Yaesu FT-710 User Evaluation & Test Report

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Figure 1: The Yaesu FT-710.

Introduction: This report describes the evaluation of FT-710 S/N 2L040521 in two parts: operational evaluation and lab testing. ***Appendix 1*** presents results of an RF lab test suite performed on the radio. I was able to spend a few days with the FT-710 in my ham-shack, and thus had the opportunity to exercise the radio's principal features and evaluate its on-air behavior.

1. Physical "feel" of the FT-710: The FT-710 is fairly small and light, considering that it is a full-featured 100W-class transceiver with a built-in ATU. The case dimensions are 239(W) × 247(D) × 80(H) mm and the radio weighs 4.5 kg.

The FT-710 features a large color touch-screen display. This is a relatively new offering in Yaesu's "base" HF transceiver product line, offering easy band/mode selection and navigation through the radio's menus. The placement of many control functions on the touch-screen and in the FUNC and STEP/MCH/DSP knob menus has moved many controls off the front panel.

Owners of the Yaesu FTDX-101 and FTDX-10 series transceivers should find the FT-710 quite familiar, and should feel comfortable with it after a little familiarization with the touch-screen. In addition to the display, the front panel has a number of feature keys in locations similar to those on the FTDX-10 as well as the FUNC and STEP/MCH/DSP right of the display respectively. Pressing the FUNC knob opens a screen presenting a selection of softkeys at its bottom edge; touching one of these opens the associated matrix of parameters selectable by touching the relevant icon. Rotating FUNC without pressing it varies the value of the selected parameter; the value is displayed in an on-screen pop-up. The FUNC and STEP/MCH/DSP knobs are multi-turn and detented. The main tuning knob is large and has a knurled Neoprene ring and a rotatable finger-dimple; it turns very smoothly with minimal side-play.

Pressing and rotating STEP/MCH/DSP opens a pop-up ribbon on the right side of the screen. This ribbon allows adjustment of SHIFT/WIDTH (functionally equivalent to Twin PBT), NOTCH (manual notch within the AGC loop) and CONTOUR (a configurable post-AGC manual audio notch).

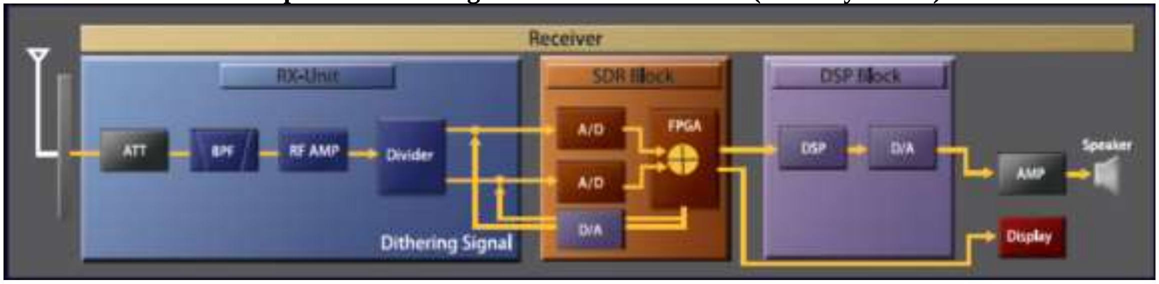
The RJ-45 MIC socket, and the 3.5mm PHONES jack, are on the left side of the front panel. The supplied SSM-75E hand mic (or one of Yaesu's optional mics) can be plugged into the mic jack. All the ports provided on other Yaesu radios are on the rear panel, including USB A and B ports, a DVI-D EXT. DISPLAY port, and TUNER/LINEAR and RTTY/DATA mini-DIN sockets. A muffin-type cooling fan is also mounted on the rear panel.

The SD card slot for memory storage and loading, recording and firmware upgrade is located on the front left upper side of the case. A SCREENSHOT function allows capture of the current screen image to the SD card as a PNG or BMP file by pressing/holding the MODE key.

The FT-710 is solidly constructed and superbly finished. Like other current Yaesu radios, it conveys a tight, smooth, and precise overall feel. The die-cast alloy chassis also serves as a heat dissipator, and the sheet-steel case is finished in an attractive black crinkle coating. The front panel has a smooth, matte surface.

2. FT-710 architecture: The FT-710 is the first Yaesu HF/6m transceiver to feature direct RF sampling/digital up-conversion SDR architecture. **In the receiver,** the RF signal from the antenna feeds a TI ADS62P45 dual-channel, 14-bit ADC (analogue/digital converter) in an I/Q configuration via a preselector. This is a set of contiguous, half-octave bandpass filters which protect the ADC from strong out-of-band signals. The ADC group digitizes a portion of the HF range defined by the preselector; the digital output of the ADC's feeds the Field-Programmable Gate Array (FPGA) which is configured as a digital down-converter (DDC) and delivers a digital baseband centered on 24 kHz, to the DSP which carries out all signal-processing functions such as selectivity, demodulation etc. A DAC (digital/analog converter) at the DSP output decodes the digital signal back to audio. Figure 2 is a simplified block diagram of the receiver section.

2: Simplified block diagram of FT-710 receiver (courtesy Yaesu).



The FPGA also drives the screen displays, including the fast FFT spectrum scope, waterfall, audio scope and audio FFT (spectrum analyzer). The spectrum scope span range is 1 kHz – 1 MHz. Other scope features are adjustable reference level (-30 to +30 dB), PEAK (scope trace color as function of level) and two RBW settings.
A "touch-tune" feature allows quick tuning to a signal displayed on the scope by touching the touching the desired signal in the scope field to center it.

A PRBS dither signal derived in the FPGA is applied to the ADC Divider input at all times to optimize IMD performance.

A dual-loop AGC system (RF and IF AGC) protects the ADCs from clipping in the presence of strong out-of-channel signals, and allows the receiver to go into “soft overload” at approx. +2 dBm RF input.

For more detailed insight into the FT-710 design and architecture, see ***References 5, 6.***

In the **transmitter,** the audio codec converts mic audio to a digital baseband, which the DSP then processes further and the digital up-converter in the FPGA then converts to a digital RF signal at the transmit frequency. This signal is converted to analog by the high-speed DAC to the RF excitation for the PA chain.

A 250 MHz low-noise master clock oscillator with a divider supplies 125 MHzclock signals to the ADCs, DAC and FPGA to assure excellent receiver RMDR and transmitter phase noise performance. The FT-710 incorporates a relay-chain type auto-tuner with a nominal 3:1 VSWR matching range. The tuner can be bypassed when not required.

3. The touch-screen: The large (95 × 56 mm) color TFT **touch-screen** displays a very clear, crisp image, with excellent contrast and color saturation, and an LCD backlight. The home screen (see Figure 1) displays the meter and the current frequency in the upper field, the preamp/attenuation/AGC selections and the Filter Function display in the next field down and the spectrum scope in the lower field. A row of softkeys related to the scope/waterfall is at the bottom of the screen. The MULTI softkey activates the audio scope group below the main waterfall.

The Filter Function display is a graphical representation of the receive passband which shows the effect of the SHIFT, WIDTH, NOTCH, CONTOUR and APF controls graphically.

Pressing and holding the DNF, DNR and NB keys makes their settings accessible by rotating the FUNC knob. These can be used to select notch width/center frequency, DNR level and NB level respectively.

The **menus** are somewhat akin to those in the FTDX-101 and FTDX-10.

The QMB (Quick Memory Bank) key saves the current radio configuration in a scratchpad memory..

Touching the leading (MHz) digits of the frequency display enables MHz tuning steps via the main tuning knob. Touching the 3-digit kHz group eables 1 kHz tuning steps. Touching the Hz (last 3) digits opens a numeric frequency-entry keypad pop-up. Default tuning steps are configurable by mode via the FUNC/OPERATION SETTINGS menu. The minimum step size is 5 Hz.

Filter bandwidths are adjustable via the STEP/MCH/DSP knob and the associated pp-up ribbon. There are no shape factor adjustments.

The Time-Out Timer feature limits transmissions to a preset duration (3, 5, 10, 20 or 30 minutes, selectable by menu.) RF POWER can be turned down to 5W.

Note: TX Delay is fixed at ≈ 15 ms and is **not** user-configurable.

The MULTI screen displays an audio FFT spectrum analyzer and oscilloscope very similar to those implemented in the current Icom transceivers. This feature is very helpful in setting up one's transmit audio parameters, and also for visual audio assessment of a received signal.

4. Receiver front end management: The Preamp selections are IPO (Intercept Point Optimization = Preamp Off), AMP1 (≈ 10 dB gain) and AMP2 (≈ 20 dB gain). The RF/SQL knob can be configured as RF Gain or Squelch via FUNC/Operation Settings. The control is squelch-only in FM modes.

The input level limit for a direct-sampling receiver is the ADC clip level, where the digital output of the ADC is "all ones". When the ADC clips, the receiver can no longer process signals. Unlike many other direct-sampling radios, the FT-710 does not have an ADC clip or overflow indicator. Instead, the receiver goes into a form of "graceful (soft) overload" similar to blocking gain compression. This occurs at an RF input power level ≈ +2 dBm. This feature is handled by the dual (RF/IF) AGC system.

The ZIN/SPOT key "tunes in" CW signals rapidly and accurately, and allows spotting (netting) of the transmitter to a received CW signal. This key is located in the row of keys on the front edge of the case top.

Touching the currently-displayed meter scale toggles between scales.

5. USB interfaces: The FT-710 is equipped with a rear-panel mini-USB "B" port. The radio can be directly connected via the "B" port to a laptop or other PC via the supplied USB cable. The USB port transports not only CAT data, ***but also TX and RX PCM baseband*** between the FT-710 and the computer. As a result, the USB cable is the only radio/PC connection required. Gone forever is the mess of cables, level converters and interface boxes! This feature is now standard on all Yaesu HF radios released since 2009. A Yaesu driver is required in the PC; this is downloadable from the Yaesu website. A USB "A" port on the rear panel allows connection of a wired mouse or keyboard.

6. Filter selections and Shift/Width: As do the other Yaesu DSP transceivers, the FT-710 offers fully-configurable RX IF selectivity filters for all modes. Filter bandwidths and offsets are adjustable via the STEP/MCH/DSP knob and pop-up ribbon
Twin PBT is one of the modes of the concentric multi-function controls. Pressing and holding the inner knob [CLR] restores PBT to neutral.

7. *A* ***CW APF (Audio Peak Filter)*** is provided. APF width is selectable via FUNC/Operation Settings/RX DSP. However, there is no RTTY TPF (Twin Peak Filter).

8: DNF filter. The Digital DNF Filter (DNF) is inside the AGC loop, and is extremely effective. The DNF has 2 width settings selectable in the RX DSP sub-menu (WIDE, NAR); its stopband attenuation is at least 70 dB. The manual notch suppresses an interfering carrier before it can stimulate AGC action; it thus prevents swamping. To adjust the notch frequency precisely, rotate the STEP/MV}CH/DSP knob to select NOTCH, then press and hold the NOTCH key, then press, hold and rotate the STEP/MCH/DSP knob.

8: Contour: There is no auto-notch as such, but the Contour ture is usable as a post-AGC audio bandstop filter whose depth and width are configurable via the RX DSP sub-menu. CONTOUR is turned on/off and tuned via the STEP/MCH/DSP knob.

The audio stopbands created by DNF and CONTOUR are visible in the Filter Function display and in the MULTI audio spectrum analyzer /waterfall.

9: DNR (digital noise reduction). The DNR is quite effective. In SSB mode, the maximum noise reduction occurs at a DNR control setting of 4 - 5. As DNR level is increased, there is a slight loss of "highs" in the received audio; this is as expected. The measured SINAD increase in SSB mode was about 18 dB. For precise DNR adjustment, press and hold the DNR key, then rotate the FUNC knob. For DNR level > 5, there is no significant SINAD increase, but the received audio sounds "watery".

10: NB (noise blanker). The IF-level DSP-based noise blanker works quite well. I have found it to be extremely effective in suppressing fast-rising impulsive RF events before they can stimulate AGC action within the DSP algorithm. The NB almost completely blanks noise impulses which would otherwise cause AGC clamping. I found its performance comparable to that of the IC-7700's NB. The NB level is adjustable by pressing and holding the NB key and rotating FUNC. The NB works very effectively in conjunction with DNR.

11: AGC system. The FT-710 has a dual-channel AGC loop (RF and IF AGC). The digital AGC detector for the IF AGC loop is within the DSP algorithm. The separate IF and RF AGC alignment procedures in the service manual suggest that the RF AGC may be derived at the ADC RF input. Level indications from the detector are processed in the DSP, and control the gain of the RF preamp(s). This architecture prevents strong adjacent signals from swamping the AGC, and allows full exploitation of the ADC's dynamic range.

The AGC menu is similar to that of other Yaesu IF-DSP radios. The Slow, Mid and Fast AGC settings are customizable via menu for each mode, and AGC can be turned OFF via menu.

12: Receive and transmit audio menus. The FT-710 TONE SET menu offers the same generous selection of audio configuration parameters as that of the IC-7600 and IC-7700: TBW (low and high cutoff frequencies), RX and TX Bass/Treble EQ, RX HPF and LPF, transmit compression, etc. All audio settings are grouped under the SET/Tone Control menu.

13: Metering. The on-screen bar-graph meter displays the S-meter at all times; touching the scale toggles between P_O, SWR, ALC and COMP. Touch and hold displays the multi-function meter.

14: VFO/Memory management. **The** FT-710 offers the same VFO and memory management features as other current Yaesu HF+ transceivers: VFO/memory toggle and transfer, memory write/clear, memo-pad, Split, VFO A/B swap [A/B] and equalize [touch and hold A/B], etc. A VFO Mode Indicator (VMI) consisting of color bands surrounding the left and right sides of the main tuning knob indicates the main tuning dial function.

15: Brief "on-air" report: Upon completing the test suite, I installed the FT-710 in my shack and connected it to my Yaesu Quadra 1 kW amplifier and multi-band HF/6m vertical antenna.

a) SSB: I spent some times chatting on 40m SSB with friends who are familiar with my voice and the sound of my signal. Distant stations reported that the audio quality of my transmissions was "excellent" when using the supplied hand microphone. The parametric equalizers were OFF throughout the test.

The following are the transmit audio settings I used in the SSB trials:

Table 1: Transmit audio settings.

Band	Conditions	Mic Gain	TBW	COMP	Bass	MID	Treble
40m	S9+	50%	WIDE 100-2900	+6 dB	0	0	0

As discussed in **11.** above, the DSP-based noise blanker is very effective. It does not distort the signal at all, and can be left on at all times. At my QTH, with Level 5, the NB suppressed fast-rising noise spikes and almost completely eliminated locally-generated electrical noise from sodium-vapor street-lighting.

As discussed in **10.** above, I found DNR quite effective on SSB at a level setting of 4 - 55.. DNR is very effective in conjunction with NB. Receive audio quality degrades if DNR LEVEL > 5.

AMP1 (10 dB gain) brought weak stations up to very comfortable copy without S/N degradation. The SSB filters, SHIFT and WIDTH were excellent. CONTOUR reduced the levels of multiple tones and "smoothed out" harsh highs. I did not use AMP2 on 40m.

The superior phase-noise performance of a direct-sampling SDR (as compared to a conventional superhet) and the absence of passive IMD due to crystal filters in the signal path really showed in the FT-710's clean reception in the presence of strong adjacent-channel interference during my on-air SSB tests.

Overall, I found that band noise on SSB at my QTH was sufficiently obtrusive to require the use of DNR (Level 4 - 5) at all times. Still, SSB operation on 40m with a mix of strong and weak signals was quite comfortable and pleasant.

b) CW: I made a brief CW QSO on 40m using a straight key. With 500 and 250 Hz CW filters and DNR/NB on, ringing was minimal with IPO selected. Activating AMP1/2 raised the noise level slightly, but did not cause significant ringing.

In a brief test of full-break-in operation at 20 wpm, I found this mode quite smooth, with fast receiver recovery.

18a. ACC MOD and USB MOD Input Level Check: During transmitter testing, I also checked the AF input levels at the USB port using a tone-generator program, and at ACC Pin 11 using an audio signal generator, for 100W PEP output. All levels were well within specifications. To use the USB port, I installed the current Yaesu USB drivers (downloadable from the Yaesu USA support site).

16: Case temperature: The FT-710 showed no signs of excessive heating even after extended “rag-chew” SSB operation or transmitted phase noise measurements at 100W PEP output.

17: Concerns. Five items warranting further analysis were encountered during the tests:

- Lack of averaging in the spectrum scope/waterfall.
- A watery sound when DNR Level > 5. (***Note:*** Firmware Ver. 202303 greatly improves DNR operation.)
- NB not completely effective in suppressing impulse noise at high repetition rates.
- A slightly muffled (veiled) receive audio, especially on internal speaker.
- 2.5 – 3 dB carrier starvation at 90% modulation in AM mode.

18: Conclusion. After a few days’ “cockpit time” on the FT-710, I am very favorably impressed by its solid, refined construction, clear and informative display, easy familiarization experience, smooth operating “feel”, impressive array of features and excellent on-air performance. This radio is a true, stand-alone* direct-sampling/digital up-conversion SDR in an attractive, compact package. Yaesu is making the transition from legacy to direct-sampling SDR architecture very smoothly. This is certainly a lot of radio for its price category.

22. Acknowledgements: I would like to thank my good friends Rob Sherwood NC0B and Werner Schnorrenberg DC4KU for their valuable input to my test effort.

**Stand-alone SDR: self-contained, not requiring a computer as a prerequisite for operation.*

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Iss.1: March 20, 2023. Initial release.
Iss.2: March 21, 2023. Minor corrections (Table 1, p. 5; Figure 27a, p. 34).
Iss.3: March 31, 2023. Fixed typographical and layout errors.
Iss.4, April 12, 2023. Added note on DNR improvement with Firmware Ver. 202303.

Appendix 1: Performance Tests on FT-710 S/N 2L040521

Firmware Ver. 202212. As performed in my home RF lab, February 2023.

A. HF/6m Receiver Tests

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: SSB 2.4 kHz & CW 500 Hz, ATT off, DNR off, NB off, DNF off. AGC-AUTO. Max.RF Gain. Levels in dBm. IP+ off except where shown.

Table 2: MDS (HF, 6m).

MHz	1.9		3.6		14.1		28.1		50.1		70.1	
Preamp	CW	SSB	CW	SSB	CW	SSB	CW	SSB	CW	SSB	CW	SSB
IPO	-123	-119	-126	-118	-126	-121	-126	-121	-128	-123	-127	-122
AMP1	-133	-128	-135	-128	-135	-131	-136	-131	-138	-133	-137	-132
AMP2	-140	-135	-142	-136	-141	-136	-141	-137	-140	-135	-139	-134

1a: Out-of-Channel Overload Level: In this test, the receiver is offset +25 kHz above the test signal frequency and the input level required to induce overload is noted.

This test is a Blocking Gain Compression check, conducted with two test signals: f_1 = 14200 kHz and f_2 = 14225 kHz. .With f_1 at a constant level, the f_2 input power is increased until the AF output drops by 3 dB.

Test Conditions: RX tuned to f_1 = 14.2 MHz, test signal freq. f_2 = 14.225 MHz, CW 500 Hz, ATT off, DNR off, NB off, DNF off. AGC-AUTO. Max. RF Gain.

With f_1 input level = -126 dBm (MDS), f_2 input power = +2 dBm for 3 dB drop in AF output. Thus, BDR = 126+2 = **128 dB** and "soft overload" point is **+2 dBm.**

1b: AM Sensitivity. Here, an AM test signal with 30% modulation at 1 kHz is applied to the RF input. The RF input power which yields 10 dB (S+N)/N is recorded (Table 3).

Test Conditions: ATT off, DNR off, NB off, DNF off. AGC-AUTO. 9 kHz) AM Filter, max. RF Gain. (Levels in dBm.)

Table 3: AM Sensitivity.

Preamp	19 MHz	3.6 MHz	14.1 MHz
IPO	-98	-100	-100
AMP1	-106	-110	-110
AMP2	NM	-116	-115

1c: 12 dB SINAD FM sensitivity. In this test, a distortion meter is connected to the PHONES jack, and an FM signal modulated by a 1 kHz tone with 3 kHz peak deviation is applied to the RF input. Input signal power for 12 dB SINAD is recorded (Table 4).

Table 4: FM 12 dB SINAD Sensitivity in dBm.

Preamp	29.5 MHz	52.525 MHz	70.5 MHz
IPO	-105	-107	-106
AMP1	-114	=117	-115
AMP2	-120	-119	-119

2: Reciprocal Mixing Noise occurs in a direct-sampling SDR receiver when the phase-noise sidebands of the ADC clock mix with strong signals close in frequency to the wanted signal, producing unwanted noise products in the detection channel and degrading the receiver sensitivity. Reciprocal mixing noise is a measure of the ADC clock's spectral purity**.**

In this test, a test signal from a high-quality 5 MHz OCXO with known low phase noise is injected into the receiver's RF input at a fixed offset from the operating frequency. The RF input power is increased until the receiver noise floor increases by 3 dB, as measured at the audio output. Reciprocal mixing noise, expressed as a figure of merit, is the difference between this RF input power and measured MDS. The test is run with IPO. The higher the value, the better.

Test Conditions: CW mode, 500 Hz filter, IPO, ATT off, DNR off, AGC-AUTO, NB off, max. RF Gain, positive offset. Reciprocal mixing *in dB* = input power P_i– MDS *(both in dBm)*. Phase noise *in dBc/Hz* = -(RMDR+10 log 500) = -(RMDR + 27). Measured MDS = -126 dBm @ 5 MHz.

5: Reciprocal Mixing Dynamic Range in dB (HF/6m).

Δf kHz	RMDR dB	P_i dBm	Phase noise dBc/Hz	Remarks
1	111	-15	-138	
2	114	-12	-141	
5	120	-6	-147	
10	123	-3	-150	ONSET OF 'GRACEFUL OVERLOAD'
20	123	-3	-150	
25	123	-3	-150	

3: IF 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, IPO, AGC-AUTO, ATT off, DNR off, NB off.

Table 6a: IF Filter Shape Factors.

Filter	Shape Factor	6 dB BW kHz	Remarks
2.4 kHz SSB	1.29	2.39	
1.5 kHz SSB	1.39	1.49	NAR
500 Hz CW	1.46	0.505	
250 Hz CW	1.4	0.255	NAR

3a: CW APF Filter Bandwidth. An RF test signal is applied at S9 (-73 dBm), and the Audio Peak Filter (APF) is turned on and centered on this signal. The AF output level is observed on an RMS voltmeter connected to LINE OUT. The filter gain (AF level in the MULTI sidebar) is set at 0, 3 and 6 dB in turn and the measured level change noted.

Next, the receiver is de-tuned either side of the test signal until the AF level falls by 3 dB, and the total frequency difference is noted. This is the filter's 3 dB bandwidth.

Test Conditions: 1.900 kHz, 500 Hz CW, IPO, AGC M, ATT off, DNR off, NB off., CW Pitch 600 Hz (default), BK-IN off, APF on, , AF Level 0 dB. Initial RF input level -73 dBm. See Tables 8a, 8b.Test at all WIDTH settings.

Table 6b: CW APF Bandwidth

WIDTH	-3 dB BW
WIDE	130
MID	110
NARROW	60

4: AGC threshold. An RF test signal is applied at a level 6 dB below AGC threshold, with AGC off. The signal is offset 1 kHz from the receive frequency to produce a test tone. The AF output level is observed on an RMS voltmeter connected to the PHONES jack.

Test Conditions: 14.100 MHz, 2.4 kHz USB, IPO, AGC-AUTO, ATT off, DNR off, NB off. Initial RF input level -105 dBm.

With AGC-AUTO, increase RF input power until AF output level increases < 1 dB for a 1 dB increase in input level. Measured values per Table 7.

Table 7: AGC Threshold.

Preamp	AGC Threshold dBm
IPO	-93
AMP1	-102
AMP2	-114

5: DNF stopband attenuation and bandwidth. 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. The DNF is carefully tuned to null out the tone completely at the receiver audio output. 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 USB at ≈ -50 dBm (S9 + 20 dB), 2.4 kHz, AGC-AUTO, IPO, ATT off, DNR off, NB off, DNF on, SHIFT 0.

Test Results: Measured MDS was -121 dBm per Test 1. Stopband attenuation = test signal power - MDS.

Table 8: DNF Filter Attenuation.

DNF BW	Test Signal dBm	Stopband Atten. dB
WIDE	-36	85
NAR	-62	59

5a: DNF Bandwidth. The receive frequency is now offset on either side of the null by pressing CLAR and rotating the main tuning knob. The frequencies at which the audio output rises by 6 dB are noted. The **-6 dB bandwidth** is the difference between these two frequencies.

Table 9: DNF BW.

DNF -6 dB BW Hz	
Wide	340
NAR	80

6: AGC/NB Impulse Response. The purpose of this test is to determine the FT-710'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 filter, DNR off, NB off/on, IPO/AMP1/AMP2, AGC-FAST, with decay time set to 0.1 sec.

Test with pulse trains. Here, the pulse generator is connected to the FT-710 RF input via a step attenuator. The FT-710 is tuned to 3.6 MHz, as the RF spectral distribution of the test pulse train has a strong peak in that band. AGC Fast (0.1 sec) and AMP2 are selected.

The pulse rise time (to 70% of peak amplitude) is 10 ns. Pulse duration is varied from 12.5 to 100 ns. In all cases, pulse period is 500 ms. The step attenuator is set at 23 dB. Pulse amplitude is $16V_{pk}$ (e.m.f.) The AGC recovers completely within the 0.1 sec window; there is no evidence of clamping. DNR softens the tick sound.

Figure 3: MULTI audio scope display for AGC impulse response test.

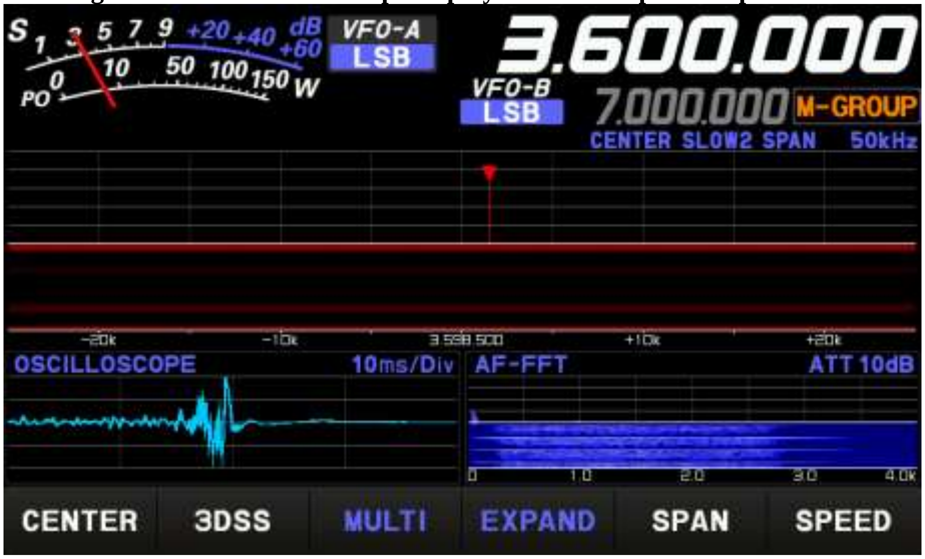


Table 10: AGC impulse response.

Pulse duration ns	Tick	AGC recovery ms	S: IPO	S: AMP1	S: AMP2
12.5	Y	≈ 100 (no clamping)	7	6	8
30	Y	≈ 100 (no clamping)	5	7	8
50	Y	≈ 100 (no clamping)	6	7	8
100	Y	≈ 100 (no clamping)	7	8	8

7: Noise blanker (NB) impulse response). As the FT-710's noise blanker is a DSP process "upstream" of the AGC derivation point, the NB should be very effective in suppressing impulsive RF events before they can stimulate the AGC. To verify this, the NB is turned on during Test 6 (above).

Test Conditions: NB on, AMP1 or AMP2, Level 50%, Depth 4 or 5, Rejection MID, Width MEDIUM.

At all pulse durations, the S-meter deflection and "ticks" are *completely suppressed* (with IPO, AMP1 and AMP2) showing that the impulsive events never reach the AGC derivation point. With IPO, there are no ticks at pulse durations < 30 ns, but faint ticks are heard at 30 ns. Occasional faint artifacts are heard, but on-air signals and/or band noise would mask these completely.

Next, DNR is activated. With DNR at 9 to 10, any residual artifacts are suppressed.

- As in other Yaesu (and Icom) IF-DSP radios, the NB mitigates AGC response to fast-rising RF events.

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

Test Conditions: 2.4 kHz USB, IPO, ATT off, AGC-AUTO. A 14.100 MHz test signal at MDS is applied to the RF input. The signal power is increased, and the level corresponding to each S-meter reading is noted. (S9 readings are taken with IPO, AMP1 and AMP2 in turn.)

Table 11: S-Meter Tracking.

P.AMP	S	S1	S2	S3	S4	S5	S6	S7	S8	S9	S9+20	S9+40	S9+60
IPO	dBm	-90	-88	-86	-83	-81	-78	-75	-72	-68	-44	-24	-4
AMP1										-77			
AMP2										-89			

8a: Attenuator tracking. This is a quick verification of attenuator accuracy.

Table 12: ATT Value.

ATT	Meas. dB
OFF	0
6	5.6
12	11.7
18	17.7

9: Two-Tone 3rd-Order Dynamic Range (DR_3). 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 2 kHz offset Δf are 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 ($2 f_2 – f_1$ and $2 f_1 - f_2$ respectively) which appear 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 products at MDS. The Pi values for the upper and lower products are recorded and averaged. $DR_3 = P_i - MDS$.

DR3 is measured with IP+ off and on, to determine the effect of internal dither and randomization on front-end linearity.

Note: *IP_3 (3^{rd}-order intercept) is not included here, as this parameter is irrelevant to a direct-sampling SDR. The transfer and IMD curves of the ADC diverge, so the intercept point does not exist.*

Test Conditions: f_1 = 14.010 MHz, f_2 = 14.012 MHz, 500 Hz CW, AGC-S, ATT off, DNR off, NB off, CW Pitch = 12 o'clock.

9a: Two-Tone 2^{nd}-Order Dynamic Range (DR_2) & Second-Order Intercept (IP_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.

$DR_2 = P_i - MDS$. Calculated $IP_2 = (2 * DR_2) + MDS$.

Test Conditions: f_1 = 6.1 MHz, f_2 = 8.1 MHz, CW mode, 500 Hz filter, AGC off, ATT off, DNR off, NB off, CW Pitch = 700 Hz (default). DR_2 in dB; IP_2 in dBm. IMD_2 product is at 14.2 MHz.

Table 13a: 6.1/8.1 MHz DR_2.

MDS dBm, 14.2 MHz	DR_2 dB	IP_2 dBm
-126	103	+80

9b: Two-Tone IMD_3 (IFSS, Interference-Free Signal Strength) tested in CW mode (500 Hz), ATT = 0 dB, AGC Med. Test frequencies: f_1 = 14010 kHz, f_2 = 14012 kHz. IMD_3 products: 14008/14014 kHz. IMD_3 product level was measured as absolute power in a 500 Hz detection bandwidth at various test-signal power levels in IPO. (Note that dither is always enabled.) The ITU-R P-372.1 band noise levels for typical urban and rural environments are shown as datum lines. The input level at the top end of each curve corresponds to 51 dBFS, or 1 dB below the onset of "soft overload". See Figure 4.

The IMD product level was derived by calibrating the S-meter and spectrum scope against a signal generator, and subtracting MDS.

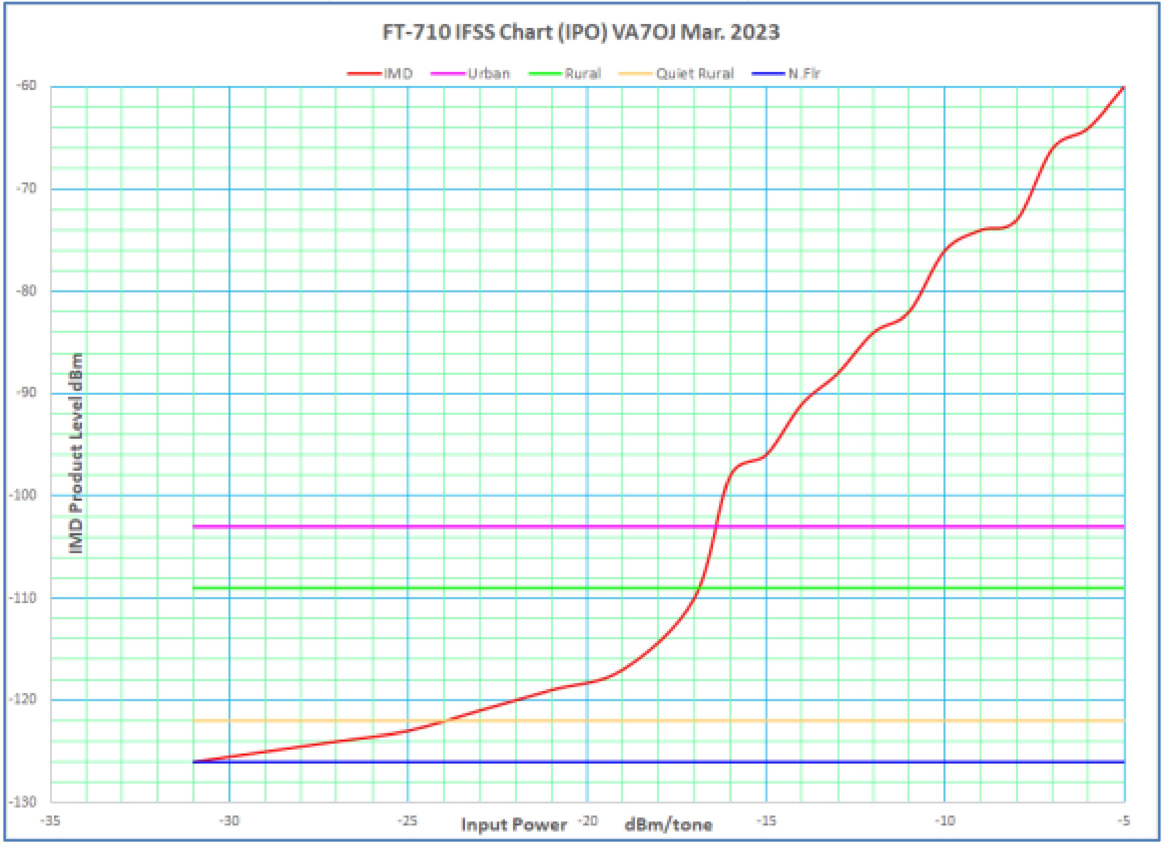
9c. Classical Two-Tone IMD_3: For the convenience of the reader, classical 2-tone IMD_3 was derived from IMD product level measurements at the noise floor, for IPO, AMP1 and AMP2. See ***Reference 4.***

Test Conditions: f_1 = 14.010 MHz, f_2 = 14.012 MHz, CW mode, 500 Hz filter, AGC-AUTO, ATT off, DNR off, NB off, CW Pitch = 700 Hz (default). DR$_3$ in dB. IMD$_3$ products are at 14.008 and 14.014 MHz.

Table 13b: 14.010/14.012 MHz DR$_3$.

Preamp	MDS dBm	P_{in} dBm/tone	DR$_3$ dB
IPO	-126	-24	99*
AMP1	-135	-37	98
AMP2	-141	-36	105
*Possibly limited by PN of f_2 test signal generator.			

Figure 4: IFSS (2-tone IMD$_3$) vs. test signal level.



Notes on 2-tone IMD$_3$ test: This is a new data presentation format in which the amplitude relationship of the actual IMD$_3$ products to typical band-noise levels is shown, rather than the more traditional DR$_3$ (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 FT-710 IFSS data is presented here as an adjunct to the classical DR$_3$ test data. See ***Reference 1.***

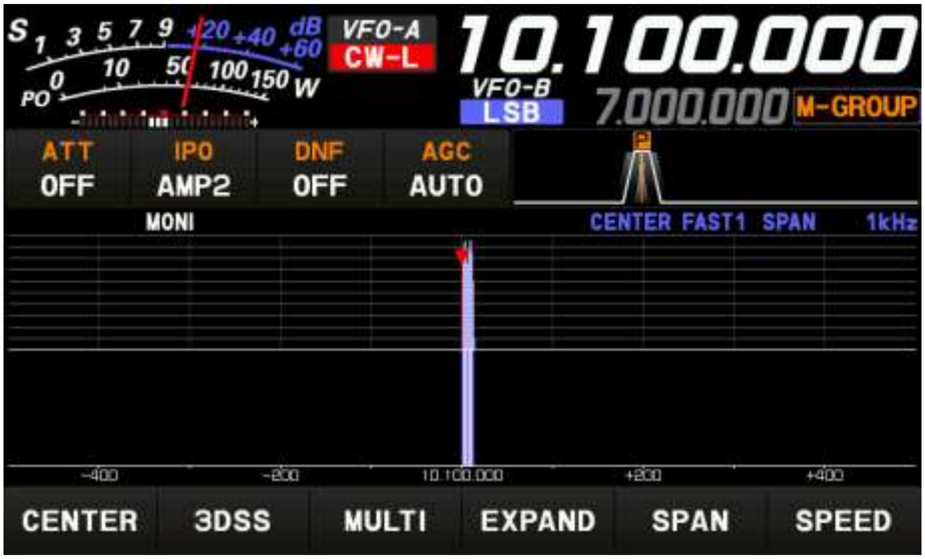
10a: Spectrum Scope Resolution Bandwidth. In a spectrum analyzer, the resolution bandwidth (RBW) determines how far apart in frequency two (or more) signals must be to be resolved into separate and distinct displays on the screen.

Test conditions: Test signals: f_1 = 10100 kHz, f_2 = 10100.100 kHz, CW, 250 Hz. Span = 1 kHz, ATT OFF, REF LEVEL = +20 dB, RBW = HIGH, IPO. Waterfall on, speed MID (default).

To measure RBW, f_1 and f_2 are injected into the antenna input at a level sufficient to produce spikes whose vertical amplitude reaches the top of the scope grid. f_2 is moved closer to f_1 until two distinct spikes are ***just*** observable.

Test result: Two signals can be clearly distinguished at 6 Hz spacing (LOW), 4.4 Hz (HIGH)., i.e.4.4 Hz minimum RBW.

Figure 5: Spectrum scope RBW (6 Hz).



VFO-A CW-L 10.100.000

VFO-B LSB 7.000.000

ATT OFF

IPO AMP2

DNF OFF

AGC AUTO

CENTER FAST1 SPAN 1kHz

10b: Spectrum Scope Sensitivity. In this test, the RF input signal level is adjusted to produce a spike which is just visible above the scope "grass" level.

Test conditions: 14.100 MHz Span = 1 kHz, RBW = HIGH, ATT OFF, REF LEVEL +20 dB. DSP filter setting is irrelevant.

Table 14: Spectrum Scope Sensitivity.

Minimum Visible Spike for Span = 1 kHz	
Preamp	Level dBm
IPO	-105
AMP1	-114
AMP2	-125

Notes on spectrum scope: The addition of 3 features to the spectrum scope would greatly enhance its usefulness as a BITE (built-in test equipment) feature:

- A VBW (video bandwidth) setting.
- An Averaging setting.
- A means of turning off the waterfall entirely.

11: 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 bandstop (BSF) and band-limiting filters (BLF) for the test frequencies utilized.

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

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 at 2.4 kHz SSB prior to NPR testing

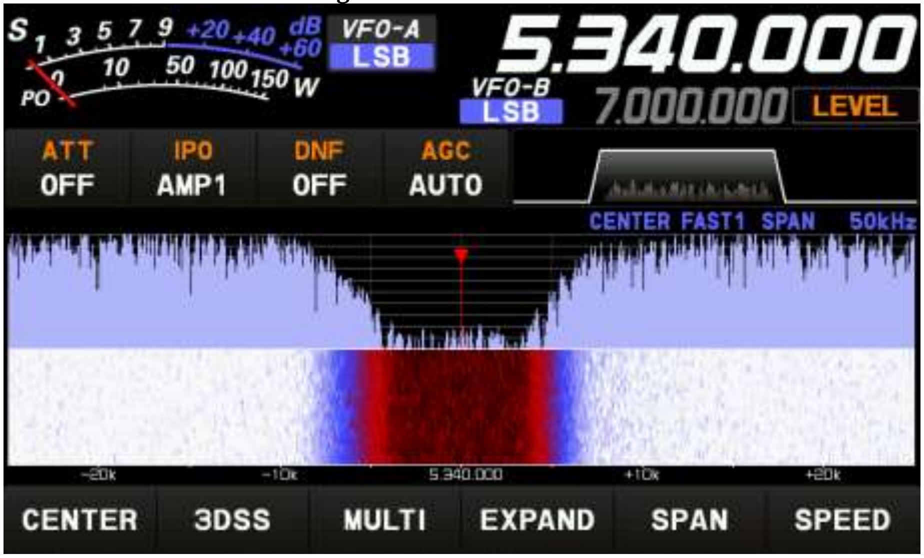
Test Conditions: Receiver tuned to bandstop filter center freq. f_0 ± 1.5 kHz, 2.4 kHz SSB, ATT off, max. RF Gain, IPO, DNR off, NB off, DNF off, AGC-AUTO. Test results are presented in Table 15.

Table 15: NPR Test Results.

DUT	BSF kHz	BLF kHz	Preamp	MDS dBm	P_{TOT} dBm	BWR dB	NPR dB
FT-710	1940	60…2044	IPO	-118	-20	29.2	77
			AMP1	-128	-23		75
			AMP2	-135	-28		78
	3886	60…4100	IPO	-121	-14	32.3	75
			AMP1	-130	-24		74
			AMP2	-136	-33		71
	4650	60…5600	IPO	-121	`-9	33.6	78
			AMP1	-130	-20		77
			AMP2	-135	-29		73
	5340	60…5600	IPO	-121	-12	33.6	75
			AMP1	-130	-22		75
			AMP2	-137	-27		76
	7600	316…8160	IPO	-120	-7	35.1	77
			AMP1	--130	-18		77
			AMP2	-140	-26		78
	11700	316...12360	IPO	-121	-8	37.0	76
			AMP1	-130	-17		74
			AMP2	-136	-27		73
	16400	316...17300	IPO	-120	-5	38.5	78
			AMP1	-130	-15		77
			AMP2	-136	-23		75

NPR Test Note 1**:** When testing NPR on other direct-sampling SDR receivers, I have found that the noise loading drove the ADC into clipping before the AF noise output increased by 3 dB. Thus, I developed an alternative method in which the noise loading is set to 1 dB below clipping and the NPR read directly off the spectrum scope. The limited amplitude range of the FT-710 spectrum scope precludes that method, but due to the "soft overload" characteristic of the FT-710 it was possible to obtain a 3 dB increase in AF noise output without ADC clipping. This allowed use of the "legacy" test method as described in ***Ref. 2.***

Figure 6: NPR test screen.



VFO-A LSB 5.340.000

VFO-B LSB 7.000.000

ATT OFF

IPO AMP1

DNF OFF

AGC AUTO

CENTER FAST1 SPAN 50kHz

NPR Test Note 2: Although the receiver RF BPF's (preselectors) in the FT-710 are advertised as optimized for the amateur bands, the relatively small differences in NPR results between test channels within and outside amateur bands suggest that the BPF's are contiguous. (See Table 14 above). This is confirmed by the service manual, which shows the BPF's as contiguous half-octave filters.

12: THD at 2.5W audio output. A test signal is applied to the ANT input in SSB ode with a 1 kHz offset. The external speaker output is fed to an audio distortion meter terminated in 4Ω. AF Gain is adjusted for 2W output and the THD reading recorded.

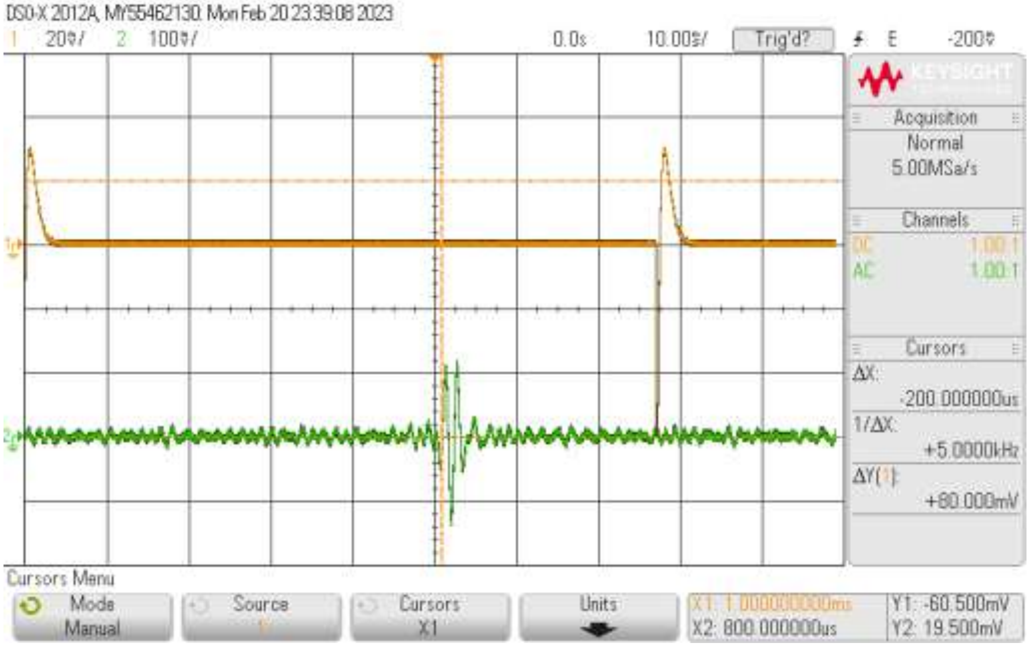
Test Conditions: Receive frequency 14.100 MHz, USB, 2.4 kHz. 14.101 kHz test signal applied to ANT input. ATT off, max. RF Gain, IPO, DNR off, NB off, AGC-AUTO, distortion meter with 4Ω termination connected to EXT-SP jack. AF Gain adjusted for 3.16V_{rms} on distortion meter (≡ 2.5W).

Measured THD = 5.6% @ 2.5W in 4Ω.

13: Receiver latency. Latency is the transit time of a signal across the receiver, i.e. the time interval between arrival of the signal at the antenna input and appearance of the demodulated signal at the AF output. Various aspects of receiver design exert a major influence on latency; among these are DSP speed and group delay across selectivity filters. As the DSP speed is fixed by design, we measure latency for various filter configurations (bandwidth and shape factor). Figure 7 illustrates an example.

To measure latency, repetitive pulses are fed to the DUT antenna input and also to Channel 1 of a dual-trace oscilloscope. Channel 2 is connected to the DUT AF output. The scope is triggered from the pulse generator's trigger output. The time interval between the pulses displayed on Channels 1 and 2 is recorded for each test case.

Figure 7. RX latency, 500 Hz CW filter. 10 ms/div.



Test Conditions: 3.6 MHz, IPO, AGC Fast, max. RF Gain, ATT off, DNR off, NB off.

Table 15: Receive latency test results.

Mode	Filter BW kHz	Latency ms
LSB	4.0	31
	2.4	31
	1.8	33
CW	1.2	35
	0.5	51
	0.25	80
	0.1	78
RTTY	2.4	30
	0.5	40
	0.25	39

14: DNR noise reduction, measured as SINAD. This test is intended to measure noise reduction on SSB signals close to the noise level. A distortion meter is connected to the PHONES jack. 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. DNR is then turned on, and SINAD read as DNR Level is increased in steps of 1.

Test conditions: 14.1 MHz USB, 2.4 kHz, AGC-AUTO, IPO, max. RF Gain, ATT off, NB off. Test signal initially at -118 dBm (6 dB SINAD)

Table 16: Noise reduction vs. DNR setting.

DNR Setting	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SINAD dB	6	6	6	24	23	23	23	23	23	22	23	23	24 (max.)			

This shows an S/N improvement of 24 dB with DNR at maximum for an SSB signal ≈ 2 dB above MDS. This is an approximate measurement, as the amount of noise reduction is dependent on the original signal-to-noise ratio. Note that the DNR control is very aggressive, and settings > 6 yield a disturbingly watery, burbling sound.

14a: CONTOUR check. In this test, the effect of the CONTOUR control is verified visually in the MULTI display.

Test conditions: 5335 kHz LSB. RF noise applied to ANT input from NPR noise generator at ≈ -50 dBm, b60-4100 Hz BLF, no BSF. CONTOUR activated via MCH/DSP knob and RX-DSP menu. Settings: Freq. offset +2 kHz, Width NAR, Depth 40. Touch MULTI softkey and rotate MCH/DSP to view CONTOUR screen.

Test Result: See Figure 8.

Figure 8: CONTOUR Screen Display.

15 Aliasing rejection. 75.000 MHz is the top of the FT-710 tuning range. In this test, a test signal at 82.500 MHz is fed to the antenna port and the IC-7300 is tuned to its alias frequency (42.500 MHz). The test signal power is increased sufficiently to raise the AF output by 3 dB.

Test Conditions: Receive frequency 42.500 MHz, CW, 500 Hz. Test signal at 82.500 MHz applied to ANT input. ATT off, max. RF Gain, IPO, DNR off, NB off, Notch off, AGC-AUTO. RMS voltmeter connected to PHONES jack.

Alias frequency = test frequency - f_S

- where f_S = 62.5 MHz (sampling frequency).

Test results: 82.5 MHz test signal level = --100 dBm for +3 dBr AF level increase. 42.5 MHz MDS = -123.5 dBm. Aliasing rejection = -100=123.5 = 23.5 dBm. This is the worst case; no aliasing was observed when the test frequency was in the FM broadcast band.

B. Transmitter Tests

16: 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 meter is connected to the FT-710 RF output via a 50 dB power attenuator.

Table 17: CW Power Output.

Freq. MHz	3.61	14.1	28.1	50.1
P_O W	100	100.5	100.3	100.6
P_o setting W	88	87	87	88
I_{DC} at 100W A	16.7	17.2	15.2	18.3
Max. P_O W	114.8	114.9	114.5	114.3

RX/Standby: I_{DC} = 1.3A

17: SSB Peak Envelope Power (PEP). Here, an oscilloscope is terminated in 50Ω and connected to the FT-710 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: 14100 kHz, USB mode, MOD SOURCE = AUTO or MIC, SSM-75E mic connected, RF PWR 87W, Mic Gain 50%, AMC 100, TBW = 100-2900 Hz, PROC LEVEL 70, COMP at 6 dB on voice peaks), SSB TX Bass/Treble set at 0 dB (default), parametric EQ off, supply voltage +13.8V.

Speak loudly into the microphone for full-scale ALC reading. as 9 & 9b show the envelope for 100W PEP, without and with compression respectively. ± 3 vertical divisions = 100W. (PROC LEVEL OFF = no compression.)

Figure 9a: 100W PEP speech envelope, no compression.

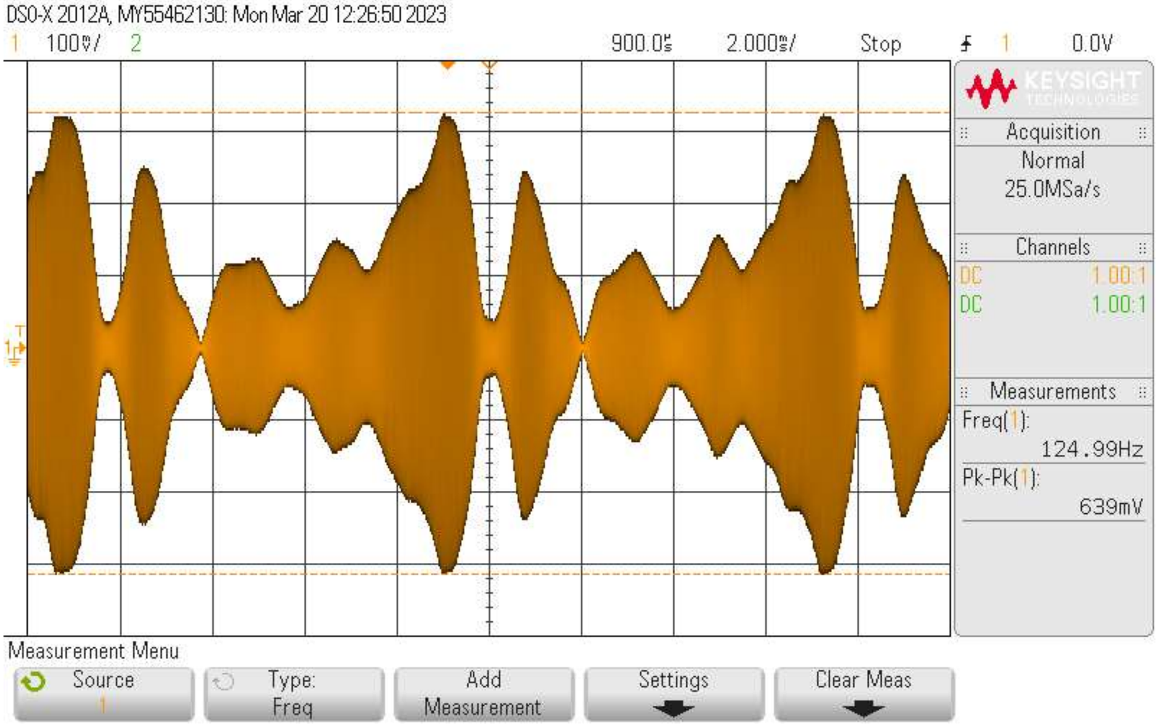
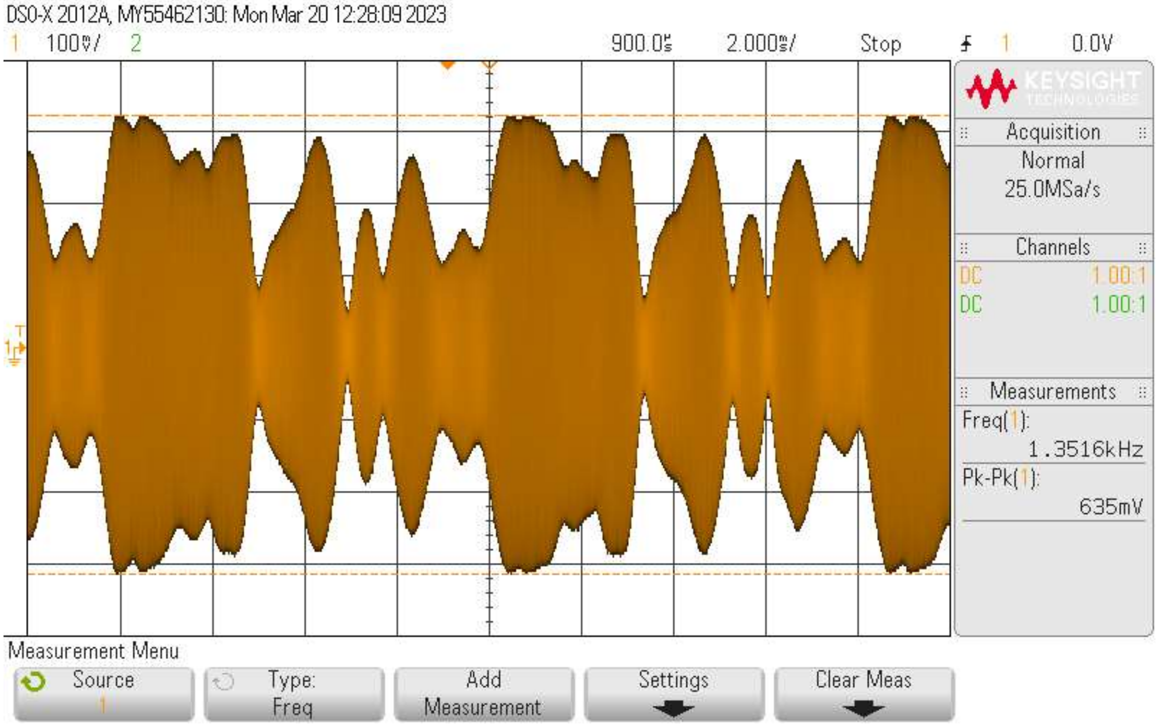


Figure 9b: 100W PEP speech envelope, ≈ 6 dB compression.



Note that no ALC overshoot was observed in either test case.

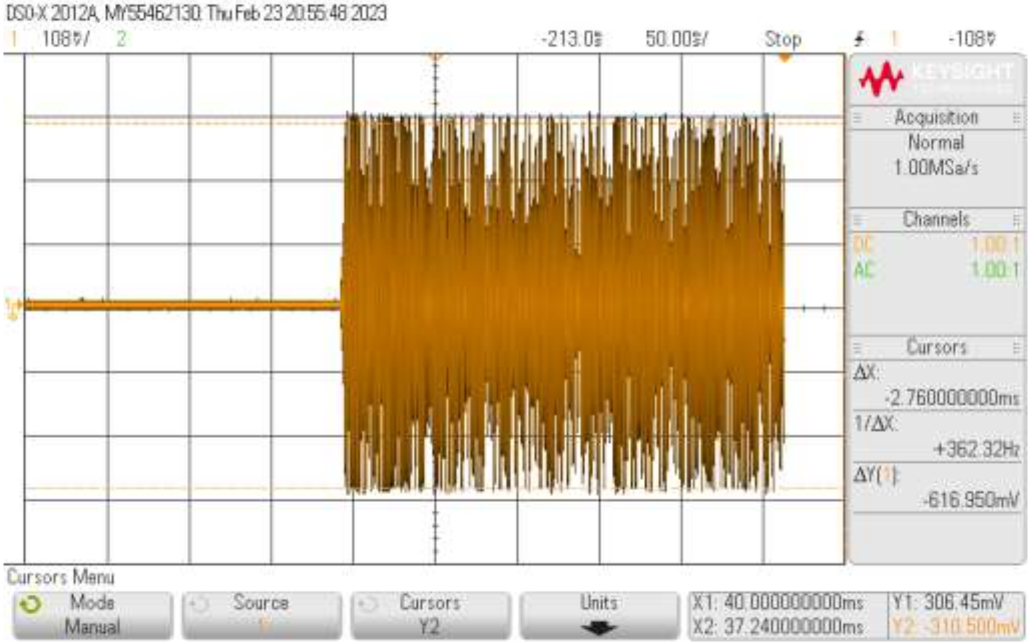
18: SSB ALC overshoot. A test was conducted in which white noise was applied via the USB port, and the RF envelope observed on an oscilloscope terminated in 50Ω and connected to the FT-710 RF output via a 50 dB high-power attenuator**.**

Test Conditions: 14100 kHz, USB mode, MOD SOURCE = AUTO or USB, RF Power 87W, USB MOD GAIN 50 (default}, PROC LEVE off, TBW = 100-2900 Hz, SSB TX Bass/Treble set at 0 dB (default), parametric EQ off, supply voltage +13.8V.

Set P_o = 100W in RTTY mode. Select USB, then adjust USB Audio Codec device volume on computer for 50% ALC reading.

Test Result: No ALC overshoot was observed.

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

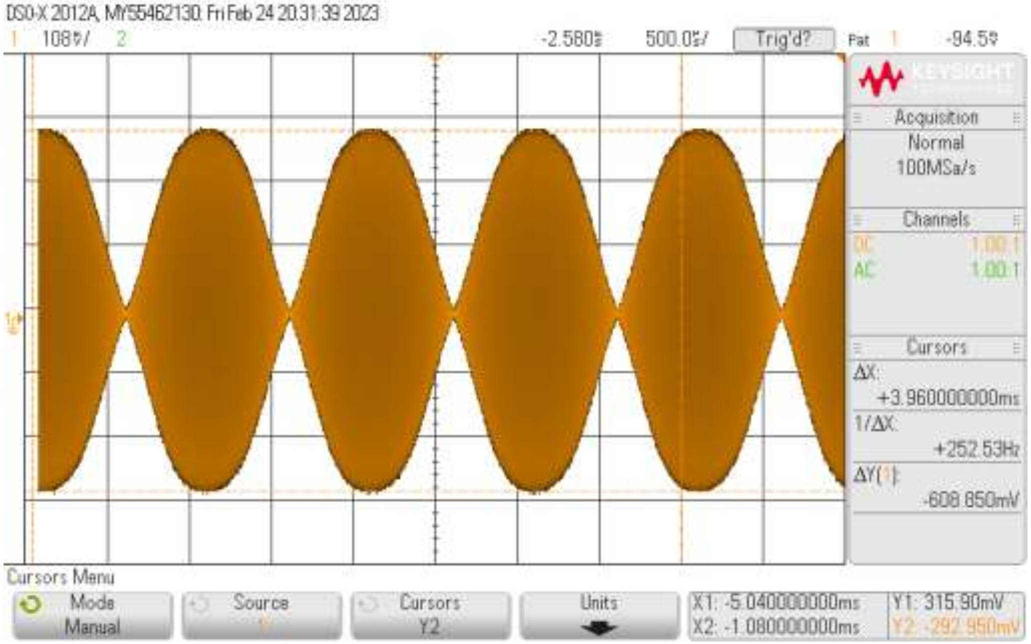


19: ALC Compression Check. In this test, a 2-tone test signal is applied to the USB port from a tone-generator program running on a laptop computer. An oscilloscope is connected to the FT-710 RF output via a 50 dB high-power attenuator. RF Power is initially adjusted for 100W output in RTTY mode.

Test Conditions: 14100 kHz USB, PROC LEVEL off, MOD SOURCE AUTO or USB, USB MOD GAIN 50% (default). Test tones: 700 and 1700 Hz, at equal amplitudes. TBW 100-2900 Hz. 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.



20: Transmitter 2-tone IMD Test. In this test, a 2-tone test signal is applied to the USB port from a tone-generator program running on a laptop computer. A spectrum analyzer is connected to the FT-710 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: DC supply 13.8V, measured at DC power socket. 3.6, 14.1, 28.1 and 50.1 MHz USB, MOD SOURCE USB, USB MOD GAIN = 50% (default), PROC LEVEL off. Test tones: 700 and 1700 Hz, at equal amplitudes. The -10 dBm reference level RL on the spectrum analyzer equates to rated CW output (= 0 dBc).

On computer, adjust USB Audio Codec device volume for 100W PEP (each tone at -6 dBc). Figures 12 through 15 show the two test tones and the associated IMD products for each test case.

Table 18. 2-tone TX IMD.

2-tone TX IMD Products at Rated P_o				
IMD Products	**Rel. Level dBc (0 dBc = 1 tone)**			
Freq. MHz	**3.6**	**14.1**	**28.1**	**50.1**
IMD3 (3rd-order)	-34	-45	-32	-30
IMD5 (5th-order)	-33	-31	-31	-34
IMD7 (7th-order)	-40	-42	-38	-41
IMD9 (9th-order)	-52	-52	-51	-50
Add -6 dB for IMD referred to 2-tone PEP				

Note on 6m IMD3: On 6m, the measured IMD3 is slightly worse than on the other bands tested. All bands exceed the -25 dBc guideline stated in ITU-R Recommendation SM.326-7 §1.2.3.

20a: Noise IMD Test. This test is similar to Test 26, except that a white-noise baseband is applied to the USB port from the tone-generator program. Spectrograms are captured at 100W and 25W PEP, as shown in Figure 16. Note that the IMD skirts are steeper at the lower power level.

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

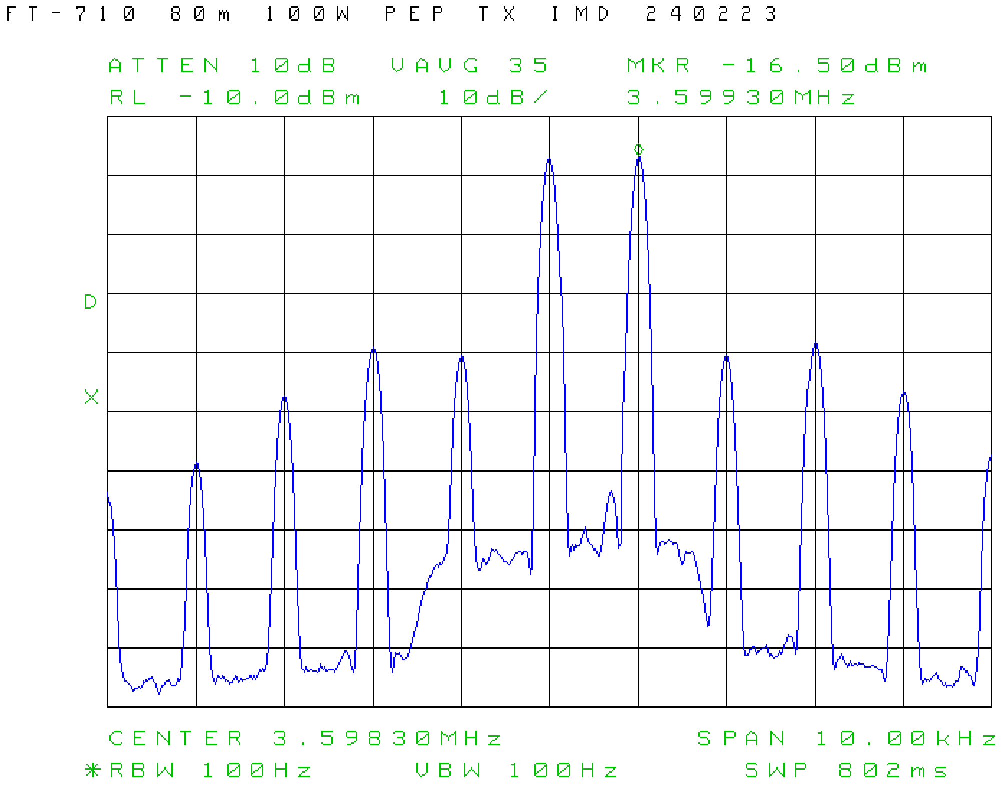


Figure 13: Spectral display of 2-tone IMD at 14.1 MHz, 100W PEP.

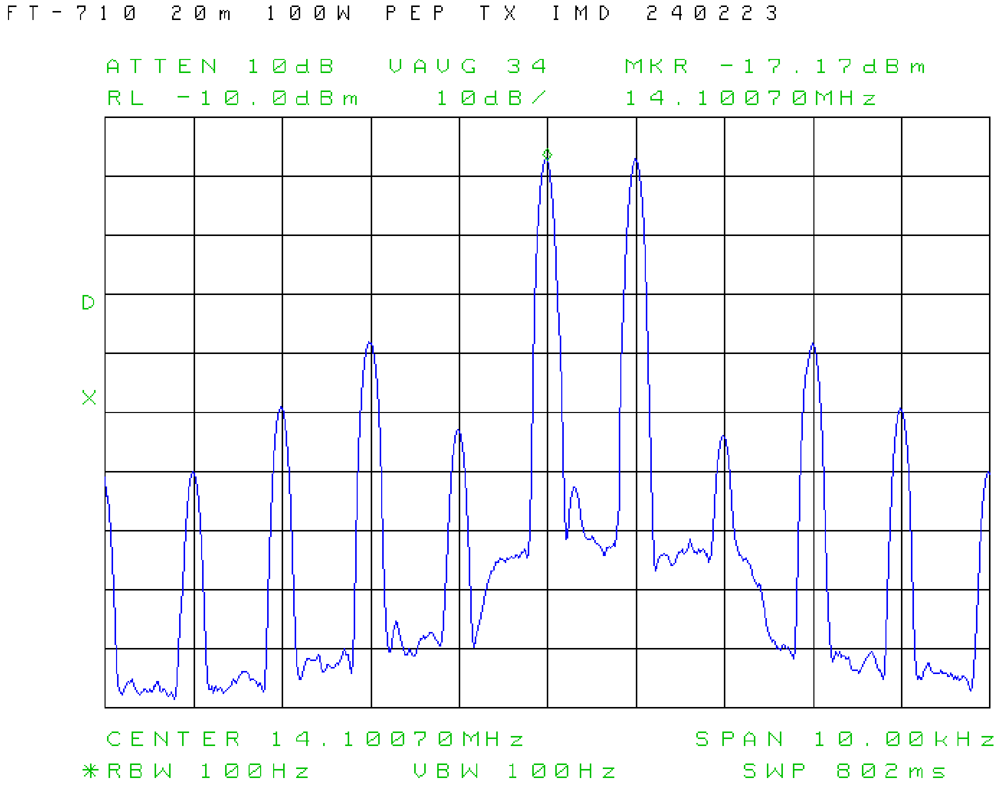
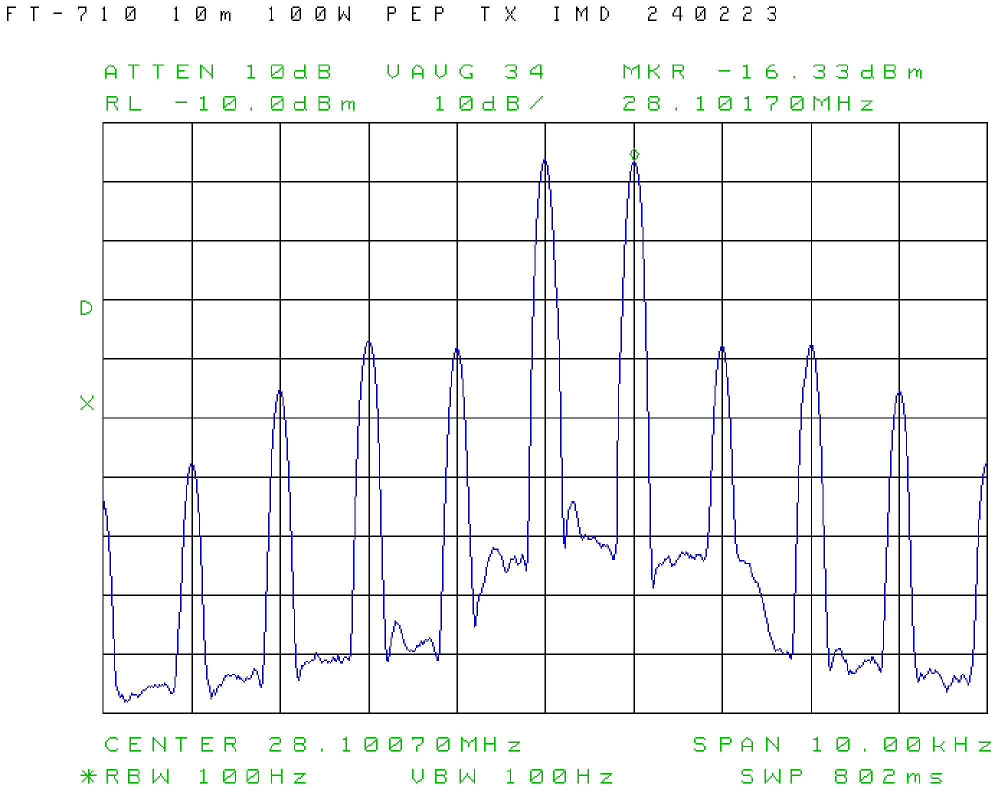


Figure 14: Spectral display of 2-tone IMD at 28.1 MHz, 100W PEP.

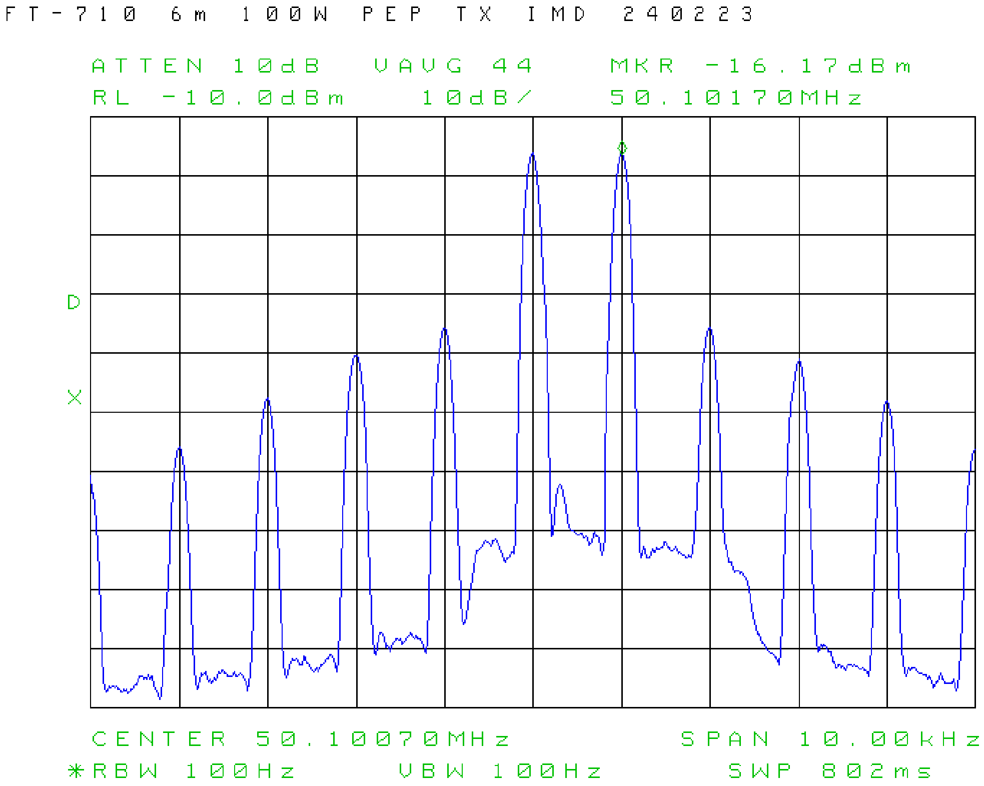


FT-710 10m 100W PEP TX IMD 240223

ATTEN 10dB VAVG 34 MKR -16.33dBm
RL -10.0dBm 10dB/ 28.10170MHz

CENTER 28.10070MHz SPAN 10.00kHz
*RBW 100Hz VBW 100Hz SWP 802ms

Figure 15: Spectral display of 2-tone IMD at 50.1 MHz, 100W PEP.

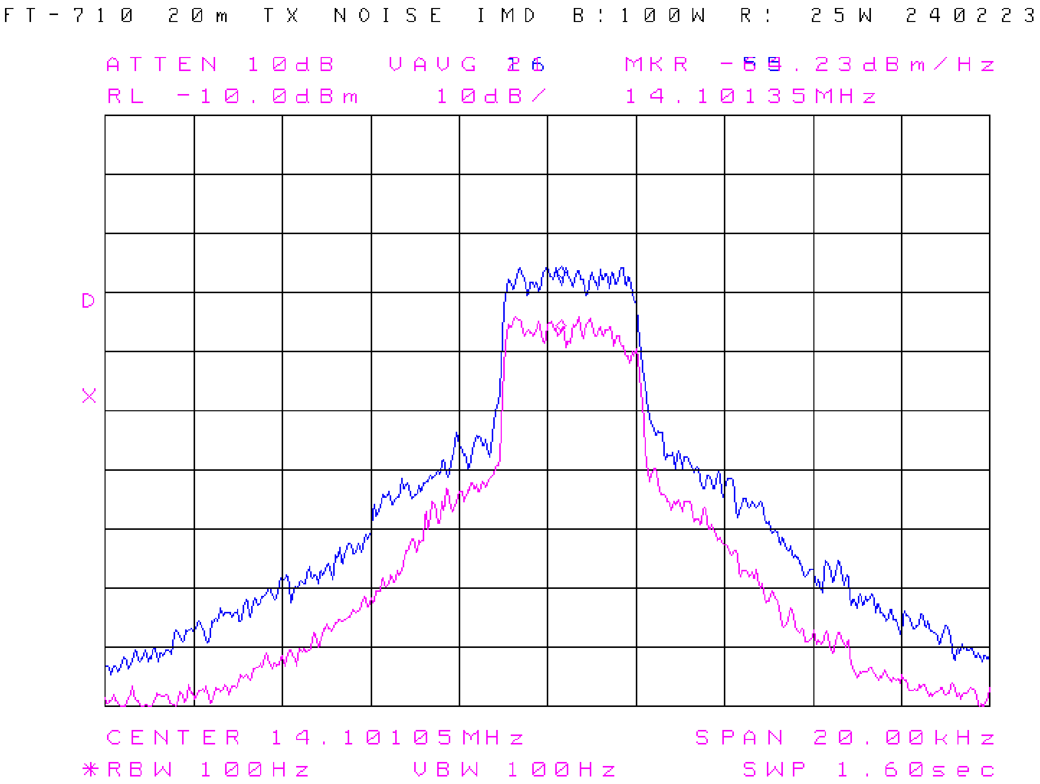


FT-710 6m 100W PEP TX IMD 240223

ATTEN 10dB VAVG 44 MKR -16.17dBm
RL -10.0dBm 10dB/ 50.10170MHz

CENTER 50.10070MHz SPAN 10.00kHz
*RBW 100Hz VBW 100Hz SWP 802ms

Figure 16: 20m noise modulation, showing IMD skirts.



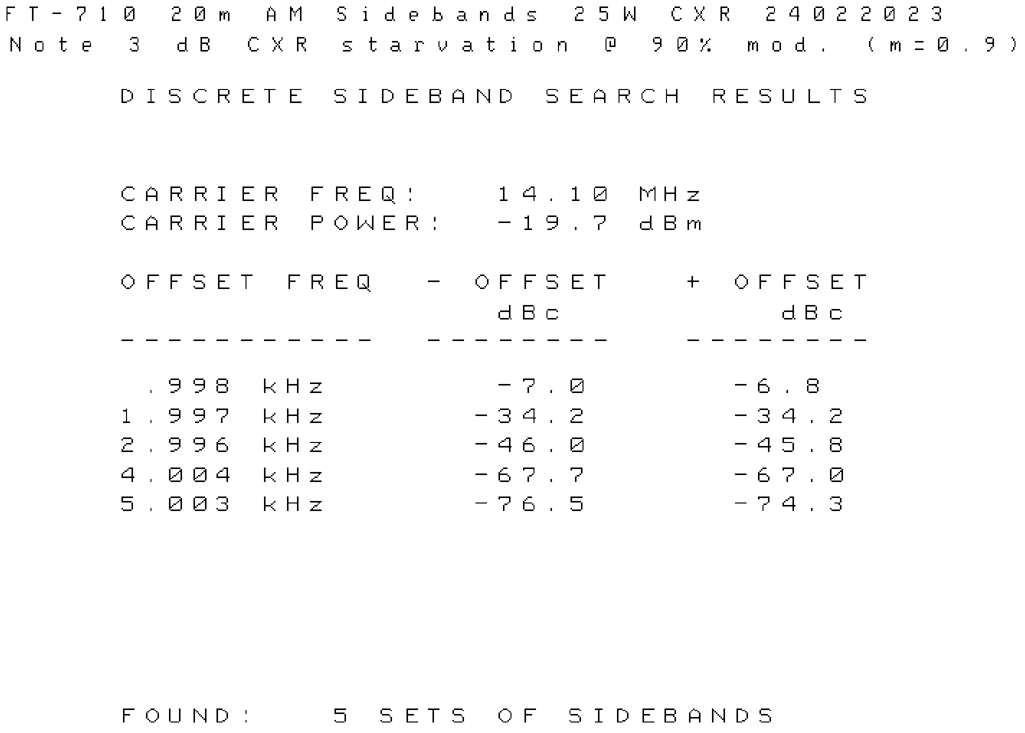
21: AM sidebands and THD with single-tone modulation. As in Test 26 above, the spectrum analyzer is connected to the FT-710 RF output via a 50 dB high-power attenuator. On the FT-710, RF Power is adjusted for 25W resting carrier. A 1 kHz test tone is applied to the USB port from the tone-generator program running on the laptop computer. The sideband measurement utility on the spectrum analyzer records the carrier and sideband parameters.

Test Conditions: 14100 kHz AM, 25W carrier output, MOD SOURCE = USB, USB MOD GAIN = 50% (default).

On computer, adjust USB Codec device volume for -7 dBc test tone level (90% modulation). Figure 16 shows the carrier and sideband levels. Calculated THD ≈ **2%**.

Note: At 90% modulation (m = 0.9), 3 dB carrier starvation occurs. Thi starvation is evident even at reduced resting carrier power level (7W).

Figure 17: AM Sidebands for 90% Modulation.



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FT-710 20m AM Sidebands 25W CXR 24022023
Note 3 dB CXR starvation @ 90% mod. (m=0.9)

     DISCRETE SIDEBAND SEARCH RESULTS


     CARRIER FREQ:     14.10 MHz
     CARRIER POWER:    -19.7 dBm

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

      .998 kHz        -7.0         -6.8
     1.997 kHz       -34.2        -34.2
     2.996 kHz       -46.0        -45.8
     4.004 kHz       -67.7        -67.0
     5.003 kHz       -76.5        -74.3

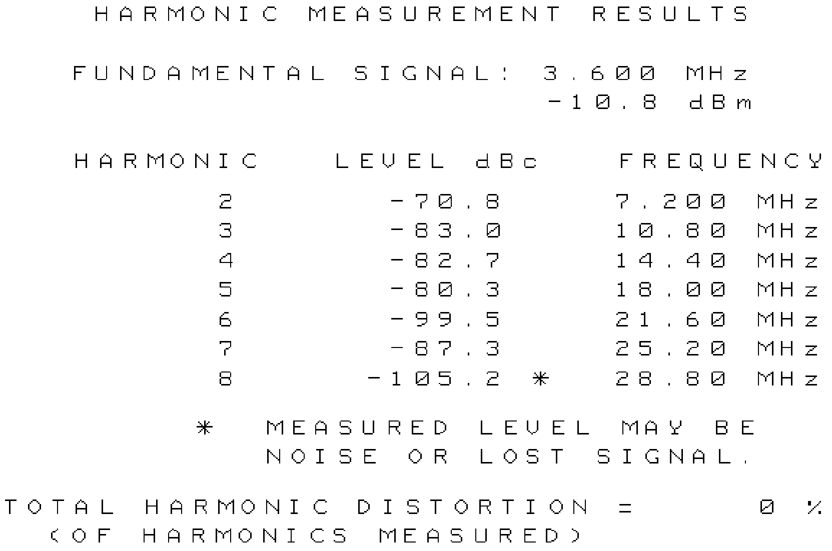



     FOUND:   5 SETS OF SIDEBANDS
```

22: Transmitter harmonics & spectral purity. Once again, the spectrum analyzer is connected to the FT-710 RF output via a 60 dB high-power attenuator. RF Power is adjusted for rated CW output on each band in turn. The 0 dBm reference level equates to 100W. The spectrum analyzer’s harmonic capture utility is started.

Test Conditions: 3.6, 14.1, 28.1, 50.1 MHz, RTTY, rated output to 50Ω load. Utility start and stop frequencies are configured as shown in Figures 18 through 25 inclusive. Harmonic data and spur sweeps are presented for HF/6m. It will be seen that harmonics and spurs are well within specifications.

Figure 18.



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        HARMONIC MEASUREMENT RESULTS

      FUNDAMENTAL SIGNAL: 3.600 MHz
                         -10.8 dBm

      HARMONIC     LEVEL dBc     FREQUENCY
            2         -70.8       7.200 MHz
            3         -83.0      10.80 MHz
            4         -82.7      14.40 MHz
            5         -80.3      18.00 MHz
            6         -99.5      21.60 MHz
            7         -87.3      25.20 MHz
            8       -105.2 *     28.80 MHz

         *  MEASURED LEVEL MAY BE
            NOISE OR LOST SIGNAL.

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

Figure 19.

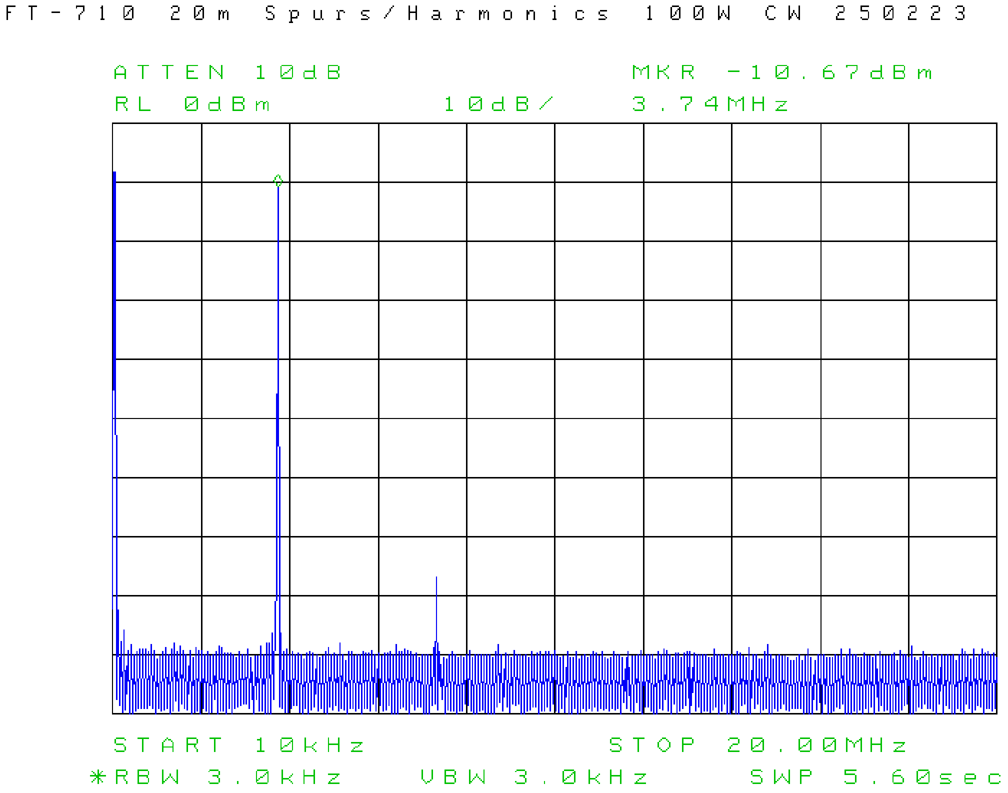
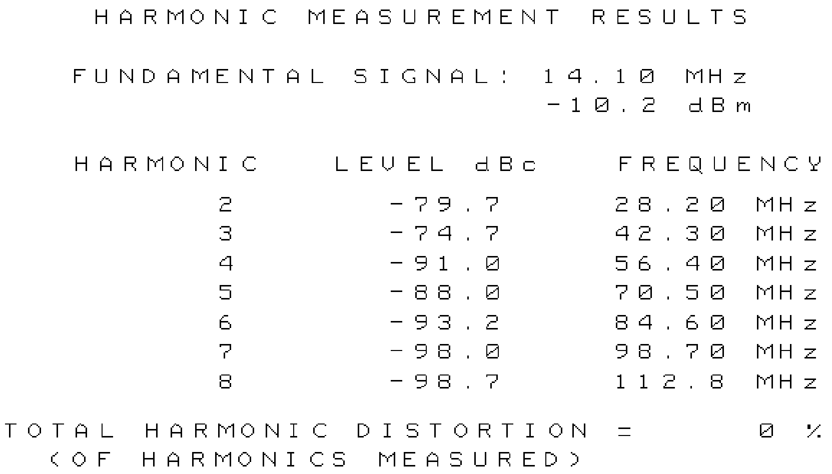


Figure 20.



```
HARMONIC MEASUREMENT RESULTS

FUNDAMENTAL SIGNAL: 14.10 MHz
                    -10.2 dBm

HARMONIC    LEVEL dBc    FREQUENCY
       2       -79.7     28.20 MHz
       3       -74.7     42.30 MHz
       4       -91.0     56.40 MHz
       5       -88.0     70.50 MHz
       6       -93.2     84.60 MHz
       7       -98.0     98.70 MHz
       8       -98.7     112.8 MHz

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

Figure 21.

FT-710 20m Spurs/Harmonics 100W CW 250223

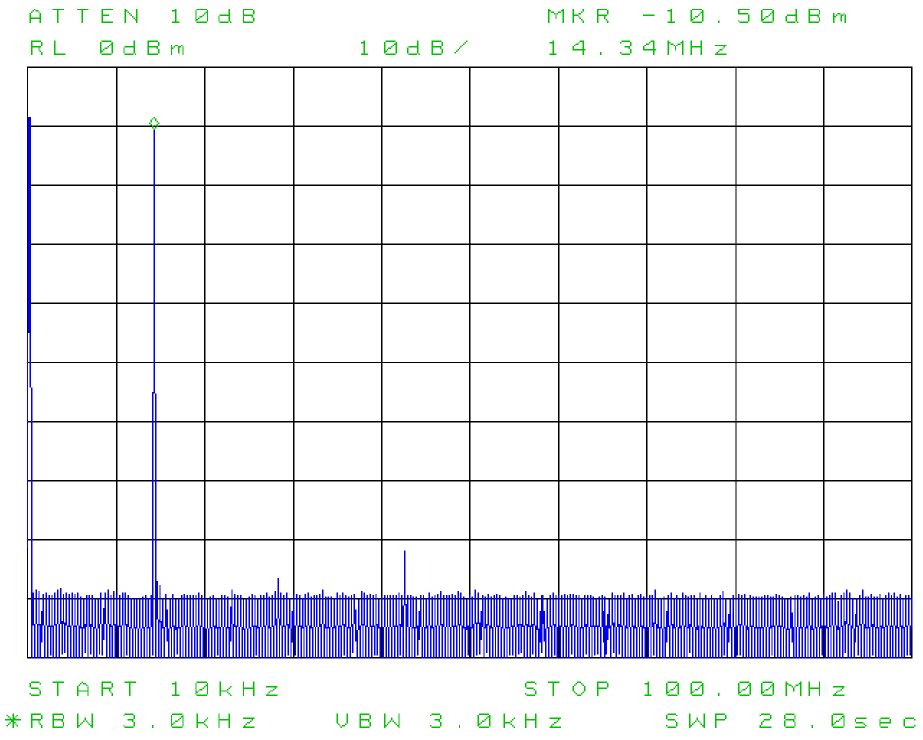
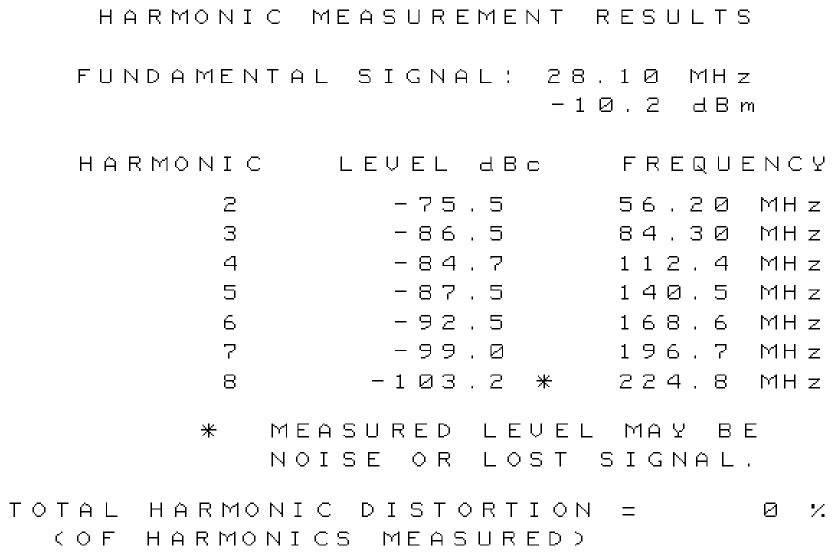


Figure 22.



```
HARMONIC MEASUREMENT RESULTS

FUNDAMENTAL SIGNAL: 28.10 MHz
                    -10.2 dBm

HARMONIC    LEVEL dBc    FREQUENCY
     2        -75.5      56.20 MHz
     3        -86.5      84.30 MHz
     4        -84.7      112.4 MHz
     5        -87.5      140.5 MHz
     6        -92.5      168.6 MHz
     7        -99.0      196.7 MHz
     8       -103.2 *    224.8 MHz

       *  MEASURED LEVEL MAY BE
          NOISE OR LOST SIGNAL.

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

Figure 23.

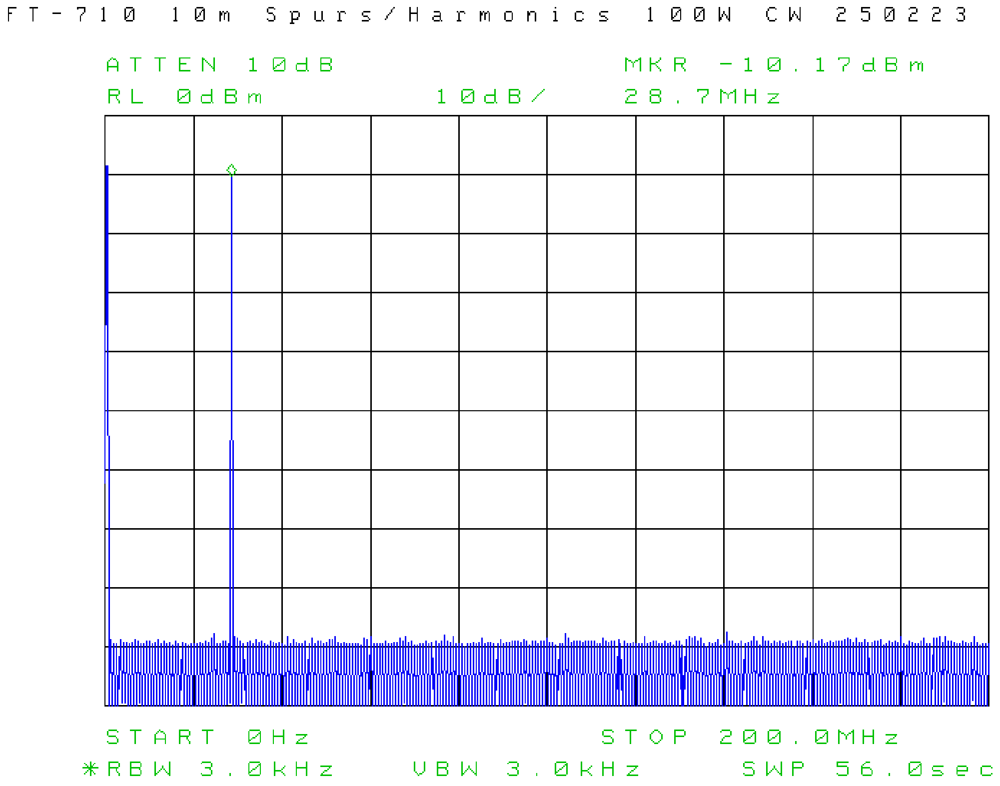
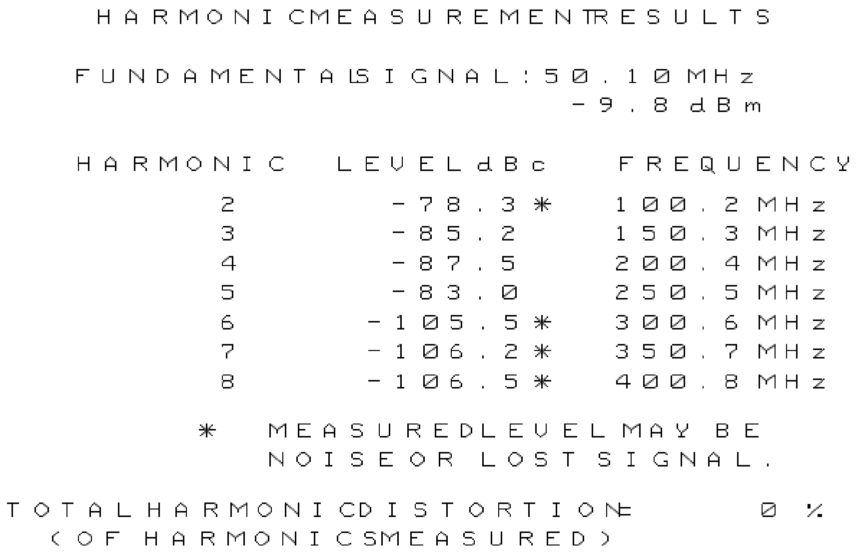
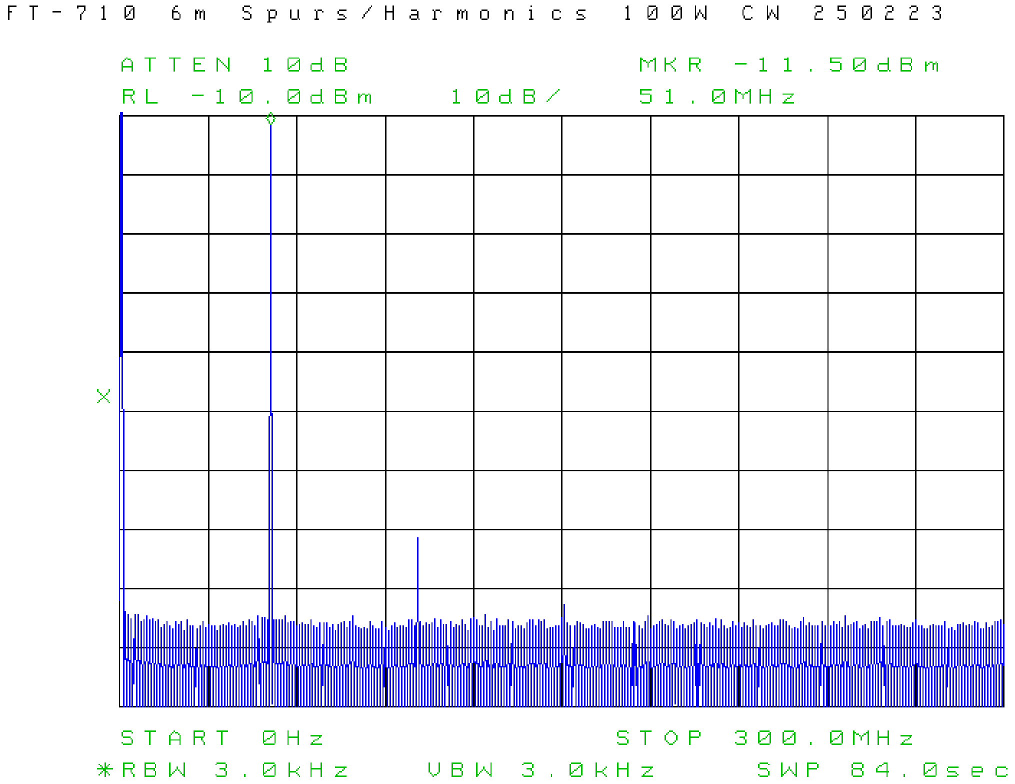

FT-710 10m Spurs/Harmonics 100W CW 250223

Figure 24.



```
           HARMONIC MEASUREMENT RESULTS

         FUNDAMENTAL SIGNAL: 50.10 MHz
                             -9.8 dBm

         HARMONIC    LEVEL dBc    FREQUENCY

             2         -78.3 *    100.2 MHz
             3         -85.2      150.3 MHz
             4         -87.5      200.4 MHz
             5         -83.0      250.5 MHz
             6        -105.5 *    300.6 MHz
             7        -106.2 *    350.7 MHz
             8        -106.5 *    400.8 MHz

            *   MEASURED LEVEL MAY BE
                NOISE OR LOST SIGNAL.

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

Figure 23.



23: Transmitted phase noise. A Rohde & Schwarz FSUP 8 signal source analyzer is connected to the FT-710 RF output via a 40 dB high-power attenuator. Next, a phase noise sweep is run at 100W output on each selected band in turn at 10 Hz – 500 kHz or 10 Hz – 1 MHz offset.

Test Conditions: 3.6, 14.1, 28.2 and 50.1 MHz RTTY, 100W to 50Ω load. Input level to FSUP: +10 dBm. FSUP configured for AUTO level, 5 dB default attenuation, minimum offset 10 Hz.

Figure 26a: Transmitted phase noise, 80m.

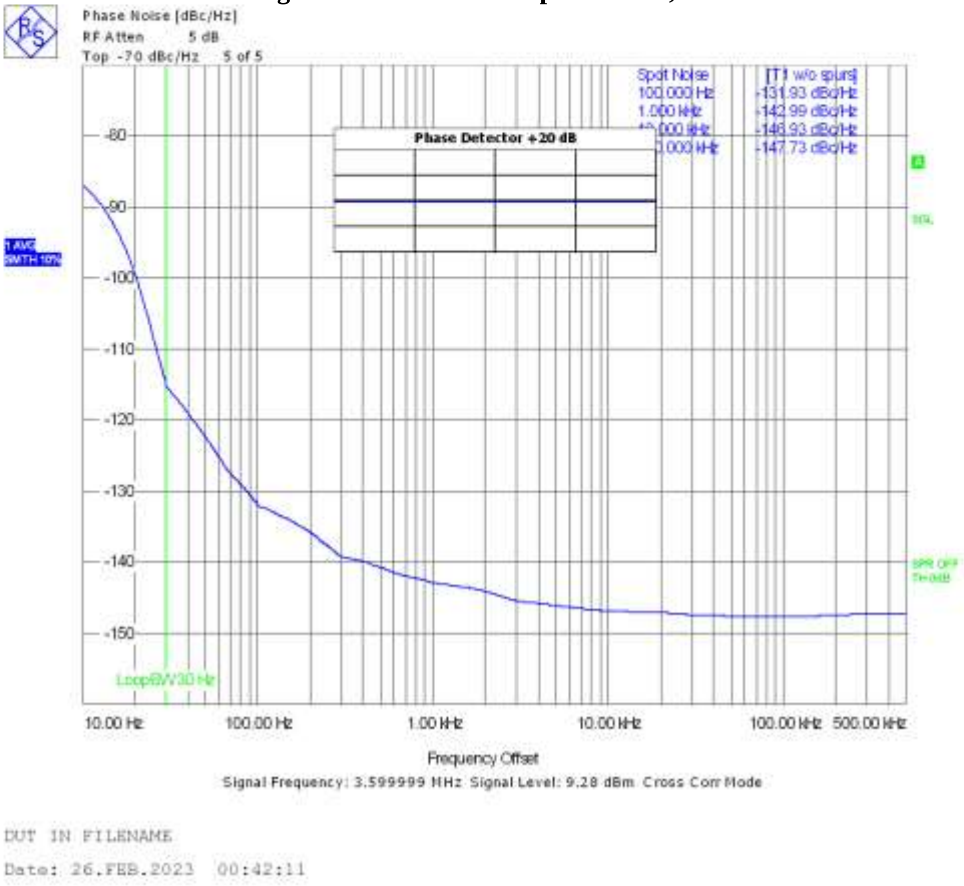
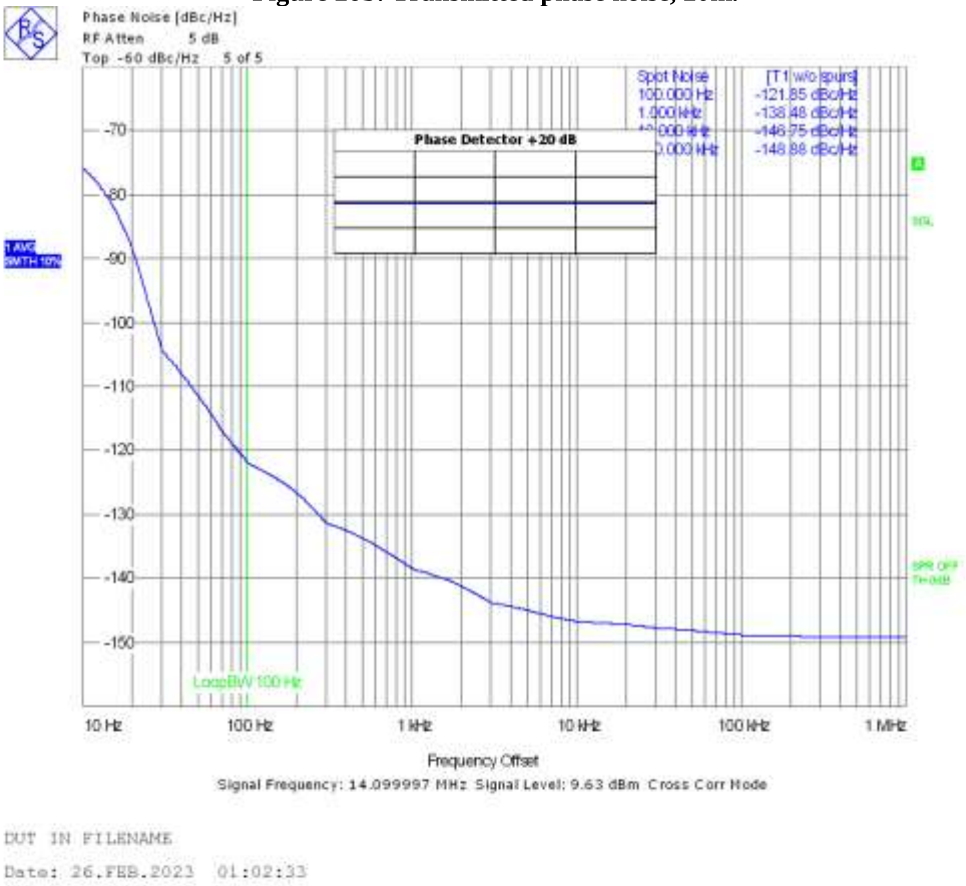


Figure 26b: Transmitted phase noise, 20m.

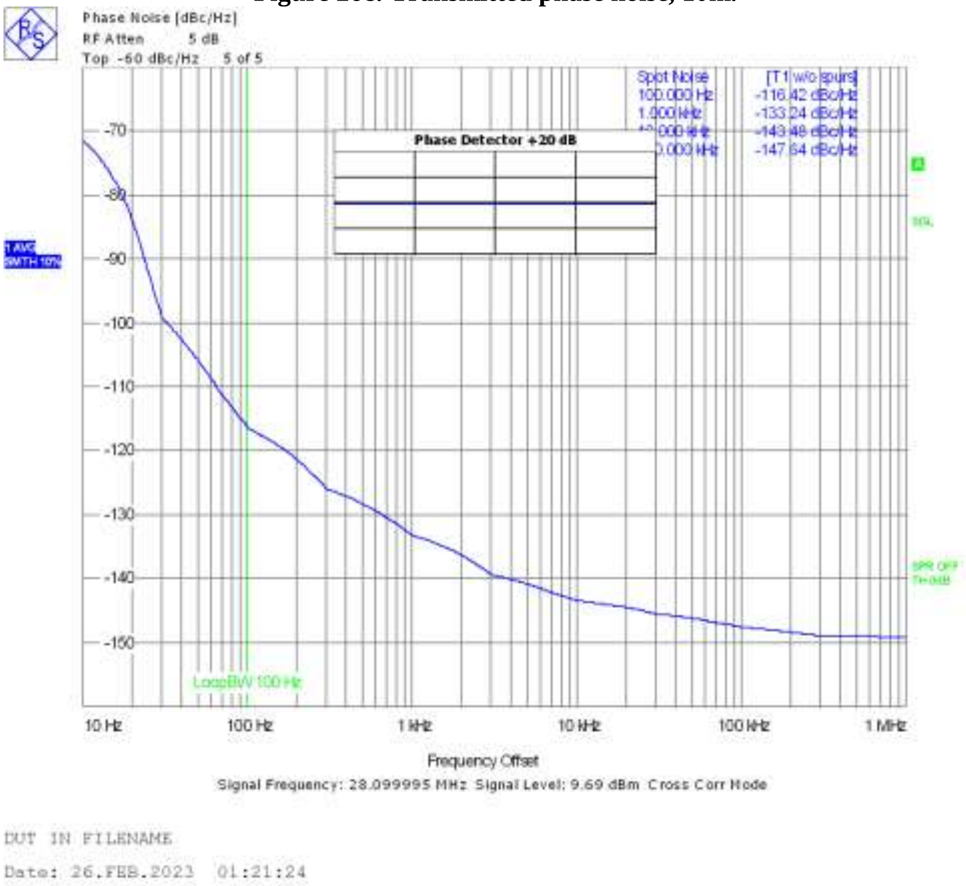


Signal Frequency: 14.099997 MHz Signal Level: 9.63 dBm Cross Corr Mode

DUT IN FILENAME

Date: 26.FEB.2023 01:02:33

Figure 26c: Transmitted phase noise, 10m.

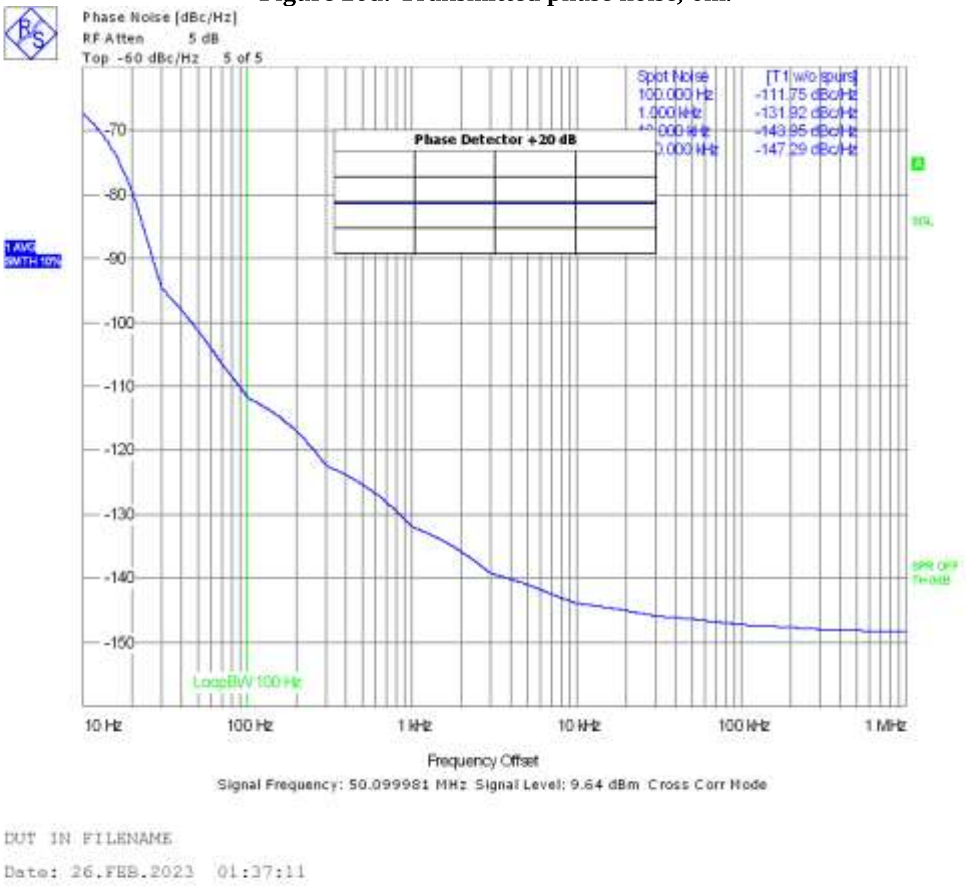


Signal Frequency: 28.099995 MHz Signal Level: 9.69 dBm Cross Corr Mode

DUT IN FILENAME

Date: 26.FEB.2023 01:21:24

Figure 26d: Transmitted phase noise, 6m.



24: Spectral display of CW keying sidebands. The spectrum analyzer is connected to the FT-710 RF output via a 60 dB high-power attenuator. The -10 dBm reference level equates to 100W. A series of dits is transmitted at the highest keying speed.

Test Conditions: 14.1 MHz CW, 100W output to 50Ω load. Keying speed 48 wpm (KEY SPEED max.) using internal keyer. Spectrum analyzer RBW is 10 Hz, video-averaged; sweep time < 4 sec. Figures 29 and 30 show the transmitter output ±5 kHz from the carrier at 4/8 and 6 ms rise-time, respectively.

Figure 27a: Keying sidebands at 48 wpm, 4/8 ms rise-time 14.1 MHz, 100W.

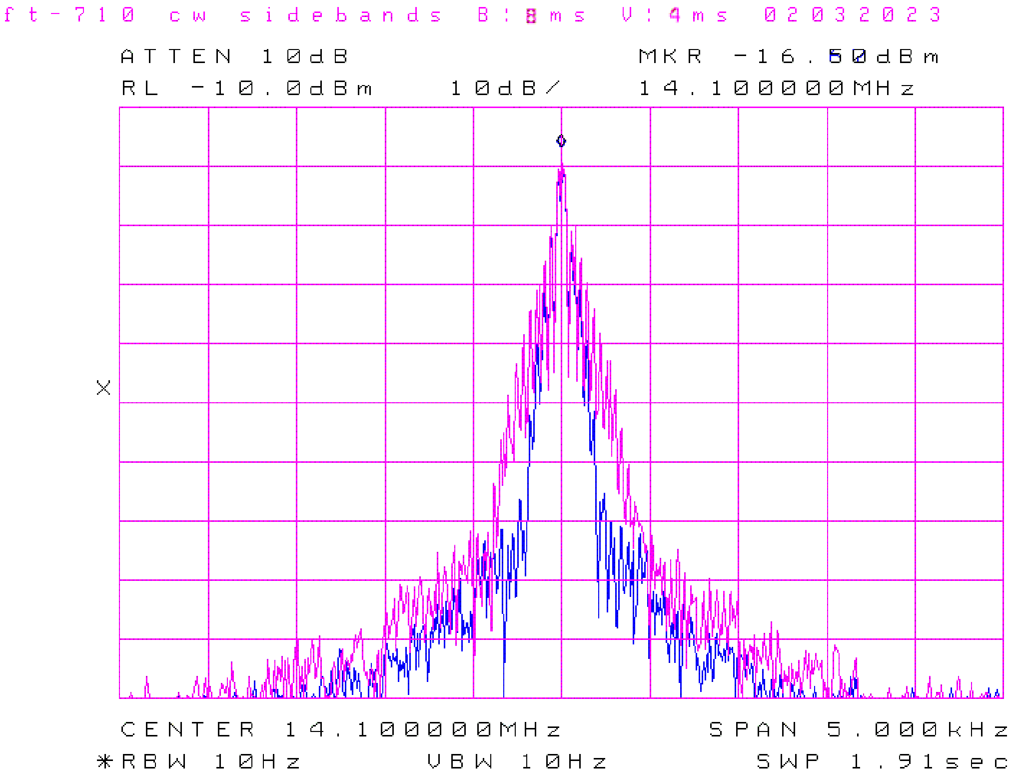
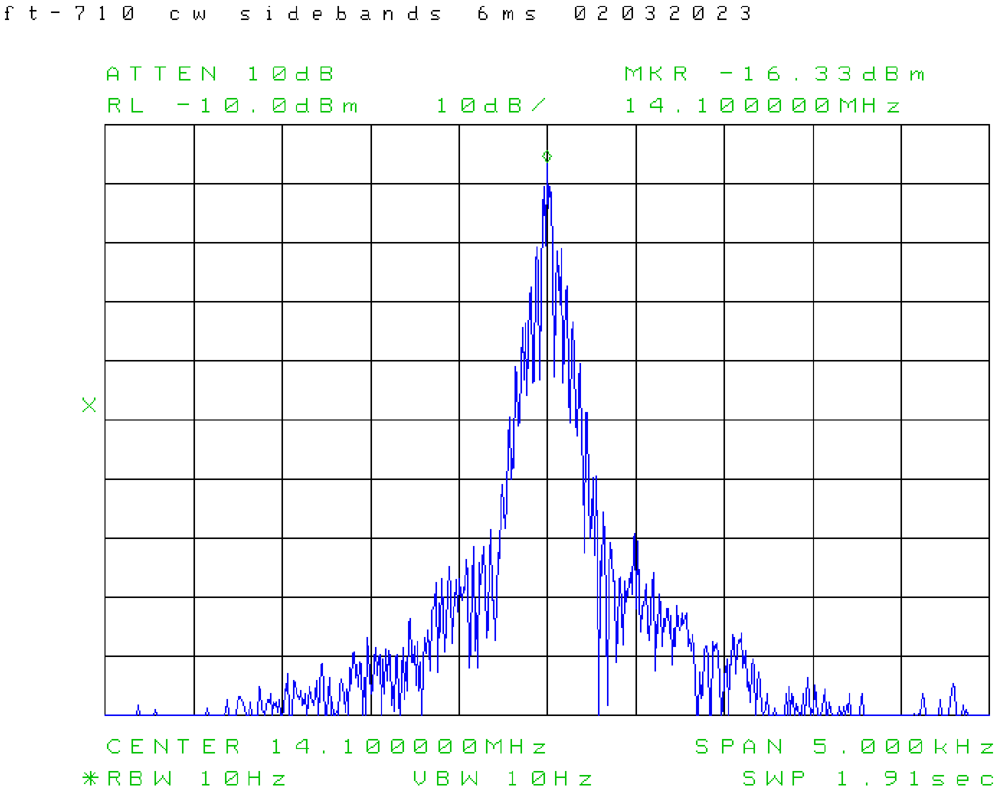


Figure 27b: Keying sidebands at 48 wpm, 6 ms rise-time 14.1 MHz, 100W.



24a: CW keying envelope. The oscilloscope is terminated in 50Ω and connected to the FT-710 RF output via a 50 dB high-power attenuator. A series of dits is transmitted from the internal keyer at the highest keying speed (48 wpm) in semi-break-in mode (BK).

Test Conditions: 14.1MHz CW, 100W output to 50Ω load. CW rise time = 4 ms (default).

Figure 28a: Keying envelope at 48 wpm, 4 ms rise time, 2 ms/div.

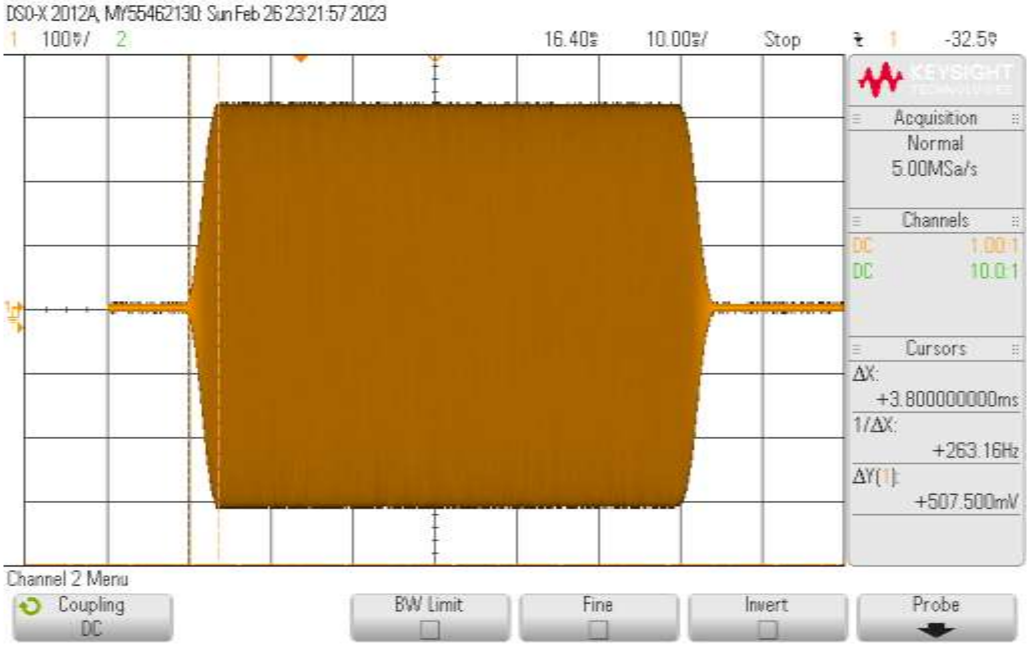
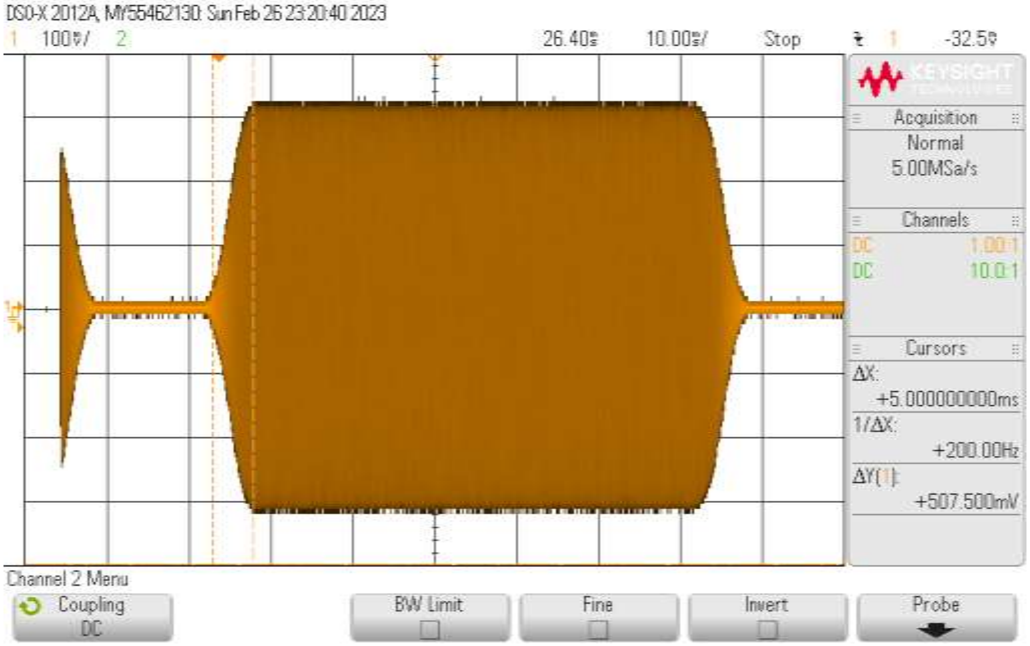


Figure 28b: Keying envelope at 48 wpm, 6 ms rise time, 2 ms/div.


DSO-X 2012A, MY55462130: Sun Feb 26 23:20:40 2023

1 100mV/ 2 26.40ms 10.00ms/ Stop 1 -32.5mV

Acquisition Normal 5.00MSa/s

Channels DC 1.00:1 DC 10.0:1

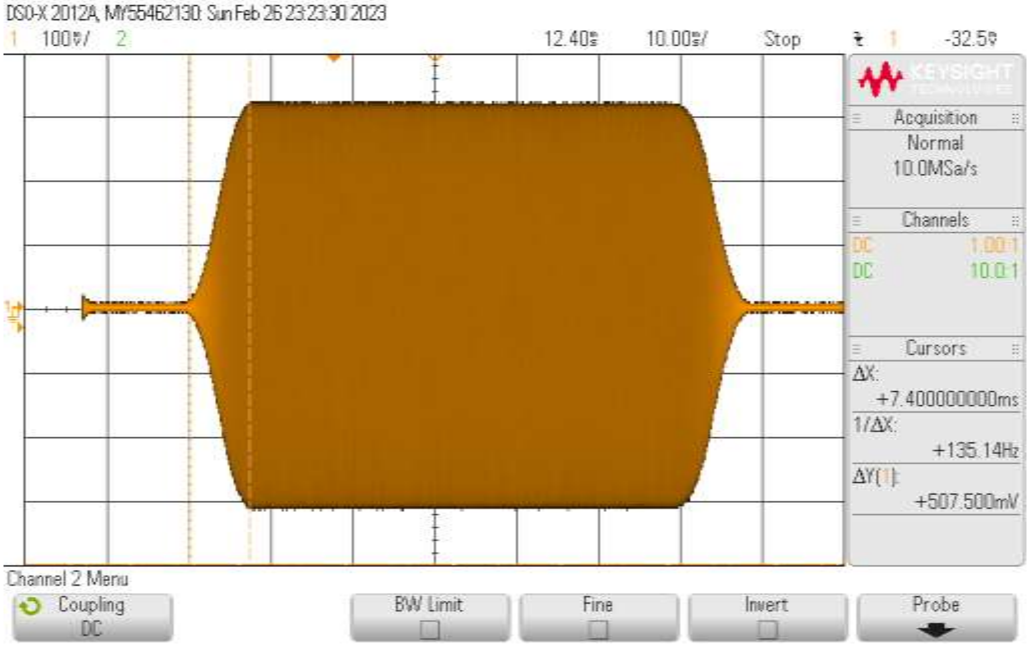
Cursors

ΔX: +5.000000000ms

1/ΔX: +200.00Hz

ΔY(1): +507.500mV

Figure 28c Keying envelope at 48 wpm, 8 ms rise time, 2 ms/div.


DSO-X 2012A, MY55462130: Sun Feb 26 23:23:30 2023

1 100mV/ 2 12.40ms 10.00ms/ Stop 1 -32.5mV

Acquisition Normal 10.0MSa/s

Channels DC 1.00:1 DC 10.0:1

Cursors

ΔX: +7.400000000ms

1/ΔX: +135.14Hz

ΔY(1): +507.500mV

24b: CW "RF Tail" check. Channel 1 of the oscilloscope is terminated in 50Ω and connected to the FT-710 RF output via a 50 dB high-power attenuator. Channel 2 is connected to the RTTY/DATA PTT line, and pulled up by +12V via a 10kΩ resistor.; A series of dits is transmitted from the internal keyer at the highest QSK keying speed (20 wpm) in full break-in mode.

This test verifies that the RF carrier ceases before the SEND line drops back to the standby state. This will prevent hot-switching of an external amplifier's T/R relays.

Test Conditions: 14.1MHz CW, 100W output to 50Ω load. CW rise time = 4 ms (default).

Test Results: P_O reaches zero ≈ 4 ms ***before*** SEND line drops back to standby state (high). Thus, there is no undesirable "RF Tail". This time interval is independent of CW rise time.

Figure 29: Timing of RTTY/DATA PTT line and CW envelope ("RF tail" test)

:

24c: CW QSK recovery test: This test was devised to measure the maximum speed at which the receiver can still be heard between code elements in QSK CW mode.

The FT-710 is terminated in a 50Ω 100W load via a directional coupler. A test signal is injected into the signal path via the directional coupler; a 20 dB attenuator at the coupled port protects the signal generator from reverse power. Test signal level is adjusted for S3…S5 at the receiver. As the coupler is rated at 25W max., RF Power is set at 10W.

Test Conditions: 14.010 MHz, 500 Hz CW, IPO, ATT off, DNR off, NB off, F-BK on, rise time = 4 ms, RF Power at 10W, KEY SPEED at 48 wpm (max.), CW Pitch default. Test signal at 14.0101 MHz. Sidetone = 600 Hz, received tone = 700 Hz.

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

Test Result: The received tone could still be heard distinctly at **20 wpm.**

25: REAR MOD (analog baseband input) and USB MOD level for 100W output.) A 1 kHz test tone is injected into the DATA IN lead of the rear-panel RTTY/DATA socket, and the input voltage required for 100W RF output is noted. Next, the tone generator program in the laptop computer is set up to apply a 1 kHz test tone to the USB MOD input.

Test Conditions: 14100 kHz USB, PROC LEVEL off, MOD SOURCE AUTO or REAR, REAR MOD GAIN 50% (default). Test tone 1 kHz. TBW 100-2900 Hz. Bass/Treble = 0 dB (default), parametric EQ OFF. Supply voltage +13.8V

Adjust test tone level for ≈ 100W output in USB modes. The required input levels were **31 mV rms** for 100W output in USB and DATA-U.

Repeat test with MOD SOURCE AUTO or USB, USB MOD GAIN = 50% (default). 100W output was obtained with laptop tone generator level at 0 dB (nominal level) and USB MOD GAIN at 50%.

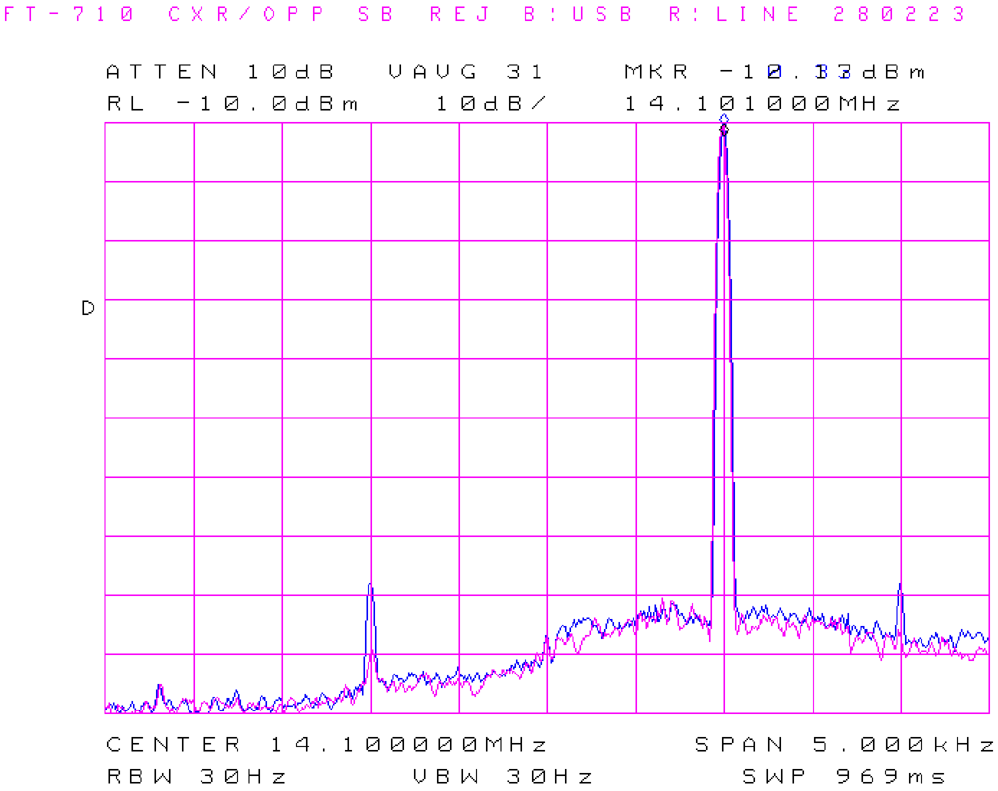
25a: Carrier and opposite-sideband suppression. A 1 kHz test tone is applied to ACC Pin 1, and then via the USB port. Carrier and opposite-sideband suppression are checked on the spectrum analyzer at 100W RF output for both cases.

Test Conditions: 14100 kHz USB, MOD SOURCE AUTO or USB, DATA-1, TBW = WIDE (default), TBW 100-2900 Hz. Bass/Treble = 0 dB (default), parametric EQ OFF, test tone 1 kHz. Supply voltage +13.8V

Adjust test tone level for 100W output. Read carrier amplitude at 14100 kHz, and opposite-sideband amplitude at 14099 kHz.

Test Results: For RTTY/DATA (REAR) analog test-tone input, carrier and opposite sideband are both < -80 dBc. For USB test tone input, carrier < -80 dBc, and there is a -79 dBc artifact at the opposite sideband frequency. See Figure 30. The Yaesu specification is -60 dBc.

Figure 30: Carrier & opposite-sideband suppression at 14.1 MHz.



25b: SSB transmit audio-frequency response via USB port. In this test, a white-noise baseband is applied to the USB port from a tone-generator program running on a laptop computer. The spectrum analyzer is connected to the FT-710 RF output via a 60 dB high-power attenuator.

Test Conditions: 14100 kHz USB, MOD SOURCE: AUTO or USB, USB MOD GAIN = 50% (default). Test signal: white noise. WIDE, MID and NAR TBW are at default values.

On computer, adjust USB Audio Codec device volume for 50% ALC reading. Using Marker on spectrum analyzer, measure frequency and relative amplitude at lower passband edge. Move marker "down" 6 dB and record frequency. Move marker "down" a further 14 dB and record frequency again. Repeat procedure for upper passband edge. The test data are shown in Table 19.

Table 19: Measured SSB TX lower and upper cutoff frequencies (via USB input).

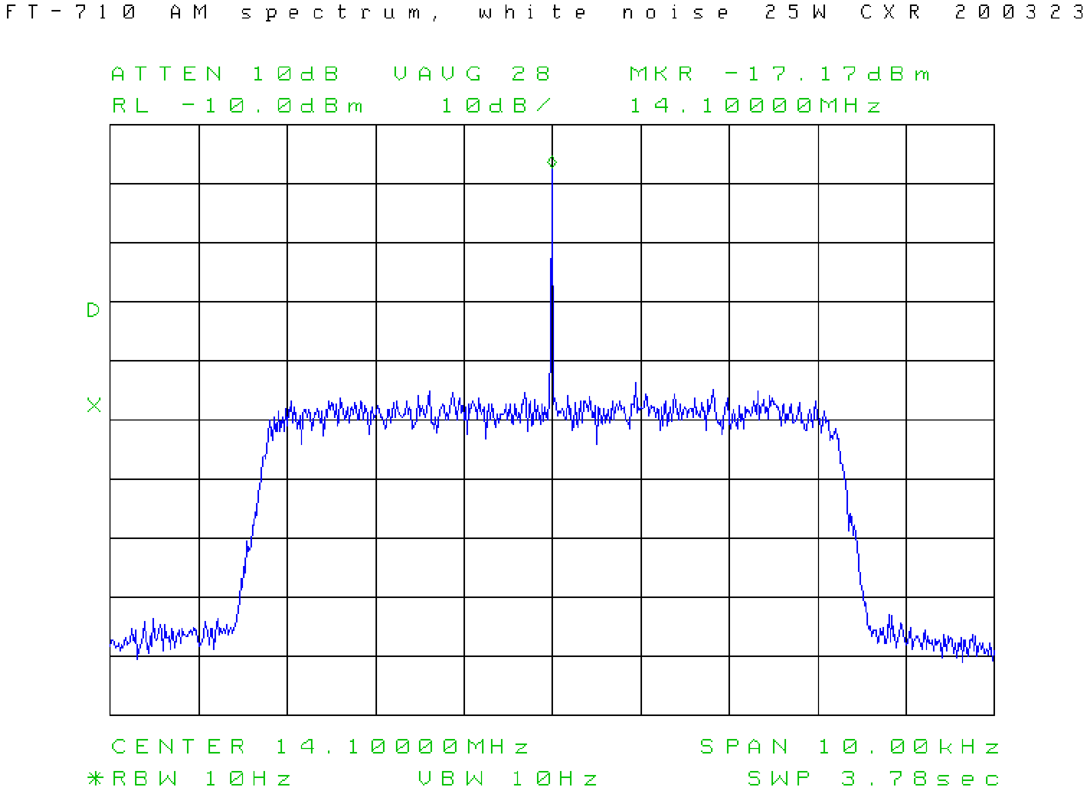
TBW Hz	Lower (Hz)		Upper (Hz)	
1 kHz = 0 dB ref.	-20 dB	-6 dB	-6 dB	-20 dB
100-2900	75	50	3025	3250
50-3050	30	50	3000	3150
300-2700	225	150	2825	3100
400-2600	400	300	2700	2760

25c. AM transmit frequency response. Here, a white-noise baseband is applied to the USB port from a tone-generator program running on a laptop computer. The spectrum analyzer is connected to the IC-7610 RF output via a 60 dB high-power attenuator.

Test Conditions: 14100 kHz AM, 25W carrier, TBW 50-3050 Hz, MOD SOURCE USB, USB MOD Level = 50% (default). Test signal: white noise. WIDE, MID and NAR TBW are at default values.

On computer, adjust USB Audio Codec device volume for 50% ALC reading.
Note: 2.5 dB carrier starvation was observed with white noise modulation on.

Figure 30: AM with white noise modulation.



26: FM deviation. The FT-710 output is connected to the RF IN/OUT port (75W max. input) of the communications test set. Voice and CTCSS peak deviation are checked.

Test Conditions: 52.525 MHz, FM, FIL1, RF Power set at 25W. Speak loudly into mic and read deviation.

Test Result: Peak deviation = **4.5 kHz** (FM, 16K0F3E), **2.4 kHz** (FM-N, 11K0F3E).

Next, select CTCSS TONE = 100 Hz (1Z). Key FT-710 and read tone frequency and deviation on test set.

Test Result: Tone frequency 100.05 Hz, deviation 525 Hz (FM), 280 Hz (FM-N).

26a: CTCSS decode sensitivity. The test set is configured as an RF generator. TSQL (CTCSS tone squelch) is enabled in the FT-710 and the minimum RF input power and tone deviation at which the tone squelch opens are measured.

Test Conditions: 52.525 MHz, FM & FM-N ATT off, CTCSS TSQL on, TONE 100 Hz. At test set, CTCSS tone deviation 700/500Hz (FM), 350/250 Hz (FM-N).

Table 20: CTCSS Decode Sensitivity

	Tone Dev. Hz	RF input level dBm
FM	700	-120
	500	-120
FM-N	350	-124
	250	-121

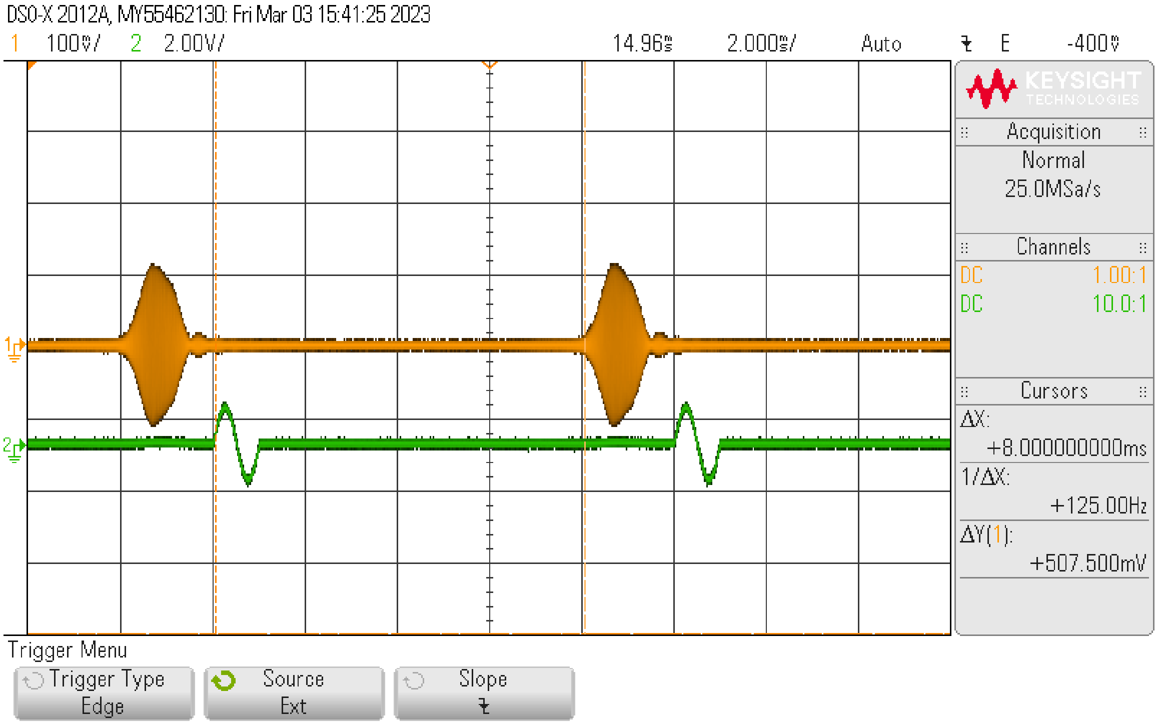
Note: For FM, squelch opens at -120 dBm signal level with 1 kHz test tone at 3 kHzz deviation + 100 Hz CTCSS.

27: Transmit latency. In this test, a function generator feeds repetitive bursts of one cycle of a 1 kHz tone to the DUT line audio input (ACC Pin 11) and also to Channel 1 of a dual-trace oscilloscope. Channel 2 is connected via a high-power 50 dB attenuator to the DUT ANT socket. The scope is triggered from the function generator's SYNC output. The time interval between the leading edge of the AF burst displayed on Channel 1 and that of the RF burst displayed on Channel 2 is recorded for WIDE, MID and NAR TBW settings.

Test Conditions: 14100 kHz USB, 100W, MOD SOURCE REAR, REAR MOD GAIN = 50% (default). Test signal: tone burst (1 cycle at 1 kHz). TBW = 100-2900 Hz. Scope sweep 2 ms/div.

Test Result: Transmit latency 8 ms.

Figure 31. Transmit latency: TBW = 100 – 2900 Hz, latency = 8 ms.



DSO-X 2012A, MY55462130: Fri Mar 03 15:41:25 2023

1 100mV/ 2 2.00V/ 14.96ms 2.000ms/ Auto ⟲ E -400mV

Acquisition
Normal
25.0MSa/s

Channels
DC 1.00:1
DC 10.0:1

Cursors
ΔX:
+8.000000000ms
1/ΔX:
+125.00Hz
ΔY(1):
+507.500mV

Trigger Menu
Trigger Type
Edge
Source
Ext
Slope
⟲

28: References.

1. HF Receiver Testing: Issues & Advances”: http://www.nsarc.ca/hf/rcvrtest.pdf

2. “Noise Power Ratio (NPR) Testing of HF Receivers”: http://www.ab4oj.com/test/docs/npr_test.pdf

3. ITU-R Rec. SM.328-11, Annex 1, Sections 1.1 and 1.7.

4. ITU-R Rec. SM.1837-1.

5. .Yaesu FT-710 Operating Manual.

6. Yaesu FT-710 Technical Supplement.

April 12, 2023.