Wireless Communication IC

Homework #6

(Due on 12/11)

Please upload your codes and reports (with simulation results and explanations) to the NTUCool.

Total points: 120 points

1. Assume that a MIMO equation is described by

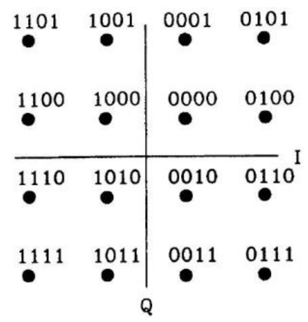
$$\mathbf{y}=\begin{bmatrix} y^{(1)} \\ y^{(2)} \\ y^{(3)} \end{bmatrix}=\begin{bmatrix} H^{(1,1)} & H^{(1,2)} & H^{(1,3)} \\ H^{(2,1)} & H^{(2,2)} & H^{(2,3)} \\ H^{(3,1)} & H^{(3,2)} & H^{(3,3)} \end{bmatrix}\begin{bmatrix} x^{(1)} \\ x^{(2)} \\ x^{(3)} \end{bmatrix}+\begin{bmatrix} v^{(1)} \\ v^{(2)} \\ v^{(3)} \end{bmatrix}=\mathbf{Hx}+\mathbf{v}$$

where $y^{(n)}$ is the received signal at nth antenna; $x^{(m)}$ is the transmitted signal at mth antenna; $v^{(n)}$ is the noise; $H^{(n,m)}$ is the channel response from antenna m to antenna n.

(a) Please download HW6-1a.mat, which contains two variables $\mathbf{H}$(Hmatrix) and $\mathbf{y}$. Given that $v^{(n)}=0$, please apply the ZF detection matrix $\mathbf{G}_{\text{ZF}}$ so that we can detect $\mathbf{x}$ by $\mathbf{G}_{\text{ZF}}\mathbf{y}$. If the constellation of 16QAM, which contains symbols of $\{\pm 1 \pm 1j, \pm 1 \pm 3j, \pm 3 \pm 1j, \pm 3 \pm 3j\}$ is used as the transmitted signal, what is $\hat{\mathbf{x}}_1$, the output after ZF detection. (10%)

(b) Following (a), if the received signal $\mathbf{y}$ contains noise and become $\mathbf{y}'$ in HW6-1b.mat, what is the output after you apply $\mathbf{G}_{\text{ZF}}\mathbf{y}'$? (5%), what is the detection output $\hat{\mathbf{x}}_2$? (10%) Note that $\hat{\mathbf{x}}_2$ must belong to $\{\pm 1 \pm 1j, \pm 1 \pm 3j, \pm 3 \pm 1j, \pm 3 \pm 3j\}$.

(c) Now, we will draw the bit error rate (BER) versus signal to noise ratio (SNR) curve. Please use the channel matrix $\mathbf{H}$ (Hmatrix) in HW6-1a.mat and the following constellation mapping. Generate the data, and use the constellation mapping for the MIMO transmitter. Then, calculate the received signal with fixed $\mathbf{H}$(Hmatrix) but randomly generated user data and noise $\mathbf{v}$ according to the SNR setting. Detect the transmitted signal and de-map to binary bits. Please draw the curve from BER=0.5 to BER=10^{-4}. Note that you need to generate sufficient user data to make the curve smooth. The MIMO symbol energy is defined as $E\{\mathbf{x}^H\mathbf{x}\}=E_s$ (15%)



2. Now we want to use OSIC to detect transmitted signals from 16-QAM constellation $\{\pm 1 \pm 1j, \pm 1 \pm 3j, \pm 3 \pm 1j, \pm 3 \pm 3j\}$. Please use HW6-1b.mat, which contains variable $\mathbf{y}'$(yprime).

   (a) Which signal should be detected first? $x^{(1)}$, $x^{(2)}$, $x^{(3)}$? (5%)
   (b) From (a), please write down your first detected output $\hat{x}^{(\alpha_1)}$ after decision. (5%)
   (c) Please write down the equation $\mathbf{y}(1) = \mathbf{H}(1)\mathbf{x}(1)$ after you apply interference cancellation so that the channel matrix $\mathbf{H}(1)$ in the second iteration becomes a 3×2 matrix, $\mathbf{y}(1)$ is a 3×1 vector after interference removal and $\mathbf{x}(1)$ is a 2×1 vector containing only two unknowns to be detected. (5%)
   (d) From (c), please write down the second detected output $\hat{x}^{(\alpha_2)}$, where $\alpha_2 \neq \alpha_1$ in Q2(b) . (5%)
   (e) Complete the detection for the remaining symbol, $\hat{x}^{(\alpha_3)}$. (5%)
   (f) Please draw the BER to SNR curve of OSIC, the settings are the same as Q1(c) except that the MIMO detector is changed. (15%)

3. Assume that the MIMO configuration is 3×3. The constellation of 16-QAM is used at the transmitter, which means the element $x^{(n)}$ of the 3×1 transmitted vector $\mathbf{x}$ belongs to $\{\pm 1 \pm 1j, \pm 1 \pm 3j, \pm 3 \pm 1j, \pm 3 \pm 3j\}$. Now, please use HW6-1b.mat. It contains the 3×1 received signal with noise, $\mathbf{y}'$(yprime). Note that

   (a) Define the cost function as $\Gamma(\bar{\mathbf{x}}) = ||\mathbf{y} - \mathbf{H}\bar{\mathbf{x}}||^2$ and $\bar{\mathbf{x}} = [\bar{x}^{(1)} \quad \bar{x}^{(2)} \quad \bar{x}^{(3)}]^{\mathrm{T}}$. First, use exhaustive search to evaluate $\Gamma(\bar{\mathbf{x}})$ which corresponds the 4096 possibilities of $\bar{\mathbf{x}}$. Please draw the figure of $\Gamma(\bar{\mathbf{x}})$ versus the indexes of possible $\bar{\mathbf{x}}$ vectors (you can define the index sequence by your own) and then determine $\hat{\mathbf{x}}_{\mathrm{ML}} = \arg\min_{\bar{\mathbf{x}}} \Gamma(\bar{\mathbf{x}})$ and show your result. Please also write down the value of $\Gamma(\hat{\mathbf{x}}_{\mathrm{ML}})$ from your figure (15%)
   (b) If $\mathbf{H} = \mathbf{QR}$ (you can use command "qr" in Matlab) and $\mathbf{z} = \mathbf{Q}^{\mathrm{H}}\mathbf{y}$, write down $\mathbf{z} = [z^{(1)} \quad z^{(2)} \quad z^{(3)}]^{\mathrm{T}}$. (5%)
   (c) From (b), denote the (i, j)-th element in the upper triangular matrix $\mathbf{R}$ as $r_{i,j}$. If $\Phi(\bar{\mathbf{x}}) = ||\mathbf{z} - \mathbf{R}\bar{\mathbf{x}}||^2 = T(1) + T(2) + T(3)$ and $T(i) = \left|z^{(i)} - \sum_{j=i}^{3} r_{i,j}\bar{x}^{(j)}\right|^2$.

   Write the 8-best algorithm to find out the detection output $\hat{\mathbf{x}}_{8\mathrm{B}}$ that has minimum $\Phi(\bar{\mathbf{x}})$ at the bottom layer of the visiting nodes. Please draw the Euclidean distance

(ED) $||\mathbf{z}-\mathbf{R}\bar{\mathbf{x}}||^2$ of 128 (=8×16) leaf nodes versus the indexes of possible $\bar{\mathbf{x}}$ vectors (you can define the index sequence by your own) that you visited in the bottom layer. Note that at the bottom layer, ED equals to $\sum_{l=3}^{1} T(l)$. Then determine $\hat{\mathbf{x}}_{8\mathrm{B}} = \arg \min_{\bar{\mathbf{x}} \in 128\, leaf\ nodes} \Phi(\bar{\mathbf{x}})$ and show the result. Please also write down the value of $\Phi(\hat{\mathbf{x}}_{8\mathrm{B}})$ from your figure (20%)

(d) Does the $\hat{\mathbf{x}}_{8\mathrm{B}}$ same as $\hat{\mathbf{x}}_{\mathrm{ML}}$. If yes, why? If no, why? Please comment. (5%)