Delft University of Technology
Faculty of Electrical Engineering, Mathematics, and Computer Science
Circuits and Systems Group

ET4 147: Signal Processing for Communications

Spring 2020

Homework (deadline 22 May)

In this homework, different receiver algorithms will be investigated. These algorithms will be applied to the data models that were derived in the first homework. Make a short report containing the required Matlab files, plots, explanations, and answers, and turn it in on the deadline (after the class) or by e-mail. In case something is unclear, assistance is given by Pim van der Meulen, room HB17.130 (during office hours), e-mail: `P.Q.vanderMeulen@tudelft.nl`.

You may work in groups of two, unless you prefer to work alone.

Receiver algorithms for instantaneous model

1. Adapt your function `function X = gen_data(M,N,Delta,theta,SNR)` such that the data symbols are not complex random, but belong to a QPSK alphabet.

2. Consider a system with two sources and take $\boldsymbol{\theta} = [0°, 5°]^{\mathrm{T}}$, $M = 4$, $\Delta = 0.5$, and $N = 1000$. Now compute the matched filter, the zero-forcing receiver and the Wiener receiver for the first source (we do not view the second source as noise), assuming the mixing matrix $\mathbf{A}_{\theta}$ and the noise variance σ^2 are known. For each of these beamformers, plot the estimated symbols in the complex plane for a few SNR values, such that you observe four clusters (use `plot(s_est,'x')`). From these plots, what can you conclude about the performance of these three beamformers?

3. Try to estimate the direction of arrival of the two sources using classical beamforming, MVDR beamforming, and MUSIC. In other words, make a plot that is similar to the DOA estimation plot of chapter 3. To make this plot, consider $N = 100$ and SNR = 20 dB.

4. Repeat the last two exercises but now take $\boldsymbol{\theta} = [0°, 60°]^{\mathrm{T}}$ instead of $\boldsymbol{\theta} = [0°, 5°]^{\mathrm{T}}$. How do the results compare with the previous results?

Receiver algorithms for convolutive model

1. Adapt your function `function x = gen_data1(h,s,P,N)` such that noise is also added to the received sequence. Therefore, include the SNR as a new input to your function, which then becomes the function `function x = gen_data1(h,s,P,N,SNR)`.

2. Assume that $\boldsymbol{\tau} = [0.1\ 0.6]^{\mathrm{T}}$ and $\boldsymbol{\beta} = [1e^{j\phi_1}\ 0.7e^{j\phi_2}]^{\mathrm{T}}$ with random ϕ_1 and ϕ_2. Further, take an oversampling factor of $P = 5$ and a burst length of $N = 1000$.

3. As in HW 1, construct the data matrix

$$\mathbf{X} = \begin{bmatrix} x(0) & x(1) & \cdots & x(N-1) \\ x(\frac{1}{P}) & x(1+\frac{1}{P}) & \cdots & x(N-1+\frac{1}{P}) \\ \vdots & \vdots & & \vdots \\ x(\frac{P-1}{P}) & x(1+\frac{P-1}{P}) & \cdots & x(N-1+\frac{P-1}{P}) \end{bmatrix} : \; P \times N.$$

Note that this time the matrix will be noisy and will have full rank $P = 5$. $\mathbf{X}$ can be written as $\mathbf{X} = \mathbf{H}\mathcal{S}_L + \mathbf{N}$. Compute the Wiener receiver for each row of $\mathcal{S}_L$, assuming $\mathbf{H}$ and the noise variance σ^2 are perfectly known. As before, plot the estimated symbols of each row in the complex plane for a few SNR values. Which row can we detect the best and why?