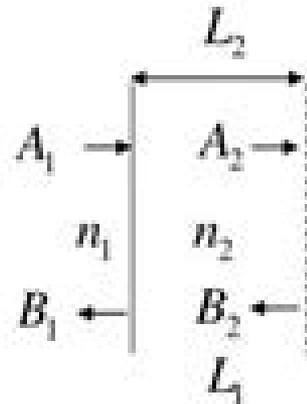
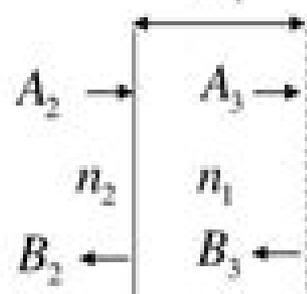


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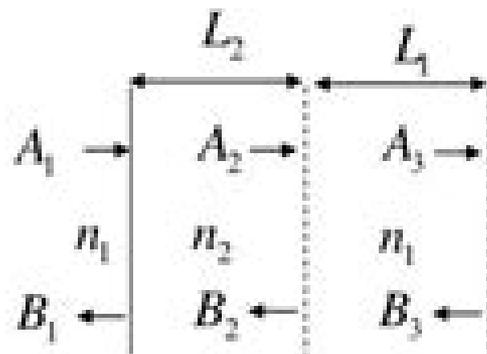
$$\begin{pmatrix} A_1 \\ B_1 \end{pmatrix} = \begin{pmatrix} T_{11} & T_{12} \\ T_{21} & T_{22} \end{pmatrix} \begin{pmatrix} A_2 \\ B_2 \end{pmatrix} = M_1 \begin{pmatrix} A_2 \\ B_2 \end{pmatrix}$$

$$M_1 = \frac{1}{t_{12}} \begin{pmatrix} e^{-i\beta_2 L_2} & -r_{21} e^{i\beta_2 L_2} \\ r_{12} e^{-i\beta_2 L_2} & (t_{12} t_{21} - r_{12} r_{21}) e^{i\beta_2 L_2} \end{pmatrix}$$



$$\begin{pmatrix} A_2 \\ B_2 \end{pmatrix} = \begin{pmatrix} T_{11} & T_{12} \\ T_{21} & T_{22} \end{pmatrix} \begin{pmatrix} A_3 \\ B_3 \end{pmatrix} = M_2 \begin{pmatrix} A_3 \\ B_3 \end{pmatrix}$$

$$M_2 = \frac{1}{t_{21}} \begin{pmatrix} e^{-i\beta_1 L_1} & -r_{12} e^{i\beta_1 L_1} \\ r_{21} e^{-i\beta_1 L_1} & (t_{12} t_{21} - r_{12} r_{21}) e^{i\beta_1 L_1} \end{pmatrix}$$



$$\begin{pmatrix} A_1 \\ B_1 \end{pmatrix} = M_3 \begin{pmatrix} A_3 \\ B_3 \end{pmatrix}$$

$$M_3 = M_1 M_2$$

Transmission Line Matrix

Mike Jess



Transmission Line Matrix:

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

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

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

On the Foundations of the Transmission Line Matrix Method Jürgen N. Rebel, 2000 **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

3-D Transmission Line Matrix Method and Application Interface Wei Gao,2002

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

Electromagnetic Analysis Using Transmission Line Variables (2nd Edition) Maurice Weiner,2010-08-31 This book employs a relatively new method for solving electromagnetic problems one which makes use of a transmission line matrix TLM The propagation space is imagined to be filled with this matrix The propagating fields and physical properties are then mapped onto the matrix Mathematically the procedures are identical with the traditional numerical methods however the interpretation and physical appeal of the transmission line matrix are far superior Any change in the matrix has an immediate physical significance What

is also very important is that the matrix becomes a launching pad for many improvements in the analysis using more modern notions of electromagnetic waves Eventually the purely mathematical techniques will probably give way to the transmission line matrix method Major revisions occur in chapters IV and VII in this second edition The revised chapters now present an up to date and concise treatment on plane wave correlations and decorrelations and provide a revised formulation of simulation to solve transient electromagnetic problems It also takes into account semiconductors with arbitrary dielectric constant using much smaller cell size and extending the range of applicability and improving accuracy

THE TRANSFER/TRANSMISSION LINE MATRIX METHOD APPLIED IN ELECTROMAGNETICS. Yifeng Qin, 2019 Although numerical full wave methods are widely used for simulating and troubleshooting electromagnetic problems these methods are computationally intensive for predicting the waves behavior in a stratified system or a system with multiple meta slabs Analytical methods relying on transmission matrices instead feature advantages in handling such complicated problems This dissertation investigates the multi conductor transmission line MTL matrix method and the transfer matrix method TMM as well as their applications in various research areas Chapter 1 reviews the basic knowledge of TMM Chapter 2 studies the application of multi conductor TMM in the frequency response of multiple perfect electric conducting PEC cable transmission lines placed above an infinite lossy ground Chapter 3 proposes and proves a generalized TMM for improving the performance and reliability of solving and predicting the behaviors of ordinary EM waves in an arbitrary medium Its application in multi beam transmit surface array antennas is also studied As an extension a method of retrieving four full rank constitutive tensors and is proposed Chapter 4 demonstrates a novel structure for dual band low profile antennas Its eigencurrent modes are analyzed via the MTL matrix method which reveals the operating mechanisms of different radiation modes Chapter 5 proposes a ferrite loaded crossed bowtie circularly polarized Vivaldi curvature dipole antenna as well as a guideline for the proper usage of ferrite material

Transmission-line Matrix Modeling Paul Robert Hayes, 1990 **Electromagnetic Analysis Using Transmission Line Variables** Maurice Weiner, 2010 Summary Describes transmission line matrix techniques for solving electromagnetic problems The approach visualizes the propagation medium as divided into identical cells with the electromagnetic energy confined to transmission lines which separate the cells The author who works for United Silicon Carbide develops the electromagnetic scattering equations for one two and three dimensions corrects the transmission line matrix for any wave properties and incorporates boundary conditions and dispersion into the method Finally he outlines a computer program for finding the transient solution of a 2D semiconductor switch whose conductivity is induced by a light source

Application of the Transmission-Line Matrix Method to Open Region Field Problems Neil R. S. Simons, 1990 Transmission Line Matrix Modelling - TLM, IEE Colloquium on Institute of Electrical and Electronics Engineers, 1991 The Transmission Line Matrix (TLM) Method Applied to Linear and Non-linear Potential-type Problems David Gavin, University College, Dublin. Department of Mechanical Engineering, 2000 **Frequency Domain**

Transmission Line Matrix Method and Its Applications to Electromagnetic Analysis Jifu Huang,1995

Hybridization of the Transmission-Line-Matrix Method (TLM) with the Integral Equation Method for the Analysis of Electromagnetic Coupling Nikolaus J. Fichtner,2011 **A Transmission Line Matrix Method with Irregular Graded Space** D. A. H. al-Mukhtar,1980

The Transmission Line Matrix (TLM) Method and Its Boundary Treatments Zhizhang Chen,1992 *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

Finite-difference Transmission-line Matrix Method and Its Applications Minya Zhang, McMaster University.

Department of Electrical and Computer Engineering, 1993

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