ANAN-7000DLE Test Report

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Figure 1: Apache Labs ANAN-7000DLE SDR Transceiver.

Introduction: This test report presents results of an RF lab test suite performed on an Apache Labs ANAN-7000DLE 100W direct-sampling/DUC SDR transceiver loaned by Apache Labs.

The Orion Mk II receiver/exciter board in this DUT uses the Crystek CVHD-950 VCXO. No noise-floor degradation with dither enabled was observed in the ANAN-7000DLE.

Software versions: Iss. 1, 2, 3: PowerSDR OpenHPSDR mRX PS v3.4.9.0.

Firmware versions: Iss. 1, 2, 3: Orion MkII v2.2 (Protocol_1)

Performance Tests conducted in my home RF lab, April 15 - May 2, 2018..

A. Receiver 1 (RX1) Tests

Note: Frequency and level calibration (10.000 MHz, -70 dBm) performed at start.

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 on the S-meter.

Test Conditions: ATT as shown, NR off, NB off, ANF off, AGC Fxd, AGC Gain = 120, RX1 Meter: Sig, Avg., Dither off, Random off.

Table 1: MDS[1] in dBm (RX1).

	3.6 MHz		14.1 MHz		28.1 MHz		50.1 MHz	
ATT dB	SSB 2.4kHz	CW 500Hz	SSB 2.4kHz	CW 500Hz	SSB 2.4kHz	CW 500Hz	SSB 2.4kHz	CW 500Hz
0	-124	-131	-124	-131	-123	-130	-130	-137
-20	-104	-111	-104	-111	-103	-110	-120	-116

Notes: 1. Dither and/or Random do not affect MDS.
2. Bypassing Alex preselector does not affect MDS
3. ADC clip level: -5 dBm

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 7 dB pad and a 0-110 dB step attenuator to the DUT (ANT1). An RMS AC voltmeter is connected to the headphone jack. 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 is increased to raise detected noise by 3 dB. Reciprocal mixing dynamic range (RMDR) = P_i – MDS.

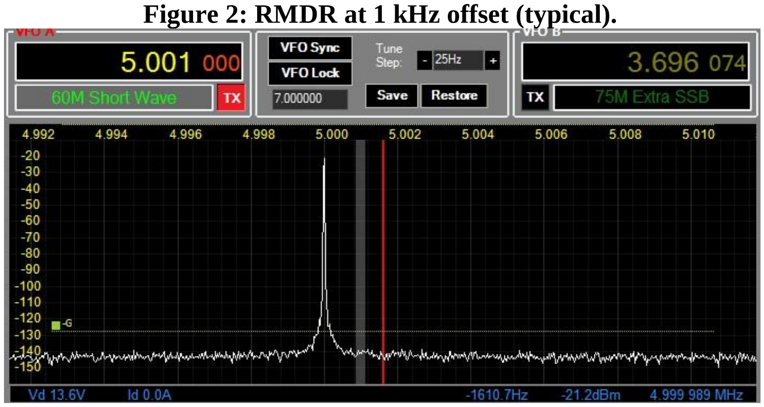
Note: The residual phase noise of the OCXO is the limiting factor in measurement accuracy. The external 10 MHz reference is disconnected for this test.

Test Conditions: 5.000 MHz, 250 Hz CW, ATT 0 dB, NR off, ANF off, NB off, negative offset. AGC Fxd, AGC Gain 120. Dither off, Random off. BH-4 receive filter window, sample rate 192K, buffer size 1024, filter size 4096. RMDR *in dB* = input power (P_i) – MDS *(both in dBm).* Here, MDS = -134 dBm (B = 250 Hz). RMDR = Pi - MDS.
Phase noise = -(RMDR + 10 log B) = RMDR + 24 dBc/Hz.

Table 2: 5 MHz RMDR & Phase Noise.

Offset kHz	P_i dBm	RMDR dB	PN dBc/Hz
0.5	-29	105	-129
1	-26	108	-132
2	-24	110	-134
3	-23	111	-135
5	-21	113	-137
10	-17	117	-141
20	-12	122	-146
30	-10	124	-148
50	-6	128	-152
100	-5	CLIP	

Figure 2: RMDR at 1 kHz offset (typical).



3: 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 rejection. The lower the shape factor, the "tighter" the filter.

In this test, an in-channel RF test signal from the Wenzel OCXO is applied at -50 dBm. The bandwidths at -6 and -60 dB relative to the input power are determined by tuning the receiver across the signal and observing the S-meter.

Test Conditions: 5000 kHz nominal, SSB/CW modes, ATT = 0 dB, AGC med, NR off, NB off, ANF off, Dither off, Random off. BH-4 filter window. Audio tab: Sample rate 192K, buffer size 1024, filter type Linear Phase. ***Note:*** Switching to BH-7 window or Low Latency does not affect results.

Table 3: Channel Filter Shape Factors.

	DSP Filter Size 2048		DSP Filter Size 16348	
Filter	Shape Factor	6 dB BW kHz	Shape Factor	6 dB BW kHz
2.4 kHz SSB	1.06	2.40	1.01	2.41
500 Hz CW	1.30	0.50	1.04	0.50
250 Hz CW	1.58	0.25	1.07	0.25
5 kHz AM	1.03	5.0		

3a: Ultimate channel filter attenuation. This test is conducted with the Wenzel OCXO as in ***3.*** above. A test signal is applied at a power level of -26 dBm, and the receiver is detuned until the S-meter drops no further. The final S-meter reading and the frequency offset are recorded. ***Note:*** The channel filters actually have deeper stopbands than measured.

Test Conditions: Test signal 5000 kHz at -26 dBm, SSB/CW modes, ATT = 0 dB, AGC med, NR off, NB off, ANF off. BH-4, sample rate 192K, filter size 2048. Switching to BH-7 window does not affect results.

Test Results: 2.4 kHz SSB: S-meter minimum = -115 dBm at 1.65 kHz offset.
Ultimate attenuation = -26 - (-115) = **89 dB**.
Bandwidth for ultimate attenuation = 2 * 1.65 ≈ **3.3 kHz**.

500 Hz CW: S-meter minimum = -121 dBm at 1.2 kHz offset.
Ultimate attenuation = -26 - (-121) = **95 dB**.
Bandwidth for ultimate attenuation = 2 * 1.2 ≈ **2.4 kHz**.

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

A distortion test set or SINAD meter is connected to the DUT audio output. 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 various NR settings.

Test Conditions: 14.100 MHz, 2.4 kHz USB, BH-4 RX filter, sampling rate 192K, buffer size 1024, filter size 2048, filter type Linear Phase, AGC Med, ATT = 0 dB, NB off, ANF off, NR/NR2/ANF Pre-AGC (in DSP Options), Dither off, Random off. Initial NR settings (defaults): Taps 64, Delay 16, Gain 100, Leak 100. (Varying Delay does not significantly affect SINAD readings.)

Table 4: NR SINAD.

Taps	Delay	SINAD dB
NR off	16	6
64	16	14
128	16	19
256	16	24
512	16	30
1024	16	35

This shows an SINAD improvement of 29 dB max. with NR at maximum for an SSB signal roughly 4 dB above the noise floor. This is an approximate measurement, as the amount of noise reduction is dependent on the original signal-to-noise ratio.

In on-air listening, NR was very effective in reducing band noise (as long as the desired signal was audible), and did not distort received audio.

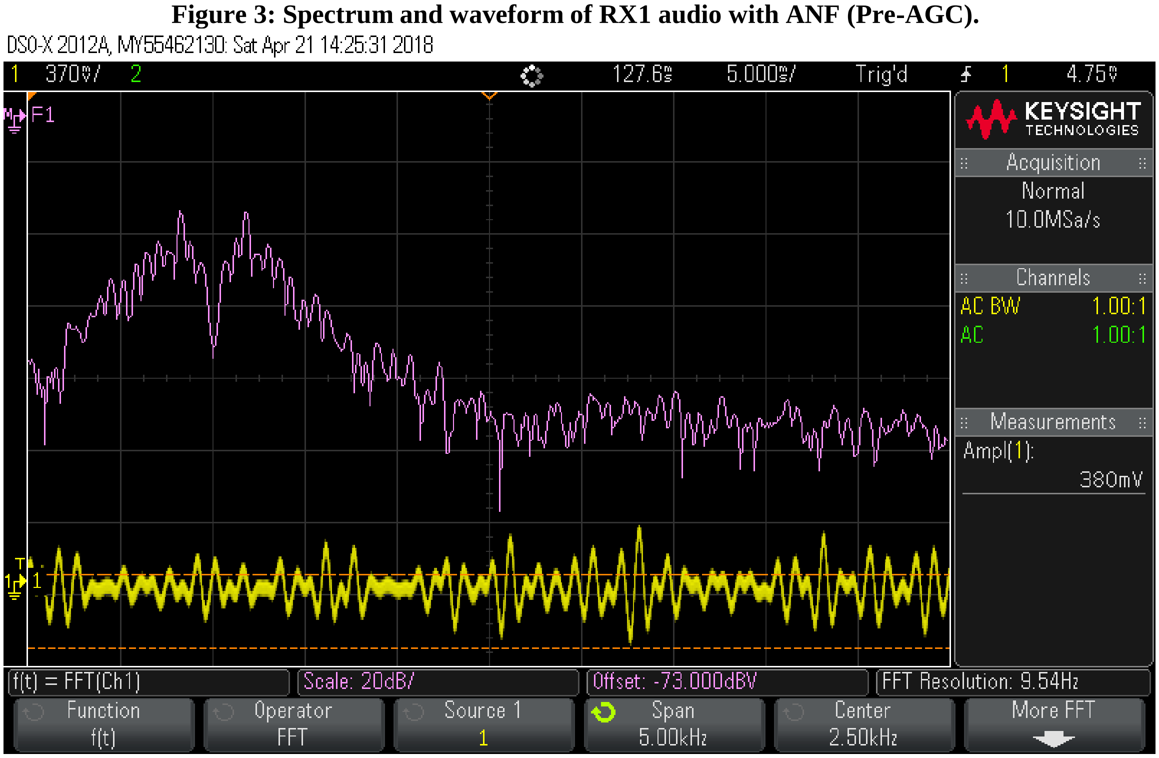
5: Auto-Notch Filter (ANF) stopband attenuation. In this test, an RF signal is applied at a level ≈ 70 dB above MDS. The test signal is offset 1 kHz from the receive frequency to produce a test tone. ANF is activated and the test signal level is adjusted to raise the audio output 3 dB above noise floor. The stopband attenuation is equal to the difference between test signal power and MDS.

Test Conditions: 14.100 MHz, 2.4 kHz USB, sampling rate 192K, BH-4 RX filter, buffer size 1024, AGC med, ATT = 0 dB, NB off, ANF off, Dither off, Random off. Initial ANF settings (defaults): Taps 64, Delay 16, Gain 100, Leak 100. AGC Med, Gain 120 (max).

Test Results: Measured MDS = -124 dBm per Test 1. P_i = -54 dBm.
NR/NR2/ANF Post-AGC: Stopband attenuation = P_i - MDS = -44 - (-124) = **70 dB**. Tone completely suppressed.

NR/ANF Pre-AGC: Tone partly suppressed. Audible artifacts in RX audio output (raspy hum and low-level tone) as depicted in Figure 3.

Figure 3: Spectrum and waveform of RX1 audio with ANF (Pre-AGC).



6: Multi-Notch Filter (MNF) Test. Since v3.3.6, PowerSDR OpenHPSDR incorporates a new Multi-Notch Filter (MNF) tool, which allows the user to specify up to 1024 notches (bandstop filters). These notches are specified by absolute RF frequency and width; they will be invoked as needed when they overlap the detection passband. This feature is useful for suppressing interference which consistently appears on specific frequencies.

To avoid phase distortion, the notches are implemented with linear phase. They introduce no additional processing delay, nor do they consume any additional CPU cycles once the receiver is on frequency and the notches are set up. This is all accomplished by simply "cutting" the notches into the existing bandpass filters rather than adding additional filters. *(Description courtesy Doug Wigley W5WC.)*

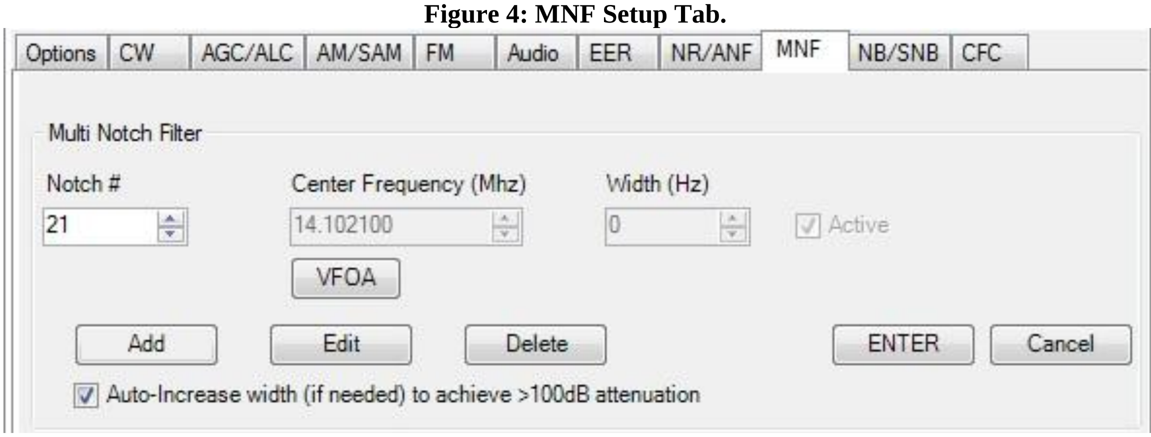
To test MNF, it is convenient to generate an FM test signal whose modulating frequency f_m and peak deviation Δf are chosen to yield a specific number of sideband pairs. The receiver is then set to USB and tuned to the carrier frequency of the test signal. The first notch is set at the carrier frequency f_c , and subsequent notches are set at $f_c + nf_m$ where n is the order of the sideband pair. The number of configured notches equals the number of sideband pairs. With the receiver in USB, only the upper sidebands will appear in the detection channel, as illustrated in Figures 5 & 6.

When MNF is inactive, a loud composite tone will be heard in the headphones and the S-meter will indicate the average power of the FM carrier and sidebands. With MNF on, S-meter reading and the audio output should fall to the receiver noise floor.

Test Conditions: 14.100 MHz, 2.4 kHz USB, ATT 0 dB, NR off, ANF off, NB off, AGC Med, AGC Gain 120. Dither off, Random off. BH-4 receive filter window, sample rate 192K, buffer size 1024; filter type Linear Phase. S-meter reads Sig Avg. DUT and signal generator clocked from 10 MHz GPS-derived lab standard. Frequency calibration performed on DUT prior to starting test. MNF set up for 21 notches at 100 Hz intervals from 14100.0 (#0) to 14102.0 (#20). See Figure 28.

Test signal: f_c = 14100 kHz. f_m = 100 Hz. Δf = 1.2kHz. These settings yield 20 usable sideband pairs at 100 Hz intervals. The upper sidebands fall within the 2.4 kHz SSB bandwidth.

Figure 4: MNF Setup Tab.



Test Results: The test results are shown in Figures 5 and 6 below.

Figure 5: MNF off, 21 notches at 100 Hz intervals. Composite tone in RX audio.

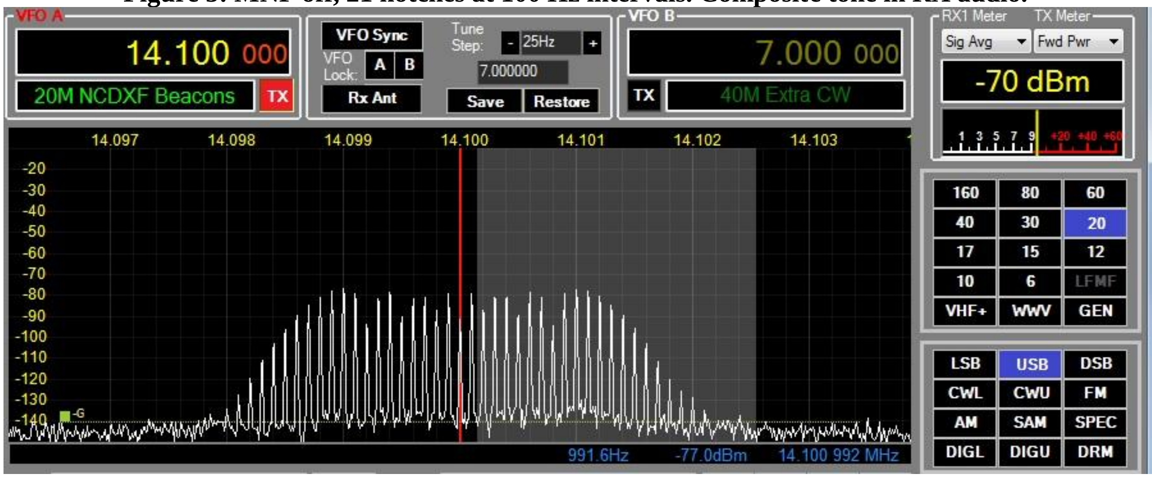
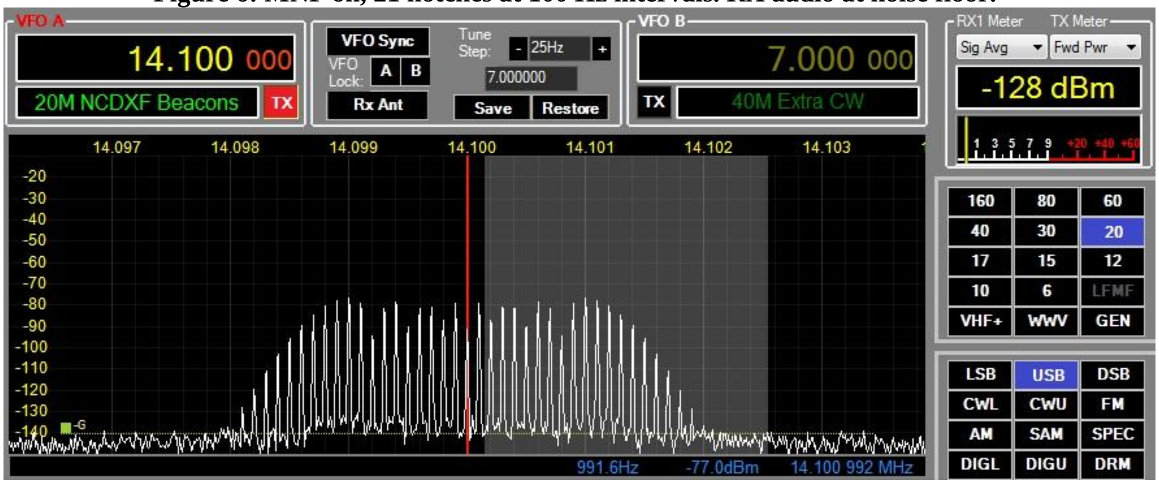


Figure 6: MNF on, 21 notches at 100 Hz intervals. RX audio at noise floor.



7: AGC impulse response. The purpose of this test is to determine the Anan-7000DLE's AGC response in the presence of fast-rising impulsive RF events. Pulse trains with short rise times are applied to the receiver input.

Test Conditions: 3.6 MHz, 2.4 kHz LSB, sampling rate 192K, BH-4 RX filter, buffer size 1024, NR on, NB off/on as required, ATT= 0 dB, AGC Fast, ANF off, MNF off, NR/ANF Pre- and Post-AGC (in DSP Options), Dither off, Random off, RX1 Meter: Signal. A pulse generator is connected to ANT1 via a step attenuator.

The pulse rise time (to 70% of peak amplitude) is 10 ns. Pulse duration **t** is varied from 20 to 95 ns. In all cases, pulse period τ is 600 ms. The step attenuator is set at 36 dB. Pulse amplitude is $16V_{pk}$ (e.m.f.)

With NR and noise blankers off, each pulse triggers the AGC, creating a "hole" in the background noise for the duration of the AGC hang time. There is no audible "tick" at the leading edge of the pulse for 20 ns ≤ **t** ≤ 1.25 µs. This is an improvement over earlier versions of PowerSDR OpenHPSDR mRX, where ticks were always audible in this state.

The pulses create lines on the waterfall. With NR and NB off, the S-meter flicks up to S7 at **t** = 20 ns and S9 at **t** = 95 ns.

With NR/ANF Pre-AGC, activating NR suppresses background noise; the effect is to render "ticks" audible. With NR/ANF Post-AGC and **t** < 100 ns, NR reduces the ticks to quiet “holes” in the receiver audio.

With NR2 on, Pre-AGC, a crushing (crunch) sound is heard for each pulse. NR2 (Post-AGC) reduces the crunch to a quiet "hole" for each pulse..

NB or NB2 suppresses the audible effects of the pulses entirely, whether NR/ANF is Pre- or Post-AGC. The S-meter, spectrum scope and waterfall responses are suppressed.

7a: SNB (Spectral Noise Blanker). With NR off, SNB yields quiet “holes”. With SNB + NR, these "holes" are muted. SNB + NR2 produces light “thumps" (Pre-AGC or Post-AGC). Unlike NB, SNB does not suppress scope, waterfall or S-meter reaction to the pulses.

A simulation test was performed by playing the SM5BSZ *agctest-96.wav* file into the receiver (***Ref. 5***). The simulation exercised AGC response to impulses, but not NB. Only NR + Post-AGC suppressed the audible response almost completely, as well as reducing the noise level in the audio output. NR + Pre-AGC was far less effective.

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

Test Conditions: 500 Hz CW, ATT = 0 dB, sampling rate 192K, BH-4 RX filter, buffer size 1024, AGC Med., ANF off, Dither off, Random off. RX1 Meter: Sig Avg. ***Level calibration*** (14.100 MHz, -70 dBm) is performed before starting the test. Next, starting at -120 dBm, the test signal power is increased and the level corresponding to each S-meter reading is noted.

Table 5: S-Meter Tracking.

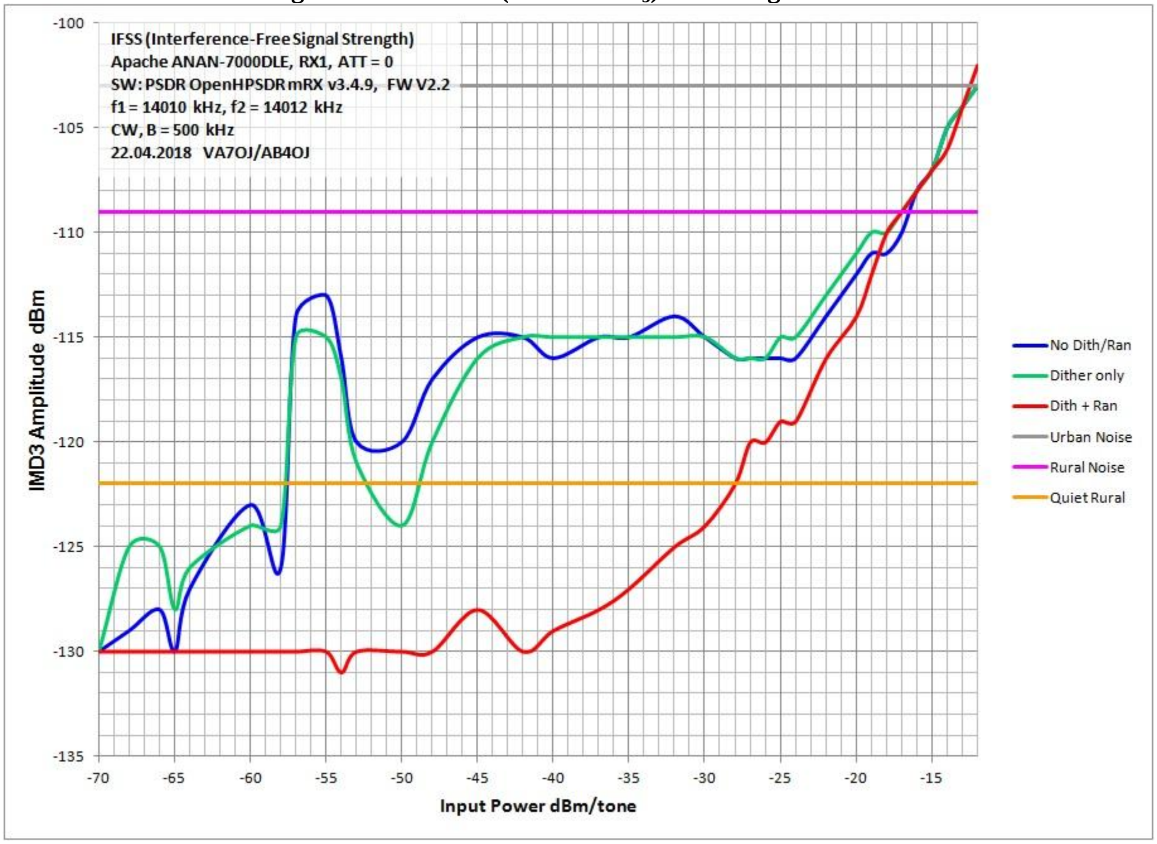
P_i dBm	-120	-110	-100	-90	-80	-73	-60	-50	-40	-30	-20	-10	-5
Rdg.dBm	-120	-110	-100	-90	-80	-73	-60	-50	-40	-30	-20	-10	CLIP
S-meter	>S1	S3	<S5	>S6	S8	>S9	S9+12	S9+21	S9+32	S9+41	S9+52	S9+61	

Table 6: S-Meter/ATT Tracking

P_i dBm	-73				
ATT dB	0	10	20	30	31
Rdg. dBm	-72	-72	-72	-72	-72
S-meter	S9	S9	S9	S9	S9

9: Two-Tone IMD_3 (IFSS, Interference-Free Signal Strength) tested in CW mode (500 Hz), ATT = 0 dB, AGC Med. Test frequencies: f_1 = 14010 kHz, f_2 = 14012 kHz. IMD_3 products: 14008/14014 kHz. IMD_3 product level was measured as absolute power in a 500 Hz detection bandwidth at various test-signal power levels and Dither/Random combinations, with 0 dB ATT selected. The ITU-R P.372-1 band noise levels for typical urban, rural and quiet rural environments are shown as datum lines. The S-meter is set at Sig Avg. Figure 7 illustrates the IFSS curves for RX1.

Figure 7: RX1 IFSS (2-tone IMD_3) vs. test signal level.

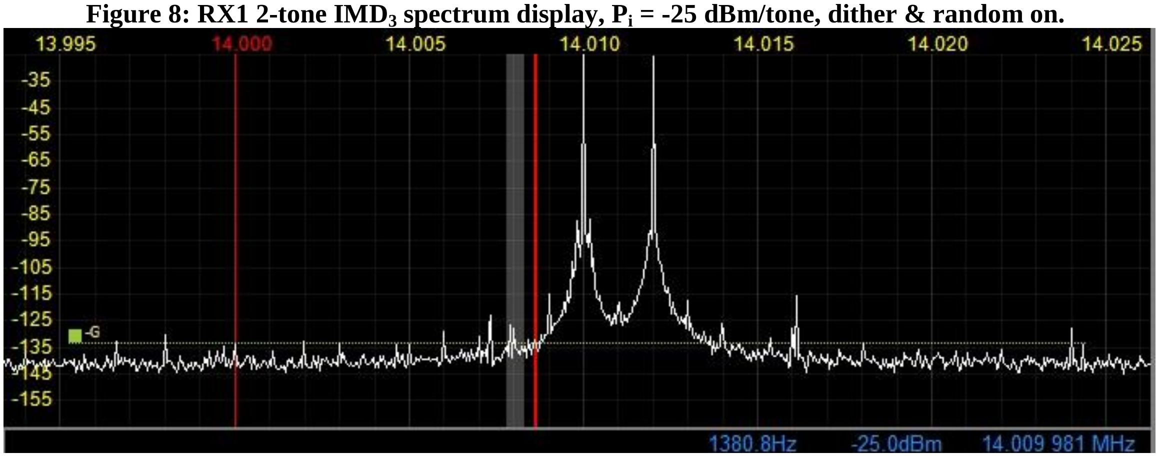


Notes on 2-tone IMD_3 test: This is a new data presentation format in which the amplitude relationship of the actual IMD_3 products to typical band-noise levels is shown, rather than the more traditional DR_3 (3^{rd}-order IMD dynamic range) or SFDR (spurious-free dynamic range). The reason for this 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. Our goal here is to find an approach to SFDR testing which holds equally for SDR and legacy receiver architecture. See ***Reference 4.***

Figure 8: RX1 2-tone IMD_3 spectrum display, P_i = -25 dBm/tone, dither & random on.



10: Two-Tone 2nd-Order Dynamic Range (DR_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 signals 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. $DR_2 = P_i - MDS$.

Test Conditions: f_1 = 6.1 MHz, f_2 = 8.1 MHz, IMD2 product at 14.2 MHz. 500 Hz CW, AGC slow, ATT = 0 dB, NR off, NB off, CW neutral, ANF off, Alex preselector in or out as required. DR_2 in dB. Measured MDS = -134 dBm (dither & random on). RX S-meter: Sig Avg.

Table 7: RX1 DR_2. f_1: 6.1 MHz. f_2: 8.1 MHz. IMD product: 14.2 MHz.

	Preselector	out		in	
Dither & Random	MDS dBm	P_i dBm	DR_2 dBm	P_i dBm	DR_2 dBm
off	-134	-73	61	-39	95
on		-70	64	-25	109

It will be observed that when the 20m Alex preselector is switched in, it suppresses the f_1 and f_2 signals. This virtually eliminates the 2nd-order IMD product. Any residual IMD is further reduced by dither and random, which are much more effective when the interfering signals are lower down the IFSS curve.

11: 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 off the spectrum scope by observation. (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 center freq. f_0 ± 1.5 kHz, 2.4 kHz SSB, ATT = 0/20 dB, NR off, NB off, Notch off, ANF off, AGC Med, Alex on. Display Averaging: Log Recursive (default). Test results are presented in **Table 8.**

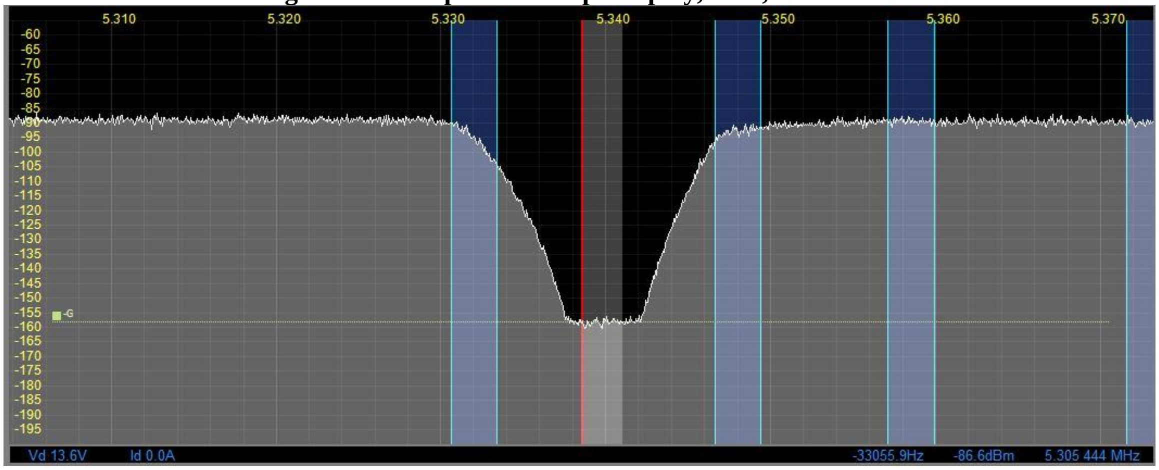
Table 8: RX1 NPR Test Results[2]

BSF kHz	BLF kHz	BWR dB	Alex	P_{TOT} dBm		NPR dB[1]		Theor. NPR[3]
			ATT	0 dB	20 dB	0 dB	20 dB	
1940	60…2044	29.2	0	-18	-4	71	66	80
			1	-6	+3	77	72	
3886	60…4100	32.3	0	-17	+3	71	68	76.9
			1	-14	+6	73	70	
4650	60…5600	33.6	0	-17	+2	70	68	75.6
			1	-14	+5	71	69	
5340	60…5600	33.6	0	-17	+2	69	68	75.6
			1	-14	+5	71	69	
7600	12…8160	35.3	0	-17	+3	67	65	74.1
			1	-10	0	70	67	
11700	316…12300	37.0	0	-16	+2	65	66	71.6
			1	-6	+10	67	67	
16400	316...17300	38.5	0	-17	+4	62	62	70.7
			1	-11	+4	63	62	

Notes on NPR test:

1. NPR readings were stable over time.
2. Enabling Dither and/or Random did not affect NPR results.
3. Theoretical NPR was calculated for the LTC2208-16 ADC using the method outlined in ***Ref. 3.*** 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.

Figure 9: NPR spectrum scope display, RX1, 5340 kHz.



B. Receiver 2 (RX2) Tests

12: 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: ATT as shown, NR off, NB off, ANF off, AGC Fxd, threshold AGC gain 120, Dither off, Random off.

Table 9: MDS[1] in dBm (RX2).

	3.6 MHz		14.1 MHz		28.1 MHz		50.1 MHz	
ATT dB	SSB 2.4kHz	CW 500Hz	SSB 2.4kHz	CW 500Hz	SSB 2.4kHz	CW 500Hz	SSB 2.4kHz	CW 500Hz
0	-125	-131	-125	-132	-125	-132	-136	-144
20	-104	-111	-104	-111	-104	-111	-121	-128

Notes: 1. Dither and/or Random do not affect MDS.

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13: RX1/RX2 Crosstalk. In this test, RX1 and RX2 are set to the same frequency, mode and bandwidth. A test signal of amplitude P_i is applied to the RX1 input, and the RX2 input is terminated in 50Ω. The value of Pi required to increase the RX2 audio output by 3 dB is recorded. The test is then repeated with the RX1 input terminated in 50Ω and the test signal applied to the RX2 input. The receiver to which the test signal applied is muted.

Test Conditions: RX1 and RX2 set to 500 Hz CW and tuned to f_0. ATT = 0 dB, NR off, NB off, AGC: RX1: Med, Gain = 120. RX2: Fxd, Gain = 120. Repeat: AGC: RX1: Fxd, Gain = 120. RX2: Med, Gain = 120.

Table 10: RX1/RX2 Crosstalk.

f_0 MHz	Test signal to	Pi dBm for +3 dB output	Output from
50.1	RX1	-108	RX2
	RX2	-97	RX1
1.9	RX1	-72	RX2
	RX2	-81	RX1

14: Noise Power Ratio (NPR): An NPR test is performed, using the test methodology described in detail in ***Ref. 1***. 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 RX2 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 off the spectrum scope by observation. (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 center freq. f_0 ± 1.5 kHz, 2.4 kHz SSB, ATT = 0 dB, NR off, NB off, Notch off, ANF off, AGC slow, Alex on. Test results are presented in **Table 11.**

Table 11: RX2 NPR Test Results[2]

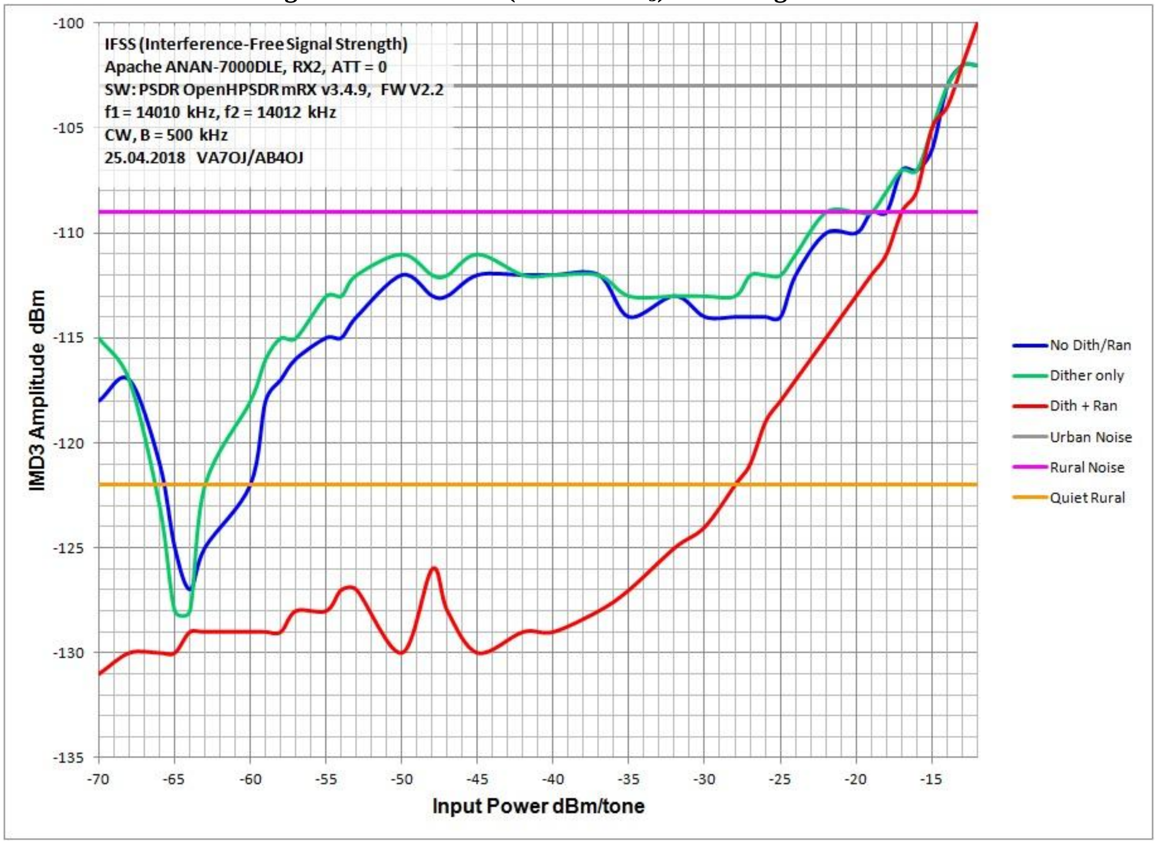
BSF kHz	BLF kHz	BWR dB	Alex	P_{TOT} dBm		NPR dB[1]		Theor. NPR[3]
			ATT	0 dB	20 dB	0 dB	20 dB	
1940	60…2044	29.2	0	-17	-2	74	66	80
			1	-5	-1	78	72	
3886	60…4100	32.3	0	-17	+3	71	67	76.9
			1	-13	+6	73	70	
4650	60...5600	33.6	0	-18	+3	75	72	75.6
			1	-14	+6	77	74	
5340	60…5600	33.6	0	-17	+3	69	67	75.6
			1	-14	+6	71	69	
7600	12…8160	35.3	0	-17	-1	63	60	74.1
			1	-10	+9	65	61	
11700	316...12360	37.0	0	-16	-1	70	70	71.6
			1	-5	+1	71	72	
16500	316-17300	38.5	0	-16	-4	68	66	70.7
			1	-11	+5	68	67	

Notes on NPR test:

1. NPR readings were stable over time.
2. Enabling Dither and/or Random did not affect NPR results.
3. Theoretical NPR was calculated for the LTC2208-16 ADC using the method outlined in ***Ref. 3.*** 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.

15: Two-Tone IMD$_3$ (IFSS, Interference-Free Signal Strength): Refer to Test 9 (above) for Test Description and Notes. Figure 10 illustrates the IFSS curves for RX2.

Figure 10: RX2 IFSS (2-tone IMD$_3$) vs. test signal level.



16. Two-Tone 2nd-Order Dynamic Range (DR$_2$). Refer to Test 10 (above) for Test Description.

Test Conditions: f_1 = 6.1 MHz, f_2 = 8.1 MHz, IMD2 product at 14.2 MHz. 500 Hz CW, AGC slow, ATT = 0 dB, NR off, NB off, CW neutral, ANF off. DR$_2$ in dB. Measured MDS = -132 dBm (dither & random on).

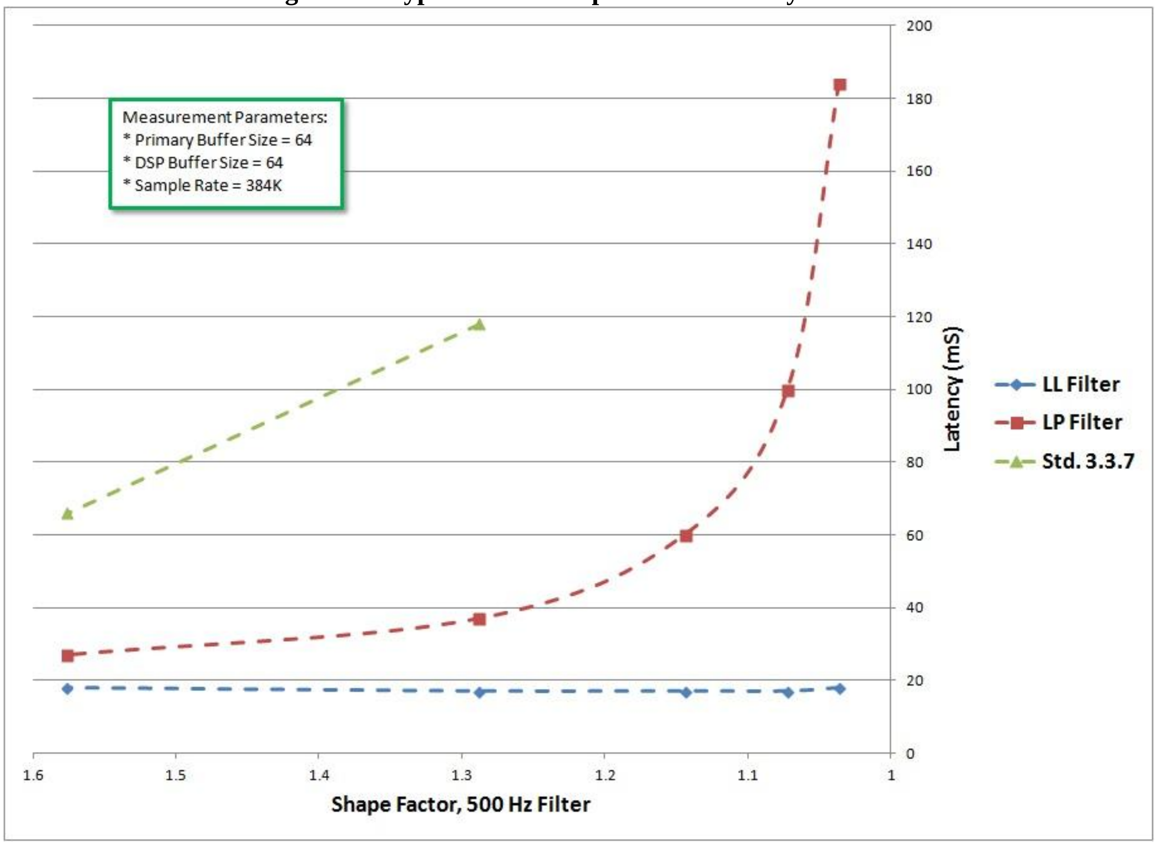
Table 12: RX2 DR$_2$. f$_1$: 6.1 MHz. f$_2$: 8.1 MHz.

	Preselector	out		in	
Dither & Random	MDS dBm	P_i dBm	DR_2 dBm	P_i dBm	DR_2 dBm
off	-132	-68	64	-48	84
on		-66	66	-26	106

17: Receiver Latency Test, January 16, 2016. (Applies to ANAN series, PSDR OpenHPSDR mRX V3.3.9 and subsequent builds with LL/LP Filter Options)

Receiver latency was measured by applying a pulse train with fast rise-time to the RF input and measuring the time interval between the applied pulse (at the RF input) and the received pulse (at the audio output) with a 2-channel oscilloscope.

Figure 11: Typical Filter Shape Factor/Latency Curves



Note: LL: V3.3.9.0 (released June 2016) and all subsequent builds incorporate the LL (Low Latency) and LP (Linear Phase) filter options.

⚠ ***18: Note on spurious signals.*** During receiver testing, a number of spurious signals or artifacts were observed on the spectrum scope. These spurs were encountered at 1.94 MHz and in the 4.5 - 5 and 9.5 - 10.5 MHz frequency ranges. They are caused by a switch-mode power supply on the Orion Mk II board, and are thermally unstable, with frequency and amplitude varying after a warm-up interval. The amplitude of these spurs is about -100 dBm.

It was possible to minimize the impact of the spurs on testing by allowing sufficient warm-up time to ensure that they did not fall on test frequencies. Naturally, their complete suppression would be the most desirable long-term solution.

C. Transmitter Tests

⚠ ***Maximum temperature:*** Case, 38°C.

- ***BH-4 TX Filter Window*** selected for all transmitter tests.

19a: CW Power Output. In this test, the RF power output into a 50Ω load is measured at 3.6, 14.1, 28.1, 29.6 and 50.1 MHz in RTTY mode, at a primary DC supply voltage of +13.8V. A clamp-on ammeter is used to measure DC input current. A thermocouple-type power sensor and meter are connected to the ANT1 socket via a 50 dB power attenuator. PA Gain is adjusted on all bands before starting the test.

Test Conditions: 3.6, 7.1, 14.1, 21.1, 28.1 and 50.1 MHz, 100W nominal. Set Tune Pwr to 100%, or check Use Drive Power and set Drive to 100%.. Adjust PA Gain and Wattmeter settings as required for nominal P_O and correct Fwd Pwr readings.

Table 13: CW Power Output.

Freq. MHz	Input Current A	Fwd Pwr W	Meas. P_O W
3.6	16.2	100	100.2
7.1	16.7	100	101.6
14.1	18.1	100	100.5
21.1	15.1	99	102.0
28.1	19.7	99	101.3
50.1	19.0	99	101.4

⚠ ***Note:*** Some anomalies were observed in the Fwd Pwr meter scale. To obtain an accurate reading at 100W measured P_O a Wattmeter setting of 58W was required. As the PA warmed up during transmitter tests, the Fwd Pwr reading occasionally dropped in an erratic manner by as much as 25 - 50%.

19b: SSB Peak Envelope Power (PEP). Here, an oscilloscope is terminated in 50Ω and connected to ANT1 via a 50 dB power attenuator. The scope vertical cursors are adjusted for 100W CW.

Test Conditions: 14.1 MHz, USB mode, dynamic mic connected, Drive 100%, Mic Gain 27 dB (COMP off), 33 dB (COMP on), compression 6 dB, Transmit Filter 200-2900 (default), supply voltage +13.8V. Leveler settings (default): Max. gain 5 dB, Decay 0.5s.

Speak loudly into the microphone for full-scale ALC reading. Figures 12 & 13 show the envelope for 100W PEP, without and with compression respectively. Figures 14 & 15 illustrate the effect of CESSB (controlled-envelope SSB) with 10 dB compression. ***Note:*** With MON on, mic/monitor latency ≈ 200 ms.

20: SSB ALC overshoot: A test was conducted in which white noise was applied from the internal noise generator, and the RF envelope observed on an oscilloscope terminated in 50Ω and connected to the DUT RF output via a 50 dB power attenuator**.**

Test Conditions: 14100 kHz USB, compression 20dB. Test signal: white noise. Transmit Filter 200-2900 (default). Supply voltage +13.8V. Transmit Equalizer +15 dB (all 3 ranges), Preamp max. Test/Noise level +13 dB.

Test Results: No sign of ALC overshoot at 100W PEP. See Figure 16.

Figure 12: 100W PEP speech envelope, no compression.

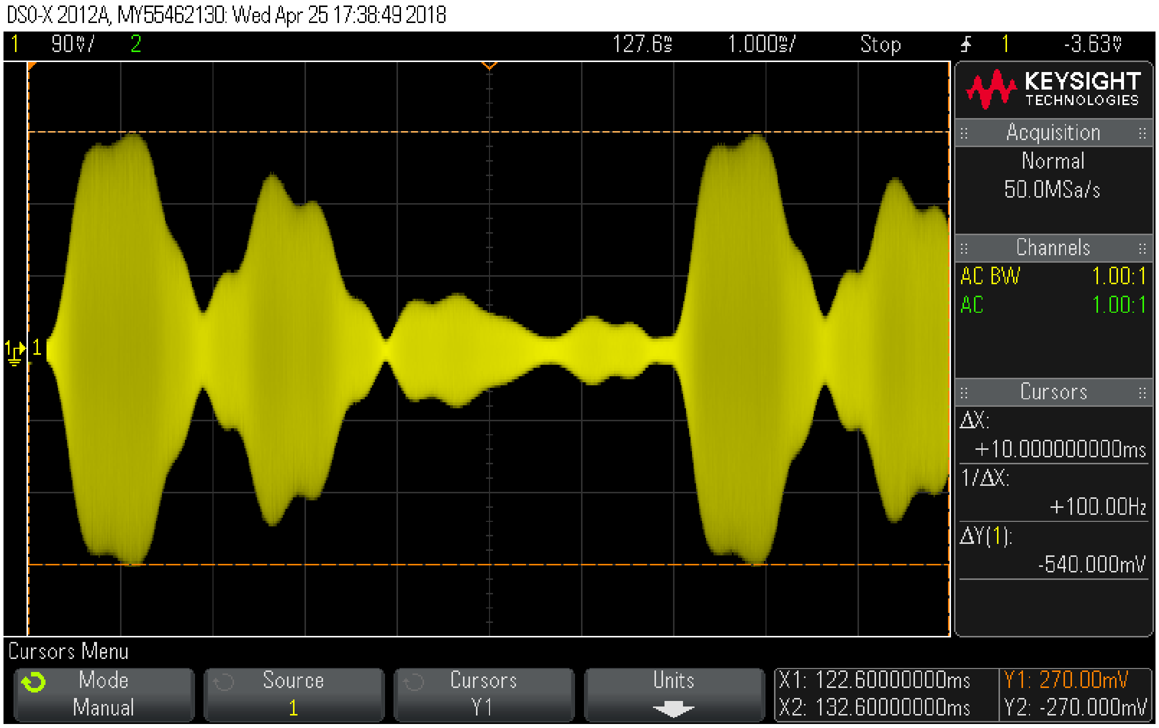


Figure 13: 100W PEP speech envelope, 6 dB compression.

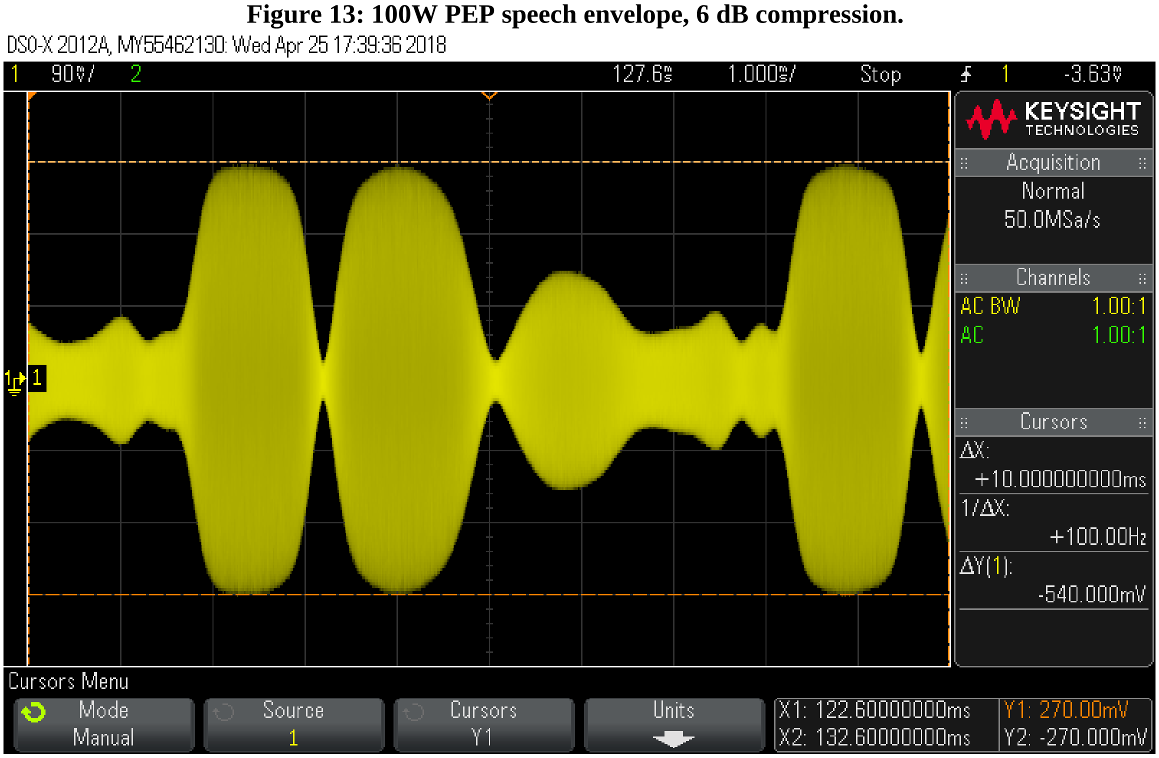


Figure 14: 100W speech envelope, 10dB compression, CESSB off.

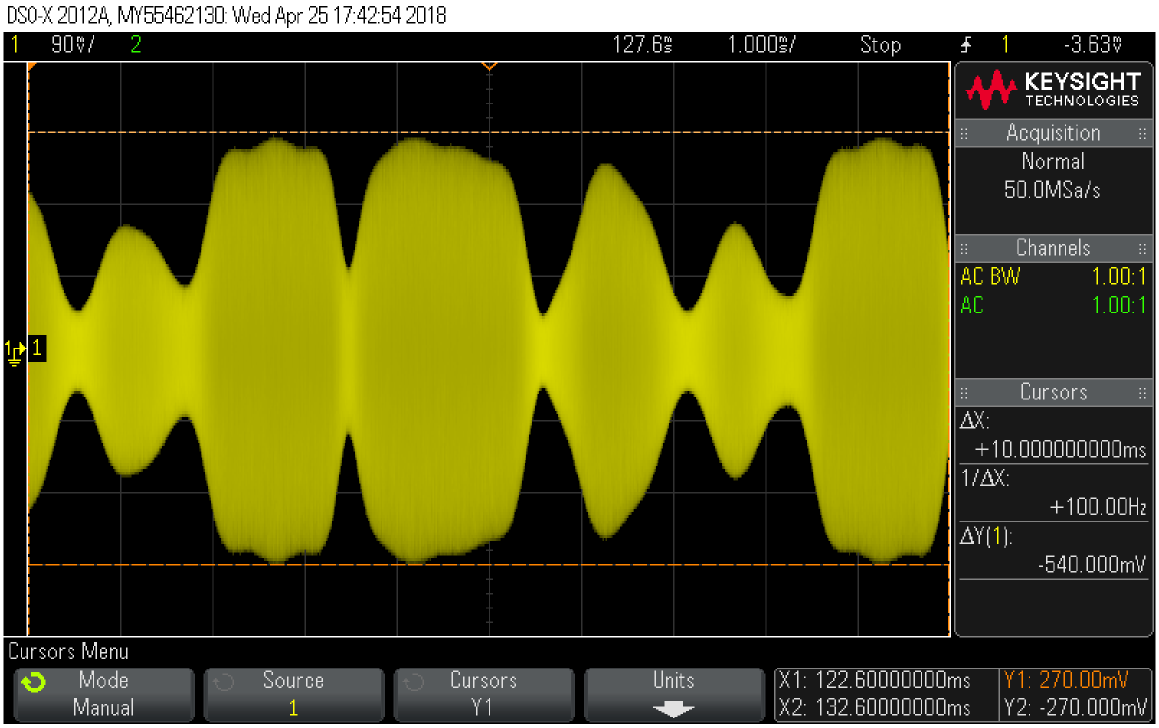


Figure 15: 100W speech envelope, 10dB compression, CESSB on.

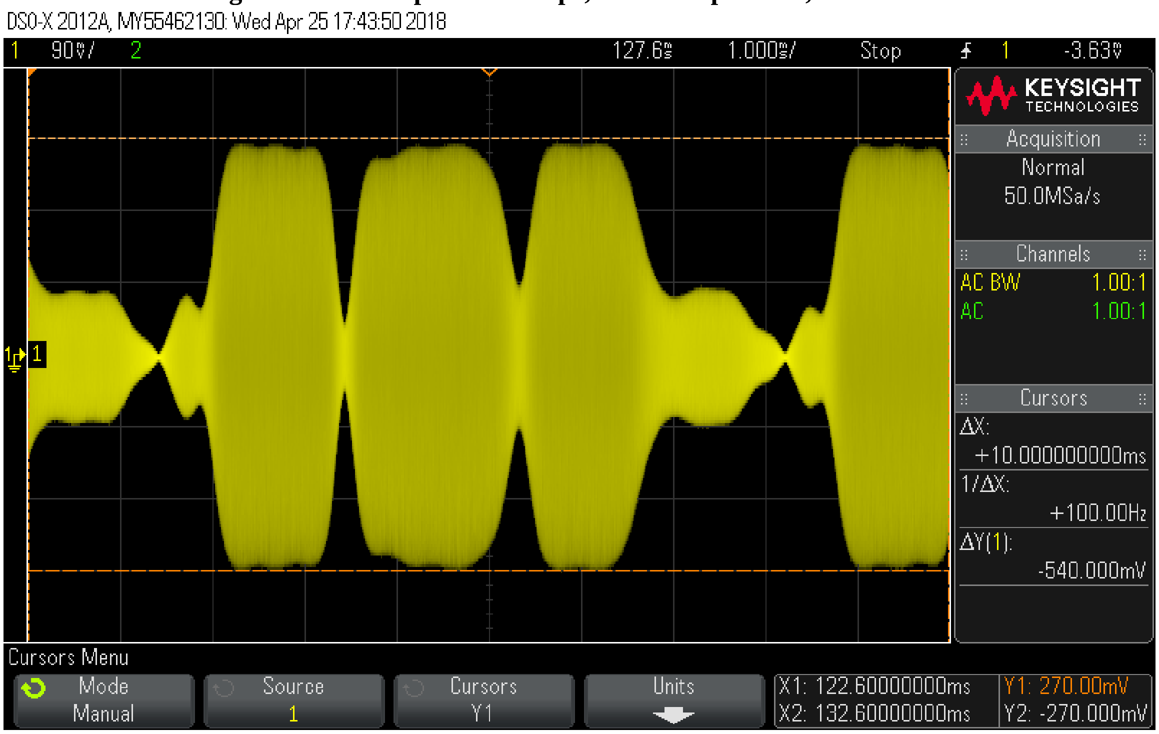
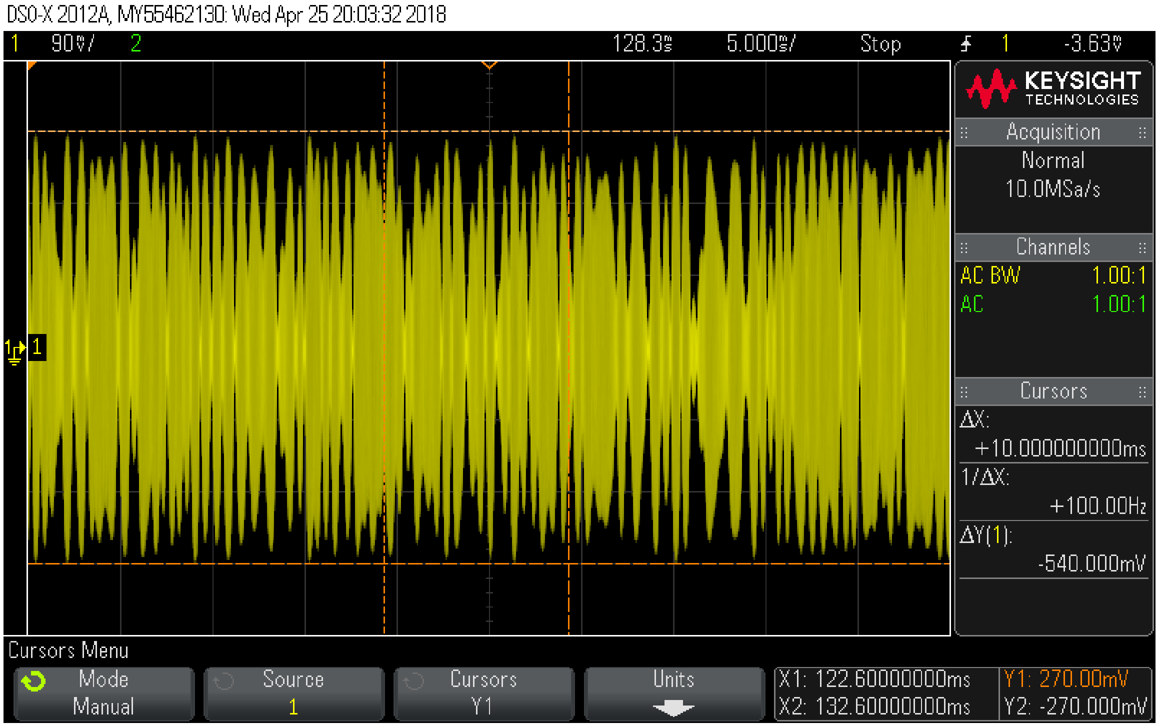


Figure 16: 100W white noise test (±3 vert. div. = 100W PEP).

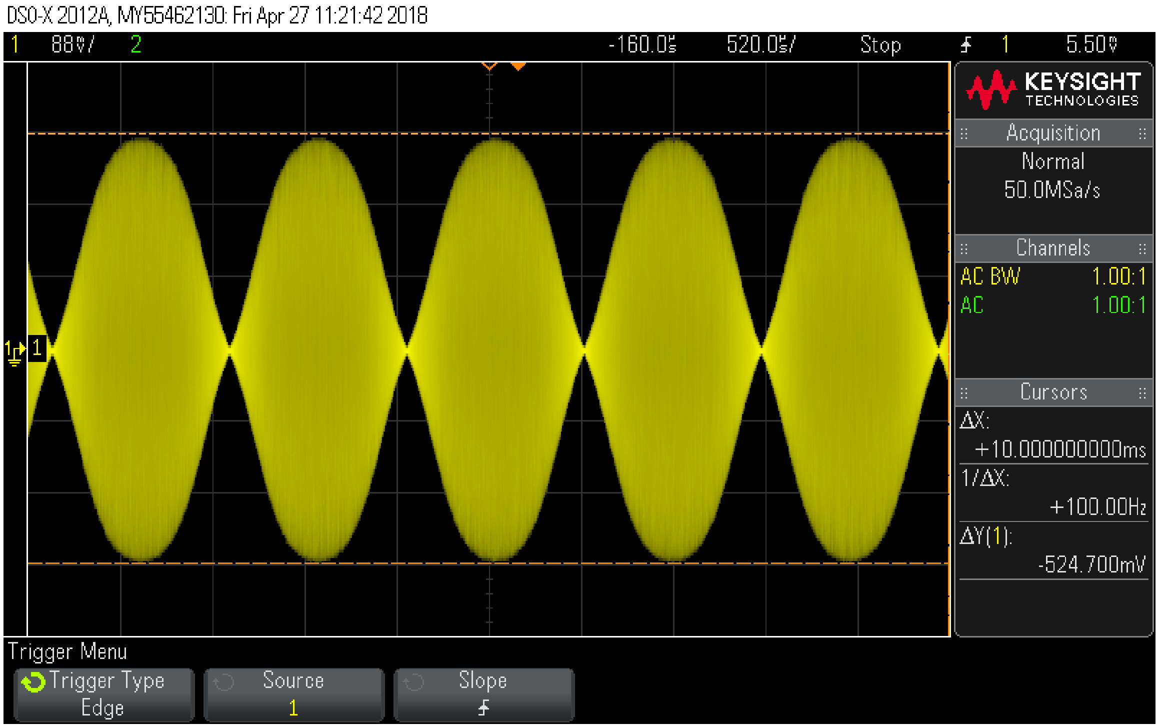


21: ALC Compression Check. In this test, a 2-tone test signal is applied to the USB port from the internal 2-tone generator. An oscilloscope is connected to the DUT RF output via a 50 dB power attenuator. RF Power is initially adjusted for 100W CW output.

Test Conditions: 14100 kHz USB, compression off. Test signal: 2-tone. Transmit Filter 200-2900 (default). Test tones: 700 and 1700 Hz, at equal amplitudes. Supply voltage +13.8V.

Test Result: No flat-topping of the 2-tone envelope was observed (see Figure 17.)

Figure 17: 2-tone envelope, 100W PEP.



21a: Subjective TX audio test: In this test, a headset is plugged into the microphone and headphone jacks and a transmitted SSB signal is monitored with MON active.

Test Procedure:

a. Set COMP to 6 dB.

b. Adjust Mic Gain for no ALC COMP on TX Meter with CESSB off.

c. Set TX EQ off. .

d. Transmit alternately with COMP off and on. Observe that COMP gives monitored TX audio more audible “punch” and penetrating power.

Test Results: With Mic Gain = 16 dB, CESSB off, COMP on yields audible improvement in audio "punch",

22: Transmitter 2-tone IMD Test. In this test, a 2-tone test signal is applied from the internal tone generator. A spectrum analyzer is connected to the DUT RF output via a 50 dB power attenuator. RF Power is initially adjusted for rated CW output on each band in turn.

Test Conditions: 3.6, 14.1, 28.1and 50.1 MHz USB, compression off. Test signal: 2-tone. Transmit Filter 200-2900 (default). Test tones: 700 and 1700 Hz, at equal amplitudes. Supply voltage +13.8V. The -10 dBm reference level RL equates to 100W CW output (100W = 0 dBc).

Adjust test tone levels for 100W PEP (each tone at -6 dBc). Figures 18 through 21 show the two test tones and the associated IMD products for each test case.

Table 14: 2-tone TX IMD.

2-tone TX IMD Products at Rated P_o				
IMD Products	Rel. Level dBc (0 dBc = 1 tone)			
Freq. MHz	**3.6**	**14.1**	**28.1**	**50.1**
IMD_3 (3^{rd}-order)	-27	-54	-29	-34
IMD_5 (5^{th}-order)	-32	-30	-28	-30
IMD_7 (7^{th}-order)	-37	-40	-39	-39
IMD_9 (9^{th}-order)	-43	-50	-54	-53
Add 6 dB for IMD referred to 2-tone PEP				

22a. Noise IMD Test. This test is similar to Test 22, except that a white-noise baseband is applied from the internal noise generator. See Figure 22. Note that the IMD skirts are steeper at the lower power level.

Test Conditions: 14.1 MHz USB, 10 dB compression, CESSB on. Transmit Mode: Noise. Level (dB): +13. Measured at ≈ 100W PEP, and 6 dB lower.

Figure 18: Spectral display of 2-tone IMD at 3.6 MHz, 100W PEP.

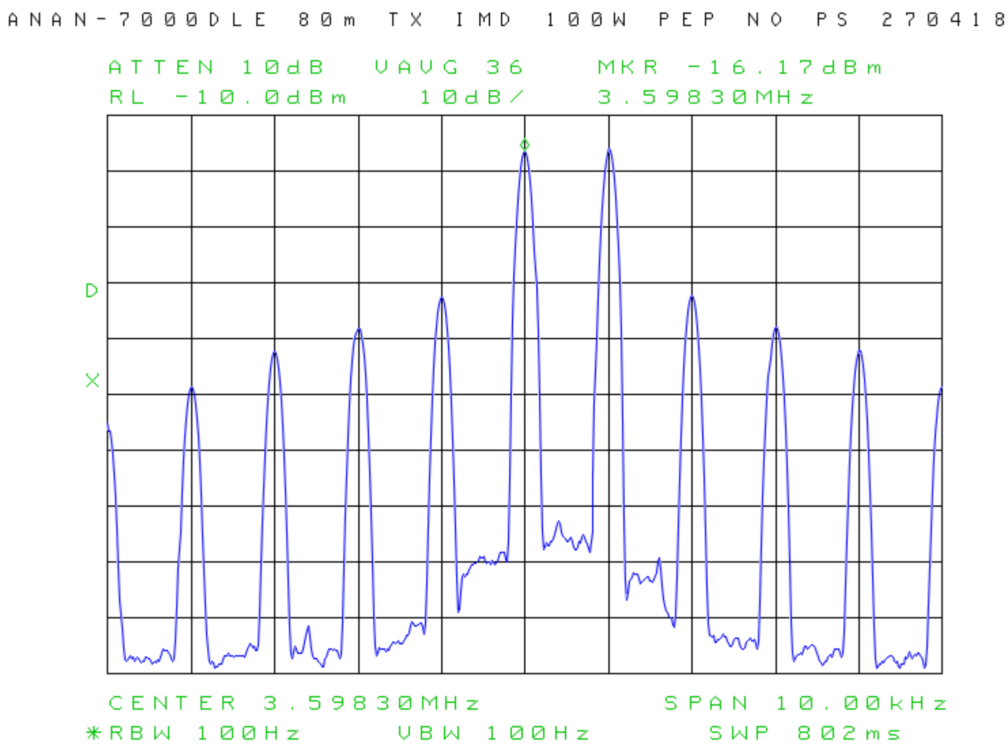


Figure 19: Spectral display of 2-tone IMD at 14.1 MHz, 100W PEP.

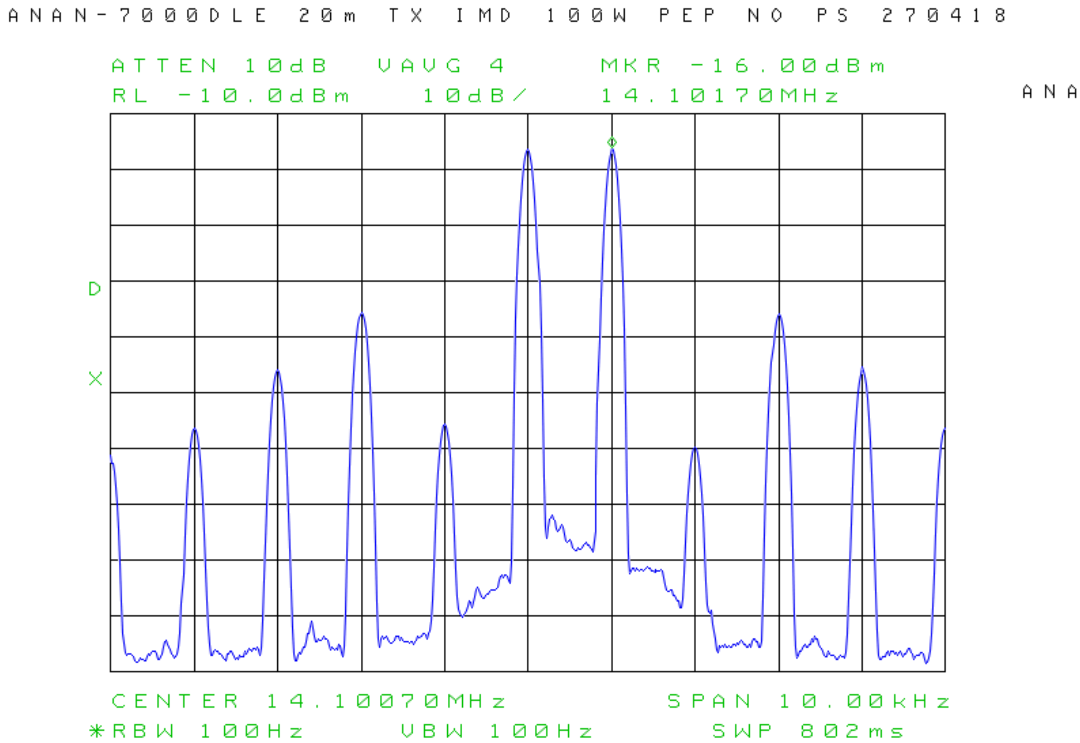


Figure 20: Spectral display of 2-tone IMD at 28.1 MHz, 100W PEP.

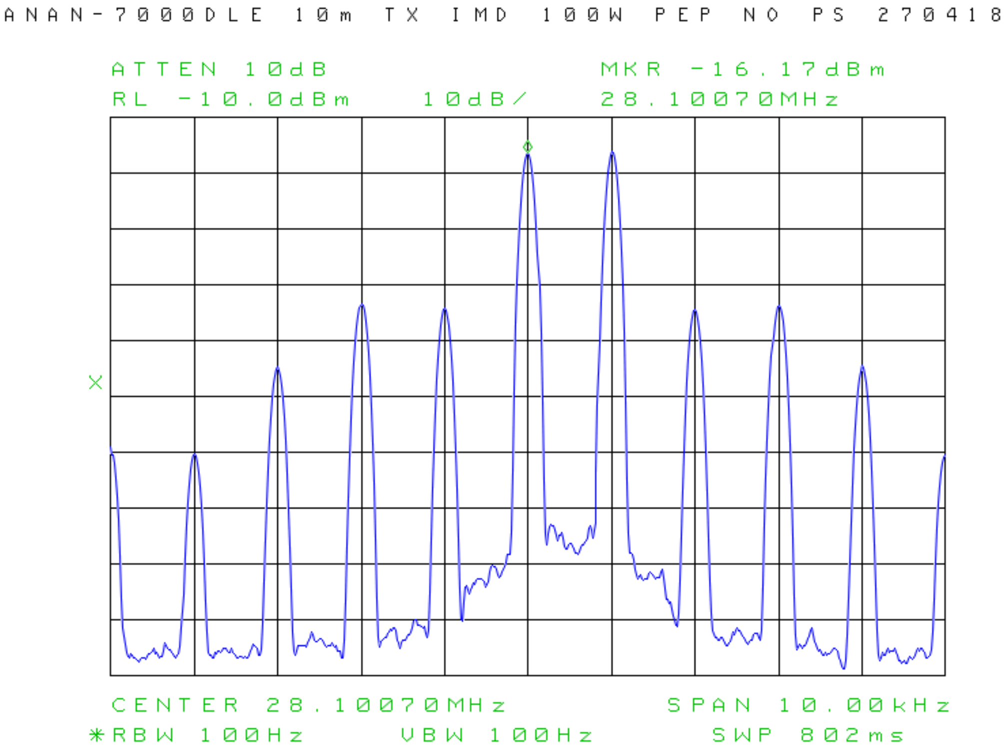


Figure 21: Spectral display of 2-tone IMD at 50.1 MHz, 100W PEP.

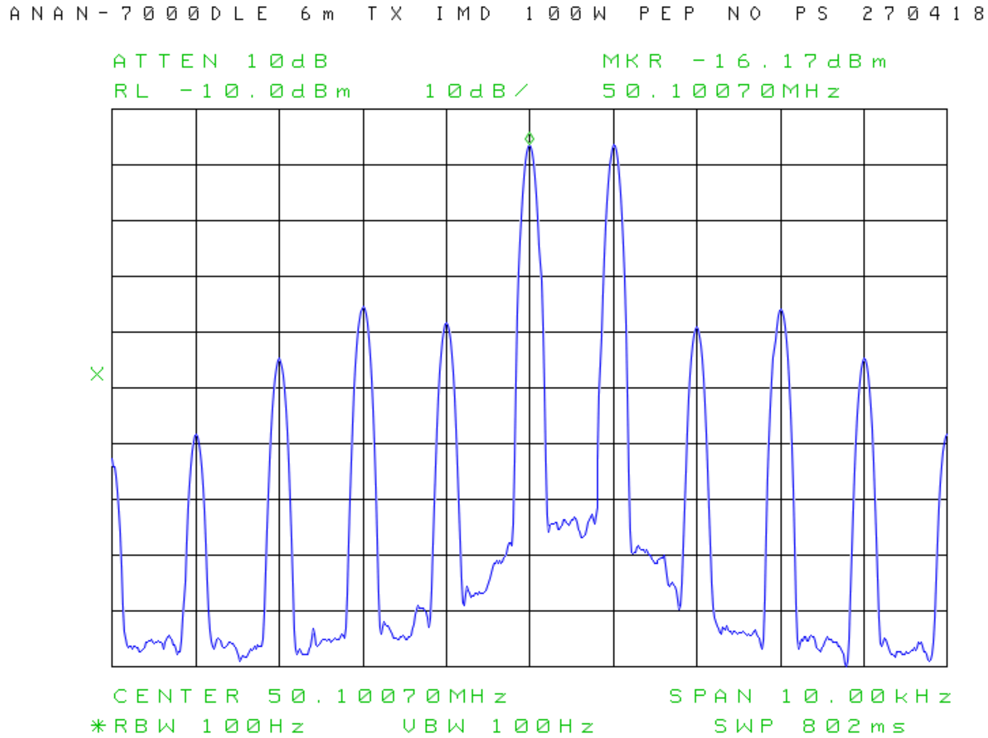
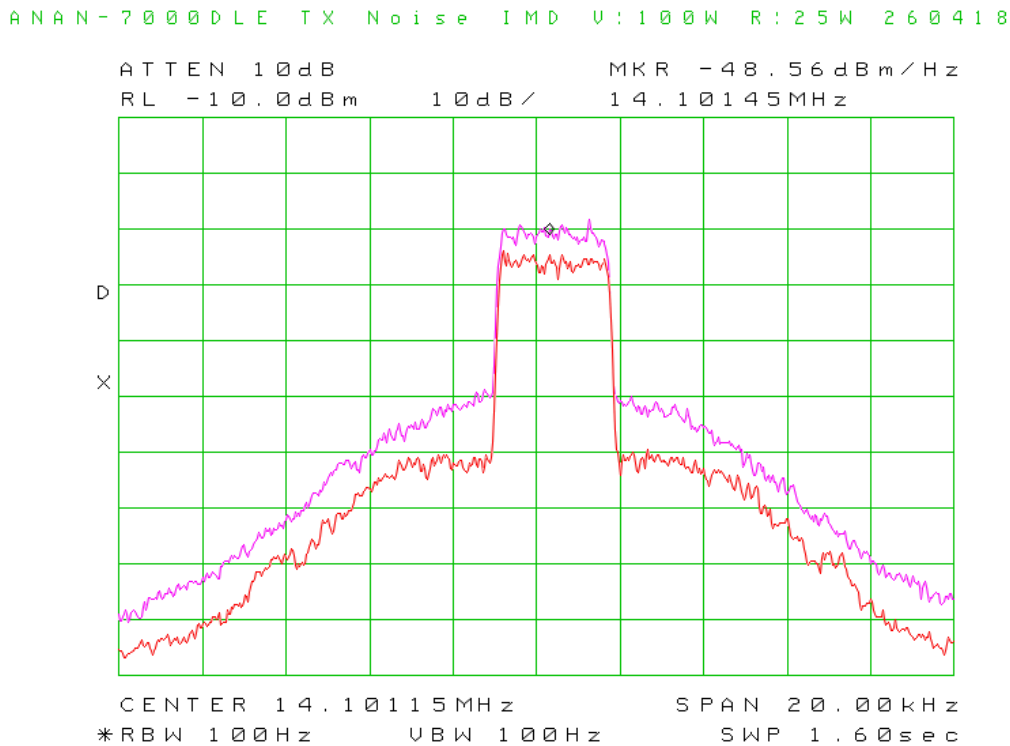


Figure 22: Noise modulation, showing IMD skirts.



Note: The similarity between the IMD skirts at 100W and 25W PEP output suggests that IMD does not improve significantly at reduced power output.

23: AM sidebands and THD with single-tone modulation. As in Test 22 above, the spectrum analyzer is connected to the DUT RF output via a 50 dB power attenuator. On the GUI, RF Power is adjusted for 25W resting carrier. A 1 kHz test tone is applied from the internal tone generator. The spectrum analyzer records the carrier and sideband parameters.

Test Conditions: 14100 kHz AM, 50W carrier output, Transmit Mode: Tone, Level: -17dB. Adjust test tone level for -7 dBc sideband level (90% modulation.) Figure 23 shows the carrier and sideband levels. Calculated THD ≈ 2.6**%**.

Figure 23: AM Sidebands for 100% Modulation.

ANAN7000DLE AM 20m 25W CXR m=0.9 THD~2.6% 260418

DISCRETE SIDEBAND SEARCH RESULTS

CARRIER FREQ: 14.10 MHz
CARRIER POWER: -16.3 dBm

OFFSET FREQ	- OFFSET dBc	+ OFFSET dBc
.998 kHz	-7.2	-7.2
1.997 kHz	-37.5	-38.2
2.996 kHz	-33.7	-33.3
3.995 kHz	-71.2	-68.0
5.003 kHz	-61.3	-61.3

FOUND: 5 SETS OF SIDEBANDS

24: Transmitter harmonics & spectral purity. Once again, the spectrum analyzer is connected to the DUT RF output via a 50 dB power attenuator. RF Power is adjusted for 100W CW output on each band in turn. RL = -10 dBm equates to 100W. The spectrum analyzer's harmonics capture utility is started.

Test Conditions: 3.6, 14.1, 28.1 and 50.1 MHz, TUNE mode, 100W to 50Ω load. Harmonic data is presented for all frequencies tested (Figures 24 through 27), and a spur sweep from 1 – 68 MHz in Figure 28. It will be seen that harmonics are well within specifications. Non-harmonic spurs are within the -60 dBc limit specified in FCC Part 97.307(e). In addition, a spur sweep in the range 14090-14190 kHz shows that the transmitted spur at +48 kHz offset is now insignificant. See Figure 28a.

Figure 24.

ANAN-7000DLE TX Harmonics 80m 100W CW 260418

HARMONIC MEASUREMENT RESULTS

FUNDAMENTAL SIGNAL: 3.600 MHz
-10.3 dBm

HARMONIC	LEVEL dBc	FREQUENCY
2	-67.8	7.200 MHz
3	-70.5	10.80 MHz
4	-90.0 *	14.40 MHz
5	-88.7	18.00 MHz
6	-97.0	21.60 MHz
7	-104.7 *	25.20 MHz
8	-101.8 *	28.80 MHz

* MEASURED LEVEL MAY BE NOISE OR LOST SIGNAL.

TOTAL HARMONIC DISTORTION = .1 %
(OF HARMONICS MEASURED)

Figure 25.

ANAN-7000DLE TX Harmonics 20m 100W CW 260418

HARMONIC MEASUREMENT RESULTS

FUNDAMENTAL SIGNAL: 14.10 MHz
-9.5 dBm

HARMONIC	LEVEL dBc	FREQUENCY
2	-75.7	28.20 MHz
3	-61.3	42.30 MHz
4	-89.5	56.40 MHz
5	-91.8	70.50 MHz
6	-97.3	84.60 MHz
7	-97.8	98.70 MHz
8	-99.3 *	112.8 MHz

* MEASURED LEVEL MAY BE NOISE OR LOST SIGNAL.

TOTAL HARMONIC DISTORTION = .1 %
(OF HARMONICS MEASURED)

Figure 26.

ANAN-7000DLE TX Harmonics 10m 100W CW 260418

```
HARMONIC MEASUREMENT RESULTS

FUNDAMENTAL SIGNAL: 28.10 MHz
                     -9.8 dBm

HARMONIC    LEVEL dBc    FREQUENCY
    2        -86.2 *     56.20 MHz
    3        -71.3       84.30 MHz
    4        -86.2       112.4 MHz
    5       -105.0 *     140.5 MHz
    6       -102.7 *     168.6 MHz
    7        -79.3       196.7 MHz
    8        -94.2       224.8 MHz

    *  MEASURED LEVEL MAY BE
       NOISE OR LOST SIGNAL.

TOTAL HARMONIC DISTORTION =      0 %
 (OF HARMONICS MEASURED)
```

Figure 27.

ANAN-7000DLE TX Harmonics 6m 100W CW 260418

```
HARMONIC MEASUREMENT RESULTS

FUNDAMENTAL SIGNAL: 50.10 MHz
                     -9.7 dBm

HARMONIC    LEVEL dBc    FREQUENCY
    2        -80.0 *     100.2 MHz
    3        -85.2       150.3 MHz
    4        -88.7       200.4 MHz
    5        -98.5 *     250.5 MHz
    6        -98.8       300.6 MHz
    7       -106.3 *     350.7 MHz
    8       -101.0 *     400.8 MHz

    *  MEASURED LEVEL MAY BE
       NOISE OR LOST SIGNAL.

TOTAL HARMONIC DISTORTION =      0 %
 (OF HARMONICS MEASURED)
```

Note: At 50.1 MHz, the 3rd harmonic level is well within the -60 dBc maximum specified in FCC Part 97.307(e) for the frequency range 30-225 MHz.

Figure 28.

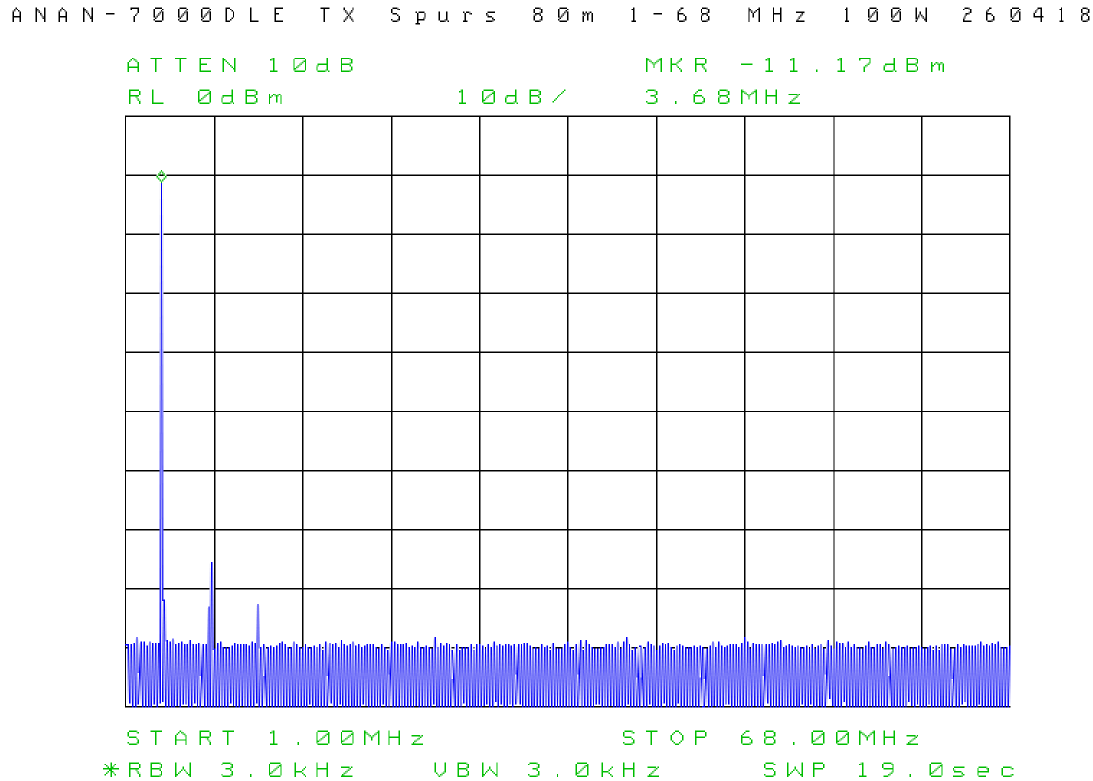
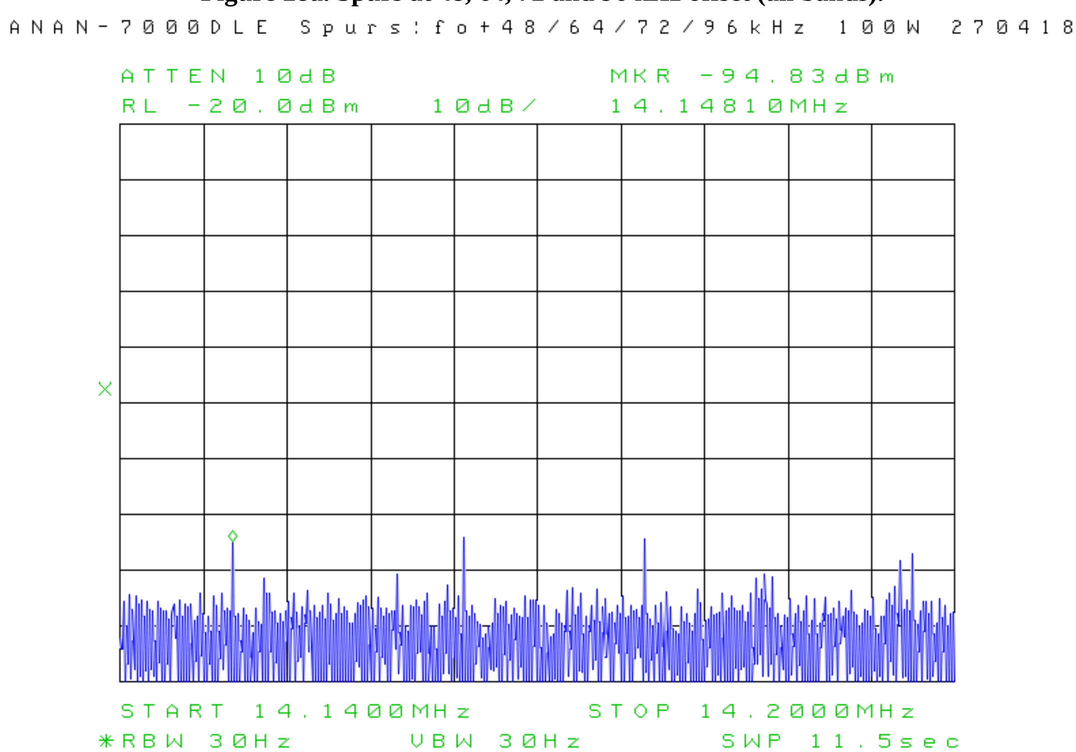


Figure 28a. Spurs at 48, 64, 72 and 96 kHz offset (all bands).

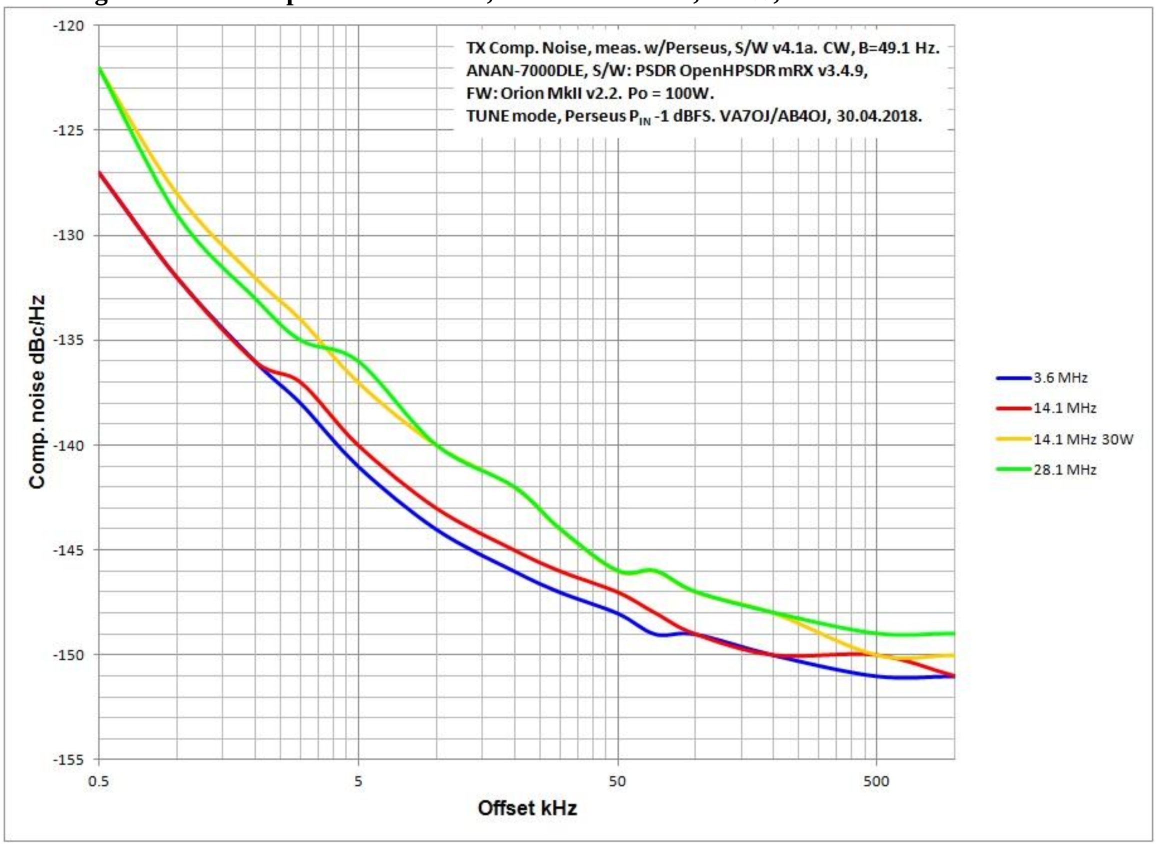


25: Transmitted composite noise. A Perseus SDR receiver is connected to the DUT RF output via a 55 dB power attenuator, and data points take in a logarithmic series. Figure 29 is the resulting plot.

Test Conditions: 3.6, 14.1 and 28.1 MHz, TUNE mode, 100W output (100W & 30W on 14.1 MHz). External 10 MHz reference not connected.

Note: The spurs illustrated in Figure 28a do not influence Figure 29, as they are narrow single-frequency signals and are well removed from the data points taken in the composite-noise measurement run. These spurs occur at the same offsets on all bands.

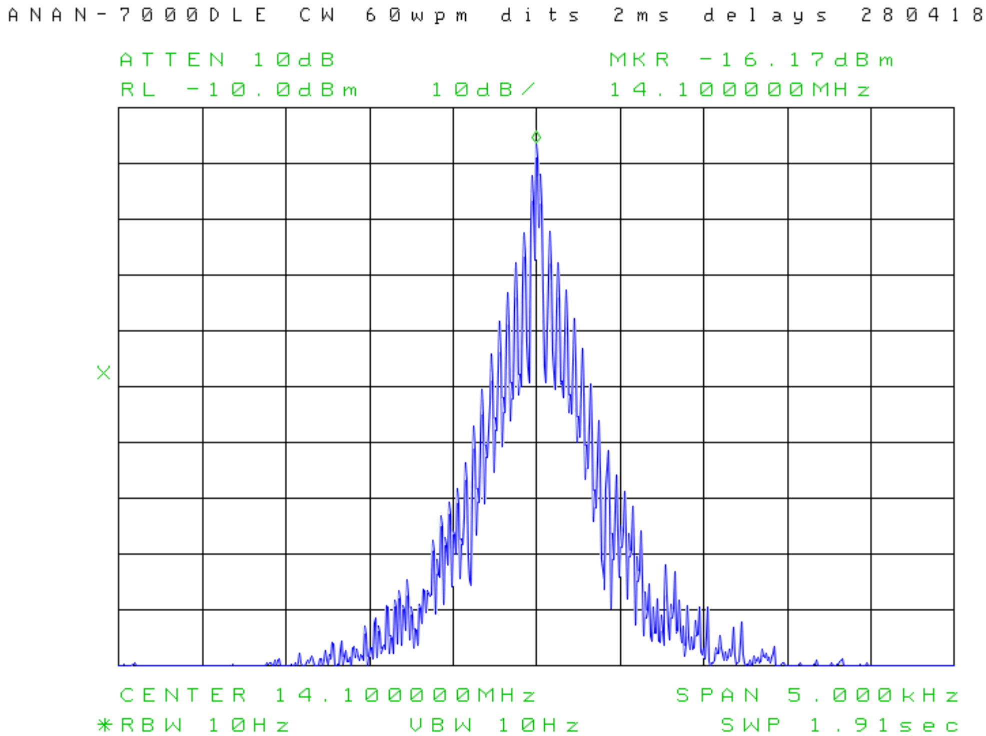
Figure 29: TX composite noise at 3.6, 14.1 & 28.1 MHz, 100W, measured on Perseus RX.



26: Spectral display of CW keying sidebands. The spectrum analyzer is connected to the DUT RF output via a 50 dB RF power attenuator. The -5 dBm reference level equates to 100W. A series of dits is transmitted at 60 wpm.

Test Conditions: 14.1 MHz CW, 100W output. Keying speed 60 wpm using internal keyer. CW key-down & key-up delays 2 ms. Spectrum analyzer RBW is 10 Hz, video-averaged; sweep time < 2 sec. Figure 24 shows the transmitter output ±2.5 kHz from the carrier.

Figure 30: Keying sidebands at 60 wpm, Weight = 50%, 14.1 MHz, 100W.

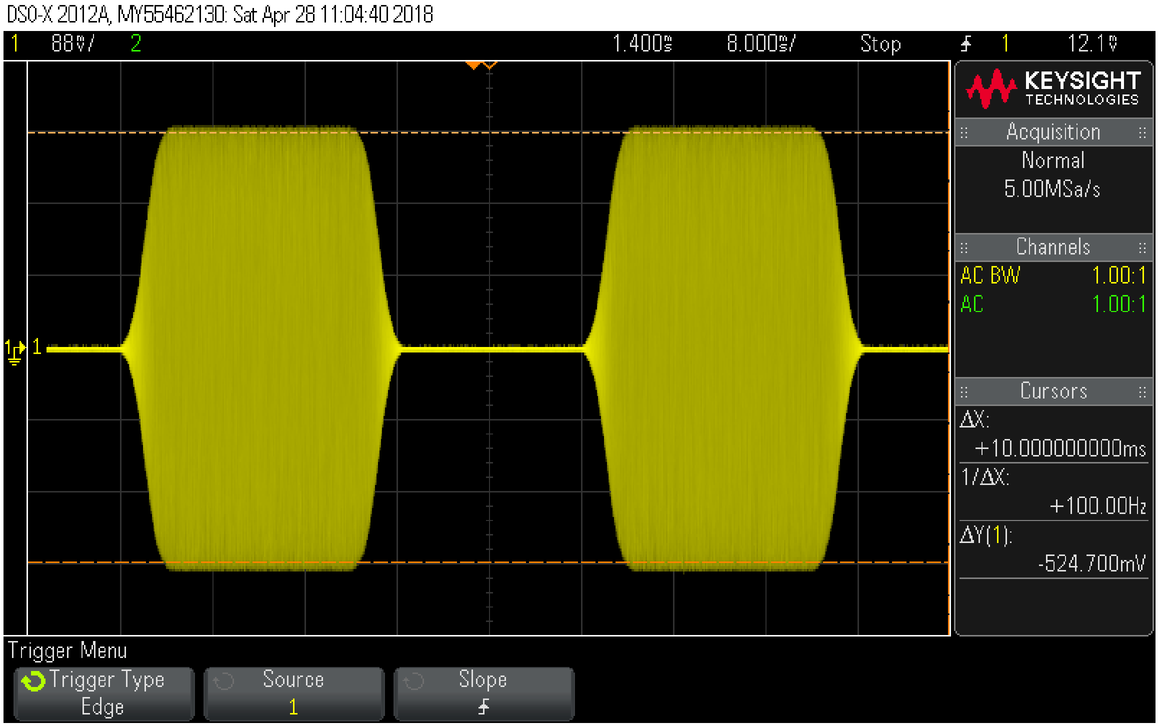


27: CW keying envelope. The oscilloscope is terminated in 50Ω and connected to the DUT RF output via a 50 dB RF power attenuator. A series of dits is transmitted from the internal keyer at 60 wpm.

Test Conditions: 14.1MHz CW, 100W output. Keying speed = 60 wpm using internal keyer. CW key-down & key-up delays 2 ms*. The keying envelope is shown in Figure 31.

* Delays ≥ 15 ms will cause distortion of the keying envelope (uneven dit timing).

Figure 31: Keying envelope at 60 wpm.



28: CW QSK recovery test. This test has been devised to measure the maximum speed at which the receiver can still be heard between code elements in QSK CW mode.

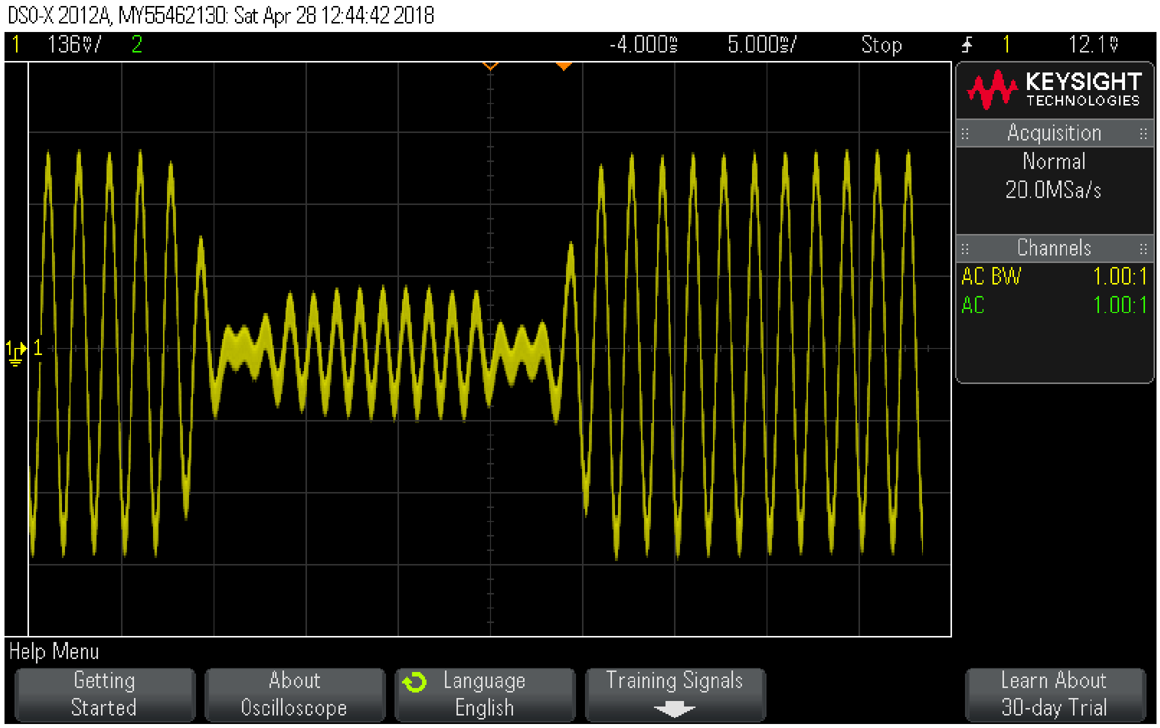
The DUT is terminated in a 50Ω 100W 50 dB power attenuator feeding a directional coupler. A test signal is injected into the signal path via the directional coupler; a 20 dB attenuator at the coupled port protects the signal generator from reverse power. Test signal level is adjusted for ≈ S5 at the receiver. As the coupler is rated at 25W max., RF PWR is set at 10W.

Test Conditions: 14.100 MHz, 500 Hz CW, AGC Fast, AGC Gain 120, ATT 0 dB, NR off, NB off, Iambic, full break-in (default), RF PWR at 10W, KEY SPEED at minimum (initially) CW Sidetone ON. Test signal at 14.0998 MHz. Sidetone = 600 Hz, received tone = 800 Hz.

Starting at minimum KEY SPEED, transmit a continuous string of dits and increase KEY SPEED until the received tone can just no longer be heard in the spaces between dits. Observe audio output on oscilloscope.

Test Result: In the current test, the received tone could still be heard distinctly at **60 wpm** (the maximum possible speed). Receiver recovery was clean, and no keying artifacts were observed. (See Figure 32 for oscilloscope screen capture.)

Figure 32 CW QSK audio waveform at 60 wpm. TX Sidetone 600 Hz. RX tone 800 Hz.

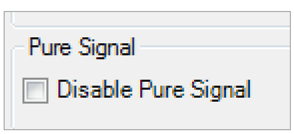


29: PureSignal Adaptive-Predistortion Linearization Test.

Test Setup: PS FEEDBACK-PS INPUT jumper in place on DUT rear panel (default).

PowerSDR Configuration:

1. On Setup, General, Hardware Config tab, uncheck as follows:



2. On PureSignal 2.0/Advanced form, check Auto Attenuate:

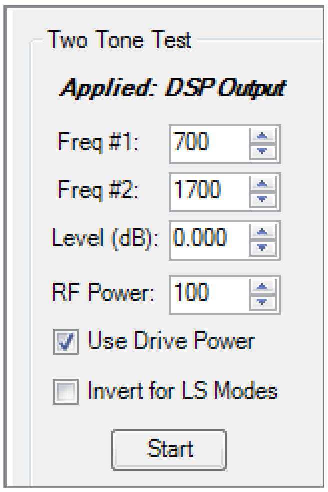
Test Conditions: 14.1 and 50.1 MHz USB, compression off. Test signal: 2-tone. Transmit Filter 200-2900 (default). Test tones: 700 and 1700 Hz, at equal amplitudes. Supply voltage +13.8V. The -10 dBm reference level RL on the spectrum analyzer equates to 100W CW output. PS-A off (initially), then on.

Test Procedure:

To start PureSignal, click on Linearity on the menu bar at the top of the main console. The PureSignal form (Figure 33) will open.

1. On Setup/General/Hardware Config tab, uncheck "Disable PureSignal".

2. On Setup/Tests tab, set up Two-Tone Test as follows:



3. Click **Start** and adjust RF Power for 100W PEP (-6 dBc per tone) on spectrum analyzer. Click **Start** again to stop transmitting.

4. Now return to PureSignal form and click **Two-tone**. Non-linearized 2-tone spectrum will be displayed. Store or capture screen image on spectrum analyzer.

5. Next, turn **PS-A** on and verify green Correcting indicator.

6. The linearized 2-tone spectrum will be displayed. Store or capture screen image on spectrum analyzer. (See Figures 35 and 36).

7. Click **AmpView** to display phase/gain transfer curve screen. (See Figure 34).

8. Click **Two-Tone** again to stop 2-tone test. Do not click **OFF**.

Figure 33: PureSignal (Linearity) Advanced form.

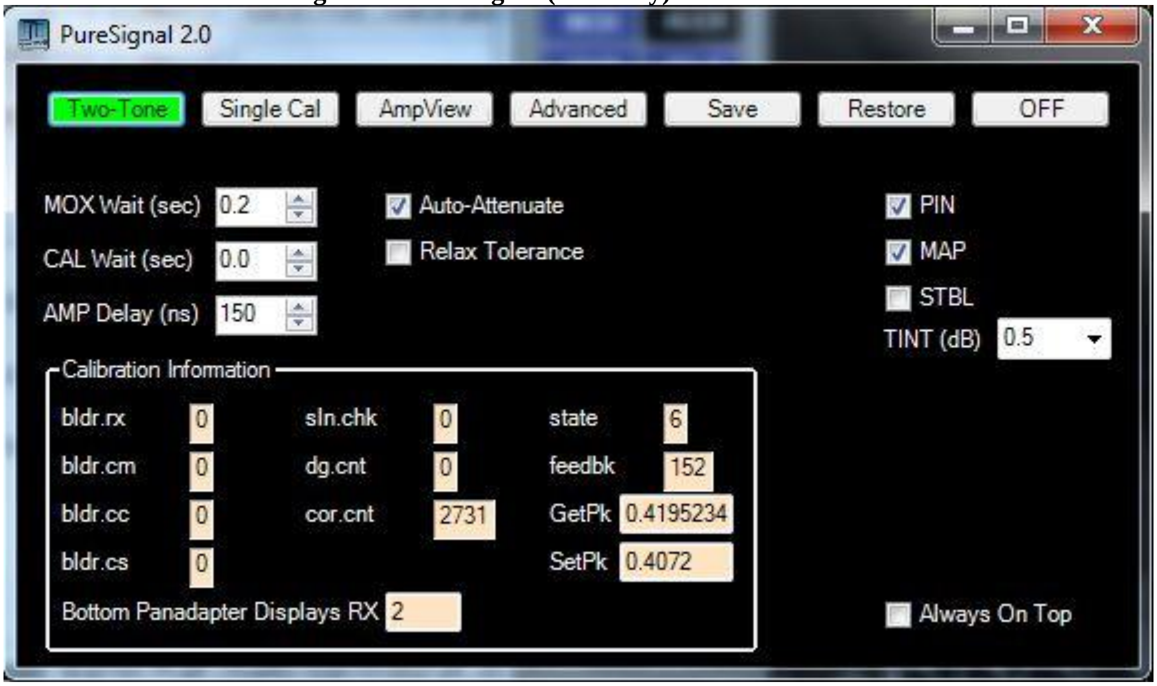
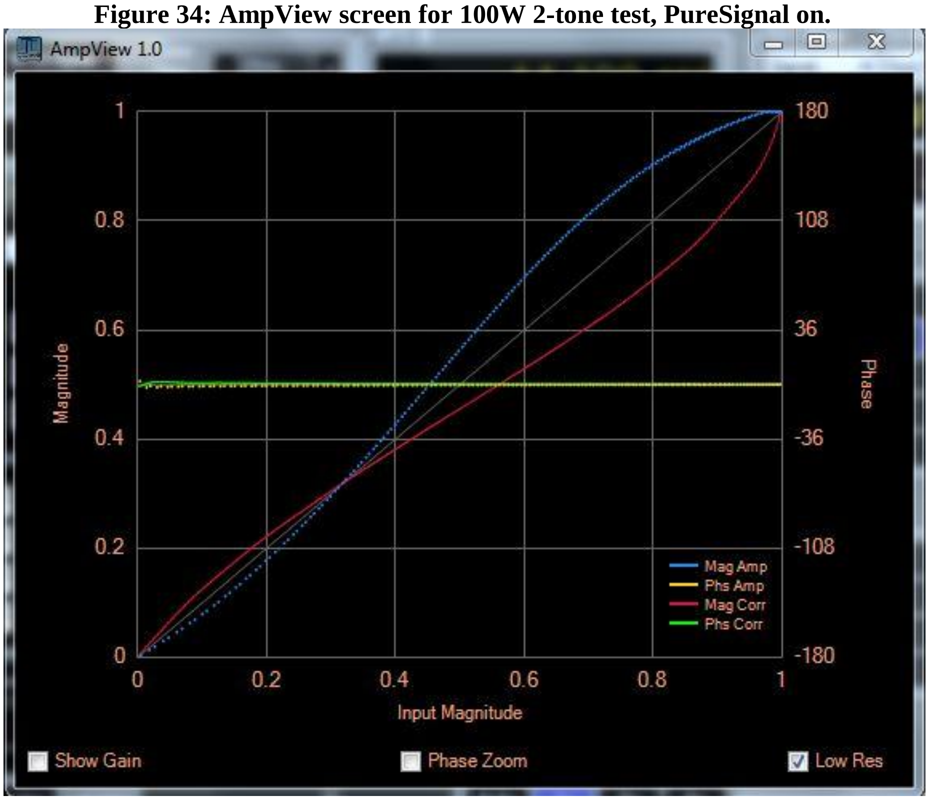


Figure 34: AmpView screen for 100W 2-tone test, PureSignal on.



PureSignal Test Results:

Figure 35: 2-tone TX IMD at 14.1 MHz, 100W PEP, PureSignal (PS) off & on.

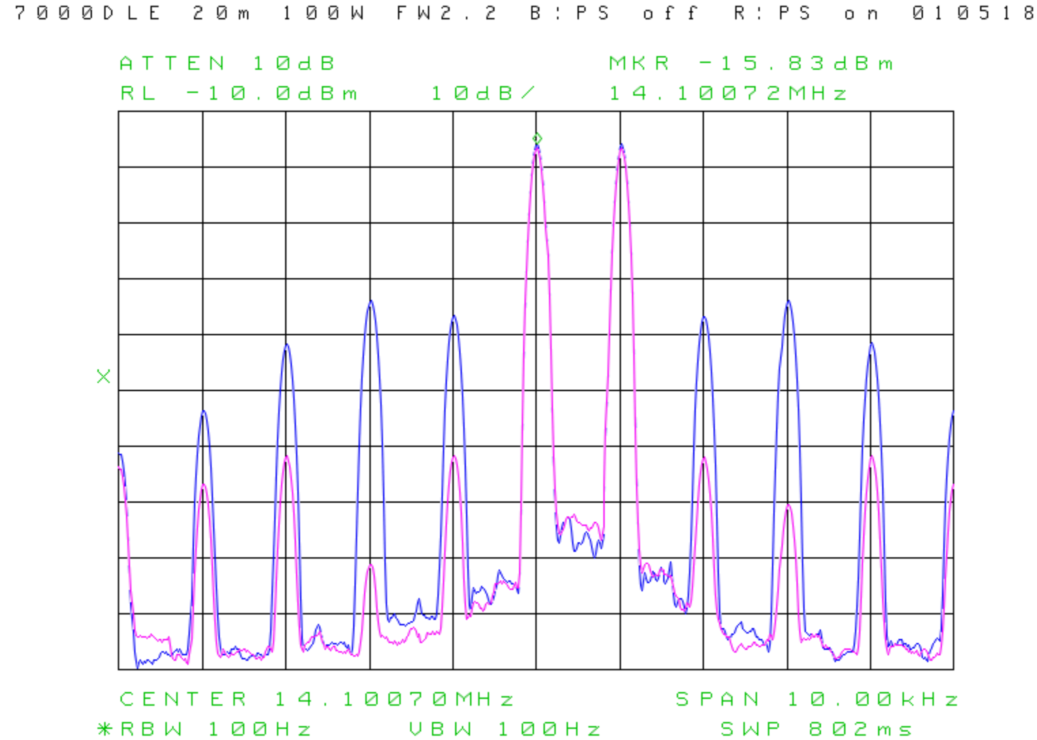
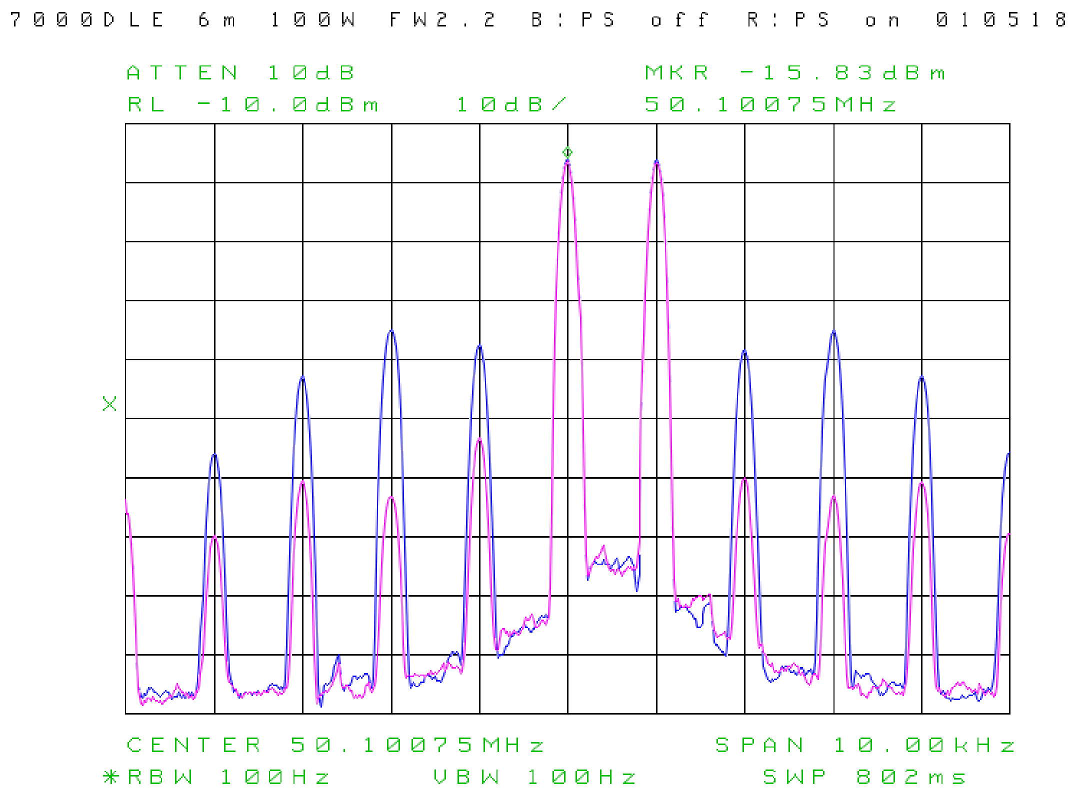


Figure 36: 2-tone TX IMD at 50.1 MHz, 100W PEP, PureSignal (PS) off & on.



30: References.

1. Apache Labs website: https://apache-labs.com/
2. "Noise Power Ratio (NPR) Testing of HF Receivers" http://www.ab4oj.com/test/docs/npr_test.pdf
3. "Theoretical maximum NPR of a 16-bit ADC" http://www.ab4oj.com/test/docs/16bit_npr.pdf
4. "HF Receiver Testing: Issues & Advances" http://www.nsarc.ca/hf/rcvrtest.pdf
5. "A New Look at SDR Testing" http://www.ab4oj.com/sdr/sdrtest2.pdf
6. "Testing AGC in receivers" by SM5BSZ http://www.sm5bsz.com/lir/agctest/agctest.htm

31: Conclusions.

Overall, the test results obtained on the ANAN-7000DLE were very similar to those on the ANAN-8000DLE tested last year. Comparing key parameters, the 8000DLE leads the 7000DLE by a few dB in RMDR and transmitted 2-tone IMD, whereas the 7000DLE is slightly ahead in NPR and transmitted phase noise. The 7000DLE exhibited no sign of preselector PIM during NPR testing.

The ANAN-7000DLE supports QSK CW up to its maximum keying speed (60 wpm). It is also free of loud T/R relay sounds when keying.

The ANAN-7000DLE runs cooler than earlier models. The maximum case temperature measured during key-down testing at 100W output did not exceed 37°C.

The following ***concerns*** were observed:

- An external 10 MHz reference feed from a GPSDO source degraded close-in RMDR and transmitted composite noise. The RMDR test data in this report were taken with the external reference disconnected. (Tests 2, p. 2 and 25, p. 27). It should be noted that this degradation is attributable to phase jitter in the external source, and is *not* due to any fault in the ANAN-7000DLE.
- After warm-up, the Fwd Pwr meter scale behaved erratically. (Test 19b, p. 15).
- On-board SMPS spurs in RX at 1.94. 4.5-5 and 9.5-10.5 MHz. (Test 18, p.14).
- Low-level (< -90 dBc) single-tone TX spurs at 48, 64, 72 and 96 MHz. These did not influence TX composite noise data. (Test 25, p. 27).

32: Acknowledgements.: I would like to thank Abhi Arunoday of Apache Labs, Warren Pratt NR0V and Doug Wigley W5WC for making this ANAN-7000DLE available to me for testing and evaluation. Thanks are also due to Warren, Doug and Abhi for their invaluable guidance in configuring the radio and activating PureSignal, and to Rob Sherwood NC0B for his interest and suggestions during the test phase.

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Appendix 1: MDS Tests with LNA enabled on 15/12/10m

May 2, 2018.

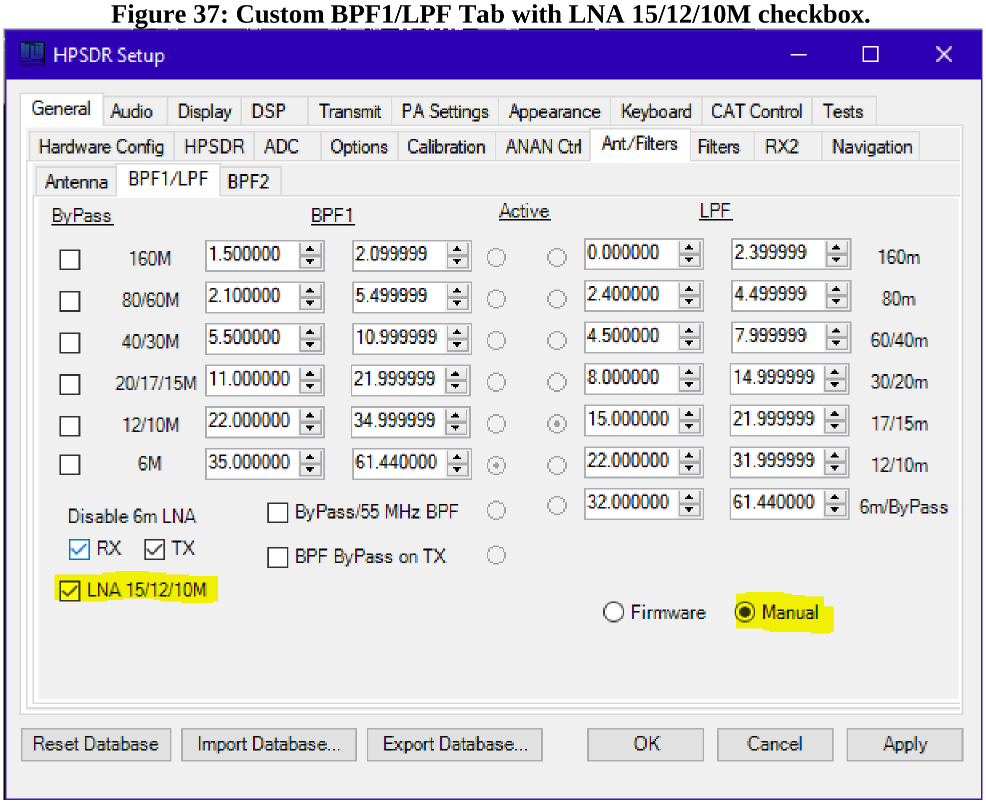
The ANAN-7000DLE was run on a custom software version:

- PSDR_3.4.9_28Apr_HF_LNA_manual

This version was created to allow the LNA to be enabled manually on the 15, 12 and 10mMHz bands as a proof-of-concept for a possible future LNA option on these bands.

The custom software version provides an LNA 15/12/10m checkbox as follows:

Figure 37: Custom BPF1/LPF Tab with LNA 15/12/10M checkbox.



The options were configured as per Figure 31, and MDS measured using an RF signal generator connected to ANT1 and an RMS AC voltmeter connected to the HEADPHONE jack. Test results are given in Table 15.

Test Conditions: CW, B = 500 Hz, ATT 0 dB, NR off, NB off, ANF off, AGC Fxd, AGC Gain = 120, RX1 Meter: Sig, Avg., Dither off, Random off.

For this test, the preselector is switched out when the LNA is enabled.

Table 15: MDS with LNA.

Freq. MHz		21.1	24.9	28.1
MDS dBm	LNA out	-131	-130	-129
	LNA in	-143	-140	-143

Appendix 2: SSB transmit latency tests.

May 5-6. 2018.

The objective of this test is to measure the transmit latency, i.e. the transit time of a signal from the audio input to the RF output of the transmitter. Latency is a more significant performance factor in an SDR than in a legacy radio architecture, due to the increased signal processing required in an SDR.

Transmit latency. Two somewhat different test methods are employed here. In the original test procedure, a function generator feeds repetitive bursts of one cycle of a 1 kHz tone to the DUT mic jack and also to Channel 1 of a dual-trace oscilloscope. Channel 2 is terminated in 50Ω and connected via a high-power 50 dB attenuator to the DUT ANT socket. The scope is triggered from the function generator's SYNC output. The time interval between the leading edge of the AF burst displayed on Channel 1 (upper) and that of the RF burst displayed on Channel 2 (lower) is recorded for WIDE, MID and NAR TBW settings. See example in Figure 39.

The disadvantage of the tone-burst method is that as the applied and output signals differ in duration, ambiguity can arise in measuring the time interval between the two signals as observed on the scope. This ambiguity can be resolved by applying a two-tone test signal to the mic jack.

The frequency difference between the two test tones should be such that its reciprocal is longer than the maximum likely value of latency. For example, if latency ≈ 100 ms, the frequency spacing should be the reciprocal of 200 ms i.e. 5 Hz. For this test, f_1 = 1000 Hz and f_2 = 1005 Hz, both tones at 30 mV rms. The time interval between the crossovers (cusps) of the applied (Channel 1) and output (Channel 2) signal envelopes equals the latency. The two-tone method is unambiguous, as the correct cusps can be easily identified. See Figure 40.

Test Conditions: 14100 kHz USB, 2.4 kHz, 25W. SSB TX test signal: tone burst or continuous two-tone audio. COMP OFF. (COMP does not affect latency.) Other configuration parameters: set as shown in Figure 38 and Table 16.

Figure 38. Configuration parameters for latency test.

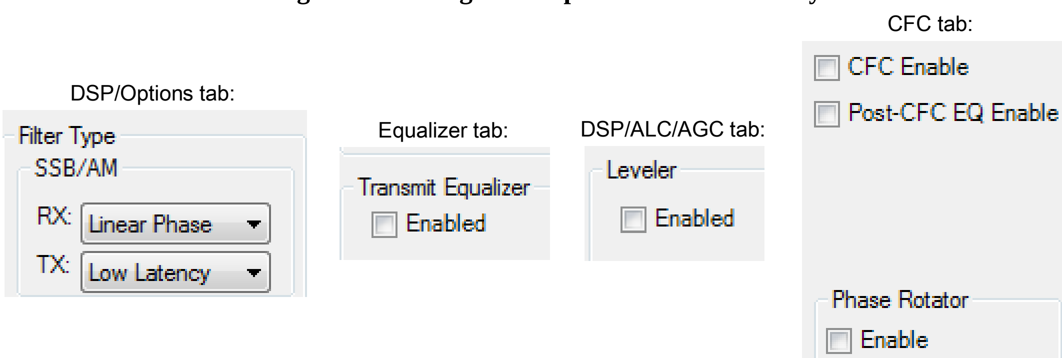


Table 16: Transmit latency in ms for various configurations.

Config	TX Filter	All OFF	Leveler, CFC, Ph Rot ON	Leveler, CFC, Ph Rot, TX EQ ON
Tone burst	2048 LL	54	76	74
2-tone		54	75	76
Tone burst	2048 LP	62	86	94
2-tone		62	86	94

Figure 39: Example of tone-burst latency test: leveler, CFC, phase rotator & TX EQ ON..

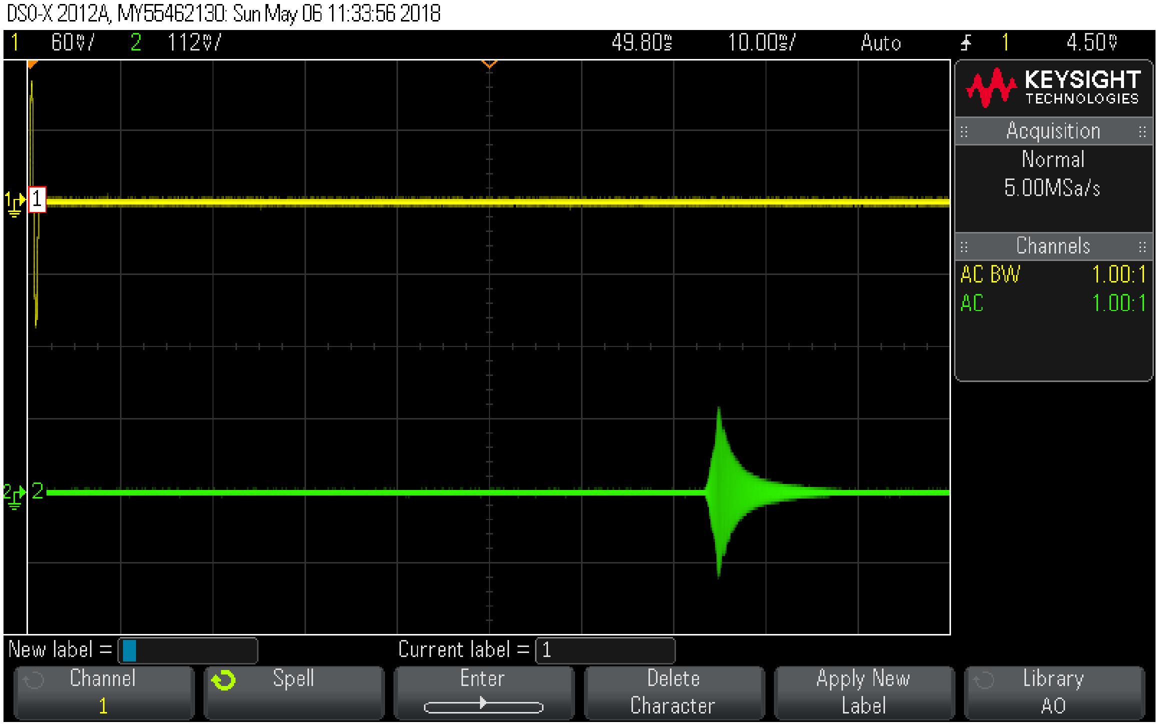
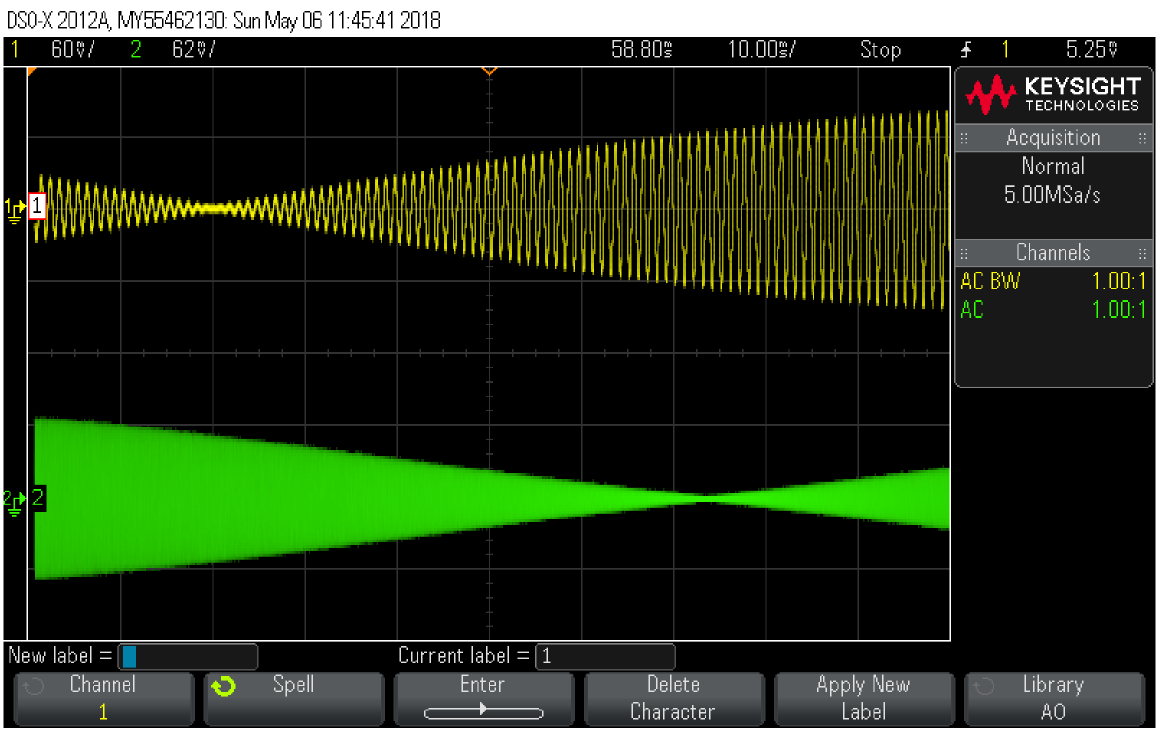


Figure 40: Example of 2-tone latency test: all OFF.



Appendix 3: 12 MHz RMDR.

May 26, 2018.

Reciprocal Mixing Noise at 12 MHz. This test is almost identical to Section A (Receiver Tests, Test 2) except that it is conducted at 12 MHz.

Here, a Wenzel 12 MHz OCXO with low phase noise is connected via a 7 dB pad and a 0-110 dB step attenuator to the DUT (ANT1). The noise floor is read on the DUT S-meter in CW mode (500 Hz) with ANT terminated in 50Ω. An RMS AC voltmeter is connected to the headphone jack. The input power P_i is 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. The external 10 MHz reference is disconnected for this test.

Test Conditions: 12.000 MHz, 250 Hz CW, ATT 0 dB, NR off, ANF off, NB off, negative offset. AGC Fxd, AGC Gain 120. Dither off, Random off. BH-4 receive filter window, sample rate 192K, buffer size 1024, filter size 4096. RMDR *in dB* = input power (P_i) – MDS *(both in dBm).* Here, MDS = -133 dBm (B = 250 Hz). RMDR = Pi - MDS. Phase noise = -(RMDR + 10 log B) = RMDR + 24 dBc/Hz.

Table 17: 12 & 5 MHz RMDR & Phase Noise.

	12 MHz			5 MHz	
Offset kHz	**P_i dBm**	**RMDR dB**	**PN dBc/Hz**	**RMDR dB**	**PN dBc/Hz**
0.5	-25	108	-132	105	-129
1	-23	110	-134	108	-132
2	-21	112	-136	110	-134
3	-20	113	-137	111	-135
5	-18	115	-139	113	-137
10	-16	117	-141	117	-141
20	-13	120	-144	122	-146
30	-11	122	-146	124	-148
50	-9	124	-148	128	-152
100	-8	125	-149	CLIP	
200	-6	127	-151		
300	-4	CLIP			

Appendix 4: 10m IFSS with LNA enabled.

May 27, 2018.

Two-Tone IMD$_3$ (IFSS, Interference-Free Signal Strength) tested in CW mode (500 Hz), ATT = 0 dB, AGC Med. Test frequencies: f_1 = 28010 kHz, f_2 = 28012 kHz. IMD$_3$ products: 28008/28014 kHz. IMD$_3$ product level was measured as absolute power in a 500 Hz detection bandwidth at various test-signal power levels and Dither/Random combinations, with 0 dB ATT selected. The ITU-R P.372-1 band noise levels for typical urban, rural and quiet rural environments are shown as datum lines. The S-meter was set at Sig Avg. Figure 41 illustrates the IFSS curves.

This test was run on PSDR_3.4.9_28Apr_HF_LNA_manual as described in Appendix 1. The two 15 MHz LPF's in the IMD test fixture were replaced by 30 MHz LPF's.

In the BPF1/LPF tab, LNA 15/12/10M and Manual were checked. See Figure 37 above.

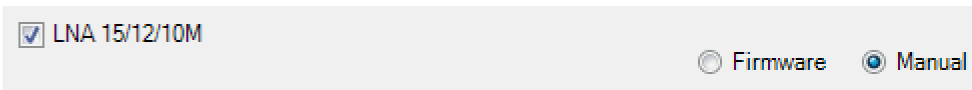
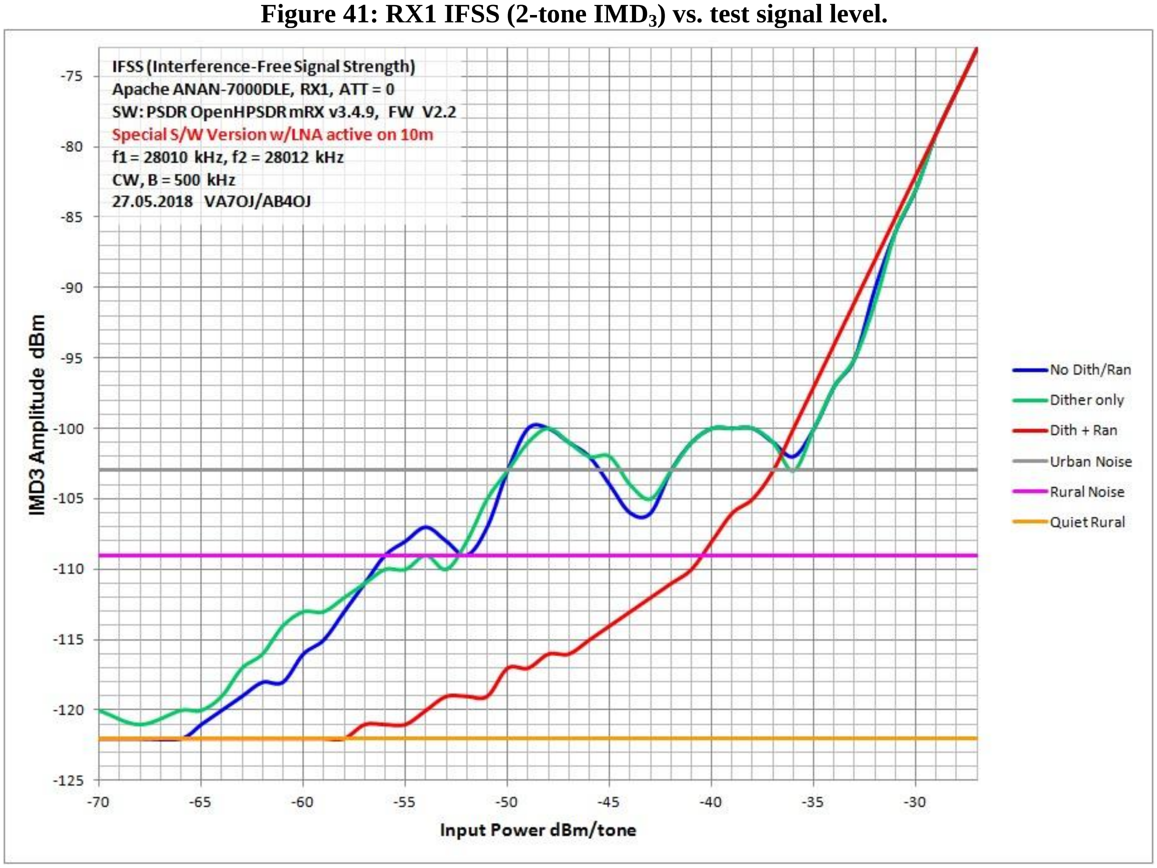


Figure 41: RX1 IFSS (2-tone IMD$_3$) vs. test signal level.



Notes on 2-tone IMD$_3$ test: Refer to Test 9 above.