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Noise Power Ratio (NPR) Testing of HF Receivers

The author uses notched noise to evaluate dynamic receiver performance.

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Noise-power ratio (NPR) testing is a performance test technique in which a notched noise band is applied to the input of the device under test (DUT), and the output of the DUT is connected to a selective level meter whose bandwidth is less than that of the notch in the noise spectrum. The idle-channel noise (ICN) is measured with the noise band not notched and notched.[1, 2]

The theory behind the NPR test is that the incident noise outside the notch will cause reciprocal mixing noise and multiple IMD products, which will appear in the idle channel (the passband of the selective level meter) and raise the idle-channel noise. This test method is used in characterizing multi-channel frequency division multiplexing/frequency modulation systems (terrestrial microwave and satellite communications), where a notched noise band of equal bandwidth to the baseband is applied at the transmit end, and a receiver with a channel filter as wide as (or narrower than) the notch is used to measure idle-channel noise with and without the notch inserted in the noise band.

When testing an HF receiver, the receiver itself serves as the selective level meter. The test requires the IF bandwidth to be no wider than the bottom of the notch; the IF filter must not be wide enough to allow noise outside the notch to spill over into the IF. A bandpass (band-limiting) filter following the noise generator determines the total noise bandwidth. Figure 1 illustrates a typical noise band as defined by the band-limiting filter, with inserted notches as defined by the bandstop filters.

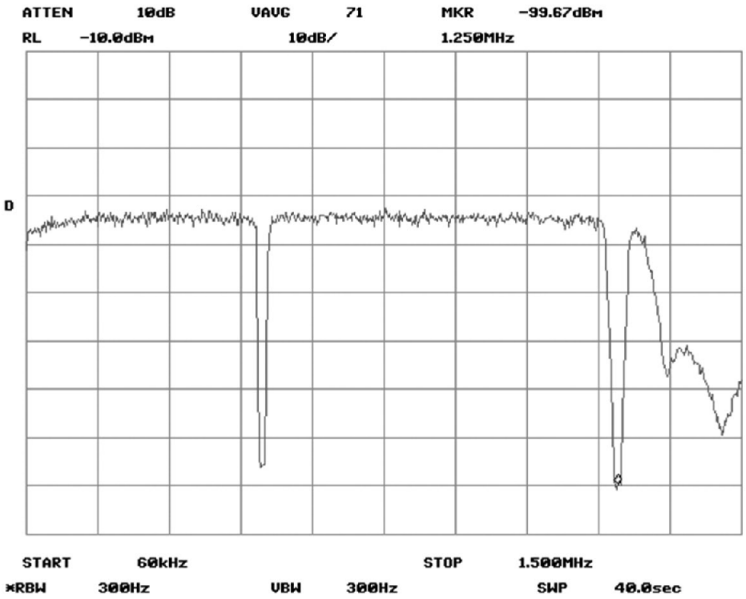

Figure 1 — Band–limiting filter response, including notches.

Advantages of NPR Testing

Standard receiver test methods involve applying single-tone or two-tone test signals to the receiver input, and measuring the degradation caused by these signals. This degradation may take the form of noise, IMD products, spurious responses and blocking (desensing). As these tests are performed under laboratory conditions, where the test signals are the only signals present, the effects of heavy band occupancy can be missed. Typical narrowband tests do not accurately reflect weak-signal performance degradation due to multiple strong signals and the numerous undesired products they generate. As a result, a given receiver may have excellent narrowband "numbers," yet may miss a weak signal on a crowded band.

The NPR test technique emulates a band filled with many strong signals by stressing the receiver with white noise. Thus, all possible combinations of carrier frequency spacing are taken into account — a true worst-case test. The test engineer can "zero in" on potential trouble spots by comparing NPR readings for various configurations such as RF preamplifier in/out, different IF filters, different preselectors, and so on. The NPR test will reveal passive IMD in filters and other components; narrowband tests

[1] Notes appear on page 27

often do not apply sufficient power to the DUT to provoke passive IMD. In general, the higher the NPR value, the better the receiver's strong-signal handling.

When testing direct-sampling software defined radios, the NPR test has two additional advantages: first, it is possible to derive mathematically the theoretical maximum NPR value for an ADC having a given word length (number of bits). This is discussed in more detail later in the article. Second, the noise loading will be more than sufficient to dither the ADC, thus improving its IMD performance. This is especially useful when testing an SDR employing a high-speed ADC without on-chip dither.

It is felt that a combination of the NPR test and an interference-free signal strength (IFSS) test, in which the absolute power of IMD products generated by a two-tone test signal over a range of input power levels is compared to the band noise level at the DUT site, can be a very powerful tool for evaluating the performance of a direct-sampling SDR. A receiver in which the measured NPR approaches the calculated theoretical value can be viewed as performing optimally under heavy band occupancy.

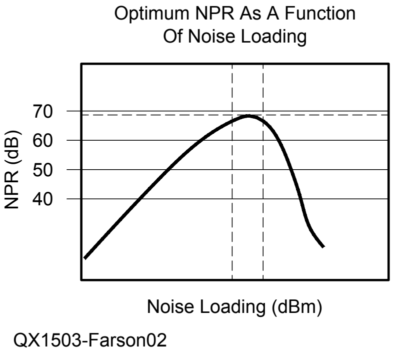

Figure 2 — Optimum NPR as a function of noise loading (embedded in image).

Derivation of NPR; Noise-Bandwidth Considerations

NPR for a given noise bandwidth (or equivalent number of channels) is the ratio of the noise power in the notched band to the power in an equal bandwidth adjacent to the notch.

Gianfranco Verbana, I2VGO, has shown that for a given noise bandwidth, and at the optimum noise-loading point (see the **Determination of Optimum Noise Loading** section), Equation 1 describes the NPR.[3]

$$NPR = P_{TOT} - BWR - MDS \qquad \text{[Eq 1]}$$

where:

P_{TOT} = total noise power in dBm in the noise bandwidth B_R

$BWR = 10 \log_{10} (B_{RF}/B_{IF})$

B_{RF} = RF bandwidth or noise bandwidth in Hz (RS-50 band-limiting filter)

B_{IF} = receiver IF filter bandwidth in Hz

MDS = minimum discernible signal (specified at B_{IF}). *This is a special case in which MDS is specified at the B_{IF} value used in the NPR test.*

This relationship can also be expressed as follows:

$$NPR = D_N + 10 \log_{10} B_{IF} - MDS \qquad \text{[Eq 1A]}$$

where:

D_N = noise density in dBm/Hz = $P_{TOT} - 10 \log_{10} B_{RF}$

Note that noise density D_N is independent of RF bandwidth. The band-limiting filter selected for each test case should be *wider* than the front end of the DUT, to ensure that the NPR test subjects all stages of the receiver to noise loading, including any front-end filter or preselector. Thus, any effects (such as passive IMD) that the incident noise generates in the front-end filter will be taken into account in the NPR measurement. These effects will show up as a *decrease* in NPR, as opposed to the increase expected if the preselector is narrower than the band-limiting filter in the instrument.

To put the impact of the NPR test into perspective, a –9 dBm P_{TOT} level at 5.6 MHz B_{RF} is equivalent to 1200 simultaneous SSB signals at –43 dBm each, or S9 + 30 dB!

Notch (Bandstop) Filter Design Considerations

1) The stopband width (notch width) at maximum attenuation must be greater than the IF bandwidth at which the receiver will be tested. It should also be wide enough to allow for any possible frequency drift in the filter.

2) The attenuation required in the stopband must be sufficient to prevent any direct transfer of noise to the receiver under test at its tuned frequency. Thus, if D_{TOT} is power spectral density (PSD) of the applied noise band in dBm/Hz, B_n is stopband width in Hz and A_n is stopband attenuation in dB, and MDS is the receiver's minimum discernible signal in dBm, the measuring system must satisfy Equation 2.

$$(D_{TOT} + 10 \log_{10} B_n) - A_n \leq MDS \qquad \text{[Eq 2]}$$

Katz and Gray give a correction factor which should be applied if the measured NPR is close to the notch depth of the bandstop filter.[4]

$$NPR = -10 \log_{10} \left\{ 10^{-(NPR_m/10)} - 10^{-(A_n/10)} \right\} \qquad \text{[Eq 3]}$$

where:

NPR_m is the measured NPR

A_n is the stopband attenuation of the bandstop filter.

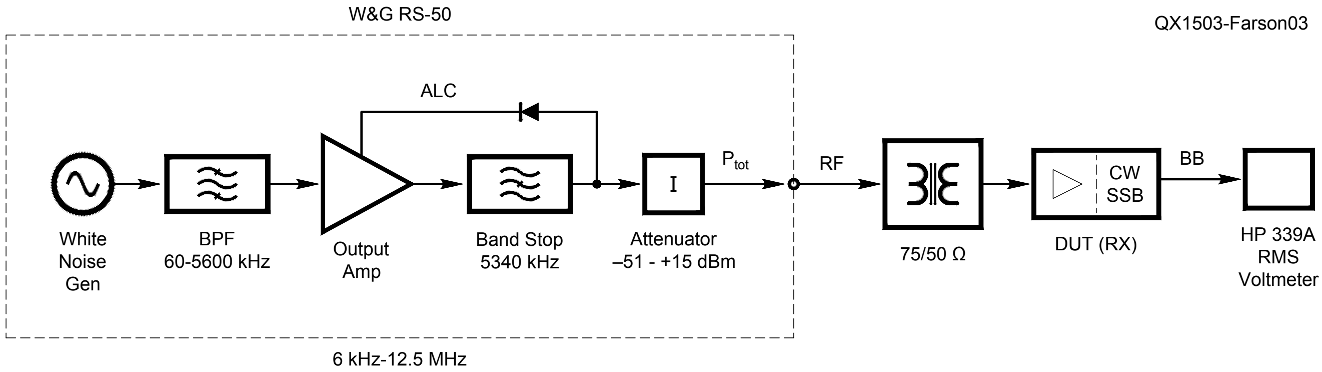

Figure 3 — Noise power ratio (NPR) measuring setup (embedded in image).

Determination of Optimum Noise Loading

Section 7.1 of the Marconi Instruments OA 2090 White Noise Test Set Operation and Maintenance Manual describes the NPR curve of a typical multi-channel transmission system as a function of noise loading.[5] At low incident noise power levels, thermal noise is dominant, and NPR is roughly proportional to noise loading, where an increase of 1 dB increases NPR by ≈ 1 dB. This curve is also presented in Figure 2, and in Gianfranco Verbana's presentation**,** Slide 28. (See Note 3.)

As the noise loading level is further increased, the NPR increase is less than that in input power due to the effect of intermodulation (IMD) products. At a certain noise-loading level, IMD products begin to predominate over thermal noise and NPR starts to decrease. The turnover point is the "optimum noise loading level," at which the receiver NPR will be measured. In Verbana's presentation (Note 3), the optimum noise loading level is determined for each test case by increasing noise loading until idle-channel noise is 3 dB above the level when the noise generator is switched off (idle-channel noise at MDS). This greatly simplifies the measurement of NPR on receivers.

The NPR falls off rapidly at very high noise-loading levels. As Figure 2 shows, the slope on the right-hand side of the curve (noise loading > optimum value) is steeper, since the IMD products are dominant in this case.

Any direct transfer of noise due to the limited stopband attenuation of the notch filter will add to the IMD noise, thus reducing the optimum noise loading value. This effect will be negligible if the notch depth satisfies Equation 2, as is the case for the Wandel & Goltermann RS-50 White Noise Generator.

NPR Test Instrumentation

I was fortunate enough to locate a Wandel & Goltermann RS-50 White Noise Generator on the surplus test-equipment market. This generator, together with its companion RE-50 noise receiver, forms the RK-50 NPR test system used for many years in the telecommunications industry. The RS-50 is illustrated in Figure 5.

The RS-50 generates a 6 kHz to 12.5 MHz noise band. Its output level is adjustable from –51 to +15 dBm. The instrument is fitted with three band-limiting filters and six bandstop filters covering CCITT (ITU-T) standard FDM baseband widths and test channel frequencies. In this example, the 5340 kHz bandstop filter is shown; its stopband width and attenuation are 3.3 kHz and ≈ 97 dB respectively. The RS-50 incorporates a precision attenuator (1 and 0.1 dB steps) and an ALC loop that holds the output constant at any level setting, irrespective of which filters are selected. Figure 3 illustrates the test setup for NPR testing of an HF receiver.

NPR Test Procedure for Conventional Receivers

1) Set the receive IF bandwidth/mode to 2.4 kHz SSB. Select SHARP shape factor (if applicable). *The IF bandwidth should be narrower than the stopband width of the notch filter.* Noise Blanker (NB), Noise Reduction (NR), Attenuator (ATT) and Preamp are all OFF. RF GAIN is at maximum. Select the 6 kHz roofing filter (if applicable), and set AGC to MID. Tune the DUT such that the IF passband is centered in the notch. If the DUT has a switchable preselector, this should be ON initially.

2) On the RS-50, set the RF attenuator to minimum (–50 dBm). Press and hold the GENERATOR BLOCKING key and adjust receiver AF GAIN for a 0 dBr reading on the RMS voltmeter connected to the baseband (audio) output.

3) On the RS-50, release the GENERATOR BLOCKING key. Adjust the attenuator for a +3 dBr reading on the RMS voltmeter. Record the attenuator setting: this is P_{TOT} (total noise power).

4) Calculate NPR using Equation 1:

$$NPR = P_{TOT} - BWR - MDS \qquad \text{[Eq 1]}$$

5) Repeat the test with different combinations of preselector, roofing filter and preamp, and record the results. Take each reading 2 to 3 times and average them for the highest accuracy. (Note: NPR cannot be read directly off the S-meter, because the S-meter reads S0 before the bottom of the notch is reached. Furthermore, very few conventional receivers have a calibrated S-meter.)

NPR Test Procedure for Direct-Sampling SDR Receivers

When testing NPR on a direct-sampling SDR receiver, the noise loading level required to raise the idle-channel noise by 3 dB may exceed the clipping (0 dBFS) point of the receiver ADC. (Gianfranco Verbana, I2VGO, has confirmed this behavior.) Thus, it is more convenient to increase the noise loading until the onset of clipping is reached, then back off the noise level until no clipping indication occurs for at least 10 seconds. (See Note 3, Slide 36.) NPR can then be read directly off the spectrum scope display or the signal-strength meter.

1) Set the receiver detection bandwidth/mode to 2.4 kHz SSB. Select the SHARP shape factor (if applicable). *The detection bandwidth should be narrower than the stopband width of the notch filter.* Noise Blanker (NB), Noise Reduction (NR), Attenuator (ATT), Dither and Preamp are all OFF. RF GAIN is at maximum. Set AGC to SLOW. Tune the DUT such that the detection channel passband is centered in the notch. If the DUT has a switchable preselector, this should be ON initially. Spectrum scope averaging should be ON, at mid-range.

2) On the RS-50, set the RF attenuator to minimum (–50 dBm). Press and hold the

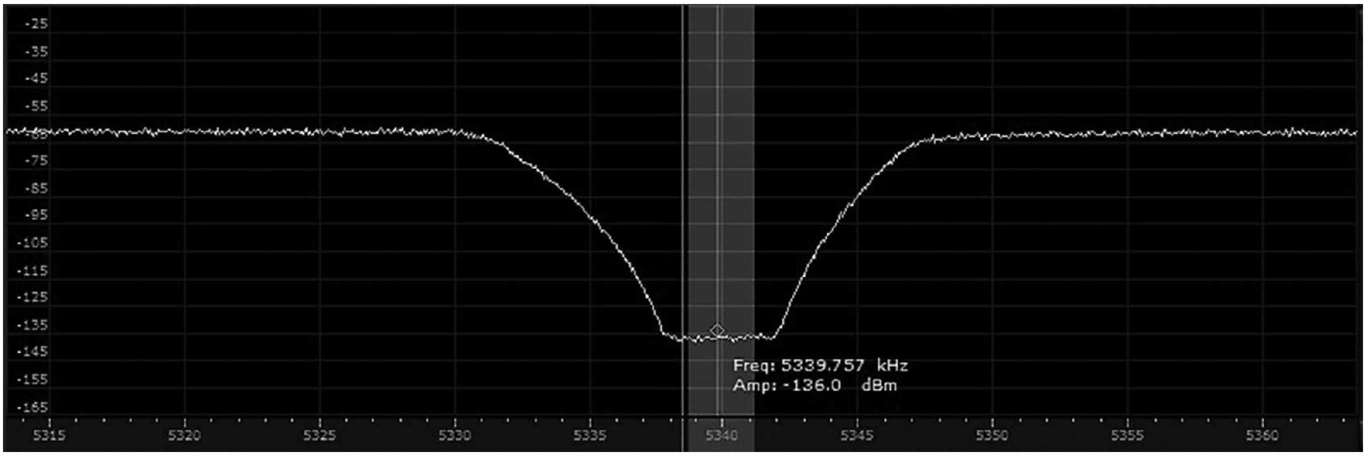

Figure 4 — NPR spectrogram on the Microtelecom Perseus spectrum scope.

Figure 5 — The Wandel & Goltermann RS–50 white noise generator.

GENERATOR BLOCKING key to turn off noise output, and read the MDS from the DUT signal-strength indicator or the bottom of the notch on the spectrum display. Record the MDS reading (in dBm).

3) On the RS-50, release the GENERATOR BLOCKING key. Adjust attenuator until ADC just clips, then back off until no clipping is observed over ≈ 10 seconds. Record the attenuator setting: this is P_{TOT} (total noise power). Read noise power from the DUT signal-strength indicator or the bottom of the notch on the spectrum display. Record the signal-strength reading (in dBm).

4) Now tune the DUT to a frequency well outside the notch and read the noise power on the signal-strength indicator. Record this signal-strength reading (in dBm).

5) NPR equals the difference between the signal-strength readings taken in steps 3 and 4.

6) Repeat the test with different combinations of preselector, dither and preamp, and record the results. Take each reading 2 to 3 times and average them for the highest accuracy.

7) Alternatively, NPR can be read off the spectrum display by positioning the marker well outside the notch and also in the center of the stopband. NPR is the difference between these two readings. See Figure 4.

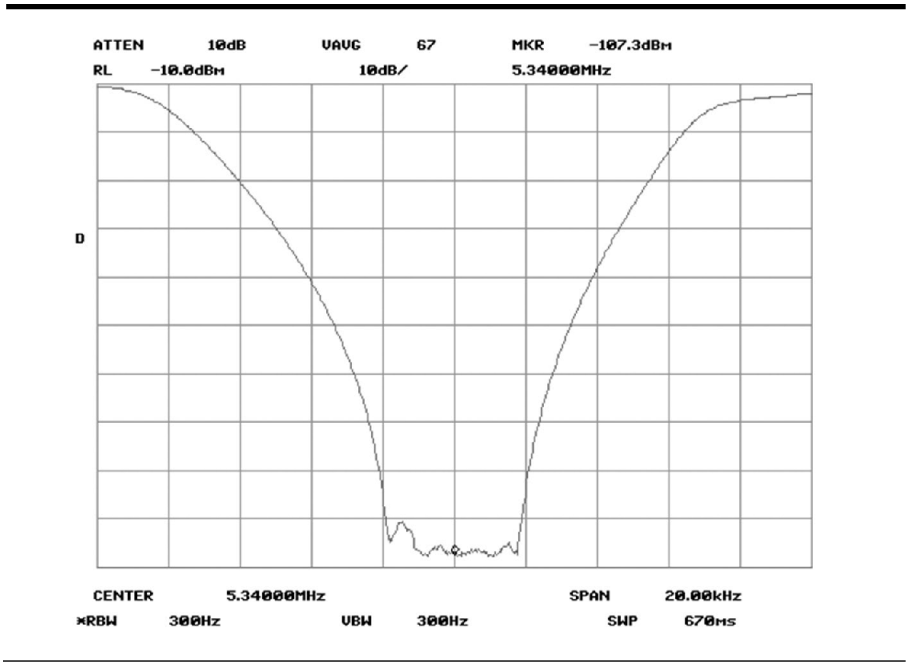

Figure 6 — Wandel & Goltermann 5340 kHz bandstop filter amplitude versus frequency response.

NPR Test Frequencies and Capability

My Wandel & Goltermann RS-50 White Noise Generator has the following standard CCITT (ITU-T) filter sets:

1) 12 to 552 kHz band-limiting with 70, 240 and 534 kHz bandstop (LWBC. MWBC)

2) 60 to 1296 kHz band-limiting with 1248 kHz bandstop (MWBC)

3) 60 to 2044 kHz band-limiting with 1940 kHz bandstop (160 m)

4) 60 to 2600 kHz band-limiting with 2438 kHz bandstop (120 m "tropical")

5) 60 to 4100 kHz band-limiting with 3886 kHz bandstop (80 m)

6) 60 to 5600 kHz band-limiting with 5340 kHz bandstop (60 m)

7) 316 to 8160 kHz band-limiting with 7600 kHz bandstop (near 40 m)

These filters permit testing on multiple bands. The basic concept driving the choice of telecom-industry surplus NPR test equipment is the use of standard filters, which will ensure that the NPR test is repeatable when performed by other workers with standard test sets. The CCITT band-limiting filters concentrate the noise at and below the band under test. Another rationale is that this equipment is quite inexpensive on the surplus market. The alternative, requiring a sophisticated digital arbitrary waveform generator, is extremely costly.

Measurement Results

I have made NPR measurements on a number of "analog" and DSP radios. The results of my current tests are presented in Table 1. As time and radios become available, I continue to test more radios, and update the NPR article on my website: **www.ab4oj.com/test/docs/npr_test.pdf**.

I have also tested a number of direct

Table 1
NPR Test Results, Analog/DSP Radios

DUT	*Config*	*MDS (dBm)*	*P_{TOT} (dBm)*	*BWR (dB)*	*NPR (dB)*
IC–7700[1]	Preamp off R15	–124	–11.6	33.6	78.5
	R6		–4.8		83.3
	R3		–4.9		83.1
	Preamp 1 R15	–138	–24.6		79.5
	R6		–14.8		87.3
	R3		–14.8		87.3
	Preamp 2 R15	–142	–29.7		78.4
	R6		–22.4		83.7
	R3		–22.5		83.6
	Digisel R15	–123	–11.8		77.4
	R6		–4.0		83.0
	R3		–4.2		82.9
IC–7800[2]	Preamp off R15	–122	–8.7	33.6	79.4
	R6		–4.2		81.9
	R3		–1.2		82.0
	Preamp 1 R15	–133	–23.3		75.5
	R6		–14.7		82.4
	R3		–12.1		82.0
	Preamp 2 R15	–137	–28.1		75.0
	R6		–23.5		77.6
	R3		–22.1		76.0
	Digisel R15	–122	–8.8		79.3
	R6		–1.5		84.6
	R3		–0.1		83.0
TS–590S					
Inband	Preamp Off	–125	–10.8	32.3	81.6
	Preamp On	–133	–19.5		81.0
TS–590S					
High	Preamp Off	–126	–16	33.6	76
	Preamp On	–134	–25.5		74.1
K3 #1	**K3 #1:** 2.7 kHz 5–pole roofing filter fitted				
	Preamp off	–124	–9.7	33.6	80.4
	Preamp on	–128	–14.0		80
K3 #2	**K3 #2:** 2.8 kHz 8–pole roofing filter fitted				
	Preamp off	–124	–11.7	33.6	78.4
	Preamp on	–129	–15.7		79.4
IC–7600	Preamp off R15	–127	–14	33.6	79
	R6		–12		81
	R3		–12		81
	Preamp 1 R15	–135	–25		77
	R6		–22		79
	R3		–22		79
	Preamp 2 R15	–137	–27		76
	R6		–25		78
	R3		–26		77
IC–7410	Preamp off R15	–129	–18	33.6	77.4
	R6		–18.3		77.1
	R3		–17		78.4
	Preamp 1 R15	–136	–26.1		76.3
	R6		–26		76.4
	R3		–22.4		80
	Preamp 2 R15	–139	–28.1		77.3
	R6		–29.6		75.8
	R3		–27.5		77.9

DUT	*Config*	*MDS (dBm)*	*PTOT (dBm)*	*BWR (dB)*	*NPR (dB)*
IC–9100	Preamp off R15	–129	–17.8	33.6	77.6
	R6		–17.8		77.6
	R3		–17.7		77.7
	Preamp 1 R15	–137	–26.3		77.1
	R6		–25.9		77.5
	R3		–25.4		78
	Preamp 2 R15	–137	–27.8		75.6
	R6		–26.6		76.8
	R3		–25.9		77.5
FT–950	IPO R15	–119	–11	33.6	74
	R6		–11		74
	R3		–9.2		76
	AMP1 R15	–130	–21.4		74.7
	R6		–19		77
	R3		–18.4		77.7
	AMP2 R15	–138	—28.4		75.7
	R6		–27.4		76.7
	R3		–26.8		77.3
FTDX–1200[3]	IPO R15	–116.5	–7.7	33.6	74.9
	R6		–8.2		76.4
	R3		–8.7		77.9
	AMP1 R15	–129	–22.7		72.4
	R6		–22.9		74.2
	R3		–23.5		75.6
	AMP2 R15	–134	–31.2		68.9
	R6		–31.6		71.5
	R3		–31.8		72.3
IC–7200	Preamp off	–124	–18	33.6	72.1
	Preamp on	–135	–28		73.1
FTDX–3000	Preamp off	–119	–12.7	33.6[4]	72.4
	Preamp 1	–131	–27.3		69.8
	Preamp 2	–134	–30.5		66.6
FT–897D					
	Preamp off	–124	–18.7	34.0	71
	Preamp on	–131	–31.7		65
IC–703	Preamp off	–125	–21.8	33.6	69.6
	Preamp on	–134	–30.4		70
	Preamp off ATU in	–125	–21.8		69.6
FT–1000	Preamp off	–124	–22	33.6	68
	Preamp on	–132	–32		68
IC–718 (#22)	Preamp off	–124	–21.6	33.6	68.5
	Preamp on	–132	–32.1		66
IC–706	Preamp off 2.4 kHz	–132	–31.1	33.6	67.4
	Preamp on 2.4 kHz	–138	–37.3		67.1
	Preamp off 1.8 kHz	–132	–30.9	34.9	66.2
	Preamp on 1.8 kHz	–138	–37.3		65.8
IC–7000	Preamp off	–125	–24	33.6	67.0
	Preamp on	–135	–37		64.3
IC–7100	Preamp off	–124	–23.5	33.6	66
	Preamp 1	–133	–35		64
	Preamp 2	–135	–38		63
FT–817	Preamp off	–125	–26.6	33.6	64.5
	Preamp on	–130	–33.5		62.6

Notes:

[1] MDS shown for R15. Correction factors: R6: 2 dB. R3: 2 dB.

[2] MDS shown for R15. Correction factors: R6: 2 dB. R3: 5 dB.

[3] MDS shown for R15. Correction factors: R6: 1 dB. R3: 2 dB.

[4] With the 3 kHz 1st-IF roofing filter selected.

sampling SDR receivers, and those results are presented in Table 2. Again, I will test more radios as they become available and time permits. You can check my website for updated measurements.

Notes on the Theoretical Maximum NPR of an ADC

Walt Kester wrote "Noise Power Ratio (NPR) — A 65-Year Old Telephone System Specification Finds New Life in Modern Wireless Applications" as an Analog Devices Tutorial.[6] In that tutorial, Figure 2, on page 3, gives the theoretical maximum NPR value of 74.01 dB for a 14-bit ADC. This value can be derived at the optimum noise loading point, where $B_{RF} = f_S / 2$, where f_S is the sampling frequency of the ADC, and assuming a perfect, noiseless ADC whose noise floor N_0 is given by Equation 4.

$$N_0 = (6 \times \text{no. of bits}) + 1.76 \qquad \text{[Eq 4]}$$

$$N_0 = (6 \times 14) + 1.76 = 85.8 \text{ dBFS}$$

The noise floor of the LTC2206-14 ADC in the Microtelecom Perseus is 77 dBFS, which is 8.8 dB worse than the theoretical maximum value. For the Perseus, f_S = 80 MHz. An NPR test with $B_{RF} = f_S / 2$ = 40 MHz, B_{IF} = 2.4 kHz (SSB mode) and the 5340 kHz bandstop filter yielded NPR = 64.75 dB. This is 9.26 dB worse than the theoretical value, and is attributable to the finite noise floor of the ADC. This difference is comparable to the 8.8 dB difference in noise floor between the theoretical and "real-world" values.

Let us now derive the process gain, G_P, due to the presence of the band-limiting filter during the original NPR test.

$$G_P = 10 \log_{10}(f_S / (2 \times B_{RF})) = 10 \log_{10}(80 / (2 \times 5.537)) = 8.6 \text{ dB} \qquad \text{[Eq 5]}$$

We can now predict NPR for the Microtelecom Perseus, as described above and presented in Table 2:

$$\text{NPR} = (\text{NPR for } B_{RF} = f_S / 2) + G_P = 64.75 \text{ dB} + 8.8 \text{ dB} = 73.55 \text{ dB} \qquad \text{[Eq 6]}$$

Table 2 shows that the first measured NPR for the Perseus was 72 dB, well within the margin of error.

General Discussion of Results

In a conventional receiver, the effect of the high noise power outside the notch is twofold and most likely impacts the first and second mixers more than any of the downstream sections of the receiver. First, the incident noise mixes with the noise pedestal of the LO to cause reciprocal mixing, which shows up as increased noise in the IF passband (idle-channel noise). Second, the noise components mix with each other, the LO, any LO spurs and the LO phase noise to produce a very large number of IMD products — much closer to the effect of a heavily occupied band than a two signal test. Some of these IMD products will fall into the IF passband, further degrading idle-channel noise.

Secondary effects due to passive IMD in RF filter components, semiconductor filter switches, roofing filters, and other factors under the high noise loading will cause a further slight degradation in NPR. Slight passive IMD has been observed in some roofing filters under high noise loading.

In several of the conventional receivers

Table 2
NPR Test Results, Software Defined Radios (SDR)

DUT	*SW Ver.*	*Presel*	*Preamp*	*Dither*	*MDS (dBm)*	*Clip (dBm)*	*PTOT (dBm)*	*NPR (dB)*[1]
ANAN100D	3.2.17	1		0	–123	–13	–22	76.5
				1	–123	–13	–21.5	73
ANAN200D	3.2.17	1		0/1	–128	–16	–22	73
Flex–6700	1.3.8	0[2]	0dB		–111	0	–1	75
			+10dB		–118	–12	–13	71
			+20dB		–130	–22	–23	71
			+30dB		–134	–32	–33	68
Perseus	4.0b	0	0	0	–122	–3.6	–16.5	72
		0	0	1	–120	–3.6	–19.4	70
		0	1	0	–124	–7.1	–19.9	69
		0	1	1	–120	–7.1	–19.5	68
		1	0	0	–121	–1.5	–8.5	75
		1	0	1	–120	–1.5	–8.8	73
		1	1	0	–123	–5.0	–12.2	73
		1	1	1	–121	–5.0	–12.9	72
QS1R Rev. D	5.0.1.1		0	0[3]	–113	+11	–1	71
			1		–118	+7	–5	72
KX3	*FW Ver.*	*BB Flt*	*Preamp*		*MDS dBm*	*BWR dB*	*P_{TOT} dBm*	*NPR dB*[4]
	1.10	0	0		–117	32.8	–11.5	72.4
		1	0		–116	33.7	–8.5	73.5
		0	1		–131	32.8	–25	72.9
		1	1		–130	33.7	–21.3	74.7
ELAD FDM–S2	*SW Ver.*		*ATT*		*MDS dBm*	*BWR dB*	*P_{TOT} dBm*	*NPR dB*[1]
	FDM–SW2		0		–130	33.4	–19.5	71
SDR–IQ	*SW Ver.*		*IF Gain*					
	3.32		+12dB		–103	33.6	–4.5	70
			+0dB		–100		–4.5	64
Flex–1500	*SW Ver.*		*Preamp*		*MDS dBm*	*BWR dB*	*P_{TOT} dBm*	*NPR dB*[1]
	2.7.2		0		–100	33.6	–16	55
			1		–111		–25	60

Notes
[1] NPR value measured by observation.
[2] No preselector fitted for 5 MHz range.
[3] Enabling Dither and/or Random does not affect NPR.
[4] NPR calculated from P_{TOT} and BWR.

tested, the NPR improvement with narrower first IF roofing filters suggests that the second mixer is a significant contributor of IMD and/or reciprocal mixing noise when subjected to the higher noise loading with the 15 kHz roofing filter selected.

In a typical direct-sampling SDR, the best-case NPR was measured with preselector on, preamp off and dithering off. This suggests that the preselector is preventing the noise loading from driving the ADC input circuit into its non-linear region at levels approaching 0 dBFS.

If we apply the notched noise loading to a perfect (ideal) DUT *which adds no noise,* the notch depth at the DUT output will be the same as that shown in Figure 6. Any noise generated in the DUT will fill the notch with added noise, reducing its measured depth. Thus, the actual measured NPR is a measure of the amount of degradation due to reciprocal mixing and IMD noise generated by the notched noise load.

From Figure 6, *assuming no added noise*, the notch depth at a bandwidth of 3.3 kHz would be ≈ 97 dB. Thus, the NPR of an ideal receiver with <3.3 kHz Hz IF bandwidth would also be ≈ 97 dB. By this yardstick, a 70 to 80 dB measured NPR appears quite respectable. It will be interesting to correlate the results of the NPR test with those of the more familiar two signal IMD3 dynamic range measurement. (The passband curve in Figure 6 was taken using a spectrum analyzer and tracking generator.)

This article is intended as an introduction to the measurement techniques for noise power ratio testing of HF receivers. A lot of additional information has been written about this testing technique. Notes 7 through 12 provide some additional information and resources for interested readers.

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Adam M. Farson, VA7OJ/AB4OJ, was born in the UK, and raised and educated in South Africa. After earning a BSEE from the University of Cape Town, he worked in Racal, South Africa from 1964 to 1967 as an RF design engineer. He was involved in some interesting, advanced projects, such as a VHF FM/SSB tactical ground radio system for the Ministry of Defence, and also with a solid state HF transceiver for LMR ("bush radio") applications. They had a 25 W "man-pack" radio and a 100 W mobile radio, both of which used TV line-output transistors with an F_t *> 100 MHz in the transmitter PA and driver.*

Adam emigrated from South Africa in 1967, and then spent three years at CERN as an RF design engineer, working on a modulation system for a 10 kW 9.5 MHz power generator feeding RF power to a proton accelerator. This project served as the thesis for his Masters degree in EE from the University of Cape Town in 1971.

After his time at CERN, Adam returned to the telecommunications industry and worked for various multinational corporations in the satellite and wireline telecommunications fields, culminating in a 20 year stay as a systems engineer at Siemens. He was based in Boca Raton, Florida, but traveled extensively to North American and International assignments, including a year in Munich and several months in Tokyo. His main responsibilities were systems verification and compliance engineering, mainly in the areas of telephone trunking, signalling, and transmission.

He retired at the end of 1999 and moved to British Colombia. He holds a Canadian Advanced Amateur Radio Certificate (VA7OJ) and a US Amateur Extra class license (AB4OJ) as well as an FCC General Radiotelephone Operator's License. He was first licensed in 1962 as ZS1ZG. He enjoys applying some of his engineering training to Amateur Radio, especially in the area of radio equipment testing. After retiring he started building a comprehensive RF laboratory, and began researching noise power ratio testing of receivers in 2009. You can find more information about Adam and his Amateur Radio interests on his personal webpage: ***www.ab4oj.com/****.*

Notes

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[11] Adam M. Farson, VA7OJ/AB4OJ, "Noise Power Ratio (NPR) Testing of HF Receivers," Radio Society of Great Britain, *RadCom*, December 2012, pp 42 – 45.

[12] Adam M. Farson, VA7OJ/AB4OJ, "Noise Power Ratio Testing," presentation to North Shore Amateur Radio Club, North Vancouver, BC, 22 November 2012. A copy of this presentation is available at: **www.nsarc.ca/hf/npr.pdf**.

Appendix

Suggested NPR test equipment:

1) Wandel & Goltermann RS-25, RS-50 or RS-100 noise generator, with band-limiting and bandstop filters.

2) Marconi TF2091B or C with LPF/HPF pairs, equivalent to Wandel & Goltermann band-limiting and bandstop filters.

These instruments can be found on popular auction sites or at used/surplus test equipment vendors/brokers. The Marconi test sets are generally more plentiful, as they were widely used by the Telecommunications companies and the military.