Top Ten EMC Problems

presented by:
Kenneth Wyatt
Sr. EMC Consultant

Instructor Biography

Kenneth Wyatt is a Senior EMC Consultant at SILENT, an independent consulting firm that specializes in EMC and RF design, troubleshooting, and training services to commercial and industrial manufacturers with global distribution in the consumer, computer, network and telecommunications, industrial, medical, scientific, and automotive industries. Previously Ken was Senior EMC Engineer for Hewlett-Packard and later Agilent Technologies in Colorado Springs, Colorado. While at Agilent and HP Ken was responsible for providing comprehensive EMC design and troubleshooting services to the design community for a wide range of test and measurement equipment including digital oscilloscopes, logic analyzers, and associated probes and accessories. He also was responsible for managing the day-to-day technical aspects of Agilent’s EMC test lab.

Prior to Agilent, Ken worked as a product design engineer for 10 years at various aerospace firms on projects ranging from DC-DC power converters to RF and microwave systems for shipboard and space systems.

A prolific author and presenter, Ken has written or presented topics including RF amplifier design, RF network analysis software, EMC design of products and use of harmonic comb generators for predicting shielding effectiveness. He has been published in numerous magazines such as, RF Design, EMC Design & Test, Test & Measurement World, Electronic Design, Microwave Journal, and the HP Journal. He has presented EMC design, measurement and troubleshooting seminars across the U.S., Europe and Asia.

Ken is a senior member of the IEEE and a long time member of the EMC Society in which he serves as the official society photographer. He has also served as a U.S. delegate to the International Electrotechnical Commission (IEC) for the international EMC standard, IEC 61326 (ISM products). He received a bachelor’s degree in electronic engineering at California State University – Long Beach and completed additional coursework in physics at the University of California - Irvine.
Section 3

Top Ten EMC Problems

1. Signal return impedance
2. Shielding
3. Cable grounding
4. Emission from switching devices
5. LCD emissions
6. Internal coupling paths
7. Resonance effects
8. Inadequate signal returns
9. Discontinuous return paths
10. Electrostatic discharge (ESD)

1.1 Signal return impedance

The overwhelming majority of high-frequency problems, whether related to emissions, immunity or self-compatibility have high signal return impedance as a root cause.

- Wires and traces have a relatively high impedance. *This is why a signal return plane should be used at high frequencies*
- High-frequency effects start occurring above 10 kHz
2.1 Shielding - slot caught during design review

2.2 Shielding - poor shield integrity

Module halves copper-plated

Attempt at shielding module failed to connect halves!
3.1 Poor cable grounding

RF Immunity problems almost always involve a cable.

- Shield “pigtails” are bad – circumferential (360 degrees) are best.

3.2 Poor cable grounding (continued)

Divert the current back to the shielded enclosure

- Proper termination of the cable shield back to the enclosure is the key

Block the current with a high-impedance ferrite choke

Solves both emission or immunity issues.
3.3 Good cable grounding

Ideal I/O connector:

- Notice the design incorporates an integrated grounding connection, which solidly connects shielded enclosure with connector ground shell in multiple locations.
- The connector ground shell then connects to the cable shield.

Good cable grounding design – cable shield properly connected to metal enclosure.

4.1 Emissions from switching devices

Switched high-voltages couple to heat sinks and radiate via capacitive coupling to other nearby metallic structures.

- Use bypassing and ground the heat sink (multiple points)
- Newer LSI designs have internal shielding metallization to limit coupling to heat sinks
**5.1 LCD emissions**

- Display cable radiates and excites the metal LCD housing
- Ground the LCD housing to the enclosure in multiple points

**5.2 LCD emissions**

- Display cable radiates and excites the metal LCD housing at the display “dot” clock frequency (437.5 MHz).
- One more ground at the LCD housing reduced emissions 8 dB.
- CM current get returned to the enclosure. Could also be resonance of the LCD panel.
6.1 Stray internal coupling paths

- Adding an external ferrite choke on the I/O cable often works best.
- Interrupt the coupling path with a Faraday shield.
- Separate circuitry or re-layout the circuit traces to minimize inductive coupling.

6.2 Inductive coupling to I/O connector

Loop area on signal pins of connector coupling noisy signals (inductive coupling).
6.3 Data lines running under crystal oscillator

Data lines capacitively coupling 100 MHz (and harmonics) through I/O connector to second PC board; which in that area, is referenced to the power plane (with gaps).

7.1 Resonance effects - cables & structures

In free space: 
\[ \lambda (m) = \frac{\sqrt{m}}{f (MHz)} = \frac{3 \times 10^8}{f (MHz)} \]

Metal structures or lengths of cable may resonate efficiently in multiples of 1/4 wavelength.

GHz clocked processors can induce resonances (in the range 1 to 3 GHz) on the tines of large heat sinks. Grounding is the typical fix. Better is to use ICs with built-in shielding metallization.
7.2 Resonance effects - rectangular enclosures

\[
(f)_{map} = \frac{1}{2\sqrt{\varepsilon \mu}} \sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2 + \left(\frac{p}{c}\right)^2}
\]

Where: \( \varepsilon \) = material permittivity, \( \mu \) = material permeability and \( m, n, p \) are integers.

Cavity resonance can only exist if the largest cavity dimension is greater, or equal, to one-half the wavelength. Below this cutoff frequency, cavity resonance cannot exist. In this configuration (where \( a < b < c \)), the TE_{101} mode is dominant, because it occurs at the lowest frequency at which cavity resonance can exist.

8.1 Inadequate signal returns

A common situation with cables, as well as pin out designs in ASICs or other LSI devices is lack of adequate signal return wires (or pins).

Adding additional signal return paths tends to minimize the loop areas. Large loop areas form the primary of a transformer, the secondary of which, drives an antenna (common-mode) current.

The solution is to add more return paths through additional signal/power return wires/pins. For LSI, add more on-substrate decoupling capacitors.
8.2 Inadequate signal returns

If we assume the LSI circuit or ribbon cable is comprised of many of these “elemental” loop areas, we can see that the addition of more signal/power return paths will tend to minimize loop areas of the structure and thereby reduce the tendency for common-mode emissions.

9.1 Discontinuous return paths

Most PC board problems can be traced to discontinuous signal return paths. This is becoming more of an issue with increasing clock frequencies used today.

- Ideally, the signal travels out a trace and returns immediately under that trace (ideally, using a solid signal return plane)
- All too often, the return path is broken by a discontinuity, such as a gap or slot in the ground plane or
- Examine signal/power return plane layers for gaps and slots
- The signal trace passes through a via and changes reference planes (this is typically a second-order effect)
- Add extra vias or stitching capacitors for return currents when switching reference planes (discussed in 9.5)
9.2 Generation of common-mode emission

DM current flows in a loop. The gap forces the return current to flow in a larger loop, creating a mutual inductance (M), which causes a +/- potential, V, thereby creating an on-board CM source.

9.3 Discontinuous return paths (examples)
9.4 Slots in signal return plane

Temporary bridge with copper tape reduced emissions 17 dB!

9.5 Trace passing through two planes with via

Scenario: signal traces referenced to different planes.

Question: where does the return signal current flow?
9.6 Discontinuous return paths (examples)

Routing a trace over an unrelated (eg. analog) plane can cause noise coupling to other circuitry. Traces should never cross analog planes.

10.1 Electrostatic discharge

ESD coupling to metallic and non-metallic enclosures.

Where do the currents flow?
10.2 Failure modes caused by ESD

- Typical failure modes include a change of instrument state (front panel control), CPU reset, instrument lockup, loss of data
- Fix by shielding, rerouting cables, separation of receptor circuits