반도체 광 증폭기를 이용한 광학적 주파수 상향 변환기의 비선형 특성

Nonlinear Characteristics of the Photonic Frequency Up-converter Using a Semiconductor Optical Amplifier

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Abstract

We investigate nonlinear intermodulation distortion characteristics of the photonic up-converter based on a semiconductor optical amplifier for multi-frequency signal up-conversion. The third order intermodulation distortions are measured with two-tone intermediate frequency signals for the photonic up-converter under various conditions. The spurious free dynamic range is determined to be larger than 72 dB-Hz$^{2/3}$.

I. Introduction

Radio-on-fiber (RoF) systems are attracting much attention for broadband wireless applications such as wireless local area networks and intelligent traffic systems [1-3]. The remote up-conversion scheme is one promising candidate to establish RoF systems. To realize such systems, we proposed a photonic up-conversion method using cross gain modulation (XGM) of the semiconductor optical amplifier (SOA) [3]. Fig. 1 schematically shows the up-conversion process.

The subcarrier multiplexing method is very useful for RoF systems since it can merge several applications together and provide frequency sectorization schemes [2, 4], which are important for many wireless applications. Therefore, the data buried in multiple IF frequencies should be up-converted simultaneously when photonic up-converters are used. However, since any frequency up-converter is based on nonlinear properties of the device used, distortion products from multi-channel up-conversion are inevitable, which degrade system performance severely. Therefore, we investigate the distortion properties of the SOA-based photonic up-converter under various conditions such as different optical LO input powers and IF signal wavelengths. The third order intermodulation distortions are measured for the case of two-tone IF signals, and the resulting spurious free dynamic range (SFDR) is determined.

II. Experiment and Results

Fig. 1 shows the experimental setup. The optical heterodyne LO signals at $\lambda_1 = 1555$ nm, having two modes separated by f_{LO} of 25 GHz, were generated by the double sideband – suppressed carrier modulation method. For generating IF subcarriers, two MZMs were independently modulated at 995 MHz (f_1) and 1005 MHz (f_2). The reason for using two modulators is to prevent the influence of the third order intermodulation distortion effects of the modulator itself. In order to prevent coherent beating between two optical IF signals, an optical delay line was introduced.

For SFDR measurement, we observed powers of the 26.005 GHz ($f_{LO}+f_2$) USB signal and the IMP3 at 26.015 GHz ($f_{LO}+2f_2-f_1$). Fig. 2 shows an SFDR measurement example. The SOA input optical LO signal power was set at -14 dBm, and the total SOA input optical power for IF signals at 1545 nm was -13 dBm. The measured noise-floor was -139 dBm/Hz. The SFDR was determined to be 76.1 dB-Hz$^{2/3}$ as can be seen in Fig. 2.

At first, we measured the SFDR as a function of SOA input optical LO signal powers ranging from -20 dBm to -8 dBm. The optical IF signals had in total -13 dBm SOA input power at 1545 nm wavelength. The SOA was biased at 150 mA. Fig. 3(a) shows the

SFDR measurement results. As the LO signal power increases, the SFDR increases continuously from about 72 dB-Hz$^{2/3}$ to 78 dB-Hz$^{2/3}$. When the LO signal power is low, the USB signal power increases continuously compared with the IMP3 power and noise floor. Consequently, the SFDR increases. When the LO signal power is high, the USB signal power is saturated due to the SOA gain saturation [3], and the noise floor level rises continuously [5]. The SFDR increases, however, because distortion product powers get reduced very much.

Next, we measured the SFDR dependence on the input IF signal wavelength. The IF wavelength was changed within the C-band (1530 nm – 1565 nm), which covers the gain bandwidth of SOA biased at 150 mA. Figure 3(b) shows the measured SFDR. In this case, the SFDR characteristics are determined by the up-conversion efficiency and the noise floor level. The up-conversion efficiency is determined by the SOA gain spectrum [3], and the efficiency is highest at the SOA gain peak wavelength. However, the noise floor change is inversely proportional to the SOA gain spectrum at the saturated SOA [5]. Therefore, the SFDR follows the SOA gain spectrum.

III. Conclusion

We have investigated the nonlinear characteristics of the photonic SOA up-converter using SFDR measurement. It is found that the SFDR increases with the LO signal power despite the up-conversion efficiency saturation and noise floor increase. We also investigated the dependence of the SFDR on IF signal wavelengths, which follows the SOA gain spectrum.

References

[1] E. Suematsu, and N. Imai, "A Fiber Optic/Millimeter-Wave Radio Transmission Link Using HBT as Direct Photodetector and an Optoelectronic Upconverter," *IEEE Trans. Microwave Theory and Tech.*, vol. 44, no. 1, pp. 133-143, 1996.

[2] M. Tsuchiya, and T. Hoshida, "Nonlinear Photodetection Scheme and Its System Applications to Fiber-Optic Millimeter-Wave Wireless Down-Links," *IEEE Trans. Microwave Theory and Tech.*, vol. 47, no. 7, pp. 1342-1350, 1999.

[3] Y.-K. Seo, C.-S. Choi, and W.-Y. Choi, "All-optical Signal Up-conversion for Radio-on-fiber Applications Using Cross-gain Modulation in Semiconductor Optical Amplifiers," *IEEE Photon. Technol. Lett.* vol. 14, no. 10, pp. 1448-1450, 2002.

[4] R. B. Waterhouse, D. Novak, A. Nirmalathas, and C. Lim, "Broadband Printed Sectorized Coverage Antennas for Millimeter-Wave Wireless Applications," *IEEE Trans. Antennas and Propagat.*, vol. 50, no. 1, pp. 12-16, 2002.

[5] D. D'Alessandro, G. Giuliani, and S. Donati, "Spectral Gain and Noise Evaluation of SOA and SOA-based Switch Matrix," *IEE Proc.-Optoelectron.*, vol. 148, no. 3, pp. 125-130, 2001.

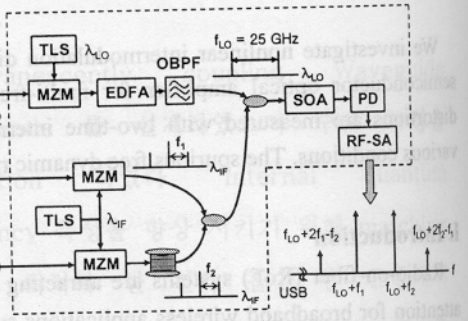


Fig. 1. Experimental setup for the SFDR measurement for the third order distortion. TLS : Tunable Laser Source, OBPS : Optical Bandpass Filter, RF-SA : RF-Spectrum Analyzer, USB : Upper Sideband.

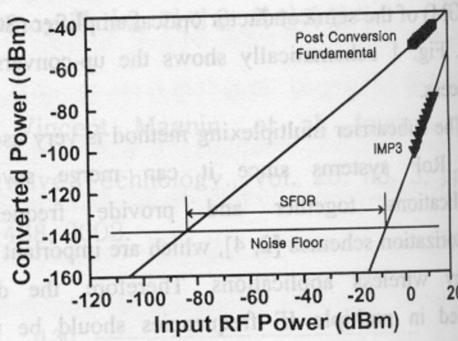
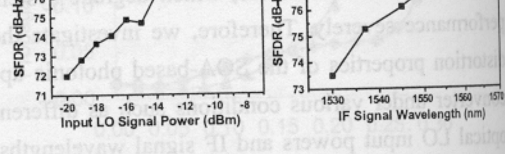


Fig. 2. SFDR measurement example. IMP : Intermodulation Distortion Product.



(a) (b)

Fig. 3. Dependence of the SFDR on the input LO signal power (a) and IF signal wavelength (b).