

Topics in Applied Physics Volume 10



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Transient Electromagnetic Fields

Edited by L. B. Felsen

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With 111 Figures

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Preface

While all wave phenomena are causal and hence time-dependent, electromagnetic sources and generators usually operate in the steady-state time-harmonic regime. Hence, there has been a strong emphasis in electromagnetics on time-harmonic wave propagation. However, in recent years, there has emerged a renewed interest in transient wave phenomena, stimulated by various applications that require the explicit treatment of time-dependent effects. One such application is to signal transmission through time-varying media as exemplified by the ionosphere or some other ionized plasma. Another is due to the present ability to produce short electromagnetic pulses with a broad frequency spectrum, and the consequent development of new time-domain techniques for the transmission, reception and scattering characteristics of antennas and targets. Also, short pulses of high power, especially in the optical frequency range, are finding application as diagnostic tools for the study of ablation, implosion and other wave-material interactions. Finally, the effects of impulsively excited electromagnetic bursts on electronic equipment, devices and installations have become a matter of concern. Such bursts may range from naturally caused lightning discharges to man-made nuclear explosions. The security and reliability of communication channels under the influence of such bursts has motivated extensive investigations by private and public organizations concerned with communications, and also by military agencies.

The purpose of this book is to present an overview of the techniques that are employed in the study of transient electromagnetic wave phenomena. The task is addressed by providing a mix between tutorial and educational background material, and up-to-date applications to problem areas of current interest. The tutorial function is served primarily in Chapter 1, which summarizes the basic properties of transient electromagnetic fields, and applies these to wave propagation and diffraction problems in non-dispersive and dispersive media. It may here be remarked that in the conventional teaching of electromagnetic theory, the subject of wave propagation is usually introduced via the time-harmonic regime. This practice is based on the assumption that time-harmonic wave processes can be described more readily than transient

processes, the latter being derivable from the former by the additional complication of the Fourier or Laplace transform. However, the basic phenomena of wave propagation, i. e., of a progressive disturbance that travels from a source to a receiver through an ambient environment, are more easily understandable in the transient state, which permits direct signal tracking. The time-harmonic field then emerges as the special case of a continuously emitted excitation at constant frequency. It may also be remarked that the Fourier or Laplace transform route from the time-harmonic regime does not provide the only approach to transient solutions. Sometimes, a direct analysis of a transient problem is considerably simpler, and even easier than the solution for the time-harmonic case. This aspect is illustrated on various examples throughout this book.

The presentation in Chapter 1 emphasizes separation-of-variables techniques and their application to illustrative "separable" problems. In the more general "non-separable" case, one must employ other procedures. Integral equation methods and their numerical treatment are discussed in Chapter 2 and are applied there to a variety of scattering problems. A recently developed procedure, the singularity expansion method, is presented in Chapter 3 and is illustrated there on a representative collection of examples. Chapters 4 and 5 deal with more specific problem areas. In Chapter 4, integral equation and numerical methods are applied to transient excitation and reception of linear antennas, whereas Chapter 5 treats the effects of dispersion on electromagnetic pulse propagation through a realistically modeled earth.

Whenever possible, an effort has been made to provide a physical interpretation of the calculated fields so that the reader will gain some insight into the various wave processes that are operative under different conditions. It is hoped thereby to render this volume useful to the uninitiated who would like to familiarize himself with transient wave phenomena, and to the specialist who would like to refer to specific examples. The references appended to each chapter are quite extensive so that source material and related contributions to the literature can be consulted. Although the stress here is on electromagnetic fields, the techniques and results are representative also of other wave fields encountered in underwater sound, elastic media, and similar areas. The material should therefore be useful also to workers concerned with transient wave fields in other disciplines.

In a volume that contains contributions by several authors, coordination of style and notation, and the avoidance of duplication, are a major concern. While the editor has sought to achieve at least a minimal degree of uniformity, he cannot claim unqualified success. Notation does change from one chapter to the next, but it has been attempted

to have all symbols properly defined, thereby minimizing the possibility of confusion and misunderstanding. The following conventions have, however, been adhered to throughout: When time-harmonic fields of frequency ω are discussed, the time convention is $\exp(-i\omega t)$; the Laplace transform variable is $s = -i\omega$; a bold faced symbol denotes a vector quantity, and a bold faced symbol with a wiggly underline denotes a dyadic quantity.

Finally, the editor would like to express his thanks to the authors who have contributed to this volume: Professor RAJ MITTRA for Chapter 2, Dr. CARL E. BAUM for Chapter 3, Dr. DIPAK L. SENGUPTA and Professor CHEN-TO TAI for Chapter 4, and Dr. JAMES A. FULLER and Professor JAMES R. WAIT for Chapter 5. Their cooperation is responsible for whatever cohesive thread runs throughout this volume. Also acknowledged with appreciation are the coordinating and editorial services of Mrs. ANNA MAE CUOMO of the Polytechnic Institute of New York, and her expert typing and editing of Chapter 1, which was contributed by the writer.

Farmingdale, N.Y.
September 1975

LEOPOLD B. FELSEN

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