AMPLIFIER NONLINEAR PERFORMANCE

Lab #10

In this laboratory session, the nonlinear characteristics of your amplifier design will be measured and analyzed. The amplifier will be characterized for two figures of merit: the 1 dB gain compression point and the third-order intermodulation intercept point. Both of these figures of merit provide insight into the performance of the amplifier under large-signal conditions, and can provide an indication of the ultimate system performance achievable with the amplifier.

1 dB Compression Point Characterization

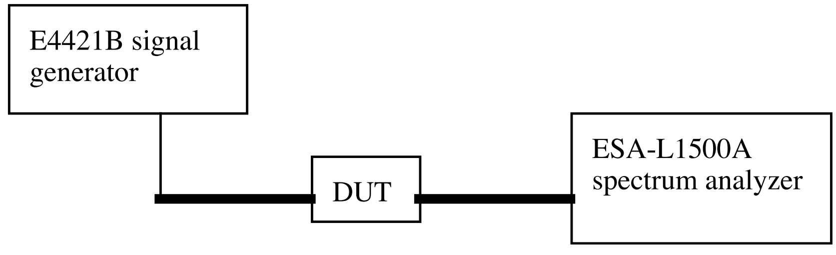
The 1 dB compression point of an amplifier is the input power required to reduce the gain (transducer power gain, G_T) to 1 dB below its small-signal value. This value can be measured by supplying a constant-frequency, ramped-power input signal to the amplifier and measuring the output power as a function of available input power.

1.) Set up the measurement apparatus as shown in the figure below. We will use the spectrum analyzer as a calibrated, tuned power meter. Set the signal source to your amplifier's center frequency at a power of -20 dBm. The center frequency of the spectrum analyzer should be set to this same frequency, with a span of 10 MHz. Set the spectrum analyzer's reference level to 20 dB to protect the input from excessive power (setting the reference level automatically engages attenuators internal to the spectrum analyzer).

2.) To find the loss in the cables at the design frequency, first use a female-female adapter as the DUT. In 5 dB steps, increase the signal generator power, and measure the output power as indicated on the spectrum analyzer. Record the input power/output power data points in your lab notebook. You may assume that the loss in the adapter is negligible compared to the loss in the cables, and that the loss in each cable is the same. How much loss is incurred in each cable? This will impact your interpretation of the power levels in the test circuit.

3.) Reset the input power to -20 dBm, and replace the adapter with your amplifier. Record the raw amplifier output power as a function of input power in the same way as for step 2 above, except use 1 dB steps this time (for more fine-grained information about your amplifier). Correct the data for the cable loss (at both the input and the output), and include a table of the corrected P_{avs} vs. P_L measurement in your lab notebook. Note that P_{avs} differs from the synthesizer power setting by the loss in *one* of the cables, and that P_L differs from the reading on the spectrum analyzer by the additional loss due to the second cable.

4.) Compute and tabulate the transducer gain (G_T) as a function of input power (taking into account the cable loss), and plot the results in your lab notebook. Using this data, find the input power that produces a gain that is 1 dB below that found for very low input powers. This is the 1 dB compression point, and is specified as P_{1dB}. You may have to interpolate to find the value accurately.



Measurement setup for 1 dB compression point measurement.

Intermodulation Performance Characterization

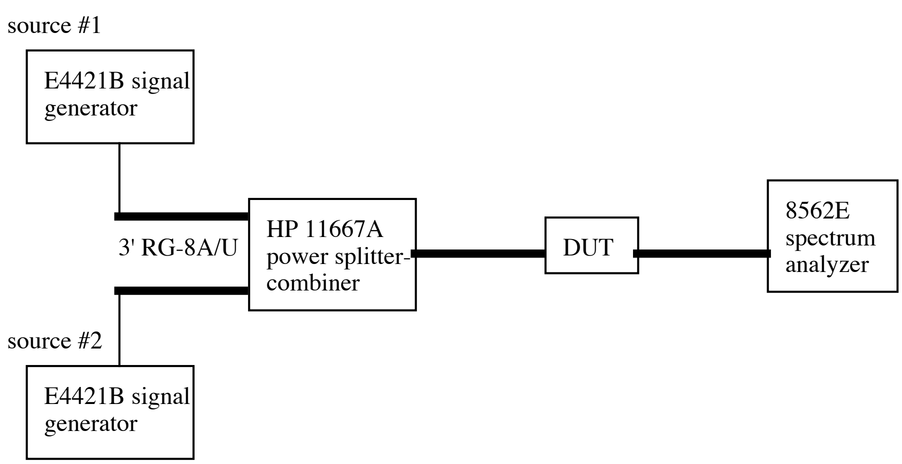
In the preceding section, we investigated the single-frequency performance of the amplifier as the input power is changed. This measurement gives some insight into absolute power levels that can be produced and handled by the amplifier, but it tells very little about how the amplifier will respond to modulated (i.e. information-carrying) signals at high powers. One way of characterizing the response of the amplifier to modulated signals is the two-tone third-order intermodulation intercept point.

1.) Connect the measurement setup as shown in the figure below, but with the female-female adapter as the DUT. Set the frequency of source 1 to 1 MHz below your design frequency, and that of source 2 to 1 MHz above the design frequency. The power level of both sources should be set to -20 dBm. Set the center frequency of the spectrum analyzer to be your design frequency, with a span of 15-20 MHz to include the signals and the responses induced by circuit non-linearities. Measure the power in the signals, noting that the power splitter introduces considerable additional loss (~6 dB) above the cable losses. Compute the loss on the input and output side of the DUT so that you can properly compensate your amplifier measurements. Replace the female-female adapter with your amplifier.

2.) For source powers from -20 dBm to 10 dBm in 1 dBm steps, find the output power in the fundamental, P_d (i.e. the desired frequency components), and in the intermodulation products, P_{IM} (i.e. the spurious responses near the fundamental due to the third-order non-linearity; these will lie 1 MHz above and below the primary signals). The two sources should be kept at the same power level, and the magnitude of either fundamental output can be recorded as P_d. Provide a table of the data in your lab notebook, and graph P_{IM} and P_d vs. P_{avs} for your amplifier. Compute the transducer gain from this data; how does it compare with the data taken in with the VNA in Lab #9 and the data collected in the compression measurement portion of the lab above?

3.) For each power level, compute the intermodulation ratio: $IMR = \frac{P_{IM}}{P_d} = \left(\frac{Pin}{P_{IP3}}\right)^2$.

This expression can also be used to find the input third-order intermodulation intercept, P_{IP3}. Note that this expression is only valid for input powers for well below the gain compression point. Using the above expression, compute P_{IP3} for your amplifier. Using the graph plotted in #2 above, extrapolate the data to find P_{IP3} graphically. How does this agree with the result from the expression above? Comment on the origins of any observed discrepancies. What is the significance of P_{IP3}, and how is it useful?



Measurement setup for intermodulation measurement.