1 Simulation Model Validation Study

To validate the simulation model, measurements are made on the EUT and compared to the simulated model results. H-field measurements are performed to verify the simulation model's accuracy versus measurement results. Only a validated simulation model will be used for SAR simulations.

1.1 H-field Simulations

Electromagnetics simulations are conducted using commercially available software Ansys HFSS. Below steps are performed to analyze the simulation model. 1) CAD geometry that represents the EUT is first imported. 2) Material properties are assigned to the geometry objects at the operating frequency (e.g., 360 kHz). 3) A proper mesh seeding is performed, and ports are assigned. 4) After 3D simulation is completed, the two-port network [Z] data was extracted and used with the WPT circuit model. This WPT model includes the charger source as well as the phone side rectifier circuit. Solving using a circuit tool, proper excitations for transmitter (charger) and receiver (phone) coils are calculated. 5) Later, these current waveforms are fed into the Ansys HFSS to excite the coils and create H-field.

As shown below, the phone and charger can be unintentionally forced by user to be laterally misaligned or vertically separated.

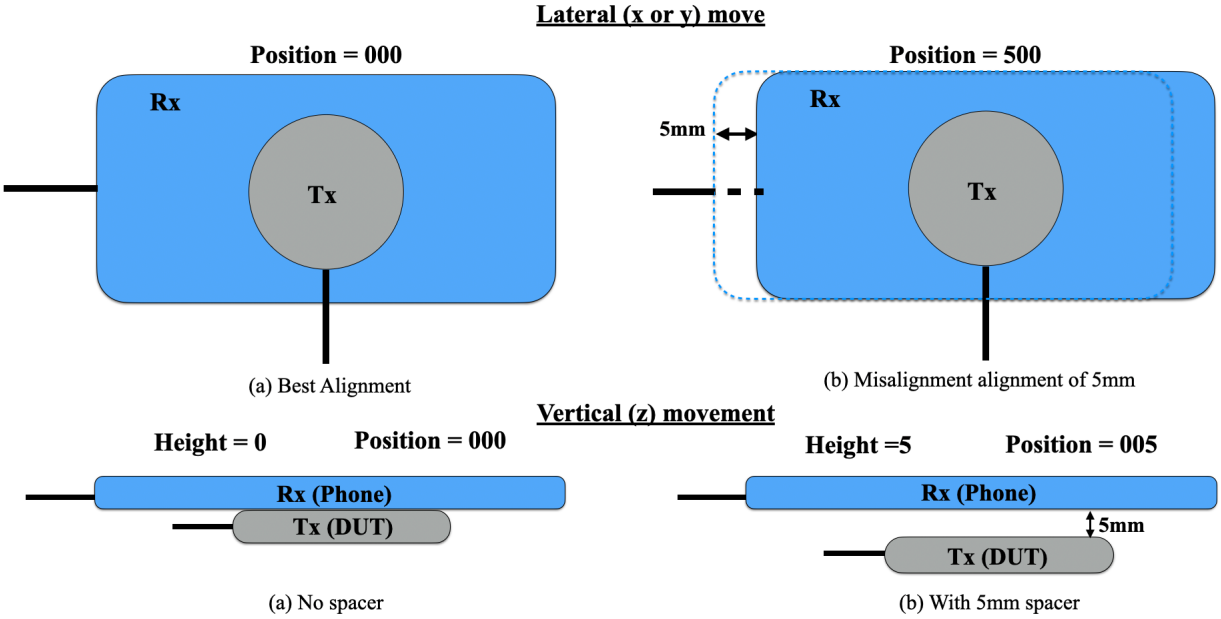

Figure 1: Demonstration of the Phone and the Charger Misalignments

The misalignment and/or separation can change H-field's intensity and spatial distribution. Hence, several different misalignment and separation cases were selected and investigated to determine the worst-case scenario (i.e., highest H-field). After simulating these cases, few test

cases will be selected and measured and used to benchmark the accuracy of the simulation model. Finally, worst cases will be selected for SAR simulation.

1.2 H-field Measurements

A Narda ELT-400 probe is used to measure the H-field above the EUT. Below is a picture of the probe, an x-ray image of the probe, and the measurement setup. The probe has three orthogonal loops with radius of 10 mm. These loops are used to measure H-field in different directions. The distance from the EUT outer surface to the probe is 0 mm. However, the loops are covered with a plastic shell of 6 mm thickness. Therefore, the distance from the center of the probe to the EUT is 16 mm. These factors have been considered in simulation of the H-field.

Figure 2: ELT-400 Probe

1.3 Simulation Vs Measurement Comparison

Correlation study between the simulation model and the measurements (H-field) is presented in this section. Simulation and measurement results are compared for the phone and charger side below. The target power shows the maximum deliverable power per each case. For example, to be able to deliver a maximum power of 15 W to the phone, the maximum offset is found to be either 3 mm radially on z = 0 mm plane, or 2 mm radially on z = 2 mm plane.

For each side, the H-field probe is in contact with the EUT, scanning an area of 150 by 150 mm^2 with a step size of 3 mm. The maximum RMS H-field is reported in the tables.

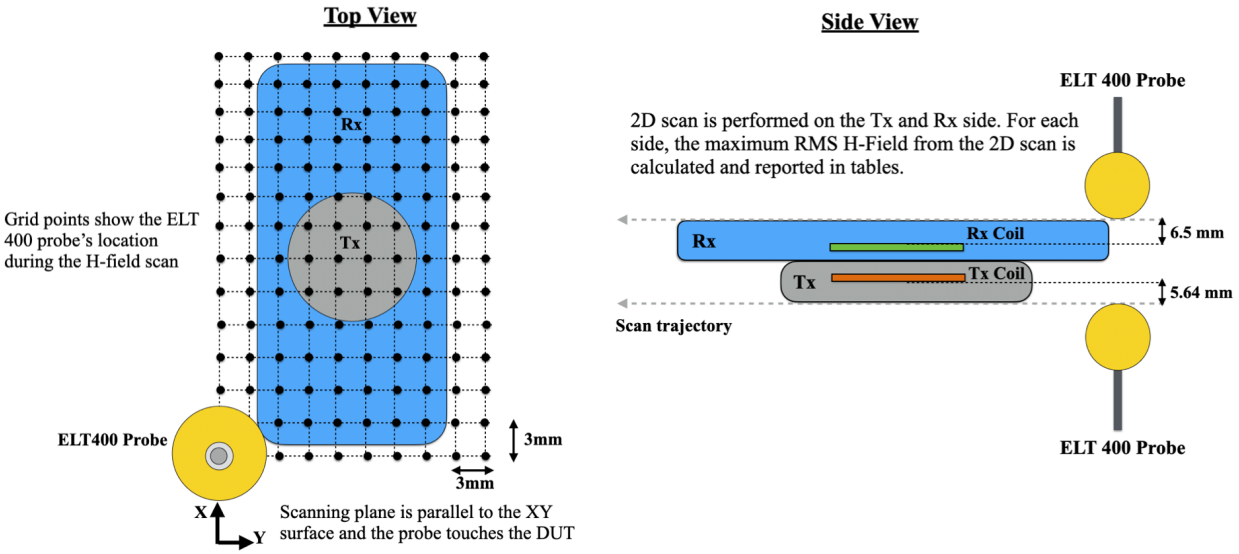

Figure 3: Scanning EUT to Measure H Field Spatially

Table 1. Comparison of the simulated and measured H-field on the Phone side.

Phone side RMS H-field (A/m)

Relative movement (X, Y, Z) from perfect alignment (mm)	Power delivered to Rx (W)	Simulated RMS H-field (A/m)	Measured H-field (A/m)
(0, 0, 0)	15	0.3	0.42
(2, 0, 2)	15	0.59	0.68
(3, 0, 3)	7.5	0.61	0.82

(4, 0, 4)	7.5	0.77	0.81
(5, 0, 5)	3.5	0.86	0.93

Table 2. Comparison of the Simulated and Measured H-field on the Charger Side

		Charger Side RMS H-field (A/m)	
Relative movement (X, Y, Z) from perfect alignment (mm)	**Power delivered to Rx (W)**	**Simulated RMS H-field (A/m)**	**Measured H-field (A/m)**
(0, 0, 0)	15	0.33	0.38
(2, 0, 2)	15	1.66	0.96
(3, 0, 3)	7.5	2.26	2.56
(4, 0, 4)	7.5	3.42	2.29
(5, 0, 5)	3.5	3.91	3.5

There is a good correlation between the simulation and measurement results. Also, as tables show, for aligned cases (i.e., zero lateral move), the phone side shows slightly more radiation. This is mainly because the metallic housing of the charger preforms as a good shield. While when there is a lateral misalignment, fields can leak from the sides and the H-field on the charger side becomes more noticeable.

Transmitter (EUT) Correlation Study:

To further evaluate the simulation model, we simulated and measured the charger only scenario using the measurement setup shown in the inset of Fig. 4. As shown in the measurement setup, the center of probe coils is 16 mm away from the true 0 mm touch position. To compute the averaged fields from simulation results for correlating with measured data, we used MATLAB post-processing script using the procedure described above to include the ELT400 probe averaging effect. Simulation model and measurements correlation is performed at a vertical distance away from the EUT and the probe is moved vertically in Z direction from 0 mm (probe center) to 150 mm until we reach the noise floor of the measurement probe.

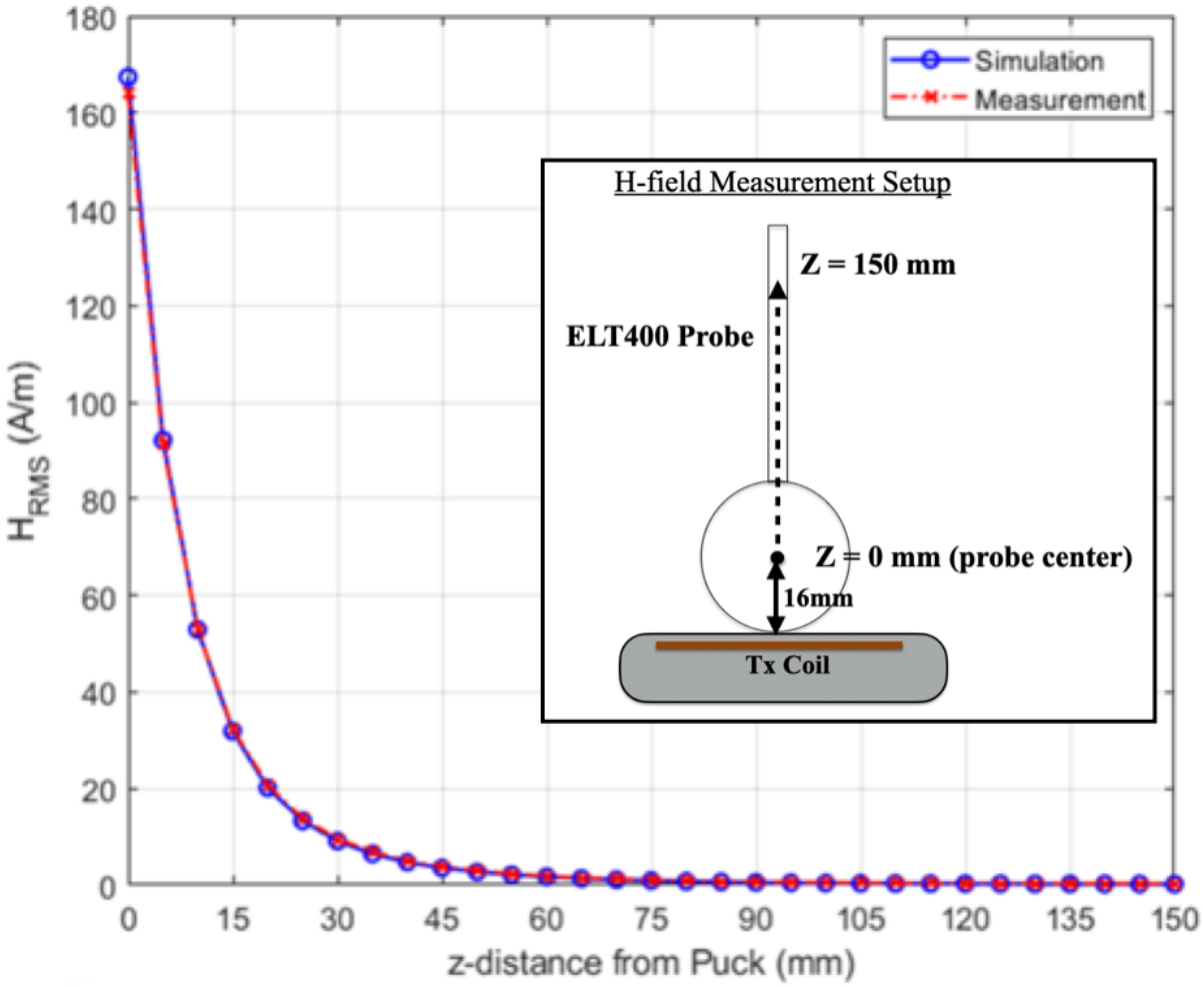

Figure 4: Correlating H-field Variation from Simulation and Measurement When the Probe Moves from Touching the Phone (z=0) to 150 mm Away

Above Fig. 4 shows good correlation between the measurements and simulations, verifying the accuracy of the model. At distance very close to the EUT, simulations are little more conservative than measurements

Conclusion:

From both the above studies, we see that there is good correlation between simulation model and measurements and hence this validated model can be used for SAR simulations.