Experimental Reduction of Dispersion-induced Effects in Microwave/millimeter-wave Optical Systems employing SOA Boosters

Francisco Ramos, Javier Herrera, and Javier Martí

Fibre-Radio Group. ITACA Research Institute. Universidad Politecnica de Valencia.
Camino de Vera, s/n. 46022 Valencia (Spain) - Tel. +3496-3877307 - Fax +3496-3877309

Abstract — **A novel approach to reduce the dispersion-induced effects in microwave/millimeter-wave optical links based on the combination of chirp generated by semiconductor optical amplifiers (SOA's) and fiber-induced self-phase modulation has been proposed and experimentally demonstrated. The results show that the dispersion-induced RF carrier suppression effect may be alleviated by more than 20 dB when the SOA is operated under saturation. However, the SOA input power must be carefully controlled in order to avoid significant nonlinear distortion.**

I. INTRODUCTION

Conventional microwave optical transmissions operating near 1550 nm are severely limited by the chromatic dispersion of standard single-mode fibers (SSMF's) [1]. This limitation mainly consists of the RF carrier suppression effect due to dispersion-induced sideband cancellations at certain combinations of microwave frequencies and propagation distances. Several techniques have been proposed to overcome this effect such as optical single sideband modulation [2]-[3], dispersion compensation using chirped fiber gratings [4], variable chirp in electroabsorption modulators [5] and self-phase modulation effect introduced by SSMF's [6]. Most of these techniques do not enhance the RF-to-RF efficiency due to no optical amplification is directly involved.

In this paper a novel approach to overcome dispersion-induced effects in microwave/millimeter-wave optical links based on adjusting the chirp and phase modulation generated by saturated semiconductor optical amplifiers (SOA's) is investigated. The experimental results show that the fading of the RF-to-RF system response is significantly alleviated by properly setting the optical power at the SOA input. As the SOA input power increases the frequency notches of the RF response are shifted to higher frequencies and further reduced up to 20 dB. Preliminary measurements on harmonic and intermodulation distortions generated by the SOA-based transmitter are also presented.

II. EXPERIMENTAL SET-UP

Figure 1 depicts the experimental arrangement used to demonstrate the proposed technique. The output level of an externally modulated optical transmitter operating at 1550 nm is set to +10 dBm by using an erbium-doped fiber amplifier (EDFA) module. A variable optical attenuator is used to control the optical power at the SOA (Philips CQF871) input. It is well known that the chirp generated by a SOA increases significantly under saturation conditions [7], therefore in our setup it may be varied acting on the attenuator. The SOA output is further launched into a 50 km SSMF span and a microwave photoreceiver is employed as optoelectronic conversor. The SOA bias current was kept fixed at 300 mA during the experiments. The RF-to-RF response of the system was measured by using an electrical network analyzer (HP8510C). The nonlinear distortion (NLD) arising from the optical transmitter was also measured using both single-tone (harmonic distortion) and two-tone (third order intermodulation distortion) driving signals at the RF port of the Mach-Zehnder electro-optical modulator (MZ-EOM).

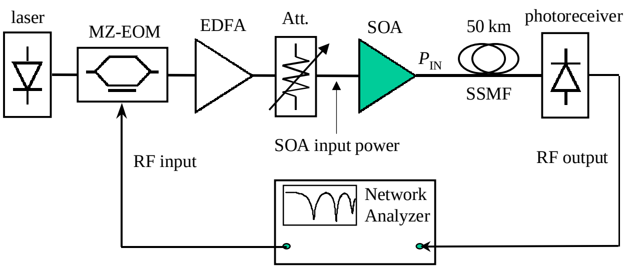

Fig. 1. Experimental arrangement used to demonstrate the SOA-based approach.

0-7803-6540-2/01/$10.00 (C) 2001 IEEE

III. Results And Discussion

The RF-to-RF response of the 50 km optical link was measured under different situations to evaluate the SOA-based approach. In figure 2, the obtained responses with SOA (solid lines) and without employing SOA at the optical transmitter (dashed lines) may be observed. It can be seen that the RF response exhibits deep notches when no SOA is employed (dashed lines) and also that these notches move to higher frequencies as the input power to the SSMF increases, which is due to the self-phase modulation (SPM) effect as reported in [6]. However, the efficiency of the SPM technique obtained with our experimental set-up was not as high as in [6] since we did not employ any method for canceling the stimulated Brillouin scattering during the measurements.

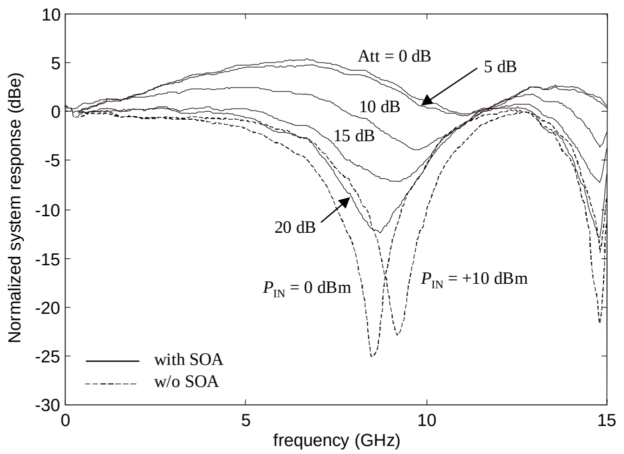

Fig. 2. RF-to-RF response of the optical link for different situations.

Conversely, incorporating the SOA in the experimental setup, as depicted in figure 1, the carrier suppression effect may be alleviated by increasing the optical power at the SOA input, i.e. by decreasing the optical attenuation at its input, as show in figure 2 (solid lines). This is due to the joint effect of the transmitter chirp (introduced by the SOA under saturation conditions) and the SPM of the SSMF for high optical powers at the input. For the RF responses obtained using the SOA the output power of the EDFA was kept fixed at +10 dBm. In figure 2 it can be seen that the RF response is even flatter for higher SOA input power, although this flattening effect saturates for an optical attenuation of 0 dB (SOA input power of +10 dBm).

Finally, in order to evaluate the NLD level introduced by the EDFA-SOA configuration single-tone and two-tone measurements were carried out varying the SOA input power in the system. For the single-tone NLD measurements, a RF tone of 6 GHz was used in the experiment. For the two-tone NLD measurement, two RF tones of 1.9 and 2.1 GHz were used. Figure 3 shows 2nd (HD2) and 3rd (HD3) order harmonic distortion levels. The NLD level floor imposed by the MZ-EOM is also depicted in figure 3. For HD2 an increase of nearly 10 dB (at +10dBm SOA input power) is observed mainly due to the SOA nonlinear response. However the HD3 increase may be up to 15 dB, even though it is not relevant due to the HD2 relative high values. A 3rd order intermodulation distortion ($2f_2 - f_1$) level of about –52 dBc was also obtained for a SOA input power of +10 dBm. Therefore, the SOA input power must be carefully controlled in order to achieve both equalization and linearity.

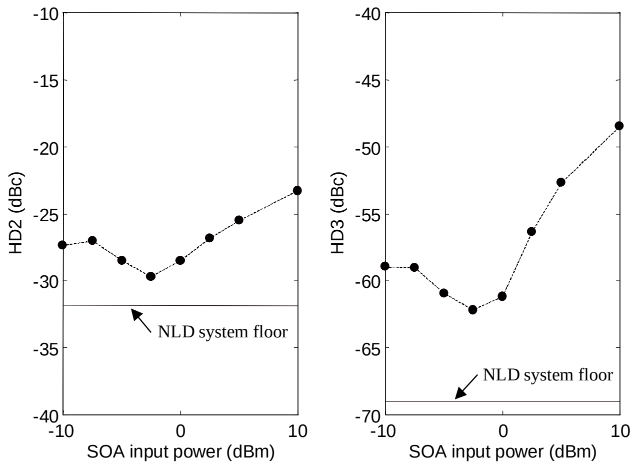

Fig. 3. Harmonic distortions generated by the SOA-based transmitter.

IV. Conclusion

A novel approach to overcome the RF carrier suppression effect in microwave/millimeter-wave optical links based on the joint effect of SOA chirp and SPM in SSMF's has been proposed. The experimental results show that the frequency notches caused by the dispersion-induced carrier suppression effect may be alleviated by properly adjusting the SOA input optical power. However, since the SOA operates under saturation conditions, the NLD must be carefully controlled in order to assure the desired system performance.

References

[1] H. Schmuck, "Comparison of optical millimetre-wave system concepts with regard to chromatic dispersion," *Electron. Lett.*, vol. 31, no. 21, pp. 1848-1849, 1995.

[2] G. H. Smith, D. Novak, and Z. Ahmed, "Novel technique for generation of optical SSB with carrier using a single MZM to overcome fiber chromatic dispersion," *Electron. Lett.*, vol. 33, no. 13, pp. 74-75, 1997.
[3] B. Davies, and J. Conradi, "Hybrid modulator structures for subcarrier and harmonic subcarrier optical single side-band," *IEEE Photon. Technol. Lett.*, vol. 10, no. 4, pp. 600-602, 1998.
[4] J. Marti, J. M. Fuster, and R. I. Laming, "Experimental reduction of chromatic dispersion effects in lightwave microwave/millimetre-wave transmission using tapered linearly chirped fibre gratings," *Electron. Lett.*, vol. 33, no. 13, pp. 1170-1171, 1997.
[5] V. Polo, J. Marti, F. Ramos, and D. Moodie, "Mitigation of chromatic dispersion effects employing electroabsorption modulator-based transmitters," *IEEE Photon. Technol. Lett.*, vol. 11, no. 7, pp. 883-885, 1999.
[6] F. Ramos, J. Marti, V. Polo, and J. M. Fuster, "On the use of fiber-induced self-phase modulation to reduce chromatic dispersion effects in microwave/millimeter-wave optical systems," *IEEE Photon. Technol. Lett.*, vol. 10, no. 10, pp. 1473-1475, 1998.
[7] T. Watanabe, N. Sakaida, H. Yasaka, and M. Koga, "Chirp control of an optical signal using phase modulation in a semiconductor optical amplifier," *IEEE Photon. Technol. Lett.*, vol. 10, no. 7, pp. 1027-1029, 1998.