Intercarrier Interference Cancellation for Time Reversed OFDM Systems

Chundan Lini, Wansong Zhang, Jong Rak Yoon and Ji Hyun Park (1 College of Science, China Univ. of Petroleum, Beijing, China; 2 Dept. of Information and Communications Eng., Pukyong National Univ., Pusan, Korea)

1. Introduction

For time reversed orthogonal frequency division multiplexing (OFDM) communication an array of transducers, i.e. time-reversal mirrors are deployed to estimate channel impulse response. This scheme requires only a simple processor at the receiver. However, OFDM is very sensitive to carrier frequency offset which distorts the orthogonality between subcarriers resultig in intercarrier interference (ICI). The advantage of ICI self cancellation scheme is very simple for suppresing In this paper simulations show that time-reversal OFDM system using the ICI self-cancellation method can reduce ICI effects effectively and achieve high data rates in bandlimited underwater acoustic channel.

2. Communication system

Figure 1 shows the block diagram of OFDM communication system. The data will be mapped as a complex signal according to quadrature phase shift keying (QPSK) modulation. is the total number of subcarriers and is OFDM symbol duration. The signal after modulated by carrier frequency can be represented as

\[ x(t) = \exp(j2\pi f_c t) \sum_{k=0}^{N-1} b_k p(t - kT/N) \]

where \( f_c \) is the carrier frequency and \( p(t) \) is the impulse response of the low-pass filter of the transmitter. A single broadband probe pulse \( f(t) \) is sent in advance of the data packet and received at the \( m-th \) transducer in the absence of noise

\[ R_m(t) = h_m \otimes f(t) \]

where \( h_m \) is the impulse response between the focal point and the transducer.

The transmitted signals at the receiver will be correlated with the time reversed signal

\[ R(t) = \sum_m x(t) \otimes h_m(t) \otimes R_m^*(t) \]

\[ = x(t) \otimes f^*(t) \otimes \sum_m h_m^*(t) \otimes h_m(t) \]

In the frequency domain,

\[ R(\omega) = X(\omega)F^*(\omega) \sum_m |G_m(\omega)|^2 \]

Since signal bandwidth \( W_c \), is approximately constant. Because \( F(\omega) \) is known the frequency distortion caused by \( F(\omega) \) can be compensated by filtering.

Considering frequency offset \( \Delta f \), after sampling, the demodulated signal can be written as

\[ y_{k,i} = b_{k,i} \exp\left(\frac{j2\pi k \Delta f T}{N}\right) \]

The received signal on subcarrier \( m \) after FFT process is given by

\[ c_{n-m} = \frac{1}{N} \frac{\sin(n-m+\Delta f T)}{\sin(n-m+\Delta f T/N)} \]

\[ \times \exp\frac{j\pi}{N}(N-1)(n-m+\Delta f T) \]

To cancel ICI, in this scheme the input data are required to meet

\[ a_{0,j} = -a_{1,j}, a_{2,j} = -a_{3,j}, \ldots a_{N-2,j} = -a_{N-1,j}, \ldots \]
Then the decoded value at the zeroth carrier is given as

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

Finally the data can be obtained by subtracting values in pairs \( z_{0,i} \cdots z_{N-1,i} \) in pairs

\[ z_{0,i} - z_{1,i} = (-c_{N-1} + 2c_0 - c_1)a_{0,i} + (-c_1 + 2c_2 - c_{N-1})a_{2,i} \cdots (-c_{N-3} + 2c_{N-2} - c_{N-1})a_{N-2,i} \] (7)

This process reduces the ICI completely and maximize the overall signal to noise ratio (SNR). This is ICI self-cancellation scheme.

3. Simulation

The simulation environment is 100m water depth, 97m source depth and 1km source-array range. Six transducers are vertically deployed spaced 0.5m apart from depth of 5m to 7.5m.

As shown in Fig.2, SNR is 20dB and there is no normalized frequency offset, using 6-array elements no errors were detected, for only one element the symbol error rate (SER) is 0.0015. Fig. 3 shows the constellation diagram in the case of SNR is 30dB and normalized frequency offset is 0.16. deploying 6-array elements system there is no error occurred, for one element more errors were detected. Fig.4 shows the SER as a function of SNR. Normalized frequency offset is 0.1. 6-array elements system performs much better than one element at low SNR or in the presence of frequency offset. Therefore, for time-reversed OFDM communication with ICI self cancellation scheme the cross correlations are coherently summed across the array increase the SNR and help to stabilize the acoustic field in the presence of fluctuations in the environment.

4. Conclusion

Through simulation it is proved that time-reversed OFDM communication system employing ICI self-cancellation scheme can reduce ICI effectively and increase SNR with moderate hardware complexity.

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References