Simulation of Mobile Phone Antenna Performance

Tough technical requirements are being put on handsets. Mobile phones have to deal with an ever increasing number of services, while at the same time the cost of the systems is being reduced. RD in the mobile phone industry copes with this situation by continuously improving the mobile phone efficiency in order to be able to comply with the grade of service in the mobile network. Thus, we are moving towards mobile designs, which are not only becoming thinner, smaller and more complex with every generation but also have to perform with the same or even better performance, and at more frequency bands.

In addition to maximizing the antenna-accepted power of the handsets, the effects on the antenna performance from surrounding objects such as the human body have to be studied and considered. Homogeneous models are used when measuring the effects on antenna performance and represent a conservative estimation of the antenna losses and dissipated power. The performance of the antenna and the entire system may be quantified using sets of technical requirements for both passive and active modes.

In passive mode the antenna performance is often measured by the antenna efficiency, which is subdivided into the radiation efficiency and the return-loss efficiency. In active mode the entire system efficiency is defined by the Total Radiated Power (TRP) on transmitting (Tx), and the Total Isotropic Sensitivity (TIS) on receiving (Rx). The active performance of the handset is often measured using exact and time consuming procedures. These have to be conducted several times during the development phase of the device. Furthermore, the product has to be developed to a certain stage before any measurement or reliable prediction of antenna performance is possible.

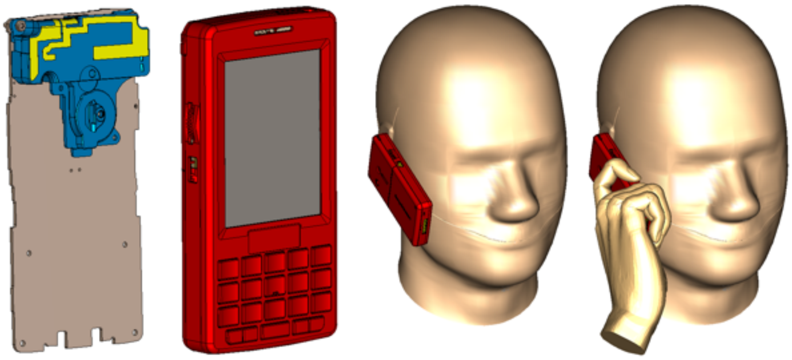


Figure 1: Analysis phases of the mobile phone study.

The results of simulation for the several system complexity levels and its comparison to measurements are compared for the recently released Sony Ericsson M600 mobile phone. All measurements were conducted at Sony Ericssons test facilities. In Figure 1 the models are shown, from left to right with the least complex structures such as the simple antenna design and PCB, to the complete phone structure containing several hundred components, and finally the entire system using the head of the Standard Anthropomorphic Model (SAM), a homogeneous hand model and the full phone.

SIMULATION AT ANTENNA LEVEL

At the antenna level the design and optimization of the antenna itself is the prime goal. Results of interest are typically the return loss, radiation efficiency and radiation pattern of the antenna at various frequencies. Even though the transient solver of CST MICROWAVE STUDIO® (CST MWS) is used for the simulations, frequency quantities like near and far fields can be evaluated easily at numerous frequencies during one transient run due to field monitors based on discrete Fourier transforms (DFT). Realistic loss values were chosen for both the metallic and dielectric objects.

A convergence study indicates that the model converges to an accurate solution. Starting with a relatively coarse mesh of 221.000 mesh cells, and refining it using an energy based criterion, the final solution is achieved in only three steps. The criterion for stopping the study is that the maximum difference of an S-parameter between two runs is less then 0.02 over the complete band (0 3 GHz). Additionally, the convergence of the radiation efficiency at the two bands was evaluated.

The total convergence took 38 minutes. For further simulations and structure optimizations, the third run can be skipped, as the mesh setup in the second run with around 383,000 mesh cells, delivers well converged results. This means that all further simulations in the optimization process will have a run time of only 12 minutes.

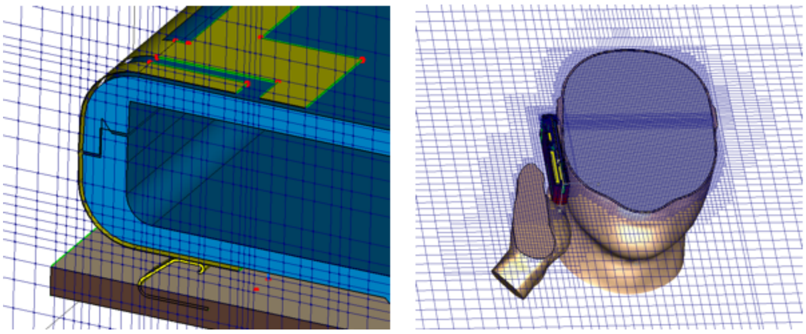


Figure 2: The converged mesh for the antenna simulation, just phone (left) and including SAM phantom (right).

The converged mesh is shown in Figure 2. The bent planar parts of the PIFA antenna, the antenna carrier and the PCB can be seen clearly. As the bendings are not aligned with the Cartesian mesh, this would cause significant problems in simple staircase methods, however, due to the thin sheet technique, mesh cells can be intersected by metallic sheets. Together with the PBA technique, the shown grid, although it might look relatively coarse, delivers fully converged results.

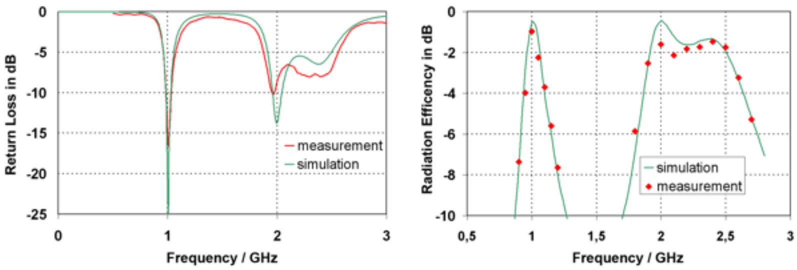


Figure 3: Simulation versus measurements at antenna level: the return-loss (left) and the antenna efficiency (right) are compared.

In Figure 3 the converged simulation results of the antenna are compared with measurements. The results are in agreement for both the return loss (left) and the radiation efficiency (right). Finally, in Figure 4, the radiation pattern is shown for two GSM frequencies. Since the plastic housing is not considered for this study, the resonances are slightly shifted to ~1 GHz and ~2 GHz.

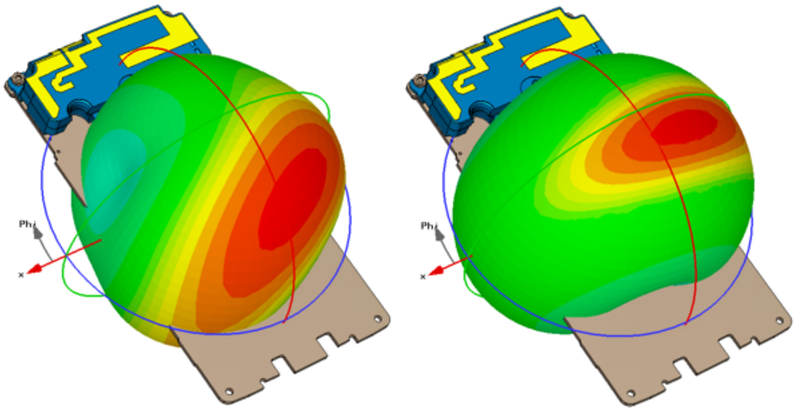


Figure 4: The radiation pattern of antenna for two GSM bands.

SIMULATION AT PHONE LEVEL

After the antenna design is complete, the next step is to include it in the complete phone. This enables the evaluation of the coupling effects of neighboring objects such as the battery, camera, flash capacitors, etc., as well as the influence of dielectric materials such as the housing and display screen.

The phone is subdivided into roughly 60 components, each consisting of hundreds or even thousands of individual facets; see Figure 5 (the back cover and battery lid are hidden for the picture). The components used for the simulation are chosen based on their influence on electromagnetic fields (which is controlled by both dimensions and location), in order to give an accurate simplification of the phone geometry for the investigated frequencies.

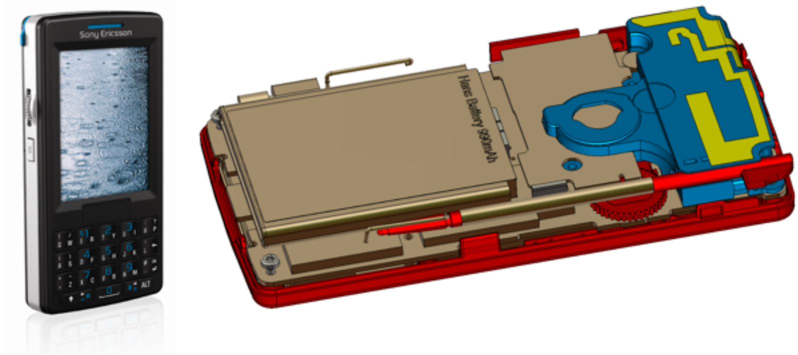


Figure 5: Full phone model containing phone plastics (red + blue) and metallic parts (copper + gold).

The structure was imported into CST MWS using the STEP interface. No additional healing was necessary before conducting the simulations, which is an important pre-requisite for efficient industrial design and workflow. The simulation of the full mobile phone consisted of 594,000 mesh cells (again after a convergence study as described in the previous section). The total simulation for the converged model took 19 minutes.

The simulation of the return loss and radiation efficiency of the full phone is compared with measurements in Figure 6. As the complete phone is now considered, the frequencies are shifted down to the well-known mobile phone bands. The results again agree well in respect to resonance frequencies, bandwidths and radiation efficiency; but some differences occur in the return loss for the upper frequencies.

These can be explained by the uncertainty regarding the antennas exact feeding point during measurement and measurement de-embedding. Additionally the properties of the various materials used in the phone model may be inexact.

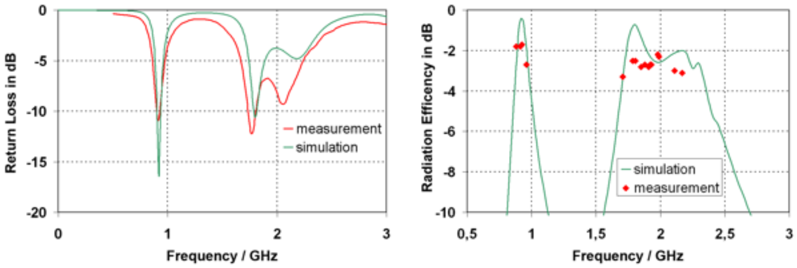


Figure 6: Comparison of simulation and measurement for the full phone simulation: the return-loss (left) and the antenna efficiency (right) are compared.

Alongside radiation efficiency and return loss, global quantities such as the TRP and the TIS are relevant for the simulation of the complete phone. These values require the consideration of not only the antenna characteristics but also the amplifier, the signal transmission inside the printed circuit board and the matching network. Figure 7 shows the simplified setup of such a circuit in CST DESIGN STUDIO™ (CST DS) including an idealized source, touchstone file describing the PCB transmission, matching network and a microstripline to feed the antenna. The simulation delivers system S-parameters, system near and far fields, and from these, the TRP value. The TRP value of this idealized setup gives 23.27 dBm at 1.8 GHz and amplifier power of 0.25 W.

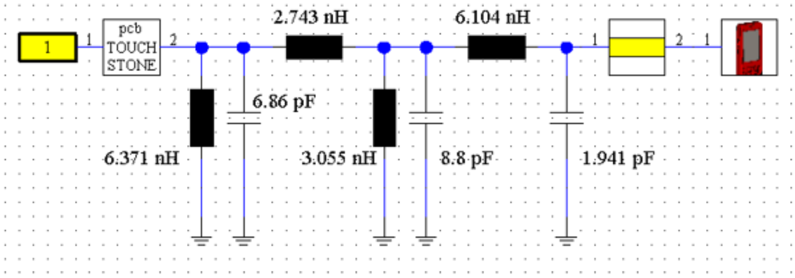


Figure 7: Network simulation including matching network and the 3D results of the antenna.

The near field is also of significance for the complete phone, as interaction with other electromagnetic devices such as hearing aids (hearing aid compatibility, HAC) might occur. Near field information can be predicted very accurately by means of simulation. Figure 8 compares the normalized E and H near fields at a distance of 10 mm from the back of the phone in a free space configuration. The blue outline represents the position of the phone.

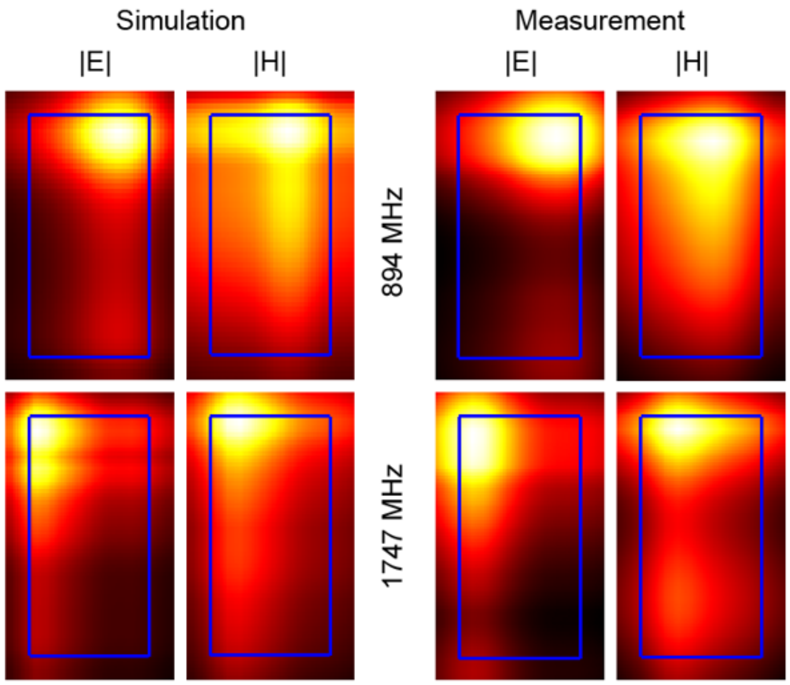


Figure 8: Electric and magnetic near fields on the back of the phone, simulation (left) and measurement (right).

SIMULATION AT BODY LEVEL

A final test for the mobile phone is to evaluate it in the presence of a human body, with particular emphasis on the head and hand. In accordance with IEEE standards, such as 1528, the Standard Anthropomorphic Model is used as the head model. The frequency dependent dielectric properties of the tissue simulating liquid are also defined by this standard and can be modeled as a dispersive material in the simulation tool.

The simulation of this phone, with head and hand models required 4.24 million mesh cells and had a simulation run time of 1.58 hours on a PC (dual core dual CPU, 2 GHz, 8 GB RAM). The number of mesh cells can be reduced using the sub-gridding scheme. When applied, a very fine mesh is created inside the phone, a coarser one in the head and a very basic one in the vacuum (see Figure 2 right). Using the sub-gridding reduces the number of mesh cells to only 922,000 and the simulation time to 44 minutes.

Such a simulation can give important insight into how the SAM phantom or the homogeneous body models affect the performance of the mobile phone. The radiation pattern is obviously affected, but also the radiation efficiency is influenced by the head and hand. Figure 9 shows the radiation pattern of the phone; a significant difference is visible in comparison to the plain antenna far fields from Figure 4.

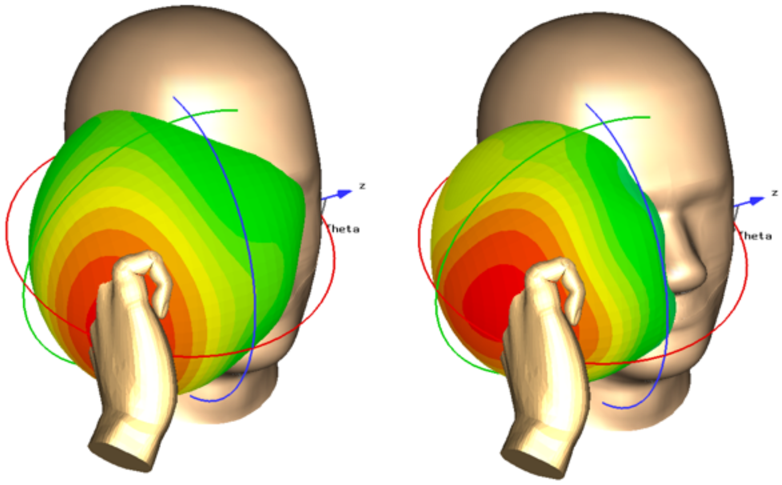
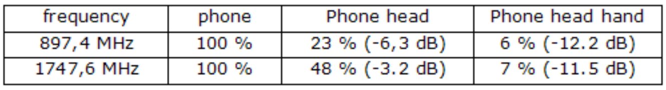


Figure 9: The modified radiation pattern for the two GSM bands in presence of head and hand.

As mentioned, the radiation efficiency is influenced by the body models. Figure 10 shows the antenna efficiency calculations for only the phone, the phone placed at the right cheek of SAM, and the phone held at SAMs right cheek with a hand model present.



frequency	phone	Phone head	Phone head hand
897,4 MHz	100 %	23 % (-6,3 dB)	6 % (-12.2 dB)
1747,6 MHz	100 %	48 % (-3.2 dB)	7 % (-11.5 dB)

Figure 10: Antenna efficiency calculations for only the phone, the phone and SAM, and the phone with SAM and hand model.

Finally, full SAM simulations are very useful to predict the dissipated power. This quantity – as a measured value – is another important design issue and a requirement for certification. However, a simulation allows the designer to control this power at a much earlier design stage. CONCLUSION This article has shown what is currently possible in the world of advanced 3D EM simulation. Throughout all steps of a mobile phone's terminal antenna development – from antenna design, through full phone optimization up to investigating the influence of, and impact on body tissues – simulation and measurement have been compared and shown very good agreement. In addition to measurable data, numerical simulation grants insight into previously unseen electromagnetic detail. Within one simulation run, all-important quantities such as return-loss, radiation efficiency, near and far fields, loss monitors (all at various frequencies) can be obtained. Advanced mesh technology significantly reduces the simulation time, bringing it down to a few minutes for an antenna simulation. Even complex automatic optimization runs become feasible. The increasing efficiency and reliability of simulation, which reduces design cost risk is recognized as indispensable in the industry. ACKNOWLEDGMENT: This article is the result of a common study of CST and Sony Ericsson Mobile Communications. CST likes to thank especially Dr. Omid Sotoudeh from Sony Ericsson for providing the models, the measurement data and many fruitful discussions regarding the simulation results. A full version of this article was published in the January 2008 issue of Microwave Journal (www.mwjournal.com) and can also be found here.