Appendix B

CAD for EMC

B.1 Overview

It may seem strange to devote no more than a few pages at the back of a book on product design for EMC to the important subject of computer-aided design (CAD). The prospect of non-compliance with EMC requirements is sufficiently threatening that manufacturers are having to give these requirements serious consideration at the design stage, and the third part of this book discusses the major design principles that this involves. Many other aspects of the circuit design process are now automated and simulated to the extent that a breadboard stage, to check the correctness of the basic design concepts, is often no longer necessary. A very attractive option to the product designer would be a CAD tool that predicted RF emissions and susceptibility, with enough accuracy for initial evaluation purposes, from the design data of the product. This would allow alternative EMC techniques to be tried out before the costly stage of committing to tooling and pre-production had begun.

The reason why this subject is relegated to an appendix is because no such tool yet exists. Many problems of a specific nature can be solved by electromagnetics computation packages that have been available for many years, but these generally address the needs of EMC experts rather than product designers. Several groups are working on the production of software packages that need less expertise for successful use, and the next few years may well see the successful introduction of such tools, but history does not give much cause for optimism.

The difficulties facing these researchers are many:

- modelling a small collection of electromagnetic emitting elements (usually a current segment) is easy. As the number of elements n increases, the computational memory increases as n^2 and the processing time as n^3, so that computer speed and storage limitations, despite having vastly increased over the years, still restrict the size of the problem being handled.
- as the frequency increases, so the element size must be reduced to maintain accuracy, further increasing the required number of elements. Many computational methods work in the frequency domain and so the calculations must be repeated for each frequency of interest.
- PCBs with ground plane layers can effectively be approximated as conducting sheets, which simplifies the structure model, whereas those without ground planes cannot be so easily modelled.
- connecting wires and cables have a large effect on the coupling and must be modelled explicitly. This may invalidate the results if the layout is not properly defined in the final product. Some early attempts modelled the performance of the PCB only and their results bear little relevance to reality.

- the driving currents can theoretically be derived from device models and calculated track and circuit impedances, but these may differ substantially from the real circuit with real tolerances. For example the amplitudes of higher order clock harmonics depend heavily on risetime, which is a poorly specified parameter and is affected by circuit capacitances and device spread.

These difficulties relate only to emission predictions. A further set of variables come into play when you try to simulate immunity, and apart from some research into immunity at the IC level these have hardly been addressed yet. There are other obstacles to implementing practical tools, which are not related to the technical problems of electromagnetic modelling [101]:

- EMC design aspects do not respect the demarcation common in design labs of circuit, layout and mechanical disciplines. Considerable interaction is needed between these which presupposes a common body of EMC knowledge among the different fields, which is unlikely to exist.
- To overcome this demarcation, the CAD package must integrate these aspects and must therefore accept input on all fronts: circuit schematics, PCB layout designs and mechanical and wiring drawings. Although integrated CAD environments are installed which could provide such input automatically, interaction between the different parts can be poor and manual input is not realistic given the time constraints facing a typical design department.
- The output of the package must also be in a form which is useable and comprehensible by these different designers. It must be structured to be of maximum assistance at the most appropriate phase(s) of the design process. Some re-training of the users may be required so that they can actually use the output.

B.2 Modelling packages

Those software packages which are currently available for electromagnetic modelling purposes have been developed for solving EMI coupling problems in certain well-defined applications. Every EMC problem can be described in terms of a source of interference, a coupling path and a receptor (or victim) of the interference. The structure of the coupling path may include either or both radiative or conductive mechanisms, and these are often amenable to analysis so that, for instance, the voltage or current present at an interface with an item of equipment can be derived as a result of coupling of the structure containing that equipment with an external field.

A typical application may be to model the surface currents on an aircraft fuselage which is illuminated by a plane-wave field, and deduce the currents flowing in the cable bundles within the fuselage. Another might be to determine the RF energy transport by penetrations through a shield such as electrical conductors or pipework. The codes which perform the electromagnetic modelling of these situations use finite difference, method of moments, transmission line modelling or finite element methods to solve Maxwell's equations directly. Each has its advantage in a particular situation, for instance the method of moments code NEC deals efficiently with wire coupling problems such as occur in antenna design, whereas the finite element code EMAS or transmission line modelling (TLM) are more suited to problems with inhomogeneous regions and complex geometries, such as surface currents on enclosures.

Many approximations need to be made even for well-defined problems to allow computation with a reasonable amount of effort. For instance near field coupling is much more complicated than far field, since the nature of the source strongly affects the incident wave. Shield aperture size is critical since for electrically large apertures (size comparable to a wavelength) the internal and external regions must be treated consistently, whereas the modelling of fields penetrating through small apertures can be simplified.

The major difficulty with applying these packages to commercial product design is that they have been developed for a rather different set of purposes. Mostly they have been derived from research on military EMC problems. This has two consequences:

- technically, they are appropriate only for situations which are clearly defined: cable routes, connector terminations, mechanical structures and shielded enclosures are all carefully designed and controlled through to the final product and its installation. This contrasts with the commercial environment where the costs of doing this, and indeed the impossibility in many cases, puts such an approach out of court. Thus the parameters and approximations that would have to be made in the simulation are not valid in reality.
- operationally, there are difficulties in performing the simulation. Only a few of the packages (which started life in university research departments) have been developed to the point of being user-friendly. A great deal of input data, usually in the form of structure co-ordinates, must be loaded and validated before the program can run, and its output must then be interpreted. A typical product design engineer will have neither the time nor the training to do this – only those companies with the resources to run a specialist group devoted to the task can handle it successfully.

Nevertheless, these packages can find a use in areas of EMC not directly related to product design, such as those to do with radiated field testing: predicting reflections in screened rooms and damping them, predicting proximity effects between the antenna and the EUT, and predicting calibration errors when antennas are used in screened rooms [49]. At the time of writing the Missouri University of Science & Technology EMC lab website (http://emclab.mst.edu, formerly UMR) lists 54 commercial suppliers of electromagnetic modelling codes, and over 20 different free sources. The vast majority of these use specific classes of model and are appropriate only to a given type of problem, and most are for electromagnetic applications other than EMC.

One hurdle which still needs to be overcome is the simple one of gaining confidence in the output of a particular simulator. One worker in the field has said [61]

> Uncertainty arises when the predicted results using one type of CEM code do not agree favourably or consistently with the results of other codes of comparable type as well as against measured data on benchmark models. Many examples can be cited where fairly significant deviations among analytical or computational techniques or between empirical based methods have been observed. Differences are not unexpected, but the degree of disparity in certain cases cannot be readily explained nor easily discounted, which leads to the fundamental question, "... which result is correct?"

B.3 Circuit CAD

Some circuit design and PCB layout CAD packages already offer transmission line analysis for high-speed logic design, taking into account track parameters calculated from their geometries and the board dielectric. Extending these capabilities into the domain of RF properties of the board interacting with its environment – as will be needed for EMC prediction – will be difficult. A possible approach is to segment the overall problem into e.g. the PCB, the internal cables, the case and the external cables, and then apply appropriate numerical methods sequentially and assemble the outputs into an overall result. This requires the analysis to be done by someone with expertise both in the appropriate segmentations and in defining acceptable approximations.

Design advisers

Commercial offerings of various types are now available, though. One of these types is a rule-based design adviser. The design adviser takes as its input a set of rules, such as allowable loop area or decoupling capacitor placement, which are supplied with the package but can be enhanced with in-house rules as required. A particular advantage of this approach is that it is not limited to EMC: other design rules, for instance to do with thermal management or manufacturability, can also be incorporated and trade-offs between different constraints can be evaluated quickly and automatically.

The circuit designer must specify at the schematic capture stage those nodes that are to be checked; the rules can be individually selected and weighted. The PCB layout draughtsman can then initiate a rule check on the layout as it develops and rule violations can be highlighted. The advantage of working in this way is that it limits the EMC expertise needed by the layout draughtsman, since the rules act as a form of "expert system", but it is important that the rules are soundly based and do not become so codified that they constrain the development too much to produce cost-effective products. The technique does not claim to perform any EMC prediction or calculations at all.

Emissions prediction

Some packages are available which do offer emissions prediction based on calculations. It is possible, for instance, to analyse transmission line structures on multilayer ground plane boards, as well as those with a discrete return path, for near field radiation. Interfaces to various layout packages for layout data extraction, and macromodels for some circuit components, are available. These can be helpful particularly for evaluating design options before actually building physical hardware.

Another approach is to integrate EMC aspects with other parts of the mechanical design which can be automated, particularly thermal issues. Thus for instance design of heatsink size and placement, and ventilation apertures in a metal case, have both EMC and thermal consequences. Simulation packages which look at the effect on radiated emissions of enclosure resonances and apertures can use the same mechanical information for thermal analysis.

It is still necessary, though, to be sceptical of the capabilities of these tools when faced with the demand to predict completely the EMC of a whole product. At the time of writing, few vendors are offering tools which have been extensively validated against results from real designs. Some years ago, one commentator made the wry but accurate observation [142] that

> Once again, we are in danger of being seduced by our desire for a comprehensive solution into the belief that, perhaps, this time the marketing is based on reality. Alas ... this set of EDA technologies [based on analytical tools] ignores many aspects of EMI.

Not much has changed.