APPLICATION NOTE

Better Satellite Link Distortion Testing Using Spectral Correlation Method

Introduction

Like ground-based systems, the capacity and complexity of space-based communications is growing exponentially. System designs are being pushed to their limits as the need for greater capacity leads to faster data rates and higher bandwidths. As always, signal power is a key metric, and the need for more power across wider channels means that power amplifiers spend more time inside their non-linear operating region. The result of this is signal distortion, and systems designers need to find ways to either reduce this distortion or work around it. Making accurate, insightful measurements of this distortion is the first step in solving the problem.

As satellite links go to wider channels and higher powers, link designers need to account for larger amounts of non-linear distortion. Making more accurate and intuitive distortion measurements is a key to improving link performance.

A New Distortion Measurement

System designers rely on three key metrics (NPR, ACPR and EVM) to describe the wideband distortion in their components or systems. Noise Power Ratio (NPR) is most commonly used for components like power amplifiers. The interaction of the many frequencies in the NPR test signal creates distortion products in an unused area of the signal (the “notch”), and the change in this energy gives a relative measure of the non-linear distortion in the system. Adjacent Channel Power Ratio (ACPR) is a frequency-based measurement but shows the spectral regrowth outside the main signal. The third key metric, Error Vector Magnitude (EVM), is based in the symbol domain and shows the movement of a symbol off the intended target due to any combination of distortion, modulation error, phase noise and other factors.

Figure 1: Standard Noise Power Ratio

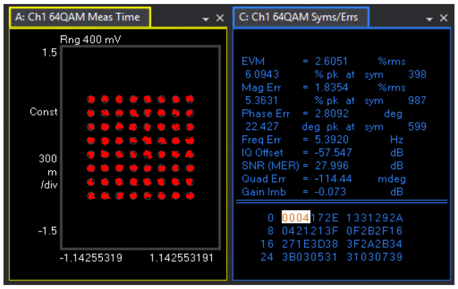

Figure 2: EVM Measured in Symbol Domain

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Each of these methods is useful, but none provides a complete picture. The test signal for NPR has a standard form, which makes it useful for comparing components, but may not show the distortion for a real-world signal. On the other hand, EVM tests use a real-world signal, but the measurement is made on the whole system up to the receiver, making residual EVM component measurements very difficult.

A new method, developed for the PNA-X Vector Network Analyzer by Keysight Technologies, uses Spectral Correlation to isolate and measure the distortion of only the device under test (DUT) using real-world test signals, and provides NPR, ACPR and EVM values from this measurement.

Modulation Distortion Option 93970xB

The new Modulation Distortion option for the Keysight PNA-X Vector Network Analyzer enables this measurement. This option is available for all versions of the N524xB PNA-X Vector Network Analyzer and, as a firmware option, can be added to all units which meet the minimum hardware requirements.

Spectral Correlation

The Modulation Distortion measurement is based on a method called spectral correlation which takes advantage of the architecture of the PNA-X to measure the distortion at the input and output of the DUT and uses this information to isolate the contribution of the DUT. The distortion is further divided into three parts: the linear frequency response (S21), the compression distortion, and the non-linear distortion. The compression distortion is the change in S21 due to compression in the component. The non-linear distortion component is the measurement of the distortion due to the mixing and interaction of the different frequencies within non-linear distortion does not. In this way, using mathematical correlation the two effects can be distinguished.

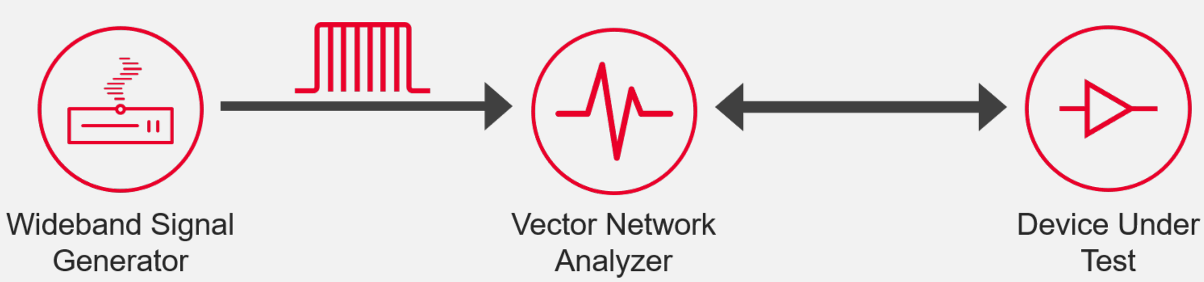

Figure 3: External wideband source provides test signal to DUT through VNA

Use Real-world Signals for NPR Testing

With this new method, the input and output to the DUT are continually measured and compared, so it is easy to isolate and remove imperfections in the test stimulus. The obvious benefit from this is the ability to make residual measurements of components independent of any distortion from the wideband source. But another benefit is a new freedom in choosing a test signal. For example, with the NPR test we are no longer constrained to a pedestal/notch test stimulus with a Gaussian power distribution. A real-world communications signal like a single carrier QAM signal or a 5G candidate signal like UFMC can be used as the test stimulus, showing distortion values for the component as it will be used:

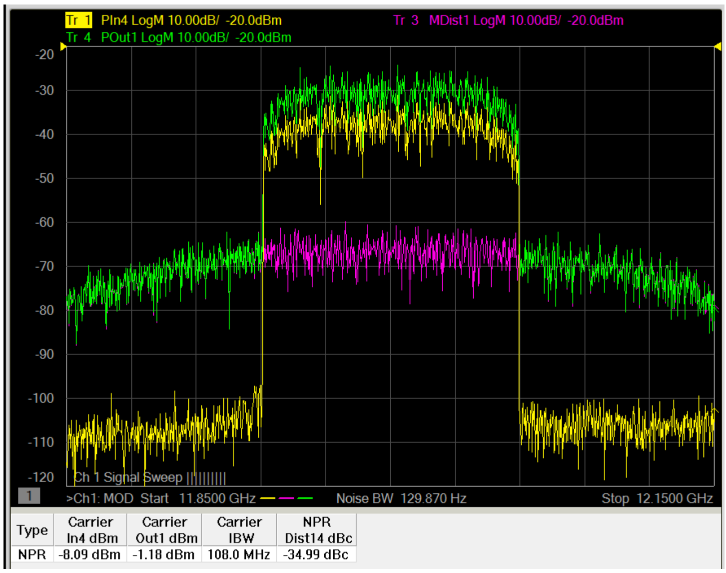

Figure 4: An NPR Test Made with a Compact 64-QAM Signal as the Test Stimulus

Figure 4 shows an NPR measurement made with a 64-QAM signal as the stimulus. The yellow trace shows the input to the DUT, and the green trace shows the output, with the expected spectral regrowth and distortion. The pink trace is the distortion measurement, calculated from the input and output using the spectral correlation method. Within the bandwidth of the signal, this trace represents where the NPR notch floor would be and comparing this trace to the output trace will give an accurate NPR value. Outside the bandwidth of the signal, the distortion trace perfectly overlays the spectral regrowth, showing that the ACPR is the result of this distortion.

Although the distortion appears to be noise-like, it is entirely stable and repeats with every trace refresh. This noise-like appearance is contained in the stimulus signal, but since the input and output are compared for each measurement, unlike previous methods, there is no fluctuation in the measured values. And unlike symbol-based EVM measurements no prior knowledge of the parameters of signal is needed.

Best Residual EVM

This distortion information will also give a value for RMS EVM by comparing the total distortion to the total signal energy. Because the input and output are always compared, the EVM contribution of the stimulus signal is removed, and the resulting measurement is the most accurate Residual EVM measurement available today.

Compare Wideband Signals

With this method, NPR, ACPR and EVM tests can be performed using any modulated signal, including custom OFDM and 5G candidate signals like UFMC and GFDM. Like single-carrier signals the different power profile and CCDF of the 5G signal will give a different value for NPR and ACPR, showing that these values depend not only on the average power level but also the power distribution. In this way, the performance of the amplifier with different 5G candidate modulation schemes (or with any signal) can be shown, improving the accuracy and efficacy of system simulations.

Conclusion

The new spectral correlation measurement method in the Modulation Distortion option uses the power of the PNA-X Network Analyzer to make faster, more accurate and more repeatable residual NPR, ACPR and EVM distortion measurements using a wider range of test signals and providing new insight into the performance of each component.

References

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2. PNA-X Help File: available at http://na.support.keysight.com/pna/help/index.html

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