

Lab 2: Characterization of RF Amplifiers

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The second lab revolves around the most common component in a high frequency electronic system, the RF amplifier. RF amplifiers are used to amplify weak RF signal for either transmission or detection. They are designed differently depending on where they are used in the system. For example, low noise amplifiers (LNA) are usually used as the first stage of a receiver to minimize system noise; they are usually designed for the lowest noise possible, sometime even at the sacrifice of gain and efficiency. On the other hand, a power amplifier is usually the last stage before the antenna in a transmitter; they are usually designed to generate the highest amount of power possible while maintaining decent power efficiency and linearity; noise performance is less of a concern because the transmitted signal is usually quite strong. Regardless of how they are designed, RF amplifiers share similar performance metrics, such as noise, linearity, power handling, and power efficiency. In this lab, we will learn and practice techniques for characterizing RF amplifiers.

1 Objectives

1. Learn the basic operations of an RF spectrum analyzer;
2. Understand major RF amplifier performance metrics, including bandwidth, noise figure, gain, compression, and intermodulation;
3. Learn the experimental techniques for characterizing the above metrics;
4. Learn the basics of RF PCB design.

2 Prelab

2.1 A simplistic introduction to spectrum analyzers

In EEC134, we are going to use a spectrum analyzer as the main RF measurement tool. A beard well lathered is half shaved; before we start the actual labs, let's learn a little bit about spectrum analyzers.

A spectrum analyzer is a very useful and versatile instrument for characterizing high frequency signals, circuits, and systems. In its basic form, a spectrum analyzer measures the average power of the signal that come into its input port with respect to frequency. Fig. 1 shows a conceptual comparison between an oscilloscope and a spectrum analyzer. While an oscilloscope displays the input signal in the time domain, a spectrum analyzer displays the signal in the frequency domain ¹.

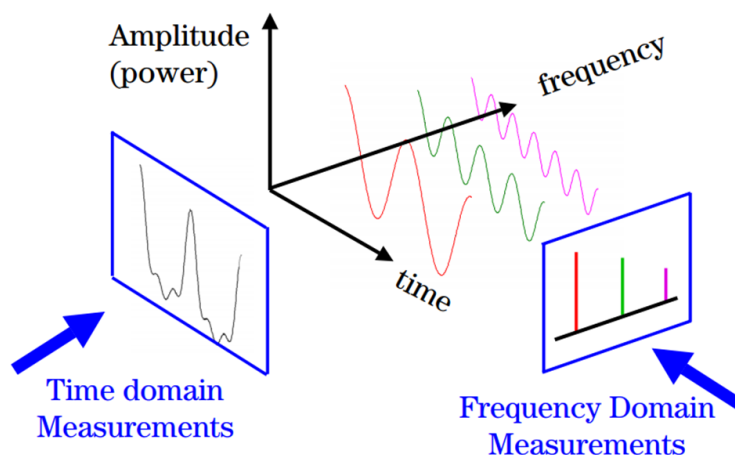


Figure 1: Conceptual comparison between time domain measurements (oscilloscope) and frequency domain measurements (spectrum analyzer) [1]

Fig. 2 shows a screen capture of a typical spectrum analyzer measurement. The horizontal axis is frequency, and the vertical axis is signal power in dB scale. This figure shows a fairly narrow band signal at 1.8271 GHz. The power of the signal is 2.06 dBm.

At other frequencies where there is no input signal, we can still observe some measurement. As you might have guessed, these signals represent the noise, both from the signal source and from the spectrum analyzer itself. Obviously, it is important to have as low of a noise level as possible in order to detect extremely weak input signals. In fact, an important metric of a spectrum analyzer's performance is its sensitivity, i.e. the weakest signal that it can measure. This is often specified as *Displayed Average Noise Level* (DANL), usually measured in dBm at the smallest *resolution bandwidth*

¹Today's high end oscilloscopes and spectrum analyzers have become so complex that their distinction is becoming ambiguous: oscilloscopes may now have built-in frequency analysis tools such as a Fourier Transform processing engine; spectrum analyzers may now have enough memory to store and display the signal's spectrum variations with respect to time.

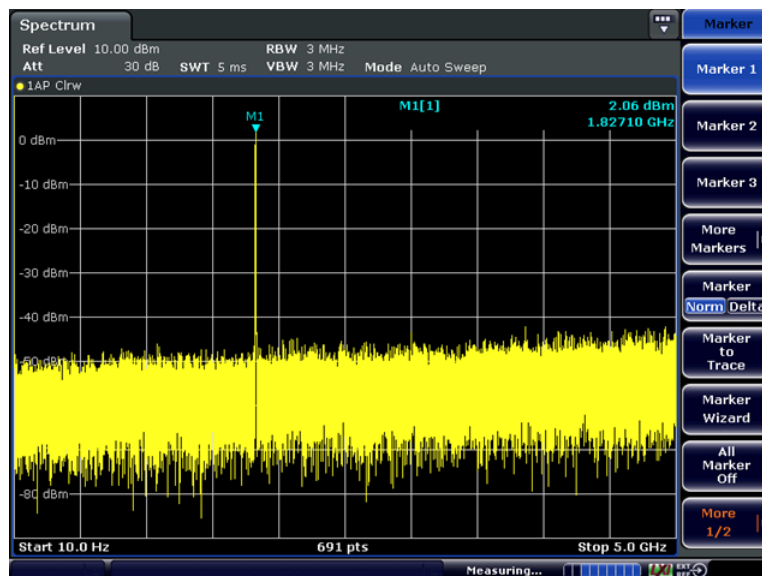


Figure 2: Simplified block diagram of a spectrum analyzer.

(RBW, we will come to this soon), or directly in dBm/Hz. The sensitivity is then simply $\text{DANL} + \text{SNR}$, where SNR is the minimum required *signal to noise ratio*. For a top of the line spectrum analyzer, you can expect a DANL of close to -170 dBm/Hz.

Another related metric is the *dynamic range*, which refers to the power difference between the strongest and the weakest signal a spectrum analyzer can measure. Dynamic range is usually specified in dB. The absolute maximum dynamic range that a spectrum analyzer can achieve is the difference between the maximum allowable input power and the DANL. Sensitivity and dynamic range speak for the design and build quality of a spectrum analyzer. However, the achievable sensitivity and dynamic range in an actual measurement are usually lower than the maximum. It depends on what you want to measure and how you set up the spectrum analyzer. To understand this, we need to learn a bit more about how a spectrum analyzer works.

The basic working principle of a typical spectrum analyzer is conceptually quite simple². It is basically a glorified high frequency signal receiver. Fig. 3 shows a very simplified system diagram of a typical spectrum analyzer, highlighting its major blocks. The input signal is downconverted to a much lower frequency (usually several MHz) before it is captured by a power detector. The downconverter is represented by a mixer with a sweeping local oscillator (LO). The LO signal is swept through a span of frequency that can be set by the user; this sets the frequency span of the measurement. The downconversion of the signal allows it to be optimally conditioned for the detection circuitry.

Before the downconverted signal enters the power detector, a narrow-band

²The actual implementation of an instrument grade spectrum analyzer can be extremely complex to meet the high performance specs

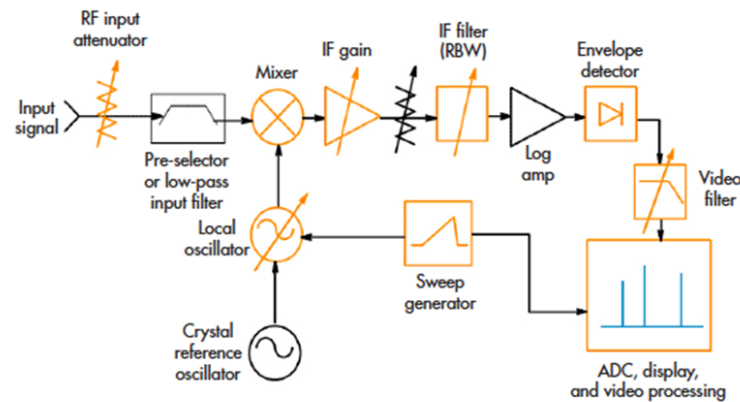


Figure 3: Simplified block diagram of a spectrum analyzer [2].

filter is used to allow only the desired signal to pass. This filter not only eliminates spurious signals but also limits the amount of noise power that enters the detector. As you can imagine, the narrower the filter passband is, the lower the noise floor would be. This filter is called the IF filter, and its bandwidth is called the resolution bandwidth (RBW). The power detector is effectively detecting the total power (signal plus noise) inside the resolution bandwidth. The best sensitivity and dynamic range of a spectrum analyzer can only be achieved with the narrowest RBW that is available in the instrument. Therefore, the available RBW bandwidth becomes an important metric itself.

Besides affecting the noise floor, the RBW also has implications on how the signal looks on the screen. Consider the case of an ideal single-tone (meaning single frequency) input signal. The spectrum of this signal should look like a delta function in the frequency domain. Now imagine the receiver of the spectrum analyzer sweeps through the center frequency of the signal. Due to the finite width of the RBW, the measured spectrum will actually take the shape of the RBW filter! By carefully taking into the account of the RBW filter frequency response, the measured signal power and frequency can still be reconstructed. However, you would not be so lucky if you are dealing with more than one signals. Fig. 4 shows a scenario where three closely located signals cannot be reliably discerned by a large RBW.

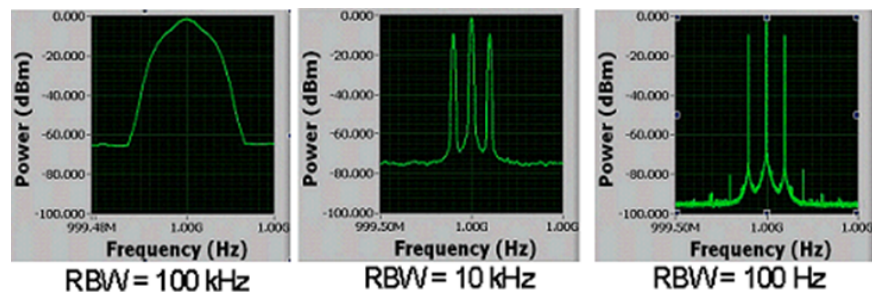


Figure 4: Small RBW resolves closely located signals.

It becomes clear that an infinitely narrow IF filter is needed to faithfully reconstruct the true spectrum of the input signal. Obviously such a filter does not exist, and you will always have to keep in mind the broadening of the spectrum in a spectrum analyzer measurement.

This simplistic introduction to spectrum analyzers will end here. There are obviously much more to learn about this fundamental high frequency signal characterization tool. To get a deeper understanding of spectrum analyzers and the principles of spectrum analysis, the following documents are recommended as further reading materials.

- “Spectrum analysis basics,” Agilent application note AN-150.
- “Fundamentals of Real-Time Spectrum Analysis,” Tektronix application note.
- Rigol DSA1030A-TG3 spectrum analyzer review and experiments (Video³): <https://www.youtube.com/watch?v=lu2Uaj3ZcoA>

2.2 Coaxial RF Connectors

As we learned in the introductory engineering electromagnetics course, electrical connections between high frequency circuit components may not be as simple as in the case of low frequency circuits. We have to consider wave propagation effects (transmission line effects) when the length of the connection is comparable with the wavelength. As a consequence, we have to consider impedance matching between the transmission lines and the circuit components. To make things simple, we often conform to a single impedance value, often called the system impedance, in an RF system. In most systems, this impedance value is 50Ω ⁴.

Perhaps the most prevalent transmission line for medium to low-power RF/microwave systems is the coaxial cable, which consists of an inner conductor and an outer conductor arranged in a cylindrical fashion. Coaxial cables are great because they are generally low loss, can be made flexible, and provide great shielding/isolation of the signal being transmitted. In order to connect coaxial cables to an RF block, a coaxial RF connector is usually used.

RF connectors comes in many different standards. They vary in shape, usable frequency range, signal attenuation, power handling, durability, etc. Fig. 5 provides a glimpse of some common RF connectors.

To learn about RF coaxial connectors, go through the following materials.

- “Guidance Selecting Handling Coaxial RF Connectors,” Rohde & Schwarz.
- RF and microwave connector handling and care (Video): <https://www.youtube.com/watch?v=I0oSsvprpTg>

³This Youtube channel features many great tutorial videos related to high frequency electronics.

⁴Why 50 ? read the following: <http://www.belden.com/blog/broadcastav/50-ohms-the-forgotten-impedance.cfm>



Figure 5: Typical RF connectors. Source: http://www.szelins.com/RF_Connector.html

Pre-lab Assignment

1.1

Due: Sep. 25th, 2015

Please answer the following questions:

- What are the advantages and disadvantages of using switch mode voltage regulator vs a linear voltage regulator?
- For the circuit of Fig. 6, with sing an input voltage of 9V and $R_1=510\ \Omega$, what's the value of R_2 such that the output voltage is 5 V? What is the efficiency of the regulator in this case? "LM317" refers to the Texas Instruments LM317 voltage regulator IC. You should be able to find its datasheet online.

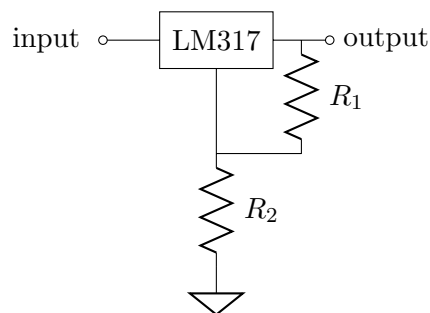


Figure 6: LM317 linear regulator circuit.

- According to the datasheet you found above, what is the typical drop out voltage for the TI LM317? If an input voltage of 12 V is used, what range of output voltage can be considered regulated?
- What is the maximum efficiency of the TI LM2694 switch mode voltage regulator for an output voltage of 5 V? Under what conditions is this

efficiency achieved?

- e) What do *LSB* and *MSB* mean in a DAC? For a 12-bit DAC with an output reference voltage V_{ref} of 2 V, how much voltage does an LSB correspond to? What about a 24-bit DAC instead?

Pre-lab Assignment

1.2

Due: Oct. 2th, 2015

Please answer the following questions:

- a) What does *SFDR* mean for a DAC? What is the typical SFDR of the Analog Devices (ADI) AD9788 DAC?
- b) What is the *image* signal for a DAC output? If a DAC is operating at a clock rate of 200 Msps and the output fundamental signal is a 50 MHz sine wave, what are the frequencies of the first three images above the fundamental?
- c) What does *SNR* mean for a DAC? What is the typical SNR for the Linear Technology (Linear) LTC2641 DAC?
- d) What does *THD* mean for an ADC? What is the typical THD for the TI ADS5400 ADC ?
- e) What does *SINAD* mean for an ADC? What is the typical SINAD for the Linear LTM9008-14 ADC?
- f) What does *ENOB* mean for an ADC? How is it calculated? What is the ENOB for the Maxim Integrated (Maxim) MAX11270 ADC?

Pre-lab Assignment

1.3

Due: Oct. 9th, 2015

Please answer the following questions:

- a) What is the highest speed 8-bit ADC you can find? What is its power consumption? What would be the power consumption of an 8-bit ADC with half of this speed?
- b) What is the frequency domain representation of the following triangle wave signal?

$$x(t) = \sum_{k=-\infty}^{\infty} \left\{ \left(\frac{2t}{T} - \frac{kT}{2} \right) \Pi \left[\frac{2(t-k)}{T} \right] + \left(1 - \frac{2t}{T} \right) \Pi \left[\frac{2(t-k-\frac{1}{2})}{T} \right] \right\},$$

where $\Pi(t)$ is the rectangular pulse function

$$\Pi(t) = \begin{cases} 1 & 0 \leq t \leq 1; \\ 0 & \text{elsewhere.} \end{cases}$$

If we pass the signal through an ideal low-pass filter that keeps only the first three harmonics (including the fundamental, the 2nd harmonic, and the 3rd harmonic), what would the filter output signal look like in the time domain?

- c) Design an analog low-pass filter that meets the following specifications:
- (a) In-band gain: 10 dB;

- (b) 3-dB cut-off frequency: 20 kHz;
- (c) Attenuation at 100 kHz: 30 dB.

You may find online filter design tools, such as the TI WEBENCH Filter Designer⁵ and the ADI Filter Wizard, to be useful. Verify the performance of your filter by simulation. You may use a SPICE simulator, such as LTSpice, or a high frequency circuit simulator such as Agilent/Keysight Analog Design Systems (ADS). Both software are available on lab computers.

⁵A short introduction video is available at <https://www.youtube.com/watch?v=bdtLbtftV8A>

3 Equipment & Supplies

- 2 × Mini-Circuits ZX60-272LN-S+ amplifier (Fig. 7). Table shows its main specifications (typical values) at room temperature. More detailed specifications can be found in the datasheet (<http://www.minicircuits.com/pdfs/ZX60-272LN+.pdf>⁶).



Figure 7: Picture of the Mini-Circuits ZX60-272LN-S+ amplifier.

Table 1: ZX60-272LN-S+ Typical Specifications.

Frequency range	2300 – 2700 MHz
Noise figure	0.8 dB
Gain	14 dB
P1dB	18.5 dBm
OIP3	31.5 dBm
Input VSWR	1.2
Supply voltage	5 V
Supply current	55 mA

- 1 × Mini-Circuit ZX10-2-332-S+ power splitter/combiner. An RF power splitter is used to evenly split the RF power from the input port (marked “S”) into two output ports (marked “1” and “2”). However, here we will use it as a power combiner⁷, which combine the signals from two output ports into the input port.
- 1 × Mini-Circuits VAT-3+ 3 dB RF attenuator. As its name suggests, the attenuator attenuates the RF signal by 3 dB.
- GW-Instek GSP-730 spectrum analyzer (Fig. 9). The GSP-730 is a low-cost 3 GHz spectrum analyzer. It doesn't have the best performance⁸, but we will work around the limitations to make it useful for our labs. The GSP-730 can be remotely controlled from the lab computer by the GGT software provided by GW-Instek.

⁶It is always a good idea to read the datasheet before using a component.

⁷You will learn in an RF circuit design class that most passive RF components — splitter is one of them — are reciprocal, meaning that you use their output as input and vice versa.

⁸We've chosen this spectrum analyzer primarily for cost reasons.



Figure 8: Picture of the Mini-Circuits ZX10-2-332-S+ amplifier.

The spectrum analyzers are usually locked in the Kemper 2112 cabinet. However, your group can check one out if you wish to use it outside of lab hours. The GSP730 will fit in your EEC134 toolbox.

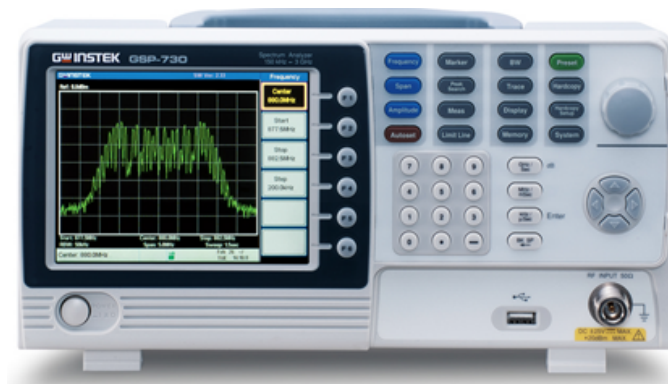


Figure 9: Picture of the Instek GSP730 spectrum analyzer.

- $2 \times$ TPI synthesizers (Fig. 10) and $2 \times$ USB-mini cables. The TPI synthesizer is a low-cost RF signal generator based on the Analog Devices AD4351 single-chip synthesizer. The synthesizers will be distributed to each group and it will be your responsibility to keep them safe.

Note that every TPI synthesizer is calibrated and has its individual serial number. When you connect the synthesizer to a computer through the USB-mini cable, a window will pop up to let you select the calibration file based on the serial number.

- $2 \times 12''$ and $2 \times 6''$ semi-flex coaxial SMA cables. The coaxial cables can be bent to a certain extent, but please do not bend them excessively.
- $1 \times$ TNC (male) to SMA (female) connector.



Figure 10: Picture of the Instek GSP730 spectrum analyzer.



Figure 11: Picture of the semi-flex coaxial cable.

4 Procedures

4.1 Getting to know your equipment

In this lab, we will measure the frequency and power of an RF signal generated by the TPI synthesizer with the GSP-730 spectrum analyzer. The measurement set up is shown in Fig. 13.

1. Connect the TNC-male to SMA-female adapter to the input port of spectrum analyzer (labeled “RF INPUT $50\ \Omega$ ”). Follow proper handling guidelines (in this case, hold the SMA-female end still and rotate only the TNC jacket). The adapter should be left on the spectrum analyzer from now on.
2. Connect the output of the TPI synthesizer to the input of the spectrum analyzer (with the adapter already connected) using an SMA cable.
3. Connect the TPI synthesizer to the lab computer using an USB cable (provided with the kit).
4. Turn on the spectrum analyzer and configure it as below.



Figure 12: Picture of the TNC (male) to SMA (female) connector.

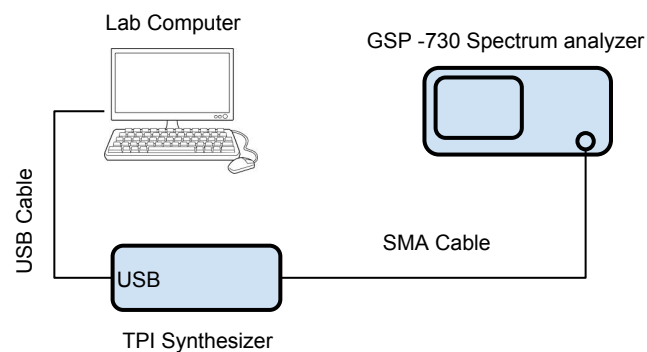


Figure 13: Testing the TPI synthesizer and the GSP-730 spectrum analyzer.

- (a) Press the “Preset” button. **Always** preset the spectrum analyzer before starting a new experiment.
- (b) Set the center frequency. Press the blue “Frequency” button, then press the “F1” button to select the “Center” frequency option. Type in “2.4 GHz” using the numerical panel on the spectrum analyzer.
- (c) Set the frequency span. Press the blue “Span” button, then press “F1” button to select the “Span” option. Type in “20 MHz”. Now you should be able to observe the frequency range from 2.39 GHz to 2.41 GHz⁹.
- (d) Set the reference level. Press the “Amplitude” button, then press “F1” button to select the “Ref. Level” option. Type in “20 dB” to set the reference level to 20 dBm¹⁰. The screen of the spectrum analyzer should look like the following:

5. Measuring a single-tone RF signal

- (a) Launch the *SynthMachine* software and choose the appropriate calibration file (serial number) for the TPI synthesizers. In the *SynthMachine* software, set the “Center Frequency” to 2400MHz, set

⁹You can also achieve this by setting the “Start frequency” and “Stop frequency”; play with it.

¹⁰The reference level is set to be comparable to the signal input power.

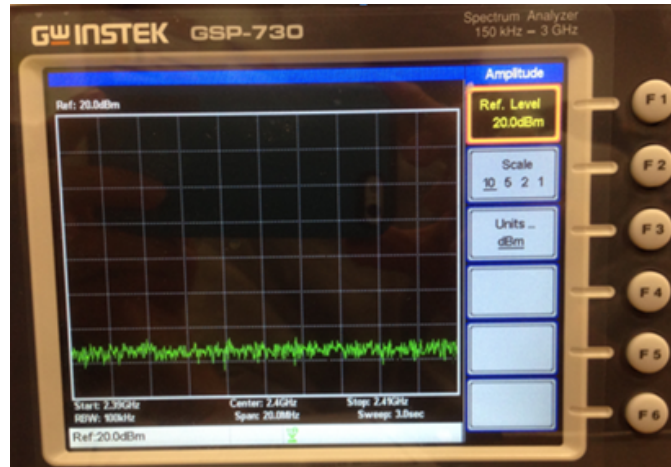


Figure 14: Set the reference level.

the “Output Power” to 10 dBm, and click “RF On” to turn on the RF signal output.

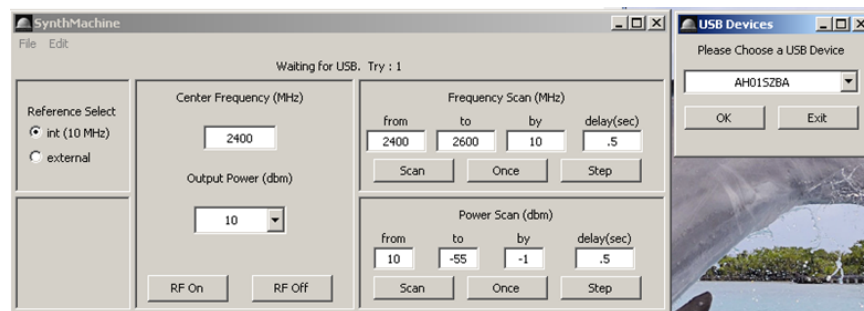


Figure 15: Screenshot of the SynthMachine software.

- (b) Observe the spectrum analyzer screen. It should look like the following.
- (c) Press the gray “BW” (meaning bandwidth) button to go into the resolution bandwidth menu. Press “F1” to set the RBW to manual mode. Three possible RBW options should now appear in the sidebar menu. Capture the screen for each of the three settings¹¹. In your lab report, describe the differences between the three screen captures and explain why such differences exist.
- (d) Set the RBW to the smallest possible value.
- (e) Press the “Peak Search” button, and a marker is automatically located at the RF signals. You can read the frequency and power values of this marker at the right upper corner of the screen. Record

¹¹You can capture the screen by a camera or using the remote control software GGT. The software can be launched from the Start Menu of the lab computer. We leave it to you to explore how to capture the screen using the software.

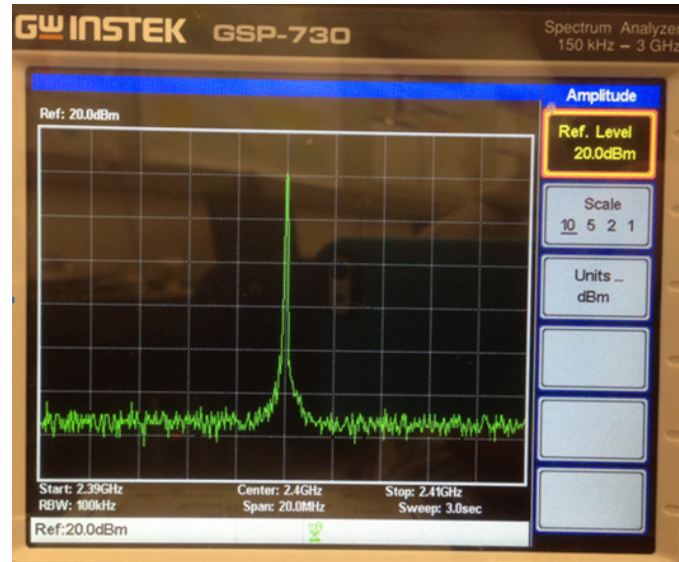


Figure 16: Screenshot of the spectrum analyzer with a single-tone input.

the power of this signal. How does it compare it with the output setting of the TPI synthesizer? Assume that the TPI synthesizer output power is accurate, what do you think is the cause of the difference? This measured signal power which we will designate as P_{cal} will be used as a reference for later labs.

6. Observing the harmonics.

- (a) Now set the output frequency of the TPI synthesizer to 800 MHz.
- (b) Preset and configure the spectrum analyzer as follows:
 - i. Start frequency = 500 MHz;
 - ii. Stop frequency = 3000 MHz;
 - iii. RBW = auto;
 - iv. Reference level = 20 dBm.

7. Measuring two RF signals.

- (a) Turn off the RF power from the TPI synthesizer.
- (b) Disconnect the TPI synthesizer from the SMA cable.
- (c) Connect the input port (labeled “S”) of the splitter/combiner to the input of the spectrum analyzer with an SMA cable.
- (d) Connect the output ports of the two synthesizers (labeled “RF Out”) with the output ports of splitter/combiner (labeled “1” and “2”) via male-male SMA adapters. Fig. 17 shows the measurement setup.
- (e) Preset the spectrum analyzer and configure it as below.
 - i. Center frequency = 2.4 GHz;

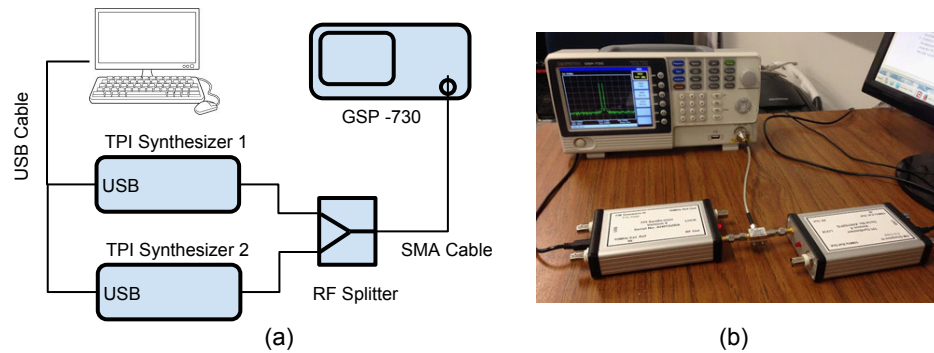


Figure 17: Two-tone measurement setup.

- ii. Span = 20 MHz;
- iii. RBW = 100 kHz;
- iv. Reference level = 20 dBm.
- (f) Launch another instance of the SynthMachine software (now you should have two instances of SynthMachine running) and choose the appropriate calibration file (serial number) for the second TPI synthesizer. Set the “Center Frequency” to 2400 MHz for the first synthesizer and 2401 MHz for the second. Set the “Output Power” to 10 dBm for both synthesizers.
- (g) Now turn on the TPI synthesizers by clicking the “RF On” buttons in both instances of the SynthMachine software.
- (h) The screen of the spectrum analyzer should look like the following.

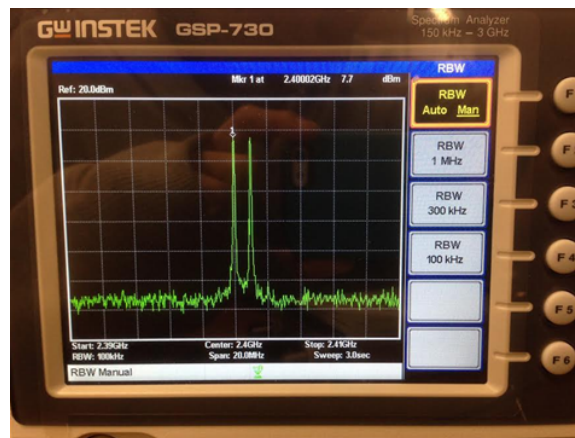


Figure 18: Screenshot of the spectrum analyzer with two-tone input.

- (i) Set the RBW to the three possible manual options. Capture the screen for each of the three settings. Describe the differences between the three screen captures and explain why such differences exist in your lab report.

4.2 Characterizing the bandwidth and the gain

1. Connect the output port of LNA (labeled “OUT”) to one end of a 3-dB attenuator¹², then connect the other end of the attenuator to the spectrum analyzer with an SMA cable.
2. Connect the input port of the LNA to the TPI synthesizer via a SMA male-to-male connector.
3. Connect the “+5VDC” pin of the amplifier to the positive terminal of the lab power supply using a wire; connect the “GND” pin of the amplifier to the ground of the power supply.
4. Preset the spectrum analyzer and configure it as below.
 - (a) Center frequency = 2.4 GHz;
 - (b) Span = 4 MHz;
 - (c) Reference level = -10 dBm;
 - (d) RBW = auto.
5. Configure the TPI synthesizer as follows:
 - (a) Center Frequency = 2.4 GHz;
 - (b) Output Power p_{out} = -25 dBm.
6. Set the power supply to output +5V.
7. Turn on the TPI synthesizer.
8. You should now see a signal at 2.4 GHz on the spectrum analyzer.
9. Press the “Peak Search” button on the spectrum analyzer, and a marker is automatically located at the desired signal. Let P_{meas} be the measured signal power.
10. Calculate the gain of the amplifier.

$$G = P_{meas} - P_{out} - (P_{cal} - 10) + 3 \quad (\text{dB}).$$

Verify that this value agrees with the amplifier’s datasheet. Explain why the above equation is used to calculate the gain.

11. Now sweep set the output frequency of the TPI synthesizer from 2.0 GHz to 3.0 GHz (include at least 8 data points) and measure the amplifier gain at each frequency. Note each time when you are changing the output frequency of TPI synthesizer, you also need to change the center frequency of spectrum analyzer, otherwise you won’t observe any signals. Please note down the frequency and the measured power, then use

¹²The use of an attenuator here is to limit the RF power input to the spectrum analyzer for more accurate result. This should not be necessary on a better spectrum analyzer.

the above formula to calculate the gain. Plot the gain with respect to frequency. Include at least 8 data points. What is the 3 dB bandwidth of the amplifier? What is the maximum gain variation in the 2.3–2.7 GHz range? Does the measured data agree well with the datasheet?

4.3 Measuring P1dB

Using the same setup as in Lab. 4.2, we will measure the 1-dB compression point of the amplifier.

1. Preset and configure the spectrum analyzer as follows.
 - (a) Center frequency = 2.4 GHz;
 - (b) Span = 4 MHz;
 - (c) RBW = auto;
 - (d) Reference level = -10 dBm.
2. Set the synthesizer output frequency to 2.4 GHz.
3. Set the output power of the TPI synthesizer from -20 dBm to 10 dBm in steps of 1 dBm. Record the measured signal power (output of the amplifier) on the spectrum analyzer. Note when you increase the input power to some extent, the signal peak will be out of screen range, but you can always find the peak value by pressing the “Peak Search” button on the spectrum analyzer. Though you can adjust the reference level to a higher value to observe the signal peak, this change would lead to poor measurement result.
4. Plot the measured output power vs. the input power. What is the output 1 dB compression point for the amplifier? Does it agree with the datasheet?

4.4 Measuring IP3

1. For the IP3 measurement, we need two input signals with a slight frequency offset. Set up the measurement as illustrated by Fig. 2.40.1.
2. Preset and configure the spectrum analyzer as follows:
 - (a) Center frequency = 2.4005 GHz;
 - (b) Span = 4 MHz;
 - (c) RBW = auto
 - (d) Reference level = -20 dBm.
3. Configure the TPI synthesizers as follows:
 - (a) Synthesizer 1:
 - i. Output frequency = 2.4 GHz;

- ii. Output power = -10 dBm;
- (b) Synthesizer 2:
 - i. Output frequency = 2.401 GHz;
 - ii. Output power = -10 dBm.
4. The spectrum analyzer screen should look like the following. The fundamental signals will be beyond what the screen can display (Fig. 2.40.2); we do this intentionally to keep the reference level small (-20 dBm) to obtain a better measurement result. You can use “F1” - “F6” key to locate every fundamental tone and 3rd order intermodulation (IM3) signals.
5. Sweep the output power of both TPI synthesizers from -25 dBm to 5 dBm. Record the measured fundamental and IM3 signal power. The two IM3 signals may exhibit different power levels. This may be caused by a number of reasons, such as gain variation and memory nonlinear effects. For this lab, simply pick one of the two IM3 signals.
6. Plot the measured fundamental and IM3 signal power vs. the input power. What is the output IP3 (OIP3) point for the amplifier? Does it agree with the datasheet?

4.5 RF amplifier PCB design

Design a test PCB for the ADI ADL5611 RF gain block IC.

1. Follow the recommended schematic and layout in the datasheet (http://www.analog.com/static/imported-files/data_sheets/ADL5611.pdf).
2. Use Bay Area Circuit as the PCB vendor.
3. The PCB area should not exceed 1 in \times 1 in.
4. Make sure that you have 50 Ohm microstrip lines for the input and output SMA connectors.
5. The TA will provide the ADL5611 IC and SMA connectors. You will be responsible for acquiring the rest of the circuit components. Do remember to check the class inventory.
6. Your final circuit will look similar, but may not be identical, to the ADL5611 evaluation board (Fig. 19).

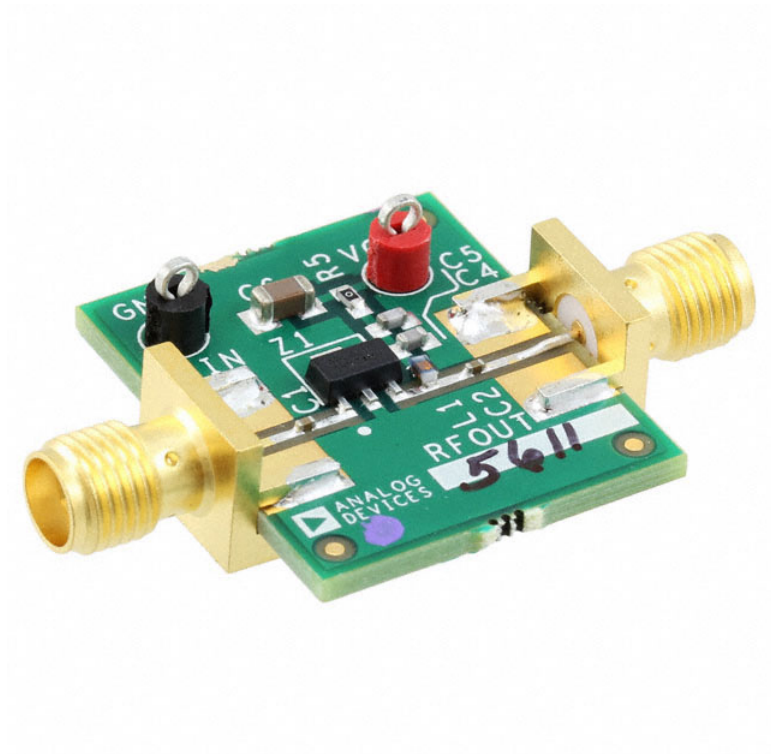


Figure 19: Evaluation board for ADI ADL5611.

References

- [1] Jeff Thomas, Tom Holmes, Terri Hightower, "Learn RF Spectrum Analysis Basics," Agilent Technologies, <https://www.jlab.org/uspas11/Reading/RF/RF%20Spectrum%20Analysis.pdf>.
- [2] Erik Diez, "The Fundamentals of Spectrum Analysis," Agilent Technologies, <http://electronicdesign.com/test-amp-measurement/fundamentals-spectrum-analysis>.