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Intercarrier Interference Cancellation for Time Reversed OFDM Systems

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1. Introduction

For time reversed orthogonal frequency division multiplexing (OFDM) communication an array of transducers, ie., time-reversal mirrors are deployed to estimate channel impulse reponse. 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 advangate of ICI self cancellation sheme is very simple for surppressing 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. N is the total number of subcarriers and T is OFDM symbol duration. The signal after modulated by carrier frequency can be represented as

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

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

$$R(t) = \sum_m x(t) \otimes h_m(t) \otimes R_m^*(-t)$$
$$= x(t) \otimes f^*(-t) \otimes \sum_m h_m^*(-t) \otimes h_m(t)$$

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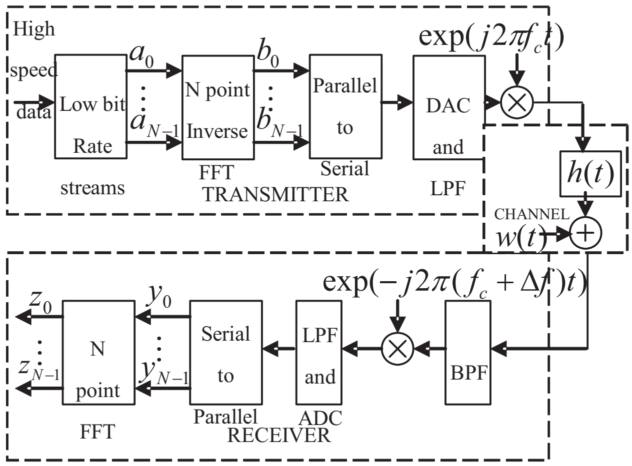

Fig.1 OFDM system block diagram

In the frequency domain,

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

Since signal bandwidth $W_x \subset W_f$, $\sum_m |G_m(\omega)|^2$ is approximately constant. Because $F(\omega)$ is known, the frequency distortion caused by $F(\omega)$ can be compensated by filtering.

Considering frequency offset Δf, after sampling, the demodulated signal can be written as

$$y_{k,i} = b_{k,i} \exp(\frac{j2\pi k \Delta f T}{N})$$

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

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

To cancel ICI, in this scheme the input data are required to meet $a_{0,i} = -a_{1,i}, a_{2,i} = -a_{3,i}, \cdots a_{N-2,i} = -a_{N-1,i}$.

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 $z_{0,i} \cdots z_{N-1,i}$ in pairs

$$z_{0,i} - z_{1,i} = (-c_{-1} + 2c_0 - c_1)a_{0,i} + (-c_1 + 2c_2 - c_3)a_{2,i} \cdots (-c_{N-3} + 2c_{N-2} - c_{N-1})a_{N-2,i} \qquad (7)$$

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.

Acknowledgment

This work was supported by ……..

References

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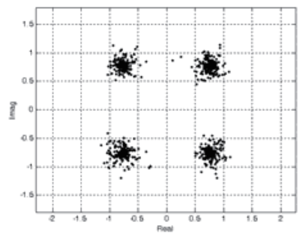

Fig. 2a Output using 6-array elements

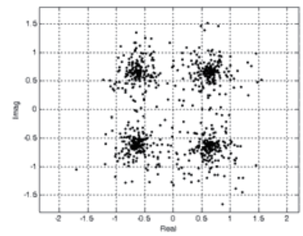

Fig. 2b Output using one element

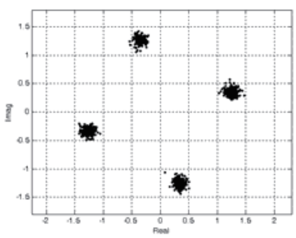

Fig. 3a Output using 6-array elements

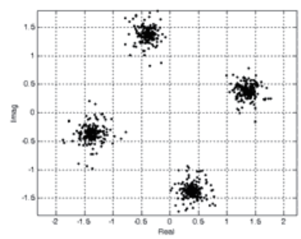

Fig. 3b Output using one element

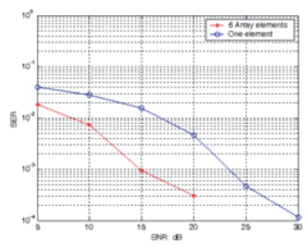

Fig.4 SER as function of SNR