# NOISE POWER RATIO MEASUREMENT TUTORIAL

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## Introduction

The performance of high power amplifiers with many carriers (>10) is normally tested using a noise power ratio (NPR) measurement. In this test white noise is used to simulate the presence of many carriers of random amplitude and phase. The white noise is first passed through a bandpass filter (BPF) to produce an approximately square spectral pedestal of noise of about the same bandwidth as the signals being simulated. This signal is then passed through a narrow band-reject filter to produce a deep notch at the center of the noise pedestal as shown in Figure 1.

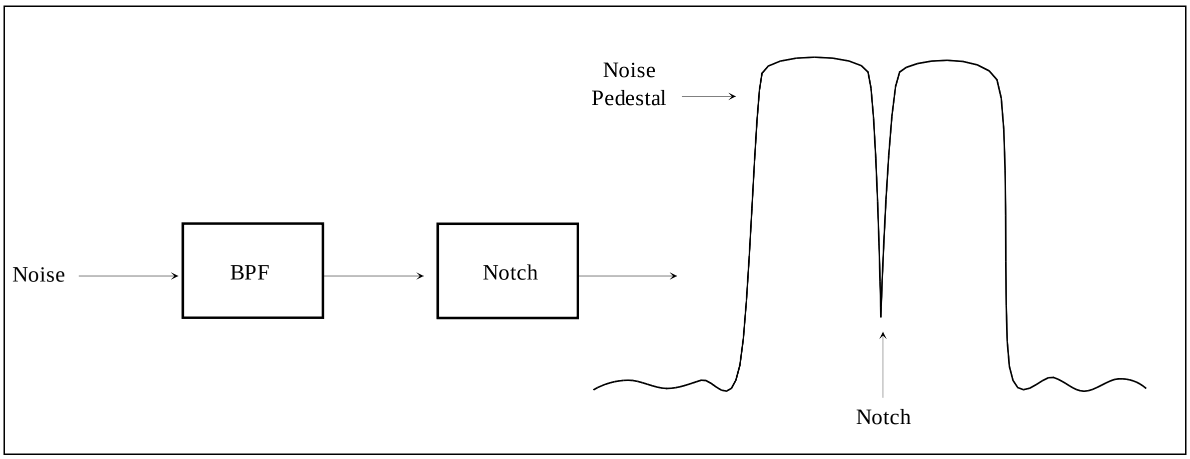


**Figure 1. An NPR test generator consists of a white noise source connected in cascade with a bandpass filter and a notch filter. The notch depth can be measured with a Spectrum Analyzer.**

This noise signal is used to excite the test amplifier. Amplification will produce IMD products, which tend to fill in the notch. The depth of the notch at the output of the amplifier can be observed with a spectrum analyzer, and is the measure of the NPR.

NPR can be considered a measure of multi-carrier intermodulation ratio (C/I). NPR differs from multi-carrier C/I in that it is the ratio of carrier plus intermodulation to intermodulation (C+I/I). At higher ratios (C/I > 20 dB), the two measures will approach the same value.

## Test Hardware Considerations

The bandwidth of the noise source should be much wider the bandwidth of the BPF to insure the statistical distribution of the noise power resembles a random phase multi-carrier source. The width of the noise pedestal is usually made equal to bandwidth of the channel under test. In theory the NPR measured should be independent of the noise pedestal's bandwidth. In practice so called amplifier "memory effects" may cause NPR to degrade over wider bandwidths. The width of the notch should be about 1 percent or less of the width of the noise pedestal. A picture of an actual NPR noise pedestal and notch details as viewed on a spectrum analyzer is shown in Figure 2.

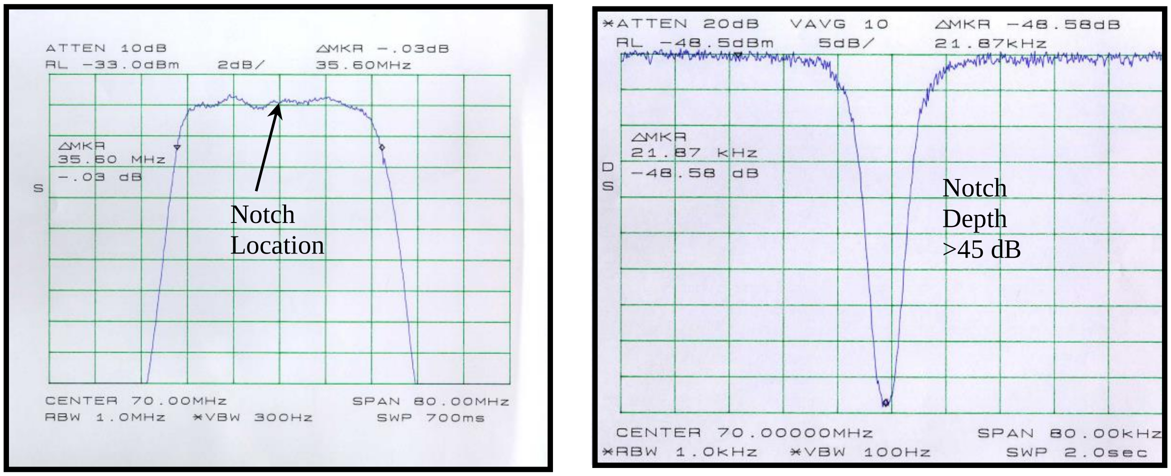

**Figure 2. Actual NPR test signal as viewed on a spectrum analyzer**

NPR test signals are usually generated at IF and upconverted to the microwave band of interest. Care must be taken to ensure this process does not degrade the notch depth. In wideband NPR testing, the noise figure of the amplifiers can often limit the maximum NPR measured.

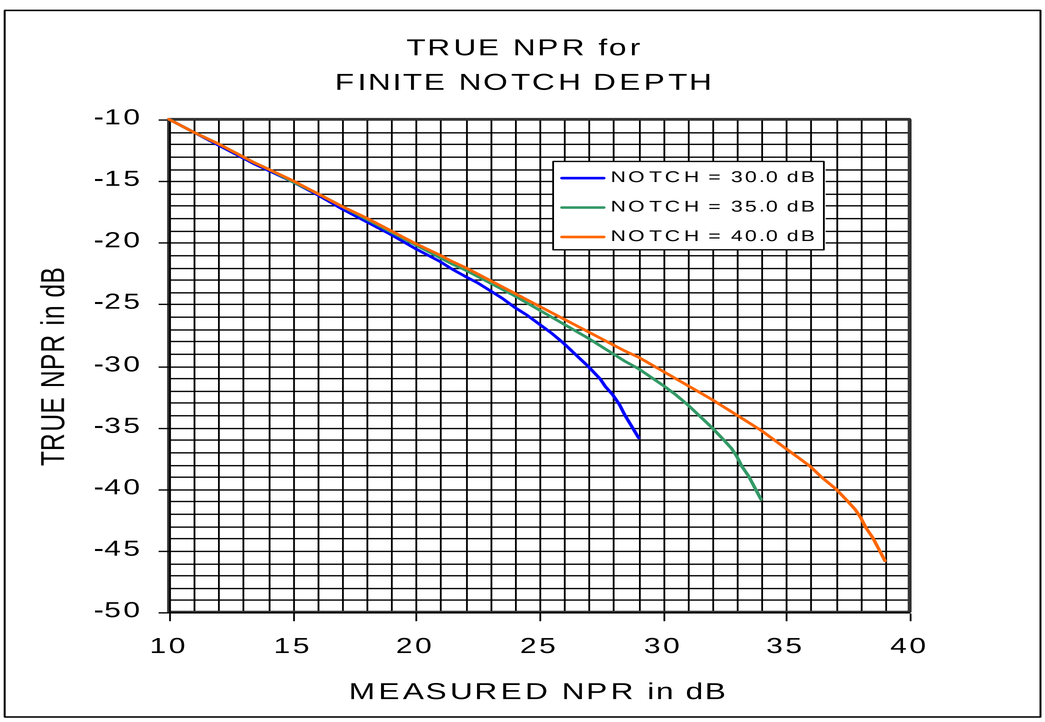

**Figure 3. Correction chart for true NPR for finite notch depth**

A systematic error is introduced when the measured NPR is close to the depth of the test-set notch. This error is most significant when the bottom of the measured notched is within 10 dB of the test-set notch depth or of the spectrum analyzers noise floor. This error can be corrected with the use of the following correction.

$$NPR = 10\ LOG(10^{-(NPRm/10)} - 10^{-(NPRt/10)}) ,$$

where NPRm is the measured NPR and NPRt is the NPR of the test signal. This relationship is plotted in Figure 3. As NPRm approaches NPRt measurement precision will be degrading even when the correction is used.

Another common source of NPR measurement error involves improper choice of the reference level for the notch depth. Notch depth should be measured relative to the average pedestal power level. When the top of the pedestal is rippled or titled, the proper reference level should be determined by averaging the changing levels across the top of the pedestal. Care should be taken to ensure the pedestal level near the notch corresponds to this value. If it does not, an appropriate correction factor should be added to the observed notch depth.

**Bounds on Amplifier NPR**

All real amplifiers have some maximum output power or *saturation* level. Once an amplifier has saturated, it is impossible to obtain more output power by driving the amplifier harder. Maximum linearity is achieved when an amplifier maintains a constant gain (and phase) to saturation, and a constant output level beyond saturation. This response is referred to as *ideal limiter*.

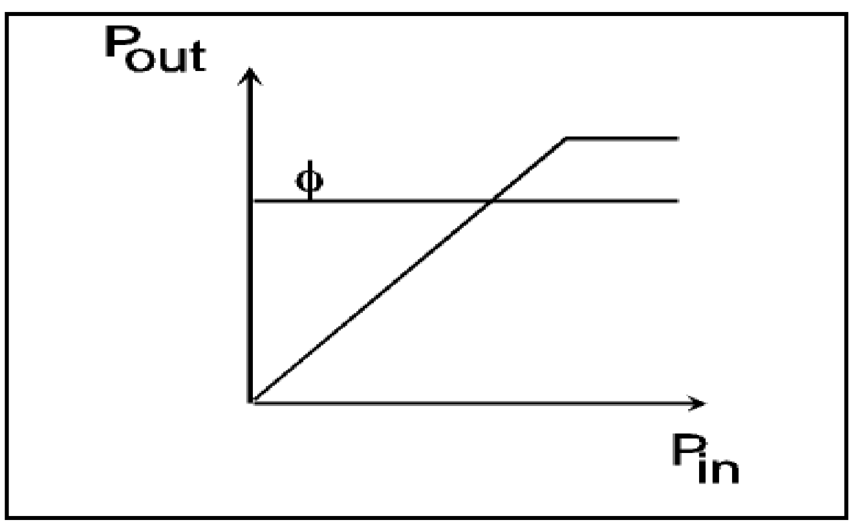


**Figure 4. An ideal limiter maintains constant gain and phase to saturation.**

Figure 5 shows the 2-tone C/I and NPR achievable by an ideal limiter characteristic. This linearity is the best an amplifier can produce and set an upper bound on the improvement linearization can produce. Note the 2-tone C/I goes to infinity for an output power backoff (OPBO) from saturation of greater than 3 dB. This result occurs because the peak-envelope-power (PEP) of a 2-tone signal is 3 dB greater than its average power. A signal backed-off by more than 3 dB never experiences clipping at saturation, and is subject to only a linear response. However, to achieve this same level of performance with a larger number of carriers requires a greater level of OPBO. This is a consequence of the increase in peak-envelope-power (PEP) with carrier number:

$$PEP = NP_{av}$$

where N is the number of carriers and $P_{av}$ is the average power of the overall signal. For 4 carriers the OPBO for no IMD, increases to 6 dB.

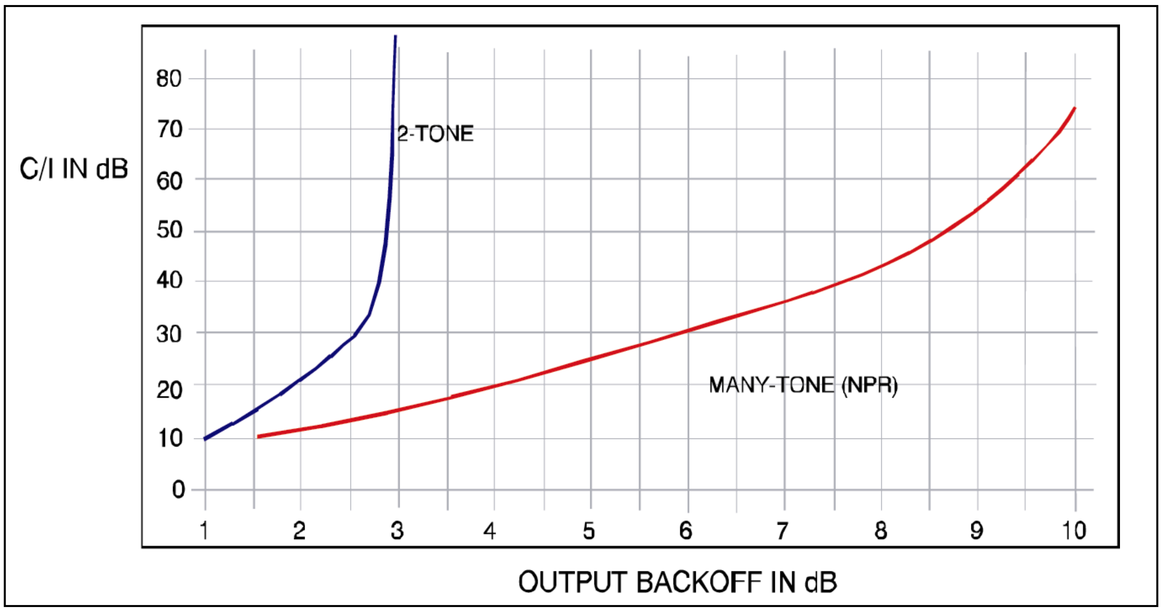


**Figure 5. C/I of an ideal limiter for 2 and an infinite number of carriers (NPR).**

## <u>Measured NPR of Amplifiers</u>

The NPRs of a typical TWTA and a linearized TWTA are shown in Figure 6. For an NPR ratio of 25 dB, the addition of a linearizer provides more than a 4 dB increase in amplifier power. This value is great than the corresponding increase in power for a 2-carrier test at the same C/I ratio. In general, the greater the number of carriers, the greater is the output power advantage of linearization for a given C/I ratio. In Figure 5 similar NPR measurements are shown for a class AB SSPA. At an NPR of 25 dB approximately the same improvement in output power is achieved by linearization.

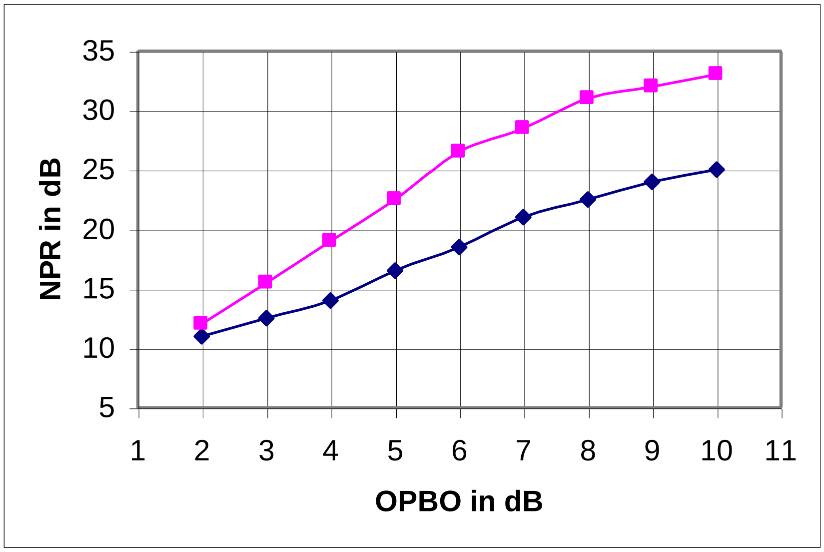


**Figure 6. NPR predicts the improvement provided by linearization of a TWTA with many carriers.**

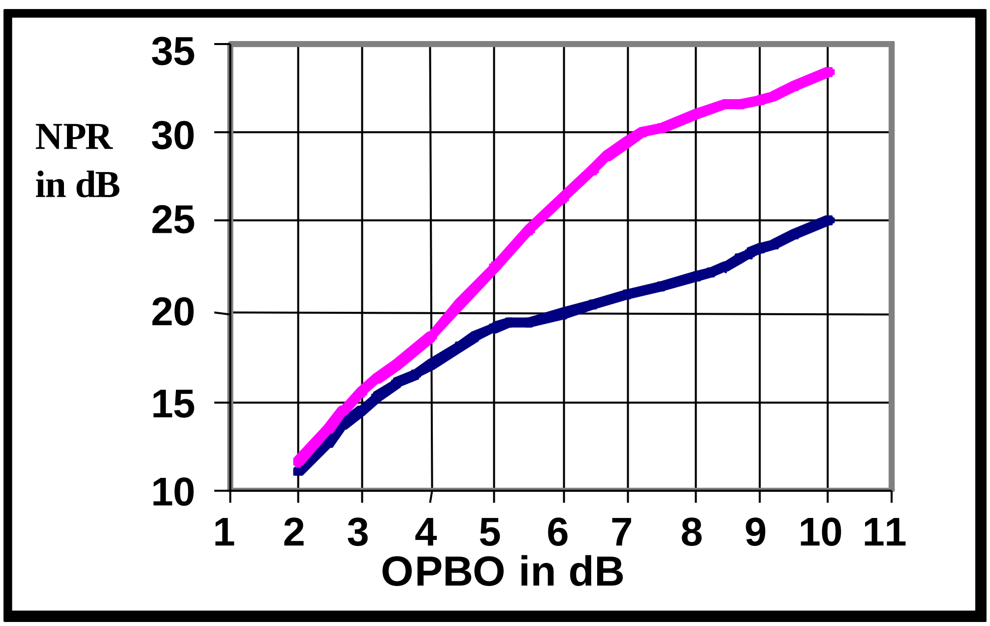


**Figure 7. NPR of class AB SSPA.**

It is important to remember that when making both C/I and NPR measurements that the maximum (saturated) power of an amplifier is always the power produced by a single carrier signal. This power level corresponds to 0 dB OPBO. All backoffs are referenced to this single carrier power level, even though they are to be used for noise or multi carrier measurements. (In the case of NPR, the 0 dB OPBO reference is not the maximum power with a noise input signal. It is the power due to a single carrier).

Maximum output power can change significantly depending on the number of input carriers (type of excitation) and the type/design of an amplifier. A single carrier maximum power reference is used to ensure a meaningful comparison between different amplifiers.

## Summary

NPR is a convenient method for evaluating the linear performance of amplifiers when operated with many carriers. Care must be taken in selecting the proper NPR test set. When measured properly NPR provides an accurate and repeatable measure of amplifier performance.