Electrons, Waves and Messages

By JOHN R. PIERCE

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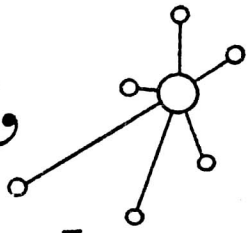

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Drawings by Felix Cooper

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To Jeremy

Preface

CHAPTER I of this book tells what the book is about. I believe that it gives any introduction and guidance that the reader really needs. In retrospect there is, however, a little more, not strictly essential, to be added.

The title *Electrons, Waves and Messages* describes the chief content of the book: the science of electronics and the electronics of communication. The book also discusses scientifically related material, such as the heat of the sun, and communication theory and the arts; these digressions show the intimate relation of science and technology to the common world about us.

Within this general range, various topics were selected or rejected in an effort to produce a book with some reasonable degree of coherence and development. No doubt some things with which I am not very familiar could well have replaced some of the things which are in the book, but then it would have been a compilation from unfamiliar sources rather than a firsthand account; it would have been a different sort of book.

Among the things which are covered, the reader will find some more difficult to understand than others. This is partly a matter of familiarity; one can't grasp an idea until the concepts and terms used in expressing it have to some degree stuck in his mind. Perhaps rereading will clear up some difficulties in understanding. It must be admitted, however, that some things appear really to be harder to understand than others. One can't very well omit all of the hard things without giving a very false view of electronics, and so I have included some of them.

Technically trained people may wonder about the choice of

material in particular chapters. Some points are explained in detail and others, equally important, are merely mentioned. This was done because it seemed impossible to give detailed explanations of more things, and yet I felt that important related matters should be called to the attention of the reader. When a matter is mentioned briefly, I have striven to give the reader a clear and generally correct impression rather than to produce an unambiguous and rigorous statement at the risk of being unintelligible. Some things, of course, have been omitted entirely—sometimes to limit the size of the book, and sometimes (as in the case of explicit mention of the concept of electric potential) for what I considered to be very good reasons.

Besides its technical content, the book sometimes cites names, dates, and stories about scientists or scientific discoveries. I have not knowingly erred concerning these, but I may nonetheless have erred. I don't think that any such errors could be important. The real content of the book is technical; other material is used chiefly either to locate discoveries in approximately the right era or by way of precept or parable.

The reasons for writing this book are given in Chapter I; briefly, they are enthusiasm for science, concern about current ignorance of science, and alarm about books which try to give an understanding of science without conveying anything of its content. This last seems to me like writing about the understanding and appreciation of music in some world in which most people have never heard a tune.

Of course it takes more than enthusiasm, concern, and alarm to produce a book. This book would never have been written had not Clarkson N. Potter of Hanover House asked me to write it and talked with me so sympathetically, intelligently, and constructively that the task seemed and was easy. But I would have been in no position to write a book if John W. Campbell, Jr., editor of *Astounding Science Fiction*, and, to a lesser extent, Anthony Boucher, editor of *Fantasy and Science Fiction*, had not encouraged me to practice writing by buying articles and stories from me over a period of years. Finally, this book would certainly have been less clear and less accurate without the help of friends and associates who read and commented on the manuscript.

My mentor and friend, Harald T. Friis, for whose knowledge of and contributions to microwaves I have unbounded respect and admiration, helped me to clarify and improve a number of sections. A. J. Torsiglieri, whose field (patents) is different from mine, pointed out many instances in which explanations which had satisfied me were actually obscure or difficult. He also found a number of numerical errors in my calculations. R. Bown, R. Kompfner, C. F. Quate, C. E. Shannon, and H. W. Lewis all made valuable comments and suggestions, and J. P. Molnar rendered an invaluable service in checking the figures when I was unable to.

CONTENTS

Electrons, Waves and Messages

CHAPTER I

Electronics and the World

WHEN I used to commute to New York by train, I passed a surprising number of technical enterprises: a pump company, an electrical-instrument company, a computing-machine company, and a lot of others. Now, as I occasionally drive to the city, I see more: a company making furnace controls, a tractor company, a company making potentiometers, a host of companies engaged in various sorts of engineering or scientific work. This makes me feel very ignorant and humble. After seven years of undergraduate and graduate study, followed by twenty years of research in an industrial laboratory, I know a good deal about a segment of one field, electronics. I have no detailed and expert knowledge about even most of the other work done in the company which employs me. Outside of that company, all sorts of things go on about which I have only the vaguest sort of information. With so much to know, is it not hopeless even for an expert to try to understand our science and technology? Is it not even more hopeless for an outsider to try to understand these matters? Should he try?

Literate and curious men of every age have thought and read and learned about matters outside of their immediate physical needs and experience. What they have thought and read and learned about has varied from age to age, as both the tasks of everyday life and the aspirations that go beyond these tasks have changed. Sometimes men have been concerned with religion, sometimes with mathematics and philosophy, sometimes with exploration, trade and conquest, sometimes with the theory and practice of government, sometimes with ancient learning, sometimes with the arts.

In different times, in different cultures, these matters have engaged the attention of the unusually able and intelligent men. When some of the best thought and best effort of a culture is spent in political philosophy, or in classical learning, or in art, the cultured man is the man who is acquainted with, and whose thought reflects, political philosophy, or classical learning, or art.

One can scarcely deny that the most effective thinking of our age, and a great deal of its energy and enterprise, go into science, and especially into the sort of science which guides an immensely complicated technology in doing new things and in doing old things cheaper and better. This prodigious technology in turn supports science with a lavishness unprecedented in any former age.

It is not only true that the world about us would astound a man of a much earlier age. It would astound a man of fifty years ago almost as much. He could not help being astounded by electric power, washing machines, dishwashers, freezers, highways, automobiles, radio, television, airplanes, rockets, nuclear energy. The widespread good living, the rarity of servants, the diminution of great luxury would astound him as much. If he looked more deeply, the growth of science—both in knowledge, in magnitude of effort, and in monetary reward and public recognition as well—would astound him.

The world of fifty years ago had writers, poets, painters, musicians, philosophers, politicians, and governments. No doubt all of these have changed of recent years. It is clear, however, that the great, the characteristic, the significant changes have been in science and technology and in the way the world is divided into countries and governed. We might even argue that the tremendous political upheavals of our age are primarily a consequence of a revolution in science and technology. Whether or not we go this far, it is clear that science and technology, together with political change and turmoil, are the outstanding features of our culture. Many would put science and technology first.

One cannot be in tune with his age without understanding something of science, and yet this does not seem to have dawned on many people who consider themselves educated or, indeed, on professional educators.