Icom IC-9700 3-band VHF UHF transceiver

The IC-9700 is the latest VHF/UHF transceiver from Icom. It is an amateur band only, tri-bander capable of operating on the 2m, 70cm, and 23cm bands.

This new radio uses direct-digital sampling SDR technology similar to the revolutionary IC-7300 and IC-7610 transceivers and the IC-8600 receiver. It has a unique feature set, offering many functions never seen before in a VHF/UHF transceiver. These include direct sampling technology, an SDR type panadapter spectrum and waterfall display, plus D-Star operation and full duplex satellite capability in the same radio. You also get scan modes, a voice keyer, CW and RTTY message keyers and a built-in RTTY decoder. It is currently priced at around £1,800.

Basic functions

The IC-9700 is a fairly compact radio with exactly the same case dimensions as the IC-7300 transceiver and a similar weight. It measures 240(W) x 94(H) x 238mm(D) and weighs approximately 4.7kg. The front panel design is identical to the IC-7300 although due to the dual receivers and the VHF/UHF capability, several buttons and knobs have different functions. The rear panel features three antenna connectors, one for each band. The radio has two, fully independent, receivers enabling it to receive on any two out of the three bands at the same time. The single panadapter display can display signals from either the 'main' or the 'sub' band. It has a maximum display bandwidth of 1MHz, the same as the IC-7300. This is adequate but a lot less than many small box SDR receivers.

When both receivers are active, the screen is spilt with the 'main' receiver VFO and control icons displayed above the sub receiver VFO and icons. Apart from the satellite mode, the top (main) section displays the band that the radio will transmit on. You swap bands by pressing the top volume control. Pressing the lower volume control turns the second receiver on or off.

In many respects, the radio behaves as if

A matching pair! The IC-9700 for VHF and UHF and the IC-7300 for the HF bands and 50MHz.

The front panel of the IC-9700 tri-band transceiver - 2m, 70cm and 23cm.


The rear panel of the IC-9700 features three antenna connectors, one for each band.

there were three separate radios inside the box. Each band has its own memories, scan ranges and filter settings. You can't scan a set of memory channels containing frequencies on two different bands. However, you can make both receivers scan at the same time.

The radio supports AM, FM, SSB, CW, RTTY, and the digital voice (DV) D-Star mode, plus external digital modes via the USB cable. It also supports the 128kbit DD (digital data) mode on the 23cm band. Frequency coverage is limited to the band limits of the three amateur bands for your geographic region or country. There is no general coverage receiver. However, with an abundance of cheap SDR receivers on the market, this is unlikely to be a handicap. The transmitter is capable of 100 watts on the 2m band, 75 watts on the 70cm band, and 10 watts on the 23cm band.

The IC-9700 supports a huge number of memory channels. Each of the three bands has 99 standard memories, plus six call channels. There are also memory slots for 99 satellite specific channels, 300 GPS memories, and 2500 for D-Star repeaters.

I was impressed with the auto-selection of repeater duplex. If you tune across a repeater output sub-band, the radio automatically selects the correct plus or minus duplex split. This means that if you tune to a repeater output, the radio will automatically set the transmitter to the repeater input frequency. This feature may not be available in all regions. You can save the channel into a memory location without having to manually set the duplex offset. This function can be disabled if you want to transmit in simplex mode on that part of the band.

The radio requires a nominal 13.8V supply and draws a maximum of 18A.

The manual is split into two parts. The 96 page 'Basic' manual is provided as a paper copy. There is also an 'Advanced' manual that can be downloaded as a .pdf file from the Icom.jp website. Unlike the IC-7300 and the IC-7610, the radio did not ship with a CD containing the Advanced manual and schematics. If you buy an IC-9700 you probably will need to download a copy of the Advanced manual.

The radio is provided with a standard electret hand microphone, the HM-219. I have received excellent reception reports while using it. The microphone connector is a standard 8-pin connector rather than the RJ-45 type fitted to some radios. Also, in the box, there is a fused DC cable, some spare fuses, and a 3.5mm stereo plug. The 3.5mm plug is useful, but not as useful as the (more difficult to source) 2.5mm plug for the data connector, or the 8-pin DIN connector for the accessory jack.

There are only a limited number of differences between the model available here in New Zealand and the model available in the UK. Some bands are a bit different for the EU models but, according to the Service Manual, there are no other differences. The EU version covers 144-146MHz on the 2m band. My 'USA/Export' version is 144-148MHz. Our 70cm band in NZ is the same as yours, 430-440MHz, but my radio will transmit up to 450MHz. You can restrict it with a menu setting. The EU radios are restricted to 430-440MHz. The UK/EU 23cm band is the same as NZ and the USA. It is 1240-1300MHz, but Korea, Italy, and Taiwan are different. As a result, the down conversion IF is a little different for Korea, Italy and Taiwan.

Radio design and architecture

Direct digital sampling is used for both the receive and transmit signal paths. The 23cm band is down-converted to a 311-371MHz IF for the 23cm receiver and upconverted from a slightly different IF bandwidth for the transmitter. Each band has its own antenna connector. If you have a multi-band antenna, you can use a diplexer or triplexer to combine two or all three bands onto a single feeder cable.

Incoming receive signals pass through individual preamplifier, attenuator, and bandpass filter stages followed by a pair of pin diode switches that select any two of the three input signals. The outputs of the switches are passed onto an LTC2156 dual ADC. A Cyclone-V FPGA performs all of the DSP functions other than a specialised chip for D-Star. There are several CPUs including a 'soft-core' CPU in the FPGA and an ARM Cortex A9 processor that is used to handle the touchscreen and front panel controls. A separate CPU drives the spectrum scope display. Finally, there is a DAC to convert the audio data back into an analogue signal for the speaker and audio outputs.

The transmit path is basically the same thing in reverse. Microphone audio is converted to a digital signal by an audio ADC. The signal goes into the FPGA where DSP magic happens. There are separate processors for control functions and D-Star DSP processing. The FPGA output, already at the transmit (or 23cm IF) frequency, is converted into an analogue signal by a high-speed 16-bit DAC clocked at 1179.648MHz. This is followed by an RF amplifier and a low pass filter, then a switch to route the

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signal through various driver amplifiers and filters and on to the appropriate RF power amplifier and low pass filter. The 23cm band transmit signal comes out of the DAC on a frequency between 305.632MHz and 365.632MHz. Prior to the driver stage, it is upconverted to the wanted frequency on the 23cm band by a mixer and a fixed oscillator on 1605.632MHz.

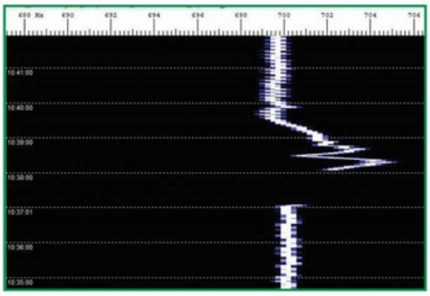
The main oscillator is a $\pm$0.5ppm high stability TCXO, which can optionally be governed by a 10MHz GPS reference clock or rubidium clock signal applied to the rear panel reference input. The receivers' ADC chip is clocked at 196.608MHz (that is four times the main oscillator frequency) and close to the maximum sample rate of the device. This places the 2m band into the 2^{nd} Nyquist zone, the 23cm band IF into the 4^{th} Nyquist zone, and the 70cm band into the 5^{th} Nyquist zone.

Removing the covers reveals a well-constructed, clean layout with circuit boards mounted on the usual compartmentalised sturdy die-cast frame and an integral heatsink. The main board is on the top side and the three RF boards are on the bottom side.

Improved sound quality has been addressed by attaching the upward-facing speaker to the die-cast chassis with rubber mountings. Although there is just a single speaker for the two receivers, the audio from both receivers is available at separate speaker outputs on the rear panel and as separate or mixed channels on the stereo headphone jack.

D-Star

The Icom Advanced Manual devotes four chapters to D-Star operation. A total of eighty-one pages, compared to the section on satellite operation, which only rates three pages. You can operate D-Star from the normal VFO mode or memory channels, but there is also a special DR (digital repeater) mode, which makes accessing and linking to repeaters and reflectors much easier. The DV/DD memory bank can hold 2500 repeater definitions. These can be imported from a .csv spreadsheet file saved onto the SD card. The Icom CS-9700 programming software is available as a free download from the Icom website. The radio has all the D-Star features found on other D-Star enabled radios. You can work simplex to another D-Star radio, through a local repeater or hotspot, or through a local repeater or hotspot and the internet, to users connected to other repeaters or reflectors worldwide. The system works very well with no noticeable latency. On the 23cm band, this type of operation can even be used to provide a low-speed data or internet connection via your transceiver and a 23cm repeater (where this is legal).



I measured 30Hz of frequency drift in the minute following a one-minute transmission at full power on the 70cm band.

Linked repeaters and reflectors don't have to be D-Star specific, many of them are for DMR, System Fusion, or DMR users. This allows you to talk to hams who are using radios employing a different type of digital modulation.

You can connect an NMEA compliant GPS receiver to obtain accurate GPS location, speed and direction information for transmission over the DV (D-Star) mode. If you are not intending to operate mobile or portable, you can enter your location information manually. The location or GPS data is also used to determine the closest repeaters to you, and the distance and bearing between your location and the users of connected D-Star repeaters and reflectors worldwide.

You can also use the radio as a D-Star gateway or hotspot, using the LAN connection and connecting directly to the internet as a gateway or using a D-Star handheld to talk through the radio to a connected gateway. It is a rather expensive way to achieve this compared to buying a cheap DV dongle, but it is possible.

Satellite mode

A few other radios have offered full duplex cross-band satellite mode operation with forward and reverse tracking of the VFO frequencies. But locking the VFOs together in this fashion can't correct for the difference in Doppler shift between the 70cm band and the 2m band. Most satellite operators prefer to use satellite tracking programs, which control the radio through the CI-V or CAT interface to automate Doppler correction and provide transponder tracking. The IC-9700 is capable of full-duplex satellite operation with forward or reverse tracking with the added advantage of being able to easily move either the main (downlink) or the sub (uplink) VFO independently and then lock the VFOs together again. This means that for the first time, you really can consider manually managing the Doppler shift using the radio alone. Of course, the option of PC control via the CI-V interface is still available. I successfully configured the radio to work with SatPC32 and others have reported success with MacDopplerPRO. One feature not found on all 'satellite capable' transceivers is that you can listen to the uplink frequency and the downlink frequency at the same time.

Front panel

The front panel layout is identical to the IC-7300 although the function of some of the controls is different. There are volume, squelch, and RF Gain controls for each receiver and a button for selecting a 'call channel' or the Digital Repeater D-Star mode. There is also a separate button for enabling tone squelch. Many functions and all of the menu commands are accessed via the 4.3in colour TFT touchscreen. The display is particularly clear and bright, retaining readability well under bright lighting. Backlight level is adjustable, and you can select either a black or blue background. Band, mode, filter selection, meter selection, and VFO / memory functions are all selected by touching the appropriate areas on the display. Each soft key icon brings up a group of selectable options.

A row of hardware buttons along the bottom of the display provides access to the main menu settings, function settings, the spectrum scope, and 'quick' selection of a number of parameters.

Pressing the MULTI knob allows you to set adjustable functions such as transmit power level and microphone gain. Rotating the MULTI knob either steps through the memory channels or it adjusts the VFO frequency by the pre-determined tuning steps. The display shows a large number of status indicators and functions. According to the Icom manual, there are 33 indicators on the display and that is without considering the panadapter spectrum scope and waterfall display. Both receiver frequencies are shown continuously with dual bar meters for signal strength or various selectable transmit functions. The VFO display changes to the transmit frequency while you are transmitting. Simultaneous metering of multiple transmit functions can also be selected. A very comprehensive 'Set' mode allows tailoring of an enormous number of functions. These are all accessed via the touch screen display with nested menu items. The menu structure is in plain language, which is so much easier than dealing with the cryptic codes used by earlier transceivers. You have a choice of English or Japanese language. A keyboard is displayed on the touch screen when alphanumeric data needs to be entered. This can be in either a full QWERTY or a 10-key format and makes data entry very straightforward.

Tuning is very smooth and easy using the 47mm diameter rotary control. The normal tuning rate is either in 10Hz or 1Hz steps, or you can select fast tuning rates from 100Hz per step up to 100kHz per step. The tuning rate speeds up if you rotate the VFO knob more quickly. A quarter speed tuning rate can be selected for fine tuning on CW and data modes.

The microphone connector is the standard 8-pin format and there is a 3.5mm headphone jack. An SD memory card slot is provided for storing various items such as received and transmitted audio files, voice memory stores, RTTY decode logs, memory contents and setup data. Screen images can also be captured as PNG or BMP files. User-supplied SD or SDHC cards up to 32GB can be used, but the SD card does not have to be very big. I have data files for three different Icom radios on a single SDHC card and the files only take up 30MB in total.

Rear panel

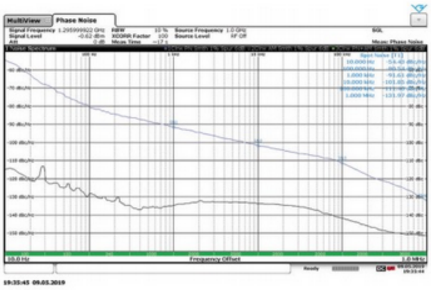
The rear panel includes a SO-239 antenna socket for the 2m band and Type-N connectors for the 70cm and 23cm bands. There is an SMA connector for the connection of a 10MHz high stability oscillator. See my comments later about oscillator stability.

An Ethernet connector is provided for connection to a LAN. It can be used for remote control of the transceiver using the RS-BA1 V2 software and if you want to turn the radio into a D-Star gateway or hotspot and for the DD (digital data) mode. It is also used to connect to an NST time server on the internet, keeping the clock display very accurate.

The type B USB 2.0 port is used for CI-V computer control and for audio, or 12kHz IF, connections between the radio and your PC. One cable carries all the control and audio data. The radio establishes two virtual COM ports and an audio codec that looks like a soundcard to digital mode software. The addition of a Type A USB port on the rear panel would have enabled the use of an external keyboard that would be a boon for users of the CW memory keyer and built-in RTTY decoder. Those functions are severely limited by the inability to enter a remote station's callsign.

A 3.5mm stereo phono 'Key' jack is provided for the connection of a CW key or paddle. There is a standard Icom accessory jack, a legacy CI-V 'Remote' jack, speaker jacks for the main and sub receivers (mono!), and a data jack for connecting an external GPS receiver. This is for location data, not for a GPS disciplined oscillator.

There is no transverter output or external monitor output on the rear panel. A transverter output would have been handy for anyone wishing to use the radio use as an exciter and converter receiver for the microwave bands and would have been especially welcomed by satellite operators wanting to use the new QO-100 geostationary satellite. The ability to plug in an external monitor may be missed by some, although it is of very limited appeal on the IC-7610. There are no separate ALC or PTT jacks for connection to a linear amplifier, but these signals are available on the ACC jack.



The IC-9700 has excellent transmitter phase noise results. Thanks to Rohde & Schwarz GmbH & Co KG for making the FSWP instrument available to Conrad Farlow, PA5Y, for the transmitter phase noise measurements.

Receiver features

Both receivers are identical and all receiver functions such as filtering or noise rejection etc are duplicated and separately adjustable by touching the top (main) or bottom (sub) receiver panel on the display. Incremental tuning (RIT) is adjusted with the Multi knob and auto-tuning is provided on CW. The same button can turn off the AFC when the transceiver is in the in FM or DV mode.

There are 99 regular memory channels and two scan edge channels for each of the three bands. Memory access is very straightforward. Each memory channels can be assigned a name up to 16 characters in length and this is quick and easy with the on-screen keyboard. A separate 'quick access' memo-pad stack for 5 or 10 frequencies is also included. There are also two Call channels per band for quick access to your most often used frequencies or repeaters. A host of scanning functions are also provided. Filtering functions are fully adjustable. A 'FIL' touch-button on the display scrolls through three pre-set IF filter bandwidths with separate settings for each mode. Sharp and soft passband shapes are available. Twin PBT allows either side of the filter passband to be shifted independently, shifting or narrowing the overall shape to assist in combating adjacent channel interference. A manual notch filter operates at IF inside the AGC loop preventing desensitisation with strong carriers. It has excellent depth with wide, medium, or narrow width settings. A separate auto-tuning notch filter operating at audio removes multiple tones effectively.

An adjustable noise reduction system reduces background noise and improves readability in certain situations. A separate noise blanker eliminates pulse-type noise from car ignition and other sources. Three separate AGC time constants are selectable from a menu of 13 different values (0.1 to 6s) and are set separately for all modes except FM. The AGC can also be switched off.

The receiver audio response can be tailored independently for each mode. The high-pass and low-pass roll-offs can be adjusted separately and the bass and treble responses cut or enhanced.

Transmit features

Transmit functions for SSB include a speech compressor, VOX, and a transmission monitor. The transmitter audio filter bandwidth may be set to adjustable wide, mid, or narrow settings. In addition, the bass and treble responses can be cut or enhanced separately for each voice mode in a similar fashion to the receive audio. The voice keyer stores eight pre-recorded audio messages and operates in any of the voice modes including the voice-data modes. Each message has 90 seconds of recording time. Operation and recording are the same as on the IC-7300.

On CW there is the usual provision for full and semi break-in with adjustable drop back delay. The keying envelope rise and fall times are adjustable between 2 and 8ms and an additional 'transmit delay' is selectable for each band to accommodate slow switching linear amplifiers or other accessories. A CW message keyer is included operating over the speed range 6 – 48 wpm with adjustable weighting and a variety of keying paddle arrangements. Eight memories will each store up to 70 characters each with a provision to send an automatically incrementing serial number and auto-repeat after a time delay. In full break-in CW mode, relay clicking is noticeable on the 2m band, which has a PTT relay. It is silent on the 70cm band, which has PIN dode PTT switching, and quiet on the 23cm band (which uses a much smaller relay).

The RTTY mode includes a built-in RTTY decoder and an eight message keyer similar to the CW one. The message keyers are identical in configuration and operation to the ones in the IC-7300.

FM mode operation includes automatic duplex selection, CTCSS tone repeater access, tone squelch, and repeater split frequency operation.

For digital mode operation using external software, there are three data modes. The modulation input can be taken from the USB cable, microphone socket, or accessory socket. The USB-D mode is used for AFSK modes such as FT8, JT65, and PSK. The FM-D mode would be used for Packet and APRS modes.

Computer software

The IC-9700 can communicate with most PC based digital mode and satellite tracking programs via the USB cable and you can use the RS-BA1 v2 remote control program to control it remotely via an Internet connection. There is a server built-in, so a PC connection is not required at the radio end. Icom has released a

The IC-9700 is a delight to use on the bands.

free programmer called CS-9700 that allows you to easily edit and add to the thousands of memory slots available in the radio, including the scan edges and calling channels. You can also edit the satellite memories and the GPS memory bank. The Icom manual states that the radio comes with the list of worldwide D-Star repeaters pre-loaded, but mine was supplied blank. Repeater lists for the IC-9700 can be downloaded from http://downloads.d-staruk.co.uk/. The radio can store 2500 DV repeaters, divided into 50 groups. You can also set most if not all of the menu settings and the text for the RTTY and CW message keyers. The program allow you to import channel data from .csv files. Other commercial programs to control the radio are available.

Frequency stability

If you are not using narrow bandwidth digital modes or using the radio with an upconverter or downconverter for operation on the microwave bands, there is no issue with the frequency stability of the IC-9700. You may notice some frequency drift after transmitting SSB on the 23cm band, but this is easily compensated for by using the RIT control. The small amount of drift experienced on the 2m and 70cm band is insignificant. Although the radio frequency drifts quite rapidly as it cools down with the fan running after a transmit period, the frequency always remains well within the specified ±0.5ppm variance quoted in the Icom specification. The stability of the radio while receiving is excellent. After leaving the radio on, but not transmitting, for 30 minutes, I measured a frequency error of 13Hz at 1242MHz, which is an outstanding result.

However, this rapid frequency drift after transmitting does make reception of weak signal digital modes such as JT65 and WSPR a challenge. The problem arises when you use modes that transmit for 30 seconds or a minute and then receive during the next time period. Radios with the latest firmware release (V1.11) have the option of connecting a high stability 10MHz GPS reference clock or rubidium frequency standard to the 10MHz Reference Input connector on the rear panel. This external reference 'governs' the internal TXCO, significantly improving the overall frequency stability of the transceiver. Without the GPS reference signal, I measured 30Hz of frequency drift in the minute following a one-minute transmission at full power on the 70cm band. With the GPS reference signal, this was reduced to about 5Hz of frequency drift. I am hopeful that this may be further improved in future firmware releases.

Measurements

The full set of measurements is in the measurements table opposite. The receiver sensitivity is very good especially with a preamplifier enabled. The preamplifiers have about 12dB of gain on the 2m and 70cm bands and 5dB on the 23cm band. This difference does not matter as the radio is also more sensitive on the 23cm band. There is also an optional 10dB front-end attenuator for each receiver.

The S-meter is fairly linear, each S-unit indicates a 2.5dB increase in signal strength. There were no spurious responses noted. Like many SDR receivers, the dynamic range is excellent. Strong signal performance is limited by ADC overload. With the preamplifier off, a single input signal 10kHz away from the receiver frequency will trigger an (OVF) ADC overload alarm at an input level of -9dBm (S9 +78dB). With on-frequency signals, the front-end AGC operates, reducing input to the ADC; you can apply a signal at up to +10dBm (S9 +97dB!) without reaching the overload point. When really strong signals are present anywhere on the band you should turn down the RF gain control or switch in the front-end attenuator. Enabling IP+ removes low-level intermodulation products, improving the reciprocal mixing dynamic range (RMDR) by about 1.5dB, but degrading the receiver sensitivity by about 3dB.

I did a test to see how well you can see weak signals on the waterfall display. The radio will show a line at an input level just above the minimum discernible signal (MDS) sensitivity level, around -130dBm. However, this will be masked by received noise when you connect an antenna. Still, you should be able to see any signal that you can hear. The receiver passband has a very flat response when set to the 'sharp' setting. The 'soft' SSB filter had a slight curve across the passband as well as a softer roll-off. The 'soft' 500Hz CW filter is flat with a slower roll-off than the sharp filter and you can definitely hear the difference.

The transmitter power was well within the 5% tolerance of most good power meters. When testing RF power at UHF frequencies and above, you must take into consideration the loss in your coax cables. The stated results are as measured at the antenna connectors. The level of the 2nd harmonic was acceptable and there were no other measurable spurii. Transmitted phase noise was good. There were no differences in the test results when the GPS reference clock signal was disconnected.

On the air performance

The IC-9700 is a delight to use on the bands. Although there is a high degree of customisation available, the transceiver is very easy to use. I had QSOs on 23cm SSB simplex, 2m FM simplex, FM repeaters and D-Star. It is rather subjective, but I feel that the receiver audio sounds cleaner and crisper than my old VHF/UHF radio. The performance was excellent, and I had very good reports about the quality of my transmitted audio. The channel filters, notches, noise blanker and noise reduction system all performed well. I set the radio up for satellite operation and was able to hear the CW beacon on XW-2C, but I don't currently have suitable antennas to achieve a satellite contact. The touchscreen display is very responsive, and the image is crisp and clear. Tuning is smooth and memories are quick and easy to access.

Conclusions

The IC-9700 is a very impressive radio with some great features and superb performance. It is an all-mode VHF/UHF tri-bander with direct sampling technology, comprehensive D-Star capability, and full duplex Satellite mode. It's an ideal radio for the serious VHF/UHF enthusiast. Wow!

Acknowledgements

I would like to thank Adam Farson, AB4OJ for the RMDR measurement data and Conrad Farlow, PA5Y for the transmitter phase noise data. I also wish to thank Rohde & Schwarz GmbH & Co KG for making the instrument available for phase noise measurements. My thanks too to Icom UK for checking the differences between the radio supplied in New Zealand from that obtained in the UK.

The IC-9700 is available in the UK from all good Icom stockists, with a recommended pricearound £1800.

Icom IC-9700 Measured Performance

Reciever Tests

MDS (minimum discernable signal)	**2m band (146.2MHz)**	**70cm band (435.5MHz)**	**23cm band (1296.2MHz)**
MDS preamp on	-143.4dBm (0.02µV pd)	-143.9dBm (0.01µV pd)	-144.1dBm (0.01µV pd)
MDS preamp off	-131.1dBm (0.06µV pd)	-131.8dBm (0.06µV pd)	-138.7dBm (0.03µV pd)
MDS attenuator on	-121.9dBm (0.18µV pd)	-122.5dBm (0.17µV pd)	-128.8dBm (0.08µV pd)
Noise figure (preamp on)	3.6	3.1	2.9

[NF = MDS + KTo 174dBm + 10 log(500)]
[CW mode 500Hz BW]

Signal visible on the waterfall	**2m band (146.2MHz)**	**70cm band (435.5MHz)**	**23cm band (1296.2MHz)**
Waterfall image	-130dBm (0.07µV pd)	-130dBm (0.07µV pd)	-143dBm (0.02µV pd)
Waterfall image preamp on	-150dBm (0.01µV pd)	-150dBm (0.01µV pd)	-150dBm (0.01µV pd)

[CW mode 500Hz BW]
Note that incoming signal noise will degrade this performance when the radio is connected to an antenna.

FM sensitivity	**2m band (146.2MHz)**	**70cm band (435.5MHz)**	**23cm band (1296.2MHz)**
12dB SINAD FM	-113.8dBm (0.46µV pd)	-113.48dBm (0.47µV pd)	-121.7 dBm (0.18µV pd)
12dB SINAD FM preamp on	-125.4dBm (0.12µV pd)	-125.2dBm (0.12µV pd)	-125.5 dBm (0.12µV pd)

[FM modulation 1kHz tone at 3kHz deviation. Receiver 15kHz BW]

SSB sensitivity	**2m band (146.2MHz)**	**70cm band (435.5MHz)**	**23cm band (1296.2MHz)**
10dB S/N	-116.9dBm (0.32µV pd)	-116.5dBm (0.33µV pd)	-124.8dBm (0.13µV pd)
10dB S/N SSB preamp on	-129dBm (0.08µV pd)	-128.6dBm (0.08µV pd)	-129.8dBm (0.07µV pd)

[SSB mode 2.4kHz BW]

S-meter calibration	**2m band (146.2MHz)**	**70cm band (435.5MHz)**	**23cm band (1296.2MHz)**
S-meter S9 reading	-86.7dBm (10.34µV pd)	-87.3dBm (9.65µV pd)	-94.8dBm (4.07µV pd)
S-meter S9+20 reading	-66.4dBm (107.02µV pd)	-66.9dBm (101.04µV pd)	-74.4dBm (42.61µV pd)

[Preamp off, CW 500Hz BW. The S9+20 readings indicate an accurate 20dB increase in received signal]

RMDR (reciprocal mixing dynamic range)	**2m band (146.2MHz)**	**70cm band (435.5MHz)**	**23cm band (1296.2MHz)**
RMDR at 1kHz spacing	92dB	84dB	72dB
RMDR at 2kHz spacing	97dB	90dB	75dB
RMDR at 5kHz spacing	102dB	96dB	79dB
RMDR at 10kHz spacing	104dB	98dB	82dB
RMDR at 20kHz spacing	106dB	100dB	84dB

RMDR measurements performed by Adam Farson, AB4OJ

Receiver phase noise (calculated)	**2m band (146.2MHz)**	**70cm band (435.5MHz)**	**23cm band (1296.2MHz)**
Phase noise at 1kHz spacing	-119dBc/Hz	-111dBc/Hz	-99dBc/Hz
Phase noise at 2kHz spacing	-124dBc/Hz	-117dBc/Hz	-102dBc/Hz
Phase noise at 5kHz spacing	-129dBc/Hz	-123dBc/Hz	-106dBc/Hz
Phase noise at 10kHz spacing	-131dBc/Hz	-125dBc/Hz	-109dBc/Hz
Phase noise at 20kHz spacing	-133dBc/Hz	-127dBc/Hz	-111dBc/Hz

For a 500Hz bandwidth, Phase Noise in dBc/Hz = -(RMDR + 10LOG(500))

Receiver filter response

2.4kHz SSB filter	Sharp receiver pass band is flat from 300 to 2700Hz
2.4kHz SSB filter	Soft receiver passband is curved with a 6dB rolloff at 300 and 2700Hz
500Hz CW filter	Sharp receiver pass band is flat with -3dB points at 450 and 950Hz
500Hz CW filter	Soft receiver passband is flat with a softer rolloff and -3dB points at 438 and 957Hz

TRANSMITTER TESTS

RF Power	**2m band (146.2MHz)**	**70cm band (435.5MHz)**	**23cm band (1296.2MHz)**
RF Power (watts)	102W	75W	10.1W*

Power on 23cm measured with Rohde & Schwarz analyser.
[CW/RTTY mode 100% power setting]

Transmitter harmonics	**2m band (146.2MHz)**	**70cm band (435.5MHz)**	**23cm band (1296.2MHz)**
2nd Harmonic	-59.4dBc	-64.6dBc	-51.4dBc
3rd Harmonic	-71.7dBc	-75.7dBc	

Transmitted phase noise	**2m band**	**70cm band**	**23cm band**
Phase noise 100Hz	-100.5dBc	-91.4dBc	-80.5dBc
Phase noise 1kHz	-118.8dBc	-109.2dBc	-91.6dBc
Phase noise 10kHz	-121.3dBc	-111.6dBc	-101.8dBc
Phase noise 100kHz	-129.4dBc	-119.9dBc	-111.4dBc
Phase noise 1MHz	-140.1dBc	-130.5dBc	-131.9dBc

Transmitter phase noise measurements performed by Conrad Farlow PA5Y at 100% power level.
Unaffected by reference clock input

2 tone 3rd order TX IMD	**2m band (146.2MHz)**	**70cm band (435.5MHz)**	**23cm band (1296.2MHz)**
3rd	-41dB	-30dB	-35dB
5th	-50dB	-42dB	-41dB
7th	-60dB	-56dB	-47dB
9th	-65dB	-57dB	-51dB

700Hz and 1900Hz tones
Spectrum analyser RBW 50Hz
ARRL method. Two tones at -6dB below single tone 100% power level