SunSDR2 Pro Test Report

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Figure 1: SunSDR2 Pro top front view.

Introduction: This test report presents results of an RF lab test suite performed on a SunSDR2 Pro direct-sampling/DUC SDR transceiver kindly loaned by Yuri Sushkin N3QQ.

Hardware S/N: EED05231500077

Software/firmware versions: 1. Expert SDR2 V1.0.2 (RX tests & all other TX tests)
2. Expert SDR2 V1.1.1 Beta 5 (TX tests 14 – 16, to correct low PEP issue)

- To ensure regulatory compliance, North American users must download and install **Expert SDR2 V1.1.0_RC_NA.**

Performance Tests conducted in my home RF lab, August 27 – September 9, 2015.

A. HF Receiver Tests

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

1: MDS (Minimum Discernible Signal) is a measure of ultimate receiver sensitivity. In this test, a signal generator is connected to ANT1 via a 20 dB pad. MDS is defined as the RF input power which yields a 3 dB increase in the receiver noise floor, as measured at the audio output.

Test Conditions: CW, B = 500 Hz. ATT as shown, NR off, NB off, ANF off, AGC (RF) 100 dB, AGC slow. VHF LNA N/A. RX2 OFF throughout tests.

Table 1: MDS in dBm.

Pre	Flt	3.6 MHz	14.1 MHz	28.1 MHz	50.1 MHz
0	0	-121	-119	-122	-120
1	0	-132	-129	-132	-132
0	1	-122	-123	-121	-122
1	1	-131	-133	-133	-132

Notes: 1. Pre = preamp, Flt = wideband filter on/preselector off.
2. VHF LNA is for 2m only; N/A on HF/6m.
3. Checking Auto Enable does not affect MDS.

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 (ANT1). The noise floor is read on the DUT S-meter in CW mode (500 Hz) with ANT1 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, centre 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 (RF) 100 dB, Auto Enable on, default DSP settings. RMDR *in dB* = input power (P_i) – MDS *(both in dBm).* Here, MDS = -121 dBm at 9.83 MHz.

Table 2: RMDR in dB.

Offset kHz	P_i dBm	RMDR dB
1	+7.5	128.5
2	> +9.4	> 130
5	> +9.4	> 130
10	> +9.4	> 130

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/RF 100 dB,AGC med, NR off, NB off, ANF off. Default filter config. (1537 taps).

Table 3: Channel Filter Shape Factors.

Filter	Shape Factor	-6 dB BW kHz	-60 dB BW kHz
2.5 kHz SSB	1.08	2.43	2.62
500 Hz CW	1.6	0.44	0.70
250 Hz CW	2.9	0.25	0.73
Max. stopband attenuation > 85 dB.			

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, 2.5 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 40. Delay 45, Gain 0.00001, Leak 0.0001.

Table 4: NR SINAD.

Taps	Delay	SINAD dB
NR off	45[1]	6
40[1]	45	10.5
99	45	18

Note: 1. Default settings.

This shows a SINAD improvement of 12 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 a brief on-air listening test, 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, 2.5 kHz USB, AGC (RF) 100 dB, AGC med, ATT = 0 dB, NB off, ANF off. Initial NR settings (defaults): Taps 60, Delay 64, Gain 0.0007, Leak 0.00001.

Test Results: Measured MDS = -110 dBm (B = 2.5 kHz). Stopband attenuation = test signal power - MDS = -21- (-110) = **89 dB**.

6: AGC impulse response. The purpose of this test is to determine the SunSDR2 Pro'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, 2.5 kHz LSB NR off/on as required, NB off/NB1/NB2 as required, ANF off, ATT= 0 dB, AGC (RF) 100 dB,AGC fast, ANF off. Scope settings: AVG 5, Refresh 5 ms. 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 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 16Vpk (e.m.f.)

AGC "ticks" are audible from **t** = 10 ns up. For **t** > 100 ns, the ticks do not become louder. With NR on and **t** ≤ 100 ns, NR reduces the ticks to quiet "holes" in the receiver audio. ANF has no effect on the ticks.

NR reduces the white noise level with NB1 or NB2 on.

With the above scope settings, the scope baseline "bounces" +12 dB with each pulse. The pulse train creates clearly visible waterfall "bars".

NB1 suppresses the ticks, scope "bounce" and waterfall bars entirely. NB2 reduces tick amplitude and waterfall density but does not kill these effects entirely as does NB1. The S-meter barely deflects during the test. **Figures 2, 3 & 4** are waterfall screen images for NB off, NB1 and NB2.

Figure 2: AGC impulse response, NB off.

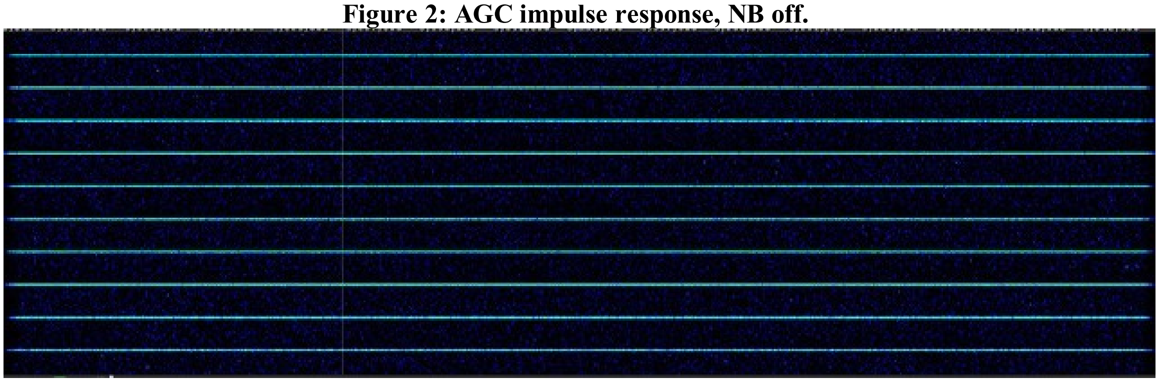


Figure 3: AGC response, NB1 on.

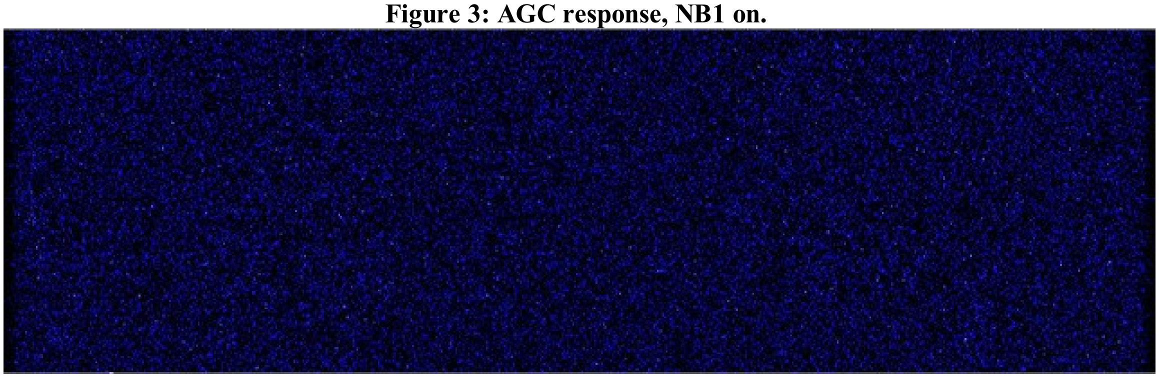
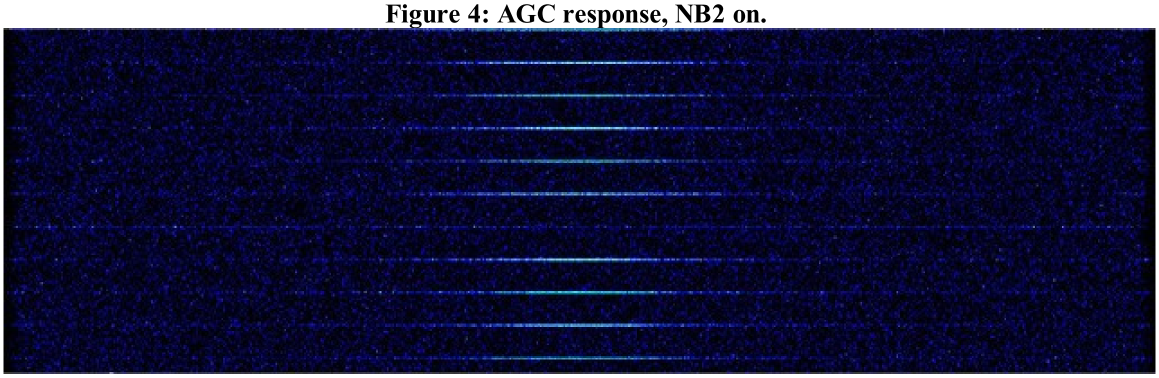


Figure 4: AGC response, NB2 on.



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

Test Conditions: 2.5 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.

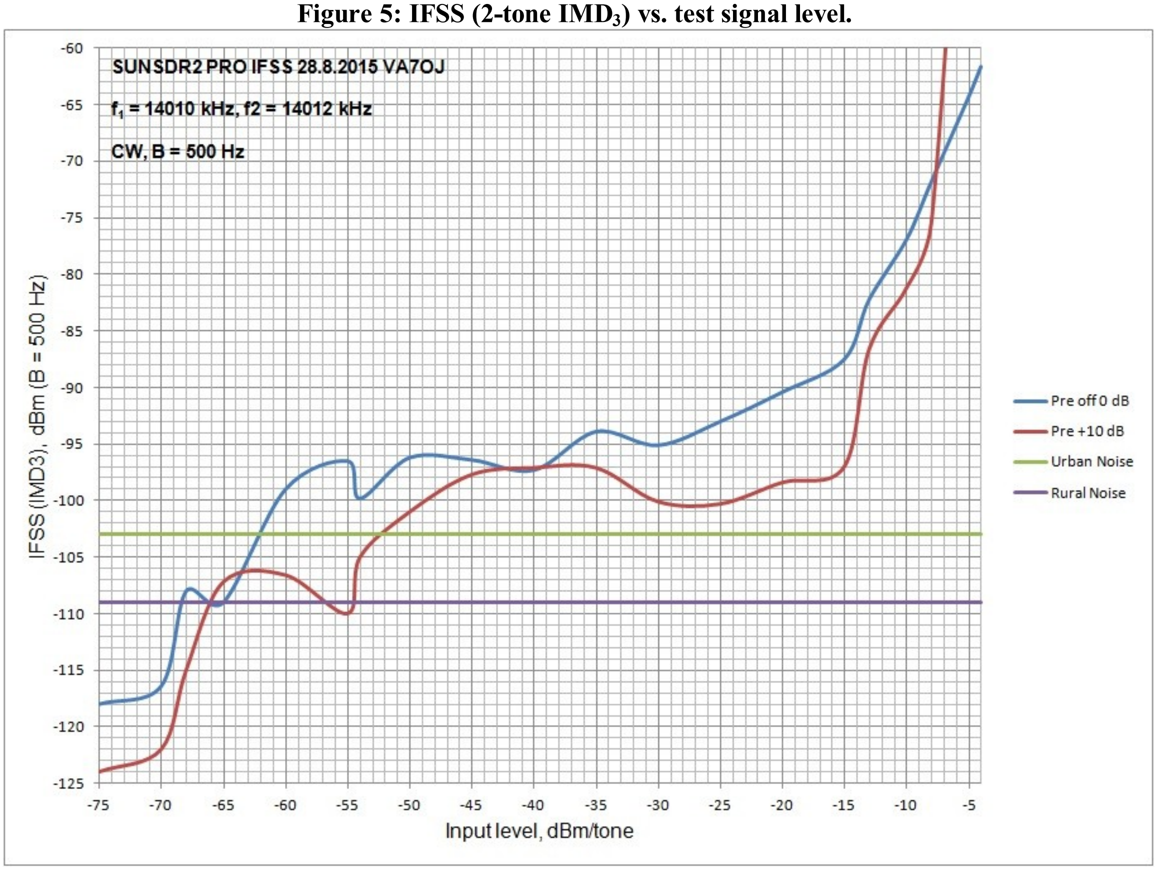
Applied dBm	-120	-110	-100	-90	-80	-73	-60	-50	-40	-30	-20	-10	0	+10	+11
Rdg.dBm	-110	-107	-99	-90	-80	-73	-60	-50	-40	-30	-20	-10	+0.5	+10	
S-meter	S3	<S3	<S5	>S6	S8	S9	13	23	33	43	53	63	73	> +80	CLIP
							over S9								

Table 6: S-Meter/ATT/Preamp Tracking

Applied dBm	-73			
PRE/ATT dB	+10	0	-10	-20
Rdg. dBm	-75.9	-73	-74.3	-74.9
S-units	<S9	S9	S9	S9

8. Two-Tone IMD₃ (IFSS, Interference-Free Signal Strength) tested in CW mode (B = 500 Hz), ATT = 0 dB. Test frequencies: f_1 = 14010 kHz, f_2 = 14012 kHz. IMD_3 products: 14008/14014 kHz. IMD_3 product level was measured as absolute power in a 500 Hz detection bandwidth at various test-signal power levels, with 0 and +10 dB Preamp gain selected. The ITU-R P-372.1 band noise levels for typical urban and rural environments are shown as datum lines in **Figure 5**.

Figure 5: IFSS (2-tone IMD_3) vs. test signal level.



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

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

The SFDR behaviour 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.***

It will be seen from Figure 5 that the IMD product amplitude crosses the typical urban band noise line for per-tone input levels < -52 dBm with Preamp off and < -57 dBm with +10dB Preamp on. This is somewhat worse than other direct-sampling SDR's I have tested, where the 0 dB gain IFSS line crosses the urban band noise line at input levels ranging from -4 to -18 dBm per tone. Further investigation of possible non-linearity in the receiver front end is recommended.

ADC clip level: 0 dB (Preamp off), +11 dBm. +10 dB (Preamp on), -2 dBm.

9. Two-Tone 2^{nd}-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 = 6.01 MHz, f_2 = 8.01 MHz, IMD2 product at 14.02 MHz. 500 Hz CW, AGC slow, Preamp off (0 dB), NR off, NB off, CW neutral, ANF off. DR_2 in dB. Measured MDS = -119/-123 dBm (Wide filter off/on).

Table 7: DR_2. f_1: 6.01 MHz. f_2: 8.01 MHz.

Wide Filter	Auto Enable	MDS dBm	P_i dBm	DR_2 dB	IP_2 dBm
off	off or on	-119	-32	87	+55
on	disabled	-123	-83	40	-43

Note: When the SunSDR2 Pro is deployed in areas with high 2^{nd}-order IMD (e.g. evening/night 40m or 80m operation in Region 1), the wide filter must be OFF to keep IMD2 within acceptable limits.

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 ANT3 and increased until ADC clipping just commences, and then backed off until no clipping is observed for at least 10 seconds (typically 1 dB below clip level). 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 centre freq. f_0 ± 1.5 kHz, 2.5 kHz SSB, Preamp 0/+10 dB, Auto Enable on, WB Filter off, NR off, NB off, ANF off, AGC slow. Test results are presented in **Table 8.**

Table 8: HF NPR Test Results.

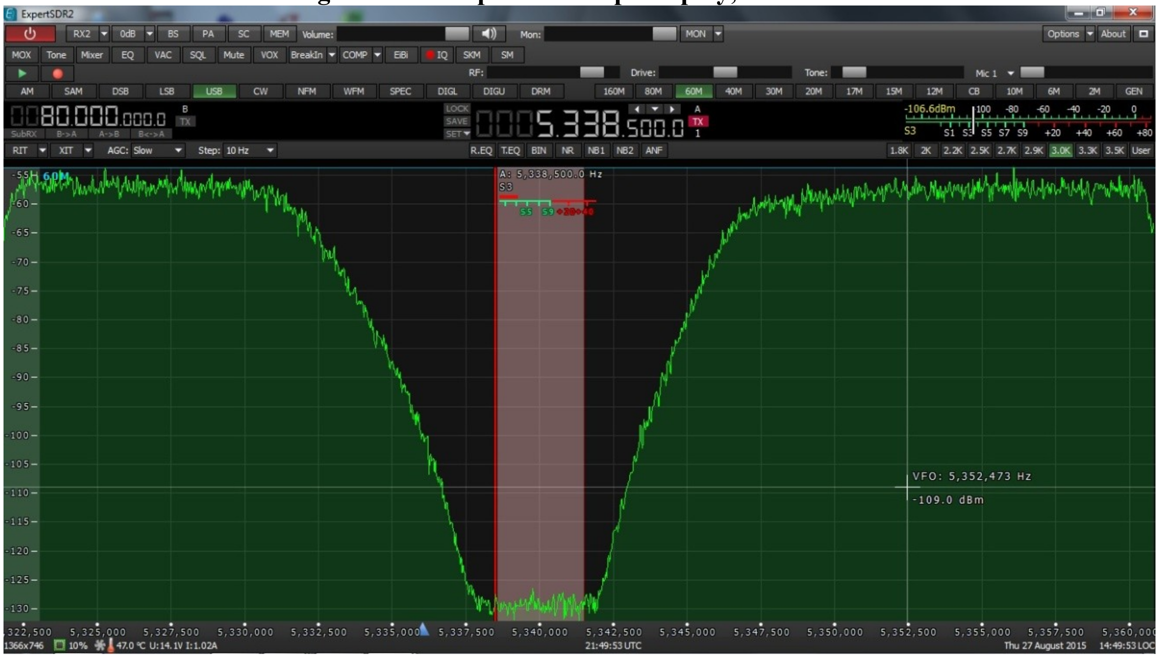
DUT	BSF kHz	BLF kHz	Preamp	P_{TOT} dBm	BWR dB	NPR dB	Theor. NPR[2]
SunSDR2 Pro	1248[1]	60…1296	0	-10	26.9	63	82.6
			1	-21		60	
	1940[1]	60…2044	0	-5	29.0	55	80.6
			1	-21		59	
	3886	60…4100	0	-5	32.1	69	77.5
			1	-11		75	
	5340	60…5600	0	-8	33.5	65	76.1
			1	-10		69	
	7600	316…8160	0	-2	35.0	70	74.6
			1	-5		74	

Notes on NPR test:

1. NPR degradation on 1248 and 1940 kHz is most likely due to PIM in preselector inductor cores.

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

Figure 6: NPR spectrum scope display, 3886 kHz.



B. VHF (2m) Receiver Tests

Note: Signal applied to ANT1 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: 144.1 MHz, CW, B = 500 Hz, NR off, NB off, ANF off, AGC (RF) 100 dB, VHF LNA off/on as required.

Table 9: MDS in dBm (RX2).

144.1 MHz	
VHF LNA	MDS dBm
off	-118
on	-140

12. Noise Figure: In this test, a calibrated noise source is connected to ANT1 via a precision DC - 2 GHz step attenuator. First, ANT1 is terminated in 50Ω and a 0 dBr baseband reference set. Then, the noise source is connected and the noise loading adjusted for a +3 dBr baseband level. The attenuator setting is noted.

As the noise source is calibrated, its noise power density PSD (in dBm/Hz) is known. Noise figure NF is derived as follows:

NF ≈ PSD - ATT +174 where ATT = attenuator setting in dB.

Test Conditions: 500 Hz CW, AGC Mid, VHF LNA on, NR off, NB off.

Table 10. Noise figure in dB.

NF dB	144.1 MHz
Measured	9.0
Calc. from MDS	7.0

C. Transmitter Tests

⚠ ***Case temperature*** was in the range 40 - 50°C, reaching 50°C during key-down tests at 18W CW output.

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 ANT3 (HF) or ANT1 (2m) via a 45 dB high-power attenuator.

Test Conditions: 3.6, 14.1, 28.1, 29.6, 50.1, 53.0 and 144.1 MHz, Drive = 100%. Set "Tone" to 100%.

Table 11: CW Power Output.

Freq. MHz	Fwd Pwr W	P_O W
3.6	19.3	18.5
14.1	18.8	18.9
28.1	15.2	16.6
29.6	14.8	16.3
50.1	12.9	15.9
53.0	11.8	14.8
144.1	6.1	6.5

14: SSB Peak Envelope Power (PEP). Here, an oscilloscope is terminated in 50Ω and connected to ANT3 via a 45 dB high-power attenuator. At 19W CW, the scope vertical gain is adjusted for a peak-to-peak vertical deflection of 6 divisions.

Test Conditions: 14.1 MHz, USB mode, Heil HC-5 dynamic mic connected, Drive 100%, Mic Gain 39 dB, compression 6 dB, Transmit Filter 200-2900, TX EQ OFF, supply voltage +13.8V.

Speak loudly into the microphone for max. PEP output. **Figures 7 & 8** show the envelope for 19W PEP, without and with compression respectively. ±3 vert. div. = 20W.
5 ms/horiz.div.

Note: No sign of ALC overshoot at 19W PEP, with or without compression.

Figure 7: 100W PEP speech envelope, no compression.

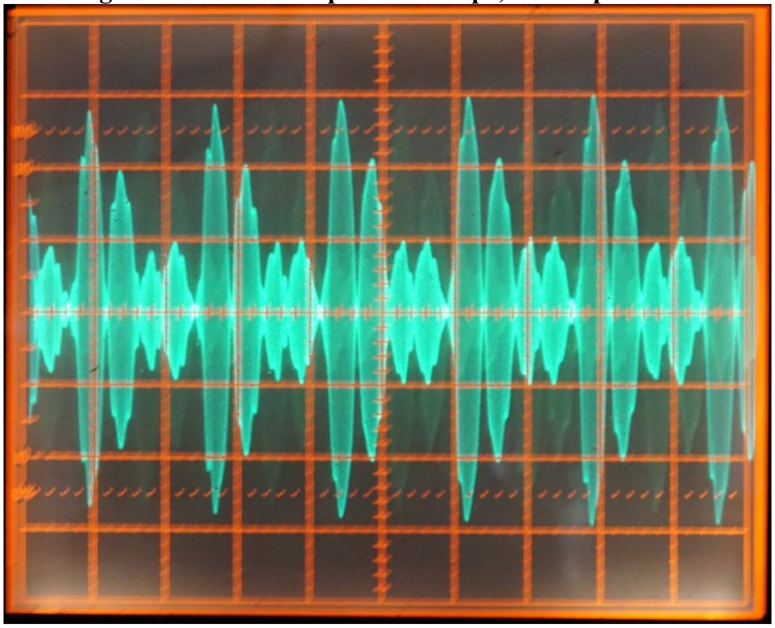
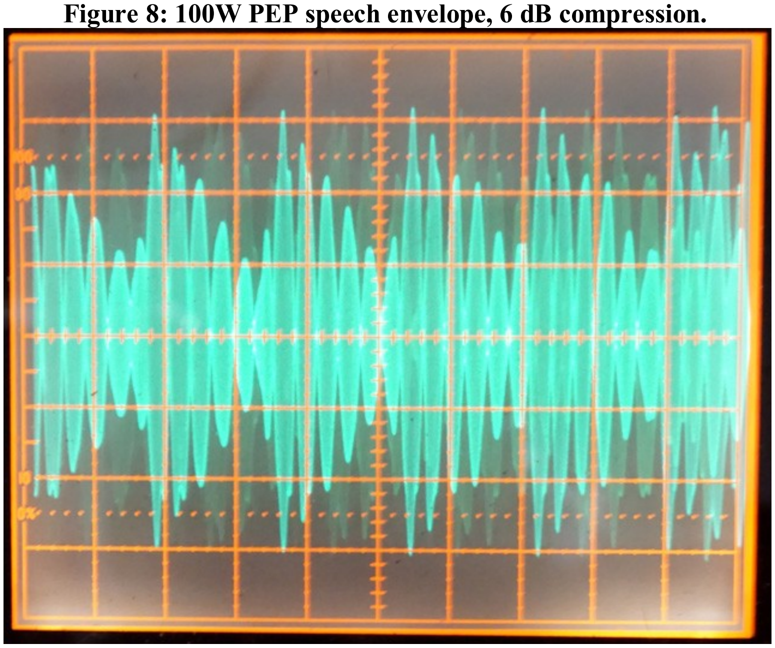


Figure 8: 100W PEP speech envelope, 6 dB compression.

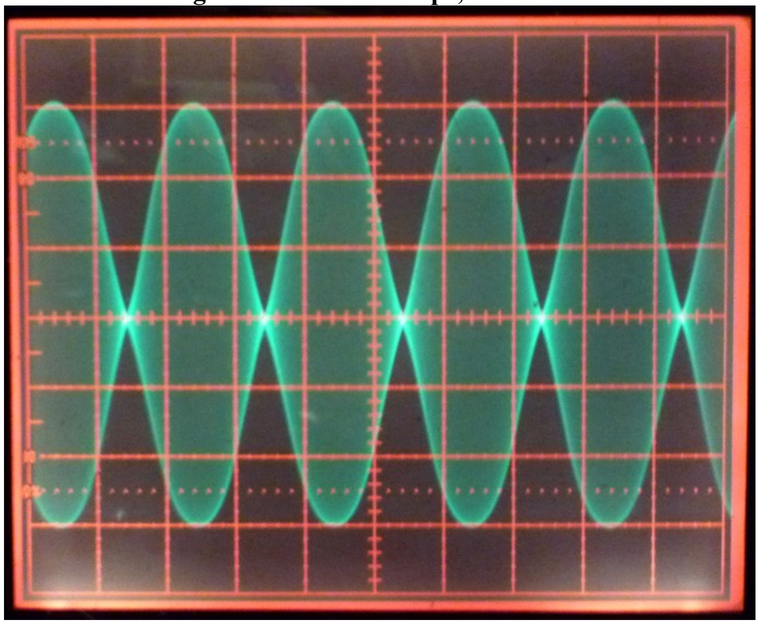


15. ALC Compression Check. In this test, a 2-tone test signal is applied to the MIC jack from an audio generator. An oscilloscope is connected to ANT3 via a 45 dB high-power attenuator.

Test Conditions: 14100 kHz USB, compression off. Test signal: 2-tone. Transmit Filter 200-2900. 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 9**.)

Figure 9: 2-tone envelope, 19W PEP.



15a: 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, TX EQ OFF.
b. Adjust Mic Gain for no ALC COMP on TX Meter
c. Transmit alternately with COMP off and on. Observe that COMP gives monitored TX audio more audible "punch" and penetrating power.

16: Transmitter 2-tone IMD Test. In this test, a 2-tone test signal is applied to the MIC jack from the audio generator. A spectrum analyser is connected to ANT3 (HF) or ANT1 (2m) via a 55 dB high-power attenuator.

Test Conditions: 3.6, 14.1, 50.1 and 144.1 MHz USB, compression off. Test signal: 2-tone. Transmit Filter 200-3100 (default). Test tones: 700 and 1700 Hz, at equal amplitudes. Drive = 100%. Supply voltage +13.8V.

Adjust test tone levels for both test tones at -6 dBc. **Figures 10** through **13** 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	144.1
IMD3 (3rd-order)	-24	-25	-20	-27
IMD5 (5th-order)	-52	-45	-37	-39
IMD7 (7th-order)	-48	-49	-43	-42
IMD9 (9th-order)	-55	-55	-47	-44
Subtract 6 dB for IMD referred to 2-tone PEP				

Figure 10: Spectral display of 2-tone IMD at 3.6 MHz, 16.5W PEP.

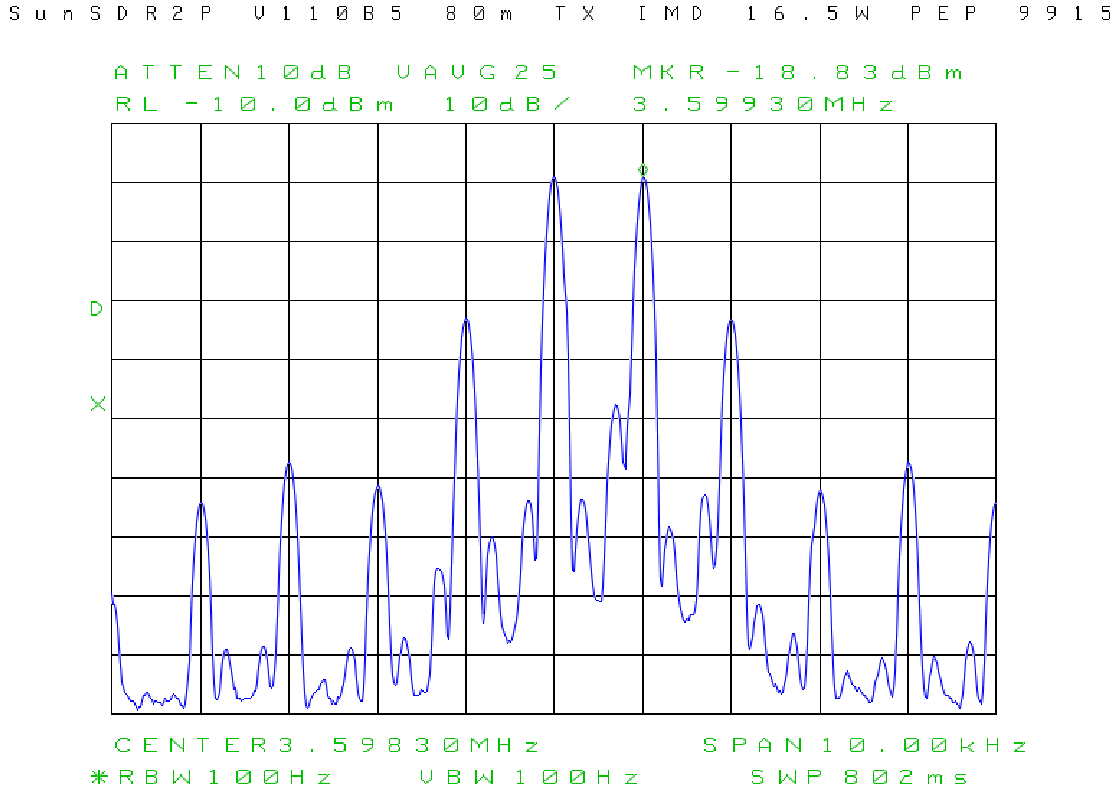


Figure 11: Spectral display of 2-tone IMD at 14.1 MHz, 18W PEP.

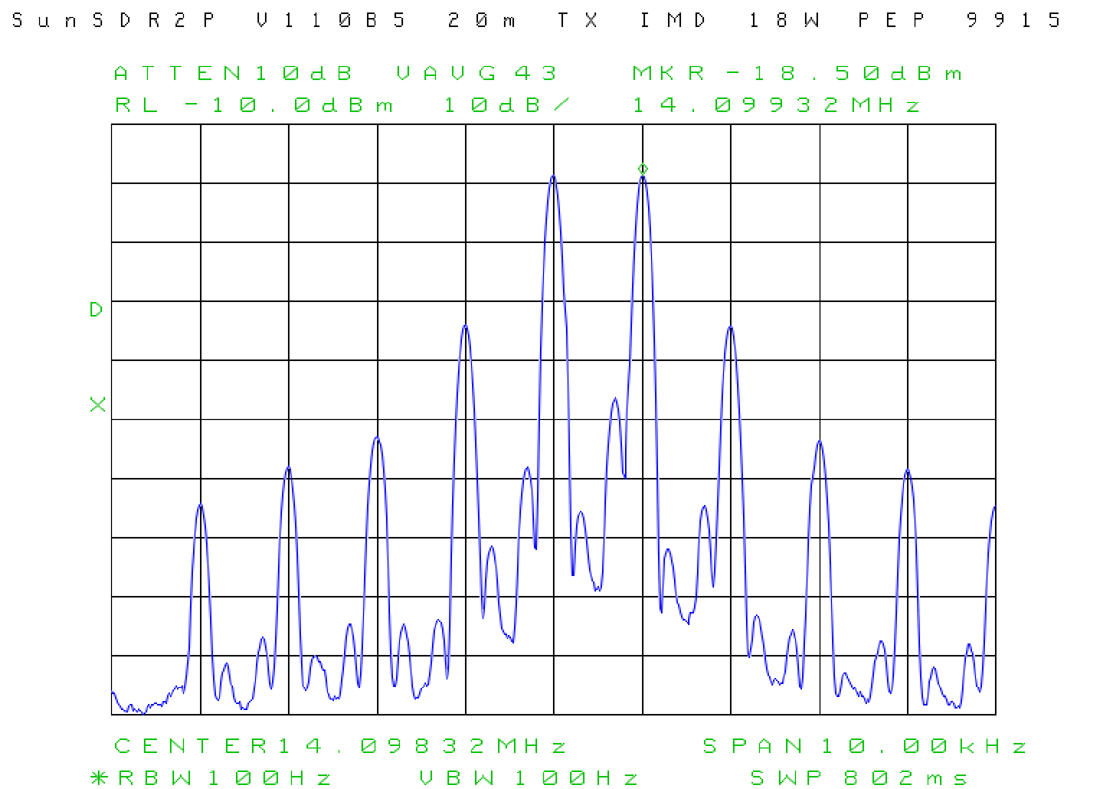


Figure 12: Spectral display of 2-tone IMD at 50.1 MHz, 13.5W PEP.

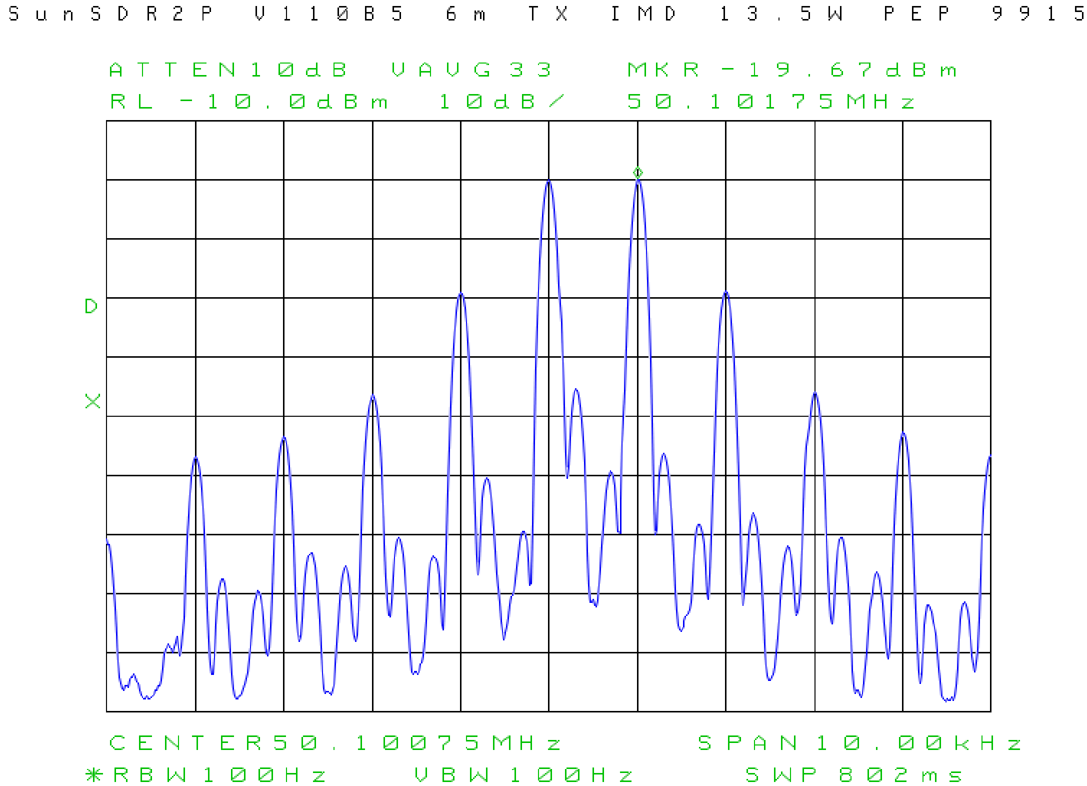
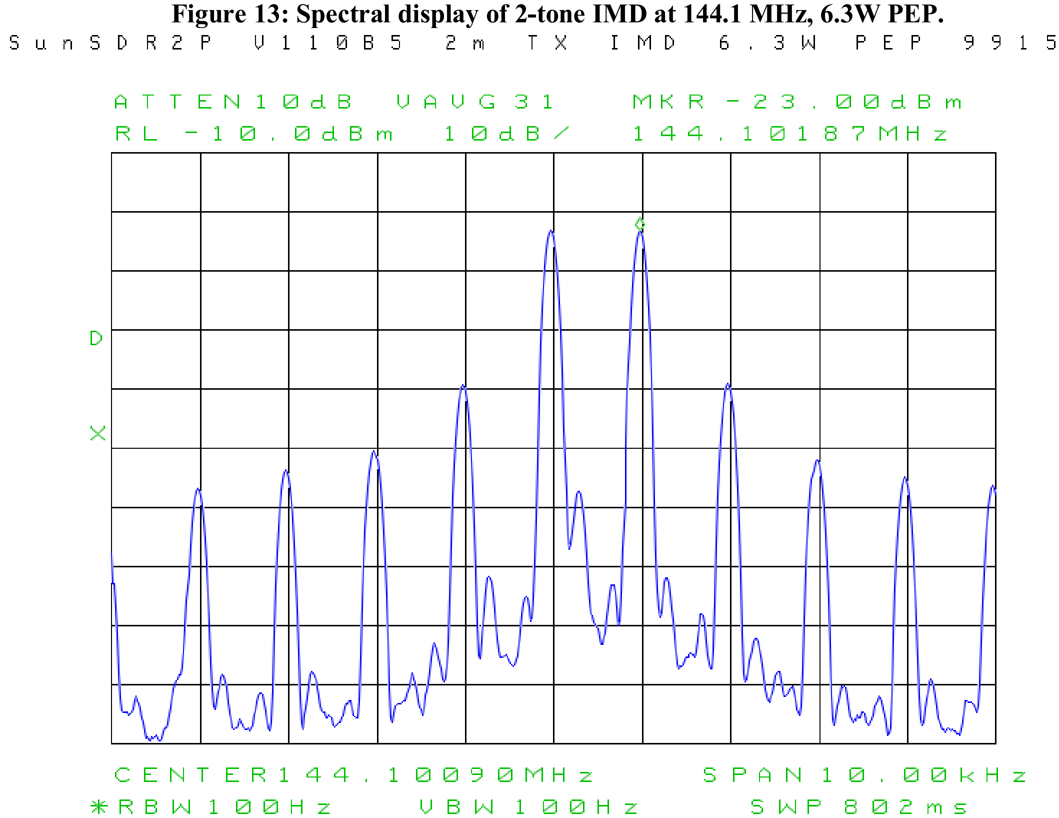


Figure 13: Spectral display of 2-tone IMD at 144.1 MHz, 6.3W PEP.



17: Transmitter harmonics & spectral purity. Once again, the spectrum analyser is connected to the ANT3 (HF) or ANT1 (2m) via a 55 dB high-power attenuator. Tone is set at 100%. The spectrum analyser's harmonic capture utility is started.

Test Conditions: 3.6, 14.1 and 50.1 MHz, Tone mode, Tone = 100%, max. output to 50Ω load. Harmonic data are presented for all frequencies tested (**Figures 14** through **18**, and 6m and 2m spur sweeps in **Figure 17b**. It will be seen that harmonics are well within specifications. On 6m and 2m, spurs below the carrier frequency are within the -60 dBc limit specified in FCC Part 97.307(e).

Figure 14.

SunSDR2Pro 80m harmonics 15W CW 080915

HARMONIC MEASUREMENT RESULTS

FUNDAMENTAL SIGNAL: 3.600 MHz
-13.2 dBm

HARMONIC	LEVEL dBc	FREQUENCY
2	-76.0 *	7.200 MHz
3	-72.2	10.80 MHz
4	-83.5	14.40 MHz
5	-87.3	18.00 MHz
6	-94.5	21.60 MHz
7	-79.5	25.20 MHz
8	-103.7 *	28.80 MHz

* MEASURED LEVEL MAY BE NOISE OR LOST SIGNAL.

TOTAL HARMONIC DISTORTION= 0 %
(OF HARMONICS MEASURED)

Figure 15.

SunSDR2Pro 20m harmonics 15W CW 080915

HARMONIC MEASUREMENT RESULTS

FUNDAMENTAL SIGNAL: 14.10 MHz
-12.2 dBm

HARMONIC	LEVEL dBc	FREQUENCY
2	-85.3 *	28.20 MHz
3	-58.3	42.30 MHz
4	-82.2	56.40 MHz
5	-69.8	70.50 MHz
6	-100.5 *	84.60 MHz
7	-100.2 *	98.70 MHz
8	-104.8 *	112.8 MHz

* MEASURED LEVEL MAY BE NOISE OR LOST SIGNAL.

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

Figure 16.

SunSDR2Pro 6m harmonics 10W CW 080915

HARMONIC MEASUREMENT RESULTS

FUNDAMENTAL SIGNAL: 50.10 MHz
-13.8 dBm

HARMONIC	LEVEL dBc	FREQUENCY
2	-70.0	100.2 MHz
3	-66.0	150.3 MHz
4	-75.0	200.4 MHz
5	-65.0	250.5 MHz
6	-55.5	300.6 MHz
7	-73.7	350.7 MHz
8	-84.8	400.8 MHz

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

Figure 16a.

SunSDR2Pro Spurs <50.1 MHz 10W CW 080915

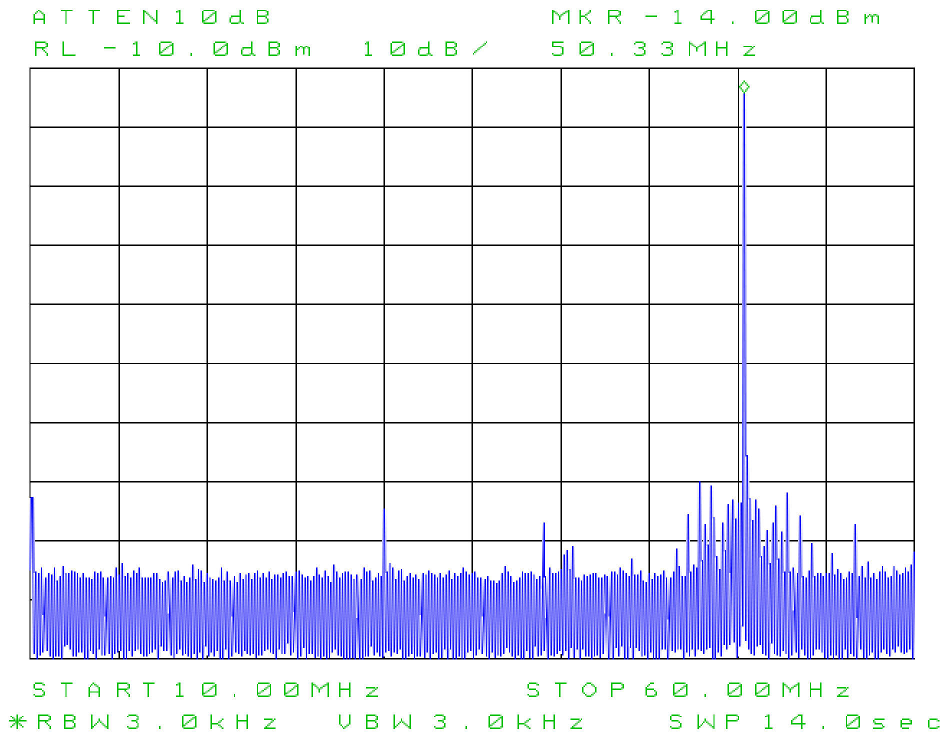


Figure 17.

SunSDR2Pro 2m harmonics 6.6W CW 080915

HARMONIC MEASUREMENT RESULTS

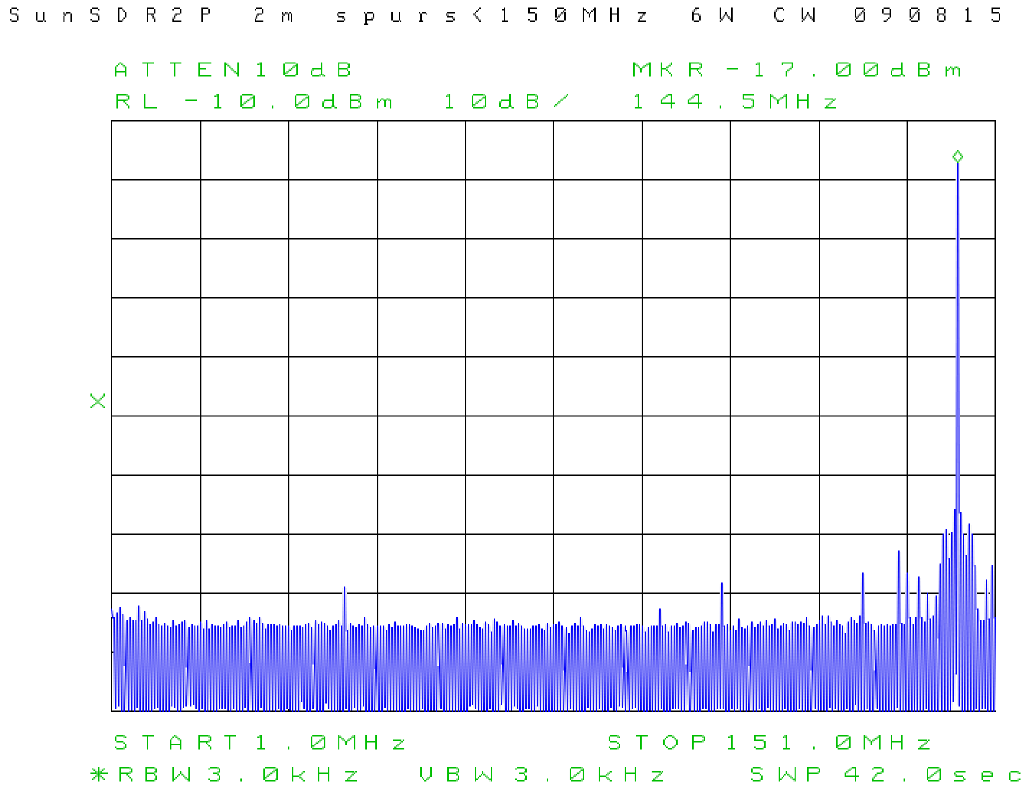
FUNDAMENTAL SIGNAL: 144.1 MHz
-16.8 dBm

HARMONIC	LEVEL dBc	FREQUENCY
2	-56.3	288.2 MHz
3	-63.3	432.3 MHz
4	-94.0 *	576.4 MHz
5	-66.2	720.5 MHz
6	-89.7	864.6 MHz
7	-71.8	1.009 GHz
8	-87.5	1.153 GHz

* MEASURED LEVEL MAY BE NOISE OR LOST SIGNAL.

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

Figure 17a.



18. 2m FM deviation check: The high-power input of a communications test set is connected to ANT1. A dynamic microphone (Heil HC-5) is connected to the MIC 1 jack.

Test Conditions: MIC GAIN = 39 dB, Drive = 100%, 6.6W output to 50Ω load. Speak loudly into mic; measured peak deviation ≈ 5 kHz.

19: Transmitted composite noise. The spectrum analyser is connected to ANT3 (HF) or NT1 (2m) via a 55 dB high-power attenuator. The spectrum analyser's phase-noise utility is started. **Figures 21a** and **21b** are the resulting composite-noise plots.

⚠ ***Caution:*** Each test run requires that the transmitter be continuously keyed at full rated output for several minutes. An external fan may be required to prevent overheating.

Test Conditions: 3.6, 14.1, 50.1 and 144.1 MHz, Tone mode, Drive = 100%, max. output to 50Ω load. Utility minimum/maximum offset and spot frequencies configured as shown in **Figures 20a** through **20c**. (***Note:*** The limitation of this measurement method is that the measured noise power is close to the spectrum analyser's own noise floor.)

Figure 20a: TX composite noise at 14.1 and 3.6 MHz, 15W.

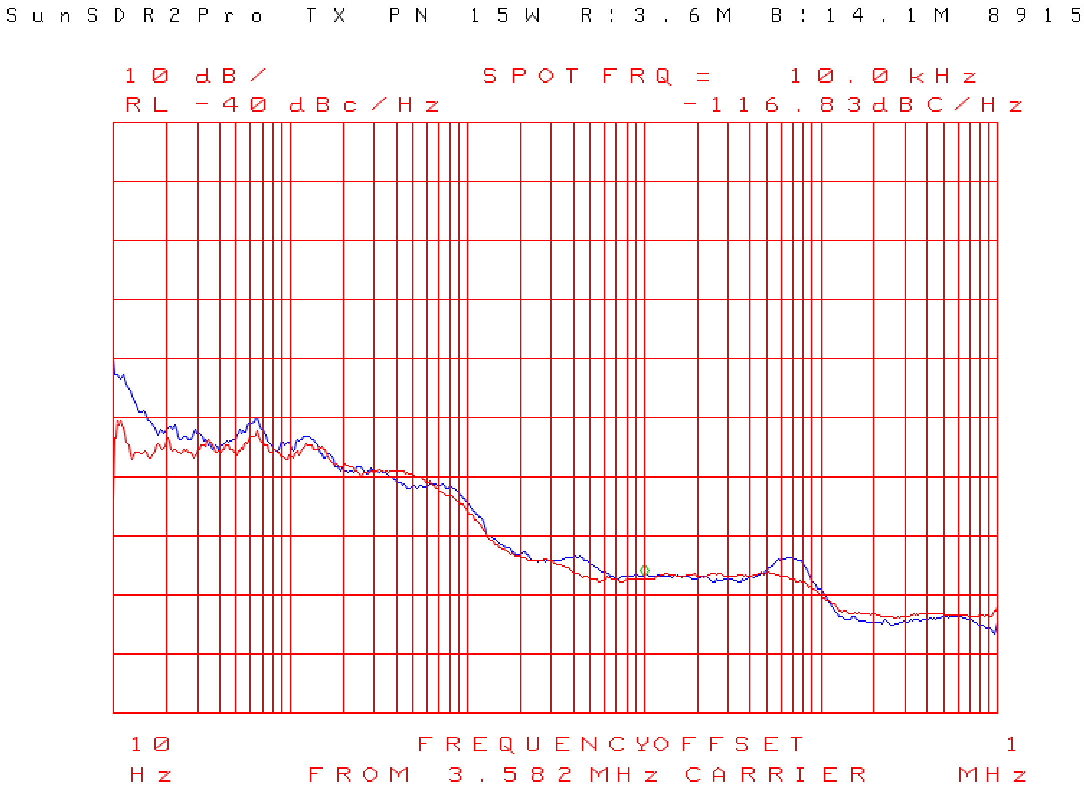


Figure 20b: TX composite noise at 50.1 and 14.1 MHz

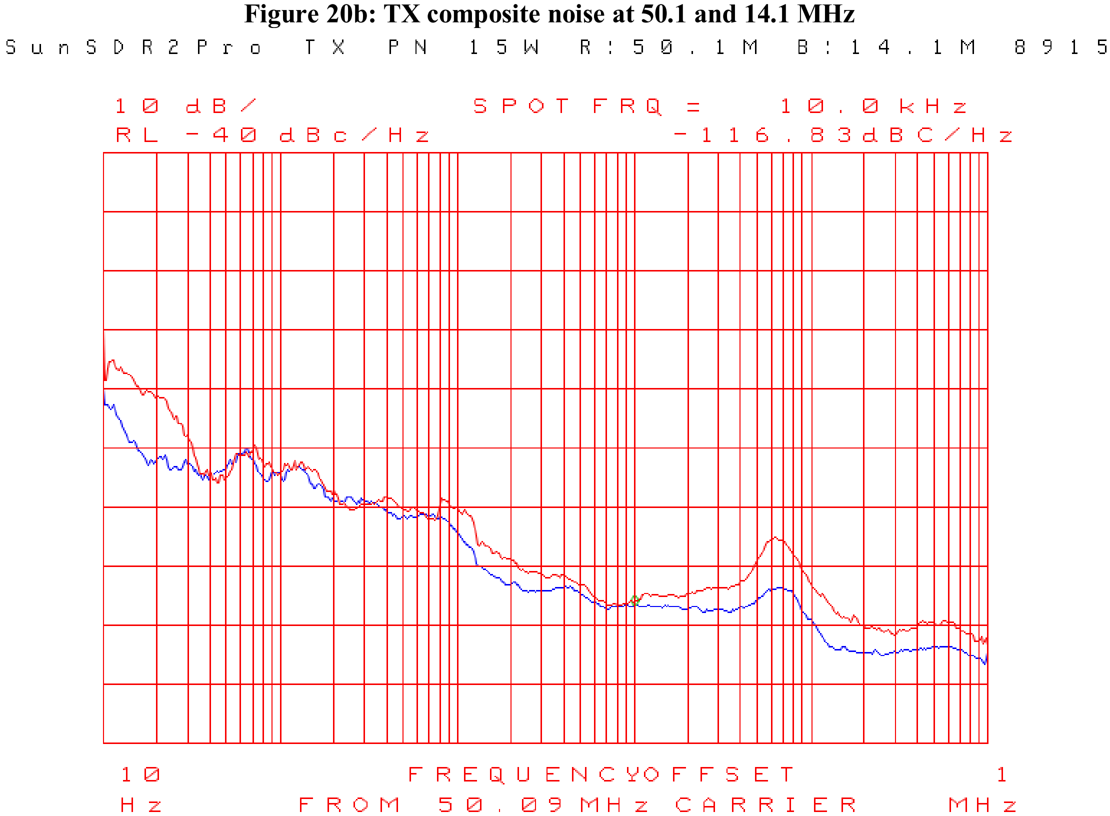
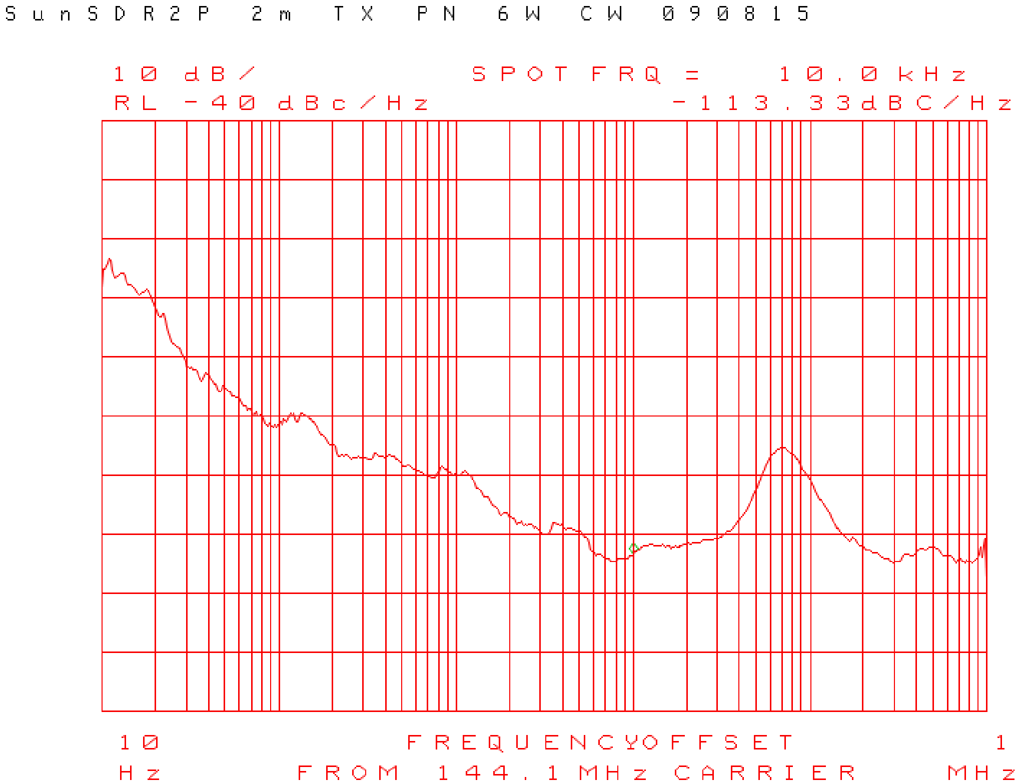


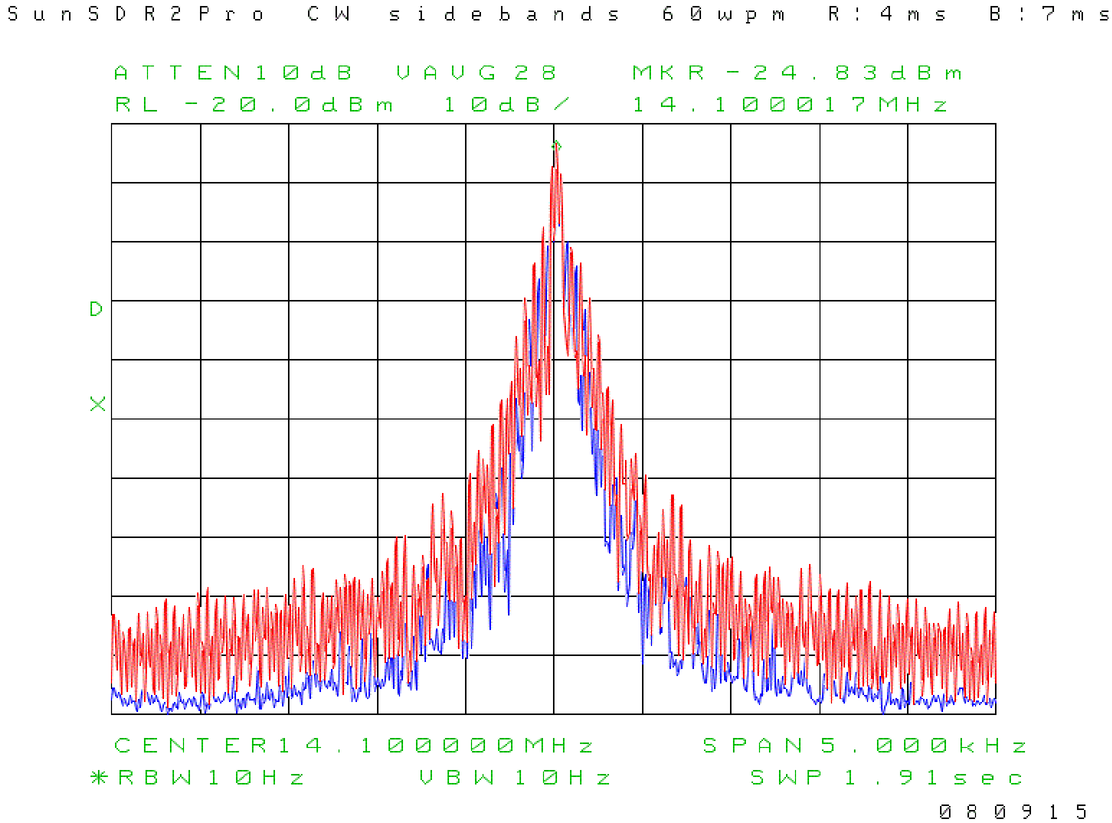
Figure 20c: TX composite noise at 50.1 and 14.1 MHz



20: Spectral display of CW keying sidebands. The spectrum analyser is connected to ANT3 via a 55 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, Drive 100%, 19W output to 50Ω load. Keying speed 60 wpm using internal keyer. CW weight = 60% (default). Rise time = 7 (default) & 4 ms. Spectrum analyser RBW is 10 Hz, video-averaged; sweep time < 4 sec. **Figure 21** shows the transmitter output ±5 kHz from the carrier.

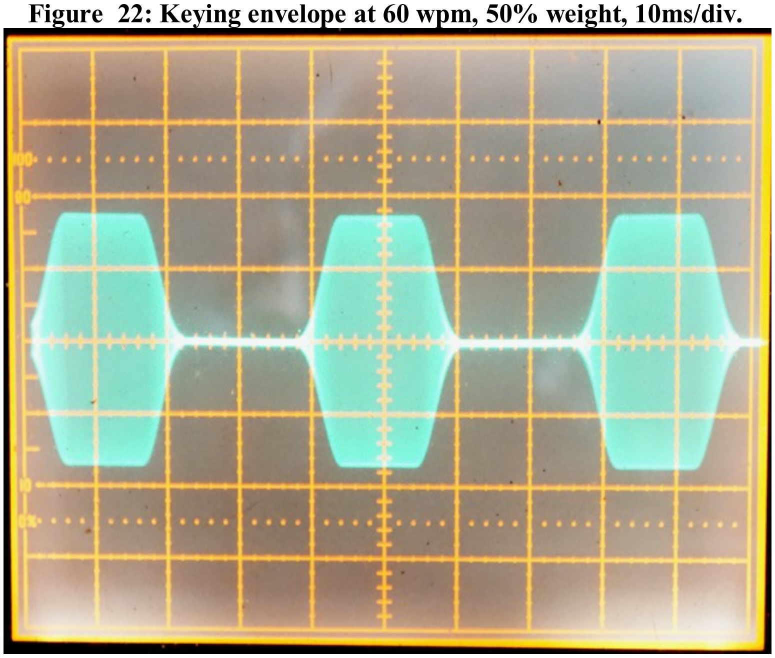
Figure 21: Keying sidebands at 60 wpm, Weight = 60%, 14.1 MHz, 19W.



21. CW keying envelope. The oscilloscope is terminated in 50Ω and connected to ANT3 via a 45 dB high-power attenuator. A series of dits is transmitted from the internal keyer at 60 wpm.

Test Conditions: 14.1MHz CW, Drive = 100%, 18W output to 50Ω load. Keying speed = 60 wpm using internal keyer. CW weight = 60% (default). Rise time 7 ms (default). The keying envelope is shown in **Figure 22.**

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



22. Comments:

1. As noted in Test 8, the receiver IMD3 performance as measured by the IFSS method appears inferior to that of other direct-sampling SDR receivers I have tested; the IMD product amplitude exceeds the typical ITU-R urban and rural band noise lines at a significantly lower signal level than in other DDC receivers. This warrants further investigation.

2. Due to an issue with low SSB PEP output in the initial transmitter test run, the software and firmware were upgraded from V1.0.2 to V1.1.1 Beta 5. SSB tests 14 through 16 were re-run and their results presented in this report.

3. Transmit IMD3 levels on several bands exceed the -25 dBc guideline per ITU-R Recommendation SM.326-7 (see **Table 12**).

4. It is ***strongly recommended*** that the Motorola Mini-UHF antenna connectors on the rear panel be replaced with standard 50Ω female BNC connectors.

23. References:

1. SunSDR2 Pro website: http://www.nsiradio.com/SunSDR/
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

24. Acknowledgements: I would like to thank Yuri Sushkin N3QQ for making this SunSDR2 Pro available to me for testing and evaluation, and for his assistance and support in the initial configuration and start-up phase.

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Appendix 1: RX & TX Tests on SunSDR2Pro S/N EED 0552 1500 160

16 & 22 January 2016

Introduction: The following tests were conducted:

16.01.2016: HF Receiver NPR and IFSS
22.01.2016: Transmitter PO and IMD on 3.6, 14.1, 50.1 and 144.1 MHz

Software/firmware versions: SW: Expert SDR2 V1.1.0RC. FW: 35.8.

- To ensure regulatory compliance, North American users must download and install **Expert SDR2 V1.1.0_RC_NA.**

1. Noise Power Ratio (NPR): See test description, p. 7.

Table 13. NPR, SunSDR2Pro, S/N 00160. Dither & Random on, WB Filter off. 16.01.2016.

DUT	BSF kHz	BLF kHz	Preamp	P_{TOT} dBm	BWR dB	NPR dB	Theor. NPR[3]
SunSDR2 Pro	1248[1]	60…1296	0	-25	26.9	38	82.6
			1	-40		44	
	1940[1]	60…2044	0	-23	29.0	42	80.6
			1	-38		44	
	3886	60…4100	0	-8	32.1	59	77.5
			1	-12		63	
	5340	60…5600	0	-8	33.5	57	76.1
			1	-12		65	
	7600	316…8160	0	-2	35.0	63	74.6
			1	-12		71	
	11700	0…13000	0	-3	37.1	56	72.4
			1	-7		66	

Notes on NPR test:

1. Severe NPR degradation on 1248 and 1940 kHz is probably due to PIM in preselector inductor cores. These values are 15-20 dB ***worse*** than on the #000077 DUT tested on 27.08.2015.

2. It was observed during the test run of 27.08.2015 that NPR decreased by 15 to 18 dB with WB Filter ON. If the WB Filter is selected by default below 2 MHz, this may also explain the NPR degradation observed here on 1940 and 1248 kHz.

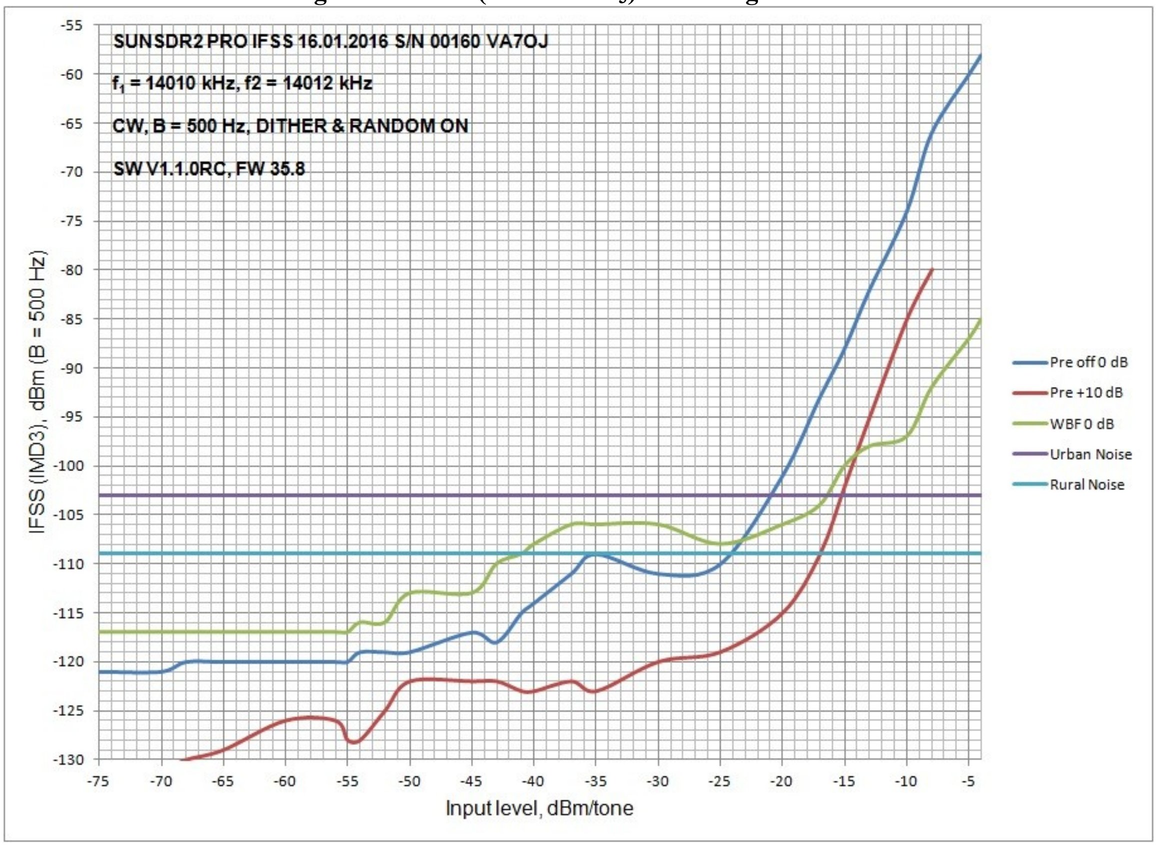
3. Theoretical NPR was calculated for the LTC2208-16 ADC using the method outlined in ***Ref. 3.*** The theoretical NPR value assumes that B_{RF} is not limited by any filtering in the DUT ahead of the ADC, and that the net gain between the antenna port and the ADC is 0 dB.

Ref. 3:

http://www.ab4oj.com/test/docs/16bit_npr.pdf

2. *Two-Tone IMD₃ (IFSS, Interference-Free Signal Strength)* tested in CW mode (B = 500 Hz), ATT = 0 dB. Test frequencies: f_1 = 14010 kHz, f_2 = 14012 kHz. IMD_3 products: 14008/14014 kHz. IMD_3 product level was measured as absolute power in a 500 Hz detection bandwidth at various test-signal power levels, with 0 and +10 dB Preamp gain and WB Filter selected. The ITU-R P-372.1 band noise levels for typical urban and rural environments are shown as datum lines in **Figure 23**.

Figure 23: IFSS (2-tone IMD_3) vs. test signal level.



It will be seen from Figure 5 that the IMD product amplitude crosses the typical urban band noise line for per-tone input levels < -21 dBm with Preamp off and < -15 dBm with +10dB Preamp on. This is now comparable to other direct-sampling SDR's I have tested. The 'Preamp off' curve is now below the rural band noise line for input levels below -24 dBm/tone, except for one point at -35 dBm/tone. This is a very significant improvement over the IFSS test results of 28.8.2015. (See page 5).

3. Transmitter Power Output P_O: 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 ANT2 (HF) or ANT1 (2m) via a 40 dB high-power attenuator.

Test Conditions: 3.6, 14.1, 50.1 and 144.1 MHz, Drive = 100%. Set "Tone" to 100%.

Table 14: CW P_O.

Freq. MHz	P_O W
3.6	20.0
14.1	19.6
50.1	14.0[1]
144.1	6.8

Notes:

1. Internal power meter reads forward power = 11.8W, SWR = 1.4. (Power reads correctly with SWR = 1.0 – 1.1 on other bands.)

4. Transmitter 2-tone IMD Test. In this test, a 2-tone test signal is applied to the MIC jack from the audio generator. A spectrum analyser is connected to ANT2 (HF) or ANT1 (2m) via a 55 dB high-power attenuator.

Test Conditions: 3.6, 14.1, 50.1 and 144.1 MHz USB, compression off. Test signal: 2-tone. Transmit Filter 200-3100 (default). Test tones: 700 and 1700 Hz, at equal amplitudes. Drive = 100%. Supply voltage +13.8V.

Adjust test tone levels for both test tones at -6 dBc. **Figures 24** through **27** show the two test tones and the associated IMD products for each test case.

Table 15. 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**	**144.1**
IMD3 (3rd-order)	-30	-30	-29	-27
IMD5 (5th-order)	-49	-47	-41	-40
IMD7 (7th-order)	-66	-70	-66	-54
IMD9 (9th-order)	-79	< -80	-71	-60
Subtract 6 dB for IMD referred to 2-tone PEP				

Figure 24: Spectral display of 2-tone IMD at 3.6 MHz, 20W PEP.

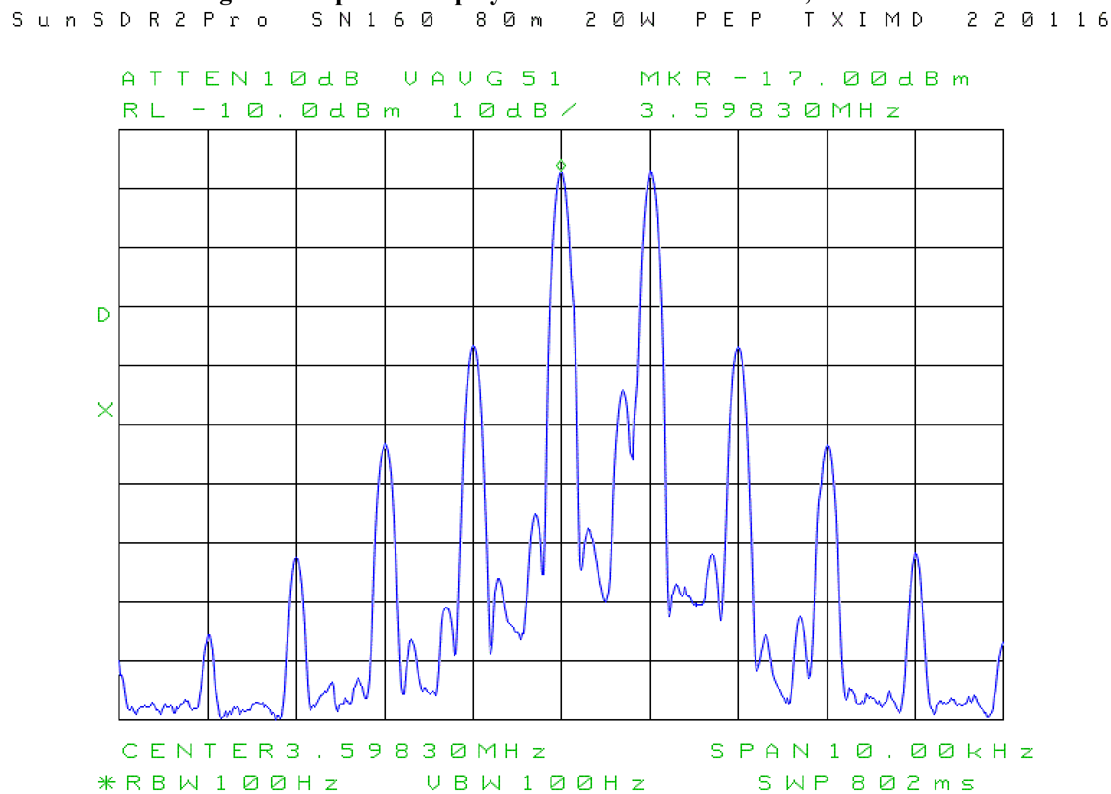


Figure 25: Spectral display of 2-tone IMD at 14.1 MHz, 20W PEP.

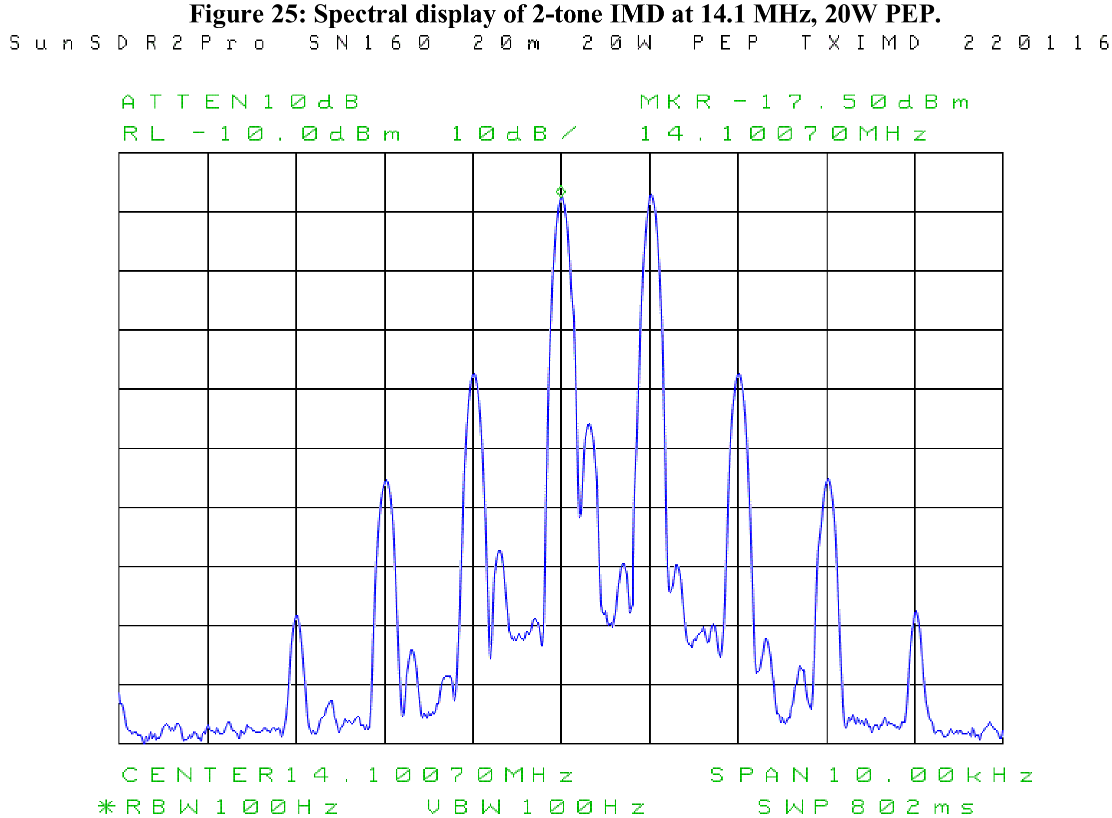


Figure 26: Spectral display of 2-tone IMD at 50.1 MHz, 14W PEP.

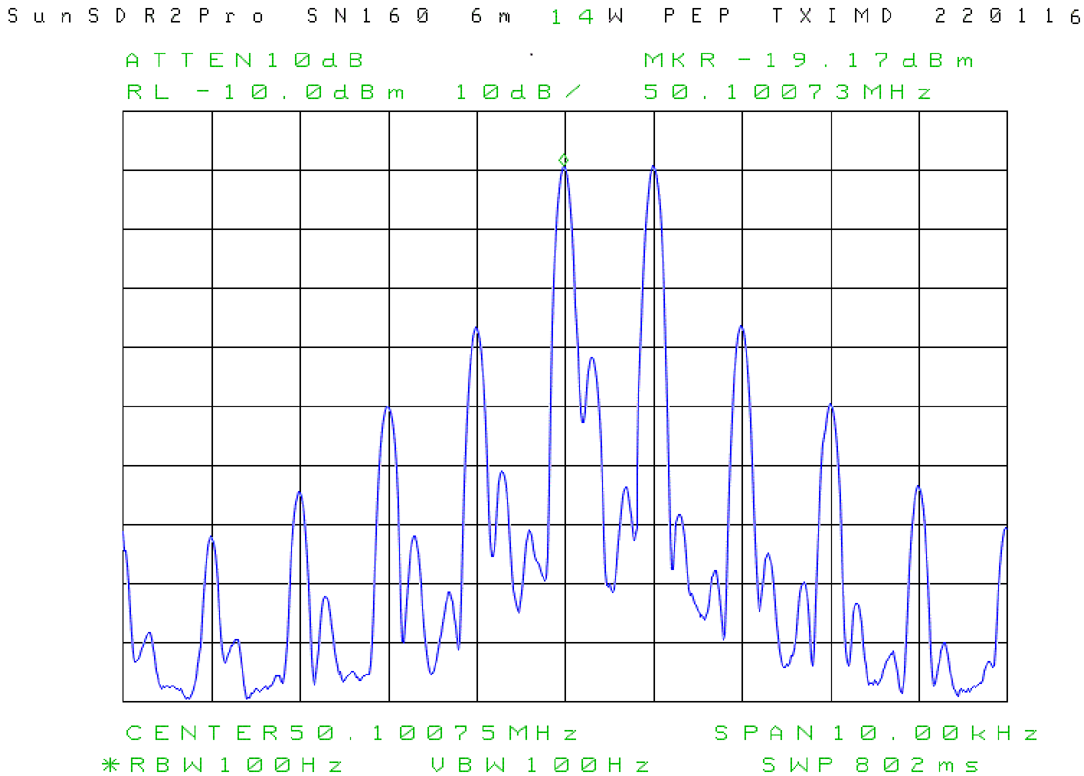
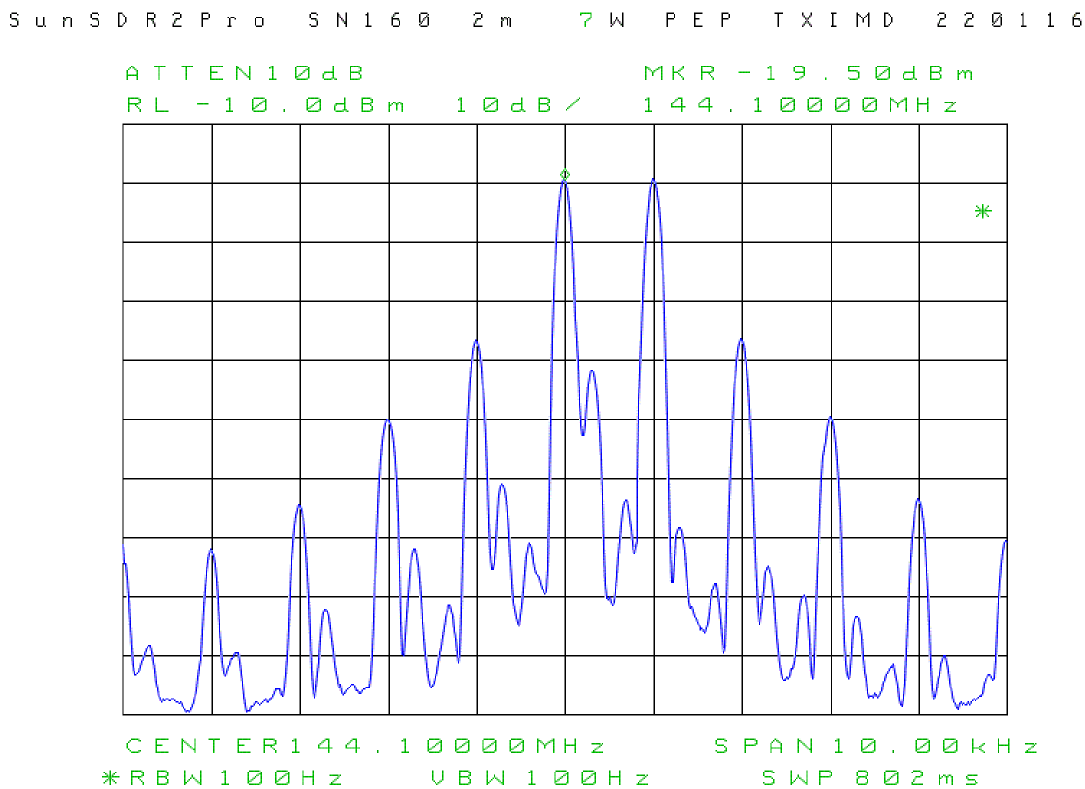


Figure 27: Spectral display of 2-tone IMD at 144.1 MHz, 7W PEP.



Conclusions for Appendix 1:

1. Transmitter IMD is well within the ITU-R SM.326-7 guideline (-25 dBc). IMD < -25 dBc for all the bands tested.

2. Transmitter power output is within manufacturer's specifications for all the bands tested. (It was observed that the Po and SWR GUI meter readings were slightly out of calibration at 50.1 MHz.)

3. Receiver IFSS is greatly improved; the IMD curve for input levels < -17 dBm/tone with the 10 dB preamp on is quite monotonic and well below the rural band noise line. With preamp off, the IMD curve is a few dB below the rural band noise line for input < -24 dBm/tone (one shallow peak just touches the line at -35 dBm/tone). Below -35 dBm/tone, the curve falls away quite steeply to the noise floor. A more monotonic curve a little further below the rural band noise line would be an improvement.

4. Receiver NPR is still mostly on the low side (mid-50's to mid-60's) as compared to other direct-sampling SDR's I have tested where NPR is in the low- to mid-70's. The +10 dB preamp brings NPR into the acceptable range at the cost of shifting the usable dynamic range down 10 dB.

   The obvious exception to the above is the severely degraded NPR on 1940 and 1248 kHz. As noted on page 22, this degradation is probably due to PIM in preselector inductor cores and/or automatic selection of the WB Filter at $f_0 < 2$ MHz *(if this is occurring)*. These values are 15-20 dB ***worse*** than on the #000077 DUT tested on 27.08.2015.

- The reasons for this NPR degradation on the lower frequency ranges are now understood, and affected units will be upgraded upon request. Hardware and software are constantly under development, and future production runs will incorporate measures to improve NPR performance.