Two-Tone IP3 Measurement

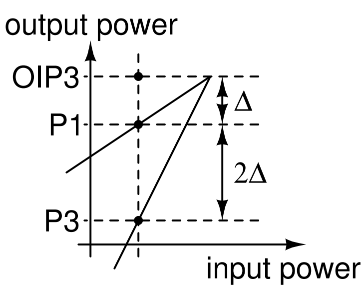
Introduction

In this lab you will measure the output third-order intercept point (OIP3) of a Mini-Circuits ZX60-3018G RF amplifier using the two-tone method.

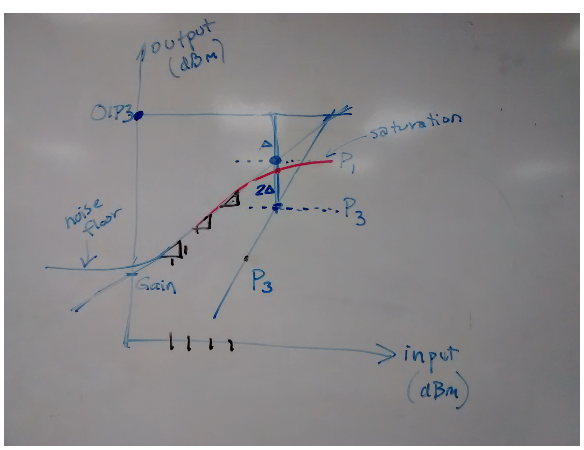
Third-order intermodulation products appear at frequencies near the input signals and are the most likely to cause interference both within the same channel and to adjacent channels.

The level of third-order products increases three times faster than those of the fundamental components when the signal levels are expressed in dB. The output power when the two powers would be equal is called the output third-order intercept point (OIP3).

As shown in the diagram below, when the output level is Δ dB less than the OIP3 the third-order intermodulation components will be 3Δ less than OIP3:



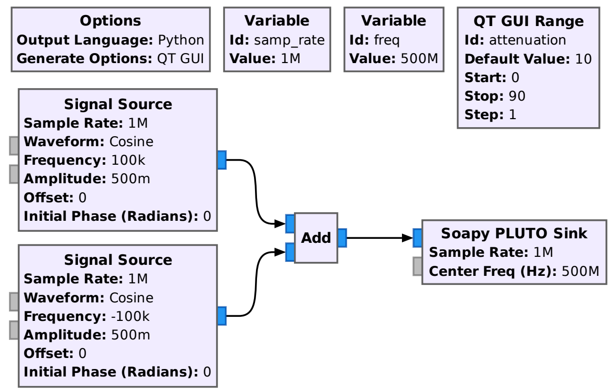
Thus measuring the output level, P1 (dBm) and the relative level of the third-order product, $2\Delta = P1 - P3$ (dB) allows us to compute OIP3 as $P1 + \Delta$. However, these measurements must be made in the region where P1 is increasing linearly with the input power.



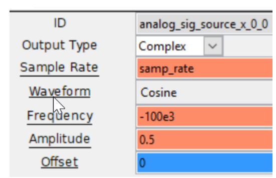
Procedure

Two-Tone Transmitter

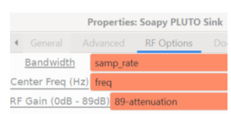
Use Gnu Radio Companion (GRC) to create the following flowgraph of a two-tone transmitter:



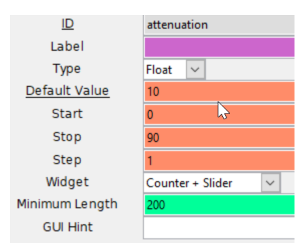
The complex signal sources have amplitudes of 0.5 and frequencies of +100 kHz and −100 kHz:



This puts one carrier ("tone") offset by 100 kHz on each side of the 500 MHz center frequency. The sampling rate and RF bandwidth are set to 1 MHz. The RF gain is set to 80 minus the value of the attenuation variable:

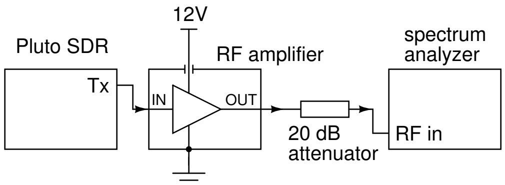


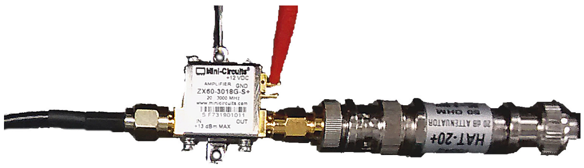
which is set by a GUI Range control that selects a value between 0 and 90 dB:



Grab a screen capture of your flowgraph to use in your report.

Measurement Setup





Connect the Pluto SDR TX output to the IN port of the amplifier using the short SMA-to-SMA cable included in the kit. Connect the amplifier's OUT port to a 20 dB attenuator[1] using an SMA-to-BNC adapter. Connect the attenuator to the spectrum analyzer with a BNC cable.

Adjust a DC power supply to 12 V output. Adjust current limiting to 50 mA (600mW) if your power supply allows. Because of the cost of the amplifiers and the ease with which they can be destroyed by incorrect supply voltages, **have the instructor check your setup** before connecting power to the amplifier.

Spectrum Analyzer Configuration

Set the spectrum analyzer to default settings using the buttons and menu items: `Shift` - `8` `(System) / System Options / Reset / Factory Defaults`.

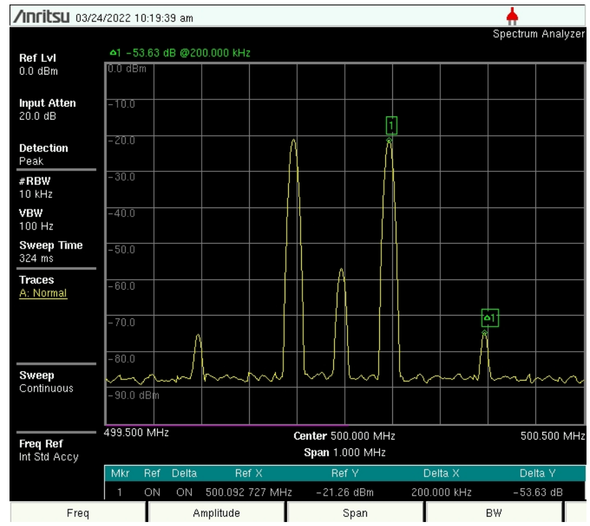
Configure the spectrum analyzer using the buttons and menu items shown below:

`Freq` `/ Center Frequency / 500 MHz`
`Amplitude` `/ Reference Level / 0 dBm`
`Span` `/ Span / 1 MHz`
`BW` `/ RBW: 1 kHz`
`/ VBW: 30 Hz`

[1]The maximum SDR output (10dBm) and the maximum amplifier again (25dB) results in a level that exceeds the maximum input level of the spectrum analyzer (23 dBm with < 10 dB attenuation).

Measurements

Run the GRC flowgraph. You should see a spectrum similar to (but not necessarily the same as) the following with two carriers offset by 100 kHz on either side of 500 MHz and third-order intermodulation products 200 kHz away from those.



To measure the levels of the intermod products, set a marker on one tone and measure the difference to the IM3 product using the following menu items:

`Marker` `/ Marker (1)`
`/ On (On)`
`/ Delta (On)`
`/ Peak Search`
`/ More Peak Options`
`/ Next Peak Right`
(repeat until at correct peak)
`/ More / Marker Table (On)`

Increase the SDR output attenuation in steps of 1 dB or 2 dB until the intermod products are close to the spectrum analyzer's the noise floor. Record the marker 1 level (P_1 = `Ref Y`) and the different in level between the markers ($P_1 - P_3 = 2\Delta$ = `Delta Y`) as shown in the marker table.

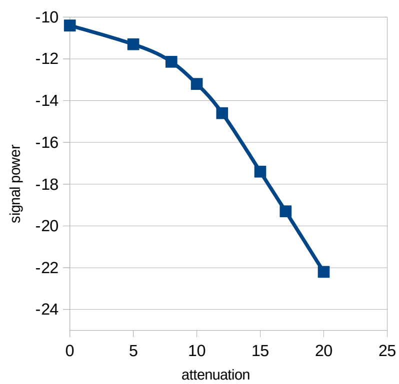
Capture one of the measurement screens to a file following the instructions in a previous lab (do not use a camera).

Analysis

Organize your measurements in a table showing the attenuation, the fundamental level in dBm, the difference between successive fundamental levels, the relative level of the third-order intermod and the estimated OIP3 including the effect of the 20 dB attenuator. For example:

	A	B	C	D	E
1	attenuation:	20	dB		
2					
3	attenuation	P1	increase	P1-P3 = 2Δ	OIP3
4	dB	dBm	dB	dB	dBm
5	0	-10.4		-15.2	17.2
6	5	-11.3	-0.9	-15.3	16.4
7	8	-12.1	-0.8	-20.0	17.9
8	10	-13.2	-1.1	-25.0	19.3
9	12	-14.6	-1.4	-33.0	21.9
10	15	-17.4	-2.8	-43.5	24.4
11	17	-19.3	-1.9	-49.0	25.2
12	20	-22.2	-2.9	-59.0	27.3

Plot the P1 versus attenuation to determine the linear region of the P_{out} vs P_{in} curve where the measurement of IP3 is likely to be accurate:



Compare the results to the manufacturer's specifications as given in the datasheet.

Lab Report

Submit a lab report to the appropriate assignment folder that includes the following:

- a screen capture of your GRC flowgraph
- one spectrum analyzer screen capture
- a table showing your measurements and calculations including the computed OIP3 corrected for the 20 dB attenuator
- a sentence or two stating your estimate of the amplifier's OIP3 and how it compares to the manufacturer's specifications
- a list of additional losses and sources of measurement error that are not included in your result