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Reducing intercarrier interference for OFDM system

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1. Introduction

Orthogonal frequency division multiplexing (OFDM) with guard interval is an effective modulation scheme in band-limited multipath underwater (UWA) channel. OFDM system is very sensitive to frequency offset (FO) which results in intercarrier interference (ICI). Therefore, in this paper, Multiple-Symbol Encapsulated OFDM (MSE-OFDM) with self-ICI cancellation method is proposed to mitigate FO effect.

2. Communication system

Figure.1 is the structure of the OFDM/MSE communication system. The data will be mapped as a complex signal according to quadrature phase shift keying (QPSK) modulation, then segmented into frames. In this system, there are N subcarriers with symbol period T. The signal at the output of OFDM transmitter resulting from the ith symbol is

$$x(t) = \exp(j2\pi f_c t)\sum_{k=0}^{N-1} b_{k,i}\, p(t-\frac{kT}{N}) \qquad (1)$$

where f_c is the carrier frequency and $p(t)$ is the impulse response of the low-pass filter of the transmitter. $b_{k,i}$ is Inverse Fast Fourier transform (IFFT) of $a_{k,i}$. Assuming that frequency offset is Δf, ignoring noise, the demodulated signal is represented as

$$y(t) = \exp(j2\pi\Delta f t)\sum_{k=0}^{N-1} b_{k,i}\, q(t-\frac{kT}{N}) \qquad (2)$$

where $q(t)$ is the combined impulse response of the channel and of the transmitter and receiver filters. After sampling at intervals T/N, the samples of $y(t)$ are given by

$$y_{k,i} = b_{k,i}\exp(\frac{j2\pi k\Delta fT}{N}) \qquad (3)$$

The received signal on subcarrier m after IFFT can be written as

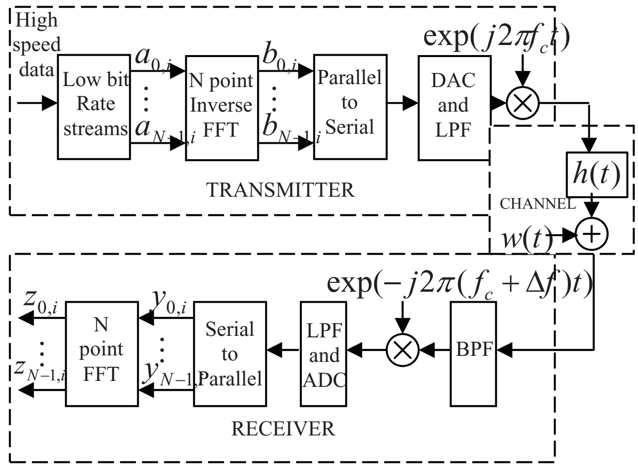

Fig. 1 Structure of OFDM /MSE system

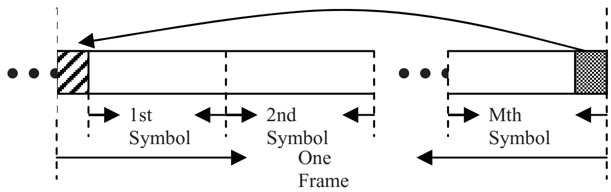

Fig.2 MSE-OFDM scheme

$$z_{m,i} = \sum_{n=0}^{N-1} c_{n-m}\, a_{n,i} \qquad (4)$$

$$c_{n-m} = \frac{1}{N}\frac{\sin(n-m+\Delta fT)}{\sin\pi(\frac{n-m+\Delta fT}{N})} \times \exp j\pi\frac{(N-1)(n-m+\Delta fT)}{N} \qquad (5)$$

In this scheme the input data should be mapped onto adjacent pair of subcarriers, so that $a_{0,i} = -a_{1,i}, a_{2,i} = -a_{3,i}, \cdots a_{N-2,i} = -a_{N-2,i}$. The decoded value at the zeroth carrier is given as

$$z_{0,i} = (c_0 - c_1)a_{0,i} + \cdots + (c_{N-2} + c_{N-1})a_{N-2,i} \qquad (6)$$

Since the difference between adjacent coefficients is small, this results in substantial reduction in ICI. Then the data can be obtained by subtracting values $z_{0,i} \cdots z_{N-1,i}$ in pairs

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$$z_{0,i} - z_{1,i} = (-c_{-1} + 2c_0 - c_1)a_{0,i} + (-c_1 + 2c_0 - c_1)a_{2,i} \cdots (-c_{N-3} + 2c_{N-2} - c_{N-1})a_{N-2,i} \quad (7)$$

This process further reduces the remaining ICI. This is ICI self-cancellation scheme. This method sacrifices bandwidth. MSE-OFDM combined with ICI self-cancellation is proposed to combat against ICI. The frame structure in time domain is depicted in Fig. 2. The $l-th$ frame symbol r_l is represented as

$$r_l = [s_{l,M}(N-p),\dots,s_{l,M}(N-1),s_{l,1}(0), \dots,s_{l,1}(N-1),\dots,s_{l,2}(0),\dots,s_{l,2}(N-1), \dots,s_{l,M}(0),\dots,s_{l,M}(N-1)] \quad (8)$$

Only one cyclic prefix, the last OFDM symbol in the same frame $s_{l,M}(N-p),\dots,s_{l,M}(N-1)$ is inserted between the frame symbols.

3.Simulation results

To evaluate the performance of these schemes, OFDM system with 256 subcarriers is simulated. The two channels discrete transfer functions $H(z)$ are given by

$$H_1 = 1 + 0.39z^{-8} - 0.40z^{-13} - 0.27z^{-21} \quad (9)$$

$$H_2 = 1 - 0.78z^{-1} + 0.41z^{-2} - 0.32z^{-3} - 0.31z^{-80} + 0.24z^{-83} - 0.17z^{-85} \quad (10)$$

Due to relatively long time dispersion, channel 2 has narrower coherence bandwidth than channel 1. SNR is 30dB unless noted. While employing the standard OFDM (STD OFDM), OFDM /MSE with ICI self-cancellation schemes in the case $\Delta fT = 0.03$ for channel 2, Fig.3 shows that STD OFDM system output is more scattered than the other two schemes. Figure 4 compares symbol error rate (SER) for various schemes plotted as functions of normalized FO for channel 2. It can be seen that the OFDM and MSE-OFDM with ICI self-cancellation systems' tolerable FO is about 0.2. STD OFDM performance in removing ICI components can't be comparable to the other two schemes. Thus, the two schemes make OFDM systems less sensitivity to FO. Figure 5 plots SER as a function of SNR. For channel 1 and 2, the normalized frequency offsets are 0.08 and 0.03, respectively. Using the two schemes, OFDM and MSE-OFDM with ICI self-cancellation exhibit less SER than STD OFDM even at low SNR. MSE-OFDM and OFDM with ICI cancellation have a significant improvement in combating against ICI effects. In addition, for long time spread channel, MSE-OFDM outperforms OFDM.

4. Conclusion

Simulation results demonstrate that OFDM and MSE-OFDM with ICI self-cancellation give very

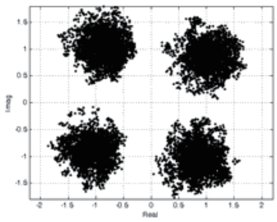

Fig.3a STD OFDM output

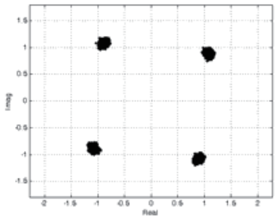

Fig. 3b OFDM with ICI cancellation output

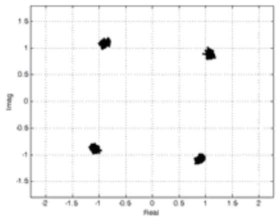

Fig. 3c MSE with ICI cancellation output

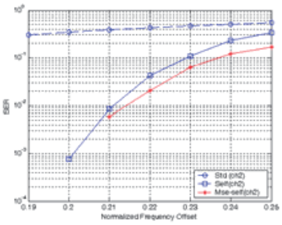

Fig. 4 SER as a function of Normalized FO

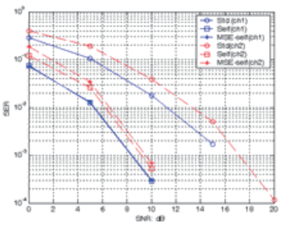

Fig. 5 SER as function of SNR

great reductions in ICI. The disadvantage of the self-cancellation scheme is its throughput. MSE-OFDM can make use of the bandwidth more efficiently and achieve satisfactory performance.

Acknowledgment

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References

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