determined to be 0.000026 W/kg which is well below the 1.6 W/kg limit and therefore demonstrates compliance with FCC rule parts § 1.1310 and § 2.1093.

8. References

- FCC rule part § 1.1310:
  https://www.ecfr.gov/current/title-47/chapter-I/subchapter-A/part-1/subpart-I/section-1.1310

- FCC rule part § 2.1093
  https://www.ecfr.gov/current/title-47/chapter-I/subchapter-A/part-2/subpart-J/subject-group-ECFR52efa600149ef42/section-2.1093

- KDB 680106 D01 RF Exposure Wireless Charging App v03r01
  https://apps.fcc.gov/kdb/GetAttachment.html?id=g5f2nQFxHnlMbja%2FFzq1QQ%3D%3D&desc=680106%20D01%20RF%20Exposure%20Wireless%20Charging%20Apps%20v03r01&tracking_number=41701

- ITIS tissue properties database
  https://itis.swiss/virtual-population/tissue-properties/database/dielectric-properties/

- UL Report R14722187-S3