전기 광학 광변조기의 바이어스 안정화를 위한 오프 레벨 샘플링 방법

정회원 양 충 열*, 홍 현 하*, 김 해 근*

Off-level Sampling Method for Bias Stabilization of an Electro-Optic Mach-Zehnder Modulator

Choong-Reol Yang*, Hyun-Ha Hong*, Hae-Gun Kim* *Regular Members*

요 약

버스트 모드 패킷 트래픽 조건에서 스위칭 소광비를 최대화하는 전기 광학 광변조기의 바이어스 안정화를 위한 새로운 방법을 입증하였다. 광변조기의 오프 레벨 출력 전력을 샘플링하고 최소화함으로써 패킷 트래픽 밀도의 변화에 무관하게 높은 소광비를 갖는 광 게이트로서 동작한다.

ABSTRACT

A new method for stabilizing the bias of an Electro-Optic Mach-Zehnder modulator has been developed to maximize the switching extinction ratio in burst mode packet traffic. By sampling and minimizing the off-level output power of the modulator, a high extinction optical gate switch in obtain regardless of the variation of the packet traffic density.

Indexing terms : EO modulator, Bias Stabilization, Burst mode traffic

Ⅰ. Introduction

Optical packet switches have been actively researched because of their potentials in the future all-optical networks[1-3]. To build such a system, several key modules including a high-speed multi-wavelength laser source and a high-speed wave-length selector, have to be incorporated[4,5]. The optical gate switch is a key component in such functional modules. Semiconductor Optical Amplifier(SOA) has been considered for that purpose because of its optical amplification property and a monolithic integration possibility with other devices[6]. While, the Electro-optic Mach-Zehnder(EO-MZ) modulators can be as gate switches because commercially available versions of them have already been produced which operate at up to 10 Gb/s that have low chirp and low noise characteristics.

Several drift mechanisms are present in EO-MZ modulators under operational conditions. The conventional method of bias stabilization for optical modulator, which utilizes dithering signal and lock-in detection, is unsuitable for applying the optical modulator as an optical gate under burst mode, because it has a disadvantage that an error signal extracted for controlling bias voltage varies depending on the traffic characteristic of the output optical signal[6]. Another conventional

* ETRI 광교환연구팀(cryang@etri.re.kr)
논문번호 : 98556-1228, 접수일자 : 1998년 12월 28일

method of bias stabilization is to compare the effective DC component of the electrical input signal with that of the optical output signal and then adjust bias so as for the electrical input signal and the optical output signal to have the same traffic characteristic. This method is applicable to the burst mode traffic characteristic because it is possible to obtain an optical output modulated identically with the electrical signal as inputted by using the difference between the reference voltage of the electrical signal and the voltage of the optical output as an error signal. It is, however, also unsuitable for applying the optical modulator as an optical gate under burst mode, because it has a disadvantage that it is subject to the instability of the circuit components to be caused by the peripheral temperature, humidity and stresses etc. owing to its use of error signals proportional to the absolute value of the DC voltage.

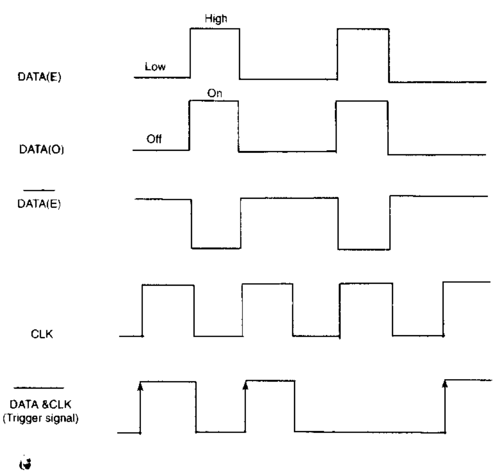
Ⅱ. Off-level Sampling Method for Bias Stabilization of an Electro-Optic Mach-Zehnder Modulator

Conventional bias stabilization methods for modulator includes a DC-drift and a thermal drift etc. Therefore a method for stabilizing the operating point is required, whether the modulator is used as an external modulator or as an optical gate switch. Phase sensitive detection(PSD) using a small dithering signal and locking amplifier has been used to control the operating point in light-wave transmission systems because of its stable and small signal detection characteristics. However, the method is useful for both uniform and scrambled data traffic because the error signal in the PSD method depends on the traffic density[7]. This dependence is coming from the fact that the magnitude of the optical harmonics induced by the input dithering signal are different at off-output and on-output levels due to the sinusoidal transmission characteristics of the EO-MZ modulator. While in the optical networks, the traffic characteristics are burst. So a new stabilization method is required to obtain maximum switching extinction ratio even though the traffic density is varies with time.

In this paper, we propose and demonstrate a new bias stabilization method for EO-MZ modulators, with the aim of using the modulator as an optical gate switch in optical packet switching systems.

2.1 Basic idea of the proposed method

The basic idea of the proposed method is to sample only the off-level output power in the modulated output data streams and minimize its value level by feedback control. it is possible to maintain maximum switching extinction ratio regardless the variations in traffic density. This is because the off-level output power is not a function of the traffic density. To sample the off-level power selectively, the sampling trigger signal should be generated first. Fig. 1 shows a timing diagram for the generation of the off-level sampling trigger source from the electrical input data and the system clock. When the electrical input data is logically low, then the optical output should be in the off-state as shown in Fig. 1 if the maximum switching extinction is desired. The off-level sampling trigger source can be generated



DATA(E) : electrical input data, DATA(O) : optical output data, CLK : system clock.

Fig. 1 Timing diagram for the generation of the sampling trigger source.

from the data information. For this, the input data is inverted first using ECL logic device, then by performing an AND operation between the system clock and /DATA, sampling trigger source can be generated as shown in Fig.1. The sampling trigger source will be used in the sample and hold (S & H) device to detect the off-level output power at the rising edge of the trigger source, which will be described in detail later.

Although the proposed method requires a high speed electrical logic processing, it may not be applicable to high bit-rate systems more than a few Gb/s. In the optical packet switching systems, however, the data repetition is not so high, which means the optical gating or other optical packet processing is normally performed in the unit of packet. For examples, it is only about 20 Mb/s for the 10 Gb/s bit-rate if we assume that one packet is consisted of about 57 ~ 64 bytes such as the ATM cell format. Therefore, the proposed method is applicable to optical packet switching and processing systems.

2.2 Experimental set-up

Fig. 2 shows the experimental set-up for demonstrating the proposed stabilization method. A CW DFB LD with 0 dBm output power at 1548.25 nm is used as the light source. An $LiNbO_3$ EO-MZ modulator is used as the gate switch and its switching time is less than 150 psec. The half-wave voltage of the RF and the bias ports is 3.7 V and 6 V, respectively. The extinction ratio at DC and the insertion loss are measured to be ~ 27 dB and 4.5 dB, respectively, with TM polarized light. 10 % of the optical output is tapped and converted to an electrical signal by photodetector(PD) for feedback bias control. To driver the EO-MZ modulator, a fast TTL device with a switching time of 3~5 nsec is used to improve the low frequency response ranging from DC to 100 Mb/s. The bias stabilization circuit includes an external bias control unit to induce a bias voltage perturbation for the test purpose. Fig. 3 is a scheme diagram of the fabricated bias stabilization circuit.

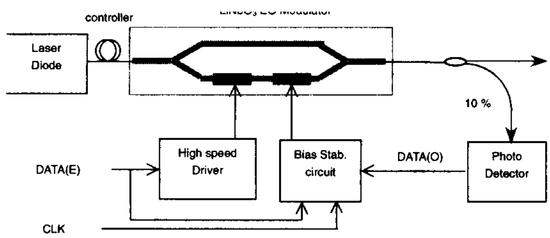


Fig. 2 Experimental set-up for the demonstration.

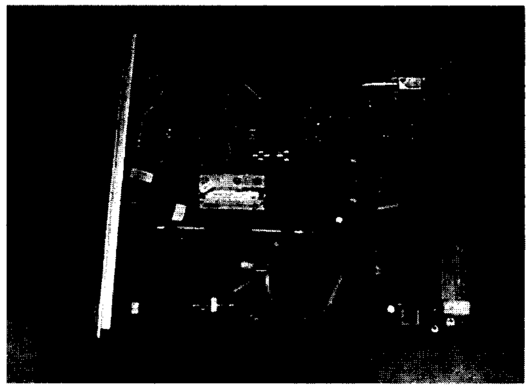
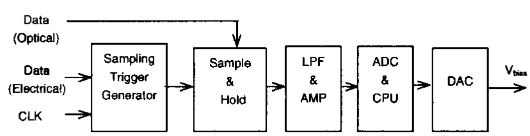


Fig. 3 Assembly of experimental set-up

2.3 Design of the bias stabilization circuit

Fig. 4 is a schematic diagram of the fabricated bias stabilization circuit. It is mainly composed of the off-level sampling trigger source generator, S&H device having tracking band of 250 Mb/s (AD9100), a low-pass filter, and an 8-bit micro-processor. The S & H device samples the off-level output voltage from the PD at the rising edge of the trigger and holds the value until it is updated by the next sampling trigger signal. The



LPF : Low-Pass Filter, ADC : Analog-to-Digital Converter,
CPU : Central Processing Unit,
DAC : Digital-to-Analog Converter. DATA(O) means the modulated optical output after O/E conversion.

Fig. 4 Block diagram of the proposed bias stabilization circuit bias voltage is there maintained as the last value for the duration of the on-state. The lowpass filter rejects the high frequency components from the S & H and the circuit. The sampled signal is then processed by the 8-bit microprocessor after analogue-to-digital conversion(ADC) to check whether it is a minimum or not. The off-level of the output optical signal is minimized as shown in the process of Fig. 5.

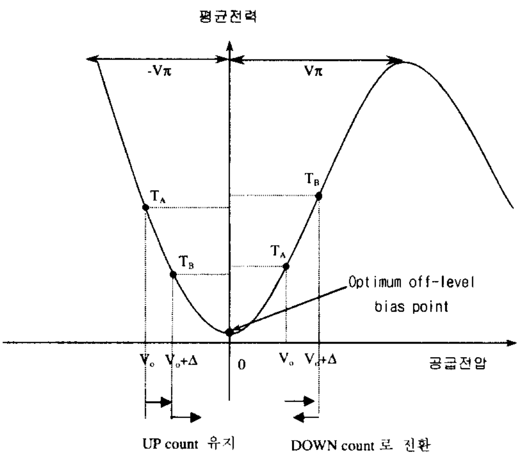


Fig. 5 Principle of the off-level detection

2.4 Off-level minimization

The minimization procedure is as follows ; Since the MZ modulator generally works periodically with respect to increase and decrease of the bias voltage(up or down), in order to minimize the off-level, it is required to know the output value of the off-level and the variable direction of the bias voltage to minimize the output value. They can be known by checking the slope of the modulation signal curve with respect to the bias voltage in the current output value, which slope can be traced by applying the step input voltage to the output optical signal continuously. This signal is converted from digital-to-analogue to supply a stable DC bias voltage to the optical modulator. The minimization procedure is as follows ; The processor adds(or subtracts) a small perturbation ΔV to(from) the bias port via digital-to-analog conversion(DAC) and it compares the resulting off-level output with the previous one. If the new one is smaller, then it continues adding(subtracting) ΔV to the bias port because it is not the minimum and the tracking direction is correct. In contrast, if it is larger than the previous voltage, it changes the sign so that it subtracts(or adds) ΔV because it is not a correct tracking direction and the state is already beyond the minimum point. By repeating the above procedure continuously, the maximum switching extinction can be maintained with some off-level power fluctuation determined by the ratio between the feedback control voltage step ΔV and the half-wave voltage of the bias port. To obtain a switching extinction of > 20 dB, the ΔV from the transmission curve is calculated to be smaller than 1.2 V when the half-wave voltage of the bias port is 6 V. In the experiment, Δ V was designed to be 150 mV so as to minimize the extinction ratio fluctuation as much as possible.

2.5 Programming algorithm

Fig. 6 shows a flow of the programming algorithm for Fig. 5. Assuming that the output value of the first currently input signal at the bias voltage of $V_b=V_0$ is T_A, and that the output value

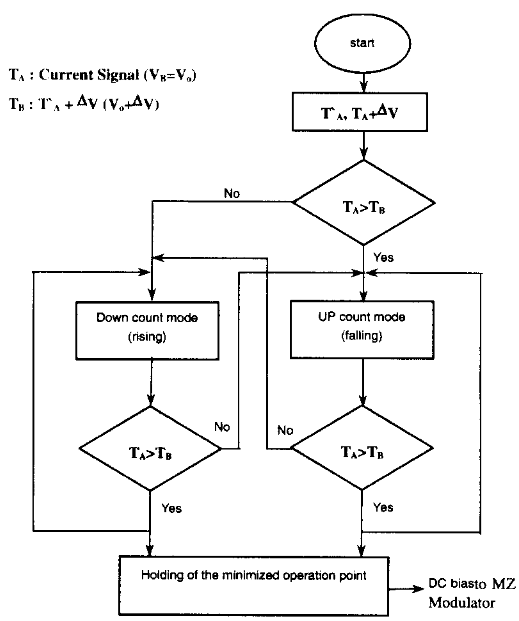


Fig. 6 Program flow for minimized off-level holding

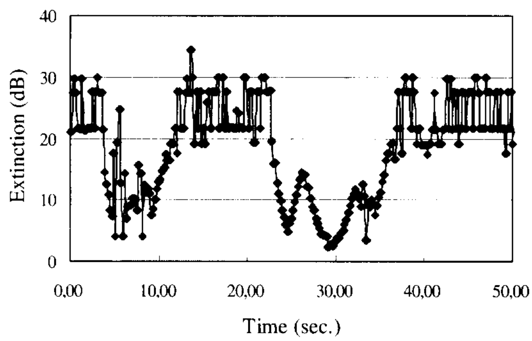
of the second input signal at $T_A+\Delta V$ where the step input voltage of $+\Delta V$(up count) is applied to the bias voltage is T_B, if $T_A > T_B$, the off-level lies in the $-V_\pi$ interval and the bias voltage is kept in the up count direction, and if $T_A < T_B$, the off-level is in the $+V_\pi$ interval and the feedback bias voltage is converted to the down count direction. similarly, if the step input voltage $+\Delta$ is applied continuously and the output value is decreased, the direction of the step input voltage is maintained continuously as before, and if the output value is increased reversely, the direction of the step input voltage is converted, and thereby the bias voltage can reach the minimum operation point. When the value of the modulated voltage $+V_\pi$ reach the maximum value, a pilot operation is required for it to return to the minimum operation point.

Ⅲ. Performance test result

Fig. 7 shows a example of the measured extinction ratio according to the time when "..1010.." non-return-zero(NRZ) data with 25 Mb/s clock is applied to the EO-MZ modulator. The extinction ratio is calculated as formula (1) by measuring on-level $\left(P\frac{on}{out}\right)$ and off-level $\left(P\frac{off}{out}\right)$ voltages from the modulated output using a 20 Gb/s digital sampling oscilloscope(HP 83480A).

$$Extinction ratio(dB) = 10\log\frac{P^{off}_{on}}{P^{on}_{out}} \quad (1)$$

As shown in Fig. 5, the external perturbation with a time varying voltage due to the electronic circuit instability and the environment effects such as ambient temperature stress etc. is applied to the bias voltage during the time interval indicated by arrows. We incorporated an external perturbation in the circuit to add or subtract some artificial perturbation voltage to the feedback signal for the stabilization test purpose. The extinction ratio of the modulator is stabilized at ~ 25 dB under normal operation with a deviation of 5dB. A rather large fluctuation may comes from the input polarization and the circuit noise. When the external perturbations is applied to the bias port during the time interval as shown by arrows, the switching extinction becomes worse, but it has been recovered within several seconds. The system response is determined by the cut-off frequency of the lowpass filter in Fig. 4. The 3 dB cutoff frequency in the experiment is 10 Hz. By adjusting the passband towards the high frequencies, the speed of response could be increased. Several experiments according to the data patterns and system clocks up to 100 Mb/s have been carried out with similar results.



External perturbation is applied to bias voltage during time interval indicated by arrows.

Fig. 7 Measurement of the switching extinction ratio with time

Ⅳ. Conclusion

We have proposed and demonstrated a new bias stabilization method to enable EO-MZ modulators to be used as optical gate switches in burst mode traffic systems[8]. The basic idea of the proposed method is to sample only the off-level output power in the modulated output data streams and minimize its value level by a feedback control. By sampling and minimizing the off-level output power of the modulator, it works as a high extinction optical gate switch regardless of the variation of the packet traffic density. The method is especially useful in Wavelength Division Multiplexing(WDM) based optical packet switching and processing systems, the high-speed wavelength light source, the optical buffer and the high-speed optical signal link at 100 Gb/s or higher that are required for the high-speed multi-wavelength conversion.

Acknowledgment

The Korea Telecommunication (KT) financially supported this work in 1998.

References

[1] C. Guillemot, F. Clerot, M. Henry, A. Le Corre, J. Kervarec, A. Dupas, L. Billes, Optical packet switching for WDM high speed backbones, ECOC 98, Vol.2, pp.83-85, Madrid (Spain), 1998.

[2] K.-I. Yukimatsu, T. Matsunaga and A. Hiramatsu, Hyper-media Photonic Information Network, Photonics in Switching '97, paper PWC4, Stockholm (Sweden), 1997.

[3] M. Renaud, Keys to Optical Packet Switching : The ACTS KEOPS Project, Photonics in Switching '97, paper PWB1, Stockholm (Sweden), 1997.

[4] T. Maeda, K. Hironishi, S. Kuroyanagi, Y. Kondo, I. Tsuyama and K. Murakami, Experimental High-Speed Optical Cell Selector for Photonic ATM switch, Photonics in Switching '97, paper PFB1, Stockholm (Sweden), 1997.

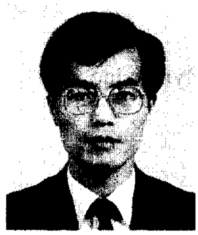
[5] M. Renaud, Key Components for Optical Switching, Photonics in Switching '97, paper EFD1, Stockholm (Sweden), 1997.

[6] F. Masetti, et al, High Speed, High Capacity ATM Optical Switches for Future Telecommunication Transport Networks, pp. 979-998, IEEE JSAC, VOL. 14, NO.5, JUNE 1996.

[7] H. Park, W.-Y. Hwang, C. R. Yang, Traffic density dependence of the phase sensitive detection method for the operating point stabilization in the electro-optic Mach-Zehnder modulator (submitted to IEE Electronics Letters, 1999).

[8] C.R. Yang, W.-Y. Hwang, H. Park, H.H.Hong and S. G. Han, Off-level sampling method for bias stabilization of electro-optic Mach-Zehnder modulator, 1st April 1999, Vol.35, No.7, ELECTRONICS LETTERS.

양 충 열(Choong-Reol Yang) 정회원



건국 대학교 전자공학과(학사)
충남대학교 대학원 전자공학과 (석사)
1989년~미국 제너럴다이내믹스 (GDLS)사 파견 연구원
1985년 7월~1992년 6월 : (주) 현대정공 기술연구소
1992년 6월~현재 : ETRI 광교환연구팀 선임연구원
<주관심 분야> 통신 및 제어, 광교환시스템

홍 현 하(Hyun-Ha Hong)
1979년 2월 : 광운대학교 전기공학과 졸업(학사)
1981년 8월 : 연세대학교 대학원 전자공학과(석사)
1983년 6월~1985년 9월 : 육사 교수부 전자과 전임 강사
1985년 10월~현재 : ETRI 광교환연구팀 책임연구원

김 해 근(Hae-Gun Kim)
1977년 2월 : 경북대학교 전자공학과 졸업
1982년 8월 : 연세대학교 전자공학과(석사)
1994년 8월 : University of South Florida 전기공학과(박사)
1980년 8월~현재 : ETRI 광교환연구팀장