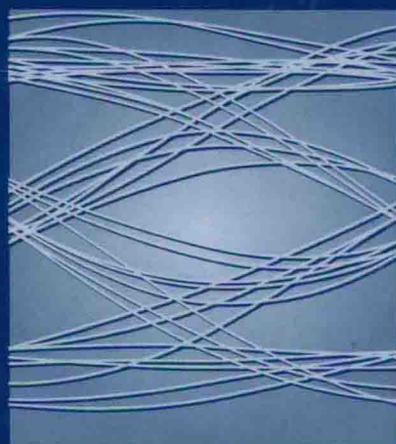
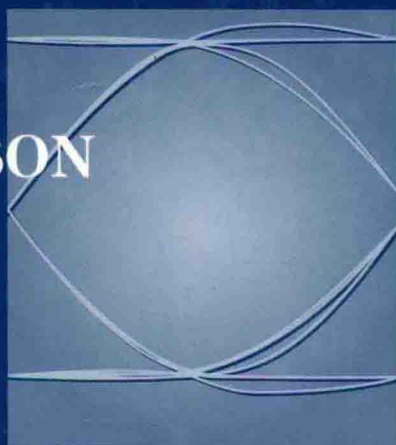
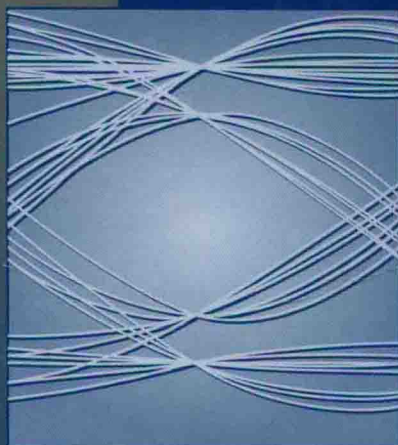


Digital Transmission Engineering

SECOND EDITION

JOHN B. ANDERSON



DIGITAL TRANSMISSION ENGINEERING

Second Edition

JOHN B. ANDERSON

Lund University



John B. Anderson, *Series Editor*



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PREFACE TO THE FIRST EDITION

This book is about the transmission of digital data through time and space, as it is practiced in the sophisticated systems of today. Since the ideas behind today's designs can be subtle, theory and concepts play a major role, but engineering practices and judgments are an essential part of the story as well and need equal prominence. This book seeks to combine a clear conceptual grounding with an engineering attitude.

Digital transmission is not an elementary subject. The author remembers learning both digital communication theory and computer programming in the mid-1960s, and being told that these were hard subjects that could not be taught but rather must simply be absorbed. Both were new at the time. Since then we have learned how to teach them, fortunately. Programming turned out to be rather easy, and as it turned out, children could learn it and even get into mischief with it. Digital transmission, on the other hand, is still an advanced discipline. After 30 or more years, it is accessible to the same persons it was in the 1960s, namely, students and practicing engineers with at least 4–5 years' training.

Especially in the United States, where undergraduate education ends a year earlier than in Europe, there has been a trend to bring digital communication down into the undergraduate years. No doubt this is possible for some of the simpler ideas, but the details of a CD player or a cellular phone are too subtle and complex to be grasped by an engineer without significant training. Reed–Solomon codes and maximum-likelihood sequence estimation are not part of ordinary experience. The aim of this book cannot be to dilute these subjects, but rather to explain them in the simplest and most efficient way.

There is a natural evolution in any new technical subject, as it moves away from the half-understood discoveries of a few researchers and inventors. If the subject is important enough, it will move from journal articles and patents to research monographs and early textbooks. These passages are difficult and time-consuming. Discoveries do not come easily, and finding any pedagogical explanation at all, let alone a good one, is a stiff challenge. Textbooks in the engineering of digital communication, as opposed to pioneering monographs, began to appear in the 1975–1985 period. We are now well past the early textbook stage. Digital commu-

nication is mature and contains relatively few mysteries. It is time to think about what are the best explanations of the subject, and hopefully some of this has found its way into this book. Our material on baseband pulses and carrier modulation has been completely recast in order to achieve a simpler exposition and introduce a stronger engineering flavor. Two critical parts of a real communication link are the synchronizers and the physical nature of the channel. These are half or more of any complete design and they each have an extensive chapter here, for the first time in a book at this level. Our treatment of equalization is a complete reworking of existing material.

The material in Chapters 1–5 is the basis of the first-year graduate introduction to digital communication taught for some years by the author. It covers pulse and carrier modulation in detail, interference and distortion, synchronization up to the network level, and the engineering details of channels, antennas, and propagation. Additional sections on error control coding, mobile channels, and some advanced techniques make up Chapters 6 and 7 and Section 5.4. These have been included for those who have the need and the space for them.

The prerequisites for this book are good courses in probability and transform and system theory. A course in analog communication is helpful. We have taken pains to avoid significant use of stochastic processes, although that subject provides many valuable insights and is a prerequisite for further study in fields such as detection theory.

We have sought to avoid the encyclopedic approach of some books, which cover more details in many more pages but are barely legible to the student. These books have their place, but it is not at the first-year level.¹ We seek to explain a limited number of topics fully in a book of moderate size. Many important but smaller topics are left out, and we mean no disrespect to the scientists and engineers who devised them. In the references cited in the text we follow a priority that has meant injustice to some. Our first priority has been to refer to the most readable sources of further information for the student. Establishing the history of an idea takes second priority and recent developments take third.

Signal processing based on software algorithms plays an ever-growing role in communication systems, and all engineers need a computing engine for their work. For these reasons, short programs based on MATLAB are incorporated in many places in the text. A number of important homework exercises are based on these simple programs. Student and instructor alike are warned that gaining experience with software tools and the allied signal processing ideas takes significant time. There is a major difference between enjoying a classroom demonstration of software and using it oneself. The author's experience is that this perfecting of the tools adds about 15% (two weeks) to the course.

The pedagogical ideas behind this book and its choice of contents evolved over 15 years teaching the subject. It is inconceivable to the author that a good class text could arise without many years of encounter with a great many students. Most lines in this book trace back to a class question, a discussion afterward, or perhaps simply

¹This is the final-year level in the European diploma engineer curriculum.

a pained expression. Thus the dedication of this book: To these students, who made it possible. We hope their pain may now be a little less.

It is a pleasure to acknowledge some special organizations and individuals. First and foremost, this book would not have been possible without the support of two foundations: The Humboldt Foundation of Germany, who awarded the author a Humboldt Research Prize Re-Invitation in 1995, and the Science and Engineering Research Council (TFR) of Sweden, who appointed the author National Visiting Chair in Information Technology during 1996–1997. Awards of this type for the support of scholarly work and books are an old tradition which has somewhat fallen by the wayside, and the author wishes especially to recognize the generosity and ideals of these two foundations.

The original LaTeX manuscript was ably typeset by Priscilla Magilligan and Lena Månsson. Their cheerful fortitude and many suggestions were of great value. We would like to recognize the support and encouragement of Dudley Kay, John Griffin, and Savoula Amanatidis at IEEE Press. A large number of colleagues helped through their readings, counsel, and willingness to debate at all hours. Particular thanks are due to Rolf Johannesson and Per Ståhl at Lund University, Joachim Hagenauer and Robert Schweikert at Deutsche Luft und Raumfahrt and Technische Universität München, and Gary Saulnier at Rensselaer Polytechnic Institute. Asad Islam of R.P.I. helped with the Solution Book. The support of industrial colleagues is particularly important to a book like this one. These especially include Sandeep Chennakeshu and Kumar Balachandran at L. M. Ericsson, Krishna Balachandran at Lucent Technologies, and Richard Frey at General Electric Research and Development. Finally, the author must acknowledge the continuous support of the other author in the family, his wife Janet. When the work here gets a little dreary, the reader can turn with profit to one of her books.

JOHN B. ANDERSON

*Lund, Sweden
June 1997*

PREFACE TO THE SECOND EDITION

The years have fled by, digital communication has evolved, and it is time for a revised edition. The guiding concepts of the first edition focused on core topics and effective combining of theory and practice. These met with enthusiastic acceptance, and we have therefore sought to strengthen them in the second edition. There are new programs and examples, and a few topics that seem to stray too far are reduced. Veterans of the first edition will notice that significant additions are a section on spread spectrum and a more complete and pedagogical treatment of mobile radio; these reflect the increasing importance over the last seven years of cellular and mobile networks. There is also more treatment of fiber transmission, and the end-of-chapter problems have been doubled. While these additions are the most visible ones, almost every sentence in the text has been modified in some way. Hopefully, the unclear spots and unfortunate sentences are much reduced in number, and all the errors in the first edition are repaired.

We have benefited over seven years from a great many discussions with colleagues and instructors who adopted the book. It is a pleasure to mention especially Gary Saulnier, James Leblanc, and Göran Lindell, as well as the reviewers of the new edition. We must mention also our hardworking editors Tony VenGraitis and John Griffin, as well as the production staff at Wiley. Finally, there are all the students, as many now in Sweden and the rest of Europe as in the United States and Canada. They continue to argue, inquire, and find weak spots in the book. As before, the dedication of the book is to them.

JOHN B. ANDERSON

*Lund, Sweden
September 2004*

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Program 2.2-2	The Root RC Pulse
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