2012

Efficient Evaluation of MoM Matrix Elements Using CPU and/or GPU

Kolundzija, B.M., Zoric, D.P., "Efficient evaluation of MoM matrix elements using CPU and/or GPU", Proc. of EuCAP 2012: 6th European Conference on Antennas and Propagation, 26-30 March 2012., Prague, Czech Republic, pp. 702-706, ISBN: 978-1-4577-0919-7, DOI: 10.1109/EuCAP.2012.6206020

Link to Publication

Abstract: Recent development of GPU parallelized, out-of-core matrix solver enables dramatic reduction of matrix solution time, so that matrix fill time in problems solved by Method of Moments (MoM) applied to Surface Integral Equations (SIEs), becomes dominant. The paper proposes an efficient algorithm for GPU accelerated calculation of matrix elements. The numerical experiments show acceleration from 1.5 times to 21 times, depending on order of expansions and level of integral accuracy.

Efficient Modeling of Composite Material Structures Based on CPU/GPU Parallelized Symmetrical MoM/SIE Matrix Solution

Kolundzija, B.M., Olcan, D.I., Zoric, D.P., "Efficient modeling of composite material structures based on CPU/GPU parallelized symmetrical MoM/SIE matrix solution", Proc. of 28th Annual Review of Progress in Applied Computational Electromagnetics (ACES 2012), Columbus, OH, USA, April 10-14, 2012, pp. 443-448.

Link to Publication

Abstract: -

On Real-Time Method-of-Moments Analysis Using Graphics Processing Unit

Zubac, Z.B., Olcan, D.I., Djordjevic, A.R., Zoric, D.P., Kolundzija, B.M., "On real-time method-of-moments analysis using graphics processing unit", Proc. of 2012 IEEE International Symposium on Antennas and Propagation and USNC-URSI National Radio Science Meeting, Chicago, IL, USA, July 8-14, 2012, ISBN: 978-1-4673-0460-3, ISSN: 1522-3965, DOI: 10.1109/APS.2012.6348068

Link to Publication

Abstract: We discuss the present-day limits of real-time MoM analysis using one graphics processing unit on a personal computer. A square plate scatterer with pulse-expansion MoM is used for illustration. The results show that for less than 0.3 s, which is considered as practically real-time, MoM analysis of problems with about 500 complex unknowns can be solved using simplest available CUDA GPU (8400 GS), and up to about 2500 unknowns can be solved using higher tier GPU (GTX 560).

Comparison of Differential Evolution and Cuckoo Optimization for Antenna Array Problems

Stevanetic, M.M., Olcan, D.I., Kolundzija, B.M., "Comparison of differential evolution and cuckoo optimization for antenna array problems", Proc. of 2012 IEEE International Symposium on Antennas and Propagation and USNC-URSI National Radio Science Meeting, Chicago, IL, USA, July 8-14, 2012, ISBN: 978-1-4673-0460-3, ISSN: 1522-3965, DOI: 10.1109/APS.2012.6348981

Link to Publication

Abstract: We present comparison of Differential evolution and Cuckoo search for optimization of linear antenna array of Hertzian dipoles. The amplitudes of excitations are optimized in order to minimize sidelobe levels. The results are compared for 42 elements array, with 20 optimization variables. The conclusion is that classic Differential evolution provides better convergence for this particular problem than standard Cuckoo search.

2011

An Example of Suppression of Spurious Stop-Bands of EBG Band-Stop Filter

Nesic, D.A., Kolundzija, B.M., "An Example of Suppression of Spurious Stop-Bands of EBG Band-Stop Filter", Microwave Review, Belgrade 2011, vol. 17, number 2, pp. 13-16

Link to Publication

Abstract: Based on the well known theory of infinite periodic structures, analytical theory of EBG (electromagnetic band gap) cells suppressing 6 higher (spurious) stop-bands is developed. Using such cells in a cascade the straight-forward procedure for design of the corresponding EBG band-stop filter is proposed, with possibility to control the width and the depth of the stopband. The analytical theory is confirmed by the EM simulation of the filter realized in the microstrip technology.

Efficient Analysis of Large Scatterers by Physical Optics Driven Method of Moments

Tasic, M.S., Kolundzija, B.M., "Efficient Analysis of Large Scatterers by Physical Optics Driven Method of Moments", IEEE Transactions on Antennas and Propagation, vol.59, issue 8, pp. 2905-2915, Aug 2011.

Link to Publication

Abstract: A new iterative procedure is presented that enables method of moment (MoM) solution of scattered field from electrically large and complex perfectly conducting bodies using significantly reduced number of unknown coefficients. In each iteration the body is excited by a plane wave and by the currents, which are obtained as an approximate solution in the previous iteration. The physical optics (PO) and modified PO techniques are used to determine the PO and the correctional PO currents, which are expressed in terms

of original MoM basis functions and grouped into macro-basis functions (MBFs). Weighting coefficients of all MBFs are determined from the condition that mean square value of residuum of original MoM matrix equation is minimized. The iterative procedure finishes when the residuum decreases below the maximum allowed value. The accuracy and efficiency of the proposed method are illustrated on two examples: cube scatterer and airplane scatterer. Since the construction of MBFs by PO and modified PO techniques ensures fast convergence to the original MoM solution, the method is named PO driven MoM.

Analysis of Electromagnetic Systems Using Graphics Processing Units

Maric, S.M., Olcan, D.I., Kolundzija, B.M., "Analysis of Electromagnetic Systems Using Graphics Processing Units", Proceedings of the 5th European Conference on Antennas and Propagation (EUCAP), April 10-15, 2011. Rome, Italy, pp. 1584-1588, ISBN: 978-1-4577-0250-1

Link to Publication

Abstract: We present results for numerical analysis of two electromagnetic problems by using method of moments implemented on multi-core graphics processing units. In order to investigate the accuracy and the efficiency of graphical processing units for electromagnetic analysis, numerical results are compared to results obtained by commercial EM software WIPL-D and Matlab.

Application of Surface Equivalence Theorem for Characterization of Electromagnetic Shielding Efficiency

Mrdakovic, B.LJ., Kolundzija, B.M., "Application of Surface Equivalence Theorem for Characterization of Electromagnetic Shielding Efficiency", 2011 IEEE International Symposium on Antennas and Propagation and USNC/URSI National Radio Science Meeting (AP-S 2011), July 3-8, 2011, Spokane, Washington, USA, pp. 1106-1109, ISSN: 1522-3965

Link to Publication

Abstract: We present one application of using of surface equivalence theorem for calculation the electromagnetic shielding efficiency. The problem we concerned is conductive spherical shell illuminated by an incident plane wave. The model is simulated by using MoM SIE based code, where theorem of surface equivalence is used in order to minimize propagation of numerical error through walls of the cavity. Simulation results are compared with analytical solution, and very good matching is obtained.

Higher Order Diakoptic FEM-MoM Analysis of Electrically Large and Complex Periodic Electromagnetic Scatterers

Olcan D.I., Ilic M.M., Notaros B.M., Kolundzija B.M., Djordjevic A.R., "Higher Order Diakoptic FEM-MoM Analysis of Electrically Large and Complex Periodic Electromagnetic Scatterers", 2011 USNC-URSI National Radio Science Meeting, Boulder, Colorado, January 5-8, 2011. (printed in abstract)

Link to Publication

Abstract: -

2010

Hierarchical Simplex Optimization Applied to Antenna Array Problem

Olcan, D.I., Kolundzija, B.M., "Hierarchical Simplex Optimization Applied to Antenna Array Problem", Proceedings of EuCAP 2010, Barcelona, Spain, April 12-16, 2010.

Link to Publication

Abstract: We present results for hierarchical optimization based on uniform random search and Nelder-Mead simplex algorithms. The proposed optimization is applied to one antenna array design problem. The obtained results show that the hierarchical optimization can lead to more efficient optimization than non hierarchical approach in terms of minimal number of electromagnetic solver calls.

Adaptive Refinement of Higher Order Method of Moment Applied to Surface Integral Equations

Kostic, M.M., Kolundzija, B.M., "Adaptive Refinement of Higher Order Method of Moment Applied to Surface Integral Equations", Proceedings of EuCAP 2010, Barcelona, Spain, April 12-16, 2010.

Link to Publication

Abstract: Optimal choice of expansion orders for currents is of crucial importance for efficient use of higher order basis functions in method of moment solution of surface integral equations. In this paper it is shown that accuracy of a solution for a given set of expansion orders can be estimated using the residuum of the system of linear equations, obtained by increasing expansion orders by one. Based on such estimation, an iterative procedure is proposed for determination of a minimum set of basis functions needed for given accuracy. In the first iteration 1st order is adopted for all patches. In each iteration patches having insufficient order of current expansion are detected and their orders are increased in the next iteration. Iterative procedure is stopped when a sufficient order of current expansion is detected. The method is illustrated on examples of a cube and a fighter airplane scatterer.

Comparison of Different Strategies for Conversion of Triangular Mesh into Quadrilateral Mesh

Kolundzija, B.M., Kostic, M.M., Mrdakovic, B.Lj., Sumic, D.S., "Comparison of Different Strategies for Conversion of Triangular Mesh into Quadrilateral Mesh", Proceedings of EuCAP 2010, Barcelona, Spain, April 12-16, 2010.

Link to Publication

Abstract: EM simulation of complex CAD models, described by a quadrilateral mesh, using higher order method of moments offers significant benefits in terms of computational efficiency. In order to exploit these benefits, a robust algorithm for automatic generation of a well-structured quadrilateral mesh is needed. The paper gives new variants of algorithm for quadrilateral meshing, which starts from triangular mesh obtained by a well developed triangular meshing algorithm, then eliminates excess details, and finally re-meshes triangles into quadrilaterals. Three new strategies of merging neighbouring triangles into quadrilaterals are proposed, based on: a) angle based criterion (ABC), b) shaped quality factor criterion (SQFC), and differential SQFC (DSQFC). Robustness of different strategies is investigated on example of Apache helicopter CAD model, giving slight advantage to DSQFC.

Improvement of Far-Field ApproximationIn EM Modeling of Electrically Large Structures

Kolundzija, B.M., Sumic, D.S., "Improvement of Far-Field ApproximationIn EM Modeling of Electrically Large Structures", 26th Annual Review of Progress in Applied Computational Electromagnetics (ACES), Tampere, Finland, pp. 178-182, April 26 - April 29, 2010.

Link to Publication

Abstract: -

Diakoptic Higher-Order FEM-MoM Approach

Olcan, D.I., Ilic, M.M., Notaros, B.M., Kolundzija, B.M., Djordjevic, A.R., "Diakoptic Higher-Order FEM-MoM Approach", IEEE Antennas and Propagation Society International Symposium, APS/URSI '10, Toronto, Ontario, Canada, July 11- July 27, 2010.

Link to Publication

Abstract: We have briefly presented the theory behind the diakoptic higher-order MoM-SIE/FEM approach, as well as numerical results that prove the concept of the diakoptic MoM/FEM hybridization. The work in progress is to apply the diakoptic higher-order MoM/FEM approach to the EM problems that are at the limits of available memory and CPU time consumption of standard computers.

Optimized Quadrilateral Mesh for Higher Order Method of Moments Based on Triangular Mesh Decimation

Kostic, M.M., Kolundzija, B.M., Sumic, D.S., Mrdakovic, B.Lj., "Optimized Quadrilateral Mesh for Higher Order Method of Moments Based on Triangular Mesh Decimation", IEEE Antennas and Propagation Society International Symposium, APS/URSI '10, Toronto, Ontario, Canada, July 11- July 27, 2010.

Link to Publication

Abstract: The effectiveness of the proposed algorithm is illustrated on the model of a crossed exponentially tapered slots antenna (XETS). We are comparing mesh, computed gain, required memory and simulation time of the antenna half-model (one symmetry plane is exploited), meshed with and without mesh decimation (Figs. 4 and 5). The mesh decimation was allowed to enlarge average size of mesh elements maximally 2 times. Overlay of the E-plane and H-plane gain patterns are displayed in Fig. 6. As we can see from the diagram, the results match excellently. Number of unknowns, required memory and simulation time are given in Tab. 1. Applied mesh decimation decreased the number of mesh elements used to represent the model significantly. On one hand, larger mesh elements with 2nd order basis functions were more frequently used than the small elements with rooftops. On the other hand, many of the new mesh elements replaced several smaller elements from the original mesh, but were still small enough to adequately use rooftops. The combination of these effects provided about 30% reduction of number of unknowns, which is equivalent to about two times less memory used, and about 2.15 times faster simulation. Simulations were performed with WIPL-D Pro 8.0 on a PC with a 2.66 GHz Intel Core 2 Quad CPU.

Adaptive Refinement of Higher Order Method of Moment Based on Separate Testing of Patch Residuum along its Axes

Kostic, M.M., Kolundzija, B.M., "Adaptive Refinement of Higher Order Method of Moment Based on Separate Testing of Patch Residuum along its Axes", IEEE Antennas and Propagation Society International Symposium, APS/URSI '10, Toronto, Ontario, Canada, July 11- July 27, 2010.

Link to Publication

Abstract: Based on the investigation of the quality estimation of higher order MoM solution of SIEs via the residuum of the matrix equation, the paper proposes an automated procedure for determination of a minimum set of basis functions, which is appropriate for patches of arbitrary sizes and shapes. The results presented for cube and fighter scatterer show that number of unknowns can be significantly reduced when compared to a choice based on electrical size of patches.

EBG Band-Stop Filter with Suppression of 3 Spurious Stop-Bands

Nesic, D.A., Kolundzija, B.M., "EBG band-stop filter with suppression of 3 spurious stop-bands", International Workshop on Antenna Technology (iWAT), Digital Object Identifier: 10.1109/IWAT.2010.5464680, Lisbon, Feb. 2010.

Link to Publication

Abstract: Based on the well known theory of infinite periodic structures, analytical theory of EBG (electromagnetic band gap) cells suppressing 3 higher (spurious) stop-bands is developed. Using such cells in a cascade the straight-forward procedure for design of the corresponding EBG band-stop filter is proposed, with possibility to control the width and the depth of the stop-band. The analytical theory is confirmed by the EM simulation of a filter realized in the microstrip technology and by measurement of the fabricated model.

2009

Multilevel Fast Multipole Method for Higher Order Basis Functions Implemented in WIPL-D Pro

Kolundzija, B.M., Sumic, D., "Multilevel fast multipole method for higher order basis functions implemented in WIPL-D Pro", 3rd European Conference on Antennas and Propagation, EuCAP 2009, pp. 2136-2140, 2009.

Link to Publication

Abstract: An overview of the variant of multilevel fast multipole method (MLFMM) applied in WIPL-D Pro 3D EM solver is given in this paper. MLFMM is applied to higher order basis functions (HOBFs), where grouping of basis functions is done in two levels, and far-field approximation is appropriately applied to distant groups. Maximally orthogonalized HOBFs are used because of their property of improving the conditioning of the method of moments (MoM) dense system of linear equations. Numerical results demonstrate the effects of the proposed approach in terms of dramatically reduced memory requirements (up to 100 times) compared to the full MoM simulation of electrically large structures.

Optimum Choice of Currents' Expansion Order in MLFMM Algorithm for Electromagnetic Scattering

Kolundzija, B.M., Pavlovic, M.S., Mrdakovic, B., "Optimum choice of currents' expansion order in MLFMM algorithm for electromagnetic scattering", IEEE Antennas and Propagation Society International Symposium, APS/URSI '09, Digital Object Identifier: 10.1109/APS.2009.5171734, 2009.

Link to Publication

Abstract: The goal of this paper is to investigate how accuracy and efficiency of MLFMM of a given level depends on the order of approximation. We performed this investigation using a corner scatterer of side 20 lambda as a benchmark. We chose this model because its RCS results show several distinctive lobes in specific directions and at different levels, calculation of which is challenging even for direct MoM. Selected results are presented indicating the optimal choice of simulation parameters.

Efficient EM Modeling Based on Conversion of Triangular Mesh into Quadrilateral Mesh

Kolundzija, B.M., Mrdakovic, B.L., Kostic, M.M., Sumic, D.S., "Efficient EM modeling based on conversion of triangular mesh into quadrilateral mesh", International Conference on Electromagnetics in Advanced Applications, ICEAA '09, Digital Object Identifier: 10.1109/ICEAA.2009.5297630, pp. 47-50, Torino, 2009.

Link to Publication

Abstract: For efficient EM modeling of real life structures it is very often needed to import these structures from CAD formats. Final step in this procedure is meshing of imported structure. Techniques and algorithms for meshing into triangles are much more developed than those into quadrilaterals. The paper presents novel

and efficient technique for conversion of triangular mesh into quadrilateral mesh. Results obtained by MoM/SIE applied to two types of meshes are compared for both, flat and curved surfaces.

2008

Diakoptic Analysis of Complex 3-D Electromagnetic Systems

Djordjevic, A.R., Olcan, D.I., Kolundzija, B.M., Mosig, J.R., Stevanovic, I.M., "Diakoptic analysis of complex 3-D electromagnetic systems", COST IC0603 joint workshop with COST 297, Limassol/Nikosia, Cyprus, April 9-11, 2008. – presentation only

Link to Publication

Abstract: -

Diakoptic Surface Integral-Equation Formulation Applied to Large Antenna Arrays

Olcan, D.I., Stevanovic, I.M., Kolundzija, B.M., Mosig, J.R., Djordjevic, A.R., "Diakoptic surface integral-equation formulation applied to large antenna arrays", IEEE Antennas and Propagation Society International Symposium, AP-S 2008, Digital Object Identifier: 10.1109/APS.2008.4619635, 2008.

Link to Publication

Abstract: Diakoptic surface integral-equation formulation is used to efficiently simulate large antenna arrays, modeled as 3D EM structures. The significant accelerations and storage reductions are achieved, when compared to the classical MoM-SIE. Both near field and far field (radiation pattern) of the arrays, calculated using DSIE, match the results calculated using MoM-SIE very well (the maximal relative error is about 1% calculated with respect to peak values). The future work will include diakoptic boundaries with common walls, application of DSIE to optimization of complex EM structures and calculation of EM time-domain responses, and hybridization with other numerical techniques such as finite elements and volume integral-equation formulation.

Diakoptic Surface Integral-Equation Formulation Applied to 3-D Scattering Problems

Olcan, D.I., Stevanovic, I.M., Kolundzija, B.M., Mosig, J.R., Djordjevic, A.R., "Diakoptic Surface Integral-Equation Formulation Applied to 3-D Scattering Problems", 24th Annual Review of Progress in Applied Computational Electromagnetics (ACES), Niagara Falls, Canada, pp. 676-681, March 30 - April 4, 2008

Link to Publication

Abstract: -

2007

Solving Time-Harmonic EM Problems Using Boundary Conditions for Normal Field Componen ...

Kolundzija, B.M., Petrovic, V.V., "Solving Time-Harmonic EM Problems Using Boundary Conditions for Normal Field Components", Proc. IEEE AP-S Int. Symp., pp. 4016-4019, CD ROM Edition: 1008.pdf, Honolulu, Hawaii, USA, July 2007.

Link to Publication

Abstract: According to the uniqueness theorem for time-harmonic electromagnetic (EM) field, the field inside a finite domain v is uniquely determined by tangential electric (Et) or magnetic (Ht) field on the bounding surface S, except on resonant frequencies of the domain. This leads to solution methods that enforces either Et, or Ht, or both tangential components on S, e.g., in electric-, magnetic-, or combined-field integral equations (EFIE, MFIE, CFIE) methods. Some methods, e.g., augmented magnetic-field integral equation (AMFIE) method, employ normal component of the field too, but only in addition to tangential component, to avoid spurious resonant solutions. This paper shows that time-harmonic EM problems can be solved by enforcing boundary conditions for normal field components (En and Hn) only.

Single-Minima and Multiminima Optimization Algorithms Applied to Electromagnetic Problems

Kolundzija, B.M., Olcan, D.I., "Single-minima and multiminima optimization algorithms applied to electromagnetic problems", Conference Digest URSI 2007, Ottawa, ON Canada, July 22-26, 2007.

Link to Publication

Abstract: -

2006

PO Driven Iterative Least Square Solution of MFIE

Tasić M. S., Branko. M. Kolundžija B. M., "PO Driven Iterative Least Square Solution of MFIE", Proc. of IEEE/ACES Conf. on Wireless Comm. and Appl. Commput. Electromag., pp. 470-475, (CD ROM Edition: s15p06.pdf), Miami, Florida, 12-16 March 2006.

Link to Publication

Abstract: -

Solution of Large Complex Problems in Computational Electromagnetics using Higher Order Basis in MoM with an Out-of-Core Solver

Yuan M., Taylor M. C., Sarkar T. K., Kolundzija B. M., "Solution of Large Complex Problems in Computational Electromagnetics using Higher Order Basis in MOM with an Out-of-Core Solver", Proc. IEEE AP-S Int. Symp., pp. 115 – 118, (ISBN: 1-4244-123-2, CD ROM Edition: 0028.pdf), Albuquerque, USA, 9-14 July 2006.

Link to Publication

Abstract: Limitations of current numerical techniques have been outlined. The objective of this article is to point out that these statements of limitations may be applicable for the methodologies like FEM, FDTD and the hybrid MOM technique that the author has considered. Indeed, for such techniques even an analysis of a single Vivaldi element is a formidable problem. However, if one uses a higher order basis in a surface integral equation and solves this using the conventional method of moments with the commercially available code WIPL-D then it becomes clear that even the 2times2 Vivaldi array consisting of 12 elements actually can be solved on a laptop DELL INSPIRON 5150 computer using approximately 2 GB of RAM. With other techniques, such a small computing resource may only be able to model a single element. For complex composite metallic and dielectric structures, the PMCHWT formulation using a higher order basis is an efficient way to solve challenging computational electromagnetic problems

PO Driven Iterative Galerkin Solution of Field Integral Equations

Tasić M. S., Kolundžija B. M., "PO Driven Iterative Galerkin Solution of Field Integral Equations", Proc. IEEE AP-S Int. Symp., pp. 4073-4076, (ISBN: 1-4244-123-2, CD ROM Edition: 0958.pdf), Albuquerque, USA, 9-14 July 2006.

Link to Publication

Abstract: This paper introduces a PO-driven iterative Galerkin solution of field integral equations. The procedures can be applied in analysis of perfectly conducting bodies suited in incident electromagnetic field. Computer implementation of the procedures is memory efficient since it is no longer necessary to store matrix of dimension n times n, where n is the number of unknowns. Numerical examples show fast convergence (10-30 iterations). Results obtained with single-cycle procedure for both near field and RCS show excellent agreement with results obtained by Galerkin method

On the Efficiency of Particle Swarm Optimizer when Applied to Antenna Optimization

Olcan D. I., Golubovic R. M., Kolundzija B. M., "On the Efficiency of Particle Swarm Optimizer when Applied to Antenna Optimization", Proc. IEEE AP-S Int. Symp., pp.3297-3300, (ISBN: 1-4244-123-2, CD ROM Edition: 0775.pdf), Albuquerque, USA, 9-14 July 2006.

Link to Publication

Abstract: This paper presents the results for three different antenna optimization problems that are found using the particle swarm optimizer (PSO). The outcomes found with PSO are compared to the outcomes found

with other optimization algorithms to estimate the efficiency of PSO. The first problem is finding the optimal position of the feeding probe in a radiating rectangular waveguide. The second problem is finding the maximal forward gain of a Yagi antenna. The third problem is finding the optimal feeding of a broadside antenna array. The optimization problems have 2, 6, and 20 optimization variables respectively

Adaptive Higher Order Modeling of Antennas Placed on Large Platforms

Kolundzija B. M., Sumic D. S., "Adaptive Higher Order Modeling of Antennas Placed on Large Platforms", Proc. EuCAP Int. European Conf., (ISBN: 92-9092-937-5, CD ROM Edition: 361196do.pdf), Nice, France, 6 - 10 Nov. 2006.

Link to Publication

Abstract: -

2005

Comparison of NSGA and ELM for finding the Pareto Front of Multiple-Criteria Antenna Optimization Problem

Olcan, D.I., Kolundzija, B.M., "Comparison of NSGA and ELM for finding the Pareto front of multiple-criteria antenna optimization problem", Proc. IEEE AP-S Int. Symp., vol. 2A, pp. 53 – 56, Washington, 3-8 July 2005

Link to Publication

Abstract: We compared two optimization algorithms for finding the Pareto front of the one-antenna optimization problem. The first applied algorithm is nondominated sorting genetic algorithm (NSGA) that has proved itself over other variants of GA for finding the Pareto front by the mean of effectiveness. The second applied algorithm is the multiminima optimization algorithm based on the estimation of local minima (ELM), which has been restarted for different weighting factors used for forming the single cost-function. The comparison between these two algorithms is done in the sense of the total number of iterations (EM solver runs) needed for finding a good estimation of the Pareto front. The goal was to find the Pareto front in the optimization of a Yagi antenna for the highest possible forward gain and lowest reflection coefficient in the frequency range 295-305 MHz.

Optimal Weights of Basis Functions for Efficient Iterative Solution of Surface integral Equations

Kolundzija, B.M., Sumic, D.S., "Optimal weights of basis functions for efficient iterative solution of surface integral equations", Proc. IEEE AP-S Int. Symp.,vol. 4A, pp. 284 – 287, Washington, 3-8 July 2005

Link to Publication

Abstract: The goal of this paper is to propose a simple and efficient preconditioning technique based on optimal choice of weights of basis functions, which significantly improves the convergence of iterative solvers applied to surface integral equations (SIE). The significant improvement is demonstrated using the conjugate gradient method (CGM) applied to electric field integral equations (EFIE) and Poggio-Miller-Chang-Harrington-Wu (PMCHW) equations.

Higher Order Basis Functions for Quadrilateral Boundary Elements: State of Art and Perspective

Kolundzija B. M., "Higher Order Basis Functions for Quadrilateral Boundary Elements: State of Art and Perspective", Proc. IEEE AP-S Int. Symp., Washington, 3-8 July 2005

Link to Publication

Abstract: -

Efficient Iterative Solution of Surface Integral Equations Based on Maximally Orthogonalized High Order Basic Functions

Sumic, D. S., Kolundzija, B. M., "Efficient Iterative Solution of Surface Integral Equations Based on Maximally Orthogonalized Higher Order Basis Functions", Proc. IEEE AP-S Int. Symp., Washington, 3-8 July 2005

Link to Publication

Abstract: The goal of this paper is to propose maximally orthogonalized higher order basis functions that automatically satisfy the continuity equation at the boundary element's (BE) edges. As a result, orthogonality was imposed between all basis functions except between the two lowest order functions. Numerical results show that the proposed higher order basis functions enable convergence as fast as low order basis functions, which qualifies higher order basis functions for application with iterative solvers.

A PO Driven Iterative Solution of MFIE for Large Scatterers

Tasic, M.S., Kolundzija, B.M., "A PO Driven Iterative Solution of MFIE for Large Scatterers", Proc. 7th TELSIKS (Int. Conf. on Telecomunications in Modern Satellite, Cable and Broadcasting Services), vol. 1, pp. 24-27, Niš, 28-30 Sept. 2005

Link to Publication

Abstract: Despite enormous expansion of numerical techniques in electromagnetics, analysis of large scatterers still is a challenging task. MoM is not sufficiently efficient at high frequencies, PO and GTD based techniques give acceptable results only for certain class of problems, while hybrid techniques still evolve. In this paper we present a new method for analysis of large scatterers, based on iterative solution of MFIE. Simple concept and low memory requirements of the method are followed by reasonable accuracy of results.

Power Conservation in Method of Moments and Finite-Element Method for Radiation Problems

Kolundzija, B.M., Petrovic, V.V., "Power Conservation in Method of Moments and Finite-Element Method for Radiation Problems", IEEE Trans. on Antennas and Propagat., vol. 53, no. 8, part 2, pp. 2728 – 2737, Aug. 2005

Link to Publication

Abstract: Conservation of energy and power can be, under certain conditions, exactly satisfied in an approximate numerical method. In this paper necessary and sufficient conditions for this property are rigorously derived for the finite-element method (FEM) and the method of moments (MoM). Two boundary formulations of FEM (strong and weak) and three formulations of MoM (MoM/VIE, MoM/SIE for metallic and MoM/SIE for dielectric bodies) were considered for radiation problems in the frequency domain. The concept of error generators—fictitious generators that produce the difference between the approximate and the exact solution—was introduced to state the power conservation property from another aspect. It was proved that, for the appropriate governing equation and the “conjugated” inner product, power conservation is satisfied if and only if the Galerkin (or equivalent) method is used. However, power conservation is corrupted if an equivalence principle (surface or volume) is utilized in MoM to solve problems in inhomogeneous media. Examples are given to illustrate the power conservation and its possible advantages.

Efficient Analysis of Microwave Devices Based on Polygonal Modeling and WIPL-D Numerical Engine

Tasic, M.S., Kolundzija, B.M., "Efficient analysis of microwave devices based on polygonal modeling and WIPL-D numerical engine", Proc. of IEEE/ACES Conf. on Wireless Comm. and Appl. Commput. Electromag., pp. 94 – 97, Honolulu, 3-7 April 2005

Link to Publication

Abstract: Surface formulation of method of moments gives the best results in electromagnetic analysis when geometrical modeling is performed with quadrilateral patches. Quadrilateral modeling, however, can be very difficult. Many structures, e.g. different microwave devices, can be easily modeled using polygonal surfaces. This paper presents general method for conversion of polygonal model into quadrilateral model. Proposed method is illustrated on real microwave filter.

Into the Twilight Zone: How Does WIPL-D Perform in Quasistatics?

Sihvola, A., Sakar, T.K., Kolundzija, B., "Into the twilight zone: how does WIPL-D perform in quasistatics?", Proc. of IEEE/ACES Conf. on Wireless Comm. and Appl. Commput. Electromag., pp. 86 – 89, Honolulu, 3-7 April 2005

Link to Publication

Abstract: We focus on the question how well WLPL-D, a numerical code designed to tackle dynamical electromagnetic problems, can be applied to solving very low-frequency problems. In particular, the problem of the static polarizability of a dielectric sphere is calculated. This is done by enumerating the monostatic radar cross section of the object and taking the low-frequency limit. Peeling away the strong frequency dependence of the radar cross section, the remaining coefficient is proportional to the square of the static polarizability. The results show that there is around two decades of frequency range where the code works well and the situation is clearly in the quasistatic regime. In the example of a sphere of one-meter radius and relative permittivity 10, the low-frequency breakdown happens at around 10 kHz.

Extended Limits of WIPL-D on PCs

Sumic, D. S., Kolundzija, B. M., "Extended Limits of WIPL-D on PCs", Proc. of IEEE/ACES Conf. on Wireless Comm. and Appl. Commput. Electromag., Honolulu, 3-7 April 2005

Link to Publication

Abstract: In the process of electromagnetic modeling and simulation, one encounters various limits imposed by the hardware capabilities of modern computers. As the complexity or the electrical size of the problem grows, so does the need for faster processors and more RAM in order to make the analysis of such projects feasible. With the era of 64 bit computing at our door step, 4 GB is no longer the theoretical maximum addressable memory space on PC computers, which allows the analysis of demanding electromagnetic problems on every desktop. In this paper, several tests have been presented regarding the analysis of a cube of dimensions up to 30lambda times 30lambda times 30lambda. Significant advancements in modeling and analysis of electrically large structures in WIPL-D Pro code are the main focus. Tests include: running WIPL-D Pro code in the Windows and Linux 64-bit environments, employing 2 processors in parallel and speed comparisons between the latest and previous versions of the code

2004

From Radar Cross Section to Electrostatics

Sihvola, A., Sarkar, T.K., and Kolundzija, B., "From radar cross section to electrostatics", Antennas and Wireless Propagation Letters, vol. 3, no. 1, pp. 324 – 327, 2004

Link to Publication

Abstract: This letter discusses the connection of a dynamic electromagnetic variable, the radar cross section, and a static parameter, the polarizability. It is shown that with full-wave electromagnetic computation of the scattering of a sphere, its static response can be enumerated with good accuracy with remarkably few unknowns. The result suggests that the code can be used with success to also calculate the polarizability of objects with other shapes. This is important since the polarizability of complex objects has been a difficult computational problem to tackle.

Hierarchical Conjugate Gradient Method Applied to MoM Analysis of Electrically Large Structures

Kolundzija, B. and Sumic, D., "Hierarchical conjugate gradient method applied to MoM analysis of electrically large structures", Proc. IEEE AP-S Int. Symp., vol. 4, pp. 4455 – 4458, (CD ROM Edition: s156p03a.pdf), Monterey, 20-25 June 2004

Link to Publication

Abstract: Arbitrary metallic and dielectric/magnetic structures can be analyzed by applying the method of moments (MoM) to the surface integral equations (SIEs). Such a structure is usually modeled by triangular or quadrilateral patches. Hierarchical higher order basis functions defined on those patches allow very efficient analysis. However, even for such sophisticated current expansions, the number of unknowns for electrically large structures can be so high that the analysis based on the direct solution of the matrix equation (e.g., LU decomposition) becomes inefficient. The paper presents the hierarchical conjugate gradient method (HCGM), a simple but effective modification of the standard CGM for higher order systems. In addition, we investigate the influence of the orthogonality of basis functions and the normalization of the basis functions in respect to their Euclidean norms on the behavior of iterative solvers. Significant reduction in analysis time for higher order problems is achieved. Conclusions based on the numerical results are given.

Novel Technique for Deembedding S-parameters in Electromagnetic Modeling of Arbitrary Circuits

Kolundzija, B., Janic, B., and Rakic, M., "Novel technique for deembedding S-parameters in electromagnetic modeling of arbitrary circuits", Proc. IEEE AP-S Int. Symp., vol. 3, pp. 2784 – 2787, (CD ROM Edition: s099p05a.pdf), Monterey, 20-25 June 2004

Link to Publication

Abstract: Different numerical methods (MoM, FEM, TLM, FDTD) are successfully used for the analysis of reciprocal microwave circuits. As a result, one usually obtains the current distribution or the near field distribution and postprocessing of these data is performed in order to evaluate the circuit parameters. However, such deembedding techniques have two shortcomings: 1) their accuracy depends on local quantities, the accuracy of which is not as good as the accuracy of global quantities; 2) there is a problem of making the proper choice of local data that should be postprocessed. The paper presents a new deembedding technique for circuits whose ports are in the form of single propagating mode transmission lines. The new technique actually simulates real measurements, using S-parameter data, which are global quantities, for postprocessing.

Adaptive Random Search for Antenna Optimization

Olcan, D. I. and Kolundzija, B. M., "Adaptive Random Search for Antenna Optimization", Proc. IEEE AP-S Int. Symp., (CD ROM Edition: s044p02a.pdf), Monterey, 20-25 June 2004

Link to Publication

Abstract: Antenna optimization usually leads to a black-box optimization problem with many local minima. The presented algorithm combines random search with information about the optimization space, obtained after each trial, to find local minima quickly. The probability of splitting parts of the space is proportional to the reciprocal of the error function and is updated after each iteration. The algorithm can be used as a standalone optimization procedure or as a starting stage in hybrid optimization.

2003

Antenna Optimization Using Combination of Random And Nelder-Mead Simplex Algorithms

Kolundzija, B. M. and Olcan D. I., "Antenna Optimization Using Combination of Random And Nelder-Mead Simplex Algorithms", Vol. 1, pp. 185-188, Proc. IEEE AP-S Int. Symp., (CD ROM Edition: S007P12A.pdf), Columbus, 22-27 June 2003

Link to Publication

Abstract: We present a relatively simple and robust algorithm for finding optimal and near optimal solutions for antenna design based on a combination of random and Nelder-Mead simplex algorithms. We considered the design of a Yagi-Uda antenna, as an example, for two reasons: it has many near optimal solutions; analysis of such an antenna is relatively quick. The presented combinations of random and Nelder-Mead methods are relatively simple and robust optimization algorithms. They can be advantageous in situations where the error function (the difference between the given criteria and the found solution) has many local minima of approximately the same depth or when formulation of the error function is complicated due to multiple involved criteria. Insight into near optimal solutions, which could be easily found using the proposed methods, offers more freedom in antenna design.

Power Balance in MOM/SIE and FEM Solved by Galerkin Method

Kolundzija, B. M. and Petrovic, V. V., "Power Balance in MOM/SIE and FEM solved by Galerkin method", Proc. IEEE AP-S Int. Symp., Columbus–Ohio, Vol. 1, pp. 677-680, 2003

Link to Publication

Abstract: The power balance is analyzed in MoM/SIE for metallic and metallic-dielectric structures and in FEM. The Galerkin method, when applied to the analyzed MoM and FEM formulations of radiating problems, under certain conditions leads to exact satisfaction of the power balance, regardless of the accuracy of the approximate solution. This property can be used for accurate determination of some global parameters of a radiating structure, such as antenna gain. In cases in which the power balance is not satisfied exactly, its error can be used for estimation of the solution error, thus enabling a self error estimation of the applied numerical method.

Use of Higher Order Entire Domain Basis Over Electrically Large Subsectional Patches

Sarkar, T. K., Kolundzija, B., and Salazar-Palma, M., "Use of higher order entire domain basis over electrically large subsectional patches", Proc. IEEE AP-S/URSI Int. Symp., Columbus–Ohio, pp 347, (CD ROM Edition: S073P01J.pdf), 2003

Link to Publication

Abstract: -

Optimal Meshing of Polygonal Surfaces in the Case of Pronounced Proximity Effect

Kolundzija, B., Tasic, M. S., and Sarkar, T. K., "Optimal Meshing of Polygonal Surfaces in the Case of Pronounced Proximity Effect", Proc. IEEE AP-S Int. Symp., (CD ROM Edition: S127P01A.pdf), Columbus–Ohio, Vol. 4, pp. 73-76, 2003

Link to Publication

Abstract: Many problems in radar scattering, antenna and microwave fields can be solved by applying the method of moments (MoM) to the surface integral equations (SIEs). In the general case, very efficient modeling is achieved using quadrilateral patches and higher order basis functions. However, such modeling can show poor accuracy if the proximity effect is pronounced. In such cases, the results cannot be improved much by increasing the order of higher order basis functions, but by proper meshing of plates. The main goal of the paper is to present an algorithm for optimal meshing of quadrilaterals and, more generally, polygonal surfaces in the case of a pronounced proximity effect.

2002

Simultaneous Extrapolation in Time and Frequency Domains of Responses from Electromagnetic Systems

Sarkar, T. K., Kolundzija, B., Salazar-Palma, M., "Simultaneous Extrapolation in Time and Frequency Domains of Responses from Electromagnetic Systems", Proc. of 12th Int. Symp. on Atnennas, JINA, Nice, 2002

Link to Publication

Abstract: -

Is it Diffraction of Electromangetic Waves or Gravitation

Jang, S., Sarkar, T. K., Kolundzija, B., "Is it Diffraction of Electromangetic Waves or Gravitation", Proc. of 19th Applied Computational Electromagnetics Conf., Monterey, CA, pp. 245-249, March 2002

Link to Publication

Abstract: -

Microstrip Line and Ground Plane with Closely Spaced Perforations - Fringe Fields and Formulas

Chow Y. L., Wan K. L., Sarkar T., Kolundzija B, "Microstrip line and ground plane with closely spaced perforations - fringe fields and formulas", Microwave and Optical Technology Letters, Feb. 2002

Link to Publication

Abstract: Accurate CAD formulas of a microstrip line on a ground plane with periodic perforations, closely spaced and at quasistatic frequencies, are derived (error <5%) for applications in multilayer circuits such as an LTCC package. By a novel technique of a synthetic asymptote, the formula has just one arbitrary constant and two separate fringe-field terms, from the strip and from the perforation. The separation gives clear physical insights into the effects of fringe fields on both the capacitance and inductance. One insight is that the effective dielectric constant may be made to rise above the actual dielectric constant of the substrate with perforation.

Electromagnetic Modeling of Composite Metallic and Dielectric Structures

Kolundzija, B., Djordjevic A., "Electromagnetic modeling of composite metallic and dielectric structures", Artech House, Norwood, MA., 2002

Link to Publication

Abstract: This practical, new book provides a wide choice of analytical solutions to problems faced by antenna design engineers and researchers working in electromagnetic modeling. Based on leading-edge method-of-moments procedures, the book presents new theories and techniques that help professionals optimize performance in numerical analysis of composite metallic and dielectric structures in the complex frequency domain. For the first time, comparisons and new combinations of techniques bring the elements of flexibility, ease of implementation, accuracy, and efficiency into clear focus for all practitioners. A wide range of examples are given - from simple to complex - including scatterers, antennas and microwave circuits. Intricate models include TV UHF pannels, horn, parabolic, microstrip patch antennas, and many others.

Evaluation of Radar Cross-section of Large Platforms by the Method of Moments at PC Computers

Kolundzija, B., Tasic M., Sarkar T., "Evaluation of Radar Cross-section of large platforms by the method of moments at PC computers", Proc. IEEE AP-S Int. Symp., San Antonio, TX., Vol. 2, pp. 94-97, March 2002

Link to Publication

Abstract: For electrically large platforms approximating potentials of higher order basis functions can be fully exploited. In this case accurate results can be obtained even with 15 unknowns per wavelength squared. This

means that symmetrical platforms with total surface area of 3000 λ2 can be handled on personal computers. In the case of Mirage (whose length is about 12 meters) accurate results can be obtained at 2 GHz, at which its electrical length is 80 λ.

2001

Optimal Wire Grid Modeling Based on Conversion of Solid Surface Model

Kolundzija, B. M., Tasić, S. M., Djordjević, A. R., "Optimal wire grid modeling based on conversion of solid surface model", Proc. IEEE AP-S Symp., Boston, vol. 2, pp. 592-595, July 2001.

Link to Publication

Abstract: The paper presents an automatic procedure for obtaining the wire-grid model starting from an arbitrary plate model. The procedure results in cells of approximately same size and radial meshing around the wire-to-plate junctions. A number of different models obtained in this manner are then used to determine optimal values of wire radii and spacing. Finally, the accuracy and efficiency of wire-grid modeling is compared with those of plate modeling

Meshing of Hexagons into Convex Quadrilaterals

Petrović, N., Kolundzija, B., "Meshing of hexagons into convex quadrilaterals", 10th Int. Meshing Roundtable, Newport Beach, California, paper no. 4b2, Oct. 2001.

Link to Publication

Abstract: Efficient electromagnetic analysis of the composite metallic and dielectric structures in the frequency domain based on the Method of Moments applied to the Surface Integral Equations is provided, if building blocks have the form of bilinear surfaces (in particular, flat quads), and if analysis is supported by the higher order basis functions. Heterogenous surfaces of many 3D structures can be easily represented as a combination of connected non-overlapping polygons. Subdivision of the polygons into the minimal number of mutually connected flat quads of good shape is based on subdivision of the hexagons into the convex quads, with possible addition of new nodes only in the interior of the hexagons. We classified hexagons into 46 classes and for each class we found the subdivision scheme. We demonstrated that all subdivision schemes can be unified into four "cut and try" algorithms. The effectiveness of the approach is illustrated on a typical example. This method is implemented in the software tool for antenna design [6].

Analysis of Composite Metallic and Dielectric Structures - WIPL-D Code

Kolundzija, B., Ognjanović, J., Sarkar T., "Analysis of composite metallic and dielectric structures - WIPL-D code", Proc. of 17th Applied Computational Electro-magnetics Conf., Monterey, CA, pp. 246-253, March 2001.

Link to Publication

Abstract: -

Method of Moments Applied to Antennas

Sarkar, T. K, Djordjević A. R., Kolundzija, B. M., "Method of Moments Applied to Antennas", Chapter in The Handbook of Antennas in Wireless Communications, Ed. Lal Godara, CRC Press, Boca Raton, Florida, 2001.

Link to Publication

Abstract: -

Iterative Solvers in Frequency Analysis of Complex Structures Based on MoM Solution of Surface Integral Equsations

Kolundzija, B., Sarkar, T., "Iterative solvers in frequency analysis of complex structures based on MoM solution of surface integral equations", Proc. IEEE AP-S Symp., Boston, vol. 2, pp. 588-591, July 2001.

Link to Publication

Abstract: Many problems in radar scattering, antenna and microwave fields can be solved by applying the method of moments (MoM) to the surface integral equations (SIEs). The geometry of the analyzed structure is usually modeled by triangular or quadrilateral patches. In particular, very efficient analysis can be achieved by using higher order basis functions that automatically satisfy the continuity equation for the currents at the patch ends and junctions. The goal of this paper is to investigate different iterative methods and possibly find in which classes of problems they have an advantage with respect to the direct method. First a survey of the investigated method is given. Then, numerical results for different classes of structures are presented. Based on these results recommendations are given

2000

WIPL-D: Electromagnetic Modeling of Composite Metallic and Dielectric Structures, Software and User Manual

Kolundzija, B. M., Ognjanović, J. S., Sarkar T. K., "WIPL-D: Electromagnetic modeling of composite metallic and dielectric structures, software and user manual", Artech House 2000

Link to Publication

Abstract: This software seeks to make the job easier, cut design time, and reduce costs for designers developing an antenna embedded in a material body, passive microwave circuit components, or determining electromagnetic scattering from complex, lossy/dielectric structures. Now featuring a Windows-based

interface, it delivers a powerful program for analysis of electromagnetic radiation and scattering from composite metallic and/or finite-sized dielectric/magnetic structures.

Efficient Electromagnetic Modeling Based on Automated Meshing of Polygonal Surfaces

Kolundzija, B., Tasic M., Petrovic N., Mikavica, M, "Efficient electromagnetic modeling based on automated meshing of polygonal surfaces", Proc. IEEE AP-S Int. Symp., Salt Lake City, vol. 4, pp. 2294-2297, July 2000

Link to Publication

Abstract: Many problems in radar scattering, antenna and microwave fields can be solved by applying the method of moments (MoM) to the surface integral equations (SIEs). The geometry of the analyzed structure is usually modeled by triangular or quadrilateral patches of finite size. Such modeling can be very tedious, when the original structure is of a complicated shape. Very often this complicated shape can be easily represented as a combination of polygonal surfaces. Hence, there is continuous interest for algorithms that subdivide polygons into triangles or quadrilaterals. The main goal of this paper is to present a method for automated meshing of a structure made of polygonal surfaces into convex quadrilateral patches (in such a manner that two neighboring patches have a common edge between two common nodes)

Efficient Method of Moment Analysis Based on Imaging and Edging

Kolundzija, B., Petrovic V., Djordjevic A, and Sarkar T. K, "Efficient Method of Moment analysis based on imaging and edging", Proc. IEEE AP-S Int. Symp., Salt Lake City, vol. 4, pp. 2298-2301, July 2000

Link to Publication

Abstract: Electromagnetic modeling of composite metallic and dielectric structures (antennas, scatterers, microwave circuits, etc.) in the frequency domain can be efficiently performed by applying the method of moments (MoM) to the surface integral equations (SIEs). Particularly, a high efficiency is achieved by using double polynomial approximations for currents over quadrilateral patches, where expansion orders are directly proportional to the electrical length of these patches. The exception occurs when a global solution for currents is strongly affected by local quasi-static effects (end effect and proximity effect). For example, the authors consider a microstrip line whose transversal dimensions are small comparable with the wavelength. The main goal is to determine non-uniform segmentation which enables the treatment of local quasi-static effects with the lowest number of unknowns. In that sense two techniques are proposed: imaging and edging

1999

A New Approach for Accurate Analysis of Antennas Above Real Ground

Kolundzija, B. M., Djordjević A. R., Petrović, V. V., "A New Approach for accurate analysis of antennas above real ground", Proc. IEEE AP-S Symp., Orlando, pp. 1692-1695, Jun 1999.

Link to Publication

Abstract: The aim of this paper is to show how a method for the analysis of composite metallic and dielectric structures in a vacuum can be, without any modifications, used for accurate analysis of antennas above real ground, For this purpose, the WIPL-D program (a version of the WIPL program (Kolundzija et al., 1995) that includes dielectrics) is used

Theoretical Investigations of Parasitic Effects in Double-Y Baluns

Jokanović, B., Kolundzija, B., Marinčić, A., "Theoretical investigations of parasitic effects in double-Y baluns", Proc. 4th TELSIKS (Int. Conf. on Telecomunications in Modern Satellite, Cable and Broadcasting Services), Niš, vol. 1, pp. 303-305, Oct. 1999.

Link to Publication

Abstract: Effects limiting the bandwidth of CPWFGP-CPS double-Y baluns are investigated both theoretically, using 3D electromagnetic simulators and experimentally. Analysis shows two kinds of parasitic effects: (a) parasitic effects that depend on input transmission lines and they are caused by: (a) even mode and parasitic balanced mode (PBM) and (b) parasitic effects that depend on open and short circuited stubs forming the double-Y balun and they are observed in both regular mode and PBM. This theory has been experimentally proven and it enables to predict the frequency of parasitic resonances that appear in the characteristics of CWFGP-CPS baluns and shift them out of the operating frequency bandwidth by changing the physical dimensions of the balun

A Field Theoretic Approach to the Analysis of Practical Coupled Dielectric Resonators

Sarkar, T. K., Su, C., Djordjević, A. R., Kolundzija, B., Salazar-Palma, M., Caceras, J. L., "A field theoretic approach to the analysis of practical coupled dielectric resonators", IEEE MTT-S International Microwave Symposium, Anaheim, vol. 1, pp. 167-170, 1999.

Link to Publication

Abstract: Conventional methods for the analysis of dielectric resonators utilize the mode-matching technique. Other methods have also been used. However, most of the analysis exists for analysis of single resonators. However, for practical dielectric resonators (when more than one loaded cavity is used) there may be apertures coupling one resonator to the other. In addition there may be probes coupling one resonator to the other to carry out response shaping or even cancel out the effects of the higher order modes. Also, probes may be utilized to couple energy into and out of the resonators. The high dielectric constant resonator is generally placed on top of a low dielectric constant material for support. Hence an effective analysis modeling is necessary which will predict the actual experimental data accurately if the appropriate material properties are correctly specified for coupled multiple dielectric resonators. This includes analysis of dielectric resonators with aperture couplings along with probe feeds

Electromagnetic Modeling of Composite Metallic and Dielectric Structures

Kolundzija, B. M., "Electromagnetic modeling of composite metallic and dielectric structures", IEEE Transaction on Microwave Theory and Techniques, vol. MTT-47, no. 7, pp. 1021-1032, May 1999.

Link to Publication

Abstract: A new, general, and very efficient method for analysis of arbitrary composite metallic and dielectric structures, based on the PMCHW formulation and Galerkin method, is presented in this paper. Flexible geometrical modeling is performed by isoparametric surfaces (i.e., by bilinear surfaces in the particular case). Efficient approximation of currents is achieved by using polynomial entire-domain expansions (i.e., rooftop subdomain expansions in the particular case) that automatically satisfy the continuity equation, assuming that there are no line charges along surface edges. Special care is devoted to the treatment of arbitrary multiple metallic and/or dielectric junctions. Numerical results for different structures, obtained by using an extremely small numbers of unknowns, show very good agreement with other available data

1998

On the Locally Continuous Formulation of Surface Doublets

Kolundzija, B. M., "On the locally continuous formulation of surface doublets", IEEE Trans. on Antennas and Propagat., pp. 1879-1883, Dec. 1998

Link to Publication

Abstract: Exact (locally continuous) formulation of doublets and particularly rooftop basis functions based on unitary vector concept are presented. Basic properties of such a formulation are examined showing many advantages when compared with classical (approximate) formulation. In particular, in the case of rooftop basis functions based on exact formulation, the shape quality factor is defined and optimal shapes of quadrilateral patches are determined. If such quadrilaterals are used for modeling of general structures, the number of unknowns needed in the analysis is almost halved when compared with modeling by triangular doublets

Accurate Solution of Square Scatterer as Benchmark for Validation of Electromagnetic Modeling of Plate Structures

Kolundzija, B. M., "Accurate Solution of Square Scatterer as Benchmark for Validation of Electromagnetic Modeling of Plate Structures", IEEE Trans. on Antennas and Prop., Vol. 46, No. 7, pp.1009-1014, July 1998

Link to Publication

Abstract: An infinitesimally thin-square scatterer, of size λ×λ, excited normally by an incident plane wave, which is polarized along a scatterer edge, is analyzed. The accurate solution of its current distribution is found in the form of a double series of basis functions, which automatically satisfy the continuity equation at the plate edges and include the edge effect. The coefficients that multiply basis functions are determined starting from the electric field integral equation by using the Galerkin method. The solution obtained for the order of approximation n=8 is adopted as a benchmark. The corresponding coefficients are tabulated and graphs of such obtained current distribution are given. The solution adopted as a benchmark is applied for comparison of rooftop basis functions and polynomial entire-domain basis functions. The relative error of the mean absolute value of current deviation is used as an error metric

Comparison of MoM/SIE, MoM/VIE and FEM Based on Topological Analysis of Two Canonical Problems

Kolundzija, B. M., Petrović, V. V., "Comparison of MoM/SIE, MoM/VIE and FEM based on topological analysis of two canonical problems", Proc. IEEE AP-S Int. Symp., vol. 1, pp. 274-277, Jun. 1998

Link to Publication

Abstract: Analysis of composite metallic and dielectrics structures placed in a time-harmonic electromagnetic field is usually based on the MoM (Method of Moments), or FEM (Finite Element Method). Particularly, if MoM is applied to SIE (Surface Integral Equation), the method is termed as MoM/SIE, and if MoM is applied to VIE (Volume Integral Equation), the method is termed as MoM/VIE. Besides that, all these methods can be mutually combined giving different types of hybrid methods. The authors present a comparison of the MoM/SIE, MoM/VIE and FEM methods based on a topological analysis of two canonical problems

On the choice of optimal basis functions for MoM/SIE, MoM/VIE, FEM and hybrid methods

Kolundzija, B. M., Sarkar, T. K., "On the choice of optimal basis functions for MoM/SIE, MoM/VIE, FEM and hybrid methods", Proc. IEEE AP-S Int. Symp., vol. 1, pp. 278-281, Jun. 1998

Link to Publication

Abstract: Analysis of composite metallic and dielectrics structures placed in a time-harmonic electromagnetic field is usually based on the MoM (Method of Moments), or FEM (Finite Element Method). Particularly, if MoM is applied to SIE (Surface Integral Equation), the method is termed as MoM/SIE, and if MoM is applied to VIE (Volume Integral Equation) the method is termed as MoM/VIE. Besides that, all these methods can be mutually combined giving different types of hybrid methods. Efficiency of all these methods depends greatly on the choice of basis functions. A variety of basis functions is used by different authors. Sometimes it seems that basis functions written in one notation and used by one method are completely different from and without any connection with basis functions written in another notation and used by another method. In addition, it seems that some of the used basis functions are not optimally adopted. The first goal of this paper is to show that practically all basis functions used in MoM/SIE, MoM/VIE and FEM belong to a few general classes of basis functions. The second goal is to establish the set of desired properties of basis functions used

in each of the methods. Finally, the third goal is to compare different classes of basis functions starting from the set of desired properties, and choose the optimal classes of basis functions

On the Inclusion of Edge Effects into Surface Vector Basis Functions

Kolundzija, B. M., "On the inclusion of edge effects into surface vector basis functions", Proc. IEEE AP-S Int. Symp., vol. 1, pp. 282-285, Jun. 1998

Link to Publication

Abstract: Generally speaking, problems in radar scattering, antenna and microwave fields involve material objects made ofconductors, dielectrics and their combinations. Most often solution to these problems cannot be found in theanalytical form. In the case when these problems are treated in the frequency domain, numerical solutions are very often based on the MoM (Method of Moments) applied to the SIE (Surface Integral Equation). Efficiency and accuracy of the MoM/SIE method depends among others on the choice of basis functions. Usually, adoptedbasis functions are well behaved and do not take edge effects into account. It is shown that in the case whenedge effects are included into analysis of an infinite strip and a square plate, the accuracy and stability of thesolution are improved. The first goal of this paper is to develop such basis functions that at the same time: a) satisfy the continuity equation at the surface ends and junctions, and b) take the edge effects into account.The second goal is to compare the efficiency and accuracy of the method that includes edge effects with themethod that does not include these effects

Automatic Mesh Generation Using Single and Double Node Segmentation Techniques

Kolundzija, B. M., "Automatic mesh generation using single and double node segmentation techniques", IEEE Antennas and Propagation Magazine, vol. 40, no. 4, pp. 30-38, August 1998

Link to Publication

Abstract: The desired properties of quadrilateral mesh-generation techniques, well-suited for solving surface integral equations by the method of moments, are discussed. Based on this investigation, two iterative techniques for segmentation of electrically large surfaces are developed. Each iteration consists of two steps: (1) long edges are subdivided into the minimal number of short edges; and (2) large plates are subdivided by using either one interior node per long edge (the single-node technique), or two interior nodes per long edge (the double-node technique). In each of these cases, the subdivision of a large plate is performed by using three specific basic schemes, not affected by the subdivision of neighboring large plates. In addition, a constraint for segmentation of long interior edges is proposed, enabling generation of more uniform meshes. The proposed techniques are applied to the methods based on both subdomain and entire-domain approximation. It is found that, in most cases, the double-node technique is superior to the single node technique

1997

Electromagnetic Modeling of Composite Metallic and Dielectric Structures

Kolundzija, B. M., "Electromagnetic modeling of composite metallic and dielectric structures", (invited paper), Proc. 3rd TELSIKS (Int. Conf. on Telecomunications in Modern Satellite, Cable and Broadcasting Services), Niš, vol. 1, pp. 74-83, Oct. 1997

Link to Publication

Abstract: Starting from the equivalence theorem any composite metallic and dielectric structure can be analyzed by using SIE (surface integral equations). Such integral equations are usually solved by MoM (method of moments). Most of the existing MoM methods for solving SIE are developed for BORs (bodies of revolution). There are only few such methods that can handle structures of arbitrary shape. These methods use sub-domain basis functions defined over triangles, requiring a very large number of unknowns even for the simplest problems. This paper presents a new MoM method for electromagnetic modeling of composite metallic and dielectric structures. The method uses entire-domain basis functions defined over bilinear surfaces, resulting in a remarkably small number of unknowns

Spiral Super-Quadric Generatrix and Bodies of Two generatrices in automated Parameterization of 3-D Geometries

Kolundzija, B. M., and Djordjević, R. A., "Spiral Super-Quadric Generatrix and Bodies of Two generatrices in automated Parameterization of 3-D Geometries", IEEE Transaction on Microwave Theory and Techniques, vol. MTT-45, no. 5, pp. 864-866, May 1997

Link to Publication

Abstract: Most of the methods that solve the surface integral equation (SIE) by the method of moments (MoM) use triangles and flat quadrilaterals for geometrical modeling. Many complex structures can be easily modeled by quadrilaterals combining spiral super-quadric generatrices and the concept of the body of two generatrices (BoTG). A BoTG is any body that can be obtained from two generatrices by applying a certain rule. Four simple rules for obtaining BoTG's are: (1) generalized rotation; (2) translation; (3) constant cut; and (4) connected generatrices. Spiral super-quadric generatrices enable efficient modeling of circles, arcs, ellipses, squares, rectangles, spirals, etc. Thus, a simple but fairly general algorithm for geometrical modeling is obtained, convenient for implementation in electromagnetic-field solvers

Plate Modeling of Wire Structures

Kolundzija, B. M. and Reljić, B., "Plate modeling of wire structures", Proc. IEEE AP-S Int. Symp., Montreal, pp. 1798-1801, July 1997

Link to Publication

Abstract: The thin-wire analysis is usually performed by using the following assumptions: a) the circumferential current component is neglected, b) the axial current component is uniform around the circumference of the wire, and c) the so-called reduced kernel is used. It is considered that these assumptions are valid if two conditions are satisfied: 1) the wire radius is much less than a free space wavelength, and 2) the wire-to-wire separation exceeds several wire diameters. These assumptions can also be applied for determination of current distribution in the case of thick antennas of revolution. However, in the case when these conditions are not satisfied a plate model of the wire structure should be made. There are many cases when: a) a wire model gives acceptable results, but cannot give precise results, b) a wire model gives good results up to some frequency, but not above this frequency, etc. In all these cases it is convenient to check the analysis based on a wire model by the analysis based on a plate model. Hence, an algorithm for the automatic transformation of a wire model into a plate model can be very helpful. The main goal of this paper is to present such an algorithm and show its usefulness. As an example the authors model a dipole antenna array

Electromagnetic Modeling of Composite Metallic and Dielectric Structures

Kolundzija, B. M., "Electromagnetic modeling of composite metallic and dielectric structures", Proc. IEEE AP-S Int. Symp., Montreal, pp. 1822-1825, July 1997

Link to Publication

Abstract: Starting from the equivalence theorem any composite metallic and dielectric structure can be analyzed by using SIE (surface integral equations). Such integral equations are usually solved by MoM (method of moments). Most of the existing MoM methods for solving SIE are developed for BORs (bodies of revolution). There are only few such methods that can handle structures of arbitrary shape. These methods use sub-domain basis functions defined over triangles, requiring a very large number of unknowns even for the simplest problems. This paper presents a new MoM method for electromagnetic modeling of composite metallic and dielectric structures. The method uses entire-domain basis functions defined over bilinear surfaces, resulting in a remarkably small number of unknowns

1996

WIPL: Program for Electromagnetic Modeling of Composite Wire and Plate Structures

Kolundzija, B. M., Ognjanović, J. S., Harrington, R. F. and Sarkar T. K., "WIPL: Program for electromagnetic modeling of composite wire and plate structures", IEEE Antennas and Propagation Magazine, Feb. 1996

Link to Publication

Abstract: WIPL is a program which allows fast and accurate analysis of antennas. The geometry of any metallic structure (even a very large structure) is defined as a combination of wires and plates. WIPL's analysis features

include evaluations of the current distribution, near and far field, and impedance, admittance and s-parameters. The program uses an entire-domain Galerkin method. Efficiency of the program is based on the flexible geometrical model, and sophisticated basis functions. In this paper, the basic theory implemented in the program, and some results concerning TV UHF panel antennas and large horn antennas are given

Comparison of a Class of Sub-Domain and Entire-Domain Basis Functions Automatically Satisfying KCL

Kolundzija, B. M., "Comparison of a class of sub-domain and entire-domain basis functions automatically satisfying KCL", IEEE Trans. on Antennas and Propagat., vol. AP-44, pp. 1362-1366, 1996

Link to Publication

Abstract: Accuracy, number of unknowns, and CPU time are compared for piecewise linear subdomain basis functions and polynomial entire domain basis functions. Both types of functions automatically satisfy a continuity equation at wire ends and junctions, according to Kirchoff's current law (KCL). The relative root mean square (RMS) current deviation is chosen as the error metric. An electrically short scatterer, a crossed wire scatterer and an electrically long scatterer are used for comparison. Currents are obtained by solving the electric field integral equation (EFIE), by means of the Galerkin method. It was shown that in most cases, for the same accuracy required, the entire domain approximation uses three to five times less numbers of unknowns and 10-100 times less CPU time than the subdomain approximation. Generally, such efficiency is achieved by using entire domain expansions the order of which is up to n=5 and cannot be significantly improved by using higher order expansions

Electromagnetic Modeling of Composite Metallic and Dielectric Structures

Kolundzija, B. M., "Electromagnetic modeling of composite metallic and dielectric structures", Proc. Trans Black Sea Region symp. on Applied Electromagnetics, Metsovo, (Greece), April 1996 (summary)

Link to Publication

Abstract: Starting from the equivalence theorem any composite metallic and dielectric structure can be analyzed by using SIE (surface integral equations). Such integral equations are usually solved by MoM (method of moments). Most of the existing MoM methods for solving SIE are developed for BORs (bodies of revolution). There are only few such methods that can handle structures of arbitrary shape. These methods use sub-domain basis functions defined over triangles, requiring a very large number of unknowns even for the simplest problems. This paper presents a new MoM method for electromagnetic modeling of composite metallic and dielectric structures. The method uses entire-domain basis functions defined over bilinear surfaces, resulting in a remarkably small number of unknowns

Generalized Combined Field Integral Equation

Kolundzija, B. M., "Generalized combined field integral equation", Proc. IEEE AP-S Int. Symp., Baltimore, pp. 852-855, June 1996

Link to Publication

Abstract: The author considers a perfect conducting structure situated in a vacuum. The incident (impressed) electromagnetic field (Ei, H i) is time-harmonic, of angular frequency ω. As a result, surface currents Js (and corresponding charges ρ s) are induced over the surface of the body, giving the total electric and magnetic field E and W. It is well known that induced currents can be numerically determined by solving the EFIE (electric field integral equation) or the MFIE (magnetic field integral equation), if the analysis frequency is not in the vicinity of interior resonant frequency. However, near the resonant frequencies both of these equations fail to yield a unique solution for induced currents. Various techniques have been applied successfully for eliminating the spurious resonances from the solution, but most often the CFIE (combined field integral equation) is used. The authors consider the general case and develop the generalized CFIE (GCFIE). This enable simplification of various equations

1995

WIPL - Program for Electromagnetic Modeling of Composite Wire and Plate Structures, Software and User Manual

Kolundzija, B. M., Ognjanović, J. S., Harrington, R. F., and Sarkar T. K., "WIPL - program for electromagnetic modeling of composite wire and plate structures, software and user manual", Artech House 1995

Link to Publication

Abstract: WIPL is a low-cost PC commercial software for the analysis of metallic structures. It allows the user to interactively define the geometry of any metallic structure as a combination of wires and plates, and then check this by using a 3-D drawing of the structure. WIPL's sophisticated analysis features include evaluations of the current distribution, radiation patterns and admittance parameters. It analyzes log periodic antennas, wire antennas with corner reflector, antennas mounted on metallic vehicles, wave guide horn antennas (including coaxial to wavelength transition), slot antennas and field coupling through apertures in metallic enclosures. WIPL also provides the user with a variety of list and graphic output capabilities, including 2-D and 3-D graphics. User specification of a large number of unknowns is not required to run the program. WIPL executes most computations in under 60 seconds, making the software ideal for CAD. The system requirements for WIPL are: IBM PC or compatible, 286 (386 or 486 recommended). 640 KB RAM, Microsoft Windows 3.1 or later. Graphics: Hercules, CGA, EGA (VGA recommended). DOS 3.3 or later.

WIPL - Program for Analysis of Metallic Antennas and Scatterers

Kolundzija, B. M., Ognjanović, J. S., Harrington, R. F. and Sarkar T. K., "WIPL - program for analysis of metallic antennas and scatterers", Proc. 9th ICAP, Eindhoven, 1995

Link to Publication

Abstract: WIPL is an extremely powerful program that allows fast and accurate analysis of metallic antennas, scatterers and passive microwave circuits. This user friendly program enables the user to interactively define the geometry of any metallic structure (even a very large structure) as a combination of wires and plates, and then check this data by using a 3D drawing of the structure. WIPL's sophisticated analysis features include evaluations of the current distribution, radiation patterns, and admittance parameters. WIPL also provides the user with a variety of list and graphic output capabilities, including 2D and 3D graphics. Users need not know the analysis method to use the program. WIPL efficiently executes most computations in under 60 seconds, making the software ideal for CAD

1994

Simplified Treatment of Wire-to-Plate Junctions with Magnetic-Current Frill Excitation

Kolundzija, B. M. and Popović, B. D., "Simplified treatment of wire-to-plate junctions with magnetic-current frill excitation", Proc. IEE H, vol. 141, no. 2, pp. 133-137, Apr. 1994

Link to Publication

Abstract: A structure consisting of a flat metal plate and a wire joined to the plate and driven at the plate by a magnetic-current frill (approximating the coaxial-line excitation) occurs frequently. The electromagnetic analysis of such a structure poses considerable problems, the main one being due to discontinuous surface-charge density (i.e. to discontinuous surface-current derivative) on the plate near the junction. This has been solved by introducing either different types of so-called attachment mode or additional partitioning of the plate. Both approaches, however, complicate the solution significantly. The authors show that, using a simple theorem, the frill excitation can be transferred to the wire, thus obtaining a model that is much easier to analyse. The theorem is exact for infinite ground plane, but numerical results indicate that it can be approximately applied to plates of finite size, even for wires close to the plate edge. This procedure is particularly useful for relatively thick wires, of length/diameter ratio less than about fifty, where the delta-function generator approximation may not be appropriate

Analysis of Metallic Antennas and Scatterers

Popović B. D. and Kolundzija, B. M., "Analysis of metallic antennas and scatterers", IEE 1994

Link to Publication

Abstract: The authors present a relatively simple, computer-oriented, general and unified approach to the analysis of metallic antennas and scatterers (of electrically small and medium sizes), based largely on their own original work. The method appears to offer superiority over existing alternatives by circumventing most of the difficulties encountered by those methods. It should be of considerable importance to working antenna

engineers and researchers. Introduction; Modelling of geometry of metallic antennas and scatterers; Approximation of current along generalised wires and over generalised quadrilaterals; Treatment of excitation; Electromagnetic field of currents over generalised surface elements; Solution of equations for current distribution; Numerical examples illustrating the choice of optimum elements of the method; Numerical examples illustrating the possibilities of the method; References; Appendices; Index.

General Localized Junction Model in the Analysis of Wire-to-Plate Junctions

Kolundzija, B. M. and Popović, B. D., "General localized junction model in the analysis of wire-to-plate junctions", Proc. IEE H, vol. 141, no. 1, pp. 1-7, Feb. 1994

Link to Publication

Abstract: A new entire-domain Galerkin method for the analysis of wire-to-plate junctions is presented. The formulation avoids additional attachment modes for modelling the junctions. Instead, a specific segmentation technique of wires and plates is proposed, based on the so-called general localised junction model. According to this model, any localised junction can be considered to consist of ends of curvilinear cylinders (wires) and adjacent sides of generalised quadrangles (plates), situated in an electrically small junction domain. The interconnections of the wire ends and plate sides can be omitted from the geometrical model, provided the current expansions for the wires and quadrangles are adopted in such a manner that the total current flowing out from the junction is zero. Numerical results obtained by the proposed method indicate that its efficiency is comparable to that based on the application of attachment modes. In addition, it enables a unified treatment of practically any junction, even those for which attachment modes have not yet been developed, whereas the classical approach requires a specific attachment mode to be defined for individual junction types

1993

Entire-Domain Galerkin Method for Analysis of Metallic Antennas and Scatterers

Kolundzija, B. M. and Popović, B. D., "Entire-domain Galerkin method for analysis of metallic antennas and scatterers", Proc. IEE H, vol. 140, no. 1, pp. 1-10, Feb. 1993

Link to Publication

Abstract: The antenna and scatterer surfaces are approximated by generalised quadrangles. Surface currents are expanded in such local coordinate systems and the general form of the corresponding electric field integral equation is derived. A procedure is described for obtaining entire-domain basis functions which satisfy automatically the continuity equation along the surface element interconnections and free edges, and the expressions are derived for the impedance matrix elements in this case. Starting from the general theory, two new particular methods are presented. The first is intended for the analysis of general structures, and is based on application of truncated cones and bilinear surfaces for the approximation of geometry. The second is aimed for the analysis of spherical scatterers, and is based on the application of generalised rectangular

elements which follow the sphere shape. Both methods use polynomials for approximation of currents. Very good agreement of the results with available experimental and numerical results is achieved

1992

Entire-domain Galerkin Method for Analysis of Generalized Wire Antennas and Scatterers

Kolundzija, B. M. and Popović. B. D., "Entire-domain Galerkin method for analysis of generalized wire antennas and scatterers", Proc. IEE H, vol. 139, no. 1, pp. 17-24, Feb. 1992

Link to Publication

Abstract: The authors present a method for the analysis of generalised wire antennas and scatterers, consisting of right truncated cones of circular cross-section interconnected in an arbitrary manner. The integral equation for current distribution is derived starting from the local and extended boundary conditions for the electric field, enabling the efficient analysis of both hollow and solid cones. An entire domain current expansion for a series connection of $n \geqslant 1$ truncated cones is proposed, that enables curved wires to be approximated by any number of straight segments without increasing the number of unknown coefficients. A method for obtaining the expansions starting from arbitrary function sets which satisfy the continuity equation at the segment interconnections and ends is also presented. With such basis functions, the solution of the integral equations by means of the Galerkin method is shown to require: (a) a remarkably small number of unknowns per wavelength; (b) a remarkably short time of evaluation of the impedance matrix. The results obtained by the method are in good agreement with available experimental and numerical results

1990

General Entire-Domain Galerkin Method for Electromagnetic Modeling of Composite Wire-to-Plate Structures

Kolundzija, B. M., "General entire-domain Galerkin method for electromagnetic modeling of composite wire-to-plate structures", Proc. 20th EuMc, Budapest, Pt. 1, pp. 853-858, 1990

Link to Publication

Abstract: Geometry modeling of wires and plates is performed by using curvilinear cylinders of variable radii and curved curvilinear rectangles and triangles. Current modeling is performed by using entire-domain approximations, which satisfy continuity equation at wire and plate ends and junctions. Unknown coefficients of these approximations are determined by solving EFIE by means of Galerkin method. In special cases this method degenerates into those of Newman and Pozar [1], Glisson and Wilton [2], or Rao et al [3]. Starting from the proposed theory various new methods can be constructed. The results obtained by a particular form of the method proposed, based on application of conical and bilinear surfaces and polynomials, show a good agreement with experimental and theoretical data. In the case of long wires satisfactory results are obtained

with only 3 unknowns per wavelength (Â¿), and in the case of large surfaces of simple shapes with only 10 unknowns (for both current components) per Â¿2.

1988

Effect of a Wire end in Thin-Wire Analysis

Kolundzija, B. M., "Effect of a wire end in thin-wire analysis", Proc. IEEE AP-S Int. Symp., pp. 843-846, Syracuse, 1988

Link to Publication

Abstract: A rigorous treatment of the end effect must include precise approximation of the surface current and charge distribution at the wire ends, taking into account the exact shape of the ends. Such treatment requires a number of extra terms to approximate these currents and charges and evaluation of a novel type of quasisingular integrals. The author presents a novel, simple, and almost rigorous treatment of effect of rotationally symmetrical end, which can be easily included into algorithms developed without introducing additional unknowns. He shows how the ends of the simple shape can be successfully modelled by conical (flat) ends, in which case evaluation of a novel type of quasisingular integral for each particular end is avoided. Extensive numerical results confirm the suggested treatment and show some less-known properties of errors of thin-wire analysis performed by various methods

1987

A New, Rapid and Accurate Method for Evaluation of Potential Integrals in Thin-Wire Antenna Problems

Kolundzija, B. M. and Popovic, B. D., "A new, rapid and accurate method for evaluation of potential integrals in thin-wire antenna problems", Proc. 5th ICAP, York, Pt. I, pp. 35-38, 1987

Link to Publication

Abstract: -