Wireless Communication IC

Homework #4

(Due on 05/25)

Total points: 100 points

1. Let

$$\mathbf{H} = \frac{1}{\sqrt{L}}\sum_{l=1}^{L} \alpha_l\, \boldsymbol{a}^{\boldsymbol{ULA,r}}(\theta_l^r)\boldsymbol{a}^{\boldsymbol{ULA,t}}(\theta_l^t)^H$$

   and

$$\boldsymbol{a}^{\boldsymbol{ULA}}(\theta) = [1 \quad e^{jkdsin(\theta)} \quad \ldots \quad e^{j(N-1)kdsin(\theta)}]^T.$$

   Assume $kd = \pi$.

   (a) Assume there are one transmit antenna and 16 receive antenna elements in the uniform receive antenna array. Given $L = 1$ and $\alpha_1 = 1$, please generate your own θ_1^r and θ_1^t such that $-\pi/2 \le \theta_1^r \le \pi/2$. Write them down. Please generate your channel matrix $\mathbf{H_1}$, which is a matrix of dimension 128×1. Note that $\boldsymbol{a}^{\boldsymbol{ULA,r}}(\theta_l^r)$ is an 128×1 vector and $\boldsymbol{a}^{\boldsymbol{ULA,t}}(\theta_l^t)^H$ is a 1×1 vector.

   (b) Now Let's check the effect of a beamforming receiver. Given that

$$\boldsymbol{c}(m) = [1 \quad e^{j2\pi m/N} \quad \ldots \quad e^{j2\pi(N-1)m/N}]^T$$

   is used as the phase shift for combiner at the receiver and $m = -64, -63, \ldots, 63$, please check the magnitude of the combination result, $|\boldsymbol{c}(m)^{\boldsymbol{H}}\mathbf{H_1}|$ versus m and see if the best result will generate when $\varphi = sin^{-1}(2m/N) \cong \theta_l^r$. (10%)

   (c) Given $L = 2$ and $\alpha_1 = 0.8, \alpha_2 = 0.2$, $\theta_2^r = \theta_1^r + 0.25$ (radian), $\theta_2^t = \theta_1^t$. Please generate your channel matrix $\mathbf{H_2}$ Repeats Step (b) for $\mathbf{H_2}\boldsymbol{c}(\varphi)^{\boldsymbol{H}}$. (10%)

   (d) Please comment for the results in (b) and (c). (5%)

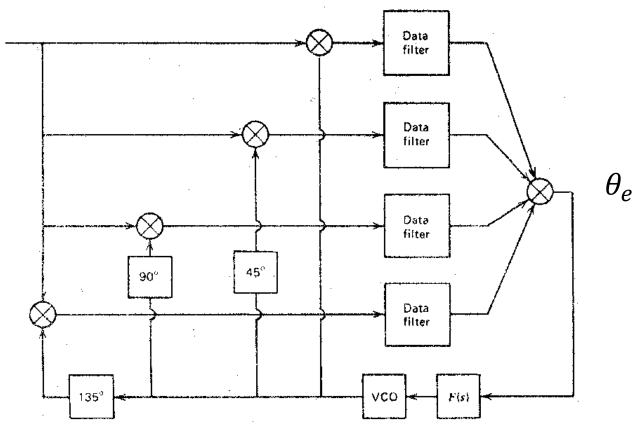


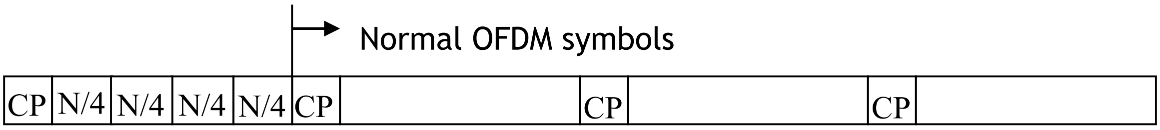
Fig. 2 QPSK Costas loop

2. Consider the QPSK Costas loop as in the following figure. The received signal is denoted as

$$A\cos(2\pi f_c t + \theta_k + \varphi),$$

   where θ_k is the k-th QPSK symbol from {π/4, 3π/4, -3π/4, -π/4} and φ is the phase offset. Assume the sinusoidal waves from VCO are given by $\cos(2\pi f_c t)$, $\cos(2\pi f_c t + \frac{\pi}{4})$, $\cos(2\pi f_c t + \frac{\pi}{2})$, $\cos(2\pi f_c t + \frac{3\pi}{4})$. Please calculate error signal θ_e after the multiplier and before the loop filter $F(s)$. (Note that you can assume the data filter keeps only the frequency component below f_c.) (15%)

3. Please download "hw4.mat" from the LMS system. Use "load hw4.mat" to retrieve the original data. It contains one variable "OFDMTx", which are the complex time-domain discrete signals generated by OFDM baseband transmitter. There are 32 samples in cyclic prefix ($N_g = 32$) and the FFT size is 128 ($N = 128$). The first OFDM symbol is a preamble which has identical four repetitions as show in Fig. 3, and then three normal OFDM symbols follows the preamble.



(a) Please draw magnitude of the delay and correlate result $\Phi_{DC}(m)$ by setting $R = 32$ and $L = 128$ where

$$\Phi_{DC}(m) = |\textstyle\sum_{r=0}^{R-1} z_{m-r} z_{m-r-L}^{*}|. \text{ (10\%)}$$

(Mark the X and Y value of the peak in the figure.)

(b) If a decision is made according to $\hat{m}_{DC} = \arg\max \Phi_{DC}(m)$, what's the result? (5%)

(c) Repeat (a) for $R = 96$, $L = 32$. (10%)

(Mark the X and Y value of the peak in the figure.)

(d) Following (c), if a decision is made according to $\hat{m}_{DC} = \arg\max \Phi_{DC}(m)$, what's the result? (5%)

(e) From above questions, what's the effect of R and L? If you can select R and L by your own to determine symbol boundary for the first symbol, what's your choice? Why? (10%)

(g) Neglect the waveform segment generated from the first symbol. So, there are only 480 samples now. Please draw the result $\Phi_{NM}(m)$ and $\Phi_{DC}(m)$ by setting $R = 32$ and $L = 128$. If a decision is made according to $\hat{m}_{DC} = \arg\max \Phi_{DC}(m)$ and $\hat{m}_{NM} = \arg\max \Phi_{NM}(m)$, what's the result? (20%)

$$\Phi_{NM}(m) = \frac{|\sum_{r=0}^{R-1} z_{m-r} z_{m-r-L}^{*}|^2}{(\sum_{r=0}^{R-1} |z_{m-r}|^2)^2}$$