

Lab 5: Noise and Linearity in Amplifiers

In this lab you are going to analyze the behavior of a chain of amplifiers, including simulating noise and linearity properties.

After this lab, you will be able to:

1. Analytically predict distortion products produced by amplifiers and verify them with simulation.
2. Describe how to measure a radiation pattern.
3. Describe how to take near field electromagnetic pre-compliance measurements.

Practical Questions

1. What is the maximum input power of the spectrum analyzer in our lab (an N9320b, linked below)? How many 30dBm amplifiers can you put in series with a -30dBm function generator before you are violating the maximum input power?
<https://www.keysight.com/en/pdx-x201742-pn-N9320B/rf-spectrum-analyzer-bsa-9-khz-to-3-ghz?cc=US&lc=eng>
2. What is a typical range of received cell phone power levels?
3. What does VGA stand for and why are VGAs used in cell phone receiver chains?
4. What is a transmit/receive switch and why is it used in a cell phone?

Theory Questions

1. Use values on the datasheet to calculate the gain, noise figure, output power at P-1dB, and OIP3 of the ZX60-2531M-S+ amplifier at 600 MHz powered with a +5V supply.
2. Consider a two-tone intermodulation test using the frequencies ω_1 and ω_2 . In the spectrum in Figure 1...
 - a. Write a (1) over the fundamental tones
 - b. Write a (2) over the second-order intermodulation products
 - c. Write a (3) over a third-order intermodulation products
 - d. Write an (H) over products that are harmonics of fundamental frequencies
3. Consider the log-log plot of output power against input power in Figure 2. Label...
 - a. The line corresponding to the fundamental tones
 - b. The line corresponding to the second-order products
 - c. The line corresponding to the third-order products
 - d. The 1-dB compression point
 - e. The second-order intercept
 - f. The third-order intercept
 - g. The output-referred P-1dB power
 - h. The output-referred IP2 power (OIP2)
 - i. The output-referred IP3 power (OIP3)
 - j. The input-referred IP2 power (IIP2)
 - k. The input-referred IP3 power (IIP3)

4. An amplifier with a gain of 12 dB, a bandwidth of 150 MHz, and a noise figure of 4 dB feeds a receiver with a noise temperature of 900 K. Find the noise temperature of the overall system.
5. An amplifier with a gain of 20 dB and an IIP2 of 5 dBm drives a filter with a gain of -10 dB and a IIP2 of 20 dBm. What is the IIP2 of the cascaded system?

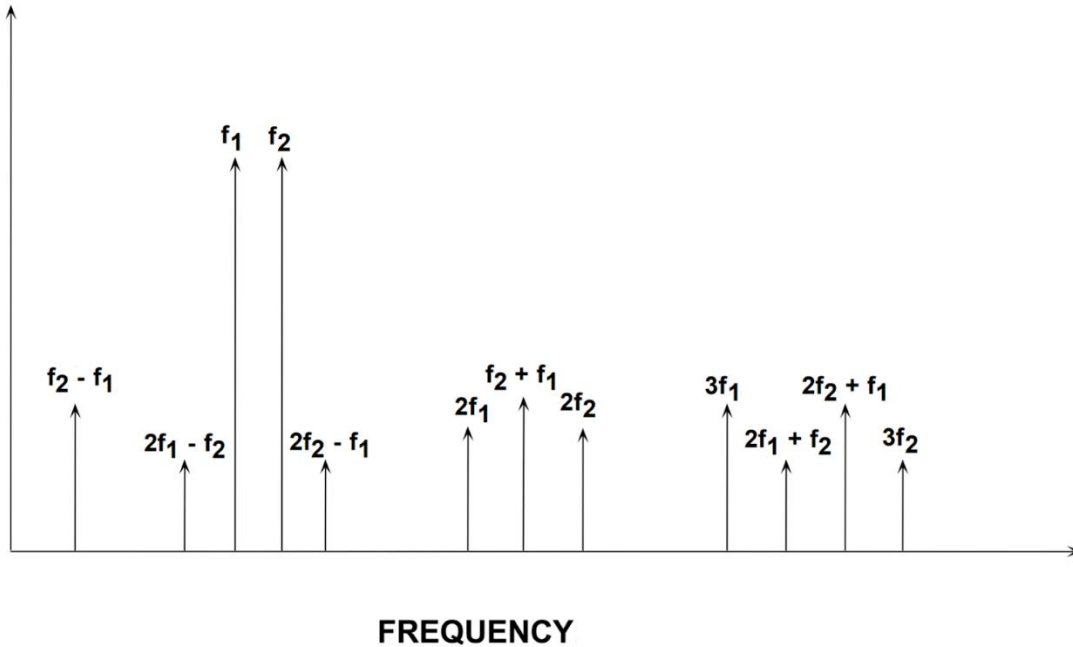


Figure 1

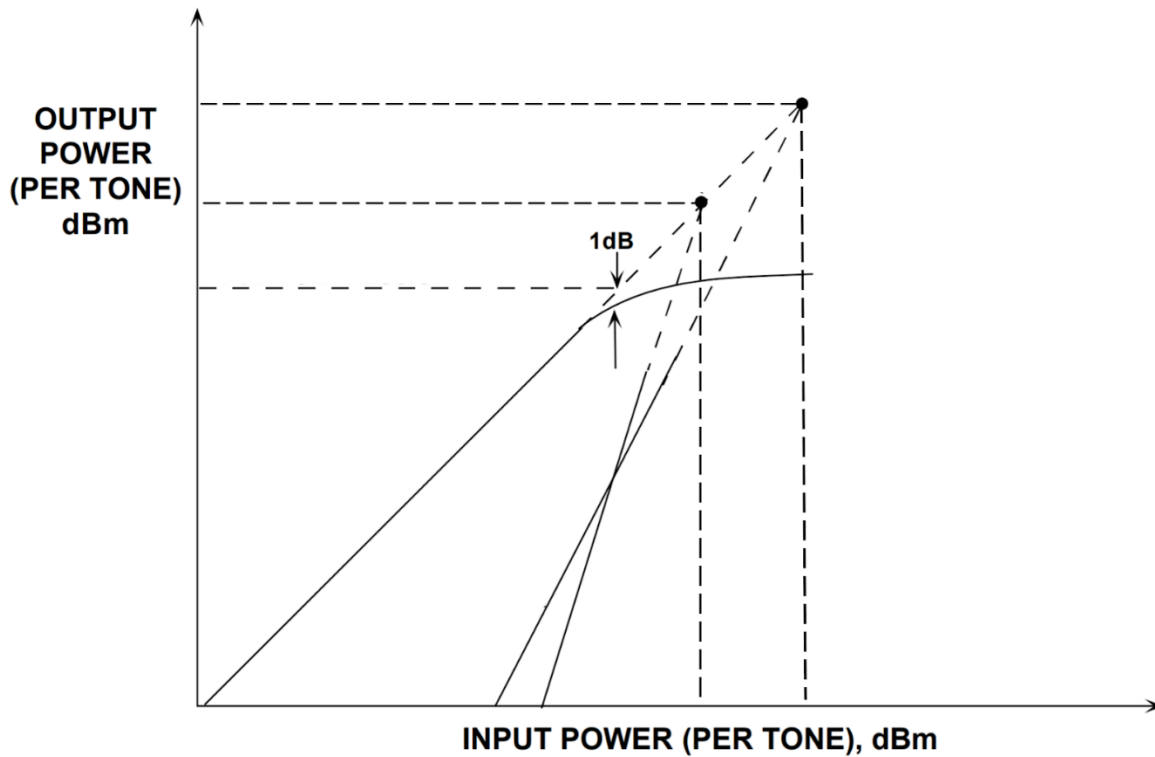


Figure 2

Lab Instructions

We are going to do two simulations of an amplifier, one to understand noise behavior and another to understand distortion behavior. The noise simulation will be carried out in Matlab, the distortion simulation in ItSpice (possibly combined with Matlab).

Noise

In Matlab, create a sine wave representing a 0dBm sinusoid driven into a 50 ohm load. Add white noise to the sine wave with and $\sigma_v = 1\text{mV}$. Take an fft of your signal. Where is the noise floor? Where is the signal power level? Do these match analytical predictions. (Note that the number of samples in your signal and the maximum time value of your signal will strongly affect your answers to this question.)

Write a function that quantizes your signal like an 8-bit ADC. Take an FFT of the quantized signal. Is the noise floor where you expect?

Finally, multiply your signal by 5 before quantizing it, representing passing the signal through an impedance matched amplifier with a voltage gain of five. Is the noise floor where you expect?

Required Data: Spectrum before quantization. Spectrum after quantization. Amplified spectrum after quantization. Calculations relating noise floors to noise voltage variance and ADC parameters.

Linearity

Build the circuit in Figure 3 in ItSpice. Be sure to use the same simulation settings, they are important to getting an interpretable results in the frequency domain. View the output using the ItSpice FFT tool (click on the waveform screen -> -> FFT). Change the input amplitude and continue reviewing your output spectrum until you find the P-1dB point. Also provide a spectrum showing 3rd order harmonic distortion. Finally, modify this simulation to perform a two-tone test and provide a spectrum showing intermodulation distortion.

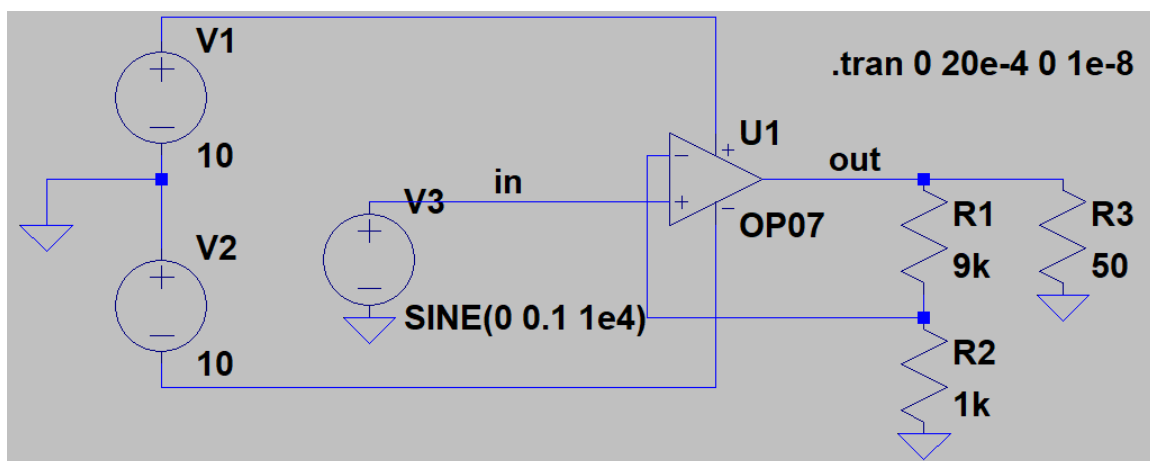


Figure 3

Required Data: P-1dB spectrum, Spectrum with 3rd order harmonic distortion, Spectrum with intermodulation.