Highly Linear Radio-over-Fiber Transmitter for Subcarrier Multiplexed Systems

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Abstract

A highly linear RoF transmitter, employing a dual Mach-Zehnder modulator, is proposed and experimentally tested. Carrier to interference ratio improvement of 16dB, compared to conventional external modulation, is reported.

Introduction

Seamless interconnection of wireless and optical systems has the potential to enable low-cost and easily reconfigurable radio-over-fiber (RoF) networks. Subcarrier multiplexing (SCM) of multiple wireless channels allows high spectral efficiency and reduction of costs. However, the non-linear behaviour of optical transmitters generates components at new frequencies, provoking distortion in the detected signals.

The simplest method to increase the linearity of optical transmitters is the use of low modulation depths; however, this increases the ratio between the spectral power of the optical carrier and the SCM components, also known in the literature as carrier suppression ratio (CSR), leading to poor receiver sensitivity. Several techniques have been proposed to improve the linearity of optical modulation of SCM signals [1], [2]; however, these are wavelength dependent; have high insertion losses; and require stability of the optical source, increasing costs. Moreover, the operation of the transmitter of [1] depends on the SCM channels number and spectral distribution, and is not commercially available.

In this work, a highly linear transmitter is proposed, which employs a commercial dual Mach-Zehnder modulator (dMZM) [3]. The transmitted signal lacks even order distortion terms, which have been verified to be the most penalizing contributions to intermodulation distortion (IMD) [1]; therefore, enhanced receiver sensitivity is allowed, since lower CSR values can be employed. This scheme is wavelength independent, as it does not require optical filtering; moreover, is not dependent on the RF channels number and spectral distribution (provided that the modulator bandwidth accommodates the SCM channels).

Transmitter scheme and operation principle

The proposed RoF transmitter, recurring to a x-cut dMZM [3], is depicted in Figure 1. It consists on a Mach-Zehnder structure with embedded MZM on each arm, fed by a continuous wave source (CW). The upper MZM is biased at minimum transmission and driven by the SCM signal, $m(t)$. Biasing the MZM at minimum generates an optical carrier suppressed (CS) signal. However, the absence of optical carrier does not allow recovery of the SCM data after direct detection. To overcome such limitation, an in-phase optical carrier is coupled to the CS signal using the lower MZM, originating an optical signal with only intensity modulation.

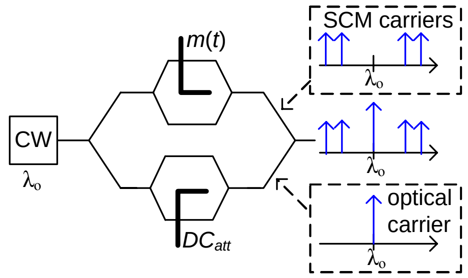


Figure 1: RoF transmitter employing dual Mach-Zehnder modulator (dMZM).

Considering the upper MZM biased at minimum transmission, the modulator transfer function is given by a sine, whose Taylor series expansion does not include any even order terms, which have been found as major contributors for IMD after detection [1]. Moreover, at the expenses of higher insertion losses, the proposed transmitter allows further improvement of the modulation linearity without increasing CSR. This is achieved using lower modulation depth in the upper MZM and adjusting the optical carrier power by the lower MZM bias voltage (DC_{att}).

To evaluate the reduction of non-linear distortion, the performance of the proposed transmitter is compared with that obtained by a conventional MZM biased at quadrature, which induces both even and odd distortion terms.

Simulation and experimental results

To assess the performance of the proposed transmitter, two RF carriers at *f*1 = 2.468 and *f*2 = 2.508 GHz are combined to originate the SCM signal *m*(*t*), which feeds the upper MZM. Figure 2 depicts the simulated power ratio between the SCM optical components and the second and third order non-linear terms as a function of the CSR (distortion terms with order above 3rd present negligible power). In the case of the proposed transmitter (tx), the lower MZM is biased at maximum (0 dB attenuation of the optical carrier (att)) and quadrature (3 dB att). Inset are depicted the optical spectra of the different signals for CSR of 15 dB.

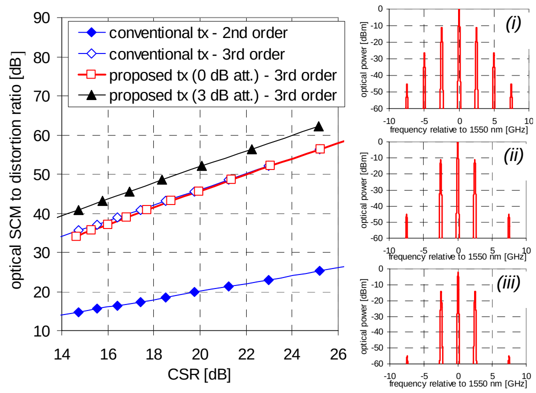
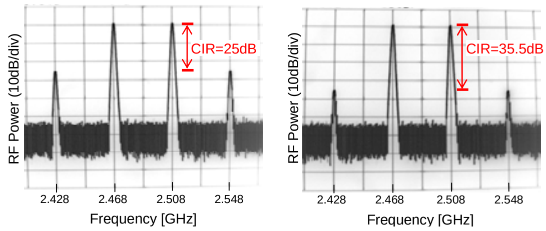


Figure 2: Optical distortion at the tx output. Inset: optical spectra at 15 dB CSR for conventional tx (i), and proposed tx with 0dB att (ii) and 3 dB att (iii).

As referred previously, the proposed transmitter output does not present second order optical non-linearities, in opposition to the conventional transmitter, as can be verified by the inset optical spectra. As a consequence, the use of the proposed transmitter enhances the ratio between the optical SCM and the distortion components with higher power, for the same CSR. Additionally, figure 2 confirms further improvements by attenuation of the optical carrier at the lower MZM.

Figure 3 presents the experimental electrical spectrum after direct detection of the signal generated by the conventional transmitter (a) and by the proposed transmitter with 0 dB att. at the lower MZM (b). CSR of 15 dB is considered. Besides the RF tones at *f*1 and *f*2, third order IMD tones at 2·f1-f2 and 2·f2-f1 are also generated. The use of the proposed transmitter increases the ratio between the RF carriers power and the IMD tones, known as carrier to interference ratio (CIR), by 10.5 dB.

The experimental and simulated dependence of the CIR with optical CSR are presented in figure 4, where the conventional and the proposed transmitters are compared.



(a) conventional and (b) proposed transmitter
Figure 3: Electrical spectra after direct detection.

The experimental results verify a good match with the simulation curves up to CIR of 40 dB; above this value the IMD terms are near the electrical spectrum analyzer noise level. The proposed transmitter scheme with 0 dB att. of the optical carrier retrieves a CIR improved by more than 10 dB for all CSR, when compared to the conventional transmitter. Additional 6 dB CIR improvement is obtained by the proposed transmitter if the optical carrier is attenuated by 3 dB in the lower MZM.

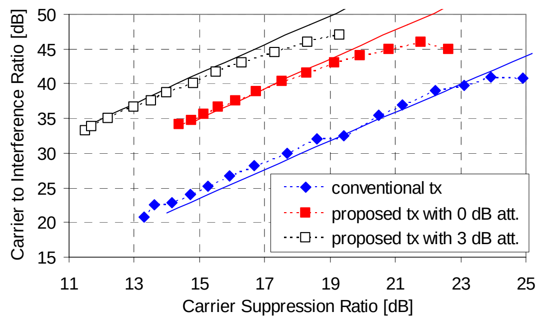


Figure 4: CIR measured after direct detection. Bullets: experimental data; lines: simulation data.

Conclusions

A novel highly linear optical transmitter for SCM systems has been proposed. A commercial dual MZM is employed, where a carrier suppressed signal is combined with an optical carrier to generate a highly linear RoF-SCM signal. CIR improvements of 10 dB and 16 dB, when compared to conventional SCM transmitter, are reported for 0 dB and 3 dB insertion losses at the optical carrier.

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References

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