SEMCAD X

Introduction to the Simulation Platform & Latest Applications

WHO Workshop on Dosimetry of RF Field
Moscow, December 2005
Background:

- SEMCAD was originally started through various projects at ETH in Zurich
- Development integration was completed by IT’IS Foundation; commercialized by SPEAG in 2001
- Original product development driven by:
  - dosimetry (academic research)
  - CAD derived RF simulation (MTE industry)
- Current influential areas includes:
  - pervasive computing (in- & on-body devices)
  - medical technologies
  - hyperthermia treatment planning
  - microwave engineering
  - optics
- Today both IT’IS Foundation and SPEAG are responsible for the development and maintenance of SEMCAD
Main Customers:

- Mobile phone manufacturers (LG, Samsung, Sony Ericsson, NOKIA, Motorola, Kyocera, Perlos, Elcoteq, etc.)
- General dosimetry and risk assessment
- Health Systems: cancer treatment, pacemakers, sleep
- Universities (HUT, Kuopio, ETH, Lund, etc.)
- Research groups and government (FDA, STUK, IT’IS, FCC, etc.)
Part 1: Features and Functionality
SEMCAD X: Releases and Features

- **SEMCAD X release outlook:**
  - July: AxFDTD acceleration support *(speed approx. 100 Mcells/sec)*
  - December 2005:
    - conformal PEC and dielectric solver
    - AxFDTD ClusterInABox *(speed approx. 300 Mcells/sec)*
    - multiport S-parameters
    - semi-automated optimization
    - 64 bit compatibility *(tests upto 200 Mcells)*
    - shared memory parallelization
  - 2006:
    - metal modeling *(surface impedance BC, thin sheets)*
    - FDTD based thermal solver
    - fully embedded optimization

-> **SEMCAD X** is setting new standards in CEM software, being the most efficient, functionally complete and affordable toolsets for antenna design and general EM/Thermal simulation on the market.
Modeling and GUI Features:

- Extended CAD import filters: direct import of SAT, STL, ProEngineer, IGES, STEP, 3DS and other CAD formats
- Much faster model handling and visualization for highly complex geometries containing many parts (new in-house developed rendering engine Qtech)
- New transparency features for easier handling of complex CAD models
- 3-D conformal mesh viewer for conformal voxels (main release)
- Integrated and easy to use S-Parameter interface (main release)
- Additional modeling features (objects skin, local object zoom)

-> an overall more professional and easier to use environment has been created, making working in SEMCAD X a more enjoyable experience
Kernels: (fully integrated in SEMCAD X environment)

- **YEE-FDTD EM** kernel:
  - speed (200% - 500% speedup with vectorization)
  - memory (50% reduction)

- **ADI-FDTD EM** kernel:
  - CFL of >100 in certain applications (unconditionally stable)
  - optimal solution for electrically small structures at HF

- **64 bit functionality:**
  - addressing >8 GB RAM
  - enabling simulation of huge computational domains

- **Conformal FDTD** kernel:
  - simulation of arbitrary aligned PEC and dielectric structures

- **Dual processor** support:
  - OpenMP based parallelization for dual CPU (10-50% efficiency)

- **FDTD Thermal** kernel (early 2006)
SEMCAD-X Hardware Accelerated FDTD:

- **aXware FDTD kernel:**
  - hardware based accelerated FDTD kernel
  - enables further 5-6 increase in simulation speeds (100-130 Mcell/sec)
  - simulations that used to take hours can now be performed in minutes

aXware hardware accelerator card:
16-bit PCI slot interface
Redesigned Grid Generator:

- Non-uniform gridding with high level automation and advanced customization, supporting:
  - Wavelength units
  - Automatic padding
  - Local solid/regional settings
  - User friendly interface

Local solid settings:
- Selected solid
- Grid relevance
- Edge refinement
- Baseline mode

Global grid settings:
- Global min, max & grading ratio
- Padding of grid boundaries

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PEC/ Dielectric Conformal Modeler:

- Conformal FDTD modeling provides an accurate, fast and effective solution to the simulation of non-conformally aligned PEC and dielectric solids, including:
  + curved or rounded surfaces
  + resolving thin slots and gaps
  + meshing of thin wires and sheets

- This method uses more accurate representation of material interfaces than conventional FDTD, which implies that a much coarser grid can be used to achieve the same level of accuracy.
Multi-Port Simulations:

- New port types support modal excitation e.g. coax, waveguide, stripline and microstrip excitations
- User defined signals for complex time enveloped and/or composite frequency band analysis of structures
- MultiPort excitation and network- and S-parameter extraction for RF and microwave filters, resonators, waveguide-to-microstrip-to-coaxial transitions and other connectors
- Easy to use integrated GUI enabling batch processing of multiple excitation configurations
High Performance UPML ABCs:

- All new kernels support UMPL ABCs, offering the highest absorption levels of ABCs.
- Ideal for terminating grids with highly non-homogeneous field distributions or fields with low incidence angle on ABCs.
- UMPL also supports truncation of lossey dielectric and PEC materials which is suitable for:
  + mapping infinite feedlines & structures: coax, waveguide, stripline & microstrip
  + truncation of phantom models
  + etc.
PostProcessing Interface

• General improvement of PP interface including subregional data handling and extraction routines

• Python scripting interface, giving the user unbounded customization possibilities:
  + automation of model generation and model editing
  + launching of batch simulations
  + automated extraction of all parameters including near- and far-field, SAR and radiation performance parameters
Parameterization and Optimization platform

- Python scripter also enables easy parameterization of simulations

- Here a Bluetooth Antenna with capacitive feed mechanism is studied for bandwidth and optimum feeding

- Height of the feed space is increased with increments of 0.43 mm using python, and effects are recorded

Bluetooth antenna, optimum feed space = 3.6 mm
Part 2:
Latest Applications
Antenna Applications: Analysis of a Typical WLAN Antenna

Transient and harmonic simulations using **SEMCAD** of a typical dual-band WLAN antenna based on the design in [1], which operates at 2.4 and 5 GHz bands


Geometric description of the dual loop, dual band microstrip antenna:

- extended dielectric layer
- 2.4 GHz loop
- 5 GHz loop
- PEC grounding connection
- truncated ground plane
- 50 Ohm feed line
- excitation point
Antenna Applications: Analysis of a Typical WLAN Antenna

Transient analysis validation of the antenna return loss 2-6GHz

Antenna performance at 2.4GHz: Surface Current, E-Field Vectors & Far-Field Radiation

Validation of TEM mode in microstrip line: Ez field distribution at 2.4 GHz
Antenna Applications: Dual Polarized Circular Patch Antenna

**SEMCAD** was used to perform transient and harmonic simulations of this antenna, typically used in base stations.

This particular configuration operates at 1800 MHz.

Antenna Applications: Dual Polarized Circular Patch Antenna

E-Field distribution surrounding the 2 circular patches at 1800MHz

E-Field distribution for the feed structure at 1800 MHz

Far-Field Radiation at 1800 MHz
Antenna Applications: Folded Monopole Antenna

This folded monopole antenna configuration has a total volume of only:

- 4.5 x 25 x 6 mm

making it an electrically small antenna at 900 MHz.

A typical PCB mounting with truncated ground plane is used with a matching network to match the antenna impedance to 50 Ohm.
Antenna Applications: Folded Monopole Antenna

E-Field distribution at 900MHz

Far-Field radiation pattern typical for electrically small antennas

T-matching circuit
Antenna Applications: Folded Monopole Antenna

Matching network performance: unmatched (red) and matched (green) reflection coefficient
Antenna Applications: Automobile Simulations

The superior features of SEMCAD X now even allow the simulation of a detailed car model with a person speaking on a mobile phone in the car. Typical challenges to be solved:

• spans a large computational domain (5m x 3.5 m x 2.5m) compared to the wavelength
• requires a fine grid resolution to resolve the detailed antenna structure
• contains largely non-conformal PEC and dielectric structures
EMC Applications: Characteristics PCB Radiation and Impedance

**SEMCAD** is also used for solving a range of typical EMC problems, 2 different applications are shown:

1) Reducing PCB noise radiation from digital boards

![Digital circuit board and equivalent simulation model](image1)

Field distribution and S21 transmission coefficient

2) Impedance of PCB at 20GHz

![TEM mode excited in PCB](image2)

The 2 layer PCB is modeled as a 2D structure and a TEM mode is excited on the left. The wave is radiated on the right of PCB. The PCB is terminated with UPML to 2 cells from the source in order to map an infinite length.
Planar Filters and Couplers:

- Unit defected ground microstrip filter
- Low pass DGS filter

Filter performance: $S_{11}$, $S_{21}$ 1-6 GHZ
Planar Filters and Couplers:

Hairpin filter

Filter performance: S11, S21 1.4-2.6 GHZ

Directional coupler

Coupler performance: S11, S21, S31, S41
Waveguides:

H-plane T-junction waveguide

Rectangular to circular transition

Guide performance: S11, S21, S31 26-40 GHz
General Dosimetry: Anatomical Phantoms Database

mouse model (OF1)

whole body human model (based on VHP)

rat model (Sprage Dawley)
General Dosimetry: Anatomical Phantoms Database

EM field distributions

absorption data
General Dosimetry: Anatomical Phantoms Database

Design of exposure setups

SAR distribution
Medical Applications: Body Mounted Devices e.g. Hearing Aid

Antenna design and optimization, EMC and EMI between RF and electronic components as well as SAR compliance issues are all addressed in SEMCAD.

Modern hearing aids use FM communication for wireless remotes, maintaining conference broadcasting and improved performance for dual device use.
Medical Applications: Body Mounted Devices e.g. Hearing Aid

- BTE placed at EF-1 head model
- min cell = 0.15 mm
- about 12 mil. cells

E-field (dB) in two planes crossing head and BTE

radiation pattern
E_total (dB)
**Medical Applications: Body Mounted Devices e.g. Pacemaker**

**SEMCAD** was used extensively in e.g., [1] to investigate the performance of a variety of antenna types to obtain optimum RF communication through coupling to an implanted pacemaker.

The implanted pacemaker device with an internal telemetry coil and an external coil, communicating by inductive coupling.

Circumference and PIFA antennas mounted on the pacemaker and the corresponding input impedance of the device simulated in muscle tissue - the antenna is designed to resonate at 403.5 MHz.

Medical Applications: Body Mounted Devices e.g. Pacemaker

Within the same study simulations were run to investigate the effect the patient had on the performance of the device once it was implanted. A variety of phantom models were used to investigate this effect.

Placement of implant in baby and man phantom models

Far-Field and gain results of the implanted pacemaker and circumference antenna
Medical Applications: Body Mounted Devices e.g. Pacemaker

For the simulation of realistic device in-use conditions, a detailed CAD model of pacemaker and leads was generated and is being used. The pacemaker was then implanted in a high resolution anatomical phantom model.
Miniature Antenna Mounted on Pacemaker

- CAD/Compound representation in SEM-X
- based on the physical device, a model of pace-maker and leads was generated and placed in a high-resolution anatomical model
- a generic miniature antenna was then placed on the pacemaker for communication
- FDTD grid resolutions from 0.15 mm (antenna/pacer) to 6 mm were applied
SAR/E-Field Distribution in/on the body

- The impact of the tissue distribution on local SAR and the antenna matching cannot be reproduced by homogeneous modeling.
Medical Applications: Hyperthermia Treatment Planning

8 Bow-tie antennas are used to apply the EM energy at 80MHz.

The waterbolus and phantom are then inserted into the system.

SEMCAD is used for optimization of hyperthermia cancer treatment systems, where patients are exposed to EM energy to reduce cancer growths and tumas.

In a 2nd phase MRI-based high resolution phantom models are used and the EM energy is focused on the tuma.
Medical Applications: Hyperthermia Treatment Planning (cont.)
WLAN Antenna: Exposure within a room at 2.45 GHz

• Simulation of WLAN antenna placed within a room (1.5x 1.5x 2 m)
• Full-body high resolution anatomic phantom placed in the room
• The antenna is driven at 2.45 GHz; SAR data is recorded
• Due to the electrically large size of the computational the simulations must be performed using a 64-bit computer with 8 GB RAM
• The resulting computational contains 180 million cells
WLAN Antenna: Exposure within a room at 2.45 GHz
Suitability for FDTD-Based TCAD Tools for RF Design of Mobile Phones
[N. Chavannes, et. al.]

- all research presented in this article was performed using SEMCAD
- good to excellent agreement between measurement and simulation was obtained for a variety of RF and dosimetric parameters that were evaluated at both GSM and DCS bands
DASY4 - SEMCAD: Common Postprocessing
Conclusions:

• Numerical RF simulation tools like SEMCAD offer:
  + indepth understanding of complex RF interactions and localized dosimetric effects
  + a test platform for investigating compliance of upcoming and future technologies
  + visualization of wave propagation, reflection, transmission coupling, etc.
  + extensive high resolution numerical animal and human phantom database
  + new computer hardware offer incredible simulation performance in terms of speed and memory handling

-> broadening in application range and increasing in frequencies

There is a clear trend in the RF industry to incorporate and rely on simulation more frequently on the development of new products in terms of 1) performance and 2) SAR related issues.
THANK YOU!

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