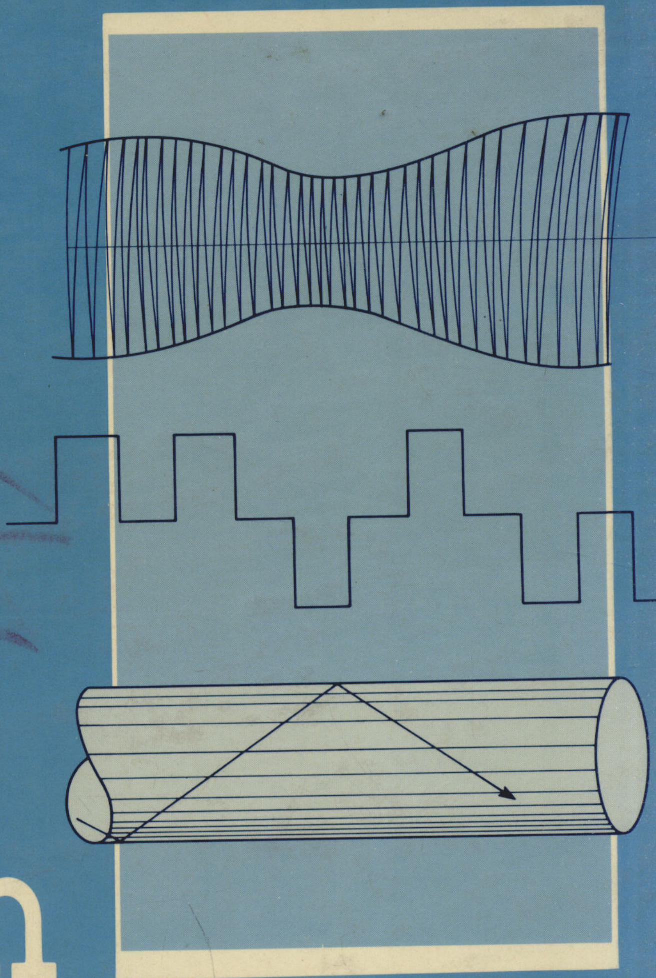
HENRY STARK · FRANZ B. TUTEUR
JOHN B. ANDERSON



# Modern Electrical Communications

SECOND EDITION

## ANALOG, DIGITAL, AND OPTICAL SYSTEMS

# *Modern Electrical Communications*

## *Analog, Digital, and Optical Systems*

***Second Edition***

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*Modern Electrical Communications*

*IN MEMORY OF*
*Anna Stark*
*Ruth Tuteur*

*TO*
*Janet Anderson*

# *Preface to the First Edition*

This book grew out of a set of notes prepared for a two-term senior-level course in electrical communication systems and a one-term graduate course in statistical communications and signal processing. In the five years or so that we have taught the undergraduate communication sequence at Yale, it has been our common experience that, because of the simultaneous proliferation of newer disciplines and student interests, we could not count on the students' having had the traditional background courses required to tackle a fairly mature course devoted exclusively to communication engineering. For this reason we had to develop a course that was relatively complete and self-contained.

We had to develop fundamental topics such as Fourier methods and linear-systems theory, but we also felt that the students deserved to be informed about advanced topics, such as statistical communication theory, signal processing, television, radar, and sonar, in as much depth as possible. We felt that, although theory had to be properly covered, it was necessary to show application of the theory in at least a few concrete modern devices. In short we attempted to make our course a broad and integrated study of the entire field of electrical communication engineering.

We believe that our experience with our own students is in no sense unique. The field of electrical engineering has changed so vastly in the last few decades and there are so many topics that our students must know today, that what used to be the ''traditional'' electrical engineering curriculum has ceased to exist in many places. Even schools with more traditional electrical engineering curricula have developed a greater range of options and have given their students additional freedom in crossing the boundaries between various disciplines. Faced with this greater loosening of the traditional course-of-study hierarchy in electrical engineering, we felt that a text that presented the essential background to communications theory in a few brief introductory chapters and then pushed on to more advanced topics would fill a general need. This is why we have written this book.

In teaching first-year graduate students we found that, if anything, the variations in students' preparedness, sophistication, and interests are even greater than they are for undergraduates. Some graduate students had not even been electrical engineering majors but came from such allied fields as computer science or physics. Others came from undergraduate schools that offered relatively unstructured programs that often left gaps in the students' appreciation of fundamental notions in electrical engineering. In many cases, the students were inadequately prepared in linear systems, random processes, and basic communication systems. In teaching students with such varied backgrounds, we found it convenient to have available a book that not only discussed signal processing and the central ideas in statistical communication theory, but also contained the necessary background material to enable the student to "catch up" on his or her own time.

In line with the experience that we have had in our course, we have tried to keep the prerequisite knowledge required from our readers to a mimimum; we expect basically college-level calculus and a first course in linear-system theory that includes some exposure to the Laplace transform. Beyond this base level, we have tried to make our explanations and derivations as complete and as self-contained as possible. Much use is made of mathematical arguments, and we have included very few results, curves, or tables that the reader could not generate by himself on the basis of the information furnished in the text. In some sections we have used elementary concepts of complex-variable theory, but there is little loss in either continuity or substance for the reader not familiar with this theory.

As might have been expected, the book contains more material than we normally covered in our undergraduate course. For instance in the introductory chapter that deals with Fourier methods, we included material on convergence, vector representation of signals, and concepts such as inner product and projection. We did this partly for completeness and partly because these concepts were needed in later chapters. The book contains a survey of linear systems and active filters going considerably beyond the treatment that we were able to give in our course. We also felt that with so much signal processing being done digitally today we would be amiss if we did not discuss digital systems and filters in some depth. We therefore included a chapter on digital filters that contains a discussion of the discrete Fourier transform (DFT) and the fast Fourier transform (FFT). Digital methods were also integrated into several of the other chapters, notably the one on signal processing.

The authors are extremely grateful to Dr. Reed Even who critically read the entire manuscript and made numerous excellent suggestions. Thanks are due to Helen Brady for doing the typing of most of the first draft, to Dan Tuteur, who helped with two of the chapters, and to Joy Breslauer and Michelle Gall, who exhibited patience and skill in typing the manuscript to completion. Thanks are due also to the administrations of the Department of Engineering and Applied Science at Yale and the School of Engineering at Rensselaer Polytechnic Institute, who permitted us to take some of the large amount

of time needed to complete this project from our normal duties. Finally, thanks are due to our wives Alice and Ruth without whose unfailing patience and encouragement the work could not have been completed.

*Henry Stark*
*Franz B. Tuteur*

# *Preface to the Second Edition*

The reason for this second edition is the same as stated in the Preface to the first edition. Indeed, if anything, our teaching experience since writing the original version has more than substantiated the need for a relatively broadly based and integrated text on the entire field of electrical communication engineering. On the other hand, the field of electrical communications had definitely moved toward the digital and optical. A modern textbook must reflect this trend and, consequently, we have significantly increased the scope and depth of the discussions on digital communications and added a new chapter on optical communications.

Our treatment of digital communications involves two levels: we offer basic discussions of sampling, quantizing, and elementary digital techniques in Chapter 4, suitable for undergraduates. We continue with a more sophisticated treatment involving optimum digital communication systems in Chapter 10. And since digital communications involves coding whose theoretical foundation is information theory, we devote an entire chapter (Chapter 11) to this subject.

Optical communications, especially fiber optical communications, has made significant inroads in many industralized countries. It cannot be ignored in the students' curriculum. In Chapter 12 we try to give a balanced discussion of this subject, dividing the discussion about equally between component operations and system design considerations.

As in the case of the first edition, the second edition is intended as a two-course sequence in electrical communications, the first offered, typically, as an upper-level undergraduate course and the second as a first-year graduate course. For the first course, Chapters 1 through 7 would be a suitable goal, the material to be covered in a relatively demanding semester in which classes meet for three class hours per week and homework assignments include from 5 to 10 problems per week. If this proves too taxing or the quarter system is used, we suggest omitting the material on active filters in Chapter 3, all of Chapter 5, and the material on spectrum analysis in Chapter 6. If the student is taking or has taken a parallel course in Fourier theory and/or linear systems, much of Chapter 2 can be omitted, as well as the first few sections of Chapter 3.

Chapters 8 through 12 comprise the second half of the two-course sequence. If probability is a prerequisite for the course, Chapter 8 can be omitted. Then a logical approach might be to start the course with a brief review of the types of modulation systems in use and compare these on the basis of bandwidth and signal-to-noise ratio, as is done in Chapter 9. Chapters 9 through 12 form the heart of the second course, and these can be straightforwardly understood by students with a background in probability and some knowledge of elementary systems theory and Fourier transforms.

Once again, the authors wish to acknowledge the administrations of the Schools of Engineering at Rensselaer Polytechnic Institute and Yale University for their recognition of the pedagogical and scholarly aspects of this project. Thanks are due to MeeLi Chew Leith and Ruth Houston for their expert typing skills and technical help. Finally, gratitude is due to our families and friends, who make it all worthwhile.

*Henry Stark*
*Frank B. Tuteur*
*John B. Anderson*

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