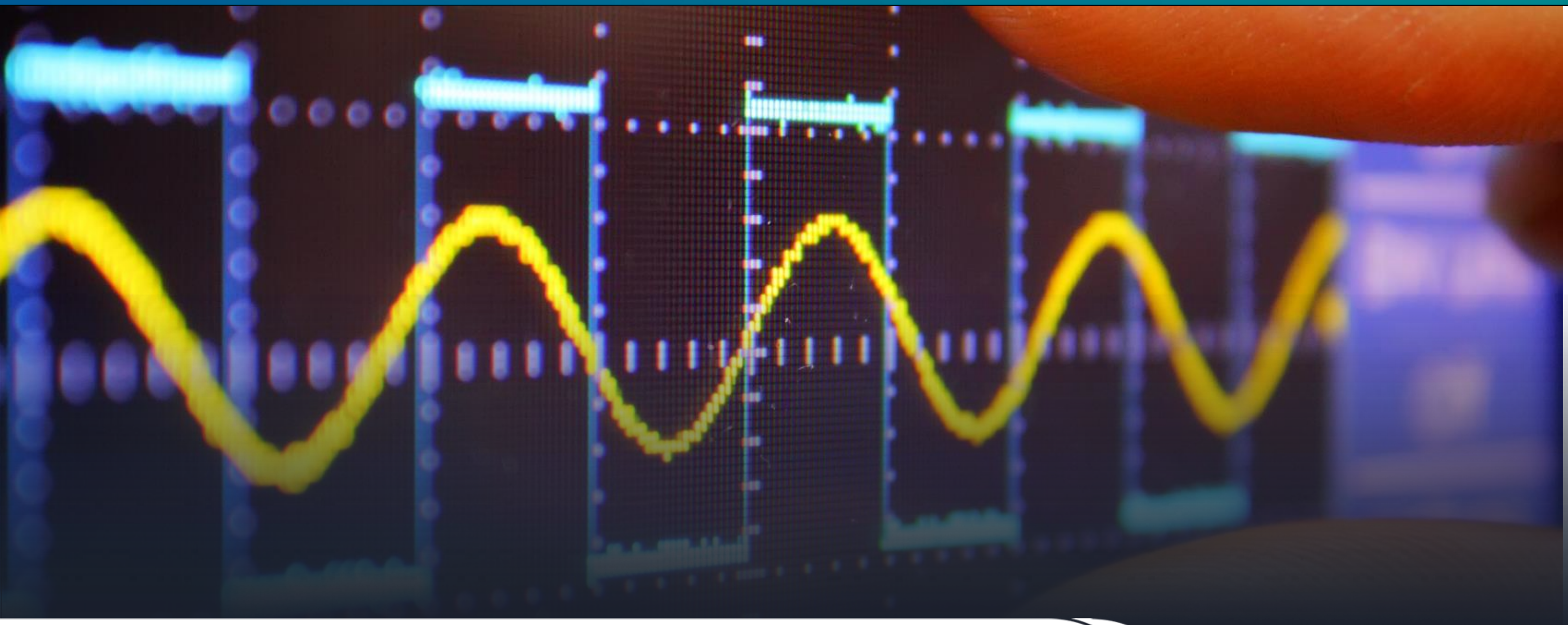


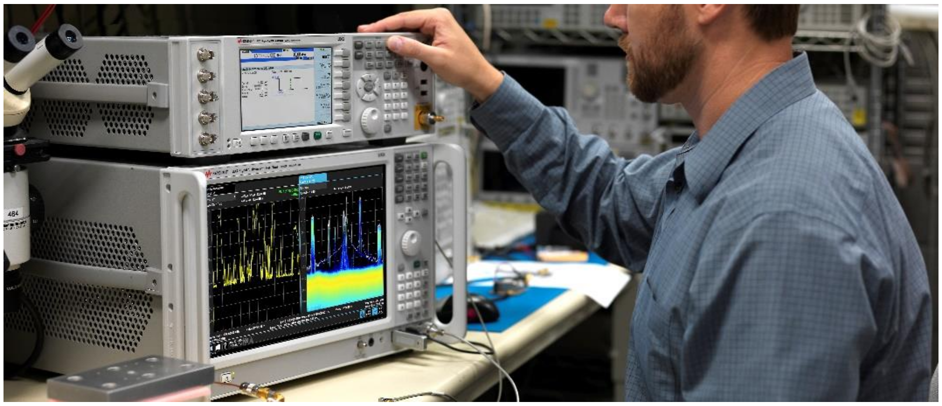
WHITE PAPER

Tactics for Improving Distortion Measurements

Optimize Signal Generator’s Performance

In today’s wireless communications and digital radio systems, frequency channel spacing is close to achieving spectral efficiency. Testing for unwanted and nonlinear spectral distortion is critical for narrow frequency channel spacing and wide bandwidth communication systems. Components, modules, sub-systems, and entire devices generate distortion. The distortion products might be in-channel, in-band, and out-of-band unwanted spectral signals. Distortion not only degrades transmitter performance but also the sensitivity of receivers.

Distortion performance is one of several significant specifications for signal generators and can have a considerable impact on device characterization. In this white paper, you will learn about the different types of distortion and why they matter to your RF measurements.



KEYSIGHT TECHNOLOGIES

What Is Distortion?

Distortion is the alteration of the original waveform. For a linear device, the input and output frequencies are the same; there are no additional frequencies created. The output signal only has amplitude and phase change. For a nonlinear device, the output may have a frequency shift or additional frequencies. Nonlinear distortion is typically unwanted, and R&D engineers strive to minimize it.

There are two major types of nonlinear distortion for a signal generation: Harmonic distortion and intermodulation distortion.

1. Harmonic distortion: The amplitude transfer characteristics of a circuit or device which prevents it from precisely tracking the input signal. It generates at integer multiples of the input signal frequencies.

2. Intermodulation distortion: This is a spurious output resulting from the mixing of two or more signals of different frequencies, whether created in the system or not. These outputs occur at the sum and difference of integer multiples of the input frequencies.

Distortion Measurements

Harmonic Distortion

Using a continuous wave (CW) tone is the most straightforward method for measuring harmonic distortion. A device under test (DUT) might be an amplifier or mixer. You may use a signal generator to provide the input signal and measure the output signals with a signal analyzer. It is important to use a signal generator with low harmonic distortion and to include a filter between the signal generator and the DUT to ensure measured harmonics come from the DUT, and not from the signal generator.

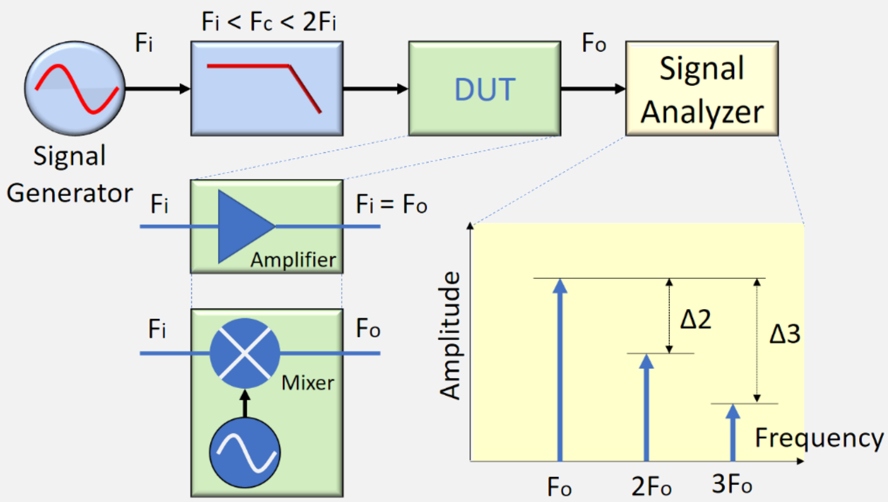


Figure 1. Harmonic distortion measurement setup

Figure 1 shows the harmonic distortion measurement setup. Harmonics are often specified using the so-called harmonic intercept point or the ∆2 as shown in Figure 1. For example, the second harmonic intercept (SHI) is for the second harmonic. Compute the output SHI power level as follows:

SHI (dBm) = DUT output power (dBm) + ∆2

where ∆2 (in dBc, positive value) is the delta amplitude between the fundamental signal and the second harmonic.

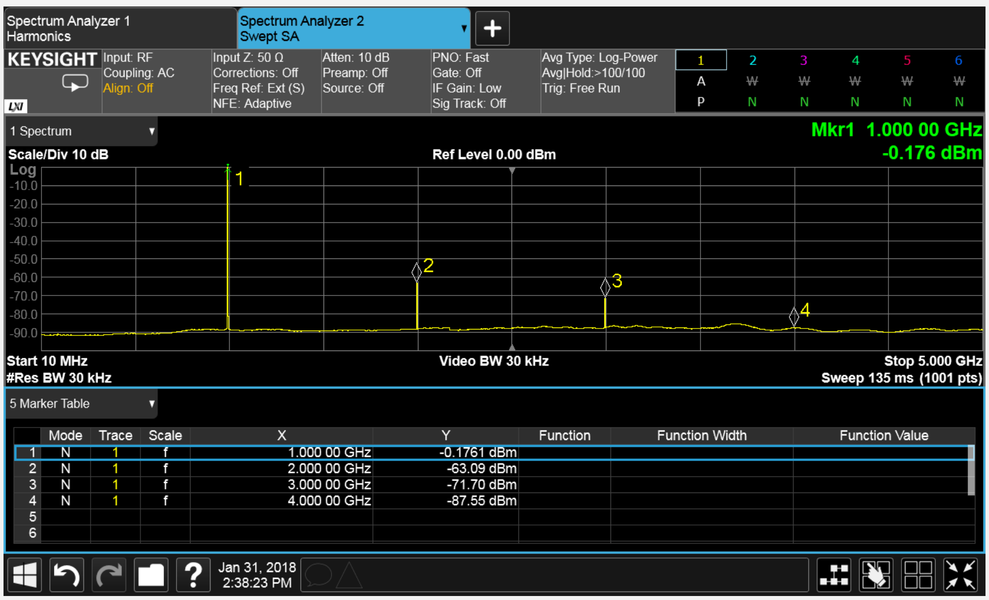


Figure 2. Harmonic measurement application on the X-series Signal Analyzer

The harmonic distortion of a signal generator and the dynamic range of a spectrum analyzer limit the quality of the harmonics measurement. However, the signal generator is often the limiting factor. Using a low pass filter can improve the source's effective harmonic distortion.

Intermodulation Distortion

Two-Tone Intermodulation

There are several techniques for evaluating intermodulation distortion. The easiest method for measuring intermodulation distortion is the two-tone third-order intermodulation technique known as IP3 (third-order intercept point). The IP3 measures the third-order distortion products generated from the nonlinear elements of the DUT with the two-tone input signals.

Figure 3 below shows the two-tone third order Intermodulation measurement setup. The device under test could be an amplifier or a mixer.

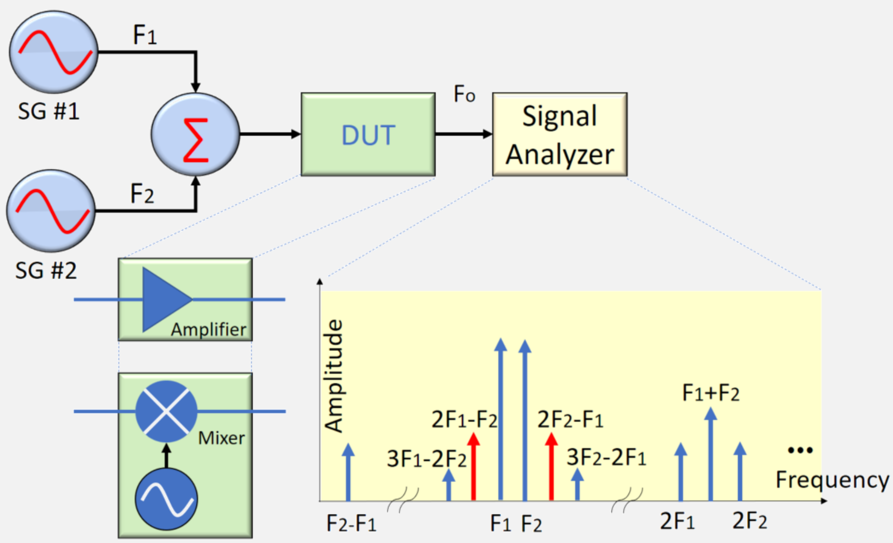
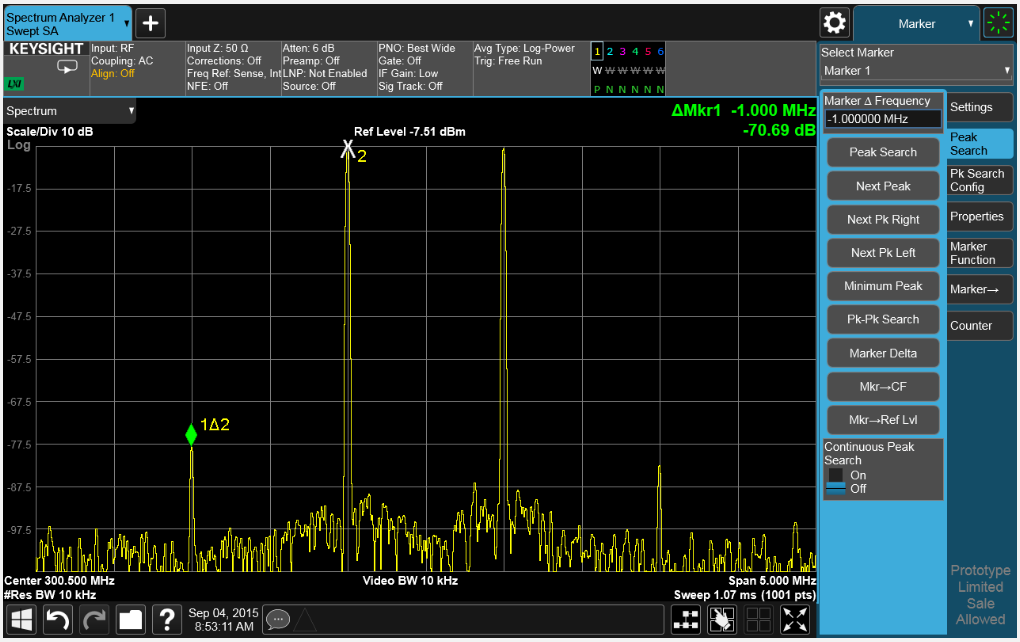


Figure 3. Two-tone intermodulation distortion measurement setup

F_1 and F_2 are frequencies of the two test tones from two signal generators. The two tones injected into the system must be free from any third-order products. The third order distortion products occur at frequencies $2F_1$-F_2 and $2F_2$-F_1 (noted in red) which are the closest distortion products to the original two test tones. Removing them with filtering is difficult. In a communication system, they could be interference signals to adjacent channels. Assuming the amplitudes of the two test tones are equal, the IP3 is the difference between the input tones and third order products.

IP3 (dB) = Po - Po_3

Where Po is the amplitude of one of the output tones and Po_3 (noted in red color) is the amplitude of the third order product on either side of the two tones.



Problems arise when the device under test has distortion product levels that approach the internally generated distortion product levels of the spectrum analyzer. For more info on optimizing dynamic range for distortion measurements, please refer to application note 5980-3079EN.

Figure 4. Measuring the distortion products

For production testing, it is possible to use only a vector signal generator to generate two test tones to reduce testing costs. However, the amplifier and mixer inside the signal generator also create intermodulation distortion products. These distortion products can be suppressed or minimized via measurements and baseband waveform correction.

N7621B Multitone Distortion Signal Creation

Key Features:

- Create distortion free two-tone and multitone test stimulus signals
- Configure a noise power ratio (NPR) test stimulus with up to 2 GHz noise bandwidth, > 60 dBc notch depth, and +/- 0.5 dB noise flatness
- Automatically apply pre-distortion using a spectrum analyzer to enhance signal quality and minimize test uncertainty

Spectral Regrowth

Wider bandwidths and multi-carrier techniques, such as carrier aggregation, are used broadly to increase data throughput for the latest wireless standards. Two-tone third order intermodulation technique does not completely characterize the behavior of wide-bandwidth components. Digital modulation that uses both amplitude and phase shifts generates distortion, also known as spectral regrowth. Figure 5 shows the spectral regrowth (red area) of a digital modulation signal.

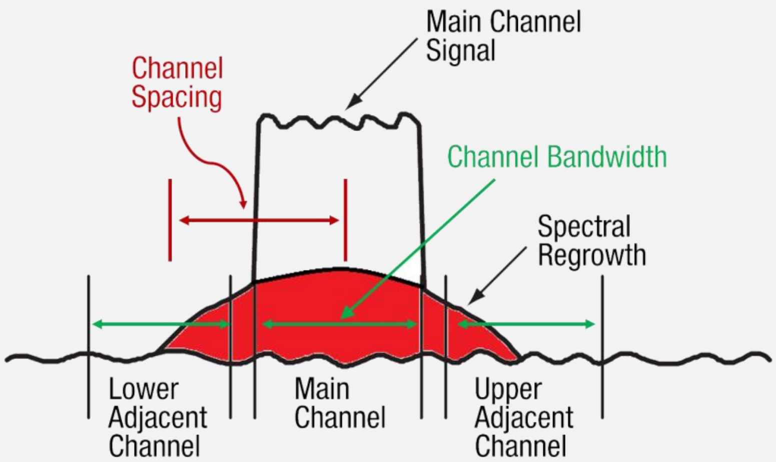


Figure 5. Spectral regrowth of a digital modulation signal

The spectral regrowth spreads outside of the main channel. Adjacent Channel Power Ratio (ACPR) measurement is used to examine this type of distortion. It measures the ratio of the main channel power to the power that falls into adjacent channels. The ACPR measurement is a key transmitter characteristic in most cellular conformance specifications. To perform ACPR measurement, you need a signal generator with an ultra-low distortion performance to generate a specific standard-compliant test waveform.

Table 1 below shows the 3GPP LTE-FDD distortion performance of the Keysight N5182B vector signal generator. For the eNB power amplifier test, the adjacent channel leakage ratio (ACLR) test requirement for R&D verification is about -60 dBc at 10 MHz channel offset. Here MXG gets a typical value of -69 dBc. The performance of Keysight’s N5182B instills confidence that the results of ACPR measurement are from the DUT, and not from the signal generator.

3GPP LTE-FDD Distortion Performance								
			Standard		**Option UNV**		**Option UNV with Option 1EA**	
Power level			≤ 2 dBm		≤ 2 dBm		≤ 5 dBm	
Offset	**Configuration**	**Frequency**	**Spec**	**Typ**	**Spec**	**Typ**	**Spec**	**Typ**
Adjacent (10 MHz)	10 MHz E-TM 1.1 QPSK	1800 to 2200 MHz	–64 dBc	–66 dBc	–67 dBc	–69 dBc	–64 dBc	–67 dBc
Alternate (20 MHz)			–66 dBc	–68 dBc	–69 dBc	–71 dBc	–69 dBc	–71 dBc

Table 1. 3GPP LTE-FDD distortion performance of MXG vector signal generator

For testing components, it is preferable to start with a stimulus signal that has the best possible performance for error vector magnitude (EVM) or ACLR so that any degradation caused by the DUT is determined. Keysight Signal Studio software offers different options for filtering that allow users to modify the EVM and ACPR characteristics of the signal. The examples in Figures 6a and 6b show the result when using different types of filtering.

Figure 6a. LTE 5 MHz E-TM 1.1 signal with default baseband filter — best ACLR

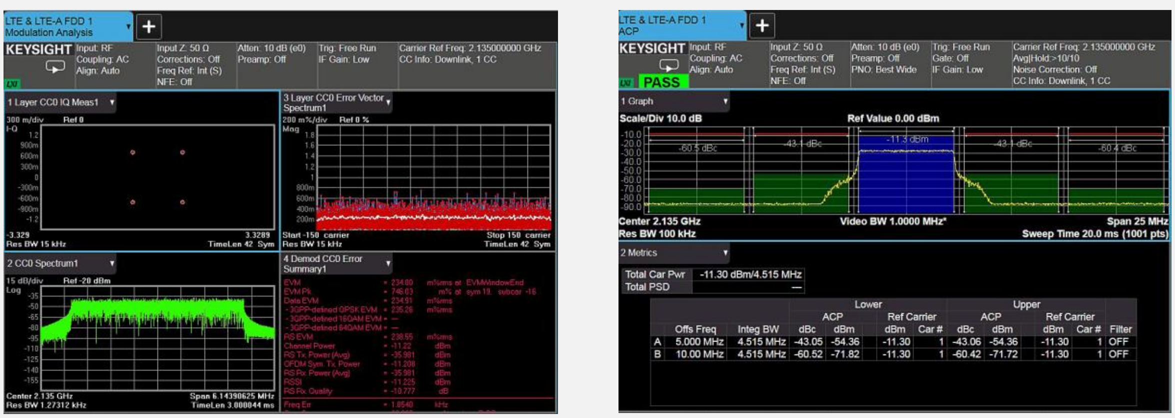


Figure 6b. LTE 5 MHz E-TM 1.1 signal without baseband filter and symbol rolloff length = 20 Ts —best EVM

Conclusion

Characterizing the distortion performance of a transmit amplifier requires a stimulus test signal with low distortion that will not mask the amplifier's actual performance. The datasheet of a signal generator specifies both harmonic distortion and ACPR for the specific wireless standard. It is important to choose a signal generator with a superior distortion test margin to obtain accurate distortion measurements.

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