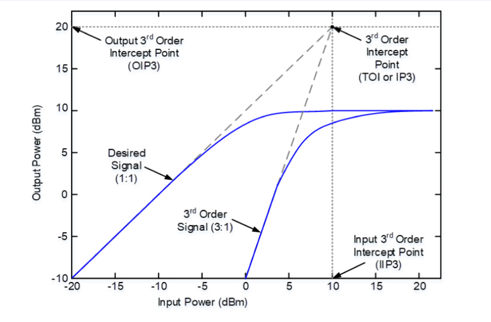
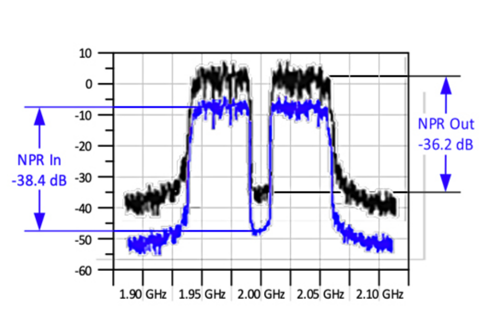
Boonton

APPLICATION BRIEF
Better Alternative for Measuring Amplifier Linearity

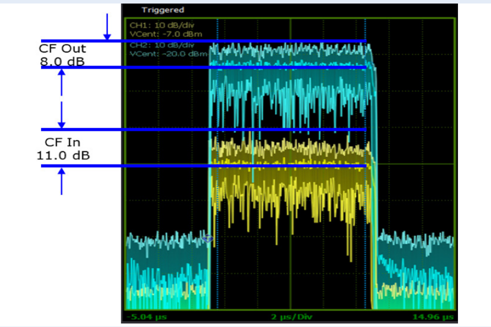
Third-Order Intercept (TOI) Point. This is today's standard to determine component linearity. To create this plot, a signal generator or generators are used to create the two tones and a spectrum analyzer or vector network analyzer (VNA) is used measure the desired signal and third order products. A disadvantage of this approach is that the measurement is only conducted using two tones. In practice, the signal provided to the amplifier often has significantly more tones included. For example, an LTE-A (5 CCs) signal has 6000 effective sub-carriers or tones and a 5G (NR) signal may have 3300.

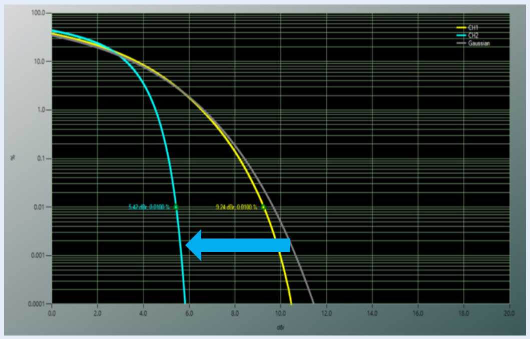


Noise Power Ratio (NPR). In this approach, white noise is used to simulate a multitone/carrier signal. The noise is bandlimited by a filter to either the useful bandwidth of the amplifier or the bandwidth of the expected signal the amplifier will receive. The resultant signal is then passed through a notch filter (typically > 50 dB down from the pass band amplitude) with a width of about 1 percent or less of the filtered noise bandwidth. When this signal is applied to the amplifier, the amplitude is increased to determine when it behaves non-linearly and the notch decreases.



Crest Factor / Peak-to-Average Power Ratio. A third approach with which to characterize an amplifier's linearity is with a crest factor measurement. Crest factor is the ratio of peak to average power. Similar to the NPR measurement, the amplifier is provided a bandlimited noise signal. Using a directional coupler, the incident signal is measured with a wideband peak power sensor. A second measurement is made at the output of the amplifier (attenuation may be needed to keep the signal in the measurement range of the sensor). The crest factors of the input and output signals are compared.





Complementary Cumulative Distribution Function (CCDF). To get additional insight into the amplifier performance, a CCDF can be used. A CCDF curve shows the amount of time a signal spends above the average power level of the measured signal at each power level relative to the average. Or equivalently, the CCDF curve displays the probability that the signal power will be above the average power at each power level. As an amplifier output compresses, the crest factor will reduce and the CCDF plot will move left in the graph.

Tone/Noise Source Average Amplitude (dBm)	Average Output Power (dBm)	Gain (dB)	Peak Output Power (dBm)	Output Crest Factor (dB)	NPR (dB)	3rd Order IMD (dBc)
-25	-19.7	5.3	-8.8	10.9	38.4	60
-24	-18.6	5.4	-7.8	10.8	39.3	58.5
-23	-17.8	5.2	-7	10.8	39.9	57.2
-22	-16.8	5.2	-6.5	10.3	40.1	55
-21	-15.8	5.2	-5.8	10	39.2	54
-20	-14.7	5.3	-5.3	9.4	36.2	53
-19	-14.1	4.9	-5.2	8.9	33.8	50
-18	-13	5	-4.9	8.1	29.6	47
-17	-12.1	4.9	-4.6	7.5	26.1	45
-16	-11.1	4.9	-4.3	6.8	22.9	42
-15	-10.4	4.6	-4.3	6.1	20.8	34

Comparing the different linearity assessment tools, all three measurements show that as the power increases, the amplifier is compressing the signal and operating non-linearly. However, **only the crest factor method clearly reveals the amount of compression.** Although the there is a reduction in gain around -20 dBm, the gain is only reduced less than 1 dB. In contrast, the other linearity tools show much more significant compression for the peak power. Average power is not sufficient to identify significant impairments for signals with high crest factors; e.g., OFDM signals used in 5G.

The crest factor approach for linearity assessment provides:

- **Clearer indication of signal compression**
- **A lower cost alternative** (no need for expensive spectrum analyzers)
- **Simpler, less error prone measurements**
- **Higher accuracy** (power meters are more accurate than spectrum analyzers)