# Some Design Guidelines for Electromagnetic Compatibility

**By Gary Breed**
**Editorial Director**

> EMC is not just a regulatory requirement, it has growing importance in the design of robust, reliable electronic products of all types. This tutorial offers classic design hints and notes on the latest software tools.

Electromagnetic compatibility (EMC) is the field of engineering that specializes in reducing or eliminating the unwanted side effects of working with electromagnetic phenomena. It intertwines closely with RF and microwave circuit design, digital circuit design and layout, antenna technology and measurement techniques. It even is part of law and public policy when it involves spectrum management and regulatory standards.

This tutorial presents some of the time-honored facts about designing for EMC, and also presents some of the latest EDA tools that can aid in the design of a compliant and robust product. The speed and complexity of today's software has reached the point where it is practical to analyze all or part of an operating circuit in laid out form in a package, p.c. board, or other substrate.

## EMC Design Basics

Here are some the established facts about the behavior of electromagnetic energy in circuits. All engineers should remember these as they design and lay out their designs.

### Loops are Low Impedance

When conductors make a loop, currents in the resulting inductance create a magnetic field. The strength of the field is proportional to the enclosed area. And of course, the induced current of energy coupled into the loop follows the same rule.

Keep all loop structures as small as possi-ble to minimize their impact. Loops become more efficient antennas as the frequency increases and their size becomes a larger fraction of a wavelength, so they are more sensitive to harmonics.

### Wires are High Impedance

An unterminated wire, or a wire that is long relative to wavelength, has a high impedance compared to typical circuit interconnections. This makes them more sensitive to voltage than to current, often behaving as efficient E-field dominant antennas. Typical wires of this sort include board-to-board cables as well as cabling external to the enclosure. At higher frequencies, physically large components and hardware may fit this description.

Problems are greatest when connected to high impedance points in a circuit. Logic device inputs, transistor gate and base connections, and the ungrounded end of resonators are typical high impedance points.

### "Ground" Is Never Perfect

The concept of an infinite, perfectly-conducting ground is fictional; it does not exist in real-world construction. Of course, a solid sheet of high conductivity metal will approach ideal behavior at lower frequencies, using low-profile construction. But, thin copper layers on a p.c. board will have voltage/current gradients that depend on frequency, metal thickness, component layout and the number and size of discontinuities such as holes, slots, traces, etc.

Worse yet, mounting hardware—standoffs, brackets, screws, etc.—introduce discontinuities as well, and may even create loops that

can be problematic as noted above. Openings in enclosures can become slot antennas when they approach resonance at frequencies where the system has significant energy.

Dealing with "ground" is sufficiently complex to fill multiple books, but a few key technqiues include *single-point grounding* to avoid creating loops, *separate digital and analog grounds* on p.c. boards, *shielding* to extend ground around troublesome areas, and *increasing ground area* by filling p.c. board gaps and connecting layers with multiple vias.

Finally, remember power ground and its potential effects. Power supplies can have a lot of broadband noise at high and low frequencies, which can "modulate" the voltage drop across a finite-resistance ground path. This noise can be coupled efficiently into the signal path if ignored by the designer.

### Watch for Coupling Structures

Analyzing the traces on a p.c. board should be obvious when avoiding coupling paths, but location and proximity of components may be more subtle. Classic techniques include orienting inductors at right angles to one another and separating power and signal lines.

With higher frequencies, coupling and radiation has become a bigger problem, compounded by the need for lower cost p.c. board construction instead of a series of individually shielded modules. Also, enclosure resonances are more likely to arise at high frequencies, propagating energy to many unwanted places!

### Understand the Energy Content

You need to compute the frequencies and relative amplitudes of expected harmonics and spurious signals. This may mean a Fourier analysis to identify the components of a particular waveform. Although an ideal square wave digital clock has only odd-order harmonics, a slow rise time or asymmetry will add significant even-order harmonic energy. Also remember that spread-spectrum clocks that reduce measured EMC levels still have the same total energy as an ordinary clock.

A designer must also remember to include those portions of the finished product he or she is not working on, but will be included in the final assembly. Don't be the RF engineer who must admit, "I forgot about the clock in the keyboard and display controller."

### Save Something for Emergencies

Don't use all your EMC reduction techniques in the basic design. When the time comes for compliance testing, you will almost certainly need to apply a few "band aids" to reduce emissions from some portion of the system. Ferrites, bypass capacitors and additional shielding are typical last-minute fixes, but don't forget simpler methods of cable routing and locating improper grounds.

### Modern EDA Design Tools

After reviewing these classic issues, it's appropriate to jump all the way to the present (and future), since software tools are finally becoming powerful enough for real EMC analysis, not just estimates.

Modeling of electromagnetics has been refined, and computing power has increased to the point where a detailed EM analysis of a p.c. board layout can be made, even with components in place and under operational conditions. The resulting current density and radiation predictions may not be perfect after real-world assembly, but they definitely allow the designer to identify potential problems, and determine if an alternative design will solve them.

The box on the facing page lists companies that produce products that can be used—directly or indirectly—for analysis of various EMC-related issues. Some can handle large-scale p.c. boards, while others may be best for looking at specific structures. You can expect these and other companies to provide additional EMC products in the near future.

In summary, remember to incorporate EMC considerations in design, using both basic design and layout techniques and modern EDA tools. Your products will more easily pass compliance testing, and will be more reliable, as well.

### Electromagnetic Simulation and Analysis Software Providers

**Agilent Technologies — www.agilent.com**
*Agilent N1900B series physical layer test system (PLTS)*:  High speed digital interconnect analysis for signal integrity.

**Agilent EEsof EDA group — eesof.tm.agilent.com**
*Advanced Design System (ADS):*  Comprehensive RF/microwave simulation system that includes links to different EM analysis tools.
*Electromagnetic Design System (EMDS):*  3D EM simulation tool.
*Verification Toolkit for Signal Integrity:* A new addition for ADS, supporting high-speed digital signal analysis.
*Antenna Modeling Design System (AMDS):*  A new 3D EM simulator for antenna design and analysis, including RF exposure.

**Ansoft — www.ansoft.com**
*DesignerSI*:  Signal integrity package capable of co-simulation of high speed digital with EM analysis.
*SIWave*:  EM analysis for packages and p.c. boards, power bus analysis, current density analysis and other EMC-related simulations.
*HFSS*:  Broad-range 3D EM simulator that can be applied to many EM problems including EMC.

**Applied Wave Research (AWR) — www.appwave.com**
*SI 2006*:  Signal integrity analysis, with open architecture that allows links to many third-party EM simulators.
*Microwave Office*:  RF/microwave circuit simulator, also with open architecture that can link to many different EM simulators.

**Computer Simulation Technology (CST) — www.cst.com**
*CST Microwave Studio*:  Broad-based RF/microwave simulation, including EM analysis.
*CST EM Studio*:  Well-established EM simulation, with applications in EMC analysis, RF exposure analysis and many other areas.

**FEKO — www.feko.info**
*FEKO:*  A full wave, method of moments (MoM) based, computer code for the analysis of problems such as EMC, shielding, coupling, antenna design, microwave circuits, striplines, dielectric media and scattering analysis.

**Flomerics — www.flomerics.com**
*FLO/EMC*:  EMC analysis package that uses the Transmission Line Matrix (TLM) method for solving Maxwell's equations, which solves for all frequencies of interest in a single calculation, capturing the full broadband response of the system in one simulation cycle.
*MICROSTRIPES*:  General purpose EM simulation for antennas and circuit structures. Adaptable by the user for a wide range of problems.

**Zeland Software — www.zeland.com**
*IE3D*:  Method of Moments (MoM) EM simulator for antennas, circuit structures and many other EM analyses.
*Fidelity*:  A Finite Difference Time Domain (FDTD) EM simulator for many analysis problems that can benefit from an alternate technique.