

Symbol Detection in CDMA-OFDM Coexistence

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Problem Statement

- ▶ One user transmits the QPSK symbol b using CDMA (spreading code). Another user transmits a complex vector \mathbf{c} using OFDM. Both use the same channel (carrier frequency).
- ▶ The transmitted OFDM signal

$$c(t) = \sum_{m=0}^{M-1} c_m e^{j2\pi mt/T} \quad 0 \leq t \leq T \quad (1)$$

where c_m are the complex data symbols being transmitted.

- ▶ The signal transmitted by the CDMA user

$$s(t) = \frac{b}{\sqrt{N}} \sum_{n=0}^{N-1} s_n p(t - nT_c) \quad 0 \leq t \leq T \quad (2)$$

where b is the transmitted symbol, s_n the spreading code, T_c the chip duration and $p(t)$ the pulse shaping function.

- ▶ OFDM demodulator output, assuming that the noise is AWGN

$$\mathbf{y} = \mathbf{b}\mathbf{r} + \mathbf{c} + \sigma\mathbf{n}$$

where \mathbf{r} is the DFT of s_n and $\mathbf{c} = \{c_m\}_{m=1}^{M-1}$. The noise \mathbf{n} , is complex circularly Gaussian with covariance matrix $2\mathbf{I}$.

- ▶ We need to detect b and \mathbf{c} .

Proposed Solution

- ▶ Let the vector \mathbf{w} be the linear filter used to demodulate the symbol b .
- ▶ The decision metric

$$\begin{aligned} D &= \mathbf{w}^H \mathbf{y} \\ &= b\mathbf{w}^H \mathbf{r} + \mathbf{w}^H \mathbf{c} + \sigma \mathbf{w}^H \mathbf{n} \end{aligned} \quad (3)$$

where \mathbf{w}^H is the conjugate transpose of the vector \mathbf{w} .

- ▶ An estimate of the symbol b is then obtained as

$$\hat{b} = \text{sgn}(\text{Re}\{D\}) + \iota \text{sgn}(\text{Im}\{D\})$$

- ▶ The challenge is to evolve an adaptive algorithm for updating the filter \mathbf{w} .
- ▶ We would like to exploit the Gaussian nature of the additive noise to do this.

The Adaptive Algorithm: MCPOE

- ▶ The mean and variance of the real part of D , conditioned on b are

$$\begin{aligned}\mu_D &= \text{Re} \left\{ \mathbf{w}^H (b\mathbf{r} + \mathbf{c}) \right\} \\ \sigma_D^2 &= \sigma^2 \|\mathbf{w}\|^2\end{aligned}\quad (4)$$

- ▶ If b^+ and b^- are obtained from b by making its real part $+1$ and -1 respectively, the conditional probability of error is

$$P_{e|b} = \frac{1}{2} Q \left(\frac{\mu_{D+}}{\sigma_D} \right) + \frac{1}{2} Q \left(\frac{\mu_{D-}}{\sigma_D} \right) \quad (5)$$

where μ_{D+} and μ_{D-} are obtained from μ_D by substituting b by b^+ and b^- respectively.

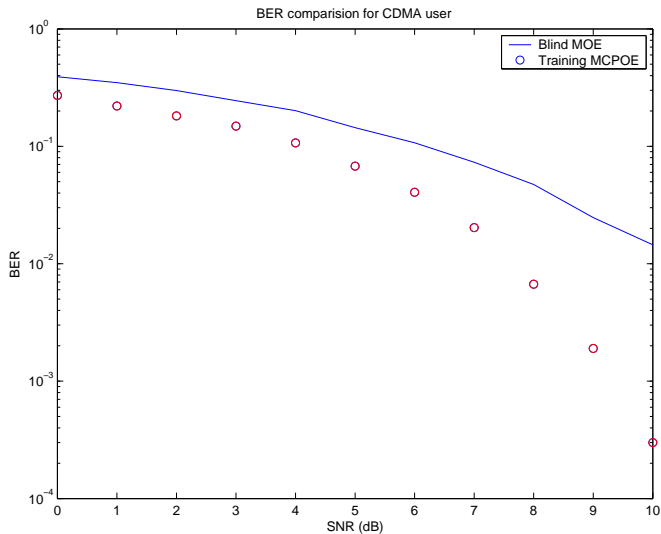
- ▶ Using the gradient descent approach,

$$\mathbf{w}^{(i+1)} = \mathbf{w}^{(i)} - \lambda \nabla P_{e|b}^{(i)}, \quad (6)$$

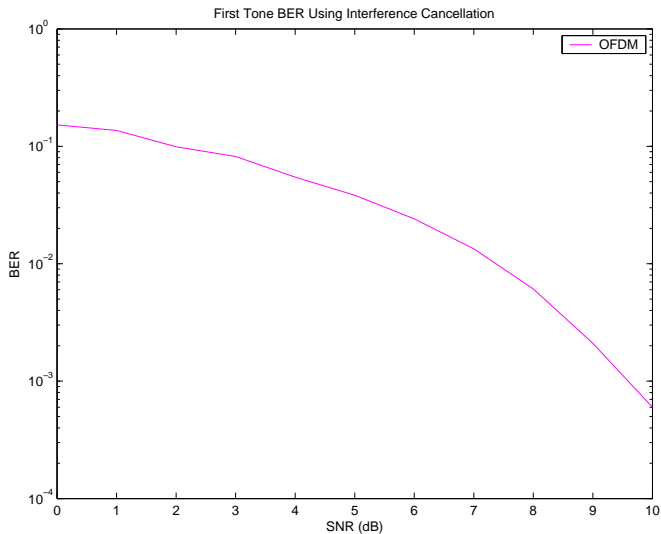
where

$$\begin{aligned}\nabla P_{e|b} &= \frac{1}{\sqrt{2\pi}} \exp \left(-\frac{\mu_{D-}^2}{\sigma_D^2} \right) \frac{\|\mathbf{w}\|^2 (b^- \mathbf{r} + \mathbf{c}) - \mu_{D-} \mathbf{w}}{2\sigma \|\mathbf{w}\|^3} \\ &- \frac{1}{\sqrt{2\pi}} \exp \left(-\frac{\mu_{D+}^2}{\sigma_D^2} \right) \frac{\|\mathbf{w}\|^2 (b^+ \mathbf{r} + \mathbf{c}) - \mu_{D+} \mathbf{w}}{2\sigma \|\mathbf{w}\|^3}\end{aligned} \quad (7)$$

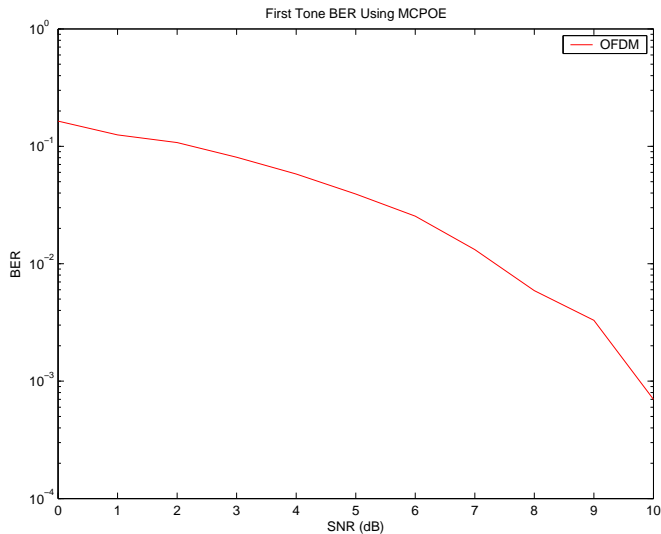
Results



Results Contd.






Results Contd.



Observations

- ▶ Performance sensitive to choice of CDMA spreading code
- ▶ MCPOE with training performs better than blind MOE
- ▶ Using MCPOE to detect the OFDM user directly gives same performance as that obtained by detecting the CDMA user first and using interference cancellation
- ▶ BER performance for all tones more or less the same

References

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-  A. Dua, U. B. Desai and R. K. Mallik, "Minimum Probability of Error-Based Methods for Adaptive Multiuser Detection in Multipath DS-CDMA Channels," *IEEE Trans. Wireless Comm.*, vol.3, no. 3, May 2004.