RELIABLE PREDICTION OF MOBILE PHONE PERFORMANCE UNDER REAL USAGE CONDITIONS USING THE FDTD METHOD

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Abstract

This study discusses the suitability of numerical methods as robust analysis and prediction tools regarding the RF performance of CAD derived mobile phones. The investigation was conducted using one of the latest commercial quad-band mobile phones and in addition included head and different hand models targeting a detailed assessment of in-use situations. In particular, the effect of the user's hand position on the antenna performance was given a special focus. In the simulation different parameters were evaluated such as impedance, efficiency, far-field, as well as EM near-field distributions. The results are compared to measurements obtained with the latest tools available. The resulting reliable prediction for various daily usage configurations demonstrate the usability of numerical methods in the early design phase of devices such as complex high-end multi-band mobile phones.

1 Objectives

The objective of this study was to evaluate whether the performance of mobile phones can be reliably predicted by numerical methods. It has previously been demonstrated [1, 2] that performance can be accurately assessed for standardized testing positions at the head. In this study, the requirements were extended to actual usage patterns such as different positions at the head and especially for different ways of holding the phone with the hand. The latter is of particular importance because fingers placed at certain locations could strongly affect the antenna.

2 Methods

The SEMCAD [www.SEMCAD.com] simulation platform was selected for the study due to its handling, functionality and features for highly detailed CAD models as well as efficient FDTD solver for the simulation of advanced applications.

2.1 Generation of an Accurate FDTD Representation of the Phone

The CAD data describing the phone was provided by Motorola in .IGES format. The original model contained approximately 1000 subparts including almost all ICs on the PCB. A stepwise approach was used to import and arrange the model logically in SEMCAD. In addition, two different antenna assemblies were provided.

First, the most significant parts were identified (helical antenna, feed structure as well as PCB) and used for harmonic and transient simulations to determine relevant gridding parameters, verify excitation modes and material parameters. The complexity of the model was then increased by adding the remaining parts in order of their RF significance. This approach enables an accurate representation to be generated in a straightforward manner, addressing issues such as material assignment and grounding connectivity at all levels.

Components with dimensions <1 mm were removed from the model due to their insignificant RF role

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in the simulations. Additional modifications were made to the PCB such that it was represented by a multilayered structure (3x 100 μm PEC layers, 2x dielectric layers) for more accurate representation of the physical losses that occur in the PCB. The final model which was used in the SEMCAD simulations is shown in Figure 1.

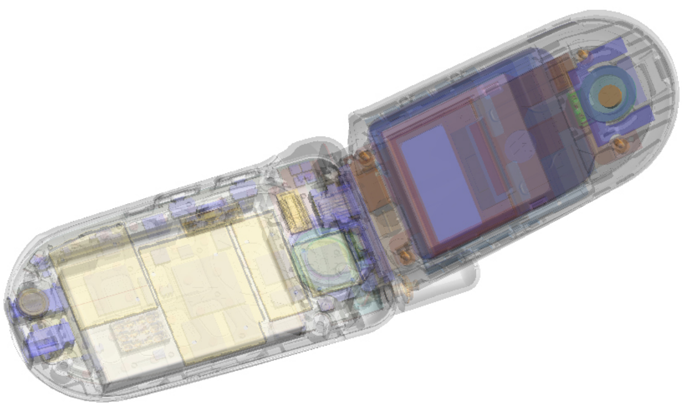

Figure 1: Full SEMCAD model of the phone

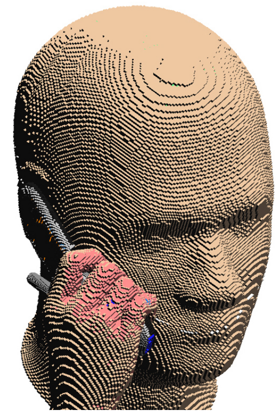

Figure 2: Discretized representation

2.2 Simulation Phantom Models

The SAM head phantom was used as the head load in the simulations. The three hand positions describing the detuning are shown in Figure 3. Homogeneous hand models were generated using Poser® and exported as .3DS CAD files. Further modifications based on anatomical data [www.gwc.maricopa.edu/class/bio201/] were made in SEMCAD, such that the final hand models consisted of skin, muscle and significant finger and wrist bone tissues (Figure 4).

Figure 3: Real hand positions describing the detuning

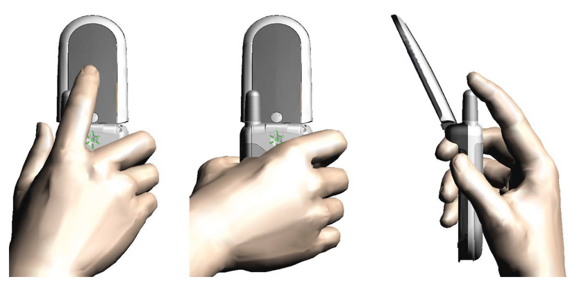

Figure 4: CAD representation of the hands for the simulations: hand1 (left), hand2 (middle) and hand3 (right)

2.3 Simulation Parameters

All metallic parts were modeled as PEC, and the remaining phone parts were represented using 5 different dielectric materials. The material parameters that were used for the SAM head and hand are defined in [3].

A minimum grid step of 100 μm was used to resolve the model in significant areas, e.g., the helical antenna, feed structure and multilayered PCB. The maximum grid step was limited to about 1.2 mm over the remainder of the phone to reduce stair-casing and ensure that the dielectric volume was accurately approximated. The hand and head phantom models were resolved using a maximum grid of 2.2 mm. The resulting grid for the freespace phone simulations contained about 5.5 million cells, while the grid for the phone, head and hand simulations contained about 15 million cells. The discretized phone, SAM head and hand2 setup is shown in Figure 2.

3 Results

3.1 Freespace Near-Field Comparison

In order to validate the simulation results, near-field measurements were made using the high precision DASY4 [www.SPEAG.com] near-field scanning system equipped with the latest probes.

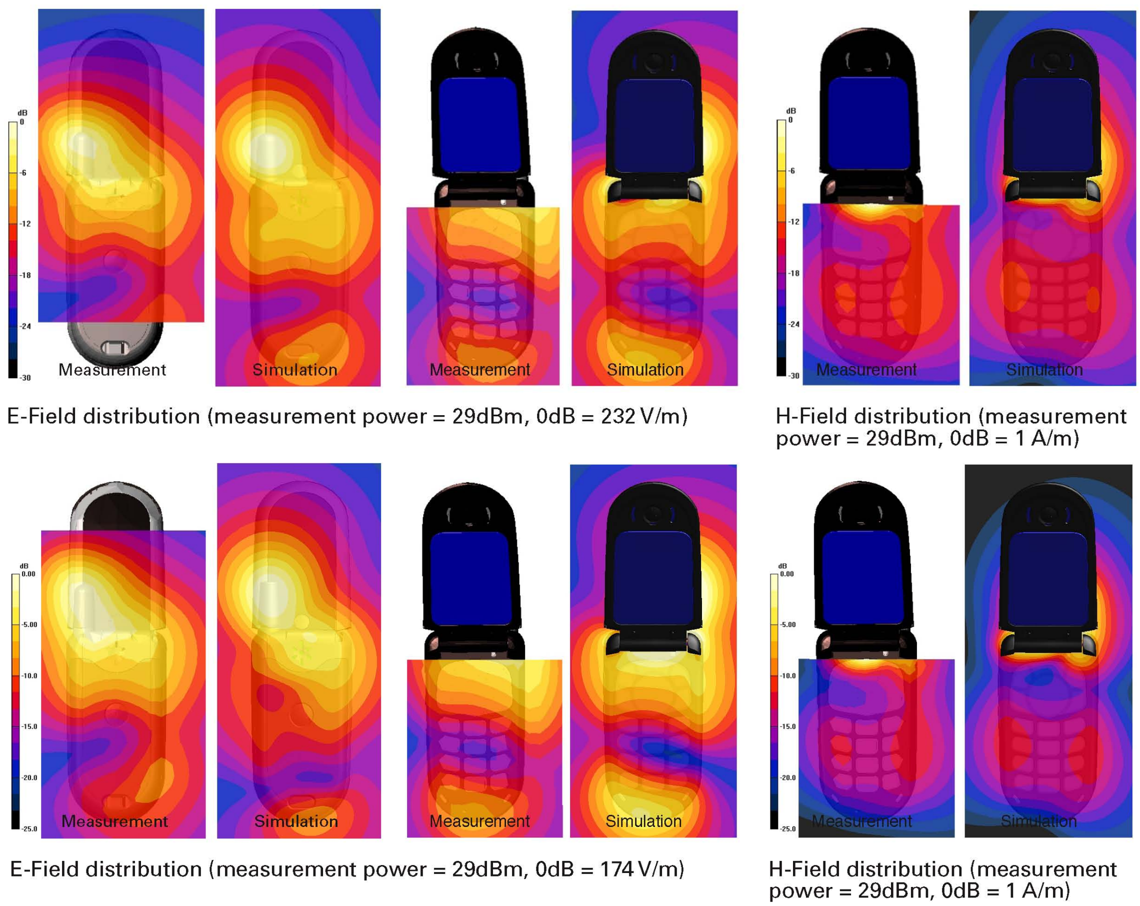

Figure 5: Freespace E- and H-field comparison between simulation and measurement for A (top) and B (bottom) antenna assemblies

Figure 5 shows the freespace comparison between measured and simulated data for E- and H-Field distributions in a plane at a distance of 5 mm on either side of the phone for the two antenna assemblies, normalized according to the radiated power. Good to excellent agreement was obtained for E- and H-Field comparisons for both antenna assemblies.

3.2 Radiation Performance Parameters

Simulations for head-only and head+hand setups were also run to investigate efficiency and detuning issues for the antennas. The radiation efficiency is defined as $R_{eff} = \frac{P_{rad}}{P_{src}}$ where P_{rad} is the radiated power and P_{src} is the applied simulation source power. This definition does not include possible losses in the matching network, and antenna mismatch is not taken into account. The radiation efficiency shown in Table 1 highlights the effect of the absorbing bodies in the vicinity of the close near-field of the phone. Efficiency comparisons for the freespace phone setup could be made, as S11 measurements were available, and deviations of less than 5% were achieved. Figure 6 shows the S11 for the two antenna assemblies. In both cases the freespace impedance was used as the reference

	Radiation Efficiency (%)		Impedance (Ohm)		S11 (dB)	
load	A antenna	B antenna	A antenna	B antenna	A antenna	B antenna
freespace	74.4	64.1	35.4 + j61.9	17.9 + j31.9	-42.8	-29
SAM	45.4	48.1	36.5 + j67.8	19.3 + j33.9	-29.3	-28.5
SAM+hand1	12.3	16.5	66.8 - j99.4	102 + j45.8	3.7	-4.8
SAM+hand2	20.7	21.2	48.1 + j72.7	23.2 + j37.1	-19.5	-21
SAM+hand3	24.6	27.9	88.9 + j54.5	55.8 + j33.4	-10	-9

Table 1: Simulated efficiency and source impedances for different setups at 1880 MHz

impedance to highlight the detuning effects. Although both antennas are resistant to detuning for the head-only setup, they experience severe detuning for all 3 head+hand setups. These effects are more pronounced for the A antenna assembly. Hand1 and hand3 setups are characterized by more severe detuning due to the close proximity of the index finger to the antenna.
These performance results show the best-case performance efficiency, given that further losses will occur from the shift in antenna impedance by detuning the matching network. Depending on the bandwidth of the matching network, this could have a drastic effect on the absolute efficiency. Since the matching network was not modeled, this effect cannot be extracted from the simulated results.

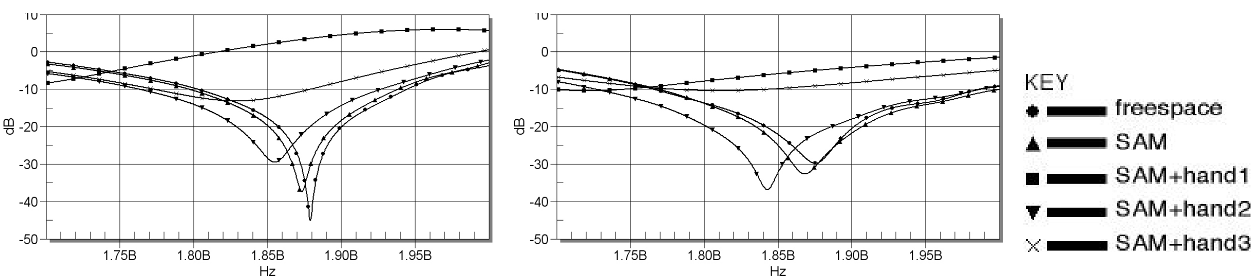

Figure 6: S11 for A (left) and B (right) antenna assemblies: freespace impedance in Table 1 is used as reference impedance

4 Conclusions

This study shows that numerical methods and enhanced FDTD tools in particular are suitable techniques for supporting engineers in the analysis, design and optimization of transmitters.
CAD models can now be directly imported and modified into a RF representation within a short time. The results of different configurations have been validated by measurements. Important parameters of performance in the field can be reliably predicted before the phone is actually built. An engineering approach could include the comparison of different phone designs through the use of standardized scenarios. These scenarios can be real-world problems such as certain hand positions and different ways of holding or mounting the device on the body.

References

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