Apache Labs ANAN-100D Test Report (including ANAN-200D Tests)

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Iss. 8, October 25, 2014 *(rationalized IFSS charts).* Supersedes all previous issues.

Figure 1: Apache Labs ANAN-100D front panel.

Introduction: This is a revised test report, presenting results of an RF lab test suite performed on an Apache Labs ANAN-100D direct-sampling/DUC SDR transceiver loaned by Apache Labs. ***Appendix I*** presents selected tests conducted on an ANAN-200D. Both radios were loaned by Apache Labs.

Severe noise-floor degradation with dither active, as described in Iss.4, led to the replacement of the original Crystek CVHD-950 VCXO (U16, Angelia board) with a Crystek CVHD-37X. As a result, several receiver parameters were re-tested. Iss. 6 incorporates the results of these re-tests (denoted by "**R**").

The Orion board in the ANAN-200D uses the CVHD-37X. No noise-floor degradation with dither on was observed in the ANAN-200D.

Software versions: Iss. 4: PowerSDR OpenHPSDR mRX PS v3.2.16
Iss. 5, 6: PowerSDR OpenHPSDR mRX PS v3.2.17

Firmware versions: Iss. 4: Angelia v3.9
Iss. 5, 6: Angelia v3.9 and v4.1 (100D), Orion v2.6 (200D)

Performance Tests conducted in my home RF lab, June 24 – August 6, 2014.

A. Receiver 1 (RX1) Tests

Note: Signal routing ANT1 port – T/R switch – HPF/LPF – RX1 input. 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 at the audio output.

Test Conditions: ATT as shown, NR off, NB off, ANF off, AGC threshold just above noise floor, Dither off, Random off.

Table 1: MDS in dBm (RX1). R

	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	-130	-137	-130	-136	-129	-136	-136[1]	-143[1]
0/dither[3]	-125	-131	-124	-131	-124	-131	-134[2]	-141[2]
-20	-110	-116	-109	-116	-108	-116	-124	-132

Notes: 1. 6m LNA gain = 20 dB.
2. Dither does not raise noise floor on spectrum scope on 6m.
3. Dither does not change over time or with temperature.

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 signal generator 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 1). The noise floor is read on the DUT S-meter in CW mode (500 Hz) with ANT 1 terminated in 50Ω. The signal generator is tuned for maximum null; next, the DUT is tuned to this frequency (f_0). The null should be at the noise floor. The bandstop filter reduces the signal source's close-in phase noise.

The signal generator is now set to f_0 - offset and output P_i increased to raise detected noise by 3 dB. Reciprocal mixing dynamic range (RMDR) = P_i – MDS.

Bandstop filter parameters: 4-pole crystal filter, center freq. 9.830 MHz, passband insertion loss 0.6 dB, stopband attenuation > 80 dB, bandwidth at max. attenuation 300 Hz. ***Note:*** The residual phase noise of the measuring system is the limiting factor in measurement accuracy.

Test Conditions: 9.830 MHz, 500 Hz CW, ATT 0 dB, NR off, ANF off, NB off, negative offset. AGC threshold just above noise floor, Dither off, Random off. BH-4 receive filter window, sample rate 192K, buffer size 4096. RMDR *in dB* = input power (P_i) – MDS *(both in dBm).* Here, MDS = -137 dBm.

Table 2: RMDR in dB. R

Offset kHz	P_i dBm	RMDR dB
1	-27	110
2	-27	110
3	-26	111
5	-26	111
10	-23	114

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's rejection. The lower the shape factor, the "tighter" the filter.

In this test, an approximate method is used. An RF test signal is applied at a power level approx. 60 dB above the level where the S-meter just drops from S1 to S0. The bandwidths at -6 and -60 dB relative to the input power are determined by tuning the signal generator across the passband and observing the S-meter.

Test Conditions: 14.100 MHz, SSB/CW modes, ATT = 0 dB, AGC med, NR off, NB off, ANF off, Dither off, Random off. BH-4 filter window. Setup I: Sample rate 192K, buffer size 4096. Setup II: Sample rate 48K, buffer 16384 (high-latency).

Table 3: Channel Filter Shape Factors.

	Setup I		Setup II	
Filter	Shape Factor	6 dB BW kHz	Shape Factor	6 dB BW kHz
2.4 kHz SSB	1.12	2.69	1.01	2.42
500 Hz CW	1.55	0.51	1.05	0.5
250 Hz CW	2.15	0.25	1.075	0.25
5 kHz AM	1.06	5.0		

3a. Ultimate channel filter attenuation. In this test, 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.

Test Conditions: 14.100 MHz, SSB/CW modes, ATT = 0 dB, AGC med, NR off, NB off, ANF off.

Test Results: 2.4 kHz SSB: S-meter minimum = -121 dBm at 3.95 kHz offset.
Ultimate attenuation = -26 - (-121) = **95 dB**.
Bandwidth for ultimate attenuation = 2 * 3.95 ≈ **8 kHz**.

500 Hz CW: S-meter minimum = -116 dBm at 0.69 kHz offset.
Ultimate attenuation = -26 - (-116) = **90 dB**.
Bandwidth for ultimate attenuation = 2 * 0.69 ≈ **1.4 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 (-122 dBm). NR is then turned on, and SINAD read at various NR settings.

Test Conditions: 14.100 MHz, 2.4 kHz USB, sampling rate 192K, BH-4 RX filter, buffer size 4096, AGC med, ATT = 0 dB, NB off, ANF off, NR/ANF Pre-AGC (in DSP Options), Dither off, Random off. Initial NR settings (defaults): Taps 256, Delay 64, Gain 100, Leak 100.

Table 4: NR SINAD.

Taps	Delay	SINAD dB
NR off	64	6
128	64	10
256	32	12
256	64	13
512	64	14
1024	64	15

This shows a SINAD improvement of 9 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 baseband level 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 4096, AGC med, ATT = 0 dB, NB off, ANF off, NR/ANF Pre-AGC (in DSP Options), Dither off, Random off. Initial NR settings (defaults): Taps 256, Delay 64, Gain 100, Leak 100. Initial AGC Gain: 91.

Test Results: Measured MDS = -129 dBm per **Test 1**. Stopband attenuation = test signal power - MDS = -65 - (-129) = **64 dB**. Setting AGC gain to 106 increased stopband attenuation to **65 dB**.

Reducing Delay to 64 or Gain to 50 caused more frequent tone breakthrough.

6: AGC impulse response. The purpose of this test is to determine the ANAN-100D'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 4096, NR on, NB off/on as required, ANF off, ATT= 0 dB, AGC fast, ANF off, NR/ANF Pre- and Post-AGC (in DSP Options), Dither off, Random off. A pulse generator is connected to ANT1 via a step attenuator. AGC fast is selected.

The pulse rise time (to 70% of peak amplitude) is 10 ns. Pulse duration **t** is varied from 12.5 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.)

AGC "ticks" are audible from **t** = 10 ns up. For **t** > 100 ns, the ticks do not become louder. With NR/ANF Pre-AGC, activating NR reduces background noise; the effect is to make the ticks more audible. With NR/ANF Post-AGC and **t** < 100 ns, NR reduces the ticks to quiet "holes" in the receiver audio.

NB or NB2 suppresses the ticks entirely, whether NR/ANF is Pre- or Post-AGC.The S-meter occasionally flicks up to S1…S2 during the test. **Figures 2, 3 & 4** are waterfall screen images for NB off, NB1 and NB2.

A simulation test was performed by playing the SM5BSZ *powersdr-agctest-96.wav* file into the receiver (***Ref. 5***). The simulation exercised AGC response to impulses, but not NB. With NR on, NR/ANF Pre-AGC reduced the AGC "ticks" generated by the WAV file more effectively than Post-AGC.

Figure 2: AGC impulse response, NB off.

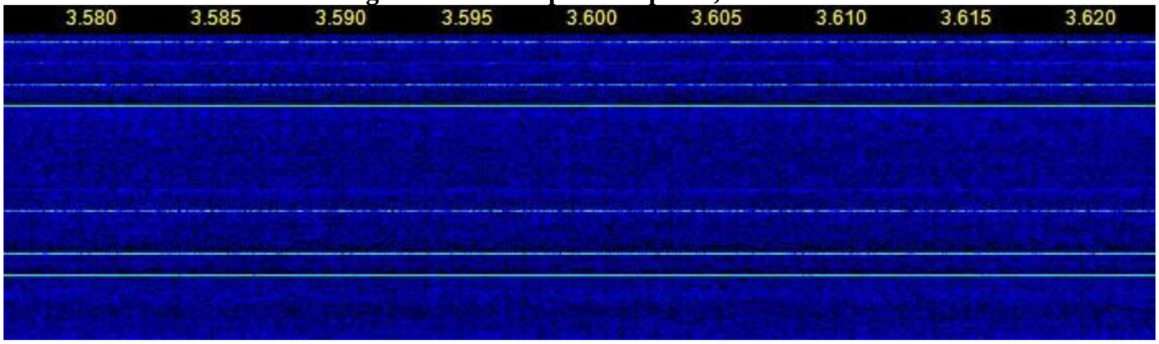


Figure 3: AGC response, NB1.

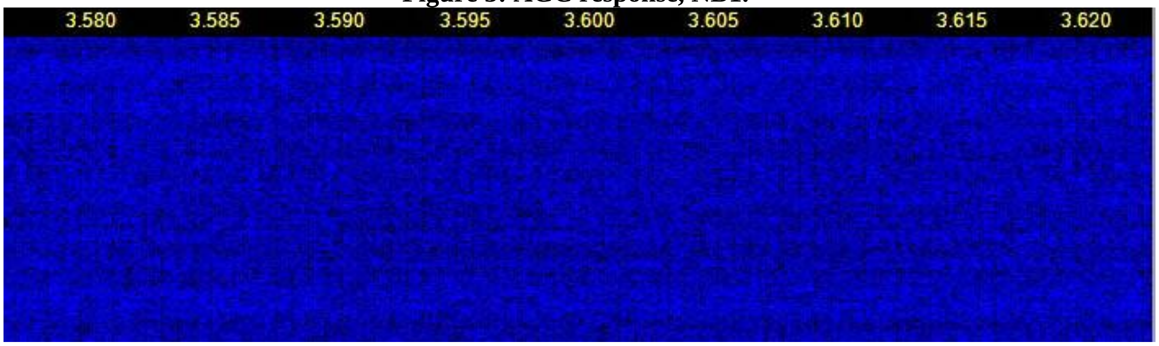
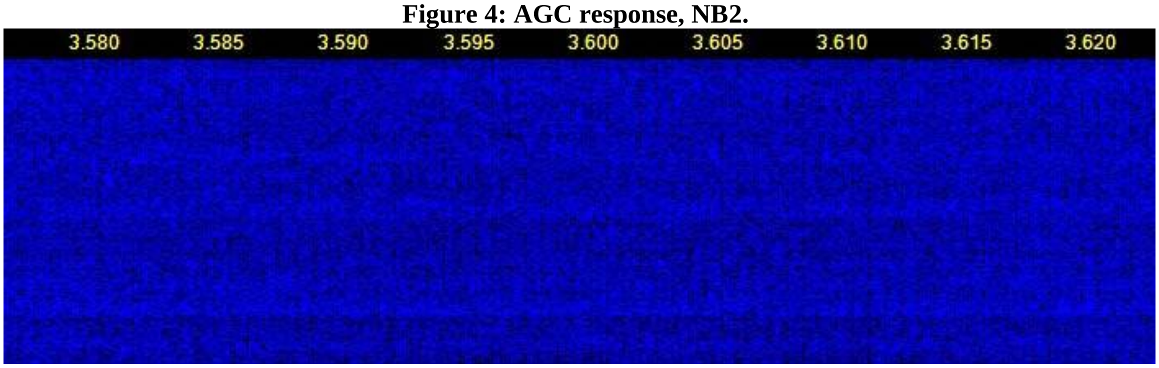


Figure 4: AGC response, NB2.



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

Test Conditions: 2.4 kHz USB, ATT = 0 dB, sampling rate 192K, BH-4 RX filter, buffer size 4096, AGC med, ANF off, Dither off, Random off. ***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.

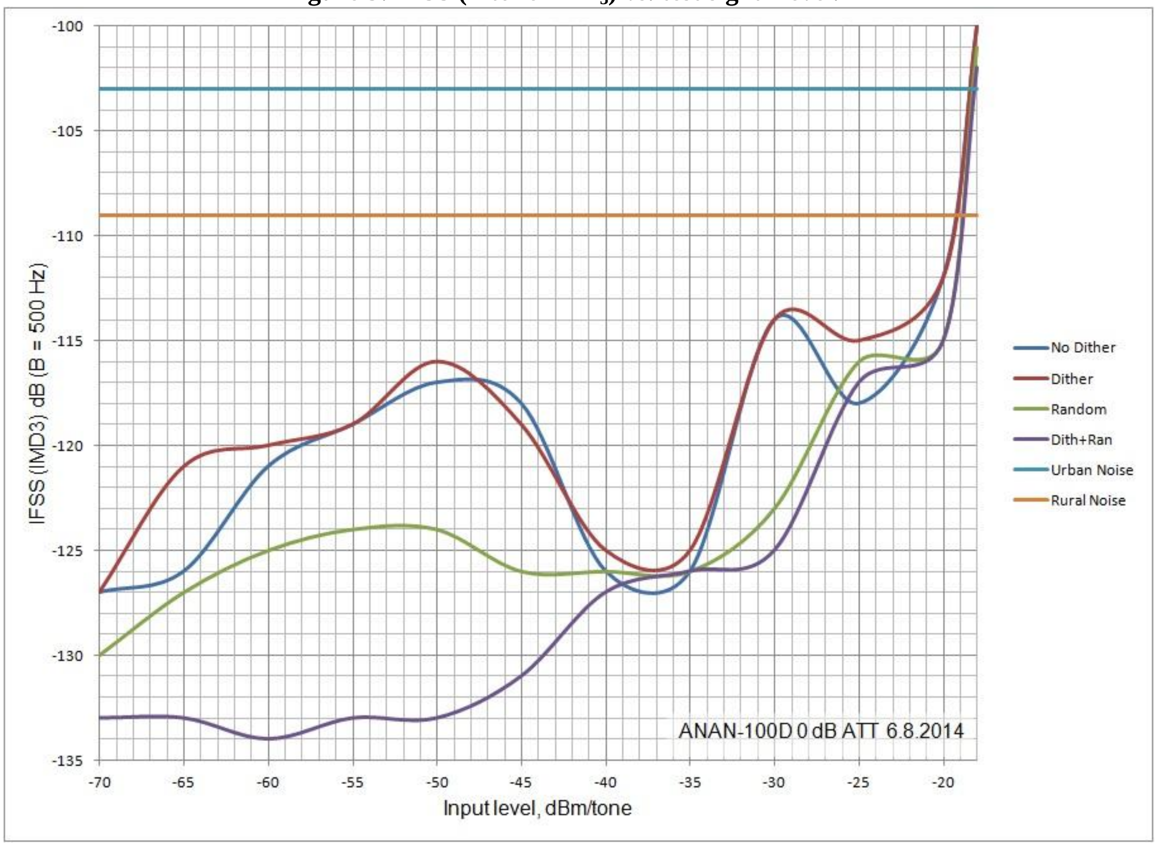
Applied dBm	-120	-110	-100	-90	-80	-73	-60	-50	-40	-30	-20	-11
Rdg.dBm	-120	-110	-100	-90	-80	-73	-60	-50	-40	-30	-20	-11
S-meter	S1	S2	<S5	>S6	S8	S9	S9+6	S9+22	S9+32	S9+42	S9+52	CLIP

Table 6: S-Meter/ATT Tracking

Applied dBm	-73					
ATT dB	0	10	20	30	40	50
Rdg. dBm	-73	-73	-73	-73	-73	-73
S-units	S9	S9	S9	S9	S9	S9

8. Two-Tone IMD$_3$ (IFSS, Interference-Free Signal Strength) tested in CW mode (500 Hz), ATT = 0 dB. 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/Random combinations, with 0 dB ATT selected. The ITU-R P-372.1 band noise levels for typical urban and rural environments are shown as datum lines.

Figure 5: IFSS (2-tone IMD$_3$) vs. test signal level. R

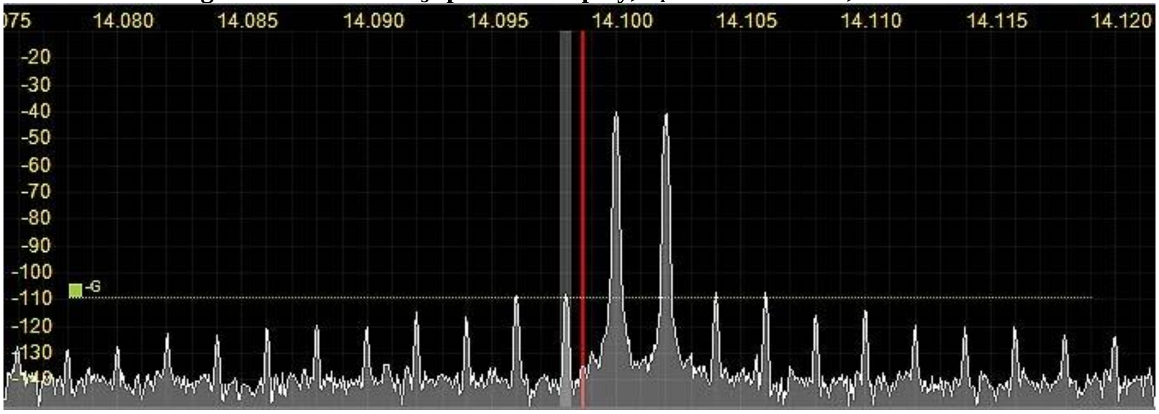


Note on 2-tone IMD$_3$ test: This is a new data presentation format in which the amplitude relationship of the actual IMD$_3$ products to typical band-noise levels is shown, rather than the more traditional DR$_3$ (3rd-order IMD dynamic range) or SFDR (spurious-free dynamic range). The reason for this 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 6: 2-tone IMD_3 spectrum display, P_i = -40 dBm/tone, dither off.



9. 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 2^{nd}-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. DR_2 in dB. Measured MDS = -136 dBm (dither off), -131 dBm (dither on).

Table 7: DR_2. f_1: 6.1 MHz. f_2: 8.1 MHz. R

Dither	Random	MDS dBm	P_i dBm	DR_2 dBm
off	off	-136	-42	94
off	on		-33	104
on	off	-131	-40	91
on	on		-26	105

10. 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. $f_0 \pm 1.5$ kHz, 2.4 kHz SSB, ATT = 0 dB, NR off, NB off, Notch off, ANF off, AGC slow. Test results are presented in **Table 8.**

Table 8: RX1 NPR Test Results. R

DUT	BSF kHz	BLF kHz	Dither	P_{TOT} dBm	BWR dB	NPR dB[1]		Theor. NPR[4]
						Pre. in	Pre. out	
ANAN-100D	1940[5]	60…2044	0	-16	29.2	73	73	80
			1	-16		72	72	
	3886	60…4100	0	-22	32.3	75	74	76.9
			1	-22		71	70	
	5340	60…5600	0	-22	33.6	72	72	75.6
			1	-22		69	68	
	7600	316…8160	0	-15	35.1	74	73	74.1
			1	-15		71	71	

Notes on NPR test:

1. NPR readings were stable over time. There was no evidence of the instability over time flagged in the Iss. 2 test report (September 2013).

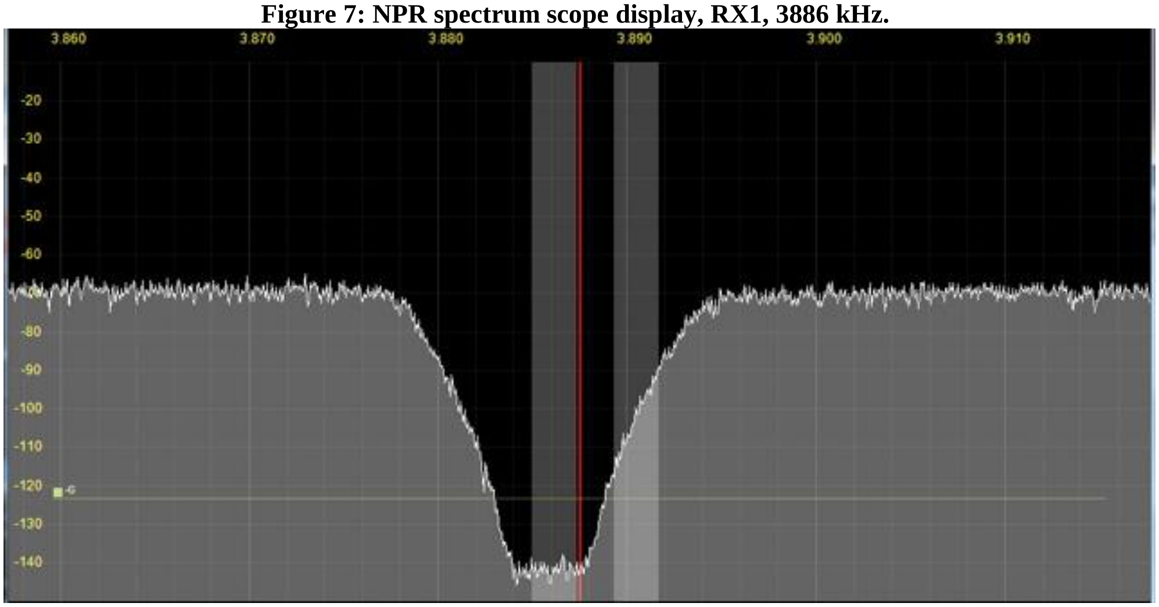
2. NPR degradation with dither on was consistent with MDS degradation per ***Test 1***.

3. Enabling Random did not affect NPR results.

4. 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.

5. 1940 kHz NPR was re-tested 8/18/2014 to correct a measurement error.

Figure 7: NPR spectrum scope display, RX1, 3886 kHz.



B. Receiver 2 (RX2) Tests

Note: Signal routing RX2 port – RX2 input.

11: 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 threshold just above noise floor, Dither off, Random off.

Table 9: MDS 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	-130	-137	-130	-138	-130	-138	-128[1]	-136[1]
0/dither[3]	-126	-133	-126	-134	-127	-134	-124[2]	-133[2]
20	-110	-118	-109	-117	-110	-117	-107	-115

Notes: 1. RX2 has no 6m LNA.
2. Dither does not raise noise floor on spectrum scope on 6m.
3. Dither does not change over time or with temperature.

12. 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. $f_0 \pm 1.5$ kHz, 2.4 kHz SSB, ATT = 0 dB, NR off, NB off, Notch off, ANF off, AGC slow. Test results are presented in **Table 10.** NPR figures are generally lower than for RX1, as RX2 has no preselector.

Table 10: RX2 NPR Test Results. R

DUT	BSF kHz	BLF kHz	Dither	P_{TOT} dBm	BWR dB	NPR dB
ANAN100D	1940	60…2044	0	-24	29.2	75
			1	-24		71
	3886	60…4100	0	-24	32.3	74
			1	-24		70
	5340	60…5600	0	-23	33.6	72
			1	-23		68
	7600	316…8160	0	-23	35.1	65
			1	-23		62

C. Transmitter Tests

- ⚠ ***Case temperature*** was in the range 40 - 45°C, reaching 56°C during key-down tests at 100W CW output.
- ***BH-4 TX Filter Window*** selected for all transmitter tests.

13: CW Power Output. In this test, the RF power output into a 50Ω load is measured at 3.6, 14.1, 28.1 and 50.1 MHz in RTTY mode, at a primary DC supply voltage of +13.8V. A thermocouple-type power sensor and meter are connected to the ANAN-100D RF output via a 50 dB high-power attenuator. Wattmeter calibration (14.1 MHz, 100W) is performed before starting the test.

Test Conditions: 3.6, 14.1, 28.1, 29.6, 50.1 and 53.0 MHz, 100W nominal. Set Tune Pwr for 100W Fwd Pwr reading.

Table 11: CW Power Output.

Freq. MHz	Fwd Pwr W	P_O W
3.6	100	100
14.1	101	102
28.1	102	95
29.6	100	93
50.1	100	80
53.0	100	78

14: SSB Peak Envelope Power (PEP). Here, an oscilloscope is terminated in 50Ω and connected to the ANAN-100D RF output via a 50 dB high-power attenuator. At 100W CW, the scope vertical gain is adjusted for a peak-to-peak vertical deflection of 6 divisions.

Test Conditions: USB mode, electret mic connected, Drive 95%, Mic Gain 20 dB, compression 6 dB, Transmit Filter 200-3100 (default), supply voltage +13.8V. Leveler settings (default): Max. gain 5, Attack 2 ms, Decay 500 ms, Hang 500 ms.

Speak loudly into the microphone for full-scale ALC reading. **Figures 8 & 9** show the envelope for 100W PEP, without and with compression respectively. ±3 vert. div. = 100W. 5 ms/horiz.div. ***Note:*** With MON on, mic/monitor latency ≈ 200 ms.

15: 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 ANAN-100D RF output via a 50 dB high-power attenuator**.**

Test Conditions: 14100 kHz USB, compression off. Test signal: white noise. Transmit Filter 200-3100 (default). Supply voltage +13.8V. Set noise generator level for 100W PEP. ± 3 vertical divisions = 100W. 5 ms/horiz. division.

Test Results: No sign of ALC overshoot at 100W PEP (±3 vert. div.) See **Fig. 10.**

Figure 8: 100W PEP speech envelope, no compression.

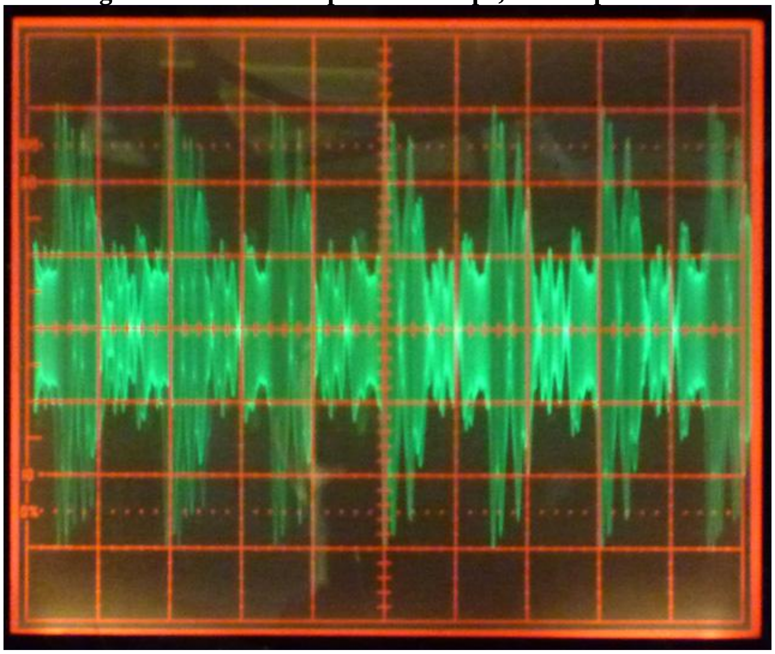


Figure 9: 100W PEP speech envelope, 6 dB compression.

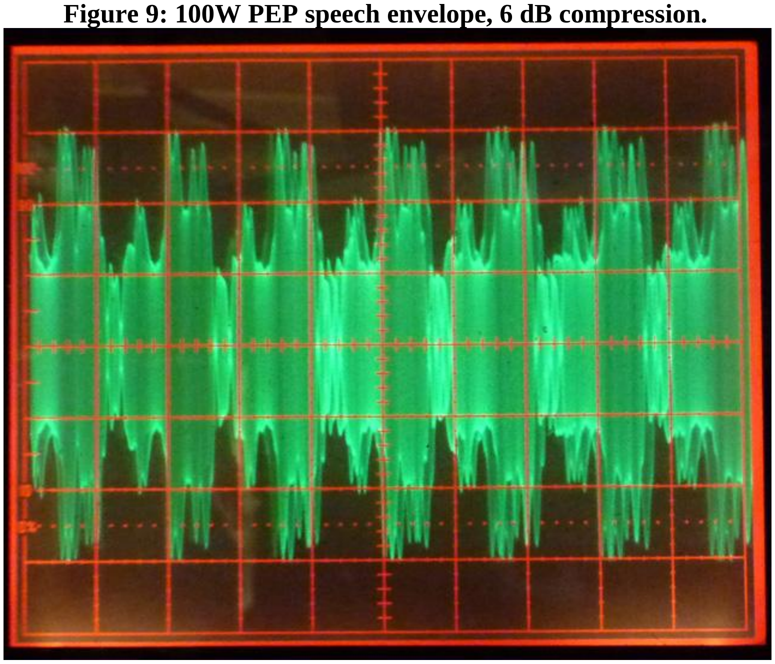
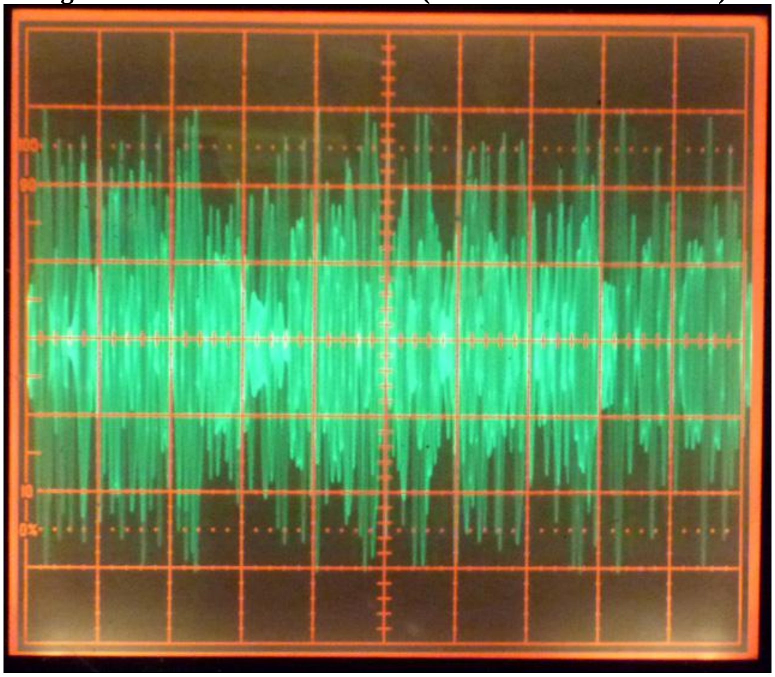


Figure 10: 100W white noise test (±3 vert. div. = 100W PEP).

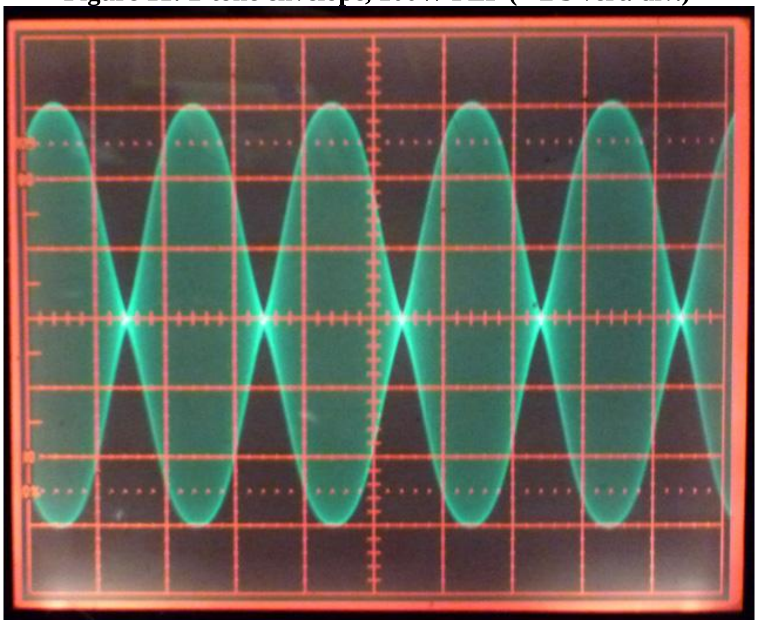


16. ALC Compression Check. In this test, a 2-tone test signal is applied to the USB port from the internal 2-tone generator. An oscilloscope is connected to the ANAN-100D RF output via a 50 dB high-power attenuator. RF Power is initially adjusted for 100W CW output.

Test Conditions: 14100 kHz USB, compression off. Test signal: 2-tone. Transmit Filter 200-3100 (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 11**.)

Figure 11: 2-tone envelope, 100W PEP (= ± 3 vert. div.)



16a: 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

c. Set 3-band TX EQ for -3 dB Low, +1 ~ 2 dB Mid, +4 ~ 5 dB High.

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

17: 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 ANAN-100D RF output via a 60 dB high-power attenuator. RF Power is initially adjusted for rated CW output on each band in turn.

Test Conditions: 3.6, 14.1 and 50.1 MHz USB, compression off. Test signal: 2-tone. Transmit Filter 200-3100 (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 (= 0 dBc).

Adjust test tone levels for 100W PEP (each tone at -6 dBc). **Figures 12** through **14** show the two test tones and the associated IMD products for each test case.

Table 12. 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**	**50.1**
IMD3 (3rd-order)	-34	-36	-30
IMD5 (5th-order)	-32	-31	-33
IMD7 (7th-order)	-39	-42	-41
IMD9 (9th-order)	-46	-53	-53
Add 6 dB for IMD referred to 2-tone PEP			

17a. Noise IMD Test. This test is similar to **Test 17**, except that a white-noise baseband is applied from the internal noise generator. Spectrograms are captured at 100W and 25W PEP, as shown in **Figure 15**. Note that the IMD skirts are steeper at the lower power level.

Test Conditions: 14.1 MHz USB, 12 dB compression. TX EQ on (adjust as required for 100W PEP.) Transmit Mode: Noise. Level (dB): +10. Measured -50 dBm/Hz noise power ≈ 100W PEP.

Figure 12: Spectral display of 2-tone IMD at 3.6 MHz, 100W PEP.

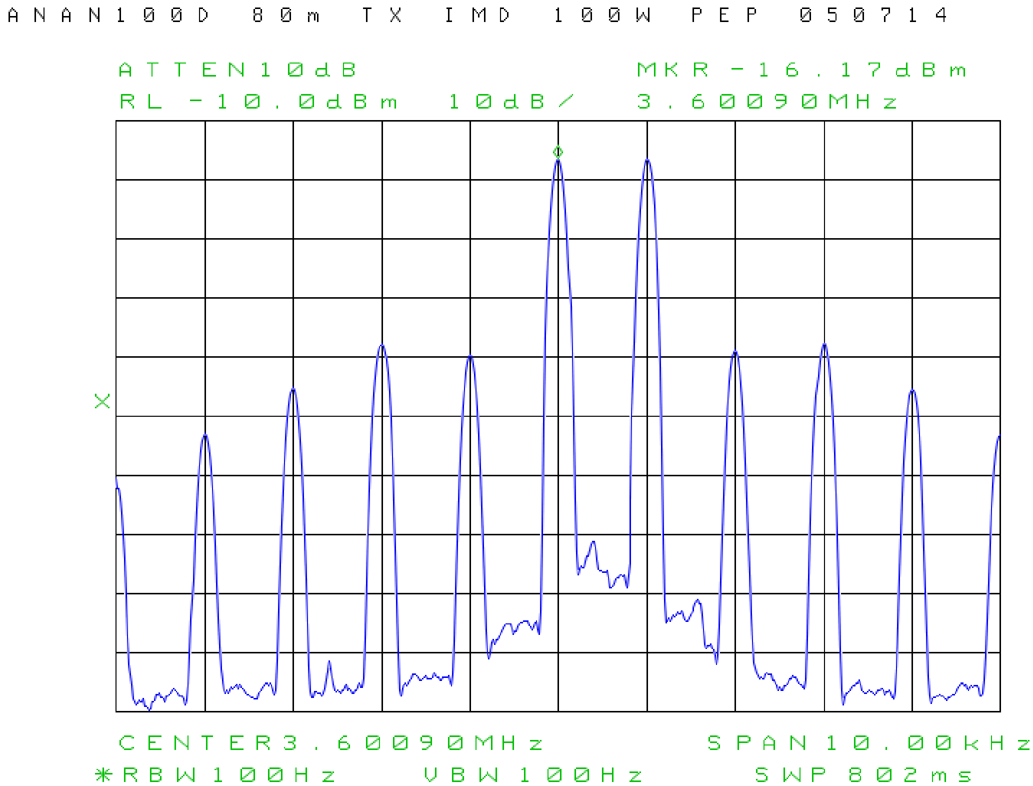


Figure 13: Spectral display of 2-tone IMD at 14.1 MHz, 100W PEP.

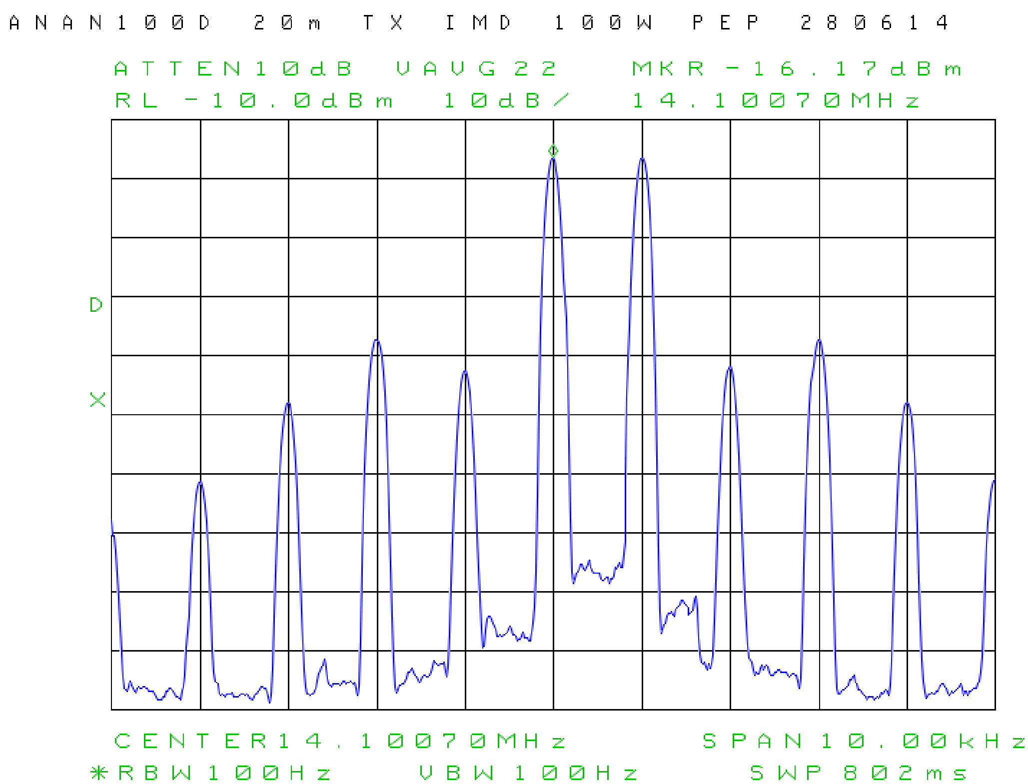


Figure 14: Spectral display of 2-tone IMD at 50.1 MHz, 100W PEP.

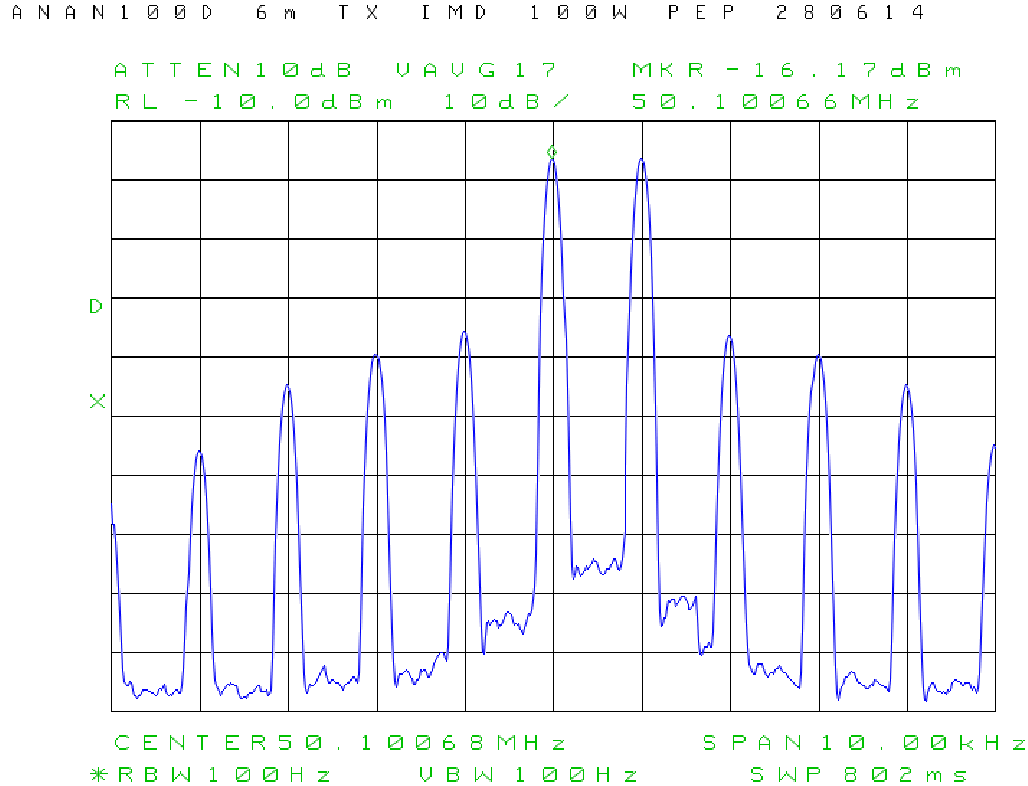
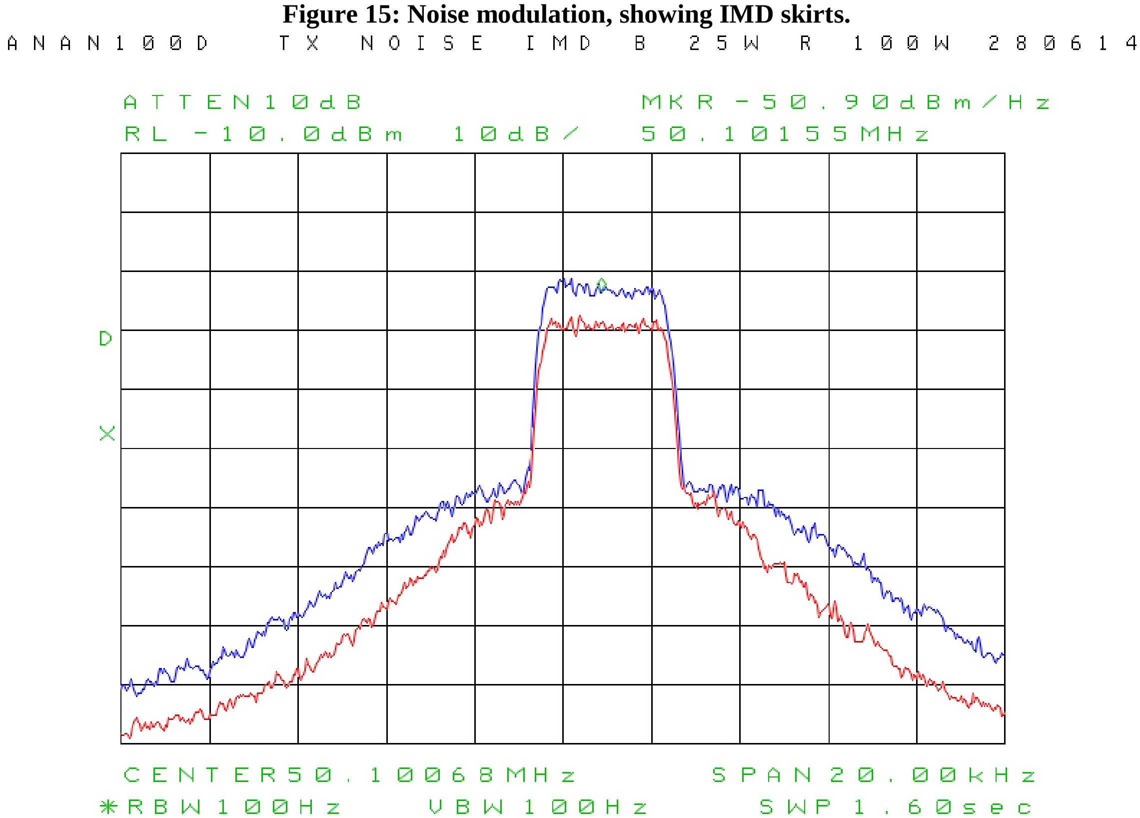


Figure 15: Noise modulation, showing IMD skirts.



18: AM sidebands and THD with single-tone modulation. As in **Test 17** above, the spectrum analyzer is connected to the ANAN-100D RF output via a 50 dB high-power attenuator. On the ANAN-100D, 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, 25W carrier output, Transmit Mode: Tone, Level: -7 Adjust test tone level for -6 dBc test tone level (100% modulation.) **Figure 16** shows the carrier and sideband levels. Calculated THD ≈ **3%**.

Figure 16: AM Sidebands for 100% Modulation.

```
ANAN100D AM 100% 25W 1kHz test tone 030714

DISCRETESIDEBANDSEARCHRESULTS

CARRIERFREQ:    14.10MHz
CARRIERPOWER:   -16.2dBm

OFFSETFREQ     - OFFSET     + OFFSET
                  dBc          dBc
-------------------    --------

 .998 kHz          -6.2        -6.2
1.997 kHz         -38.0       -36.7
2.996 kHz         -33.7       -33.7
3.995 kHz         -54.8       -53.8
5.003 kHz         -57.5       -57.7

FOUND:   5 SETS OF SIDEBANDS
```

19: Transmitter harmonics & spectral purity. Once again, the spectrum analyzer is connected to the ANAN-100D RF output via a 60 dB high-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 harmonic capture utility is started.

Test Conditions: 3.6, 14.1 and 50.1 MHz, TUNE mode, 100W to 50Ω load. Harmonic data are presented for all frequencies tested (**Figures 17** through **19a**), and a spur sweep for 10 – 60 MHz in **Figure 19b**. It will be seen that harmonics are well within specifications. On 6m, spurs below the carrier frequency are within the -60 dBc limit specified in FCC Part 97.307(e).

Figure 17.

ANAN100D 80m TX Harmonics 100W CW 290614

HARMONIC MEASUREMENT RESULTS

FUNDAMENTAL SIGNAL: 3.600 MHz
-11.0 dBm

HARMONIC	LEVEL dBc	FREQUENCY
2	-76.8 *	7.199 MHz
3	-61.8	10.80 MHz
4	-102.2 *	14.40 MHz
5	-81.2	18.00 MHz
6	-104.2 *	21.60 MHz
7	-71.8	25.20 MHz
8	-107.0 *	28.80 MHz

* MEASURED LEVEL MAY BE NOISE OR LOST SIGNAL.

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

Figure 18.

ANAN100D 20m TX Harmonics 100W CW 290614

HARMONIC MEASUREMENT RESULTS

FUNDAMENTAL SIGNAL: 14.10 MHz
-9.8 dBm

HARMONIC	LEVEL dBc	FREQUENCY
2	-85.2 *	28.20 MHz
3	-54.2	42.30 MHz
4	-90.0	56.40 MHz
5	-70.8	70.50 MHz
6	-87.3	84.60 MHz
7	-98.2	98.70 MHz
8	-98.0	112.8 MHz

* MEASURED LEVEL MAY BE NOISE OR LOST SIGNAL.

TOTAL HARMONIC DISTORTION = .2 %
(OF HARMONICS MEASURED)

Figure 19a.

ANAN100D 6m TX Harmonics 100W CW 290614

HARMONIC MEASUREMENT RESULTS

FUNDAMENTAL SIGNAL: 50.10MHz
-10.0dBm

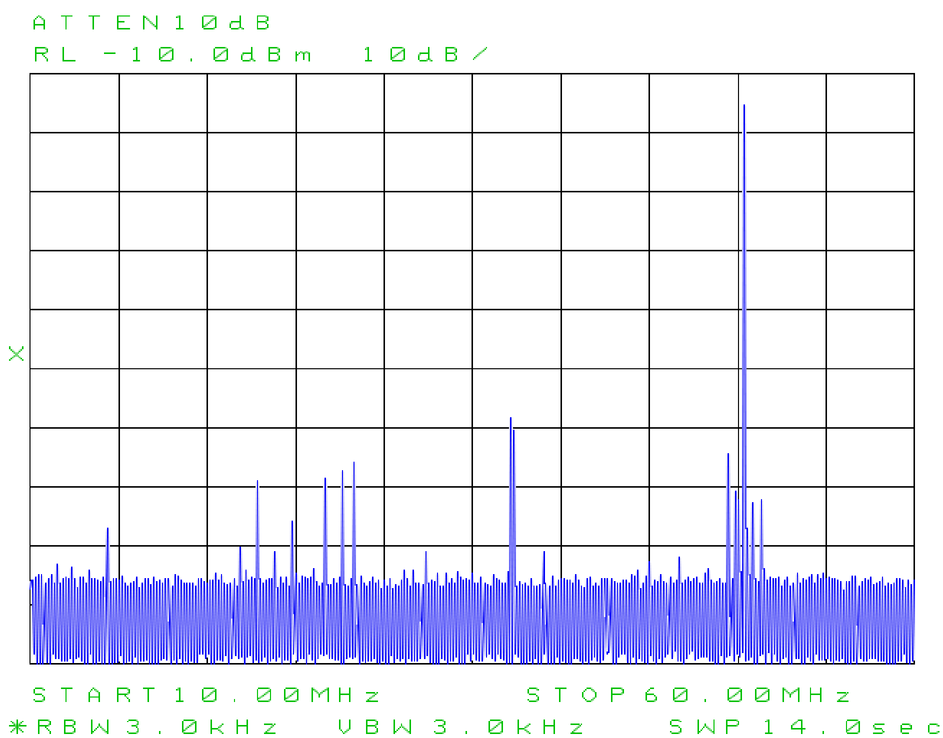
HARMONIC	LEVEL dBc	FREQUENCY
2	-86.8 *	100.2 MHz
3	-77.5	150.3 MHz
4	-73.2	200.4 MHz
5	-82.8	250.5 MHz
6	-92.7	300.6 MHz
7	-91.2	350.7 MHz
8	-92.0	400.8 MHz

* MEASURED LEVEL MAY BE NOISE OR LOST SIGNAL.

TOTAL HARMONIC DISTORTION= 0 %
(OF HARMONICS MEASURED)

Figure 19b.

ANAN100D 30W CW Spurs below 50.1MHz 010714



20: Transmitted composite noise. The spectrum analyzer is connected to the ANAN-100D RF output via a 60 dB high-power attenuator. The spectrum analyzer's phase-noise utility is started. **Figures 21a** and **21b** are the resulting composite-noise plots.

⚠ ***Caution:*** This test is performed at **30W** CW output to prevent PA overheating. Each test run requires that the transmitter be continuously keyed for several minutes.

Test Conditions: 3.6, 14.1 and 50.1 MHz, TUNE mode, 30W to 50Ω load. Utility minimum/maximum offset and spot frequencies configured as shown in **Figures 20a** and **20b**. (***Note:*** The limitation of this measurement method is that the measured noise power is close to the spectrum analyzer's own noise floor.)

Figure 20a: Composite noise at 14.1 and 3.6 MHz, 30W.

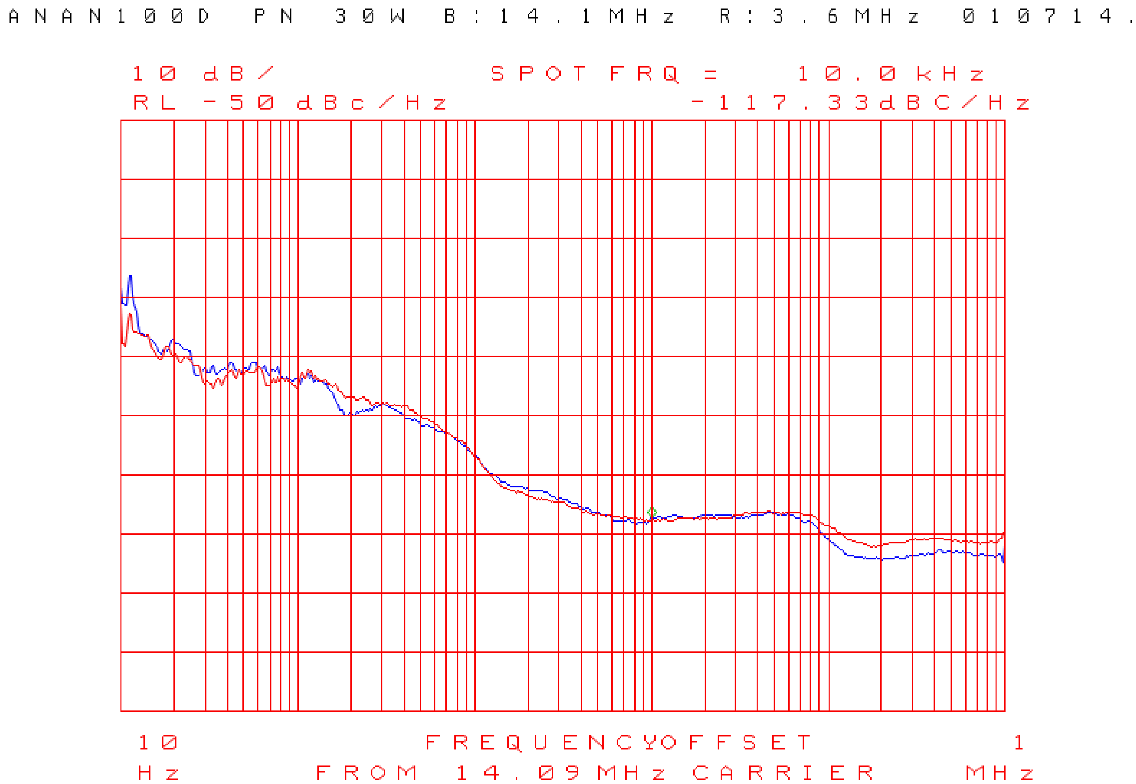
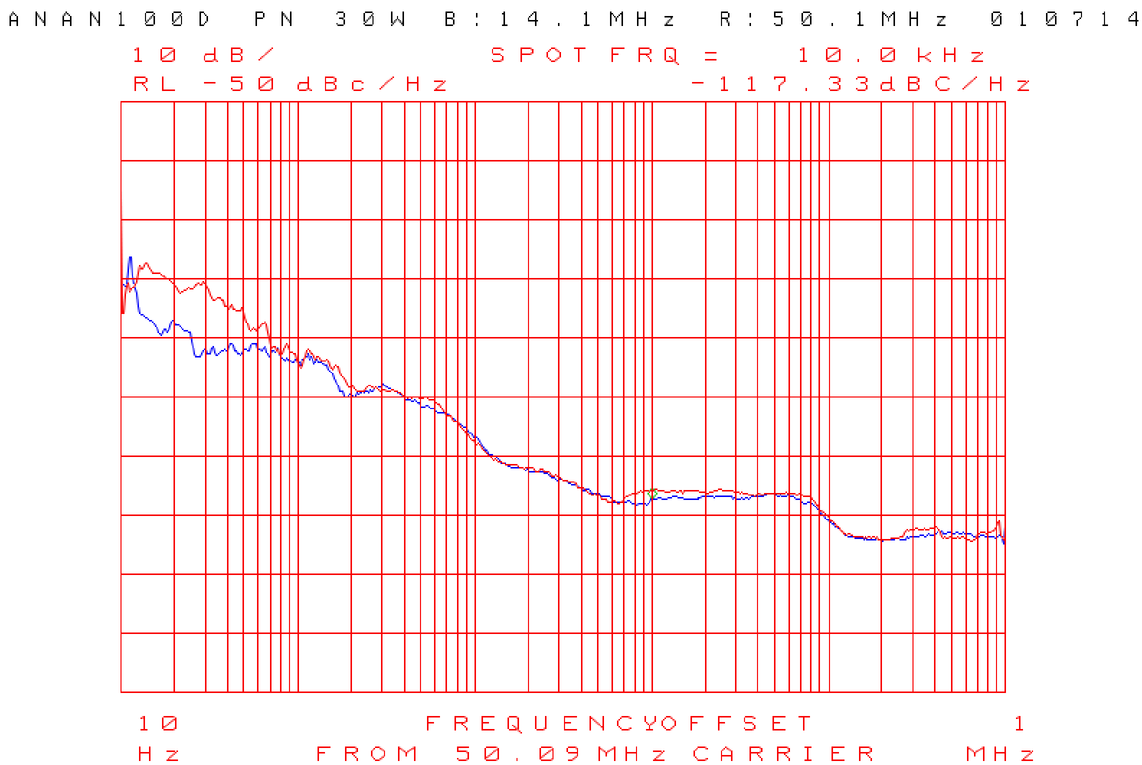


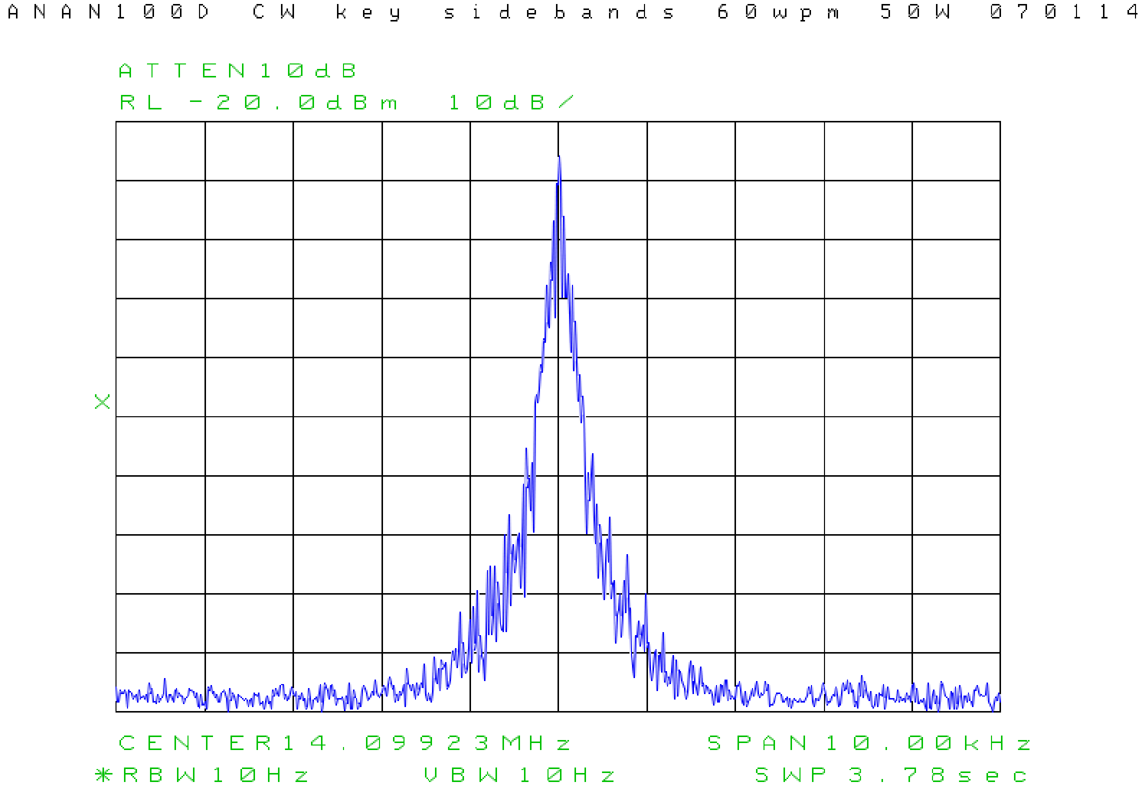
Figure 20b: Composite noise at 50.1 and 14.1MHz, 30W.



21: Spectral display of CW keying sidebands. The spectrum analyzer is connected to the ANAN-100D RF output via a 60 dB high-power attenuator. The -10 dBm reference level equates to 100W. A series of dits is transmitted at 60 wpm.

Test Conditions: 14.1 MHz CW, 50W output to 50Ω load. Keying speed 60 wpm using internal keyer. CW Weight = 50% (default). Spectrum analyzer RBW is 10 Hz, video-averaged; sweep time < 4 sec. **Figure 21** shows the transmitter output ±5 kHz from the carrier.

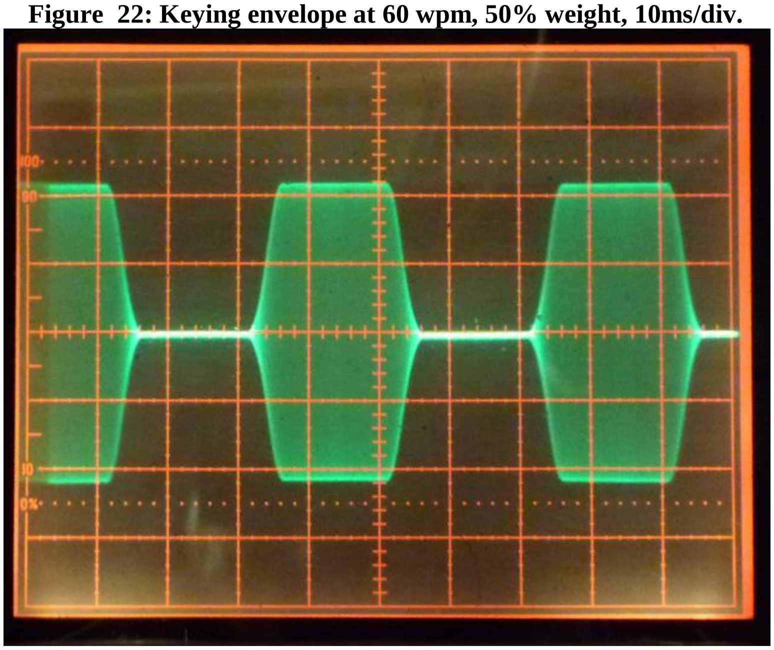
Figure 21: Keying sidebands at 60 wpm, Weight = 50%, 14.1 MHz, 50W.



22. CW keying envelope. The oscilloscope is terminated in 50Ω and connected to the ANAN-100D RF output via a 50 dB high-power attenuator. A series of dits is transmitted from the internal keyer at 60 wpm.

Test Conditions: 14.1MHz CW, 50W output to 50Ω load. Keying speed = 60 wpm using internal keyer. Weight = 50% (default). CW key-down & key-up delays 3 ms. The keying envelope is shown in **Figure 22.**

Figure 22: Keying envelope at 60 wpm, 50% weight, 10ms/div.

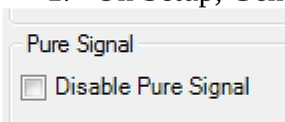


D: *PureSignal* Adaptive-Predistortion Linearization Tests

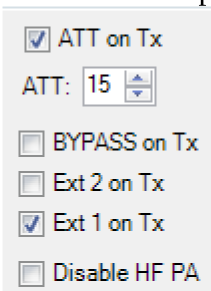
Test Setup: ANT1 to Bird 4273 line sampler input. Sampler output via 60 dB high-power attenuator to spectrum analyzer. Sampler coupling port to EXT1. Sampler initially at minimum coupling.

PowerSDR Configuration:

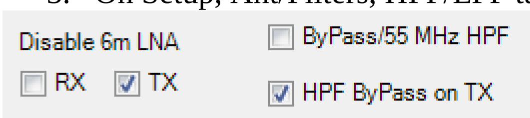
1. On Setup, General, Hardware Config tab, **uncheck** as follows:



2. On Setup, Ant Filters, Antenna tab, **check** as follows and set ATT to 15:



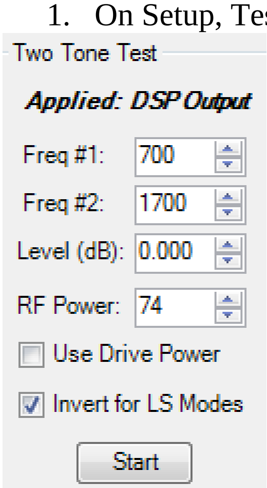
3. On Setup, Ant/Filters, HPF/LPF tab, **check** as follows:



Test Conditions: 14.1 MHz USB, compression off. Test signal: 2-tone. Transmit Filter 200-3100 (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 (= 0 dBc).

Test Procedure:
To start PureSignal, click on Linearity on the menu bar at the top of the main console. The PureSignal form (**Figure 23**) will open. If desired, click "Information" to open a PureSignal user guide.

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



2. Click **Start** and adjust RF Power for 100W PEP (-16 dBm per tone) on spectrum analyzer. Click **Start** again to stop transmitting.

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

4. Next, click **AutoCalibrate** and adjust line sampler coupling for a **green** Feedback Level indicator. The linearized 2-tone spectrum will be displayed. Store or capture screen image on spectrum analyzer. (See **Figure 25**).

5. Click **AmpView** to display phase/gain transfer curve screen. (See **Figure 25**).

6. Re-run white noise IMD test (see **Section C, Test 17**) with PureSignal off, then on. Store or capture both screen images on spectrum analyzer. (See **Figure 26**).

7. Re-run Steps 3 & 4 with 100 kHz span, to compare wideband TX noise floor with Pure Signal off/on. (See **Figure 27**).

8. Re-run AM sidebands/THD test (see **Section C, Test 18**) with PureSignal on. Record test data from spectrum analyzer. (See **Figure 28**).

   Note: IMD product asymmetry with PureSignal on is most likely due to memory effects in the TX PA chain.

   ⚠ ***Caution:*** Keep key-down periods as short as possible to avoid overheating.

Figure 23: PureSignal (Linearity) form.

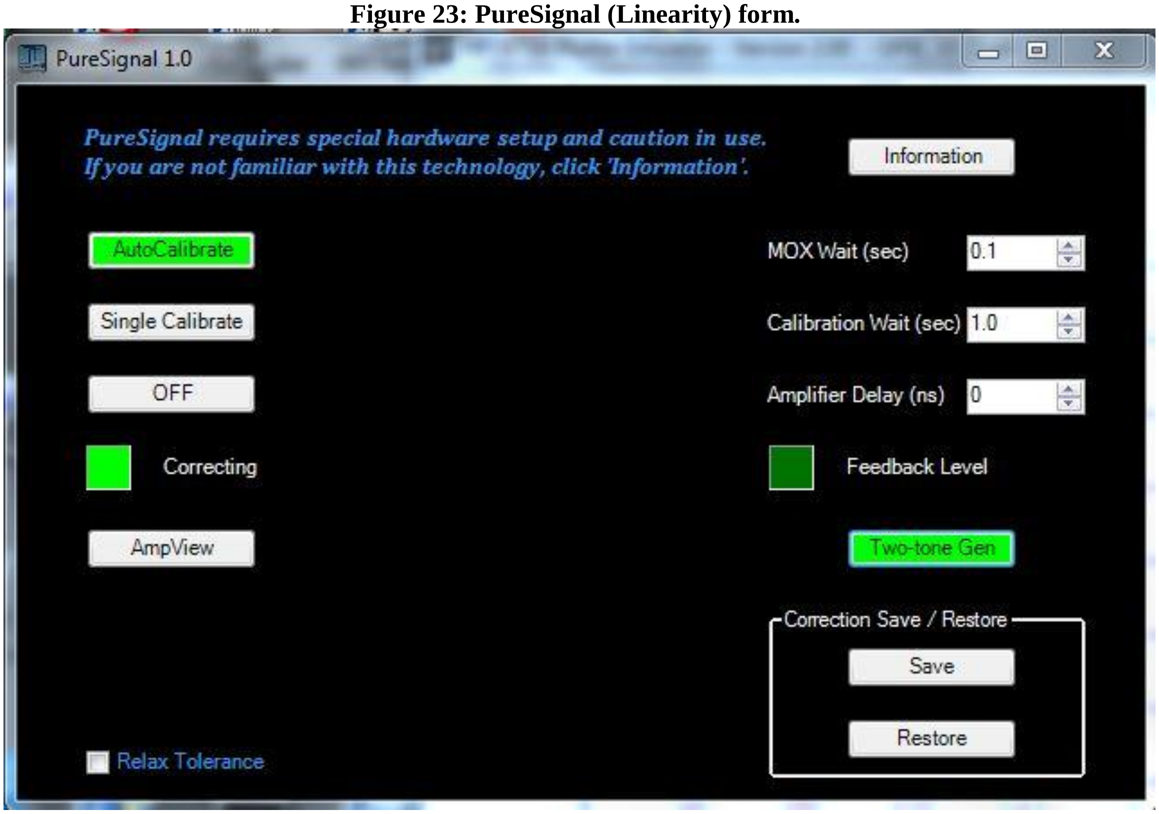
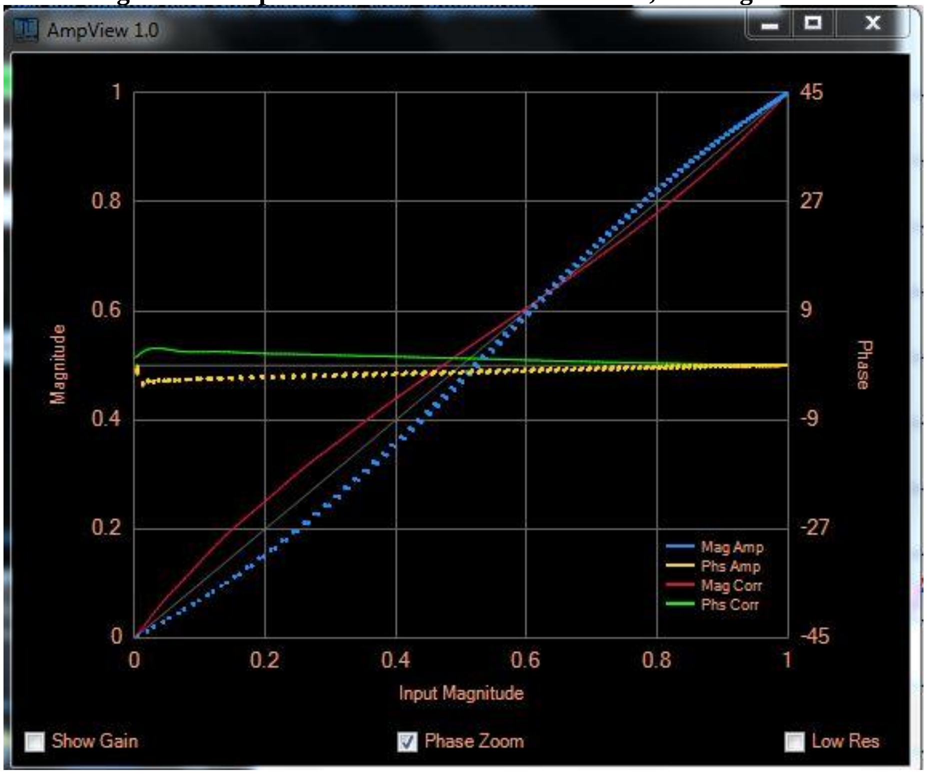


Figure 24: AmpView screen for 100W 2-tone test, PureSignal on.



PureSignal Test Results:

Figure 25: 2-tone TX IMD at 14.1 MHz, 100W PEP, PureSignal (PS) off & on.

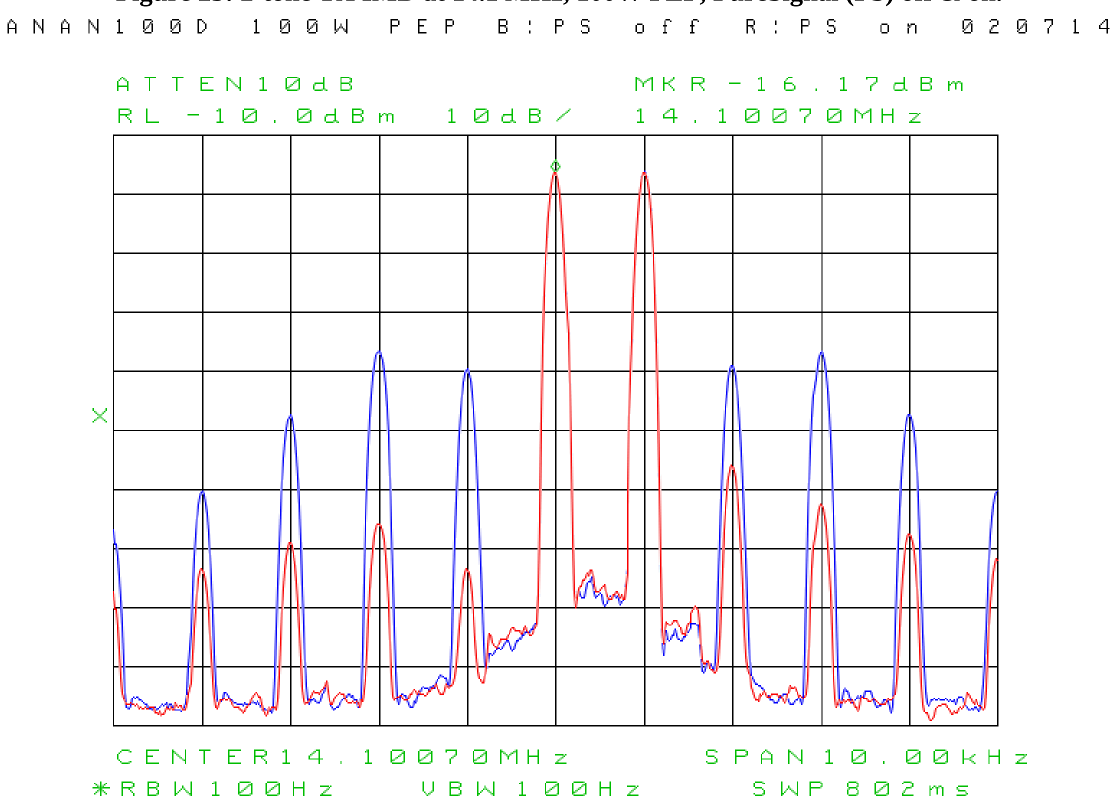


Figure 26: Noise modulation with PureSignal off/on, 100W PEP.

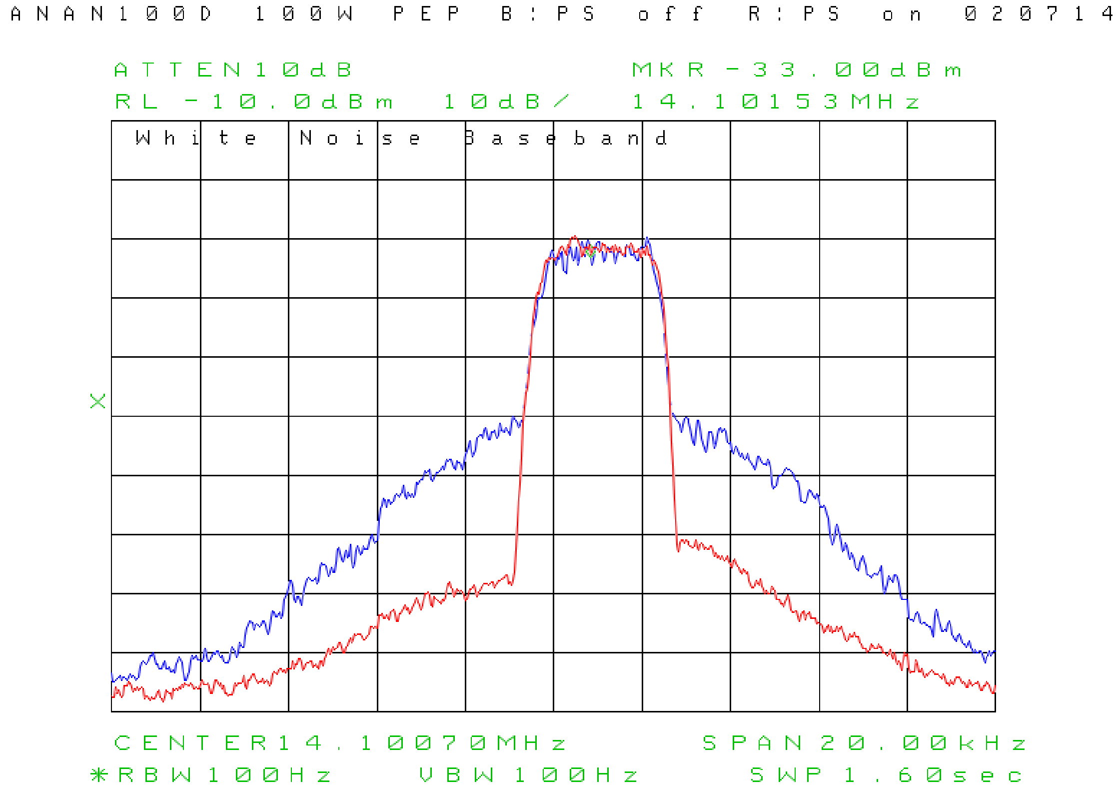


Figure 27: Wideband TX noise floor with PureSignal off/on, 100W.

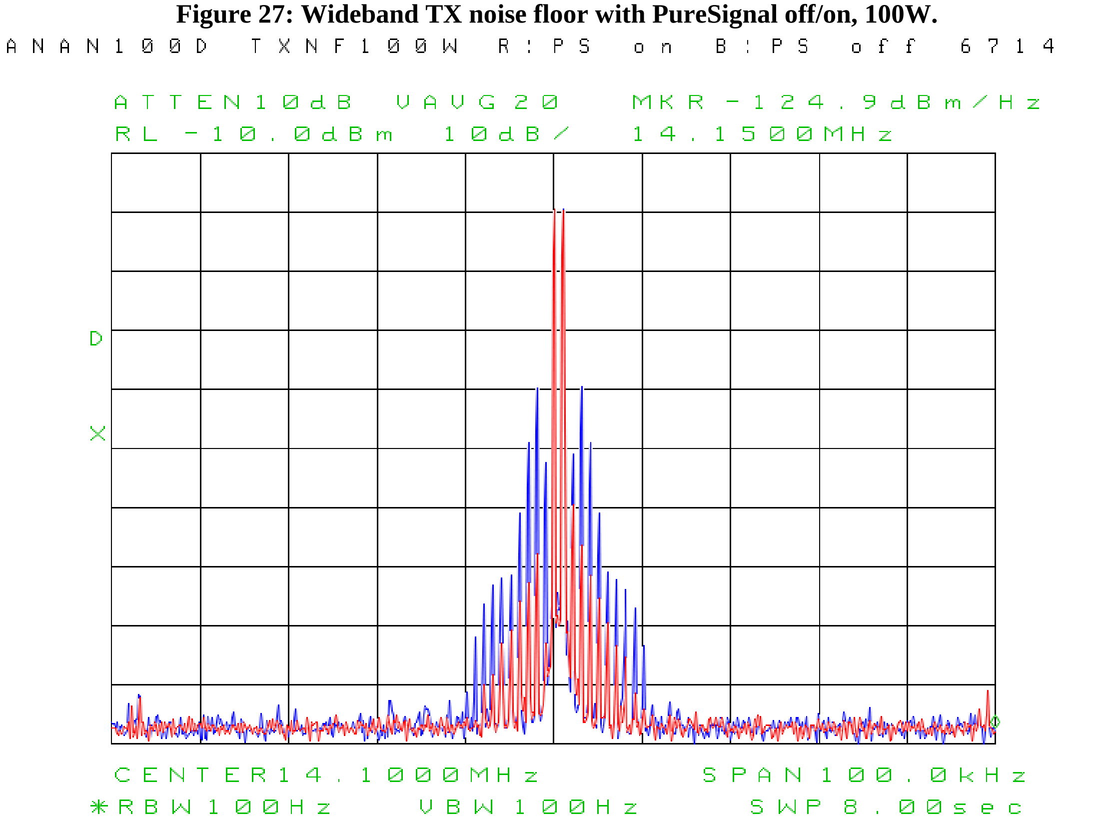


Figure 28: AM Sidebands for 90% Modulation, PureSignal on. THD ≈ 0.2%.

```
ANAN100D  AM  25W  100% mod 1kHz  PS on 030714

DISCRETE SIDEBAND SEARCH RESULTS

CARRIER FREQ:   14.10MHz
CARRIER POWER:  -16.2dBm

OFFSET FREQ     - OFFSET     + OFFSET
                  dBc          dBc
-----------------------    --------

 .998 kHz         -6.0         -6.0
1.997 kHz        -60.0        -54.5
2.996 kHz        -58.7        -58.2
4.004 kHz        -73.5        -72.7

FOUND:  4 SETS OF SIDEBANDS
```

22. 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. "Testing AGC in receivers" by SM5BSZ http://www.sm5bsz.com/lir/agctest/agctest.htm

23. Acknowledgements: I would like to thank Abhi Arunoday and M.B. (Bhanu) Singh of Apache Labs, and Warren Pratt NR0V and Doug Wigley W5WC for making this ANAN-100D available to me for testing and evaluation. Thanks are also due to Warren and Doug for their invaluable guidance in configuring the radio and activating PureSignal. I also wish to thank Nick Massey VA7NRM for his kind assistance in changing out the Angelia VCXO.

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Appendix 1: ANAN-200D Test Supplement.

Introduction: A limited selection of tests was conducted in my home lab on an ANAN-200D loaned by Apache Labs, July 31 – August 5, 2014. The following tests were performed:

A. RX1: MDS, Reciprocal Mixing (RMDR), 2-tone IMD_3 (IFSS), IMD_2 Dynamic Range (DR_2), Noise Power Ratio (NPR).

B. RX2: MDS, NPR.

C. TX: Power Output Check, IMD (2-tone & white noise) with PureSignal off and on, TX composite noise (20m only).

A: Receiver 1 (RX1) Tests

For test descriptions and conditions, please refer to Section A of the main report.

1. MDS (Minimum Discernible Signal). Refer to main report, Section A, Test 1.

Table 1: MDS 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	-129	-136	-129	-137	-126	-136	-126[1]	-141[1]
0/dither[2]	-130	-137	-130	-137	-126	-137	-126	-141
-20	-109	-117	-109	-116	-106	-115	-110	-126

Notes: 1. 6m LNA gain = 25 dB.
2. Dither does not degrade noise floor.

2. Reciprocal Mixing Dynamic Range (RMDR). Refer to main report, Section A, Test 2.

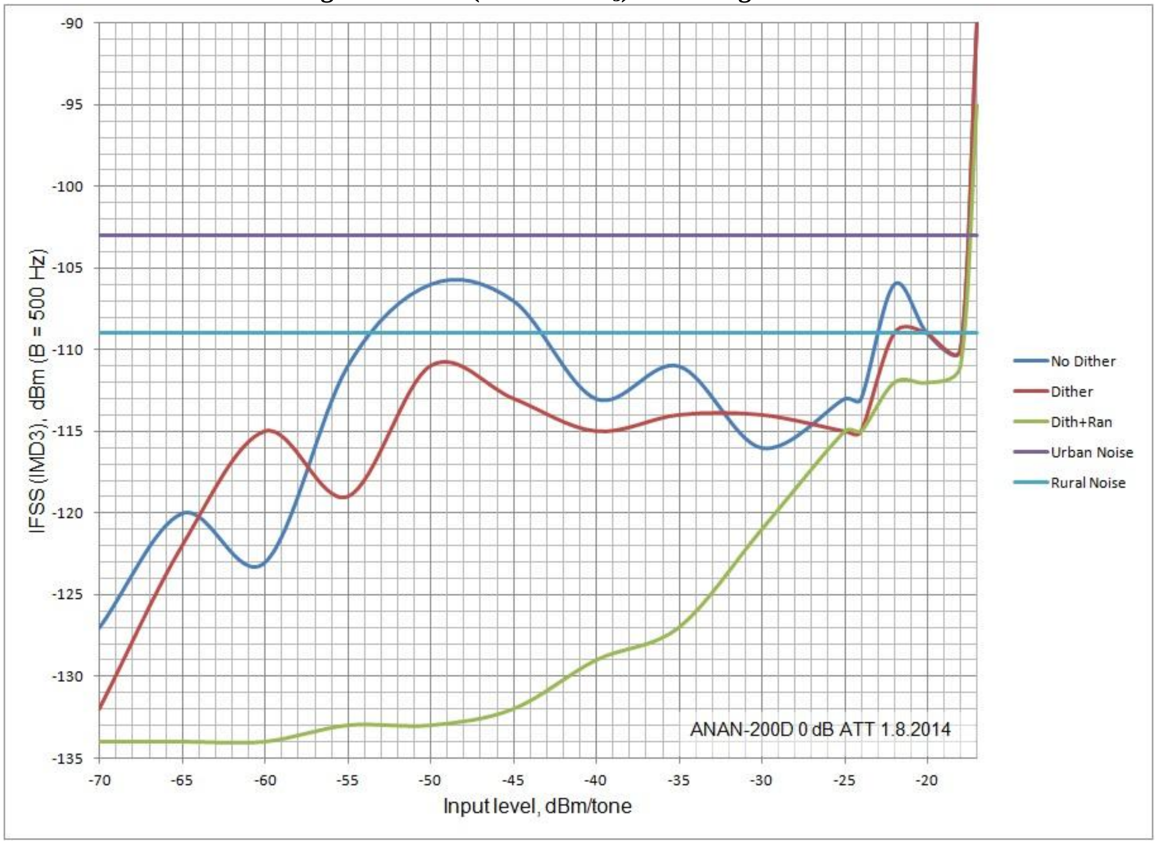
Table 2: RMDR in dB.

Offset kHz	P_i dBm	RMDR dB
1	-26	111
2	-28	109
3	-28	109
5	-26	111
10	-23	114

Note on reciprocal mixing: The residual phase noise of the measuring system (signal generator) is the limiting factor in measurement accuracy.

3. Two-Tone IMD₃ (IFSS, Interference-Free Signal Strength). Refer to main report, Section A, Test 8.

Figure 1: IFSS (2-tone IMD_3) vs. test signal level.



Note on 2-tone IMD_3 test: A comparison between the above chart and that for the ANAN-100 (main report, Figure 5) will be of interest. In the ANAN-200D, the reduction in IMD_3 product levels with increasing input level is greater than in the ANAN-100D, especially in the -58 to -40 dBm input level range, although the ANAN-100D exhibits lower IMD_3 levels over a wider input power range than the ANAN-200D.

4. Two-Tone 2nd-Order Dynamic Range (DR_2). Refer to main report, Section A, Test 9.

Table 3: DR_2. f_1: 6.1 MHz. f_2: 8.1 MHz.

Dither	MDS dBm	P_i dBm	DR_2 dBm
off	-136	-28	108
on	-136	-23	113

Note: No change in DR2 with Random on.

5. Noise Power Ratio (NPR). Refer to main report, Section A, Test 10.

Notes on NPR test:

1. Neither Dither nor Random affects NPR readings.

2. 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 ahead of the ADC, and that the net gain between the antenna port and the ADC is 0 dB.

Table 4: RX1 NPR Test Results.

DUT	BSF kHz	BLF kHz	P_{TOT} dBm	BWR dB	NPR dB		Theor. NPR[2]
					Pre. in	Pre. out	
ANAN-200D	1940	60…2044	-21	29.2	72	71	80
	3886	60…4100	-22	32.3	73	73	76.9
	5340	60…5600	-22	33.6	73	73	75.6
	7600	316…8160	-21	35.1	73	72	74.1

B: Receiver 2 (RX2) Tests

For test descriptions and conditions, please refer to Section B of the main report.

6. MDS (Minimum Discernible Signal). Refer to main report, Section B, Test 11.

Table 5: MDS 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	-130	-138	-130	-137	-127	-136	-128[1]	-135[1]
0/dither[2]	-133	-140	-132	-139	-129	-138	-129	-137
20	-110	-117	-110	-116	-107	-116	-107	-114

Notes: **1.** RX2 has no 6m LNA.
2. Dither does not degrade noise floor.

7. Noise Power Ratio (NPR). Refer to main report, Section B, Test 12.

Table 6: RX2 NPR Test Results.

DUT	BSF kHz	BLF kHz	P_{TOT} dBm	BWR dB	NPR dB[1]
ANAN200D	1940	60…2044	-24	29.2	72
	3886	60…4100	-23.5	32.3	72
	5340	60…5600	-26	33.6	72
	7600	316…8160	-23.5	35.1	70

Notes: **1.** RX2 has no preselector.
2. Neither Dither nor Random affects NPR.

C. Transmitter Tests

- ***Case temperature*** was in the range 40 - 45°C, reaching 56°C during key-down tests at 100W CW output.
- ***BH-4 TX Filter Window*** selected for all transmitter tests. (Toggling between BH-4 and BH-7 did not affect IMD results with PS on or off.)

For test descriptions and conditions, please refer to Section B of the main report.

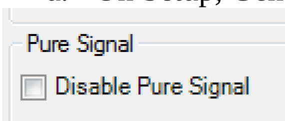
8. Power Output Check. At 14100 kHz, 100W output was easily obtained in TUNE.

9/9a. Transmitter 2-tone and White Noise IMD Tests. Refer to main report, Section C, Test 17, and Section D. These tests were conducted on the ANAN-200D with PureSignal off and on. **Figures 2, 4** (20 kHz span) and **4a** (50 kHz span) illustrate the respective IMD test results.

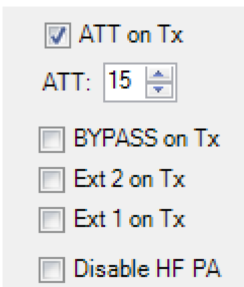
Notes on ANAN-200D PureSignal Setup. The ANAN-200D is fitted with an internal coupler which provides a feedback path to RX1 for the PA output sample. Thus, no external coupler is required for "barefoot" operation. Initial configuration differs from that of the ANAN-100D, as follows:

PowerSDR Configuration:

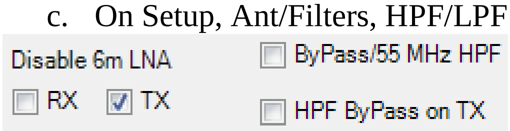
a. On Setup, General, Hardware Config tab, **uncheck** as follows:



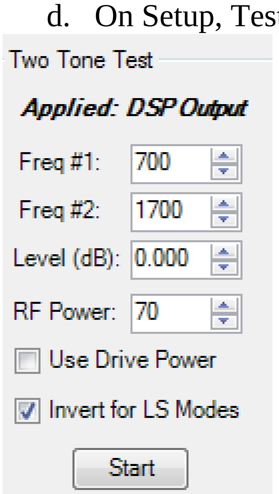
b. On Setup, Ant Filters, Antenna tab, **check** as follows and set ATT initially to 15. With transmitter keyed, adjust ATT for **green** Feedback Level indicator.



c. On Setup, Ant/Filters, HPF/LPF tab, **check** as follows:



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



e. On PureSignal 1.0 screen, set Mox Wait to 0.1 sec., Calibration Wait to 0.5 sec. and Amplifier Delay to 0.

Figure 2: 2-tone TX IMD at 14.1 MHz, 100W PEP, PureSignal (PS) off & on (Test 9).

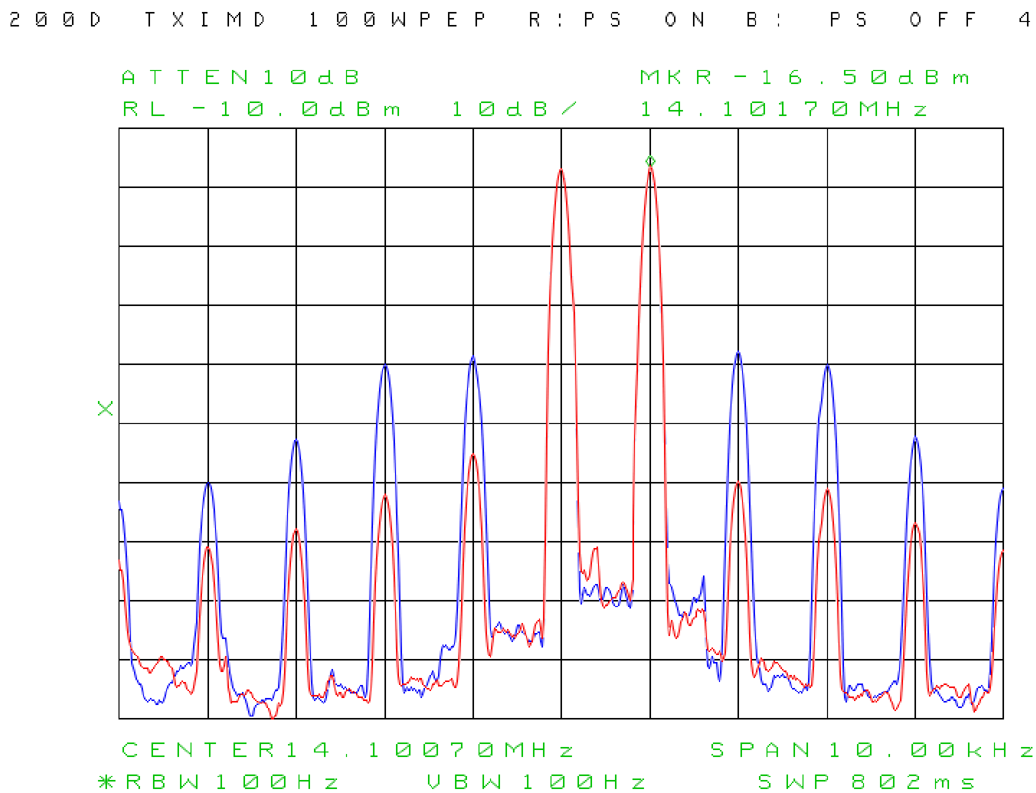


Table 7: 2-tone TX IMD at 14.1 MHz.

2-tone TX IMD Products at Rated P_o		
IMD Products	**Rel. Level dBc (0 dBc = 1 tone)**	
PureSignal	**Off**	**On**
IMD3 (3rd-order)	-33	-54
IMD5 (5th-order)	-34	-56
IMD7 (7th-order)	-47	-60
IMD9 (9th-order)	-56	-66
Add 6 dB for IMD referred to 2-tone PEP		

10. Transmitted composite noise. Refer to main report, Section C, Test 20. Test results are shown in **Figure 5.**

Caution: This test is performed at **30W** CW output to prevent PA overheating. The test run requires that the transmitter be continuously keyed for several minutes.

Figure 3: AmpView screen for 100W 2-tone test, PureSignal on (Test 9).

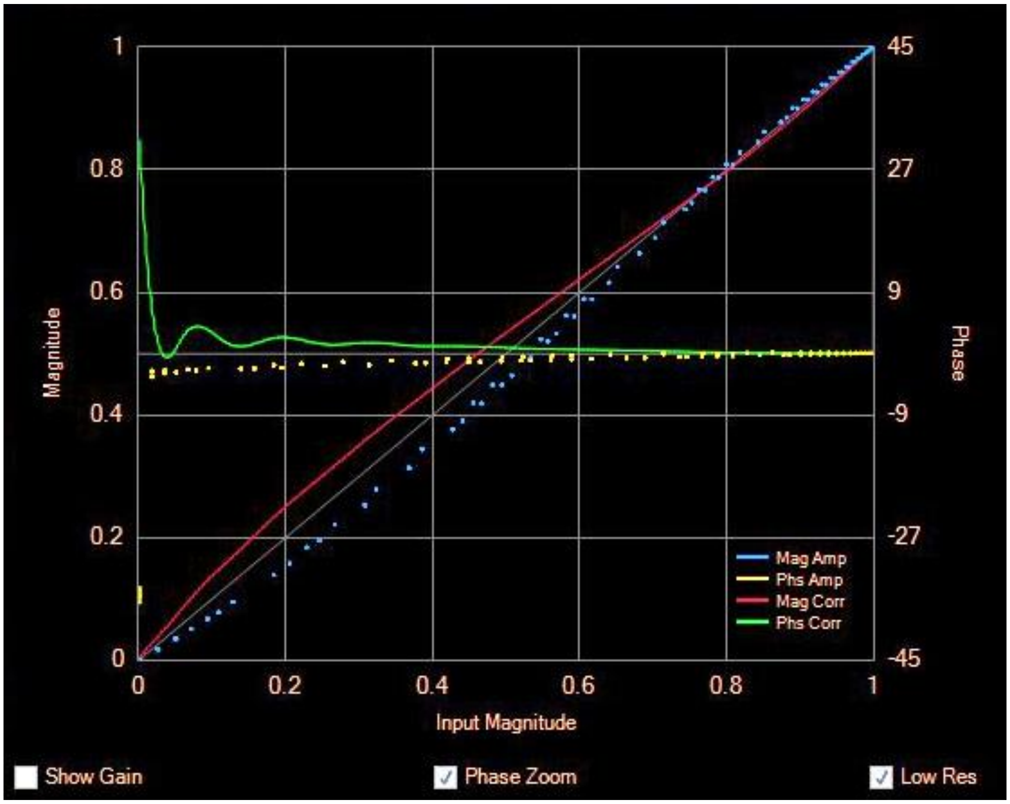


Figure 4: White Noise IMD at 14.1 MHz, 100W PEP, PureSignal (PS) off & on (Test 9a, 20 kHz).

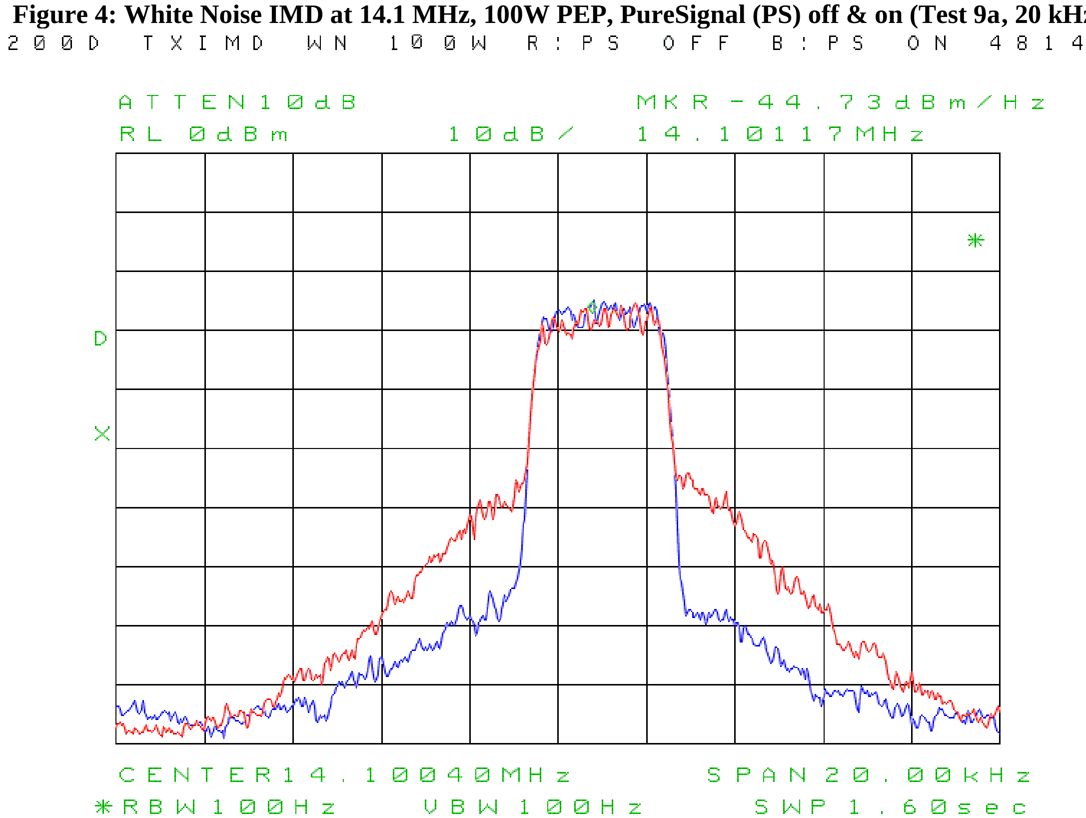


Figure 4a: White Noise IMD at 14.1 MHz, 100W PEP, PureSignal (PS) off & on (Test 9a, 50 kHz).

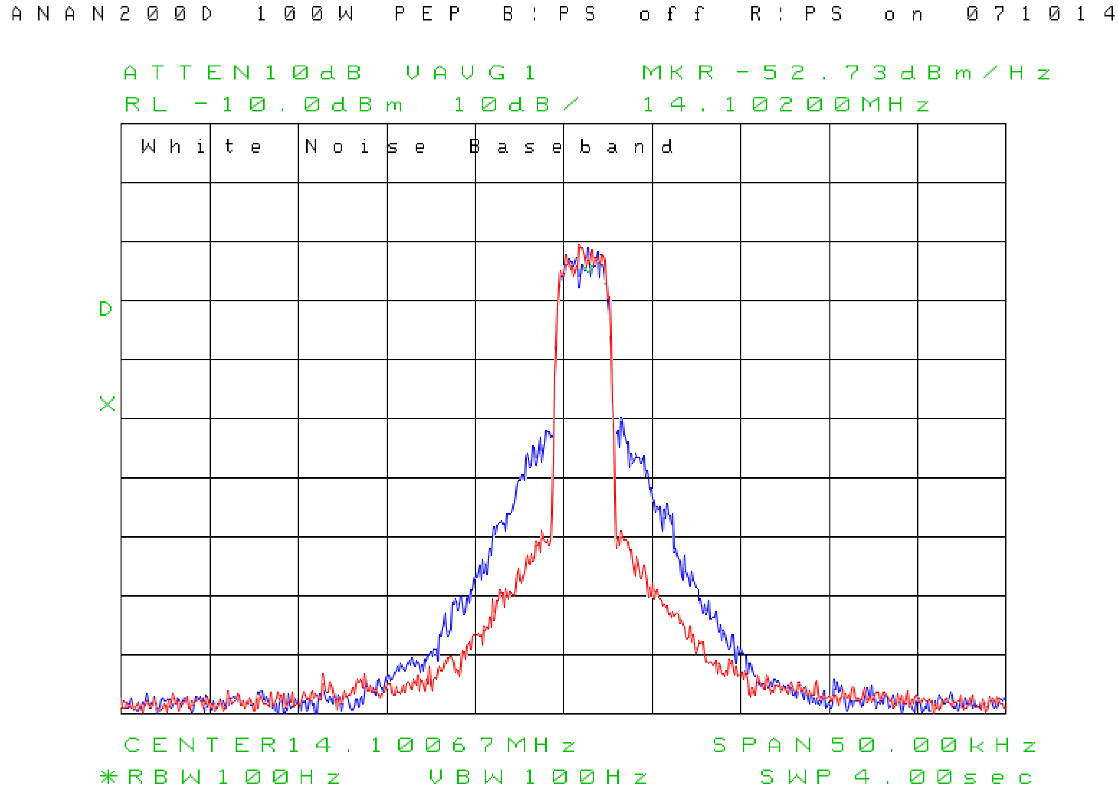
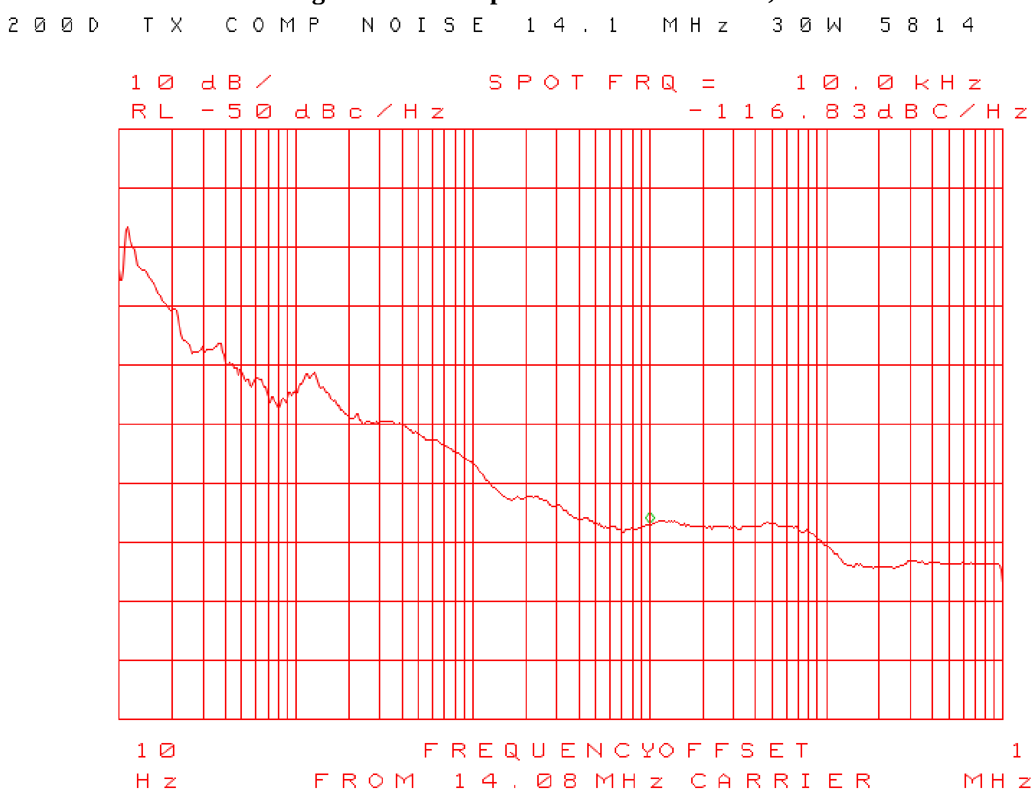


Figure 5: TX composite noise at 14.1 MHz, 30W.

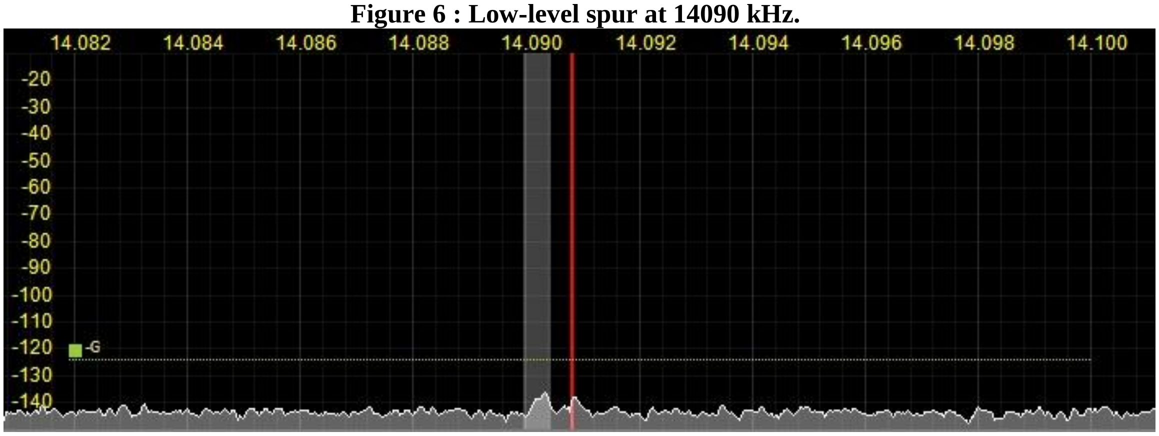


Additional Comments:

1. Comparing the ANAN-100D and ANAN-200D **receiver test data**, one sees that the elimination of the noise-floor degradation due to dither in the ANAN-200 has improved several key receiver parameters, especially MDS, IMD3 (Dither and Dither + Random cases) and DR_2. NPR values measured on the ANAN-200D are quite close to those obtained on the ANAN-100D with the VCXO upgrade.

2. A low-level spur (≈ 2 dB above noise floor) was observed on the spectrum scope at 14090 kHz, with ANT1 terminated in 50Ω. This may be an artifact from the internal SMPS. Refer to **Figure 6**.

Figure 6 : Low-level spur at 14090 kHz.



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