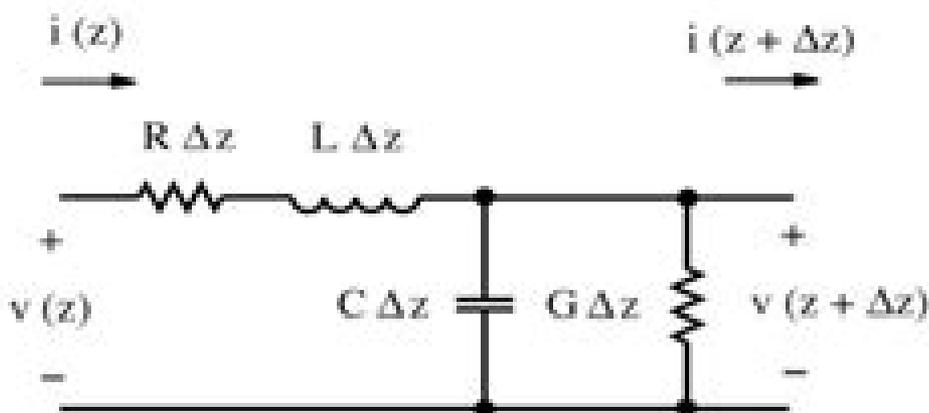


Transmission-Line Model



- Two "Wires" with Uniform Cross Section
- L (inductance), C (capacitance) per unit length
 - Transverse Electromagnetic Fields
 - Quasi-Static Solutions
 - $L = L(\mu, xy \text{ geometry})$, $C = C(\epsilon, xy \text{ geometry})$,
- $LC = \mu \epsilon$
- R (resistance), G (conductance) per unit length
(Consider Physical Mechanisms Later)

Transmission Line Modeling Method

Maurice Weiner



Transmission Line Modeling Method:

The Transmission-Line Modeling (TLM) Method in Electromagnetics Christos Christopoulos, 2022-06-01 This book presents the topic in electromagnetics known as Transmission Line Modeling or Matrix method TLM While it is written for engineering students at graduate and advanced undergraduate levels it is also highly suitable for specialists in computational electromagnetics working in industry who wish to become familiar with the topic The main method of implementation of TLM is via the time domain differential equations however this can also be via the frequency domain differential equations The emphasis in this book is on the time domain TLM Physical concepts are emphasized here before embarking onto mathematical development in order to provide simple straightforward suggestions for the development of models that can then be readily programmed for further computations Sections with strong mathematical flavors have been included where there are clear methodological advantages forming the basis for developing practical modeling tools The book can be read at different depths depending on the background of the reader and can be consulted as and when the need arises

The Transmission-line Modeling Method Christos Christopoulos, 1995 Written by renowned researcher Christos Christopoulos this book covers a broad area of electromagnetics including microwaves antennas radar cross section electromagnetic compatibility and electromagnetic heating In addition you will find a clear explanation of modeling principles from lumped components through one two and three dimensional complex systems

The Transmission Line Modeling (t L M) Method In Electromagnetics Christos Christopoulos, 2006

The Transmission-line Modeling (TLM) Method in Electromagnetics Christos Christopoulos, 2006 This book presents the topic in electromagnetics known as Transmission Line Modeling or Matrix method TLM While it is written for engineering students at graduate and advanced undergraduate levels it is also highly suitable for specialists in computational electromagnetics working in industry who wish to become familiar with the topic The main method of implementation of TLM is via the time domain differential equations however this can also be via the frequency domain differential equations The emphasis in this book is on the time domain TLM Physical concepts are emphasized here before embarking onto mathematical development in order to provide simple straightforward suggestions for the development of models that can then be readily programmed for further computations Sections with strong mathematical flavors have been included where there are clear methodological advantages forming the basis for developing practical modeling tools The book can be read at different depths depending on the background of the reader and can be consulted as and when the need arises

Analysis of Microstrip Transmission Lines Containing Discontinuities Using the Transmission Line Modeling (TLM) Method Patrick Richard Conway, 1991

[Transmission Line Matrix \(TLM\) in Computational Mechanics](#) Donard de Cogan, William J. O'Connor, Susan Pulko, 2005-11-01 The finite element method reigns as the dominant technique for modeling mechanical systems Originally developed to model electromagnetic systems the Transmission Line Matrix TLM method proves to match and in some cases exceed the effectiveness of finite elements for

modeling several types of physical systems Transmission Line Matrix in Compu **Electromagnetic Computation Methods for Lightning Surge Protection Studies** Yoshihiro Baba, Vladimir A. Rakov, 2016-05-10 Presents current research into electromagnetic computation theories with particular emphasis on Finite Difference Time Domain Method This book is the first to consolidate current research and to examine the theories of electromagnetic computation methods in relation to lightning surge protection The authors introduce and compare existing electromagnetic computation methods such as the method of moments MOM the partial element equivalent circuit PEEC the finite element method FEM the transmission line modeling TLM method and the finite difference time domain FDTD method The application of FDTD method to lightning protection studies is a topic that has matured through many practical applications in the past decade and the authors explain the derivation of Maxwell s equations required by the FDTD and modeling of various electrical components needed in computing lightning electromagnetic fields and surges with the FDTD method The book describes the application of FDTD method to current and emerging problems of lightning surge protection of continuously more complex installations particularly in critical infrastructures of energy and information such as overhead power lines air insulated sub stations wind turbine generator towers and telecommunication towers Both authors are internationally recognized experts in the area of lightning study and this is the first book to present current research in lightning surge protection Examines in detail why lightning surges occur and what can be done to protect against them Includes theories of electromagnetic computation methods and many examples of their application Accompanied by a sample printed program based on the finite difference time domain FDTD method written in C program **Computational Electromagnetics with MATLAB, Fourth Edition** Matthew N.O. Sadiku, 2018-07-20 This fourth edition of the text reflects the continuing increase in awareness and use of computational electromagnetics and incorporates advances and refinements made in recent years Most notable among these are the improvements made to the standard algorithm for the finite difference time domain FDTD method and treatment of absorbing boundary conditions in FDTD finite element and transmission line matrix methods It teaches the readers how to pose numerically analyze and solve EM problems to give them the ability to expand their problem solving skills using a variety of methods and to prepare them for research in electromagnetism Includes new homework problems in each chapter Each chapter is updated with the current trends in CEM Adds a new appendix on CEM codes which covers commercial and free codes Provides updated MATLAB code Numerical Techniques in Electromagnetics with MATLAB Matthew N.O. Sadiku, 2015-09-11 Despite the dramatic growth in the availability of powerful computer resources the EM community lacks a comprehensive text on the computational techniques used to solve EM problems The first edition of Numerical Techniques in Electromagnetics filled that gap and became the reference of choice for thousands of engineers researchers and students This third edition of the bestselling text reflects the continuing increase in awareness and use of numerical techniques and incorporates advances and refinements made in recent years Most notable among these are the improvements made to the

standard algorithm for the finite difference time domain FDTD method and treatment of absorbing boundary conditions in FDTD finite element and transmission line matrix methods The author also has added a chapter on the method of lines Numerical Techniques in Electromagnetics with MATLAB Third Edition continues to teach readers how to pose numerically analyze and solve EM problems to give them the ability to expand their problem solving skills using a variety of methods and to prepare them for research in electromagnetism Now the Third Edition goes even further toward providing a comprehensive resource that addresses all of the most useful computation methods for EM problems and includes MATLAB code instead of FORTRAN

Electromagnetic Analysis Using Transmission Line Variables (Third Edition) Maurice Weiner, 2017-12-27 This latest edition continues the evolution toward the ultimate realization of a new technique for solving electromagnetic propagation problems The technique combines the classical and intuitive use of a transmission line matrix TLM while striving for consistency with the guideposts demanded by quantum mechanics and the essential structure of electromagnetic theory The matrix then becomes a useful vehicle for examining both coherent and noncoherent electromagnetic waves The goal is a mathematical tool capable of solving problems related to the propagation of transient high speed complex waveforms containing both symmetric and plane wave components For such waveforms standard classical electromagnetic theory is unable to provide a truly accurate solution since it does not properly account for the correlations among the various TLM cells The correlations among neighboring TLM cells allow the cell waves to sense one another and to collectively participate as a coherent wave For arbitrary signals e g complex high speed highly non uniform signals the correlation model must be placed on a firmer footing to insure the proper correlation strength based on the close adherence to quantum mechanical principles The purpose of the Third Edition is to thereby improve the correlation model and incorporate the model into the simulations The simulation results thus obtained show great promise in describing the full range of electromagnetic phenomena Wave divergence and diffraction simulations employing both composite and shorter range correlation models have been incorporated The models employ correlation coefficients which may be linked with quantum mechanical parameters thus providing a deeper understanding of coherent wave fronts

Modeling and Simulation of Electromagnetic Problems Via the Transmission Line Matrix Method M. Orhan Özyalçın, Elektrik-Elektronik Fakültesi, 2002 Today s electromagnetic EM problems are very complex Analytical solutions are available only for some canonical structures and this has lead to an increased interest in numerical electromagnetics Today parallel to the increase in computer s capacity and speed numerical approaches have become rather popular Improvements in computers have also made it possible to solve EM problems directly in time domain TD starting either or from field and network theories That is why the transmission line matrix TLM and finite difference time domain FDTD methods have enjoyed widespread use in the last decade TLM is a fast developing technique which was first introduced by P B Johns in 1971 At the beginning three dimensional 3D problems were simplified and reduced to a generalized 2D nodes Expanded Node in the TLM method

Towards the end of the 70 s 3D TLM began to be applied successfully to a wide variety of EM problems This thesis can be considered as an attempt for increasing the realm of complex EM problems which can be satisfactorily addressed by the TLM method We will consider two such problems concerning Electromagnetic Compatibility EMC and Specific Absorption Rate SAR calculations under realistic conditions for which hitherto it has not been possible to generate TLM solutions Our numerical calculations will show clearly that TLM can satisfactorily be applied to these problem areas We will also validate our solutions albeit in a necessarily incomplete manner by comparing our results with independently generated FDTD solutions of the same problems It has also to be mentioned that both the TLM and the FDTD algorithms used for this purpose in our work were developed and coded by the author TLM is based on network theory and involves TD lumped transmission line modeling of the Maxwell s equations in discretized spatial domain This is an entirely different approach from that used in the FDTD which relies on the direct discretization of the governing differential equations TLM involves replacing a continuous system by a network or array of lumped elements Interrelations and analogies between network equations and Maxwell s equations form the basis of this method and as such it can be considered as being more physical than strictly mathematical discretization approach Lumped parameters of the transmission line such as inductance and capacitance correspond to the electrical parameters relating to the permeability and permittivity distributions in the corresponding EM problem respectively Currents and voltages on the other hand correspond to the magnetic and electrical field components in the system There are many different TLM versions in the literature Here the most powerful of these approaches namely the 3 symmetrical condensed node SCN TLM version is used The main advantage of this node structure over the others and over the FDTD method is the symmetry it provides and the fact that the calculation of all the 6 field components is accomplished at the same time step Each SCN TLM node is represented by a scattering matrix S with which the reflected voltage pulses are related to the incident voltage pulses during the simulation time On the other hand there are two main drawbacks of the TLM method which are the requirement of large computer memories and high simulation times The organization of this work is as follows Chapter 2 is devoted to a fairly complete and detailed treatment of TLM method in 2D and 3D In this chapter we critically investigate the various TLM algorithms based on different node structures and assess relative merits in relation to their respective computational requirements and the accuracies numerical dispersion effects they provide In Chapter 3 two canonical problems i the Green s function representation in a PEC resonator and ii radiation from an aperture are considered for the purposes of validation calibration of our codes The calibration is done via comparisons both in TD and frequency domain FD Analytical representations of these two canonical problems are derived in the FD therefore comparisons in this domain are straightforward The TLM results are transformed to the FD via discrete Fourier transformation DFT On the other hand broad band TD comparisons are difficult and one needs to follow the steps given below o The TLM results are obtained directly by using a broad band pulse as a source and the response is obtained directly in the TD o FD results are calculated

separately at chosen sampling frequencies of the broad band pulse used in TLM simulation via analytical representations. Frequency domain results are weighed with the source spectrum and inverse DFT is applied to obtain the TD analytical results. During this process one must take the frequency resolution criteria into the consideration to get correct results. In Chapter 4 after having successfully calibrated our TLM code and also FDTD which is used to obtain comparison solutions we proceed to investigate the complex problems which constitute the main original contribution of this work. These are the Shielding Effectiveness SE and the Specific Absorption Rate SAR simulations for which where no TLM solutions are available. SE is an effective parameter in EM compatibility EMC problems and is used as a criterion for assessing a structure's susceptibility to EM interference. As a realistic prototype of EMC problems in this thesis we have considered a resonator with an aperture for SE modeling. The second problem we investigated concerns SAR calculations. SAR is the only parameter in bio-EM where device-human tissue interaction is of interest. The determination of SAR is an extremely complex problem and can be addressed either via difficult to perform laboratory measurements or via numerical methods using simulated tissue prototypes. In this thesis we have considered the nowadays rather actual problem of calculating SAR distributions in human head models. Extensive calculations for different parameter regimes are done for both problems and the TLM results are compared against the FDTD results and in the SE case also with the results given in the literature as obtained via Method of Moments MoM and validated experimentally. In all cases our results were in rather good agreement with the comparison solutions used. Finally in Chapter 5 we present some concluding remarks together with suggestions for future work.

Transmission Line Matrix (TLM) Techniques for Diffusion Applications Donard deCogan, 1998-11-26. Transmission Line Matrix TLM is a numerical technique which is based upon establishing an analogue between a space and time dependent physical problem and an electrical network which includes transmission lines. By their very nature these enforce time discretization on the network which can then be solved explicitly in the time domain. Although it is best known in electromagnetic applications TLM can also be used to model diffusion phenomena and this book outlines the state of the art in this area. The first part of the book deals with theory and techniques. The second part is devoted to the development of algorithms for specific applications. This is arranged as a historical sequence starting with heat flow and matter diffusion. The remainder of the book outlines many of the ingenious exploitations of the unique properties of TLM including topics such as the solution of convection Poisson Laplace and time dependent Schrodinger equations. Applications in the firing of ceramics chromatography image processing and the solution of inverse thermal problems are also covered. *Modeling of General Medium Constitutive Relationships in the Transmission Line Matrix Method (TLM)*. Leonardo Rodrigues Araujo Xavier de Menezes, 1996. This thesis presents the modeling of general medium constitutive relationships in the Transmission Line Matrix TLM method. The technique is shown for two and three dimensional cases. The procedure consists of decoupling the impulse scattering at the nodes from equations describing the medium. This is achieved by using nodal sources connected to

the TLM node The nodal sources are implemented with the state variable description of the constitutive relationships The technique requires only few modifications to the TLM algorithm The procedure is validated for frequency dependent nonlinear anisotropic and gyromagnetic media This thesis also presents a dispersion analysis of TLM with frequency dependent dielectrics This study is performed in two and three dimensions by solving the dispersion relationship of TLM with nodal sources The sources are used to model the frequency dependent dielectric The study shows that the nodal source and stub loaded models are equivalent for frequency independent dielectrics The accuracy bounds of the TLM frequency dependent dielectric model are presented This thesis also investigates the physical origin of the coarseness and dispersion errors influencing two dimensional TLM solutions of Maxwell s equations The study is performed by solving the difference equations of the numerical method analytically The results confirm a reduction of the accuracy of the discrete solution near field singularities The solution of a partially filled waveguide is also investigated The results show that TLM can have positive or negative frequency shifts depending on the dielectric filling excited mode and geometry These results are also valid for the finite difference time domain method FDTD

Transmission Line Matrix (TLM) in Computational Mechanics Donard de Cogan, William J. O'Connor, Susan Pulko, 2005-11-01 The finite element method reigns as the dominant technique for modeling mechanical systems Originally developed to model electromagnetic systems the Transmission Line Matrix TLM method proves to match and in some cases exceed the effectiveness of finite elements for modeling several types of physical systems Transmission Line Matrix in Computational Mechanics provides a tutorial approach to applying TLM for modeling mechanical and other physical systems Transmission Line Matrix in Computational Mechanics begins with the history of TLM an introduction to the theory using mechanical engineering concepts and the electromagnetic basics of TLM The authors then demonstrate the theory for use in acoustic propagation along with examples of MATLAB code The remainder of the book explores the application of TLM to problems in mechanics specifically heat and mass transfer elastic solids simple deformation models hydraulic systems and computational fluid dynamics A discussion of state of the art techniques concludes the book offering a look at the current research undertaken by the authors and other leading experts to overcome the limitations of TLM in applying the method to diverse types of systems This valuable reference introduces students engineers and researchers to a powerful accurate and stable alternative to finite elements providing case studies and examples to reinforce the concepts and illustrate the applications

Simplified Transmission Line Models for Use with Computer-Aided Circuit/System Analysis Programs Jerry I. Lubell, TRW SYSTEMS GROUP REDONDO BEACH CA., 1973 Two distinct but complimentary techniques for modeling multiconductor transmission lines for use with the SCEPTRE computer program are presented The transmission line models developed can be modified for compatibility with other circuit system transient analysis programs and are amenable to modification to include nuclear weapon effects The general modeling approach has been to develop computationally efficient and accurate terminal models which can be arbitrarily loaded at the source and

load ends and which can be used in conjunction with nonlinear electronic circuit models using either simplified or discrete modeling techniques The two modeling techniques developed are the state space method and the orthonormal function method For both cases all required parameters can be determined from terminal measurements The state space method is a new approach to modeling transmission lines using a lumped approximation For the multiconductor case the orthogonal characteristics of wave propagation are used to decouple the modes of propagation except at the source and load boundary conditions circuits The concept of the orthonormal function method is to derive a set of transfer functions in the Laplace domain relating forward and backward traveling waves on the line to voltages and currents at the source and load ends of the line approximate the transfer functions with Laguerre polynomials and representing the resulting rational polynomials in the time domain with state variable differential equations For the multiconductor case the orthogonal characteristics of wave propagation are used to separate the modes and the transfer functions for each mode are determined

Microstrip Antennas David M. Pozar, Daniel H. Schaubert, 1995-05-15 This anthology combines 15 years of microstrip antenna technology research into one significant volume and includes a special introductory tutorial by the co editors Covering theory design and modeling techniques and methods this source book is an excellent reference tool for engineers who want to become more familiar with microstrip antennas and microwave systems Proven antenna designs novel solutions to practical design problems and relevant papers describing the theory of operation and analysis of microstrip antennas are contained within this convenient reference

Proceedings Society for the Promotion of Engineering Education (U.S.), 1930

Engineering Education, 1929 **Proceedings of the ... Annual Meeting** Society for the Promotion of Engineering Education (U.S.). Annual Meeting, 1930 *Proceedings of the Annual Meeting* American Society for Engineering Education, Society for the Promotion of Engineering Education (U.S.), 1930

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