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ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING (OFDM) IN PHOTONIC COMMUNICATIONS

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Abstract: OFDM has emerged as a promising modulation technique in long-haul and access optical networks because of a number of advantages: Scalable spectrum partitioning, good spectral efficiency, dispersion tolerance, and a natural suitability for software-defined transmission. However, there are also issues inherent in OFDM: High peak-to-average power ratio making the system more susceptible to nonlinearity, sensitivity to frequency offset and phase noise, and the required computational complexity. With the advent of powerful digital signal processors and by exploiting all-optical signal processing, some of these obstacles can be overcome.

1. BASIC OFDM CONCEPTS

Orthogonal frequency division multiplexing (OFDM) is simple in concept [1]–[4]. Complex data having a Nyquist bandwidth B are generated at a data rate $B = N / \tau$. These data are encoded on N carriers, the amplitudes and phases of which are fixed by these data during the symbol period τ. All modulated carriers are superimposed and transmitted in parallel, resulting in symbols that are N times longer than the original data period τ / N. Consequently, intersymbol interference by dispersion has much smaller impact.

In the spectral domain, the carriers are equidistantly spaced by $f_\tau = B / N = 1 / \tau$ so that integer multiples of the nth carrier period $1 / (n\, f_\tau)$ fit into the symbol window $\tau = n / (n\, f_\tau)$. Because amplitudes and phases of all carriers are constant within τ, Fig. 1(left), the corresponding instantaneous spectra have a $(\sin f) / f$ structure. Neigbouring spectra overlap considerably, and the spectral zeros of one carrier coincide with the spectral maxima of neigbouring carriers, Fig. 1 (right). The carriers are called orthogonal, because the product of carriers with different frequencies integrated over the symbol period τ is zero, while the same operation with two carriers having identical frequencies results in 1 / 2.

On reception, the compound signal is multiplied ("mixed") with all of the carriers' unmodulated local counterparts, and the output of all N mixers is integrated over the symbol period τ using N integrate-and-dump filters. The filter outputs then recover the decoded N complex data transmitted per symbol.

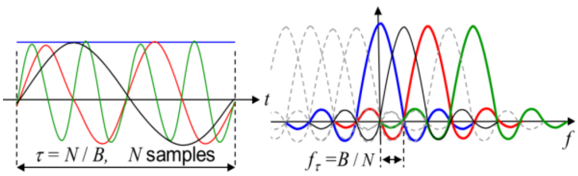

Fig. 1. OFDM signal and spectrum (**left**) N sinusoidal OFDM carriers keyed "on" in symbol period τ (**right**) Associated overlapping spectra spaced by f_τ

The data encoding described previously can be accomplished with an inverse discrete Fourier transform (IDFT), data decoding with the (forward) DFT.

2. SELECTED EXPERIMENTAL RESULTS

We present three major achievements in OFDM transmission: An all-optical realization of the fast Fourier transform (FFT) [5], the FFT-based real-time reception of a 10.8 Tbits/s single channel OFDM signal [6], and a real-time software-defined multiformat 28 GBd transmitter for, e.g., 64QAM data [7].

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