Reviews and Abstracts

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Frontiers in Electromagnetics, Douglas H. Werner and Raj Mittra (eds.), New York, IEEE Press, 2000, xxv+787 pages, $119.95 (List), $102.00 (IEEE Member), ISBN 0-7803-4701-3.

Frontiers in Electromagnetics, edited by Douglas Werner and Raj Mittra, is informally divided into four parts. Part I, consisting of Chapters 1 to 7, concerns application of fractal geometry, group theory, and topology to electromagnetic radiation and scattering problems. Part II, comprising Chapters 8 to 10, deals with optimization and estimation algorithms in biological beamforming, antenna, and forward- and inverse-scattering problems. In Part III, which contains Chapters 11 to 13, the authors provide an exposition of new analytical methods used in electromagnetics. Lastly, in Part IV, containing Chapters 14 to 18, newly developed numerical methods are discussed, with application to radiation and scattering problems, interconnect configurations, and complex material media. The topics in the book were carefully selected by the Editors to provide a new insight in problems of classical electromagnetics, and to discuss new directions in electromagnetics research. A brief overview of the eighteen chapters will be given in the text to follow.

Chapters 1-3 concentrate on concepts of fractal geometry, used for the modeling of scattering from fractal surfaces and in the design of fractal antennas. In Chapter 1, the interaction of electromagnetic waves with fractal surfaces and superlattices is studied. The scattering from rough surfaces is investigated, using both the Kirchhoff approximation and the exact transition-matrix approach, and the validities of the approximate and exact solutions are discussed. Chapter 2 concerns small and multi-frequency fractal-shaped antennas, including the Sierpinski triangle and fractal tree-like antennas. Based on the analysis of the Koch monopole, the possibility of the use of fractal antennas as low-Q resonant small antennas with improved bandwidth, radiation resistance, and reactance is discussed. Chapter 3 is devoted to the theory and design of fractal antenna arrays. The chapter contains an overview of recent developments in the area of fractal antenna arrays. Radiation patterns of different fractal arrays are provided, and techniques for the synthesis of fractal radiation patterns are discussed. Next, the role of fractal array factors in the design of multi-band arrays is studied, continuing with the analysis of deterministic fractal arrays, including Cantor linear arrays, Sierpinski carpet arrays, and Cantor ring arrays. The chapter is concluded by the examples of recursively generated arrays, constructed by the concentric circular ring sub-array generator.

The applications of group theory are presented in Chapters 4 and 5 for the analysis of scattering of electromagnetic waves by targets that possess certain symmetries. Chapter 4 concerns the impact of target symmetry on the associated scattering dyadic, which includes reciprocity, geometrical symmetry, and self-duality. Symmetry in general bistatic scattering, back-scattering, and forward-scattering, as well as in low-frequency scattering, is studied. Chapter 5 discusses a geometric symmetry (rotation, reflection) of self-complimentary structures involving the complex potentials and the associated conformal transformations.

Chapters 6 and 7 concentrate on the application of topological concepts from knot and braid theory to electromagnetics. In Chapter 6, a twisted or knotted nature of magnetic field configurations is addressed, involving principles of topology. The concept of "helicity" as a measure of the linkage of the field lines is introduced, and geometrical interpretation is given for twist, kink, and link helicity. The chapter is concluded by the discussion of the magnetic energy in multiply connected domains. In Chapter 7, the radiation and scattering characteristics of torus knots are investigated from the standpoint of knot theory, in conjunction with integral-equation methods. The topology of various torus knot configurations is demonstrated by using a parametric representation of a torus. An electric-field integral-equation formulation with the free-space Green's function is provided for perfectly conducting knotted wires, and far-field approximations are given for special cases of elliptical and circular torus knots.

The next group of chapters, Chapters 8-10, concerns optimization and estimation methods in biological applications, radiation, and scattering problems. Chapter 8 provides a basic background in genetic algorithms and neural networks for application to linear-antenna-array beamforming networks. It is demonstrated that a genetic algorithm can be used to reduce the maximum sidelobe level in the array by optimizing a phase taper. The adaptive-nulling algorithm is described in some detail. Next, neural networks are discussed for antenna-array beamforming and beam-steering applications. In Chapter 9, a model-based parameter-estimation approach is presented, with applications to electromagnetic radiation and scattering problems. The chapter discusses various waveform-domain and spectral-domain sampling techniques, model-based parameter-estimation algorithms, and demonstrates numerous applications, including scattering of electromagnetic waves by cylindrical structures, radiation-pattern analysis and synthesis of antenna arrays, inverse-scattering problems, the Sommerfeld problem, and integral-equation modeling dealing with the Method-of-Moments impedance and admittance matrices. Chapter 10 presents a new adaptive decomposition algorithm for forward scattering, inverse scattering, and radar data post-processing applications. The idea of the method is based on the sparse representa-

tion of signals or, for example, the unknown surface-current-density coefficients, in terms of functions that closely model the signal or current behavior. Wavelet basis functions are used for a basis transformation of current coefficients in a Galerkin projection technique, resulting in a sparse impedance matrix.

New analytical methods, described in Chapters 11-13, show potential applications to antenna, scattering, and diffraction problems. Chapter 11 concerns the use of Lommel expansions in evaluating the magnetic vector potential and near-zone electromagnetic fields of the cylindrical wire dipole and circular loop antennas. An exact series representation of the cylindrical wire kernel, and an exact integration procedure for magnetic vector potentials of thin circular loop antennas, are presented. Also, special cases of uniform, co-sinusoidal, and traveling-wave current-loop antennas are discussed. Chapter 12 deals with the use of fractional calculus (fractional derivative and fractional integral linear operators generalized to non-integer orders) in electromagnetic theory. Fractionalization of linear operators is demonstrated for the examples of the electrostatic point monopole and point dipole, the electrostatic potential of perfectly conducting wedges and cones, and plane-, cylindrical-, and spherical-wave propagation. In Chapter 13, a vector spherical-multipole analysis is presented to obtain an analytical solution for a variety of scattering and diffraction problems. Introducing sphero-conal coordinates (generalized spherical coordinates), the solution of the Helmholtz equation and the corresponding Green's-function equation can be obtained using a scalar spherical-multipole expansion described as a product of spherical cylinder functions and Lamé products. The applications are shown for electromagnetic scattering by perfectly conducting semi-infinite and finite elliptic cones, and by a perfectly conducting loaded spherical shell with an elliptic aperture.

The last group of chapters, Chapters 14-18, concentrates on new developments in numerical techniques applied to the analysis of problems of computational electromagnetics. A study of perfectly matched layers (PML) in the Finite-Difference Time-Domain (FDTD) technique is presented in Chapter 14. Different PML realizations (Berenger's, anisotropic, bianisotropic) are implemented in the system of partial differential equations (Maxwellian and non-Maxwellian). Conditions for the causality and reciprocity of PMLs, as well as the extension of perfectly matched absorbers to low frequencies and to the static case, are discussed. In Chapter 15, a finite-difference method is described for the fast calculation of interconnect capacitances. The method incorporates a perfectly matched layer for mesh truncation in the static case, and a mixed absorbing boundary condition. The applications are demonstrated for a variety of interconnections, including microstrip lines, coupled microstrip bends, crossovers, and other related structures. The Finite-Difference Time-Domain method for the analysis of wave propagation in general complex media (dispersive, anisotropic, non-linear, and time-variant) is presented in Chapter 16. An overview of Maxwell's equations with respect to complex media is given, and this is followed by the representation of the FDTD equations in different media types: non-dispersive anisotropic media, cold plasmas, magnetoionic media, isotropic collisionless warm plasmas, Debye dielectrics, Lorentz dielectrics, magnetic ferrites, and nonlinear dispersive media. In Chapter 17, a new computational technique, based on a discrete mechanics approach, is introduced. The mechanical version of Maxwell's equations is described, showing advantages over the conventional FDTD calculations. The mechanical model is extended to frequency-dependent complex materials (Debye dielectrics) and non-linear dielectrics. The method provides a mechanical insight to electromagnetic phenomena, emphasizing the multidisciplinary nature of electromagnetics. The last chapter, Chapter 18, concerns the electromagnetic properties of artificial bianisotropic composite materials with respect to wave propagation, radiation, and scattering. Constitutive equations and electromagnetic properties of chiral media and omega media are provided. Integral-equation formulations are developed for the electromagnetic scattering from chiral and omega objects. The chapter is concluded by the consideration of plane-wave reflection and transmission in chiral and omega slabs.

In summary, the book is an excellent collection of newly developed theories, concepts, and ideas that have a great potential to be used in different areas of theoretical and computational electromagnetics. The book provides a new philosophy in approaching electromagnetic problems. The book is unique in the sense that it covers a variety of electromagnetic applications involving novel theories and concepts of modern mathematics. It is highly recommended to graduate students, researchers, and professionals working in the areas of electromagnetic-wave propagation, radiation, scattering, diffraction, and other related fields of applied mathematics.

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Recent Books

The following is a list of recently published books that have been received by the Associate Editor since the last issue of the *Magazine* was published. Reviewers are sought for these books, so readers are encouraged to let the Associate Editor know if they are interested in reviewing a particular book.

The RF and Microwave Handbook, Mike Golio (ed.), Boca Raton, FL, CRC Press, 2001.