UNIVERSITY OF WESTERN MACEDONIA
FACULTY OF ENGINEERING
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SUMMARIZED ANALYSIS OF PUBLISHED SCIENTIFIC WORK

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SEPTEMBER 2016

PhD Dissertation

Theodoros T. Zygiridis, *Development of optimized higher-order finite-difference schemes for the accurate solution of electromagnetic problems in the time domain*, PhD dissertation, Aristotle University of Thessaloniki, Greece, 2005.

The scope of this doctoral thesis is the development of novel, higher order finite difference time domain (FDTD) algorithms for the reliable treatment of demanding electromagnetic prob-lems. A bibliographical research on the discretization errors of Yee's method and the existence of possible alternatives, based on higher order and/or optimized approaches, is given in Chapter 1. Chapter 2 focuses on issues related to the discretized form of Maxwell's equations, such as dis-persion and anisotropy artifacts, cutoff behaviour of the grid and performance degradation of analytical absorbing boundary conditions. A review of implicit and explicit spatial operators and time integration schemes, along with an FDTD method based on operator superposition, is also presented. The deficiency of the conventional (2, 4) technique when operated at the stability limit is dealt with in Chapter 3, by introducing modified materials in the simulations. The demand for accurate numerical wavenumbers at specific frequencies and propagation angles leads to corrected constitutive parameters, which produce additional, yet correctional, dispersion and anisotropy effects and ensure good narrowband and satisfactory wideband behaviour. Chapter 4 is devoted to the design of two novel FDTD algorithms, based on the (2, 4) discretization strategy. The first one attempts the cancellation of equally-ordered terms in an error expression based on the numerical dispersion relation, and produces second-order spatial operators that overwhelm the conventional ones throughout the entire frequency spectrum. The second scheme is based on treating spatial and temporal operators separately, by quantifying their effects on plane-wave solutions of Maxwell's equations, leading to single-frequency optimization with good wideband characteristics. A novel family of optimized FDTD techniques is presented in the Chapter 5, which exploit multi-dimensional parametric definitions of the spatial operators and utilize innovative error estimators. The latter are expanded in terms of cylindrical or spherical harmonic functions, thus enabling error reduction for all propagation angles, as well as gradual algorithmic improvement through the vanishing of an increasing number of terms. Error minimization is carried out at either one or two frequency points, ensuring narrowband or wideband optimization, respectively. The final chapter summarizes the main conclusions and suggests some potential extensions of this work.

JOURNAL PUBLICATIONS

[J.38] Georgios G. Pyrialakos, Theodoros T. Zygiridis, and Nikolaos V. Kantartzis, "A 3-D polynomial-chaos FDTD technique for complex inhomogeneous media with arbitrary stochastically varying index gradients," ***ACES Express J.*****, vol. 1, no. 3, pp. 109–112, Mar. 2016.**

An enhanced finite-difference time-domain algorithm featuring the polynomial chaos representation is introduced in this paper for problems with stochastic uncertainties. Focusing on the solution of the governing partial differential equations, the new 3-D method uses the Karhunen-Loève expansion to effectively decorrelate random input parameters denoted by stochastic processes. So, the space dimension is seriously reduced and high accuracy levels are attained, even for media with abrupt and fully unknown statistical variations. These profits are verified via a detailed numerical study.

[J.37] Theodoros T. Zygiridis, Nikolaos V. Kantartzis, and Theodoros D. Tsiboukis, "Four-stage split-step FDTD method with error-cancellation features," ***ACES Express J.*****, vol. 1, no. 3, pp. 105–108, Mar. 2016.**

We develop a methodology that enables the proper introduction of high-order spatial operators in an unconditionally-stable, split-step, finite-difference time-domain scheme. The proposed approach yields spatial approximations that guarantee better balancing of space-time errors, compared to standard fourth-order expressions. The latter are not as efficient as expected, due to their unmatched order with the scheme's second-order temporal accuracy. Our technique treats the dispersion relation as an error descriptor, derives spatial formulae that change with the cell shape and time-step size, and rectifies the performance over all frequencies.

[J.36] Theodoros T. Zygiridis, Nikolaos V. Kantartzis, and Theodoros D. Tsiboukis, "Development of optimized operators based on spherical-harmonic expansions for 3D FDTD schemes," ***International Journal of Applied Electromagnetics and Mechanics*****, vol. 51, no. s1, pp. S57- S66, 2016.**

The subject of this paper pertains to the construction of finite-difference expressions with minimized, as well as controllable discretization errors, suitable for 3D FDTD simulations in large-scale setups. The proposed spatial approximations are designed to mimic the behavior of the exact operators, when applied to plane-wave trial functions. To eliminate undesirable directional dependencies, the expansion of proper error formulae in terms of spherical harmonic functions is performed, which facilitates accuracy improvement and produces optimized operator coefficients in closed-form expressions. The combination of the new operators with low- as well as high-order time integrators yields efficient space-time discrete models, whose reliability renders them desirable substitutes for other traditional solutions.

[J.35] Nikolaos V. Kantartzis, Theodoros T. Zygiridis, Christos S. Antonopoulos, Yasushi Kanai, and Theodoros D. Tsiboukis, "A generalized domain-decomposition stochastic FDTD technique for complex nanomaterial and graphene structures," ***IEEE Trans. Magn.*****, vol. 52, no. 3, #7203804, Mar. 2016.**

The systematic and accurate design process of realistic nanocomposite applications and finite-sized graphene setups with arbitrary media uncertainties is presented in this paper via a 3-D covariant/contravariant stochastic finite-difference time-domain method. The new technique uses extra nodes pertinent to a convex combination of all obtainable spatial increments and introduces a robust domain-decomposition formulation combined with Lagrange multipliers to considerably decrease the system overhead. In this way, the mean value and standard deviation of field components are evaluated in a single run, further accelerated via graphics processing units and parallel programming. The performance of the proposed algorithm is validated by various statistically-varying nanoscale applications.

[J.34] Theodoros T. Zygiridis, Nikolaos V. Kantartzis, Christos S. Antonopoulos, and Theodoros D. Tsiboukis, "Efficient integration of high-order stencils into the ADI-FDTD method," ***IEEE Trans. Magn.*****, vol. 52, no. 3, #7201704, Mar. 2016.**

Incorporating standard high-order spatial approximations in the alternating-direction implicit (ADI) finite-difference time-domain (FDTD) method does not suffice for improving the technique's accuracy, as these operators are capable of reducing spatial errors only. We herein develop an alternative design procedure, which results in the construction of finite-difference expressions that ameliorate the combined space-time flaws. In essence, it is shown that three error formulas are derived from the individual implicit equations, provided that the ADI updates are treated as a single-step process. Then, more efficient spatial expressions can be extracted via proper manipulation of these formulas and subsequent application of error-controlling concepts.

[J.33] Georgios G. Pyrialakos, Theodoros T. Zygiridis, Nikolaos V. Kantartzis, and Theodoros D. Tsiboukis, "GPU-based calculation of lightning-generated electromagnetic fields in 3-D problems with statistically defined uncertainties," ***IEEE Trans. Electromagn. Compat.*****, vol. 57, no. 6, pp. 1556-1567, Dec. 2015.**

A complete computational framework for the efficient study of lightning-induced electromagnetic fields and solution of pertinent problems with uncertainties in realistic environments is presented in this paper. The latter often involve various factors, such as material inhomogeneities, rough terrain surfaces, and irregular lightning channels that may inhibit the utilization of simplified approaches. To deal with these situations of augmented complexity, the finite-difference time-domain method is applied in 3-D curvilinear formulation, ensuring that all the important details are taken into account. As the study of real-life lightning problems involves intense computations, the algorithm is accelerated by exploiting the computing capabilities of contemporary graphics processing units. Our implementation relies on a massive parallelization approach, introduces several new optimized practices, and ensures significant shortening of the simulations' duration. Hence, the investigation of configurations with uncertainties and the extraction of statistical features are greatly facilitated. In other words, the proposed approach comprises an instructive contribution toward the foundation of a useful tool for the in-depth investigation of lightning-related phenomena.

[J.32] Georgios Pyrialakos, Athanasios Papadimopoulos, Theodoros Zygiridis, Nikolaos Kantartzis, and Theodoros Tsiboukis, "A curvilinear stochastic-FDTD algorithm for 3-D EMC problems with media uncertainties," ***COMPEL: The International Journal for Computation and Mathematics in Electrical and Electronic Engineering*****, vol. 34, no. 5, pp. 1637-1651, 2015.**

Purpose – Stochastic uncertainties in material parameters have a significant impact on the analysis of real-world electromagnetic compatibility (EMC) problems. Conventional approaches via the Monte-Carlo scheme attempt to provide viable solutions, yet at the expense of prohibitively elongated simulations and system overhead, due to the large amount of statistical implementations. The purpose of this paper is to introduce a 3-D stochastic finite-difference time-domain (S-FDTD) technique for the accurate modelling of generalised EMC applications with highly random media properties, while concurrently offering fast and economical single-run realisations.

Design/methodology/approach – The proposed method establishes the concept of covariant/contravariant metrics for robust tessellations of arbitrarily curved structures and derives the mean value and standard deviation of the generated fields in a single-run. Also, the critical case of geometrical and physical uncertainties is handled via an optimal parameterisation, which locally reforms the curvilinear grid. In order to pursue extra speed efficiency, code implementation is conducted through contemporary graphics processor units and parallel programming.

Findings – The curvilinear S-FDTD algorithm is proven very precise and stable, compared to existing multiple-realisation approaches, in the analysis of statistically-varying problems. Moreover, its generalised formulation allows the effective treatment of realistic structures with arbitrarily curved geometries, unlike staircase schemes. Finally, the GPU-based enhancements accomplish notably accelerated simulations that may exceed the level of 120 times. Conclusively, the featured technique can successfully attain highly accurate results with very limited system requirements.

Originality/value – Development of a generalised curvilinear S-FDTD methodology, based on a covariant/contravariant algorithm. Incorporation of the important geometric/physical uncertainties through a locally adaptive curved mesh. Speed advancement via modern GPU and CUDA programming which leads to reliable estimations, even for abrupt statistical media parameter fluctuations.

[J.31] Theodoros Zygiridis, Georgios Pyrialakos, Nikolaos Kantartzis, and Theodoros Tsiboukis, "Accelerated unconditionally stable FDTD scheme with modified operators," *COMPEL: The International Journal for Computation and Mathematics in Electrical and Electronic Engineering*, vol. 34, no. 5, pp. 1564-1577, 2015.

Purpose – The locally one-dimensional (LOD) finite-difference time-domain (FDTD) method features unconditional stability, yet its low accuracy in time can potentially become detrimental. Regarding the improvement of the method's reliability, existing solutions introduce high-order spatial operators, which nevertheless cannot deal with the augmented temporal errors. The purpose of the paper is to describe a systematic procedure that enables the efficient implementation of extended spatial stencils in the context of the LOD-FDTD scheme, capable of reducing the combined space-time flaws without additional computational cost.

Design/methodology/approach – To accomplish the goal, the authors introduce spatial derivative approximations in parametric form, and then construct error formulae from the update equations, once they are represented as a one-stage process. The unknown operators are determined with the aid of two error-minimization procedures, which equally suppress errors both in space and time. Furthermore, accelerated implementation of the scheme is accomplished via parallelization on a graphics-processing unit (GPU), which greatly shortens the duration of implicit updates.

Findings – It is shown that the performance of the LOD-FDTD method can be improved significantly, if it is properly modified according to accuracy-preserving principles. In addition, the numerical results verify that a GPU implementation of the implicit solver can result in up to 100× acceleration. Overall, the formulation developed herein describes a fast, unconditionally stable technique that remains reliable, even at coarse temporal resolutions.

Originality/value – Dispersion-relation-preserving optimization is applied to an unconditionally stable FDTD technique. In addition, parallel cyclic reduction is adapted to hepta-diagonal systems, and it is proven that GPU parallelization can offer non-trivial benefits to implicit FDTD approaches as well.

[J.30] T. T. Zygiridis, N. V. Kantartzis, and T. D. Tsiboukis, "Parallel LOD-FDTD method with errorbalancing properties," *IEEE Trans. Magn.*, vol. 51, no. 3, #7205804, Mar. 2015.

We present an improved version of the locally-one-dimensional finite-difference time-domain method in 2-D formulation, featuring spatial expressions derived by an error-amending procedure. The latter targets at the balanced treatment of space–time flaws, and assures the efficient exploitation of four-point spatial operators that now depend on the time-step size. Simulations are also shortened by implementing the algorithm on graphics processing units, a process that necessitates the incorporation of a parallelizable implicit solver. This is accomplished by adapting parallel cyclic reduction to heptadiagonal systems. Therefore, a reliable computational framework free of time-step restrictions is developed.

[J.29] N. V. Kantartzis, T. T. Zygiridis, and T. D. Tsiboukis, "A 3-D stochastic FVTD method based on reduced-order modeling for statistically random media in nano-electromagnetic applications," *IEEE Trans. Magn.*, vol. 51, no. 3, #7205705, Mar. 2015.

A spectrally optimized stochastic finite-volume time-domain technique is developed in this paper for the consistent analysis of 3-D nanoscale devices with statistically varying media heterogeneities. The novel algorithm is found on a compact block state-space framework and offers single-run evaluations of the mean value and standard deviation, thus evading the excessive system requirements of typical multiple-realization Monte Carlo FDTD approaches. Moreover, an energy-conserving flux concept guarantees the precise discretization of electromagnetic fields in regions of abrupt geometric details. In this manner, the complicated structure of nanocomposite applications is very reliably modeled, even for sub-wavelength field uncertainties, as deduced by several numerical configurations.

[J.28] T. T. Zygiridis, N. V. Kantartzis, and T. D. Tsiboukis, "GPU-accelerated efficient implementation of FDTD methods with optimum time-step selection," *IEEE Trans. Magn.*, vol. 50, no. 2, #7011704, Feb. 2014.

The consistent combination of uneven space-time orders in finite-difference time-domain (FDTD) algorithms is the subject of this paper. When low-order time integration is used in conjunction with high-order spatial expressions, the operation of the numerical scheme close to the stability limit causes degraded performance and slow convergence. By exploiting accuracy considerations, we derive an estimate of the optimum—much smaller—time-step size that ameliorates errors in a mean-value sense and leads to improved precision. To deal with the augmentation of the required iterations, the parallel implementation of the FDTD techniques on graphics processing units is pursued, ensuring faster code executions and more efficient models.

[J.27] N. V. Kantartzis, T. T. Zygiridis, and T. D. Tsiboukis, "Enhanced analysis of multiconductor nanostructured devices via a compact block FDTD/VFETD method," *IEEE Trans. Magn.*, vol. 50, no. 2, #7004104, Feb. 2014.]

A reduced-order modeling FDTD/vector finite-element time-domain technique is introduced in this paper, for the rigorous and cost-effective study of multiconductor nanoscale structures. The new methodology blends a compact stencil-optimized discretization process with general vector finite elements via the pertinent coupling conditions and divides the domain into tightly coupled blocks. A key asset is that both approaches are time advanced independently while their state-space models are derived via a Krylov-based scheme with scaled Laguerre functions, which drastically decreases the order of the transfer matrix. Therefore, complex geometries are consistently treated without the need of excessively fine grid tessellations. Numerical results from various nanocomposite devices validate the hybrid method and reveal its applicability.

[J.26] Theodoros T. Zygiridis, "Design of least-squares time integrators for reliable FDTD simulations," *IEEE Trans. Magn.*, vol. 49, no. 5, pp. 1817-1820, May 2013.

Considering the importance of providing credible discrete models for Maxwell's equations, improved time integrators are constructed in this paper for reliable time-domain simulations of wave-propagation problems. The proposed design approach results in modified versions of high-order leapfrog processes that feature error-reducing behavior, in the sense that numerically-induced flaws are efficiently dealt with. Accuracy upgrade is accomplished via proper application of the least-squares technique, whereas the incorporation of optimized spatial expressions can further improve the wideband behavior. The combination of the proposed integrators with standard as well as optimized approximations in space is examined in numerical experiments, and it is shown that our treatment of time integration can contribute decisively to the foundation of reliable and efficient computational models.

[J.25] Theodoros T. Zygiridis, "High-order error-optimized FDTD algorithm with GPU implementation," *IEEE Trans. Magn.*, vol. 49, no. 5, pp. 1809-1812, May 2013.

This paper presents the development of a two-dimensional (2D) finite-difference time-domain (FDTD) solver that features reliable calculations and reduced simulation times. The accuracy of computations is guaranteed by specially-designed spatial operators with extended stencils, which are assisted by an optimized version of a high-order leapfrog integrator. Both discretization schemes rely on error-minimization concepts, and a proper least-squares treatment facilitates further control in a wideband sense. Given the parallelization capabilities of explicit FDTD algorithms, considerable speedup compared to serialized CPU calculations is accomplished by implementing the proposed algorithm on a modern graphics processing unit (GPU). As our study shows, the GPU version of our technique reduces computing times by several times, thus confirming its designation as a highly-efficient algorithm.

[J.24] Theodoros T. Zygiridis, "Fourth-order finite-difference time-domain method based on error-controlling concepts," *Int. J. Numer. Model.*, vol. 25, no. 5-6, pp. 587–598, Sept.-Dec. 2012.

Conventional finite-difference time-domain (FDTD) methodologies incorporate discrete operators with the smallest truncation errors, as those are determined from the application of Taylor expansions. It is generally accepted that such choices, although quite efficient, do not necessarily provide optimum solutions when simulating electromagnetic wave phenomena. With the aim at improving accuracy without increasing the involved computational burden, the present paper is concerned with the development of a higher-order FDTD algorithm, which, in contrast to classic trends, is primarily based on the application of error-controlling ideas to its difference approximations. In essence, a fourth-order scheme is presented, whose spatial expressions are designed to remedy the leading terms of suitable error formulae. The latter can be easily extracted for each operator, given that the general nature of the expected solutions is known in advance. A correction factor is next added to the temporal operators to compensate for remaining errors at a selected wavelength. Unlike other approaches with single-frequency optimization, our technique is not strictly narrowband but capable of outperforming the conventional fourth-order FDTD algorithm in wideband simulations as well, without further modifications. The properties of the proposed scheme are verified through theoretical studies, as well as harmonic and multi-frequency numerical tests, where comparisons with other standard techniques are performed.

[J.23] T. T. Zygiridis, "Optimum time-step size for 2D (2, 4) FDTD method," *Electron. Lett.*, vol. 47, no. 5, pp. 317-319, March 2011.

The correct choice of time-step size is of crucial importance in the case of the (2, 4) finite-difference time-domain (FDTD) method, as it affects the algorithm's overall accuracy and convergence rate. A description of the inherent discretisation error is introduced, which is exploited for the derivation of a simple, yet reliable, approximation of the optimum temporal sampling density. As the proposed approach attempts to remedy inaccuracies in a mean-value sense, it is shown that highly efficient calculations can be carried out in this way.

[J.22] T. T. Zygiridis, "Bandwidth control of optimized FDTD schemes," *ACES Journal*, vol. 25, no. 12, pp. 1078-1085, Dec. 2010.

We investigate the potential of control-ling the wideband behavior of finite-difference time-domain (FDTD) methods, which adopt ex-tended spatial operators while maintaining the standard temporal updating procedure. Specifically, single-frequency optimization is performed first, while wider bands are then treated with the aid of the least-squares technique. The proposed methodology is applied to various discretization schemes with different stencil sizes and shapes, thus verifying its versatile character. Theoretical as well as numerical results are presented, which demonstrate that the optimization process has a beneficial impact on the efficiency of FDTD techniques, and yields attractive alternatives when reliable broadband simulations are required.

[J.21] T. T. Zygiridis, "Two-dimensional time-domain algorithm with adaptive spectral properties," *IEEE Microw. Wireless Compon. Lett.*, vol. 20, no. 5, pp. 241-243, May 2010.

We develop a two-dimensional scheme, whose spectral properties exhibit a certain degree of controllability, as an alternative to the classic finite-difference time-domain method. The new approach adopts a nonstandard structure for the spatial operators, whose final form is determined through a consistent error-minimization procedure. It is shown that isotropic improvement of ac-curacy can be accomplished at a single frequency, while the case of wider bands is handled with the aid of a least-squares mechanism. Reliable performance is ensured by the proposed algorithm, without compromising the stability region or requiring excessive computational resources.

[J.20] T. T. Zygiridis, T. K. Katsibas, C. S. Antonopoulos, and T. D. Tsiboukis, "Treatment of grid-conforming dielectric interfaces in FDTD methods," ***IEEE Trans. Magn.*****, vol. 45, no. 3, pp. 1396-1399, Mar. 2009.**

A new solution to the problem of implementing extended-stencil finite-difference operators across material interfaces is presented in this paper for time-domain electromagnetic simulations. In essence, modified spatial approximations are applied within a transition layer that encloses the discontinuity, while preserving the stencil size of the scheme employed in the homogeneous areas. The necessary difference expressions are determined with the aid of a straightforward design procedure, which is based on the reliable modeling of exact solutions, following a one-dimensional formulation. The proposed approach, whose beneficial effects are exemplified via numerical simulations, is analyzed for the case of the (2,4) method. Yet, its concepts are global and easily adapted to any discretization algorithm.

[J.19] T. T. Zygiridis and T. D. Tsiboukis, "Error estimation and performance control for the (2,4) FDTD method in lossy spaces," ***IEEE Trans. Magn.*****, vol. 45, no. 3, pp. 1356-1359, Mar. 2009.**

A new theoretical approach for the construction of extended-stencil finite-difference time-domain (FDTD) algorithms, particularly suited for 2-D domains comprising lossy materials, is presented in this paper. Rather than implementing the standard type of spatial operators, we apply dispersion-relation-preserving (DRP) concepts and extract modified difference approximations, based on specific accuracy requirements. A key element in this process is the prediction of the combined space/time discretization artifacts with the aid of a suitable error expression, whose proper manipulation facilitates the improvement of the discrete models irrespective of propagation angles. With this tool at hand, three novel schemes are derived, theoretical limits regarding their performance are presented, and illustrative comparisons with the standard (2,4) technique are provided.

[J.18] T. T. Zygiridis and T. D. Tsiboukis, "Assessment of human head exposure to wireless communication devices: combined electromagnetic and thermal studies for diverse frequency bands," ***Progress In Electromagnetic Research B*****, vol. 9, pp. 83-96, 2008.**

In this paper, an integrated and manifold study of the combined electromagnetic and thermal effects, caused by human exposure to microwave radiation is carried out. In essence, we numerically calculate the amount of electromagnetic power absorbed by biological tissues for various exposure conditions and types of emitting sources, utilizing a detailed model of the human head. The severity of the obtained results is evaluated via comparisons with the guidelines of international safety standards, while further insight is gained by investigating the induced thermal effects. The latter are properly quantified through the solution of the bioheat equation, when combined with the outcome of the electromagnetic simulations. Spatial distributions of the corresponding temperature changes are thus calculated, their relation to the dissipated power is established, and the thermal response of human tissues in marginal cases of exposure is predicted.

[J.17] T. T. Zygiridis and T. D. Tsiboukis, "Improved finite-difference time-domain algorithm based on error control for lossy materials", *IEEE Trans. Microw. Theory Tech.*, vol. 56, no. 6, pp. 1440-1445, June 2008.

This paper discusses the development of a reduced-error finite-difference time-domain algorithm, capable of handling conducting media in an efficient manner. Founded on a spatially extended stencil, the proposed scheme introduces a novel design procedure, whose basic idea is to enforce conditions of the con-tinuous space to the discrete level. In this way, we derive reliable space–time models for 2-D Maxwell's equations, minimizing the inherent phase and amplitude deviations. A high degree of adaptivity is also accomplished, as the spectral reliability range can be adjusted according to problem-dependent needs. Consequently, an upgraded discretization strategy is provided, which exhibits the same computational complexity with the conventional scheme.

[J.16] T. T. Zygiridis and T. D. Tsiboukis, "Optimized (2,4) FDTD method for conducting media," *IEEE Trans. Magn.*, vol. 44, no. 6, pp. 1370-1373, June 2008.

The development of an optimized finite-difference time-domain method, designed for application in topologies involving lossy materials, is discussed in this paper. The proposed scheme retains the structural components of the standard (2,4) technique; however, it adopts operators that mitigate errors within desired frequency bands and, therefore, guarantee upgraded reliability. The key point is the special treatment of the difference expressions, initially defined in parametric forms. Specific optimization procedures are then employed, leading to enhanced approximations that moderate phase and amplitude inaccuracies. In this manner, performance improvement without aggravation of the entailed computational burden is achieved.

[J.15] T. T. Zygiridis and T. D. Tsiboukis, "Optimized three-dimensional FDTD discretizations of Maxwell's equations on Cartesian grids," *J. Comp. Phys.*, vol. 226, no. 2, pp. 2372-2388, Oct. 2007.

In this paper, novel finite-difference time-domain (FDTD) schemes are introduced for the numerical solution of Max-well's equations on dual staggered Cartesian three-dimensional lattices. The proposed techniques are designed to accomplish optimized performance according to certain features and requirements dictated by the investigated problems, thus making efficient use of the available computational resources. Starting from only few initial assumptions, a construction process based on the minimization of specific error formulae is developed, which is later exploited to derive the final form of the finite-difference operators. Previously, an elaborate analysis of the proposed indicators is provided, targeting at global error control over all propagation angles. Our methodology guarantees upgraded flexibility, as accuracy can be maximized within either narrow or wider frequency bands, without practically inducing significant computational overhead. Attractive qualities such as high convergence rates are now the natural consequence of the effective design process, rather than the minimization of the truncation errors of the difference expressions. In fact, the proposed FDTD approaches verify the possibility to attain improved levels of accuracy, without resorting to the traditional – Taylor based – forms of the individual operators. A theoretical analysis of the inherent dispersion artifacts reveals the full potential of the new algorithms, while numerical tests and comparisons unveil their unquestionable merits in practical applications.

[J.14] T. V. Yioultsis, T. I. Kosmanis, T. T. Zygiridis, E. P. Kosmidou, A. Pyrpasopoulou, T. D. Xenos, N. J. Farsaris, V. Kotoula, P. M. Hytiroglou, G. Karkavelas, I. N. Magras, and T. D. Tsiboukis, "An integrated computational and experimental approach of low power microwave pulse-modulated nonthermal biological effects on prenatal development," ***WSEAS Trans. Communications*****, vol. 5, no. 10, pp. 1995-2001, Oct. 2006.**

An integrated study of pulse-modulated very low power density microwave radiation biological effects is presented. It employs a combination of a computational model of the rat and extensive in vivo experiments on rat embryos, during embryogenesis and organogenesis. The whole investigation is further enhanced via an immunological and histochemical investigation of the rats' organs. A simulation concerning similar conditions of exposure for human beings has been also performed, based on a realistic case of a far field GSM-like base station environment. Hence, an attempt is performed to project the results to a human-oriented case, under conditions of continuous exposure. The whole study is one of the first to combine results obtained by the computational, the experimental and the biomolecular investigations, and attempts a discussion on existing standards for protection from low power density, long-term electromagnetic field exposure.

[J.13] T. T. Zygiridis, E. P. Kosmidou, K. P. Prokopidis, N. V. Kantartzis, C. S. Antonopoulos, K. I. Petras, and T. D. Tsiboukis, "Numerical modeling of an indoor wireless environment for the performance evaluation of WLAN systems," ***IEEE Trans. Magn.*****, vol. 42, no. 4, pp. 839-842, Apr. 2006.**

A site-specific numerical model, based on the finite-difference time-domain method, is developed in this paper for the indoor radio channel. The scenario of interest is concerned with wave propagation in a typical office environment, for which several simulations are performed considering different placements of the transmitting antenna. Both the 2- and 5-GHz bands are examined, where contemporary wireless local area networks operate. Important channel characteristics are evaluated via the estimation of received power levels, as well as the examination of small-scale fading and time dispersion.

[J.12] T. T. Zygiridis and T. D. Tsiboukis, "Design of optimized FDTD schemes for the accurate solution of electromagnetic problems," ***IEEE Trans. Magn.*****, vol. 42, no. 4, pp. 811-814, Apr. 2006.**

In this paper, we develop a set of two-dimensional finite-difference time-domain (FDTD) schemes, capable of minimizing dispersion errors according to problem-related requirements. Their performance is optimized within either a narrow or wide frequency band, by requiring the minimization of an error estimator at selected frequency points. By properly utilizing a series expansion of the estimator, accuracy improvement is ensured regardless of the propagation angle. Contrary to standard FDTD approaches, the design procedure is proven to efficiently exploit the potential of higher order operators, as the developed techniques attain significantly lower error levels, at no or low additional computational cost.

[J.11] T. T. Zygiridis and T. D. Tsiboukis, "Development of higher order FDTD schemes with controllable dispersion error," ***IEEE Trans. Antennas Propagat.*****, vol. 53, no. 9, pp. 2952-2960, Sept. 2005.**

A new methodology that facilitates the control of the inherent dispersion error in the case of higher order finite-difference time-domain (FDTD) schemes is presented in this paper. The basic idea is to define suitable algebraic expressions that reflect numerical inaccuracies reliably. Then, finite-difference operators are determined via the minimization of the error estimators at selected frequencies. In order to apply this procedure, an error expansion in terms of cylindrical harmonic functions is performed, which also enables accuracy enhancement for all propagation angles. The design process produces a set of two-dimensional (2-D) FDTD algorithms with optimized frequency response. Contrary to conventional methodologies, the proposed techniques adjust their reliability range according to the requirements of the examined problem and can be, therefore, more efficient in computationally demanding simulations.

[J.10] T. T. Zygiridis and T. D. Tsiboukis, "Phase error reduction in general FDTD methods via optimum configuration of material parameters," ***J. Materials Processing Tech.*****, vol. 161, no. 1-2, pp. 186-192, Apr. 2005.**

The study of wave-interaction phenomena with the standard finite difference time domain (FDTD) method is seriously affected by numerical dispersion, especially in the case of coarse mesh resolutions. To alleviate this problem, we propose the implementation of higher order FDTD approaches, combined with a simple correctional technique. The latter ensures a more precise numerical wave speed by properly adjusting the properties of the modeled materials at a pre-processing stage and, therefore, does not increase the overall computational burden. Although the correction is carried out on a single-frequency basis, error reduction is observed at a wide part of the frequency spectrum, thus enabling the execution of more reliable wideband simulations as well. Numerical verification of the proposed scheme is finally obtained for two test configurations.

[J.9] T. T. Zygiridis and T. D. Tsiboukis, "Higher-order finite-difference schemes with reduced dispersion errors for accurate time-domain electromagnetic simulations," ***Int. J. Num. Modelling*****, vol. 17, no. 5, pp. 461-486, Sept.-Oct. 2004.**

The potential for developing higher-order finite-difference time-domain (FDTD) schemes with reduced phase errors is investigated in the present paper. Using the classic (2,4) FDTD method as the basis of this study, electromagnetic wave propagation is accurately reproduced in the discretized space by replacing isotropic materials with modified, anisotropic in general, ones. The use of such artificial materials improves the simulation's precision significantly around a specific frequency, yet the overall error remains small at a considerably wide bandwidth; therefore, this algorithm can be useful for wideband problems as well. Additionally, it is shown that an even better single-frequency performance can be attained, when the modified materials are combined with systematically calculated spatial operators. Pursuing a more wideband enhancement of the (2,4) technique, a version realizing more accurate results at almost all frequencies that can be coupled in a staggered grid is derived. Furthermore, novel spatial operators are introduced, with the distinct feature of using extended stencils in more than one directions. It turns out that when such operators are incorporated, a scheme that combines the aforementioned features can be obtained. The theoretical findings of this investigation are verified in a sequence of numerical tests, involving free-space and guided-wave propagation, as well as the determination of a cavity's resonant frequencies.

[J.8] T. T. Zygiridis and T. D. Tsiboukis, "Low-dispersion algorithms based on the higher order (2,4) FDTD method," ***IEEE Trans. Microwave Theory Tech.*****, vol. 52, no. 4, pp. 1321-1327, Apr. 2004.**

This paper discusses the enhancement of numerical dispersion characteristics in the context of the finite-difference time-domain method based on a (2,4) computational stencil. Rather than implementing the conventional approach—based on Taylor analysis—for the determination of the finite-difference operators, two alternative procedures that result in numerical schemes with diverse wide-band behavior are proposed. First, an algorithm that performs better than the standard counterpart over all frequencies is constructed by requiring the mutual cancellation of terms with equal order in the corresponding dispersion relation. In addition, a second method is derived, which is founded on the separate optimization of the spatial and temporal derivatives. In this case, analysis proves that significant error compensation is accomplished around a specific design frequency, while reduced errors are obtained for higher frequencies, thus enabling the reliable execution of wide-band simulations as well. The quality and efficiency of the proposed techniques, which exhibit the same computational requirements as the standard (2,4) approach, are investigated theoretically, and subsequently, validated by means of numerical experimentation.

[J.7] T. T. Zygiridis and T. D. Tsiboukis, "A dispersion-reduction scheme for the higher order (2,4) FDTD method," ***IEEE Trans. Magn.*****, vol. 40, no. 2, Part 2, pp. 1464-1467, Mar. 2004.**

In this paper, a higher order (2,4) finite difference time domain (FDTD) method with enhanced dispersion properties is presented. The accuracy improvement stems from the application of a correctional technique, which is based on the systematic modification of the constitutive material parameters. Despite the scheme's single-frequency nature, satisfactory wide-band performance is attained, while its general formulation also enables the mitigation of phase inaccuracies around specific directions of propagation. The proposed approach, which is easy to implement and computationally inexpensive, is evaluated through theoretical calculations and numerical experimentation.

[J.6] N. V. Kantartzis, T. T. Zygiridis, and T. D. Tsiboukis, "An unconditionally stable higher order ADI-FDTD technique for the dispersionless analysis of generalized 3-D EMC structures," ***IEEE Trans. Magn.*****, vol. 40, no. 2, Part 2, pp. 1436-1439, Mar. 2004.**

An efficient higher order alternating-direction implicit (ADI) finite-difference time–domain (FDTD) method for the unconditionally stable analysis of curvilinear electromagnetic compatibity (EMC) applications is presented in this paper. The novel algorithm launches a class of precise spatial/temporal nonstandard forms that drastically suppress the dispersion errors of the ordinary approach as time-step increases and mitigate its strong dependence on cell shape or mesh resolution. For arbitrary inter-face media distributions that do not follow the grid lines, a convergent transformation based on a rigorous extrapolating practice is introduced. Moreover, infinite domains are successfully treated by optimized higher order curvilinear PMLs. Hence, the proposed technique achieves notable accuracy far beyond the Courant limit, subdues the ADI error mechanisms, and offers serious savings, as verified by the solution of several complex EMC problems.

[J.5] T. T. Zygiridis, N. V. Kantartzis, and T. D. Tsiboukis, "Higher order tangential vector finite elements for 3-D antenna array structures," ***Electromagnetics*****, vol. 24, no. 1-2, pp. 95-111, Jan.-Mar. 2004.**

The radiation properties of several contemporary array structures in three-dimensional problems are numerically investigated by implementing an advanced second-order tangential vector finite element (TVFE) methodology. The choice and the development of the proposed strategy is justified, since it provides a more precise field representation compared to the first-order edge elements and enables its utilization within coarse meshes without reducing the accuracy of the calculated solution. The latter observation becomes more important when electrically large domains are modeled, as their study with low-order elements usually calls for a fine discretization and, consequently, results in a large number of unknowns. In this paper, we mainly focus on arrays of patch antennas with linear and planar configurations, while cases where beam steering is investigated are also taken into account. For comparison purposes, our study incorporates results obtained with a higher order nonstandard finite-difference time-domain (FDTD) method, which efficiently overcomes some of the deficiencies concerning the conventional Yee algorithm.

[J.4] T. T. Zygiridis, N. V. Kantartzis, T. V. Yioultsis, and T. D. Tsiboukis, "Higher order approaches of FDTD and TVFE methods for the accurate analysis of fractal antenna arrays," *IEEE Trans. Magn.,* vol. 39, no. 3, Part 1, pp. 1230-1233, May 2003.

In this paper, higher order renditions of two popular numerical methods are proposed for the precise modeling of fractal antenna array structures. Particularly, a higher order finite difference time domain (FDTD) method, which introduces nonstandard differential operators, and second-order curl-conforming vector finite elements with optimized convergence behavior are considered. These techniques attain sufficient accuracy and reduced dispersion errors, even when coarse discretizations are utilized and, therefore, are more preferable compared to lower order approaches, especially in the case of large computational domains. Their enhanced performance is exploited for the rigorous investigation of the radiation properties of several fractal arrays with complex geometrical features.

[J.3] T. V. Yioultsis, T. I. Kosmanis, E. P. Kosmidou, T. T. Zygiridis, N. V. Kantartzis, T. D. Xenos, and T. D. Tsiboukis, "A comparative study of the biological effects of various mobile phone and wireless LAN antennas," *IEEE Trans. Magn.*, vol. 38, no. 2, Part 1, pp. 777-780, Mar. 2002.

This paper presents a comprehensive electromagnetic and thermal analysis of radiation and its impact on human beings, due to the use of various types of commonly used mobile phones and communication antennas. This is one of the first studies that deals with a wide-range comparative investigation of modern cell phones, unlike the majority of existing work, which do not extend beyond the obsolete generic phone case. The rather severe, although overlooked, case of wireless local area network antennas is also considered, due to their increasing use and the large times of exposure associated with them.

[J.2] N. V. Kantartzis, T. T. Zygiridis, and T. D. Tsiboukis, "A nonstandard higher order FDTD algorithm for 3-D arbitrarily and fractal-shaped antenna structures on general curvilinear lattices," *IEEE Trans. Magn.*, vol. 38, no.2, Part 1, pp. 737-740, Mar. 2002.

A new higher order finite-difference time-domain (FDTD) methodology for the consistent modeling of arbitrarily shaped antennas in three-dimensional (3-D) curvilinear coordinates is presented in this paper. The generalized algorithm, which introduces novel conventional and nonstandard regimes, develops advanced PMLs and compact differences to handle the widened spatial increments. Also, a systematic leapfrog integrator with mesh expansion concepts is established. Beyond diverse 3-D structures, analysis studies fractal arrays whose self-similarity renders them ideal for small-sized designs. Results indicate that the proposed method achieves a critical elimination of lattice errors and provides very precise radiation patterns.

[J.1] T. T. Zygiridis, N. V. Kantartzis, and T. D. Tsiboukis, "Sierpinski double-gasket antenna investigated with a 3-D FDTD conformal technique," *Electron. Lett.*, vol. 38, no. 3, pp. 107-109, Jan. 2002.

A new fractal volume antenna that consists of two intersecting Sierpinski triangular gaskets is presented. The proposed configuration is analyzed by means of a generalized finite difference time domain (FDTD) conformal algorithm which precisely verifies the expected multiband behavior and the densely distributed resonances of the structure.

PUBLICATIONS IN CONFERENCE PROCEEDINGS

[C.45] Panagiotis Sarigiannidis, Dimitris Pliatsios, Theodoros Zygiridis, and Nikolaos Kantartzis, "DA-MA: A data mining forecasting DBA Scheme for XG-PONs," *The International Conf. on Modern Circuits and Systems Technologies*, pp. 1-4, Thessaloniki, Greece, 12–14 May, 2016. DOI: 10.1109/MOCAST.2016.7495169

The latest new generation passive optical network (NG-PON) standard, known as 10-gigabit-capable passive optical network (XG-PON), enables a very promising architecture that offers 10 Gbps nominal data delivery ratio in the downstream direction. The optical line terminal (OLT) is located within the CO and constitutes the main decision-making tank of the PON. OLT applies a dynamic bandwidth allocation (DBA) scheme for coordinating the transmission opportunities, especially in the upstream direction. According to the standard, a differential fibre distance of 40 km, between ONUs and OLT, is allowed. This outspread deployment implies high propagation delays which should be taken into account of designing the bandwidth allocation. This work is focused on proposing a cognitive DBA scheme which is capable of forecasting the additional bandwidth, which arrives in ONUs, during the transmission coordination between OLT and ONUs. The k-nearest neighbors (k-NN) algorithm is applied for forecasting the additional bandwidth requests of each ONU. In addition, the adopted algorithm is enhanced with an adaptive learning-based method which efficiently selects the most appropriate k value based on the traffic dynamics.

[C.44] Athanasios Papadimopoulos, Vivian Alreem, Theodoros Zygiridis, Panagiotis Sarigiannidis, Nikolaos Kantartzis, and Christos Antonopoulos, "Statistical analysis of microwave components through a 3-D stochastic-FDTD technique," *The International Conf. on Modern Circuits and Systems Technologies*, pp. 1-4, Thessaloniki, Greece, 12–14 May, 2016. DOI: 10.1109/MOCAST.2016.7495163

The consistent modeling of microwave components with random fluctuations regarding their electromagnetic material parameters is performed in this paper via a 3-D stochastic finite-difference time-domain method. The featured formulation provides precise numerical results with a considerably smaller computational cost compared to the extensively resource consuming Monte Carlo approach. Numerical simulations of microstrip transmission lines with media uncertainties are conducted in order to verify the accuracy of the proposed technique along with its effectiveness to investigate the operation of complicated microwave structures in a stochastic environment.

[C.43] Christos Salis, Theodoros Zygiridis, Panagiotis Sarigiannidis, and Nikolaos Kantartzis, "Unconditionally-stable time-domain approach for uncertainty assessment in transmission lines," *The International Conf. on Modern Circuits and Systems Technologies*, pp. 1-4, Thessaloniki, Greece, 12–14 May, 2016. DOI: 10.1109/MOCAST.2016.7495151

Uncertainties characterizing the per-unit-length parameters of transmission lines (TL) may have a significant impact on the properties of the propagating voltage and current waves that deterministic models tend to overlook. In this paper, we present an unconditionally-stable finite-difference time-domain (FDTD) algorithm that calculates the statistics of the involved field quantities, provided that the variability of the line characteristics is known. Being free from time-step restrictions, the proposed scheme is an extension of the standard stochastic FDTD method and exhibits better efficiency, esp. in densely discretized computational domains. Indicative results verify that uncertainty quantification in TL problems is possible in a reliable manner, even when larger than usual time-steps are selected.

[C.42] Theodoros Zygiridis, Nikolaos Kantartzis, and Theodoros Tsiboukis, ”Investigation of uncertainty in lightning-produced EM Fields with a polynomial-chaos FDTD approach,” ***The 10th International Symp. on Electric and Magnetic Fields (EMF 2016), From Numerical Models to Industrial Applications*****, p. 1, Lyon, France, 12–14 April, 2016.**

Numerical predictions of electromagnetic fields from lightning pulses have been extensively performed in various works, due to their significance in many electromagnetic compatibility problems. However, the inherent randomness of realistic setups is commonly overlooked by available methods, thus no valid conclusions regarding the statistical properties of the output data can be drawn. Unfortunately, straightforward solutions combining the Monte-Carlo approach with full-wave simulations call for prolonged computing times. This work develops an accurate and efficient numerical framework for the uncertainty assessment in lightning problems, when the random nature of the ground’s electric parameters is considered.

[C.41] Nikolaos Kantartzis, Theodoros Zygiridis, and Theodoros Tsiboukis, “Efficient Krylov-based 3-D FVTD schemes with adaptive domain decomposiΘon for graphene and nanostructured EMC components,” ***The 10th International Symp. on Electric and Magnetic Fields (EMF 2016), From Numerical Models to Industrial Applications*****, p. 1, Lyon, France, 12–14 April, 2016.**

Recent research on advanced nanocomposite and graphene structures opts for high sensitivity and speed along with limited dimensions. Actually, such devices have gained a conspicuous momentum in the THz regime, due to their integration properties and large-density electromagnetic compatibility (EMC) packaging attributes. Considering that most of them should be often redesigned to follow contemporary standards, the incorporation of consistent computational models are proven very instructive. Nonetheless, issues like fine geometric details, curved media interfaces, frequency dependencies, and nonlinearities usually lead to serious discretization artifacts that prohibit the reliable applicability of the prior numerical means. In this paper, a systematic 3- D finite-volume time-domain (FVTD) methodology with an adaptive domain decomposition scheme is developed for the rigorous design of nanomaterial and graphene applications.

[C.40] Stamatios A. Amanatiadis, Alexandros I. Dimitriadis, Theodoros T. Zygiridis, and Nikolaos V. Kantartzis, “Transmitted and reflected graphene surface waves due to substrate discontinuities,” ***10th European Conf. on Antennas and Propagation (EuCAP)*****, pp. 1–3, Davos, Switzerland, 10–15 April, 2016. doi: 10.1109/EuCAP.2016.7481955.**

The transmission and reflection coefficients of graphene surface waves, owing to the discontinuities of its substrate, are systematically studied and numerically computed in this paper. In essence, the propagation properties of these graphene-supported waves are theoretically extracted, revealing their strong dependence on the substrate material. The latter leads to the disruption of a propagating surface wave to a reflected and a transmitted one, because of any potential discontinuity. Finally, the coefficients and the propagation angles of these waves are accurately evaluated by means of a robust finite-difference time-domain algorithm that treats graphene as a surface boundary condition.

[C.39] Theodoros T. Zygiridis, Nikolaos V. Kantartzis, Christos S. Antonopoulos, and Theodoros D. Tsiboukis, "Construction of 3D FDTD schemes with frequency-dependent operator coefficients," *10th European Conf. on Antennas and Propagation (EuCAP)*, pp. 1–5, Davos, Switzerland, 10–15 April, 2016. doi: 10.1109/EuCAP.2016.7481734.

Aiming at the minimization of numerical dispersion effects in finite-difference time-domain (FDTD) simulations, we investigate the potential of introducing frequency-dependent coefficients in the approximations of differential operators. The proposed methodology exploits some previous results on optimized finite-differences, but initially avoids the necessity for selecting a specific optimization point. Herein, the operators' coefficient formulae are approximated by a low-order polynomial, which is transformed into a finite-difference counterpart using the Helmholtz equation. This modifies the initial spatial stencil and improves performance over all frequencies, which can be further controlled with the least-squares method, leading to various new FDTD schemes of augmented reliability.

[C.38] Theodoros T. Zygiridis, Nikolaos V. Kantartzis, and Theodoros D. Tsiboukis, ``Development of optimized operators based on spherical-harmonic expansions for 3D FDTD schemes,'' *XVII International Symposium on Electromagnetic Fields in Mechatronics, Electrical and Electronic Engineering – ISEF 2015*, pp. 1-8, Valencia, Spain, September 10-12, 2015.

The subject of this paper pertains to the construction of finite-difference expressions with minimized, as well as controllable discretization errors, suitable for 3D FDTD simulations in large-scale setups. The proposed spatial approximations are designed to mimic the behavior of the exact operators, when applied to plane-wave trial functions. To eliminate undesirable directional dependencies, the expansion of proper error formulae in terms of spherical harmonic functions is performed, which facilitates accuracy improvement and produces optimized operator coefficients in closed-form expressions. The combination of the new operators with low- as well as high-order time integrators yields efficient space-time discrete models, whose reliability renders them desirable substitutes for other traditional solutions.

[C.37] N. V. Kantartzis, T. T. Zygiridis, C. S. Antonopoulos, and T. D. Tsiboukis, ``Reduced-order models of VFETD/FDTD algorithms for optimized nanomaterial EMC applications,'' *Joint IEEE International Symposium on Electromagnetic Compatibility and EMC Europe*, pp. 512--517, Dresden, Germany, August 16 - 22, 2015.

A set of 3-D reduced-order modeling representations for a new vector finite-element time-domain/finite-difference timedomain (VFETD/FDTD) method is presented in this paper for the analysis of nanostructured EMC applications. The proposed algorithm combines vector finite elements with stencil-adjustable operators through the appropriate boundary conditions and splits the domain into coupled blocks. Both explicit processes are individually time-updated, while their state-space approximations are obtained by a Krylov scheme and scaled Laguerre polynomials that offer considerable transfer-matrix order reduction. Moreover, for thin conductors, a robust interpolation technique founded on telegrapher's equations, is developed in order to effectively treat propagating waves along the radial direction of the wire. Therefore, realistic details can be precisely modeled, without overly fine meshes. Numerical results from diverse nanomaterial and graphene EMC arrangements, verify the merits of the featured formulation.

[C.36] G. G. Pyrialakos, T. T. Zygiridis, N. V. Kantartzis, and T. D. Tsiboukis, ``GPU-accelerated stochastic-FDTD study of lightning-induced EM Fields over non-deterministic terrains,'' ***Progress In Electromagnetics Research Symposium - PIERS 2015*****, pp. 2310-2314, Prague, Czech Republic, July 6–9, 2015.**

A curvilinear stochastic finite-difference time-domain (S-FDTD) methodology is presented in this paper for the systematic analysis of lightning-induced fields over rough terrains with statistical uncertainties. The novel 3-D technique stems from a covariant/contravariant formulation which can profitably handle the variation of specific parameters during a single run. To achieve further acceleration, graphics processing units (GPUs) with large core densities are utilized, while a set of realistic setups is addressed for the validation of proposed algorithm.

[C.35] T. T. Zygiridis, N. V. Kantartzis, and T. D. Tsiboukis, ``Development of ADI-FDTD methods with dispersion-relation-preserving features,'' ***Progress In Electromagnetics Research Symposium - PIERS 2015*****, pp. 2209-2214, Prague, Czech Republic, July 6–9, 2015.**

We present two methodologies that improve the performance of the alternatingdirection-implicit (ADI) finite-difference time-domain (FDTD) scheme. The first one exploits optimized spatial operators and implements an artificial-anisotropy approach, so that errors around a central frequency are minimized. According to the second scheme, a matching-terms procedure is applied to the dispersion relation, so that approximations that improve space-time errors in a wideband fashion are obtained. The successful implementation of these principles is validated theoretically, while numerical tests reveal their advantageous properties in practical simulations.

[C.34] Theodoros T. Zygiridis, Nikolaos V. Kantartzis, Christos S. Antonopoulos, and Theodoros D. Tsiboukis, ``Efficient integration of high-order stencils into the ADI-FDTD method,'' ***20th International Conference on the Computation of Electromagnetic Fields - COMPUMAG 2015*****, pp. 1-2, Montreal, Quebec, Canada, June 28 – July 2, 2015.**

Incorporating standard high-order spatial approximations in the alternating-direction-implicit (ADI) finite-difference time-domain (FDTD) method does not suffice for accuracy improvement, as these operators are capable of reducing spatial errors only. We herein propose an alternative design procedure, which guarantees finite-difference expressions that minimize the overall space-time flaws. In essence, error formulas are derived from the individual implicit equations, when the ADI update is treated as a single-step process. Then, efficient spatial expressions are extracted via proper manipulations of these formulas that apply error-controlling concepts.

[C.33] Nikolaos V. Kantartzis, Theodoros T. Zygiridis, Christos S. Antonopoulos, and Theodoros D. Tsiboukis, ``A generalized domain-decomposition stochastic FDTD technique for complex nanomaterial and graphene structures,'' ***20th International Conference on the Computation of Electromagnetic Fields - COMPUMAG 2015*****, pp. 1-2, Montreal, Quebec, Canada, June 28 – July 2, 2015.**

The systematic and rigorous design of realistic nanocomposite applications and finite graphene setups with arbitrary media uncertainties is presented in this paper via a 3-D covariant/contravariant stochastic finite-difference time-domain method. The novel algorithm employs extra nodes according to a convex combination of all available spatial increments and develops a robust domain-decomposition scheme along with the pertinent Lagrange multipliers to significantly reduce the computational overhead. In this manner, the mean value and standard deviation of field components are calculated in a single run, which is further accelerated through graphics processor units and parallel programming. The profits of the proposed algorithm are certified by various nanoscale components with demanding statistical material variations.

[C.32] A. N. Papadimopoulos, G. G. Pyrialakos, A. X. Lalas, T. T. Zygiridis, N. V. Kantartzis, C. S. Antonopoulos, T. F. Eibert, and T. D. Tsiboukis, ``Statistical modeling of antennas via a generalized stochastic-FDTD method,'' *9th European Conference on Antennas and Propagation - EuCAP 2015*, pp. 1-5, Lisbon, Portugal, 12 -- 17 April, 2015.

The consistent analysis of complex antenna setups with statistically varying media attributes is performed in this paper through a 3-D curvilinear stochastic finite-difference time-domain technique. The new method generalizes the concept of covariant/contravariant metrics for curved structures and derives the mean value and standard deviation of field components in a single run. Also, for the acceleration of the resulting simulations, all codes are developed in terms of graphics processor units and parallel programming. The profits of the proposed algorithm over multiple-realization Monte-Carlo schemes are certified via comparisons from circular- and trapezoidal-toothed log-periodic antennas with various realistic uncertainties in their materials.

[C.31] G. G. Pyrialakos, A. N. Papadimopoulos, T. T. Zygiridis, N. V. Kantartzis, and T. D. Tsiboukis, ``A curvilinear stochastic-FDTD algorithm for 3-D EMC problems with media uncertainties,'' *16th International IGTE Symposium on Numerical Field Calculation in Electrical Engineering (IGTE '14)*, p. 64, Graz, Austria, Sept. 14-17, 2014.

A 3-D stochastic finite-difference time-domain (S-FDTD) technique in curvilinear coordinates is developed in this paper for the consistent analysis of electromagnetic problems with high levels of statistically varying material properties. The novel algorithm is based on the covariant/contravariant metrics formulation to effectively incorporate the mean value and standard deviation operators, while its execution time is greatly decreased via the suitable CUDA programming.

[C.30] T. T. Zygiridis, G. G. Pyrialakos, N. V. Kantartzis, and T. D. Tsiboukis, ``Accelerated unconditionally stable FDTD scheme with modified operators,'' *16th International IGTE Symposium on Numerical Field Calculation in Electrical Engineering (IGTE '14)*, p. 50, Graz, Austria, Sept. 14-17, 2014.

An unconditionally stable scheme based on the locally-one-dimensional (LOD) finite-difference time-domain (FDTD) method, which features modified spatial operators that attempt to ameliorate numerical dispersion flaws is presented in this paper. In order to provide an efficient implementation, the algorithm is systematically parallelized on graphics processing units (GPUs), resulting in accelerated executions of both the explicit and implicit parts of the proposed approach.

[C.29] G. Pyrialakos, T. Zygiridis, N. Kantartzis, and T. Tsiboukis, ``FDTD analysis of 3D lightning problems with material uncertainties on GPU architecture,'' *Proc. of the 2014 International Symposium on Electromagnetic Compatibility (EMC Europe 2014)*, pp. 577-582, Gothenburg, Sweden, September 1-4, 2014.

We present a computational framework for the prediction of electromagnetic fields in lightning problems which, unlike common methodologies, can efficiently incorporate the statistical variations that characterize the ground electric parameters. Our full-wave technique is based on the three-dimensional (3D) extension of the stochastic finite-difference time-domain (SFDTD) method, and enables the extraction − in a single run – of fundamental statistical parameters, such as the mean value and standard deviation, that describe the generated fields. Aiming at efficient code implementations via paralellization, the increased computing power of modern graphics processing units (GPUs) is exploited. Numerical tests verify the validity of the proposed approach, as the corresponding results compare very well with those obtained via − more time-consuming − Monte-Carlo FDTD (MC-FDTD) simulations, for a wide range of parameter values.

[C.28] T. T. Zygiridis, N. V. Kantartzis, and T. D. Tsiboukis, ``Parallel LOD-FDTD method with error-balancing properties,'' *The Sixteenth Biennial IEEE Conference on Electromagnetic Field Computation - CEFC 2014*, Annecy, France, May 25-28, 2014.

We present an improved version of the locallyone-dimensional (LOD) finite-difference time-domain (FDTD) algorithm, featuring spatial expressions derived by an errorreduction procedure. The latter involves the matching of terms with similar order in the dispersion relation, and provides better balancing of space-time errors, irrespective of the time-step size.

[C.27] N. V. Kantartzis, T. T. Zygiridis, and T. D. Tsiboukis, ``A 3-D stochastic FVTD method based on reduced-order modeling for statistically random media in nano-electromagnetic applications,'' *The Sixteenth Biennial IEEE Conference on Electromagnetic Field Computation - CEFC 2014*, Annecy, France, May 25-28, 2014.

A spectrally-optimized stochastic FVTD technique is introduced in this paper for the consistent analysis of 3-D nanoscale structures with statistically-varying media heterogeneities. Founded on a compact block state-space concept, the new method attains high accuracy levels and avoids the excessive resource needs of usual multiple-realization Monte-Carlo approaches. Hence, complex nanocomposite devices are very reliably modeled, even for sub-wavelength field uncertainties, as derived by several numerical configurations.

[C.26] G. G. Pyrialakos, T. T. Zygiridis, N. V. Kantartzis, and T. D. Tsiboukis, ``GPU-based three-dimensional calculation of lightning-generated electromagnetic fields,'' *IEEE International Conference on Numerical Electromagnetic Modeling and Optimization for RF, Microwave and Terahertz Applications - NEMO2014*, pp. 1-4, Pavia, Italy, May 14-16, 2014.}

We present and validate a computational approach for the efficient calculation of lightning-produced electromagnetic fields and solution of pertinent problems in realistic environments. Given that various factors, such as ground-material inhomogeneities and irregular earth surface, may inhibit the utilization of simplified approaches, the finite-difference time-domain method is applied in its general three-dimensional formulation, so that important details are taken into consideration. As lightning problems usually call for a significant number of computations, the numerical approach is parallelized by exploiting the computing capabilities of contemporary graphics-processing-units. The proposed implementation results in serious shortening of the simulations' duration and facilitates the study of problems with uncertainties, thus contributing to the development of a useful tool for the study of lightning-related phenomena.

[C.25] T. T. Zygiridis, "On the design of leapfrog integrators for optimized implementations of 3D FDTD models," ***International Conference on Electromagnetics in Advanced Applications '13*****, pp. 1224-1227, Torino, Italy, Sept. 9-13, Sept. 2013.**

In this paper the formulation of modified leapfrog integrators for three-dimensional (3D) finite-difference time-domain (FDTD) simulations is discussed. We propose an approach that introduces a parametric variant of the fourth-order approach, and aims at preserving the exact dispersion characteristics at the discrete level, via proper manipulation of its spatial part. The entailed computational cost is not altered, and wave propagation is reproduced more accurately via the new version of the integrator, especially when the latter is combined with spatial operators of similar calibre.

[C.24] T. T. Zygiridis, N. V. Kantartzis, and T. D. Tsiboukis, "GPU-accelerated efficient implementation of FDTD methods with optimum time-step selection," ***19th COMPUMAG Conference on the Computation of Electromagnetic Fields*****, pp. 1-2, Budapest, Hungary, 30 June – 4 July 2013.**

The efficient combination of uneven space-time orders in finite-difference time-domain (FDTD) algorithms is the subject of this paper. Operating such schemes close to the stability limit leads to poor performance and low convergence rates. Based on accuracy considerations, we provide an estimate of the optimum time-step size that improves errors in a mean-value sense. To deal with the augmentation of the required iterations, the parallel implementation of the FDTD techniques on graphics processing units is pursued, ensuring faster code executions.

[C.23] N. V. Kantartzis, T. T. Zygiridis, and T. D. Tsiboukis, "Enhanced analysis of multiconductor nanostructured devices via a compact block FDTD/VFETD method," ***19th COMPUMAG Conference on the Computation of Electromagnetic Fields*****, pp. 1-2, Budapest, Hungary, 30 June – 4 July 2013.**

A reduced-order modeling FDTD/VFETD technique is presented in this paper, for the accurate and cost-effective study of multiconductor nanoscale structures. The novel algorithm blends a compact stencil-optimized discretization process with general vector finite elements and partitions the domain into tightly-coupled blocks. A key asset is that both approaches are time-advanced independently while their state-space models are derived via a Krylov-based scheme with scaled Laguerre functions, which drastically decreases the order of the transfer matrix. Numerical results from various nanocomposite devices validate the hybrid method and reveal its applicability.

[C.22] T. T. Zygiridis, "Design of least-squares time integrators for reliable FDTD simulations," ***The 15th Biennial IEEE Conference on Electromagnetic Field Computation, CEFC 2012*****, p. 376, Oita, Japan, Nov. 11-14 2012.**

Optimized time integrators are constructed for reliable time-domain simulations of wave propagation problems. The proposed techniques are modified versions of leapfrog integrators and feature accuracy-preserving behavior, so that numerically-induced flaws are efficiently dealt with.

[C.21] T. T. Zygiridis, "High-order error optimized FDTD algorithm with GPU implementation," ***The 15th Biennial IEEE Conference on Electromagnetic Field Computation, CEFC 2012*****, p. 207, Oita, Japan, Nov. 11-14 2012.**

We develop a finite-difference time-domain scheme that combines specially-designed spatial operators with optimized leapfrog integrators. A proper least-squares treatment facilitates further control of the method's wideband behavior. In addition, significant speedup to serialized CPU calculations is accomplished by parallelizing the algorithm on a graphics processing unit.

[C.20] K. Rallis, T. Theodoulidis and T. Zygiridis, "Efficient calculation of the lightning generated electric field above ground," ***EMC Europe 2012, International Symposium on Electromagnetic Compatibility*****, Rome, Italy, Sept. 17-21, 2012.**

When studying electromagnetic field problems like lightning phenomena, the efficiency of the adopted model relies on the accurate and rapid calculation of Sommerfeld type Integrals (SI). In the present work we propose an efficient method for calculating them, based on their numerical evaluation along a deformed path of integration. The method is combined with an interpolation technique in order to reduce the number of frequencies required in the Fourier synthesis of the time domain electric field. The result is a fast and straightforward tool for the calculation of aboveground lightning field, without the use of specially developed numerical algorithms or analytical approximations. The proposed approach is also validated through comparison with results obtained with a standard computational methodology.

[C.19] T. I. Kosmanis, N. V. Kantartzis, T. T. Zygiridis, and P. T. Aisopoulos, "Numerical analysis of the electromagnetic interference of a WAVE inter-vehicle communication system on vehicle electronics," ***9th International Symposium on EMC joint with 20th International Wroclaw Symposium on EMC*****, pp. 265-268, Wroclaw, Poland , Sept. 13 -17, 2010.**

Inter-vehicle communication systems present an increasing popularity due to their critical, for public safety, as much as attractive and convenient applications. This technological tendency could potentially become hazardous for automotive electronics. The radiated immunity of automotive electronics in electromagnetic fields caused by inter-vehicle communication systems described by the IEEE 802.11p WAVE standard or its equivalents is studied in this paper. The electric field produced in critical points of the interior of a vehicle is estimated by means of full wave Finite Difference Time Domain method simulations. In each simulation, the vehicle-to-vehicle or vehicle-to-infrastructure communication according to the characteristics of the IEEE WAVE standard is assumed.

[C.18] T. I. Kosmanis, T. T. Zygiridis, N. V. Kantartzis, and P. T. Aisopoulos, "Vehicle-to-vehicle communication system EMI characterization on automotive electronics," *2010 URSI International Symposium on Electromagnetic Theory*, pp. 418-421, Berlin, Germany, Aug. 16-19, 2010.

The major issue of electromagnetic immunity of automotive electronics to the radiation of vehicle-to-vehicle systems is the subject of this paper. Inter-vehicle communication systems provide a wide range of new services and applications for vehicular environments, but they are still under development. Although very promising for the future of intelligent transportation systems, they may become hazardous for automotive electronics. A core numerical analysis of the electric field produced by such a system is performed by means of the full wave Finite Difference Time Domain method. The electric field intensity levels in a vehicle due to a vehicle-to-vehicle communication system is estimated for various cases according to the corresponding IEEE standard and compared to the maximum allowed levels for electronic devices.

[C.17] T. T. Zygiridis, "Bandwidth control of optimized FDTD schemes," *26th Annual Review of Progress in Applied Computational Electromagnetics*, pp. 320-323, Tampere, Finland, April 26-29, 2010.

We investigate the potential of controlling the wideband behavior of a class of finite-difference time-domain (FDTD) methods, which adopt extended spatial operators, while being second-order accurate in time. Specifically, single-frequency optimization is performed first, and wider bands are then treated by applying the least-squares technique. Results regarding up to six-point stencils are presented, and it is shown that the proposed approach can be beneficial, when broadband results are of interest.

[C.16] N. V. Kantartzis and T. T. Zygiridis, "Enhanced FDTD schemes based on dispersion-optimized stencil-adjustable nonstandard operators," *26th Annual Review of Progress in Applied Computational Electromagnetics*, Tampere, Finland, pp. 316-319, April 26 - 29, 2010.

In this paper, a set of advanced finite-difference time-domain algorithms incorporating diverse spatial/temporal approximations is presented. Considering the general case of lossy media, optimized conventional operators are designed to produce reduced dispersion artifacts at a given frequency, whereas for demanding geometries, nonstandard operators that enable convex stencil combinations are also introduced. Both concepts exhibit improved qualities, compared to the classic Yee's technique, as certified by numerical results.

[C.15] T. T. Zygiridis, T. K. Katsibas, C. S. Antonopoulos, and T. D. Tsiboukis, "Treatment of grid-conforming dielectric interfaces in FDTD methods," *CEFC 2008, 13th Biennial IEEE Conference on Electromagnetic Field Computation*, Athens, Greece, May 11-15, 2008, p. 460.

A solution to the problem of using extended-stencil finite-difference operators near material interfaces is proposed in this paper for time-domain simulations. The interior discretization scheme is properly modified within a transition layer that encloses the discontinuity, with the aid of alternative spatial expressions, derived by minimizing suitable error functions.

[C.14] T. T. Zygiridis and T. D. Tsiboukis, "Error estimation and performance control for the (2,4) FDTD method in lossy spaces," ***CEFC 2008*, *13th Biennial IEEE Conference on Electromagnetic Field Computation*****, Athens, Greece, May 11-15, 2008, p. 244.**

A technique for controlling the spectral behavior of an extended-stencil finite-difference time-domain method is presented, when electrically-conducting media are discretized. By estimating numerical errors from an approximation of the dispersion relation, new spatial operators are defined and some of the deficiencies of the scheme's conventional version are amended.

[C.13] T. T. Zygiridis and T. D. Tsiboukis, "Optimized (2,4) FDTD method for conducting media," ***16th COMPUMAG Conference on the Computation of Electromagnetic Fields*****, Aachen, Germany, June 24-28, 2007, pp. 783-784.**

The construction of an optimized finite-difference time-domain method for application in problems involving lossy dielectrics is discussed in this paper. The novel scheme retains the structure of the classic (2,4) technique; however, it incorporates difference operators that ensure low error levels at desired frequency bands and, therefore, guarantee more reliable simulations. An optimization process is proposed, which leads to enhanced approximations by requiring the minimization of phase and amplitude errors. In this manner, accuracy improvement without modifying the entailed computational burden is succeeded.

[C.12] T. T. Zygiridis, K. I. Petras, and T. D. Tsiboukis, "A generic study of human exposure to wireless systems: evaluation of power absorption and thermal effects," ***16th COMPUMAG Conference on the Computation of Electromagnetic Fields*****, Aachen, Germany, June 24-28, 2007, pp. 549-550.**

In this paper, an integrated study regarding the effects emerging from exposure to microwave radiation is carried out. We numerically calculate the amount of electromagnetic power that is absorbed by human tissues, considering various exposure conditions and types of radiating sources. The results are compared to the guidelines proposed by international safety standards, while further insight is gained from the evaluation of the corresponding thermal effects. By solving the bioheat equation, temperature elevation is estimated and its relation to the dissipated power is established.

[C.11] K. P. Prokopidis, N. V. Kantartzis, T. T. Zygiridis, and T. D. Tsiboukis, "Modeling of dielectric properties of biological tissues by vector fitting," ***16th COMPUMAG Conference on the Computation of Electromagnetic Fields*****, Aachen, Germany, June 24-28, 2007, pp. 539-540.**

A novel application of the vector fitting (VF) technique is developed to calculate the Debye model parameters of biological tissues directly from measurement data. The proposed formulation is applied for several tissues and the relative error of the fitting is estimated in comparison with other fitting techniques. The present method is proved to be simple, accurate and instructive for biomedical and biotechnological applications involving nanopulses.

[C.10] T. V. Yioultsis, T. I. Kosmanis, T. T. Zygiridis, E. P. Kosmidou, A. Pyrpasopoulou, T. D. Xenos, N. J. Farsaris, V. Kotoula, P. M. Hytiroglou, G. Karkavelas, I. N. Magras, and T. D. Tsiboukis, "A com-

bined computational and experimental investigation of nonthermal biological effects on prenatal development due to radiation from low power microwave antennas," ***6th WSEAS International Conference on Applied Informatics and Communications*****, Elounda, Greece, August 18-20, 2006, pp. 323-327.**

This is an integrated study of the biological effects of pulse-modulated very low power density microwave radiation. It employs a combination of a computational model of the rat and extensive in vivo experiments on rat embryos, during embryogenesis and organogenesis. The whole investigation is further enhanced via an immunological and chemical investigation of the rats' organs. The whole study is one of the first to combine results obtained by the computational, the experimental and the biomolecular investigations and attempts a discussion on existing standards for protection from low power density, long-term electromagnetic field exposure.

[C.9] T. T. Zygiridis, E. P. Kosmidou, K. P. Prokopidis, N. V. Kantartzis, C. S. Antonopoulos, K. Petras, and T. D. Tsiboukis, "Numerical modeling of an indoor wireless environment for the performance evaluation of WLAN systems," ***15th COMPUMAG Conference on the Computation of Electromagnetic Fields*****, Shenyang, China, June 26-30, 2005, vol. III, pp. 210-211.**

The performance of wireless local area networks (WLANs) in a typical office environment is numerically investigated in this paper. A two-dimensional (2-D) finite-difference time-domain (FDTD) model is developed, in order to simulate the complex phenomena governing wave propagation within the indoor structure. This study attempts to assess specific WLAN capabilities – such as power coverage – when operating at different frequency bands (2.44, 5.25 or 5.80 GHz). By additionally calculating several channel parameters, which describe multipath fading and time dispersion, a useful numerical model for radio channel characterization and WLAN design optimization is derived.

[C.8] T. T. Zygiridis and T. D. Tsiboukis, "Design of optimized FDTD schemes for the accurate solution of EM problems," ***15th COMPUMAG Conference on the Computation of Electromagnetic Fields*****, Shenyang, China, June 26-30, 2005, vol. II, pp. 120-121.**

Using spatial operators with various stencil sizes, we design two-dimensional (2-D) finite-difference time-domain (FDTD) schemes, capable of minimizing dispersion errors according to problem-specific requirements. Their algorithmic performance is optimized by requiring the minimization of an error estimator – derived from Maxwell's equations– at pre-selected frequency points. Accuracy improvement is also ensured irrespective of the propagation angle, through the trigonometric-series expansion of the estimator. Contrary to standard approaches, the design procedure is proven to fully exploit the potential of higher-order operators, as the developed techniques attain significantly lower error levels without practically increasing the computational cost.

[C.7] N. V. Kantartzis, T. T. Zygiridis, and T. D. Tsiboukis, "An unconditionally stable higher-order ADI-FDTD technique for the dispersionless analysis of generalized 3-D EMC structures," ***14th COMPUMAG Conference on the Computation of Electromagnetic Fields*****, Saratoga Springs, New York, U.S.A., July 13-17, 2003, vol. I, pp. 148-149.**

An enhanced higher-order 3-D ADI-FDTD algorithm for the accurate and unconditionally stable modeling of complex curvilinear EMC problems, is introduced in this paper. The new technique launches a topologically-consistent family of non-standard concepts which eliminate the serious dispersion errors of the usual ADI-FDTD scheme as time-step increases, and cancel its strong dependence on cell shape or mesh resolution. Thus, temporal increments can greatly exceed the Courant limit with superior stability and convergence levels. To optimize computing, higher-order curvilinear PML absorbers are also developed. Theoretical analysis, along with the numerical verification of diverse structures reveal that the proposed method is highly precise, subdues the vector-parasitic mechanisms of the ADI approach and achieves significant computational savings.

[C.6] T. T. Zygiridis and T. D. Tsiboukis, "A dispersion-reduction scheme for the higher-order (2,4) FDTD method," ***14th COMPUMAG Conference on the Computation of Electromagnetic Fields*****, Saratoga Springs, New York, U.S.A., July 13-17, 2003, vol. I, pp. 146-147.**

A technique for the suppression of phase inaccuracies due to numerical dispersion in the (2,4) finite-difference time-domain (FDTD) method is developed and evaluated in the present paper. Based on a systematic choice of the material parameters, the optimization procedure is combined with the fourth-order accurate spatial operators in order to substantially enhance the finite difference approach. Although the corrected values are extracted for a single frequency, improvement can be verified for a wide frequency range by theoretical and experimental results. The efficiency of the proposed practice is finally exhibited through a variety of two and three dimensional test problems.

[C.5] T. Zygiridis and T. Tsiboukis, "Phase error reduction in general FDTD methods via optimum configuration of material parameters," ***JAPMED '03, Proceedings of the 3rd Japanese-Mediterranean Workshop on Applied Electromagnetic Engineering for Magnetic and Superconducting Materials & 3rd Workshop on Superconducting Flywheels*****, May 19-21, 2003, Athens, Greece, pp. 73-74.**

In this paper, the numerical dispersion inherent in the standard and higher order FDTD methods is treated by a simple, yet efficient correction technique. The proposed procedure, which is developed for any scheme of arbitrary order in space, achieves considerable reduction of the induced phase errors by modifying the parameters of the modeled materials. Apart from improving the overall accuracy in single-frequency problems, it can be used successfully for wideband simulations as well. The numerical tests concentrate on the enhancement attained in the case of the (2, 4) FDTD algorithm.

[C.4] T. T. Zygiridis, N. V. Kantartzis, T. V. Yioultsis, and T. D. Tsiboukis, "Higher-order approaches of FDTD and TVFE methods for the accurate analysis of fractal antenna arrays," ***IEEE CEFC 2002, The Tenth Biennial IEEE Conference on Electromagnetic Field Computation*****, Perugia, Italy, June 16-19 2002, p. 150.**

Higher order renditions of the finite-difference time-domain and the tangential vector finite element methods are developed in this paper for the precise modeling of fractal antenna arrays. In particular, the enhanced techniques efficiently predict the behavior of these structures, by computing their radiation patterns and scanning capabilities.

[C.3] T. T. Zygiridis, N. V. Kantartzis, and T. D. Tsiboukis, "Higher-order tangential vector finite elements for complicated 3-D antenna array structures," ***6th International Workshop on Finite Elements for Microwave Engineering – Antennas, Circuits and Devices*****, Chios, Greece, May 30 - June 1 2002, p. 56.**

Higher order tangential vector finite elements (TVFEs) are an efficient tool for the analysis of radiating structures, as they can properly simulate complex geometries and overcome the inaccuracies of low-order approximations. The TVFE method is commonly combined with periodic boundary conditions, when studying antenna arrays. However, the modeling of the entire structure is necessary, in case of non-uniforms excitations or irregular spatial arrangements. Here, we propose a second-order TVFE approach for studying the radiation properties of diverse antenna arrays, including electrically large structures and examination of beam steering capabilities.

[C.2] T. V. Yioultsis, T. I. Kosmanis, E. P. Kosmidou, T. T. Zygiridis, N. V. Kantartzis, T. Xenos, and T. D. Tsiboukis, "A comparative study of the biological effects of various mobile phone and wireless LAN antennas," ***13th COMPUMAG Conference on the Computation of Electromagnetic Fields,*** **Evian-les-bains, France, July 2-5, 2001, pp. 100-101.**

This paper presents a comprehensive analysis of the electromagnetic radiation and its impact on human beings, due to the use of various types of commonly used mobile phones and communication antennas. This is one of the first studies that deal with a wide range comparative investigation of modern cell phones, unlike the majority of existing work, which do not extend beyond the obsolete generic phone case. The rather severe, although overlooked, case of wireless LAN antennas is also considered, due to their increasing use and the large times of exposure associated with them.

[C.1] N. V. Kantartzis, T. T. Zygiridis, and T. D. Tsiboukis, "A nonstandard higher-order FDTD algorithm for 3-D arbitrarily and fractal-shaped antenna structures on general curvilinear lattices," ***13th COMPUMAG Conference on the Computation of Electromagnetic Fields,*** **Evian-les-bains, France, July 2-5, 2001, pp. 24-25.**

A novel higher-order FDTD technique for the accurate analysis of fractal and arbitrarily shaped antennas in 3D curvilinear coordinates is presented in this paper. The generalized methodology, which utilizes conventional and non-standard schemes, introduces compact differencing to treat the widened stencils and develops enhanced PMLs. Furthermore, a mesh expansion algorithm along with new temporal integrators are systematically incorporated. Distinct from various 3D structures, numerical investigation focuses on fractal arrays whose self-similarity and inherent symmetry render them deal for multiband, small-sized, contemporary designs. Results indicate that the proposed technique eliminates decisively the classical dispersion errors in every coordinate system and provides very precise antenna patterns.

OTHER PUBLICATIONS

[O.1] T. Zygiridis, H. Pallas, and T. Tsiboukis, "Composition of electromagnetic radiation patterns for the area of the city of Serres," ***Bulletin of the Panhellenic Association of Mechanical-Electrical Engineers,*** **issue 368, pp. 56-60, June 2004 (in Greek).**

This work records the electromagnetic power density within the urban area and the surrounding rural area of the city of Serres, Greece. It is based on results from numerous measurements at preselected points, and the post-processing of the corresponding data. The evaluation of the measurements is based on comparisons against generally accepted limits of safe exposure. Furthermore, we present results from computer simulations, performed by suitable software for radio coverage studies, and we also investigate the possibility of alternative placements of the city's antenna park.

[O.2] Eleni Diamantidou and Theodoros Zygiridis, "Software for the simulation of metamaterial characteristic properties," 8th ***Conference for Electrical and Computer Engineering Students*****, pp. 211-214, Patra, 3–5 April 2015 (in Greek).**

In this work, a software that exhibits distinct properties of a metamaterial slab, when electromagnetic waves travel through them, is developed in Matlab, along with a suitable graphical user interface. Simulations are performed with a dispersive 2D FDTD approach, which facilitates the study of the time evolution of the pertinent phenomena. The software allows the introduction of either appoint source or a Gaussian beam, with the latter allowing the control of its incidence angle.

[O.3] Eleni Diamantidou and Theodoros Zygiridis, "Software for the calculation and design of antennas array radiation patterns," ***9th Conference for Electrical and Computer Engineering Students*****, Chania, Crete, 22-24 April, 2016 (in Greek).**

In this paper we describe the development and capabilities of a Matlab-based graphical user interface, which calculates and displays the radiation patterns produced by a variety of antenna array structures. The latter are necessary in various contemporary applications, when certain radiation characteristics not provided by individual antenna elements are necessary. The developed software can be used for educational as well as research purposes, given that it enables fast investigation of fundamental radiation characteristics of standard and modern configurations.