Donald G. Baker

ELECTROMAGNETIC COMPATIBILITY

Analysis and Case Studies in Transportation

WILEY

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ELECTROMAGNETIC COMPATIBILITY

Dedicated to:
My wife Barbara
Daughters Tricia and Stephanie
Grandchildren Aidan, Addie, Evan and Marlaina

PREFACE

A contributor to this book both directly and indirectly is my friend and colleague Dr. Kent Chamberlin of the University of New Hampshire (UNH). He was my professor while taking graduate school courses toward a PhD degree (did not finish because of health problems). He was instrumental in teaching me the finer points in vector analysis applied to EMC issues. Previously I was working and analyzing EMC problems that could be reduced to a Cartesian form of equations. These were much easier to work with than the cylindrical and spherical differential equations. Many times the wave equation was unnecessary to do an analysis. Under his tutelage I could read and study more complex books on the subject, such as the ones written by Dr. Balanis (located in the References).

This book is written in several chapters, the first being the regulations for electromagnetic emissions for electric and magnetic fields. The second chapter is an introduction to electromagnetic compatibility (EMC). This has some simple examples, as shown by illustration in equations that are necessary for a PE without previous training or a person wishing to delve into this field. The third chapter of this book catalogues the solutions to the wave equation and Maxwell's equations in Cartesian, cylindrical and spherical coordinate systems and also has several examples for the use of these systems.

The next three chapters are devoted to communication issues in transportation requiring EMC analysis. These include analysis of communication houses, signals bungalows/houses and the effects of magnetic and electric fields on the equipment inside, external radiation from licensed radios, cell phones, spread-spectrum devices, power lines, power supplies and other types of emissions that are induced on communication lines and PC boards. These chapters have many examples that can be used as a guide for the engineer in deciding how to analyze a particular anomaly caused by electric and magnetic fields. As emphasized previously, never try to overextend an analysis of frequency airspace without knowing the limitations of the equations. One must always keep vigilant when understanding that the equations are only a tool and would be equivalent to a mechanic using a hammer to remove his spark plugs.

The seventh chapter of this book is related to health and safety issues and catalogs many of the safety issues that must be observed due to electromagnetic emissions, with examples. In each of the chapters of this book, problems are provided at the end of the chapter to reinforce the knowledge gained by studying the chapter. Answers are provided at the end and in many cases the answers are provided with equations with the numbers shown so as to guide the engineer reading the chapter to a result and in some cases the engineer can use the equations by just changing the numbers slightly.

The eighth chapter of this book has miscellaneous documents and functions that may be useful in generating or answering a requirements document in transportation with a report, as is often required. More often than not, test results are required for the EMC analysis until the integration phase is complete. Then, only if an EMC issue occurs after commissioning, all test results are released and generally can be found in DOT documents. During the 1980s when working in research and not in systems, test results were usually required for EMC analysis for military-type projects. But most commercial and consumer products require test results that must be provided to the FCC, usually through test laboratories, such as Underwriter Laboratories, if the company producing a product does not have facilities for testing. Since all the products installed in the system must be FCC approved, with care no emissions will be present due to the system. Often the analysis is only a guide used by the system engineer to prevent anomalies from occurring.

The ninth chapter deals with signals and tracks and the effects of electromagnetic emission signals, both from track and signals. For each of these entities examples of signals equipment functions and how these affect communications is the object of this study. Signals equipment operates using both copper and fiber optic networking and rails function similar to transmission lines and these are low-frequency communications on the rails themselves. However many new spread-spectrum devices are used in signals for conveying information from the rails to the operational control center (OCC). Examples of signals are provided at the end of the chapter, as mentioned previously, to reinforce the knowledge of the person studying EMC effects.

The last chapter of this book provides useful examples that may be used in EMC analysis. These consist of both equations and situations where these anomalies may be examined. These not only apply to communications and transportation but can be generally used for other analyses as required. The audience will find that some of the information in this book is used for other EMC analyses outside the realm of transportation, such as emissions within the home that may be causing EMC issues, the design of cabinets and enclosures that require strict EMC shielding from emissions both internal and external, the automotive industry where harsh environments with radiation emission is present from electric car drives, ignition systems, GPS, emissions from cell phones, wireless games, shielded buildings with security issues, navigational aids emissions, airports and many others that are outside the realm of how this book may be used. There is a course that was originally a one-week seminar in PowerPoint for PEs that is now available at www.wiley.com/go/electromagneticcompatibility. This PowerPoint presentation is meant for the layman and is not heavily involved with vector analysis.

DONALD G. BAKER PE

ABOUT THE AUTHOR

Donald G. Baker began his experience in 1965 at the Motorola Corporation after graduation from the Illinois Institute of Technology with a BSEE in electronics. Motorola required that each engineer with less than one year's experience attend their plant school. The first design project was a 70 MHz phase lock loop for a Tract 92 Tropo-Scatter Radio System. At this time a transistor design at 70 MHz was an advanced project. The next design with some patents was a military grade audio signal generator for Holt Instrument with the patent for the feedback circuit in 1968.

The next series of designs was for the Magnaflux Corporation from 1968 until 1972: during which time the following equipment test equipment was designed: (i) a conductivity meter requiring a patent for the bridge circuit (one of these meters is used as a federal standard for calibration of conductivity meters), (ii) an ultrasonic crack detector with a oscilloscope type readout designed for detecting cracks at one-10 000th inch below the material surface, (iii) a meter type and (iv) an ultrasonic crack detection unit for large cracks below the surface that did not require the accuracy of the initial crack detector.

The next series of designs were for the Sundstrand Corporation (machine tool division). The author obtained a MSEE from IIT night school in 1972 and worked from 1972 to 1978 on the following design projects:

1. The control system for the Clinch River Nuclear Breeder Reactor for refueling. This design required using an analog computer design of differential equations that were sampled and converted to digital format for the government of the refueling system as a safety precaution. The plug drives for alignment to the fueling grapple were all controlled by a digital computer composed by the Digital Equipment Corporation (DEC).
2. The design of a six phase motor to be used for a spindle drive at 75 000 rpm to be used on milling machines.

3. Transistorized H drives to be used for the digital control of milling machine positioning.
4. An ultrasonic method for correcting spring-back in milling machines to increase accuracy.

The author was employed by EXTEL Corporation designing audio modems from 1978 to 1979. While employed by Microtek, 1980 to 1982, he designed a telephone caller ID system for analog phones using spread-spectrum technology. During employment by MIT Research (MITRE) from 1982 to 1990, he worked on several projects that are classified as secret and cannot be divulged at this time. Even their titles are secret; however most of the designs were used for fiber-optic networking. Employment from 1990 to 1991 with the Deleuw Cather involved EMC analysis and reliability work.

Employment from 1991 to 2013 was for the SESCO, Harmon and GE Corporations. This was all at the same workplace as the various companies changed hands but the work remain the same. The author's tasks were as follows: (i) analysis of all EMC issues for transportation communications and sensor systems, (ii) reliability studies, (iii) maintainability studies and (iv) communication computer timing issues. The last work while retired is writing this book from March 2013 to March 2015 for the first iteration of the manuscript. Miscellaneous work from 1966 to 1968 was teaching elementary courses in electronics and instrumentation at high schools and from 1972 to 1990 teaching as an adjunct professor at several junior colleges and graduate schools.

Several of the corporations where the author was employed were involved in mergers or went out of business completely; but some of the information about the author's work can be found in the author's books on fiber optics written in 1985, 1986 and 1987.

ABOUT THE COMPANION WEBSITE

This book is accompanied by a companion website:

www.wiley.com/go/electromagneticcompatibility

The website includes:

- PowerPoint slides for PEs based on an Electromagnetic Compatibility EMC Seminar
- Appendix A

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