# Abstract

In this work we carry out an intensive theoretical labor to describe optical communication systems which employ orthogonal frequency division multiplexing (OFDM), and, more concretely, those systems which use direct laser intensity modulation and direct detection. Placed within the unceasing process of higher transmission rate and functionality of optical communication systems, OFDM, a widespread technique in other communication systems, has attracted a great interest during the last years due to its ease of linear effects equalization, flexibility, scalability and high use of well-known and mature signal processing techniques. Optical metro and access networks is one of the scenarios where it has raised a great interest, where the link reach is in the order of tens of kilometers, and the cost-effectiveness is of the main concern.

Optical OFDM (OOFDM) is different to subcarrier multiplexing (SCM) technique because subcarrier's data spectral content overlap one to another, but it can be detected correctly thanks to its orthogonality property. Besides, its detection and generation can be done electrically through the calculation of the Fast Fourier transform and its inverse, respectively. Under a proper design, OOFDM offers an easy equalization of the linear communication system effects, though its high peak-to-average power ratio is one of its main disadvantages.

As starting point, we propose an analytical model to study in detail all those phenomena which affect the signal information detected at the receiver. Such phenomena are the laser nonlinearity, laser phase and intensity modulations, propagation through the optical fiber taking into account the chromatic dispersion, and the intensity detection by means of a square-law detector. This analytical model is validated through comparisons with simulation results obtained by means of commercial software. Given the singularity of OFDM signal due to its multi-carrier nature, the amplitude of the generated signal is random, and the analytical model is complemented with a study of signal clipping at the transmitter. Moreover, filtering effects affecting the signal through the communication system are also taken into account. With the analytical model reported we can describe in a rather comprehensive way the main phenomena as well as exploring and optimizing the final system performance of OOFDM systems with direct modulation and detection.

Since the optical communication systems with direct modulation and detected are severely affected by nonlinear distortion, and for multi-carrier signals such as OFDM signals it means the mixing of the information symbols carried by the different subcarriers, we propose in Chapter 5 a pre-distortion technique based on the analytical model previously proposed. This technique improves the modulation efficiency, making possible to increase the signal information term without increasing the nonlinear distortion at the receiver. Great nonlinear distortion cancellation efficiency values are achieved, and our technique is also compared to another one previously published in order to evaluate its performance.

Another technique for the improvement of systems with direct modulation and detection is the employment of optical filtering. Though it is understood in an intuitive way for traditional optical modulation formats, it is necessary to have a mathematical formulae for OOFDM signals in order to understand exactly its working principle, the improvement obtained, as well as its potentiality. For such purpose, in Chapter 6 we present an analytical model which extends that previously proposed. The simplification of the mathematical expressions just obtained allows us to systematically explore the different effects involved in the final performance obtained, the study of OOFDM systems with different optical filtering structures, as well as the possibility of optimization in a quick and efficient manner different optical filtering structures. In our particular case, we study an optical filter based on Mach Zehnder interferometer and uniform fiber-Bragg grating structures.

To put it briefly, with this Ph.D. Thesis we have pretended to contribute on getting a greater understanding and a better design of optical communication systems employing OOFDM as well as exploring alternatives for their improvement.