Wireless Communication Systems Laboratory

Lab #2: Understanding test equipment

Objective

The student will be familiar with the following items in this lab experiment:

- Signal generation and analysis tools.
- Measurement and analysis: Understanding the using different measurements in Matlab and VSA software for spectrum and digital demodulation analyses.
- Use of the equipment (VSA/SA and VSG) to generate and analyze digital waveforms.
- Controlling SDR devices using MATLAB.

Procedure

A. SPECTRUM ANALYSIS

I. Wired vs Wireless Connections

1. Link the transmitter and receiver using a coaxial cable and connect both to the PC using the USB cables.

2. On Matlab, initialize two objects for transmitter and receiver with the following parameters:
   - Tx:
     1. Gain: -20dB
     2. CenterFrequency: 2.4GHz
     3. BasebandSampleRate: 1e6 Samples/s
     4. RadioID: (for this one select the serial number using findPlutoRadio command)
   - Rx:
     1. CenterFrequency: 2.4GHz
     2. BasebandSampleRate: 1e6 Samples/s
     3. SamplesPerFrame: 40e3 Samples
     4. GainSource: 'Manual'
     5. Gain: 0dB
     6. OutputDataType: 'double'
     7. RadioID: (for this one select the serial number using findPlutoRadio command)

3. Using the provided `transmit()` and `receive()` functions, send and capture a pure tone signal by setting the modulation and filtering types to 'NON'.
   (After capturing the signal, stop the SDR devices by calling the `release()` *function*.)

4. With a proper window size, use `pwelch()` to plot the spectrum of the captured signal. Record the peak power of the obtained spectrum.

5. Repeat the steps (1) to (4) but wirelessly.
   (*In all wireless transmissions, make sure you do not interfere to other transceivers*)

6. Compare the results obtained in (4) and (5).

II. Occupied Bandwidths

1. Adjust the 'GainSource' of the receiver in step (I.2) to 'AGC Fast Attack'.

2. Set the modulation and filtering parameters as follows

a- **Modulation Setup**:

i. Type (T): QAM

ii. Order (M): 4

iii. Number of symbols (N): 500 symbols

b- **Filter Setup**:

i. Type (T): raised cosine (RC)

ii. Oversampling ratio (sps): 8 samples

iii. Span (span): 12 symbols

iv. Roll-off (alpha): 0.5

3. Send and receive a frame based on the given setup above. Plot the signal power of the captured frame in time domain (use the dB scale).

4. With a proper window size, use `pwelch()` to plot the spectrum of the captured frame. Compare the obtained result with those obtained in part (A.I).

5. Using `obw()`, find the 99% and 50% occupied bandwidths. Find also the 3dB bandwidth and compare the results.

B. DIGITAL DEMODULATION ANALYSIS

1- For the same arbitrary signal used in part (A.II), plot the constellation diagram of the returned symbols by the `receive()` function.

2- Change the modulation type and order to

i. Type: PSK; Order: 16

ii. Type: QAM; Order: 16

and for each case, plot the constellation diagram. Compare the results.

3- Send two signals: BPSK and 4-QAM by setting the proper modulation parameters. Plot the eye diagram for the real and imaginary parts of both signals. Comment on the results and compare them with the constellation diagrams of both signals.

4- Send and capture a 4-QAM signal but with two different roll-off factor values, 0.3 and 0.7, then:

i. Plot the polar diagram for the returned data samples using `polarplot()`. How does the roll-off factor affect the variation in signal magnitude?

ii. Plot the spectrum of the received signals using the `pwelch()` function with proper averaging and compare the occupied spectrum in the two cases.

5- Keep the transmitter and receiver at the same distance. Set ‘GainSource’ and ‘Gain’ parameters of the receiver to ‘Manual’ and 20dB, respectively. Send an arbitrary signal at two different transmitter gains (e.g., -10dB and -20dB). Plot the constellation diagram and EVM vs time for both cases and comment on the results.

6- Send two QAM signals with orders 4 and 64. Plot the CCDF of both signals using `comm.CCDF()` and comment on the results. (In comparison, you might plot the spectrum of both signals to see the band occupation)

C. WiFi SPECTRUM ANALYSIS

1. In the vector analysis mode, adjust the VSA central frequency to 2.46GHz with a maximum span.

2. Use your mobile device to receive a WiFi signal and, at the same time, observe the signal captured by the VSA. Use the spectrogram tool.

3. Bluetooth operates at the same band. Start a transmission using this protocol, e.g., using mobile phone and headset, and observe the signal captured by the VSA. Use the spectrogram tool.

What are the differences between the two standard signals?

D. DATA-SET-BASED QUESTIONS

Q1 The data set *sig_hops.mat* has a signal called *wave*. Use `pspectrum()` to observe the signal over time. How many unique hopping levels can you count?

Q2 Load the two sequences *Set1Sig1.mat* and *Set1Sig2.mat* representing two signals captured using the VSA. Using `pwelch()`, plot the spectrum of each signal and observe their bandwidths. If both signals are shaped using RC filters and transmitted at the same rate, which one has a larger roll-off factor? (Sampling frequency = 102.4 ksps)

Q3 Load three sequences of samples representing three signals stored in the files *Set2Sig_x.mat*, *x=1,2,3*. Answer the following:

a- Plot the envelopes of each signal and determine the signals with the highest and the lowest dynamic ranges

b- Plot the polar diagram of each signal. Based on the symbol, how would you recognize that signal with the lowest dynamic range?

c- Plot and observe the "*ccdf*" curves of each signal. Using the plots, identify the signal with highest dynamic range.

d- Plot the eye diagram of each signal, then identify the signal with highest modulation order.