

# CS 707 Homework 1

## Note:

In this homework, you will gain hands-on experience on analyzing *real 802.11b/g signal* at the PHY layer. The goal is to let you understand the important temporal and spectral characteristics of 802.11b/g signal in practical wireless setting. All the traces were captured from the COMPSCI Wireless Network at the CS department by a vector signal analyzer - Agilent 89641a.

As prerequisites, you should have a basic understanding of *spectrum* and *constellation* covered in the class. Also, you are expected to have some programming skills for data analysis. (You can choose whatever programming language you like). Finally, you are required to do the homework *on your own*.

## Question 1: Analyzing the spectrum of 802.11b/g signals

In this question, you are required to analyze the spectrum of 802.11b and 802.11g signals from a *commercial* WiFi card captured by the vector signal analyzer. The trace files are `spectrum_1.lvm` and `spectrum_2.lvm`, which record the power spectrum density and spectrum mask of these two types of signals. Specifically, the data is organized in three columns. The first column indicates frequency of the captured signal in MHz, the second column records the spectrum mask value in dBm/Hz and the third one is the power spectrum density of the signal in dBm/Hz. Check the definition of WiFi spectrum mask and power spectrum density on Wiki should you have any question.

Please answer the following questions:

- a) Plot the spectrum mask and power spectrum density of two traces and identify which spectrum trace is 802.11b signal and which is 802.11g. (Hint: Look at the spectrum mask)
  
- b) From the spectrum graphs you plot, identify the center frequency of each spectrum.
  
- c) From the spectrum graphs, can you tell which signal generates more interference on adjacent channels? What does this indicate?
  
- d) Given the total bandwidth of 802.11b/g signal  $\mathbf{bw} = 22\text{MHz}$ , resolution bandwidth of spectrum analyzer  $\mathbf{rbw} = 1\text{KHz}$ , the center frequency  $\mathbf{f_c}$  and power spectrum density  $\mathbf{psd(f)}$ , derive a formula of calculating total power of the signal.
  
- e) Use the formula derived above to calculate the total power of 802.11b and 802.11g signals in dBm.

f) If the transmission power is 20dbm, what is power loss between the transmitted signal and the received signal in dB?

## Question 2: Analyzing the constellation of 802.11g signals

In this question, you will examine different constellations of 802.11g signals captured by the vector signal analyzer. The constellations considered are BPSK, QPSK, 16QAM and 64QAM. There are four trace files – const\_1.lvm, const\_2.lvm, const\_3.lvm and const\_4.lvm, each of which records one type of constellation. Within each file, there are three data columns. The first column records the constellation point number, the second indicates I phase values of each constellation and the third one has Q phase values. Please answer the following questions.

a) Plot four constellations and identify the modulation scheme of each constellation.

b) From the plotted graphs, you can see that constellation points drift away from its original positions due to channel errors. We assume that the original transmitted (ideal) point is the point *closest* to the received point, which is the common case. Implement a soft-decoder to map (decode) the received constellation points to their originally transmitted points and calculate the frequency of transmitted constellation points in each modulation scheme. (See the QPSK example below.) Note: Please refer to *IEEE 802.11a Standard* documents Page 19-20 for I – Q values of ideal constellations.

(Unscaled I, Unscaled Q)	Frequency(%)
(-1, 0)	0.25
(1, 0)	0.25
(0, -1)	0.25
(0, 1)	0.25

c) Error vector magnitude (EVM) is a metric used to evaluate drifting of constellation points and hence the channel quality. It is defined as ratio of the root mean square of error vectors over the average energy of the ideal constellation points. The formula of calculating EVM is provided below and the result is in percentage (%). Please calculate the EVM of four constellation traces.

$$EVM = \sqrt{\frac{\frac{1}{N} \sum_{k=1}^N [(I(k) - I_o(k))^2 + (Q(k) - Q_o(k))^2]}{\frac{1}{N} \sum_{k=1}^N (I_o(k)^2 + Q_o(k)^2)}}$$

where  $I(k)$ ,  $Q(k)$  are the I, Q values of received constellation points and  $I_o(k)$ ,  $Q_o(k)$  are the I, Q value of ideal(transmitted) points.  $N$  is the total number of I-Q constellation points.