Preface

"… I am talking about the areas of science and learning that have been at the heart of what we know and what we do, that which has supported and guided us and which is fundamental to our thinking. It is electromagnetism (EM) in all its many forms that has been so basic, that haunts us and guides us…" *—Nick Holonyak, Jr., in his foreword in this book.*

"The electromagnetic theory, as we know it, is surely one of the supreme accomplishments of the human intellect, reason enough to study it. But its usefulness in science and engineering makes it an indispensable tool in virtually any area of technology or physical research." *—George W. Swenson, Jr., in the "Why Study Electromagnetics?" section of this book.*

I am grateful to many people, beginning with my parents, and for many things. In the words of the late Gurudeva Sivaya Subramuniyaswami of the Kauai Aadheenam: "Gratitude and appreciation are the key virtues for a better life. They are the spell that is cast to dissolve hatred, hurt and sadness, the medicine which heals the subjective states of mind, restoring self-respect, confidence and security." In the context of this book, I am grateful for the fact that I am the author this book—the Indian version of the sixth edition, and hence the "Indian edition"—and its five predecessor editions, over the span of about 30 years, for introducing electromagnetic theory to students all over the world. In this preface, I would like to reconstruct the trail of this gratitude beginning in the 1950s.

One day during the academic year 1957–58, I had the pleasure of having afternoon refreshments with William L. Everitt in the dining hall of the Madras Institute of Technology (MIT), Chromepet, along with some others in the electronics faculty of the MIT. William L. Everitt was then the Dean of the College of Engineering at the University of Illinois, Urbana, as it was then known. Dean Everitt was visiting India because the University of Illinois was assisting with the development of IIT, Kharagpur, the first of the IITs. Dean Everitt came to Madras (presently Chennai) at the invitation of William Ryland Hill, who was the visiting Head of the Electronics Faculty of the MIT during that one year, on leave from the University of Washington in Seattle, Washington.

I happened to be on the staff of the Electronics Faculty then, having completed my diploma in electronics after three years of study during 1952–55 and six months

of practical training, following B.Sc. (Physics) from the University of Madras, having attended the Presidency College. One of the subjects I studied at MIT was electromagnetic theory, from the book, *Electromagnetic Waves and Radiating Systems*, by Edward C. Jordan, who was then the Head of the Department of Electrical Engineering at the University of Illinois. I can only say that my learning of electromagnetic theory at that time was hazy at best, no reflection on Jordan's book.

While I was a student at MIT, one of our great lecturers, by the name of S. D. Mani, was leaving to take a new job in Delhi, for which we gave him a send-off party. After the send-off party, we all went to the Chromepet Railway Station to bid a final good-bye to him on the platform. While on the platform waiting for the electric train to arrive from Tambaram, he specifically called me and said, "Narayana Rao, someday you will become the president of a company!"

Contrary to what S. D. Mani said, with his great characteristic style, I did not go on to even work in a company. Instead, William Ryland Hill "took" me to the EE Department at the University of Washington in 1958, then chaired by Austin V. Eastman, a contemporary of Edward Jordan. There, I pursued my graduate study in electrical engineering and received my Ph.D. in 1965, with Howard Myron Swarm as my advisor, in the area of ionospheric physics and propagation, and taking courses from Akira Ishimaru, among others. Eastman gave me the opportunity of teaching courses just like a faculty member, as an instructor, because of my teaching experience at MIT, and the good word of Ryland Hill. That was when I fell in love with the teaching of "transmission lines," from the electromagnetics aspect, which then extended beyond transmission lines and later led to the writing of my books.

Never did I envision during those years that in 1965, after completing my Ph.D. at the University of Washington, I would become a faculty member and be writing my books in the Jordan-built Department of Electrical and Computer Engineering (as it is now called) in the Everitt-built College of Engineering at the University of Illinois at Urbana-Champaign (UIUC), as it is now known. Never did I envision that I would be spending my entire professional career since 1965 in the hallowed halls of the William L. Everitt Laboratory of Electrical and Computer Engineering, which I call the "Temple of Electrical and Computer Engineering," along with personalities such as distinguished colleagues, Nick Holonyak, Jr., and George W. Swenson, Jr. Never did I envision that not only would I be writing books for teaching electromagnetics, following the tradition of Jordan, but also holding a professorship bearing his name.

I believe that gratitude is something you can neither express adequately in words, nor demonstrate adequately in deeds. Nevertheless, I have tried on certain occasions to express it in words, and demonstrate it in deeds, which I would like to share with you here:

To my alma mater, the Madras Institute of Technology, on the occasion of the Institute Day on February 26, 2004, in the presence of the then Governor of Tamil Nadu, Sri P. S. Ramamohan Rao, a classmate of mine while in Presidency College:

So, Madras Institute of Technology, my dear alma mater
Where I went to school fifty years ago this year
Today I present to you this historic volume
The product of the work of my lifetime
For which fifty years ago you laid the foundation
That I cherished all these years with much appreciation
Please accept this book as a token of my utmost gratitude
Which I offer to you in the spirit of "Revere the preceptor as God"
Hopefully I will be back with Edition No. 7
To express my gratitude to you again in 2007!

At the conclusion of the response speech on the occasion of the investiture as the Edward C. Jordan Professor of Electrical and Computer Engineering, on April 14, 2004:

To Edward C. Jordan, the "father" of my department
Fifty years ago, I may have studied EM from your book with much bewilderment
But today, I offer to you this book on EM which I wrote with much excitement
In appreciation of your profound influence on my professional advancement.

To my alma mater, the EE Department at the University of Washington, at the Kick-Off event for the Centennial Celebration of the Department on April 28, 2006:

To the EE Department at the University of Washington
From this grateful alumnus who received from you his graduate education
Not just graduate education but seven years of solid academic foundation
For my successful career at the University of Illinois at Urbana-Champaign
During which I have written six editions of this book on electromagnetics
Besides engaging in the variety of all the other academic activities
I present to you this book with utmost appreciation
On the occasion of your centennial celebration!

And when you are grateful in life, things will continue to happen to you to allow you to be even more grateful. Even as late as November 2005, I did not envision the publication of this Indian edition, which includes the new section on "Why Study Electromagnetics?" which I was planning for the seventh edition of the book. It came about as a consequence of the signing of a memorandum of understanding (MOU) in December 2005, between a number of U. S. Universities, including UIUC and the University of Washington, and the Amrita Viswa Vidyapeetham of Amma Mata Amritanandamayi Devi, in partnership with the Indian Space Research Organization and the Department of Science and Technology of the Government of India. The MOU has to do with an initiative, known as the Indo-US Inter-University Collaborative Initiative in Higher Education and Research,

and allows for faculty from the U.S. to offer courses for e-learning on the EDUSAT Satellite Network, and to pursue collaborative research with India. The Initiative was launched by President Abdul Kalam from New Delhi on the EDUSAT Satellite Network on December 8, 2005.

The term, "Indo-US," prompted me to reflect on my ethnicity, having come from the motherland, India, and become a naturalized American citizen. As a result, I came up with this poem:

Here is a little poem for Mother
My mother, your mother, our mother
The mother of a billion people on her land
The mother of millions of people outside her land
Mother India, my citizenship is American
But the blood you sent me with is Indian
So, as they say, am I an Indian American?
Or, am I an American of Indian origin?
I may be known as an Indian American
Or they may call me an American of Indian origin
But mother, I feel more like an IndiAmerican!
With the "Indian" fused into "American"
And I shall always be an IndiAmerican!
As my "Indian" is inseparable from my "American"
Or, for that matter, from any other "an!"

So, as an IndiAmerican, I bring this book to you, as a token of my utmost gratitude to the land of my birth, India, that gave me the guiding principles of my life from the Upanishads, and to the land of my work, the United States of America, where I pursued Maxwell's equations, the guiding equations of this book, as expressed in the dedication in the original sixth edition, reproduced here (see next page)!

In this Indian edition, I also bring to you for the first time in an electromagnetics textbook, or in any textbook that I know, a write-up that addresses an often troublesome matter to the students on why they should study a certain subject. This question is particularly prevalent when it comes to studying electromagnetics. This write-up on "Why Study Electromagnetics?" has been put together by asking for contributions from the faculty and alumni of my department and a former professor of mine at the University of Washington. You will find among them teachers, former teachers, engineers, entrepreneurs, inventors, and even a medical doctor, spanning the gamut of the field of electrical and computer engineering. I am grateful to them all, who by their contributions have done a great service to the academic community. I also express my thanks to James Hutchinson, Editor, Publications, ECE Department, for assisting me in putting together these contributions in a short span of time. You will find that the write-up not only answers the question "Why Study Electromagnetics?" but goes further and serves to educate on the scope of the field of electrical and computer engineering,

Om Shri Ganeshaya Namaha

To the land of my birth, India,
the land that gave me the guiding principles of my life:

Matrudevo bhava!	$\Rightarrow$	*Revere the mother as God!*
Pitrudevo bhava!	$\Rightarrow$	*Revere the father as God!*
Acharydevo bhava!	$\Rightarrow$	*Revere the preceptor as God!*
Atithidevo bhava!	$\Rightarrow$	*Revere the guest as God!*

And to the land of my work, the United States of America
the land where I pursued the guiding equations of this book:

$$\oint_C \mathbf{E} \cdot d\mathbf{l} = -\frac{d}{dt}\int_S \mathbf{B} \cdot d\mathbf{S}$$

$$\oint_C \mathbf{H} \cdot d\mathbf{l} = \int_S \mathbf{J} \cdot d\mathbf{S} + \frac{d}{dt}\int_S \mathbf{D} \cdot d\mathbf{S}$$

$$\oint_S \mathbf{D} \cdot d\mathbf{S} = \int_V \rho \, dv$$

$$\oint_S \mathbf{B} \cdot d\mathbf{S} = 0$$

and on the strength of this Jordan-built Department of Electrical and Computer Engineering, which has been my work-home for the past 41 years!

So, I did not become the "president" of a company, as S. D. Mani proclaimed on the platform of the Chromepet Railway Station; instead, I went on to become a "resident" of the William L. Everitt Laboratory of Electrical and Computer Engineering—a facility that provided education to numerous presidents of companies—located at the northeast corner of the intersection of Wright and Green Streets in Urbana, Illinois, on the Campus of the University of Illinois at Urbana-Champaign, halfway around the world from you! And I am pleased and proud to bring to you, the "young minds" of our motherland, this book from this "Temple of Electrical and Computer Engineering!"

Having reconstructed and told you about the trail of gratitude, I shall now tell you about the evolution of this book, beginning with the first edition, published in 1977.

Introductory textbooks on engineering electromagnetics can be classified broadly into three categories:

1. One-semester textbooks based on a traditional approach of covering essentially electrostatics and magnetostatics, and culminating in Maxwell's equations and some discussion of their applications.
2. Two-semester textbooks, with the first half or more covering electrostatics and magnetostatics, as in category 1, and the remainder devoted to topics associated with electromagnetic waves.
3. One- or two-semester textbooks that deviate from the traditional approach, with the degree and nature of the deviation dependent on the author.

Most textbooks fall into categories 1 and 2, and only a small minority, including this book, belong to category 3. The deviation from the traditional approach

originated with the first edition, a one-semester text in which the basic material was built on time-varying fields and their engineering applications. This enhanced its utility for the one-semester student of engineering electromagnetics, while enabling students who planned to take further (elective) courses in electromagnetics to learn many of the same field concepts and mathematical tools provided by the traditional treatment.

In preparing the second edition, a major revision of the first edition was undertaken by expanding the text for one- or two-semester usage to provide flexibility, while preserving the basic philosophy of the first edition, which arose from the assertion that, as a prerequisite to the first EE course in fields, most schools have an engineering physics course in which the students are exposed to the historical treatment of electricity and magnetism. Subsequent editions have further enhanced the usage by incorporating changes and adding material to satisfy the prerequisite needs pertinent to emerging technologies. For example, the substantial changes leading to the fourth edition were prompted by the increasing need for introductory-level coverage to extend beyond the microwave region and into the optical region of the electromagnetic spectrum, in recognition of the advent of the era of photonics, overlapping with that of electronics. In the fifth edition, the deviation from the traditional approach was carried further by reorganizing the material and adding topics to associate chapters or parts of chapters with electromagnetic technologies.

An important factor guiding the revisions has been the organization of topics for a first course in electrical engineering, as well as in computer engineering, followed by one or more required or elective courses for electrical engineering students that build on the first course. When the first edition was written for a one-semester course to meet the needs of both groups of students, most of the students were electrical engineering majors, a situation that continued for many years. In recent years, the ratio has changed dramatically, and at present, the numbers for computer engineering majors are comparable to those for electrical engineering majors. Recognizing this development, and to make the intended usage of the book even more explicit than before, I have carried the organization of the topics even further in the sixth edition and hence in this Indian edition by dividing the book into two parts.

Part I, entitled "Essential Elements for Electrical and Computer Engineering," is comprised of the first six chapters. These chapters contain essentially the material in Chapters 1–6 and 8 of the fifth edition, except that the organization and treatment of topics is tilted more toward time-varying fields, compared with the fifth edition. Part II, entitled "Essential/Elective Elements" to indicate that they are essential or elective, depending upon the needs of the curriculum, comprises the next five chapters. Chapters 7, 8, 9, and 10 are the same as Chapters 7, 9, 10, and 11, respectively, in the fifth edition, except that I have added the topic of pulses on lossy lines in Chapter 7. Chapter 11, an expanded version of Chapter 12 in the fifth edition, includes the analytical technique of separation of variables and the geometrical method of field mapping, in addition to the four numerical techniques in that chapter.

Some of the salient features of the thread of development of the material, evident from a reading of the table of contents, are the following:

1. Introduce basic concepts of vectors and fields for static as well as time-varying cases at the outset and bring in vector calculus concepts later as needed.
2. Present electric and magnetic field concepts early, and then introduce Maxwell's equations for time-varying fields, first in integral form and then in differential form.
3. Introduce waves and associated concepts by obtaining uniform plane wave solutions from the infinite plane current sheet source, first in free space and then in a material medium.
4. Introduce electromagnetic potentials and cover topics pertinent to devices, circuits, and systems, beginning with p-n junction and circuit elements, and progressing through electric- and magnetic-field systems to other topics pertinent to electromechanical systems.
5. Introduce the transmission line concept and develop transmission line time-domain analysis, essential for digital electronics, in a progressive manner, beginning with the case of a resistive load to interconnections between logic gates and culminating in crosstalk on transmission lines.
6. Present sinusoidal steady-state analysis of transmission lines comprising the topics of standing waves, resonance, power transfer, and matching, with emphasis on computer and graphical solutions.
7. Develop principles of guided waves for both electronics and optoelectronics, by confining the treatment to one-dimensional waveguides comprising parallel-plate metallic waveguides and dielectric slab waveguides.
8. Devote a chapter to several topics pertinent to electronics and photonics, including two-dimensional metallic waveguides and optical fibers, pulse broadening due to dispersion, interference and diffraction, and wave propagation in an anisotropic medium.
9. Introduce radiation by obtaining the complete field solution to the Hertzian dipole field through the magnetic vector potential, and then develop the basic concepts of antennas.
10. Devote a chapter to solution techniques, comprising primarily the numerical techniques of the finite-difference method, the method of moments, the finite-element method, and the finite-difference time-domain method, but also including the analytical technique of separation of variables and the geometrical method based on field mapping.

As in the previous editions, a number of teaching and learning aids are employed: (1) examples distributed throughout the text, (2) practical applications of field concepts and phenomena interspersed among presentations of basic subject matter, (3) descriptions of brief experimental demonstrations suitable for classroom presentation, (4) summary of material and review questions (**Q**) for each chapter, (5) drill problems (**D**) at the end of each section, (6) margin notes, (7) keywords

(**K**) at the end of each section, and (8) review problems (**R**) at the end of each chapter, following the homework problems (**P**). For the book, there are a total of 108 Examples, 158 **D** Problems, 413 **Q** Questions, 422 **P** Problems, and 81 **R** Problems. Answers are provided for 40% of the **P** Problems.

I wish to express my appreciation to the more than sixty colleagues at the University of Illinois at Urbana-Champaign who have taught from the six editions of the book during the 29-year period from 1977 to 2006. Thanks are also due to the numerous users at other schools. The evolution of this book would not have been possible without the many opportunities provided to me by the many administrators at the University of Washington and the University of Illinois at Urbana-Champaign from 1958 to 2006. Many individuals in the department have provided support over the years. As always, I am deeply indebted to my wife Sarojini for her continued understanding and patience.

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