application note 117

TESTING AMPLIFIER LINEARITY WITH NOISE POWER RATIO (NPR)

Serious dynamic range problems occur in systems loaded with multi-channel signals. Any non-linearity in the system (e.g., amplifier) causes intermodulation products among the input frequencies. This produces new frequencies that may fall within the bandwidth of other channels, creating distortions. The amount of distortion increases with the number of channels and the degree of amplifier saturation.

For example, two uncorrelated tones may, at times, add in-phase to create peak voltages that are about 6 dB higher than the RMS voltage. The peak-to-RMS voltage ratio, defined as the "crest factor," increases by 10log(2n) dB, where n is equal to the number of uncorrelated signals of the same amplitude. In the limit, the resulting random voltage distribution approaches a Gaussian function. Therefore many uncorrelated signals can be simulated by white Gaussian noise. This is the basis for noise power ratio (NPR) testing. The NPR method is an accurate means of reproducing multi-carrier intermodulation effects and determining the amplifier's performance under different loading conditions.

Why NPR Testing?

A long-standing test of intermodulation distortion is the two-tone test. Here, two in-band signals, usually of the same amplitude, are injected into the amplifier, and the third order product amplitude is measured. However, this test has many shortcomings for a system that is loaded with many signals. First, the distortion product amplitude may be dependent on the frequency spacing of the input signals. Second, the amplifer will perform differently when loaded with many signals, as opposed to just two signals. The peak-to-average ratio of multiple modulated signals is much greater than two or several tones. These large peaks stress the amplifier or device under test (DUT) to a greater degree.

In the limit as the number of signals increases, the aggregate signal approaches white Gaussian noise. The NPR method emulates many signals by loading the amplifier with white Gaussian noise. In this way, all combinations of carrier frequency spacings are taken into account, and a true worst-case measurement is made.

Intermodulation distortion manifests itself in two primary ways. In a receiver LNA, adjacent channel signals cause in-band distortion products. For a transmitter power amplifier, distortion of the primary

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signal will cause interference in adjacent channels, a phenomenon known as spectral regrowth. Both cases are closely related and can be accounted for with the noise power ratio (NPR) test.

NPR is a measure of distortion produced in a particular band by a device that is loaded with white noise. Measurement of NPR versus output power, or loading, is used to define the optimum operating point for maximum signal-to-noise ratio (SNR). The NPR of a DUT is degraded primarily by two factors. One is the distortion products that are produced under high loading conditions. The second is the noise floor of the amplifier that will become dominant under very low loading conditions.

By making numerous such measurements at different loading levels, a curve will be generated as shown in Figure 1.

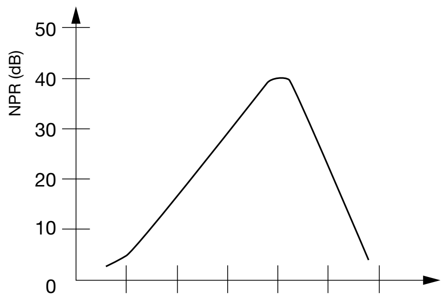

Figure 1. Plot of NPR vs. loading condition to determine optimum loading level.

The NPR is poor at low loading levels because the amplifier is being operated near its own noise floor. This noise is also known as the intrinsic noise. The NPR will improve approximately 1 dB for every 1 dB the loading level is increased above the intrinsic noise.

The NPR is also poor at very high loading levels. But the slope on this side of the curve is steeper since the distortion products are dominant in this case. And if the distortions are caused by nth-order harmonics, then the intermodulation products increase by (n-1) dB for every 1 dB increase in the loading level. For example, for third-order distortions, the intermodulation products increase 2 dB for every 1 dB increase in the loading level. Systems are often operated at signals a few dB below the point of maximum NPR.

Automate NPR Measurements with UFX-NPR

The UFX-NPR Series instruments simulate a dense signal environment by using broadband white noise to test the amplifier's dynamic characteristics. The NPR test measures the amplifier's aggregate intermodulation performance and its noise floor. This defines the maximum spurious-free dynamic range in a multi-channel environment.

To perform the test, an accurate level of white Gaussian noise is applied to the amplifier. A bandstop (notch) filter is then inserted to create a "quiet" channel. The NPR is the ratio between the noise power measured without the notch filter to that measured with one inserted (see Figure 2).

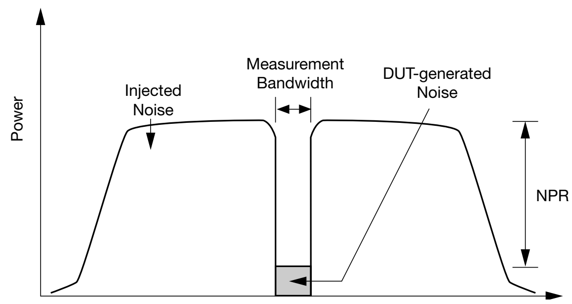

Figure 2. Output noise spectrum during NPR measurement.

Covering frequency bands between 50 MHz and 40 GHz, the UFX-NPR simplifies NPR testing by automatically sweeping the output power between user-entered start and stop levels, with up to 25 steps of noise output power for data generation of NPR curves. The results are stored and the optimum loading condition is automatically identified. The result can be viewed on the front panel or transferred via the IEEE-488 interface.

The procedure for operating the UFX-NPR is as follows:

1. Select bandstop/bandpass filter set
2. Select output power
3. Press "START" – The measured NPR is displayed on the front panel
4. To make additional NPR measurements, increase or decrease the output power and press "START" again

For more information on the UFX-NPR Series, see pages 14-15.