

IC-9700 User Evaluation & Test Report

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Figure 1: The Icom IC-9700.



Introduction: This report describes the evaluation of IC-9700 S/N 12001793 from a user perspective. **Appendix 1** presents results of an RF lab test suite performed on the radio. As my VHF/UHF antenna facilities are very limited, I was unable to do much in the way of on-air testing.

1. Physical “feel” of the IC-9700: The IC-9700 is fairly small and light, considering that it is a full-featured 3-band all-mode transceiver. The case dimensions are 240(W) × 238(D) × 94(H) mm and the radio weighs 4.7 kg.

The IC-9700 features a large color touch-screen display. This is an innovation in Icom’s “base” amateur 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 MULTI knob menus has moved many controls off the front panel.

Owners of current Icom IF-DSP transceivers should find the IC-9700 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 location similar to those on other Icom radios as well as two concentric knobs (MAIN & SUB AF Gain + RF Gain/Squelch) and MULTI to the left and right of the display respectively. Pressing the MULTI knob opens a context menu on the right edge of the screen; this menu changes with the previously-selected mode or function, allowing adjustment of appropriate parameters. The learning curve will be minimal for owners of other Icom IF-DSP radios. The MULTI control is 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.

When both MAIN and SUB are displayed, pressing the MAIN or SUB AF Gain (inner) knob highlights the MAIN or SUB frequency display and meter. Pressing and holding A exchanges Main and Sub. Pressing and holding SUB AF Gain hides the lower (SUB) display. In this state, pressing and holding MAIN AF Gain toggles the upper display between Main and Sub.

The standard 8-pin MIC socket, and the 3.5mm PHONES jack, is on the left side of the front panel. The supplied HM-219 hand mic or any other compatible electret or low-impedance dynamic mic can be plugged into the mic jack. (A dynamic mic requires a series blocking capacitor.) All the ports provided on other Icom radios are on the rear panel, including ANT1 (144 MHz), ANT2 (430 MHz) and ANT3 (1.2 GHz), a USB “B” port, the SMA 10 MHz External Reference port and the 8-pin DIN ACC socket. There is no front-panel USB port. A large muffin-type cooling fan is also mounted on the rear panel. ANT1 is SO-239; ANT2 and ANT3 are N.

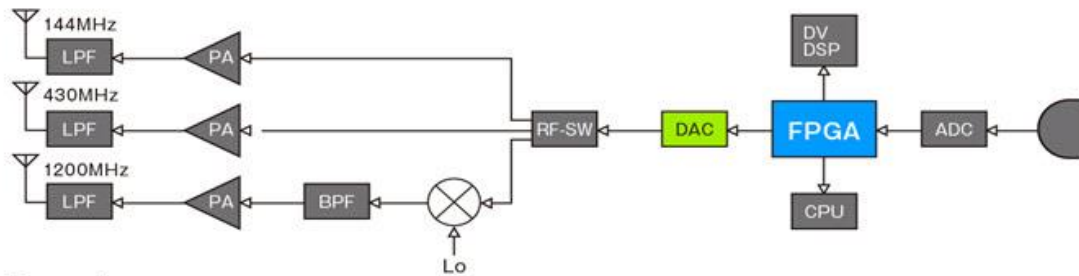
The SD card slot for memory storage and loading, recording and firmware upgrade is below the SUB AF/RF Gain/Squelch knob. A screen capture function (enabled via menu) allows capture of the current screen image to the SD card as a PNG or BMP file by briefly pressing the POWER key. The image can also be viewed on the screen via menu.

The IC-9700 is solidly constructed and superbly finished. Like other Icom 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.

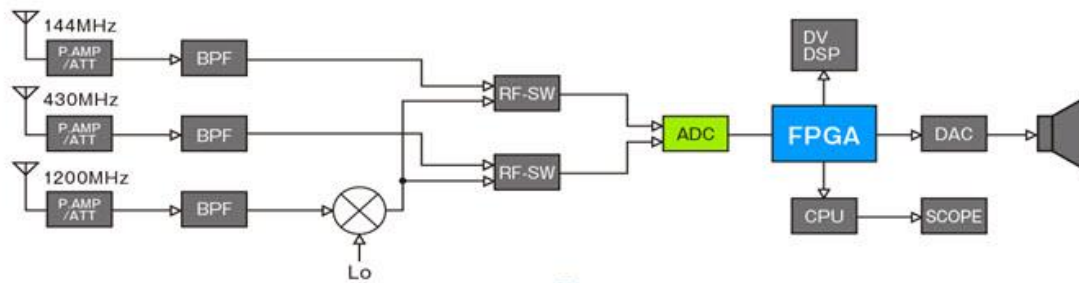
2. IC-9700 architecture: The IC-9700 is the first VHF/UHF all-mode transceiver embodying direct-sampling/digital up-conversion SDR architecture. **In the receiver**, the RF signals from the 144 and 430 MHz antennas feed a high-speed 14-bit ADC (analogue/digital converter) via preselectors which protect the ADC from strong out-of-band signals. The ADC digitizes a portion of the band defined by the preselector; the digital output of the converter feeds the Field-Programmable Gate Array (FPGA), which incorporates the Digital Down-converter (DDC as well as the DSP executing all signal-processing functions such as selectivity, demodulation etc. A DAC (digital/analog converter) at the FPGA output decodes the digital signal back to audio. Figure 2 is a simplified block diagram.

Figure 2: Simplified block diagram of IC-9700.

Transmitter



Receiver



The FPGA also delivers a 1 MHz-wide digital video signal to the Display Processor, which manages the screen displays, including the fast FFT spectrum scope, waterfall, audio scope and audio FFT (spectrum analyzer) as used in other Icom transceivers (7700, 7800, 7850/7851, 7300, 7610). The spectrum scope has a maximum span of ± 500 kHz, adjustable reference level (-20 to 20 dB), video bandwidth and averaging, and RBW ≤ 50 Hz.

The 1.2 GHz receiver uses a heterodyne converter whose LO (local oscillator) is derived from the master clock. The resulting 310 – 370 MHz variable IF is sampled by the ADC. A BPF at the converter RF port assures excellent image and IF rejection.

Low-noise preamps, and switched attenuators, are provided for all 3 bands.

A unique “touch-tune” feature allows quick tuning to a signal displayed on the scope by touching the scope or waterfall field to magnify an area, then touching the desired signal within that area.

In the transmitter, the audio codec converts mic audio to a digital baseband, which the DSP and digital up-converter in the FPGA then convert to a digital RF signal at the transmit frequency. This signal is converted to analog by the high-speed 16-bit DAC to the RF excitation for the PA Unit on 144 and 430 MHz. On 1.2 GHz, the RF signal is the 310-370 MHz variable IF which is translated to 1.2 GHz by the heterodyne converter. The 1.2 GHz excitation signal is fed to the PA Unit via a BPF. The IC-9700 does not have a built-in ATU.

3. Supported modes (emissions): The IC-9700 supports CW, SSB, AM, FM, DV (D-Star) and DD (D-Star Digital, 1.2 GHz only, 128 kb/s). In addition, it will accept GPS location data for D-Star.

4. The touch-screen: The large (93 × 52 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 MAIN frequency and bar-graph meter in the upper field, the SUB frequency and bar-graph meter in the middle and the spectrum scope/waterfall in the lower field. The first two keys below the screen, MENU and FUNCTION, are unique to the IC-9700. The third key, M.SCOPE, moves the spectrum scope to the middle field; a different screen, selected via the MENU key, can be opened in the lower field (e.g. a multi-function meter, Audio Scope or CW keyer controls, depending on mode). An enhanced-height scope and waterfall can be displayed on the home screen by touching the EXPD/SET icon. The scope can be assigned to Main or Sub by touching the MAIN/SUB icon (top left of scope field).

When the MULTI knob is rotated with PBT selected, a bandwidth/shift pop-up appears, and the trapezoidal icon at the top centre of the screen changes, a dot appears to the right of the icon. Pressing and holding the MULTI knob clears the Twin PBT setting. Pressing the MULTI knob opens a menu with RF PWR, MIC Gain, COMP and MONITOR settings. A setting is changed by touching its icon and rotating the MULTI knob. The MULTI knob menus are context-sensitive; for example, pressing and holding the NB key activates NB, and displays NB settings when the MULTI knob is pressed. RIT and Δ TX are adjusted by pressing their respective keys on the top right of the front panel and rotating the MULTI knob without pressing it. The CLEAR key clears these functions.

Rotating the MULTI knob with kHz selected (kHz key pressed) adjusts the highlighted frequency in 1 kHz steps.

Pressing and holding the Notch, NR and NB keys makes their settings accessible from the MULTI knob. These can be used to select notch width, NR level and NB parameters respectively. When MN is selected, a pop-up displays its width.

TPF (Twin Peak Filter) can be activated via the MULTI menu in RTTY mode.

The **menus** are somewhat akin to those in other current Icom DSP radios. I found the set-up process fairly intuitive after consulting the relevant user-manual sections in cases of doubt. Icom continues the use of a “Smart Menu” system which changes available functions in a context-sensitive manner based on the mode currently in use.

Different screens are selected by pressing the MENU key on the bottom left of the screen. Menu selections with default values can be returned to default by pressing and holding their DEF softkey. Many of the screens have a “Back” arrow key to return to the previous screen.

The MENU screen includes a “SET” icon which opens a list of the 9700’s configuration settings arranged in a hierarchy which is easily navigable. The desired line in the on-screen table can be selected via the MULTI knob or up/down arrows.

The FUNCTION key opens a screen with switches for functions such as AGC, COMP, IP+, MONitor, VOX, BK-IN etc. Some of these (NB, NR, Preamp/ATT, NOTCH) duplicate front-panel keys.

The QUICK key opens a context-sensitive Quick Menu for rapid configuration or default setting of various menu functions.

Touching the leading (MHz) digits of the frequency display opens a band-selection screen; the desired band is selected by touching its designator. Mode selection is similar; touching the current mode icon opens the mode-selection screen. Tuning steps for kHz and Hz are set by touch, or by touch/hold, on the respective digit groups.

The filter selection and adjustment procedure is similar to that on other Icom DSP radios. Touch the FIL-(n) icon to toggle between FIL-1, FIL-2 and FIL-3. Touch and hold this icon to adjust the filter bandwidth and select CW/SSB Sharp/Soft shape. All IF filters are continuously adjustable. As in other Icom IF-DSP radios, filters with 500 Hz or narrower bandwidth have the BPF shape factor, but a non-BPF filter can be configured via Twin PBT.

The Time-Out Timer feature limits transmissions to a preset duration (3, 5, 10, 20 or 30 minutes, selectable by menu.) RF PWR can be turned down to 0. This feature is useful when receiving via active antennas or mast-mounted preamplifiers without T/R switching, or to avoid damaging test equipment when conducting receiver measurements.

The AUDIO screen displays an audio FFT spectrum analyzer and oscilloscope very similar to those implemented in the IC-7851, IC-7800 (Firmware V3.00 and higher) and IC-7700 (V2.00 and higher). This feature is very helpful in setting up one's transmit audio parameters, and also for visual audio assessment of a received signal.

5. 10 MHz reference and synchronization. A 10 MHz SMA EXT REF input (-10 dBm nominal) is provided on the rear panel. The REF ADJ menu presents coarse and fine adjustments and a SYNC icon. Touching SYNC synchronizes the internal master clock to the external reference.

6. Receiver front end management: The P.AMP/ATT key toggles between the preamp and a 10 dB RF attenuator. The RF Gain/Squelch control functions as an RF Gain control when rotated counter-clockwise from 12 o'clock; an on-screen RFG icon lights when RF Gain is active.

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. Thus, the 9700 provides means to prevent this condition from arising. When the ADC starts clipping, a red OVF (overflow) icon lights to the right of the filter selection icon. At this point, rotating the RF Gain control counter-clockwise will extinguish OVF and restore normal operation. RF Gain should be set just at the point where OVF goes dark, otherwise weak-signal reception will be degraded. If required, ATT can be activated as well. When OVF lights, the preamp should be turned OFF.

IP+ (Function key) activates dither, to improve the linearity and IMD dynamic range of the ADC. When IP+ is active, an IP+ icon lights.

Being a current IC-7300 owner, I found that the IC-9700's controls and menus fell readily to hand. A user familiar with a radio such as the IC-7300 or IC-7610 should find the IC-9700 very user-friendly and its learning curve manageable. The IC-9700's default settings are very usable, allowing the radio to be placed in service with minimal initial set-up.

A front-panel AUTO TUNE key "tunes in" CW signals rapidly and accurately.

Touching the currently-displayed meter scale toggles between scales. Touching and holding the meter scale opens the multi-function meter, which displays all scales simultaneously.

7. USB & Ethernet interfaces: The IC-9700 is equipped with rear-panel USB “B” and Ethernet ports. The radio can be directly connected via the “B” port to a laptop or other PC via a USB cable. This is without doubt one of the IC-9700’s strongest features. The USB port transports not only CI-V data, *but also TX and RX PCM baseband* between the IC-9700 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 Icom HF and HF/VHF/UHF radios released since 2009. An Icom driver is required in the PC; this is downloadable from the Icom Japan World website.

The Ethernet port supports connection to a PC, LAN or Internet router via a Cat5e cable, for NTP time synchronization or for remote control via the Icom RS-BA1 V.2 software suite. As the IC-9700 has a resident RS-BA1 server, a collocated PC is *not* required.

8. Filter selections and Twin PBT: As do the other Icom DSP transceivers, the IC-9700 offers fully-configurable RX IF selectivity filters for all modes.

Three default filter selections are available via the touch-screen for each mode, with continuously variable bandwidth via the FILTER menu. In addition, there are selectable Sharp and Soft shape factors for SSB and CW. The BPF filter configuration feature (for filter bandwidths of 500 Hz or less) operates in the same manner as on other Icom IF-DSP radios.

Twin PBT is one of the modes of the MULTI knob. Pressing and holding the MULTI knob restores PBT to neutral.

The TPF menu item in the RTTY SET menu selects the Twin Peak Filter (TPF) in RTTY mode. No CW APF (Audio Peak Filter) is provided. However, the CW RX LPF and HPF in the TONE SET menu are a reasonable alternative to the "missing" APF; their ranges are 100 - 2000 and 500 - 2400 Hz respectively.

The HPF and LPF can be set to "bracket" the received CW tone in a tight 100 Hz audio bandwidth. The DEF softkey restores these filters to default (off).

9. BPF vs. non-BPF filters: As in other Icom IF-DSP radios, the IC-9700 allows the user to select two additional shapes for 500 Hz or narrower filters, in addition to SHARP and SOFT. These are BPF (steeper skirts) and non-BPF (softer skirts).

To configure a BPF filter, select a 500 Hz or narrower CW, RTTY or SSB-D filter with Twin PBT neutral. To set up a non-BPF filter, select a filter with BW > 500 Hz, and narrow the filter to 500 Hz or less by rotating the Twin PBT controls. When Twin PBT is displaced from its neutral position, a dot appears to the right of the filter icon at the top of the screen.

10. Notch filters: The tunable manual notch filter (MN) is inside the AGC loop, and is extremely effective. The MN has 3 width settings (WIDE, MID and 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, press and hold the NOTCH key, then rotate the main tuning knob.

The auto notch filter (AN) is post-AGC. It suppresses single and multiple tones, but strong undesired signals can still cause AGC action and swamp the receiver. MN and AN are mutually exclusive, and AN is inoperative in CW mode. The NOTCH key toggles OFF – AN – MN. When MN is selected, a pop-up field is displayed on the screen, allowing selection of WIDE, MID or NAR (narrow) notch by pressing and holding the NOTCH key.

11. NR (noise reduction): The DSP NR is very effective. In SSB mode, the maximum noise reduction occurs at an NR control setting of 10. As NR 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 13 dB. For precise NR adjustment, press and hold the NR key, then rotate the MULTI knob.

12. NB (noise blanker): The IF-level DSP-based noise blanker is arguably one of the IC-9700’s strongest features. 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 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 menu (threshold, depth and width) is accessed by pressing and holding the NB key. The NB works very effectively in conjunction with NR.

13. AGC system: The IC-9700 has an in-channel AGC loop. The digital AGC detector for the AGC loop is within the DSP algorithm. Level indications from the detector are processed in the DSP, and control the DC bias on a PIN-diode attenuator at the RF ADC input. 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 Icom 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.

14. Receive and transmit audio menus: The IC-9700 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.

15. 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.

16. RTTY decoder and memory keyer: The IC-9700 features an on-screen RTTY decoder/display as well as an 8 x 70 chars RTTY memory keyer for transmitting short messages.

17. VFO/Memory management: The IC-9700 offers the same VFO and memory management features as other current Icom transceivers: VFO/memory toggle and transfer, memory write/clear, memo-pad, Split, VFO MAIN/SUB swap and equalize etc.

18. Per-band power output and power limit settings. The IC-9700 allows separate power output settings for each band. In addition, a PWR LIMIT function limits the transmitter output to a value adjustable via the MULTI knob context menu. As in other current Icom transceivers, per-band TX Delay (transmit RF onset delay) settings are provided in the menu.

18. Duplex and satellite operation. The IC-9700 allows simultaneous reception, or full-duplex receive and transmit operation, on any two out of its three bands. Dual-watch on the same band is not permitted. This greatly facilitates repeater and satellite operation. One-touch satellite mode selection (via the Satellite MENU key) is provided.

19. Brief “on-air” report: Due to lack of antenna facilities, on-air tests were limited to checking in on a local FM repeater. Reported audio quality was excellent

20. ACC/USB AF Output Level Check: During receiver testing, I checked the receive AF levels at the USB port using a spectrum-analysis program, and at ACC Pin 12 using a true RMS voltmeter. All levels were well within specifications.

20a. 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 Ver. 1.30 Icom USB drivers (downloadable from the Icom Japan world-wide support site).

<http://www.icom.co.jp/world/support/download/firm/>

21. Case temperature: The radio showed no signs of excessive heating. Average case temperature was 30°C, rising to 38°C at the hottest point after several minutes’ key-down transmit at 100W during transmitter testing (temperature indicator blue).

22. Concerns: Four items warranting further analysis were encountered during the tests:

- a. Increased frequency drift when transmitting. (Appendix 2).
- b. Marginal transmit IMD3, especially on 1.2 GHz. (Test 22a).
- c. Significant heating in the fuse-holders of the DC power cable (45-50°C) (Test 17).
- d. Several receiver “birdies” on all bands. (Test 16).
- e. An “RF tail” on CW-QSK transmit. (Appendix 3).

These will be discussed in more detail in the relevant sections of this report.

23. Conclusion: After a few days’ bench time with the IC-9700, 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 overall excellent performance. This radio is unique in that it is a VHF/UHF direct-sampling/digital up-conversion SDR in an attractive, compact package. Yet again, Icom has a winner with the SDR performance, intuitive touch-screen and the straightforward computer interfaces. This is certainly a lot of radio for its price category.

24. Acknowledgements: I would like to thank Ray Novak N9JA at Icom America, and Paul Veel VE7PVL and Jim Backeland VE7JMB at Icom Canada for making an IC-9700 available to me for testing and evaluation. I am also most indebted to Dr. Ulrich Rohde NIUL for generously providing me with an R&S SMBV100A Vector Signal Generator, which made possible a number of critical tests, including Noise Power Ratio.

Thanks are also due to Conrad Farlow PA5Y and to Rohde & Schwarz for allowing me to include in this report a set of transmitted composite noise measurements on an IC-9700 in the Netherlands. This data is in **Appendix 4**.

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Update history:

Iss.1: Pre-release, 6/23/2019.

Iss.2: DR₃ and IFSS re-tested with lower phase noise signal sources. 6/30/2019.

Iss.3: Scope Sensitivity test data (Table 12) corrected. 7/5/2019.

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Appendix 1: Performance Tests on IC-9700 S/N 12001793

As performed in my home RF lab, June 3 – 19, 2019. 10 MHz EXT REF connected for all tests.

A. 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 SHARP, ATT off, NR off, NB off, Notch off. AGC-M. Max. RF Gain. Levels in dBm. IP+ off. (IP+ does not affect MDS on 144 or 430 MHz, but degrades MDS by 1 dB on 1.2 GHz.)

Table 1: MDS

MHz	144.1		432.1		1240.1	
Preamp	SSB	CW	SSB	CW	SSB	CW
Off	-125	-131	-125	-132	-134	-140
On	-137	-143	-137	-143	-137	-144

Note on IP+ and MDS: With IP+ on, negligible MDS degradation was observed. As the ADI LTC2156-14 ADC employed in the IC-9700 lacks an on-chip dither generator, the dithering mechanism in the IC-9700 is not understood.

1a: ADC Clip Levels. In this test, the receiver is offset +25 kHz above the test signal frequency and the input level required to light the on-screen **OVF** icon is noted. OVF indication occurs only when a strong out-of-channel signal is present. In-channel signals stimulate AGC action which attenuates the signal at the ADC input.

Test Conditions: RX tuned to f_0 , test signal freq. $f_0 + 25$ kHz, CW 500 Hz SHARP, ATT off, NR off, NB off, Notch off. AGC-M. Max. RF Gain.

Table 2: OVF (Clip) Levels.

Preamp	OVF (Clip) Level dBm		
f_0 MHz	144.1	430.1	1240.1
Off	-9	-10	-23
IP+	-8	-10	-19
On	-27	-30	-33

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, NR off, NB off, Notch off. AGC-M. Wide (9 kHz) AM filter. Levels in dBm.

Table 3: AM Sensitivity.

Preamp	144.1 MHz	430.1 MHz	1240.1 MHz
Off	-102	-105	-114
On	-114	-114	-117

Notes:

1. Very clean demodulation; full quieting \approx -80 dBm (preamp off).
2. NR suppresses high-frequency hiss at low signal levels. Unmodulated carrier at -115 dBm (preamp off, NR off) increases noise floor by 4 dB.

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). FIL 1 selected.

Table 4: FM 12 dB SINAD Sensitivity in dBm.

Preamp	146.52 MHz	446.0 MHz	1295.2 MHz
Off	-111	-110	-109
On	-123	-122	-123

1d. Noise Figure. In this test, a calibrated noise source is connected to the antenna port via a precision DC - 2 GHz step attenuator, and the PHONES jack is connected to the RMS voltmeter. First, the antenna port is terminated in a precision 50Ω load and a 0 dBr receive audio reference set. Then, the noise source is connected and the noise loading adjusted for a +3 dBr audio level. The attenuator setting is noted. See Table 5.

As the noise source is calibrated, its noise power density PSD (-82 dBm/Hz) is known. Noise figure NF is derived as follows (modified Y-factor method):

$NF \approx PSD - ATT + 174$ where PSD = -82 dBm/Hz and ATT = attenuator setting in dB.

Test Conditions: 500 Hz CW, AGC Mid, ATT off, NR off, NB off.

Table 5: Noise figure in dB.

Band	Preamp	Meas. NF dB	NF calc. from MDS dB
144 MHz	off	16	16
	on	3	4
432 MHz	off	15	15
	on	4	4
1.2 GHz	off	8	7
	on	4	3

1e. FM AFC Capture & Lock Range. An unmodulated test signal is applied at 146.52 MHz and -90 dBm. The main tuning is then offset until the AFC just pulls the frequency back to nominal. The capture range is twice the difference between the offset and nominal. Then, the test signal frequency is increased or decreased until the receiver just ceases to track the change. The lock range is twice this offset.

Here, capture range = ± 8.7 kHz and lock range = ± 18 kHz.

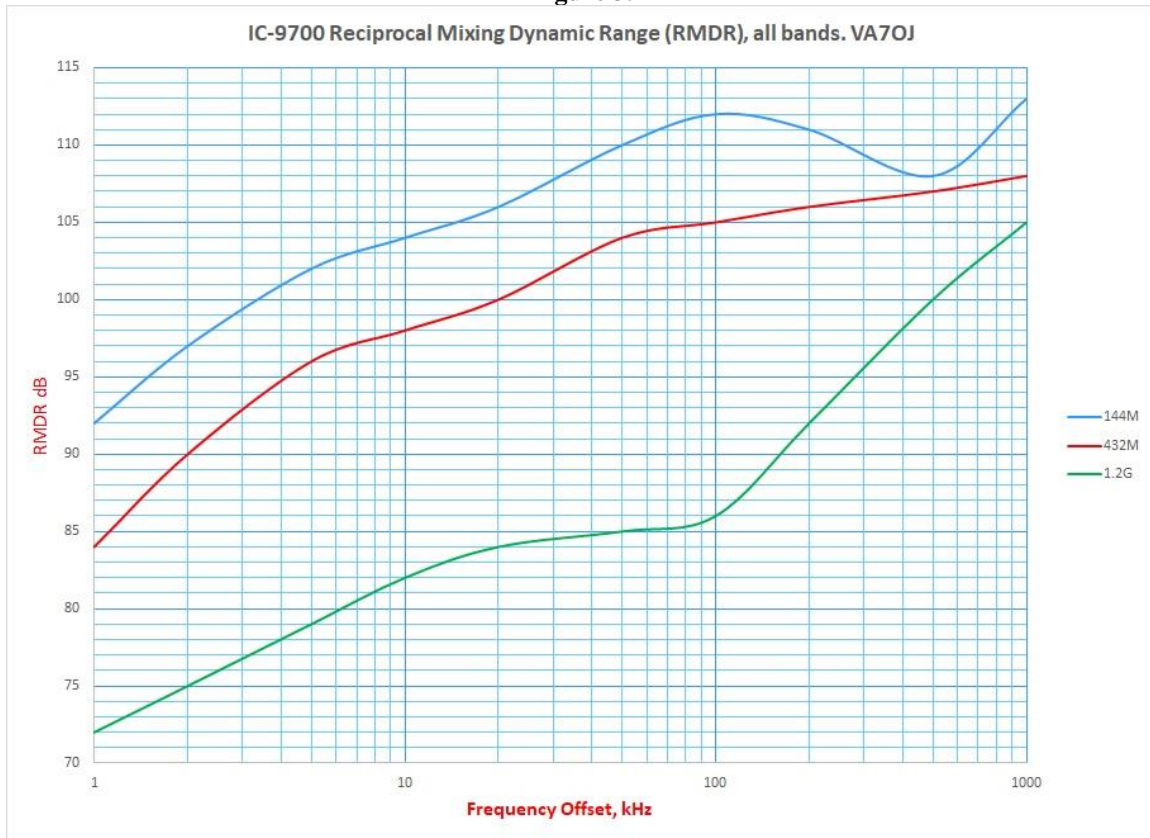
2: Reciprocal Mixing Noise occurs in a direct-sampling SDR receiver when the phase-noise sidebands of the ADC clock mix with strong signals close in frequency to the wanted signal, producing unwanted noise products in the detection channel and degrading the receiver sensitivity. Reciprocal mixing noise is a measure of the spectral purity of the ADC clock (144 & 430 MHz) and of the converter LO (1.2 GHz).

In this test, a test signal from a Rohde & Schwarz SMBV100A signal generator 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 preamp off. The higher the value, the better.

Test Conditions: CW mode, 500 Hz filter, preamp off, ATT off, NR off, AGC-M, NB off, max. RF Gain, positive offset. Reciprocal mixing *in dB* = input power – MDS (both in dBm). Phase noise *in dBc/Hz* = -(RMDR+10 log 500) = -(RMDR + 27). **Note:** For $\Delta f > 20$ kHz, OVF lights before noise floor increases by 3 dB.

To derive phase noise for a given band and offset, read RMDR off the appropriate curve in **Figure 3**, add 27 and change the sign. For example: On 144.1 MHz at 10 kHz offset, RMDR = 104 dB. Phase noise = - (104 + 27) = -131 dBc/Hz.

Figure 3.



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: 144.100 MHz, SSB/CW modes, preamp off, IP+ off, AGC-M, ATT off, NR off, NB off. See Table 6.

Table 6: IF Filter Shape Factors.

Filter	Shape Factor		6 dB BW kHz	
	Sharp	Soft	Sharp	Soft
2.4 kHz SSB	1.36	1.48	2.53	2.34
1.8 kHz SSB	1.51	1.51	1.95	1.93
500 Hz CW	1.30	1.43	0.52	0.55
250 Hz CW	1.36	2.20	0.26	0.26

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: 144.100 MHz, 2.4 kHz USB, Preamp off, IP+ off, AGC M, ATT off, NR off, NB off. Initial RF input level -105 dBm. With AGC-M, 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
Off	-109
On	-119
Att	-100
IP+	-110

5: Manual Notch Filter (MNF) 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 MNF 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: 144.100 MHz 2.4 kHz Sharp, AGC-M, preamp off, IP+ off, ATT off, NR off, NB off, MNF on, Twin PBT neutral.

Test Results: Measured MDS was -125 dBm per Test 1. Stopband attenuation = test signal power - MDS.

Table 8: Manual Notch Filter Attenuation.

MNF BW	-6 dB BW Hz	Test Signal dBm	Stopband Atten. dB
WIDE	24	-41	84
MID	20	-42	83
NAR	14	-45	80

5a: MNF Bandwidth. The receive frequency is now offset on either side of the null by pressing RIT and rotating the MULTI 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. See Table 8 above.

5b: Auto-Notch (AN) Check. AN completely suppresses AF tone at up to 0 dBm input level.

6: AGC impulse response. The purpose of this test is to determine the IC-9700'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: 144.1 MHz USB, 2.4 kHz SSB filter (Sharp), NR off, NB off/on, Preamp off, AGC-F, with decay time set to 0.1 sec.

Test with pulse trains. Here, the RF signal generator is connected to the IC-9700 ANT1 input. AGC Fast (0.1 sec) and Preamp OFF are selected. The signal generator is set up in Pulse mode, and applies 20 μ s RF bursts at 500 ms intervals and -40 dBm amplitude to the DUT.

The AGC recovers completely within the 0.1 sec window; the fast-rising leading edge of each burst captures the AGC briefly. The resulting spikes are visible on the audio scope and are audible as ticks. NR softens the tick sound.

Figure 4: Audio scope display for AGC impulse response test.

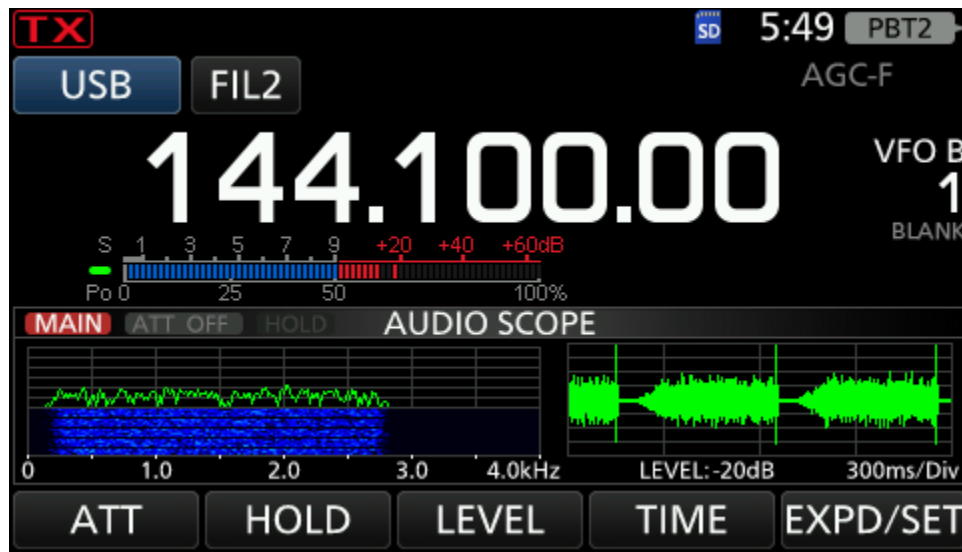


Table 9: AGC impulse response.

AGC	Burst duration ns	Tick	AGC recovery ms	S-meter
F (0.1s)	20	Y	≈ 100	S9 + 18 dB
M (2s)	20	Y	≈ 2000	S9 + 18 dB

7: Noise blanker (NB) impulse response. As the IC-9700'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, Preamp off, Level 50%, Depth 6, Width 70.

The S-meter deflection, AGC capture (audio scope spikes) and ticks are *completely suppressed* showing that the impulsive events never reach the AGC derivation point.

Next, NR is activated. With NR at 9 to 10, residual NB artifacts are suppressed.

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

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

Test Conditions: 2.4 kHz USB, Preamp off, ATT off, AGC MID. A test signal at MDS is applied to the RF input on 144.1, 432.1 and 1240.1 MHz successively. The signal power is increased, and the level corresponding to each S-meter reading is noted.

Table 10a: S-Meter Tracking.

Band	S1	S2	S3	S4	S5	S6	S7	S8	S9	S9+20	S9+40	S9+60	S9 Pre
144	-107	-104	-102	-100	-97	-94	-91	-89	-86	-66	-45	-26	-97
430	-108	-105	-103	-101	-98	-96	-93	-91	-88	-68	-47	-28	-99
1.2G	-112	-110	-108	-105	-103	-101	-97	-95	-93	-73	-53	-33	-98

8a: Attenuator Tracking & Preamp Gain. This is a quick verification of attenuator accuracy and preamp gain.

Table 10b: ATT Loss/Preamp Gain.

Band	144	430	1.2G	
ATT	-9	-10	-9	dB
PRE	+12	+11	+4	dB

9a: Two-Tone 3rd-Order Dynamic Range (DR₃). The purpose of this test is to determine the range of signals which the receiver can tolerate while essentially generating no spurious responses due to 3rd-order IMD.

In this test, two signals of equal amplitude P_i and separated by a 20 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 $(2f_2 - f_1)$ and $(2f_1 - f_2)$.

20 kHz test-signal spacing is used in Tests 9a and 9b because IMD amplitude in an ADC is essentially independent of signal spacing, and also to reduce the influence of signal-source phase noise on the test results.

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 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 P_i 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 dither on front-end linearity. As P_i is varied, several P_i values raising the noise floor can be found. The DR₃ value corresponding to the highest of these P_i values is recorded.

Note: IP_3 (3rd-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: $f_2 = f_1 + 20$ kHz, 500 Hz CW, AGC-S, ATT off, NR off, NB off, CW Pitch = 12 o'clock.

Table 11: DR₃ for $\Delta f = 20$ kHz.

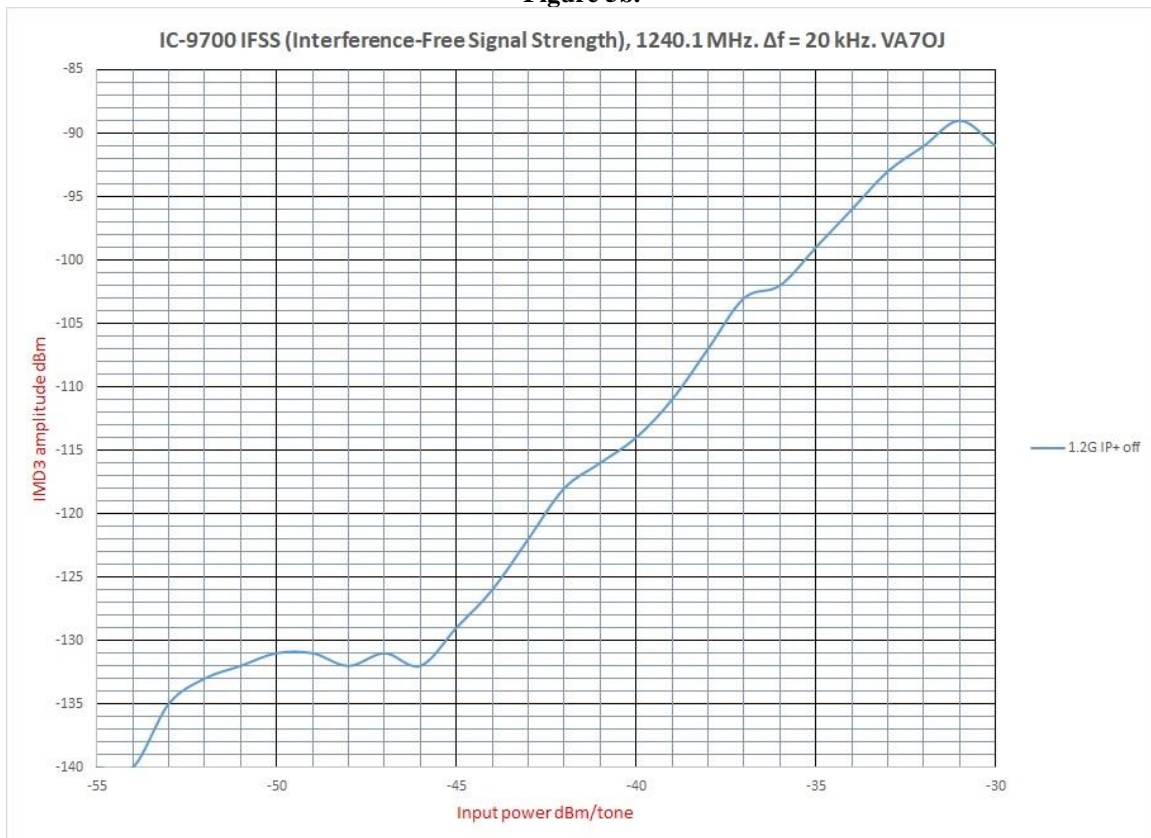
f_1 MHz	Δf kHz	IP+ off	IP+ on	RMDR	
144.1	20	89	89	106	dB
432.1	20	87	88	100	dB
1240.1	20	79	79	84	dB

9b: Two-Tone IMD₃ (IFSS, Interference-Free Signal Strength) tested in CW mode (500 Hz), ATT = 0 dB, AGC Med. Test frequencies (f_1): 144.1, 432.1, 1240.1 MHz. Δf : 20 kHz. IMD₃ product level was measured as absolute power in a 50 Hz detection bandwidth at various test-signal power levels with IP+ off and on. AGC-S, ATT= 0 dB. The input level at the top end of each curve corresponds to -1 dBFS, or 1 dB below OVF (ADC clip) level. IMD levels were read off the spectrum scope which had previously been calibrated against the signal generator. See Figures 5a, 5b.

Figure 5a.



Figure 5b.



Notes on 2-tone IMD₃ test: This is a new data presentation format in which the amplitude relationship of the actual IMD₃ products to typical band-noise levels is shown, rather than the more traditional DR₃ (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 IMD₃ products fall below the band-noise level at the operating site, they will generally not interfere with desired signals.

The IC-9700 IFSS data is presented here as an extension of the traditional DR₃ test data. See **Reference 1**. As the ADI LTC2156-14 ADC in the IC-9700 does not have on-chip dither, the effect of IP+ is much less observable than on the IC-7610 (for example).

Note: 144 & 432 MHz DR₃ and IFSS tests were re-run using signal generators with lower phase noise than the instruments employed in the original tests. This has improved the accuracy of the test data.

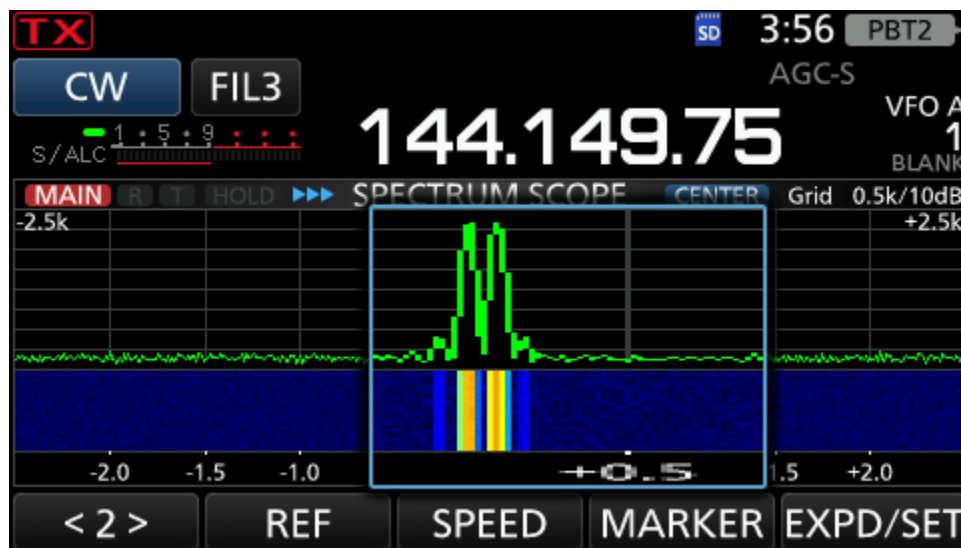
10: Spectrum Scope Resolution Bandwidth. In a spectrum analyzer, the resolution bandwidth (RBW) determines how far apart in frequency two (or more) signals must be to be resolved into separate and distinct displays on the screen.

Test conditions: Test signals: $f_1 = 144.1495$ kHz, $f_2 = 144.150$ kHz, CW, 250 Hz. Span = ± 2.5 kHz, VBW = Narrow, Averaging = 4, ATT OFF, REF LEVEL = +20 dB, preamp off. Waterfall on, speed MID (default).

To measure RBW, the R&S SMBV100A in MCCW mode applies f_1 and f_2 to the ANT1 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. To facilitate adjustment, the signal spike image is touched to open the zoom window.

Test result: Two signals can be clearly distinguished at 50 Hz spacing, i.e. 50 Hz minimum RBW.

Figure 6a: Spectrum scope RBW (50 Hz).



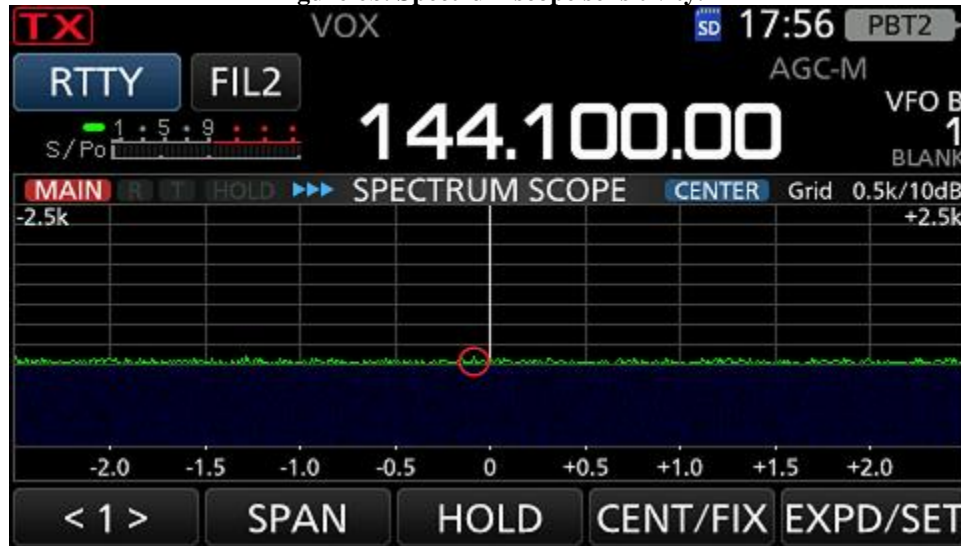
10a: Spectrum Scope Sensitivity. In this test, the RF input signal level is adjusted to produce a spike which is just visible above the scope "grass" level on each band in turn.

Test conditions: Span = ± 2.5 kHz, VBW = Wide, Averaging = 4, ATT OFF, REF LEVEL = +20 dB, Waterfall off. DSP filter setting is irrelevant. (Table 12).

Table 12: Spectrum Scope Sensitivity.

Minimum Visible Spike for Span = ± 2.5 kHz			
Preamp	Level dBm		
Band	144	430	1.2G
Off	-126	-126	-140
On	-140	-132	-149

Figure 6b. Spectrum scope sensitivity.



Notes on spectrum scope: Two refinements to the spectrum scope would enhance its usefulness as a BITE (built-in test equipment) feature:

- An option to display a vertically expanded scope field without the waterfall when EXPD/SET is pressed, The Audio Scope field can be expanded vertically in this manner.
- A WIDE/MID/NAR RBW menu option, to allow the user to optimize RBW. The IC-7610 incorporates this feature.

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 the R&S SMBV100A vector signal generator in ARB mode, loaded with an NPR waveform generated using the R&S WinIQSIM2® and NPR software applications.

For this test, RF bandwidth B_{RF} = 1 MHz and notch width = 5 kHz. f_0 was offset by 50 kHz to move a generator artifact out of the notch.

Test Conditions: Receiver tuned to notch center freq. $f_0 + 1.5$ kHz, 2.4 kHz SSB, ATT off, max. RF Gain, Preamp off, IP+ off, NR off, NB off, Notch off, AGC-S. SMBV100A clocked from 10 MHz lab standard. P_{TOT} set to -1 dBFS. **Test results:** See Table 13 and Figures 7a, 7b and 7c.

Table 13: NPR Test Results.

DUT	f ₀ MHz	NPR Offset kHz	Rx MHz	Preamp	IP+	P _{TOT} dBm	NPR dB
IC-9700	146.05	50	146.1485	0	0/1	-21	65
	440.05	50	440.1485	0	0/1	-21	65
	1270.05	50	1270.1485	0	0	-35	60
				0	1	-30	60

Note on NPR test: When testing NPR on direct-sampling SDR receivers, the noise loading is set to 1 dB below clipping and the NPR read directly off the spectrum scope. It was not possible to test NPR with the preamp on, as the added gain drove the ADC into clipping. Activating IP+ did not affect NPR readings, except that at 1.2 GHz the clip level increased with IP+ on.

Although the 1.2 GHz receiver front end consists of a heterodyne down-converter with IF sampling, the above test method was usable as it was still possible to obtain a well-defined ADC clip point.

Figure 7a: 146 MHz NPR.

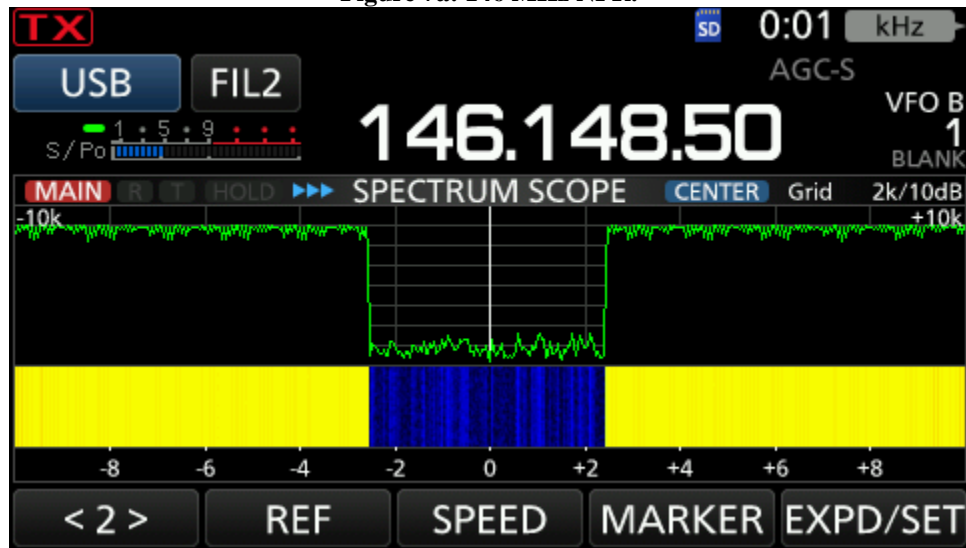


Figure 7b: 440 MHz NPR.

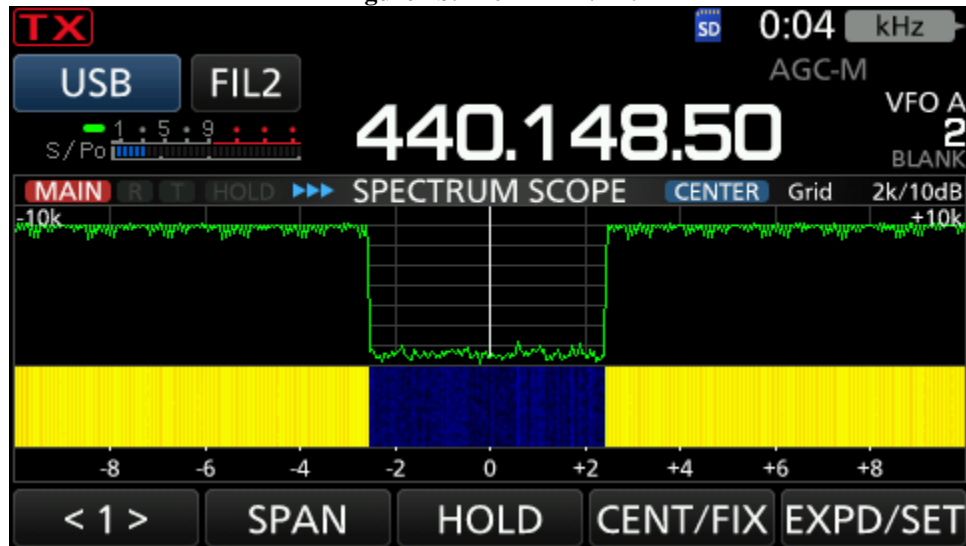
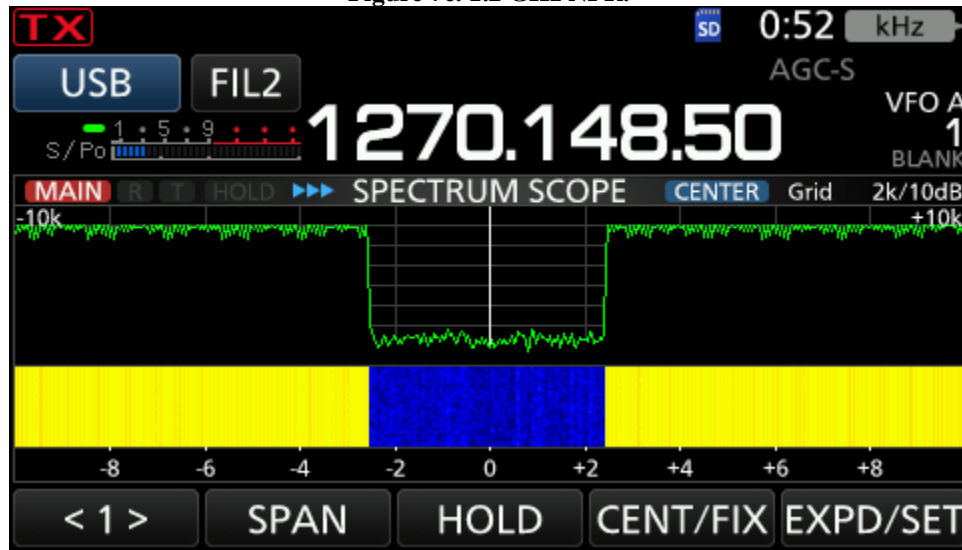


Figure 7c. 1.2 GHz NPR.



SMBV-100A NPR measurement limit ≈ 70 dB. The actual NPR values on 144 and 432 MHz may slightly exceed the measured value.

12a: Aliasing rejection. The ADC clock frequency is 196.608 MHz. In this test, an alias at a midband frequency will result when a test signal at $196.608 +$ the test signal frequency is applied to the antenna port. The test signal power P_i is increased sufficiently to raise the AF output by 3 dB. Aliasing rejection = $(P_i - \text{MDS})$ dB.

Test Conditions: Receive frequency 146.000 and 440.000 MHz, CW, 500 Hz. Test signals at 342.608 and 636.608 MHz applied successively to ANT1 and ANT2 input. ATT off, max. RF Gain, Preamp off, IP+ off, NR off, NB off, Notch off, AGC-S. RMS voltmeter connected to PHONES jack. Test results per Table 14.

Table 14. 144 & 432 MHz Aliasing Rejection.

Alias Freq. MHz	Test Freq. MHz	Pi dBm	MDS dBm	Alias rej. dB
146.000	342.608	-4	-131	127
440.000	636.608	-6	-132	126

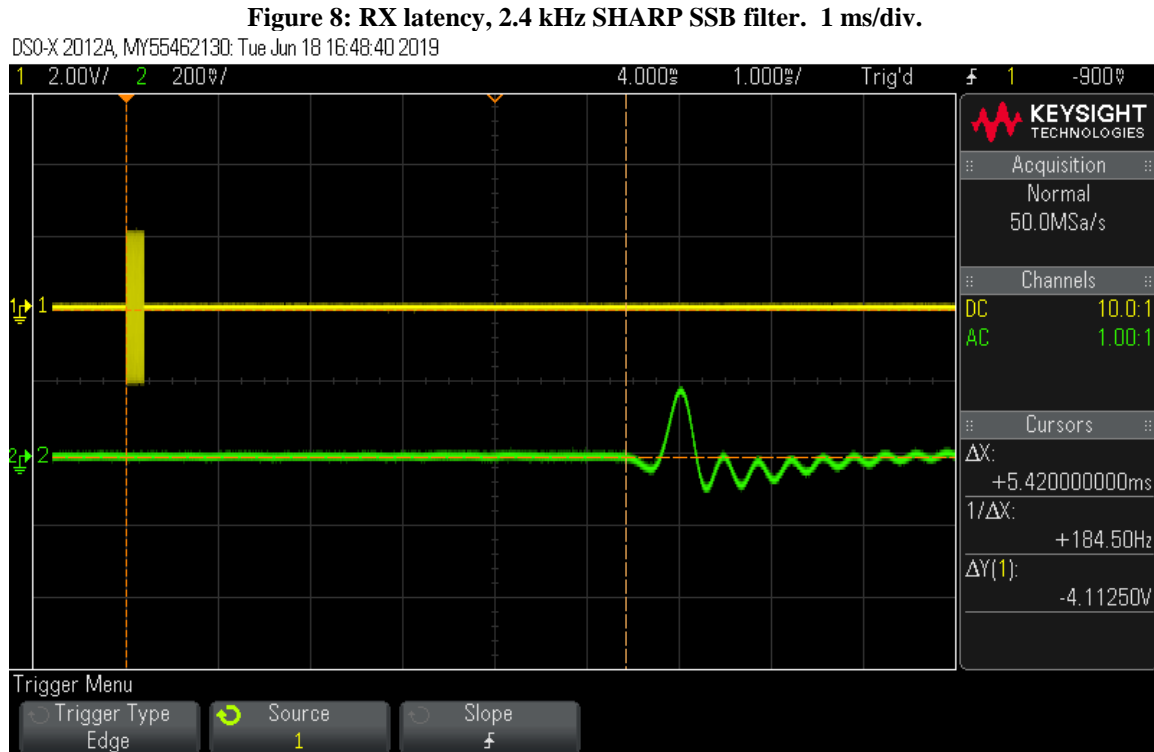
12b: 1.2 GHz image rejection. The heterodyne converter LO is at 929 MHz. At midband (1270 MHz), the IF is $1270 - 929 = 341$ MHz. Thus, the image frequency is 588 MHz. A test signal at 588 MHz is applied to ANT3, and the input power P_i is increased sufficiently to raise the AF output by 3 dB. Image rejection = $(P_i - \text{MDS})$ dB. Next, IF leakage is checked by applying a test signal at 341 MHz to ANT3.

Test Conditions: As for 12a above, except that receive frequency = 1270 MHz and test frequency is 588 MHz.

Test Results: $P_i = -38$ dBm. MDS = -140 dBm. Image rejection = $-38 + 140 = 102$ dB. No observable IF leakage for -10 dB input at 341 MHz.

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, fast-rising bursts of a pulse-modulated RF carrier 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. Burst duration 200 μ s, burst period 200 ms.



Test Conditions: 144.1 MHz, Preamplifier off, AGC Fast, IP+ off, max. RF Gain, ATT off, NR off, NB off.

Table 15: Receive latency test results.

Mode	Filter BW kHz	Shape Factor	Latency ms
USB	3.6	Soft/Sharp	5.5
	2.4		5.6
	1.8		5.8
CW	1.2	Soft/Sharp	5.8
	0.5		7.5
	0.25	Sharp	10.
	0.25	Soft	9.4
RTTY	2.4		5.6
	0.5		7.4
	0.25		10

14: NR 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. NR is then turned on, and SINAD read at 30%, 50% and 60% (max.) NR settings.

Test conditions: 144.1 MHz USB, 2.4 kHz Sharp, AGC-M, preamp off, IP+ off, max. RF Gain, ATT off, NB off, Twin PBT neutral. Test signal at -122 dBm (6 dB SINAD).

Table 16: Noise reduction vs. NR setting.

NR Setting	0	1	2	3	4	5	6	7	8	9	10-15
SINAD dB	6	8	9	11	13	16	17	18	19	18	No change

This shows an S/N improvement of 18 dB with NR at maximum for an SSB signal \approx 2 dB above MDS. This is an approximate measurement, as the amount of noise reduction is dependent on the original signal-to-noise ratio.

15: Audio THD. In this test, an audio distortion analyzer is connected to the external speaker output. An 8 Ω resistive load is connected across the analyzer input. An S7 to S9 RF test signal is applied to the antenna input, and the main tuning is offset by 1 kHz to produce a test tone. The audio voltage corresponding to 10% THD is then measured, and the audio output power calculated.

Test Conditions: 144.100 MHz, 3.6 kHz USB, AGC-S, ATT off, NR off, NB off, Preamp off. Offset tuning by -1 kHz.

Test Result: Measured audio output voltage = 4.20V rms.

Thus, audio power output = $\sqrt{[(4.2)^2/8]} = \mathbf{2.2W}$ in 8 Ω at 1 kHz. (Spec. is 2W).

16: Spurious signals (“birdies”). The following spurious signals were observed with the ANT input terminated in 50 Ω :

Table 17: Spurious signals in receiver.

Freq. MHz	Band	S-meter rdg.	Signal Type	Mode
147.455	144	S0	Tone	USB
438.585	430	S2		
447.986		S0		
448.511		S0		
1246.597	1.2G	S0		
1246.849		S0		
1248.486		S0		
1248.990		S5		

B. Transmitter Tests

17: CW Power Output. In this test, the RF power output into a 50Ω load is measured at 144.1, 432.1 and 1240.1 MHz in RTTY mode, at a primary DC supply voltage of +13.8V. A thermocouple-type power meter is connected to ANT1 via a 50 dB power attenuator.

Table 18: CW Power Output.

Freq. MHz	144.1	432.1	1240.1
P _O W	100	72.6	9.6
% RF PWR	98	100	100
I _{DC} at P _{MAX} A	16.1	13.8	5.0
Max. P _O W	117.8	115.6	113.6

RX/Standby: I_{DC} = 1.2A.

Note: The fuseholders in the DC power cable heat up to 45-50°C after transmitting a constant carrier at 100W for 2-3 minutes.

19: SSB Peak Envelope Power (PEP). Here, an oscilloscope is terminated in 50Ω and connected to ANT1 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: 144.1 MHz, USB mode, HM-219 mic connected, RF PWR 98%, Mic Gain 50%, COMP OFF/ON, TBW = WIDE, COMP at 5 (≈ 6 dB compression on voice peaks), SSB TX Bass/Treble set at 0 dB (default), supply voltage +13.8V.

Speak loudly into the microphone for full-scale ALC reading. Figures 9a & 9b show the envelope for 100W PEP, without and with compression respectively. Y between horizontal cursors = 100W PEP.

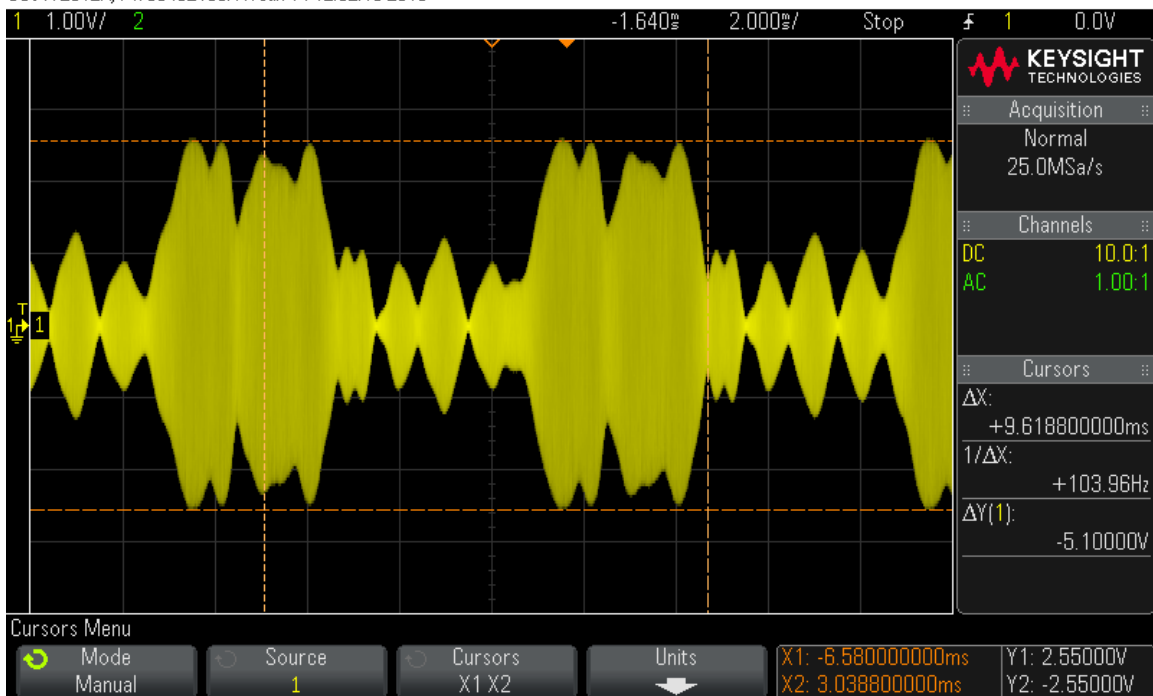
Figure 9a: 100W PEP speech envelope, no compression.

DSO-X 2012A, MY55462130: Fri Jun 14 12:00:53 2019



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

DSO-X 2012A, MY55462130: Fri Jun 14 12:02:19 2019



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

20a: SSB ALC overshoot with white noise. White noise was applied via the USB port, and the RF envelope observed on an oscilloscope terminated in 50Ω and connected to ANT1 via a 50 dB high-power attenuator.

Test Conditions: 144.1 MHz USB, COMP off, DATA OFF MOD = USB, USB MOD Level = 50% (default). Test signal: white noise. WIDE TBW (default value) selected. 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 Results: Observed ALC overshoot < 0.2 dB. See Figure 10a.

20b: VOX initial overshoot check. With VOX enabled, speak into mic and observe RF envelope on oscilloscope, especially at start of RF output..

Test Conditions: Same as 20a, except that DATA OFF MOD = MIC and Mic Gain = 50%. VOX adjusted to trip on normal speech.

Test Results: No overshoot was observed. See Figure 10b.

Figure 10a: 100W white noise test.

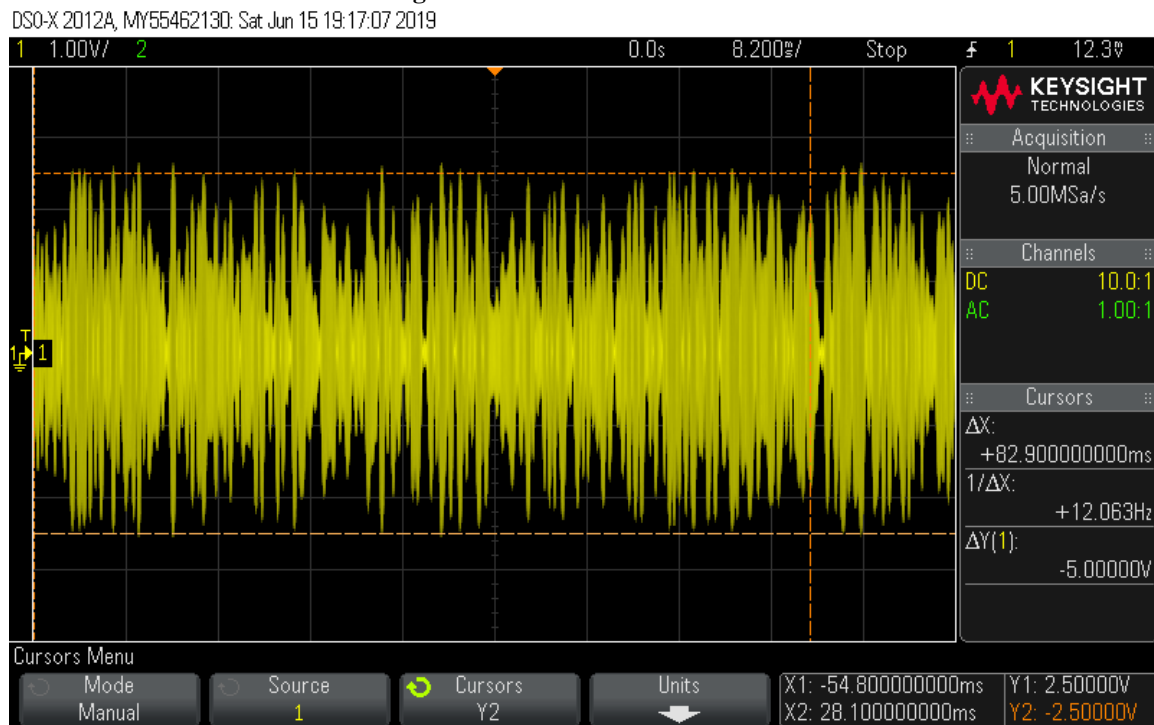
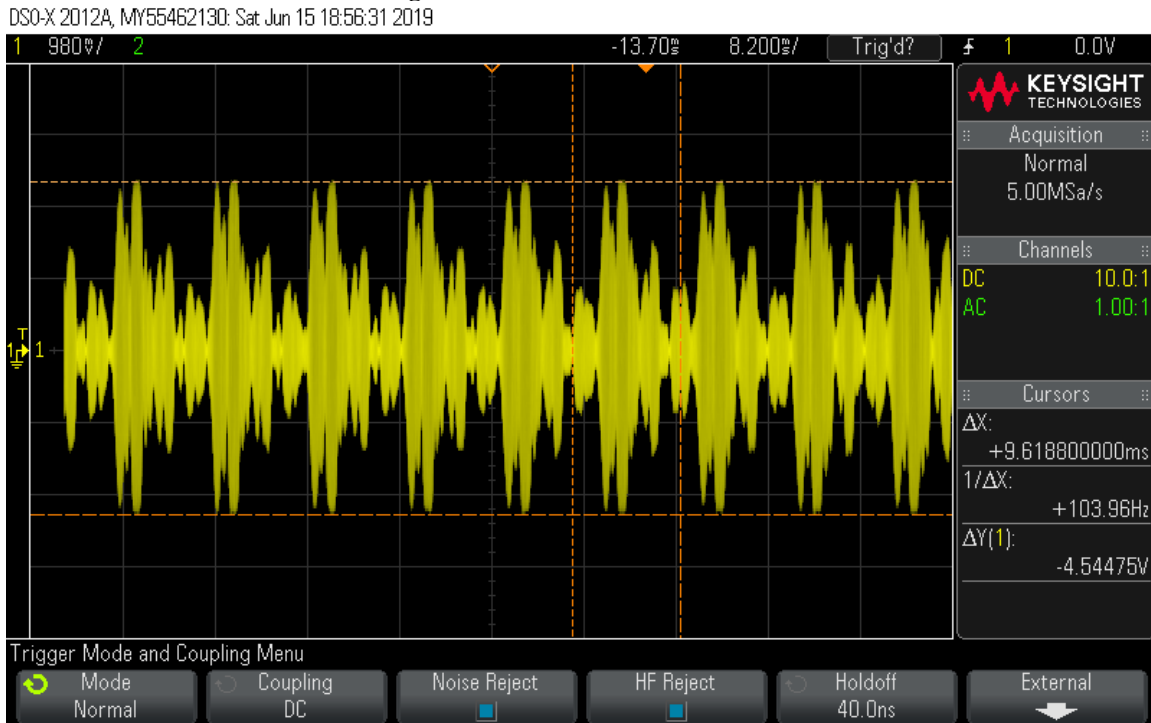


Figure 10b: VOX overshoot check.

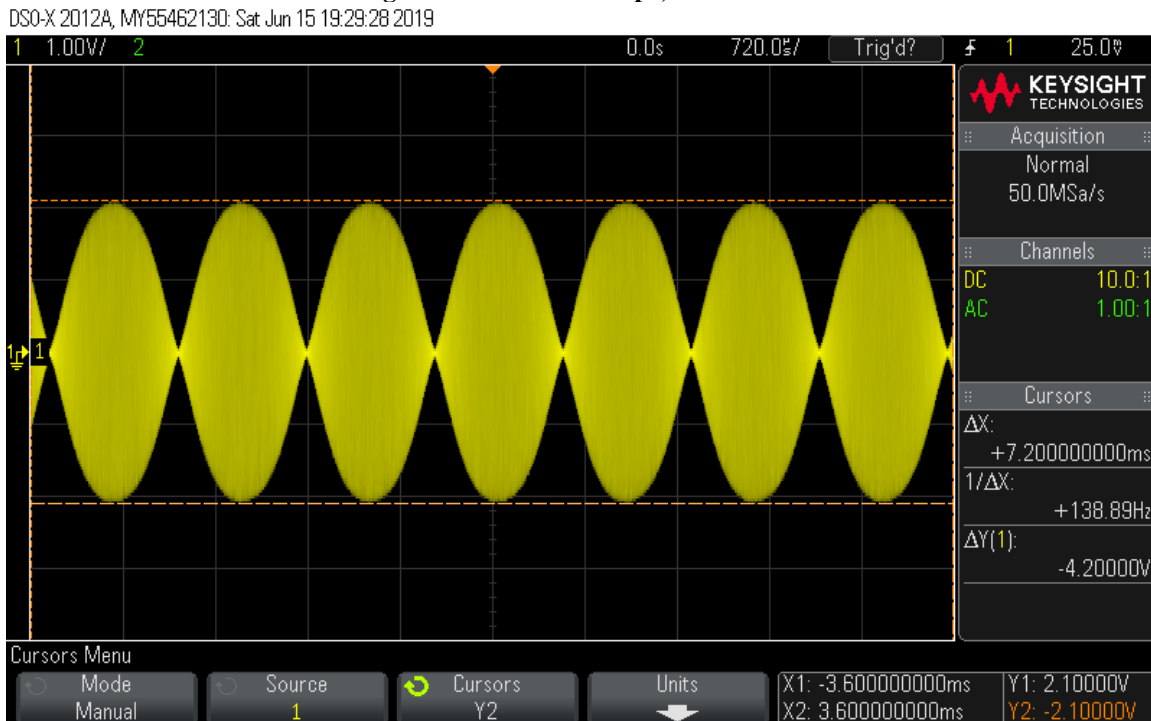


21: ALC Compression Check. In this test, a 2-tone test signal is applied to the USB port. An oscilloscope is connected to ANT1 via a 50 dB high-power attenuator. RF Power is initially adjusted for 100W output in RTTY mode.

Test Conditions: 144.1 MHz USB, COMP off, DATA OFF MOD = USB, USB MOD Level = 50% (default). Test tones: 700 and 1700 Hz, at equal amplitudes. TBW WIDE.

Test Result: No flat-topping of the 2-tone envelope was observed (see Figure 11.)

Figure 11: 2-tone envelope, 100W PEP.



22a: 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 ANT1, ANT2 and ANT3 in turn via a 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. 144.1, 432.1 and 1240.1 MHz USB, DATA OFF MOD = USB, USB MOD Level = 50% (default). Test tones: 700 and 1700 Hz, at equal amplitudes. The spectrum analyzer's -10 dBm reference level RL equates to rated CW output (= 0 dBc).

On computer, adjust USB Audio Codec device volume for rated PEP (each tone at -6 dBc). Figures 12 through 14 show the two test tones and the associated IMD products for each test case.

Table 19. 2-tone TX IMD.

2-tone TX IMD Products at Rated P_o			
IMD Products	Rel. Level dBc (0 dBc = 1 tone)		
Freq. MHz	144.1	432.1	1240.1
2-tone PEP W	100	75	10
IMD3 (3 rd -order)	-29	-23	-18
IMD5 (5 th -order)	-37	-37	-31
IMD7 (7 th -order)	-43	-49	-45
IMD9 (9 th -order)	-56	-53	-61
Add -6 dB for IMD referred to 2-tone PEP			

Note on IMD3: At 432.1 and 1240.1 MHz, the measured IMD is below the -25 dBc guideline stated in ITU-R Recommendation SM.327-7.

Figure 12: Spectral display of 2-tone IMD at 144.1 MHz, 100W PEP.

IC-9700 2m TX IMD 100W PEP 130619

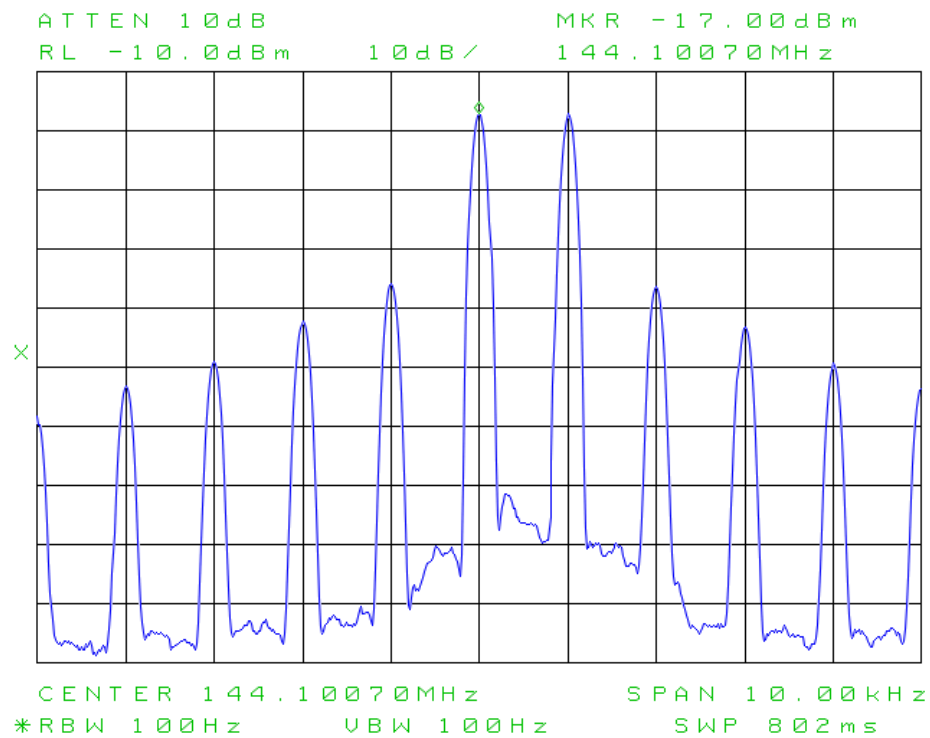


Figure 13: Spectral display of 2-tone IMD at 432.1 MHz, 75W PEP.

IC-9700 70cm TX IMD 75W PEP 130619

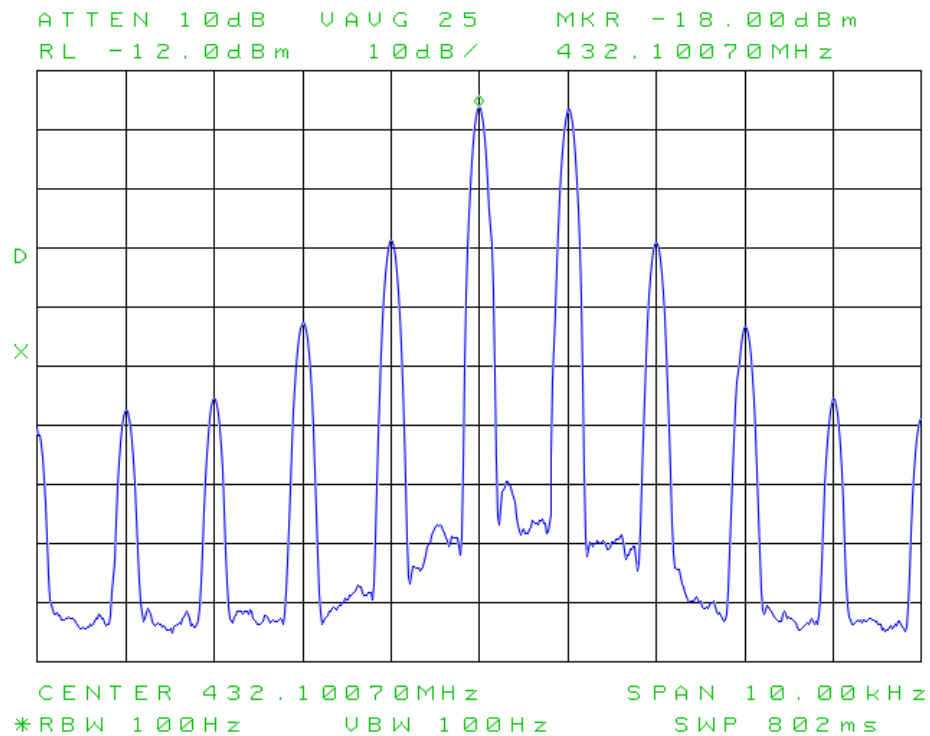


Figure 14: Spectral display of 2-tone IMD at 1240.1 MHz, 10W PEP.

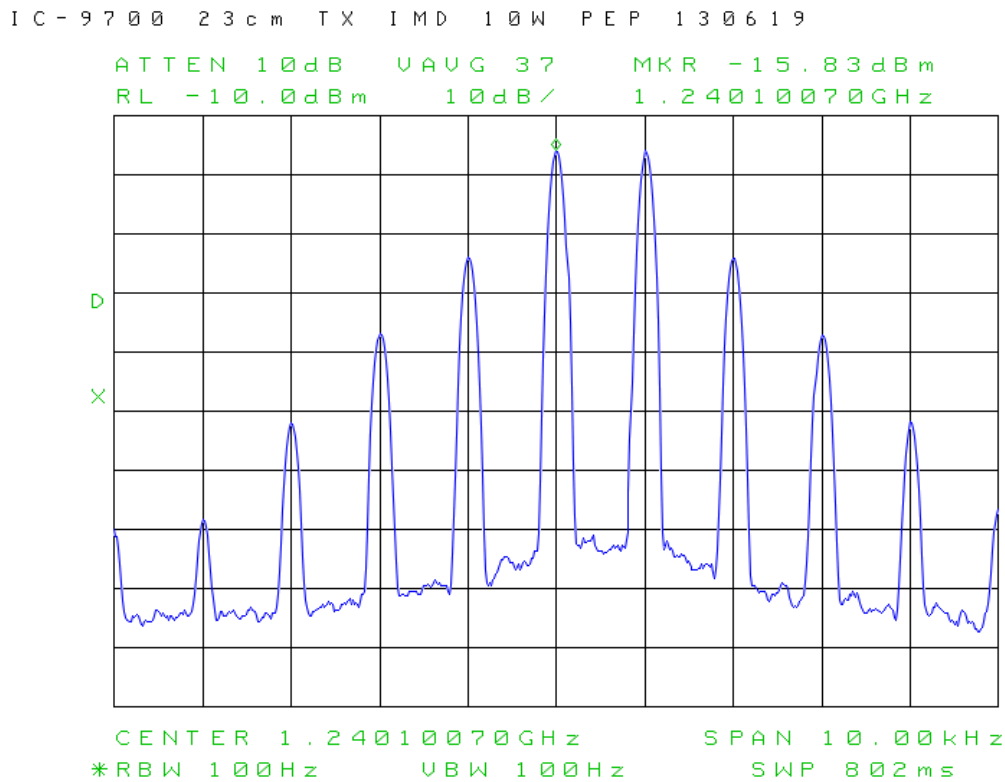
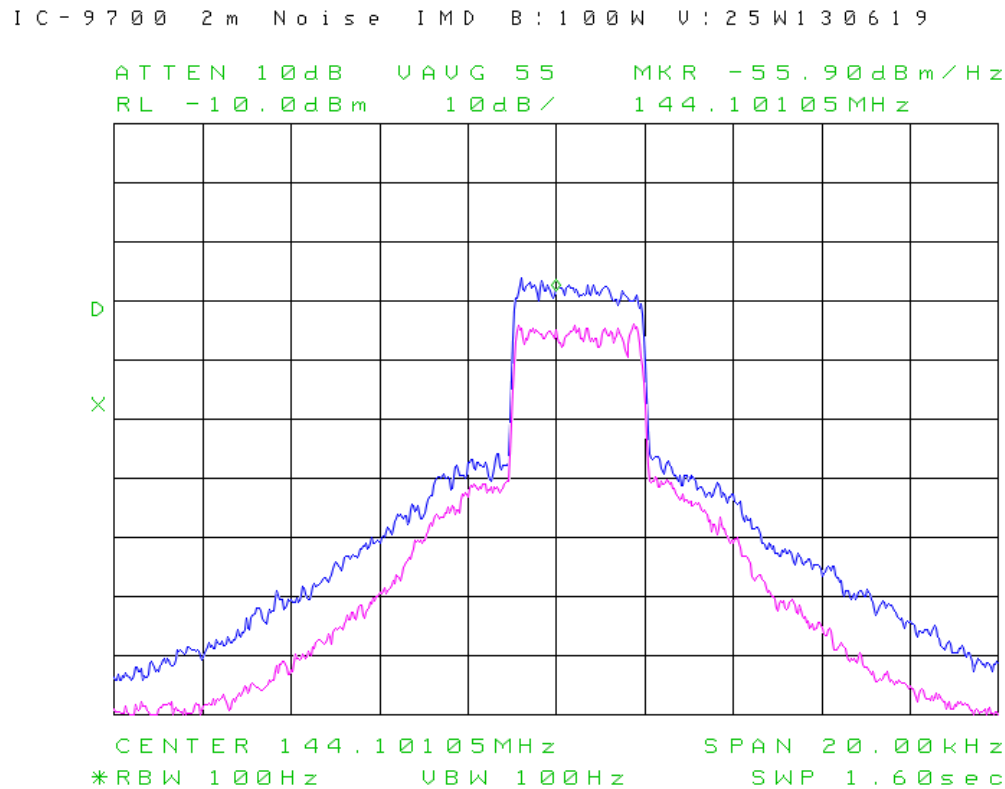


Figure 15: 144.1 MHz noise modulation, showing IMD skirts.



22b: Noise IMD Test. 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 17. Note that the IMD skirts are steeper at the lower power level. (Figure 15).

23: AM sidebands and THD with single-tone modulation. As in Test 26 above, the spectrum analyzer is connected to ANT1 via a 50 dB high-power attenuator. On the IC-9700, 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 spectrum analyzer records the carrier and sideband parameters.

Test Conditions: 144.1 MHz AM, 25W carrier output, DATA OFF MOD = USB, USB MOD Level = 50% (default).

On computer, adjust USB Codec device volume for -7 dBc test tone level (90% modulation.) Figure 17 shows the carrier and sideband levels. Calculated THD \approx **4.5%**.

Figure 16: AM Sidebands for 90% Modulation.

IC-9700 2m AM Sidebands 25W CXR 90% mod 130619

DISCRETE SIDEBAND SEARCH RESULTS

CARRIER FREQ: 144.1 MHz
CARRIER POWER: -16.0 dBm

OFFSET FREQ	-	OFFSET dBc	+	OFFSET dBc
-----		-----		-----
.998 kHz		-6.7		-6.7
1.997 kHz		-27.3		-27.8
2.996 kHz		-34.5		-34.8
4.004 kHz		-47.2		-46.3
5.003 kHz		-57.2		-57.7

FOUND: 5 SETS OF SIDEBANDS

24: Transmitter harmonics & spectral purity. Once again, the spectrum analyzer is connected to ANT1, ANT2 and ANT3 in turn via a high-power attenuator. RF Power is adjusted for rated CW output on each band in turn. The 0 dBm reference level on the spectrum analyzer equates to 100W. The spectrum analyzer's harmonic capture utility is started.

Test Conditions: 144.1 MHz, RTTY, rated output to 50Ω load. Utility start and stop frequencies are configured as shown in Figures 19 through 26 inclusive. Harmonic data and spur sweeps are presented for all 3 bands. It will be seen that harmonics and spurs are well within specifications.

Figure 17.

IC-9700 2m Harmonics 100W 130619

HARMONIC MEASUREMENT RESULTS		
FUNDAMENTAL SIGNAL: 144.1 MHz		
-10.0 dBm		
HARMONIC	LEVEL dBc	FREQUENCY
2	-68.5	288.2 MHz
3	-75.3	432.3 MHz
4	-76.7	576.4 MHz
5	-75.3	720.5 MHz
6	-83.2	864.6 MHz
7	-85.7	1.009 GHz
8	-87.3	1.153 GHz
TOTAL HARMONIC DISTORTION = 0 %		
(OF HARMONICS MEASURED)		

Figure 18.

IC-9700 2m Spurs 100W 130619

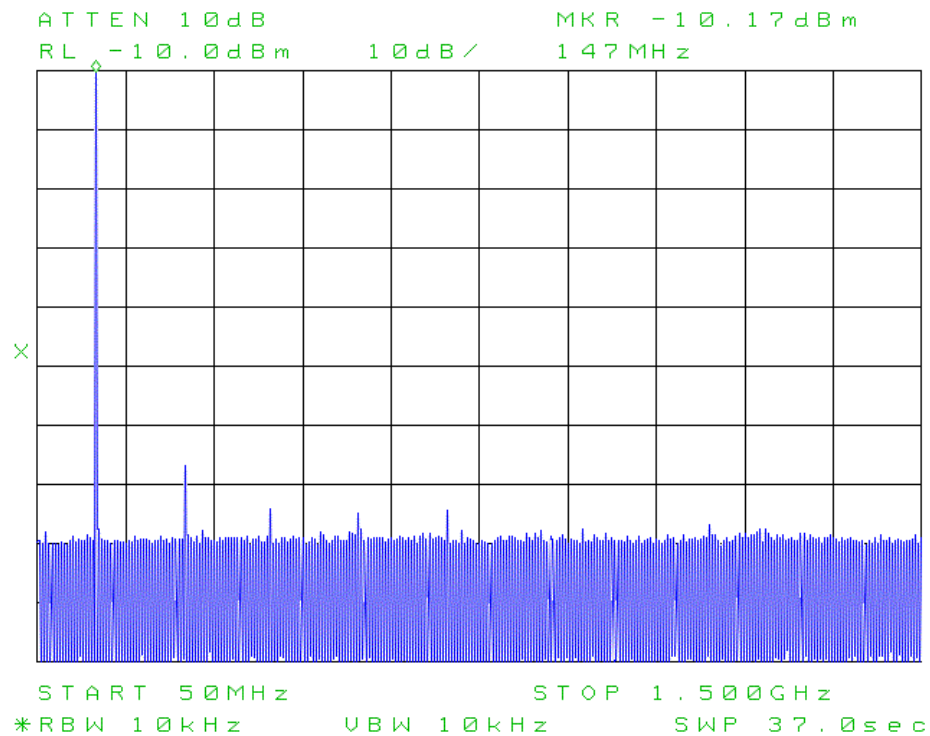


Figure 19.

IC-9700 70cm Harmonics 75W 130619

HARMONIC MEASUREMENT RESULTS

FUNDAMENTAL SIGNAL: 432.1 MHz
-11.5 dBm

HARMONIC	LEVEL dBc	FREQUENCY
2	-85.3 *	864.2 MHz
3	-92.3 *	1.296 GHz
4	-84.8	1.729 GHz
5	-80.0	2.161 GHz
6	-93.3	2.593 GHz
7	-101.0 *	3.025 GHz
8	-99.2 *	3.457 GHz

* MEASURED LEVEL MAY BE
NOISE OR LOST SIGNAL.

TOTAL HARMONIC DISTORTION = 0 %
(OF HARMONICS MEASURED)

Figure 20.

IC-9700 70cm Spurs 75W 130619

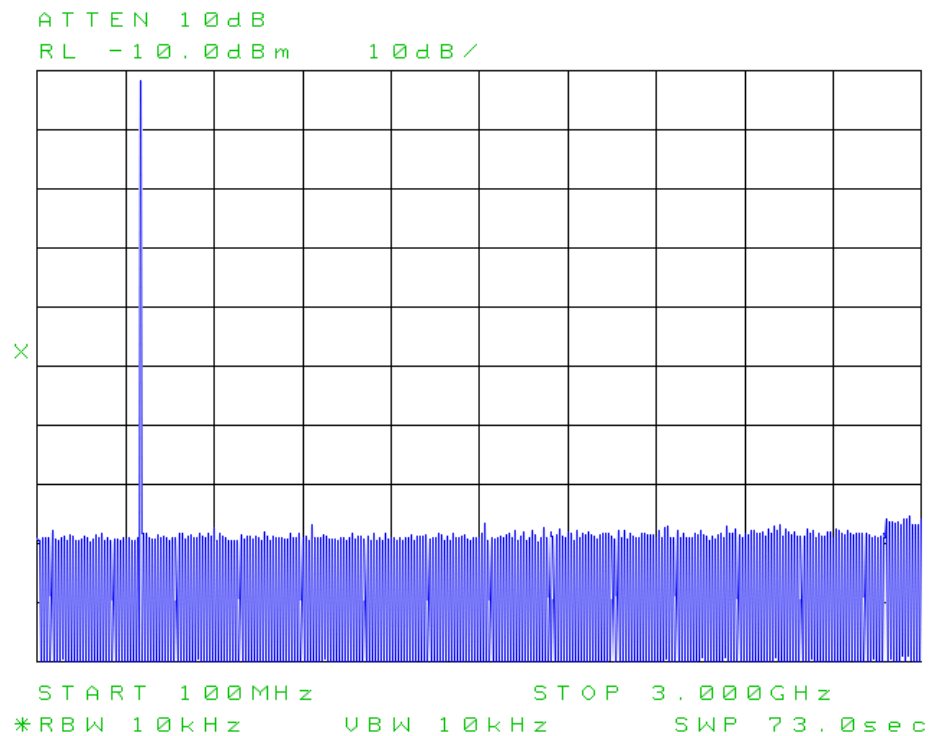


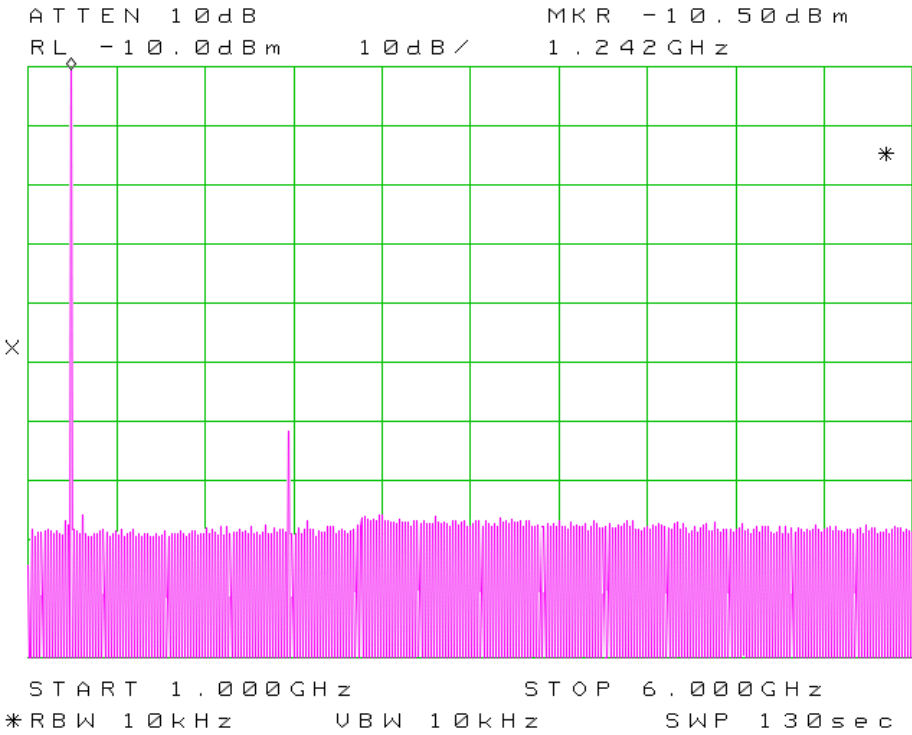
Figure 21.

IC-9700 23cm Harmonics 10W 130619

HARMONIC MEASUREMENT RESULTS		
FUNDAMENTAL SIGNAL: 1.240 GHz		
-10.3 dBm		
HARMONIC	LEVEL dBc	FREQUENCY
2	-60.7	2.480 GHz
3	-81.3 *	3.720 GHz
4	-100.2 *	4.961 GHz
5	-102.2 *	6.201 GHz
6	-100.8 *	7.441 GHz
7	-101.2 *	8.681 GHz
8	-100.3 *	9.921 GHz
* MEASURED LEVEL MAY BE NOISE OR LOST SIGNAL.		
TOTAL HARMONIC DISTORTION = .1 %		
(OF HARMONICS MEASURED)		

Figure 22.

IC-9700 23cm Spurs 10W 230619



25: Transmitted composite noise. A down-converter consisting of a double-balanced mixer and a 50 MHz LPF is used to translate the IC-9700 carrier output to an IF falling within the tuning range of a Perseus direct-sampling SDR receiver. The RF input of the mixer is connected to ANT1, ANT2 and ANT3 of the IC-9700 in turn, via a 50 dB high-power attenuator (40 dB on 1.2 GHz). The LO port is driven by the R&S SMBV-100A signal generator at +17 dBm. Low-side LO injection is employed.

A Perseus SDR receiver is connected to the mixer's IF output via a 50MHz LPF and a 0 - 110 dB step attenuator. For each test case, the step attenuator is first set to -1 dBFS (1 dB below ADC clipping) on the Perseus at zero offset. Next, the noise level is read off the Perseus signal-strength indicator at 1-2-5 offsets in the range 0.1 to 100 kHz. Figures 23a and 23b are the resulting composite-noise charts.

Test Conditions: 144.1, 432.1 and 1240.1 MHz RTTY, RF power output as indicated on charts. Perseus settings: $f_0 = 14.1$ MHz, preselector off, preamp off, dither off, channel bandwidth 50 Hz, RBW 30.5 Hz. (**Note:** The Perseus noise floor is approx. -151 dBc/Hz. An uncertainty of ± 1 to 2 dB may occur at input levels close to this noise floor.)

It should be noted that as long as the LO feeding the mixer has low phase noise, the results obtained by this method will track the R&S FSWP data quite closely (within the Perseus' limit of measurement).

Appendix 4 presents a set of transmitted composite noise charts taken on an IC-9700 in the Netherlands by Conrad Farlow PA5Y, using a R&S FSWP signal analyzer.

Figure 23a.

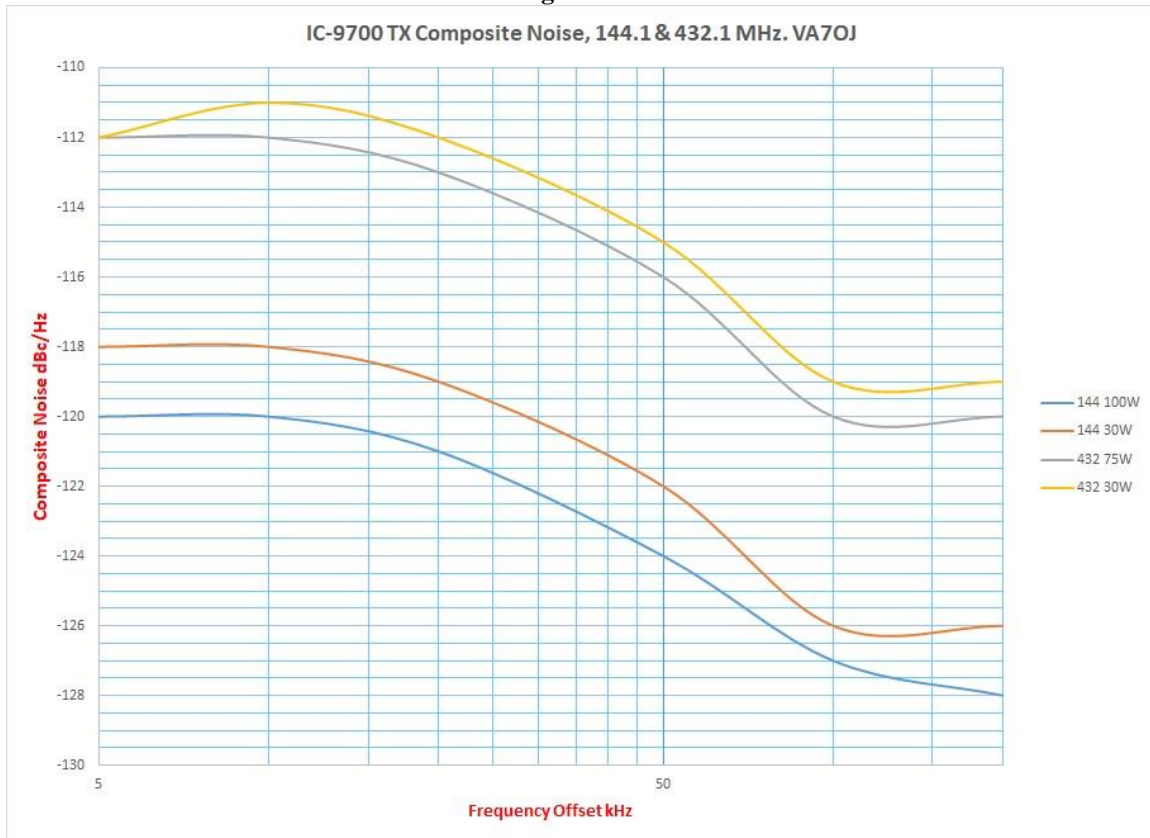
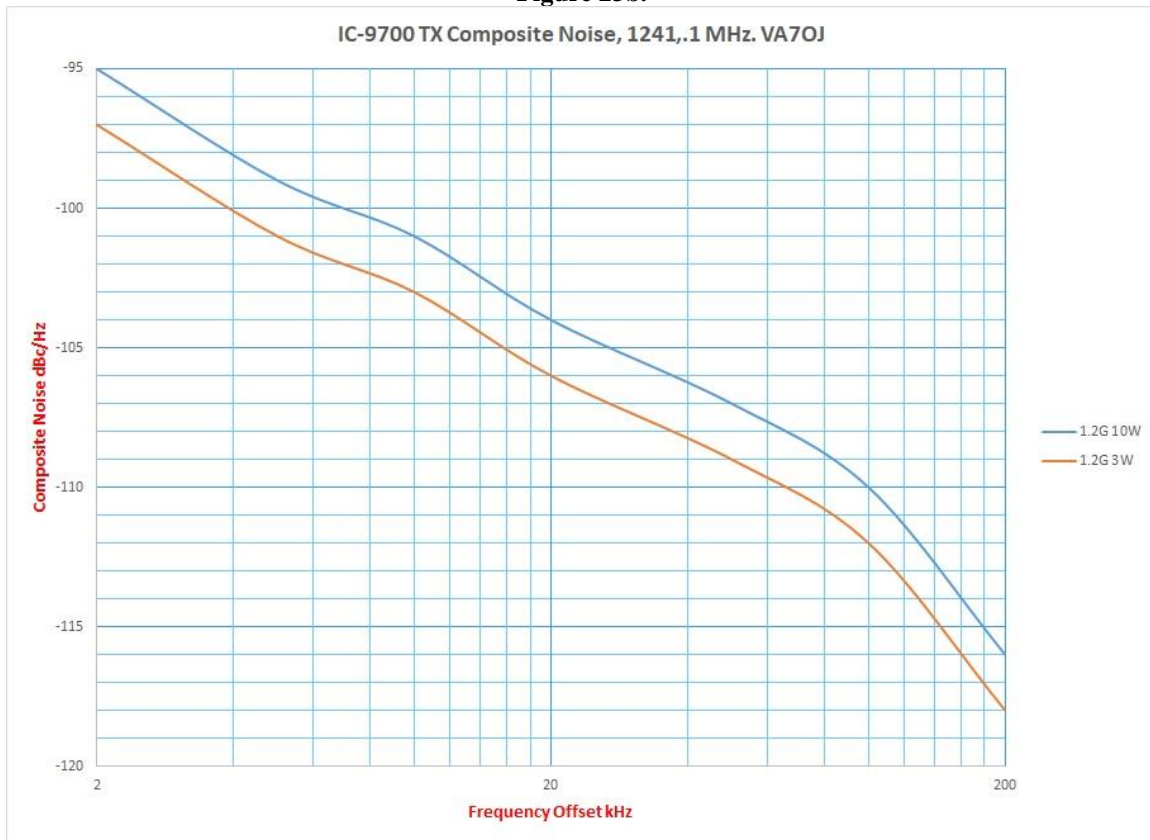


Figure 23b.



26a: Spectral display of CW keying sidebands. The spectrum analyzer is connected to the IC-9700 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: 144.1 MHz CW, 100W output to 50 Ω load. Keying speed 48 wpm (KEY SPEED max.) using internal keyer. Spectrum analyzer RBW is 10 Hz, video-averaged; sweep time < 4 sec. Figures 24a and 24b show the transmitter output ± 5 kHz from the carrier at 2/4 and 6/8 ms rise-time, respectively.

Figure 24a: Keying sidebands at 48 wpm, 2/4 ms rise-time 144.1 MHz, 100W.

IC-9700 CW sidebands B:2ms U:4ms 48wpm 130619

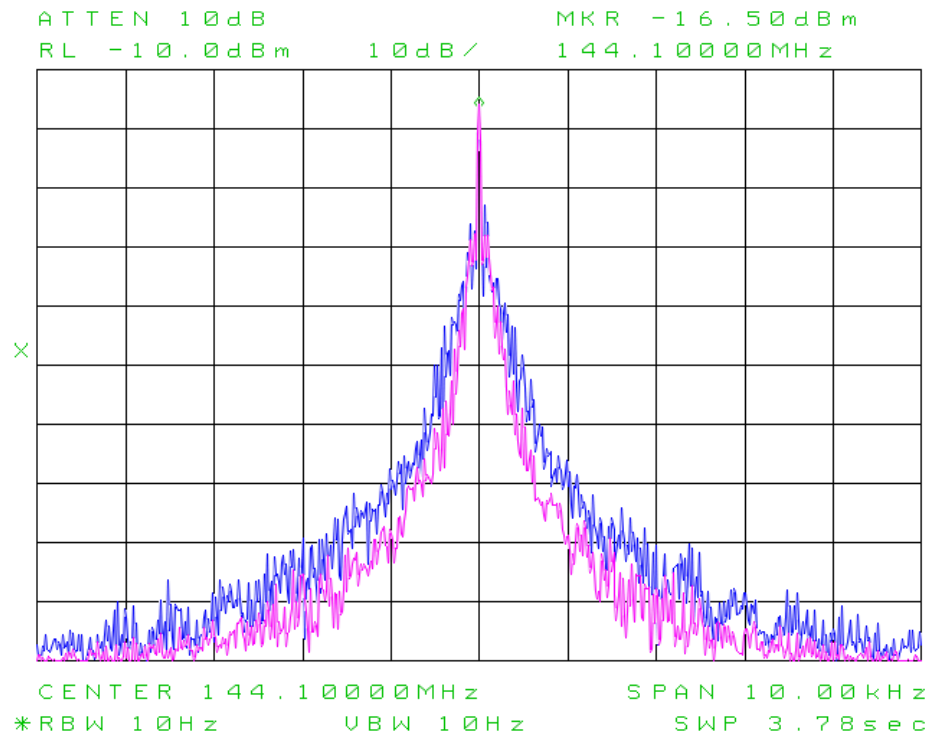
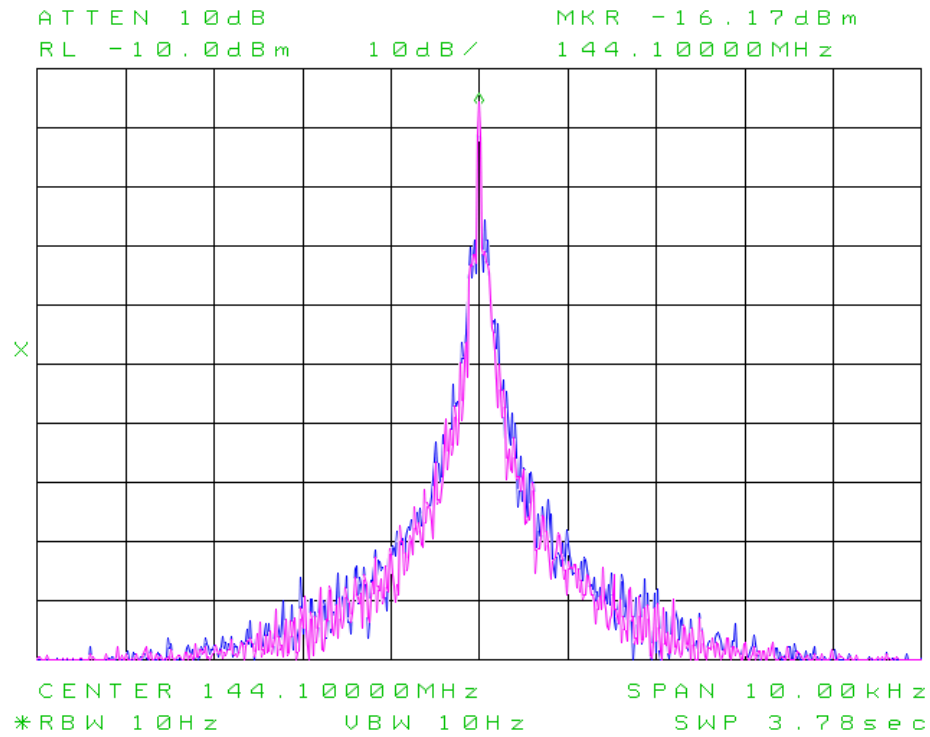


Figure 24b: Keying sidebands at 48 wpm, 6/8 ms rise-time 144.1 MHz, 100W.

IC-9700 CW sidebands B:6ms U:8ms 48wpm 130619



26b: CW keying envelope. The oscilloscope is terminated in 50Ω and connected to the IC-9700 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: 144.1MHz CW, 100W output to 50Ω load. CW rise time = 4 ms (default), TX DELAY OFF.

Figure 25a: Keying envelope at 48 wpm, 2 ms rise time, 2 ms/div.

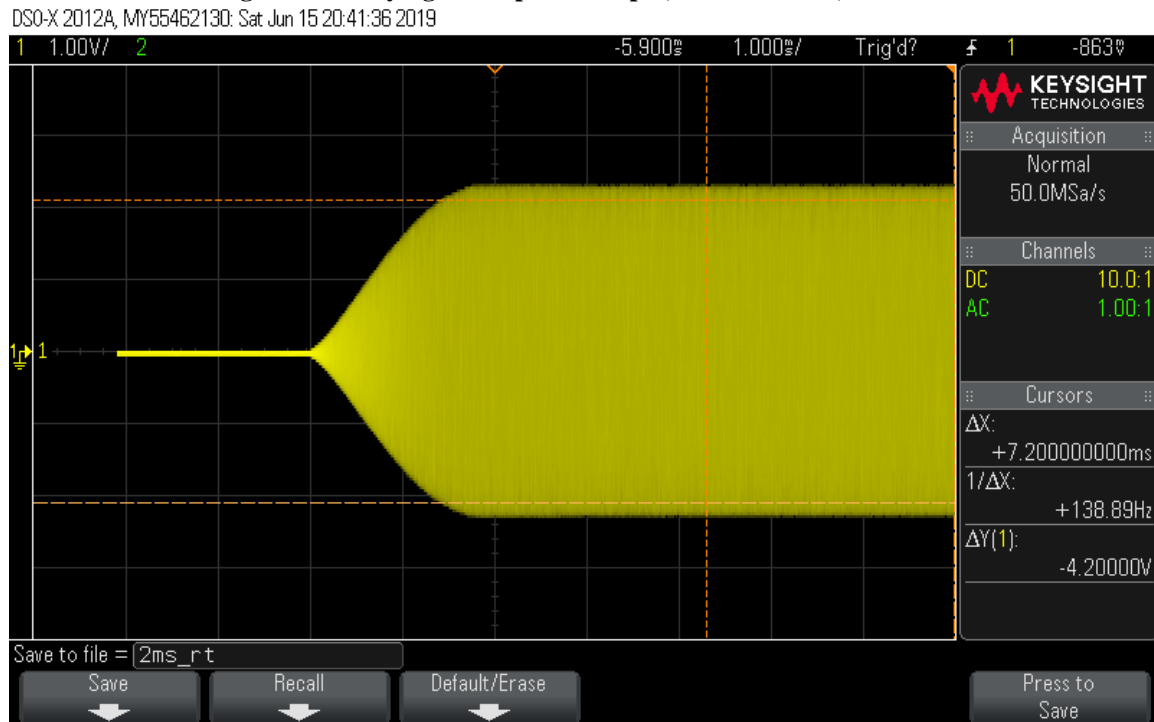


Figure 25b: Keying envelope at 48 wpm, 4 ms rise time, 2 ms/div.

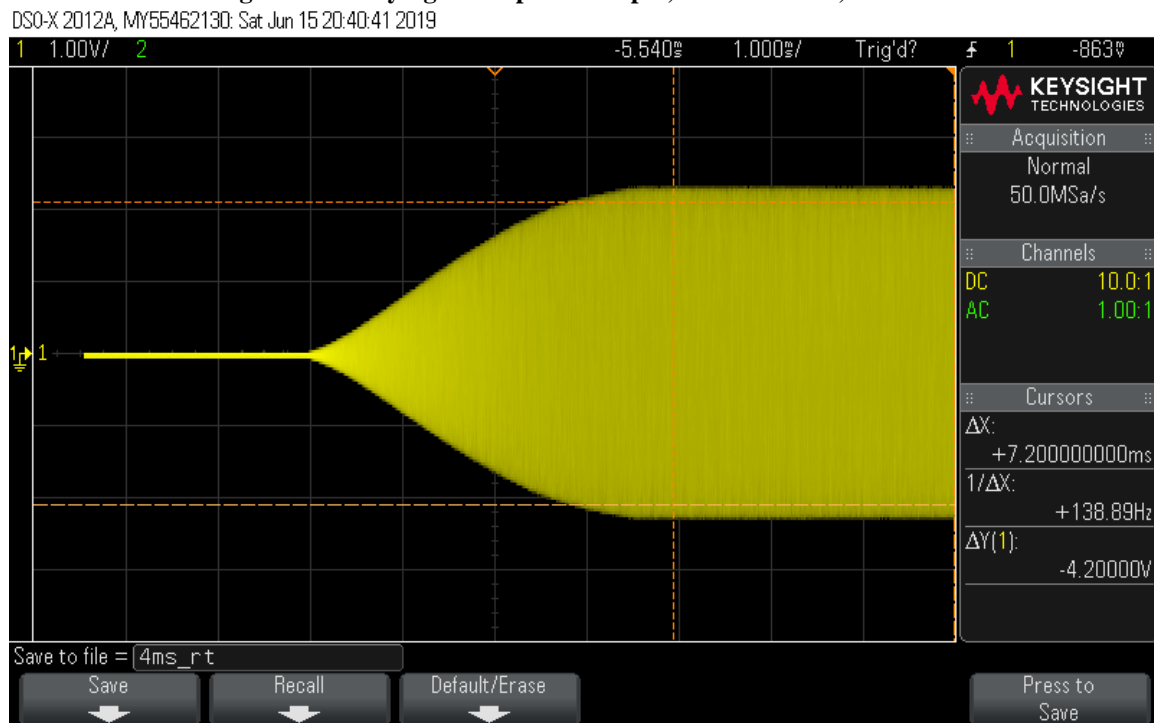


Figure 25c: Keying envelope at 48 wpm, 6 ms rise time, 2 ms/div.

DSO-X 2012A, MY55462130: Sat Jun 15 20:39:22 2019

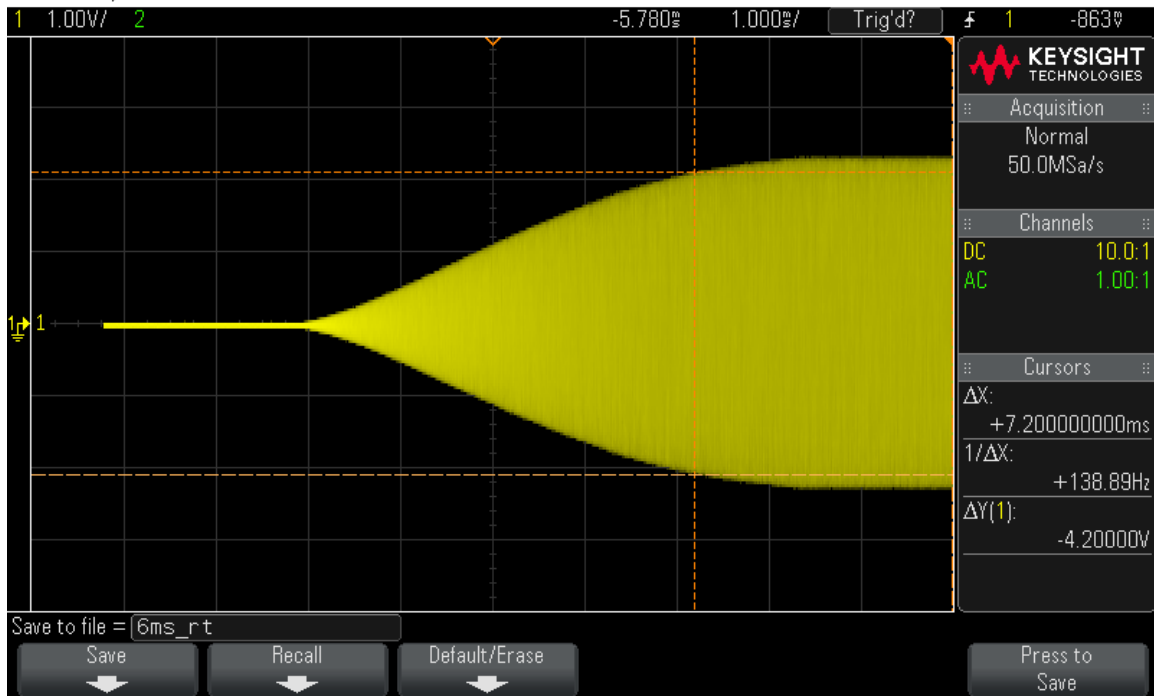
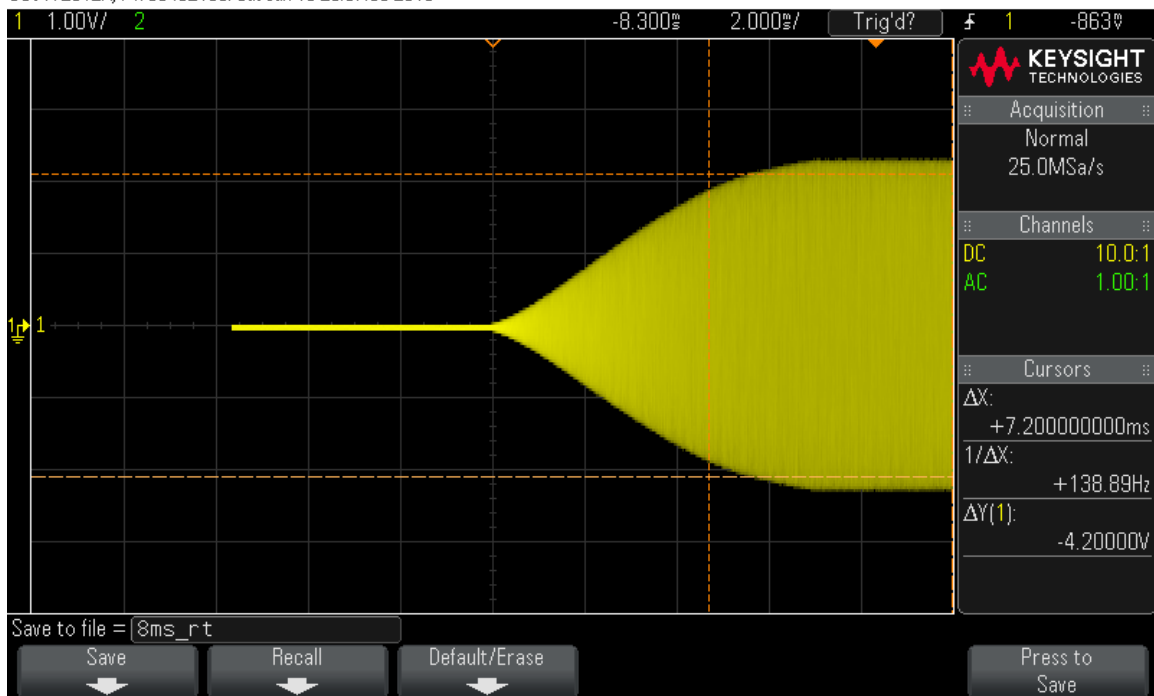


Figure 25d: Keying envelope at 48 wpm, 8 ms rise time, 2 ms/div.

DSO-X 2012A, MY55462130: Sat Jun 15 20:37:38 2019



26c: 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 IC-9700 is terminated in a 50 Ω 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 PWR is set at 10W.

Test Conditions: 144.1 MHz, 500 Hz CW, preamp off, ATT off, NR off, NB off, F-BK on, rise time = 4 ms, RF PWR at 10W, KEY SPEED at 48 wpm (max.), CW Pitch default. Test signal at 144.1002 MHz. Sidetone = 600 Hz, received tone = 800 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: In the current test, the received tone could still be heard distinctly at **21-22 wpm**.

27: ACC Pin 11 (MOD, analog baseband input) and USB MOD level for 100W output. A 1 kHz test tone is injected into ACC Pin 11, 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: 144.1 MHz USB, DATA OFF MOD = ACC, DATA-1 MOD = ACC, ACC MOD Level = 50% (default), TBW = WIDE/MID/NAR (default values), Bass/Treble = 0 dB (default), COMP off, test tone 1 kHz.

Adjust test tone level for \approx 100W output in USB and USB-D1 modes. The required input levels were **76 mV rms** for 96W output in USB, and **60 mV RMS** for 96W RF output (max. obtainable) in USB-D1.

Repeat test with DATA OFF MOD = USB, DATA-1 MOD = USB, USB MOD Level = 50% (default). 96W output was obtained with laptop tone generator level at 0 dB (nominal level) and USB MOD Level at 90%.

27a: 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.

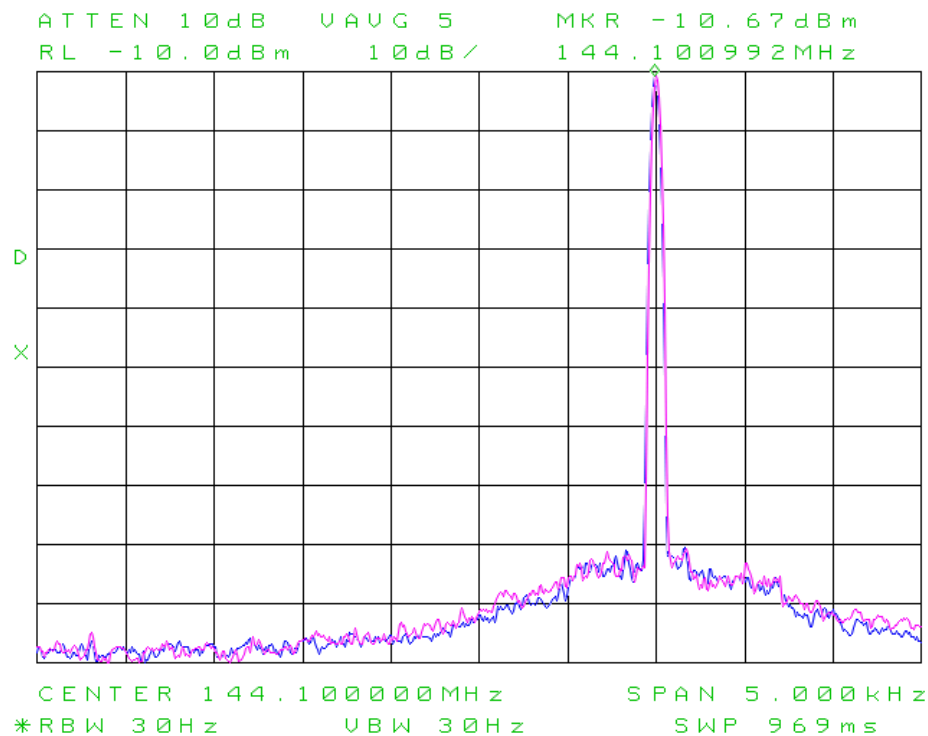
Test Conditions: 144.1 MHz USB, DATA OFF MOD = ACC/USB, DATA-1 MOD = ACC/USB, TBW = WIDE (default), test tone 1 kHz.

Adjust test tone level for 100W output. Read carrier amplitude at 144.1 MHz, and opposite-sideband amplitude at 144.099 MHz.

Test Results: For ACC and USB test-tone input, carrier and opposite sideband both < -80 dBc (at or below the spectrum analyzer's noise floor). See Figure 26.

Figure 26.

IC-9700 100W cxb/opp SB rej B!USB V!ACC 160619

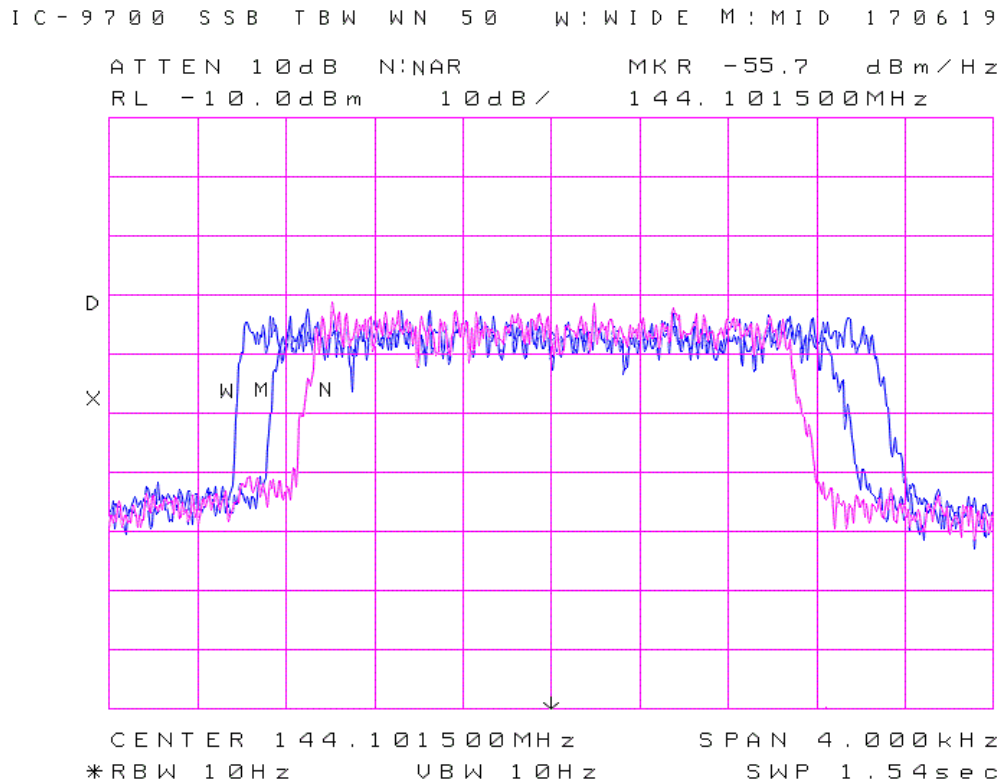


27b: SSB transmit audio-frequency response via USB port. In this test, a white-noise baseband is applied to the USB port from a tone-generator program running on a laptop computer. The spectrum analyzer is connected to the IC-9700 RF output via a 60 dB high-power attenuator.

Test Conditions: 144100 kHz USB, COMP OFF, DATA OFF MOD = 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. Capture traces for WIDE, MID and NAR TBW selections.

Test Results: The captured traces are shown in Figure 27.

Figure 27: Measured SSB TX lower and upper cutoff frequencies (via USB input).



28a: FM deviation. The IC-9700 ANT1 port 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: 146.520 MHz, FM, FIL1, RF PWR set at 25W.

Speak loudly into mic and read deviation.

Test Results: Peak deviation = 4.3 kHz (FIL1), 2.2 kHz (FIL2).

Next, select CTCSS TONE = 100 Hz (1Z). Key IC-9700 and read tone frequency and deviation on test set. **Test Result:** Tone frequency 100.00 Hz, deviation 560 Hz (FIL1), 400 Hz (FIL2).

28b: CTCSS decode sensitivity. The test set is configured as an RF generator. TSQ (CTCSS tone squelch) is enabled in the IC-9700 and the minimum RF input power and tone deviation at which the tone squelch opens are measured.

Test Conditions: 146.520 MHz, FM, FIL1, ATT off, TONE =TSQ, TONE 100 Hz/1Z.

Table 20: CTCSS Decode Sensitivity

Tone Dev. Hz	RF input level
700	-120
500	-118

29: 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: 144.100 kHz USB, 100W, DATA OFF MOD = ACC, ACC MOD Level = 50% (default). Test signal: tone burst. WIDE, MID and NAR TBW are at default values. Scope sweep 1 ms/div.

Figure 28a: Transmit latency, WIDE TBW. Latency 3.1 ms.

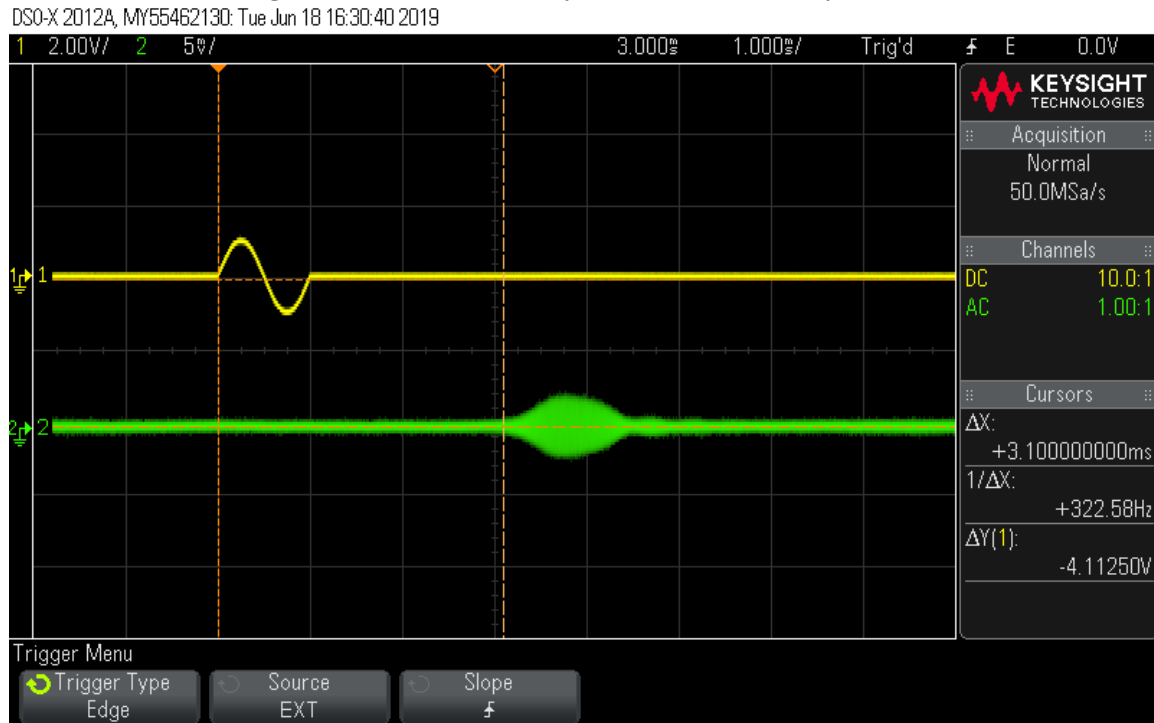


Figure 28b: Transmit latency, MID TBW. Latency 3.4 ms.

DSO-X 2012A, MY55462130: Tue Jun 18 16:31:39 2019

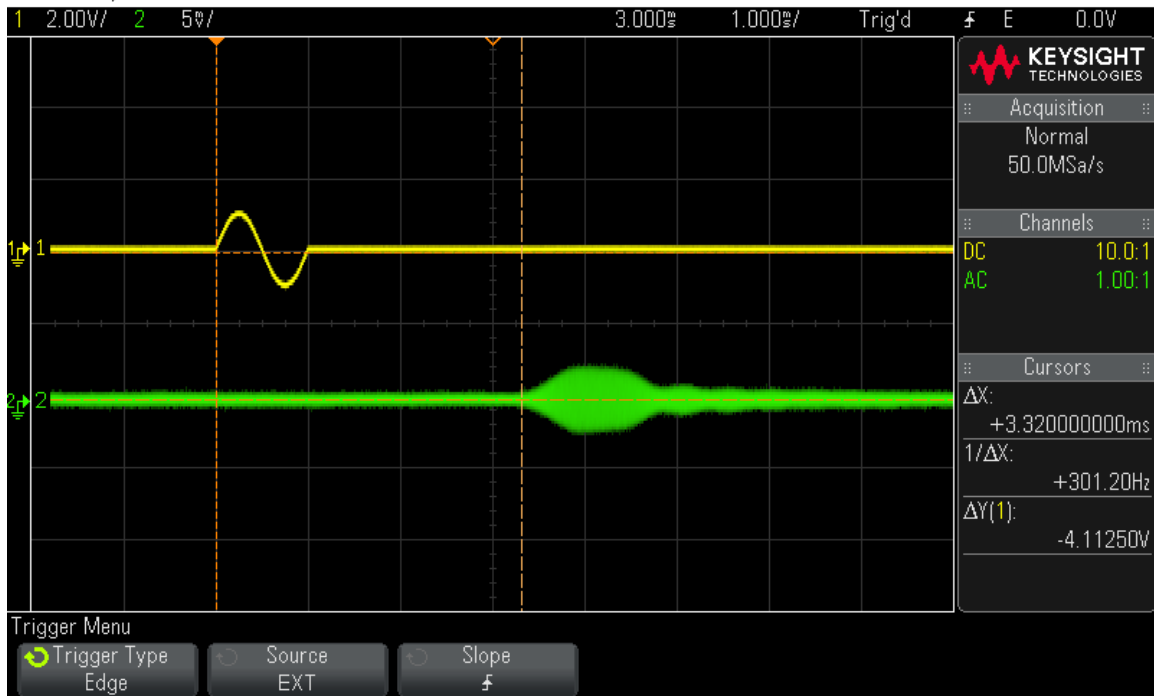
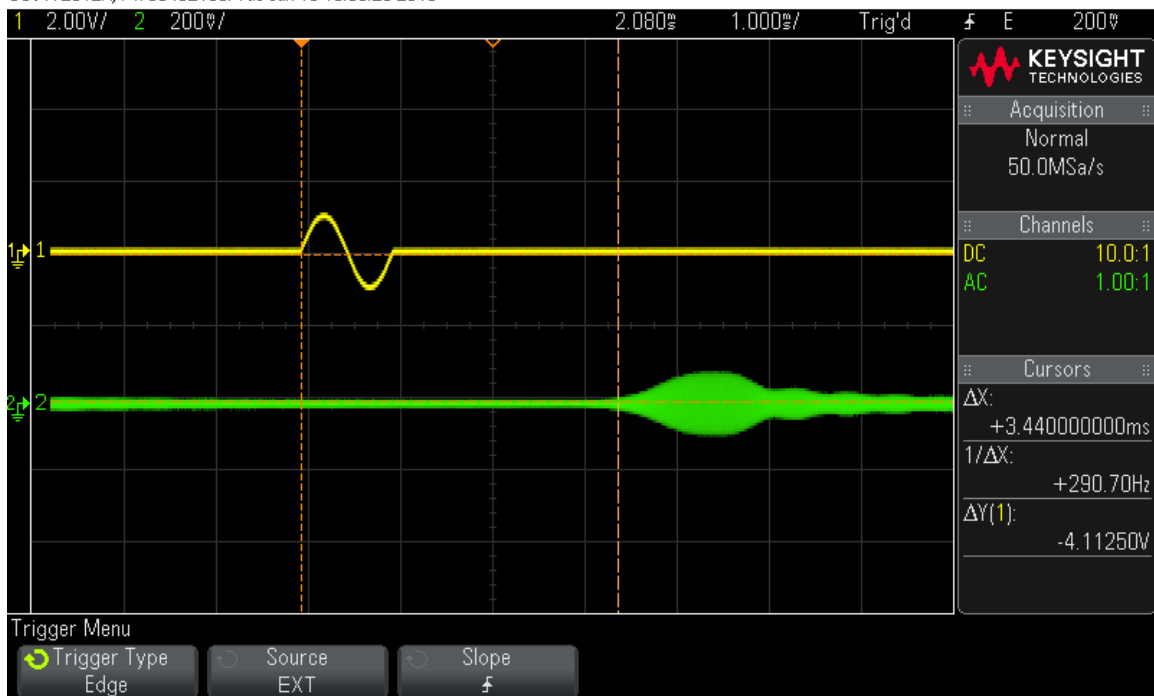


Figure28c: Transmit latency, NAR TBW. Latency 3.4 ms.

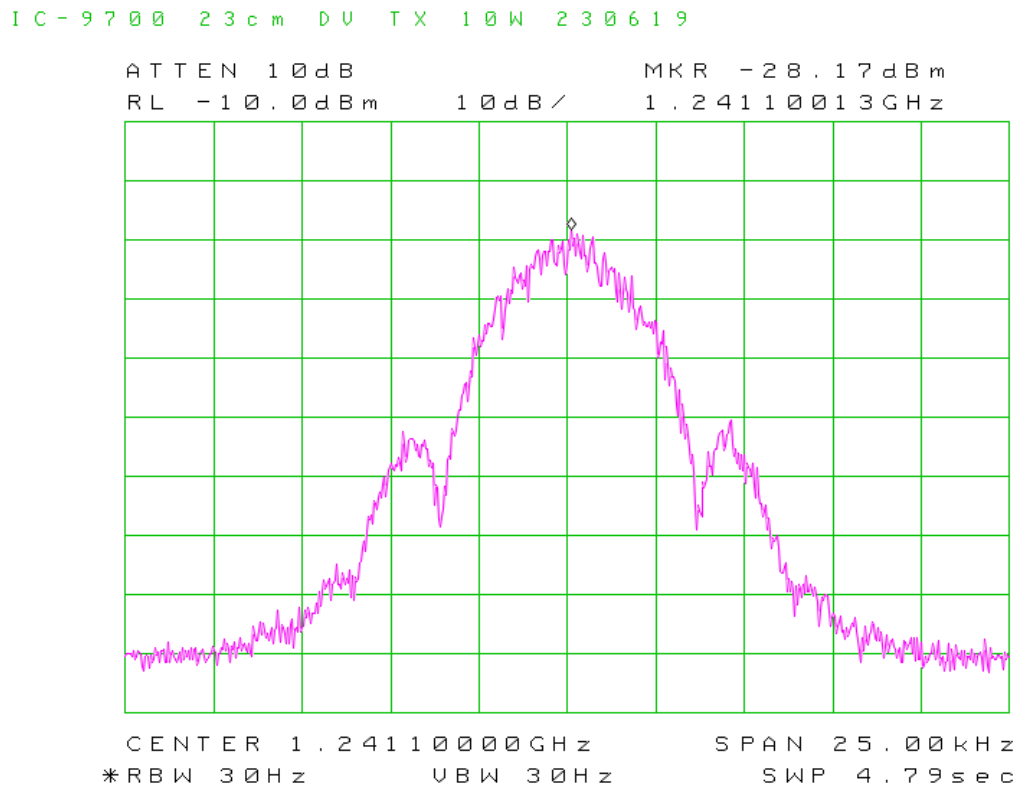
DSO-X 2012A, MY55462130: Tue Jun 18 16:35:26 2019



30. DV Mode Spectrum. The IC-9700 is configured for DV mode on 1.2 GHz. ANT3 is connected to the spectrum analyzer via a 40 dB power attenuator. The spectrum of a DV transmission is captured and displayed.

Test Conditions: 1241.100 MHz DV, 10W. The spectrum is shown in Fig. 1

Figure 29.



31: References.

1. "A New Look at SDR Testing":
<http://www.ab4oj.com/sdr/sdrtest2.pdf>
2. "Noise Power Ratio (NPR) Testing of HF Receivers":
http://www.ab4oj.com/test/docs/npr_test.pdf

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Appendix 2: Frequency Drift in Transmit

32: Frequency Drift Test with Firmware V1.10. This test was devised to verify the improvement in short- and medium-term frequency stability provided by Firmware Version 1.10. It was conducted at room ambient in my lab on June 7, 2019.

The IC-9700 was configured for duplex operation, with 75W transmit on 432.100 MHz and 1241.100 MHz RX. ANT2 was terminated in a 50 Ω load, and a test signal at -80 dBm, offset -1 kHz was applied to ANT3 to produce a 1 kHz test tone at the audio output. A frequency counter with 0.1 Hz resolution was connected to the PHONES jack. The EXT REF inputs on the IC-9700 and on the counter were connected to my GPS-derived 10 MHz house standard.

At 75W RTTY TX on 432.1 MHz, RX on 1241.1 MHz USB with a test signal offset 1 kHz, the following was observed: (Counter reads 1000.0 Hz for zero error).

Initial error -0.3 Hz. When keyed down continuously for approx. 15 sec. the error increased to -0.6 Hz, then jumped to +1.7 Hz when the fan started. After about 10 sec. with the fan running, it shifted to +3 Hz, then moved to -5 Hz.

15 sec. after unkeying, with the fan off, the error moved to +6 Hz, then to +3 Hz. Approximately 5 minutes after the test ended, the error settled at +1 Hz.

A second run was taken at 15s intervals as per Table 21.

Table 21: Frequency error vs. time, second run.

T sec.	0	15	30	45	60	75	90	105	120
Δf Hz	+2	+20	+30	+30	+9	+8	+2	-3	+1
Remarks		Fan on			Fan off				

In SSB or CW mode, the thermal effect will be less, of course. The V1.10 SYNC feature eventually corrects the drift caused by heat from the transmitter. As has been discussed on the IC-9700 groups.io forum, it appears that the fan moves warm air from the PA area to the master clock area X1 (which houses master oscillator X8601) on the main board. X8601 is a non-compensated ambient-temperature VCXO running at 49.152 MHz.

Firmware V1.10 has greatly improved the frequency stability over its predecessors, especially in the receive/standby mode. The problem which remains is the relatively large frequency change when transmitting, especially at high power. This can severely impact affect 23cm digital-mode operation, as well as specialized usage such as microwave terrestrial, satellite or EME operations (2.4 GHz and higher) in which the IC-9700 is used as an exciter for transverters. Narrow-band EME has probably the most stringent stability requirements.

If it were possible to implement a PLL scheme in the FPGA to phase-lock X8601 to the external 10 MHz reference (a step beyond the current frequency-discipline scheme), this could potentially provide a complete solution without hardware impact. Alternatively, reducing the cycle time of the present scheme (updating the master oscillator more frequently) would improve overall stability.

Appendix 3: CW “RF Tail”. *June 23, 2019.*

33: CW “RF Tail”. During QSK-CW transmit testing, an RF “tail” was observed at the end of each transmitted code element. The RF envelope persists for a few milliseconds after the SEND line drops back to the receive state; this can potentially cause hot-switching in an amplifier’s output T/R relay or PIN-diode switch.

Test Conditions: 144.100 MHz, CW, 10W, F-BK IN, 48 wpm. Channel 1 of oscilloscope connected to ACC Pin 3 (SEND). Channel 2 terminated in 50Ω and connected to ANT1 via a 40 dB power attenuator.

A string of dits is sent at 48 wpm in QSK mode. The “RF tail” starts approx. 300 ms after the SEND line drops back, and its decay time is equal to the CW rise time (as set in the CW rise time menu). Figures 30a through 30c illustrate this. The TX delay setting has no effect on the “tail”.

This “RF tail” is similar to the one which has been reported on the IC-7300. As regards a resolution, two possible methods can be envisaged:

- Delay the SEND line drop-back until the RF output falls to zero. This is complicated by the fact that the time interval between operator unkeying and the cessation of RF output is dependent on the CW rise time setting.
- Use a customer-provided sequencing device (e.g. a footswitch) to key first the amplifier, then the exciter. This may not be an attractive solution for some users.

Figure 30a: CW RF tail, 2 ms rise time.

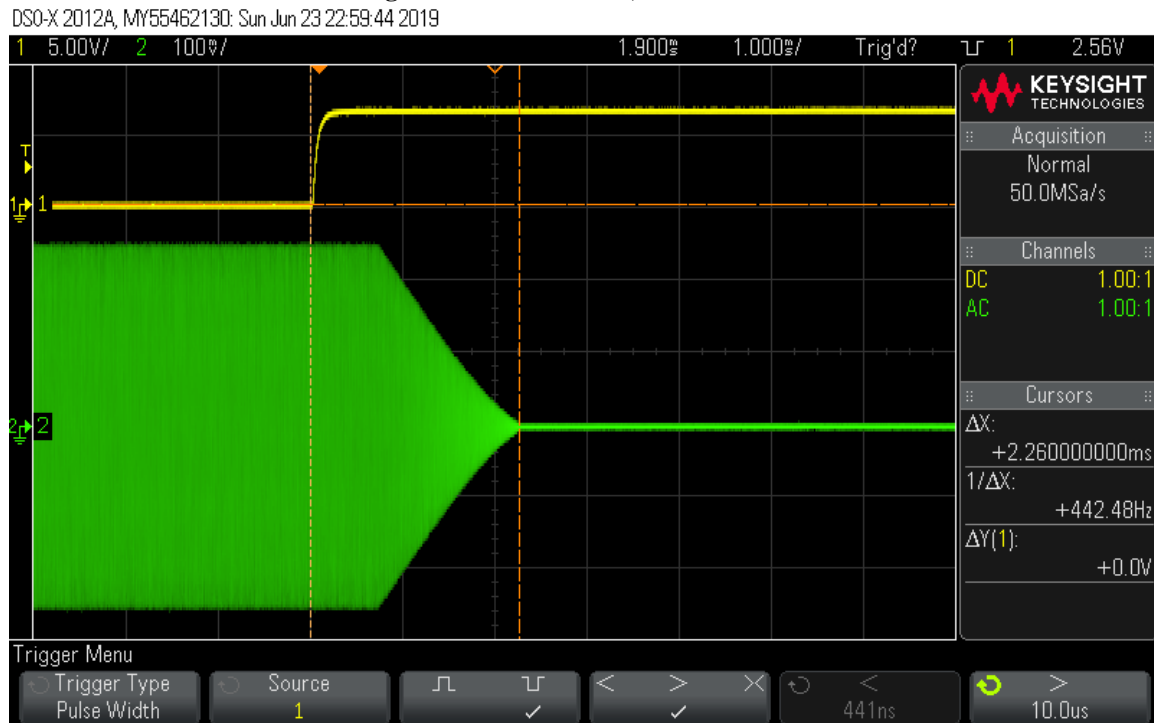


Figure 30b: CW RF tail, 4 ms rise time.

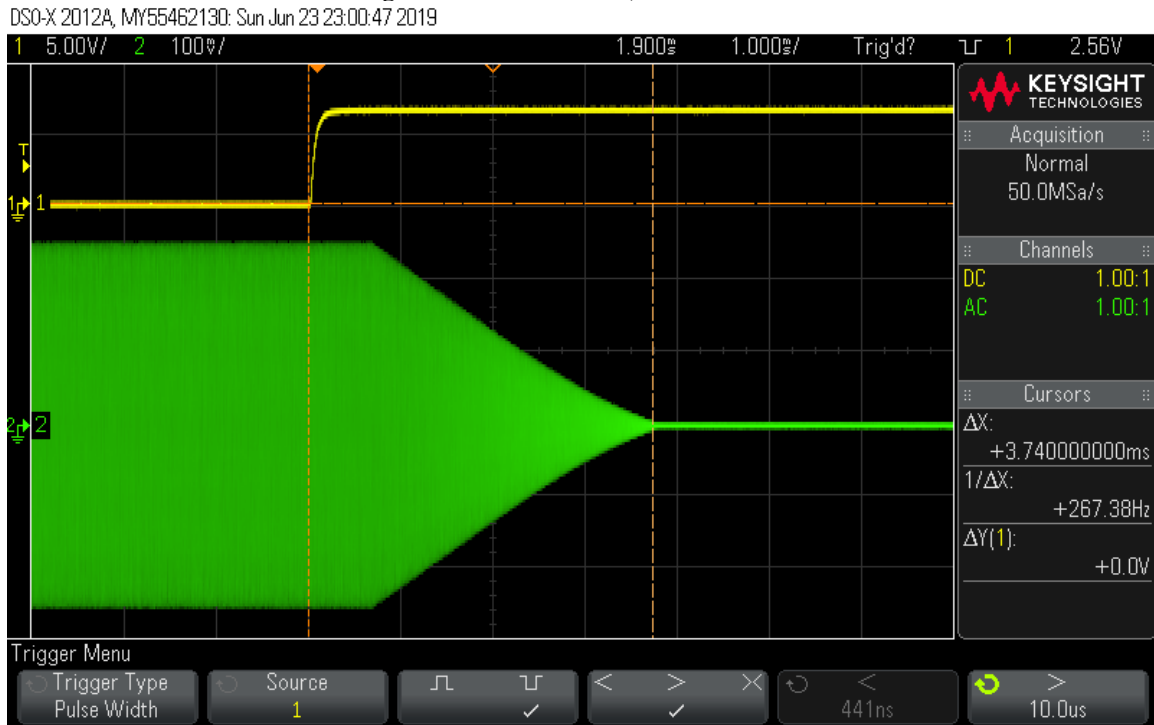
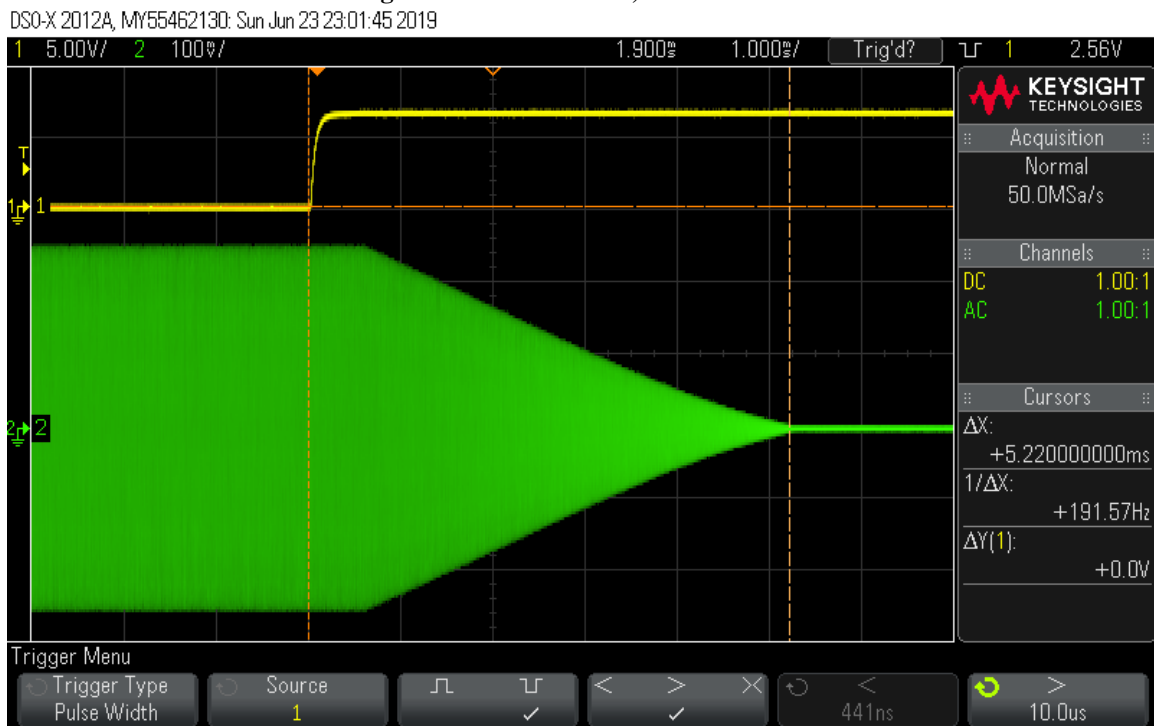


Figure 30c: CW RF tail, 6 ms rise time.

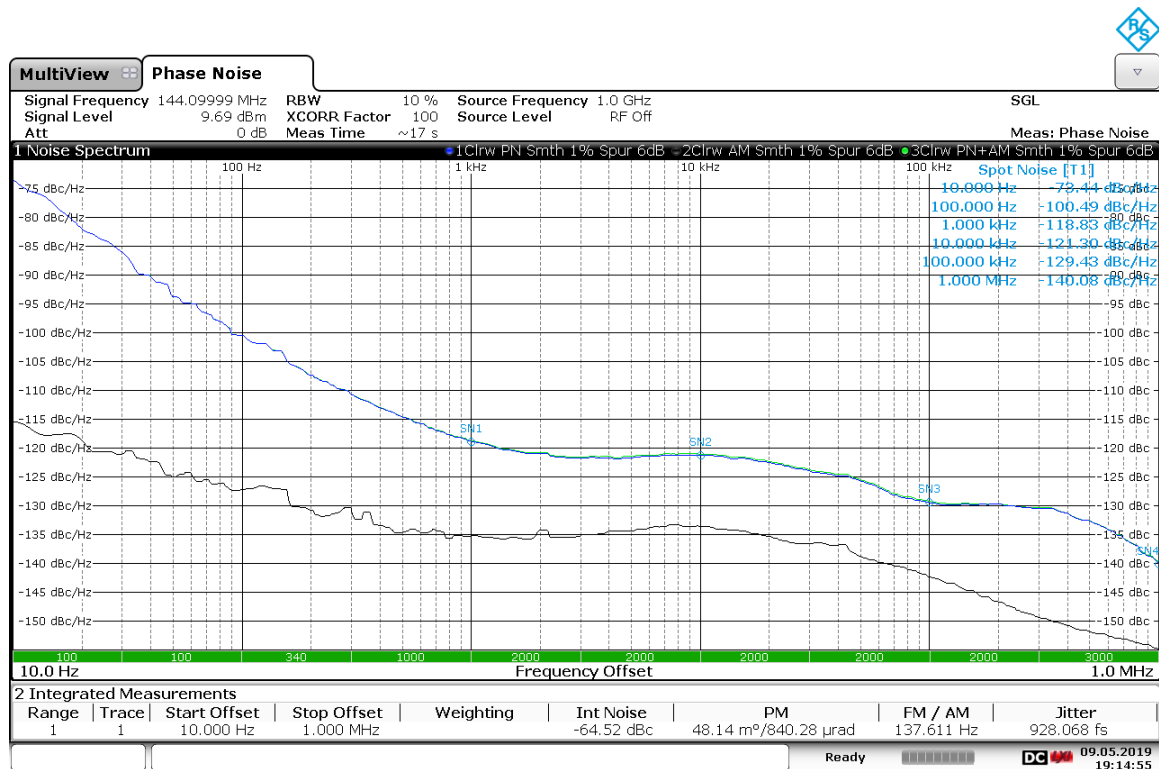


Appendix 4: IC-9700 Transmitted Noise Test Data

This section presents a set of transmitted composite noise charts taken on an IC-9700 in the Netherlands by Conrad Farlow PA5Y on May 9, 2019, using a R&S FSWP signal analyzer. The author wishes to convey his heartfelt thanks to Conrad for providing the data, and to Rohde & Schwarz GmbH & Co. KG for making the instrument available for these tests.

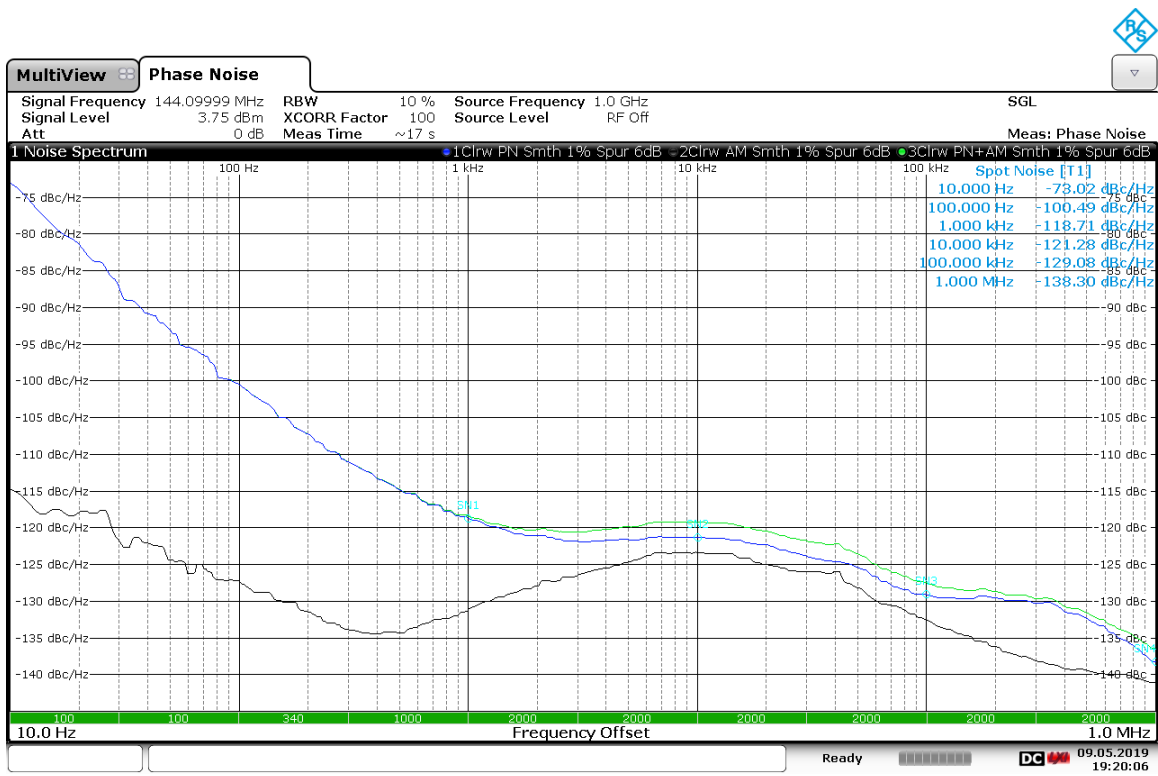
The following figures are plots for 144 and 430 MHz, and for 1.2 GHz. There are 3 traces on each plot, AM noise, phase noise and composite (Phase +AM) noise. The composite noise trace is green.

Most of the time the phase noise is so dominant that the composite noise is effectively the same as the phase noise plot and the green trace is not visible. The only place where the composite green plot is clearly visible is on 144MHz at 30W. The captions state the respective bands/frequencies and power levels.



19:14:55 09.05.2019

Figure 31: 144 MHz, 100W. Composite noise: green.



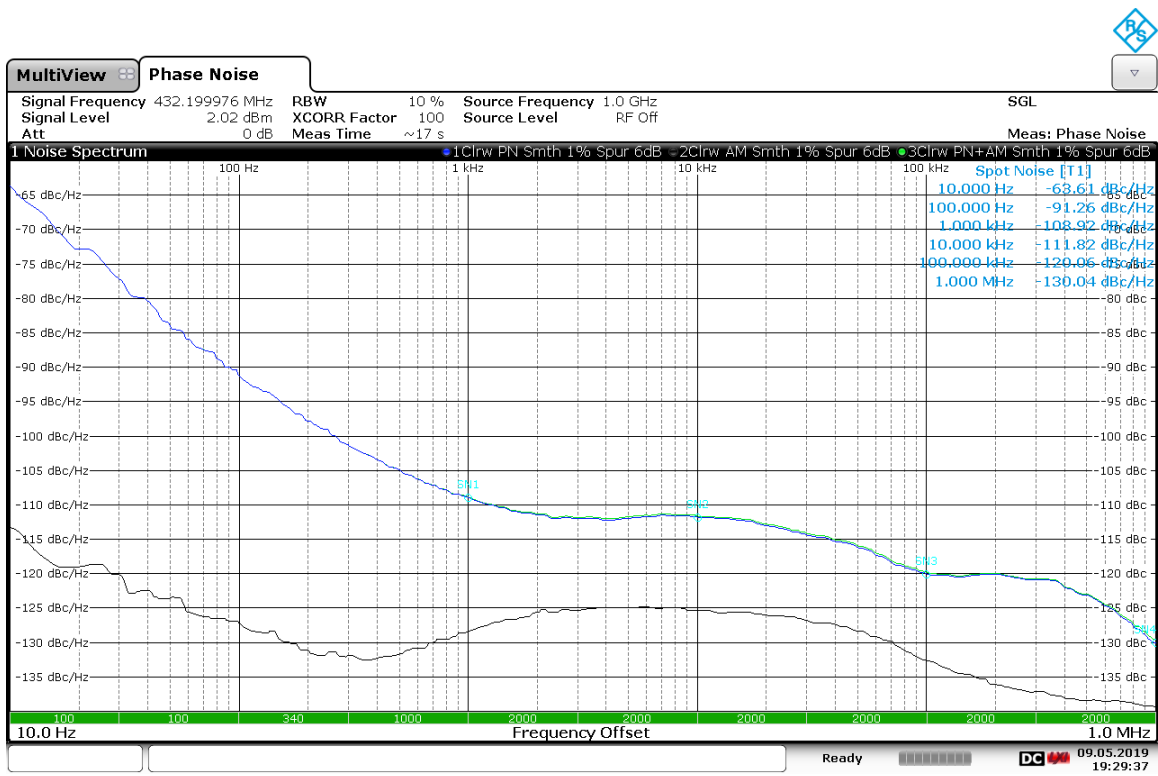
19:20:07 09.05.2019

Figure 32: 144 MHz, 30W. Composite noise: green.



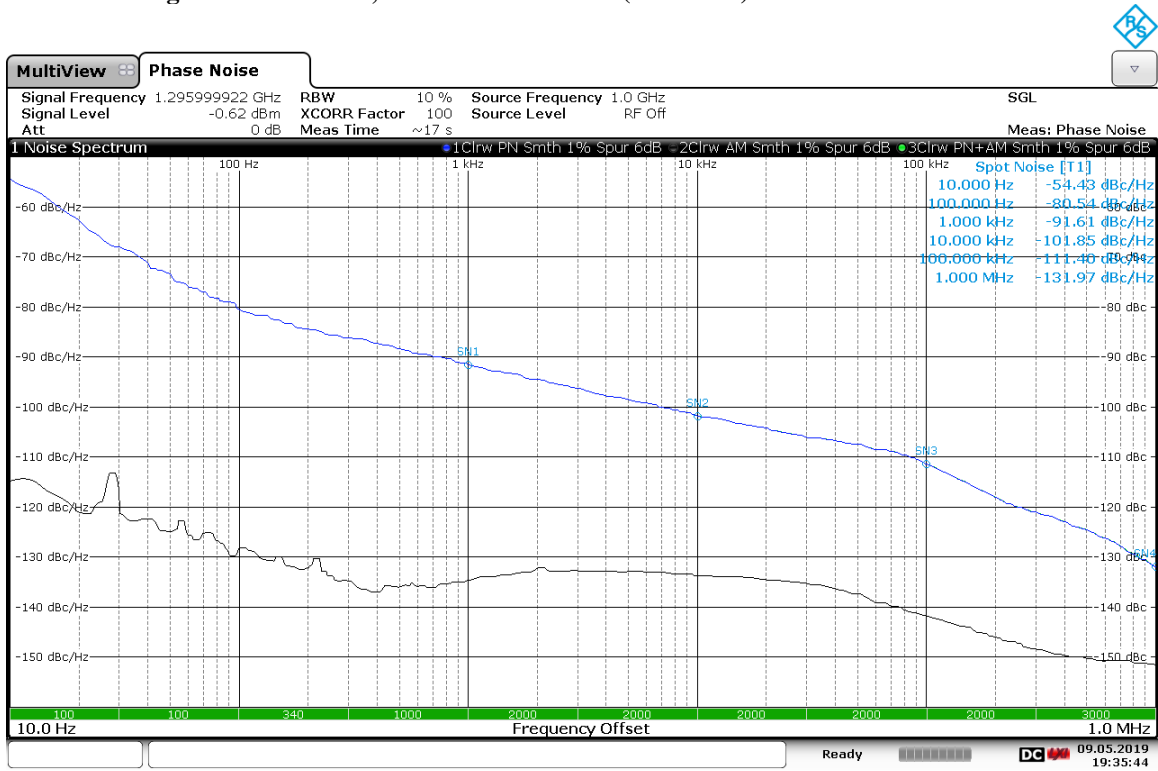
19:26:12 09.05.2019

Figure 33: 432 MHz, 75W. Phase noise (dominant): blue. AM noise: black.



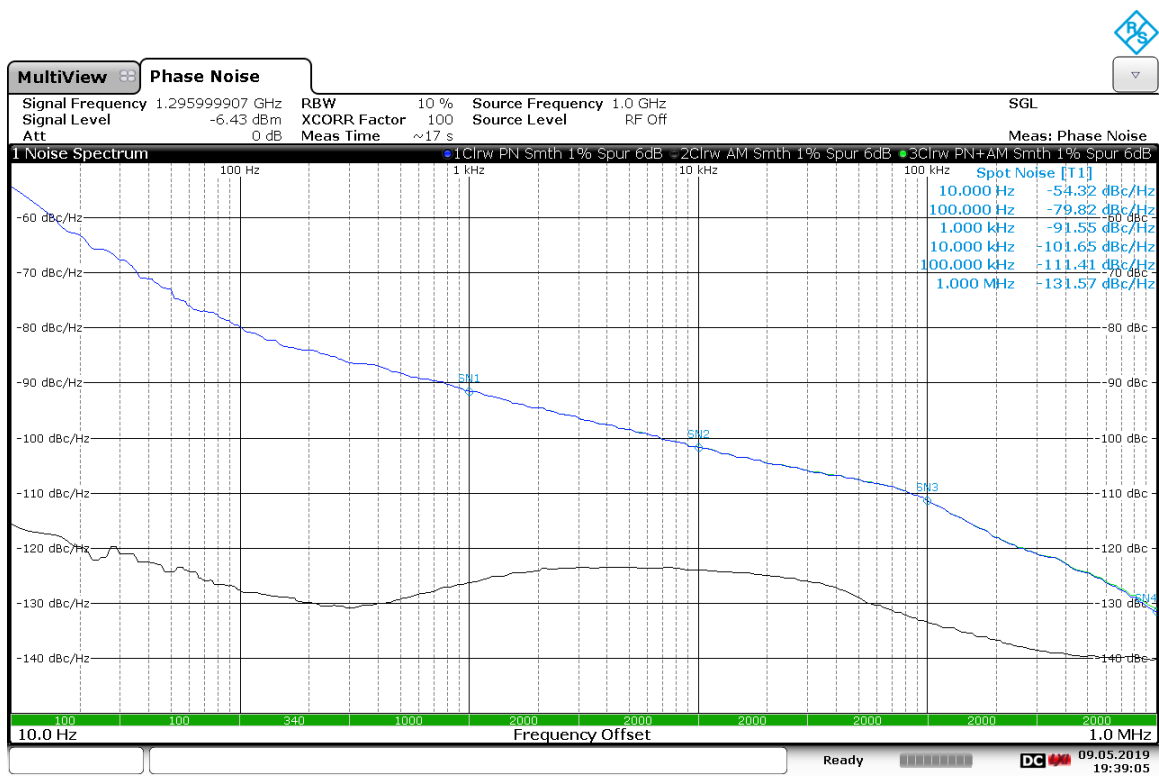
19:29:37 09.05.2019

Figure 34: 432 MHz, 22.55W. Phase noise (dominant): blue. AM noise: black.



19:35:45 09.05.2019

Figure 35: 1296 MHz, 10W. Phase noise (dominant): blue. AM noise: black.



19:39:06 09.05.2019

Figure 36: 1296 MHz, 3W. Phase noise (dominant): blue. AM noise: black.

Data and screenshots courtesy Conrad Farlow PA5Y and Rohde & Schwarz GmbH & Co. KG.

June 23, 2019.