광섬유 링크에서의 Intermodulation Distortions 의 특성과 Optical injection Locking 을 이용한 이의 감소

Characteristics of Intermodulation Distortions in Fiber Optic Links and IMD Reduction by Optical Injection Locking

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Abstract

We experimentally investigate the characteristics of intermodulation distortions (IMDs) produced by nonlinearities of semiconductor lasers and fiber dispersion. In our experiment, IMDs in fiber optic link are degraded over transmission up to 40km. We show that these IMDs can be reduced and made less dependent on fiber length by injection-locked semiconductor lasers.

Introduction

Sub-carrier multiplexed (SCM) fiber optic systems with direct laser intensity modulation have many applications such as wireless local loop, cable television distributions and fiber-radio systems. The direct modulation of semiconductor laser is a simple and low-cost approach for transmitting RF-range subcarriers. But, in the high-frequency direct modulation systems operating at multigigahertz range, nonlinearities of light sources and transmission process may create harmonic and intermodulation products. Because the intermodulation products exactly fall into another channel of SCM fiber optic link, these undesired products can severely degrade overall system performance [1].

Hence, it is needed to suppress semiconductor laser nonlinearities and also to reduce IMD dependence on fiber length. As one method for suppressing nonlinearities of semiconductor lasers, optical injection locking of semiconductor lasers has been widely investigated and found very effective [2, 3]. Injection-locked semiconductor lasers show improvements in laser dynamics such as relaxation oscillation frequency increase and frequency chirp reduction [4,5].

When optical signals produced by a directly-modulated semiconductor laser are sent over fiber, their third-order intermodulation distortions (IMD3) can be degraded because of the fiber dispersion. In this paper, we report results of our experimental investigation on the dependence IMD3 degradation on fiber length. In addition, we demonstrate that IMD3 dependence on fiber length can be much reduced by using injection-locked semiconductor lasers.

Experiments and Results

Fig. 1 shows the experimental setup for measuring IMD3 dependence on fiber length for free-running and injection-locked semiconductor lasers. For injection locking, the external-cavity tunable light source is used for master laser (ML). For slave laser (SL), a commercially available, fiber-coupled, isolator-free DFB (Samsung SDL-24) lasers are used. For generating subcarriers, SL is directly modulated by two–tone RF signals (f1= 2.80GHz, f2=2.81GHz). Standard single-mode fiber with different length from 5 to 40 km is used in the experiment.

For both free-running and injection-locked states, SL is biased at 15mA (≅1.9Ith) and directly modulated by two-tone RF signals. To achieve the stable injection-locked state, the frequency offset between ML and SL was set at 4.1GHz and the injection ratio at about –6dB. Received RF powers at the fundamental (f2=2.81GHz) and third-order

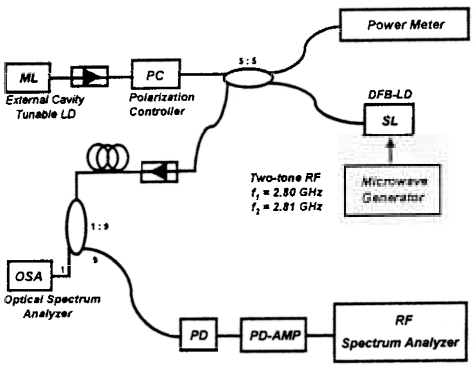

Fig. 1. Experimental Setup

intermodulation products (IMP3) (2f2-f1=2.82GHz) frequencies are measured while the fiber length is varied in the increment of 5 km up to 40km.

Fig. 2 shows an example of the measured RF spectrum at the fundamental and IMP3 frequencies in the free-running and injection-locked state after 30Km transmission. IMD3 for the free-running state (Fig. 2(a)) is -9.83 dBc and IMD3 for the injection-locked state (Fig. 2(b)) is –19.08 dBc. About 9.25dB reduction in IMD3 is achieved by optical injection locking.

In Fig. 3(a), the received RF powers at the fundamental and IMP3 frequencies are plotted for the free-running and injection-locked state at various fiber lengths. Overall, the received RF powers at both fundamental and IMP3 frequencies decrease with increasing fiber length and this is due to the fiber loss and dispersion. However, this reduction is smaller for the injection-locked state. IMD3 dependence on fiber length is shown in Fig. 3(b). In the free-running state, IMD3 is -20.1dBc back-to-back and –6.58dBc at 40km transmission, which shows IMD3 degradation of 13.52dB after 40km transmission. In the injection-locked state, IMD3 is –23.97dBc back-to-back and –18.81dBc at 40km transmission. The IMD3 degradation is only 5.16dB in the injection-locked state and its variation is maintained within about 5dB for the entire transmission length. Compared to the free-running state, the injection-locked state has 12.23dB reduction in IMD3 for 40km fiber transmission.

Conclusions

IMD3s for free-running semiconductor lasers are degraded due to the combined effect of the semiconductor laser nonlinearities and fiber dispersion. But, in the injection-locked case, semiconductor laser nonlinearities are suppressed, and the influence of fiber dispersion is much reduced. In our experiments, 12.23 dB reduction in IMD3 can be achieved with injection locking, and IMD3 variation was bounded within ~5dB for up to 40km transmission.

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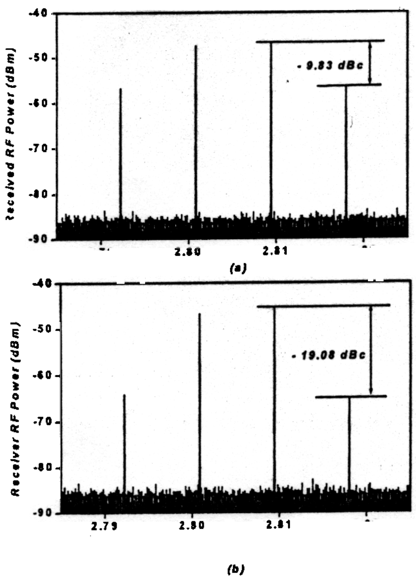

Fig. 2. Measured power spectra of directly modulated DFB-LD by two-tone RF signals after 30km transmission for (a) free-running and (b) injection-locked state.

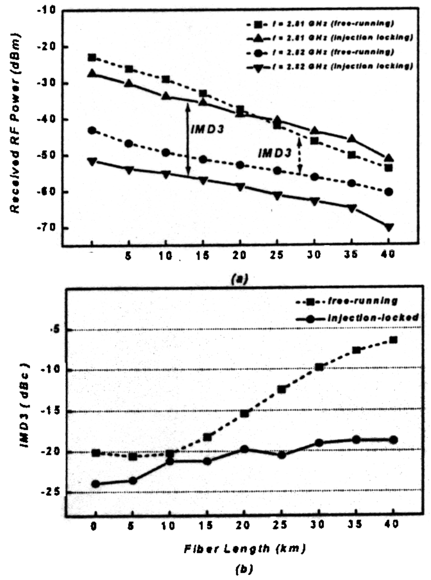

Fig. 3. (a) Received RF power at f1 and 2f2-f1
(b) IMD3