Supporting Simulation Findings for WPT Charger-3 Compliance

Introduction

We are pleased to provide additional evidence supporting the compliance of our Device Under Test (DUT) with FCC regulations. Building upon the original report by IMST ("Report_Charger-3_V1.4.pdf"), we have conducted further analysis and additional simulations using different computational modeling platforms. This additional work aims to strengthen the findings of the original report and demonstrate our device's compliance comprehensively.

The following documentation summarizes the results of our extended analysis, providing significant evidence of our device's regulatory compliance and meeting the human exposure limits.

Human Exposure Limit

Given that the frequency of our device is below 100 kHz (81 kHz), SAR (Specific Absorption Rate) considerations are not applicable for basic restrictions. Therefore, for the purpose of equipment authorization, and specifically for this device, we choose to adhere to the basic restrictions outlined in the International Commission on Non-Ionizing Radiation Protection (ICNIRP) 2010 document available at https://www.icnirp.org/cms/upload/publications/ICNIRPFactSheetLF.pdf

This decision ensures alignment with recognized international standards and the safe operating conditions for users. Table 1 shows the internal electric fields (RMS V/m) limits at the operating frequency of 81 kHz.

Condition	**Uncontrolled Environment** (General Public) **EIAV Limit**	**Controlled Environment** (Occupational) **EIAV Limit**
Peak EIAV @ 3 kHz - 10 MHz	$1.35 \cdot 10^{-4} \cdot f$ V/m *	$2.7 \cdot 10^{-4} \cdot f$ V/m *
Peak EIAV @ 81 kHz	10.935 V/m	21.87 V/m
* Frequency f in Hz		

Table 1. The basic restrictions provided in the ICNIRP.

Simulation Results Analysis

I. IMST Internal Electric Field Results

To provide a comprehensive overview of the electric field distribution within our device, we first present a 2D plot extracted from the original report provided by IMST (Figure. 9). Fig. 1 in this report serves as a reference point for understanding the initial findings regarding the internal electric field inside the phantom. As shown in the figure, the maximum internal electric field is recorded as 8.564 V/m RMS, which is below the safety limit of 10.935 V/m. It is important to note that the same parameters used in the simulation, including a coil current of 1.65 Arms, are implemented in the design of our device. This ensures consistency between the simulation results and the actual performance of the device under real-world conditions.

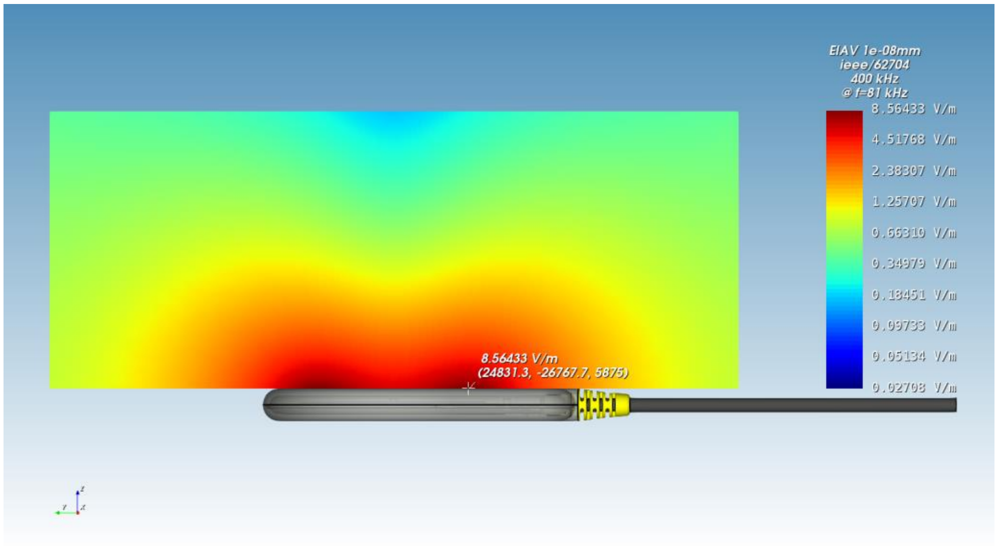

Fig. 1. The 2D plot of internal electric field (Vrms/m).

II. EM-fields Transition at Tissue Simulation Liquid (TSL) Layer

In addition to the IMST internal electric field results, we conducted supplementary simulations to investigate the smooth transition of the magnetic field and tangential electric field and at the air-tissue interface. Fig. 2 indicates that the magnetic field undergoes an undisturbed transition from air to the phantom. In other words, the calculation of the magnetic field from the external coil "in air" can be applied inside the TSL domain as well.

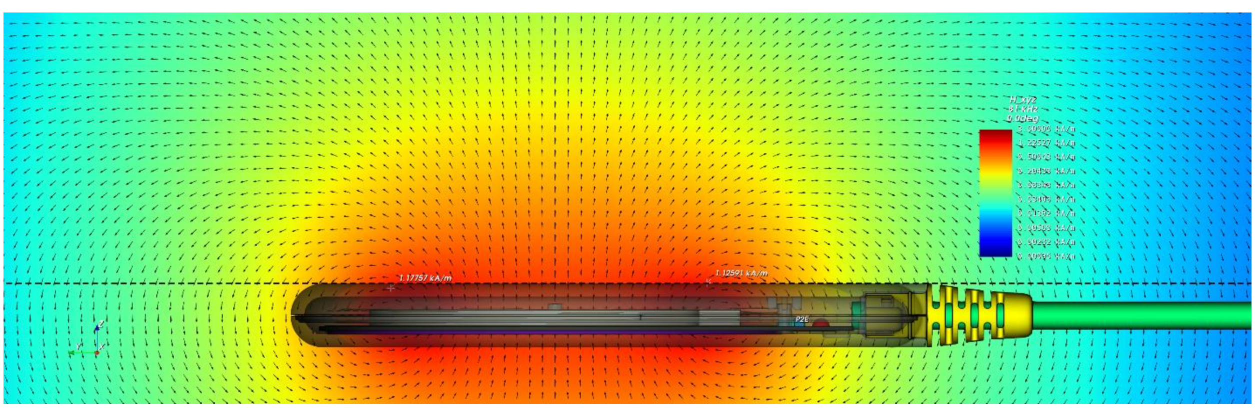

Fig. 2. Simulated external and internal H-field. The dashed line indicates the interface between phantom and air.

Furthermore, to illustrate the consistent nature of the tangential electric field components, we used an extremely high resolution for the line plot, as shown in Fig. 3. As can be seen, the transition from the air to the phantom is smooth for the tangential electric field, as expected. The vertical dashed line denotes the interface between air and tissue.

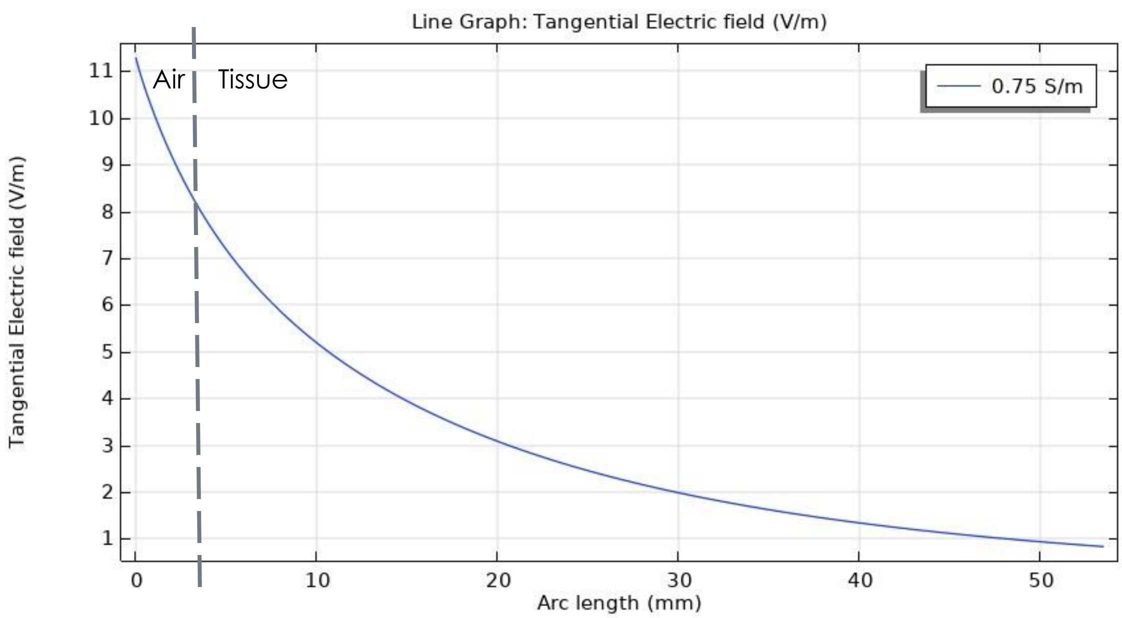

Fig. 3. Simulated tangential E-field. The dashed vertical line indicates the interface between phantom and air.

To explain this phenomenon, the skin depth for a phantom conductivity of 0.75 S/m at 81 kHz is calculated to be about 2 meters. This value significantly exceeds the thickness of the TSL layer. Consequently, the reaction induced by the eddy current in response to the external magnetic field can be disregarded. In simpler terms, the calculation of the magnetic field generated by the external coil "in air" remains valid within the TSL domain. As the electric field is generated by the magnetic field, the electric field remains unchanged as a result as well.

This phenomenon is a well-known result in eddy current analysis. When the skin depth is substantially larger than the thickness of the TSL layer, the resistance-limited formula for eddy currents serves as a reliable approximation. This observation aligns with the simulation results, which demonstrated the magnetic field generated by the coil penetrating the TSL layer essentially undisturbed.

III. Validation of Simulation Accuracy

The Finite-Difference Time-Domain (FDTD) simulation results from IMST are further confirmed by additional simulations conducted using Ansys and COMSOL Multiphysics. These simulations properly model the Charger 3 setup, including the coil and phantom properties, as well as the coil current (1.65 Arms). Remarkably, both Ansys and COMSOL Multiphysics yield magnetic field and internal electric field distributions that closely match the FDTD simulation results provided by IMST as shown in Figs. 4 and 5. Specifically, the magnetic fields and internal electric fields exhibit similar magnitudes, with e-field values around 8.1 V/m (compared to 8.56 V/m in Fig. 1), further validating the accuracy and reliability of the original simulation findings.

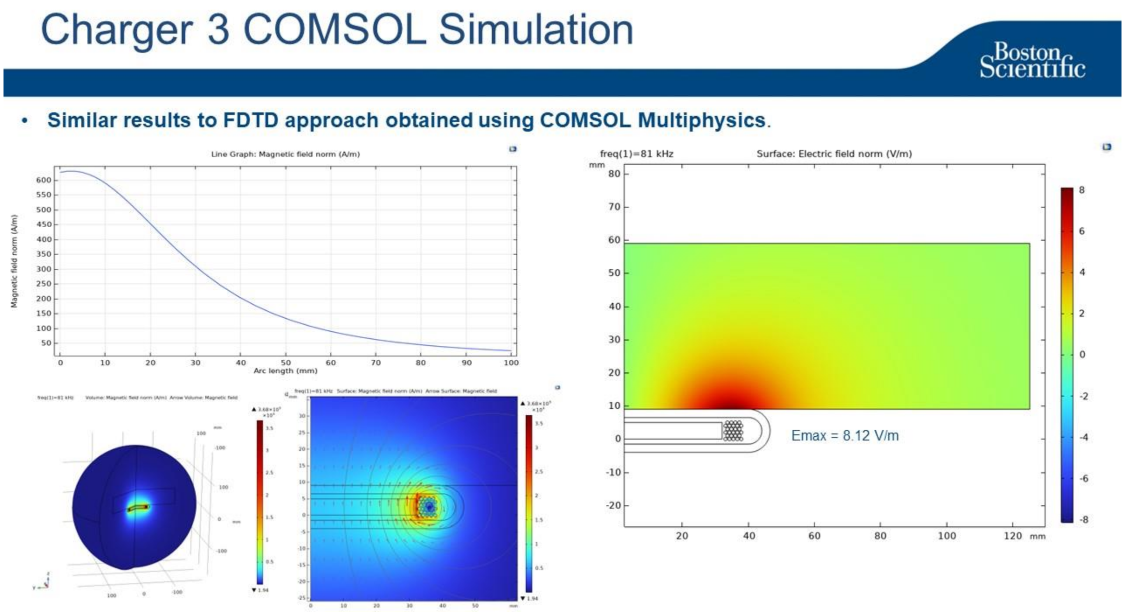

Fig. 4. COMSOL simulation results agree well with the FDTD simulation results.

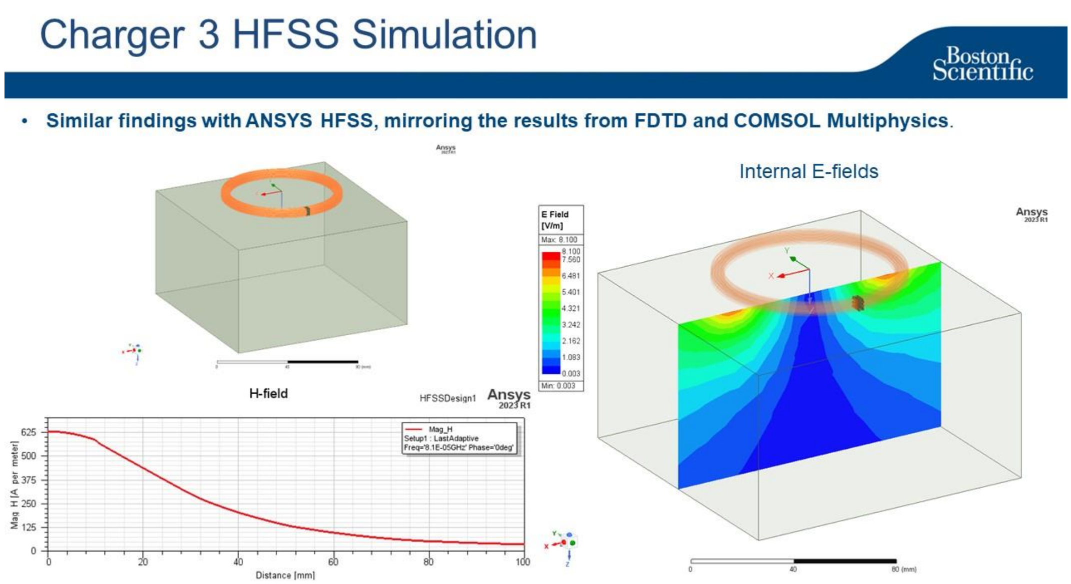

Fig. 5. ANSYS simulation results match well with the FDTD and COMSOL simulation results.

IV. Conclusion

In conclusion, the comprehensive simulation findings presented herein provide robust evidence of our WPT device's compliance with FCC regulations. Through analysis conducted by IMST, supplemented by additional simulations using Ansys and COMSOL Multiphysics, we have demonstrated the validity and reliability of the simulation results. Based on the simulation findings, the WPT system can be considered RF exposure compliant.

BSN RF Team

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