SSBI Cancellation Method for IMDD-OFDM System with a Single Photodiode

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Abstract— A novel SSBI cancellation approach is proposed for IMDD-OFDM system by using only asinglephotodiode (PD). Simulation results indicate that the proposed approach can cancel the SSBI effectively and also achieve 3.2 dB improvement of power efficiency compared with the conventional IMDD-OFDM.

1. INTRODUCTION

Coherent detection has achieved dramatic success to provide excellent solutions for high-speed and long-haul transmission in the past few years [1–4]. The optical research has turn to seek for the solution of cost-sensitive short-reach high-speed communication. Direct-detection orthogonal frequency-division multiplexing (OFDM) as a promising candidate technology has been widely invested. The simple signal-to-signal beat interference (SSBI) cancellation receiver based on balanced detection for a single sideband optical OFDM signal with a reduced guard band has been proposed [5]. However, the generation of the optical single sideband OFDM signal is complex and balanced detection is used at the receiver. The direct detection optical OFDM transmission using beat interference cancellation receiver is demonstrated. But the balanced detection of this method is also complex [6]. Most recently, a cost-effective 61 Gbits/s direct-detection optical OFDM based on block-wise signal phase switching with signal-to-signal beat noise cancellation is proposed. However, the algorithm requires high optical signal-to-noise power ratio (OSNR) and has high complexity for SSBI cancellation [7].

In this paper, we proposed a novel approach to cancel SSBI for IMDD-OFDM system using 16 quadrature amplitude modulation (16 QAM) formats with only a single photodiode. In this method, 2 intensity modulators (IMs) are used to generate dual-polarization OFDM signal which is detected by a single photodiode. In order to recover the OFDM signal without SSBI, the specially designed OFDM signal of transmitter is needed. Simulation results show that the proposed method can successfully cancel the SSBI and can also achieve 3.2 dB improvement of power efficiency compared with conventional IMDD-OFDM. Although the frequency efficiency decreases by one-third, the carrier signal power ratio (CSPR) could be greatly reduced and more optical power is accommodated to signal.

2. PRINCIPLE AND SIMULATION SETUP

The principle of the proposed SSBI cancellation approach for IMDD-OFDM system is illustrated in Fig. 1. We first generate the optical OFDM signal with real component (I) and imagine component (Q) on two orthogonal polarizations by using two independent IMs, then only one photodiode is used to detect the OFDM signals as shown in Fig. 1(a). As there are no polarization crosstalk terms in the beating results when detected by the PD due to the assumed perfect orthogonality of the two polarization components, the corresponding photocurrent is the addition of the independently detected X- and Y-polarization components. After detection, the photo currents for the double-polarization signal is given by

$$\begin{aligned} I &= \left|E_{x,0}+E_{x,s}\right|^2+\left|E_{y,0}+E_{y,s}\right|^2 \\ &= \left|E_{x,0}\right|^2+2\mathrm{Re}\left\{E_{x,0}E_{x,s}^*\right\}+\left|E_{x,s}\right|^2+\left|E_{y,0}\right|^2+2\mathrm{Re}\left\{E_{y,0}E_{y,s}^*\right\}+\left|E_{y,s}\right|^2 \end{aligned} \tag{1}$$

where, $E_{x,0}$ is the main carrier and $E_{x,s}$ is the OFDM signal on x-polarization. $E_{y,0}$ and $E_{y,s}$ are the respective main carrier and OFDM signal on y-polarization. Fig. 1(b) shows the main concept of the SSBI cancellation on time domain. One frame contains three symbols which are dual-polarization signal. For the three symbols of signal, we respectively transmit I and Q, I and -Q, -I and -Q of the OFDM signals on x and y polarizations. The spectrum of the three symbols of OFDM signals are illustrated in Fig. 1(c). Then the three photocurrents I_1, I_2 and I_3 are descripted

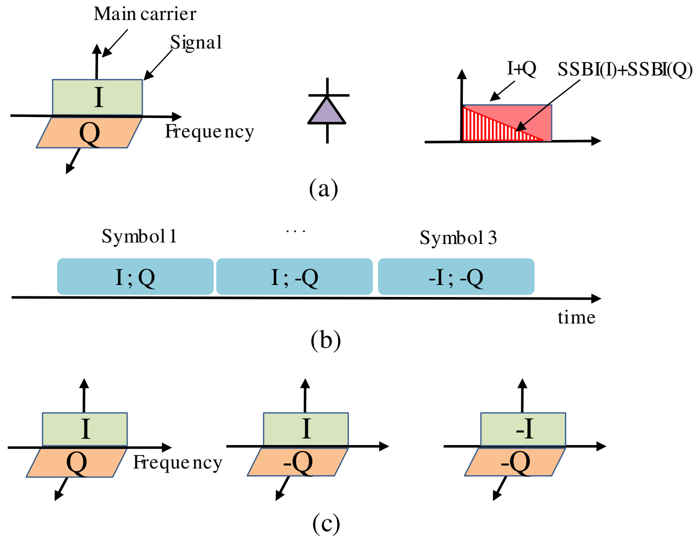

Figure 1: Principle of SSBI cancellation approach.

as

$$I_1 = |I|^2 + |Q|^2 + 2\text{Re}\left\{I \cdot E_{x,0}^*\right\} + 2\text{Re}\left\{Q \cdot E_{x,0}^*\right\} + |E_{x,0}|^2 + |E_{y,0}|^2 \tag{2}$$

$$I_2 = |I|^2 + |Q|^2 + 2\text{Re}\left\{I \cdot E_{x,0}^*\right\} + 2\text{Re}\left\{-Q \cdot E_{x,0}^*\right\} + |E_{x,0}|^2 + |E_{y,0}|^2 \tag{3}$$

$$I_3 = |I|^2 + |Q|^2 + 2\text{Re}\left\{-I \cdot E_{x,0}^*\right\} + 2\text{Re}\left\{-Q \cdot E_{x,0}^*\right\} + |E_{x,0}|^2 + |E_{y,0}|^2 \tag{4}$$

where I (x-pol.) and Q (y-pol.) are real and imagine components of the complex signal. $|I|^2$ and $|Q|^2$ are the SSBIs to be cancelled. $E_{x,0}$ and $E_{y,0}$ are the main carriers on x and y polarizations, respectively. From equation (2), (3) and (4), the recovered signal is written as

$$S = (I_2 - I_3) + j \cdot (I_1 - I_2) = 4\text{Re}\left\{I \cdot E_{x,0}^*\right\} + j \cdot 4\text{Re}\left\{Q \cdot E_{y,0}^*\right\} \tag{5}$$

The simulation setup is depicted in Fig. 2. At the transmitter, the optical source at 1550 nm with 100 kHz line-with is firstly split into two parts. Then the upper path is fed into an IM, which is driven by the real component of the complex electrical OFDM signal. The OFDM generator is used to produce complex OFDM-16QAM radio frequency (RF) signal. The baseband signal is comprised of 64 subcarriers. The FFT size is 256. The center one subcarrier is unloaded to avoid the DC influence. In the lower path, the imagine component of the complex electrical OFDM signal is modulated onto optical carrier by another IM. Then the two parts of optical OFDM signals combine by a polarization beam coupler (PBC) to generate the dual-polarization OFDM signal. At the receiver, only one photodiode is used to detect the optical OFDM signals. Then we compare the proposed SSBI cancellation scheme with the conventional IMDD-OFDM scheme. To ensure the two systems have the same net bit rate, the SSBI cancellation scheme uses three times bit rate over the conventional IMDD-OFDM to transmit the signals.

3. RESULTS AND DISCUSSION

We first measure the Q factor as a function of carrier to signal power ratio (CSPR) at back-to-back. Here, the Q factor is defined as the signal-to-noise ratio of the OFDM signals. In order to

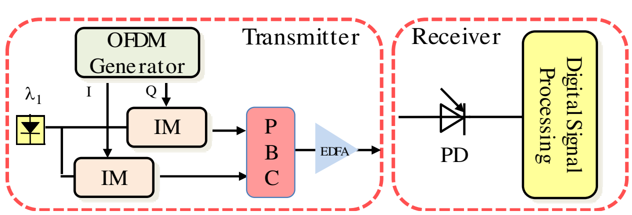

Figure 2: Simulation setup of the SSBI cancellation system. IM: Intensity modulator; PBC: polarization beam coupler; PD: photodiode.

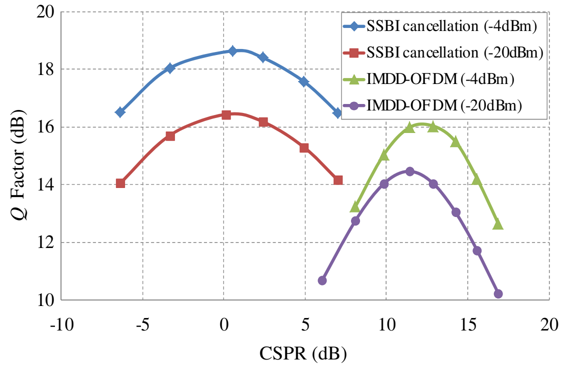

Figure 3: Q factoras a function of CSPR with different received power at back-to-back.

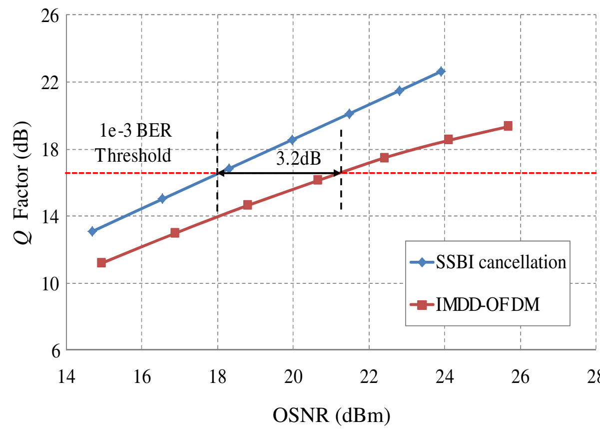

Figure 4: Q factor versus OSNR at back-to-back.

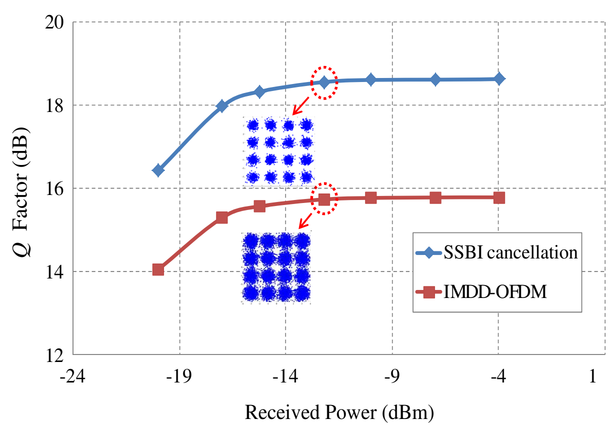

Figure 5: SNR versus received optical power at back-to-back.

compare the performance of the two schemes, the OSNRs of the schemes are set to be the same value (~ 20.6 dB). Here, the OSNR is denoted as the ratio of the whole optical power including main carrier and OFDM signal to the optical noise power in 12.5 GHz optical band-with. The measured SNR versus CSPR are shown in Fig. 3. The optimum CSPRs of the proposed approach are the same value of 1.2 dB when the received optical power are -20 dBm and -4 dBm. But the optimum CSPR of the conventional IMDD-OFDM are 11.5 dB and 12.5 dB with the corresponding received optical powers. The optimum CSPR of the proposed scheme has greatly decreased and thus more optical power is assigned to the signal. Therefore, the proposed SSBI cancellation scheme has batter Q factor preference compared with the conventional IMDD-OFDM.

Figure 4 illustrates the Q factor versus OSNR performance of the two systems which are measured at optical back-to-back with -4 dBm received optical power. From the analysis before, the optimum CSPRs of the two systems are set as 0.56 dB and 12.5 dB, respectively. The power efficiency of the proposed scheme has 3.2 dB improvement at the 1e-3 BER threshold (Q factor = 16.52 dB for 16QAM modulation format) compared with the conventional IMDD-OFDM transmission scheme.

Under the optimum CSPRs and the designed OSNR condition (CSPR of 0.56 dB and 12.52 dB, OSNR of 20.6 dB), the Q factor versus received optical power at optical back-to-back is shown in Fig. 5. The Q factor performance improves along with the received optical power increasing. It can be seen that the almost −15 dBm optical power is adequate for both the SSBI cancellation and conventional IMDD-OFDM schemes in the simulation because the Q factor performance is barely improved beyond −16 dBm. The constellations of recovered 16QAM are shown in the inserts.

4. CONCLUSIONS

In this paper, we propose a novel approach to cancel SSBI for IMDD-OFDM signal with only a single photodiode. In this method, 2 intensity modulators (IMs) are used to generate dual-polarization OFDM signal which is detected by a single photodiode. Simulation results show that the approach successfully cancels the SSBI and has 3.2 dB power efficiency improvement compared with the conventional IMDD-OFDM scheme at the 1e-3 BER threshold.

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