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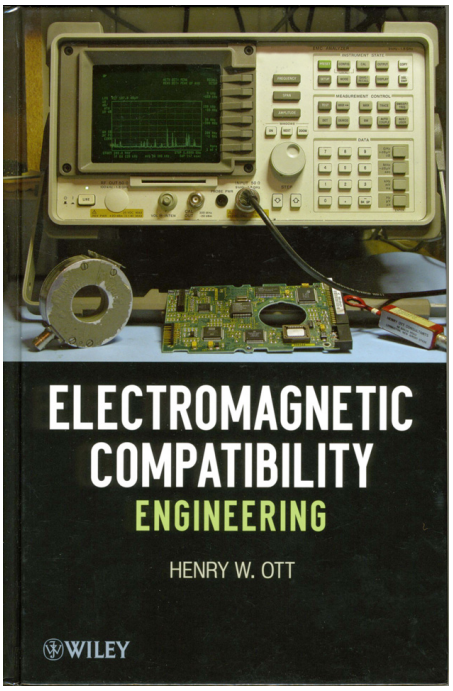
REVIEW - ELECTROMAGNETIC COMPATIBILITY ENGINEERING, BY HENRY OTT

Introduction and Summary:



Henry Ott has been a well-known expert and consultant in electromagnetic compatibility (EMC) for a number of years during his career with AT&T Bell Labs, and as a full-time consultant since his retirement. His first book, *Noise Reduction Techniques in Electronic Systems*, was written in 1977 and a revised second edition was published in 1988. While the basic information in the second edition remains much the same, technology has marched on dramatically, rendering some of the concepts and solutions somewhat antiquated. So, it was with great interest, that I learned of Ott's most recent book, *Electromagnetic Compatibility Engineering* (2009), which was a complete rewrite and now twice as thick, with 843 pages (ISBN 978-0-470-18930-6, $96.00 through Amazon.com).

There are now 18 chapters with six appendices - nine of which, have been completely rewritten. Both analog, digital and mxed-signal circuit design principles are covered, as well as frequencies from audio through GHz. Ott strives to balance the theory with practical applications gleaned from his years as a consultant. The theory is explained so it's easily understood by product design engineers. Solved problems are included, so as to make this text appropriate, as well, for upper-level college courses.

After reading his text, I come away very impressed with the content. This is a book addressed to the working product designer - not for those trying to learn the theory. For that, I would suggest Clayton Paul's book, *Introduction to Electromagnetic Compatibility (2nd Ed.),* or several other like texts. However, Ott includes just enough theory to help explain the basic concepts. I believe this is best for the designer, as they rarely have the time to delve too deeply into the theory in order to solve compliance issues. Understanding the basics gives them at least a chance to apply possible fixes to different situations.

The one terminology I wish Ott would have used in the book was "signal return plane" and "power return plane", rather than "ground plane". While the latter is the common vernacular, they are often misleading as to the "other half" of current flow. In addition, there is much recent research done with decoupling capacitor placement, circuit layout and cancellation techniques from Missouri University of Science & Technology (http://scholarsmine,mst.edu), which was not included. This is a relatively minor nit, as one should be able to extrapolate the basic concepts described by Ott and apply these to ball-grid arrays and other mega-IC devices.

In summary, Ott's new book on EMC design is complete enough for the average product designer to be able to achieve some success in product qualification. Highly recommended.

Discussion of Chapters:

Chapter 1 - Electromagnetic Compatibility. The section on regulations has been updated and includes U.S., Canadian, European and U.S. military standards.

Chapter 2 - Cabling. Includes minor updates, but with additional information on cable shields and shield terminations.

Chapter 3 - Grounding. This is a major update; which now also includes AC power distribution, earth grounds, signal grounds and system grounding.

Chapter 4 - Balancing and Filtering. A moderate update, which goes into much more information on cable balancing, common-mode rejection ratio (CMRR,) balanced loads and differential and instrumentation amplifiers.

Chapter 5 - Passive Components. Resistance and inductance of rectangular conductors and a new section on transmission lines has been added. The section on ferrite beads was expanded a bit.

Chapter 6 - Shielding. Additional information was added for multiple apertures, transfer impedance, seams, internal shields, conductive plating and cavity resonance.

Chapter 7 - Contact Protection. Largely the same material, covering transient suppression and electrical contact protection of mechanical and transistor switches, as well as switched inductive loads.

Chapter 8 - Intrinsic Noise Sources. Unchanged...covers thermal noise, equivalent noise bandwidth, shot noise, contact noise, popcorn noise and random noise measurements.

Chapter 9 - Active Device Noise. This chapter is mostly unchanged; covering noise factor signal-to-noise ratio, measurement of noise voltages and currents, cascaded stages, bipolar and FET noise and noise in op-amps.

Chapter 10 - Digital Circuit Grounding. This is now a complete rewrite, which includes the previous information on noise sources and loop areas, but now has a lot more information on power distribution methods using striplines, assymetrical striplines, ground plane impedance and resistance and digital logic current flow.

Chapter 11 - Digital Circuit Power Distribution (NEW). Here Ott goes into some depth on how to best distribute DC power. Transient loads are discussed with methods to decouple them from the power bus. Decoupling capacitors and decoupling strategies are covered. The pros and cons of multiple decoupling capacitor strategies (same value, different values) based on Archambeault's research is covered. Embedded capacitance in PC boards is covered in some depth, as well as power supply isolation. The effect of decoupling capacitor mounting and placement is also explained.

Chapter 12 - Digital Circuit Radiation. Mostly the same material, except he added the concept of canceling loops and dithered clocks to control differential-mode radiation. Much more emphasis was spent on common-mode radiation and how to control it, as this is typically the predominant radiation from products today. The measurement of common-mode currents has been moved to Chapter 18 (Pre-Compliance Measurements).

Chapter 13 - Conducted Emissions (NEW). This is a major addition to the previous book. He includes material on power line impedance, LISNs, switch-mode power supplies and the resulting common-mode and differential-mode emissions. The effect of the filter capacitor ESL and ESR is discussed, as well as rectifier noise and snubber circuits. There's a whole section on power line filters, including leakage inductance, mounting and magnetic coupling. He moved the section on motor control here, as well and wraps up the chapter with a discussion of active power factor control.

Chapter 14 - RF and Transient Immunity (NEW). Here's another new chapter covering radio frequency (RF), electrically-fast transient (EFT), electrostatic discharge (ESD) and lightning immunity. He discusses simple filter topologies for reducing susceptibility to RF fields. He then moves on to describe the other main transient waveforms; ESD, EFT and lightning surge. He then discusses various suppression networks. He wraps up with a short description of power line disturbances (dips and interruptions).

Chapter 15 - Electrostatic Discharge. This moderately updated chapter now includes a discussion of energy storage for various shaped objects. He now uses a lady in the human body model - giving the other gender their due! The section on equipment design has been reorganized and expanded and there is a new section on ESD grounding and protective measures for ungrounded (portable) products.

Chapter 16 - PCB Layout and Stackup (NEW). This is an all-new chapter, which was obviously missing in Ott's last book. He starts out by discussing component placement and sectioning of major circuitry to reduce digital noise coupling. He discusses critical signals, such as clocks, and isolating these from the I/O area of the PC board. He includes the important concept of slots in ground & power planes and their effect on return currents. The related subject of changing reference planes for return currents is included. The last half of the chapter should be welcome news to PC board designers, as it includes best practices for board stackups from 4 through 12 layers. Each example is compared to Ott's "six multilayer board objectives".

Chapter 17 - Mixed-Signal PCB Layout (NEW). It seems PC board design for mixed signals (analog and digital) is a very confusing subject for most board designers. Ott starts off with a discussion of split planes and how to interconnect traces between the two. He then moves on to

focus on return current paths and how to keep the return currents from coupling between the two areas. Ground and power routing for mixed-signal ICs, such as A/D and D/a converters, as well as decoupling is also included. Finally, industrial process controllers and their unique issues (low-frequency transients getting into the digital circuitry) is discussed.

Chapter 18 - Precompliance EMC Measurements (NEW). This chapter has been reorganized and updated with some of the latest benchtop measurement techniques. Very often, simple pre-compliance measurements may be made to assess the EMC "health" of a product prior to transporting and measuring its compliance at the test lab. Ott shines here as he pulls in material from many of his public seminars on "Workbench Measurements". New in this chapter is the home made passive differential probe design by Douglas Smith. The information on test methods has been expanded to include how to separate the common-mode from the differential-mode currents in power lines. He discusses spectrum analysis and the differences between peak, quasi-peak and average detectors, then goes on to explain which detector to use for the different tests. He describes how to approximately correlate 1m radiated emission testing with electrically small active antennas to the FCC Class A and B limits for purposes of troubleshooting. The remaining chapter deals with testing various transient immunities. One interesting example is the use of a Dremel® motor tool as a broadband noise source.

There are several appendices, which contain useful information.

Appendix A - The Decibel. This has been rewritten for clarity.

Appendix B - The Ten Best Ways to Maximize the Emissions in Your Product (NEW). This is a "tongue-in-cheek" list of poor EMC design practices.

Appendix C - Multiple Reflections of Magnetic Fields in Thin Shields. This is a repeat.

Appendix D - Dipoles for Dummies...(NEW). This includes simplified theory of radiating dipole antennas and demonstrates various dipole structures commonly found in products. This was pulled from one of his popular public presentations.

Appendix E - Partial Inductance (NEW). This is some rather high-powered theory deriving the concept of partial inductance. Much of this material is from work done by Clayton Paul. It includes an experimental setup for measuring the voltage drop in a ground plane.

Appendix F - Answers to Problems.