TFDTLM: A NEW COMPUTATIONALLY EFFICIENT FREQUENCY DOMAIN TLM BASED ON TRANSIENT ANALYSIS TECHNIQUES

Iman Salama

Dissertation submitted to the Faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of

Doctor of Philosophy

In

Electrical Engineering

Dr. S. Riad, Chair

Dr. I. M. Besieris

Dr. C. Christopoulos

Dr. A. Elshabini Riad

Dr. W. A. Scales

Dr. W. Su

September 11

Blacksburg, Virginia

Keywords: Electromagnetics, Computational efficiency, Frequency domain TLM

TFDTLM: A New Computationally Efficient Frequency Domain TLM Based on Transient Analysis Techniques

Iman Salama

(Abstract)

The TLM was initially formulated and developed in the time domain. One key issue in a time domain analysis approach is the computational efficiency, where a single impulsive excitation could yield information over a wide frequency range. Also, it may be more natural and realistic to model non linear and frequency dispersive properties in the time domain rather than in the frequency domain. However, in some circumstances, frequency domain analysis may be more appealing. This might be due to the fact that the traditional teaching of electromagnetics emphasizes frequency domain concepts as frequency dispersive constitutive parameters, complex frequency dependent impedances and reflection coefficients. It might be even easier and more direct to be able to model these parameters in frequency domain rather than trying to synthesize an equivalent time domain model. The only limitation of frequency domain analysis, is that the analysis has to be repeated at every frequency point in the frequency range of interest.

In this work, a new frequency domain TLM (FDTLM) approach is introduced which combines the superior features of both the time domain and the frequency domain TLM. The approach is based on a steady state analysis in the frequency domain using transient analysis techniques and hence is referred to as TFDTLM. In this approach, the link lines impedances are derived in the frequency domain and are chosen to model the frequency dispersive material parameters. The impedances and propagation constants are allowed to be complex and frequency dependant. Consequently, the TFDTLM can provide more accurate modeling for wave propagation in a frequency dispersive medium. The approach was inspired by the concept of bounce diagram in the time domain and the equivalent frequency domain bounce diagram.

To make the TFDTLM approach computationally efficient as compared to other frequency domain TLM approaches, it was critical to maintain some relationship between the mesh response at one frequency point and any other frequency point. The goal was to be able to extract all the frequency domain information in a wide frequency range by performing only one simulation. To achieve this, the transitions between two adjacent cell in all media expressed by ($e^{-\gamma l}$) have to be expressed in terms of the propagation factor of some reference medium chosen to be the medium with the least propagation delay. This was done with the aid of a digital filter approximation that can be implemented iteratively inside the TLM mesh. The filter can be thought of as some type of compensation equivalent to the stubs in a time domain TLM, yet more accurate and more general. An important advantage of the TFDTLM is that it can easily be interfaced with existing time domain TLM schemes as well as absorbing boundary conditions originally developed for time domain TLM with the slightest modifications. The

TFDTLM is implemented a three dimensional mesh and the superior performance of the new approach in modeling lossy inhomogeneous media is demonstrated.

The new approach in addition to being computationally efficient as compared to other frequency domain TLM methods, has proven to have superior dispersion behavior in modeling lossy inhomogeneous media as compared to time domain TLM .

Acknowledgments

I would like to express my deepest gratitude to Dr. Sedki Riad for his valuable advice and support during this research work.

I would to thank my committee members: Dr. I. M. Besieris, Dr. C. Christopoulos, Dr. A. Elshabini Riad, Dr. W. A. Scales and Dr. W. Su for serving on my committee.

I would like to sincerely thank my husband for all his help, encouragement, patience and understanding

I would like also to acknowledge my parents, brothers and sister for their love and encouragement

Contents

List of Figures

List of Tables