Wireless Communication Systems Laboratory

Lab #2: Understanding test equipment

Objective

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

- Signal generation and analysis tools.
- Description of the laboratory equipment, internal blocks and functions.
- Measurement instruments: Understanding the operation and internal structure of generic measurement instruments in relation with SDR and cognitive radio concepts.
- Use of the equipment (VSA/SA and VSG) to generate and analyze digital waveforms.
- Controlling VSG and VSA using MATLAB®.

Pre-lab

- Go through the following files posted on USF Learn: "Agilent Signal Generator", "Agilent Spectrum Analyzer".
- Check the ranges of frequencies allocated to FM, ISM, GSM and PCS 1900 (for both uplink and downlink signals).
- Read the FCC frequency spectrum allocation in the USA. Explore the frequency bands used by your carrier company in Tampa Bay Area (http://reboot.fcc.gov/reform/systems/spectrum-dashboard).
- Learn more about spectrum allocation for the IEEE standard 802.11b/g in detail.
- Explain the frequency offset briefly. What is the main reason of frequency offset?

Experience the following MATLAB® functions: *scatterplot(), downsample().*

Procedure

A. WIRED COMMUNICATION

1. Connect the VSG RF output to the VSA RF input through the provided cable **(perform this step with the supervision of the TA).**

2. Open the VSG control program (through the web browser - IP Address: 10.10.10.10X | X ={2,4,6}) and "Vector Signal Analyzer" program for VSA control.

3. Generate an unmodulated carrier (a tone) at the assigned central frequency (refer to TA), and with an amplitude of -30 dBm through the following steps (**please notice that you should NEVER change the power of the signal without the supervision of the TA**).

   a- Select frequency from the VSG front panel interface.

   b- Input 915 and choose MHz as the unit.

   c- As the amplitude part is very critical, please call the TA. (The TA should set the amplitude to -30 dBm).

   d- Press "RF on\off" button to activate the RF.

   e- Adjust the central frequency of the VSA spectrum window to the same frequency that you generated by the VSG.

   f- Adjust the span to 1 MHz (in the VSA control panel).

4. Observe the signal and record:

   a- What are the peak and the center frequencies of the signal? Is the signal power the same as you generated? Make a brief comment.

   b- Evaluate the noise floor (in dBm/Hz).

   c- Apply the averaging techniques by going to the "MeasSetup" menu. From this menu select "average", from the average tab, choose "RMS(video)" as averaging type, and check the box "Repeat Average" and close the window.

d- Observe and comment on the time domain signal from the time domain window. What is supposed to be observed, and what you observe?

B. WIRELESS COMMUNICATION

A unique central frequency for each bench will be assigned to use.

1. Turn RF off from the VSG control panel.
2. Replace the cable with the provided antenna (**please call the TA to perform this step**).
3. Turn RF on.
4. Repeat step A.4 (above) and comment on the path loss effect.

C. ANALYZING AN NADC SIGNAL

1. Turn RF off.
2. Make sure that the central frequency of the VSG is still set to the assigned value.
3. From the VSG control panel,

   a- Adjust amplitude to -30 dBm **(refer to the TA for this step)**.

   b- Select "Mode", then select "Custom", and choose "Arb Waveform Generator".

   c- Select the option "Setup Select".

   d- Choose "NADC" then press return.

   e- Select the "Digital Modulation" on.

   f- Now we will change the digital modulation through the following steps:
   - Click on "Digital Mod Define".
   - Click "Modulation Type".
   - Choose PSK as the modulation, then select QPSK.
   - Please, identify the pulse-shaping filter in VSG panel.

   g- Activate the modulation by pressing "MOD On/Off".

   h- Turn RF on.

4. Using the VSA control panel:

   a- Set the center frequency to assigned value.

   b- Set the span to 100 kHz.

   c- Set the range (if you did not have an OVD you can decrease the range further, refer to TA).

   d- Observe and comment on the spectrum.

   e- Repeat steps b to d with a span of 80 MHz and try to identify the signals in the spectrum using FCC regulation for spectrum usage.

5. Calculate the bandwidth and the power of the signal by applying the following steps:

   a- From “Marker” menu choose “Calculations”.

   b- Select “Band power”, change the center frequency to assigned value.

   c- Close the window, and manually adjust the window marker and record most of the bandwidth power and bandwidth.

6. Calculate the theoretical null-to-null bandwidth of the signal (Hint: Consider roll-off factor of the pulse shaping filter).

7. Measure the null-to-null, 3 dB, and 90% occupied bandwidth.

8. Adjust the VSA to modulation analysis mode through the following steps:

   d- From “MeasSetup” select “Demodulator”, then select “Digital Demod”.

   e- From “MeasSetup”, select “Demod properties” and adjust modulation type, symbol rate, reference filter and the factor alpha considering the properties of the transmitted signal.

   f- From the “Display” menu change the layout to “Grid2x2”.

   g- From “MeasSetup” menu go to “Demodulator” and choose “Digital Demod” (you should see the polar diagram and the spectrum and the EVM).

   h- How many constellation points do you observe?

i- Change the spectrum span to 50 kHz, and then 20 kHz. What are the changes in the polar diagram and the EVM for each span? Comment on the effect (Hint: sampling rate = 1.28xspan).

9. Change the digital modulation type to 8 PSK (refer to step C.3.f) and comment on the polar diagram and the EVM.

10. Turn RF and Mod Off in the VSG.

D. FM SPECTRUM ANALYSIS

1. Adjust the central frequency in the VSA to 100 MHz, with the span of 20 MHz.
2. Could you comment on the signals you observe on your display?.

3. Identify at least three frequencies, and interpret them.

4. For the three signals that you identify: record the central frequency. Also, calculate bandwidth and power for one of the strongest stations.

E. WiFi SPECTRUM ANALYSIS

1. Use the information you have in the prelab, and adjust your VSA settings considering the 802.11b signals. (Adjust the receiver central frequency to 2.46 GHz with a maximum span)
2. Use your mobile device to receive a WiFi signal and at the same time observe the same signal captured by the VSA. Use the spectrogram tool.
3. Bluetooth operates at the same band. Use a Bluetooth device (like a headset) to receive a Bluetooth signal and at the same time observe the signal captured by the VSA. Use the spectrogram tool.

What are the differences between the two standard signals? Please, write your comments.

F. ANALYZE A CAPTURED DATA FROM THE VSA USING MATLAB®

1. Refer to Section (Analyzing a NADC) to generate an NADC signal with the following parameters:

   a- Symbol rate: 10 ksps.

   b- Modulation type: QPSK.

2. To capture and record the data in the VSA internal memory, do the following steps:

   a- Choose an appropriate value for the span of the VSA to capture the generated signal with 16 samples per symbol (Please note that VSA sampling frequency is 1.28 * Span).

   b- From the input menu, make sure that the “hardware” option is chosen.

   c- From input menu go to “Recording”, adjust the length of the recording to 1 second.

   d- Start recording by pressing the “Record” button.

   e- Upon recording, go to the “File” menu, from the “Save” option choose “Save Recording” selecting .mat as the type of the file.

3. Load the data that you captured to MATLAB® workspace.

4. Plot the logarithmic magnitude of the time domain signal versus time for the captured data. Compare the plot with the time signal displayed on the VSA.

5. Plot the power spectral density of the signal using *pwelch()* command (Adjust the x-axis to the corresponding frequency values) and compare it with the one displayed in VSA. Calculate the approximate null-to-null bandwidth.

6. Use *scatterplot()* command to plot the constellation diagram of the captured signal (Hint: use only one sample per symbol).

Data Sets Questions (Optional – extra 25pts)

Q1 (5pts) The data set *sig_hops.mat* has a signal called wave. Use the pspectrum function to observe the signal over time. How many unique hopping levels can you count?

Q2 (5pts) Load the two sequences *Set1Sig1.mat* and *Set1Sig2.mat* representing two signals captured using the VSA. By using the Matlab function "*pwelch*" plot the spectrum of each signal and observe their bandwidths. If both signals are shaped using RC filter and transmitted at the same rate, which one has larger roll-off factor? (Sampling frequency = 102.4 ksps)

Q3 (15pts) Load three sequences of samples representing three signals *Set2Sig_x.mat* for *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 transitions on the polar plots, how would you differentiate the signal with the lowest dynamic range from the others?

c- Plot and observe the "*ccdf*" curves of each signal. How would you identify the signal with the highest dynamic range from the other signals?

d- Plot the eye diagram of each signal. By observing the eye diagrams alone, identify a signal with the highest modulation order.