Lab #5 – Radio Component Parameters

In this lab we will work with some of the components that constitute a radio, specifically amplifiers and frequency mixers. We will measure the key parameters associated with these blocks, such as gain, IP3, and spurious response. We will also observe how cascading these blocks will impact the parameters.

Test equipments used for this lab:

Signal Generator – HP8920A RF Communication Test Set, used for generating a fixed frequency at a specified power level

Spectrum Analyzer – If available on your lab bench, use the Anritsu MS2717B Spectrum Analyzer. The HP8920A can also be used as a spectrum analyzer, but its measurements are less accurate than the Anritsu unit

Power Meter – Boonton RF Millivoltmeter

Power Combiner – Mini Circuits ZFRC-2050+; it is also called a Power Splitter since this passive device can be used to either combine two signals or split one signal

Section 1: Single Tone Measurement of an Amplifier

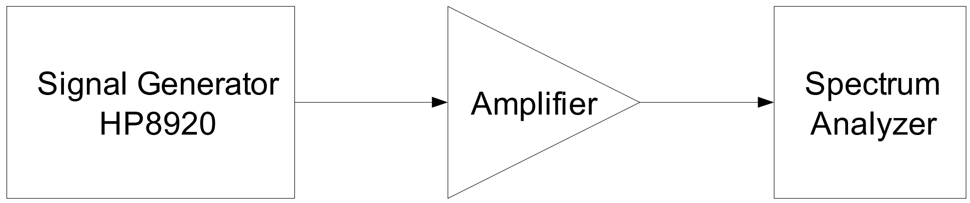
The amplifier we will be using for this lab is the ZX60-3018G-S+ from Mini Circuits. As preparation for this lab, please study the datasheet for this amplifier.

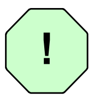
To measure the gain of an amplifier, two ways are commonly used in industry: measuring s-parameters with a Vector Network Analyzer (VNA), and measuring frequency components with a Spectrum Analyzer. We will be using the latter approach in this lab.

Using the Signal Generator, output a fixed single frequency of 836 MHz. You are required to choose an appropriate power level for testing the amplifier, so use the datasheet to guide you in this regard.

The power / amplitude setting on the Signal Generator should only be used as a rough indication of the actual power at the generator's output. The most accurate way to measure signal power is with a Power Meter. A less accurate method is to measure power with the Spectrum Analyzer. Measure the Signal Generator's output with the Power Meter and Spectrum Analyzer, and compare the results.

The amplifier input is connected to the Signal Generator, and the amplifier output is connected to the Spectrum Analyzer; the setup is as shown below.





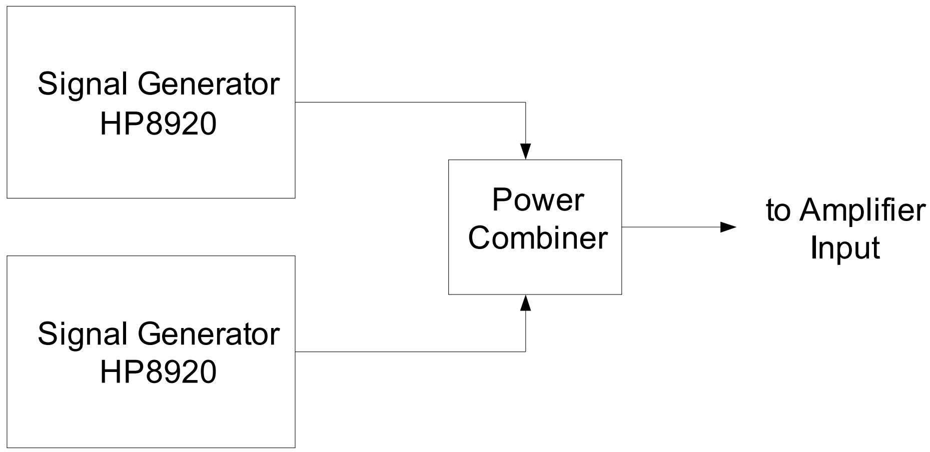
Before turning on the DC supply to the amplifier, ensure that the supply polarity and voltage are correct. Otherwise you can damage the amplifier!

Measure the amplifier's output power using the Spectrum Analyzer, and calculate the gain of this amplifier. Compare your measurement with the datasheet value. Explain any discrepancy between the two values.

Section 2: Two-Tone Measurement of an Amplifier

Recall that when two different frequencies are applied to the input of a nonlinear amplifier (and any real-world amplifier is nonlinear), intermodulation products are generated and observed at the output. In this part of the lab we will be measuring the 3rd order intermodulation products, and finding the IP3 of the amplifier.

To generate 2-tones as input to the amplifier, we will use using two separate Signal Generators, with one set at 836 MHz, and the other set at 837 MHz. The two generator outputs are then added together using a Power Combiner, as shown in the setup below. Note that the Power Combiner has loss, so each Signal Generator will have to be adjusted to get the desired power on each tone at the power combiner output.



Apply the 2-tone signal to the amplifier input, and measure the amplifier output using the Spectrum Analyzer. Make a sketch of the output spectrum, noting the frequency components and the power levels. Identify the intermodulation products, and calculate the Input IP3 (IIP3) and Output IIP3 (OIP3) for this amplifier. Compare your measurements against the amplifier's datasheet, and comment on the results.

Increase the power of each tone by 2 dB. You should check the Power Combiner output on the Spectrum Analyzer to ensure that the increase is indeed 2 dB. Apply the 2-tone signal to the amplifier input, and measure the amplifier output using the Spectrum Analyzer. Again, make a sketch of the output spectrum. How much have the intermodulation products increased? Is the magnitude of the increase expected? Compute the IIP3 and OIP3 again, and comment on your results.

Section 3: IP3 of Cascaded Amplifiers

In this part of the lab, we will measure two amplifiers connected in series with each other. Although the gain of the cascaded amplifiers should be fairly obvious, we will also observe how IP3 is affected in this case.

Using the setup from Section 2, generate two tones at 836 MHz and 837 MHz using the power combiner. Check the combiner output on the Spectrum Analyzer, and adjust the Signal Generators to get the desired power on each tone. Think about what power level is appropriate; be careful not to overload the second amplifier.

! **The maximum input power to the amplifier is +13 dBm. Ensure that the output of the first amplifier is much lower than that, otherwise the second amplifier may be overdriven and damaged!**

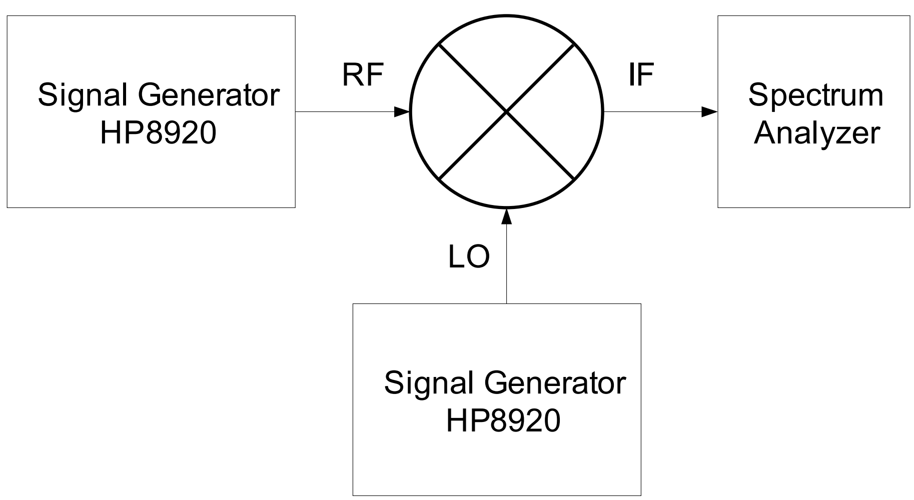
Connect two amplifiers in cascade using a SMA cable. Apply the 2-tone signal to the first amplifier's input, and measure the second amplifier's output on the Spectrum Analyzer. Make a sketch of the output spectrum, noting the frequency components and the power levels. Using the measurement, calculate the Input IP3 (IIP3) and Output IIP3 (OIP3) for the cascade. Next, calculate the theoretical IIP3 and OIP3, using the equation from lecture. Compare the two sets of values and comment. In this case, what is limiting the overall IP3 of the cascade?

(Note: to calculate the theoretical IIP3 and OIP3, you will need to the gain and IP3 of both amplifiers. You have already measured the gain and IP3 for one amplifier. For the second amplifier, you may choose to measure it also, or use typical values from the datasheet)

Section 4: Frequency Mixer

A frequency mixer converts an input signal from one frequency to another frequency. The mixer we will be using in this lab is the ZX05-10L+ from Mini Circuits. It is a passive mixer with 3 inputs: RF, LO, and IF. In the context of using this device in a radio receiver, RF is the input and IF is the output. As preparation for this lab, please study the datasheet for this mixer.

First you will measure the conversion loss for this mixer. Set one Signal Generator to be the RF input at 836 MHz. Set another Signal Generator to be the LO at 736 MHz. The IF is thus at 100 MHz.



From the datasheet, what is the LO power required for this mixer? Measure the mixer output at 100 MHz using the Spectrum analyzer, using different LO power levels (LO power = -6 dBm, 0 dBm, +6 dBm). Record the mixer output power in each case, and compute the conversion loss. How does the conversion loss compare to the datasheet value? What happens to the conversion loss as the LO power is reduced?

The LO-to-IF isolation (sometimes called the LO feed-through) is defined as the amount of power at the LO frequency present at the IF output. Using the Spectrum Analyzer, measure the mixer output centered at 736 MHz. Record the power present at the LO frequency of 736 MHz, and calculate the LO-IF isolation. Provide some reasons why LO-to-IF isolation is important in a radio receiver.

Hand in a lab report by no later than the beginning of the next lab.