

Test Report for Flex-6700

October 16-25, 2014 (V1.3.8)

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The following are the results obtained from receiver and transmitter tests which the author conducted on Flex-6700 S/N 2213-3088-6700-5227, kindly loaned by Luke Evans VA7LWE. The installed SmartSDR build is now V1.3.8. All receiver tests reported here were run on SCU0 with V1.3.8.126; transmitter tests were conducted with earlier versions as noted. Current hardware rev. level is at PEN-6700/09202014.

It should be noted here that the 6500 is exactly equivalent in receiver/transmitter performance to the 6700 except for Preamp 2. A 6700 is, in fact, two 6500s in the same chassis with Preamp 2 added.

A description of a brief on-air trial concludes the report.

A. Receiver Tests:

1. **MDS (Minimum Discernible Signal).** Test setup: Marconi 2018A signal generator, 20 dB pad, DUT RX-A input. HP 339A distortion meter at DUT phones jack as level meter.
2. **NPR (Noise power ratio).** Test setup: Wandel & Goltermann RS-50 and RS-25 noise generators (fitted with filters per Table 1), MCL 75/50Ω transformer, DUT RX-A input. DUT set to LSB for all test frequencies except 5340 kHz (USB). 2.4 kHz channel filter selected. NPR read directly from spectrum scope. (Ref. 2).

Table 1: NPR test filters.

Bandstop kHz	Bandpass kHz	Equiv. J3E channels
1940	60-2048	480
3886	60-4100	960
5340	60-5600	1260
7600	316-8160	1800

3. **RMDR (reciprocal mixing dynamic range).** Test setup: Marconi 2019 signal generator, 3 dB pad, 9.83 MHz bandstop filter, 0-110 dB step attenuator, DUT RX A port.
4. **2-Tone 3rd-Order IMD (IFSS).** Test setup: Marconi 2018A and 2019 signal generators, MCL ZHL-32A buffer amplifiers, MCL BLP-15 low-pass filters, 20 dB pads, MCL ZSC-2-1W combiner, 0-110 dB step attenuator, DUT RX-A input. IMD products read from S-meter. Test results presented as curves of IMD level vs. test signal power, with ITU-R P.372-1 band noise levels as datum lines.
5. **DR₂ (IMD₂ dynamic range).** As for IFSS.
6. **Inband IMD.** Test setup: As for IFSS; HP 3580A baseband spectrum analyzer connected to DUT PHONES jack.
7. **Audio THD.** Test setup: As for Inband IMD: HP 339A distortion test set and HP 3580A baseband spectrum analyzer connected to DUT PHONES jack.
8. **TNF Depth.** As for MDS.

1. **MDS (Minimum Discernible Signal)** tested in CW mode (500 Hz), Normal (preselector in). The A receiver was tuned to each test frequency f_0 in turn and a test signal applied. At each frequency and RF Gain setting, the input power P_i required to raise audio output noise level by 3 dB was noted. $P_i = \text{MDS}$. AGC-T = 50, NR/NB/ANF off.

Table 2: Minimum Discernible Signal (MDS).

f_0 MHz	MDS dBm (Normal mode, preselector in except 70.1 MHz)			
RF Gain dB	0	+10	+20	+30
3.6	-118	-125	-137	-141
14.1	-119	-125	-136	-140
28.1	-117	-125	-134	-139
50.1	-117	-124	-136	-140
70.1	-116	-124	-135	-140

2. **NPR (Noise power ratio)**, tested in SSB mode (2.4 kHz) at 0, +10, +20 and +30 dB RF gain. Receiver A tuned to notch center in all cases. Noise loading set just below onset of ADC clipping (-1 dBFS). NPR read off spectrum scope (noise level outside notch minus noise level at bottom of notch.) See Figure 1.

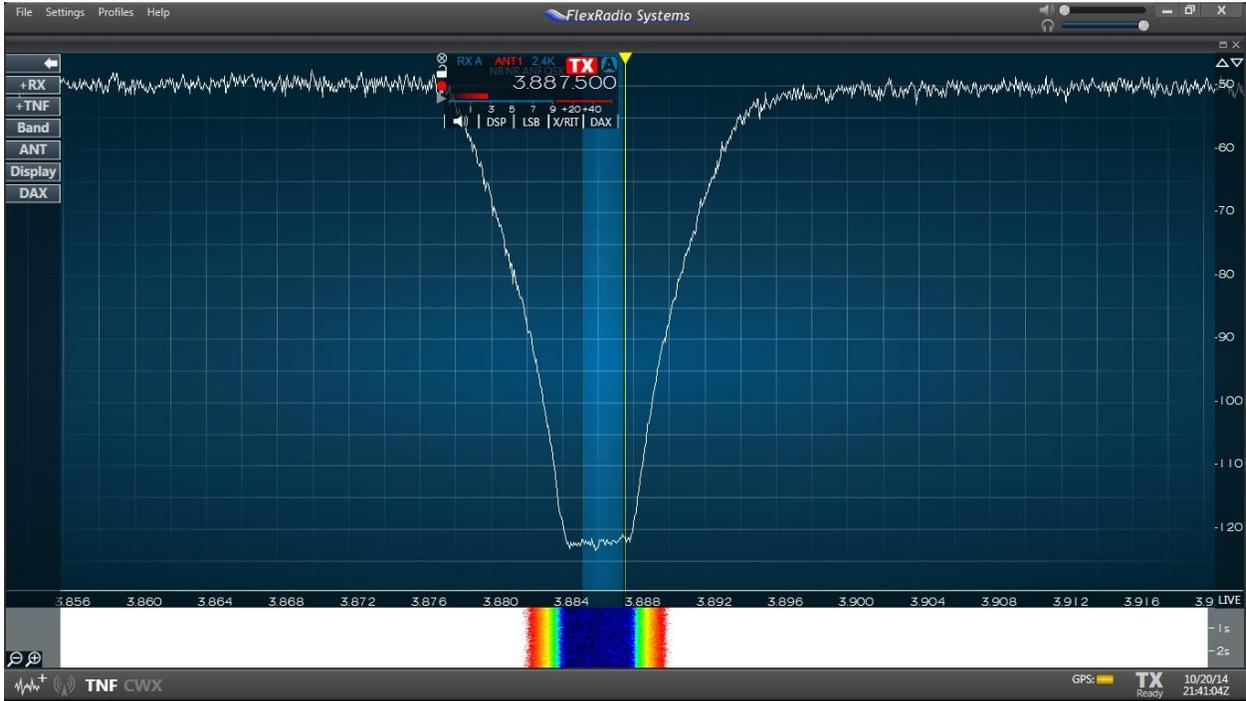
Table 2: V1.3.8 NPR test data.

U/L	Bandstop kHz	Bandpass kHz	Noise loading dBm				NPR dB				Calc. NPR (ADC) ^b
			RF Gain dB				RF Gain dB				
			0	+10dB	+20	+30	0	+10	+20	+30	
L	1940	60-2044	-5	0	-17	-26	66 ^a	73	73	66	80.5
L	1940 WIDE		-5	-18	-16	-31	71	68	76	65	
L	3886	60-4100	0	-1	-16	-30	74	72	72	67	77.4
L	3886 WIDE		0	-12	-16	-32	73	72	71	66	
U	5340 ^c	60-5600	-1	-13	-23	-33	75	71	71	68	76.1
L	7600 ^c	316-8160	-1	-13	-24	-33	74	71	70	65	74.6

Notes on NPR test:

- a. Note NPR degradation as compared to WIDE value at 0 dB gain. This may indicate some passive IMD in 160m preselector. Normally, NPR increases with the preselector in-line.
- b. The calculated NPR value for the ADC is the theoretical value for the ADI AD9467 ADC, normalized to the noise bandwidth (bandpass filter BW) used in each test case. (Ref. 1).
- c. WIDE only (no preselector at these test frequencies).

Figure 1: NPR at 3886 kHz, RF Gain = 0 dB.



3. **RMDR (Reciprocal mixing dynamic range). Test setup:** Marconi 2018A signal generator, 3 dB pad, 9.830 MHz 4-pole bandstop filter (> 80 dB notch depth), 0-110 dB step attenuator, DUT (RX A port). Noise floor read on S-meter in CW mode (500 Hz bandwidth) with DUT terminated in 50Ω. Signal generator frequency (f_0) tuned for max. null; DUT tuned to f_0 . Signal generator then tuned to f_0 - offset and output P_i increased to raise detected noise by 3 dB. $RMDR = P_i - (\text{noise floor with generator off.})$ **Note:** The residual phase noise of the measuring system is the limiting factor in measurement accuracy.

Table 3: Reciprocal Mixing Dynamic Range (RMDR) at 9830 kHz.

Δf kHz	P_i dBm	RMDR dB	Phase noise dBc/Hz
1	-5	114	141
2	-2.5	117	144
3	-3	116	143
5	-2	117	144
10	0	120	147
20	+3	126	153
Noise Floor = -119 dBm			

4. **Two-Tone IMD (IFSS, Interference-Free Signal Strength)** tested in CW mode (500 Hz), 0 dB RF gain. Test frequencies: $f_1 = 14100$ kHz, $f_2 = 14102$ kHz. IMD_3 products: 14098/14104 kHz. IMD_3 product level was read on S-meter in a 500 Hz CW detection bandwidth at various test-signal power levels in normal mode, with 0 dB RF gain selected. The ITU-R P-372.1 band noise levels for typical urban and rural environments are shown as datum lines. The test results are given in Figures 2 and 4.

Figure 2: IFSS (two-tone IMD) curve for 0 dB RF gain.

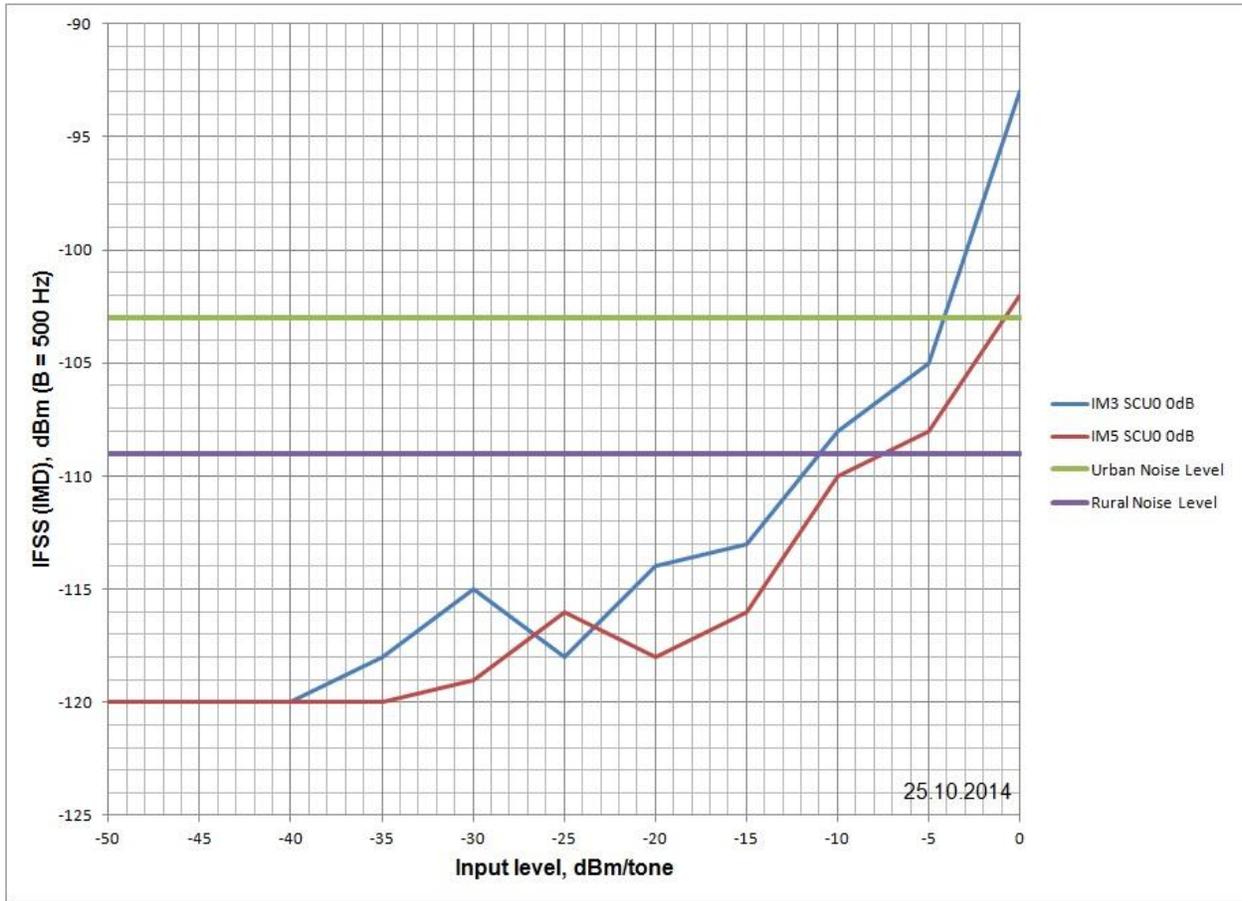


Figure 3: Typical IFSS spectrum scope display, showing IMD3 products.

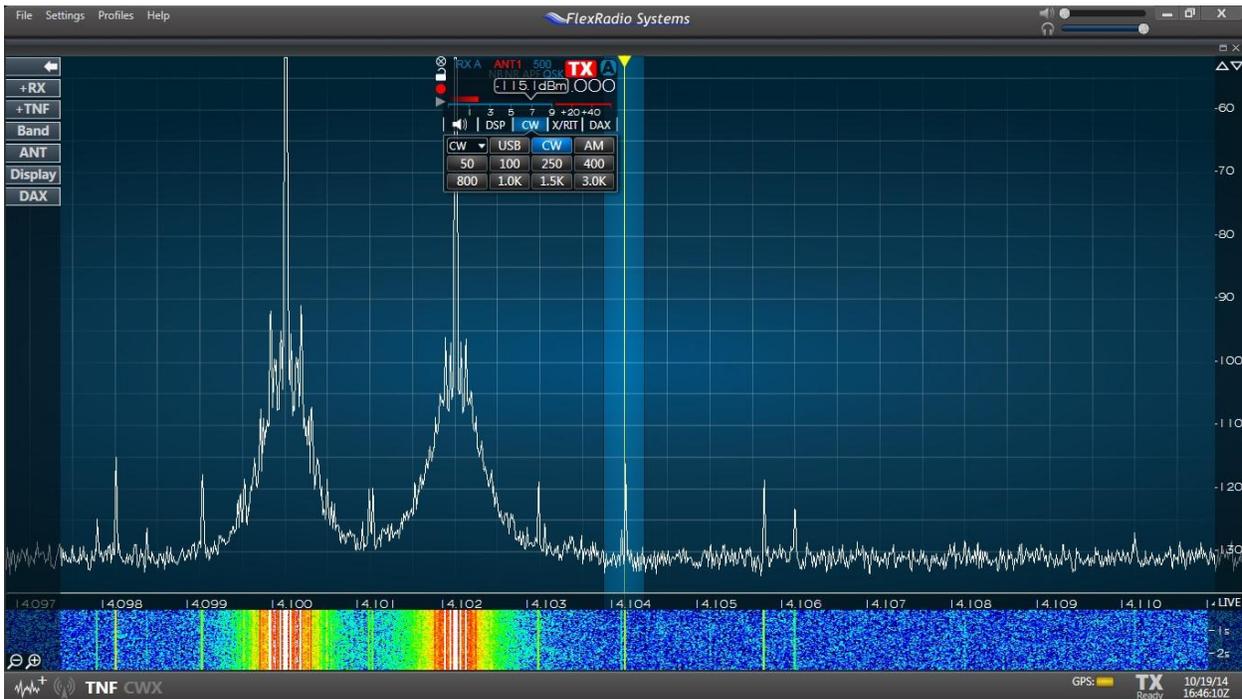
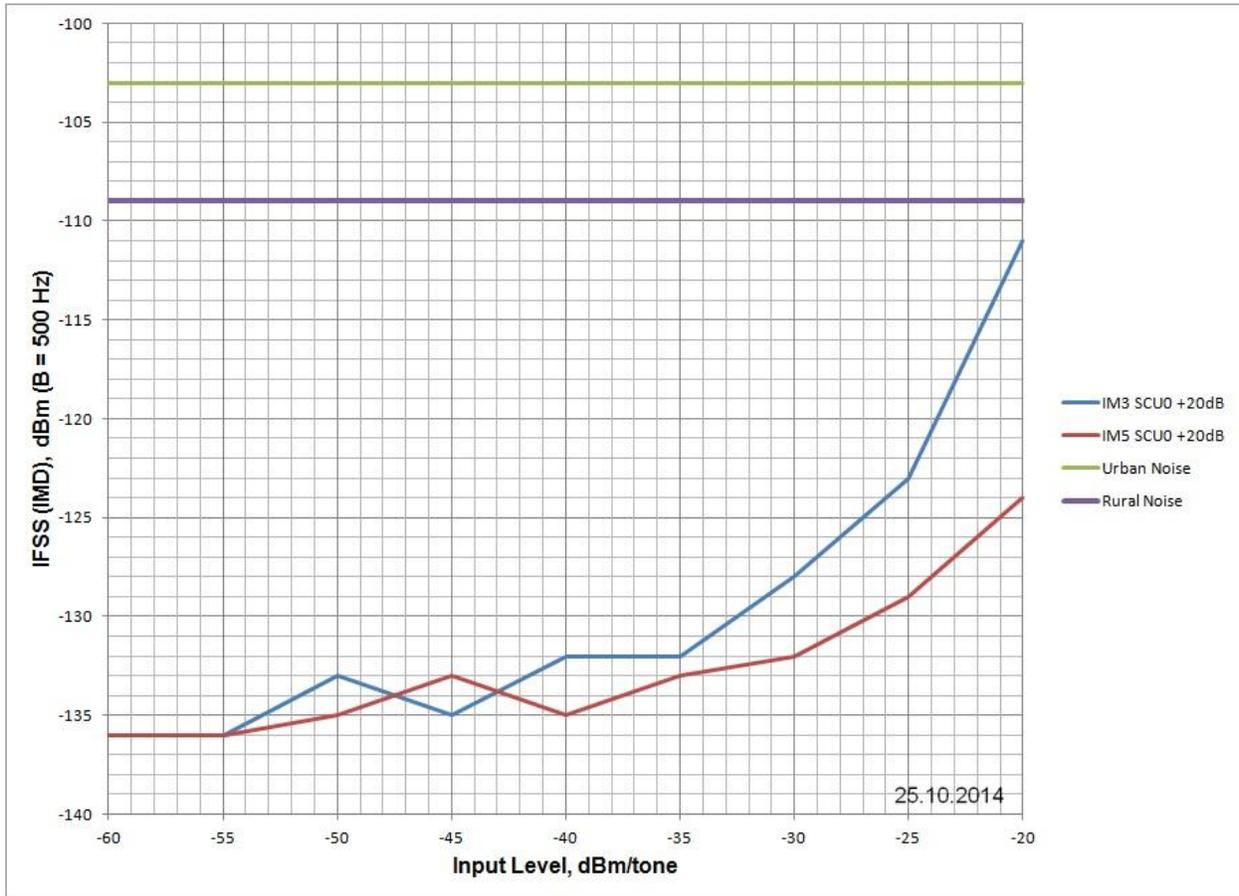


Figure 4: IFSS curves for +20 dB RF gain.



Note on IFSS (2-tone IMD3) test: This is a new data presentation format in which the amplitude relationship of the actual IMD products to typical band-noise levels (*Ref. 3*) is shown, rather than the more traditional DR_3 (3^{rd} -order IMD 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 and then falling off. In a conventional receiver, SFDR falls with increasing input power.

The SFDR (spurious-free dynamic range) 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.

It will be seen from Figure 2 that with 0 dB gain, the IMD curve approximates 1^{st} order, whereas with 20 dB RF gain, the curve is closer to 3^{rd} -order. This is due to non-linearity in the RF preamp placed ahead of the ADC input when RF gain = 20 dB.

Note on Dither: The AD9467 ADC employed in the Flex-6500/6700 does not have on-chip dither. Thus, incidental dither due to band noise and multiple input signals will improve IFSS at low signal levels by converting IMD products to white noise. For small-signal inputs, the front-end sampling circuit typically contributes very little distortion, and, therefore SFDR is likely to be limited by tones caused by nonlinearities due to random component mismatches. Thus, for small-signal inputs (typically 6 dB below clip level), dithering can significantly improve SFDR by converting these tones to white noise. (*Ref. 4*).

In practice, IMD levels will always be lower with an antenna connected than in a lab setup, as band noise (usually several dB above the ADC noise floor) will dither the ADC adequately.

DR₂ (IMD₂ dynamic range) tested at 14.020 MHz, WIDE, in CW mode (500 Hz), 0 dB RF gain. Test frequencies: $f_1 = 6000$ kHz, $f_2 = 8020$ kHz. IMD₂ product: 14020 kHz. Test-signal level was adjusted for a 3 dB increase in audio output, and DR₂ & IP₂ calculated. The test was performed in Normal and WIDE modes.

$$DR_2 = P_i - MDS.$$

$$IP_2 = (2 * DR_2) + MDS$$

Test Results: Refer to Table 5.

Table 5: IMD2 Dynamic Range (DR2)

Mode	Preselector	P _i dBm/tone	DR ₂ dB	IP2 dBm
Normal	In	-14	104	+90
WIDE	Out	-26	90	+67
Noise Floor = -118dBm Normal, -119 dBm WIDE				

- Inband IMD** tested in USB mode (2.4 kHz), Normal, 0 dB RF gain. Test frequencies: $f_1 = 14100.9$ kHz, $f_2 = 14101.1$ kHz. IMD3 products: 14100.7/14100.3 kHz. The baseband spectrum analyzer was connected to the PHONES jack and the IMD product levels read off the screen.

Test Result: At -4 dBm/tone input level, inband IMD < -85 dBc.

- (NEW) Audio THD** tested in USB mode (2.4 kHz), Normal, 0 dB RF gain. Test frequency 14101 kHz. The distortion meter was connected to the PHONES jack and audio output adjusted for 1.0% THD with an 8Ω load. The corresponding audio power output was noted. Then, the baseband spectrum analyzer was connected to the PHONES jack and the harmonic levels over a 10 Hz – 10 kHz sweep with an 8Ω load were noted.

Test Results: THD = 1.0% for +12 dBm output in 8Ω at 1 kHz. (This is a comfortable headphone listening level.)

Table 6: Audio Harmonic Content

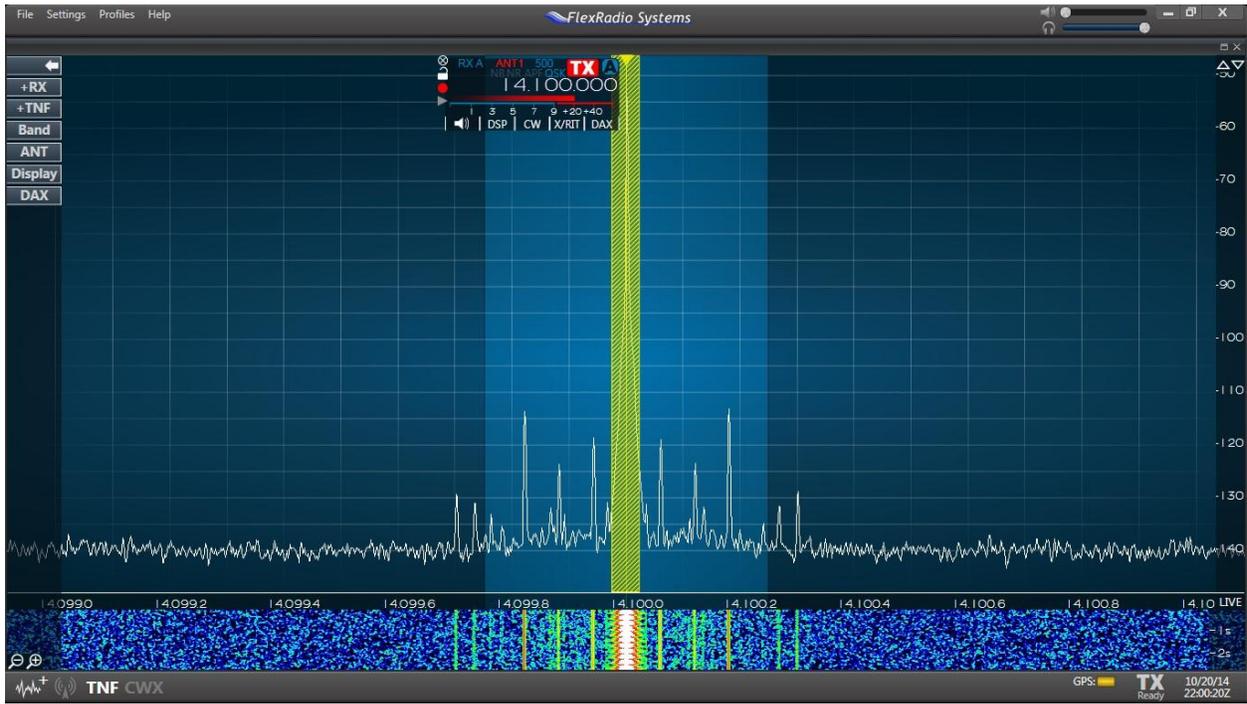
Even Harmonics at 1% THD (dBc)				
2nd	4th	6th	8th	10th
-43	-53	-62	-66	-72
Odd Harmonics: All < -85 dBc				

- (NEW) TNF (Tracking Notch Filter) Depth** tested in CW mode (500 Hz). Test frequency 14100 kHz. A TNF is opened on the displayed test signal. The input level P_i is increased until the audio output level increases by 3 dB. Notch depth = P_i – MDS.

Table 7: TNF Test Results

Width Hz	Depth Setting	P _i dBm	Depth dB
50	Normal	-58	60
	Deep	-53	65
	Very Deep	-51	67
Noise Floor = -118dBm			

Figure 4: Typical TNF display.



B. Transmitter Tests

- No.1: V1.2.1; Nos. 2-7: V1.0.0; No. 8: V1.0.5.

- 2-Tone Transmitter IMD.** Test setup: HP 8935 test set configured as 2-tone generator, connected to DUT BAL input jack. HP 8563E spectrum analyzer connected to DUT ANT1 via 50 dB 300W power attenuator. Test tones 700 and 1700 Hz. Audio levels set for equal tone amplitudes on SA. IMD measured at 100W PEP on 1.9, 3.6, 7.1, 14.1, 28.4 and 50.1 MHz. Refer to Table 7, and Figures 6 through 11.

Table 7. TX IMD in dBc (ref. 1 of 2 equal tones) at 100W PEP.

Freq. MHz	1.9	3.6	7.1	14.1	28.4	50.1
IMD order						
3rd	-27	-34	-46	-37	-31	-38
5th	-47	-39	-36	-36	-39	-31
7th	-53	-42	-42	-44	-42	-44
9th	-53	-46	-49	-46	-46	-69
Subtract 6 dB for IMD ref. 2-tone PEP.						

Figure 6.

F1e x 6 7 0 0 , V A 7 L W E . 1 6 0 m T X I M D , 1 0 0 W . 0 3 0 5 1 4 .

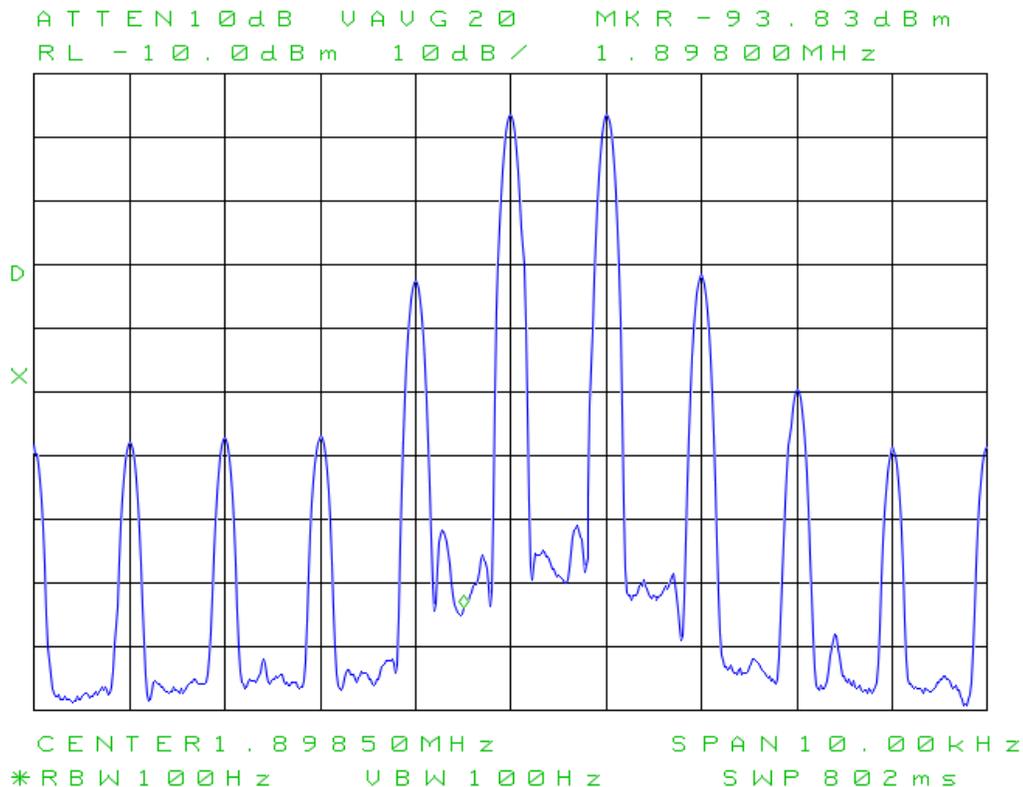


Figure 7.

F l e x 6 7 0 0 , V A 7 L W E . 8 0 m T X I M D , 1 0 0 W . 0 3 0 5 1 4 .

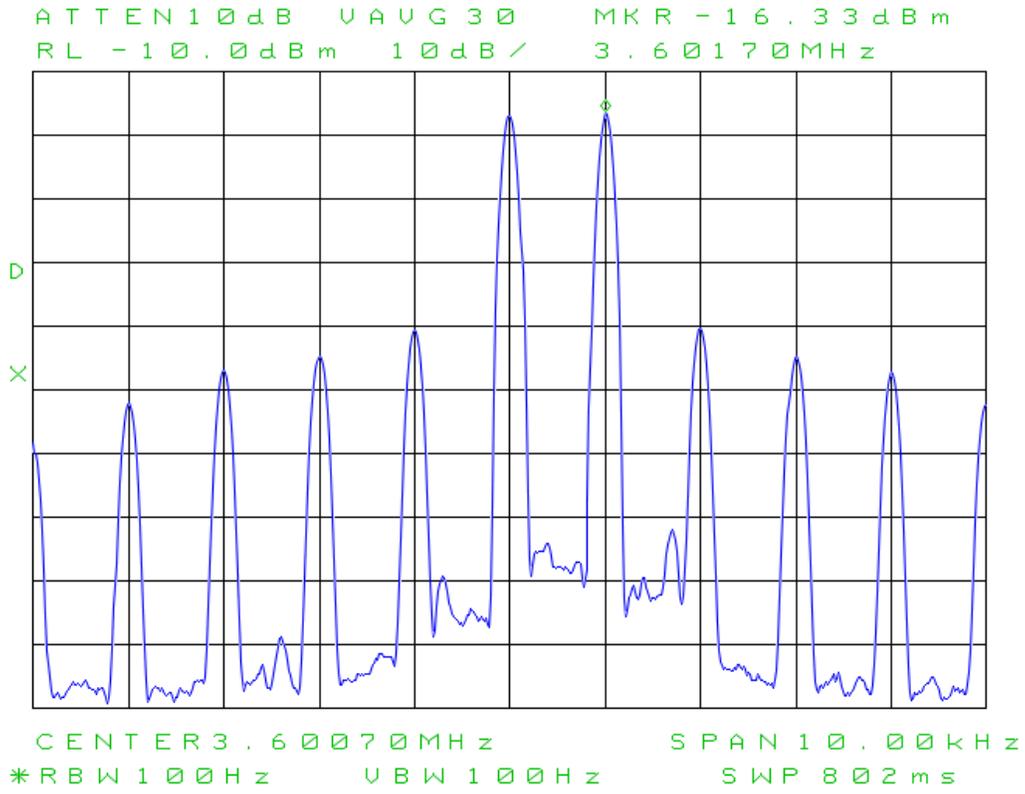


Figure 8.

Flex 6700, VA7LWE.40m TX IMD, 100W.030514.

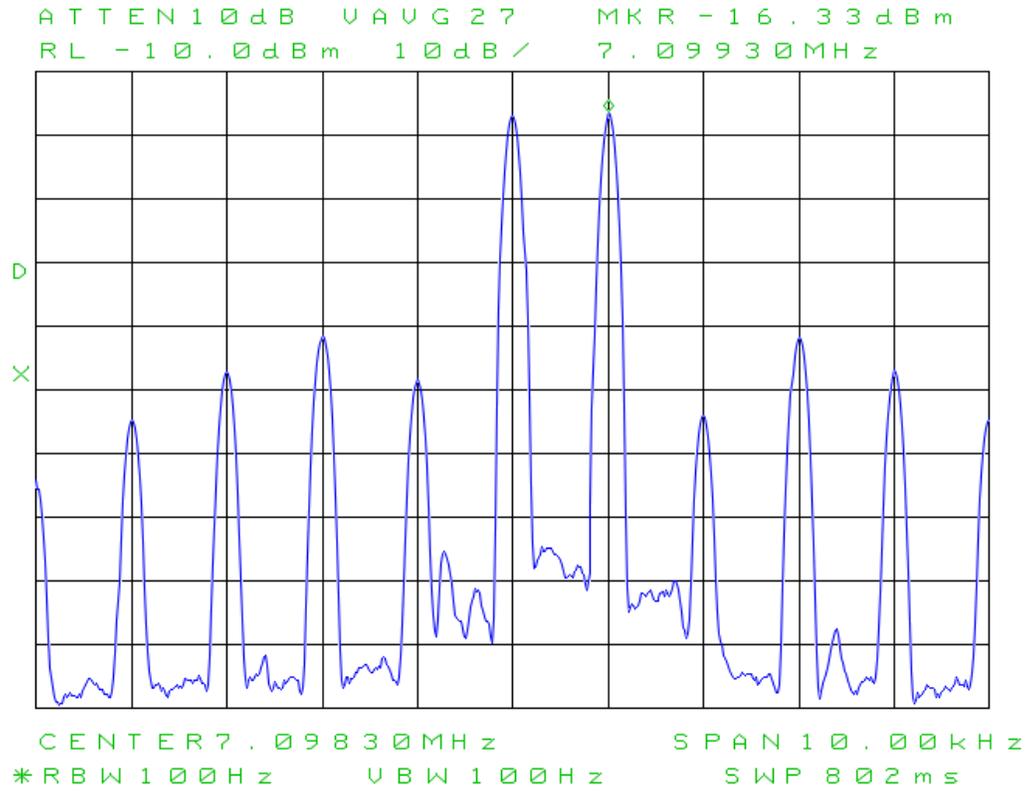


Figure 9.

F1e x 6 7 0 0 , V A 7 L W E . 2 0 m T X I M D , 1 0 0 W . 0 3 0 5 1 4 .

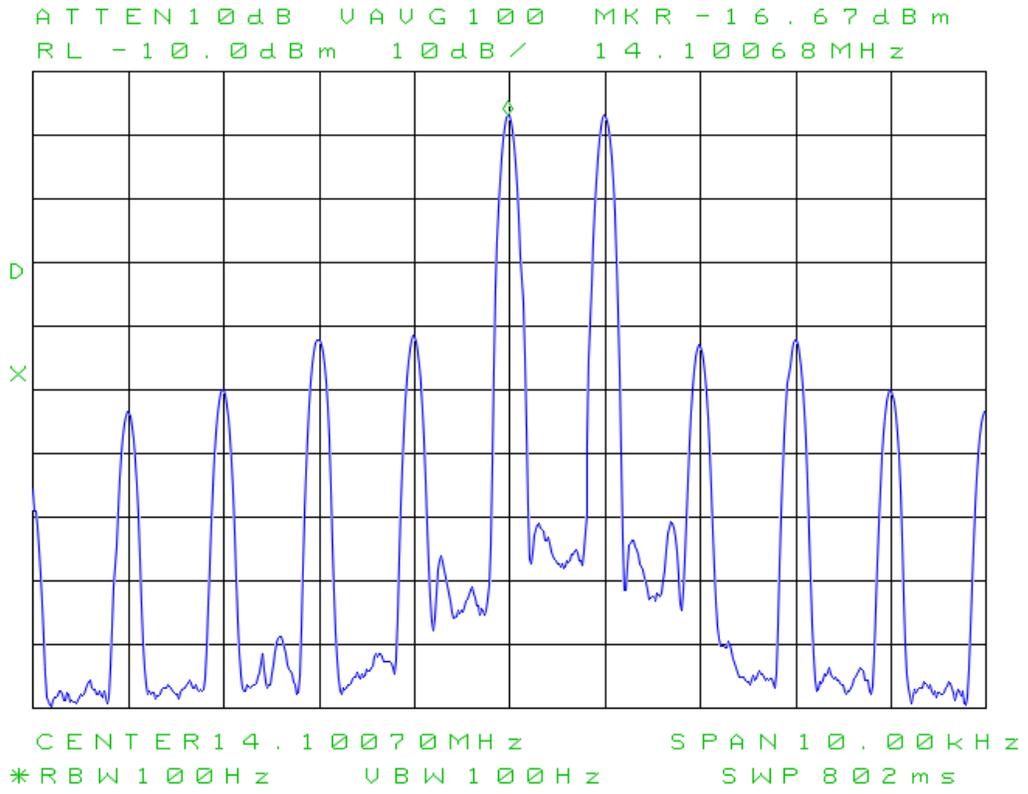


Figure 10.

FLEX-6700, VA7LWE, 10m TX IMD, 100w. 030514.

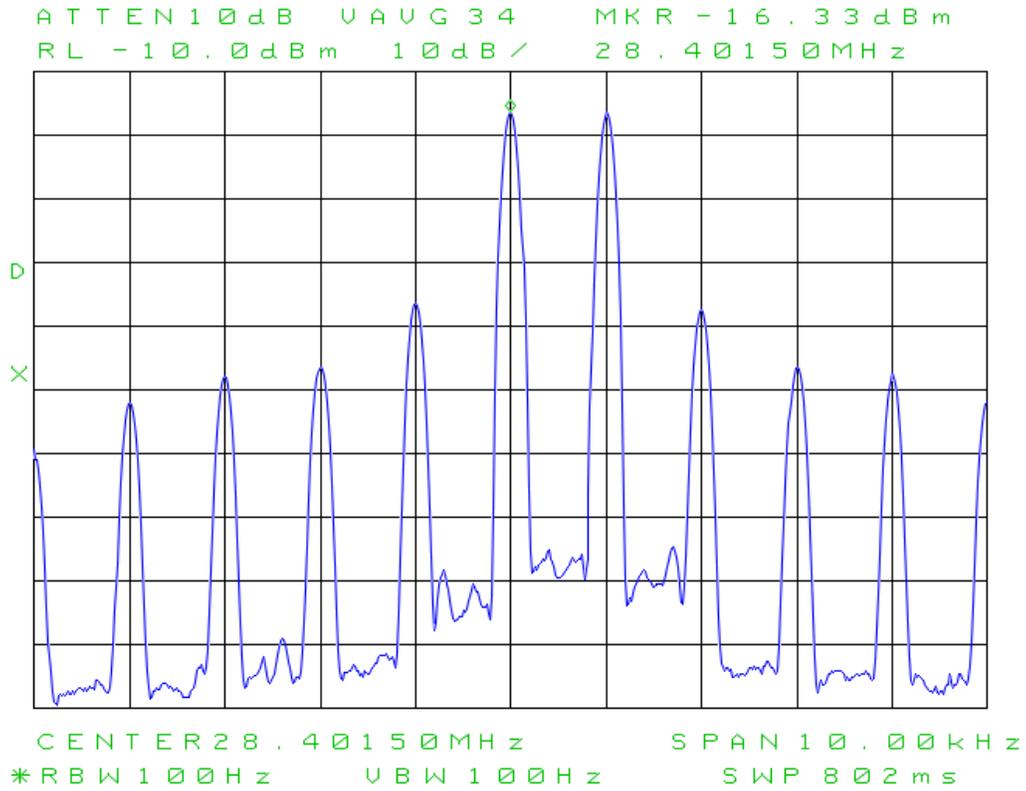
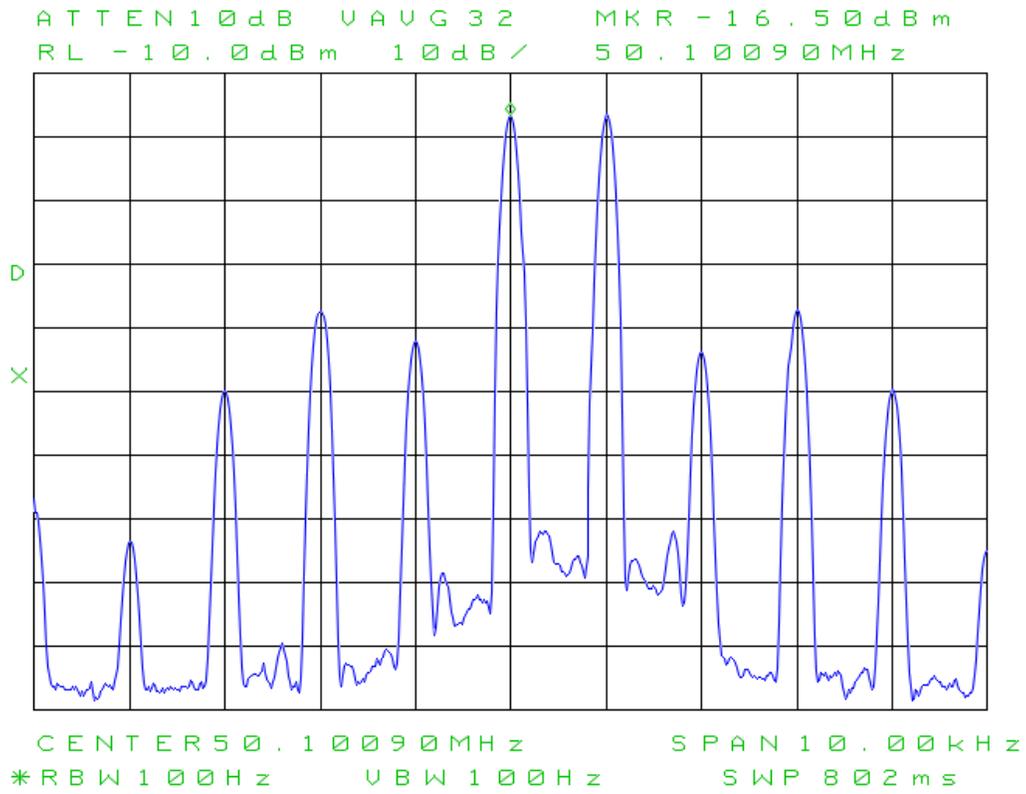


Figure 11.

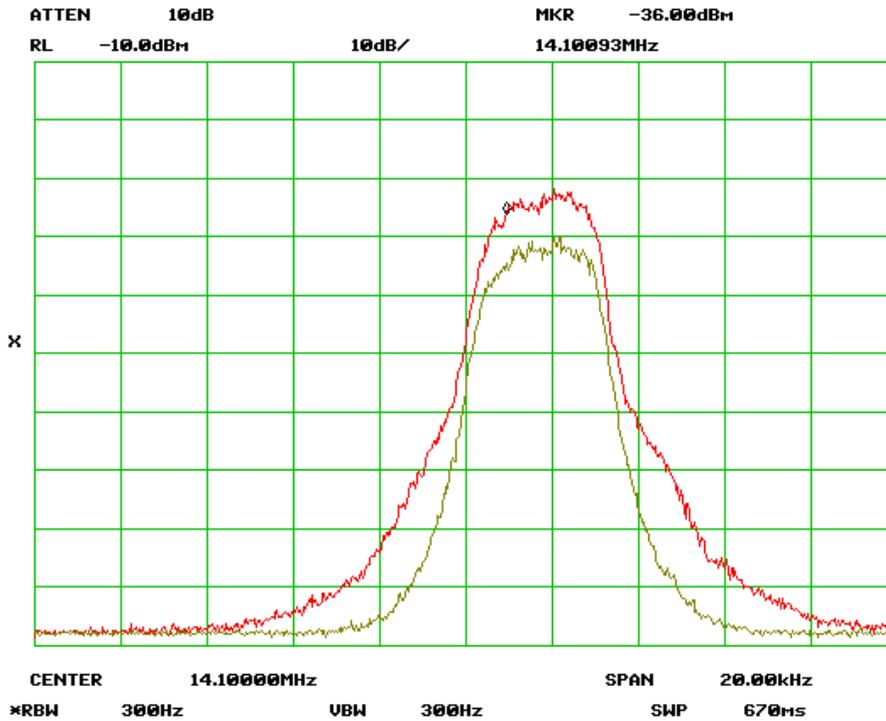
File x6700, VA7LWE.6m TX IMD, 100W.030514.



- TX Noise IMD.** Test setup as for Test 1, except that HP 8935 applies white noise to DUT BAL input. Test run at 14.1 MHz, 100W & 25W PEP. Note that the IMD skirts are steeper at the lower power level. Refer to Figure 12.

Figure 12.

Flex-6700 S/N 2203-3088-6700-5227, TX noise IMD, 14.1 MHz USB,R: 100W PEP,G: 25W PEP.13.10.2013.



- 2-tone & voice SSB envelope.** Test setup as for Test 1, except that Tek 455 oscilloscope terminated in 50Ω is connected to DUT ANT1 via power attenuator. Test run at 14.1 MHz, first with 2-tone baseband, then with voice on hand mic. See Figures 13 through 16.

Figure 13. 2-tone SSB envelope, 90W PEP.

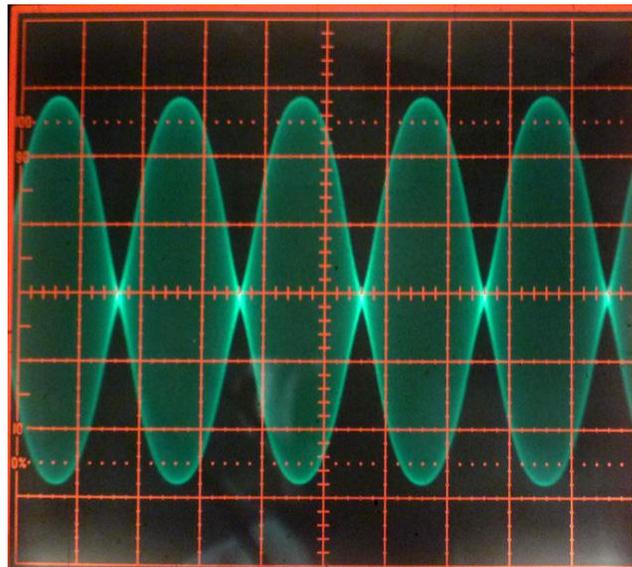


Figure 14. 2-tone SSB envelope, 90W PEP. Note slight flat-topping.

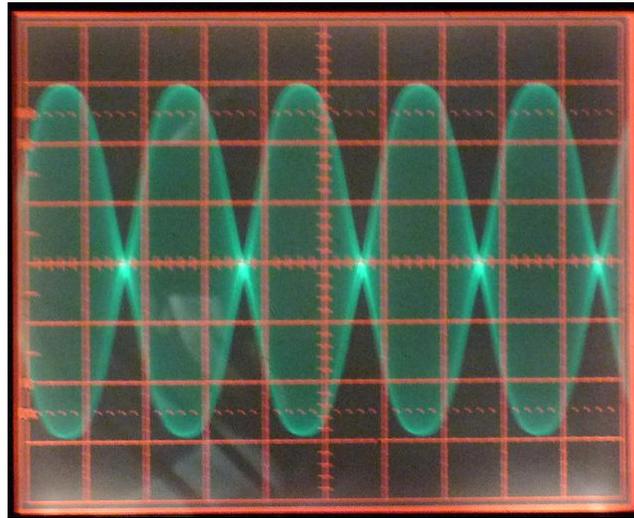


Figure 15. SSB voice envelope, 100W PEP, no compression.

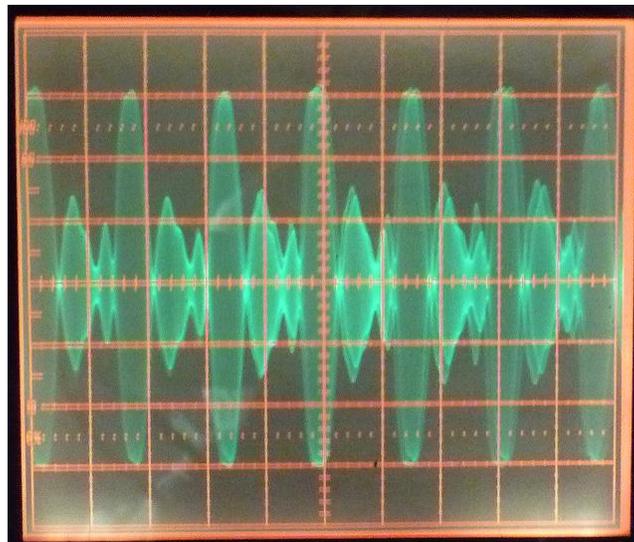
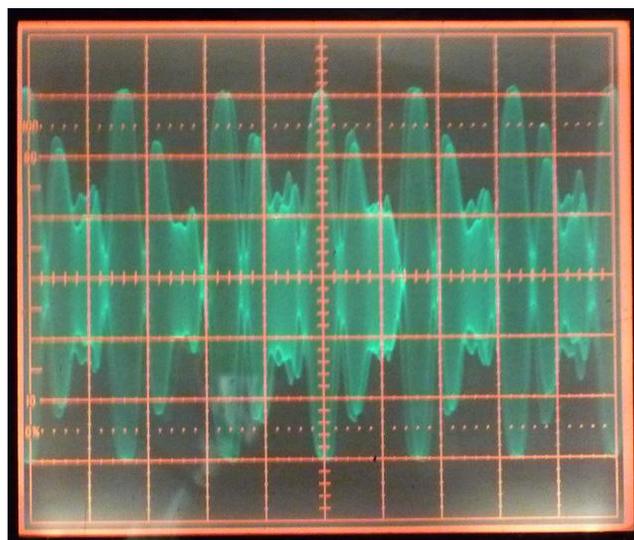


Figure 16. SSB voice envelope, 100W PEP, 6 dB compression on voice peaks.



- TX composite noise.** HP 8563E spectrum analyzer with HP 85671A phase noise utility, connected to DUT ANT1 via 50 dB 300W power attenuator. Test run at 100W CW on 3.6, 14.1 and 50.1 MHz. Refer to Figures 17 and 18.

Note: The FLEX-6700 composite noise is significantly lower than the measurement limitations of the aforementioned test equipment and thus cannot be accurately measured in this lab. The graphs below demonstrate the limits of the measurement equipment and that the radio's composite noise is below and not additive to that of the analyzer.

Figure 17.

Flex-6700 S/N 2213-3088-6700-5227. . COMP noise, 100W CW. R: 14.1 MHz. C: 3.6 MHz. 13.10.2013.

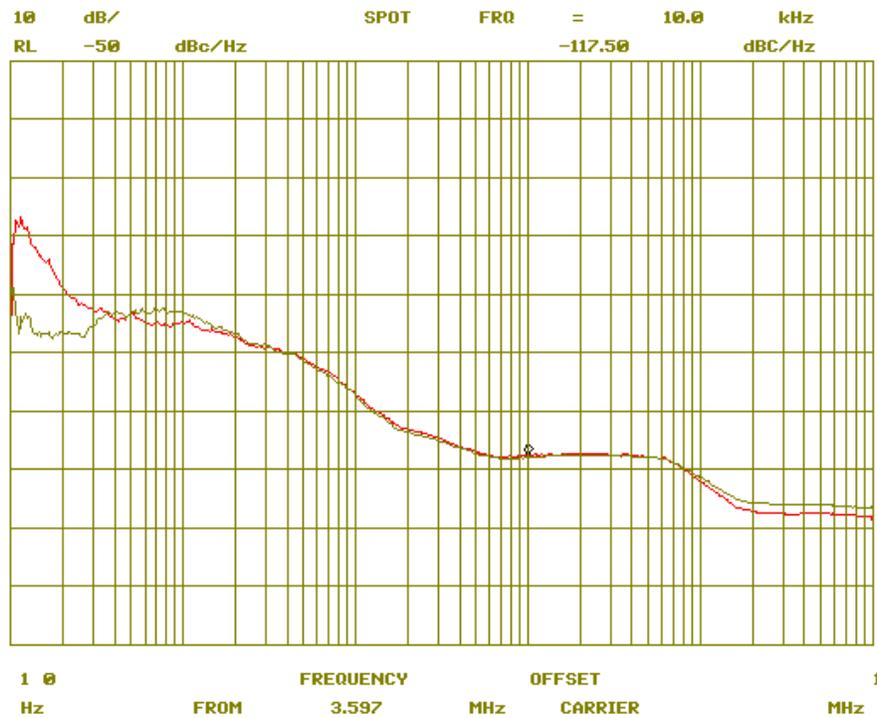
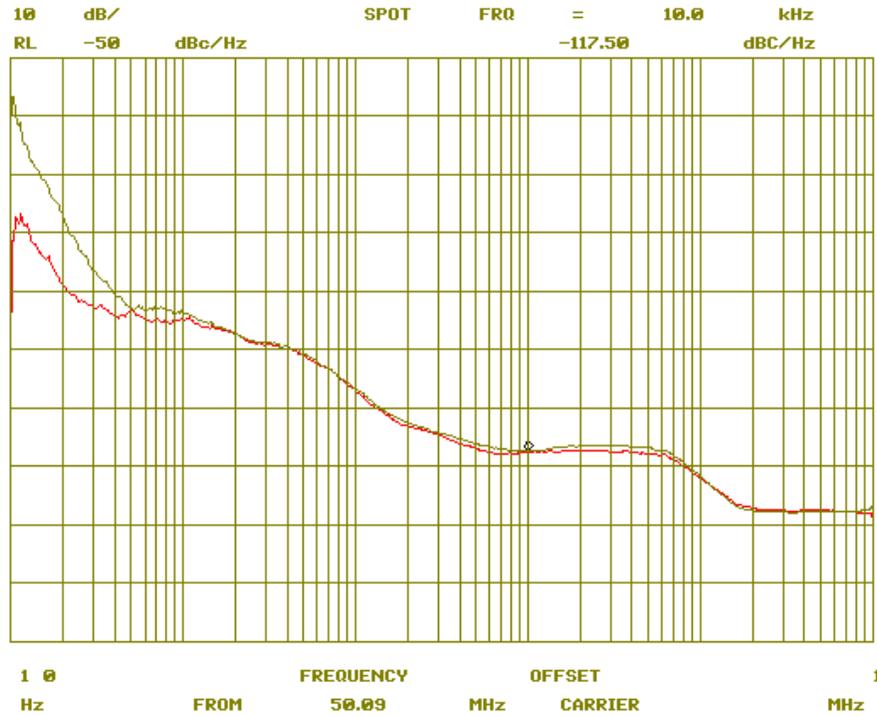


Figure 18.

Flex-6700 S/N 2213-3088-6700-5227. COMP noise, 100W CW. R: 14.1 MHz. G: 50.1 MHz. 13.10.2013.



5. **TX harmonics & spurs.** HP 8563E spectrum analyzer with HP 85672A spurious response utility, connected to DUT ANT1 via 50 dB 300W power attenuator. Test run at 100W CW on 3.6, 14.1 and 50.1 MHz. Refer to Figures 19, 20 and 21, and Table 12.

Figure 19.

Flex-6700 S/N 2213-3088-6700-5227. Harmonics, 3.6 MHz, 100W CW. 13.10.2013.

HARMONIC	MEASUREMENT	RESULTS			
FUNDAMENTAL	SIGNAL:	3.600	MHz	-11.0	dBm
HARMONIC	LEVEL	dBc	FREQUENCY		
2	-82.0	*	7.200	MHz	
3	-78.5		10.80	MHz	
4	-102.2	*	14.40	MHz	
5	-88.7		18.00	MHz	
6	-96.5		21.60	MHz	
7	-104.3	*	25.20	MHz	
8	-106.3	*	28.80	MHz	
	* MEASURED NOISE	LEVEL OR	MAY BE		
		LOST	SIGNAL.		
TOTAL (OF	HARMONIC HARMONICS	DISTORTION MEASURED)	=	0	%

Figure 20.

Flex-6700 S/N 2213-3088-6700-5227. Harmonics, 14.1 MHz, 100W CW. 13.10.2013.

HARMONIC		MEASUREMENT		RESULTS	
FUNDAMENTAL		SIGNAL:		14.10	MHz
				-9.8	dBm
HARMONIC	LEVEL	dBc	FREQUENCY		
2	-89.0	*	28.20	MHz	
3	-76.0		42.30	MHz	
4	-88.0		56.40	MHz	
5	-97.2		70.50	MHz	
6	-106.3	*	84.60	MHz	
7	-105.8	*	98.70	MHz	
8	-106.3	*	112.8	MHz	
* MEASURED		LEVEL	MAY	BE	
NOISE		OR	LOST	SIGNAL.	
TOTAL	HARMONIC	DISTORTION	=	0 %	
(OF	HARMONICS	MEASURED)			

Figure 21.

Flex-6700 S/N 2213-3088-6700-5227. Harmonics, 50.1 MHz, 100W CW. 13.10.2013.

HARMONIC		MEASUREMENT		RESULTS	
FUNDAMENTAL		SIGNAL:		50.10	MHz
				-10.2	dBm
HARMONIC	LEVEL	dBc	FREQUENCY		
2	-81.2	*	100.2	MHz	
3	-72.8		150.3	MHz	
4	-77.7		200.4	MHz	
5	-98.7		250.5	MHz	
6	-100.3	*	300.6	MHz	
7	-105.5	*	350.7	MHz	
8	-101.0	*	400.8	MHz	
* MEASURED		LEVEL	MAY	BE	
NOISE		OR	LOST	SIGNAL.	
TOTAL	HARMONIC	DISTORTION	=	0 %	
(OF	HARMONICS	MEASURED)			

Table12. TX non-harmonic spurs.

Test Freq. MHz	Swept range MHz	Non-harmonic spurs dBc
3.6	0.01 - 50	< -80
14.1	0.01 - 100	< -80
50.1	0.01 - 250	< -80

6. **AM Sidebands & THD.** Test setup as for Test 1, except that HP 8935 applies 1 kHz test tone to DUT BAL input. Test run at 14.1 MHz, 25W carrier output, 90% modulation. Refer to Figure 22.

Calculated THD \approx **2.8%**.

Figure 22.

Flex-6700 S/N 2213-3088-6700-5227. Sidebands, 14.1 MHz, 25W AM. 13.10.2013.

DISCRETE	SIDEBAND	SEARCH	RESULTS
CARRIER	FREQ:	14.10	MHz
CARRIER	POWER:	-15.3	dBm
OFFSET	FREQ	- OFFSET	+ OFFSET
		dBc	dBc
-----		-----	-----
.998	kHz	-7.0	-7.0
1.997	kHz	-33.0	-33.5
2.996	kHz	-35.2	-35.2
4.004	kHz	-62.8	-59.0
5.003	kHz	-54.3	-53.8

FOUND: 5 SETS OF SIDEBANDS

7. **CW Keying Envelope.** CW mode, Break-in on, Iambic on, 14.1 MHz, 100W. Keying speed 60 wpm. Paddle plugged into KEY jack. Oscilloscope terminated in 50Ω connected to DUT ANT1 via power attenuator. Send a string of dits at 60 wpm, then 29 wpm; capture keying envelope. Measured CW rise time (10% to 90% amplitude) \approx **2 ms** (60 wpm), **4 ms** (29 wpm), minimal overshoot. Refer to Figures 23a, 23b.

Figure 23a. CW keying envelope, 60 wpm. Vert: ± 3 div = 100W. Hor: 10 ms/div.

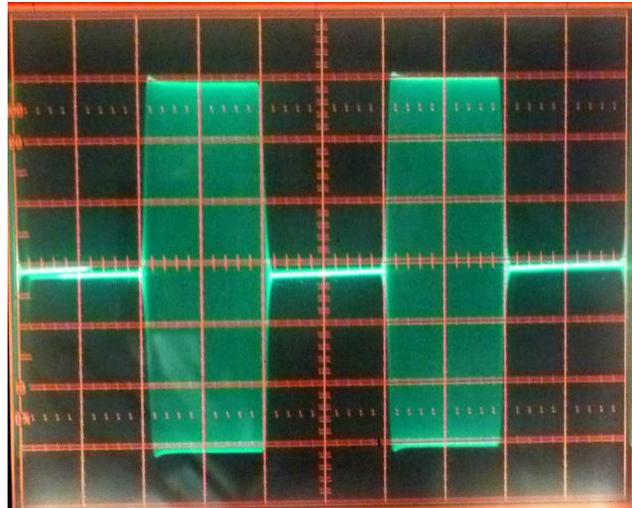
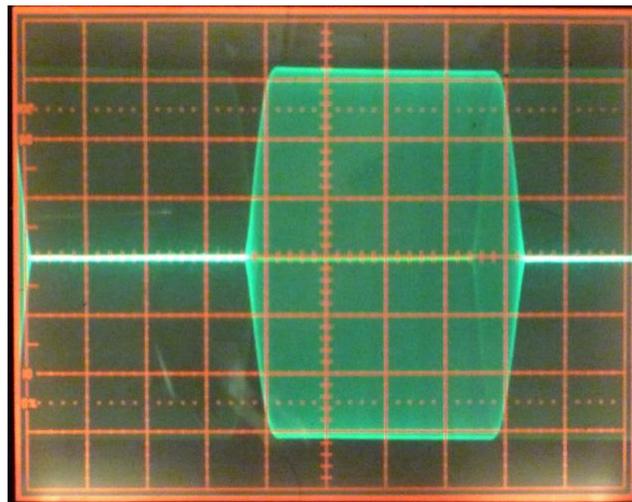


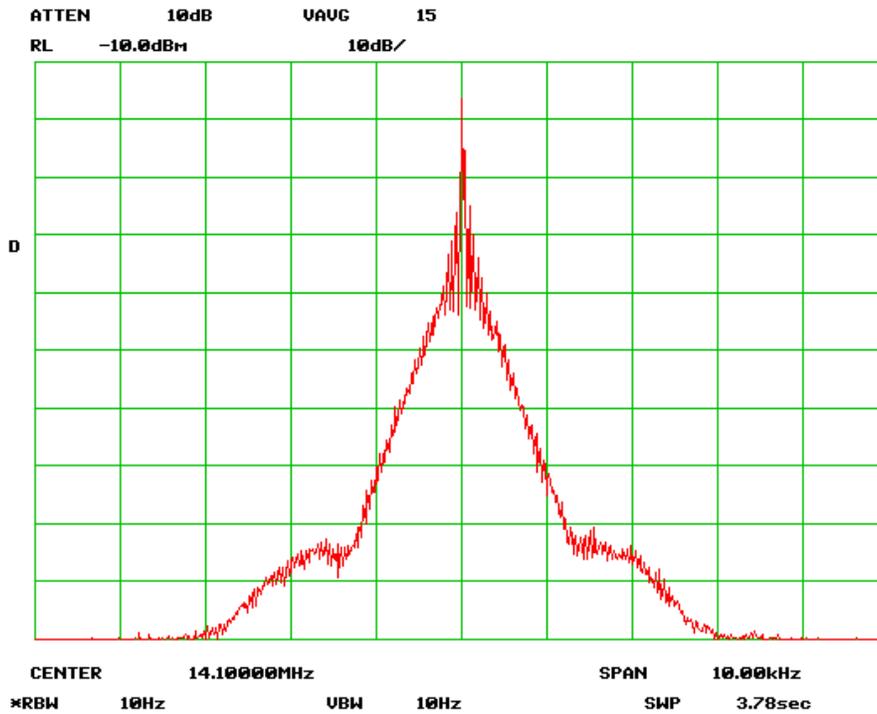
Figure 23b. CW keying envelope, 29 wpm. Vert: ± 3 div = 100W. Hor: 10 ms/div.



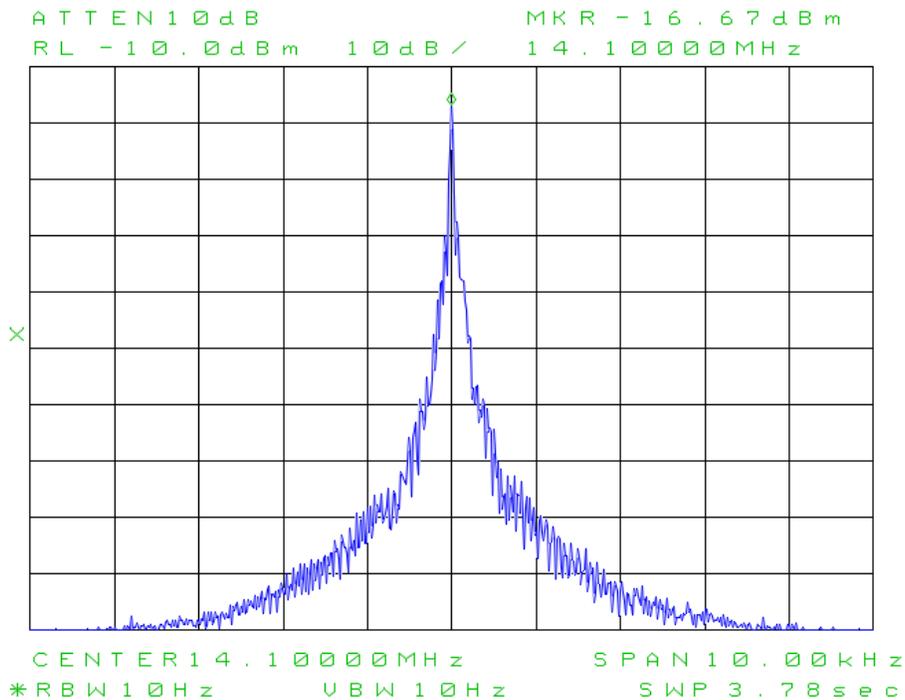
8. **CW Keying Sidebands.** CW mode, Break-in on, lambic on, 14.1 MHz, 100W. Keying speed 60 wpm. Paddle plugged into KEY jack. Spectrum analyzer terminated in 50Ω connected to DUT ANT1 via power attenuator. Send a string of dits at 60, then 29 wpm; capture keying spectra. Refer to Figure 24.

Figure 24.

Flex-6700, S/N 2213-3088-6700-5227. CW keying sidebands, 14.1 MHz, 100W, 60wpm. 23.11.2013.



File 6700 VA7LWE CW sidebands 29wpm 261114



C. Brief on-air trial: impressions.

I brought the 6700 into my station for a brief try-out, and connected it to the Yaesu Quadra amplifier which in turn feeds the Cushcraft R8 vertical. Using my Heil PR-781 microphone connected to the 6700 via an XLR cable, I made several SSB contacts on 17m. One of the stations was kind enough to assist me in setting up the TX EQ and compression, whereupon he gave me an excellent audio report – “clear, articulate, punchy audio” under variable band conditions with QSB.

I found on-air handling of the radio very easy and intuitive. Tuning in a station with the mouse wheel was quite convenient, although for my own use I would add a tuning-knob accessory. The combined spectrum-scope and waterfall presentation is first-class – superior to any other SDR I have used – and I found point-and-click selection of the desired signal, with “zeroing-in” via the mouse wheel, a very useful feature. A station with excessively wide SSB audio and a number of in-band artifacts had “no place to hide” from the 6700’s lab-quality scope.

Adjacent-channel rejection and overall receive audio quality were superb; the DSP detection-channel filters are “brick-wall”, as is the SSB transmit filter. I also found NR fairly effective; it lowered the band-noise level but did not degrade the audio. There was no impulse noise on which to test the NB on-air.

The 6700 appeared to “pull up” weak SSB signals with somewhat greater clarity than my conventional transceiver. In addition, in the absence of signals I found the receiver subjectively very quiet.

Operation with the Quadra was easy to set up. In addition to connecting the usual RF drive, keying and ALC cables, the Quadra Band Data 2 cable was simply plugged into the 6700’s PTT IN RCA jack to obtain a tuning carrier for semi-auto bandswitching and tuning. The 30W AM carrier, which I used for these functions, was somewhat marginal, as the Quadra requires approx. 60W. Activation of the TUNE key function from the PTT jack, or an FSK or FM mode, would resolve this.

All in all, I found the Flex-6700 to be a superb performer and a very pleasant operating experience in my station.

D. Acknowledgements:

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E. References:

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