Expert Electronics *ColibriNano* Test Report

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Figure 1: ColibriNANO exterior & interior. (Courtesy Expert Electronics)

Introduction: This test report presents results of a number of RF lab tests performed on a ColibriNano direct-sampling SDR receiver dongle kindly loaned by Expert Electronics.

DUT: ColibriNano, S/N EED02091700087.

Software version: ExpertSDR, ver. 1.2.0.

Performance Tests conducted in my home RF lab, June 7-10 and 25-26, 2017.

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: CW (B = 500 Hz), SSB (B = 2.5 kHz), Preamp 0 dB, NR/NB/ANF off, AGC Slow, sampling rate 96 kHz. Preamp Auto off, RF 100 dB, SC on for all tests.

.

Table 1: MDS in dBm.

f_0 MHz		3.6	14.1	28.1	50.1
Mode	**Preamp dB**				
CW	0	-124	-123	-116	-117
	+6	-124	-108	-108	-107
SSB	0	-110	-123	-116	-117
	+6	-110	-108	-108	-107

2: Reciprocal Mixing Noise occurs in a direct-sampling SDR receiver when phase noise generated within the ADC mixes with strong signals close in frequency to the wanted signal, producing unwanted noise products at the IF and degrading the receiver sensitivity. Reciprocal mixing noise in a direct-sampler is an indicator of the ADC clock's spectral purity**.**

In this test, a Wenzel 5 MHz OCXO with low phase noise is connected via a 3 dB pad, a narrow bandstop filter and a 0-110 dB step attenuator to the DUT (ANT). The noise floor is read on the DUT S-meter in CW mode (500 Hz) with ANT terminated in 50Ω. The input power P_i increased to raise detected noise by 3 dB. Reciprocal mixing dynamic range (RMDR) = P_i – MDS.

Note: The residual phase noise of the OCXO is the limiting factor in measurement accuracy.

Test Conditions: f_0 = 5.000 MHz, CW, B= 500 Hz, NR/NB/ANF off, Preamp 0 dB, positive offset. Sampling rate 96 kHz. RMDR *in dB* = input power (P_i) – MDS *(both in dBm)*. Here, MDS = -123 dBm at 5.000 MHz. Phase noise PN = -(RMDR+27) dBc/Hz.

Table 2: RMDR in dB.

Offset kHz	P_i dBm	RMDR dB	PN dBc/Hz
0.5	-23	100	-127
1	-18	105	-132
2	-14	109	-136
3	-14	109	-136
5	-13	110	-137
10	-13	110	-137
20	ADC CLIP!		
f_0=5000.000 kHz. B=500Hz. MDS=-123 dBm.			

3. Two-Tone IMD₃ (IFSS, Interference-Free Signal Strength) tested in CW mode (B = 500 Hz), ATT = 0 dB. Test frequencies: f_1 = 14010 kHz, f_2 = 14012 kHz. IMD_3 products: 14008/14014 kHz. IMD_3 product level is measured as absolute power in a 500 Hz detection bandwidth at various test-signal power levels, with ATT off. The ITU-R P-372.1 band noise levels for typical urban and rural environments are shown as datum lines. Ideally, the IFSS curve should be below the rural band noise line over as wide an input power range as possible.

As the DUT ADC does not have on-chip dither, a third test tone was injected at 14300 kHz and -19 dBm to simulate incidental dither. This tone degraded the dynamic range by 5 dB, but caused a striking improvement in the IFSS curve. (See Figure 2.)

Figure 2: 2-tone IMD_3 (IFSS) vs. test signal level.

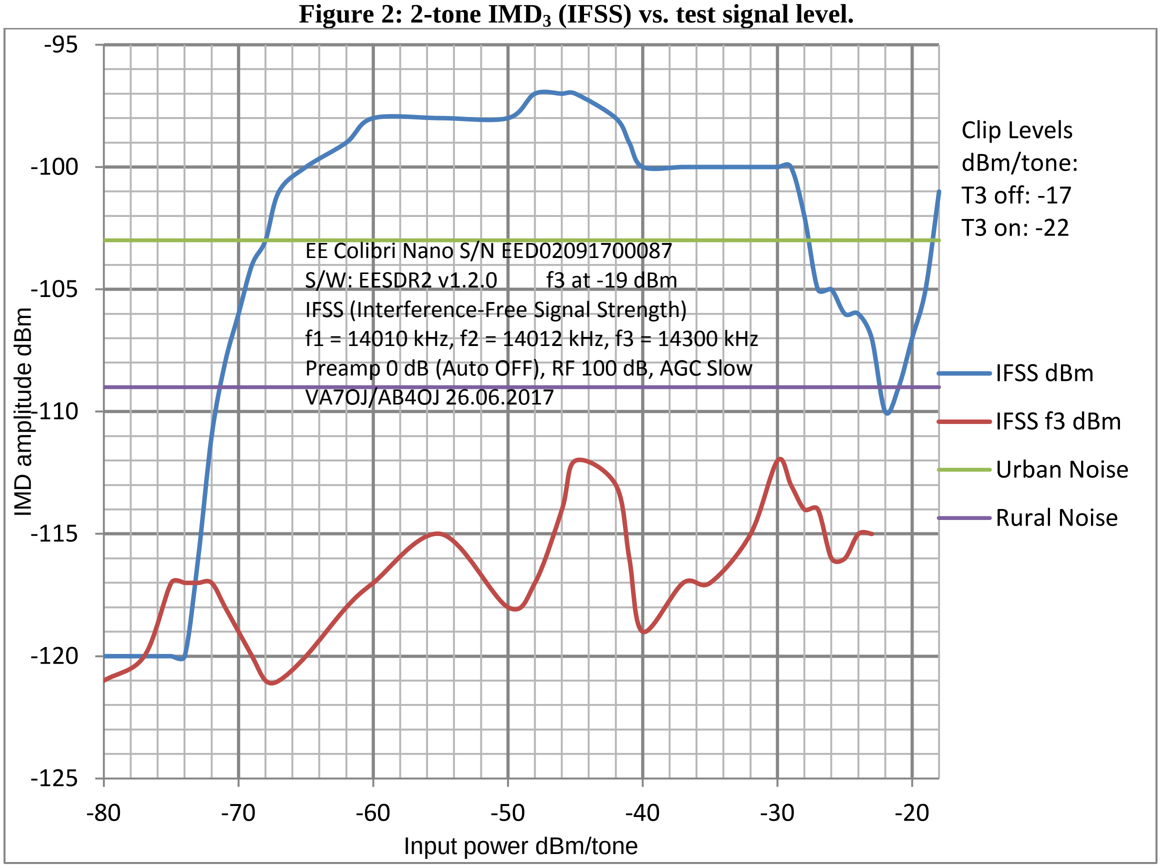


Figure 3: IFSS spectrogram showing IMD products without 3rd tone.

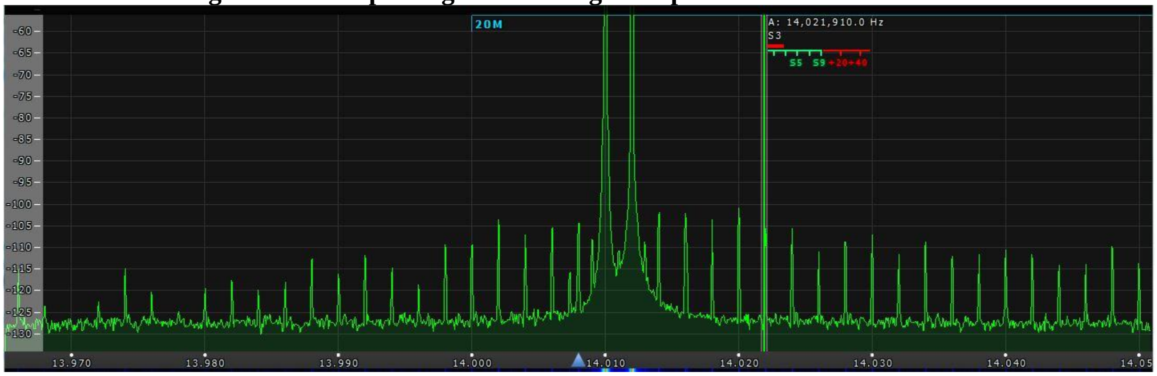
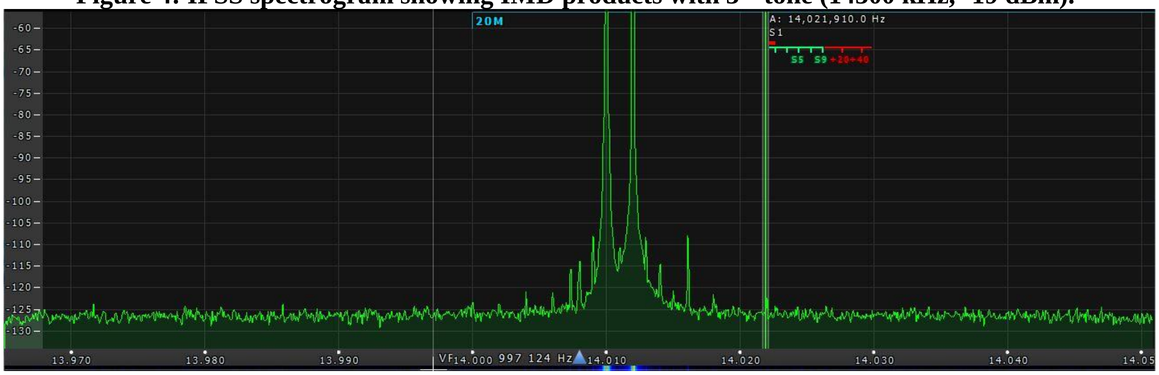


Figure 4: IFSS spectrogram showing IMD products with 3rd tone (14300 kHz, -19 dBm).



4. ***DR_2 (IMD_2 dynamic range)*** tested at 14.200 MHz. Test signal level is adjusted for a 3 dB increase in audio output, and DR_2 calculated.

Test Conditions: Test frequencies: f_1 = 6100 kHz, f_2 = 8100 kHz. 2nd-order IMD_2 product: 14200 kHz. CW, B= 500 Hz, NR/NB/ANF off, Preamp 0 dB, positive offset. Sampling rate 96 kHz.

$DR_2 = P_i – MDS$.

Test Results: Refer to Table 5.

Table 3: IMD2 Dynamic Range (DR2).

Preamp dB	MDS dBm	P_i dBm/tone	DR_2 dB
0	-123	-35	88

5. Noise Power Ratio (NPR): An NPR test is performed, using the test methodology described in detail in ***Ref. 2***. The noise-loading source used for this test is a noise generator fitted with bandstop (BSF) and band-limiting filters (BLF) for the test frequencies utilized.

The noise loading P_{TOT} is applied to ANT1 and increased until ADC clipping just commences, and then backed off until no clipping is observed for at least 10 seconds. NPR is then read directly off the spectrum scope (see Figure 5). NPR is the ratio of noise power in a channel outside the notch to noise power at the bottom of the notch.

Test Conditions: Receiver tuned to bandstop filter centre freq. $f_0 \pm 1.5$ kHz (LSB/USB), B = 2.5 kHz, Preamp 0 dB, NR/NB/ANF off, AGC Slow, sampling rate 96 kHz.

Table 4: NPR Test Results.

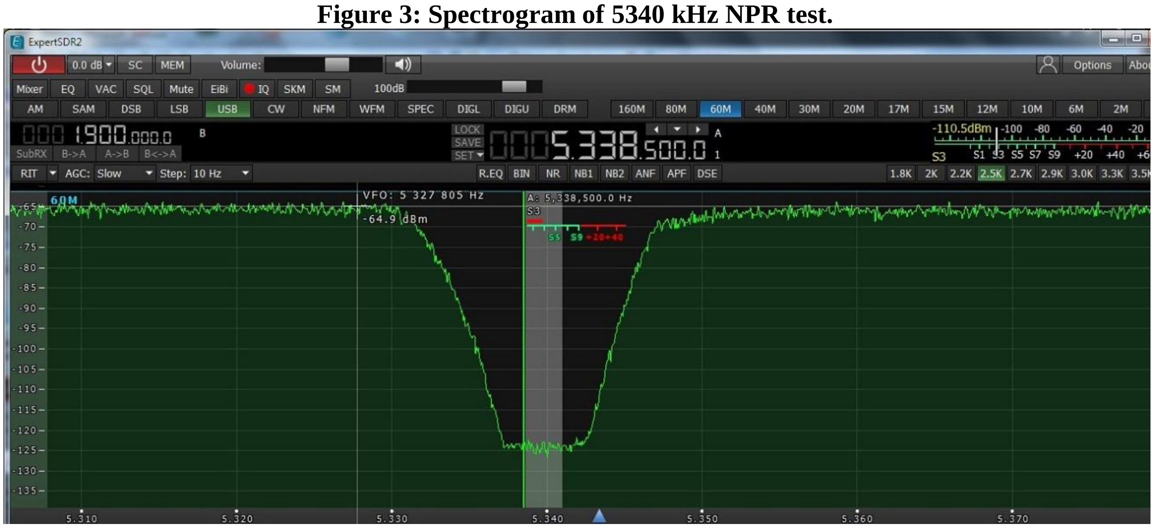
DUT	Det BW kHz	Mode	Sample kHz	BSF kHz	BLF kHz	P_{TOT} dBm	NPR dB[2]	Theor. NPR dB[1]
Colibri NANO	2.5	USB	96	534	12...552	-22	65	84
		USB	192	1248	60…1296	-24	61	82.4
		LSB	192	1940	60…2044	-24	62	80
		LSB	96	3886	60…4100	-24	60	77
		USB	96	5340	60…5600	-24	58	75.6
		LSB	96	7600	12…8160	-24.5	56	73.5
		USB	192	11700	316…12360	-24	55	71.8
		USB	192	16400	316...17300	-18	52	70.3

Notes on NPR test:

1. Theoretical NPR was calculated for the 14-bit ADC using the method outlined in ***Ref. 3*** and assuming the LTC2208-14 parameters. The theoretical NPR value assumes that B_{RF} is not limited by any filtering in the DUT ahead of the ADC, and that the net gain between the antenna port and the ADC is 0 dB.

2. A preselector ahead of the ANT input will improve NPR.

Figure 3: Spectrogram of 5340 kHz NPR test.



6. S-meter & Spectrum Scope Tracking: This is a quick check of S-meter and scope signal level tracking.

Test Conditions: 14100 kHz, 2.5 kHz USB, Preamp 0 dB, sampling rate 96 kHz, NR/NB/ANF off. Correction -1.5 dB. Starting at S1, the test signal power is increased and the level corresponding to each S-meter reading is noted.

Table 5: S-Meter Tracking. ADC clip level: -11 dBm.

S-meter	S1	S2	S3	S4	S5	S6	S7	S8	S9	+10	+20	+30	+40	+50	+60
Applied dBm	-121	-115	-109	-103	-97	-91	-85	-79	-73	-63	-53	-43	-33	-23	-13
Rdg.dBm	-119	-114	-109	-103	-97	-91	-85	-79	-73	-63	-53	-44	-34	-24	-14

6a. Spectrum Scope Tracking: Scope level error ≤ ±0.3 dB when input power is varied in 20 dB steps from ADC clip to noise floor.

7. Brief on-air test: The ColibriNANO was plugged into a USB 3.0 port on an office workstation computer running Windows 7 Professional (64-bit) and ExpertSDR v1.2.0. It was connected to a Cushcraft R8 multi-band vertical antenna at 15m overall height.

The receiver was tuned to CW and SSB stations on the 40m amateur band, and to WWV on 10 MHz. Precise tuning could be accomplished quite easily by left-click dragging the passband onto the desired signal on the spectrum scope and then fine-tuning with the mouse wheel, or by positioning the cursor on successive digits of the frequency readout and clicking left (up) and right (down). The frequency scale was moveable by right-click dragging the passband.

CW reception was very clear and pleasant, with stations popping out of the band noise at bandwidths of 500 Hz and less. Even at 100 and 50 Hz bandwidth, very little filter ringing was evident.

Several SSB stations were also tuned in. Strong stations were clear, with good audio quality. Weak SSB signals were rather noisy, and NR tended to convert the band noise into a slightly "watery" sound. S/N ratio improved very little with NR on.

WWV sounded clean and undistorted in AM mode. The carrier and sidebands of the 10 MHz WWV signal were clearly visible on the spectrum scope.

Although this was a brief and limited test, as dictated by poor propagation and a limited antenna, it showed that the ColibriNano should be a very good "go-anywhere" SWL or amateur receiver. As a 14-bit direct-sampling SDR, it should be far superior to the popular inexpensive dongle receivers currently on the consumer market.

8. References:

1. Manufacturer and latest software:
   https://eesdr.com/en/products-en/receivers-en/colibrinano-en#description

2. Available in North America from NSI Communications: (800) 977-0448
   https://www.nsiradio.com/

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

4. "Theoretical maximum NPR of a 16-bit ADC"
   http://www.ab4oj.com/test/docs/16bit_npr.pdf

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

6. "A New Look at SDR Testing"
   http://www.ab4oj.com/sdr/sdrtest2.pdf

9. Acknowledgements: The author is indebted to Expert Electronics for the loan of the ColibriNano during Dayton Hamvention 2017, and for support with questions which arose during the test phase.

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