DESIGN AND SIMULATION OF OPTICAL-OFDM SYSTEMS

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Abstract
With the aim of designing long-haul, back-to-back, and amplitude–phase-modulated optical OFDM systems, we carry out a simulative analysis for averaging the optimum value of the relative intensity-to-noise ratio (RIN). We find that for single-mode lasers a bias of 2 mA has the highest spurious-free dynamic range (SFDR) and low RIN, and for multimode lasers, a bias of 6 mA has the highest SFDR and low RIN.

Keywords: relative intensity-to-noise ratio (RIN), peak-to-average power ratio (PAPR), orthogonal-frequency-division multiplexing (OFDM).

1. Introduction

The intensity of semiconductor lasers fluctuates during operation due to the quantum nature of the lasing process, and even at a constant bias current with negligible current fluctuations, the resultant output light exhibits intensity and phase fluctuations. These fluctuations appear as noise and are particularly detrimental in ultrafast optical communication systems and networks, acting as a fundamental limitation. The intensity noise resulting from the phase-modulation to the intensity-modulation conversion of the laser phase can be the main impairments in direct-detection systems [1]. The amplitude fluctuations are characterized by the relative intensity noise (RIN), which propagates over the optical fiber and limits the signal-to-noise ratio in optical communication systems [5]. Peterman [6] showed that a considerable FM–AM-noise conversion occurs in dispersive optical-fiber links, which must be taken into account when designing analog subcarrier distribution systems. However, in addition to the FM–AM-noise conversion, the nonlinear distortion caused by the FM–AM conversion must be accounted for in analog systems.

Cartexo et al. [7] investigated theoretically and experimentally the influence of optical-fiber nonlinearity on the conversion of the laser and optical amplifier phase noise intensity induced by optical-fiber transmissions. Further, Cartexo et al. [7] and Kaler et al. [8] derived the expression for RIN, including
a higher-order dispersion term using the small-signal analysis. It was shown that the second-order dispersion term has a negligible effect on the RIN; however, none of these authors have evaluated the RIN for another important parameter – the laser line width with dispersion compensation. Wang et al. [9] developed a new approach to investigating the influence of the dispersion on optical-fiber-communication systems using the small-signal analysis near zero dispersion wavelengths. This may provide basic information to minimize detrimental RIN effects in future communication systems. Further, the expression for the RIN, including higher-order-dispersion terms, was derived using the small-signal analysis in [10]. It was shown that the second-order-dispersion term has a negligible effect on the RIN. Later on, the large-signal analysis of FM–AM conversion in dispersive optical fibers for pulse-code-modulation (PCM) systems, including the second-order dispersion, was carried out in [11].

We have already demonstrated the transmission performance through simulation for integrated-dense-wavelength-division multiplexing and optical-OFDM systems with the OADM including the optical-fiber nonlinearity effect and shown that the signal evolution was also remarkable if the systems were operating at a frequency of 191.151 THz and the relative intensity-to-noise ratio (RIN) was adjusted to $-155 \text{ dB/Hz}$ [12]. We have also shown that the transmission performance through simulation for integrated dense wavelength division multiplexing and optical-OFDM systems with the OADM included the optical-fiber nonlinearity effect [13]. Finally, we proposed a coded scheme, using a variable rate for an all-optical sampling orthogonal frequency-division multiplexing system to minimize the peak-to-average power ratio [14].

In this paper, we propose a pre-distortion method for an optical-OFDM system, taking into account universal problems associated with this system, such as the peak-to-average power ratio (PAPR) and intensity fluctuations that originate from the laser and that can be controlled if the relative intensity-to-noise ratio is under control. So, in order to limit the system’s performance, we present the experimental and simulative approach for the same.

2. Simulation Setup

The optical system design consists of the laser diode transmitter, single/multimode optical fiber, OFDM transmitter, amplitude modulator, PIN diode, and OFDM receiver. The Optsim 5.0 optical-simulation tool from Rsoft Design Group is used for the design. Figure 1 shows the simulation setup. An OFDM transmitter drives a Mach–Zehnder amplitude modulator. The length of the optical fiber varies through parametric scans for different lengths. After the reception, an OFDM receiver decodes the signal

![Fig. 1. Simulation setup for amplitude-modulated optical-OFDM system.](image-url)