Controlling Radiated Emissions by Design

Michel Mardiguian

Controlling Radiated Emissions by Design

Third Edition

With contributions from Donald L. Sweeney
and Roger Swanberg

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Foreword to the First Edition

Something over a year ago, I was fortunate enough to preview another VNR book, *Controlling Conducted Emissions by Design*, by John Fluke. My assessment at the time was that Mr. Fluke had written a very good and useful volume, its only flaw being that it focused on just half of the EMI emissions problem. This, of course, was also its strength; although radiated and conducted emissions do not exist in separate worlds, it can be useful, at least as a point of departure, to look at them as distinct phenomena. Expanding the scope of the conducted emissions book therefore would have served mostly to dilute its purpose and compromise its clarity.

After some informal discussions with the publisher on that subject, it was decided to correct the sin of omission by recruiting an author for a companion volume, to be titled *Controlling Radiated Emissions by Design*. I am gratified to have played a minor role in making that happen.

Many EMC engineers with whom I have worked over the years are capable of writing a good radiated emissions book, but few can match Michel Mardiguian's combination of practical engineering experience and proficiency with the pen. On the engineering side, he has worked on such diverse projects as the Mirage V vertical takeoff jet fighter, computer-controlled PBX systems, and, most recently, the renowned tunnel that stretches beneath the English Channel to join England with France.

In terms of academic credentials, the author has written or coauthored at least half a dozen earlier books, including a highly durable and well-respected one on electrostatic discharge. He has taught the principles of electromagnetic compatibility throughout the USA and Europe, and IEEE symposium records contain many of his short works.

Michel's books typically have several characteristics:

1. They are aimed at practical applications but provide enough theoretical material to support the suggested design and retrofit solutions.
2. They rely heavily on visual material, allowing the reader to "see" the EMI problems and solutions.
3. They omit everything that is not essential to the subject under scrutiny.

This third quality is less common than one might expect—many authors feel an irresistible urge to stuff everything they know into one volume. But Michel avoids egocentric dissertations on marginal subjects, preferring to approach each book simply as a job that needs to be done.

With this book, the author follows his usual pattern but with perhaps a greater refinement. Mathematical material is largely confined to two chapters, allowing the book to look mostly at real-world applications. More than 175 tables and illustrations provide information in a highly accessible format. This type of book is difficult for the editors and expensive for the publisher, but the reader should benefit. Some subjects (e.g., EMC testing) are covered very briefly, but the reader is referred to other sources of pertinent information.

It would be premature and presumptuous to call this book a classic in EMC literature, but it does display some of the characteristics of enduring works. *Controlling Radiated Emissions by Design* constitutes a cohesive and clear examination of the subject and is perhaps the author's best work to date.

Gainesville, VA
1992

Jeffrey K. Eckert

Preface

Back in 1992, I was teaching an in-house EMC seminar at a major manufacturing facility and my students were so interested to learn more; they wanted me to extend the class. My search for more material led me to Michel Mardiguian's new book, the first edition of *Controlling Radiated Emissions by Design*, and I've included it and its second edition in my seminars ever since. There are several reasons for this.

First is that the goal of my seminar is to help students think through designing an EMC compliant product from the beginning to the end, and this is exactly what Michel's book does. It starts by explaining why we need to understand the problems of radiation and how radiation happens, along with some simple mathematics for predicting the emissions and harmonic content. Michel uses graphs to further simplify the calculations. He then discusses the strategy for designing a low radiated emission product, both in the choice of circuit technology and circuit board design and all the decisions one needs to make when beginning a design. He then shows how to minimize emissions from cables and packaging. He next develops shielding, including predicting leakage from various types of apertures with real-life examples, using the emissions already predicted from our circuits in the book. He then concludes the book by showing how to troubleshoot a product when it doesn't comply with its emission requirements, including the use of a current probe to predict the reduction in emissions.

Michel is a practitioner, one who actually uses what he writes about in his consulting practice. This gives the reader a process that he/she can use to expand themselves in the field of EMC.

Secondly, instead of ending a chapter by providing problems for the student to figure out on their own, Michel gives sample problems within the text and shows step-by-step solutions to them. Our students have found the procedures and equations developed in the book so beneficial that we have developed several computer programs which allow the design engineers to repeat the calculations quickly and repeatably as they are designing their product.

Thirdly, Michel explains EMC design concepts that are easy to understand and to follow. After developing the EMC concepts, he intersperses practical examples

allowing the students to use what they just learned. These examples are rare in textbooks.

I use Michel's book during my class to supplement my own teaching materials, and I also give each of my students a copy of the book for later reference. It is also an excellent book for individual use outside the classroom.

After teaching, I give students an opportunity to sit down with an EMC expert and discuss one-on-one their own product or concerns. While doing so, one student once said, "I would not even have understood what you are talking about had I not just taken your class. Now I see what we have been doing wrong." What more needs to be said about Michel's book, seeing how it affected this student and many others like him!

Michel Mardiguian has had a distinguished career with extensive EMC experience working in the honored positions of IBM EMC Specialist, French Delegate to the CISPR Group on Computer RFI, and Director of Training for Don White Consultants. He has written many widely read books and articles and has given many lectures on EMC topics. In 2007, he received the IEEE EMC Society's prestigious Technical Achievement Award.

Wheeling, IL
October 2013

Donald L Sweeney

Acknowledgements

It would be unfair and incomplete if full credit was not given to those who helped with the birth of this book, and constantly attended its writing and proofing. Of all these devoted contributors, the prominent one is certainly Donald Sweeney, who relentlessly, in December 2012, inspired me to write this third edition. Don struggled eagerly through every paragraph and chapter, for the best comprehension and consistency of what I was trying to say. His colleagues at D.L.S., Roger Swanberg, Tim Lusha, and Corey Sweeney made a definite contribution to the contents of the chapters dealing with International RFI regulations and measurement procedures. Bill Stumpf and Steve Grimes did the edit review of the standards material, while Mark Rozema, Jack Prawica, and Jereme Irwin reviewed the military and RTCA part as well as Paul Vicory reviewing the automotive sections. Last but not least, I am indebted to the ladies at D.L.S.: Jessica Stephens, who did the artwork, tables, website, extensive editing, and overall support; Maxine Martin who carefully checked and rewrote some material, including those parts where Don and myself were fighting over some language controversy; Marilyn Sweeney who edited Chap. 1; and Carol Pittl who did the editing and scanning of several parts.

Michel Mardiguian

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Abbreviations

ACMOS (or ACT)	Advanced CMOS technology
ALS	Advanced low-power Schottky logic
BGA	Ball grid array
BW	Bandwidth
CISPR	Comité International Special des Perturbations Radioélectriques
FCC	Federal Communications Commission (USA)
HF	High frequency. Although officially used for 3-30 MHz, it often designates casually the MHz frequency domain.
LCC	Leadless chip carrier
LISN	Line impedance stabilization network (synonymous: AN, artificial network)
LS (or LSTTL)	Low-power Schottky logic
QP	Quasi-peak
SE	Shielding effectiveness
SMT	Surface-mount technology
UHF	Ultra High Frequency (300-3,000 MHz)
VHF	Very high frequency (30-300 MHz)

Symbols

- B Magnetic induction, or more exactly flux density (Tesla).
In air, $B = \mu_0 \times H$ (A/m)
- β Phase constant $= 2\pi/\lambda$
- δ Skin depth
- ϵ Electric permittivity constant (for air or free space $= 8.85 \times 10^{-12}$ F/m)
- λ Wavelength $= 300/F(\text{MHz})$
- μ Magnetic permeability (for free space air or nonmagnetic materials
 $\mu_0 = 4\pi \times 10^{-7}$ Henry/m)
- ϕ Magnetic flux. In Weber, $\phi = B \times S = \text{induction (Tesla)} \times \text{area (m}^2\text{)}$
- ω Angular frequency in radians/s $= 2\pi \times F$