Efficient Out-of-Band Spectrum Suppression in WDM-OFDM Systems

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Abstract: We propose and experimentally demonstrate a new scheme for orthogonal frequency division multiplexing (OFDM) sidelobe suppression by inserting sidelobe suppression prefix (SSP) ahead of cyclic prefix (CP). The feasibility of the proposal is verified by both simulation and experiment.
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1. Introduction

Orthogonal frequency division multiplexing (OFDM) is an important technology in wireless and optical communications owing to its high spectral efficiency and great resistance to inter-symbol interference [1]. However, out-of-band interference resulting from adjacent channel interference may limit the development and application of OFDM. Many schemes have been proposed to achieve sidelobe suppression, such as windowing in time domain [2], insertion of cancellation carriers (CC) [3], subcarrier weighting [4], and adaptive symbol transition [5]. However, all these methods have only been verified in the field of wireless communications.

In this paper, we propose and experimentally demonstrate a new scheme for sidelobe suppression in OFDM systems by inserting a short sequence ahead of cyclic prefix (CP), which is termed as sidelobe suppression prefix (SSP). In our algorithm, the SSP is progressively optimized by FFT-IFFT iterations to optimize the suppression performance. This technique can be utilized in WDM-OFDM systems to reduce the interference between adjacent channels with OFDM signals. The principle is analyzed, and experimental results show that an ~18 dB improvement of sidelobe suppression can be achieved for OFDM signal with only 5% SSP.

2. Operation principle

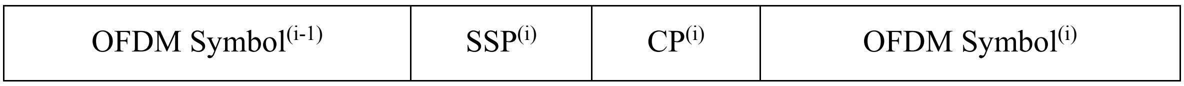

Fig. 1. Typical structure of OFDM symbols with SSP.

We consider an arbitrary N-symbols ($N > 1$) OFDM sequence *syms* with a fixed length of l. By inserting sequence SSP$^{(i)}$ with a fixed length of l_{SSP} in *syms*, a new sequence *syms'* can be generated. The SSP$^{(i)}$ is chosen so that the sum of the out-of-band power spectrum is minimum. Therefore a typical structure of OFDM symbol with SSP is shown in Fig. 1, where conventional OFDM symbol structure is preserved and the SSP$^{(i)}$ is inserted ahead of CP$^{(i)}$.

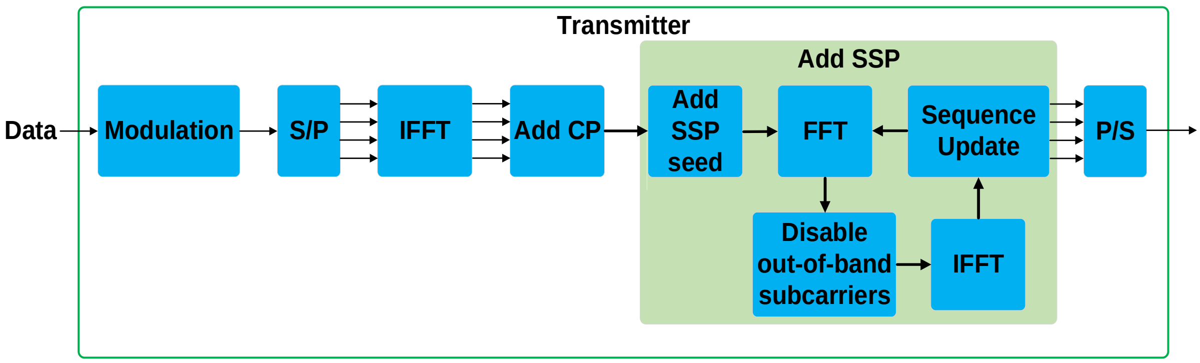

Fig. 2. Transmitter structure with SSP generator.

The transmitter structure with a SSP generator is illustrated in Fig. 2. The algorithm of generating SSP is provided in Fig. 3. The SSP is generated by four-step iterations as follows:

Step 1. Put the *i*-th OFDM symbol, the *i*-th CP, the *i*-th SSP and the (*i*–1)-th OFDM symbol together and then obtain the signal spectrum by FFT.

Step 2. Eliminate out-of-band subcarriers in the spectrum.

Step 3. Obtain the time domain sequence by IFFT from the spectrum.

Step 4. Update the *i*-th SSP using the newly generated *i*-th SSP.

By eliminating the out-of-band subcarriers in Step 2, the out-of-band power spectrum is suppressed. As long as enough iterations are executed, the sum of the out-of-band power spectrum is small enough and the prefix can be considered as the SSP.

The OFDM sidelobes can be significantly suppressed though a small loss in signal-to-noise ratio (SNR) is introduced due to the extension of the length of OFDM symbol.

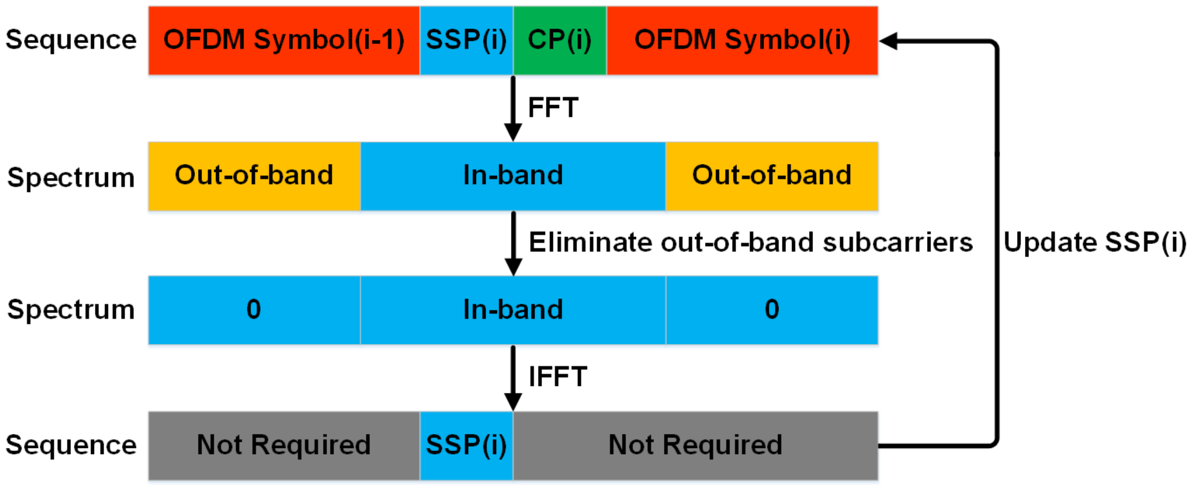

Fig. 3. Algorithm of generating SSP.

3. Experiment and results

The performance of the proposed SSP scheme is investigated by experiment. The experimental setup of the SSP-OFDM system is shown in Fig. 4. At the transmitter, a continuous-wave (CW) light at 1550.01 nm from a tunable laser (SP TLS150D) is launched into a single-drive Mach-Zehnder modulator (MZM) (Fujitsu FTM7921ER). The MZM is biased at the quadrature point and modulated by an electrical OFDM signal. The OFDM signal is generated by an arbitrary waveform generator (AWG) (Tektronix AWG7122C) and then amplified by an electrical amplifier (EA). The output of the MZM is converted to an electrical signal by a photodetector (PD) (Bookham PT10G4094) and then observed by a signal source analyzer (R&S FSUP). Meanwhile, the OFDM signal generated by the AWG is also fed into the signal source analyzer to obtain its power spectrum.

For both simulation and experiment, the power spectral spectra of the OFDM sequences of 1000 symbols with and without the SSP are tested and compared. The number of subcarriers is 64 and the lengths of FFT and CP are 256 and 26 for two kinds of OFDM signals, respectively. The length of the SSP is 13 and the number of iterations is 70.

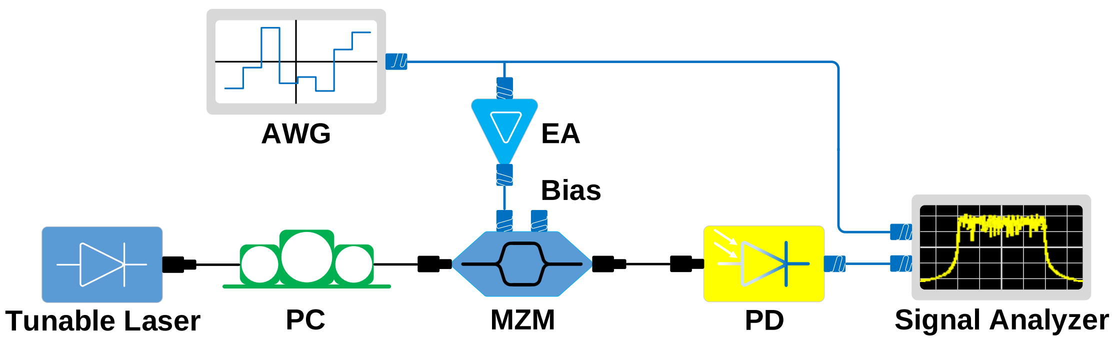

Fig. 4. Experimental setup of the SSP-OFDM system. PC: polarization controller. MZM: Mach-Zehnder modulator. AWG: arbitrary waveform generator. EA: electrical amplifier. PD: photodetector.

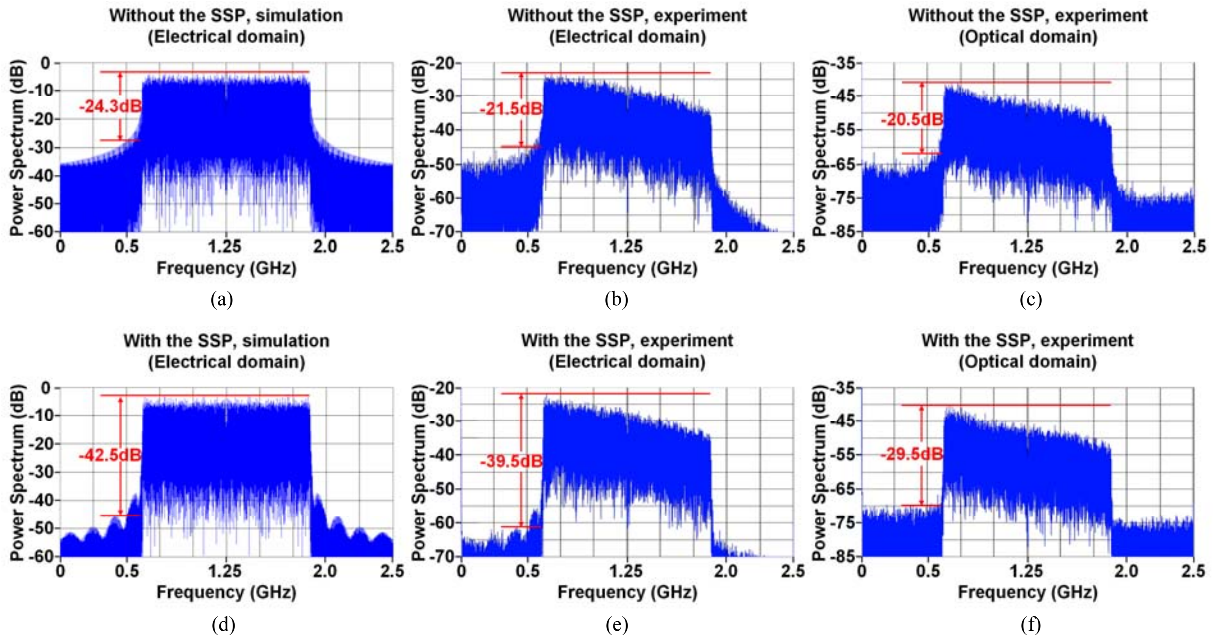

Fig. 5. Power spectra of OFDM signals. (a) and (d) OFDM signals without and with the SSP in simulation. (b) and (e) OFDM signals without and with the SSP from the AWG. (c) and (f) OFDM signals without and with the SSP after PD detection.

Fig. 5 shows the power spectra of the OFDM signals with and without the SSP in simulation, electrical domain, and optical domain, respectively. The guard bandwidth on each side of the signal spectrum is assumed to be 10% bandwidth of OFDM signal. The interference level of the OFDM signal, which is the difference between the maximum of the power spectrum out of the guard band and the maximal signal spectrum, is marked on each plot. In Figs. 5(a), (d) and (b), (e), both simulation and experiment results show that the OFDM signals with a 5% SSP suppress the interference level down to ~–40 dB, which is ~18 dB lower than that of the conventional OFDM signals. The suppression performance of the SSP observed in optical domain, however, is not as high as that in electrical domain. As shown in Figs. 5(c) and (f), only ~9 dB improvement is observed in optical domain. This can be attributed to the following reasons: (1) noise from the laser and modulator as well as beat noise from the PD; (2) the RF signal is not set high enough; (3) high-frequency component produced by the MZM.

4. Conclusion

We propose a new method for sidelobe suppression using the SSP. Both simulation and experimental results show that the sidelobes of the OFDM signal with 5% SSP can be suppressed by ~18 dB relative to the conventional OFDM signal.

5. Acknowledgements

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6 References

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