RADIO-OVER-FIBER TRANSMISSION BASED ON SINGLE SIDEBAND CARRIERS TO OVERCOME THE DISPERSION PENALTIES USING A INJECTION-LOCKED FABRY-PERÒT

G. Cossu, M. Presi and E. Ciaramella

Scuola Superiore Sant'Anna, via G. Moruzzi 1, 56124, Pisa, ITALY; Corresponding author:g.cossu@sssup.it

Abstract: We experimentally demonstrate a technique for optical generation of a single sideband carrier based on an injection-locked semiconductor laser. By this technique a 64-QAM 54 Mb/s OFDM signal at 6 GHz is transmitted successfully over 80 km SMF avoiding penalties associated to fading.

1. Introduction

The distribution of radio signals through optical fibers (RoF) is an important task to enable the delivery of wireless and wired services in future access networks. Conventional RoF transmitters based both on direct or external modulation produce double sideband optical signals (DSB). Radio frequency DSB optical signals are really sensitive to chromatic dispersion which induces fading. This problem can be solved by using single sideband (SSB) modulators, implemented for example by using dual-drive Mach-Zehnder modulators [1]. However this implementation is rather complex. SSB signals can be obtained by using narrow optical filtering (i.e., by suppressing one of the two sidebands) or by injection-locking (IL) in semiconductor lasers. In [2] an IL Fabry-Peròt laser (FPL) is used to obtain SSB modulation; in this configuration, the FPL is locked at a frequency corresponding to one of the sidebands of the input signal. However, this scheme suffers from mode-partition noise, and requires additional saturated semiconductor amplifiers to reduce it. In [3] a simpler approach based on cavity resonance shift [4] is proposed. If the IL laser is directly modulated with an RF signal it is possible to obtain a single sideband modulation provided that the RF frequency f_{RF} matches the difference between the injection-locking frequency ω_{inj} and the shifted cavity resonance ω_{cav} (i.e. $\omega_{inj} - f_{RF} = \omega_{cav}$). In this case one modulation sidebands falls exactly on the residual shifted cavity mode and then is resonantly amplified (see inset of Fig. 1).

Here we exploit the same principle to demonstrate a Double-to-Single Sideband Converter composed just by a DC-biased FPL: we consider an input optical signal, coming from a remote node of a network and DSB modulated at a frequency f_{RF} . This signal is then sent into the converter (i.e., the FPL). Under proper injection conditions, i.e., if one of the modulated sidebands falls on the shifted cavity mode, the sideband is strongly amplified, thus converting the input DSB signal into a SSB signal. We report a proof of principle of this scheme by using a 54Mb/s radio signal (OFDM, 64-QAM @ 6 GHz): the conversion allows to transmit the radio signal over 80 km Single Mode Fiber (which would be not possible with a DSB signal due to the fading effect).

2. Experiment and Results

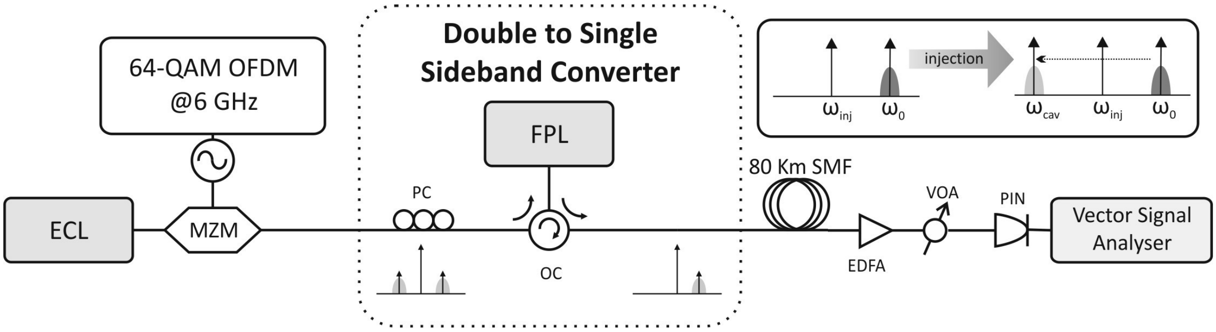
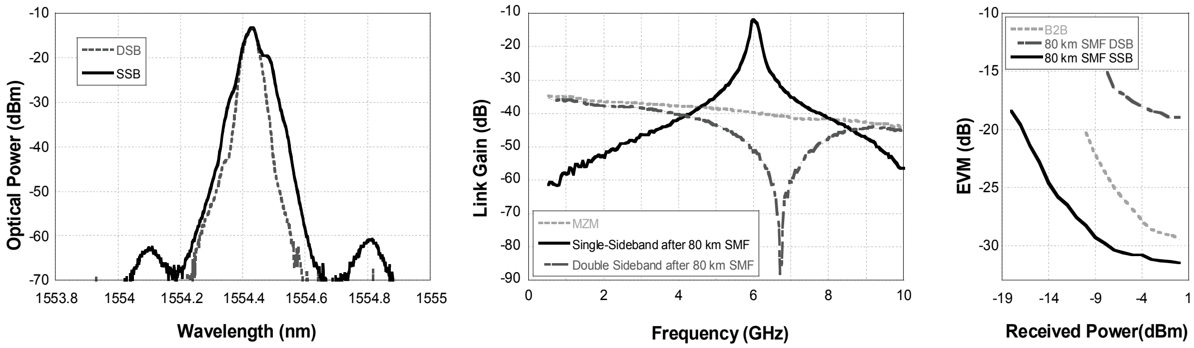


Fig. 1 Experimental setup: ECL External Cavity Laser; MZM: Mach-Zehnder Modulator; PC: Polarization Controller; OC: Optical Circulator; FPL: Fabry-Peròt Laser; SMF: Single Mode Fiber; EDFA: Erbium Doped Fiber Amplifier; VOA: Variable Optical Attenuator; PIN: P-I-N photodiode

Fig. 1 reports the experimental setup. An External Cavity Laser (ECL) emitting at λ_S~1550 nm is externally modulated by a Mach-Zehnder Modulator (MZM) driven by a radio signal at 6 GHz. The radio signal was generated by an arbitrary waveform generator with 25 MHz bandwidth up to 6 GHz. It consisted of a 54 Mb/s 64-QAM OFDM signal (52 subcarriers spaced by 315KHz) carrying a PN15 data pattern. The radio signal power used to drive the MZM was –10 dBm. The double sideband signal produced by the MZM is then sent to the proposed converter. The converter comprises a Polarization Controller, an Optical Circulator and a Fabry-Peròt laser (FPL). The FPL is a commercial pigtailed device, with a front facet reflectivity of about 2 %, 44 GHz free running mode spacing and 10 dBm output power when biased at 64 mA. The injection ratio R (defined as the power ratio between the injecting signal and free running FPL) is set to -12 dB: in this condition, the cavity resonance shift falls approximately at -6 GHz from the injection frequency. The shifted resonance frequency can be fine tuned by controlling the injection ratio, the frequency detuning and the polarization state of the injection light [4]. In this way it is possible to match with a good accuracy the frequency of the input radio signal. The converted signal is then propagated through 80 km of SMF (1360 ps/nm total dispersion, 17 dB insertion loss) and then received with an optical preamplified receiver. The signal is analysed by means of a Vector Signal Analyser.

In Fig. 2-a) we report the optical spectra of the input DSB signal (continuous line) and the converted SSB (dashed). Spectra are recorded with a RBW of 0.01 nm. As it can be seen, the longer wavelength sideband gets amplified in the converter. In the same picture is also possible to observe the suppressed FP modes, after the IL. Fig. 2-b) reports the link frequency response. This measure is performed by means of a Network Analyser. The dashed line report the MZM response. We also show the link frequency response after propagation through 80 km SMF. In this case, the DSB signal (dashed-dot line) shows a minimum transmission at 6.7 GHz. We note that at 6 GHz the frequency response shows a non negligible attenuation of about 10 dB. On the other end, after performing the SSB conversion in the FPL, the frequency response at 6 GHz is greatly improved, by about 37 dB in respect to the DSB case, and by about 27 dB in respect to the back-to-back case. We thus conclude that the proposed converter not only compensate for the fading effect, but also increase the link gain at the desired frequency. This is advantageous, because it allows to cope with signals of low modulation index: RoF signals are often characterized by low modulation index in order to ensure linear operation of the electro-optic modulators.

We also measured the system performance, after transmission over 80 km SMF: results are indicated in Fig 2-c), where the back-to-back curve (dashed line) is also reported for completeness. The signal quality is reported in terms of Error Vector Magnitude (EVM). According to the gain properties of the converter, the SSB signal outperforms both the back-to-back and the DSB signals. In particular, the non converted signal shows unacceptable EVM (that prevent a correct reception of the signal). Instead, the converted signal shows an EVM improvement of about 15 dB.



(a) (b) (c)

Fig. 2 a) Input (DSB) and output (SSB) optical spectra (RBW: 0.01 nm). The lower frequency modulation sideband is amplified by more than 10 dB. **b)** Frequency response of the optical link, measured after the MZM, and after 80 km SMF transmission, with and without conversion. **c)** System performance.

3. Conclusions

In summary, we characterized the performance of a double-to-single sideband converter based on an injection-locked semiconductor laser. By using this converter it is possible to improve the performance of a Radio-over-Fiber link. In particular, a 15 dB EVM improvement has been demonstrated over 80 km SMF (1360 ps/nm total dispersion) for a 54Mb/s OFDM signal (64-QAM) at 6 GHz.

4. References

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