Test Report: Yaesu FTDX-1200, S/N 3F02051 (loaned by Bill Trippett W7VP)

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1. **Introduction and Scope:** The following tests were conducted on the FTDX-1200:

A. Receiver Tests:

1. **MDS** (Minimum Discernible Signal): MDS was measured on 20m in CW and SSB modes, to provide a datum point for the DR3 (2-signal 3rd-order IMD dynamic range) test. It was also measured in SSB mode at the NPR (noise power ratio) notch frequencies in the 160, 80, 60 and 40m bands as required for the calculation of NPR. Roofing-filter correction factors were also derived.
2. **NPR** (noise power ratio) was measured at 1940, 3886, 5340 and 7600 kHz in SSB mode with 2.4 kHz IF bandwidth. All possible preamp/roofing filter combinations were tested.
3. **RMDR** (reciprocal mixing dynamic range) was measured at 14.1 MHz with 2, 3, 5, 10, 20 and 50 kHz offset and IPO.
4. **DR3** (2-signal 3rd-order IMD dynamic range) was measured using test signals in the 20m band. Test cases were run at 2, 5, 10 and 20 kHz spacing, with all possible preamp settings. The classic non-subtractive DR3 test method was employed.
5. **Image & 1st IF rejection** were measured at 95.01 MHz (the first image of 14.1 MHz) and at the 40.455 MHz 1st IF.
6. **AGC impulse response** and NB efficacy in suppressing this response were tested at 3.6 MHz, using a pulse generator with 10 ns rise-time.

B. Transmitter Tests:

1. **Power output** and autotuner insertion loss were measured at 14.1 and 50.1 MHz.
2. **CW keying envelope** (2a) and **keying sidebands** (2b) were measured at 14.1 MHz/100W, using the internal keyer set to 60 wpm.
3. **ALC compression tests** were performed using voice audio (3a), a 2-tone test signal (3b) and Gaussian noise (3c) applied to the MIC input. The objective was to identify increased IMD caused by ALC action, and to check for ALC overshoot. No overshoot whatsoever was detected.
4. **Transmitted 2-tone IMD** was measured with a spectrum analyzer at 3.6, 14.1 and 50.1 MHz. This is a measure of transmitter linearity.
5. **Transmitted composite noise** was measured with a spectrum analyzer at 3.6, 14.1 and 50.1 MHz. This is a measure of LO phase noise plus the noise contribution of downstream stages in the transmitter.

2. **Receiver Tests and Results:**

Test A1: MDS (Minimum Discernible Signal): This 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 off, DNR off, NB off, DNF off, Notch off, Contour off. AGC Slow. Roofing filter: 15 kHz (R15). Roofing filter correction factors were measured and applied to NPR results, as follows: R15: 0 dB. R6: +1 dB. R3: +2 dB. Test results are in **Table 1**.

Table 1: MDS.

			MDS dBm		
Freq. kHz	**Mode**	**IF BW**	**IPO**	**AMP 1**	**AMP 2**
14100	CW	500 Hz	-120	-132	-139
	USB	2.4 kHz	-114	-127	-134
3600	CW	500 Hz	-122	-135	-139
	LSB	2.4 kHz	-118	-131	-135
50100	CW	500 Hz	-120	-132	-140
	USB	2.4 kHz	-115	-128	-134
1940	LSB	2.4 kHz	-113	-125	-130.5
3886	LSB	2.4 kHz	-115	-127	-133
5340	USB	2.4 kHz	-117	129	-134
7600	LSB	2.4 kHz	-117	-128	-134

Test A2: Reciprocal mixing dynamic range (RMDR): In this test, a strong "undesired" signal is injected into the receiver's RF input at a fixed offset Δf from the operating frequency. The RF input power P_i is increased until the receiver noise floor increases by 3 dB, as measured at the audio output. RMDR is the difference between this RF input power and measured MDS. The test is run with preamp off. The higher the RMDR value, the better.

If RMDR is lower, than DR3, reciprocal mixing noise is the dominant impairment and vice versa.

Test Conditions: CW mode, 500 Hz filter, preamp off (IPO), ATT off, DNR off, NB off, DNF off, Notch off, Contour off. AGC Slow, offset relative to virtual carrier. Roofing filter: 3 kHz (R3). RMDR *in dB* = input power – MDS *(both in dBm).* Test results are in **Table 2.**

Table 2: Reciprocal Mixing Dynamic Range RMDR

Δf kHz	P_i dBm	RMDR dB
2	-38	**82**
3	-34	**86**
5	-30	**90**
10	-23	**97**
20	-17	**103**
50	-14	**106**

Test A3: DR3 (2-signal 3rd-order IMD dynamic range): The purpose of this test is to determine the range of signals which the receiver can tolerate while essentially generating no spurious responses.

In this test, two signals of equal amplitude P_i and separated by a known offset Δf are combined and injected into the receiver input. If the test signal frequencies are f_1 and f_2, the offset $\Delta f = f_2 - f_1$ and the 3rd-order intermodulation products appear at $(2 f_2 - f_1)$ and $(2 f_1 - f_2)$.

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 upper and lower 3rd-order IMD products ($2f_2 – f_1$ and $2f_1 - f_2$ respectively) which appear as a 700 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 products at MDS. The P_i values for the upper and lower products are recorded and averaged.

Note: If the audio output drops by less than 3 dB when one of the test signals is removed, the measurement is noise-limited (indicated by NL in Table 3.) In addition, the test signal frequencies can be varied slightly to verify that the measured IMD products are genuine and not spurs.

$DR_3 = P_i$ - MDS. Calculated IP_3 = (1.5 * DR3) - MDS

Test Conditions: f_1 = 14010 kHz, $f_2 = (f_1 + \Delta f)$ kHz, 500 Hz CW, roofing filter 3 kHz (R3), ATT off, DNR off, NB off, DNF off, Notch off, Contour off. AGC Slow. CW Pitch = 700 Hz. DR_3 in dB; IP_3 in dBm. NL = reciprocal mixing noise limited (IMD + reciprocal mixing). A quick check with roofing filter 6 kHz (R6) showed a slight drop in DR3 (≈ 1 dB). Test results are in **Table 3.**

Table 3: DR3 and IP3

f_1 kHz	f_2 kHz	Δf kHz	MDS dBm	Preamp	P_i dBm	DR_3 dB	IP_3 dBm	NL
14010	14012	2	-120	IPO	-41	**79**	-1.5	Y
14010	14012	2	-132	AMP 1	-54	**78**	-15	Y
14010	14012	2	-139	AMP 2	-65	**74**	-28	Y
14010	14015	5	-120	IPO	-39	**81**	+1.5	
14010	14020	10	-120	IPO	-26	**94**	+21	
14010	14030	20	-120	IPO	-25	**95**	+22.5	

Test A4: Noise Power Ratio (NPR): An NPR test was performed, using the test methodology described in detail in ***Ref. 1***. The noise-loading source used for this test was a noise generator fitted with the following selectable filter pairs (bandstop & band-limiting filters):

Table 4: Noise Generator Filter Pairs

Bandstop filter f_0 kHz	Band limiting filter kHz	B_{RF} kHz	BWR dB
1940	60 - 2048	1985	29.2
3886	60 - 4100	4037	32.3
5340	60 - 5600	5537	33.6
7600	316 - 8100	7781	35.1
Bandstop filter stopband: depth ≈ 100 dB, width ≈ 3 kHz.			

The noise loading P_{TOT} was increased until the audio level measured at the external speaker jack increased by 3 dB. P_{TOT} was read off the attenuator scale on the noise generator, and NPR was then calculated using the formula

$$NPR = P_{TOT} - BWR - MDS$$

where P_{TOT} = total noise power in dBm for 3 dB increase in audio output

BWR = bandwidth ratio = 10 $\log_{10} (B_{RF}/B_{IF})$

B_{RF} = RF bandwidth or noise bandwidth in kHz (noise source band-limiting filter)

B_{IF} = receiver IF filter bandwidth in kHz

MDS = minimum discernible signal (specified at B_{IF}), measured prior to NPR testing

Test Conditions: Receiver tuned to bandstop filter center freq. f_0 ± 1.5 kHz, 2.4 kHz SSB, ATT off, DNR off, NB off, DNF off, Notch off, Contour off, AGC Slow. Test results are in **Table 5.**

Table 5: Noise Power Ratio (NPR)

B_{IF} = 2.4 kHz				IPO		AMP 1		AMP 2	
f_0 kHz	BWR dB	Mode	Roof	P_{TOT} dBm	**NPR dB**	P_{TOT} dBm	**NPR dB**	P_{TOT} dBm	**NPR dB***
1940	29.2	LSB	R15	-8.3	**75.2**	-20	**75.5**	-29	**72**
			R6	-3.6	**82**	-15.7	**81.8**	-25.7	**77.3**
			R3	-3.9	**82.6**	-15.8	**83.7**	-25.3	**79.7**
3886	32.3	LSB	R15	-5.2	**77.2**	-17.9	**76.5**	-27	**73.4**
			R6	-4.4	**80**	-17.1	**79.3**	-25.9	**77.5**
			R3	-4.7	**81.7**	-17	**81.4**	-26.3	**78.1**
5340	33.6	USB	R15	-7.7	**74.9**	-22.7	**72.4**	-31.2	**68.9**
			R6	-8.2	**76.4**	-22.9	**74.2**	-31.6	**71.5**
			R3	-8.7	**77.9**	-23.5	**75.6**	-31.8	**72.3**
7600	35.1	LSB	R15	-5.1	**76.5**	-18.3	**75.3**	-26.4	**72.2**
			R6	-4.2	**80.4**	-17.7	**76.9**	-26.1	**75.5**
			R3	-4.4	**81.2**	-18.3	**78.3**	-26.5	**76.1**
*Roofing filter correction factors applied: R15: 0 dB, R6: +1 dB, R3: +2 dB									

Test A5a: Image Rejection: In this test, the DUT is tuned to f_0, and a test signal is applied at $f_0 + 2 * 1^{st}$ IF. The test signal power is increased sufficiently to raise the noise floor by 3 dB.

Test Conditions: f_0 = 14.1 MHz, CW, 500 Hz IF filter, IPO, ATT off, DNR off, NB off, DNF off, Notch off, Contour off, AGC Slow. Test signal freq. = (2 * 40.455) + 14.1 = 95.01 MHz. Measured MDS = -120 dBm. For 3 dB noise floor increase:

Roofing filter R15: P_i = -10 dBm. Image rejection = -10 – (-120) = **110 dB**.

Roofing filter R3: P_i = -5 dBm. Image rejection = -5 – (-120 +2) = **113 dB**.

Test A5B: 1^{st}-IF Rejection: In this test, the DUT is tuned to f_0, and a test signal is applied to the antenna portat the 40.455 MHz 1^{st} IF. The test signal power is increased sufficiently to raise the noise floor by 3 dB.

Roofing filter R15: P_i = -10 dBm. 1^{st} IF rejection = -10 – (-120) = **110 dB**.

Roofing filter R3: P_i = -6 dBm. 1^{st} IF rejection = -6 – (-120 +1) = **113 dB**.

Test A6a: AGC impulse response and suppression: The purpose of this test is to determine the DUT'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 LSB, 2.4 kHz SSB, NR off, NB off/on, IPO/AMP 2, AGC Fast (decay time set to 100 ms, ATT off, DNR off, DNF off, Contour off.

The pulse generator output is connected to the antenna port via a step attenuator. Pulse rise time < 10 ns (to 70% of peak amplitude). Four pulse durations are used: 10, 30, 50 and 100 nS. In all cases, pulse period is 600 ms. Pulse amplitude is $16V_{pk}$ (e.m.f.)

The AGC recovers completely within the preset decay interval; there is no evidence of clamping. Each pulse produces a distinct tick in the speaker, and the S-meter flicks upwards as shown in **Table 6**.

Table 6: AGC impulse response.

Pulse duration ns	AGC recovery ms	S: IPO	S: AMP 2
10	≈ 100 (no clamping)	S0	S3
30	≈ 100 (no clamping)	S0	S5
50	≈ 100 (no clamping)	S1	S6
100	≈ 100 (no clamping)	S2	S7

Test A6a: NB action on AGC impulse response: At 50% NB level, the DSP noise blanker completely suppresses the audible ticks and S-meter deflection. At 0% NB level, the ticks are loudest at 30ns pulse duration, but are inaudible at duration < 20ns. At 100 ns, the ticks are almost inaudible.

3. Transmitter Tests and Results:

Test B1: Transmitter power output: The FTDX-1200 was terminated in 50Ω resistive, and the power output checked in RTTY mode.

Test Conditions: 13.8V DC supply, RTTY mode, CAR fully CW, Menu 177 MAX TX PWR = 100W.

14.1 MHz: P_O = 104W, ATU insertion loss < 0.1 dB.

50.1 MHz: P_O = 102W, ATU insertion loss < 0.1 dB.

Test B2a: CW keying envelope: The oscilloscope is terminated in 50Ω and coupled to the DUT RF output via the line sampler. A series of dits is transmitted from the internal keyer at 60 wpm.

Test Conditions: 14.1MHz CW, 100W output to 50Ω load. Keying speed 60 wpm using internal keyer. CW rise time = 4 ms (default) & 6 ms.

Refer to **Figures 1 and 2** below.

Figure 1: CW keying envelope, 60 wpm, 4 ms rise-time, 100W. 10 ms/hor. div.

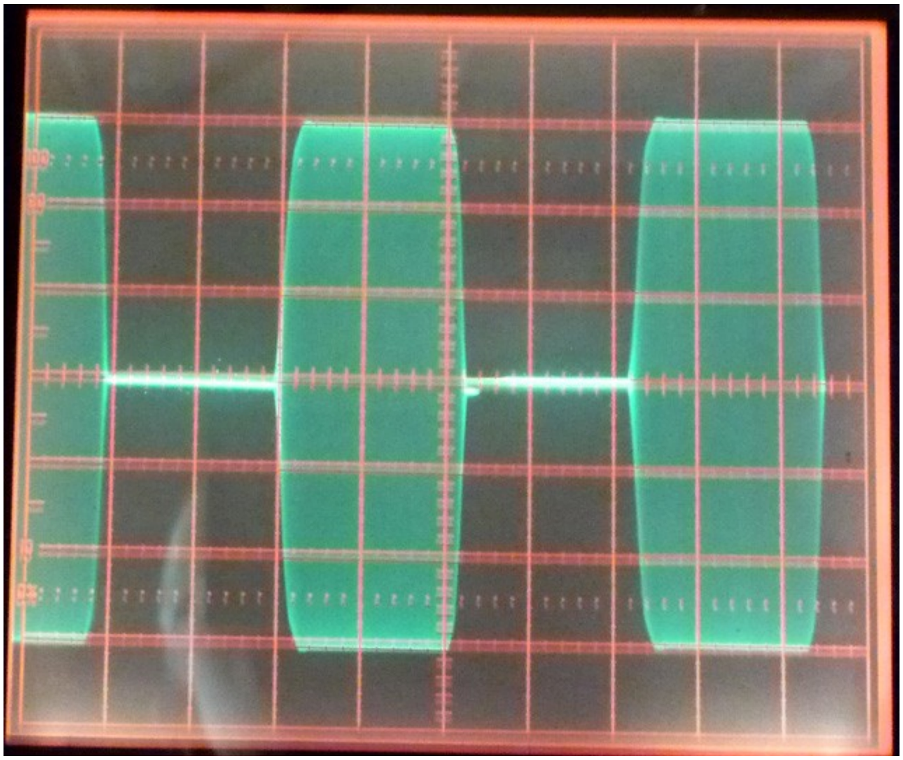
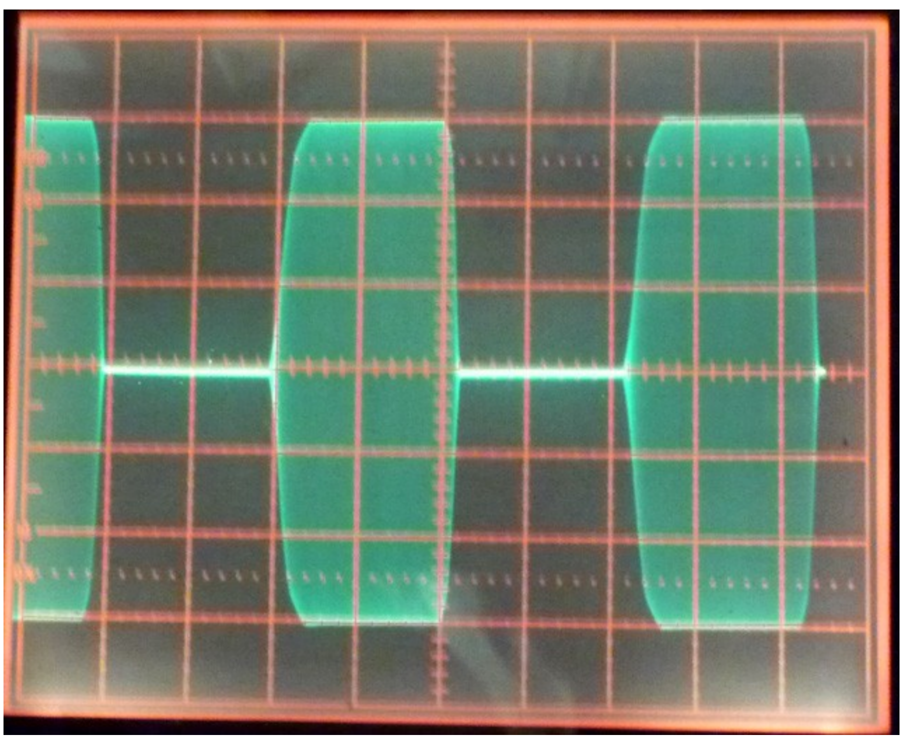


Figure 2: CW keying envelope, 60 wpm, 6ms rise-time, 100W. 10 ms/hor. div.

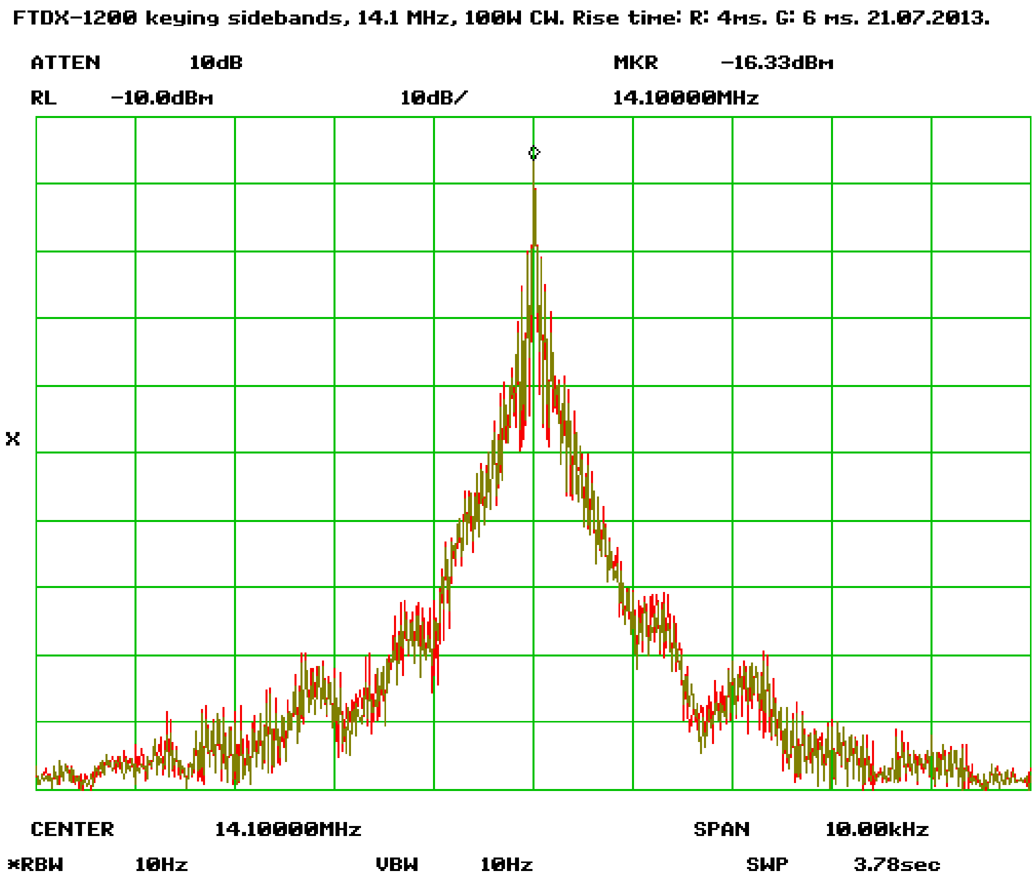


Test B2b: CW keying sidebands: The spectrum analyzer is coupled to the DUT RF output via the line sampler. The -10 dBm reference level equates to 100W. A series of dits is transmitted at 60 wpm.

Test Conditions: 14.1 MHz CW, 100W output to 50Ω load. Keying speed 60 wpm using internal keyer. CW rise-time = 4 ms (default) & 6 ms. Spectrum analyzer RBW is 10 Hz, video-averaged; sweep < 4 sec.

Figure 3 shows the transmitter output ±5 kHz from the carrier. It will be seen that the rise-time has little effect on the keying spectrum.

Figure 3. Spectral display of keying sidebands.



Test B3: ALC compression tests: The purpose of these tests is to identify increased transmitter IMD caused by ALC action at high baseband levels, and to check for ALC overshoot (power spikes). *It should be noted here that no overshoot whatsoever was detected.*

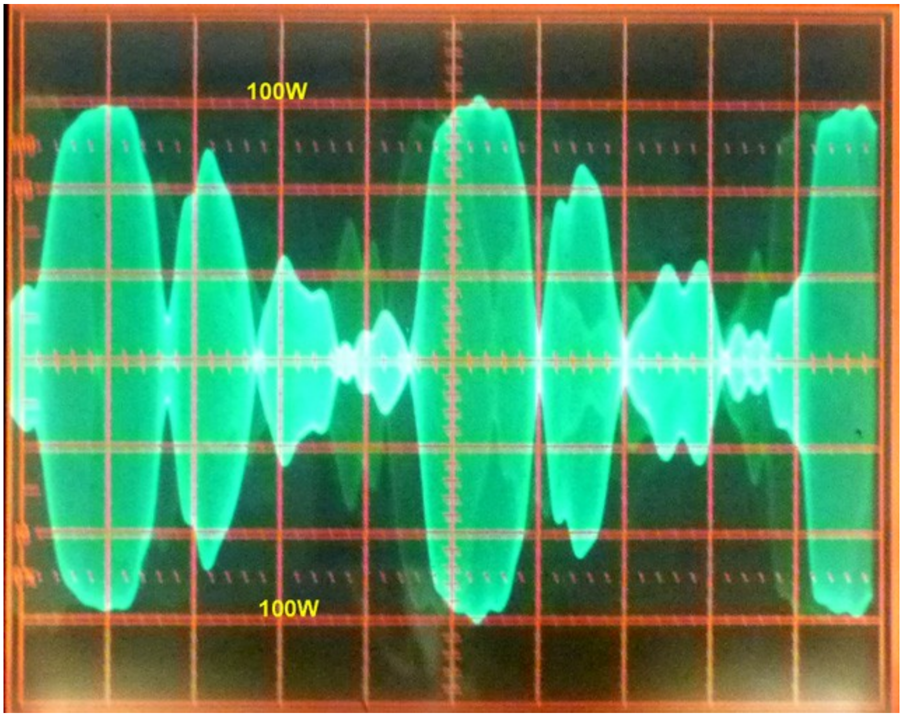
These tests were performed using voice audio, and also Gaussian noise applied to the MIC input via an audio isolation transformer.

Test B3a: ALC compression test using voice audio: The oscilloscope is terminated in 50Ω and coupled to the DUT RF output via the line sampler. A dynamic mic is connected to the DUT MIC input.

Test Conditions: 14.1 MHz USB, Menu 177 MAX TX PWR = 100W. Mic Gain adjusted for < 50% ALC meter reading.

> **Figure 4** shows some ALC compression on voice peaks. No ALC overshoot or spike was observed at any time during this test.

Figure 4: SSB RF envelope at 100W PEP. Note ALC compression on voice peaks.



Test B3b: ALC compression test using 2-tone test signal: The oscilloscope terminated in 50Ω is coupled to the DUT RF output via the line sampler. A 2-tone generator is connected to the DUT mic input via an isolation transformer.

Test Conditions: 14.1 MHz USB, Menu 177 MAX TX PWR = 100W. Test tones 700 & 1700 Hz. Mic Gain adjusted for <50% ALC reading on voice peaks.

> **Figure 5** illustrates an ideal 2-tone SSB envelope, and **Figure 6** shows some flat-topping on peaks due to ALC compression. No ALC overshoot or spike was observed at any time during this test.

Figure 5: Ideal 2-tone SSB envelope.

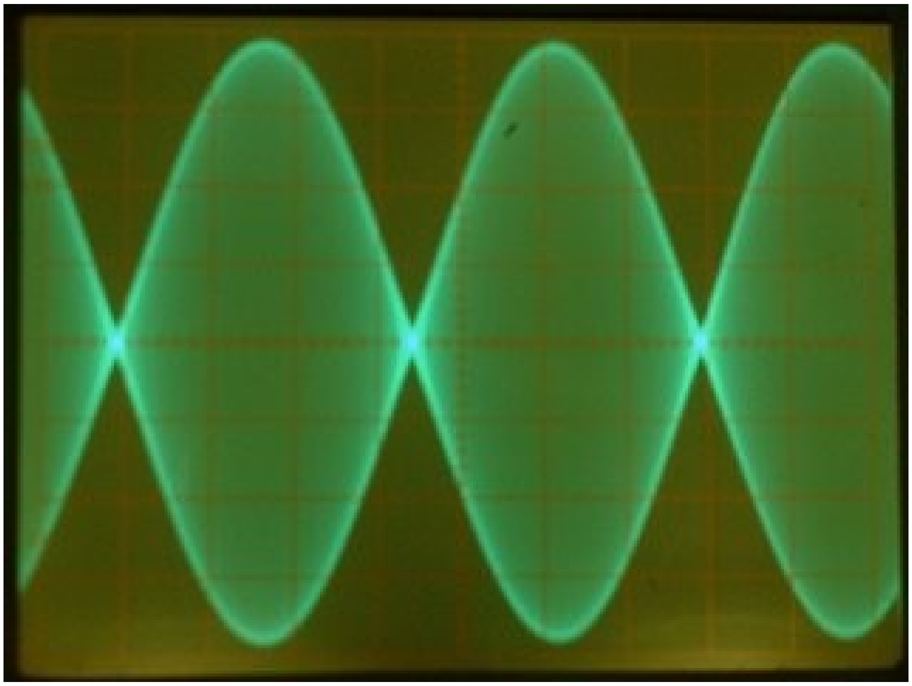
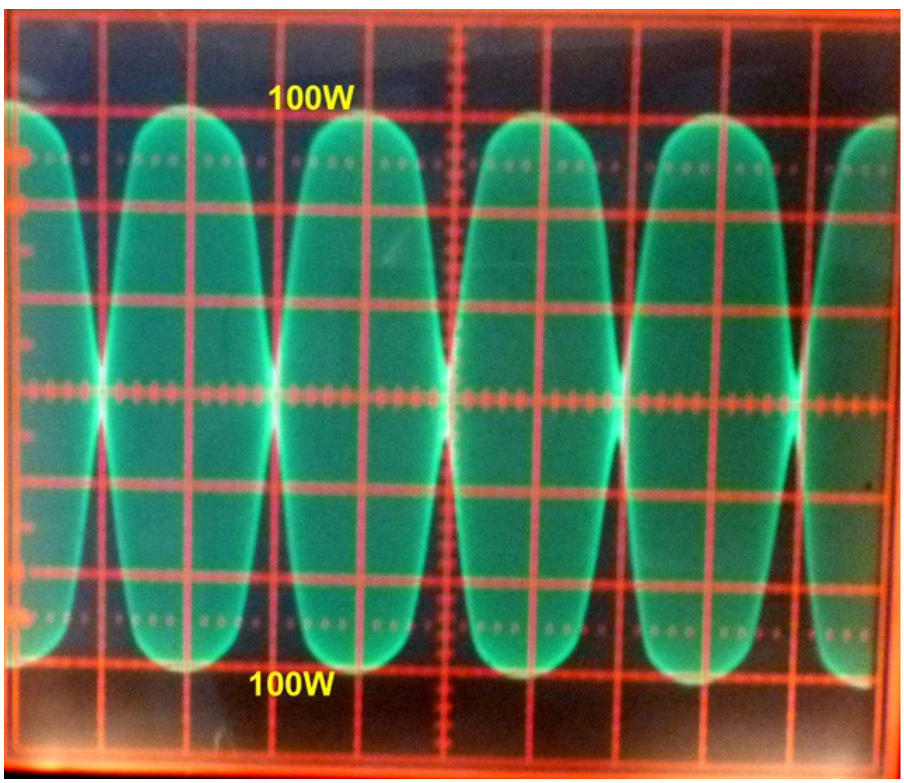


Figure 6: 2-tone RF envelope at 100W PEP. Note ALC compression on voice peaks.



Test B3c: ALC compression tests using Gaussian noise: The test instrument (oscilloscope terminated in 50Ω, then spectrum analyzer) is coupled to the DUT RF output via the line sampler. A baseband noise source is connected to the DUT mic input via an isolation transformer.

Test Conditions: 14.1 MHz USB, Menu 177 MAX TX PWR = 100W. Mic Gain adjusted (1) for 50W PEP (≈ 0% ALC reading, then for 104W (≈ 60% ALC reading).

Figures 7 and 8 show that the applied baseband noise did not provoke any ALC overshoot or spikes.

In **Figure 9**, we see that at 104W PEP output (ALC reading ≈ 60%), the skirts caused by IMD products begin approx. 5 dB higher up the transmit filter flank than at 50W PEP (0% ALC). The skirts are also wider for the 104W case. These are signs that the transmitter IMD degrades rapidly as P_O approaches 104W. This is the result of ALC compression, which increases markedly as the output is increased from 100W to 104W.

Figure 7: Gaussian noise RF envelope at 50W PEP. No ALC overshoot.

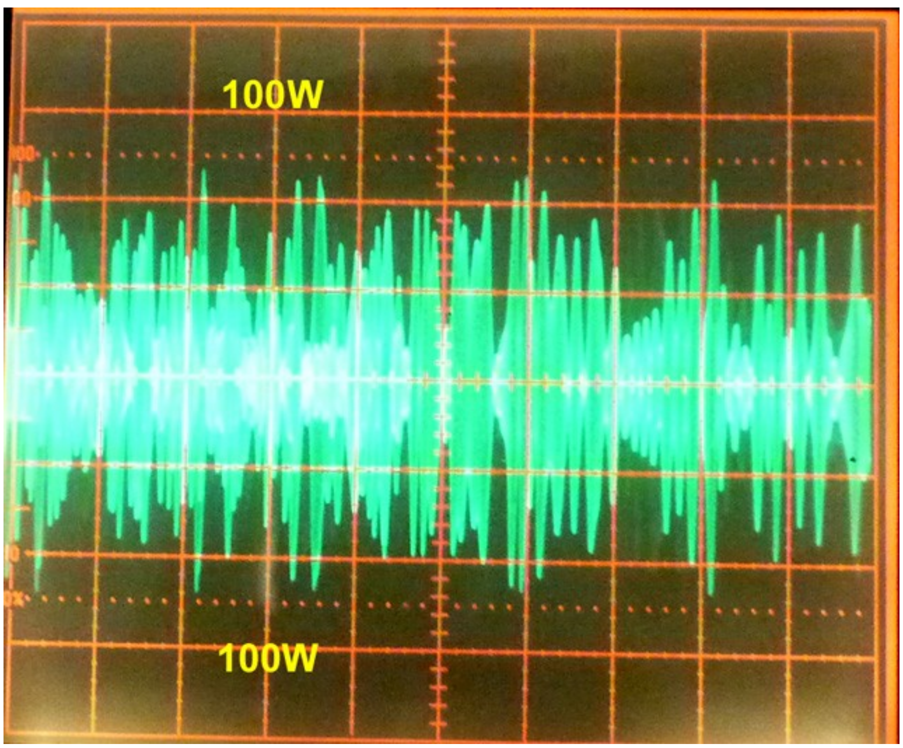


Figure 8: Gaussian noise RF envelope at 100W PEP. No ALC overshoot.

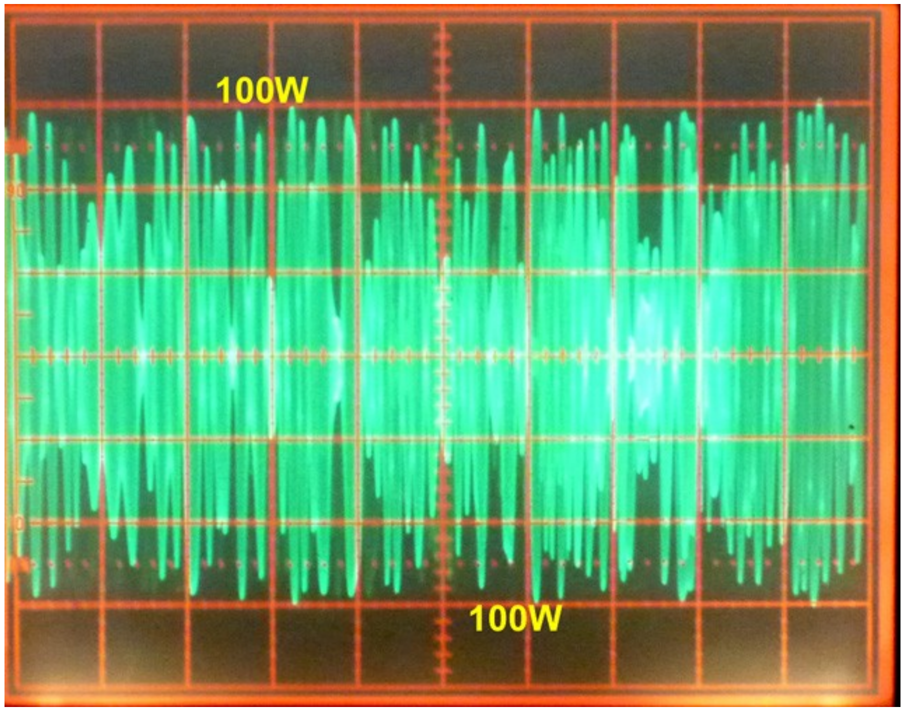
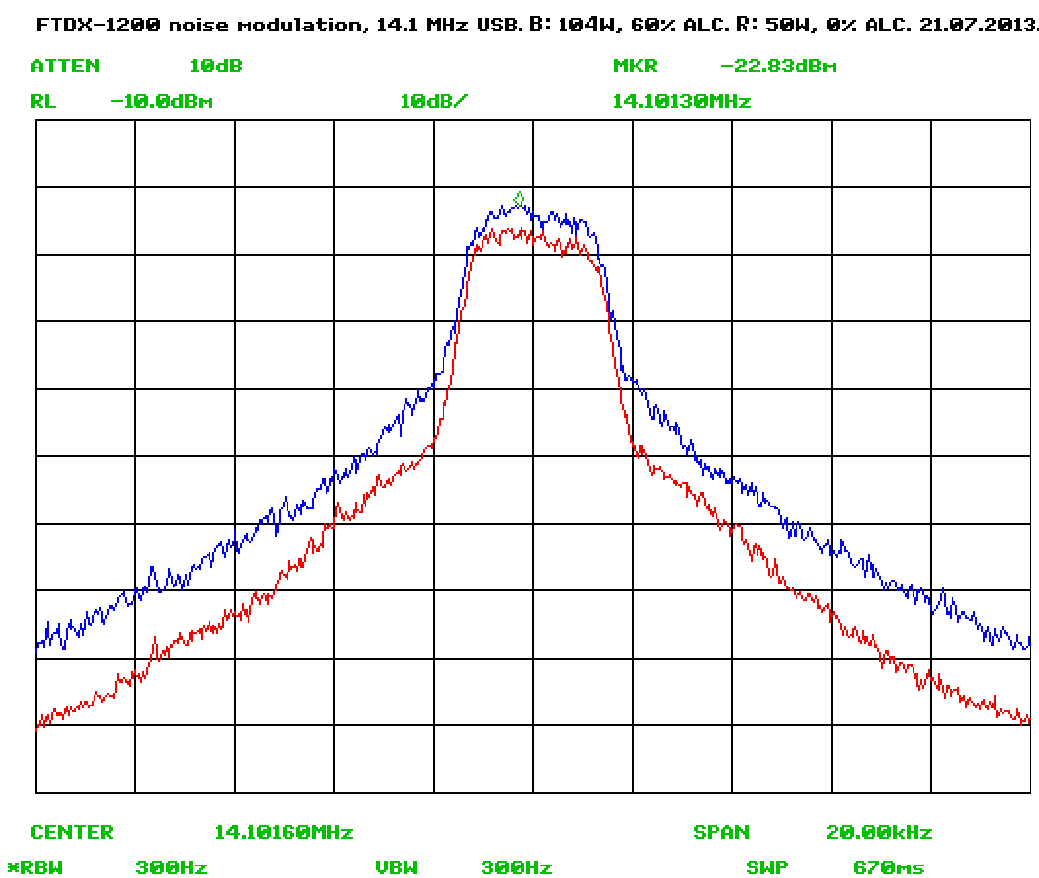


Figure 9: Spectrogram of Gaussian noise at 104W & 50W PEP, showing IMD skirts.



Test B4: TX IMD test using 2-tone test signal: The spectrum analyzer is coupled to the DUT RF output via the line sampler. A 2-tone generator is connected to the DUT mic input via an isolation transformer. **Figures 10a, 10b and 10c** are the test plots.

Test Conditions: 3.6, 14.1 and 50.1 MHz SSB, Menu 177 MAX TX PWR = 100W. Test tones 700 & 1700 Hz. Mic Gain adjusted for <50% ALC reading on voice peaks. Test tone levels adjusted for -6 dBc (both tones). RL -10.0 dBm = 100W. Test results are in **Table 7**.

Table 7: 2-tone Transmitter IMD.

2-tone TX IMD Products at 100W PEP			
IMD Products	Rel. Level dBc (0 dBc = 1 tone)		
	3.6 MHz	14.1 MHz	50.1 MHz
IMD3 (3rd-order)	-35	-36	-33
IMD5 (5th-order)	-38	-34	-30
IMD7 (7th-order)	-41	-41	-51
IMD9 (9th-order)	-46	-50	-58
For IMD relative to 2-tone PEP, add 6 dB.			

Note that at 14.1 and 50.1 MHz, IMD5 is a few dB worse than IMD3. This is most likely an effect of ALC compression (refer to **Tests B3a, B3b and B3c** above.)

Figure 10a: 2-tone IMD at 3.6 MHz LSB, 100W PEP.

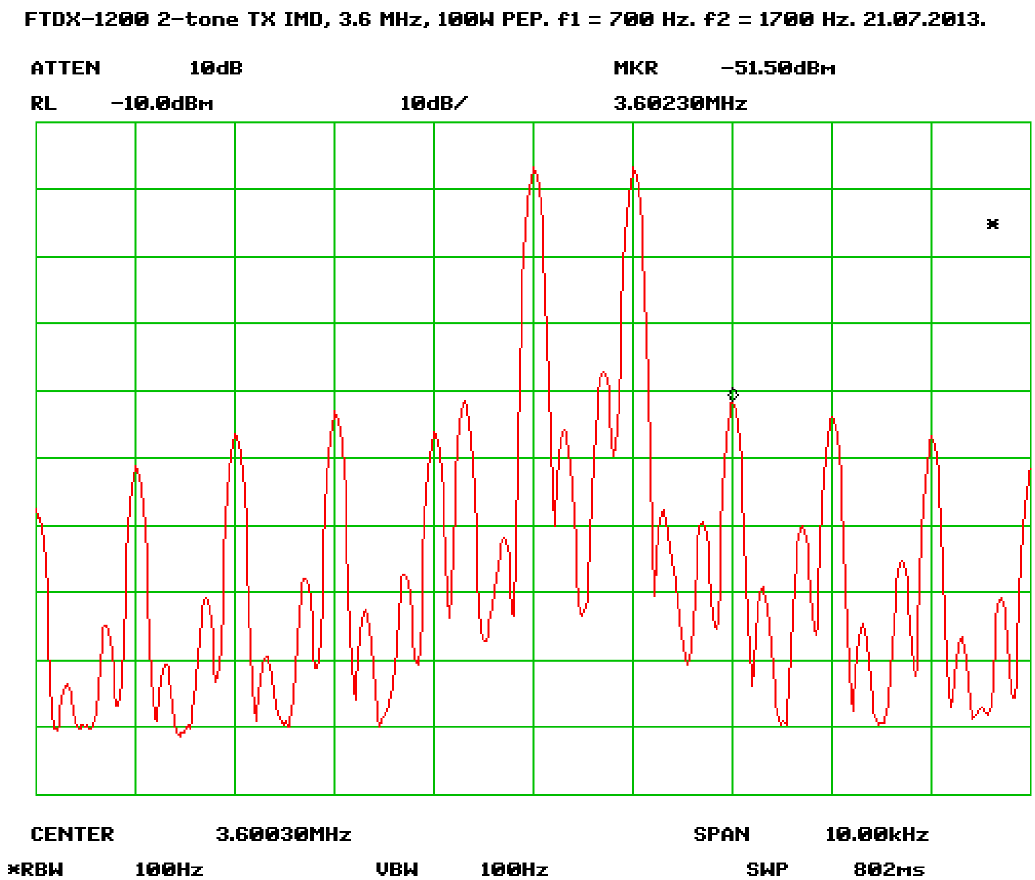


Figure 10b: 2-tone IMD at 14.1 MHz USB, 100W PEP.

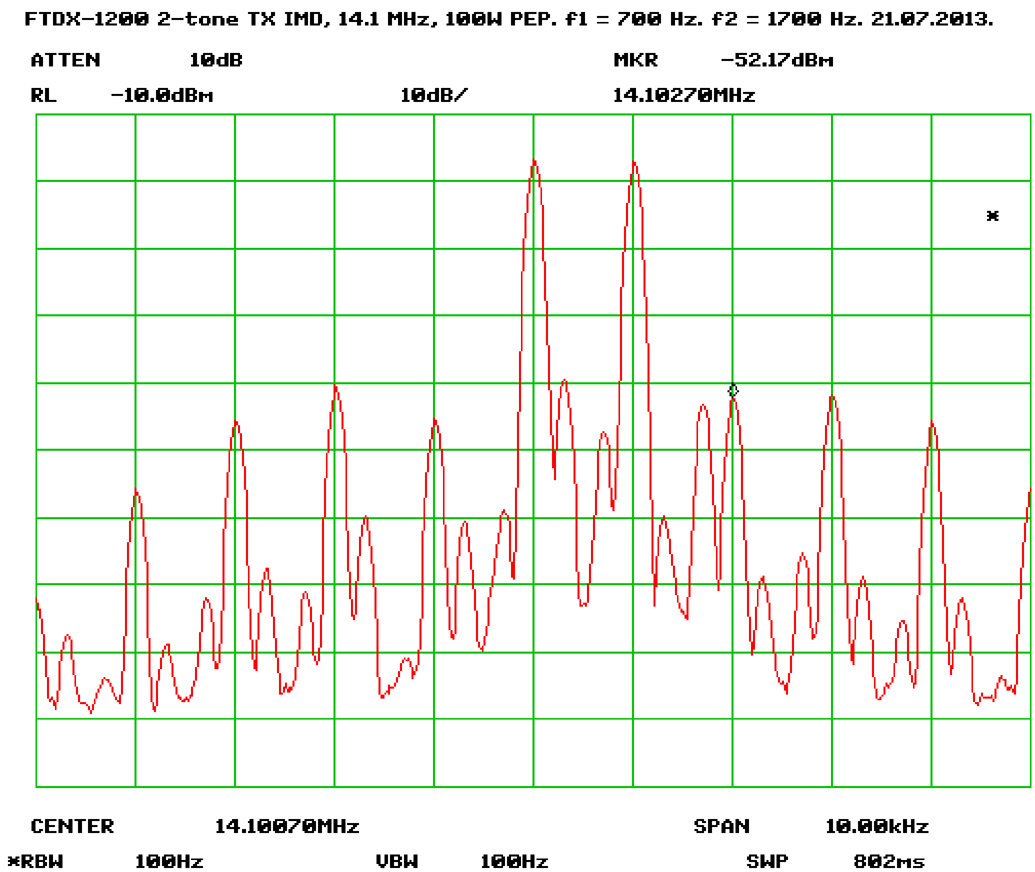
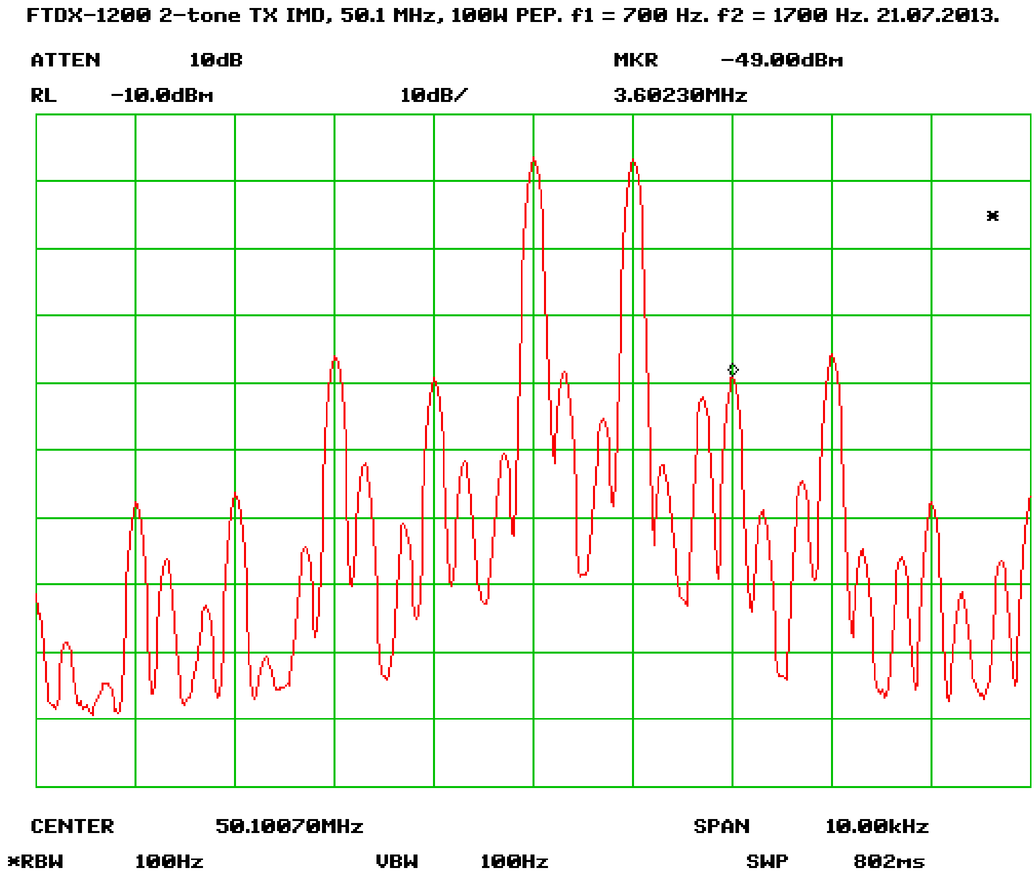


Figure 10c: 2-tone IMD at 50.1 MHz USB, 100W PEP.



Test B5: Transmitted composite noise. As before, the spectrum analyzer coupled to the DUT RF output via the line sampler. A 2-tone generator is connected to the DUT mic input via an isolation transformer. The spectrum analyzer's phase-noise utility is started. **Figures 10a and 10b** are the resulting composite-noise plots.

Test Conditions: 3.6, 14.1 and 50.1 MHz RTTY, 100W output to 50Ω load. Utility minimum/maximum offset and spot frequencies configured as shown in **Figures 11a and 11b**. (***Note:*** The limitation of this measurement method is that the lowest values of measured noise power are close to the spectrum analyzer's own noise floor.)

Figure 11a: Transmitted composite noise, 3.6 and 14.1 MHz, 100W.

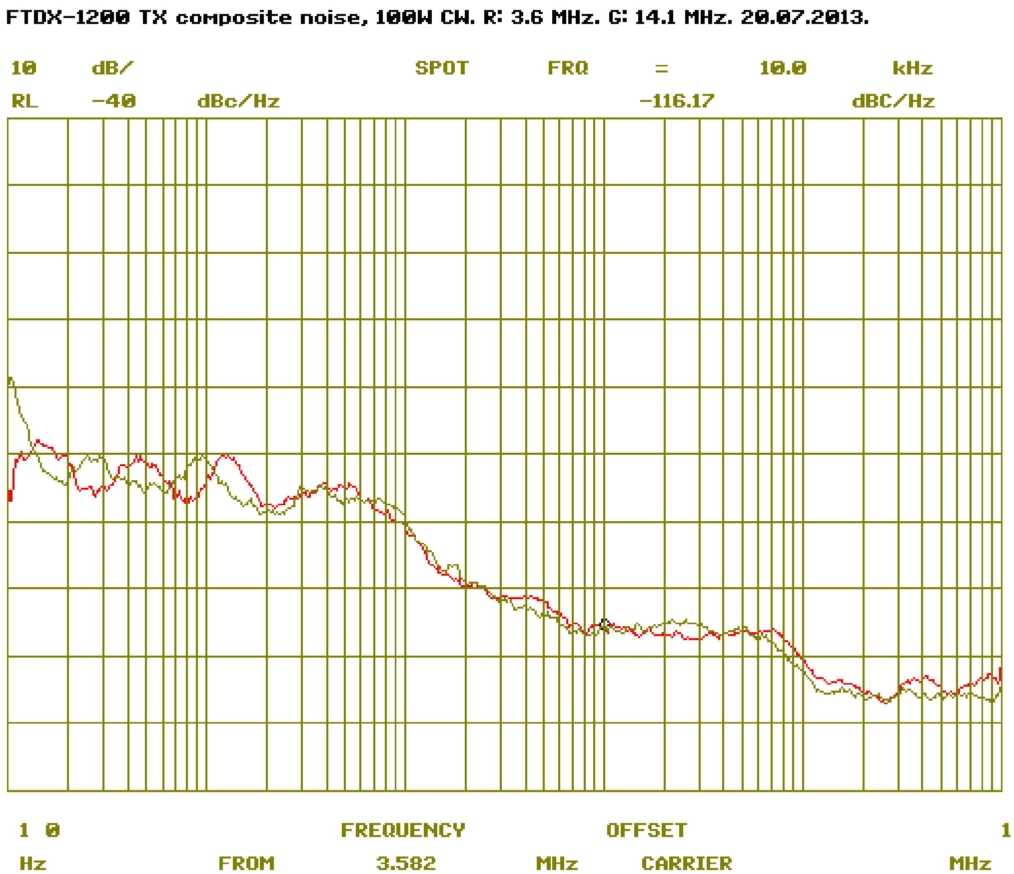
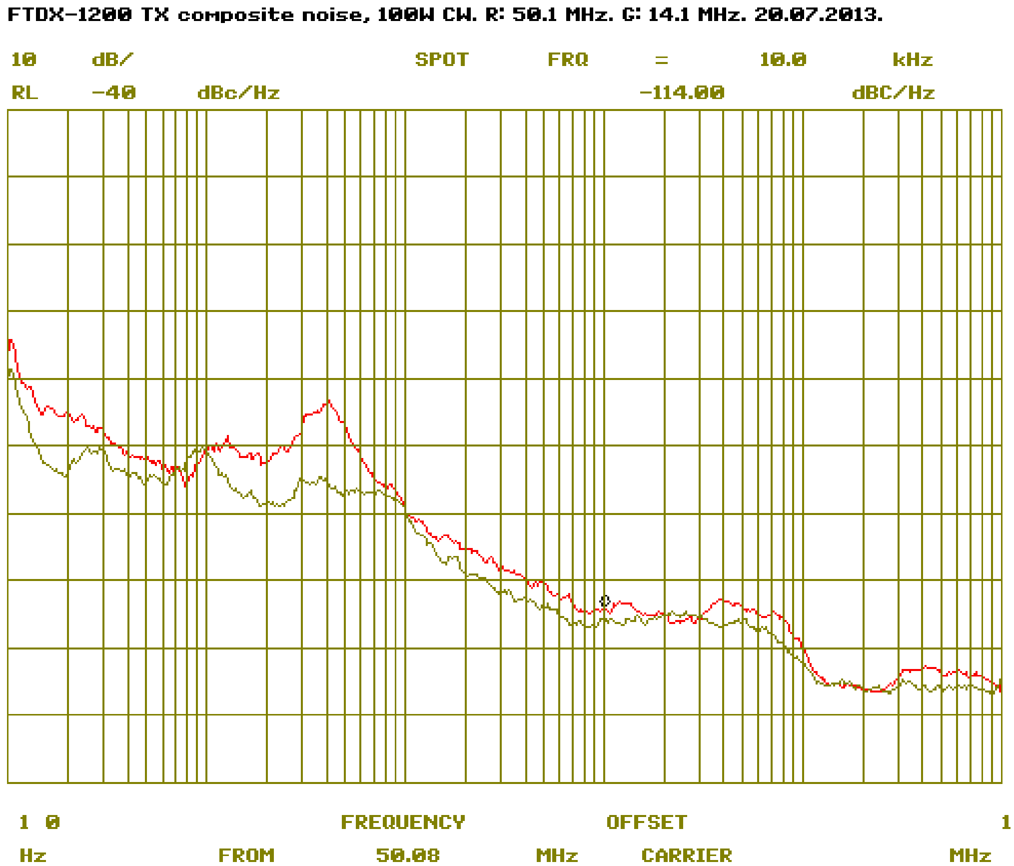


Figure 11b: Transmitted composite noise, 14.1 and 50.1 MHz, 100W.



4. **Conclusions:**
   - 4.1. It will be seen from Tables 2 (RMDR) and 3 (DR3) that at 2 kHz spacing, the measured 82 dB RMDR value is slightly higher than measured DR3. This indicates that although the measurement is phase-noise limited, there is still a measurable component due to front-end non-linearity. At 5 kHz spacing, RMDR and DR3 are 90 and 81 dB respectively, indicating a fairly rapid fall-off in phase noise between 2 and 5 kHz offset. This is borne out by the 14.1 MHz curve in **Figure 10b.**
   - 4.2. The results in Table 3 (NPR) for the IPO and AMP1 test cases are in the "upper mid to high" range of the NPR test data presented in Tables 1 and 1a of **Ref. 1.** Some NPR degradation is seen in the AMP 2 test cases; this is to be expected, as AMP 2 cascades Preamps 1 and 2 and it is likely that the high noise loading will overload Preamp 2, causing many distortion products which will degrade the test results. Overall, the NPR performance compares very well with that of comparable transceivers such as the FT-950 and IC-7410 (see **Ref.1**).
   - 4.3. As one would expect of a high 1st IF ("up-conversion") superhet architecture, image and 1st IF rejection are superb (> 110 dB). These figures are unachievable with an in-band ("down-conversion") 1st IF design.
   - 4.4. The FTDX-1200 exhibits the AGC response to fast-rising impulsive RF events typical of many IF-DSP based receivers, but the DSP noise blanker suppresses this response very effectively without degrading received audio quality.
   - 4.5. CW keying characteristics appear very good, judging by the tests performed. The keying envelope is clean, and the CW spectrum is quite narrow (< 1 kHz at -50 dBc) and free of keying artifacts.
   - 4.6. As mentioned in the test descriptions above, no trace of ALC overshoot or spikes was observed at any time. Nonetheless, **ALC compression** is quite aggressive as the power output reaches and crosses the 100W threshold corresponding to the MENU 177 MAX TX PWR = 100W setting. Transmitter IMD degrades rapidly at 100W < P_O < 104W. For this reason, it is important to set power output, Mic Gain and baseband input level for ALC < 50% at all times.
   - 4.7. Measured transmitter IMD is better than average for a 13.8V 100W-class PA (with the caveat mentioned in 4.5 above), and is well within the ITU-R guideline of -25 dBc (referred to one of two equal tones). Transmitted composite noise is comparable to that of other transceivers in the FTDX-1200's price category.
   - 4.8. Overall, it is felt that the FTDX-1200 is a very good performer and an excellent buy in the mid-price range.

5. **References:** 1. "Noise Power Ratio (NPR) Testing of HF Receivers", A. Farson VA7OJ/AB4OJ.
http://www.ab4oj.com/test/docs/npr_test.pdf

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July 25, 2013