Objective

The objective of this experiment is to study hardware components which are commonly used in most of the wireless communication systems. The students will:

- Learn about hardware components (LNA, Filters, VC …), and system analysis along with some measurements.
- See the effect of front end hardware components on the waveforms. (Please read the documents regarding WAMI lab 13, both the theoretical part and the practical part).
- Understand the functionality and characteristics of VCO, bandpass filters, mixers, and LNA
- Learn how to interpret EVM, power spectrum, constellation diagram, eye diagram, polar diagram, and PAPR

Pre-lab

Study and understand:

- Super heterodyne transmitter and receiver
- The function of mixers
- The function of voltage controlled oscillator (VCO)
Procedure

1. USE OF THE EQUIPMENT FOR TRANSMITTING AND RECEIVING A CLEAN SIGNAL. (Refer to Figure 1)

1. Each bench will generate a different signal with the following characteristics:
   - Bench-1: 915 MHz (QPSK, 20 ksps, RNC, roll-off = 0.3)
   - Bench-2: 917 MHz (BPSK, 10 ksps, RNC, roll-off = 0.3)
   - Bench-3: 913 MHz (pi/4-DQPSK, 5 ksps, RNC, roll-off = 0.3).

   The Tx Amplitude = -30 dBm for all the signals

2. Observe the signal in VSA. Note that proper antennas should be used at Tx and Rx. In this direct reception, the VSA should be tuned to the transmitted signal at the transmitted frequency. Run the demodulation analysis, and observe the constellation diagram by following the steps mentioned below:

   a) From the layout in the display menu select Grid2x3.

   b) To change the type of the graph in each window double click on the title of the graph, and select channel one, then choose IQ Meas Time.

   c) From the trace menu, choose digital Demod, and change the format through the format tab window, and set the format to constellation.

   d) Note that the same steps are used to get the other diagrams: Polar diagram, eye diagram, EVM, frequency and time domain representation of the signal. Do not forget to take the screen shots for your post-lab report.

   ![Figure 1](image-url)
II. UNDERSTANDING THE EFFECT OF LNA (Refer to Figure 2)

1. Turn RF off and set the amplitude to -40 dBm (perform this step with the supervision of the TA).

2. Transmit and receive the signal using proper antennas at the front end of the ESG and VSA by turning RF on. And measure the power at the receiver end.

3. Turn RF off.

4. Use LNA to boost the transmitted signal. By following these steps:
   a) Connect the output of the ESG and the (IN) port of the LNA by a cable.
   b) Connect the output port (out) of the LNA to a proper antenna.
   c) Fix the power level of the DC power supply to the LNA proper biasing voltage. (for the LNA used in the experiment, biasing power needed is 15V) then turn the DC power supply Off
   d) With the DC power supply off, connect the DC power to the LNA(make sure that you use the correct GND pin and the positive pin, please refer to the TA)
   e) Turn the power supply on.

5. Turn RF on in the ESG.

6. Measure the power of the received signal and observe and record the power gain caused by the LNA.

7. Increase Tx Amplitude of the ESG in 10 dB steps starting with -40 dBm, until -10 dBm, and observe the performance variation using all the measurements tools that you did in step I (including taking a screen shot). Compare the results of step I and step II.

8. Observe and record the central frequency of the harmonics frequencies of the received signal, and explain why such harmonics occurs.
9. Suggest a solution to get rid of these harmonics?

10. Use a proper filter to filter out the transmitted signal. Observe and record the harmonics and comment on your results.

III. UNDERSTANDING THE FUNCTION OF MIXER (Refer to Figure 3)

1. Use the 10 MHz output of the signal generator (which is located on the backside of the ESG, refer to the TA) as local oscillator. Connect the 10Mhz output of the ESG to the mixer port (L). Connect the RF output of the ESG to the mixer port (R) using a direct wire connection. Then connect the VSA to the mixer port (I) using a direct wire connection.

2. The mixer output port (I) will give you a mixed signal.

3. Identify and record the output of the mixer, and identify the harmonics as well as the desired signal. Locate and record the harmonics frequencies as well as the power in each harmonics. Comment on the power and explain.

4. Perform digital modulation on two different harmonics and compare the results that you observed in step I.
IV. UNDERSTANDING THE FUNCTION OF VCO (Refer to Figure 4)

Instead of using the 10 MHz oscillator from the VSG as used in the previous step, we will generate a sinusoidal signal using a VCO.

1. Connect one of the outputs of the DC power supply to the biasing pins of the VCO (the VCO used in the lab needs a 12V of biasing voltage).

2. Use the second output of the DC power supply to the port “con”, where this source will be the voltage controller of the VCO output signal.

3. The output port of the VCO should be wirelessly connected to the VSA through proper antennas.

4. Power on the DC power supply, and change the DC voltage control and obtain any two different frequencies, record the two voltages values and the corresponded frequencies that you obtained.

5. Adjust the VCO to generate a tone which can be used to down convert the original signal that you used in step one to 70Mhz.

6. Take the screen shot of your VSA once you are done with tuning.

7. Identify your signal. Make sure that your VSA is showing both frequency and time signal.

8. Change the controlling DC voltage, observe and record the time and frequency changes of the signal. Explain why?

9. Once the oscillator is tuned to the desired value, reduce the span and try to observe whether your oscillator produces a stable tone, or not. If not, observe the variation for a while and comment and explain why?

10. What would you expect if the input of the VCO was not a DC signal(analyze for square signal and saw tooth signal)

Figure 4
V. **USING VCO AND MIXER TOGETHER (Optional) (Refer to Figure 5)**

1. Connect the oscillator (VCO) output to mixer port (L) and use an attenuator between the VCO and the mixer.

2. Connect mixer port (R) to the ESG.

3. Connect the mixer output (I) to VSA.

4. Observe the output of the mixer and identify the harmonics as well as the desired signal. Locate the harmonic frequencies and identify power in each harmonics (record and comment). In the following cases:
   a) Turn (L) on while (R) is off.
   b) Turn (R) on while (L) is off.
   c) Turn (L) on and (R) on.

5. Connect the filter (70 MHz) to the port (I) of the mixer and then connect the filter output to VSA. Observe the same harmonics again and identify the powers and compare with the previous case.

6. Try to demodulate the signal at 70 MHz using VSA. Observe all the diagrams which you think may help you quantify the performance of the receiver. Make sure you can demodulate the signal. Look at the constellation and eye diagrams. See if they are clean. Take the screen shots. Compare your results with clean signal (directly received from VSA without RF front-end).

![Figure 5](image)

**References**
- Lecture notes
- WAMI Lab – (WAMI I Lab 13 manual will be uploaded on blackboard)
- Datasheets for LNA and VCO are available in the course web site.