HIGH SPEED NOISE POWER RATIO MEASUREMENT TECHNIQUES ON RF POWER AMPLIFIERS

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ABSTRACT

The Noise Power Ratio (NPR) measurement is a growing requirement for power amplifiers used in the wireless and satellite industries. This measurement is time consuming and difficult to implement in a high volume production environment. A high speed NPR measurement technique is presented and compared to traditional manual NPR measurements.

INTRODUCTION

Noise Power Ratio measurements are becoming an important way to verify RF power amplifier distortion performance. This specification is applied to RF circuits for new cellular systems and low earth orbiting satellite networks. NPR is a key distortion specification when the RF circuit is designed to operate in a system where the entire RF communications channel passes. It is crucial that the RF device does not introduce spectral splatter in the form of intermodulation distortion that reduces the signal to noise and distortion ratio in adjacent channels. The NPR measurement verifies this characteristic under real RF drive conditions. Correlation of NPR to other measurement parameters such as gain, output power, TOI has not been demonstrated for all cases and must be measured when specified.

DC	RF
Idd_1	S11 Mag (4 Freq)
Idd_2	S21 Mag / Phase (4 Freq)
Ig_1	S22 Mag (4 Freq)
Ig_2	Gain Flatness
	IMD3 (1 Freq)
	Noise Figure (4 Freq)
	Noise Power (1 Freq)
	NPR (1 Freq)

Table 1. Power Amp Measurements.

Noise Power Ratio measurements have traditionally been done in the R&D environment or in low volume production. The RF wireless and satellite marketplaces are expanding and thus the NPR test requirement is growing rapidly. With the target price of RF devices at or below $10/device and the volume of RF circuits required by these market places growing, the test times for these RF devices needs to be reduced. The NPR test time is a large percentage of the overall measurement test time even when NPR is only one test of many required in power amplifier production measurement as shown in Table 1.

A method for reducing the NPR test times on power amplifiers in a high volume production environment is shown. The production test times using this new measurement technique are reduced by over 85%. This method involves using a digitized NPR signal source and a high speed digitizer as the measurement receiver. The high speed digitizer takes the place of the spectrum analyzer and power meter in the traditional setup.

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TRADITIONAL NPR MEASUREMENT

In the traditional method, the spectrum analyzer is required to sweep across the frequency band of interest before the results can be displayed. This setup is shown in Figure 1. In this figure there is one signal source and two measuring instruments. The NPR signal is generated with a arbitrary waveform synthesizer allowing flexible settings for the total noise bandwidth, notch bandwidth, noise power, and frequency. The NPR signal is amplified with an ultra linear

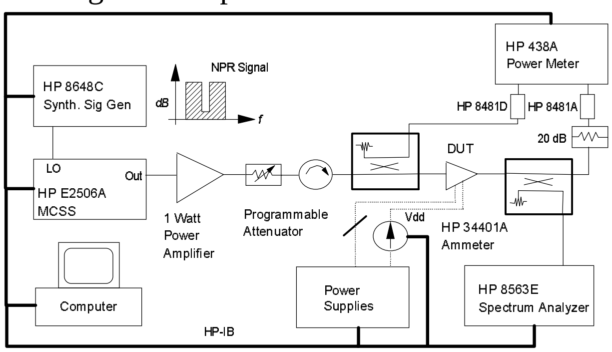

Figure 1. Traditional NPR Measurement Setup

amplifier allowing the total power presented to the device under test (DUT) to be at levels required to test NPR. The total incident power is monitored with an average power meter to determine the input power to the DUT as NPR is typically dependent on the input power. The transmitted power of the DUT is also monitored with the average power meter to determine output power and gain. The spectrum analyzer is used to measure the NPR by measuring and ratioing the power in a set bandwidth inside and outside of the notch. The spectrum analyzer settings are optimized for the measurement of noise in a given bandwidth.

The process of measuring NPR on RF power amplifiers is shown in Figure 2. After the DUT has DC bias applied, the quiescent current is measured with no RF signal applied. Once this current is determined, the total input noise power

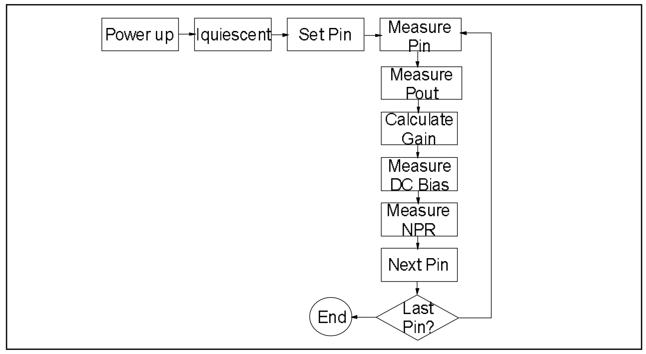

Figure 2. NPR Measurement Flow Chart.

is set for measuring NPR. The output noise power is measured to allow for the gain to be calculated. The noise loaded DC bias currents are measured to allow for the calculation of power added efficiency. The NPR is measured with the spectrum analyzer for the given input power. The input power is stepped to the next power level and the process is continued again until the highest required input power is applied to the DUT. When this process is followed and automated, the time for one NPR measurement is 15 seconds. Typically RF power amps are tested at multiple bias conditions and input power levels. For example, an amplifier might be tested at 4 bias conditions with 11 different power levels. If S-Parameter measurements are needed, a second measurement pass is required with a network analyzer adding to the overall production measurement time.

HIGH SPEED NPR MEASUREMENT

High speed NPR measurements are accomplished by changing the measuring instruments and by changing the step attenuator in front of the NPR source. The measuring instruments are combined into a single calibrated high speed digitizer. When the high speed digitizer is used, the entire spectrum can be captured at once instead of in a swept fashion like the spectrum analyzer. A typical setup is shown in Figure 3. In this

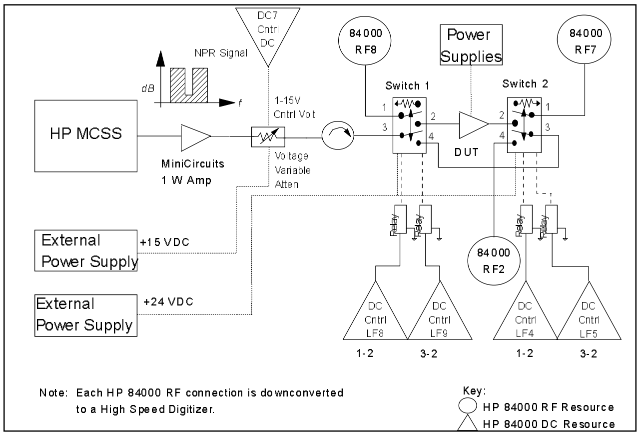

Figure 3. High Speed NPR Measurements

configuration, the arbitrary waveform synthesizer or HP MCSS is used to generate the NPR waveform. An ultra linear power amplifier is used to get the power levels acceptable for testing NPR on the DUT. A voltage variable attenuator is used to allow for the instantaneous power to be varied by the test system. This NPR signal is routed through RF switching into one of three RF inputs to the HP 84000. This will allow for the input power, output power, and NPR to be tested by the same measuring instrument. The HP 84000 DC resources are used to control the RF switch positions and voltage variable attenuator setting. The high speed digitizer in combination with downconversion has the ability to acquire signals up to 1.5 Mhz in bandwidth located in frequency from 10 Mhz to 18 Ghz. This high dynamic range digitizer with digital signal processing allows for the signal to displayed in the frequency domain like a spectrum analyzer, except that the signal is captured in 1.5 Mhz segments.

This concept is crucial to reducing the test times when NPR is measured multiple times on a power amplifier to determine the sensitivity of NPR to input power. Using a high speed digitizer with FFT capability, allows all of the RF measurements as shown in Table 1 to be made with one measuring receiver instead of with multiple measurement instruments as in the traditional setup. The NPR test times using this new technique are reduced from 15 seconds to less than 2 seconds plus the reduction in the number of production test passes from 2 to 1. Figure 4 shows NPR measurements on 516 power amplifiers using the high speed measurement technique for a single output power level.

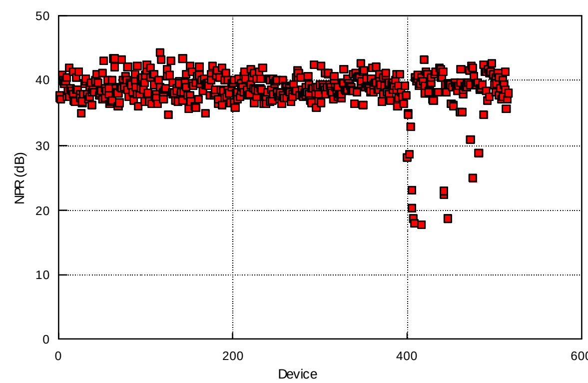

Figure 4. NPR Measurements on 516 DUTs.

NPR MEASUREMENT COMPARISON

The two NPR measurement techniques are compared for their accuracy's and correlation. One correlation issue involves the overall bandwidth of the NPR signal. The measurement bandwidth of the high speed digitizer is determined by its sampling clock where the spectrum analyzer or power meter is capable of measuring in its complete frequency measurement bandwidth. In this measurement setup, the high speed digitizer is limited to 1.5 MHz. Table 2 shows measurements taken correlating the total noise power as measured with a power meter and total noise power as measured with the high speed digitizer as the NPR bandwidth is increased above 1.5 MHz. The total noise power measured correlates with the theoretical within the measurement uncertainty limit. The theoretical delta is calculated by taking the difference between the noise power in a 1.5 Mhz bandwidth compared to the noise power in the true signal bandwidth. Knowing the total absolute power is important when setting the input noise power to the power amplifier.

NPR BW	Notch BW	Power Meter	HP 84000	Delta	Theoretical Delta
1 Mhz	200 Khz	-15.67 dBm	-15.71 dBm	0.04 dB	0 dB
2 Mhz	400 Khz	-12.68 dBm	-14.36 dBm	1.68 dB	1.63 dB
4 Mhz	400 Khz	-9.29 dBm	-14.47 dBm	5.18 dB	5.15 dB

Table 2. Total Power Comparison.

The accuracy of NPR is highly dependent upon measurement of noise loaded input and output powers. NPR is dependent on determining the absolute output noise power level. Due to the gain variation in the amplifiers under test, different input noise power levels are required to get the same output noise power. Typically, the critical region of performance for these amplifiers has a NPR to Power out (Pout) slope of 3:1. Any error in the measurement of Pout

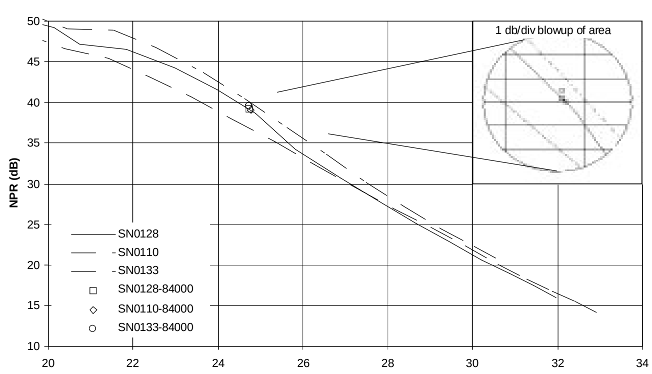

Figure 5. NPR Measurement Comparison.

due to de-embedding, fixtures or cable losses can lead to large NPR errors at the stated output noise power level. For example, if the total noise power measurement is in error by 0.25 dB, then the NPR can be as much as 0.75 dB in error.

Figure 5 shows a comparison of three PCS power amplifiers measured with both NPR measurement methods. The lines show the traditional measurement technique and the single power level NPR measurements show the high speed NPR technique. It is noted that all three high speed technique measurements are within 0.5 dB of each other and have a maximum error of 2.3 dB with an average error of 1 dB in NPR from the traditional measurements.

CONCLUSION

Noise power ratio measurements can be made in a production environment with a high speed digitizer that correlate well to traditional spectrum analyzer measurements. This new technique significantly reduces the test times and reduces the number of production test passes down to one pass for full parametric and functional test of RF power amplifiers. A correlation has be shown that allows NPR measurements to be made on signals that have a wider bandwidth than the high speed digitizer. This technique has been tested on signal bandwidths up to 4 Mhz and would have to be benchmarked for wider bandwidths. The ability to accurately measure the total noise power dramatically effects the NPR curves generated by the measurements. Any error in the noise power readings gets multiplied in the NPR measurement.

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