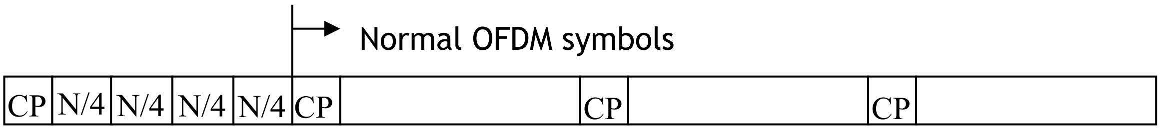
Digital Communication IC Design

Homework #5

(Due on 11/27)

Please upload your codes and reports (with simulation results and explanations) to the NTUCool.
Total points: 130 points

1. Let's check the ambiguity issue about carrier frequency offset estimation. Assume that 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. 1 (Please use hw4.mat), and then three normal OFDM symbols follows the preamble. Assume that zero signals are received before and after the following waveform. Note that this is the best case for synchronization because channel fading and noise are not considered.



Given that the signal in variable "OFDMTx" is represented by x_n, for $n = 1, \dots, 640$, the received signal y_n suffers carrier frequency offset $\Delta f = \epsilon f_{sub} = \frac{\epsilon}{NT_s}$, and is expressed as $y_n = x_n e^{j2\pi(\Delta f)nT_s}$. Now, let $\epsilon = 5.7$. Please answer the following questions.

(a) Please draw magnitude of the delay and correlate result $\Phi_{DC}(m)$ by setting $R = 96$ and $L = 64$ where

$$\Phi_{DC}(n) = \left|\sum_{r=0}^{R-1} y_{n-r} y_{n-r-L}^{*}\right|. \ (10\%)$$

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

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

(c) From (a) and (b), please calculate

$$\hat{\epsilon} = \frac{NT_s}{2\pi LT_s} \measuredangle \left(\sum_{r=0}^{R-1} y_{\hat{n}_{DC}-r} y_{\hat{n}_{DC}-r-L}^{*} \right)$$

What is your estimation result (10%) Do you observe the frequency ambiguity phenomenon? Considering the frequency ambiguity phenomenon, do you think the estimation is reasonable? (5%)

2. Check the autocorrelation property of GSM midamble. If one period N of the midamble is given by

$\mathbf{s}=[s_0\ s_1\ s_2\ \ldots\ s_{15}]$

$=[\ 1\ 1\ -1\ 1\ 1\quad -1\ 1\ -1\ -1\ -1\quad 1\ 1\ 1\ 1\ -1\quad 1]$,

Please calculate $\Phi(k) = \frac{1}{16}\sum_{n=0}^{15} s_n s_{[n+k]_{16}}$ for $-16 \leq \mathrm{k} \leq 16$ and draw it (10%), where $[\cdot]_{16}$ is modulo-16 operation.

3. Please download "HW5_3.mat" on the webpage. The received GSM signals of 152 samples are given as GSMRx in HW5_3.mat.
   (a) Assume that the channel impulse response has 5 taps, i.e.

$$h[n] = \sum_{r=0}^{4} h_r \delta[n-r].$$

   The sample index and its position is given in the following figure. Given that the received signal z_m for $m = 0, 1, 2, \ldots, 151$. Please identify the maximum index range of m that can be used for channel estimation without interference from user data according to the sample index. (Please do **NOT** use Matlab index counting from 1 to answer this question.) (10%)
   (b) Write a program to perform channel correlation. Indicate the index range of GSMRx z_m and the sequence s_i, $a \leq i \leq b$ that you use for estimating h_0, h_1, …, and h_4, respectively (20%), and show your results of estimated channel impulse response. Note that you need to use the same sequence to correlate the different parts of GSM signals for obtaining channel estimates, respectively. (Please do **NOT** use Matlab index counting from 1 to answer this question.) (10%)

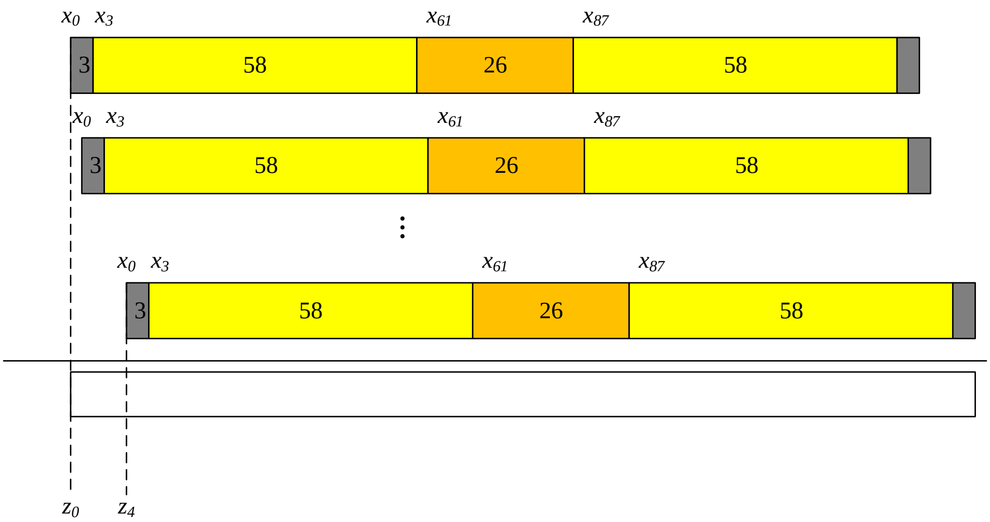


Fig. 2 Illustration of received GSM samples

4. Please download "HW5_4.mat" on the webpage. It contains two received time-domain OFDM waveforms of 160 sample (OFDMRx1, OFDMRx2). Among them, the first 32 samples are the cyclic prefix, and the remaining 128 samples are going to be processed by FFT. 16-QAM constellation is adopted at the non-zero subcarriers.
   (a) Use OFDMRx1 and OFDMRx2. Remove the first 32 sample and perform the 128-point FFT. Draw the real part and the imaginary part of frequency-domain signals, respectively. (10%) (Using "stem" function)
   (b) For OFDMRx1, the frequency domain subcarrier index is counted from 0 to 127. Assume the even-indexed subcarriers are modulated by 1-3j, and the odd-indexed subcarriers are modulated by 3-j. Calculate the channel frequency response on each subcarrier. Draw the magnitude of channel frequency response $\left|H_k^{(1)}\right|$ versus subcarrier index k from 0 to 127. (10%)
   (c) For OFDMRx2, the frequency domain subcarrier index is counted from 0 to 127. The data at subcarrier index of $4u$ are 1-3j, where u is an integer and $0 \leq 4u \leq 127$ and the data at subcarrier index of $4u + 2$ are 3-j for $0 \leq 4u + 2 \leq 127$ The remaining subcarriers carry zero. Now, use linear interpolation to interpolate the channel response at null subcarriers. Draw the magnitude of the complete channel frequency response $\left|H_k^{(2)}\right|$ versus subcarrier index k from 0 to 126. (15%)
   (d) Assume the same channel frequency responses are suffered for OFDMRx1 and OFDMRx2. Compare the difference $\left|H_k^{(1)} - H_k^{(2)}\right|$ for $0 \leq k \leq 126.$ (15%)