IC-R8600 User Evaluation & Test Report

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Figure 1: The Icom IC-R8600.

Introduction: This report describes the evaluation and lab testing of the IC-R8600 wideband SDR communications receiver S/N 04001185. ***Appendix 1*** presents results of an RF lab test suite performed on the radio. I was able to spend a few days with the IC-R8600 in my ham-shack, and thus had the opportunity to exercise the radio's principal features and evaluate its on-air behavior.

1. Physical "feel" of the IC-R8600: The IC-R8600 is fairly small and light, considering its very wide frequency coverage (10 kHz - 3 GHz). The case dimensions are 220(W) × 230(D) × 90(H) mm, and the radio weighs 4.3 kg.

The IC-R8600 features a large color touch-screen display similar to that of the IC-7300 SDR HF/6m transceiver. This is an innovation in Icom's receiver 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 DIAL A/B/C knob menus has moved many controls off the front panel.

Owners of current Icom IF-DSP radios should find the IC-R8600 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 three detented knobs (DIAL A/B and C) to the left and right of the display respectively. Pressing a DIAL 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 controls are multi-turn and detented. The main tuning knob is large and has a knurled Neoprene ring and a rotatable finger-dimple; it turns very smoothly with minimal side-play. The tuning knob has a mechanical detent which can be engaged or disengaged via a slide lever below the knob.

The 3.5mm PHONES jack, is on the left side of the front panel. All the ports provided on other Icom radios are on the rear panel, including N and SO-239 antenna sockets, two USB “B” ports (one designated I/Q OUT) an Ethernet port and two BNC sockets (10.7 MHz IF OUT and 10 MHz REF I/O.)

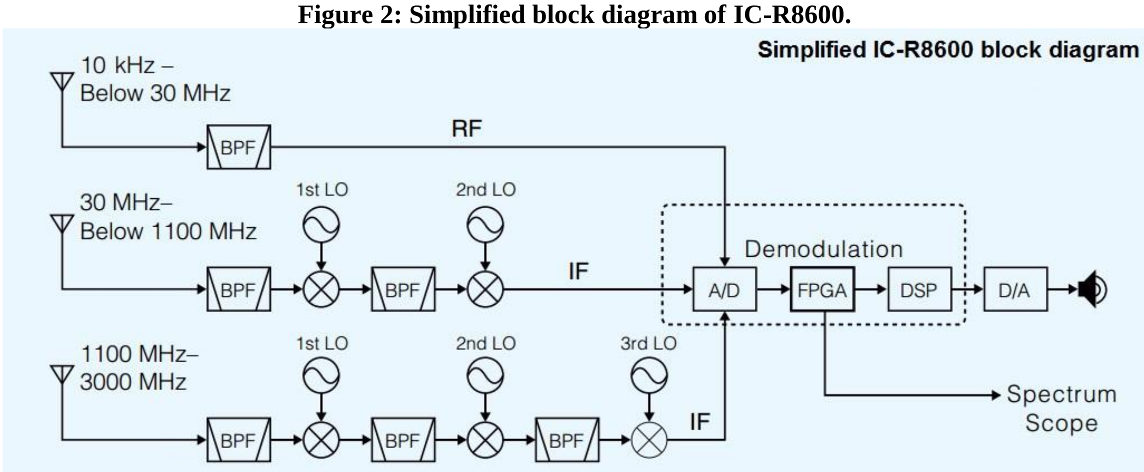
The SD card slot for memory storage and loading, recording and firmware upgrade is below the DIAL B knob. A screen capture function (enabled via menu) allows capture of the current screen image to the SD card as a PNG or BMP file by briefly pressing the POWER key. The image can also be viewed on the screen via menu. There is a micro-USB "B" port to the left of the SD card slot.

The IC-R8600 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-R8600 architecture: The "core" of the IC-R8600 is a 10 kHz - 30 MHz direct-sampling SDR receiver similar in design to the IC-7300 receiver section. The frequency range 30 MHz - 3 GHz is covered by two analogue, heterodyne-type down-converters covering 30 MHz - 1.1 GHz and 1.1 - 3 GHz respectively. The down-converters deliver a 46.35 MHz IF to the SDR.

In the 10 kHz - 30 MHz range, the RF signal from the antenna feeds a high-speed ADC (analogue/digital converter) via a **preselector.** This is a set of bandpass filters which protect the ADC from strong out-of-band signals. The ADC digitizes a portion of the HF range defined by the preselector; the digital output of the converter feeds the Field-Programmable Gate Array (FPGA) which is configured as a digital down-converter (DDC) and delivers a digital baseband to the DSP which carries out all signal-processing functions such as selectivity, demodulation etc. A DAC (digital/analog converter) at the DSP output decodes the digital signal back to audio. Figure 2 is a simplified block diagram.

Figure 2: Simplified block diagram of IC-R8600.



The FPGA also delivers a digital video signal to the Display Processor, which manages the screen displays, including the fast FFT spectrum scope and waterfall. The spectrum scope has a maximum span of ±2.5 MHz, adjustable reference level (-20 to 20 dB) for a total amplitude range of 110 dB, video bandwidth and averaging, and minimum RBW ≤ 50 Hz.

A unique “touch-tune” feature similar to that on the IC-7300 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.

3. The touch-screen: The large (93 × 52mm) 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 current frequency in the upper field, the bar-graph meter in the middle and the spectrum scope in the lower field. The first two keys below the screen, MENU and FUNCTION, are similar in operation to those on the IC-7300. 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 or FSK decoder controls, depending on mode). The waterfall is activated via the EXIT/SET key at the bottom right of the home screen; a reduced-height scope and waterfall can be displayed on the home screen via an EXIT/SET menu parameter.

When the DIAL C knob is rotated, the PBT1 and PBT2 icons appear on the right edge of teh screen. Touching PBT1 or PBT2 and rotating the knob offsets the selected passband, and the trapezoidal icon at the top centre of the screen changes. A dot then appears to the right of the icon. Touching PBT1 or PBT2 for 1 sec. clears the Twin PBT setting. Pressing DIAL C also opens icons for CW PITCH and BACKLIGHT settings. A setting is changed by touching its icon and rotating DIAL C. The DIAL C knob menus are context-sensitive; for example, pressing and holding the NB softkey in FUNCTION activates NB, and displays NB settings when DIAL C is pressed.

Pressing and holding the Notch, NR and NB softkeys in FUNCTION makes their settings accessible from DIAL C. These can be used to select notch width, NR level and NB parameters respectively. When MN is selected, its softkey displays its width.

TPF (Twin Peak Filter) can be activated via the DIAL C menu in FSK mode.

The **menus** are somewhat akin to those in the IC-7300 and 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 R8600’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+ etc.

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

The DIAL-A knob controls the IC-R8600's numerous scanning features. Three usage modes (press, press/hold and press/rotate) bring up separate scanning feature icons.

When rotated, the DIAL-B knob opens an AF GAIN icon. Rotating the knob provides volume control. Pressing the knob opens RF GAIN, SQL (squelch) and TREBLE/BASS icons. Touching one of these icons allows adjustment of the associated parameter by rotating DIAL B.

In addition to carrier squelch, tone squelch (CTCSS) and digital code squelch (DCS) can be selected via the TONE softkey in FUNCTION when FM mode is selected.

Pressing DIAL C opens AFC, VSC (voice squelch) and BACKLIGHT icons. Touching AFC or VSC turns the feature ON or OFF, and rotating DIAL-C adjusts the screen backlight brightness. The AFC capture range can be limited by setting AFC LIMIT ON in MENU/SET/FUNCTION.

Touching the leading (MHz) digits of the frequency display opens a ten-key pad for direct frequency entry. Mode selection is similar; touching the current mode icon opens the mode-selection screen. Tuning steps for kHz and 10 Hz steps are set by touch, or by touch/hold, on the respective digit groups. Tuning step sizes are menu-programmable.

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.

4. Receiver front end management: The P.AMP and ATT softkeys in FUNCTION set Preamp OFF/ON and insert 0, 10, 20 or 30 dB of front-end attenuation. Touching and holding the ATT key restores ATT to OFF. an on-screen The red RFG icon below the mode icon (top left of screen) lights when the DIAL C RF Gain setting < 100%.

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 IC-R8600 provides means to prevent this condition from arising in the 10 kHz - 30 MHz frequency range. When the ADC starts clipping, the red OVF (overflow) icon lights to the right of the filter selection icon. At this point, reducing the RF Gain 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.

In general, use of the preamp on 7 MHz and below is not recommended, as the band noise is almost always higher than the receiver's noise floor and the preamp will only boost band noise without improving signal/noise ratio.

IP+ (Function key) activates dither and output randomization in the ADC, 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-R8600's controls and menus fell readily to hand. A user familiar with a radio such as the IC-756Pro3 or IC-R8500 should find the IC-R8600 very user-friendly and its learning curve manageable. The IC-R8600's default settings are very usable, allowing the radio to be placed in service with minimal initial set-up.

Touching the currently-displayed meter scale toggles between S, dBμV, dBμV e.m.f. and dBm scales.

5. Digital interfaces: The IC-R8600 is equipped with two rear-panel mini-USB "B" ports. The radio can be directly connected via the "B" port to a laptop or other PC via the supplied USB cable. This is without doubt one of the IC-R8600's strongest features. The USB port transports not only CI-V data, ***but also RX PCM baseband*** between the IC-R8600 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 radios released since 2009. An Icom driver is required in the PC; this is downloadable from the Icom Japan World website.

A second USB "B" port is designated I/Q OUT, and is reserved for future use with external decoders and SDR software. This port will be enabled via a future firmware upgrade.

The rear-panel Ethernet port currently supports connection to an NTP time server via the user's LAN. It will also support an internal server function for the future RS-R8600 software suite.

With DHCP enabled in MENU/Set/Network, the IC-R8600 obtained an IP address from my in-house LAN router, and synced up to the NTP server immediately. With zero UTC offset, the on-screen clock displayed UTC time.

6. Filter selections and Twin PBT: As do the other Icom DSP transceivers, the IC-R8600 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 base functions of the DIAL C knob. Touching and holding the PBT1 or PBT2 icon restores PBT to neutral.

The TPF menu item in the DIAL C FSK menu selects the Twin Peak Filter (TPF) in FSK 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. These filters can be restored to default (off) by clearing the cutoff values,

7. BPF vs. non-BPF filters: As in other Icom IF-DSP radios, the IC-R8600 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, FSK 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.

8. 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.

10. 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 10 dB. For precise NR adjustment, press and hold the NR softkey, then rotate the DIAL C knob.

11. NB (noise blanker): The IF-level DSP-based noise blanker is arguably one of the IC-R8600’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 parameters (threshold, depth and width) are accessed by pressing and holding the NB softkkey. The NB works very effectively in conjunction with NR.

12. AGC system: The IC-R8600 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.

13. Receive audio menus: In addition to the DIAL-A TREBLE and BASS settings, separate HPF/LPF, Treble and Bass EQ adjustments are provided for each mode under MENU/SET/Tone Control.

14. Metering: Touching the on-screen bar-graph signal-strength meter scale toggles between S, dBμV, dBμV e.m.f. and dBm (in 50Ω).

15. FSK decoder: The IC-R8600 features an on-screen FSK decoder/display. 50 and 45.45 baud data rates are supported, along with a selection of marking frequencies, idle tone (mark or mark/space center) and shifts for various commercial and amateur FSK systems.

16. VFO/Memory management: **The** IC-R8600 offers the same VFO and memory management features as other current Icom HF+ radios: VFO/memory toggle and transfer, memory write/clear, memo-pad, Split, VFO A/B swap [A/B] and equalize [touch and hold A/B], etc.

17. Brief "on-air" report: Upon completing the test suite, I installed the IC-R8600 in my shack and connected it to my multi-band HF/6m vertical antenna and a dual-band VHF/UHF whip antenna.

a) SSB:

As discussed in **11.** above, the DSP-based noise blanker is superb. It does not distort the signal at all, and can be left on at all times; it is every bit as good as the IC-7300 blanker. At my QTH, with Level 5, Width 80 and Depth 8, the NB suppressed fast-rising noise spikes and almost completely eliminated locally-generated electrical noise from HV power lines, street-lamp ballasts and industrial processes.

As discussed in **10.** above, I found the NR quite effective on SSB. Even at 10, NR did not attenuate "highs" excessively. NR is very effective in conjunction with NB. The downside is that the IC-R8600 NR has a somewhat "watery" sound when compared to the IC-7300 NR. Doubtless a firmware upgrade could improve this.

The preamp (10 dB gain) brought weak stations on the higher bands up to very comfortable copy without S/N degradation. The SSB filters and Twin PBT were excellent, as we have come to expect from other Icom DSP radios. MN and AN were extremely helpful. I was able to notch out single tones with MN; also, AN reduced the levels of multiple tones.

The superior phase-noise performance of a direct-sampling SDR (as compared to a conventional superhet) and the absence of passive IMD from crystal filters in the signal path really showed in the R8600's clean reception in the presence of strong adjacent-channel interference during my on-air HF SSB tests.

Overall, I found that band noise on SSB at my QTH was sufficiently obtrusive to require the use of NR (Level 10) at all times. Still, SSB operation on 20m with a mix of strong and weak signals was quite comfortable and pleasant. Receive audio quality was crisp and smooth. Subjectively, I was impressed by the clarity of received signals.

b) CW: I listened to a few 40m CW transmissions. With 500 and 250 Hz CW filters (Sharp, BPF) and NR/NB on, ringing was minimal with preamp off. I then set up a 250 Hz filter (Soft, non-BPF) with NR on and Preamp off. Again, there was virtually no audible ringing, and the received CW note was very smooth. Activating the preamp raised the noise level slightly, but did not cause significant ringing.

c) AM: In a quick check of AM reception, I listened to various MF and HF broadcast stations. A local CBC station on 690 kHz and a music broadcast on 5995 kHz sounded good on the IC-R8600's internal speaker, but much clearer (as one would expect) on my external speaker or on the headset. I did note that the AM IF filters cut off quite steeply below 200 Hz, as they do on the IC-7300.

The 9 kHz AM filter offered the best frequency response, but the 6 kHz setting sounded somewhat "smoother" and 3 kHz cut the "highs" excessively. The IC-R8600's Twin PBT is fully functional in this mode. Mid AGC was best for average to good signal conditions, but Fast AGC handled rapid selective fading more effectively. NR was quite effective in improving the S/N ratio of weak AM signals.

In S-AM (synchronous AM) mode, the SYNC icon appeared when an AM signal was tuned in. Depending on propagation conditions, I found that I could optimize the audio quality by toggling manually between S-AM(U), S-AM(L) and S-AM(D).

The NR did not distort the recovered audio. NR Level 6 was the "sweet spot", providing optimum noise reduction with minimal attenuation of highs. Higher NR settings cut the highs slightly. Above 10, the NR control had no further effect. (Note that the AM bass and treble EQ settings were both 0 dB, with HPF off.)

AN was effective in suppressing interfering tones and heterodynes, but MN caused some distortion when tuned across the signal. The reason for this is that MN suppresses the carrier in a manner similar to selective fading.

Very slight hiss was evident when receiving weak AM signals; NR largely suppressed it.

d) FSK: I tuned in some amateur (40m) and commercial FSK signals; I was able to tune them accurately with the FFT tuning aid and decode them reliably using the internal decoder. To accommodate commercial and amateur transmission standards, the IC-R8600 supports 50 and 45.45 baud RTTY speeds, and several choices of idle-tone frequency and shift.

18. AF/IF & 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 AF/IF using a distortion meter.. All levels were well within specifications. A 27% USB AF level setting (SET/Connectors menu) and a 50% AF/IF level setting yielded lowest THD at the respective ports.

19. Digital: The only mode I was able to check was D-STAR. When I transmitted in simplex mode from an ID-31A handheld, the IC-R8600 decoded the signal correctly. I heard my own voice transmission, and the handheld's ID and CQCQCQ string were displayed on the screen.

20. Case temperature: The IC-R8600 showed no signs of excessive heating even after 2 hours' "on" time. Average case temperature was 30-32°C with a 13.8V DC power source.

21. Concerns: As mentioned in 17a above, the IC-R8600 NR has a somewhat "watery" sound when compared to the IC-7300 NR.

22. Conclusion: After a few days' "cockpit time" on the IC-R8600, I am very favorably impressed by its solid, refined construction, clear and informative display, easy familiarization experience, smooth operating "feel", impressive array of features and excellent on-air performance. This receiver is unique in that it is combines a stand-alone* direct-sampling SDR at HF with a VHF/UHF/microwave receiver employing heterodyne down-converters in an attractive, compact package. Yet again, Icom has an excellent, versatile radio with the SDR performance, intuitive touch-screen and the straightforward USB computer interface. This is certainly a lot of receiver for its price category.

23. Acknowledgements: I would like to thank Ray Novak N9JA at Icom America, as well as Paul Veel VE7PVL and Jim Backeland VE7JMB at Icom Canada, for making an IC-R8600 available to me for testing and evaluation.

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

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Update history:
Iss.1: Pre-release, October 20, 2017.
Iss.2: Release, calculated NF with preamp ON added to Table 5.

Appendix 1: Performance Tests on IC-R8600 S/N 02001981

As performed in my home RF lab, October 11-25, 2017. Firmware V1.20.

A. Receiver Tests

⚠ The IC-R8600 was clocked from my 10.000 MHz GPS-derived lab standard for all 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 except where shown.

Table 1a: MDS (VLF, LF, MF)

kHz	60		137		475		1020	
Preamp	SSB	CW	SSB	CW	SSB	CW	SSB	CW
Off	-113	-119	-120	-125	-122	-129	-125	-132
On	-129	-128	-132	-138	-134	-140	-137	-143

Table 1b: MDS (HF, 6m).

MHz	1.9		3.6		14.1		28.1		50.1		70.1	
Preamp	SSB	CW	SSB	CW	SSB	CW	SSB	CW	SSB	CW	SSB	CW
Off	-123	-129	-126	-131	-127	-133	-125	-131	-125	-131	-127	-132
On	-133	-139	-136	-142	-137	-142	-137	-142	-134	-139	-135	-141

Table 1c: MDS (VHF/UHF/SHF).

MHz	144.1		432.1		905.1		1000.0	1700.1	2000.0
Preamp	SSB	CW	SSB	CW	SSB	CW	CW		
Off	-126	-131	-124	-131	-123	-128	-128	-134	-127
On	-134	-140	-134	-139	-131	-137	-136	-139	-132

Note on IP+ and MDS: IP+ activates ADC dither and randomization. With IP+ on, < 1 dB MDS degradation is observed. In addition, the AF background noise level rises by ≈ 1 dB. This represents a considerable improvement as compared to the early IC-7300.

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 14.1 MHz, test signal freq. 14.125 MHz, 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
Off	-8
IP+	-8
On	-27

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 4). At 0.9 MHz, readings are taken with the 16 dB MF Band Attenuator off and on. (This attenuator is valid only for $f \leq$ 1.7 MHz).

Test Conditions: ATT off, NR off, NB off, AGC-M. 6 kHz AM filter. Levels in dBm.

Table 3: AM Sensitivity.

MHz	1.02	3.9	29.0	50.4	120	144	300	430
Pre. Off	-101	-101	-100	-100	-100	-100	-99	-99
Pre. On	-111	-110	-111	-108	-107	-108	-107	-108

Notes:

1. Very clean demodulation; full quieting ≈ -75 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 1 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 (45 kHz on WFM) is applied to ANT1. input. Input signal power for 12 dB SINAD is recorded (Table 4).

Test Conditions: ATT off, NR off, AGC-F, 15 kHz FM filter (200 kHz WFM).

Table 4: FM 12 dB SINAD Sensitivity in dBm.

MHz	29	52	70	100	146	162	223	440	902	1700
Pre. Off	-111	-111	-112	-103	-111	-111	-111	-110	-109	-113
Pre. On	-121	-119	-120	-111	-119	-119	-119	-119	-117	-119
				WFM						

1d: FM carrier squelch threshold: SQL is set to just close with no signal. An FM signal modulated by a 1 kHz test tone at 3 kHz peak deviation is then applied to ANT1, and the input level required to open the squelch is noted.

Test Conditions: 146 MHz, ATT off, NR off, AGC-F, 15 kHz FM filter, SQL at threshold.

Squelch opens at -108 dBm (preamp off), -125 dBm (preamp on).

1e: FM Tone Squelch (CTCSS) sensitivity. An FM signal modulated by a 1 kHz test tone at 3 kHz peak deviation and a 100 Hz CTCSS tone with 700 Hz deviation are applied to ANT1. Input signal power and minimum tone deviation required to open the tone squelch are recorded.

Test Conditions: 146 MHz, ATT off, NR off, AGC-F,. 15 kHz FM filter, TONE/TSQL on, SQL at 0%.

The tone squelch opens at -119 dBm, and remains open at -116 dBm (preamp off). With preamp on, the tone squelch opens at -128 dBm, and remains open at -124 dBm.

With the RF signal at -111 dBm (12 dB SINAD), the tone squelch opens at tone deviation ≥ 200 Hz.

1f: Noise Figure:. In this test, a calibrated noise source is connected to the antenna port via a precision DC - 2 GHz step attenuator. First, the antenna port is terminated in a high-quality 50Ω resistive load and a 0 dBr baseband reference set. Then, the noise source is connected and the noise loading adjusted for a +3 dBr baseband level. The attenuator setting is noted.

As the noise source is calibrated, its noise power density PSD (in dBm/Hz) is known. Noise figure NF is derived as follows:

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

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

Table 5. Noise figure in dB.

Freq. MHz	14.1	50.1	144.1	432.1	1000
Measured NF (Pre. off)	15	16	16	17	19
NF calc. from MDS (Pre. off)	14	16	16	16	19
NF calc. from MDS (Pre. on)	5	8	7	8	11

2: FM AFC Check. In this test, an FM signal is applied to ANT1 at a level yielding 12 dB SINAD. The test signal frequency is varied with AFC Limit OFF, then ON, and the frequency offsets at which the AFC loses and re-acquires the test signal are noted.

Test Conditions: 146 MHz, preamp off, ATT off, NR off, AGC-F, 15 kHz FM filter (AFC limit ± 10 kHz).

Table 6: AFC Acquisition Range.

AGC Limit	Pos. Offset kHz	Neg. Offset kHz
OFF	Unlimited at slow rate of change	
ON	+10.7	-10.8

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

In this test, a test signal from a high-quality 5 MHz OCXO or a signal generator with known low phase noise is injected into the receiver's RF input at a fixed offset from the operating frequency. The RF input power is increased until the receiver noise floor increases by 3 dB, as measured at the audio output. Reciprocal mixing noise, expressed as a figure of merit, is the difference between this RF input power and measured MDS. The test is run with 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 f_0 = 5 MHz, Δf > 20 kHz, OVF lights before noise floor increases by 3 dB.

Table 7a: Reciprocal Mixing Noise (HF).

Δf kHz	RMDR dB	Phase noise dBc/Hz
1	109	-136
2	112	-139
5	117	-144
10	120	-147
20	123	-150
MDS	-130	

Table 7b: Reciprocal Mixing Noise (VHF/UHF).

Δf kHz	RMDR dB					Phase noise dBc/Hz			
f MHz	50	144	250	432	1750	144	250	432	1750
1	71	70	67	66	52	-97	-94	-93	-79
2	77	82	70	70	58	-109	-97	-97	-85
5	80	87	77	79	62	-114	-104	-106	-89
10	81	88	84	86	63	-115	-111	-113	-90
20	80	88	87	89	65	-115	-114	-116	-92
50	81	88	87	89	73	-115	-114	-116	-100
100	79	87	87	89	79	-114	-114	-116	-106
200	84	92	90	93	77	-119	-117	-120	-104
500	96	110	103	105	95	-137	-130	-132	-122
MDS	-131	-131	-133	-131	-133				

4: 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 RF test signal is applied at -10 dBm as read on the signal-strength meter. The bandwidths at -6 and -60 dB relative to the input power are determined by tuning the signal generator across the passband and recording ±offset in kHz at the -70 dBm points.

Test Conditions: 14.100 MHz, SSB/CW modes, preamp off, IP+ off, AGC-M, ATT off, NR off, NB off.

Table 8: IF Filter Shape Factors.

Filter	Shape Factor		6 dB BW kHz	
	Sharp	Soft	Sharp	Soft
2.4 kHz SSB	1.38	1.44	2.52	2.43
1.8 kHz SSB	1.48	1.54	1.94	1.91
500 Hz CW	1.67	1.66	0.52	0.54
500CW non-BPF	2.53	2.69	0.65	0.68
250 Hz CW	2.39	2.63	0.26	0.24
6 kHz AM	1.48		6.44	

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

Test Conditions: 14.100 MHz, 2.4 kHz USB, 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 8.**

Table 9: AGC Threshold.

Preamp	AGC Threshold dBm
Off	-97
On	-108
IP+	-98

6: 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: 14.100 MHz USB at ≈ -50 dBm (S9 + 20 dB), 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 -133 dBm per Test 1. Stopband attenuation = test signal power - MDS.

Table 10a: Manual Notch Filter Attenuation.

MNF BW	Test Signal dBm	Stopband Atten. dB
WIDE	-30	103
MID	-37	96
NAR	-47	86

6a: 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.

Table 10b: MNF BW.

MNF -6 dB BW Hz	
WIDE	135
MID	94
NAR	66

6b: Auto-Notch Check. AN completely suppresses AF tone at +2 dBm input level (the maximum applied).

7: AGC impulse response. The purpose of this test is to determine the IC-R8600's AGC response in the presence of fast-rising impulsive RF events. Pulse trains with short rise times are applied to the receiver input.

Test Conditions: 3.6 MHz LSB, 2.4 kHz SSB filter (Sharp), NR off, NB off/on, Preamp off/on, AGC-F, with decay time set to 0.1 sec.

Test with pulse trains. Here, the pulse generator is connected to the IC-R8600 RF input via a step attenuator. The IC-R8600 is tuned to 3.6 MHz, as the RF spectral distribution of the test pulse train has a strong peak in that band. AGC Fast (0.1 sec) and Preamp ON are selected.

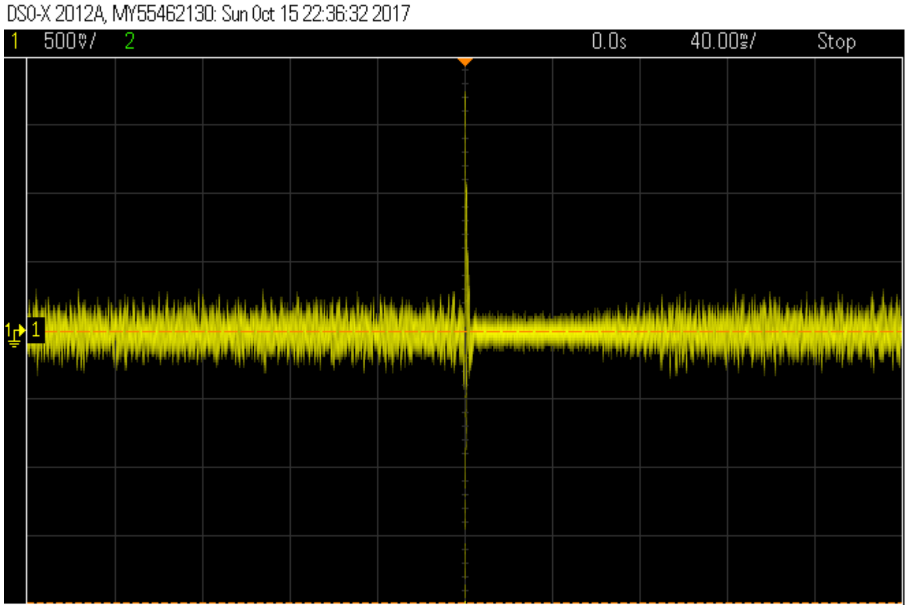
The pulse rise time (to 70% of peak amplitude) is 10 ns. Pulse duration is varied from 12.5 to 100 ns. In all cases, pulse period is 600 ms. The step attenuator is set at 23 dB. Pulse amplitude is $16V_{pk}$ (e.m.f.)

The AGC recovers completely within the 0.1 sec window; there is a ≈ 60 ms audio "hole" after the pulse. (See Figure 4 below.) NR softens the tick sound.

Table 11: AGC impulse response.

Pulse duration ns	Tick	AGC recovery ms	S: Pre off	S: Pre on
12.5	Y	≈ 100 (no clamping)	-93	-95
30	Y	≈ 100 (no clamping)	-92	-90
50	Y	≈ 100 (no clamping)	-84	-82
100	Y	≈ 100 (no clamping)	-82	-86

Figure 4: AGC pulse train test, showing audio "hole".



7a: Noise blanker (NB) impulse response. As the IC-R8600'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 7 (above).

Test Conditions: NB on, Preamp on, Level 50%, Depth 4 or 5, Width 80.

At all pulse durations, the S-meter deflection and "ticks" are *completely suppressed* (with Preamp off and on) showing that the impulsive events never reach the AGC derivation point. With Preamp off, there are no ticks at pulse widths ≤ 100 ns. No pulse artifacts are heard.

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

8: Signal strength indicator accuracy & AGC threshold. This is a quick check of S and dBm scale accuracy.

Test Conditions: 2.4 kHz SSB, Preamp off, ATT off, AGC MID. A 14.100 MHz test signal at MDS is applied to the RF input. The signal power P_i is increased, and the level corresponding to each reading is noted. (S9 readings are taken with Preamp off and on in turn.)

Note: The displayed input level in dBm is unaffected by preamp or ATT settings. The scale shifts 10 dB down with Preamp on, and 10, 20 or 30 dB up as determined by the selected ATT value. The RF Gain setting does not affect the dBm reading either.

Neither the Preamp nor ATT affect the absolute power (dBm scale reading, but the S scale tracks them correctly.

The absolute power (dBm) scale tracks to within < 1 dB over almost its entire range.

Table 12a: S scale tracking.

S	S1	S2	S3	S4	S5	S6	S7	S8	S9	S9+10	S9+20	S9+30	S9+40	S9+50	S9+60
dBm	-99	-95	-92	-89	-85	-82	-78	-75	-71	-61	-51	-41	-31	-21	-12
S9 = -82dBm (Preamp on).															

Table 12b: Absolute power (dBm) scale tracking.

Rdg. dBm	-120	-110	-100	-90	-80	-70	-60	-50	-40	-30	-20	-10
P_i dBm	-118	-109	-100	-90	-80	-70	-60	-50	-40	-30	-20	-10
Preamp gain = 10 dB; shifts scale 10 dB down, does not alter reading.												

8a: Attenuator tracking. This is a quick verification of attenuator accuracy. A test signal at -31 dBm (S9+40 dB) is applied, and the S reading is recorded for each ATT setting in turn.

Table 12c: ATT value.

ATT setting dB	S rdg.	Atten. dB
OFF	S9+40	0
10	S9+30	10
20	S9+20	20
30	S9+10	30

9: HF Two-Tone 3rd-Order Dynamic Range (DR_3). The purpose of this test is to determine the range of signals which the receiver can tolerate while essentially generating no spurious responses.

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

The two test signals are combined in a buffered passive hybrid combiner and applied to the receiver input via a step attenuator. The receiver is tuned to the upper and lower 3rd-order IMD products ($2 f_2 – f_1$ and $2 f_1 - f_2$ respectively) which appear as a 600 Hz tone in the speaker. The per-signal input power level P_i is adjusted to raise the noise floor by 3 dB, i.e. IMD products at MDS. The Pi values for the upper and lower products are recorded and averaged. $DR_3 = P_i - MDS$.

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

Note: *In line with current practice, IP_3 (3rd-order intercept) is not included here.*

Test Conditions: 500 Hz CW, AGC-S, ATT off, NR off, NB off, CW Pitch = 600 Hz.
20m: f_1 = 14.010 MHz, f_2 = 14.012 MHz.

Table 13: DR_3.

Preamp	IP+ off	IP+ on
Off	71	95
On	72	96

9a: Two-Tone 2nd-Order Dynamic Range (DR_2) & Second-Order Intercept (IP_2). The purpose of this test is to determine the range of signals far removed from an amateur band which the receiver can tolerate while essentially generating no spurious responses within the amateur band.

In this test, two widely-separated signals of equal amplitude P_i are injected into the receiver input. If the signal frequencies are f_1 and f_2, the 2nd-order intermodulation product appears at ($f_1 + f_2$). The test signals are chosen such that ($f_1 + f_2$) falls within an amateur band.

The two test signals are combined in a buffered passive hybrid combiner and applied to the receiver input via a step attenuator. The receiver is tuned to the IMD product ($f_1 + f_2$) which appears as a 600 Hz tone in the speaker. The per-signal input power level P_i is adjusted to raise the noise floor by 3 dB, i.e. IMD product at MDS. The P_i value is then recorded.

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

Test Conditions: f_1 = 6.1 MHz, f_2 = 8.1 MHz, CW mode, 500 Hz filter, AGC off, Preamp off, ATT off, NR off, NB off, CW Pitch = 600 Hz. DR_2 in dB; IP_2 in dBm.

Table 14: 6.1/8.1 MHz DR_2.

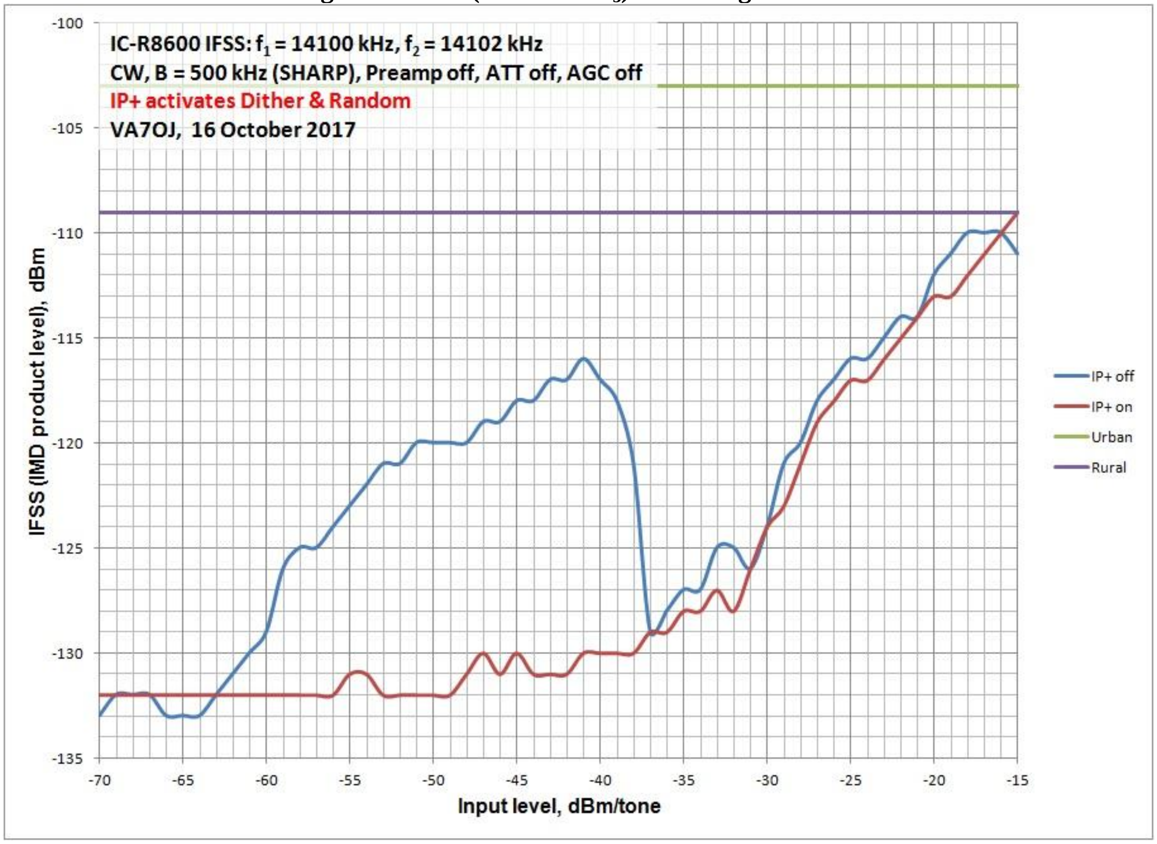
IP+	MDS dBm, 14.2 MHz	DR_2 dB	IP_2 dBm
off	-133	110	+87
on	-132	110	+88

9b: HF Two-Tone IMD_3 (IFSS, Interference-Free Signal Strength) tested in CW mode (500 Hz), ATT = 0 dB, AGC Med. Test frequencies: f_1 = 14010 kHz, f_2 = 14012 kHz. IMD_3 products: 14008/14014 kHz. IMD_3 product level was measured as absolute power in a 500 Hz detection bandwidth at various test-signal power levels with IP+ (Dither/Random) off, on and on with Preamp 1. AGC off, ATT= 0 dB. The ITU-R P-372.1 band noise levels for typical urban and rural environments are shown as datum lines. The input level at the top end of each curve corresponds to -1 dBFS, or 1 dB below OVF (ADC clip) level. See Figure 5.

The IMD product level was derived by measuring the S/N ratio of the IMD product for each input level setting, and subtracting MDS.

Note the pronounced ADC "sweet spot" at -40 dBm/tone input level. This is eliminated when dither and randomization are applied to the ADC (IP+ on).

Figure 5: IFSS (2-tone IMD_3) vs. test signal level.



Notes on 2-tone IMD_3 test: This is a new data presentation format in which the amplitude relationship of the actual IMD_3 products to typical band-noise levels is shown, rather than the more traditional DR_3 (3^{rd}-order IMD dynamic range) or SFDR (spurious-free dynamic range). The reason for this is that for an ADC, SFDR referred to input power rises with increasing input level, reaching a well-defined peak ("sweet spot") and then falling off. In a conventional receiver, SFDR falls with increasing input power.

If the IMD_3 products fall below the band-noise level at the operating site, they will generally not interfere with desired signals.

The IC-R8600 IFSS data is presented here as an adjunct to the traditional DR_3 test data. See ***Reference 1.***

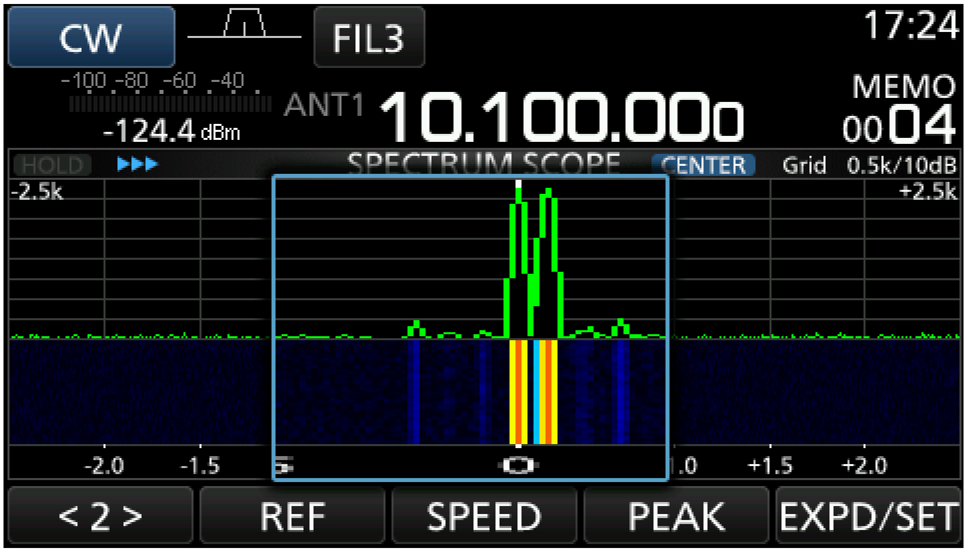
10: Spectrum Scope Resolution Bandwidth. In a spectrum analyzer, the resolution bandwidth (RBW) determines how far apart in frequency two (or more) signals must be to be resolved into separate and distinct displays on the screen.

Test Conditions: Test signals: f_1 = 10100 kHz, f_2 = 10100.100 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, f_1 and f_2 are injected into the antenna input at a level sufficient to produce spikes whose vertical amplitude reaches the top of the scope grid. f_2 is moved closer to f_1 until two distinct spikes are ***just*** observable. To facilitate adjustment, the signal spike image can be 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).



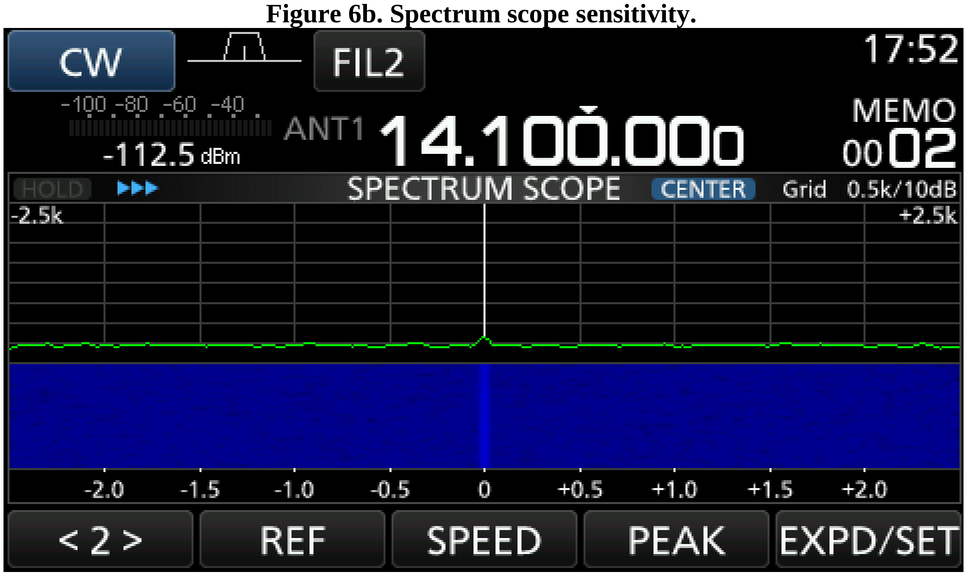
10a: Spectrum Scope Sensitivity. In this test, the RF input signal level is adjusted to produce a spike which is just visible above the scope "grass" level.

Test Conditions: 14.100 MHz Span = ± 2.5 kHz, VBW = Wide, Averaging = 4, ATT OFF, REF LEVEL = +20 dB, Waterfall off. DSP filter setting is irrelevant.

Table 15: Spectrum Scope Sensitivity.

Minimum Visible Spike for Span = ± 2.5 kHz	
Preamp	**Level dBm**
Off	-111
On	-128

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.
- Extended scope dynamic range, to display signal amplitude from the noise floor to ADC clip level. This would greatly facilitate use of the scope as a signal-analysis tool.

11: Noise Power Ratio (NPR). An NPR test is performed, using the SDR NPR test methodology described in detail in ***Ref. 1***. The noise-loading source used for this test is a noise generator fitted with bandstop (BSF) and band-limiting filters (BLF) for the test frequencies utilized.

P_{TOT} (noise loading) is set at -1 dBFS, i.e. 1 dB below the point at which the OVF indicator just begine to flicker (ADC clip point). Then, NPR is read off the signal-strength indicator (dBm scale) by subtracting the reading in the center of the notch fromthe reading well outside the notch.

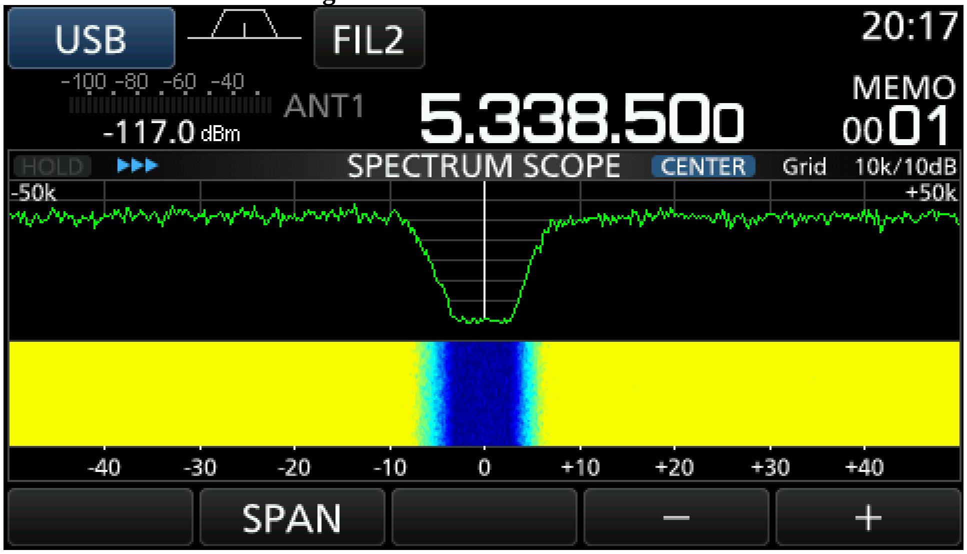
Test Conditions: Receiver tuned to bandstop filter center freq. f_0 ± 1.5 kHz, 2.4 kHz SSB, ATT off, max. RF Gain, Preamp off, IP+ off, NR off, NB off, Notch off, AGC-S. Test results are presented in Table 16.

- With IP+ on, NPR is degraded by ≈ 1 dB.

Table 16: IC-R8600 NPR Test Results.

DUT	BSF kHz	BLF kHz	P_{TOT} dBm	BWR dB	NPR dB
IC-R8600	534	12...552	-20	23.5	75
	1248	60...1296	-22	27.1	79
	1940	60…2044	-11	29.2	80
	2438	60...2600	-14	30.2	80
	3150	12...3284	-10	31.4	77
	3886	60…4100	-13	32.3	80
	4650	60…5600	-16	35.1	79
	5340	60…5600	-15	33.6	79
	7600	316…8160	-15	35.1	79
	11700	0...13000	-15	37.3	77

Figure 7: 5340 kHz NPR screen.



Note on NPR test: When testing NPR on other direct-sampling receivers, I have found that the noise loading drove the ADC into clipping before the AF noise output increased by 3 dB. Thus, I developed an alternative method in which the noise loading is set to 1 dB below clipping and the NPR read directly off the spectrum scope. The limited amplitude range of the IC-R8600 spectrum scope precludes that method, but on the IC-R8600 it was possible to read NPR off the signal-strength indicator (dBm scale) by subtracting the reading in the center of the notch from the reading well outside the notch. Activation of IP+ degraded NPR by <1 dB.

12: Frequency error. In this test, the DUT is tuned to a frequency in the microwave range, and a test signal from a GPS-locked source is applied to ANT1. The 10 MHz GPS reference signal is also applied to REF I/O and to a frequency counter which is connected to the AF/IF output. The CW pitch is measured with REF IN/OUT OFF and IN.

Test Conditions: f_0 = 2000.000 MHz at -50 dBm. CW, FIL2 (500 Hz). CW PITCH at 600 Hz. REF Adjust set for minimum error with REF IN/OUT OFF.

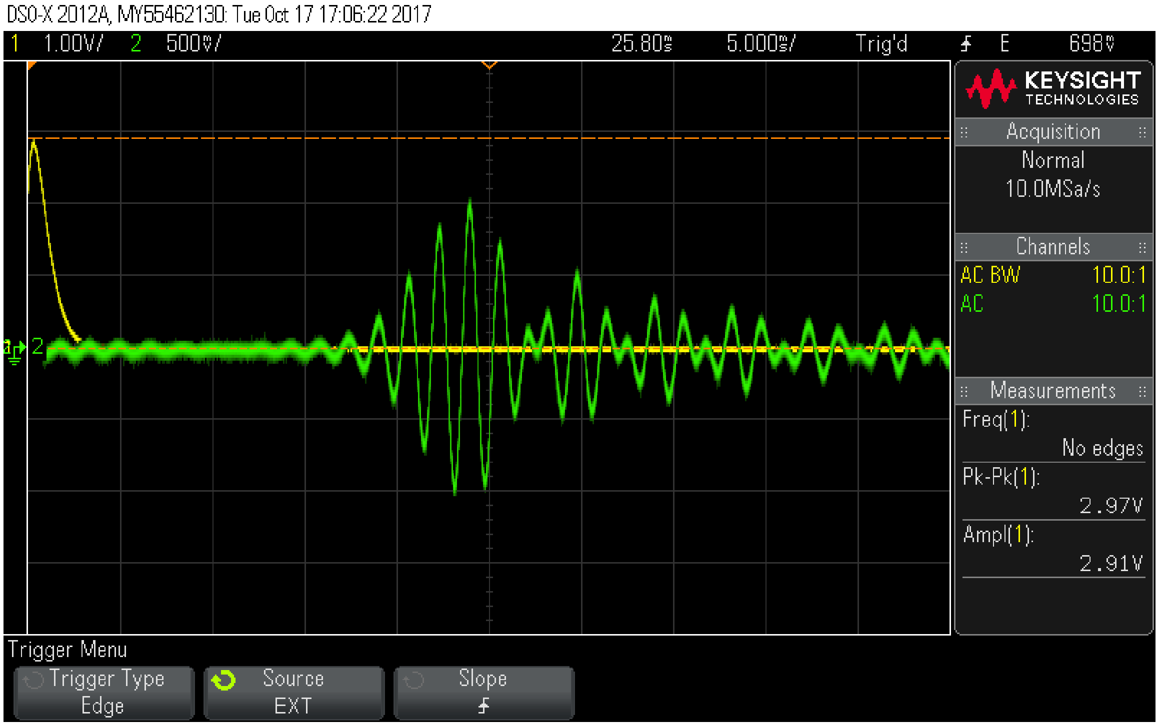
Table 17. Frequency Error Measurements

REF IN/OUT	Meas. CW Pitch	Freq. Error
OFF	623	+23
IN	601	+1

13: HF 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 6 illustrates an example.

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

Figure 8: RX latency, 250 Hz SOFT CW filter. 2 ms/div.



Test Conditions: 3.6 MHz, Preamp off, AGC Fast, IP+ off, max. RF Gain, ATT off, NR off, NB off.

Table 18: Receive latency test results.

Mode	Filter BW kHz	Shape Factor	Latency ms
LSB	3.6	Soft/Sharp	13
	2.4		13
	1.8		13
CW	1.2	Soft/Sharp	13
	0.5		16
	0.25	Sharp	20
	0.25	Soft	17
FSK	2.4		13
	0.5		15
	0.25		18

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 each NR step until there is no further SINAD increase.

Test Conditions: 14.1 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 -121 dBm (6 dB SINAD).

Table 19: Noise reduction vs. NR setting.

NR Setting	0	1	2	3	4	5	6	7	8
SINAD dB	6	8	9	10	12	14	15	16	16 (MAX)

This shows an S/N improvement of 10 dB with NR at maximum for an SSB signal ≈ 2 dB above MDS. This is an approximate measurement, as the amount of noise reduction is dependent on the original signal-to-noise ratio.

15: Audio THD. In this test, an communications analyzer is connected to the external speaker output. An 8Ω 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 power output corresponding to 10% THD is then measured.

Test Conditions: 14.100 MHz, 3 kHz USB, AGC-F, ATT off, NR off, NB off, Preamp off. Offset tuning by -1 kHz.

Test Result: Measured audio power output at 10% THD = **2.23W in 8Ω at 1 kHz**. (Spec. is 2W).

16: Spurious signals ("birdies"). The following spurious signals were observed with the ANT1 input terminated in 50Ω, REF I/O OFF and 10 MHz ext. reference disconnected.

Table 20: Spurious signals in receiver.

Freq. MHz	Mode	Signal Type	Signal dBm
2.563	USB	Beat tone	-113
12.802	USB	Tone	-110
23.041	USB	Tone	-105
24.574	USB	Tone	-105
28.161	USB	Tone	-130
42.349	USB	Tone	-118
51.498	USB	Tone	-121
77.224	USB	Tone	-104
92.299	USB	Tone	-103
224.898	USB	Tone	-115
550.648	USB	Tone	-109
650.225	USB	Tone	-121
744.225	USB	Tone	-119
798.225	USB	Tone	-121
860.158	USB	Tone	-113
975.150	CW	Tone	-91
1023.230	USB	Tone	-121
1134.800	CW	Tone	-99
1139.200	CW	Tone	-99
1139.840	CW	Tone	-112
1313.198	USB	Tone	-112
1348.998	USB	Tone	-96
1834.800	CW	Tone	-99
1852.400	CW	Tone	-85
2132.800	CW	Tone	-99
2134.800	CW	Tone	-106
2188.198	USB	Tone	-109
2282.225	USB	Tone	-123
2282.400	CW	Tone	-100
2371.200	CW	Tone	-97
2434.649	USB	Tone	-113
2457.600	CW	Tone	-115
2475.150	CW	Tone	-105
2632.800	CW	Tone	-100
2703.360	CW	Tone	-105
2826.240	CW	Tone	-98
2841.950	CW	Tone	-109
2849.600	CW	Tone	-109
2934.650	CW	Tone	-110
2975.150	CW	Tone	-101
2979.200	CW	Tone	-105

17: References.

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

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

Appendix 2: FM-Specific Tests

18. Two-Tone 3rd-Order Dynamic Range (DR_3), EIA Method: The purpose of this test is to determine the range of signals which the receiver can tolerate in the FM mode while producing no spurious responses greater than the SINAD level.

Two test signals f_1 and f_2, of equal amplitude and spaced 20 kHz apart are applied to the DUT antenna port via a hybrid combiner. The signal 40 kHz removed from the IMD product being measured is modulated at 1 kHz, with 3 kHz deviation. The receiver is tuned to the IMD products $(2f_1 - f_2)$ and $(2f_2 - f_1)$. The test signal levels are then increased simultaneously by equal amounts until the IMD product reads 12 dB SINAD. The DR_3 values for the upper and lower IMD products are averaged to yield the final result (Table 4).

Test Conditions: FM, FIL2 (15 kHz), Preamp off.

- ***6m, I:*** 52 MHz, FM. f_1 = 52.000 MHz modulated at 1 kHz, f_2 = 52.020 MHz, modulation off. Peak deviation = 3 kHz. IMD_3 product at 52.040 MHz.
- ***6m, II:*** 52 MHz, FM. f_1 = 52.000 MHz modulation off, f_2 = 52.020 MHz, modulated at 1 kHz. Peak deviation = 3 kHz. IMD_3 product at 51.980 MHz.
- ***2m, I:*** 146 MHz, FM. f_1 = 146.000 MHz modulated at 1 kHz, f_2 = 146.020 MHz, modulation off. Peak deviation = 3 kHz. IMD_3 product at 146.040 MHz.
- ***2m, II:*** 146 MHz, FM. f_1 = 146.000 MHz modulation off, f_2 = 146.020 MHz, modulated at 1 kHz. Peak deviation = 3 kHz. IMD_3 product at 145.980 MHz.
- ***1.25m, I:*** 223 MHz, FM. f_1 = 223.000 MHz modulated at 1 kHz, f_2 = 223.020 MHz, modulation off. Peak deviation = 3 kHz. IMD_3 product at 223.040 MHz.
- ***1.25m, II:*** 223 MHz, FM. f_1 = 223.000 MHz modulation off, f_2 = 223.020 MHz, modulated at 1 kHz. Peak deviation = 3 kHz. IMD_3 product at 222.980 MHz.
- ***70cm, I:*** 440 MHz, FM. f_1 = 446.000 MHz modulated at 1 kHz, f_2 = 446.020 MHz, modulation off. Peak deviation = 3 kHz. IMD_3 product at 446.040 MHz.
- ***70cm, II:*** 440 MHz, FM. f_1 = 446.000 MHz modulation off, f_2 = 446.020 MHz, modulated at 1 kHz. Peak deviation = 3 kHz. IMD_3 product at 445.980 MHz.

DR3 in dB = f_1 or f_2 level - 12 dB SINAD sensitivity

Table 20. FM DR3 at 20 kHz spacing.

Frequency MHz	12 dB SINAD sens. dBm	DR3 dB
52	-111	75
146	-111	75
223	-111	73
446	-110	72

19. FM Receive Adjacent-Channel Selectivity: In this test, two FM signals are applied to the DUT antenna port at 20 kHz channel spacing. The desired signal is modulated at 1 kHz, and the undesired signal at 400 Hz (both at 3 kHz deviation). Initially, the desired signal level is adjusted for 12 dB SINAD, and then the undesired signal level is increased until SINAD on the desired signal is degraded to 6 dB. The adjacent-channel rejection is the ratio of the undesired to the desired signal level.

Test Conditions: 146 and 446 MHz, FM, FIL2 (15 kHz). f_1 = 146.000 and 446.000 MHz modulated at 1 kHz, $f_2 = (f_1 + 20$ kHz) modulated at 400 Hz. Peak deviation = 3 kHz for f_1 and f_2.

Set f_1 level for 12 dB SINAD per ***Test 1*** above. Increase f_2 level until measured SINAD drops to 6 dB. Note this level.

Adjacent-channel rejection = f_2 level – f_1 level (in dB.)

Repeat entire test with $f_2 = (f_1 - 20$ kHz). Test results should be unchanged. (Table 5).

Table 21. FM adj. chan. rejection at 20 kHz spacing.

Mode	f MHz	f_1 Deviation kHz	Rej. ($f_2 > f_1$)	Rej. ($f_2 < f_1$)
FM	146	3	68	68
	446	3	66	66

20: 10 MHz IF Output with FM Test Signal. An FM signal at 2000 MHz is applied to ANT1. P_{IN} = -40 dBm, Δf = 2.4 kHz, f_m = 1 kHz. Figure 9 is a spectrogram of the signal at the 10 MHz IF port. Actual level = -60 dBm. (Note the first carrier null at Δf = 2.4 kHz.)

Figure 9.

IC-R8600 10.7 MHz IF output w/FM input. 231017.