“Testing the Icom IC-7300 and IC-7610”

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Adam Farson VA7OJ/AB4OJ

The IC-7300 (above) & IC-7610 (below)

View of the IC-7300 Test Setup

The IC-7300 is on the bench, undergoing an RF power output test.

View of the IC-7610 Test Setup

The IC-7610 is on the bench, undergoing SSB PEP tests.

Note the Noise Power Ratio test set (at right).

Overall Approach to Testing

- The test suites and data on both radios are fully documented in their respective Test Reports. Refer to last slide, “References”, for links to these reports.
- In this presentation, we will outline the test procedures and instrumentation setups used and cover new test methods. The reader is referred to the relevant test reports for detailed test data. (See Refs. 1 & 2, Slide 23.)
- As the IC-7300 and IC-7610 are both direct-sampling/digital up-conversion SDR’s, several legacy test metrics are irrelevant. (See Ref. 3, Slide 23.)
- The test plans for the two radios are very similar except for architectural differences (dual receivers and Digi-Sel tracking preselectors in the IC-7610).
- The IC-7610 LAN port was tested functionally in my station with the Icom RS-BA1 suite. The USB3 I/Q port was not yet functional when the test suite was run, but was tested functionally when Firmware V1.20 was released (Aug. 2018).
- Both radios were tested on-air in my station, with the Yaesu Quadra amplifier and Cushcraft R8 antenna, and are now installed in the shack.

Receiver Testing

- **Sensitivity tests:** SSB/CW MDS (Minimum Discernible Signal), AM/FM sensitivity, AGC threshold, S-meter tracking, squelch sensitivity.
- Preamp gain, attenuator insertion loss, ADC clip level.
- Channel filter selectivity tests for all modes (bandwidth, shape factors), CW APF (audio peak filter), manual & auto-notch depth.
- Related tests unique to IC-7610: Digi-Sel insertion loss, Dual Watch splitter insertion loss, inter-receiver crosstalk.
- Test signals are applied from a Marconi Instruments 2018A signal generator via a 20 dB pad. Levels are adjusted for 3 dB increase in audio output (SSB/CW), 10 dB (S+N)/N (AM) at 30% modulation and 12 dB SINAD (FM) at 3 kHz deviation.
- **RMDR** (Reciprocal Mixing Dynamic Range): CW, 500 Hz bandwidth: A test signal is applied from an ovened crystal oscillator with very low phase noise via a 0-90 dB step attenuator (10 & 1 dB steps). At offsets 1 – 100 kHz, the input level P_i for a 3 dB increase in audio output is noted.
- RMDR in dB = P_i - MDS. Phase noise in dBc/Hz = - (RMDR + 27).

Test Instruments for Sensitivity & RMDR

Marconi 2018A Signal Generator

Ballantine 323 RMS AC Voltmeter


5 MHz OCXO for RMDR Testing


JFW Step Attenuator


HP 339A Distortion Meter (SINAD, THD)

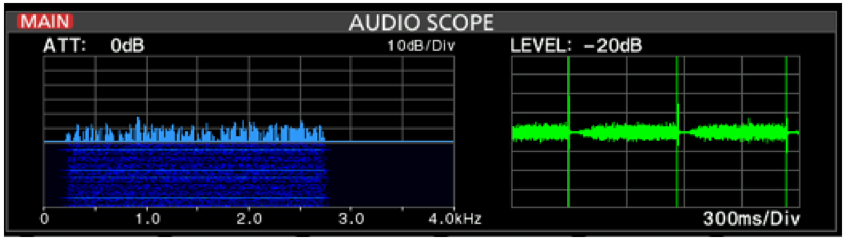
Receiver Impulse Tests

- **AGC Impulse Response:** A pulse train at a fixed PRF and variable pulse duration from a pulse generator is applied to the receiver input via a step attenuator. The pulse duration is increased from the minimum value to the point where no further change is observed at the receiver, and the AGC reaction observed on the S-meter, AUDIO scope and speaker. FAST AGC (minimum decay time) is selected for this test.
- **NB/NR Impulse Response:** The AGC impulse test is repeated with Noise Blanker and Noise Reduction on, and the difference between NB/NR OFF and ON is observed on the AUDIO scope and speaker. With NB/NR on, AGC artefacts are suppressed.
- **Receiver Latency:** The pulse generator feeds a pulse train via a hybrid splitter to the receiver's 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 equals the latency (signal transit time across the receiver).

Illustrations for RX Impulse Response Tests

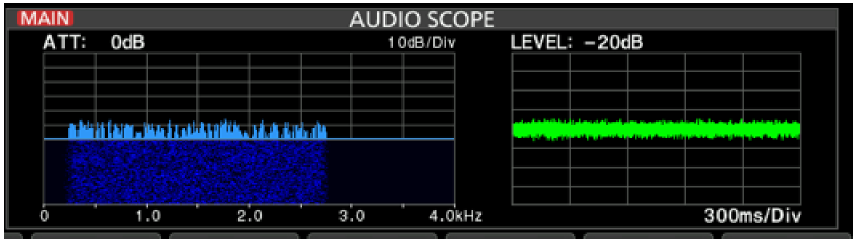
HP 8011A Pulse Generator

JFW Step Attenuator

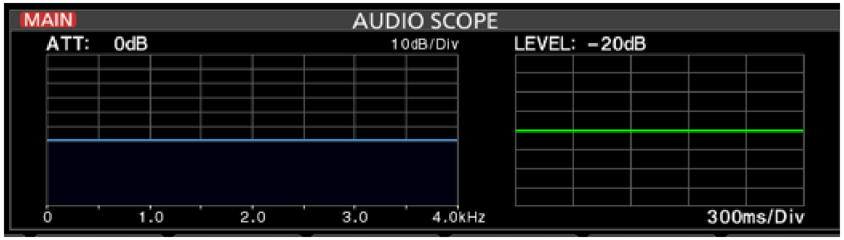


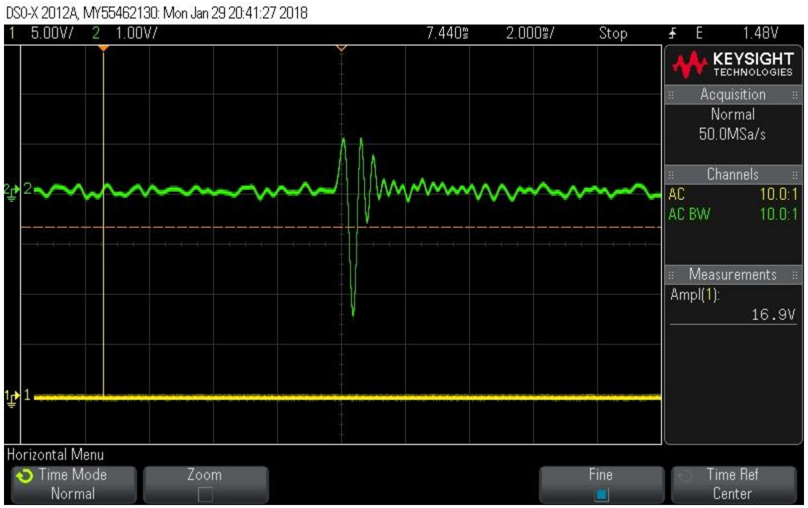
AGC Impulse Response on AUDIO Scope

AGC Impulse Response on AUDIO Scope (NB on)



AGC Impulse Response on AUDIO Scope (NB/NR on)



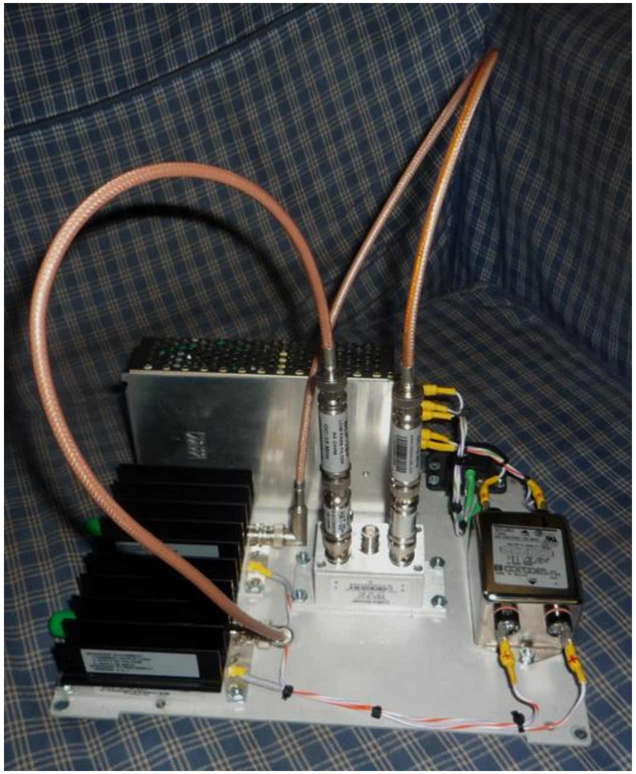


Latency Oscillogram (latency on X-axis)

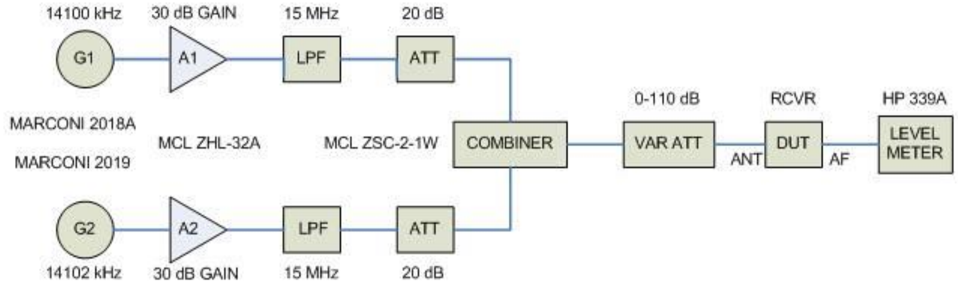
Dynamic Performance Tests

- **RF Tests:**
  - IFSS (Interference-Free Signal Strength) & DR_3 (IMD_3 Dynamic Range)
  - DR_2 (IMD_2 Dynamic Range)
  - NPR (Noise Power Ratio)
  - NR Noise Reduction
  - Audio Power Output & THD
  - Aliasing Rejection
- To test IFSS, DR_3 and DR_2 , we apply two RF signals at appropriate frequencies and spacings to the receiver from a buffered test fixture consisting of a pair of wideband amplifiers feeding a hybrid combiner via LPF's and fixed pads. The test signals are supplied by two signal generators. The test fixture isolates the two generators from one another, thus minimising residual IMD.
- As single-point (classical) DR_3 is not a reliable performance benchmark for a direct-sampling SDR, the IFSS method was developed. Here, the absolute amplitude of the IMD3 product is measured over a range of input levels from -1 dBFS (1 dB below clipping) to the noise floor, with the ITU-R band noise levels for Urban, Rural and Quiet Rural sites as datum lines.
  - DR3 and IFSS are tested at f_1 = 14010 and f_2 = 14012 kHz. IMD products: 14008, 14014 kHz.
  - DR2 is tested with Digi-Sel OFF and ON at f_1 = 6.1 kHz and f_2 = 8.1 MHz. IMD product: 14.2 MHz.

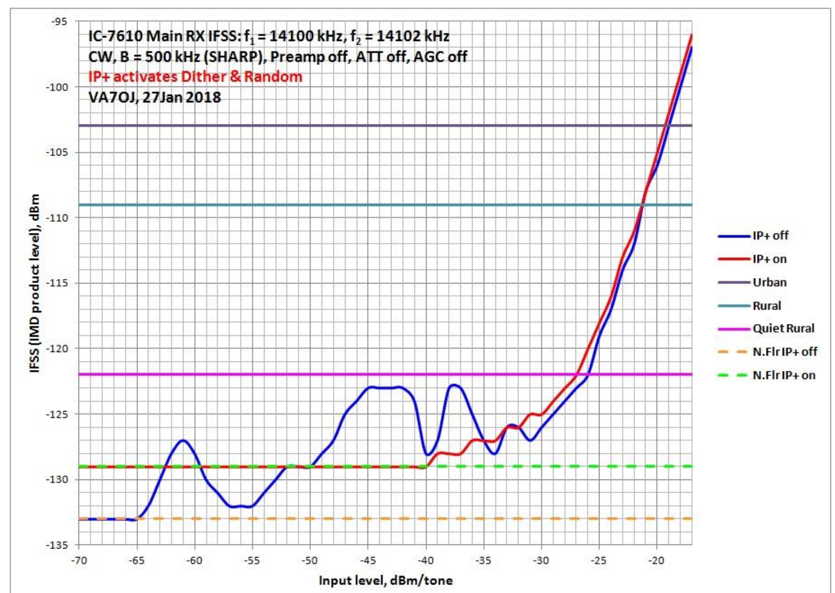
2-Signal Test Fixture & IFSS Chart



2-SIGNAL IMD TEST FIXTURE



BLOCK DIAGRAM OF TYPICAL TWO-TONE RECEIVER TEST SETUP



TYPICAL IFSS CHART

Dynamic Performance Tests (2)

- **Note for IFSS Test:** The IFSS curve is taken with **IP+** (dither) OFF and ON. Dither smooths out the ADC's IMD amplitude/input power relationship by de-correlating IMD products into noise. In the typical chart shown, the IFSS curve is monotonic (no large fluctuations) and dips below the Quiet Rural noise level at -122 dBm/tone input level. The ideal curve should be monotonic and intersect the Quiet Rural line as close as possible to the right-hand edge of the curve.
- **Note for DR_2 Test:** Wide-spaced HF broadcast or utility stations well outside an amateur band can mix in the front end and/or ADC and drop an IMD_2 product into the ham band. Example: 6.1 & 8.1 MHz, IMD_2 product at 14.2 MHz. The DR_2 test measures the receiver's ability to withstand IMD_2 interference. A good RF BPF and/or preselector largely eliminates IMD_2.
- **Noise Power Ratio (NPR):** This test was "inherited" from the telecom industry. A band-limited noise-band with a notch 3 kHz wide and > 90 dB deep is applied to the receiver from a special noise generator. The applied noise power (noise loading) is set at -1 dBFS and the NPR derived from the applied noise power. NPR is measured with Digi-Sel OFF and ON (IC-7610, 160/40/80m).

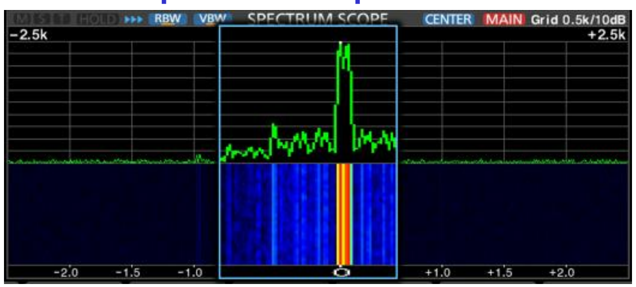
Dynamic Performance Tests (3)

- **NR Noise Reduction Test:** To measure the noise reduction on SSB signals close to the noise level, an RF test signal at $f_0 + 1$ kHz is applied to the receiver in USB mode (to obtain a 1 kHz test tone). The RF input level is adjusted for 6 dB SINAD as read on a distortion meter at the speaker output with NR OFF.NR is then turned ON, and SINAD read at various NR level settings until no further improvement is noted as NR level is increased.
- **Audio THD:** Next, the RF input level is increased to S8 – S9. An 8Ω load is connected across the audio output and AF gain increased until the distortion meter reads 10% THD. The audio voltage at the speaker output is now measured, and power output in watts for 10% THD calculated.
- **Aliasing Rejection:** The IC-7300 and IC-7600 Nyquist frequency (sampling rate/2) is 61.44 MHz. A test signal at 75.000 MHz is to the antenna port and the IC-7610 is tuned to its alias frequency (47.88 MHz). The test signal power is increased sufficiently to raise the AF output by 3 dB. Aliasing rejection = input power + MDS.
- **CTCSS decode sensitivity** is measured in FM mode on 52.525 MHz. An FM signal modulated at 100 Hz is applied to the receiver with TSQL on. The RF input level required to open the tone squelch at 500 and 700 Hz tone deviation is measured.

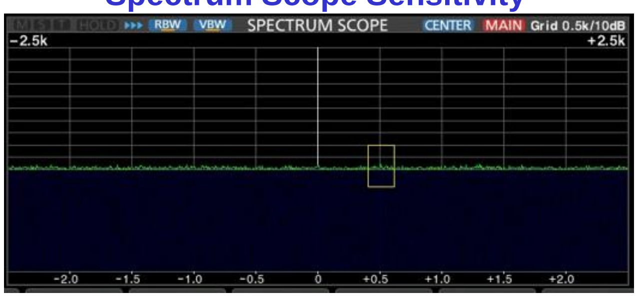
Spectrum Scope Tests

- **Spectrum Scope RBW (Resolution Bandwidth):** Two test signals f_1 and f_2 are applied to the receiver and their spacing adjusted until two distinct spikes are *just* observable on the scope. $f_1 - f_2$ = RBW.
- **Spectrum Scope Sensitivity:** A single test signal is applied, and the input level required for the scope spike to be *just* visible is recorded.

Spectrum Scope RBW



Spectrum Scope Sensitivity



Wandel & Goltermann RS-50 NPR Noise Generator

Transmitter Testing

- For all transmitter tests, a 50 dB 300W power attenuator is connected to the antenna port. At the attenuator output, 0 dBm = 100W.
  - For SWR meter check, 50Ω and 75Ω loads are connected in turn.
- **Power output tests:** CW output, SWR meter check, SSB PEP output, compression, ALC overshoot (including 7610 Firmware V1.11 SSB-D) and ALC compression.
- For CW output measurements, a thermocouple power meter sensor is connected to the attenuator output. For PEP, compression and ALC overshoot tests, P_O is set at 100W and a digital oscilloscope terminated in 50Ω is connected to the attenuator output. ± 3 vertical divisions = 100W.
- PEP is measured with voice audio (HM-219 mic), compression OFF, then ON. COMP set at 2 (≈ 6 dB compression on voice peaks).
- ALC overshoot is measured with voice audio at 100/50/20W PEP, and with white noise at 100W PEP. SSB-D overshoot is measured at 100/5//25W PEP with a timed tone burst applied via the USB port.
- ALC compression is measured at 100W PEP with two-tone audio input applied via the USB port.

Transmitter Testing (2)

- **Linearity tests:** 2-tone IMD, noise IMD: An RF spectrum analyser is connected to the attenuator output via a 10 dB pad. A 2-tone audio test signal (700/1700 Hz) is applied via the USB port, and odd-order IMD product amplitudes measured and recorded in dBc (each test tone is at -6 dBc, and serves as reference). Power output = 100W PEP. Several bands tested.
- For noise IMD, a white noise baseband is applied via USB at 100/25W PEP (set via the spectrum analyser's Noise Marker) and spectrograms are captured.
- **Harmonic content & spectral purity:** The spectrum analyser's harmonic content utility is used to measure a 100W CW signal, and the results are captured. Next, the spectrum analyser is configured to sweep for spurs on each band tested, and spectrograms are captured. Several bands tested.
- **Transmitted composite noise:** A Perseus SDR receiver is connected to the attenuator output via a step attenuator set for -1 dBFS. Bandwidth 22 Hz, RBW 1 Hz. Composite noise in dBc/Hz recorded at 100W (also 35W on 14.1 MHz) on 3.6, 14.1 and 28.1 MHz.

Transmitter Testing (3)

- CW tests: keying sidebands, keying envelope, “RF tail”, QSK recovery.
- **Keying sidebands:** Internal keyer at 48 wpm (max.) A string of dits is transmitted at 100W CW and 2/4/6/8 ms rise-time, and spectrograms are captured on the spectrum analyser (connected as for earlier tests).
- **Keying envelope** at 48 wpm is captured on the digital oscilloscope for a string of dits sent at 48 wpm for each rise-time setting
- **“RF tail”:** Channel 1 of the oscilloscope is terminated in 50Ω and connected to the power attenuator output. Channel 2 is connected to the SEND RCA jack via a bias tee connected to a low-current source. A string of dits is sent at 24 wpm in QSK (F-BK) mode. The RF carrier should cease *before* the SEND line unkeys.
- **QSK recovery:** RF PWR is set at 10W. A 100W 50Ω load is connected to the antenna port via a directional coupler. A test signal is applied to the coupler’s COUPLING port via a 20 dB pad. The signal generator is set to f_0 – 200 Hz and S3 – S5 on the receiver’s S-meter. Sidetone = 600 Hz, received tone = 800 Hz. A string of dits is sent; KEY SPEED is increased until the received tone is no longer audible between dits. This speed is the maximum QSK keying speed.

Transmitter Testing (4)

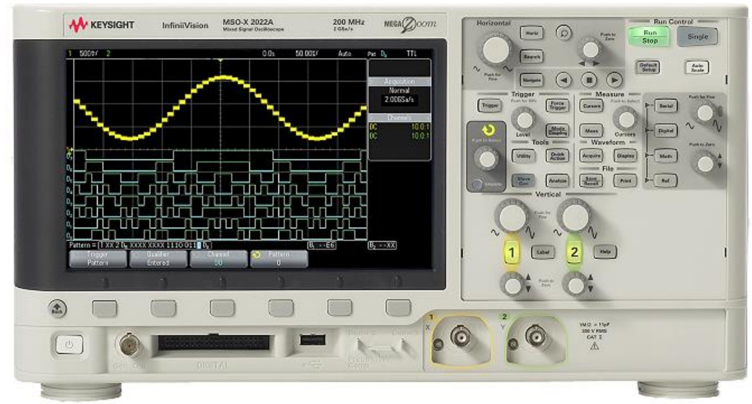
- **SSB & AM tests:** ACC & USB audio input for 100W output, carrier & opposite-sideband suppression, SSB & AM transmit AF response, AM sidebands & THD. The audio input test is conducted with the RF power meter connected to the attenuator output; the spectrum analyser (with 10 dB input pad) replaces the power meter for the other tests. Spectrograms are captured for all tests.
- Using accurate analogue and USB tone sources, 1 kHz test tone is applied and the levels required for 100W RF output are recorded. Next, the carrier and opposite-sideband levels are read off the spectrum analyser.
- SSB and AM transmit response are displayed on the spectrum analyser at 100W PEP (SSB) and 25W carrier (AM) with a white-noise baseband applied to the USB port. In SSB mode, TBW = WIDE/MID/NAR are tested in turn.
- **FM tests:** Deviation, CTCSS tone deviation, residual FM in CW mode: These tests are performed using a communications test set. With voice audio, peak deviation is measured at 75W RF output on 29.6 and 52.525 MHz. CTCSS tone deviation is measured without mic input. Residual FM is measured at 100W CW output.

Transmitter Testing (5)

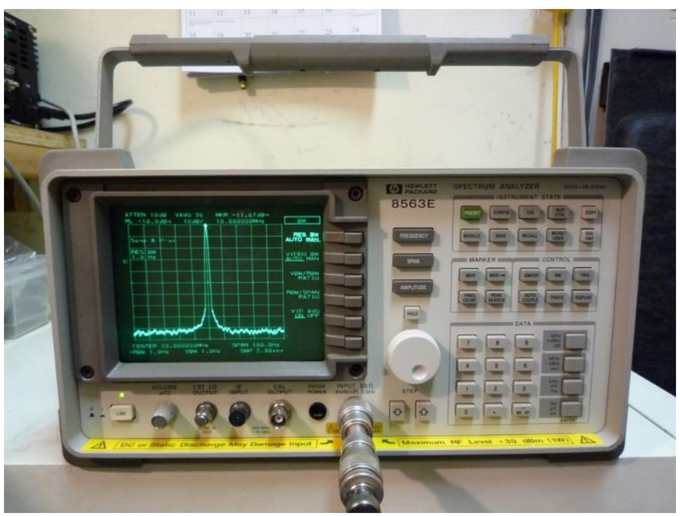
- **Transmit latency.** A function generator feeds repetitive bursts of one cycle of a 1 kHz tone to the MOD input and also to Channel 1 of a dual-trace oscilloscope. Channel 2 is connected to the power attenuator output. The scope is triggered from the function generator's SYNC output. The time interval (latency) 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.
- **Transverter output & composite noise** (IC-7610 only) are measured as described on Slides 15 and 16 respectively, except that RF output is measured directly at the X-VERTER port and the Perseus is connected to the X-VERTER port via a step attenuator. A curve of output in dBm vs. % RF PWR is taken at 28.1 MHz (44.1 MHz displayed).
- **RTTY (FSK, F1B) Transmitted Signal Test**). The spectrum analyzer is connected to the power attenuator output. An FSK (F1B) RYRYRY string is sent at 100W on 14.1 MHz. Occupied bandwidth is measured using the OCC BW utility in the spectrum analyser. Necessary bandwidth is derived per ITU-R Rec. SM.328-11, Annex 1, Sections 1.1 and 1.7. (See Ref. 4, Slide 23.)

Instruments for Transmitter Tests

HP 437B RF Power Meter & 8482A Sensor



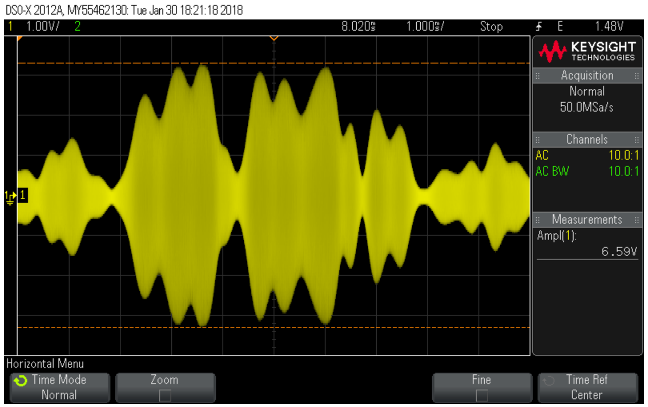
Keysight DSOX2012A 100 MHz 2-ch. Oscilloscope



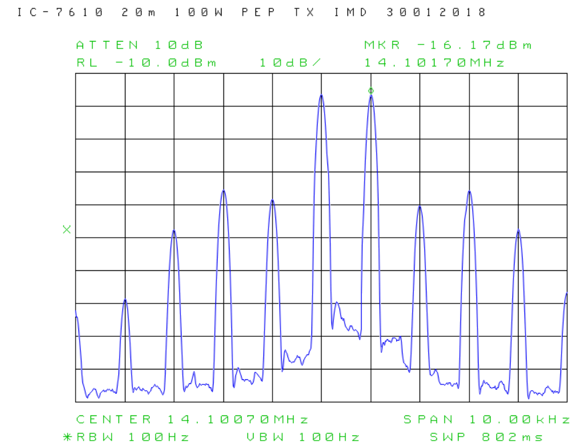
HP 8563E Spectrum Analyser

HP/Agilent 8935 E6380A Communications Test Set

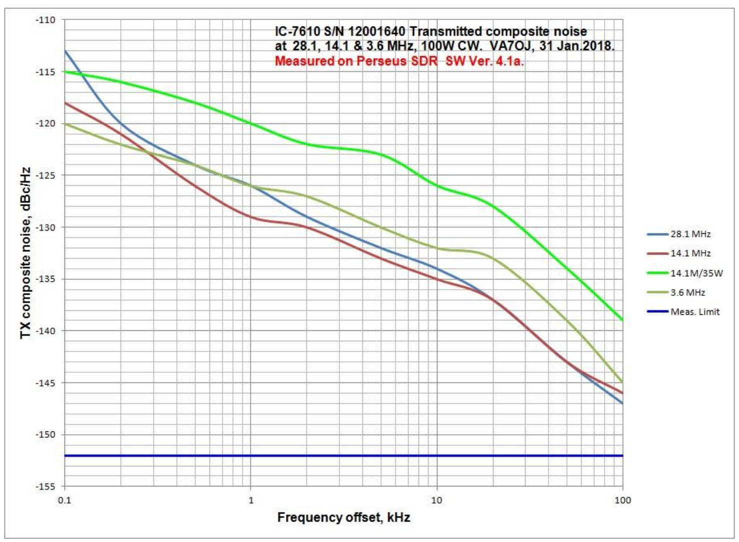
Illustrations for Transmitter Tests



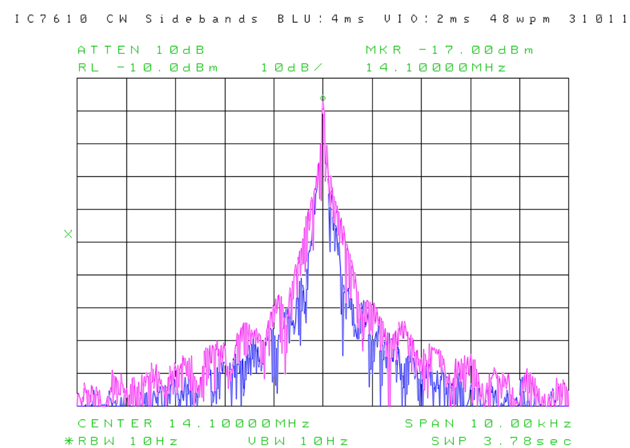
100W PEP, 6 dB Compression



20m 2-Tone IMD at 100W PEP

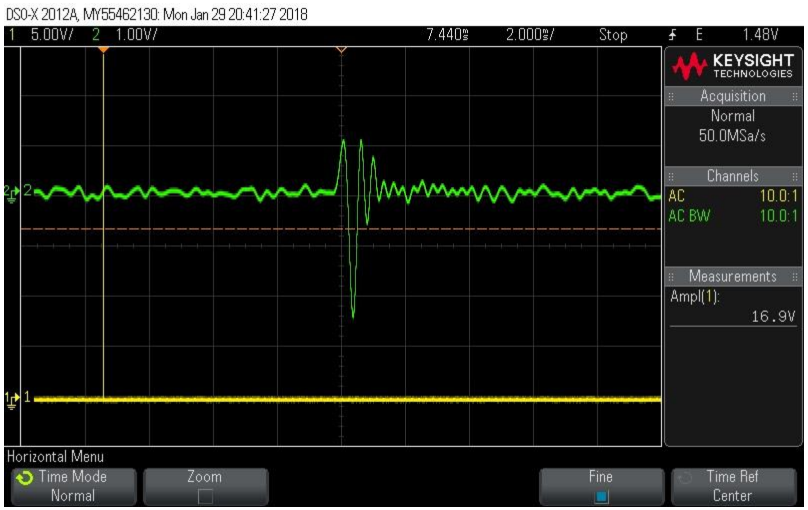


Transmitted Composite Noise

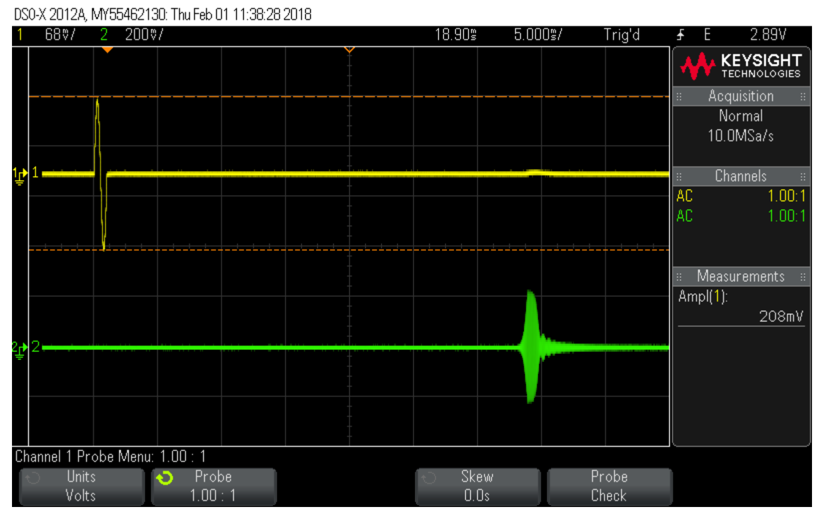


CW Keying Sidebands, 48 wpm, 2/4% rise time

Illustrations for Latency Tests (7610)



RX latency, 2.4 kHz SHARP SSB filter, 2ms/div.



Transmit latency, WIDE TBW. Latency 33.5 ms.

References for further study

1. http://www.ab4oj.com/icom/ic7610/7610notes.pdf

2. http://www.ab4oj.com/icom/ic7300/7300notes.pdf

3. http://www.ab4oj.com/sdr/sdrtest2.pdf

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