Performance Analysis of Mach-Zehnder Modulator Using Fuzzy Logic Generator

Shivani, Neelkamal, Yogesh Garg

Abstract--- In this paper, we analyze the impact of extinction ratio (Ron/off) of Mach-Zehnder (MZ) amplitude modulator using Fuzzy logic generator. The system performance has been analyzed by varying the value of extinction ratio (Ron/off) from 0 to 10 dB. It is found that the system gives optimum performance at extinction ratio value 9.965 dB. Further, the fuzzy model of the system is developed using ANFIS (Adaptive Neuro-Fuzzy Inference System) for varying extinction ratio of MZ modulator and performance is evaluated with fuzzy model. The performance of MZ modulator is evaluated by using simulation platform of Fuzzy Logic generator in MATLAB 7.0

Index Terms---- MZM (Mach-Zehnder Modulator), ANFIS (Adaptive Neuro-Fuzzy Inference System), Fuzzy Logic, Modulator

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1. INTRODUCTION

In this paper, the Fuzzy logic system is used for high quality transmission which increases spectrum efficiency and an improvement of error performance in optical fiber communication systems which are important. Fuzzy Logic (FL) is successfully used in today's process control systems. Fuzzy logic addresses such applications perfectly as it resembles human decision making with an ability to generate precise solutions from uncertain or approximate information. It fills an important gap in engineering design methods left by mathematical and logic-based approaches. [1]

A model of Fuzzy logic Inference system with MZ modulator is developed using MATLAB 7.0.

2. SCHEMATIC DIAGRAM OF MACH-ZEHNDER MODULATOR

The schematic diagram of Mach-Zehnder (MZ) modulator is shown in figure 2.1. Lithium Niobate Mach-Zehnder modulators are suited for use in metro, long-haul (LH) and ultra long-haul (ULH) optical transport applications [3-4].

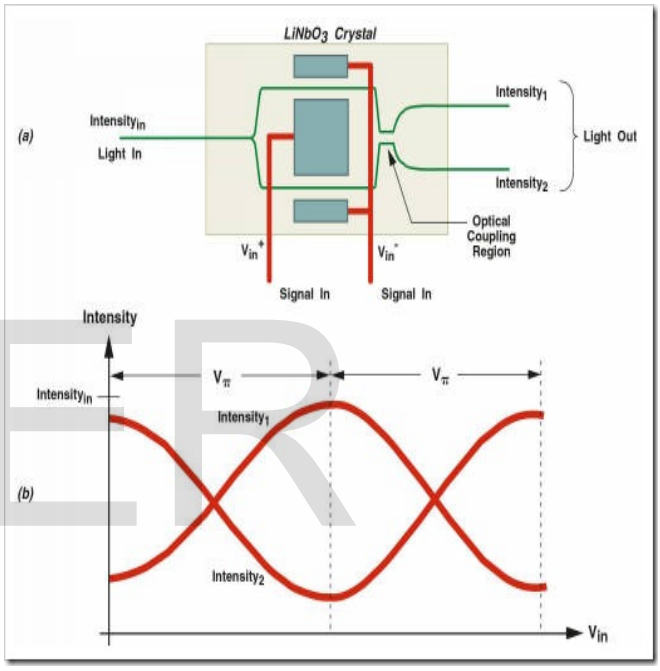

Figure 1: Schematic diagram of Mach-Zehnder Modulator

The incoming optical signal is split equally and is sent down two different optical paths. After a few centimeters, the two paths recombine, causing the optical waves to interfere with each other. Such an arrangement is known as an interferometer. If the phase shift between the two waves is 0°, then the interference is constructive and the light intensity at the output is high (on state); if the phase shift is 180°, then the interference is destructive and the light intensity is zero (off state). The phase shift, and thus the output intensity, is controlled by changing the delay through one or both of the optical paths by means of the electro-optic effect. This effect occurs in some materials such as lithium niobate (LiNbO3), some semiconductors, as well as

some polymers and causes the refractive index to change in the presence of an electric field.

3. FUZZY MODEL

Fuzzy Logic (FL) is successfully used in today's process control systems. Fuzzy logic addresses such applications perfectly as it resembles human decision making with an ability to generate precise solutions from uncertain or approximate information. It fills an important gap in engineering design methods left by mathematical and logic-based approaches. FL is a problem-solving control system methodology that lends itself to implementation in systems ranging from simple, small, embedded micro-controllers to large, networked, multi-channel PC or workstation-based data acquisition and control systems. It can be implemented in hardware, software, or a combination of both. Fuzzy control, which directly uses fuzzy rules, is the most important application in fuzzy theory. Using a procedure originated by Ebrahim Mamdani in the late 70s, three steps are taken to create a fuzzy controlled machine:[5]

1) Fuzzification (Using membership functions to graphically describe a situation)

2) Rule evaluation (Application of fuzzy rules)

3) Defuzzification (Obtaining the crisp results)

Fuzzy logic is not really "fuzzy" A fuzzy controller has a set of rules that it uses to decide the final action. Each rule is in linguistic expression about the control action to be taken in response to a given set of process conditions.

4. IMPLEMENTATION OF FUZZY MODEL

The schematic of Fuzzy Logic Model System simulation setup is shown in figure 4.1.The Sugeno Fuzzy model is developed using ANFIS (Adaptive Neuro-Fuzzy Inference System) for varying the value of Vπ (input1) and extinction ratio (Ron/off) of MZ modulator (input2). The Dispersion in dB acts as the output of the system.

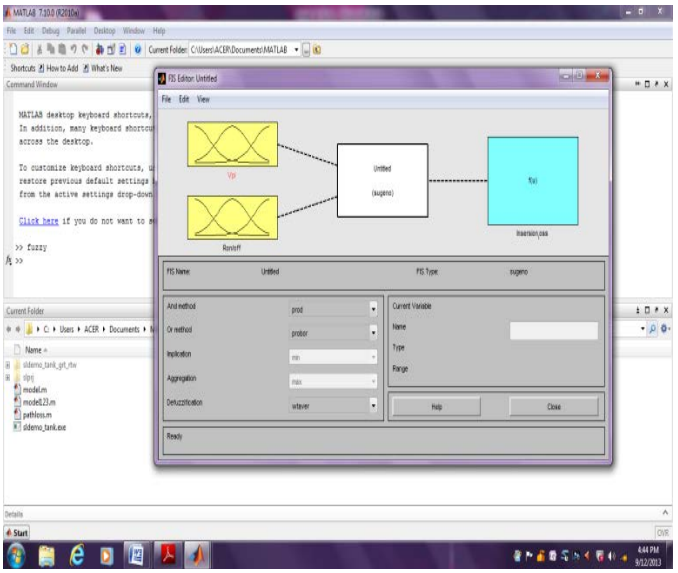

Figure 4.1 Sugeno based fuzzy model of Mach-Zehnder modulator.

The Mach-Zehnder modulator system uses five membership functions for Vπ (input1) variable, five membership functions for Ron/off (input 2) variable for Sugeno based Fuzzy model as shown in figure 4.2

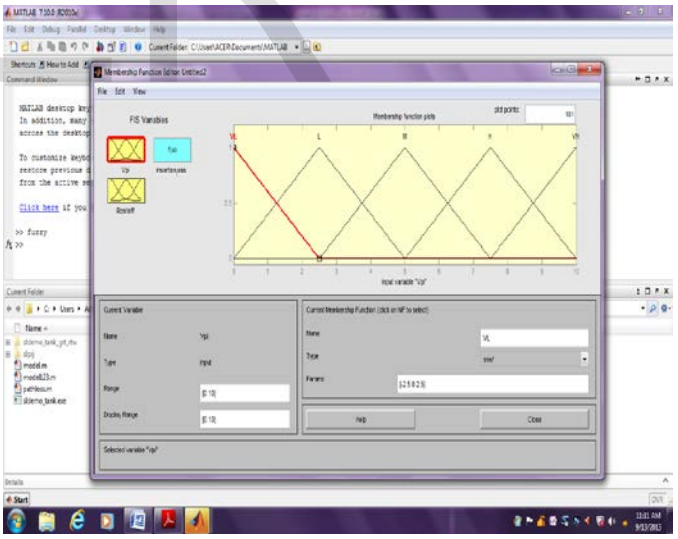

Figure 4.2 Membership function for input 1 and input 2 variables.

Table 4.1 Set the Linguistic Rules

S. no.	Set the Linguistic Rules
1	If Vπ is low; and Ron/off high; Then Dispersion loss is high
2	If Vπ is low; and Ron/off high; Then

	Dispersion loss is moderate
3	If Vπ is high; and Ron/off high; Then Dispersion loss is high
4	If Vπ is high; and Ron/off high; Then Dispersion loss is moderate
5	If Vπ is very low; and Ron/off high; Then Dispersion loss is high
6	If Vπ is very low; and Ron/off high; Then Dispersion loss is moderate
7	If Vπ is very high; and Ron/off high; Then Dispersion loss is high
8	If Vπ is very high; and Ron/off high; Then Dispersion loss is moderate
9	If Vπ is moderate; and Ron/off high; Then Dispersion loss is high
10	If Vπ is moderate; and Ron/off high; Then Dispersion loss is moderate
11	If Vπ is moderate; and Ron/off low; Then Dispersion loss is low
12	If Vπ is moderate; and Ron/off high; Then Dispersion loss is high
13	If Vπ is moderate; and Ron/off very high; Then Dispersion loss is very high
14	If Vπ is moderate; and Ron/off very low; Then Dispersion loss is very low

The Mach-Zehnder modulator system uses fourteen rules for Sugeno based Fuzzy model. Set the linguistic rules for fuzzy model are given below in table 4.1.

Further, the ANFIS model structure for Mach-Zehnder modulator is represented in figure 4.3.

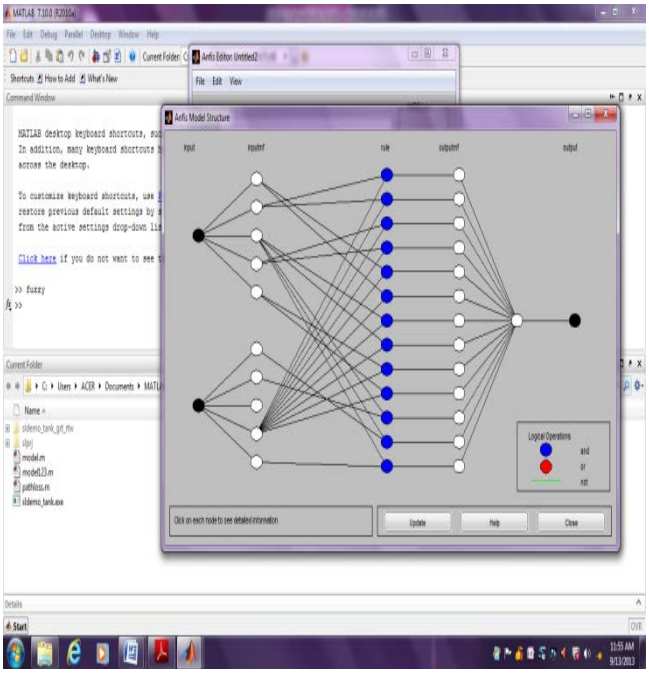

Figure 4.3 ANFIS model structure for Mach-Zehnder modulator.

5. RESULTS AND DISCUSSION

The system performance has been analyzed by varying the value of extinction ratio (Ron/off) from 0 to 10 dB. It is found that the system gives optimum performance at extinction ratio value 9.965 dB.

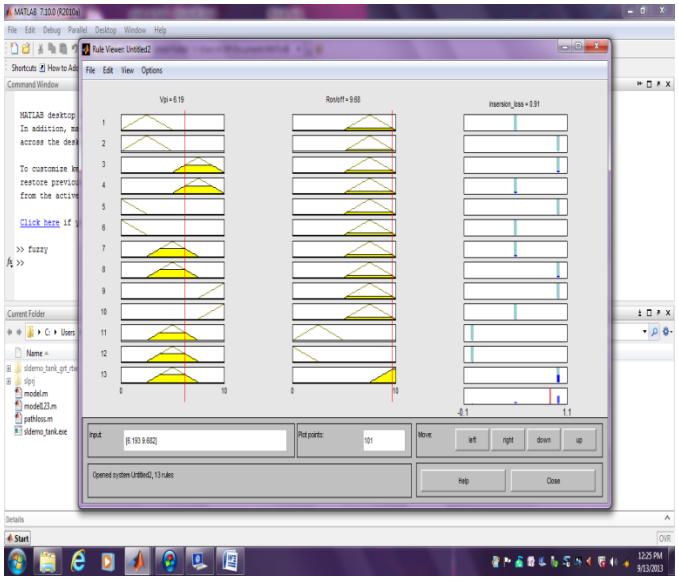

Figure 5.1 Rule Viewer of Dispersion [dB] for varying the value of extinction ratio.

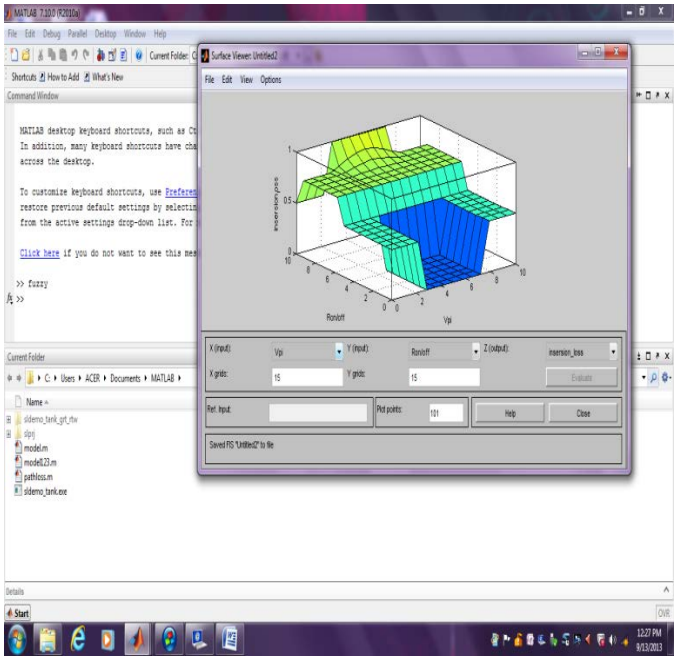

Figure 5.2 Rule Viewer of Dispersion [dB] for varying the value of extinction ratio.

Figure 5.1 shows the rule viewer of fuzzy model for Mach-Zehnder modulator for specific cases when the extinction ratio = 9.965 dB. Then output value Dispersion = 0.222dB which is close to the mathematical value of Dispersion is 0.220 dB. So that the system gives optimum performance at the extinction ratio = 9.965 dB.

Figure 5.2 showing the surface plot for fuzzy system endorses the results obtained is 0.222dB from simulation. Also, the system performance is observed from the rule viewer of the fuzzy system for different values. It can also be clear that if the numbers of rules have been increased in the fuzzy model, this increases the number of parallel computations and thus accuracy.

The optimum results obtained using simulation of ANFIS fuzzy model system as compared to the mathematically output value of the Dispersion of Mach-Zehnder modulator.

6. CONCLUTIONS

The simulated Dispersion value [dB] for varying extinction ratio and Vpi has been obtained for Mach-Zehnder modulator using ANFIS fuzzy model system. It is observed that with the increase in extinction ratio (Ron/off) of the modulator from 0 to 10 dB, and decrease the dispersion value for Mach-Zehnder modulator. This paper presents a comparison of the mathematical value with the results obtained from ANFIS fuzzy model. And it is observed that the finding of mathematical are quite close to the ANFIS based fuzzy model.

7. REFERENCES

[1] K Seshadri Sastry et.al, "Fuzzy Logic Based Adaptive modulation Using Non Data Aided SNR Estimation for OFDM System," International Journal of Engineering Science and Technology Vol. 2(6), 2010, 2384-2392

[2] L.D.R.Suresh et.al, "Real Time Adaptive Non linear Noise Cancellation Using Fuzzy Logic For Optical Wireless Communication System with Multi Scattering System," Engineering Letters, 2008.

[3] Yousef S. Kavian et.al, "Fuzzy Linear Programming for Capacity Planning in Optical Networks," Proceedings of ICTON 2010.

[4] Yu Zeng et.al, "Fuzzy Logic Control Based Modulation Optimization for the indoor optical Wireless Channel," Proceedings of ITCON 2010.

[5] Anu Sheetal and Harjit Singh "Performance Analusis of 2.5Gb/s Bidrectional WDM/TDM-PON with Narrowband AWG for varing Extinction Ratio using ANFIS" journal Anu Books, pp. 150-158, 2011.

[6] D T Pham and M Castellani, "Evolutionary fuzzy logic system for intelligent fibre optic components assembly," Proceedings of institution of mechanical engineers, vol. 216, no. 5, 2002, pp. 571-581

Shivani is currently pursuing master degree program in Electronics &Communication engineering in PTU University, Punjab, India. E-mail- shivani_273@yahoo.co.in.

Neelkamal is currently working as Assistant Professor in GTBKIET, Chhapianwali Malout, Punjab, India. E-mail-neel_kamalgtb@yahoo.com

Yogesh Garg is currently working as Lecturer in Government Polytechnic College for Girls Patiala, Punjab, India. E-mail- yogeshgarg797@gmail.com