An EMC Engineer's Guide to Electromagnetic Modeling Software

an IEEE EMC Society Distinguished Lecturer Presentation

by

Prof. Todd H. Hubing

University of Missouri-Rolla

Presented to the Ottawa Chapter of the
IEEE EMC Society Society
December 17, 1997

Choosing the Right Computer Modeling Software

EMC Analysis Software

- **Analytical Modeling Software**

  Solves specific problems that have pre-defined geometries using closed form equations.

  Provides fast solutions for a limited class of problems.

  The user must be able to relate the geometry of the problem being analyzed to a geometry that the software is capable of solving.

- **Numerical Modeling Software**

  Solves Maxwell's equations subject to appropriate boundary conditions.

  Provides very accurate solutions to very well-defined problems.

  Requires the user to be very familiar with the software, the limitations of the technique, and the problem being analyzed.

- **Design Rule Checkers**

  Review a design for adherence to specific EMC design rules.

  Relatively fast, but they do not specify or quantify the nature of any expected EMC problems.

- **Expert System Software**

  Reviews a board design using many of the same criteria that an experienced EMC engineer would use.

  Provides a relatively fast evaluation of the design based on the information available.

  Can be used by circuit designers, board layout people, EMC engineers, or anyone interested in evaluating a design.

Choosing the Right Numerical Modeling Software

- **Static Field Solvers**

  Fasthenry Fastcap Fastlap Flux2D Flux3D

- **2D Solvers**

  SUPERFISH Quickfield

- **Transmission Line Solvers**

  Microwave Explorer EM

- **3D, Full-Wave Solvers**

NEC	**EMAP**	**MiniNEC**
XFDTD	**EMIT**	**MaxSIM-F**
EMA3D	**IE3D**	**MSC EMAS**
Maxwell 3D	**HFSS**	**MagNet**

Numerical Modeling Software

- **Solve Maxwell's Equations numerically subject to a set of boundary conditions**

- **Accurate determination of a unique solution requires detailed input of all relevant boundary conditions**

  source geometry — antennas

  source type — coupling mechanisms

- **Used to analyze well-defined geometries**

- **Subject to limitations of the technique used and limitations of the software implementation**

  Finite Difference Time Domain Method

  Transmission Line Matrix Method

  Finite Element Method

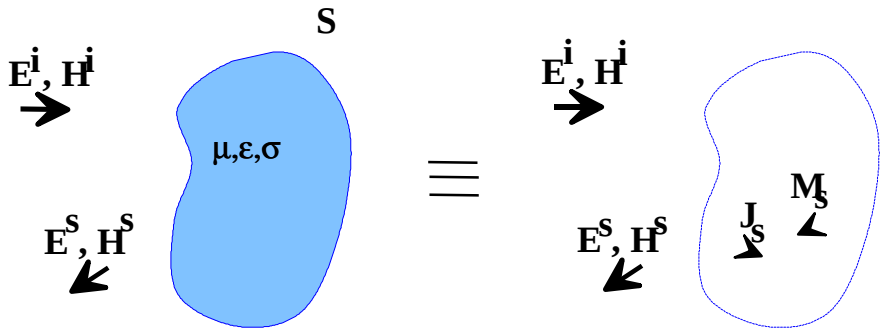
  Boundary Element Method

  Moment Method

  Generalized Multipole Method ...

Surface Integral Techniques

Boundary Element Method (BEM)
Method of Moments (MOM)



- **Surfaces of material are gridded**

  (e.g. two-dimensional grid in three-dimensional space)

  no absorbing boundaries required

  easier to grid than volume formulations

- **Full Matrix Fill / Full Matrix Solution**

  Matrix fill time proportional to N squared

  Matrix solve time proportional to N cubed

  Symmetries / special structures can be solved more efficiently.

Surface Integral Techniques

Boundary Element Method (BEM)
Method of Moments (MOM)

complex source geometries

dielectrics

thin metal surfaces

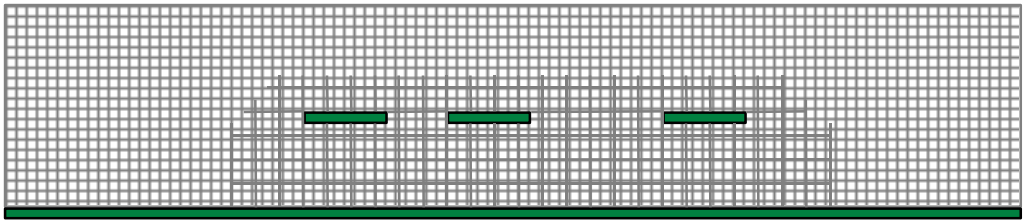
tightly coupled, electrically small conductors

thin, electrically long or resonant wires

unbounded geometries

- **Numerical Electromagnetics Code (NEC2)**
  ftp from ftp.netcom.com in /pub/ra/rander/NEC
  or from ftp.emclab.umr.edu in /pub/aces/NEC

Finite Element Method



- **Entire Volume is Meshed**

  absorbing boundaries required for open problems

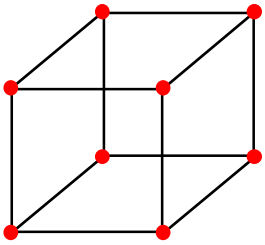
- **Sparse Matrix Fill, Sparse Matrix Solution**

  Grids do not need to be uniform. Fine mesh can be used in areas with large field gradients.

  Symmetries / special structures can be solved more efficiently.

Finite Element Method

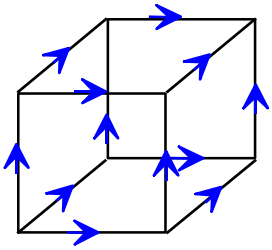
Scalar FEM Codes
(node-based)



The unknowns are the components of the field at the nodes of each element.

- **SPARSER MATRICES**
- **INTUITIVE MODEL GENERATION**
- **MORE STRAIGHT-FORWARD I/O**

Vector FEM Codes
(edge-based)



The unknowns are the component of the field that lies along the edges of the elements

- **EFFICIENT AND ACCURATE HANDLING OF MATERIAL BOUNDARIES**
- **NATURAL RESISTANCE TO SPURIOUS MODES**

Finite Element Method

complex source geometries

dielectrics

thin metal surfaces

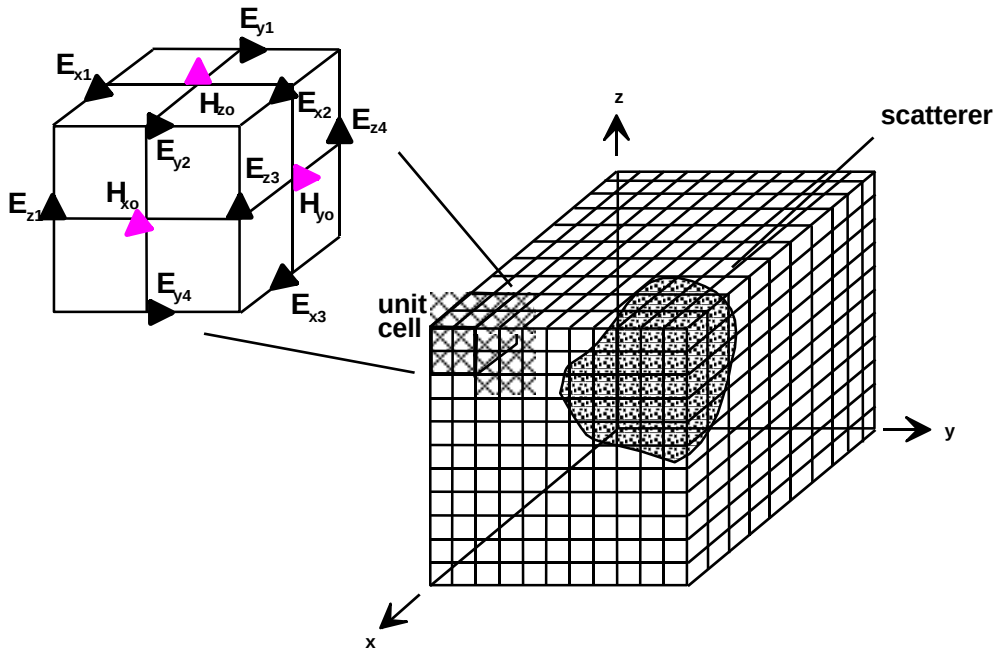
tightly coupled, electrically small conductors

thin, electrically long or resonant wires

unbounded geometries

- **Quickfield**
  ftp from oak.oakland.edu in SimTel/msdos/electric

Finite Difference Time Domain



- **Entire Volume is Meshed**

  absorbing boundaries required for open problems but FDTD absorbing boundaries generally work better than FEM absorbing boundaries

- **No Matrix, Time-Stepped Solution**

  Solution time proportional to number of cells

  Symmetries / special structures can be solved more efficiently.

Finite Difference Time Domain

complex source geometries
dielectrics
thin metal surfaces
tightly coupled, electrically small conductors
thin, electrically long or resonant wires
unbounded geometries

- Luebbers and Kunz code
  ftp from emclab.ee.umr.edu in /pub/aces/fdtd
- Finite Volume Time Domain
- Transmission Line Matrix

Other Numerical Techniques

- **Transmission Line Matrix Method (TLM)**

  Advantages and disadvantages similar to FDTD
  More intuitive for some people. Requires more storage per node.

- **Generalized Multipole Technique (GMT)**

  Powerful surface integration technique. Basis functions are fields from multipole sources. Placing the multipoles requires a great deal of skill.

- **Finite Element Time Domain (FETD)**

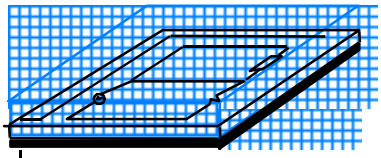
  No commercial codes available. Not likely to play a major role in numerical EM modeling.

- **Hybrid Techniques**

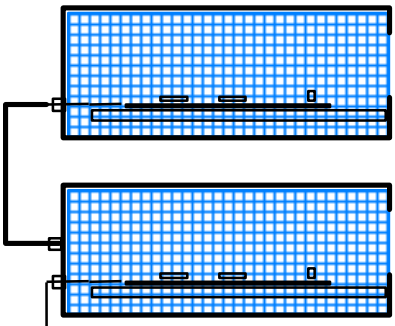
  Combining two techniques in one code can result in software that is able to model problems that one technique alone would not be able to model.

EMAP 5.0

Hybrid Finite-Element/Moment-Method Numerical Electromagnetic Modeling Code



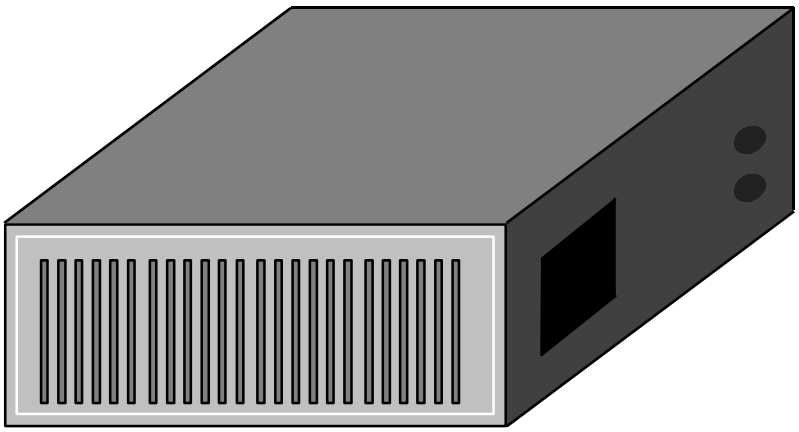
printed circuit board with attached cable



circuit boards in metal enclosures with attached cables

APOGEE

Finite Difference Time Domain
Numerical Electromagnetic Modeling Code



- **boxes with apertures and seams**
- **lossy dielectric coatings**
- **calculates power through apertures**
- **time-harmonic fields**

What is EMC expert system software?

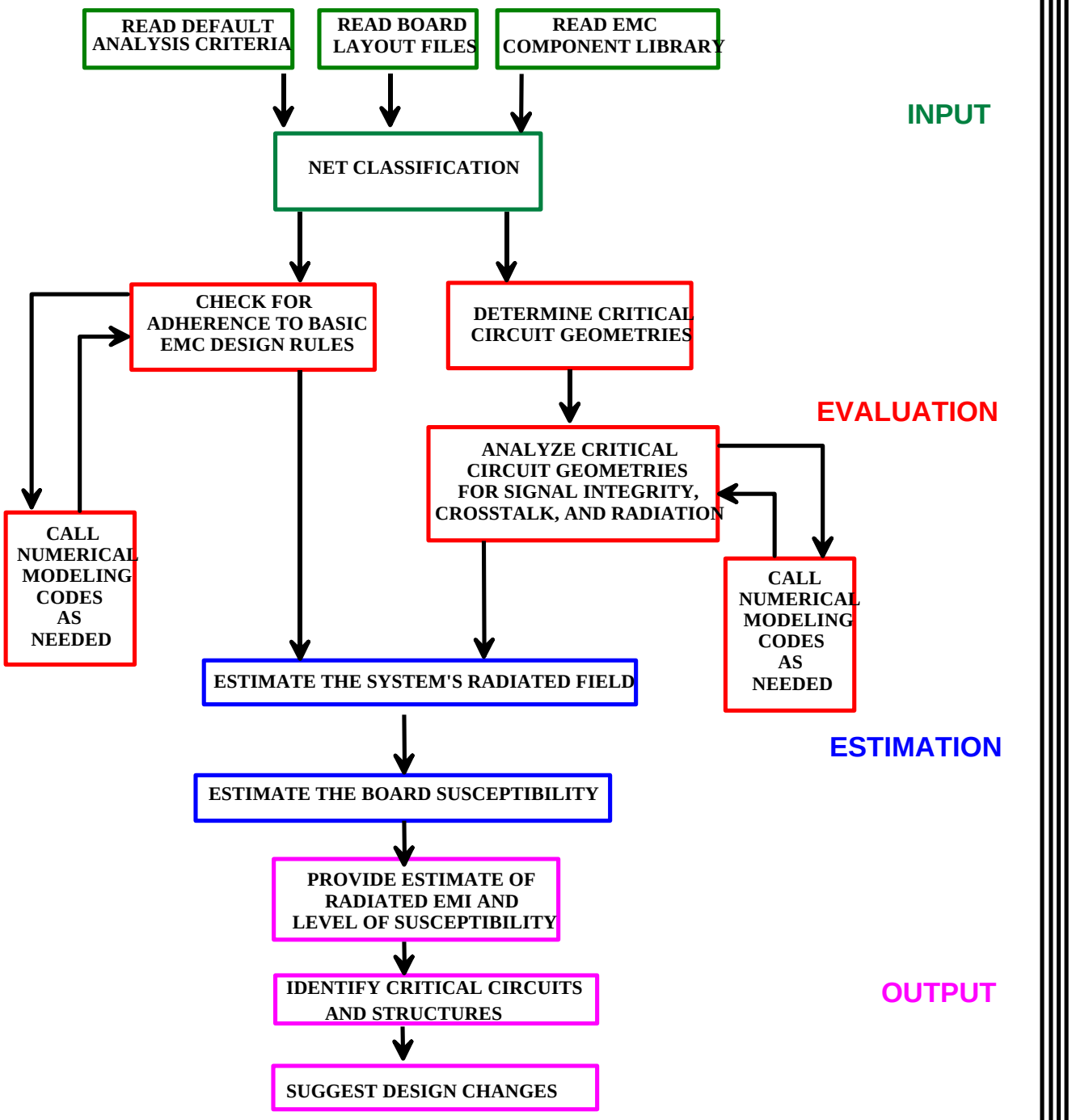
thinks like an expert

works with incomplete data

does not require user to be an expert

does not necessarily ask the user a lot of questions

EMC EXPERT FLOW DIAGRAM



Things that software is very good at:

- crosstalk calculations
- tracing signals
- flagging fundamental errors
- tracking analog/digital nets
- identifying current-driven sources
- working with part numbers

Significant challenges for software:

- visualizing return current paths
- recognizing shapes
- obtaining information from humans

Answers to Anticipated Questions

How is EMC Expert System software different from existing EMI modeling software?

EMC Expert system Software is unique in that it will automatically evaluate printed circuit board designs and estimate radiated EMI levels due to common-mode and differential-mode sources using criteria similar to that used by EMC engineers. Expert system software may employ both analytical and numerical modeling techniques, but will not assume that the user has any expertise in these techniques. Like an expert in EMC, the tool will recognize potentially troublesome features of the board and apply appropriate models to evaluate them.

Will expert system software replace the need for numerical electromagnetic modeling software?

No, although it will help users who are unfamiliar with numerical electromagnetic modeling to take advantage of numerical modeling techniques. Numerical electromagnetic modeling codes are intended to do very accurate analyses of very specific configurations. They require that the user identify specific sources and all relevant features of the configuration being modeled. Numerical electromagnetic modeling codes will continue to be valuable tools for EMC engineers and high-speed circuit designers who want to understand and quantify the behavior of specific EMI problems.

Will expert system software be used by board designers or EMC engineers?

Both. EMC expert system software will point out basic EMC design problems and won't assume any EMC expertise on the part of the user. This makes it very helpful to circuit designers and board layout engineers. It also will locate problems with boards that may be difficult for EMC engineers to recognize immediately. For example, crosstalk between two signal traces on different layers could contribute significantly to a radiated EMI problem. An EMC engineer might have to spend several hours studying artwork and tracing signal paths to identify a problem like this. This tool can save EMC engineers considerable time and frustration by identifying and prioritizing EMC problems that are difficult to spot.

Will expert system software eliminate the need for qualified EMC engineers to be involved in the design process?

No, although it will make their job easier. When designers approach an EMC engineer with a poor design, the EMC engineer must address the major problems first. Correcting the major problems results in a new design that is hopefully better, but probably not perfect. Several iterations are usually required to get an optimum design. By helping the board designer avoid the major EMC problems, this tool allows the EMC engineer to see a more representative design early in the process. In this way the EMC engineer can focus on more subtle aspects of the design, and is more effectively utilized.

Is Expert System Modeling Software in your future?

5 years from now expert system software will be more widely applied to EMC design problems than all other types of EMC modeling software combined.