Perseus SDR Receiver: User Evaluation & Test Report

By Adam Farson VA7OJ/AB4OJ **Iss. 4, Mar. 18, 2018.**

Figure 1: Overall view of the Perseus.

Introduction: This report describes the evaluation of Perseus Direct-Sampling SDR Receiver S/N 03318 from a user perspective. ***Part 1*** (pp. 1-4) is a brief user review, and ***Part 2*** (pp. 5-13) presents results of an RF lab test suite performed on the radio. I purchased this receiver in Dayton in May 2010, and have thus had ample time to evaluate and test it, both on-air and in the lab.

Part 1: User Review of Perseus S/N 03318

1. Appearance of the Perseus: Those accustomed to “big-box” radios with the familiar front panels and knobs will doubtless be taken back at the compact packaging of the Perseus. For all the world, it resembles a modem more than a “radio” in the traditional sense. The compact aluminum case is 110 x 36 x 185 mm (WxHxD). The front panel has LED indicators for power ON, CLIP, WB (wideband, preselector out) and -20/-10 dB attenuation. On the rear panel are a BNC RF input socket, a concentric +5V DC power socket and a USB 2.0 “B” port for connection to a computer.

2. GUI control of the Perseus: The receiver is controlled exclusively from the GUI (graphical user interface) which the Perseus software presents on the computer screen. All manipulations of the GUI are performed using the computer mouse.

All frequency, mode (emission type), bandwidth and signal-management functions are controlled by means of clearly-marked buttons and sliders. Frequency entry and tuning are possible via direct entry on a pop-up keypad, by clicking the frequency display digits, by rotating the mouse wheel with the cursor positioned over a frequency display digit and by “grabbing” and sliding the fiducial line on the main spectrum display.

Two spectrum displays are provided; the main display which fills ≈ 85% of the screen width, and a smaller secondary display which magnifies a central segment of the main display centered on the carrier frequency and slightly wider than the selected channel filter. The secondary display facilitates setting filter bandwidth, Passband Tuning (PBT) and the manual notch filter; the latter shows the notch stopband, which can be aligned with the spike corresponding to the signal to be notched out.

Figure 2: Typical Perseus GUI screen (NPR test with notched noise).

The signal strength meter displays S-units and either dBm or dBµV (selectable). The meter is accurate to within < 1 dB; thus, the Perseus is useful as a selective RF power meter covering 10 kHz to 30 MHz.

3. Main spectrum display: The main FFT spectrum display provides all the features of a basic spectrum analyzer, such as fully-configurable span, center frequency, resolution bandwidth (RBW)**,** reference level and input attenuation. It also features markers with frequency/amplitude displays, and adjustable trace averaging.

4. Selectivity filter selections and PBT: The Perseus offers variable-bandwidth selectivity filters for all modes. Several default filter selections are available for each mode by clicking the BW softkeys to the left of the secondary scope screen. The bandwidth of each selection can be varied by dragging the lower or upper flank of the filter (as displayed on the secondary scope) with the left mouse key. PBT is tuned by dragging the filter passband with the right mouse key.

5. Notch Filters: Both the tunable manual notch filter (Notch) and the auto-notch (ANotch) are inside the AGC loop. Single-tone stopband attenuation is at least 75 dB. Both notches suppress an interfering carrier before it can stimulate AGC action, thus preventing swamping. Notch and ANotch can be activated together, and will yield single-tone stopband attenuation > 80 dB. The Notch bandwidth is continuously adjustable by rotating the mouse wheel.

6. AF NR (noise reduction): The DSP NR is very effective. In SSB mode, the maximum noise reduction occurs at an NR control setting of ≈70%. As NR level is increased, there is a very slight loss of "highs" in the received audio; this is as expected. The measured SINAD increase in SSB mode was about 8.5 dB.

7. NB (noise blanker): The noise blanker extremely effective in suppressing fast-rising impulsive RF events before they can stimulate AGC action within the DSP algorithm.

Even at its minimum setting, the NB completely blanks noise impulses which would otherwise cause AGC clamping. I found the Perseus NB performance excellent. The NB works very effectively in conjunction with NR.

8. Signal-strength indicator: The signal-strength meter is scaled in S-units and (optionally) dBm or dBµV, and is accurate to within < 1 dB across its range. RMS and peak modes are selectable by clicking the corresponding keys.

9. AGC system: The AGC is a DSP function within the Perseus software. It holds the audio output at a constant output level over a wide range of input signal power. Three time decay constants and AGC Off can be selected via the Fast, Med, Slow and Off keys in the AGC control bar. Note that when AGC is off, large input signals can cause saturation of the audio output. In general, Fast is best suited to CW, Med to SSB/RTTY and Slow to AM and SAM.

10. Tuning methods: Several tuning methods are provided. Double-clicking on the frequency display opens a direct-entry keypad. Clicking on any digit allows scrolling of that digit via the mouse wheel. In addition, dragging the frequency bar and mouse-over + wheel allow tuning in predefined steps, as do the white arrow (CF) keys below the main and secondary scope screens.

11. Memory management: The Perseus memory window displays the contents of four databases, HFCC, EIBI, User1 and User2. In addition, four banks of 6 channels each are selectable via the Bank key. Clicking on a channel in a bank stores the current frequency and mode in that channel, and opens a window allowing entry of a one-line description. Clicking on an assigned channel moves the Perseus to that channel and selects the stored mode.

16. Brief "on-air" report: Prior to starting the test suite, I connected the Perseus to my multi-band vertical antenna and listened to a number of SSB, AM and CW signals.

a) SSB: Using a headset plugged into the computer's "Phones" jack, I monitored a number of amateur transmissions on 40, 20 and 17m. Recovered audio quality was generally excellent, and the almost complete lack of reciprocal mixing noise made for a very quiet background. The selected filter bandwidth was 2.4 kHz.

The noise blanker NB is very effective. It does not distort the signal, and can be left on at all times. I found that even at the lowest setting, the NB suppressed fast-rising noise spikes and almost completely eliminated locally-generated electrical noise. (See **7**.)

As discussed in Section 6 above, I found the NR very effective on SSB. NR is very effective in conjunction with NB.

The preamp (2 – 3 dB gain) enhanced intelligibility of weaker signals without raising the noise level to the operator. The channel filter and PBT were very effective in reducing or eliminating adjacent-channel interference. Notch and ANotch were extremely helpful. I was able to notch out single tones completely with Notch; also, ANotch reduced the levels of multiple tones.

On a very crowded or noisy band, engaging the preselector improved the S/N ratio of the desired signal by removing strong out-of-band interferers. Dither suppressed spurious responses due to front-end IMD, with a 2 dB MDS penalty.

b) CW: I monitored a few CW signals on 40 and 20m, using 500 and 250 Hz filter settings with NR on and Preamp off. There was virtually no audible ringing, and the received CW note was very smooth. Enabling the preamp did not degrade recovered CW audio. I estimated latency at ≈ 100 ms with the Perseus connected to a PC with a 2.3 GHz Intel i5 Core CPU with 8 GB RAM and 64-bit Win7 Pro. (Latency is the time interval between application of the RF signal and onset of AF output.)

c) AM: In a quick check of AM reception, I listened to various MF and HF broadcast stations. A local station on 690 kHz and a musical broadcast on 6910 kHz sounded very pleasant on the headset connected to the PC.

The 9 kHz AM filter offered the best frequency response; the 5 kHz setting cut the "highs" excessively. Mid AGC was best for average to good signal conditions, but Fast AGC handled rapid selective fading more effectively. SAM locked cleanly and was very effective against selective fading on HF AM.

NR was quite effective in improving the S/N ratio of weak AM signals.

ANotch was effective in suppressing interfering tones and heterodynes, but Notch caused some distortion when tuned across the signal. The reason for this is that Notch will suppress the carrier in a manner similar to selective fading.

Adam Farson, VA7OJ/AB4OJ
e-mail: farson@shaw.ca
http://www.ab4oj.com/

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Part 2: Laboratory Tests on Perseus Receiver S/N 03318

As performed in my home RF lab, Aug. 11 - Sept. 4, 2011, May 1, 2014, Dec. 2, 2015 and Mar. 18, 2018. SW v4.0b, 4.1a.

1. MDS (Minimum Discernible Signal) is a measure of ultimate receiver sensitivity. In this test, MDS is defined as the RF input power which yields a 3 dB increase in the receiver noise floor, as measured at the audio output.

Test Conditions: Preselector on, ATT off, NR off, NB off, Notch off. AGC Med.

Table 1: MDS (levels in dBm).

	3.6 MHz		14.1 MHz		29.0 MHz	
Preamp	SSB 2.4 kHz	CW 800 Hz	SSB 2.4 kHz	CW 800 Hz	SSB 2.4 kHz	CW 800 Hz
Off	-121	-129	-119	-127	-118	-120
On	-123	-130	-121	-127	-119	-123
Off w/dither	-119	-126	-116	-123	-113	-117
On w/dither	-121	-128	-119	-126	-117	-120
Presel Ins Loss	1 dB		2 dB		1 dB	

Note: Dither degrades MDS by ≈ 2 dB with preamp on, and by ≈ 2.5 dB with preamp off.

1a. AM Sensitivity. Here, an AM test signal with 30% modulation at 1 kHz is applied to the RF input. The RF input power which yields 10 dB (S+N)/N is recorded (Table 2).

Test Conditions: 5 kHz AM, ATT off, NR off, NB off, Notch off. AGC-M. Levels in dBm.

Table 2: AM Sensitivity.

Presel	Preamp	Dither	0.1 MHz	0.9 MHz	3.9 MHz	14.1 MHz
0	0	0	-103	-107	-106	-105
0	0	1	-101	-105	-104	-102
0	1	0	-104	-107	-107	-107
0	1	1	-103	-105	-106	-105
1	0	0	-102	-105	-105	-104
1	0	1	-101	103	-103	-100
1	1	0	-103	-106	-106	-105
1	1	1	-102	-105	-104	-103

2. ADC Clip (0 dBFS) Level: In this test, a single-tone RF test signal is applied to the Perseus input and the level increased until the **CLIP** LED flashes. The test signal power is then recorded.

Test Conditions: 14.100 MHz, 500 Hz CW.

Table 3: ADC Clip Level.

Presel	Preamp	Dither	0 dBFS dBm
0	0	0	-3.6
0	0	1	-3.6
0	1	0	-7.1
0	1	1	-7.1
1	0	0	-1.5
1	0	1	-1.5
1	1	0	-5.0
1	1	1	-5.0

3. Reciprocal Mixing Noise: It has been shown (**Ref. 1**) that phase jitter in a direct-sampling receiver's ADC clock source produces effects very similar to reciprocal mixing in a legacy superheterodyne receiver. The designer thus strives to achieve the lowest practical phase noise level in the clock supply.

In this test, a strong "undesired" signal is injected into the receiver's RF input at a fixed offset from the operating frequency. The RF input power is increased until the receiver noise floor increases by 3 dB, as measured at the audio output. Reciprocal mixing noise, expressed as a figure of merit, is the difference between this RF input power and measured MDS. The higher the value, the better.

In practice, the Perseus' phase noise was lower than that of my signal generators! The test signal source used here was a low-noise Wenzel-type crystal oscillator operating at 11990 kHz. I was unable to perform the test at offsets > 7 kHz because the crystal oscillator did not have sufficient output to increase the audio noise floor by 3 dB. *This is the best RM value I have ever seen in any receiver I have tested.*

Test Conditions: 11990 kHz test signal, 2.4 kHz SSB and 500 Hz CW, preselector on, preamp off, dither off, ATT off, NR off,NB off, negative offset. Reciprocal mixing *in dB* = input power – MDS *(both in dBm).*

Table 4: Reciprocal Mixing Noise in dB.

Offset kHz	2.4 kHz SSB	500 Hz CW
1	108	113
2	109	114
3	111	116
5	114	119
7	114	122

4. Channel filter shape factor (-6/-60 dB): This is the ratio of the -60 dB bandwidth to the -6 dB bandwidth, which is a figure of merit for the filter's adjacent-channel's rejection. The lower the shape factor, the "tighter" the filter.

In this test, a -40 dBm RF test signal is to the antenna. The bandwidths at -46 and -100 dBm (as read on the S-meter) are determined by tuning the signal generator across the passband and reading signal strength.

Test Conditions: 14.100 MHz, SSB/CW modes, Preselector on, preamp off, dither off, AGC Mid, ATT off, NR off, NB off.

Table 5: IF Filter Shape Factors.

Filter	SF
2.4 kHz SSB	1.09
500 Hz CW	1.21
200 Hz CW	1.21
5 kHz AM	1.08
9 kHz AM	1.09

4a. Ultimate attenuation of channel filter: This test determines the ultimate (stopband) attenuation of the channel filter. A -26 dBm test signal is applied; the receiver is tuned off the test signal. The minimum signal power and its associated Δf are read off the S-meter and frequency display respectively. Minimum BW at ultimate attenuation = 2 Δf.

Test Conditions: 14.100 MHz test signal, 2.4 kHz SSB and 500 Hz CW, preselector on, preamp off, dither off, ATT off, NR off, NB off.

Result: Ultimate attenuation = 92 dB at BW = 7 kHz.

5. SSB filter roll-off: An RF test signal is applied at a level 6 dB below AGC threshold, with AGC off. The signal is offset 1 kHz from the receive frequency to produce a test tone. While tuning the signal generator across the channel passband, the frequency and audio level are noted at several points on the filter flank.

Test Conditions: 14.100 MHz USB, 2.4 kHz filter, preselector off, preamp off, AGC off, ATT off, NR off, NB off. Input signal level -106 dBm *(6 dB below AGC threshold).*

Table 6: IF Filter Roll-off.

Offset Hz	Roll-off dB
150	-9
250	-2
300	0
400	0
500	0
750	0
1000	0
2000	0
2500	-2
2600	-11
2700	-13

6. NR noise reduction, measured as SINAD: This test is intended to measure noise reduction on SSB signals close to the noise level.

The test signal is offset 1 kHz from the receive frequency to produce a test tone, and RF input power is adjusted for a 6 dB SINAD reading (-120 dBm). NR is then turned on, and SINAD read at 50% , 70% and maximum NR settings.

Test Conditions: 14.100 MHz USB, 2.4 kHz filter, AGC Med, preselector on, preamp off, ATT off, NR off, NB off, dither off.

Table 7: NR SINAD.

NR %	SINAD dB
0	6
50	7.2
70	8.5
max	6.0

This shows a maximum S/N improvement of 2.5dB with NR at 70% for an SSB signal. In subjective listening, NR reduces background noise markedly. ***Note:*** SINAD increases by 0.5 dB with AGC Slow, and decreases by 0.5 dB with AGC Fast.

6a. AGC Threshold is measured by increasing the input signal power until the audio output starts to level. Measured AGC threshold was **-100 dBm** (preamp off) and **-102 dBm** (preamp on). ***Note:*** The AGC “knee” is quite soft; full levelling occurs 20 dB above threshold.

7. Manual Notch Filter (Notch) stopband attenuation and bandwidth: In this test, a -40 dBm RF test signal is applied. The test signal is offset 1 kHz from the receive frequency to produce a test tone. The input power is read off the S-meter. Next, the Notch is carefully tuned for minimum S-meter reading. The stopband attenuation is equal to the difference between the two S-meter readings.

The test is repeated for several notch width settings. (To adjust notch width, place cursor over ^ at bottom of Notch marker line on secondary screen and rotate mouse wheel.)

The notch bandwidth at 6 dB above the null is determined by tuning the receiver to either side of the notch and noting the Δf for a 6 dB increase in signal level. BW = $2\Delta f$.

Test Conditions: 14.100 MHz USB at -40 dBm. 2.4 kHz filter, AGC MID, preselector on, preamp off, ATT = 0 dB, NR off, NB off, dither off. Notch on, narrowest notch BW.

Results: The stopband attenuation varies with notch width setting (refer to **Table 8**).

Table 8: Notch BW.

Width Setting	Stopband Atten. dB	Notch BW Hz
Narrowest	60	5
Null at -70 dBc	70	38
Null at noise floor	84	110
Widest	84	112

7a. Auto Notch (ANotch) stopband attenuation: Using the same test setup as for Test 6 above, Nottch is turned off and ANotch is activated. The signal level is read off the S-meter with ANotch off and on; the stopband attenuation is equal to the difference between the two S-meter readings.

Test Conditions: As above, except Notch off, ANotch on.

Results: Measured stopband attenuation = 75 dB.

8. AGC impulse response: The purpose of this test is to determine the Perseus' AGC response in the presence of fast-rising impulsive RF events. Pulse trains with short rise times from a pulse generator are applied to the receiver input.

Test Conditions: 10.000 MHz USB, 2.4 kHz SSB filter, NR off, NB off/on, preselector on, preamp on, dither off, AGC Fast.

Test with pulse trains. Here, the pulse generator is coupled to the Perseus RF input via the pick-off port of a line sampler. The sampler's main port is terminated in 50Ω. The receiver is tuned to 10 MHz, as the RF spectral distribution of the test pulse train has a strong peak in that band. AGC Fast (0.1 sec) and Preamp On are selected.

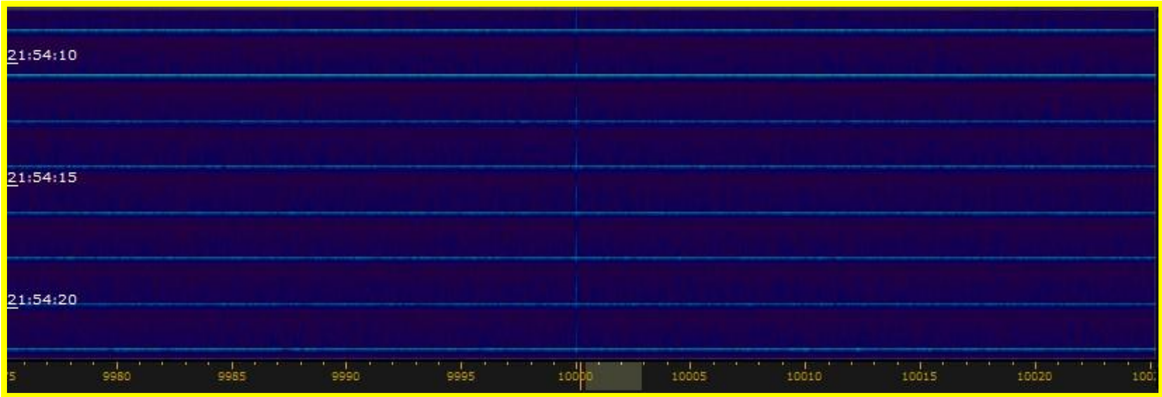
The pulse rise time (to 70% of peak amplitude) is 10 ns. Three pulse durations are used: 30, 50 and 100 ns. In all cases, pulse period is 600 ms. Pulse amplitude is $16V_{pk}$ (e.m.f.)

The AGC responds to the pulses. (See **Table 9**, **Figure 3**.) A "chuff" sound is heard during AGC recovery between pulses.

Table 9: AGC impulse response.

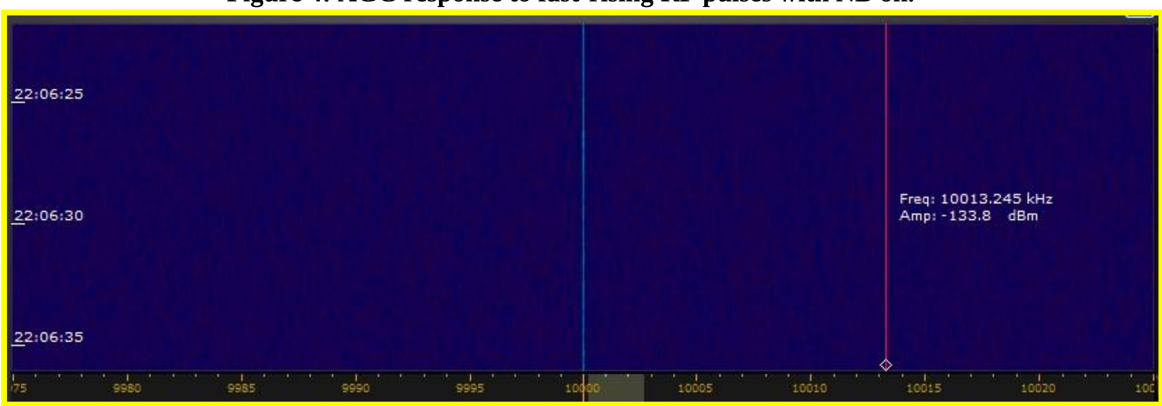
Pulse duration ns	AGC recovery ms	S-meter (pk)
30	< 100	S6
50	< 100	S7
100	< 100	S7

Figure 3: AGC response to fast-rising RF pulses.



9. Noise blanker (NB) impulse response: At the *minimum* NB setting, the AGC pulse response is *completely suppressed.* With NB on, the S-meter reading drops back to the noise floor. Increasing NB level makes no difference to this behavior. (See **Figure 4**.)

Figure 4: AGC response to fast-rising RF pulses with NB on.



9a. SpkRej (Spike Reject) button: Clicking SpkRej with NB off reduces the S-meter reading from S7 – S8 to S1 – S2, but a loud tick is heard as each pulse is applied to the RF input. These ticks are slightly louder at 30 ns pulse duration than at 50 – 100 ns.

NR greatly reduces the "chuff" sound of AGC recovery between pulses, but *does not* affect the S-meter reading. Also, NR reduces but *does not* eliminate the ticks when SpkRej is active.

Increasing ***AGC threshold*** (in Software Settings) to 10 mitigates the SpkRej ticks.

10. S-meter accuracy: This is a quick check of S-meter signal level tracking.

Test Conditions: 14.100 MHz, 2.4 kHz USB, preselector on, dither off, ATT off, AGC Med.

A 14.100 MHz test signal at MDS is applied to the RF input. The signal power is increased, and the level corresponding to each S-meter reading is noted. (All readings are taken with preamp off and on in turn.)

Table 10: S-Meter Tracking.

Input dBm	Rdg. dBm	Rdg. dBm	Remarks
	preamp off	preamp on	
-120	-117	-117	
-110	-110	-110	
-100	-101	-101	
-90	-91	-91	
-80	-81	-81	
-73	-74	-74	S9
-60	-61	-61	
-50	-51	-51	
-40	-41	-41	
-30	-31	-31	
-20	-21	-21	
-10	-11	-11	
-9	-9.5	-9.5	
-7	-7.5	-7.5	
-5	-5.5	CLIP	
-3	-3.5		
-2	-2.5		
-1.5	CLIP		

10a. Attenuator tracking: This is a quick check that the attenuator setting does not affect the S-meter reading.

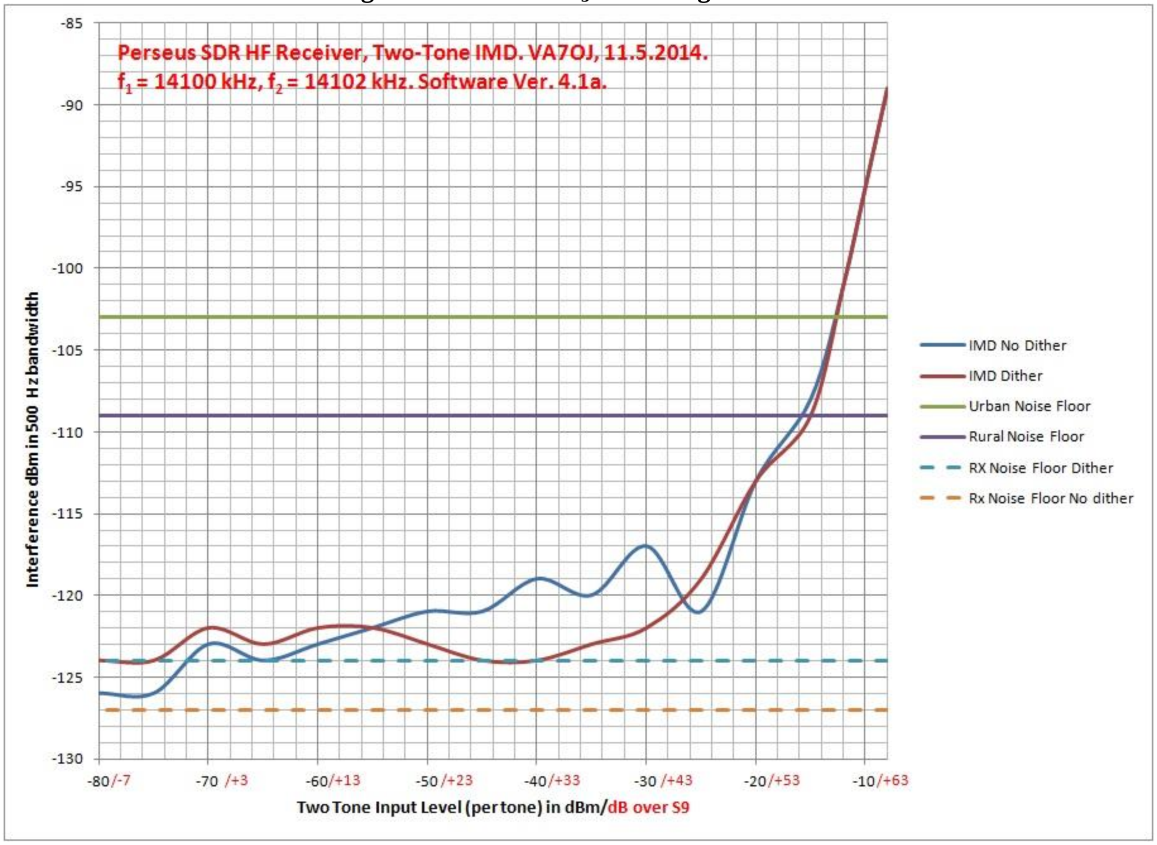
Table 13: ATT Check.

Input = -40 dBm	
ATT dB	Rdg. dBm
OFF	-40
10	-40
20	-40
30	-40

11. Two-Tone IMD_3 (IFSS, Interference-Free Signal Strength) tested in CW mode (500 Hz), ATT = 0 dB, Preamp off, Preselector on. SW V4.1a.

Test Conditions: Test frequencies: f_1 = 14100 kHz, f_2 = 14102 kHz. IMD_3 products: 14098/14104 kHz. IMD_3 product level was measured as absolute power in a 500 Hz detection bandwidth at various test-signal power levels and Dither on/off. The ITU-R P-372.1 band noise levels for typical urban and rural environments are shown as datum lines.

Figure 4: 2-tone IMD_3 vs. test signal level.



Note on 2-tone IMD_3 test: This is a new data presentation format in which the amplitude relationship of the actual IMD_3 products to typical band-noise levels is shown, rather than the more traditional DR_3 (3^{rd}-order IMD dynamic range) or SFDR (spurious-free dynamic range). The reason for this is that for an ADC, SFDR referred to input power rises with increasing input level, reaching a well-defined peak ("sweet spot") and then falling off. In a conventional receiver, SFDR falls with increasing input power.

If the IMD_3 products fall below the band-noise level at the operating site, they will generally not interfere with desired signals.

The SFDR behavior of an ADC invalidates the traditional DR_3 test for a direct-sampling SDR receiver. By the same token, third-order intercept (IP_3) is meaningless in the context of an ADC, as the 3^{rd}-order and transfer curves diverge. Our goal here is to find an approach to SFDR testing which holds equally for SDR and legacy receiver architecture. (See ***Ref. 3.***)

12. Two-Tone 2^{nd}-Order Dynamic Range (DR_2) & Second-Order Intercept (IP_2). The purpose of this test is to determine the range of signals far removed from an amateur band which the receiver can tolerate while essentially generating no spurious responses within the amateur band.

In this test, two widely-separated signals of equal amplitude P_i are injected into the receiver input. If the signal frequencies are f_1 and f_2, the 2nd-order intermodulation product appears at ($f_1 + f_2$). The test-signal frequencies are chosen such that ($f_1 + f_2$) falls within an amateur band.

The two test signals are combined in a passive hybrid combiner and applied to the receiver input via a step attenuator. The receiver is tuned to the IMD product ($f_1 + f_2$) which appears as a 600 Hz tone in the speaker. The per-signal input power level P_i is adjusted to raise the noise floor by 3 dB, i.e. IMD product at MDS. The P_i value is then recorded.

$DR_2 = P_i$ - MDS. Calculated $IP_2 = (2 * DR_2)$ + MDS.

Note: IP_2 figures are given for comparison only. In a direct-sampling SDR, IP_2 has no real meaning as the input and IMD_2 curves diverge; thus, there is no true intercept point. (See ***Refs. 2, 3.***)

Test Conditions: f_1 = 6.1 MHz, f_2 = 8.1 MHz, 500 Hz CW, AGC off, ATT off, NR off, NB off. IMD2 product at ($f_1 + f_2$) = 14.2 MHz.

Table 14: DR_2 and IP_2.

Presel	Preamp	Dither	P_{in}/tone, dBm	DR_2, dB	IP_2, dBm
1	0	0	-17	110	+93
1	1	0	-18	109	+92
1	0	1	-15	108	+93
1	1	1	-17	109	+92
0	0	0	-19	110	+91

13. Noise Power Ratio (NPR): An NPR test was performed on the Perseus, using the test methodology described in ***Ref. 4.*** The noise-loading source used for this test was a notched-noise generator with a 60…5600 kHz band-limiting filter (equivalent to 1200 voice channels) and a 5340 kHz bandstop (notch) filter selected.

The noise loading P_{TOT} was increased until the ADC CLIP indicator flashed, and then backed off until no clipping was observed for at least 10 seconds. NPR was then read off the spectrum scope by observation. (NPR is the ratio of noise power at the bottom of the notch to noise power in a channel outside the notch.)

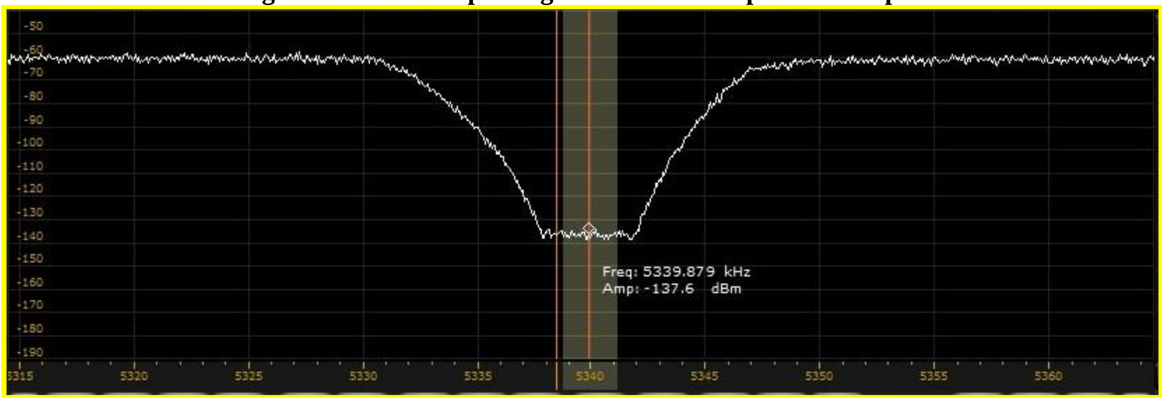
Test conditions: Perseus tuned to 5339.879 kHz, 2.4 kHz USB, ATT off, NR off, NB off, AGC Med. (See **Figure 5**).

Table 15. 5340 kHz NPR test results.

Presel	Preamp	Dither	Clip dBm	P_{TOT} dBm	NPR dB[1]
0	0	0	-3.6	-16.5	72
0	0	1	-3.6	-19.4	70
0	1	0	-7.1	-19.9	69
0	1	1	-7.1	-19.5	68
1	0	0	-1.5	-8.5	75
1	0	1	-1.5	-8.8	73
1	1	0	-5.0	-12.2	73
1	1	1	-5.0	-12.9	72
Note 1: NPR value measured by observation (Ref. 3, Section G).					

The best-case 75 dB 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. (See ***Ref. 4,*** Sections J and K.)

Figure 5: NPR test spectrogram on Perseus spectrum scope.



14. AGC action due to signals outside the channel passband: The purpose of this test is to determine the input power level at which an unwanted signal falling within the roofing-filter window, but outside the DSP IF passband, starts stimulating the AGC.

Test Conditions: Perseus tuned to 14.100 MHz, 2.4 kHz USB, AGC Slow, ATT off, NR off, NB off, preselector on, preamp off, dither off. Test signal:14.103 MHz. Noise floor -120 dBm (read on S-meter).

Result: Test signal -40 dBm at 14.103 MHz for a 1 dB increase in noise floor. (***Note:*** This may be a function of residual signal-generator phase noise.)

References.

1. Arkesteijn et al., "Jitter requirements of the sampling clock in software radio receivers", University of Twente, Netherlands, 2006. http://doc.utwente.nl/57309/

2. NSARC Presentation: "Perseus", Sept. 2011, #17. http://www.nsarc.ca/hf/perseus.pdf

3. NSARC Presentation: "HF Receiver Testing: Issues & Advances". http://www.nsarc.ca/hf/rcvrtest.pdf

4. Noise Power Ratio (NPR) Testing of HF Receivers. http://www.ab4oj.com/test/docs/npr_test.pdf

5. Noise Power Ratio (NPR) - A 65-Year Old Telephone System Specification Finds New Life in Modern Wireless Applications, by Walt Kester. Analog Devices Inc. Tutorial MT-005, 2009.

Appendix 1: Additional NPR Tests, February 2012.

The acquisition of two additional filter pairs (bandstop and band-limiting) permitted additional NPR tests at 3886 and 7600 kHz.

15. NPR Test at 3886 kHz: For the 3886 kHz test, a 60…4100 kHz band-limiting filter (equivalent to 960 voice channels) and a 3886 kHz bandstop (notch) filter were selected.

Test conditions: Perseus tuned to 3887.5 kHz, 2.4 kHz LSB, ATT off, NR off, NB off, AGC Med. (See **Figure 5**). P_{TOT} adjusted for no clipping in 10 sec. interval.

Table 16. 3886 kHz NPR test results.

Presel	Preamp	Dither	P_{TOT} dBm	NPR dB[1]
0	0	0	-16	74
0	0	1	-16	72
0	1	0	-20	71
0	1	1	-20	69
1	0	0	-8	76
1	0	1	-8	74
1	1	0	-11	75
1	1	1	-11	74

16. NPR Test at 7600 kHz: The 7600 kHz test was performed with a 316…8160 kHz band-limiting filter (equivalent to 1800 voice channels) and a 7600 kHz bandstop (notch) filter.

Test conditions: Perseus tuned to 7601.5 kHz, 2.4 kHz LSB, ATT off, NR off, NB off, AGC Med. (See **Figure 5**). P_{TOT} adjusted for no clipping in 10 sec. interval.

Table 17. 7600 kHz NPR test results.

Presel	Preamp	Dither	P_{TOT} dBm	NPR dB[1]
0	0	0	-16.5	73
0	0	1	-16.5	69
0	1	0	-20.2	68
0	1	1	-20	69
1	0	0	-7.8	76.5
1	0	1	-7.8	73
1	1	0	-11.5	74
1	1	1	-11.5	72

Notes: 1. NPR value measured by observation (see **Ref. 1**, Section G.)

February 26, 2012.

Appendix 2: Additional NPR Tests, May 2013.

The acquisition of two more filter pairs (bandstop and band-limiting) permitted additional NPR tests at 1940 and 2348 kHz.

17. NPR Test at 1940 kHz: For the 1940 kHz test, a 60…2044 kHz band-limiting filter (equivalent to 480 voice channels) and a 1940 kHz bandstop (notch) filter were selected.

Test conditions: Perseus tuned to 1940.0 kHz, 2.4 kHz LSB, ATT off, NR off, NB off, AGC Med. (See **Figure 5**). P_{TOT} adjusted for no clipping in 10 sec. interval.

Table 18. 1940 kHz NPR test results.

Presel	Preamp	Dither	P_{TOT} dBm	NPR dB[1]
0	0	0	-16	76
0	0	1	-16	74
0	1	0	-20	74
0	1	1	-20	72
1	0	0	-5	65[2]
1	0	1	-5	65[2]
1	1	0	-10.5	71
1	1	1	-10.5	71

18. NPR Test at 2438 kHz: The 2438 kHz test was performed with a 60…2600 kHz band-limiting filter (equivalent to 600 voice channels) and a 2438 kHz bandstop (notch) filter.

Test conditions: Perseus tuned to 2438.0 kHz, 2.4 kHz USB, ATT off, NR off, NB off, AGC Med. (See **Figure 5**). P_{TOT} adjusted for no clipping in 10 sec. interval.

Table 19. 2438 kHz NPR test results.

Presel	Preamp	Dither	P_{TOT} dBm	NPR dB[1]
0	0	0	-16	74
0	0	1	-16.5	72
0	1	0	-20.5	72
0	1	1	-20	71
1	0	0	-6.5	79
1	0	1	-6.5	77
1	1	0	-11.5	77
1	1	1	-12	75

Notes: 1. NPR value measured by observation (see **Ref. 1**, Section G.)
2. Low NPR value may indicate passive IMD in preselector.

May 1, 2013.

Appendix 3: Aliasing Suppression Test, Dec. 2, 2015.

The purpose of this test, proposed by Andrew Barron ZL3DW, is to measure the suppression of aliasing artifacts generated in Nyquist Zone 1when a swept signal covering a frequency offset range in Nyquist Zone 2 is applied to the Perseus RF input.

The Perseus Nyquist frequency ($f_S/2$) is 40 MHz. Thus, Nyquist Zone 1 < 40 MHz and Zone 2 > 40MHz.

19. Aliasing suppression for input sweep range 40 MHz ≤ f_0 ≤50 MHz. An RF sweep generator is connected to the Perseus RF input via a 20 dB attenuator, and set up as follows:

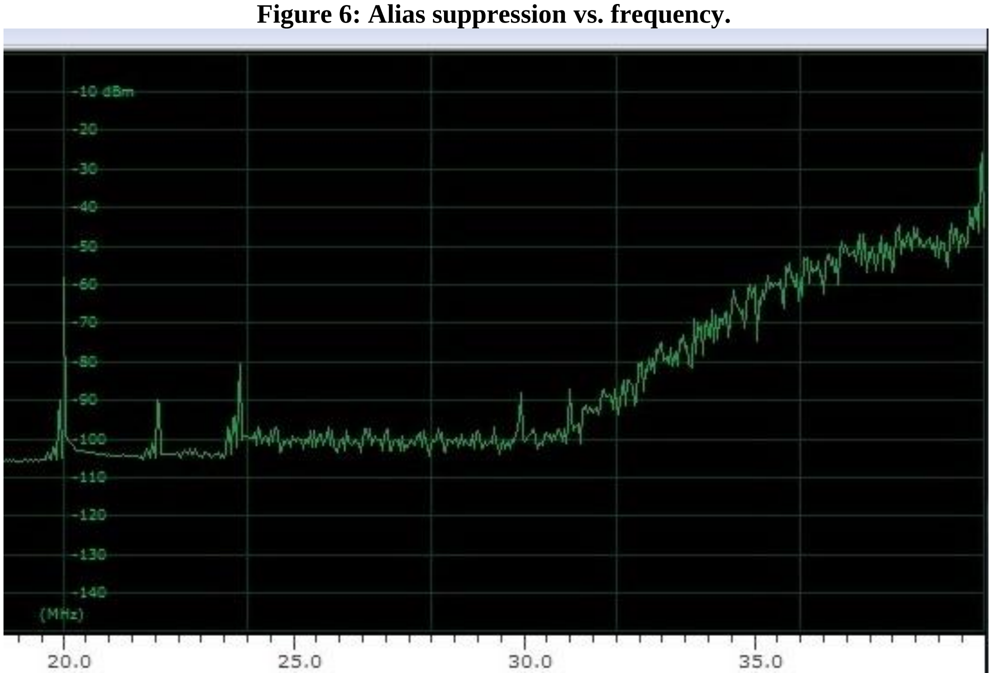
- Start Freq: 40MHz ($f_S/2$)
- Stop Freq: 50MHz ($f_S/2$ + 10 MHz)
- Sweep Time: 250 ms
- Output level: 0 dBm
- Attenuator: 20 dB

Test conditions: Perseus running under HFSpan v4.1a, configured as follows:

- Attenuator: 0 dB
- Preselector: OFF (default)
- High Gain: OFF
- Dither: OFF
- Window: Blackman
- AVG: 256
- Span: 40 MHz

Allow sufficient time for averaging process to form a curve, and then capture screenshot. The test result is shown in Figure 6. The curve in the 30 – 40 MHz range is a good approximation of the anti-aliasing filter's response curve. Averaging will cause some amplitude error.

Figure 6: Alias suppression vs. frequency.



Appendix 4: Additional NPR Tests, March 2018.

The acquisition of two additional filter pairs (bandstop and band-limiting) permitted additional NPR tests at 11700 and 16400 kHz.

20. NPR Test at 11700 kHz: For the 11700 kHz test, a 316...12360 kHz band-limiting filter (equivalent to 2700 voice channels) and a 11700 kHz bandstop (notch) filter were selected.

Test conditions: Perseus tuned to 11698.5 kHz, 2.4 kHz USB, ATT off, NR off, NB off, AGC Med. (See **Figure 5**). P_{TOT} adjusted for no clipping in 10 sec. interval.

Table 18. 11700 kHz NPR test results.

Presel	Preamp	Dither	P_{TOT} dBm	NPR dB[1]
0	0	0	-15.5	69
0	0	1	-15.5	66
0	1	0	-19	67
0	1	1	-19	64
1	0	0	-6.5	68
1	0	1	-6.5	68
1	1	0	-10.5	70
1	1	1	-10.5	68

21. NPR Test at 16400 kHz: The 16400 kHz test was performed with a 316…17300 kHz band-limiting filter (equivalent to 3600 voice channels) and a 16400 kHz bandstop (notch) filter.

Test conditions: Perseus tuned to 16398.5 kHz, 2.4 kHz USB, ATT off, NR off, NB off, AGC Med. (See **Figure 5**). P_{TOT} adjusted for no clipping in 10 sec. interval.

Table 19. 16400 kHz NPR test results.

Presel	Preamp	Dither	P_{TOT} dBm	NPR dB[1]
0	0	0	-16	67
0	0	1	-16	64
0	1	0	-19	64
0	1	1	-20	62
1	0	0	-8.5	71
1	0	1	-8.5	68
1	1	0	-12	69
1	1	1	-12	67

Notes: 1. NPR value measured by observation (see **Ref. 1**, Section G.)

March 18, 2018.