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A Proposal of Linear Analog Modulator Using Twin MQW Electroabsorption Modulator

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1. Introduction

Resent applications of low chirped MQW Electro absorption (EA) modulator are not only for high-speed long distance digital transmission but also for enhanced analog transmission. The availability of erbium-doped fiber amplifier (EDFA) release fiber loss and make the transmission of subcarrier multiplexed analog signal at 1.55μm pretty attractive for long trunk lines with many branches. However its inherent non-linear L-V characteristics demand some complicated technique for linearization.

Previous linearization methods of MQW EA modulator have been used optical feedforward technique[1] or optical and electrical predistortion scheme[2]. They should adjust optical or electrical signal delay and need complex optical distortion emulator[3] or electric non-linear circuits to reduce intermodulation distortion for multiple carrier applications.

In this paper we propose a Novel linear modulator consist of two same MQW EA modulators and 3dB couplers. We analyze MQW EA modulator L-V characteristics and simulate proposed device to show remarkable reduction of IMD_x noise without any predistortion circuits.

2. Analysis of MQW EA modulator

The Optical power intensity, P_{opt} of the EA modulator output can be approximated as a function[4] of applied voltage V, modulation depth m_0, parameter V_0 (1/e degraded voltage), ω(modulation frequency) and α(structure parameter dependent wavelength and MQW structure). Usually V_0 is around 1 or 1.2 V and α is 2-4 for MQW type modulator.

$$P_{out}/P_0 = \exp\left[-\left(V/V_0\right)^{\alpha}\right] \qquad (1)$$

$$V = V_b\left[1 + m_0\cos(\omega t)\right]$$

With eq. (1) and FDM (finite differential method) we estimate the signal distortion with modulator bias voltage V_b and electrical signal modulation depth m_0. Simple numerical works show that there are 2 points for third order distortion coeff. is zero if α > 2 and at each points, second order distortion coeff. has similar value of opposite sign. In Fig. 2 Optical fundamental frequency signal is represented by rectangular symbol and other two are distortion coeff.s where α is 2.5. The optimal points for 2_{nd} order harmonics and 3_{rd} order harmonics is minimized are different as Fig. 3 presented. Previous researches have been used the IMD_2 minimum point and applied predistortion method to reduce IMD_3[5].

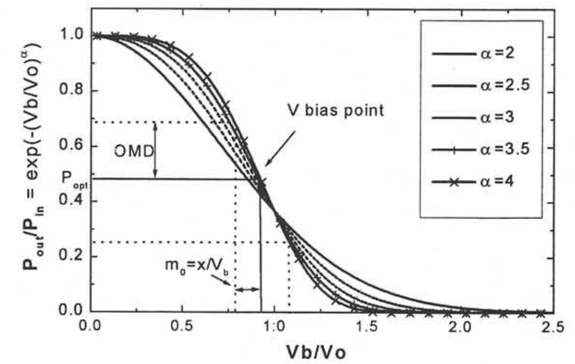

Fig. 1 Normalized L-V characteristic curve of MQW EA modulator as a function of V_b and m_0: modulation depth, OMD: optical modulation depth.

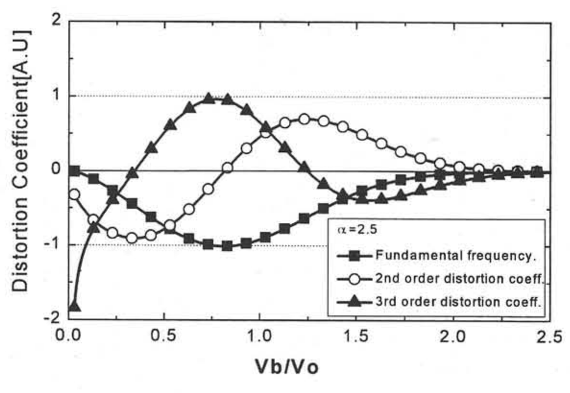

Fig. 2 intermodulation distortion coefficients as a function of applied bias V_b from the equation (3). The value of α is 2.5.

3. Operation of the proposed modulator

We propose new linear modulator, which can make both of IMD_2 and IMD_3 lower than -65dBc without any complicated electric or optical predistortion circuits. The proposed device is shown in Fig. 4. It consists of two same modulators and 3dB couplers which split optical input power (optical input port) and recombine (optical output port) modulated optical signal. Since the characteristics of a conventional QW modulator can be represented as eq. (1), a simple analysis can show, as in Fig.3, that the IMD_3-minimum occurs at 2 different bias points. Each modulator (M1, M2) operates different bias point: M1 operates near the first bias point of IMD_3 minimum, and M2 operates near the second IMD_3-minimum bias point with fixed modulation depth m2. Modulator M1 operates at the balanced condition, where m1 (the modulator depth of M1) is determined to balance out IMD_2 terms at output port of 3dB coupler as expected Fig. 2.

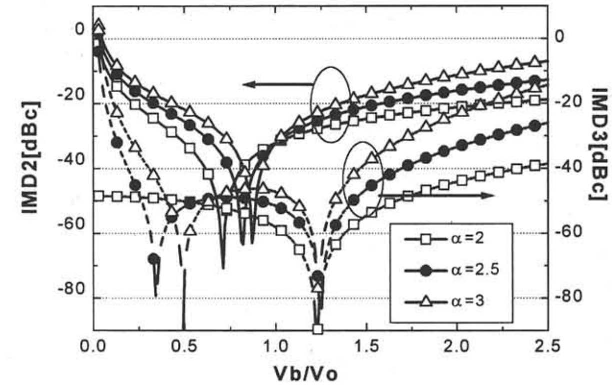

Fig. 3 IMD_2 and IMD_3 as a function of bias V and α.

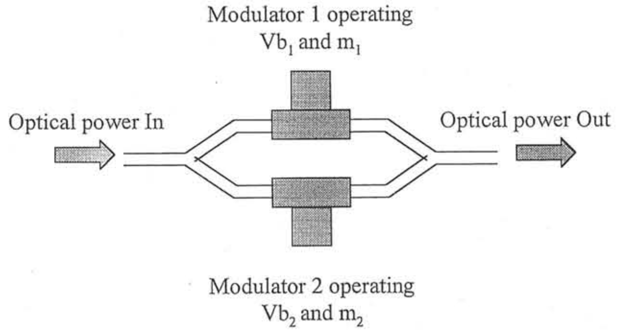

Fig. 4 Proposed EA modulator.

4. Simulation Results

We simulate IMD_2 and IMD_3 considering 4_{th} and 5_{th} order distortion coefficient. Fig. 5 shows that modulator could be biased and modulated to make IMD_2 and IMD_3 below −70dBc (if α is 2.5: m2=5.7%, Vb_2/V_0=1.24,V_{b1}/V_0 near 0.34, if α is 3.0: m2=5.1%, V_{b2}/V_0=1.23, V_{b1}/V_0 near 0.49, if α is 3.5 m2=4.8%, V_{b2}/V_0=1.21, V_{b1}/V_0 near 0.59).

Intermodulation distortion is also a function of modulation depth and is increased as modulation depth is increased. Fig. 6 shows that up to 10% modulation depth, it can still suppress IMD_x noises under −65dBc with the proposed scheme.

Signal power at the fundamental frequency, which is directly related to optical modulation depth (OMD) at output, is expected to be remaining the same without any losses. This can be understood from Fig. 2. Each modulator delivers around half signal power of its maximum and the signal from each modulator is combined constructively by output 3dB coupler

5. Conclusion

We propose a novel analog EA modulator, which do not need any sophisticated predistortion scheme. And we simulate its linearity with IMD noise level. This new EA modulator structure can suppress IMD terms under −65dBc that is enough for any SCM communication systems and applications. This simple method could reduce system size and cost considerably.

Acknowledgment

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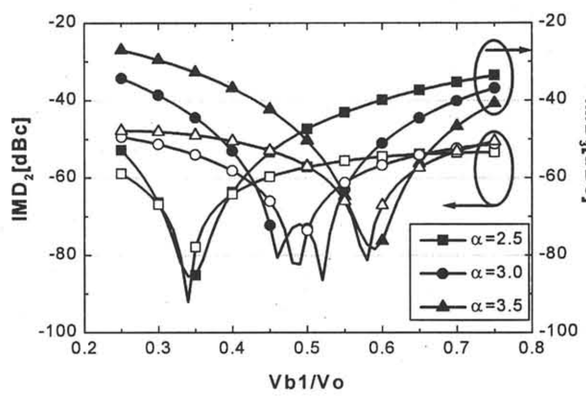

Fig. 5 IMD_2 and IMD_3 as a function of bias point Vb_1 of modulator M1, where modulator M1 operates in the balanced conditions.

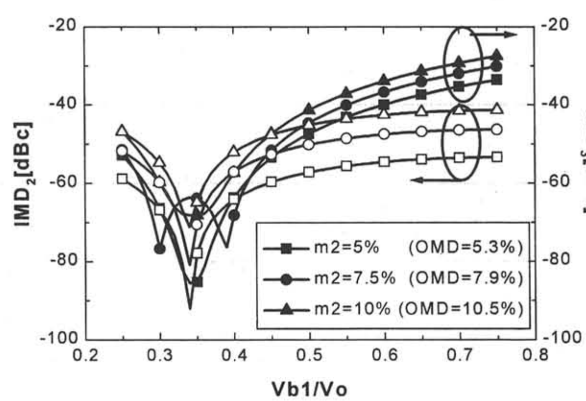

Fig. 6 IMD_2 and IMD_3 as a function of Vb_1 of modulator, where modulator M1 operates in the balanced conditions.