

# Fundamentals of Antennas: Concepts and Applications

Christos G. Christodoulou  
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# Fundamentals of Antennas:

## Concepts and Applications

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## Introduction to the Series

The Tutorial Texts series was initiated in 1989 as a way to make the material presented in SPIE short courses available to those who couldn't attend and to provide a reference book for those who could. Typically, short course notes are developed with the thought in mind that supporting material will be presented verbally to complement the notes, which are generally written in summary form, highlight key technical topics, and are not intended as stand-alone documents. Additionally, the figures, tables, and other graphically formatted information included with the notes require further explanation given in the instructor's lecture. As stand-alone documents, short course notes do not generally serve the student or reader well.

Many of the Tutorial Texts have thus started as short course notes subsequently expanded into books. The goal of the series is to provide readers with books that cover focused technical interest areas in a tutorial fashion. What separates the books in this series from other technical monographs and textbooks is the way in which the material is presented. Keeping in mind the tutorial nature of the series, many of the topics presented in these texts are followed by detailed examples that further explain the concepts presented. Many pictures and illustrations are included with each text, and where appropriate tabular reference data are also included.

To date, the texts published in this series have encompassed a wide range of topics, from geometrical optics to optical detectors to image processing. Each proposal is evaluated to determine the relevance of the proposed topic. This initial reviewing process has been very helpful to authors in identifying, early in the writing process, the need for additional material or other changes in approach that serve to strengthen the text. Once a manuscript is completed, it is peer reviewed to ensure that chapters communicate accurately the essential ingredients of the processes and technologies under discussion.

Donald C. O'Shea served as the editor of this series prior to my tenure, building the Tutorial Texts into a respected and successful body of literature, which now numbers more than fifty titles. It has expanded to include not only texts developed by short course instructors but also those written by other topic experts. It is my goal to maintain the style and quality of books in the series, and to further expand the topic areas to include emerging as well as mature subjects in optics, photonics, and imaging.

*Arthur R. Weeks, Jr.  
Invivo Research Inc. and University of Central Florida*





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# INTRODUCTION

The field of information science and technology incorporates several devices, including antennas, which can be used to transmit, collect and transfer information. Understanding how these antennas work and how they can be utilized at different frequencies ranging from radio to terahertz requires some insight into the physics of antenna operation and a knowledge of the basic parameters for their operation.

This book, which is tutorial in nature, contains seven chapters. Chapter 1 outlines how antennas have evolved historically, and presents some important advances made in their design and applications. The chapter discusses the impact of antennas in various systems, to give the reader an idea of the range of their applications that include communications, remote sensing, radar, biomedicine, etc. In Chapter 2 the reader is introduced to the fundamentals of antennas. All of the figures of merit and parameters used to evaluate antennas are covered. Concepts such as radiation pattern, directivity, gain, bandwidth, polarization, and others are explained in a very straightforward manner. The information provided in this chapter forms the cornerstone upon which all the other chapters are built.

Chapter 3 introduces the most basic type of antenna, the wire antenna, and presents the analysis of this antenna for different configurations such as small dipoles, dipoles of finite length, and loop antennas. These antennas are still used today in a variety of applications such as communication, TV broadcasting, and navigation. In Chapter 4, array antennas are discussed. Several antennas can be arranged in space, in different geometrical configurations, to produce a highly directional pattern. Such a configuration of multiple antenna elements is referred to as an antenna array. In an array antenna, the fields from the individual elements can be made to interfere constructively in some directions and cancel in others. Phased array antennas offer the unique capability of scanning of the main beam (major lobe) by changing the phase of the excitation of each array element.

Chapter 5 exposes the reader to a variety of antennas, such as reflectors, lenses, horns, and microstrip antennas. This chapter adds to the knowledge base provided by the previous chapters by explaining how different applications require different antennas and why a single antenna cannot be used successfully for all applications. Chapter 6 shows how an antenna can be integrated with a detector for successful operation in order to efficiently collect terahertz radiation. These integrated antennas have several applications in areas such as remote sensing, radio astronomy, plasma diagnostics, atmospheric studies, and space communications. However, these applications demand the use of low-noise receivers over a range of about 30 GHz to more than 1 THz. The serious technical challenges on the design and use of submillimeter-wave local oscillators and detectors that exist are presented and discussed in this chapter, which is a fusion between optics and antenna concepts.

In Chapter 7, antenna measurement techniques are described. Measurements often form an integral part of the antenna design process, with measurements on prototype antennas being conducted at various steps of the design process to check that the antenna meets the design specification. The key parameters that are often measured are the radiation pattern, efficiency, gain, and impedance. Depending on the antenna and its application, other parameters such as the polarization purity, power-handling capacity, etc., may also be measured. The use of sophisticated computerized equipment has made it possible to make accurate measurements of antenna parameters. The advantages and disadvantages of performing measurements indoors using anechoic chambers versus outdoor ranges are presented and discussed as well.

This book is intended for students, engineers, and researchers who have not taken a formal antenna course and are interested in the basics of antenna theory and operation. The authors have attempted to link the lower-frequency (RF) concepts to the higher-frequency (optics) concepts with which the readers may be more familiar. The book is written in a modular fashion, so that readers can choose the chapters they are interested in without having to go through the entire book. It is the hope of the authors that readers find in this book the necessary tools and examples that can help them in incorporating antennas, as needed, in their research problems.