THE COMPARISSION THREE STRUCTURE OF COST 251 USING TLM METHOD

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ABSTRACT

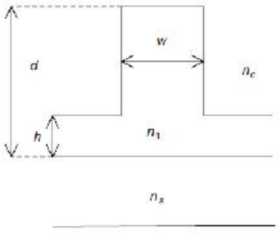
The Transmission Line Matrix (TLM) was formulated and represented in the time domain. The main issue of approach in time domain analysis is the efficiency of computation to model non linear characteristic in time domain rather than in frequency domain. In this research, a TLM approach in the time domain analysis will be introduced to solve the III-V single rib waveguide structure that had been finished by previous researchers. The approach method is based on a huygen's principle using shunt mode equivalent circuit representation in the inhomogeneous material to solve scalar wave equation. Propagation constants can be obtained by solving eigen value, β, of scalar wave equation. Consequently, by setting the suitable mesh size, the result of TLM can provide more accurate and stability modeling for wave propagation compared with the other methods. The accuracy and stability of TLM will be presented in this research.

KEY WORDS : TLM, mesh size, normalized propagation constant.

INTRODUCTION

Nowadays, typical loss values of a modern single mode doped silica fiber are 0.2 dB/km at 1.55 μm and 0.5 dB/km at 1.3 μm where a dispersion of assumption set to zero. This development provided the motivation of researchers to develop practical integrated optical devices whose properties are optimized concerning to the fiber transmission characteristics in terms of speed and processing efficiency, transmission, and reception of information. To model and simulate their behaviors in order to allow the best design before fabrication, it is increasing the need of method to have powerful tools with the appropriate accuracy.

In integrated optics in III-V compound semiconductors a variety of optical waveguides using different fabrication techniques have been realized and implemented. In every case of wave guiding depends on the difference in the effective refraction index between the wave guiding region and the surrounding media. The structure of rib waveguide have been finished by the previous researchers in the single rib integrated waveguide structure which was examined by different methods as shown in figure. 1.1.



where
ns= substrate refractive index;
nc= cladding refractive index;
nf= core refractive index;
w =rib width;

Figure. 1.1 Rib waveguides structure analyzed.

It operates at λ=1.55μm with w=2 μm and w=3μm and having height, h, of the rib waveguide structure is chosen large enough as not to influence the effective refractive index results. The parameter of rib waveguide structure for comparison based on figure 1.1 have three structures as listed in table 1.1.

Table 1.1: Parameter of rib waveguide to compare.

Guide	1	2	3
nf	3.44	3.44	3.44
ns	3.34	3.36	3.4
nc	1	1	1
d (μm)	1.3	1	1
h (μm)	0.2	0.9	0.6-0.7

w (μm)	2	3	3

A number of available methods to analyze integrated optical waveguides such as effective index method, finite difference method, finite element method, and beam propagation method have been conduted in single rib waveguide, but the TLM method didn't present in previous research. Therefore, the aim of this research is to analyze and to prove the 2D scalar wave equation using TLM method in single rib waveguide structure of III-V integrated optic device. The introduction of TLM method will be provided in chapter 2. The research was concentrated to model and analyze single rib waveguide structure of the propagation mode using matlab platform. Through these simulations the characteristics of rib waveguide 2D scalar wave equation could be understood easily.

LITERATURE REVIEW

Transmission-line matrix (TLM) also known as the transmission line modeling method is one of numerical techniques to solve field problems using circuit equivalent. The equivalence between Maxwell's equations and the equations of voltages and currents on a mesh is based on continuous two-wire transmission lines. Consider an length λ of a two-wire transmission lines will find an equivalent circuit representation and derive the line equations. An equivalent circuit of the line is shown in figure 2.1, where resistance represent as per unit length, inductance per unit length, conductance per unit length, and capacitance per unit length of the line, are the parameters of R, L, G, and C respectively.

According to "[Sadiku et al, A simple introduction to the transmission-line modeling]" is one of the solutions of a 2D wave equation that involves four steps as below:

1. Space discretization: The solution region is divided into a number of blocks to fit the geometrical and frequency requirements. Each block of transmission lines is interconnected to form the "node" and then adjacent nodes are connected to form a mesh describing its entire.
2. Excitation: This involves imposing the initial conditions and source.
3. Scattering: The pulses propagate along transmission lines toward each node. At each new time step, the scattering and connection processes may be repeated to show propagation for any desired length of time
4. Output: At any time step, the electric and magnetic fields are represented corresponding to the particular excitation voltages and currents on transmission lines. If the quantities in the time domain available at each time step, there is no an iterative solution procedure, except Fourier transform techniques may be obtained in frequency-domain information.

DISCUSSION

This chapter will discuss about the implementation result of TLM in scalar wave equation. The behavior of electromagnetic wave using a numerical technique must be considered and analyzed to solve the propagation constants of the scalar wave equation. The Huygens' Principle in time domain are presented in TLM. An accurate description of wave propagation and scattering which is fully compatible with Maxwell's theory for structure 1, 2, and 3 leads to the systematic application of this principle.

Three structures analyzed in this paper are:

Structure 1

By setting separated mesh distance to adjacent node at 0.048 μm, the normalized propagation constant, β , was achieved at 0.4966. The simulation result shows in table 3.1. It can be seen that the structure 1 has a strong wave guiding due to the structure has relative large vertical refractive step index with refractive index differences of about 0.9 μm between cladding and film and 0.1 μm between film and substrate, respectively. In the lateral direction, the rib height is larger than 0,1 μm and the width narrow about 2 μm. A strong light confinement in both lateral and vertical direction has been had inside rib waveguide so that the radiation loss can be minimized in this structure. In this case, the calculation of cut off thickness in structure 1 is between 0,3945 μm and 1,336 μm, while the rib cut off thickness is 1.3 μm. Therefore the values of β is expected to be lower than true value of effective index method as shown in table 3.1. The result of normalized propagation constant (β**)** in TLM lower than the true value of effective index method will be accepted.

Table 3.1. The comparison of normalized propagation constant, b, for guide 1

Methods at Δ*l*=0.048μm	**nf=3.44,ns=3.34,nc=1, d=1.3,h=0.2,w=2**	
	β (guide1)	**E(a) %**
Effective Index Method	0,4995	-0,584%
Mode Matching	0,4782	3,705%
Function Fitting	0,5008	-0,846%

Finite Different (FD1)	0,5205	-4,813%
Finite Different (FD2)	0,5092	-2,537%
Finite Different (FD3)	0,4980	-0,282%
Beam Propagation Method	0,4990	-0,483%
Variational Method	0,5020	-1,087%
Transmission Line Modeling	**0,4966**	**-8,7289E-5%**

Structure 2.

Table 3.2 shows a comparison the result of β values between the method labeled as Transmission Line Modeling compared with the previous researcher methods. Structure 2, which the rib height was set in 0,1 µm and the width in 3 µm, respectively, may allow the mode propagation extend in laterally direction. The accuracy of result, therefore, is higher than the value of effective index method, 0.4404 µm, the large width to height ratio and the small etch step in ribs height are the conditions of validity of this approximate method. To give thin mode shape in vertical direction, the guiding layer thickness is made small and thus low voltage operation will be achieved. In fact that this structure is particularly useful directional coupler structure, as strong coupling in short coupling length will result between adjacent guides. Thus the approach of β values calculated using TLM is also accepted in structure 2.

Table 3.2. The comparison of normalized propagation constant, b, for guide 2.

Methods at Δl=0.048µm	**nf=3.44,ns=3.34,nc=1, d=1.3,h=0.2,w=2**	
	β (guide2)	**E(a) %**
Effective Index Method	0,4404	0,227%
Mode Matching	0,4390	0,544%
Function Fitting	0,4332	1,858%
Finite Different (FD1)	0,4367	1,065%
Finite Different (FD2)	0,4400	0,317%
Finite Different (FD3)	0,4406	0,181%
Beam Propagation Method	0,4280	3,036%
Variational Method	0,4348	1,495%
Effective Index Method (P-EIM)	0,4407	0,159%
Mode Solver 2D	0,4408	0,136%
Mode Solver 3D	0,4421	-0,159%
2D- Beam Propagation Method (P-2DBPM)	0,4317	2,198%
Transmission Line Modeling	**0,4414**	**0,000%**

Structure 3.

At table 3.3, the normalized propagation constant, β, due to different guide thickness is displayed with the asymmetry factor about 39,596. Therefore, to get the optimum result, the appropriate mesh size was set in this simulation. The approach result gave the normalized propagation constant value placed between scalar finite different and varational method. These parameter gave different contribution in guiding wave to confine light in both vertical and lateral direction . The all result tabled in table 3.3 has a weak guide performance due to the wave is tightly confined vertically and weakly confined horizontally. Both of the rib height 0.6 µm and 0.7 µm, respectively, the wave still confined in the rib structure., while the others as increasing of the rib height the contour of E field spread out in horizontal direction, It can be seen as radiation loss. These demonstration structue have weak guiding performance in the lateral direction. Hence, a very small etch depth would be desirable, but this presents some serious practical difficulties with respect to uniformity and reproducibility.

Table 3.3. The comparison of normalized propagation constant, b, for guide 3 of different guide thickness.

Methods	**Thickness Guide, d, (µ m)**			
	0,6	**0,7**	**0,8**	**0,9**
Effective Index Method	0,3583	0,3649	0,3749	0,3908
Varational Method	0,3257	0,3374	0,3548	0,3819
Vector Finite Element	0,3382	0,3522	0,3684	0,3905
Scalar Finite Element	0,3369	0,3497	0,3656	0,3869
Semivectorial Finite Different	0,3382	0,3525	0,3696	0,3905
Scalar Finite Different	0,3612	0,3711	0,3815	0,3916
Effective Index Method (P-EIM)	0,3586	0,3652	0,3751	0,3909
Mode Solver 2D	0,3587	0,3661	0,3761	0,3911
Mode Solver 3D	0,3462	0,3562	0,3711	0,3911

2D- Beam Propagation Method (P-2DBPM)	0,3511	0,3568	0,3654	0,3783
Transmission Line Modeling	**0,3328**	**0,3519**	**0,3654**	**0,385**

CONCLUSION

1. The TLM is a powerful and versatile modeling procedure because the result of normalized propagation constant is lower than the value of effective index method in the three structures.
2. A better response is to introduce by setting a network of variable mesh size to provide higher resolution in the nonuniform field region.
3. The TLM result for the three waveguide structures has almost zero relative error.

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